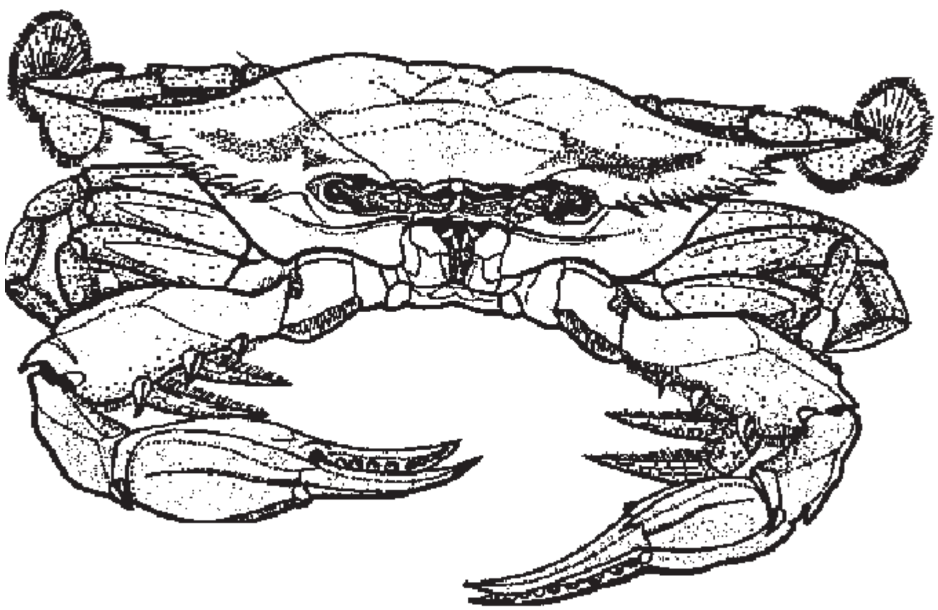
North Carolina
Fishery Management Plan

Blue Crab



North Carolina MARINE FISHERIES

Dept. of Environment and Natural Resources

December 2004

North Carolina
Fishery Management Plan

Blue Crab

North Carolina Department of Environment and Natural Resources
Division of Marine Fisheries
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1. ACKNOWLEDGMENTS

The 2004 North Carolina Blue Crab Fishery Management Plan (FMP) was developed under the direction of the North Carolina Marine Fisheries Commission (MFC) with the advice of the Crustacean Committee. The plan was prepared by the North Carolina Department of Environment and Natural Resource's Division of Marine Fisheries (DMF).

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3. EXECUTIVE SUMMARY

The goal of the 2004 North Carolina Blue Crab Fishery Management Plan (FMP) is to manage blue crabs in North Carolina in a manner, which conserves the stock, protects its ecological and economic value, and optimizes the long-term use of the resource. Plan objectives include: maintenance of the stock at a level that maximizes reproductive potential; promote harvesting practices that minimize waste; habitat protection and restoration; distinguishing between conservation goals and allocation issues; providing resource utilization for all users; conflict minimization; identifying and promoting biological, social, and economic research; maintaining the blue crab fisheries as a major source of income for commercial fishermen; and promoting education. The proposed management strategy for the blue crab fisheries in North Carolina is to 1) optimize resource utilization over the long-term, 2) minimize waste, 3) reduce conflict, and 4) promote public education on blue crab issues. The first strategy will be accomplished by protecting the spawning stock, and by protection of critical habitats. Minimization of waste will be accomplished by gear modifications, culling practices, and harvest restrictions. Conflict will be addressed through regional management. The DMF will work with other agencies and organizations to enhance public information and education.

Maximum sustainable yield (MSY) for blue crabs has been estimated to be between 38 and 46 million pounds per year (Eggleston et al. 2004). However, it is felt that these MSY estimates are not valid based on data and modeling limitations, and the significant influence of environmental variables on the population. Because of data and modeling limitations, these MSY estimates should be used as a guideline to the long-term potential of the fishery rather than as strict targets. Nevertheless, it should be recognized that none of the assessment results suggest that the high landings from the late 1990s would be sustainable. Until valid estimates of MSY can be developed, the blue crab resource will be considered overfished when annual landings decline for five consecutive years. Optimal yield for the blue crab in North Carolina is that amount of harvest of legal blue crabs which: prevents overfishing; provides for replenishment of the stock; reduces conflicts within the blue crab fisheries; reduces conflicts between the blue crab fisheries and other water-based activities; maintains the blue crab fisheries as a major source of income for commercial fishermen in coastal North Carolina in a proportion similar to that which exists at the present time in the most efficient manner; and provides sufficient opportunities for recreational harvest of blue crabs.

Issues addressed in formulating the management plan for North Carolina's blue crab fishery encompassed the following general categories: 1) environmental degradation; 2) stock protection; 3) wasteful or damaging fishing practices; 4) conflict with other users; 5) insufficient assessment data and 6) public education. Specific issues and recommendations are as follows:

1). Environmental Issues

a). Habitat - Protect, enhance, and restore habitats utilized by the blue crab.

Habitat protection, conservation, and restoration are essential to accomplish the goal and objectives of this plan. The North Carolina Marine Fisheries Commission (MFC), North Carolina Coastal Resources Commission (CRC), and North Carolina Environmental Management Commission (EMC) should adopt rules to protect blue crab critical habitats as outlined in the Coastal Habitat Protection Plan (CHPP). The Department of Environment and Natural Resources (DENR) should develop a strategy to fully support the CHPPs process with additional staff and funding. The MFC and North Carolina Division of Marine Fisheries (DMF) should continue to comment on activities that may impact aquatic habitats and work with permitting agencies to minimize impacts and promote restoration and research. Research must be conducted to investigate the impacts of trawling on various habitats. A strategy should be developed and adopted by the MFC and DENR to accomplish the actions outlined in Section 10.1.1.4. These strategies would address objectives 1, 3, 6, 7, and 8 of this plan.

b). Water quality - Protect, enhance, and restore estuarine water quality.

The MFC and DMF should continue to comment on activities (state, federal, and local permits) that may impact estuarine water quality and work with permitting agencies to minimize impacts. Additionally, the MFC and DMF should solicit and support Fishery Resource Grant (FRG) and Blue Crab Research Program (BCRP) projects that may provide information necessary for protection, management, and restoration of water quality. Water quality standards should be based on the assimilative capacity of, and impacts to, the entire system. Several plans for water quality management have recommended strategies that need to be implemented to improve water quality. A strategy should be developed and adopted by the MFC and DENR to accomplish the actions outlined in Section 10.1.2.4, and to assure that recommendations of existing and future water quality plans are addressed in a timely manner. The DENR should develop a strategy to fully support the CHPPs process with additional staff and funding. Water quality protection and restoration are essential to accomplish the goal and objectives of this plan. This strategy would address objectives 1, 3, 6, 7, and 8 of this plan.

2). Stock Protection

a). Spawning stock management - Protect the reproductive potential of blue crabs.

With increasing concerns over fluctuating blue crab landings and increasing fishing effort, there have been numerous requests to further protect the spawning stock of blue crabs in North Carolina. Blue crab recruits in any given year rely, in part, on the size of the spawning stock from which the young originated. The spawning stock includes all female crabs that survive natural and fishing mortality to reproduce. Environmental conditions (winter mortality, drought, hypoxia, hurricanes, and human development effects), diseases, predation and cannibalism are natural mortality issues of concern. Fishery independent data suggests that the size of mature females in North Carolina has been decreasing in recent years. Possible causes for the declining size of mature females are: compensatory responses (maturing at smaller sizes due to low population abundance), phenotypic plasticity (changes caused by environmental or biotic conditions), and growth overfishing (removing larger individuals from the fishery). A spawning stock-recruitment relationship for the blue crab in North Carolina has been identified. The nature of the relationship dictates a risk adverse approach to the management of the spawning stock. Implementing a seasonal maximum size for mature females could yield an increase in egg/larval production, and allow large females the opportunity to produce multiple broods over their lifetime. A seasonal (September - April) maximum size limit of 6.75 inches (with a 5 percent tolerance) for mature females is recommended, if the adjusted catch-per-unit-effort (CPUE - spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years. These actions are recommended in combination with a similar proposal for the peeler segment of the fishery.

Sanctuaries afford the greatest protection to spawners, contribute to optimum yield of this resource, and have minimal impact on the majority of fishermen. Current sanctuary boundaries need to be modified to protect spawners. In establishing new sanctuary boundaries ease of identification and enforcement must be considered. This strategy would address objectives 1, 4, 6, and 8 of this plan.

b). Peeler/soft crab harvest - Protect the reproductive potential of blue crabs.

Considerable concern has been expressed about the need to provide additional protection to the spawning stock. A seasonal (September - April) maximum size limit of 5.25 inches (with a 3 percent tolerance) for female peeler crabs is recommended, if the adjusted catch-per-unit-effort (CPUE- spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years. These actions are recommended in combination with a similar proposal for the mature female spawning stock segment of the fishery. This strategy should provide some conservation of potential spawners, while having a minimal impact on the shedder industry. Promoting educational efforts targeting harvesters/shedders on the mortality associated with the shedding of peeler crabs and peeler handling practices would help to further reduce mortality. This strategy would address objectives 1, 4, 6, 8, and 9 of this plan.

3). Wasteful or Damaging Fishing Practices

a). White line peeler harvest - Reduce mortality of white line peeler crabs.

Prohibiting or reducing the harvest of white-line peelers would minimize the harvest of "green" and white-line peelers in the peeler pot fishery, contribute to optimum yield of the resource, and have minimal impact on the majority of North Carolina's crab shedding operations. Research and crabbers, who harvest and shed their own crabs, indicate that white-line peelers when handled properly can be shed successfully with minimal mortality. Therefore, the preferred option is to prohibit the sale of white-line peelers, but allow possession by the licensee/harvester for use in the licensee's permitted shedding operation. White-line peeler crabs must be separated from pink and red-line peeler crabs where taken and placed in a separate container, with a of 5% tolerance allowed for white-line peelers in the pink/red-line peeler catch. Promoting educational efforts targeting harvesters/shedders on the mortality associated with the shedding of white-line peeler crabs and peeler handling practices would help to further reduce mortality. This strategy would address objectives 1, 2, 4, 6, 8, and 9 of this plan.

b). Ghost pots - Reduce the bycatch and mortality of blue crabs and finfish in ghost (lost) pots.

Marine Patrol should continue to document the number of abandoned pots collected during the pot clean-up period. DMF should educate fisherman and the general public about efforts to remove abandoned gear and encourage them to notify Marine Patrol of locations of said gear. The extension of the pot cleanup period by nine days (January 15 through February 7), allowing other users to retrieve ghost pots, dockside disposal for old pots, and shortening the attendance period from 7 to 5 days will reduce the number of ghost pots. To reduce mortality in ghost pots biodegradable panels will be considered for all hard and peeler crab pots, once necessary research is completed. This strategy would address objectives 1, 2, 5, 6, 7, 8, and 9 of this plan.

c). Crab pot finfish bycatch - Finfish bycatch in crab pots.

Trip Ticket data indicates that landed marketable finfish bycatch in the crab pot fishery (hard and peeler pots) accounts for less than 1% of the total landings for each species except catfish which comprises 3.6% of the total landings since 1996. Bycatch data from actively fished hard and peeler pots in the Neuse River indicates that, while flounder and other finfish species are captured in these gears, overall catch rates are low (4 organisms per trip and .007 per pot) and survival rates are high (70% hard crab pots; 99% peeler pots). These data suggest that no regulatory action is required unless a specific species stock assessment indicates that additional measures are necessary. This strategy would address objectives 6, 7, 8, and 9 of this plan.

d). Crab trawl bycatch - Minimize bycatch in the crab trawl fishery.

To minimize waste in this fishery, a 4 inch stretched mesh tailbag should be required in the western portion of Pamlico Sound including Pamlico, Pungo, Bay, and Neuse rivers. Additional data on harvest, bycatch, and economics should be collected from all trawl fisheries. This strategy would address objectives 1, 2, 4, 6, and 8 of this plan.

e). Protected Species - Crab gear interactions with endangered, threatened, and species of special concern.

With regard to bottlenose dolphin, fishermen should be educated on the potential problems of having too much free line in the water column. For sea turtle interactions with crab pots, research should be conducted on ways to minimize sea turtle damage to crab pots and the results made available to the industry. Until more information is available on the extent of sea turtle bycatch in the crab trawl fishery, it is recommended that no state action be taken on this issue. The research outlined in section 10.3.5.4 (Actions 4, 5, 6, and 7) needs to be conducted prior to the passage of any new regulations to minimize diamondback terrapin bycatch. Additionally, the goals and objectives for the conservation of diamondback terrapins in North Carolina must be clearly defined. Current information on ways to eliminate diamondback terrapin bycatch in crab pots and current distribution in North Carolina needs to be made available to crab potters. This strategy would address objectives 4, 5, 7, and 9 of this plan.

f). Channel net harvest of blue crabs

In an effort to reduce the harvest of sponge crabs, blue crab harvest from channel nets will be a limited incidental bycatch (proportion) of the shrimp harvest. The channel net proposal will be identical to the crab bycatch provisions for the shrimp trawl fishery (rule 15A NCAC 3J .0104), which provides that the weight of the crabs shall not exceed:

(A) 50 percent of the total weight of the combined crab and shrimp catch; or
(B) 300 pounds, whichever is greater.

This strategy would address objectives 2, 4 and 6 of this plan

4). Conflict

Social and economic conflicts relating to the blue crab pot and trawl fisheries.

To minimize conflicts, theft, and gear damage, address increased effort, and increase public trust utilization, the MFC needs to change the unattended pot rule from the existing 7 day period to 5 days, modify the "User Conflict" rule to resolve user conflicts on a regional basis, support the establishment of boating safety courses, and receive public comment on; opening designated long haul areas to the use of crab pots by proclamation, changing the time period when pots must be moved into designated pot areas, changing the descriptive boundaries of the designated pot areas from distance from shore to a 6 foot depth contour, and prohibiting the use of trawls in all designated pot areas modified to a 6 foot depth contour. This strategy would address objectives 5, 6, and 9 of this plan.

5). Insufficient Assessment Data

Necessary data needed to accurately assess the status of the blue crab stock are currently not available.

The MFC and DMF should prioritize research needs and implement actions to accomplish the identified research and data needs. This strategy would address objectives 1, 2, 3, 7, and 8 of this plan.

6). Public Education

Promote public education and information transfer for blue crab resource issues.

The MFC and DMF should collaborate with other agencies and groups to implement a program focused on enhancing public information and education for the blue crab resource. This program should heighten the public's awareness of the causes and nature of problems for the blue crab stock, its habitats and fisheries, and the rationale for management efforts to address these problems. A better understanding by resource users, of the blue crab's complex life history and strategies implemented by the state to regulate harvest and protect juveniles and spawning stock, is a key element in ensuring that this fishery is sustainable. This strategy would address objectives 2, 3, 5, 6, 7, 8, and 9 of this plan.

4. INTRODUCTION

4.1 LEGAL AUTHORITY FOR MANAGEMENT

Fisheries management includes all activities associated with maintenance, improvement, and utilization of the fisheries resources of the coastal area, including research, development, regulation, enhancement, and enforcement.

Many different state laws (General Statutes - G.S.) provide the necessary authority for fishery management in North Carolina. General authority for stewardship of the marine and estuarine resources by the North Carolina Department of Environment and Natural Resources (NCDENR) is provided in G.S. 113-131. The Division of Marine Fisheries (DMF) is the arm of the Department, which carries out this responsibility. Enforcement authority for DMF enforcement officers is provided by G.S. 113-136. General Statute 113-163 authorizes research and statistical programs. The North Carolina Marine Fisheries Commission (MFC) is charged to "manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources of the State of North Carolina" (G.S. 143B-289.51). The MFC can regulate fishing times, areas, fishing gear, seasons, size limits, and quantities of fish harvested and possessed (G.S. 113-182 and 143B-289.52). General Statute 143B-289.52 allows the MFC to delegate authority to implement its regulations for fisheries "which may be affected by variable conditions" to the Director of DMF by issuing public notices called "proclamations". Thus, North Carolina has a very powerful and flexible legal basis for coastal fisheries management. The General Assembly has retained for itself the authority to establish commercial fishing licenses, but has delegated to the MFC authority to establish free permits for various commercial fishing gears and activities.

The Fisheries Reform Act of 1997 (FRA 1997) establishes a process for preparation of coastal fisheries management plans in North Carolina. The FRA states: "the goal of the plans shall be to ensure the long-term viability of the State's commercially and recreationally significant species or fisheries. Each plan shall be designed to reflect fishing practices so that one plan may apply to a specific fishery, while other plans may be based on gear or geographic areas. Each plan shall:

a. Contain necessary information pertaining to the fishery or fisheries, including management goals and objectives, status of the relevant fish stocks, stock assessments for multi-year species, fishery habitat and water quality considerations consistent with Coastal Habitat Protection Plans adopted pursuant to G.S. 143B-279.8, social and economic impact of the fishery to the State, and user conflicts.

b. Recommend management actions pertaining to the fishery or fisheries.

c. Include conservation and management measures that prevent overfishing, while achieving, on a continuing basis, the optimal yield from each fishery."

Optimal yield (OY) is defined in the FRA as "The amount of fish that:

a. Will provide the greatest overall benefit to the State, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems;

b. Is prescribed on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and

c. In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in the fishery."

4.2 RECOMMENDED MANAGEMENT PROGRAM

4.2.1 Goals and objectives

The goal of the 2004 North Carolina Blue Crab FMP is to manage blue crabs in North Carolina in a manner, which conserves the stock, protects its ecological and economic value, and optimizes the long-term use of the resource. To achieve this goal, it is recommended that the following objectives be met for:

<u>Stock Protection</u>;

1. Maintain the stock of mature adult males and females at a level that maximizes reproductive potential.

2. Promote harvesting practices that minimize waste of the resource.

<u>Habitat</u>;

3. Promote the protection, restoration, and enhancement of habitats and environmental quality necessary for the conservation of the blue crab resource.

<u>Fishery Management Plan Development</u>;

4. Maintain a clear distinction between conservation goals and allocation issues.

5. Minimize conflicts among and within user groups, including non-crabbing user groups.

6. Utilize a management strategy that provides adequate resource protection, optimizes the long-term harvest and economic value, provides sufficient opportunity for recreational crabbers, and considers the needs of other user groups.

7. Identify and promote research to improve the understanding and management of the blue crab resource.

8. Maintain the blue crab fisheries as a source of income for commercial fishermen in coastal North Carolina.

<u>Public Outreach</u>;

9. Promote a program of education and public information to help the public understand the causes and nature of problems in the blue crab stock, its habitats and fisheries, and the rationale for management efforts to solve these problems.

4.2.2 Optimum yield

Optimal yield for the blue crab in North Carolina is that amount of harvest of legal blue crabs which: prevents overfishing; provides for replenishment of the stock; reduces conflicts within the blue crab fisheries; reduces conflicts between the blue crab fisheries and other water-based activities; maintains the blue crab fisheries as a major source of income for commercial fishermen in coastal North Carolina in a proportion similar to that which exists at the present time in the most efficient manner; and provides reasonable opportunities for recreational harvest of blue crabs.

Maximum sustainable yield (MSY) has been estimated by NCSU researchers (Eggleston et al. 2004) based on NCDMF trawl data from the Pamlico Sound complex and NCDMF commercial pot CPUE (landings/# NCDMF pots). Estimates of MSY (38 to 46 million pounds per year) from this stock assessment indicate that harvest might have been near or exceeding maximum sustainable yield (MSY) from 1994 - 1999. Eggleston et al. (2004) noted that a cautionary approach should be taken when interpreting biomass-based modeling results given:

1) the known limitations of surplus production models;
2) uncertainty associated with landings prior to 1994;
3) the inherent variability in CPUE data; and
4) the difficulty obtaining biologically reasonable model fits with many time series.

However, the modeling results do indicate that the blue crab stock is currently at a low biomass level, and current fishing pressure exceeds that required to produce MSY, leading to reduced yield (Eggleston et al. 2004).

MSY for the NC blue crab resource is difficult to estimate and may not be reliable, due to the crabs short life cycle and the varied and complex estuarine system in NC. The NCDMF feels that these MSY estimates are not valid due to these factors:

1) fishery-independent data sets do not allow tracking of the various life history stages and harvest data;
2) harvest and fishery-independent data between and within areas are extremely variable, both, temporally and spacially;
3) fishery-independent survey data from the Pamlico Sound complex may not be a reliable indicator of population trends in other coastal systems; and
4) environmental conditions appear to play a significant role in population variability.

Additionally, Eggleston (per comm.) noted: "Because of data and modeling limitations, these MSY estimates should be used as a guideline to the long-term potential of the fishery rather than as strict targets. Nevertheless, it should be recognized that none of the assessment results suggest that the high landings from the late 1990s would be sustainable." Until MSY can be estimated, the blue crab resource will be considered overfished when annual landings decline for five consecutive years (Figure 4.1).

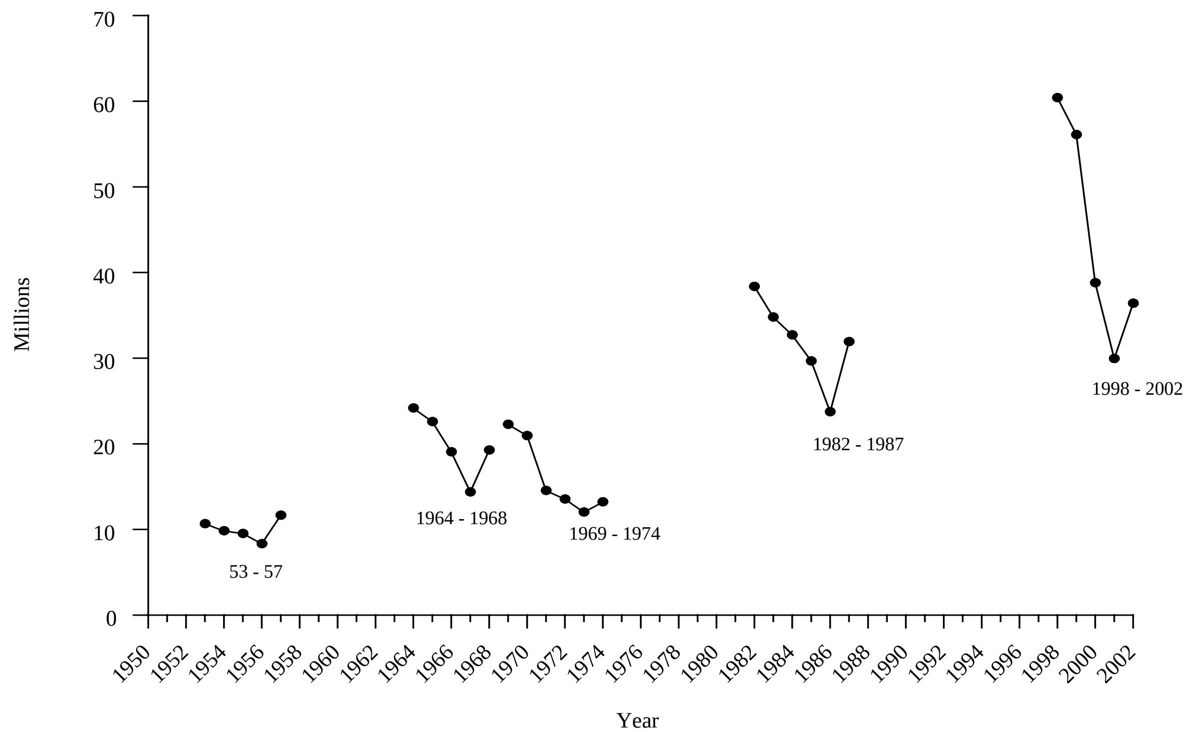

Figure 4.1. North Carolina blue crab landings, 1950 - 2002, showing historical periods of declining landings.

4.2.3 Management strategy

The goal of the 2004 North Carolina Blue Crab Fishery Management Plan (FMP) is to manage blue crabs in North Carolina in a manner, which conserves the stock, protects its ecological and economic value, and optimizes the long-term use of the resource. Plan objectives include: maintenance of the stock at a level that maximizes reproductive potential; promote harvesting practices that minimize waste; habitat protection and restoration; distinguishing between conservation goals and allocation issues; providing resource utilization for all users and conflict minimization; identifying and promoting biological, social, and economic research; maintaining the blue crab fisheries as a major source of income for commercial fishermen; and promoting education. The proposed management strategy for the blue crab fisheries in North Carolina is to 1) optimize resource utilization over the long-term, 2) minimize waste, 3) reduce conflict, and 4) promote public education on blue crab issues. The first strategy will be accomplished by protecting the spawning stock, and by protection of critical habitats. Minimization of waste will be accomplished by gear modifications, culling practices, and harvest restrictions. Conflict will be addressed through regional management. The DMF will work with other agencies and organizations to enhance public information and education.

In order to effectively accomplish these strategies, and to efficiently address the many issues outlined in this FMP, it is recommended that management should be area specific, when feasible. The current advisory structure of the MFC, Regional Advisory Committees, and the Crustacean Committee should be adequate to address area specific issues. This approach recognizes that too much management imposed from without is just as bad as too little. The state of North Carolina should allow as much flexibility as possible for fishermen to operate as they see fit. However, government has a responsibility to all citizens of the state to protect public resources. Cooperative management at the local level would allow management to be more responsive to local situations. Many of the management options discussed in Section 10 would benefit from a regional-based management approach that would allow a given strategy (e.g., conflict resolution, spawning stock management, and crab trawling) to be tailored to the needs of each area. Regional-based management was recommended by various fishermen during public meetings for the 1998 Blue Crab FMP Public Information Document (NCDMF 1998).

4.3 DEFINITION OF MANAGEMENT UNIT

The management unit includes the blue crab (Callinectes sapidus) and its fisheries in all waters of coastal North Carolina.

4.4 GENERAL PROBLEM(S) STATEMENT

Issues that should be addressed in the management of North Carolina's blue crab fishery are: 1) environmental issues; 2) stock protection; 3) wasteful or damaging fishing practices; 4) conflict; 5) insufficient assessment data, and 6) public education.

4.4.1 Environmental issues

Blue crabs rely on adequate and sufficient habitat of various types during their different life cycle stages. Loss or degradation of spawning, nursery, and molting areas and reduced deep-water habitat and crowding in shallow habitats due to low dissolved oxygen levels may have long-term impacts on crab populations. Minor or short-term habitat disruptions, such as bottom-disturbing activities (i.e., trawling, dredging, etc.) may have significant, but hard-to-measure impacts on crab populations. Specific issues, options, and potential actions are outlined in Section 10.

4.4.2 Spawning stock protection

With increasing concerns over fluctuating blue crab landings and increasing fishing effort, there have been numerous requests to further protect the spawning stock of blue crabs in North Carolina. Blue crab recruits in any given year rely, in part, on the size of the spawning stock from which the young originated. The spawning stock includes all female crabs that survive natural and fishing mortality to reproduce. Environmental conditions (winter mortality, drought, hypoxia, hurricanes, and human development effects), diseases, predation and cannibalism are natural mortality issues of concern. A spawning stock-recruitment relationship for the blue crab in North Carolina has been identified. The nature of the relationship dictates a risk adverse approach to the management of the spawning stock. Specific issues, options, and potential actions are outlined in Section 10.

4.4.3 Wasteful or damaging fishing practices

Wasteful and damaging fishing practices associated with the blue crab fishery have various and interrelated impacts on the resource and different segments of the fishery. Specific issues, options, and potential actions concerning current harvest practices are outlined in Section 10.

4.4.4 Conflict

The increase in hard and peeler crab pot numbers has resulted in more frequent and severe conflicts over fishing space between crab potters (full and part-time), other fisheries (trawlers, haul seiners, etc.), and recreational activities (swimming, fishing, boating). Conflicts may arise from damage to vessels encountering gear, and may result in fishing gear being moved, damaged, destroyed, or stolen. Also, theft of potted crabs is reputed to have increased in some areas as effort and price of the commodity has increased. Specific issues, options, and potential actions are outlined in Section 10.

4.4.5 Insufficient assessment data

Before 1995, DMF did not have a stock assessment program specifically for blue crabs, although limited information (harvest statistics, juvenile abundance) was collected through other programs. Realizing the increasing importance of the blue crab fishery to the coastal economy, crabbers petitioned the North Carolina General Assembly in 1994 to allocate funding specifically for a crab assessment project. The resulting program is focusing on the establishment of fishery-dependent and -independent databases coastwide. Specific research needs are outlined in Section 10.

4.4.6 Public education

Various agencies and groups for the most part work independently to provide educational opportunities and materials as issues arise. There is no collaborative comprehensive program among agencies and other groups to promote information transfer and exchange for blue crab resource issues. Specific issues, options, and potential actions are outlined in Section 10.

4.5 EXISTING PLANS STATUTES, AND RULES

4.5.1 Plans

There are no federal, or interstate FMP's that apply specifically to the blue crab fishery in North Carolina. In December 1998, a state FMP for blue crabs was approved for North Carolina (see Appendix 1 for a summary of actions taken). The Blue Crab FMP will be reviewed and updated at least every five years.

4.5.2 Statutes

All management authority for North Carolina's blue crab fishery is vested in the State of North Carolina. Statutes that have been applied to the crab fishery include:

- ♦ It is unlawful for any person without the authority of the owner of the equipment to take fish from said equipment. G.S. 113-268 (a)
- ♦ It is unlawful for any vessel in the navigable waters of the State to willfully, wantonly, and unnecessarily do injury to any seine, net or pot. G.S. 113-268 (b)
- ♦ It is unlawful for any person to willfully destroy or injure any buoys, markers, stakes, nets, pots, or other devices or property lawfully set out in the open waters of the state in connection with any fishing or fishery. G.S. 113-268 (c)

4.5.3 Marine Fisheries Commission Rules

Minimum Size:
Hard crab minimum size limit of 5 inches measured from tip of spike to tip of spike, except that mature females, soft, and peeler crabs are exempt. Male crabs to be used as peeler bait are exempt from the 5 inch size limit from March 1 through October 31. All crabs less than the legal size except mature females, soft, and peelers shall immediately be returned to the water from which taken. Peeler crabs shall be separated where taken and placed in a separate container. 15A NCAC 3L .0201 (a) (b).

Possession Tolerance:
10% by number in any container may be less than the minimum size limit. 15A NCAC 3L .0201 (a).

Spawning Sanctuaries:
It is unlawful to use trawls, pots, and mechanical methods for oysters or clams or take crabs with the use of commercial fishing equipment from crab spawning sanctuaries from March 1 through August 31. During the remainder of the year the Director may, by proclamation, close these areas and may impose any or all of the following restrictions: number of days, areas, means and methods which may be employed in the taking, time period, and limit the quantity. 15A NCAC 3L .0205 (a) (b) (1) (2) (3) (4) (5) and 3R .0110 (1) (2) (3) (4) (5).

Peeler and Soft Crabs:
It is unlawful to bait peeler pots, except with male blue crabs. Male blue crabs to be used as peeler bait and less than the legal size must be kept in a separate container, and may not be landed or sold. It is unlawful to possess male white line peelers from June 1 through September 1. It is unlawful to possess more than 50 blue crabs in a shedding operation without first obtaining a Blue Crab Shedding Permit from the Division of Marine Fisheries. 15A NCAC 3L .0206 (a) (b), 3O .0501, 3O .0502, 3O .0503 (c), 3O .0504, and 3P .0101.

Recreational Harvest:
Limit of 50 crabs per person per day not to exceed 100 crabs per vessel per day for non-commercial use. Vessels may be used to take blue crabs without a license if the following gears are used; seines less than 30 feet, collapsible crab traps with the largest open dimension no larger than 18 inches, a dip net having a handle not more than 8 feet in length and a hoop or frame to which the net is attached not exceeding 60 inches along the perimeter; or single bait-and-line equipment. Recreational crab pot buoys must be any shade of hot pink in color, and be no less than 5 inches in diameter and length and be engraved with the owner’s last name and initials. If a vessel is used the buoy must also be engraved with the gear owners current motorboat registration number or owner’s U.S. vessel documentation name. It is unlawful for a person to use more than one crab pot attached to the shore along privately owned land or to a privately owned pier without possessing a valid Recreational Commercial Gear License. Up to five crab pots may be used by holders of the Recreational Commercial Gear License. Peeler pots are not permitted to be used by holders of the Recreational Commercial Gear License. One multiple hook or multiple bait trotline up to 100 feet in length may be used to harvest blue crabs. Trotlines must be marked at both ends with solid buoyant buoys. Buoys must be any shade of hot pink in color, and be no less than 5 inches in diameter and length and be engraved with the owner’s last name and initials. If a vessel is used the buoy must also be engraved with the gear owners current motorboat registration number or owner’s U.S. vessel documentation name. Crab trawls are not permitted to be used by holders of the Recreational Commercial Gear License [15A NCAC 3K .0105 (a), 15A NCAC 3I .0101 (b) (1) (A) (B) (D) (E), 15A NCAC 3J .0302 (a) (b), 3J .0305 (A) (B), and 15A NCAC 3O .0302 (a) (1) (2) (3) (4) (b) (c)].

Trawls:

- ♦ The Brant Island and Piney Island military prohibited areas are closed to fishing and navigation at all times. 15A NCAC 3I .0110 (a).
- ♦ It is unlawful to use trawl nets for the taking of finfish in internal waters, except that it shall be permissible to take or possess finfish incidental to crab or shrimp trawling in accordance with the following limitations: it is unlawful to possess more than 500 pounds of finfish from December 1 through February 28 and 1,000 pounds of finfish from March 1 through November 30. The Director may close by proclamation any area to trawling for specific time periods in order to secure compliance with this rule. 15A NCAC 3J .0104 (a) (1)(2).
- ♦ It is unlawful to use trawl nets in Albemarle Sound and its tributaries. 15A NCAC 3J .0104 (b) (3)
- ♦ It is unlawful to use trawl nets from December 1 through February 28 from one hour after sunset to one hour before sunrise in portions of the Pungo, Pamlico, Bay, Neuse, and New rivers. 15A NCAC 3J .0104 (b) (5) (A) (B) (C) (D) (E).
- ♦ The Director may by proclamation, require bycatch reduction devices or codend modifications in trawl nets to reduce the catch of finfish that do not meet size limits or are unmarketable as individual foodfish by reason of size. 15A NCAC 3J .0104 (d)
- ♦ It is unlawful to use shrimp trawls for the taking of blue crabs in internal waters, except that it shall be permissible to take or possess blue crabs incidental to shrimp trawling provided that the weight of the crabs shall not exceed; 50 percent of the total weight of the combined crab and shrimp catch; or 300 pounds, whichever is greater. The Fisheries Director may, by proclamation, close any area to trawling for specific time periods in order to secure compliance with this rule. 15A NCAC 3J .0104 (f) (2) (A) (B) (3).
- ♦ It is unlawful to use nets from June 15 through August 15 in the waters of Masonboro Inlet or in the ocean within 300 yards of the beach between Masonboro Inlet and a line running 138° through the water tank on the northern end of Wrightsville Beach, a distance parallel with the beach of 4,400 yards. It is unlawful to use trawls within one-half mile of the beach between the Virginia line and Oregon Inlet. 15A NCAC 3J. 0202 (1) (2).
- ♦ From December 1 through March 31 it is unlawful to possess finfish caught incidental to shrimp and crab trawling in the Atlantic Ocean unless the weight of the combined catch of shrimp and crabs exceeds the weight of finfish; except that crab trawlers working south of Bogue Inlet may keep up to 300 pounds of kingfish, regardless of their shrimp or crab catch weight. 15A NCAC 3J .0202 (5) (a) (b)
- ♦ It is unlawful to use trawl nets upstream of the Highway 172 Bridge in New River from one hour after sunset to one hour before sunrise when opened by proclamation from August 15 through November 30. 15A NCAC 3J .0208.
- ♦ In Dare County commercial fishing gear may not be used within 750 feet of licensed fishing piers when opened to the public. Commercial fishing gear may not be used in the Atlantic Ocean off of portions of Onslow, Pender, and New Hanover counties during specified time frames. 15A NCAC 3J .0402 (a) (1) (A) (ii) (2) (A) (B) (i) (ii) (3) (A) (B) (i) (ii) (iii).
- ♦ It is unlawful to take or possess crabs aboard a vessel in internal waters except in areas and during such times as the Fisheries Director may specify by proclamation. 15A NCAC 3L .0202 (a).
- ♦ It is unlawful to take crabs with crab trawls with a stretched mesh less than 3 inches, except that the Director may, by proclamation, increase the minimum mesh length to no more than 4 inches. 15A NCAC 3L .0202 (b)
- ♦ It is unlawful to use trawls with a mesh length less than 2 inches (stretched mesh) or

with a corkline exceeding 25 feet in length for taking soft or peeler crabs. 15A NCAC 3L .0202 (c).

- ♦ It is unlawful to trawl for crabs between one hour after sunset on any Friday and one hour before sunset on the following Sunday, except in the Atlantic Ocean. 15A NCAC 3L .0202 (d) and 3J .0104 (b) (1)
- ♦ It is unlawful to use a trawl net in any primary or permanent secondary nursery area. 15A NCAC 3N .0104, 3N .0105 (a), 3R .0103 and 3R .0104.
- ♦ Special secondary nursery areas may be opened to shrimp and crab trawling from August 16 through May 14. 15A NCAC 3N .0105 (b), and 3R .0105.
- ♦ It is unlawful to use trawl nets in areas listed in 15A NCAC 3R .0106, except that certain areas may be opened to peeler trawling for single-rigged peeler trawls or double-rigged boats whose combined total headrope length does not exceed 25 feet. 15A NCAC 3R .0106.

Crab pots:

- ♦ It is unlawful to leave pots in any coastal fishing waters for more than seven consecutive days, when such pots are not being employed in fishing operations, except upon a timely and sufficient showing of hardship. 15A NCAC 3I .0105 (b) (1) (2) (A) (B) (3) (c).
- ♦ All pots shall be removed from internal waters from January 24 through February 7. Areas may be reopened, by proclamation, to the use of pots after January 28 if it is determined that such areas are free of pots. 15A NCAC 3J .0301 (a) (1)
- ♦ From May 1 through October 31 the use of crab pots is restricted in certain areas. Pots attached to shore or a pier are exempt from this regulation.
15A NCAC 3J .0301 (a) (2) and 3R .0107
- ♦ It is unlawful to use pots in any navigation channel maintained and marked by State or Federal agencies. 15A NCAC 3J .0301 (b) (1)
- ♦ It is unlawful to use pots in any turning basin maintained and marked by the North Carolina Ferry Division. 15A NCAC 3J .0301 (b) (2)
- ♦ Pots must be marked with a solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. Buoys may be any color except yellow or hot pink. The pot owner's N.C. motorboat registration number, or U.S. vessel documentation name, or last name and initials shall be engraved in the buoy, or on a metal or plastic tag attached to the buoy. Pots attached to shore or a pier are exempt from this regulation. 15A NCAC 3J .0301(c) (1) (2) (3) (d)
- ♦ It is unlawful to use crab pots in coastal waters unless each pot contains 2 escape rings that are at least 2 5/16 inches inside diameter and located in opposite outside panels of the upper chamber of the pot. Peeler pots with a mesh size less than 1 1/2 inches shall be exempt from the escape ring rule. 15A NCAC 3J .0301 (g)
- ♦ It is unlawful to use more than 150 pots per vessel in the Newport River.15A NCAC 3J .0301(h)
- ♦ It is unlawful to remove crab pots from the water or remove crabs from pots between one hour after sunset and one hour before sunrise. 15A NCAC 3J .0301(I)
- ♦ The Fisheries Director may, with the prior consent of the Marine Fisheries Commission, by proclamation close any area to the use of pots in order to resolve user conflict. 15A NCAC 3J .0301(j).
- ♦ It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating. 15A NCAC 3J .0301(k).

Crab dredging:

- ♦ It is unlawful to use or have aboard a vessel any dredge weighing more than 100 lb.
15A NCAC 3J .0303 (a).

- ♦ It is unlawful to use more than one dredge per vessel to take crabs or to use any dredges between sunset and sunrise. 15A NCAC 3J .0303 (b).
- ♦ It is unlawful to take crabs with dredges except from January 1 through March 1 in portions of Pamlico Sound. 15A NCAC 3L .0203 (a) (1) and 3R .0109.
- ♦ Crabs may be taken incidental to lawful oyster dredging provided the weight of the crabs shall not exceed 50% of the total weight of the combined oyster and crab catch; or 500 lb, whichever is less. 15A NCAC 3L .0203 (a) (2) (A) (B).
- ♦ It is unlawful to take crabs between sunset and sunrise and between sunset on any Saturday and sunrise on the following Monday, except in the Atlantic Ocean. 15A NCAC 3L .0203 (b).

Miscellaneous

- ♦ It is unlawful to possess, sell, or purchase fish under four inches in length except for use as bait in the crab pot fishery in North Carolina. 15A NCAC 3M .0103 (1).
- ♦ It is unlawful to set a trotline within 100 yards of a pound net from February 1 through May 31 in the Chowan River and its tributaries. 15A NCAC 3J .0203 (5).

4.5.4 North Carolina Wildlife Commission Rules for Blue Crabs

Nongame Fish:

- ♦ Any fish not classified as a game fish is considered a nongame fish when found in inland fishing waters (blue crabs are nongame fish).

Sale of Nongame Fish:

- ♦ When nongame fish are taken for the purpose of sale by means other than hook and line or by grabbling, a special fishing device license is required.

Special Fishing Devices:

- ♦ Special fishing devices, which may be licensed for the taking of nongame fishes, include the following: bow and arrow (except crossbows), seines, cast nets, gill nets, dip nets, bow nets, reels, gigs, spear guns, baskets, fish pots, eel pots and traps (including automobile tires).
- ♦ A noncommercial special device license is valid when no more than three special devices are used.
- ♦ A commercial special device license is required when four or more special devices are used.

Term and Use of Special Device Licenses:

- ♦ The license is valid during a license year (12 months from date of purchase).
- ♦ Each user of a special device must have his own license in possession, except that a bow net or dip net may be used by another person who has the owner's license in his possession.

Manner of Taking Nongame Fish:

- ♦ Nongame fish may be taken by hook and line or by grabbling; no fish may be taken by snagging. Special devices defined herein may be used to take nongame fish with proper license (see "Collecting Nongame Fish for Bait" and "Special Devices").
- ♦ Crab pots are a special fishing device that may not be used in inland fishing waters or in designated waterfowl impoundments located on game lands. Exception: Persons owning property adjacent to the inland fishing waters of coastal rivers and their

tributaries may set two crab pots attached to their property and a special device license is not required.

- Blue crabs taken by hook and line (other than set-hooks) from inland fishing waters or in designated waterfowl impoundments located on game lands must have a minimum carapace with 5 inches (point to point).

Using Trotlines and Set-hooks:

- It is unlawful to use live bait with trotlines, set-hooks or jug-hooks.
- Trotlines must be set parallel to the nearest shore in impounded waters.
- Each trotline and set-hook (except jug-hooks) shall have attached the name and address of the user legibly inscribed.
- Each trotline shall be conspicuously marked at each end, and each set-hook shall be conspicuously marked at one end with a prominent flag or floating object.
- Metal cans and glass containers cannot be used as markers.
- Trotlines (including throw-lines) must be fished daily, and all fish must be removed daily.
- Untended trotlines and set-hooks, as evidenced by the absence of bait, may be removed from the water by wildlife enforcement officers.

4.5.5 Other States Blue Crab Rules and Regulations

See Appendix 2 for a list of rules and regulations for other blue crab producing states.

4.5.6 Federal Regulations

Pursuant to Title 33 United States Code Section 3, the United States Army Corps of Engineers has adopted regulations, which restrict access to, and activities within certain areas of coastal and inland fishing waters. Federal Rules codified at 33 CFR 334.410 through 334.450 designate prohibited and restricted military areas, including locations within North Carolina coastal fishing waters, and specify activities allowed in these areas.

5. STATUS OF STOCK

5.1 GENERAL LIFE HISTORY

The blue crab (*Callinectes sapidus)* ranges from Nova Scotia, Canada, southward throughout the Gulf of Mexico and along most of the Atlantic coast of South America. Its scientific name translates to “savory beautiful swimmer”. Blue crabs are most common in the United States from Long Island to Mexico. Blue crabs are harvested commercially and recreationally throughout their range. The Chesapeake Bay, North Carolina, and Louisiana support the largest blue crab fisheries.

The preferred habitat of blue crabs is tidal marsh estuaries characterized by soft mud substrate and waters of moderate salinity. Blue crabs mature at approximately 12 to 18 months of age. Mating takes place in brackish areas of the estuary, while spawning occurs in high-salinity waters in the vicinity of ocean inlets. Spawning usually occurs within two months after mating in the spring or summer. However, females that mate in the fall usually delay spawning until the following spring. Peak spawning periods are April - June and August - September. The number of eggs per spawn ranges from 700,000 to 8,000,000. Females may spawn two or three times. Eggs hatch in approximately 15 days, and the first stage larvae (zoeae) are then carried offshore where they undergo seven to eight developmental stages (Costlow et al. 1959; Costlow and Bookhout 1959). Following the zoeal stages, a megalopal stage occurs which lasts from 6 to 20 days (Costlow and Bookhout 1959). The exact mechanism responsible for megalopae ingress in North Carolina is unclear, but is possibly the result of wind-driven onshore currents.

Year-class strength is initially determined by the number of postlarvae that enter the estuary and is greatly influenced by weather and current conditions encountered by planktonic crab larvae on the continental shelf. Tang (1985) and Ulanowicz et al. (1982) suggested that annual fluctuations in blue crab populations are the result of environmentally induced variations in recruitment.

Larval recruitment in North Carolina's inshore waters near the northern inlets have been correlated with the locations proximity to inlets, alongshore northerly winds, and hours of dark flood tide (Eggleston et al. 1998). Larval settlement peaks and magnitude at inshore locations of the Albemarle-Pamlico estuarine system were associated with the direction and magnitude of storm winds during a short period surrounding the passage of tropical cyclones (storms).

Juvenile blue crabs are widely distributed throughout estuaries. Although salinity influences distribution, factors such as bottom type and food availability also play a role in determining distributional patterns of juveniles. Juveniles preferentially use shallow water areas, including structural habitats such as seagrass, salt marsh, detritus and oyster shell (Eggleston unpublished data; Etherington and Eggleston 2000; Heck and Thomin 1984; Minello and Webb 1997; Orth and van Montfrans 1987; Pardieck et al. 1999; Posey et al. 1999; and Ruiz et al. 1993). Adults show a differential distribution by sex and salinity, with mature females commonly found in higher-salinity waters (> 10 ppt) and males preferring lower salinities (3 to 15 ppt). The size of mature females varies considerably (2.2-7.8 in).

The average life span is about three years with a five to eight year maximum. Age determination of crustaceans is difficult because, unlike finfish, they lack permanent hard structures. Often modal analysis of length frequency data is used in lieu of accurate age information for estimating population dynamics. Ju et al. (1999 and 2001), have focused on biochemical measures for ageing with the use of cellular oxidation products termed “lipofuscins” (LF) which accumulate as stable fluorescent by-products of cellular metabolism. Based on these results, the use of extractable LF appears a viable alternative to size-based (CW) age estimation, particularly where growth rates vary annually and regionally. For moderately large sample sizes, crabs can be accurately assigned to cohorts using LF measures, permitting a significantly improved knowledge of population dynamics and life history (Ju et al. 2001).

The blue crab has a role as both predator and prey in the ecosystem. Juvenile and larval crabs are found in the diet of many fishes, including striped bass (Manooch 1973; Speir 2001), red drum (Bass and Avault 1975; Speir 2001), Atlantic croaker (Overstreet and Heard 1978), and American eel (Wenner and Musick 1975). The blue crab is an important predator on oyster spat and juvenile hard clams (Williams 1984). The diet of blue crabs also includes fish (alive or dead), aquatic vegetation (Williams 1984), crustaceans, and annelid worms. Mansour and Lipcius (1993) suggested that, during periods of high crab abundance or low alternative prey abundance, cannibalism may serve as a self-regulating population control.

For additional information pertaining to other systems, see Guillory et al. 2001, and Chesapeake Bay Program 1997.

5.2 STOCK STATUS

The NC Division of Marine Fisheries lists the stock status for the blue crab as: “Concern”. Significantly reduced landings of “hard” blue crabs during 2000 - 2002, following the historically record high landings observed during 1996 - 1999, has caused increased industry concern for the health of the resource and fishery. Overall landings for 2002 increased slightly from the 2001 levels. “Peeler/soft crab” landings for 2002 were the lowest since 1994. The majority of the 5 million pound increase from 2001 to 2002 came from the Albemarle area, which includes Albemarle and Currituck sounds, and Alligator, Pasquotank, Perquimans, Roanoke, and Chowan rivers. A significant increase in crab pot effort was also evident in the Albemarle area. During 2002, many areas (i.e., Pamlico, Core, Bogue, Stump, and Topsail sounds; Neuse, Bay, and Newport rivers) yielded the lowest landings on record for the period from 1994-2002. Hard crab pot effort was also at a record low in the Pamlico, Core, and Croatan sounds, and in the Pamlico, Neuse, Bay, and Newport rivers. Although overall landings and/or trips were down in the noted areas for 2002, catch-per-trip (CPUE) increased from 2001 to 2002 in Pamlico, Core, Croatan, Roanoke, and Masonboro sounds; Neuse, Bay, Newport, White Oak, and Cape Fear rivers, Inland Waterway, and Lockwood Folly. Landings and effort in the Southern coastal area have remained relatively stable throughout the 1994-2002 period.

Average commercial landings for the ten year period (1993 - 2002) was 49,691,750 lb, and was valued at $34,789,064 (includes hard, soft, and peeler crab landings and value). See Section 6 for more information on blue crab landings, value, and fishing effort.

Juvenile abundance indices (JAI) have averaged 7.29 crabs (less than 60 mm) per minute for the 1987 - 1998 period (unvalidated). JAI’s for 2001 and 2002 were 7.6 and 9.4, respectively. Despite variability in abundance, there is no general downward or upward trend in recruitment.

See attached Blue Crab Stock Assessment (Appendix 20) for an in depth analysis of fishery dependent and independent data (Eggleston et al. 2004).

6. STATUS OF FISHERIES

6.1 COMMERCIAL

The blue crab supports North Carolina's most valuable commercial fishery in terms of total landings, value, processing, participation, employment, and the amount of harvest gear used (Henry and McKenna 1998). During the period 1950 – 1993, North Carolina ranked 3rd among blue crab producing states, accounting for 13% of the total blue crab harvest (Figure 6.1). However, over the last nine years (1994-2002) North Carolina has been the top blue crab producing state in the country accounting for over 24% of the total harvest (Figure 6.2; Table 6.1).

Commercial blue crab landings in North Carolina have averaged 26 million pounds (M lb) over the last 53 years, 1950 - 2002 (Figure 6.3). The major increases in landings noted during 1978 and 1994 were, in part, a function of improved data collection. The National Marine Fisheries Service (NMFS) collected commercial landings statistics in North Carolina from the 1880's until 1978. In 1978, the North Carolina Division of Marine Fisheries (NCDMF) augmented (6 port agents vs. 1 NMFS agent) landings collection under the NMFS/ North Carolina Cooperative Statistics Program. Both programs were based entirely on voluntary reporting. In 1994, NCDMF implemented a mandatory Trip Ticket Program, which is a landings information record keeping system for each commercial harvest trip. During 1994, 131 seafood dealers, who had not previously reported hard blue crab landings under the voluntary collection programs, reported approximately 14 M lb (26% of the total landings). Great caution must be used in comparing landings from the different periods because of the different collection methods and the precision of these methods. Additionally, since the inception of the Trip Ticket Program in 1994, care must be used in the interpretation of landings assigned to a specific gear and waterbody. Up to three gears and one waterbody may be reported on an individual trip ticket. On tickets with more than one gear, assignment of landings to a specific gear is a judgment call. Hence, for the gear and trips discussion in this section, only trip tickets with one gear listed are used. For blue crabs, approximately 99.2% of the total landings were reported on trip tickets with a single gear type listed. For overall landings and landings by waterbody, all reported blue crab landings are used regardless of the number of gears reported. While pots may be set in a number of waterbodies (i.e., Pamlico River and Pamlico Sound), the fisherman is supposed to report the waterbody where the majority of the catch occurred. This method might lead to over/under reporting of landings from certain waters, however there is no way to correct for this and data presented in this report shows landings as recorded. Furthermore, commercial landings data should be viewed as only a general indicator of fishing trends since they are influenced by market demand, price, fishing effort, weather, availability of alternate species, regulations, data collection techniques, and stock abundance. During the time periods of 1950 - 1977, 1978 - 1993, and 1994 - 2002 blue crab landings averaged 14, 34, and 50 M lb respectively. All three time periods had at least one, three to four year period of declining catches; 1953 – 1956, 1964 – 1967, 1969 – 1973, 1982 – 1986, and 1998 – 2001 (Figure 6.3). The percent yearly change in total crab landings is shown in Figure 6.4.

Blue crabs are divided into three main market categories; hard, peeler, and soft crabs. Average North Carolina hard crab landings since 1994 are 49 M lb with an average dockside value of $33 million. Peeler crab landings averaged 0.9 M lb and $1.7 million, while soft crabs had annual average landings of 0.7 M lb with a dockside value of $2.6 million during the same time (1994 – 2002 DMF Trip Ticket data; Table 6.2).

Since 1994, blue crabs have been landed from 28 waterbodies in North Carolina [Atlantic ocean has 5 sub-areas but is only counted as 1 waterbody in this report (NCDMF Trip Ticket Program, Table 6.3 and Figure 6.5)]. Pamlico and Albemarle sounds are the two largest producers of blue crabs accounting for over 53% of the total landings and value (Figure 6.6; Tables 6.3 and 6.4).

Blue crabs are harvested every month of the year, however 88% of the crabs are harvested from May through October (Table 6.5). The crab pot and crab trawl are the major gears used in the directed crab fisheries. Blue crabs are also caught as bycatch with other types of gear (Table 6.6). Further breakdown of gears, areas, and seasons will be discussed with respect to the various market categories and their fisheries.

6.1.1 Hard crab fishery

Hard crabs account for 97% of the total blue crab harvest. Since 1994, the annual reported landings of hard crabs have averaged 48.8 M lb (Table 6.2). While hard crab landings were the highest on record during this nine year period, the overall landings trend for this time is down (Figure 6.7). Annual landings ranged from 65.7 M lb in 1996 to 29.9 M lb in 2001 (Table 6.2). Eighty-eight percent of the hard crabs landed are caught during the six month period May through October (Table 6.7). Generally, the correlation between monthly landings and total landings is low January (R=0.14) through May (R=0.43), increases in June (R=0.82) and July (R=0.98), and then declines from August (R=0.85) through December [R=0.69 (Figure 6.8; Table 6.7)]. Hard crabs have been landed from 28 waterbodies in North Carolina (Table 6.8). The Pamlico and Albemarle sounds are the two largest producers of hard crabs accounting for 53% of the total harvest. These two areas land on average 13.3 and 12.8 M lb of hard crabs, respectively each year. As is the case with statewide landings, there has been much variation of landings in individual waters (Table 6.8). To examine these trends, waterbodies were grouped into five areas based on geographic proximity and similarity in landing trends (Table 6.9). Overall, the Pamlico Area contributes 59% to the total hard crab harvest (Table 6.10). This is followed by the Albemarle (34%), Core (4%), Southern (3%), and Ocean (<1%) areas. Hard crab landings in the Pamlico and Core areas show a strong correlation to each other and total landings (Table 6.11; Figure 6.9).

The crab pot was developed in the Chesapeake Bay in 1928 (Van Engel 1962). The first reported landings from crab pots in North Carolina were in 1953. Crab pots accounted for 30% of the hard blue crab landings from 1953 through 1962. During the remainder of the 1960's, the contribution of this gear to total hard crab landings ranged from 28% to 62% and averaged 46%. In the 1970's, crab pot harvest averaged 75% of the total hard crab landings and ranged from 63% to 85%. From 1980 to 1993, the contribution of pots to the total harvest ranged from 82% to 97% and averaged 91%. Since 1994, the crab pot has contributed, on average, 95% to the total hard crab harvest (Table 6.12).

The peak months for crab pot landings are May through October, which account for 90% of the total landings [Table 6.13 (DMF Trip Ticket data, 1994-2002)]. The major waterbodies for pot-caught hard crabs from 1994 through 2002 were Albemarle Sound (27%), Pamlico Sound (27%), and Pamlico (12%), Neuse (7%), and Bay (5%) rivers (Table 6.14). In terms of value, hard crab landings from the crab pot fishery have an average annual dockside value of $31 million. Albemarle Sound accounts for 30% of the value, followed by Pamlico Sound (24%), Pamlico River (12%) and the Neuse River [7% (Table 6.15)]. The Pamlico area accounts for 57% of the total hard crab landings from crab pots and 55% of the value (Tables 6.9, 6.16, and 6.17).

The longest running record of effort in the crab pot fishery comes from annual gear surveys, which document the reported number of pots. Reported pot use has increased from 1,200 in 1953 to over 1 million in 2002 (Figure 6.10). The spikes in reported pot numbers for 1995, 1996, and 1997 are most likely a result of early effort control meetings. During these meetings various pot limits and limited entry options were examined with limits based on historic reported pot use, hence the spikes in reported pot numbers. These data are useful for showing long term trends in catch per unit effort [CPUE (CPUE defined as total hard crab landings from crab pots/total number of reported crab pots)]. From 1953 through 1973, CPUE's fluctuated without trend. Once pot numbers started to increase dramatically in the 1970's, CPUE's stabilized for a couple of years. Since 1982, there has been an inverse relationship between reported pots and CPUE (Figure 6.11). In 1994, the NCDMF initiated a Trip Ticket Program which documents effort in terms of trips, in addition to catch. On average, there are 94,717 annual single gear trips with hard crab landings from crab pots (1994-2002). Pamlico Sound accounts for 24% of the crab pot trips, followed by Albemarle Sound (21%), and the Pamlico (15%), Neuse (8%), and Pungo rivers [4% (Table 6.18)]. Although Pamlico Sound accounts for the largest percentage of trips (Table 6.18), it ranks 4th in annual CPUE (538 pounds/trip) behind Albemarle Sound (648 pounds/trip), Alligator River (621 pounds/trip), and Currituck Sound [559 pounds/trip (Table 6.19)]. Annual CPUE estimates from 1994 through 1999 showed an upward trend; however, due to poor years in 2000 and 2001, the overall trend is down (Figure 6.12 and Table 6.19). As indicated by waterbody totals, the Pamlico area accounts for 61% of the trips, but ranks 2nd in CPUE (455 pounds/trip) behind the Albemarle area [630 pounds/trip (Tables 6.20 and 6.21; Figure 6.13)]. The average monthly distribution of crab pot trips is bell shaped, trips are lowest in January and February, increasing through July and then declining through December (Table 6.22 and Figure 6.14). Monthly total CPUE (pounds/trip) estimates show a slight increase in February compared to January, a two month decline in March and April, followed by significant increase from May through October, then slowly declining in November and December (Table 6.23 and Figure 6.14).

In 1996, the Trip Ticket Program (TTP) started to collect data on the number of pots fished during each trip. Data collected in 1996 is deemed unusable due to the large amount of null and erroneous entries. The quality of the data has improved in recent years. In 1997, 42% of the trips did not report any pot number, while in 2001 the number of non-reports was 8%. Additionally, in 1997 only 53% of the fishermen showed more than one value for pots fished on their trip tickets during the entire year, while in 2001 90% of the fishermen showed more than one value. While there are still erroneous data points in this data set (i.e., fishermen reporting they fish 8,000 pots a day), these numbers can be filtered out. This filtering is accomplished by using annual and monthly values collected in a fishery dependent (FD) sampling program that started in 1995. In this program, NCDMF employees intercept fishermen at the point of landing and collect data on the number of pots fished, soak time, landings by market grade, waterbody fished, and size and sex data on crabs. Data collected in this fishery dependent program shows a strong correlation (R>.90 in all cases) to trip ticket data, in terms of pounds per trip, the number of pots fished per trip, and pounds/per pot fished when grouped by area (Figure 6.15). Based on data from the fishery dependent program, an upper (700 pots fished per day) and lower limit (>=10 pots fished per day) were used to filter out potentially erroneous Trip Ticket data. This results in 13,041 Trip Ticket data points being omitted from the analysis. For pounds per pot estimates, only an upper limit of 15 pounds per pot was used (i.e., values greater than this were omitted). This filter resulted in an additional 166 samples being dropped from the data set (600 trips with >15lbs/pot were filtered with the trips fishing <10 pots). Table 6.24 shows the number of trip tickets with effort data (pots fished) and the number of filtered trips for each waterbody (Table 6.18 shows yearly single gear trips by waterbody). Finer estimates of fishing effort result in data that is more realistic (less biased and more precise) with regard to landing trends (Figure 6.15) and allow for better interpretation of these trends. For example, in 1999 total crab pot landings decreased by 5% and trips by 11% from 1998 values, while the various CPUE estimates either decreased (pounds/total pots reported 26%), or increased (6% pounds/trip, and 6% pounds/pots fished). Although total landings and trips in 1999 were lower than 1998 values, the percent difference was only -2% and -5% respectively, from January through August. The decline in September total landings (-31%) and trips (-38%) was most likely a function of hurricanes Dennis and Floyd (heavy unprecedented rain and subsequent flooding pushed crabs from the rivers and sounds to the Outer Banks and beyond). The increase in pounds/pot (6%) for 1999 over 1998 values is a function of record CPUE estimates for September and October (3 pounds/pot) during which time fishermen fishing along the Outer Banks were the recipients of crabs displaced from other areas by hurricane flood waters.

Given the high correlation (R=.99) between CPUE estimates from the fishery dependent data for pounds/pots fished and pounds/pots fished/soaktime (Figure 6.15), only the first estimate will be discussed with regard to Trip Ticket data. Overall there is a strong negative correlation (R=-0.74) between the number of pots fished and CPUE estimates based on pounds/pots fished. Eight of the top 10 waterbodies in terms of pounds/pots fished are located south of Core Sound (Table 6.25). These same waterbodies have the lowest number of pots fished per trip (Table 6.26). The breakdown by area tracks this trend with the South having the highest average CPUE (pounds/pots fished) at 2.19, followed by Core (2.01), Ocean (1.82), Albemarle (1.63) and the Pamlico areas [1.43 (Table 6.27)]. The average number of pots fished per trip is highest in the Albemarle area (326 pots per trip), followed by the Pamlico (281), Core (206), South (127), and Ocean (43) areas (Table 6.28). The highest average monthly CPUE's (pounds/pots fished) occur from September through December (Table 6.29; Figure 6.16). On average, the monthly number of pots fished per trip increases steadily from January through July and declines from August through December (Table 6.30; Figure 6.16).

Prior to 1964, blue crab landings by trawls were not separated by gear type (i.e., crab, shrimp, and fish trawl catches of crabs were lumped under one heading, "trawls"). From 1950 to 1963, the percent contribution of trawl-caught hard crabs to the total hard crab catch averaged 19% (Figure 6.17). During 1966 to 1969, the contribution of crab-trawl-caught hard crabs to the total harvest reached its peak (37%-50%). From 1970 to 1980, the percent of crab trawl landings ranged from 7% to 23%. The percent contribution of hard crabs landed by crab trawlers steadily declined from 16% in 1981 to 4% in 1993. Since 1994, the average contribution of this gear to the total hard crab landings has been 4% (Table 6.12).

Hard crab landings from crab trawls have been reported from 22 areas with average annual landings of 1.8 million pounds [Table 6.31 (DMF Trip Ticket data 1994-2002)]. Pamlico Sound accounts for 47% of all hard crabs landed by crab trawls and 24% of all trips landing hard crabs (Table 6.32). Other areas with significant hard crab landings from crab trawl are Pamlico (17%), Neuse (9%), and Pungo (9%) rivers (Table 6.31). Pamlico Sound has the highest CPUE (1,212 pounds per trip) for hard crabs followed by Bay River (653 pounds), Croatan Sound (610 pounds), and the Pamlico River [458 pounds per trip (Table 6.33)]. Hard crab landings are reported from every month with the highest percentage occurring in March (13%) and November [15% (Table 6.34)]. Fifty-eight percent of all crab trawl trips occur during March, April, May, and June (Table 6.35). November and December have the highest CPUE (catch per trip) for hard crabs, 1,602 and 1,502 pounds respectively (Table 6.36).

Other gears with reported commercial hard crab landings are gill nets (float, sink, drift, and runaround), pound nets, trotlines, shrimp trawls, skimmer trawls, eel pots, bull rakes, fish pots, channel nets, fyke nets, long haul seine, beach seine, hand tongs, hand rakes, crab dredge, oyster dredge, clam trawls, rod-n-reel, and by hand (Table 6.12). Combined, these gears contribute less than 1% to the total hard crab harvest.

6.1.2 Peeler and soft crab fishery

Recent developments in the peeler/soft crab fishery, notably on-shore shedding systems and the peeler pot, have promoted steady growth in landings and value since the mid 1980's (Table 6.37). Peeler crabs account for 2% of the total crab landings (pounds) and 5% of the total value of all blue crab landings (Table 6.2). Peeler and soft crab landings are usually reported by numbers. The Trip Ticket Program conversion of numbers to pounds for peeler and soft crabs is 0.33 (i.e., three peeler/soft crabs equal one pound). Since 1994, annual landings of peeler crabs have averaged 913,667 pounds with an average dockside value of $1.7 million (Table 6.2). Soft crabs account for 1% of the landings and 7% of the value of all crabs landed. Annual landings of soft crabs have averaged 662,786 pounds and $2.6 million since 1994 (Table 6.2). Landings can either be reported at the peeler or soft crab stage, which makes trends difficult to interpret. Hence, the two grades will be combined into a single category (shedders) for the remainder of this section.

From 1950 to 1993, shedder landings were significantly correlated ($R=0.46$, $P<0.002$) to hard crab landings. Since 1994, this relationship is inverse, although not significant ($R=-0.46$; $P<0.21$). However, if 2002 landings are not included in the calculation a significant negative correlation ($R=-0.72$; $P<0.40$) is seen. An early warm spring in 2002 prompted shedders to recruit into the fishery in April. Many fishermen did not have their gear in the water and missed a portion of the harvest. Traditionally, the peak month for shedder landings is May (50%), followed by June (18%), August (10%), and April [10% (Table 6.38)]. In 2002, 33% of the shedders were harvested in April and 26% in May. The change in correlation from positive (pre 1993) to negative (post 1993) reflects changes in the fishery from a bycatch (hard crab pot) to a directed fishery (peeler pot).

Pots (hard and peeler) account for 98% of shedder landings (Table 6.39). The percent contribution of hard crab pots to total shedder landings was 98% in 1994 and 1995, while in 2002 this gear contributed 60% to the total. The peeler pot contribution to the shedder harvest has increased from 4% in 1996 (first year landings for this gear were collected) to 39% in 2002. Trawls (crab, shrimp, and skimmer) account for 1.52% of the landings. Although the peeler trawl is defined by regulation [15A NCAC 3L .0202 (c)] landings for this gear are lumped with crab trawl landings. Of the three trawl gears with reported landings, crab trawls account for 1% of the total, shrimp trawls 0.4% and skimmers 0.03% (Table 6.39). Shedder landings have been reported from 16 other gears whose combined landings are less than 0.5% of the total (Table 6.39). Monthly shedder landings from pots follow overall trends with peak landings occurring in May, and June (Table 6.40). The peak month for shedder landings from crab trawls is March (32%). April accounts for 20% of the crab trawl landings, followed by May (19%) and June [16% (Table 6.41)]. Forth-five percent of the shedders landed by shrimp trawls are captured in August. July contributes 29% to the total shrimp trawl harvest, while June and September account for 11% and 8%, respectively. Ninety-three percent of the shedders harvested by skimmer trawls are taken in March and April (Table 6.41).

Albemarle Sound is the main producer of shedders (27%) with average annual landings of 425,498 pounds (Table 6.42). This is followed by Pamlico (21%), Roanoke (18%), and Croatan (12%) sounds. Although Roanoke Sound ranks 3rd in total shedder landings it ranks 2nd behind Albemarle Sound in value (Table 6.43). The Pamlico Area accounts for 59% of the shedder landings and 58% of the value (Tables 6.44, 6.45, and 6.9).

Starting in July 2000, all individuals shedding more than 50 blue crabs were required to get an annual blue crab shedding permit. This purpose of this free permit is to obtain information on the number of participants and type of systems being used in this fishery. Forty percent of the shedding operations are located in Dare County (Table 6.46). There are three main types of shedding systems used in North Carolina: flow-through, closed, and floating. The flow-through and closed systems are land based, while a floating system is water based. Flow-through systems are commonly used in operations, which are located near a natural supply of water. Water is pumped into the tanks, passes through the system and is returned to the source. A closed system involves the recirculation of water through tanks and filters. These systems are used in areas were it is impractical, due to distance or water quality, to use a natural water supply. The tanks used in flow-through and closed systems are generally, 4' wide by 8' long by 9 ¾" high and are made of either plywood, fiberglass, or polypropylene. Floating systems are located in shallow coves or bays, which are protected from excessive wind and wave action. Traditionally these floats are 12' long, 3 ½' wide and 1 ½' high. Floats are the oldest systems in use, dating back to the early part of the 20th century. Annually, approximately 233 shedding operations used flow-through systems making this the major type of system being used in North Carolina. On average, there are 5,968 flow-through shedding tanks being used annually (Table 6.47). Sixty-one percent of the flow-through tanks are located in Dare County. The number of tanks in an operation ranges from 1 to 500 with an overall average of 26 tanks per operation (Figure 6.18). Closed systems are the second most abundant shedding system used in North Carolina with an average of 1,131 tanks being used by 96 shedding operations (Table 6.47). Carteret County has 19% of the closed systems, followed by Pamlico (13%), and Hyde (11%) counties. The average number of tanks in a closed system is 11 and range in size from 1 to 78 tanks (Figure 6.19). On average, 92 floating shedders are used annually in North Carolina, by 21 fishermen (Table 6.47). Sixty-three percent are used in Dare County, followed by Carteret (22%), and Currituck (14%) counties. Operations range in size from 1 to 20 floats with an overall average of 5 (Figure 6.20). Sixty-eight percent of the shedding operations catch their own peeler crabs, 9% buy from other fishermen, and 23% do both (Table 6.48).

6.2 RECREATIONAL

Blue crabs are harvested recreationally by a variety of means. These include crab pots (rigid and collapsible), trawls (crab and shrimp), hand lines, and dip nets. Prior to July 1999, no license was required to harvest crabs recreationally unless a vessel was used. Starting July 1, 1999, anyone wishing to harvest blue crabs recreationally with commercial gear is required to purchase a Recreational Commercial Gear License (RCGL). Harvest methods exempt from this license are collapsible crab traps, cast nets, dip nets, and seines (less than 30 feet). Additionally, one pot per person may be attached to the shore along privately owned land or to a privately owned pier without possessing a valid RCGL. The bag limit on recreationally caught crabs is 50 per person per day, not to exceed 100 per vessel.

In 2001-2002, a survey was conducted to determine the 2001 harvest of blue crabs from RCGL holders (Nobles et al. 2002). The total estimated blue crab catch from RCGL holders in 2001 was 118,050 pounds. In this survey, 23.5% of the surveyed RCGL holders indicated that they targeted blue crabs. Fifty percent of all crabs were harvested along the Intracoastal Waterway, between Pamlico Sound and the Cape Fear River (Nobles et al. 2002).

A RCGL survey conducted in 2002 by the NCDMF indicated that blue crabs were the second most abundant species landed (all gears) and accounted for 13% (133,421 pounds) of the total poundage (1,016,319 pounds) caught by RCGL holders (NCDMF 2003). The Pamlico (33%), Northern (32%), and Central (21%) areas had more RCGL blue crab harvest than the southern area (14%). The peak months for blue crab harvest from crab pots were July (20%), May (19%), June (17%), and August (17%). Of the RCGL holders using crab pots, 8% used one, 18% used 2, 13% used 3, 15% used 4, 45% used 5, and 1% used 6 or more (according to rule 3O .0302 (3) the maximum number of pots that RCGL holders can use is 5). For RCGL holders using crab pots in 2002, 25,996 trips were taken. Total blue crab harvest from this gear was 117,041 pounds. The average catch per trip for RCGL fishermen using crab pots was 4.5 pounds/trip. Other RCGL gears with blue crab landings were large mesh gill nets (310 pounds), small mesh gill nets (170 pounds), shrimp trawls (15,709 pounds), fish pots (34 pounds), and trotline (156 pounds).

Estimated blue crab harvest from RCGL holders was less than 0.05% of the total blue crab commercial harvest for 2001, and 2002. While the harvest of exempted shore and pier based pots, and other non-commercial gear is unknown, it is unlikely that recreational landings are significant in North Carolina.

Table 6.1. Reported blue crab landings (hard, soft, and peeler pounds combined) from the Atlantic and Gulf coasts: 1994 – 2002 (NMFS data).

	Year								
Year	1994	1995	1996	1997	1998	1999	2000	2001	2002
North Carolina	53,513,702	46,573,251	67,080,288	56,128,246	62,076,276	57,545,212	40,543,557	32,179,956	37,592,317
Louisiana	36,764,750	36,966,523	40,001,240	43,525,813	43,656,898	46,664,148	52,031,988	41,660,353	54,347,222
Maryland	46,608,174	44,270,267	38,957,512	45,575,161	30,870,447	35,371,030	22,847,019	25,933,144	26,480,553
Virginia	35,424,970	32,569,003	34,216,731	39,064,541	34,599,284	31,437,077	28,846,173	25,057,395	27,300,529
Florida, West Coast	8,463,934	8,780,833	12,474,914	9,321,590	12,863,149	11,081,965	6,455,988	4,629,761	5,562,418
South Carolina	7,183,875	7,130,122	5,954,147	6,283,375	7,595,874	6,608,475	5,817,508	5,566,261	4,435,325
Texas	5,094,314	5,447,088	6,310,547	5,738,680	6,981,424	6,472,115	4,653,306	5,163,132	7,037,012
Georgia	8,907,755	9,376,359	5,892,466	6,432,853	5,169,703	3,992,980	3,296,255	2,767,952	1,987,349
New Jersey	5,604,056	7,697,013	3,822,884	4,562,591	5,829,331	5,579,188	5,092,764	4,724,352	6,229,082
Delaware	6,489,894	8,024,600	3,906,727	5,451,593	4,359,822	4,993,165	4,092,195	4,084,568	3,061,924
Florida, East Coast	5,394,401	3,456,489	5,583,961	5,696,013	4,532,649	4,303,773	4,637,598	2,665,671	2,231,094
Alabama	2,687,961	2,520,268	3,218,948	3,486,851	3,478,259	3,767,527	4,783,861	2,457,288	2,572,155
New York	886,840	1,743,111	2,298,351	1,178,622	1,528,285	117,572	16,054	1,245,544	3,713
Mississippi	171,667	320,844	408,525	684,598	593,182	922,544	840,243	432,223	716,628
Florida, Inland Waters	153,137	82,475	78,028	235,883	89,837	494,339	1,890,502	260,266	164,905
Connecticut	0	317	0	0	2,144	3,237	1,745	0	951
Rhode Island	0	2	0	0	0	0	0	0	9
Total	223,349,430	214,958,565	230,205,269	233,366,410	224,226,564	219,354,347	185,846,756	158,827,866	179,723,186

Table 6.2. Blue crab landings (pounds), and value by market group for North Carolina: 1994 - 2002.

		Year									
		1994	1995	1996	1997	1998	1999	2000	2001	2002	Average
Pounds	Hard crabs	52,260,168	45,033,543	65,682,500	54,353,545	60,402,332	56,094,091	38,889,273	29,939,261	36,401,344	48,784,006
	Peelers	642,238	724,442	878,382	1,022,668	976,097	942,150	998,971	1,319,202	718,852	913,667
	Soft shell	610,769	685,555	519,316	713,896	697,741	510,435	750,140	921,693	555,532	662,786
	Total	53,513,175	46,443,541	67,080,197	56,090,109	62,076,170	57,546,676	40,638,384	32,180,157	37,675,728	50,360,460
Value	Hard crabs	$26,896,282	$33,053,805	$39,957,947	$33,165,872	$40,466,879	$33,526,081	$32,189,114	$25,095,797	$29,309,421	$32,629,022
	Peelers	$771,697	$1,052,607	$1,275,729	$1,768,855	$1,932,820	$2,111,690	$1,937,359	$3,076,797	$1,458,930	$1,709,609
	Soft shell	$1,932,136	$2,132,875	$1,883,181	$2,751,311	$2,559,941	$2,174,429	$3,341,171	$4,076,909	$2,336,864	$2,576,535
	Total	$29,600,115	$36,239,286	$43,116,857	$37,686,039	$44,959,640	$37,812,199	$37,467,644	$32,249,503	$33,105,215	$36,915,166
Price per pound	Hard crabs	$0.51	$0.73	$0.61	$0.61	$0.67	$0.60	$0.83	$0.84	$0.81	$0.69
	Peelers	$1.20	$1.45	$1.45	$1.73	$1.98	$2.24	$1.94	$2.33	$2.03	$1.82
	Soft shell	$3.16	$3.11	$3.63	$3.85	$3.67	$4.26	$4.45	$4.42	$4.21	$3.86
	Total	$0.55	$0.78	$0.64	$0.67	$0.72	$0.66	$0.92	$1.00	$0.88	$0.76

Table 6.3. Total blue crab landings (hard, soft, and peeler pounds combined) for North Carolina waters: 1994 - 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico Sound	17,210,511	9,159,444	13,282,622	19,082,541	21,919,036	18,840,349	9,849,159	7,939,038	5,444,512	122,727,213	13,636,357	27.08
Albemarle Sound	10,973,133	14,611,043	20,392,711	7,974,981	12,340,281	12,784,484	13,170,480	10,512,554	16,014,432	118,774,098	13,197,122	26.21
Pamlico River	7,571,535	5,565,009	8,227,883	7,875,190	6,667,367	7,626,840	3,732,530	2,097,445	2,973,211	52,337,009	5,815,223	11.55
Neuse River	3,736,768	2,688,191	5,305,414	4,561,921	3,942,274	4,290,684	2,050,034	1,574,661	1,366,243	29,516,190	3,279,577	6.51
Currituck Sound	2,258,407	3,404,223	2,404,653	1,941,770	2,264,396	1,718,447	1,766,657	1,347,864	2,587,787	19,694,201	2,188,245	4.35
Bay River	2,165,253	1,833,870	3,898,980	3,923,504	3,094,312	1,576,629	1,156,775	515,698	428,623	18,593,644	2,065,960	4.10
Croatan Sound	2,079,458	2,059,613	3,047,266	1,900,957	2,896,949	1,836,237	738,395	956,343	857,178	16,372,398	1,819,155	3.61
Pungo River	N/C	540,376	2,249,253	2,514,498	1,692,308	2,147,732	2,159,741	862,754	1,472,347	13,639,009	1,515,445	3.01
Core Sound	1,964,839	1,112,562	2,360,392	2,156,694	1,884,183	1,584,263	909,150	858,557	441,176	13,271,817	1,474,646	2.93
Alligator River	1,341,428	1,474,549	2,212,724	662,739	1,369,231	1,315,462	1,584,339	1,018,953	2,218,578	13,198,005	1,466,445	2.91
Roanoke Sound	1,053,290	1,121,068	1,302,687	1,363,124	1,324,753	1,488,548	1,179,919	2,179,298	1,761,770	12,774,458	1,419,384	2.82
Cape Fear River	777,941	682,454	554,583	559,715	627,981	558,121	594,555	571,188	651,868	5,578,407	619,823	1.23
Newport River	396,378	334,205	355,400	402,396	457,868	388,803	253,133	229,881	214,952	3,033,015	337,002	0.67
New River	264,827	341,268	189,330	259,250	279,685	309,807	432,543	424,934	288,783	2,790,429	310,048	0.62
Inland Waterway	376,945	396,934	345,171	163,513	203,119	218,922	291,202	228,966	194,261	2,419,032	268,781	0.53
Bogue Sound	264,936	184,449	279,370	199,994	214,288	153,368	215,361	162,215	90,283	1,764,265	196,029	0.39
Stump Sound	106,524	171,856	129,233	154,984	169,961	162,149	139,446	106,546	95,202	1,235,900	137,322	0.27
White Oak River	135,293	111,011	99,068	80,150	153,312	173,757	128,929	172,884	166,830	1,221,233	135,693	0.27
Masonboro Sound	138,625	166,591	100,401	82,093	162,433	109,003	122,701	134,831	135,865	1,152,543	128,060	0.25
Topsail Sound	155,988	149,707	90,197	82,637	142,037	112,937	89,748	108,950	77,268	1,009,469	112,163	0.22
Pasquotank River	255,351	177,864	111,597	32,458	22,003	23,734	11,809	56,583	46,009	737,408	81,934	0.16
North River	142,182	43,446	61,954	63,368	211,535	47,243	28,845	45,561	41,283	685,417	76,157	0.15
Shallotte River	14,680	16,781	18,429	16,070	12,316	8,606	16,966	46,433	35,245	185,526	20,614	0.04
Chowan River	43,665	6,446	13,671	1,376	3,114	55,199	N/R	4,145	48,385	176,001	19,556	0.04
Perquimans River	61,489	39,540	9,498	N/R	5	734	1,414	1,766	14,953	129,400	14,378	0.03
Lockwood Folly	3,098	32,063	21,029	11,565	11,094	8,197	7,367	19,960	6,917	121,290	13,477	0.03
Ocean less than 3 miles	16,959	16,106	6,996	1,704	3,822	3,750	N/R	1,864	1,160	52,362	5,818	0.01
Back Bay (VA)	34	296	6,588	19,302	4,654	N/R	N/R	N/R	N/R	30,874	3,430	0.01
Ocean <3 mi, S.C.Hat.	N/R	591	1,449	1,335	1,369	1,914	436	284	564	7,942	882	0.00
Unknown	N/R	N/R	N/R	N/R	N/R	706	6,646	N/R	N/R	7,352	817	0.00
Ocean more than 3 miles	3,636	1,843	N/R	53	N/R	N/R	N/R	N/R	N/R	5,532	615	0.00
Roanoke River	N/R	N/R	1,463	4	145	N/R	6	N/R	42	1,660	184	0.00
Ocean >3 mi, S.C.Hat.	N/R	123	111	222	212	12	72	N/R	1	752	84	0.00
Ocean <3 mi, N.C.Hat.	N/R	19	75	N/R	128	41	24	N/R	N/R	287	32	0.00
Total	53,513,175	46,443,541	67,080,197	56,090,109	62,076,170	57,546,676	40,638,384	32,180,157	37,675,728	453,244,138	50,360,460	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.4. Yearly value of blue crab landings (hard, soft, and peeler pounds combined) for North Carolina waters: 1994 - 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Albemarle Sound	6,297,895	12,229,142	13,628,461	6,017,317	10,263,654	9,273,419	13,096,450	11,224,565	15,000,217	97,031,120	10,781,236	29.21
Pamlico Sound	8,730,349	6,464,472	7,917,898	11,464,371	13,957,927	11,081,650	8,231,905	7,122,782	3,673,105	78,644,459	8,738,273	23.67
Pamlico River	4,310,556	4,312,778	5,471,544	4,964,679	4,916,722	4,657,394	3,105,608	2,011,557	2,321,655	36,072,493	4,008,055	10.86
Neuse River	2,201,989	2,193,082	3,526,104	3,120,390	2,965,328	3,007,563	1,801,462	1,579,350	1,211,949	21,607,216	2,400,802	6.50
Currituck Sound	1,160,909	2,355,200	1,614,265	1,326,245	1,770,413	1,095,818	1,654,600	1,274,740	2,869,893	15,122,084	1,680,232	4.55
Roanoke Sound	1,050,806	1,108,344	1,133,142	1,824,282	1,699,925	1,561,140	1,766,820	2,793,009	2,027,925	14,965,393	1,662,821	4.50
Croatan Sound	1,409,002	1,878,217	1,954,850	1,854,519	2,113,573	1,375,108	850,122	1,225,102	813,694	13,474,188	1,497,132	4.06
Bay River	1,115,646	1,268,221	2,274,049	2,438,628	2,139,958	1,040,655	963,366	471,157	335,652	12,047,332	1,338,592	3.63
Pungo River	N/R	409,525	1,582,973	1,683,143	1,309,380	1,357,309	1,889,128	892,605	1,155,987	10,280,049	1,142,228	3.09
Alligator River	694,491	1,224,765	1,334,248	405,200	955,361	867,254	1,381,657	907,414	1,627,596	9,397,985	1,044,221	2.83
Core Sound	924,676	711,674	1,217,276	1,195,150	1,110,180	938,695	689,433	680,826	287,514	7,755,425	861,714	2.33
Cape Fear River	452,629	520,855	331,159	390,179	481,603	362,375	581,740	563,927	693,436	4,377,903	486,434	1.32
New River	142,184	285,909	127,454	192,711	195,691	218,453	411,007	386,908	245,710	2,206,029	245,114	0.66
Newport River	206,928	210,793	202,491	231,503	241,935	242,255	187,795	199,034	126,093	1,848,826	205,425	0.56
Inland Waterway	207,394	275,302	190,226	102,835	128,570	121,275	208,494	173,464	128,582	1,536,140	170,682	0.46
Bogue Sound	144,454	145,380	172,482	137,761	141,166	101,510	172,302	130,936	64,604	1,210,596	134,511	0.36
White Oak River	69,942	81,774	69,126	59,813	115,252	144,834	133,296	172,190	143,918	990,146	110,016	0.30
Stump Sound	51,923	102,471	74,748	90,938	113,070	109,167	112,055	96,638	70,622	821,633	91,293	0.25
Masonboro Sound	64,333	95,568	50,923	43,952	84,916	64,018	90,954	103,848	106,312	704,825	78,314	0.21
Pasquotank River	139,733	154,520	93,046	21,386	15,939	31,793	18,296	75,024	51,381	601,118	66,791	0.18
Topsail Sound	69,463	89,009	44,325	47,361	91,561	69,813	63,702	71,512	46,578	593,326	65,925	0.18
North River	75,140	42,368	57,110	41,058	126,444	33,506	31,441	43,694	33,416	484,178	53,798	0.15
Chowan River	28,415	6,733	9,117	1,005	2,166	43,500	N/R	3,744	29,756	124,436	13,826	0.04
Shallotte River	7,538	7,904	9,661	8,781	6,265	4,646	11,989	29,224	19,779	105,787	11,754	0.03
Perquimans River	31,855	34,845	7,154	N/R	7	677	1,206	2,083	14,919	92,746	10,305	0.03
Lockwood Folly	1,759	18,372	11,169	6,168	6,102	4,235	5,624	12,767	3,948	70,143	7,794	0.02
Ocean less than 3 miles	8,439	10,207	4,352	881	2,100	2,083	N/R	1,206	638	29,906	3,323	0.01
Back Bay (VA)	15	169	5,664	14,622	3,494	N/R	N/R	N/R	N/R	23,963	2,663	0.01
Unknown	N/R	N/R	N/R	N/R	N/R	885	6,823	N/R	N/R	7,708	856	0.00
Ocean <3 mi, S.C.Hat.	N/R	339	763	742	659	995	275	197	311	4,280	476	0.00
Ocean more than 3 miles	1,652	1,268	N/R	61	N/R	N/R	N/R	N/R	N/R	2,981	331	0.00
Roanoke River	N/R	N/R	987	2	102	N/R	4	N/R	23	1,118	124	0.00
Ocean >3 mi, S.C.Hat.	N/R	70	52	355	104	18	73	N/R	3	675	75	0.00
Ocean <3 mi, N.C.Hat.	N/R	11	36	N/R	70	157	16	N/R	N/R	290	32	0.00
Total	29,600,115	36,239,286	43,116,857	37,686,039	44,959,640	37,812,199	37,467,644	32,249,503	33,105,215	332,236,498	36,915,166	100.00

Table 6.5. Monthly blue crab total landings (hard, soft, and peeler pounds combined) for North Carolina: 1994 - 2002.

	Year											Percent
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
January	29,831	121,555	25,112	282,150	179,085	206,933	237,922	41,164	39,547	1,163,298	129,255	0.26
February	399,665	51,214	68,088	595,349	269,650	445,121	274,689	273,401	119,753	2,496,928	277,436	0.55
March	1,368,612	788,245	164,622	1,754,787	841,595	568,344	1,412,985	498,907	411,075	7,809,173	867,686	1.72
April	3,071,133	1,685,812	1,294,634	1,853,843	1,896,707	1,894,687	1,374,984	1,059,515	1,434,386	15,565,699	1,729,522	3.43
May	6,134,268	5,455,489	5,214,484	5,234,491	4,873,082	4,606,816	4,384,123	4,655,482	3,011,168	43,569,402	4,841,045	9.61
June	10,368,155	8,160,859	9,932,351	7,152,478	9,565,609	9,162,932	6,123,320	5,490,152	5,004,004	70,959,860	7,884,429	15.66
July	12,117,320	9,111,263	15,294,007	12,930,716	13,619,888	12,488,344	7,435,558	6,210,753	6,386,771	95,594,619	10,621,624	21.09
August	8,927,376	8,280,208	15,554,437	12,114,452	9,634,625	10,100,250	8,212,501	5,919,373	7,384,631	86,127,854	9,569,762	19.00
September	5,008,867	5,843,942	9,797,756	7,356,705	9,489,569	6,373,560	6,033,854	3,759,070	6,351,730	60,015,052	6,668,339	13.24
October	3,194,893	5,005,848	6,455,972	4,586,662	7,108,154	7,430,515	3,630,126	2,522,975	4,660,131	44,595,275	4,955,031	9.84
November	2,213,762	1,701,126	2,516,734	1,636,441	3,232,590	3,015,162	1,211,773	1,208,081	2,528,682	19,264,351	2,140,483	4.25
December	679,293	237,981	762,002	592,035	1,365,619	1,254,012	306,551	541,283	343,849	6,082,625	675,847	1.34
Total	53,513,175	46,443,541	67,080,197	56,090,109	62,076,170	57,546,676	40,638,384	32,180,157	37,675,728	453,244,138	50,360,460	100.00

Table 6.6. Annual blue crab total landings (hard, soft, and peeler pounds combined) for reported gears from single gear trip tickets: 1994 – 2002.

	Year											Percent
Gear	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Crab pot	50,598,339	44,645,581	63,208,358	51,859,124	57,380,295	54,440,869	38,465,581	29,455,979	35,394,640	425,448,767	47,272,085	94.63
Crab Trawl	1,889,813	1,065,055	3,088,360	3,289,745	3,083,832	1,812,344	937,138	996,971	1,016,823	17,180,081	1,908,898	3.82
Peeler Pot	N/C	N/C	59,422	145,504	581,386	515,570	558,000	937,744	535,745	3,333,372	370,375	0.74
Shrimp trawl	462,496	224,829	306,071	312,698	554,043	280,618	208,176	186,006	160,451	2,695,387	299,487	0.60
Channel net	838	1,011	1,837	4,729	1,603	5,781	37,670	85,923	60,782	200,173	22,241	0.04
Gill net set (sink)	6,601	4,741	19,839	19,123	29,504	32,589	18,557	22,786	30,006	183,745	20,416	0.04
Crab dredge	46,720	7,638	10,165	2,567	N/R	N/R	N/R	5,897	80,113	153,099	17,011	0.03
Trotline	1,269	28,737	2,578	1,936	577	2,573	19,785	9,977	56,184	123,617	13,735	0.03
Pound net	26,681	10,535	21,594	5,100	3,822	4,179	456	3,922	1,649	77,938	8,660	0.02
Rakes hand	76,315	1,280	1	N/R	N/R	N/R	N/R	N/R	N/R	77,595	8,622	0.02
Gill net set (float)	12,347	5,513	5,406	5,828	5,204	766	5,946	4,513	2,813	48,335	5,371	0.01
Skimmer trawl	221	280	5,237	3,099	2,303	503	2,291	4,674	2,510	21,118	2,346	0.00
Fyke net	280	32	388	17,369	512	100	223	24	154	19,082	2,120	0.00
Tongs, hand	10,000	605	643	N/R	N/R	N/R	N/R	N/R	N/R	11,248	1,250	0.00
Rakes bull	93	3,720	754	N/R	N/R	N/R	N/R	N/R	N/R	4,567	507	0.00
Haul seine	150	N/R	306	3,724	97	32	N/R	N/R	N/R	4,309	479	0.00
Clam dredge	40	30	4,125	N/R	N/R	N/R	N/R	N/R	37	4,232	470	0.00
Clam trawl kicking	N/R	181	20	1,185	54	229	755	996	390	3,810	423	0.00
Oyster dredge	1,366	541	95	N/R	171	213	591	358	129	3,464	385	0.00
Flounder trawl	N/R	742	N/R	N/R	N/R	939	N/R	N/R	N/R	1,681	187	0.00
By hand	1,001	643	N/R	N/R	N/R	N/R	N/R	31	N/R	1,675	186	0.00
Eel pot	N/R	261	472	9	77	685	17	38	N/R	1,558	173	0.00
Conch pot	N/R	N/R	1,090	N/R	N/R	N/R	N/R	N/R	187	1,277	142	0.00
Gill net (runaround)	79	553	N/R	331	2	29	N/R	3	1	997	111	0.00
Cast net	216	460	30	N/R	N/R	N/R	N/R	N/R	N/R	706	78	0.00
Flynet	N/R	580	60	N/R	N/R	N/R	N/R	N/R	N/R	640	71	0.00
Fish pot	5	425	N/R	96	N/R	N/R	N/R	49	7	582	65	0.00
Dip net	N/R	N/R	507	N/R	N/R	N/R	N/R	N/R	N/R	507	56	0.00
Gill net (drift)	250	43	N/R	N/R	N/R	N/R	N/R	N/R	78	371	41	0.00
Beach seine	324	N/R	N/R	N/R	N/R	N/R	24	N/R	N/R	348	39	0.00
Shrimp pound	N/R	137	167	N/R	N/R	N/R	N/R	N/R	N/R	304	34	0.00
Swipe Net	N/R	N/R	N/R	83	N/R	N/R	N/R	N/R	122	205	23	0.00
Clam dredge	N/R	133	N/R	N/R	N/R	N/R	N/R	N/R	N/R	133	15	0.00
Butterfly net	N/R	80	N/R	N/R	N/R	N/R	N/R	N/R	N/R	80	9	0.00
Scallop trawl	28	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	28	3	0.00
Rod-n-Reel	N/R	7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	7	1	0.00
Gigs	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	N/R	2	0	0.00
Total	53,135,472	46,004,373	66,737,528	55,672,252	61,643,480	57,098,018	40,255,210	31,715,890	37,342,819	449,605,040	49,956,116	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.7. Monthly hard crab landings (pounds) for North Carolina: 1994 – 2002.

	Year											Percent
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
January	29,463	121,541	24,982	282,092	178,877	206,208	237,911	41,113	39,547	1,161,732	129,081	0.26
February	399,662	51,205	67,935	595,329	269,609	444,833	274,689	273,357	119,638	2,496,255	277,362	0.57
March	1,356,294	774,541	159,254	1,744,401	836,395	563,504	1,396,275	496,530	405,387	7,732,581	859,176	1.76
April	2,886,954	1,534,895	1,226,273	1,795,265	1,723,851	1,772,560	1,254,935	949,386	1,017,739	14,161,858	1,573,540	3.23
May	5,434,216	4,637,374	4,454,805	4,200,194	4,035,128	3,897,529	3,714,055	3,398,647	2,674,646	36,446,592	4,049,621	8.30
June	10,173,267	7,945,866	9,565,651	6,831,335	9,263,203	8,825,643	5,959,796	5,091,577	4,774,492	68,430,829	7,603,425	15.59
July	12,063,468	9,063,483	15,227,046	12,797,402	13,513,528	12,366,085	7,326,298	6,091,683	6,305,049	94,754,042	10,528,227	21.58
August	8,882,365	8,180,257	15,449,179	12,002,493	9,496,346	9,980,136	7,732,974	5,685,772	7,232,742	84,642,264	9,404,696	19.28
September	4,952,086	5,788,638	9,774,457	7,299,267	9,393,789	6,346,029	5,888,724	3,657,163	6,309,097	59,409,248	6,601,028	13.53
October	3,189,942	4,997,246	6,454,281	4,577,503	7,094,027	7,423,045	3,586,765	2,505,204	4,654,940	44,482,952	4,942,550	10.13
November	2,213,176	1,700,521	2,516,641	1,636,230	3,232,045	3,014,787	1,211,331	1,207,575	2,524,219	19,256,526	2,139,614	4.39
December	679,276	237,977	761,998	592,033	1,365,537	1,253,733	305,521	541,254	343,848	6,081,177	675,686	1.39
Total	52,260,168	45,033,543	65,682,500	54,353,545	60,402,332	56,094,091	38,889,273	29,939,261	36,401,344	439,056,057	48,784,006	100.00

Table 6.8. Yearly hard crab landings (pounds) by waterbody for North Carolina: 1994 – 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico Sound	16,877,603	8,885,647	13,037,832	18,687,618	21,498,456	18,516,650	9,440,531	7,438,597	5,297,775	119,680,710	13,297,857	27.26
Albemarle Sound	10,772,068	14,273,299	20,000,489	7,630,225	11,983,411	12,390,208	12,565,056	9,747,341	15,582,519	114,944,615	12,771,624	26.18
Pamlico River	7,499,888	5,527,871	8,188,298	7,813,444	6,598,595	7,565,541	3,688,300	2,070,308	2,941,607	51,893,852	5,765,984	11.82
Neuse River	3,693,585	2,651,343	5,229,019	4,495,550	3,878,696	4,235,553	2,017,798	1,542,024	1,348,704	29,092,271	3,232,475	6.63
Currituck Sound	2,218,236	3,348,814	2,335,954	1,872,575	2,145,134	1,668,788	1,717,661	1,236,333	2,498,507	19,042,002	2,115,778	4.34
Bay River	2,147,708	1,822,560	3,886,472	3,905,733	3,074,082	1,556,229	1,140,150	501,631	418,196	18,452,759	2,050,307	4.20
Croatan Sound	1,877,489	1,766,313	2,854,368	1,604,460	2,712,422	1,690,190	619,484	743,185	741,954	14,609,863	1,623,318	3.33
Pungo River	N/C	537,639	2,245,047	2,504,660	1,684,429	2,140,409	2,151,742	858,835	1,463,293	13,586,054	1,509,562	3.09
Alligator River	1,329,788	1,458,363	2,173,821	645,564	1,346,944	1,285,184	1,542,430	984,321	2,177,036	12,943,452	1,438,161	2.95
Core Sound	1,922,675	1,071,988	2,303,079	2,129,434	1,855,509	1,547,119	871,643	820,518	418,814	12,940,778	1,437,864	2.95
Roanoke Sound	817,654	889,087	1,113,445	1,004,655	1,007,238	1,249,069	886,379	1,802,238	1,486,698	10,256,463	1,139,607	2.34
Cape Fear River	764,281	668,286	539,057	542,423	607,124	540,562	573,289	541,097	629,164	5,405,282	600,587	1.23
Newport River	376,303	314,232	330,894	382,214	443,067	364,911	231,567	201,491	195,980	2,840,658	315,629	0.65
New River	259,983	331,690	186,289	251,376	276,393	304,759	425,570	411,811	281,504	2,729,372	303,264	0.62
Inland Waterway	375,365	396,709	342,295	160,473	201,169	217,099	288,443	225,525	192,988	2,400,065	266,674	0.55
Bogue Sound	261,909	178,282	272,190	195,123	211,821	151,166	212,494	159,684	89,103	1,731,771	192,419	0.39
Stump Sound	103,823	170,486	124,092	151,814	167,741	158,118	135,536	102,067	92,380	1,206,057	134,006	0.27
Masonboro Sound	138,048	166,423	99,655	80,903	161,602	106,452	122,044	132,361	134,379	1,141,866	126,874	0.26
White Oak River	130,848	99,431	92,276	69,721	141,195	157,186	112,649	153,323	149,058	1,105,687	122,854	0.25
Topsail Sound	155,801	149,291	89,677	82,462	142,012	112,882	88,746	108,640	76,708	1,006,218	111,802	0.23
Pasquotank River	254,957	177,416	107,645	31,907	21,514	14,143	5,576	43,716	39,837	696,711	77,412	0.16
North River	139,399	35,592	53,060	60,408	206,965	43,148	19,347	40,166	38,415	636,500	70,722	0.14
Shallotte River	14,463	16,198	17,918	15,547	12,283	8,606	16,966	46,122	34,858	182,961	20,329	0.04
Chowan River	43,665	6,289	13,207	1,375	3,114	55,182	N/R	4,118	48,376	175,326	19,481	0.04
Perquimans River	61,240	39,459	9,472	N/R	5	734	1,386	1,763	14,813	128,872	14,319	0.03
Lockwood Folly	2,891	32,021	20,628	11,493	11,086	8,186	7,309	19,906	6,916	120,436	13,382	0.03
Ocean less than 3 miles	16,830	15,947	6,985	1,704	3,822	3,656	N/R	1,863	1,160	51,967	5,774	0.01
Back Bay (VA)	34	296	6,588	19,266	4,654	N/R	N/R	N/R	N/R	30,838	3,426	0.01
Ocean <3 mi, S.C.Hat.	N/R	589	1,449	1,333	1,367	1,911	435	279	564	7,926	881	0.00
Unknown	N/R	N/R	N/R	N/R	N/R	451	6,646	N/R	N/R	7,097	789	0.00
Ocean more than 3 miles	3,635	1,843	N/R	41	N/R	N/R	N/R	N/R	N/R	5,519	613	0.00
Roanoke River	N/R	N/R	1,187	4	145	N/R	6	N/R	42	1,384	154	0.00
Ocean >3 mi, S.C.Hat.	N/R	123	39	42	210	N/R	67	N/R	N/R	481	53	0.00
Ocean <3 mi, N.C.Hat.	N/R	19	75	N/R	128	N/R	24	N/R	N/R	246	27	0.00
Total	52,260,168	45,033,543	65,682,500	54,353,545	60,402,332	56,094,091	38,889,273	29,939,261	36,401,344	439,056,057	48,784,006	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.9. Area breakdown and their waterbodies for North Carolina.

Albemarle Area	Pamlico Area	Core Area	Southern Area	Ocean Area
Albemarle Sound	Croatan Sound	Core Sound	Masonboro Sound	Ocean <3 mi, N of Cape Hatteras
Currituck Sound	Roanoke Sound	Bogue Sound	Stump Sound	Ocean <3 mi, S of Cape .Hatteras
Alligator River	Pamlico Sound	Newport River	Topsail Sound	Ocean >3 mi, S of Cape Hatteras
Pasquotank River	Pamlico River	North River	Cape Fear River	Ocean less than 3 miles
Perquimans River	Pungo River		Inland Waterway	Ocean more than 3 miles
Chowan River	Bay River		Lockwood Folly	
Roanoke River	Neuse River		New River	
Back Bay (VA)			Shallotte River	
			White Oak River	

Table 6.10. Hard crab landings (pounds) by area for North Carolina: 1994 - 2002.

	Year											Percent
Area	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico	32,913,926	22,080,460	36,554,480	40,016,120	40,453,918	36,953,641	19,944,384	14,956,817	13,698,225	257,571,971	28,619,108	58.66
Albemarle	14,679,989	19,303,935	24,648,362	10,200,917	15,504,922	15,414,239	15,832,115	12,017,592	20,361,129	147,963,200	16,440,356	33.70
Core	2,700,286	1,600,093	2,959,223	2,767,179	2,717,362	2,106,344	1,335,051	1,221,859	742,311	18,149,707	2,016,634	4.13
Southern	1,945,502	2,030,534	1,511,887	1,366,210	1,720,604	1,613,849	1,770,551	1,740,851	1,597,954	15,297,943	1,699,771	3.48
Ocean	20,465	18,521	8,548	3,120	5,527	5,567	526	2,142	1,724	66,140	7,349	0.02
Unknown	N/R	N/R	N/R	N/R	N/R	451	6,646	N/R	N/R	7,097	789	0.00
Total	52,260,168	45,033,543	65,682,500	54,353,545	60,402,332	56,094,091	38,889,273	29,939,261	36,401,344	439,056,057	48,784,006	100.00

N/R=No landings reported.

Table 6.11. Correlation coefficients (bolded numbers significant at the 0.05 level or less) for area hard crab landings in North Carolina: 1994 - 2002.

	Pamlico	Albemarle	Core	Southern	Ocean	Unknown	Total
Pamlico	1						
Albemarle	-0.12	1					
Core	**0.94**	-0.04	1				
Southern	-0.36	0.07	-0.25	1			
Ocean	0.19	0.21	0.35	**0.67**	1		
Unknown	-0.28	-0.06	-0.31	0.12	-0.36	1	
Total	**0.93**	0.26	**0.90**	-0.31	0.29	-0.30	1

Table 6.12. Hard crab landings (pounds) by gear and year from single gear trip tickets for North Carolina: 1994 - 2002.

	Year											Percent
Gear	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Crab pot*	49,387,793	43,268,661	61,899,071	50,311,377	56,292,584	53,521,462	37,327,515	28,175,343	34,656,097	414,839,902	46,093,322	95.22
Crab trawl	1,865,154	1,045,482	3,073,244	3,267,234	3,063,173	1,794,072	917,568	983,370	1,011,788	17,021,084	1,891,232	3.91
Shrimp trawl	458,181	221,413	299,359	300,282	550,851	275,516	196,867	184,468	156,670	2,643,606	293,734	0.61
Peeler pot	N/C	N/C	1,525	14,329	47,575	55,329	48,675	71,082	50,603	289,117	32,124	0.07
Channel net	838	1,007	1,833	4,671	1,603	5,780	37,669	85,923	60,754	200,077	22,231	0.05
Crab dredge	46,720	7,632	10,165	2,567	N/R	N/R	N/R	5,897	79,403	152,384	16,932	0.03
Gill net set (sink)	6,138	3,762	17,265	12,240	24,864	26,073	9,740	15,771	24,646	140,499	15,611	0.03
Trotline	1,209	28,737	2,578	1,936	577	2,434	19,661	9,943	56,088	123,163	13,685	0.03
Rakes hand	76,315	1,280	N/R	N/R	N/R	N/R	N/R	N/R	N/R	77,595	8,622	0.02
Pound net	26,663	10,302	21,586	5,100	3,545	4,109	352	2,992	1,648	76,297	8,477	0.02
Gill net set (float)	11,712	1,919	4,748	5,382	3,452	520	5,330	2,425	1,751	37,239	4,138	0.01
Fyke net	280	32	388	17,359	512	100	223	24	154	19,072	2,119	0.00
Skimmer trawl	221	234	4,430	1,363	816	495	2,288	4,528	2,480	16,855	1,873	0.00
Tongs, hand	10,000	601	643	N/R	N/R	N/R	N/R	N/R	N/R	11,244	1,249	0.00
Rakes bull	93	3,714	752	N/R	N/R	N/R	N/R	N/R	N/R	4,559	507	0.00
Haul seine	125	N/R	305	3,706	97	32	N/R	N/R	N/R	4,265	474	0.00
Clam dredge(hydraulic)	40	30	4,125	N/R	N/R	N/R	N/R	N/R	37	4,232	470	0.00
Clam trawl kicking	N/R	181	20	1,185	54	229	755	996	390	3,810	423	0.00
Oyster dredge	1,366	541	65	N/R	171	213	591	358	129	3,434	382	0.00
Flounder trawl	N/R	742	N/R	N/R	N/R	939	N/R	N/R	N/R	1,681	187	0.00
Eel pot	N/R	261	456	N/R	49	683	2	5	N/R	1,456	162	0.00
By hand	1,001	345	N/R	N/R	N/R	N/R	N/R	31	N/R	1,377	153	0.00
Conch pot	N/R	N/R	1,090	N/R	N/R	N/R	N/R	N/R	187	1,277	142	0.00
Gill net (runaround)	78	553	N/R	331	N/R	N/R	N/R	N/R	N/R	962	107	0.00
Flynet	N/R	580	60	N/R	N/R	N/R	N/R	N/R	N/R	640	71	0.00
Fish pot	5	425	N/R	96	N/R	N/R	N/R	49	7	582	65	0.00
Dip net	N/R	N/R	507	N/R	N/R	N/R	N/R	N/R	N/R	507	56	0.00
Gill net (drift)	250	43	N/R	N/R	N/R	N/R	N/R	N/R	78	371	41	0.00
Beach seine	324	N/R	N/R	N/R	N/R	N/R	24	N/R	N/R	348	39	0.00
Shrimp pound	N/R	137	167	N/R	N/R	N/R	N/R	N/R	N/R	304	34	0.00
Cast net	216	N/R	30	N/R	N/R	N/R	N/R	N/R	N/R	246	27	0.00
Swipe net	N/R	N/R	N/R	83	N/R	N/R	N/R	N/R	122	205	23	0.00
Clam dredge	N/R	133	N/R	N/R	N/R	N/R	N/R	N/R	N/R	133	15	0.00
Butterfly net	N/R	80	N/R	N/R	N/R	N/R	N/R	N/R	N/R	80	9	0.00
Scallop trawl	28	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	28	3	0.00
Rod-n-Reel	N/R	7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	7	1	0.00
Gigs	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	N/R	2	0	0.00
Total	51,894,748	44,598,833	65,344,414	53,949,239	59,989,923	55,687,987	38,567,260	29,543,203	36,103,032	435,678,638	48,408,738	100.00

*=Hard and peeler pot landings combined in 1994 and 1995; N/C=No landings data collected; N/R=No landings reported.

Table 6.13. Monthly hard crab landings (pounds) from single gear crab pot trip tickets for North Carolina: 1994 - 2002.

	Year											Percent
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
January	18,990	67,708	11,958	150,001	84,038	143,609	226,528	15,141	25,193	743,165	82,574	0.18
February	187,650	25,314	51,162	179,850	130,326	322,267	188,902	193,223	37,804	1,316,497	146,277	0.32
March	950,262	530,421	114,404	1,081,991	525,193	376,868	1,173,339	338,483	221,282	5,312,243	590,249	1.28
April	2,521,247	1,380,912	815,190	1,563,613	1,318,797	1,501,276	1,173,276	797,210	919,919	11,991,441	1,332,382	2.89
May	5,162,067	4,502,141	4,194,944	3,880,451	3,686,887	3,537,573	3,456,997	3,154,118	2,547,480	34,122,659	3,791,407	8.23
June	9,750,605	7,824,168	8,994,834	6,530,187	8,849,779	8,228,188	5,759,577	4,905,782	4,643,261	65,486,381	7,276,265	15.79
July	11,766,037	8,947,636	14,827,177	12,305,553	13,016,524	12,048,636	7,226,688	5,945,844	6,224,263	92,308,358	10,256,484	22.25
August	8,664,464	8,059,383	15,155,532	11,686,004	9,084,440	9,849,524	7,606,572	5,543,863	7,120,183	82,769,964	9,196,663	19.95
September	4,739,264	5,602,162	9,311,599	6,975,307	8,928,314	6,193,856	5,775,611	3,536,835	6,237,200	57,300,148	6,366,683	13.81
October	3,063,426	4,863,334	5,889,516	4,319,205	6,875,136	7,279,761	3,471,114	2,419,405	4,583,416	42,764,312	4,751,590	10.31
November	1,995,446	1,298,221	2,001,078	1,343,548	2,669,834	2,938,293	1,097,856	929,258	1,936,587	16,210,122	1,801,125	3.91
December	568,336	167,261	531,678	295,665	1,123,316	1,101,612	171,057	396,180	159,510	4,514,615	501,624	1.09
Total	49,387,793	43,268,661	61,899,071	50,311,377	56,292,584	53,521,462	37,327,515	28,175,343	34,656,097	414,839,902	46,093,322	100.00

Table 6.14. Yearly hard crab landings (pounds) from single gear crab pot trip tickets f or North Carolina waters: 1994 - 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Albemarle Sound	10,694,389	14,072,096	19,842,886	7,483,525	11,816,606	12,253,993	12,455,019	9,580,679	15,439,562	113,638,754	12,626,528	27.39
Pamlico Sound	15,670,272	8,031,849	11,603,223	17,039,895	20,126,348	17,683,226	8,894,633	6,623,015	4,293,413	109,965,873	12,218,430	26.51
Pamlico River	6,827,121	5,268,057	7,650,630	7,353,049	5,990,532	7,055,489	3,559,119	1,996,638	2,888,082	48,588,716	5,398,746	11.71
Neuse River	3,401,441	2,555,407	4,965,394	4,030,502	3,537,016	3,968,953	1,954,920	1,494,657	1,333,475	27,241,764	3,026,863	6.57
Currituck Sound	2,184,846	3,305,799	2,289,886	1,792,864	2,111,229	1,645,164	1,703,586	1,221,694	2,485,046	18,740,114	2,082,235	4.52
Bay River	2,005,908	1,805,575	3,621,406	3,631,783	2,845,929	1,452,317	1,097,672	483,767	414,469	17,358,825	1,928,758	4.18
Croatan Sound	1,767,392	1,676,783	2,424,465	1,494,238	2,491,845	1,585,136	561,780	641,193	602,861	13,245,691	1,471,743	3.19
Alligator River	1,329,739	1,456,991	2,173,709	643,676	1,344,963	1,284,327	1,539,423	974,474	2,172,253	12,919,556	1,435,506	3.11
Pungo River	N/C	519,851	1,950,603	2,186,564	1,275,752	1,915,348	1,901,647	753,736	1,389,849	11,893,350	1,321,483	2.87
Core Sound	1,748,284	975,937	2,092,774	1,698,229	1,214,987	1,283,643	704,133	656,067	332,139	10,706,192	1,189,577	2.58
Roanoke Sound	809,548	880,330	1,025,716	974,221	979,236	1,214,742	826,614	1,710,342	1,413,942	9,834,690	1,092,743	2.37
Cape Fear River	759,769	666,006	534,358	541,130	602,785	531,685	549,781	531,796	597,661	5,314,970	590,552	1.28
Newport River	365,814	312,909	325,589	375,005	438,742	363,299	231,448	199,597	195,928	2,808,331	312,037	0.68
Inland Waterway	368,865	389,733	336,777	157,069	197,513	213,999	285,239	223,575	189,892	2,362,660	262,518	0.57
New River	196,063	285,021	164,994	209,498	266,276	274,666	350,566	287,204	195,522	2,229,809	247,757	0.54
Bogue Sound	261,728	175,906	270,449	194,644	209,563	150,835	211,608	159,043	88,902	1,722,677	191,409	0.42
Stump Sound	103,583	170,317	123,304	143,651	159,434	146,604	125,873	97,303	89,443	1,159,511	128,835	0.28
Masonboro Sound	136,999	165,030	96,650	80,504	161,166	105,025	121,118	130,651	133,550	1,130,691	125,632	0.27
White Oak River	125,019	94,048	89,270	67,252	137,137	155,559	112,268	152,451	147,619	1,080,622	120,069	0.26
Topsail Sound	154,792	146,232	88,803	77,308	135,525	108,215	84,867	106,663	73,754	976,158	108,462	0.24
Pasquotank River	252,340	174,720	102,534	28,371	15,958	11,898	5,209	37,548	36,922	665,500	73,944	0.16
North River	95,700	33,673	51,620	59,972	199,653	41,063	19,217	39,969	37,825	578,692	64,299	0.14
Shallotte River	13,886	16,173	17,918	15,531	12,177	8,606	16,966	46,122	34,773	182,152	20,239	0.04
Chowan River	43,459	6,010	13,034	1,119	3,070	55,182	N/R	3,911	47,354	173,139	19,238	0.04
Perquimans River	60,586	39,356	9,320	N/R	N/R	734	1,386	1,763	14,644	127,789	14,199	0.03
Lockwood Folly	2,891	30,077	20,099	11,142	10,097	7,649	6,711	19,624	6,901	115,192	12,799	0.03
Ocean less than 3 miles	7,362	13,877	5,686	1,081	3,784	3,656	N/R	1,863	241	37,550	4,172	0.01
Back Bay (VA)	N/R	174	6,071	19,245	4,654	N/R	N/R	N/R	N/R	30,144	3,349	0.01
Unknown	N/R	N/R	N/R	N/R	N/R	451	6,646	N/R	N/R	7,097	789	0.00
Ocean <3 mi, S.C.Hat.	N/R	N/R	717	310	463	N/R	N/R	N/R	78	1,568	174	0.00
Roanoke River	N/R	N/R	1,187	N/R	145	N/R	N/R	N/R	N/R	1,332	148	0.00
Ocean more than 3 miles	N/R	728	N/R	N/R	N/R	N/R	N/R	N/R	N/R	728	81	0.00
Ocean >3 mi, S.C.Hat.	N/R	N/R	N/R	N/R	N/R	N/R	67	N/R	N/R	67	7	0.00
Total	49,387,793	43,268,661	61,899,071	50,311,377	56,292,584	53,521,462	37,327,515	28,175,343	34,656,097	414,839,902	46,093,322	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.15. Yearly value of hard crab landings (pounds) from single gear crab pot trip tickets f or North Carolina waters: 1994 - 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Albemarle Sound	$5,731,629	$11,281,531	$12,565,627	$5,004,024	$9,108,173	$7,915,262	$10,912,988	$8,351,734	$13,351,327	$84,222,294	$9,358,033	30.25
Pamlico Sound	$7,591,219	$5,448,193	$6,641,202	$9,752,805	$12,144,440	$9,788,078	$6,882,939	$5,196,850	$2,780,105	$66,225,832	$7,358,426	23.78
Pamlico River	$3,791,333	$4,011,865	$5,086,239	$4,539,332	$4,373,051	$4,206,901	$2,914,068	$1,867,294	$2,208,314	$32,998,397	$3,666,489	11.85
Neuse River	$1,933,550	$2,039,097	$3,208,392	$2,682,262	$2,569,307	$2,695,103	$1,671,276	$1,441,455	$1,156,367	$19,396,810	$2,155,201	6.97
Currituck Sound	$1,065,261	$2,176,643	$1,444,269	$1,131,732	$1,457,615	$946,544	$1,505,607	$933,623	$2,628,644	$13,289,938	$1,476,660	4.77
Bay River	$1,007,425	$1,240,394	$2,112,560	$2,218,134	$1,940,064	$927,615	$895,922	$420,255	$311,128	$11,073,496	$1,230,388	3.98
Alligator River	$680,181	$1,196,067	$1,274,523	$373,219	$903,778	$787,787	$1,295,029	$816,967	$1,537,592	$8,865,144	$985,016	3.18
Pungo River	N/C	$390,146	$1,363,057	$1,425,796	$972,638	$1,171,378	$1,627,734	$757,777	$1,064,394	$8,772,919	$974,769	3.15
Croatan Sound	$862,505	$1,037,163	$1,286,749	$904,068	$1,515,335	$831,014	$419,067	$499,924	$413,495	$7,769,319	$863,258	2.79
Roanoke Sound	$407,122	$556,458	$536,242	$571,175	$592,454	$651,324	$577,231	$1,282,614	$1,011,795	$6,186,414	$687,379	2.22
Core Sound	$786,311	$584,169	$1,043,709	$919,528	$712,696	$725,075	$505,112	$484,756	$191,799	$5,953,155	$661,462	2.14
Cape Fear River	$421,582	$489,127	$303,234	$358,333	$436,035	$317,438	$514,422	$484,616	$609,457	$3,934,245	$437,138	1.41
New River	$93,022	$231,015	$106,004	$142,980	$178,550	$186,440	$345,498	$275,710	$178,960	$1,738,178	$193,131	0.62
Inland Waterway	$201,169	$270,395	$182,249	$94,990	$121,806	$115,458	$200,843	$163,860	$123,777	$1,474,547	$163,839	0.53
Newport River	$151,865	$180,786	$162,788	$192,677	$210,174	$187,632	$145,891	$131,596	$87,545	$1,450,954	$161,217	0.52
Bogue Sound	$139,806	$133,404	$156,858	$129,024	$134,706	$96,389	$165,880	$123,226	$62,102	$1,141,395	$126,822	0.41
White Oak River	$61,552	$59,947	$52,908	$40,079	$88,698	$105,413	$101,452	$125,976	$106,495	$742,520	$82,502	0.27
Stump Sound	$48,249	$100,083	$68,365	$78,537	$103,070	$91,647	$96,801	$81,207	$62,000	$729,960	$81,107	0.26
Masonboro Sound	$63,132	$94,522	$47,891	$41,626	$82,992	$57,497	$88,565	$96,132	$101,626	$673,983	$74,887	0.24
Topsail Sound	$68,779	$86,885	$43,059	$43,159	$85,235	$66,920	$58,912	$69,191	$43,445	$565,585	$62,843	0.20
Pasquotank River	$136,976	$151,226	$80,366	$17,719	$10,982	$7,959	$5,775	$38,641	$36,624	$486,268	$54,030	0.17
North River	$44,470	$20,585	$27,291	$35,210	$113,163	$23,050	$12,935	$30,914	$26,840	$334,459	$37,162	0.12
Chowan River	$28,325	$6,345	$8,976	$869	$2,111	$43,432	N/R	$3,549	$29,169	$122,777	$13,642	0.04
Shallotte River	$6,605	$7,042	$8,887	$7,853	$6,141	$4,646	$11,989	$28,496	$18,938	$100,597	$11,177	0.04
Perquimans River	$31,232	$34,651	$6,976	N/R	N/R	$677	$1,107	$2,075	$14,431	$91,150	$10,128	0.03
Lockwood Folly	$1,421	$17,151	$10,304	$5,859	$5,530	$3,914	$5,109	$12,447	$3,935	$65,670	$7,297	0.02
Back Bay (VA)	N/R	$99	$5,353	$14,528	$3,494	N/R	N/R	N/R	N/R	$23,475	$2,608	0.01
Ocean less than 3 miles	$3,789	$8,317	$3,686	$559	$2,079	$1,871	N/R	$1,204	$133	$21,639	$2,404	0.01
Unknown	N/R	N/R	N/R	N/R	N/R	$312	$6,823	N/R	N/R	$7,135	$793	0.00
Ocean <3 mi, S.C.Hat.	N/R	N/R	$404	$160	$254	N/R	N/R	N/R	$43	$862	$96	0.00
Roanoke River	N/R	N/R	$570	N/R	$102	N/R	N/R	N/R	N/R	$671	$75	0.00
Ocean more than 3 miles	N/R	$415	N/R	N/R	N/R	N/R	N/R	N/R	N/R	$415	$46	0.00
Ocean >3 mi, S.C.Hat.	N/R	N/R	N/R	N/R	N/R	N/R	$64	N/R	N/R	$64	$7	0.00
Total $	25,358,511	31,853,721	37,838,741	30,726,240	37,874,673	31,956,774	30,969,038	23,722,088	28,160,482	278,460,267	30,940,030	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.16. Hard crab landings (pounds) for crab pots from single gear trip tickets by area for North Carolina: 1994 - 2002.

	Year											Percent
Area*	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico	30,481,680	20,737,850	33,241,437	36,710,253	37,246,658	34,875,211	18,796,385	13,703,347	12,336,089	238,128,909	26,458,768	57.40
Albemarle	14,565,360	19,055,146	24,438,626	9,968,800	15,296,625	15,251,298	15,704,623	11,820,069	20,195,781	146,296,329	16,255,148	35.27
Core	2,471,525	1,498,425	2,740,432	2,327,850	2,062,945	1,838,839	1,166,406	1,054,675	654,793	15,815,891	1,757,321	3.81
South	1,861,865	1,962,635	1,472,173	1,303,083	1,682,108	1,552,007	1,653,388	1,595,388	1,469,114	14,551,762	1,616,862	3.51
Ocean	7,362	14,605	6,403	1,391	4,247	3,656	67	1,863	319	39,913	4,435	0.01
Unknown	N/R	N/R	N/R	N/R	N/R	451	6,646	N/R	N/R	7,097	789	0.00
Total	49,387,793	43,268,661	61,899,071	50,311,377	56,292,584	53,521,462	37,327,515	28,175,343	34,656,097	414,839,902	46,093,322	100.00

*= See table 9 for area description; N/R=No landings reported.

Table 6.17. Value of hard crab landings from single gear crab pot trip tickets by area for North Carolina: 1994 - 2002.

	Year											Percent
Area*	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico	$15,593,155	$14,723,314	$20,234,442	$22,093,572	$24,107,289	$20,271,413	$14,988,237	$11,466,168	$8,945,598	$152,423,187	$16,935,910	54.74
Albemarle	$7,673,606	$14,846,563	$15,386,660	$6,542,091	$11,486,255	$9,701,662	$13,720,506	$10,146,588	$17,597,787	$107,101,718	$11,900,191	38.46
South	$965,510	$1,356,167	$822,902	$813,418	$1,108,057	$949,372	$1,423,590	$1,337,635	$1,248,634	$10,025,285	$1,113,921	3.60
Core	$1,122,452	$918,945	$1,390,646	$1,276,438	$1,170,738	$1,032,145	$829,818	$770,492	$368,287	$8,879,962	$986,662	3.19
Ocean	$3,789	$8,732	$4,091	$720	$2,333	$1,871	$64	$1,204	$175	$22,979	$2,553	0.01
Unknown	N/R	N/R	N/R	N/R	N/R	$312	$6,823	N/R	N/R	$7,135	$793	0.00
Total	$25,358,511	$31,853,721	$37,838,741	$30,726,240	$37,874,673	$31,956,774	$30,969,038	$23,722,088	$28,160,482	$278,460,267	$30,940,030	100.00

*= See table 9 for area description; N/R=No landings reported.

Table 6.18. Yearly trips with hard crab landings from single gear crab pot trip tickets for North Carolina waters: 1994 - 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico Sound	25,889	20,957	18,161	26,755	30,442	28,057	22,208	19,794	12,064	204,327	22,703	23.97
Albemarle Sound	18,392	23,616	22,950	14,779	16,727	18,111	18,916	19,919	21,922	175,332	19,481	20.57
Pamlico River	19,512	16,628	14,231	15,140	15,676	13,054	10,803	10,138	8,744	123,926	13,770	14.54
Neuse River	7,122	6,741	8,165	8,931	8,868	7,870	6,274	6,279	5,044	65,294	7,255	7.66
Pungo River	N/C	2,037	4,993	5,962	4,629	4,864	5,686	4,830	4,834	37,835	4,204	4.44
Bay River	4,012	5,091	5,088	6,005	5,837	2,732	2,986	2,069	1,414	35,234	3,915	4.13
Currituck Sound	3,978	4,483	3,451	3,455	3,701	3,303	3,641	3,132	4,363	33,507	3,723	3.93
Roanoke Sound	2,965	2,893	2,848	3,217	2,560	3,119	2,628	5,160	3,560	28,950	3,217	3.40
Croatan Sound	3,426	3,718	4,217	3,646	5,179	2,724	1,604	2,036	1,374	27,924	3,103	3.28
Core Sound	3,516	3,425	3,444	3,360	2,650	2,653	2,173	2,107	1,011	24,339	2,704	2.86
Alligator River	2,286	2,669	3,071	1,157	2,326	1,928	2,424	2,208	2,723	20,792	2,310	2.44
Cape Fear River	2,232	2,003	1,722	1,851	1,626	1,503	1,485	1,784	1,679	15,885	1,765	1.86
Inland Waterway	1,345	2,165	1,684	1,066	1,476	1,119	1,666	1,553	1,277	13,351	1,483	1.57
New River	692	1,024	555	818	752	748	1,075	1,439	1,161	8,264	918	0.97
Masonboro Sound	1,080	1,265	666	485	805	572	575	876	748	7,072	786	0.83
Newport River	784	685	582	647	768	643	585	569	485	5,748	639	0.67
Bogue Sound	900	626	648	663	619	369	548	626	392	5,391	599	0.63
White Oak River	511	455	461	473	615	722	545	756	694	5,232	581	0.61
Topsail Sound	441	495	350	259	460	493	411	475	351	3,735	415	0.44
Stump Sound	313	423	381	444	374	388	350	322	338	3,333	370	0.39
Shallotte River	71	93	184	185	186	187	223	380	397	1,906	212	0.22
Pasquotank River	429	395	317	68	32	53	22	139	99	1,554	173	0.18
North River	342	114	45	76	457	94	41	115	132	1,416	157	0.17
Lockwood Folly	21	196	173	82	115	99	86	165	42	979	109	0.11
Perquimans River	211	81	12	N/R	N/R	3	2	10	46	365	41	0.04
Chowan River	62	9	23	4	5	117	N/R	13	130	363	40	0.04
Ocean less than 3 miles	30	32	15	16	37	33	N/R	27	10	200	22	0.02
Back Bay (VA)	N/R	1	60	66	28	N/R	N/R	N/R	N/R	155	17	0.02
Ocean <3 mi, S.C.Hat.	N/R	N/R	9	3	5	N/R	N/R	N/R	1	18	2	0.00
Roanoke River	N/R	N/R	12	N/R	1	N/R	N/R	N/R	N/R	13	1	0.00
Unknown	N/R	N/R	N/R	N/R	N/R	1	8	N/R	N/R	9	1	0.00
Ocean >3 mi, S.C.Hat.	N/R	N/R	N/R	N/R	N/R	N/R	1	N/R	N/R	1	0	0.00
Ocean more than 3 miles	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Total	100,562	102,321	98,518	99,613	106,956	95,559	86,966	86,921	75,035	852,451	94,717	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.19. Annual hard crab CPUE (pounds/trip) estimates* from single gear crab pot trip tickets for North Carolina: 1994 - 2002.

	Year									
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Albemarle Sound	581	596	865	506	706	677	658	481	704	648
Alligator River	582	546	708	556	578	666	635	441	798	621
Currituck Sound	549	737	664	519	570	498	468	390	570	559
Pamlico Sound	605	383	639	637	661	630	401	335	356	538
Bay River	500	355	712	605	488	532	368	234	293	493
Newport River	467	457	559	580	571	565	396	351	404	489
Chowan River	701	668	567	280	614	472	N/R	301	364	477
Croatan Sound	516	451	575	410	481	582	350	315	439	474
Core Sound	497	285	608	505	458	484	324	311	329	440
Pasquotank River	588	442	323	417	499	224	237	270	373	428
Neuse River	478	379	608	451	399	504	312	238	264	417
North River	280	295	1147	789	437	437	469	348	287	409
Pamlico River	350	317	538	486	382	540	329	197	330	392
Perquimans River	287	486	777	N/R	N/R	245	693	176	318	350
Stump Sound	331	403	324	324	426	378	360	302	265	348
Roanoke Sound	273	304	360	303	383	389	315	331	397	340
Cape Fear River	340	333	310	292	371	354	370	298	356	335
Bogue Sound	291	281	417	294	339	409	386	254	227	320
Pungo River	N/C	255	391	367	276	394	334	156	288	314
New River	283	278	297	256	354	367	326	200	168	270
Topsail Sound	351	295	254	298	295	220	206	225	210	261
White Oak River	245	207	194	142	223	215	206	202	213	207
Back Bay (VA)	N/R	174	101	292	166	N/R	N/R	N/R	N/R	194
Ocean less than 3 miles	245	434	379	68	102	111	N/R	69	24	188
Inland Waterway	274	180	200	147	134	191	171	144	149	177
Masonboro Sound	127	130	145	166	200	184	211	149	179	160
Lockwood Folly	138	153	116	136	88	77	78	119	164	118
Roanoke River	N/R	N/R	99	N/R	145	N/R	N/R	N/R	N/R	102
Shallotte River	196	174	97	84	65	46	76	121	88	96
Ocean <3 mi, S.C.Hat.	N/R	N/R	80	103	93	N/R	N/R	N/R	78	87
Total	491	423	628	505	526	560	429	324	462	487

*=Areas with fewer than 10 trips (unknown and ocean > 3 miles) not included.
N/C=No landings data collected; N/R=No landings reported.

Table 6.20. Yearly trips landing hard crabs by area from single gear crab pot trip tickets for North Carolina: 1994 - 2002.

	Year											Percent
Area*	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico	62,926	58,065	57,703	69,656	73,191	62,420	52,189	50,306	37,034	523,490	58,166	61.41
Albemarle	25,358	31,254	29,896	19,529	22,820	23,515	25,005	25,421	29,283	232,081	25,787	27.23
South	6,706	8,119	6,176	5,663	6,409	5,831	6,416	7,750	6,687	59,757	6,640	7.01
Core	5,542	4,850	4,719	4,746	4,494	3,759	3,347	3,417	2,020	36,894	4,099	4.33
Ocean	30	33	24	19	42	33	1	27	11	220	24	0.03
Unknown	N/R	N/R	N/R	N/R	N/R	1	8	N/R	N/R	9	1	0.00
Total	100,562	102,321	98,518	99,613	106,956	95,559	86,966	86,921	75,035	852,451	94,717	

*=See Table 9 for area description; N/R=No landings reported.

Table 6.21. Average annual area hard crab CPUE (pounds/trip) estimates* from single gear crab pot trip tickets for North Carolina: 1994 - 2002.

	Year									
Area**	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Albemarle	574	610	817	510	670	649	628	465	690	630
Pamlico	484	357	576	527	509	559	360	272	333	455
Core	446	309	581	490	459	489	348	309	324	429
South	278	242	238	230	262	266	258	206	220	244
Ocean	245	443	267	73	101	111	67	69	29	181
Total	491	423	628	505	526	560	429	324	462	487

*=Areas with fewer than 10 trips (unknown) not included. **=See table 9 for area description;

Table 6.22. Monthly trips with hard crab landings by year from single gear crab pot trip tickets for North Carolina: 1994 - 2002.

	Year											Percent
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
January	75	339	65	315	350	594	657	86	232	2,713	301	0.32
February	478	130	224	500	595	1,032	527	628	235	4,349	483	0.51
March	3,141	3,000	811	3,628	2,714	1,828	3,347	1,616	1,406	21,491	2,388	2.52
April	7,611	6,592	4,092	5,641	5,450	5,224	4,069	4,244	4,338	47,261	5,251	5.54
May	13,094	14,870	14,176	12,564	12,047	11,523	10,356	12,705	10,213	111,548	12,394	13.09
June	17,922	17,531	19,181	16,520	18,734	18,227	15,637	15,963	13,321	153,036	17,004	17.95
July	17,307	19,138	18,058	18,632	20,138	18,547	15,756	15,924	14,053	157,553	17,506	18.48
August	15,831	16,234	17,350	17,269	15,711	14,924	15,200	15,330	12,783	140,632	15,626	16.50
September	11,248	11,515	11,648	11,780	14,131	8,762	10,711	9,839	8,821	98,455	10,939	11.55
October	7,166	8,852	8,053	8,363	9,903	8,305	6,956	6,262	6,206	70,066	7,785	8.22
November	4,617	3,391	3,590	3,398	4,766	4,474	3,047	2,969	2,873	33,125	3,681	3.89
December	2,072	729	1,270	1,003	2,417	2,119	703	1,355	554	12,222	1,358	1.43
Total	100,562	102,321	98,518	99,613	106,956	95,559	86,966	86,921	75,035	852,451	94,717	100.00

Table 6.23. Average monthly hard crab CPUE (pounds/trip) by year from single gear crab pot trip tickets for North Carolina: 1994 - 2002.

	Year									
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
January	253	200	184	476	240	242	345	176	109	274
February	393	195	228	360	219	312	358	308	161	303
March	303	177	141	298	194	206	351	209	157	247
April	331	209	199	277	242	287	288	188	212	254
May	394	303	296	309	306	307	334	248	249	306
June	544	446	469	395	472	451	368	307	349	428
July	680	468	821	660	646	650	459	373	443	586
August	547	496	874	677	578	660	500	362	557	589
September	421	487	799	592	632	707	539	359	707	582
October	427	549	731	516	694	877	499	386	739	610
November	432	383	557	395	560	657	360	313	674	489
December	274	229	419	295	465	520	243	292	288	369
Total	491	423	628	505	526	560	429	324	462	487

Table 6.24. Total trips with effort data and filtered trips by type for the crab pot fishery in North Carolina: 1997 - 2002.

Waterbody	Total crab pot trips with effort data	Filtered data >700 pots	<10 pots	lbs/pot >15*	Total unusable	Percent of total trips	Total usable trips
Pamlico Sound	123,512	1,328	407	16	1,751	1.42	121,768
Albemarle Sound	120,676	6,951	114	14	7,079	5.87	113,602
Pamlico River	82,100	816	74	18	908	1.11	81,200
Neuse River	41,553	950	9	3	962	2.32	40,591
Pungo River	32,177	59	23	5	87	0.27	32,092
Roanoke Sound	24,482	47	317	9	373	1.52	24,109
Currituck Sound	21,234	284	18	15	317	1.49	20,918
Bay River	17,136	309	37	3	349	2.04	16,788
Croatan Sound	16,895	49	102	18	169	1.00	16,726
Alligator River	14,848	619	44	11	674	4.54	14,176
Core Sound	10,934	68	12	20	100	0.91	10,834
Cape Fear River	8,656	0	13	3	16	0.18	8,640
Inland Waterway	7,585	2	104	8	114	1.50	7,473
New River	5,975	2	101	6	109	1.82	5,868
Newport River	5,570	3	1	0	4	0.07	5,566
White Oak River	3,809	2	86	2	90	2.36	3,719
Masonboro Sound	3,565	1	10	1	12	0.34	3,553
Bogue Sound	2,559	9	16	0	25	0.98	2,534
Topsail Sound	2,290	0	1	4	5	0.22	2,285
Stump Sound	2,229	0	2	8	10	0.45	2,219
Shallotte River	1,286	0	3	1	4	0.31	1,283
Pasquotank River	859	9	9	0	18	2.10	841
North River	796	1	0	1	2	0.25	794
Lockwood Folly	557	0	25	0	25	4.49	532
Chowan River	269	1	3	0	4	1.49	265
Back Bay (VA)	76	0	0	0	0	0.00	76
Ocean less than 3 miles	60	0	0	0	0	0.00	60
Perquimans River	62	0	0	0	0	0.00	62
Unknown	14	0	0	0	0	0.00	14
Ocean <3 mi, S.C.Hat.	38	0	0	0	0	0.00	38
Ocean >3 mi, S.C.Hat.	1	0	0	0	0	0.00	1
Roanoke River	1	0	0	0	0	0.00	1
Total	551,804	11,510	1,531	166	13,207	2.39	538,628

*600 trips with > 15lbs/pot were dropped when the < 10 pots fished per trip filter was applied.

Table 6.25. Average CPUE (pounds/pots fished) by year and water for crab pots in North Carolina: 1997 - 2002.

	Year						
Waterbody	1997	1998	1999	2000	2001	2002	Average
Ocean <3 mi, S.C.Hat.	N/R	4.58	3.60	5.50	N/R	N/R	4.57
Shallotte River	4.46	3.05	3.04	2.87	3.33	2.84	3.08
Lockwood Folly	3.91	3.03	2.57	2.93	2.34	3.58	2.76
Newport River	4.36	2.79	2.67	1.69	2.58	2.78	2.67
Stump Sound	2.68	2.97	2.78	2.66	2.17	2.21	2.58
Inland Waterway	1.94	2.38	3.39	3.03	2.40	1.98	2.58
Cape Fear River	3.09	3.16	2.32	2.39	1.75	2.05	2.36
Unknown	N/R	N/R	0.45	3.62	N/R	N/R	2.26
Masonboro Sound	3.10	2.65	2.16	2.36	2.00	1.97	2.26
Topsail Sound	3.18	3.17	2.20	1.75	1.98	1.94	2.26
Croatan Sound	1.95	1.96	2.54	1.58	1.44	1.67	1.92
Currituck Sound	2.20	2.18	1.81	1.66	1.50	2.00	1.90
North River	1.34	2.25	1.91	1.78	1.15	1.21	1.84
Pamlico Sound	2.34	2.48	2.13	1.43	1.08	1.16	1.81
Back Bay (VA)	2.02	1.42	N/R	N/R	N/R	N/R	1.80
Core Sound	1.96	2.23	2.29	1.65	1.23	1.10	1.79
Roanoke Sound	1.39	2.05	2.06	1.64	1.55	1.64	1.70
Ocean less than 3 miles	N/R	N/R	2.27	N/R	1.60	0.97	1.63
Albemarle Sound	1.60	1.98	1.88	1.54	1.13	1.66	1.62
New River	1.22	1.82	1.93	1.84	1.62	1.19	1.59
Bogue Sound	1.10	1.78	1.93	1.71	1.52	1.35	1.56
Perquimans River	N/R	N/R	1.43	1.33	1.11	1.60	1.50
Alligator River	1.54	1.59	1.78	1.26	1.00	1.39	1.40
Pasquotank River	1.97	2.91	0.98	0.46	1.05	1.44	1.27
White Oak River	1.62	1.20	1.33	1.07	0.90	1.42	1.19
Chowan River	1.46	3.30	1.20	N/R	1.45	0.99	1.15
Pamlico River	1.41	1.05	1.51	0.92	0.62	0.90	1.09
Pungo River	1.38	1.03	1.39	1.23	0.56	0.92	1.09
Bay River	1.75	1.26	1.01	0.81	0.47	0.77	1.04
Neuse River	1.28	1.06	1.36	0.81	0.69	0.72	1.01
Roanoke River	N/R	0.73	N/R	N/R	N/R	N/R	0.73
Ocean >3 mi, S.C.Hat.	N/R	N/R	N/R	0.14	N/R	N/R	0.14
Total	1.76	1.85	1.86	1.40	1.10	1.38	1.56

Table 6.26. Average number of pots fished per trip by year and waterbody for North Carolina: 1997 - 2002.

	Year						Overall
Waterbody	1997	1998	1999	2000	2001	2002	average
Ocean >3 mi, S.C.Hat.	N/R	N/R	N/R	500	N/R	N/R	500
Bay River	348	389	455	442	398	320	399
Unknown	N/R	N/R	517	295	N/R	N/R	390
Chowan River	184	195	384	N/R	236	364	361
Alligator River	340	314	318	367	340	398	351
Neuse River	336	350	345	351	338	354	346
Albemarle Sound	308	311	325	348	346	348	334
Pamlico River	291	293	293	295	261	291	288
Currituck Sound	262	268	280	279	276	284	275
Pamlico Sound	261	259	285	263	282	289	272
Pungo River	244	235	265	253	262	266	254
Bogue Sound	321	282	258	277	202	172	249
Core Sound	282	237	209	207	256	281	236
North River	194	192	216	270	287	251	222
Croatan Sound	219	221	210	198	218	233	217
Perquimans River	N/R	N/R	300	327	178	204	209
Roanoke River	N/R	200	N/R	N/R	N/R	N/R	200
White Oak River	32	176	176	218	247	204	197
Pasquotank River	141	133	210	186	211	192	190
Roanoke Sound	177	167	186	171	197	197	186
New River	228	228	213	201	132	144	178
Back Bay (VA)	171	121	N/R	N/R	N/R	N/R	153
Cape Fear River	109	121	138	162	180	168	151
Stump Sound	118	136	134	136	130	123	130
Newport River	150	142	141	134	105	91	126
Topsail Sound	112	99	104	115	115	109	109
Masonboro Sound	62	78	86	82	77	95	82
Inland Waterway	94	66	56	64	77	101	75
Ocean less than 3 miles	N/R	N/R	37	N/R	43	39	39
Lockwood Folly	51	29	28	29	48	51	36
Shallotte River	21	24	17	25	36	35	30
Ocean <3 mi, S.C.Hat.	N/R	19	35	10	N/R	N/R	20
Total	275	271	285	284	277	290	280

Table 6.27. Average CPUE (pounds/pots fished) estimates by area in North Carolina: 1997 - 2002.

	Year						
Area	1997	1998	1999	2000	2001	2002	Total
South	2.36	2.49	2.37	2.34	1.91	1.87	2.19
Core	2.46	2.33	2.35	1.67	1.60	1.78	2.01
Ocean	N/R	4.58	2.31	2.82	1.60	0.97	1.82
Albemarle	1.70	1.98	1.85	1.52	1.16	1.68	1.63
Pamlico	1.71	1.73	1.78	1.21	0.93	1.07	1.43
Total	1.76	1.85	1.86	1.40	1.10	1.38	1.56

Table 6.28. Average number of pots fished per trip by area and year for North Carolina: 1997 - 2002.

	Year						
Area	1997	1998	1999	2000	2001	2002	Total
Albemarle	301	303	318	340	336	343	326
Pamlico	276	276	293	281	275	282	281
Core	251	212	196	193	212	192	206
South	123	118	124	131	130	133	127
Ocean	N/R	19	37	255	43	39	43
Total	275	271	285	284	277	290	280

Table 6.29. Average monthly CPUE (pounds/pots fished) estimates for North Carolina: 1997 - 2002.

	Year						
Month	1997	1998	1999	2000	2001	2002	Total
January	2.01	1.53	1.78	2.09	1.37	0.98	1.75
February	2.28	1.60	1.70	2.04	1.66	1.37	1.74
March	1.14	1.04	1.03	1.54	1.02	0.77	1.17
April	1.02	1.05	1.08	1.19	0.80	0.87	1.00
May	1.17	1.20	1.10	1.24	0.99	0.92	1.10
June	1.38	1.60	1.37	1.18	1.06	1.03	1.27
July	2.02	2.08	1.86	1.32	1.13	1.20	1.60
August	2.09	1.94	2.01	1.39	1.08	1.47	1.63
September	2.02	2.11	2.41	1.63	1.12	1.98	1.86
October	2.01	2.51	3.25	1.79	1.41	2.43	2.29
November	1.95	2.47	2.91	1.79	1.48	2.62	2.28
December	1.45	2.27	2.49	1.54	1.45	1.92	2.07
Total	1.76	1.85	1.86	1.40	1.10	1.38	1.56

Table 6.30. Average monthly number of pots fished per trip for North Carolina: 1997 - 2002.

	Year						
Month	1997	1998	1999	2000	2001	2002	Total
January	172	170	154	189	138	124	166
February	176	161	197	202	198	142	187
March	212	211	217	227	219	219	219
April	231	230	249	236	231	247	238
May	269	256	268	264	266	269	265
June	278	278	300	290	277	290	286
July	289	290	309	308	297	308	300
August	289	278	306	306	294	316	299
September	274	287	281	299	292	307	290
October	269	274	276	276	279	288	277
November	221	239	241	222	231	254	236
December	179	215	221	178	218	173	210
Total	275	271	285	284	277	290	280

Table 6.31. Yearly hard crab landings from single gear crab trawl trip tickets for North Carolina waters: 1994 - 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico Sound	733,482	702,995	1,310,093	1,490,419	1,146,573	619,455	407,132	636,641	896,318	7,943,108	882,568	46.67
Pamlico River	615,003	152,743	486,142	398,098	558,327	455,884	103,690	42,923	4,506	2,817,316	313,035	16.55
Neuse River	240,488	34,586	210,160	406,120	297,617	232,037	47,374	38,527	2,864	1,509,773	167,753	8.87
Pungo River	N/C	11,818	267,400	298,589	400,954	203,549	207,197	78,358	17,511	1,485,376	165,042	8.73
Croatan Sound	84,663	76,877	416,281	94,990	196,128	59,317	31,642	68,191	47,969	1,076,058	119,562	6.32
Bay River	139,068	13,995	264,697	265,056	226,570	102,598	41,432	17,422	3,141	1,073,978	119,331	6.31
Core Sound	26,951	14,425	32,012	267,466	225,588	95,660	53,111	58,481	10,832	784,525	87,169	4.61
New River	10,848	33,616	8,284	33,196	3,988	23,214	17,643	17,476	12,190	160,455	17,828	0.94
Roanoke Sound	3,359	1,261	70,981	8,449	535	232	6,114	24,876	11,145	126,952	14,106	0.75
Unknown	6,771	N/R	4,817	N/R	158	N/R	1,223	300	5,312	18,581	2,065	0.11
Newport River	215	624	1,336	4,499	3,967	332	N/R	N/R	N/R	10,973	1,219	0.06
North River	438	619	N/R	128	2,769	1,794	N/R	N/R	N/R	5,748	639	0.03
Ocean more than 3 miles	2,449	N/R	N/R	41	N/R	N/R	N/R	N/R	N/R	2,490	277	0.01
Inland Waterway	N/R	238	660	N/R	N/R	N/R	1,010	44	N/R	1,952	217	0.01
Lockwood Folly	N/R	1,640	N/R	N/R	N/R	N/R	N/R	N/R	N/R	1,640	182	0.01
Ocean less than 3 miles	1,318	45	N/R	N/R	N/R	N/R	N/R	N/R	N/R	1,363	151	0.01
Bogue Sound	41	N/R	N/R	183	N/R	N/R	N/R	131	N/R	355	39	0.00
Chowan River	N/R	N/R	173	N/R	N/R	N/R	N/R	N/R	N/R	173	19	0.00
White Oak River	N/R	N/R	88	N/R	N/R	N/R	N/R	N/R	N/R	88	10	0.00
Ocean <3 mi, N.C.Hat.	N/R	N/R	75	N/R	N/R	N/R	N/R	N/R	N/R	75	8	0.00
Topsail Sound	60	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	60	7	0.00
Ocean <3 mi, S.C.Hat.	N/R	N/R	46	N/R	N/R	N/R	N/R	N/R	N/R	46	5	0.00
Total	1,865,154	1,045,482	3,073,244	3,267,234	3,063,173	1,794,072	917,568	983,370	1,011,788	17,021,084	1,891,232	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.32. Yearly trips with hard crab landings, from single gear crab trawl trip tickets for North Carolina Waters: 1994 - 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico Sound	791	592	1,162	950	868	684	458	616	433	6,554	728	23.56
Pamlico River	1,463	682	611	774	1,098	860	346	279	45	6,158	684	22.14
Pungo River	N/C	57	596	939	1,203	588	703	621	130	4,837	537	17.39
Neuse River	552	191	665	696	858	430	172	161	39	3,764	418	13.53
Core Sound	79	55	104	514	428	322	174	277	20	1,973	219	7.09
Croatan Sound	170	160	465	242	370	97	46	132	81	1,763	196	6.34
Bay River	263	63	276	225	376	215	102	93	32	1,645	183	5.91
New River	35	94	47	187	62	32	45	103	77	682	76	2.45
Roanoke Sound	26	12	110	45	5	5	6	53	37	299	33	1.08
Newport River	2	1	6	10	25	3	N/R	N/R	N/R	47	5	0.17
Unknown	12	N/R	7	N/R	1	N/R	1	1	6	28	3	0.10
North River	3	3	N/R	1	7	5	N/R	N/R	N/R	19	2	0.07
Inland Waterway	N/R	5	4	N/R	N/R	N/R	2	2	N/R	13	1	0.05
Ocean less than 3 miles	12	1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	13	1	0.05
Bogue Sound	1	N/R	N/R	4	N/R	N/R	N/R	1	N/R	6	1	0.02
Ocean more than 3 miles	5	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	6	1	0.02
Chowan River	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Lockwood Folly	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Ocean <3 mi, N.C.Hat.	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Ocean <3 mi, S.C.Hat.	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Topsail Sound	1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
White Oak River	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Total	3,415	1,917	4,057	4,588	5,301	3,241	2,055	2,339	900	27,813	3,090	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.33. Average annual CPUE (pounds/trip) estimates* from single gear crab trawl trip tickets for North Carolina: 1994 - 2002.

	Year									
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Pamlico Sound	927	1,187	1,127	1,569	1,321	906	889	1,034	2,070	1,212
Unknown	564	N/R	688	N/R	158	N/R	1,223	300	885	664
Bay River	529	222	959	1,178	603	477	406	187	98	653
Croatan Sound	498	480	895	393	530	612	688	517	592	610
Pamlico River	420	224	796	514	508	530	300	154	100	458
Roanoke Sound	129	105	645	188	107	46	1,019	469	301	425
Ocean more than 3 miles	490	N/R	N/R	41	N/R	N/R	N/R	N/R	N/R	415
Neuse River	436	181	316	584	347	540	275	239	73	401
Core Sound	341	262	308	520	527	297	305	211	542	398
Pungo River	N/R	207	449	318	333	346	295	126	135	307
North River	146	206	N/R	128	396	359	N/R	N/R	N/R	303
New River	310	358	176	178	64	725	392	170	158	235
Newport River	108	624	223	450	159	111	N/R	N/R	N/R	233
Inland Waterway	N/R	48	165	N/R	N/R	N/R	505	22	N/R	150
Total	546	545	758	712	578	554	447	420	1,124	612

*Areas with fewer than 10 trips not included.

Table 6.34. Monthly hard crab landings (pounds) from single gear crab trawl trip tickets in North Carolina: 1994 - 2002.

	Year											Percent
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
January	1,747	42,822	1,475	128,894	93,272	56,037	5,628	19,540	13,693	363,108	40,345	2.13
February	175,596	23,515	12,302	411,421	136,246	112,871	77,829	69,500	80,792	1,100,072	122,230	6.46
March	386,149	229,283	43,679	613,002	300,366	172,005	198,384	148,260	176,602	2,267,730	251,970	13.32
April	289,770	101,896	384,706	148,338	320,224	208,270	30,283	125,725	30,635	1,639,846	182,205	9.63
May	195,915	40,376	149,277	235,521	184,862	203,221	121,048	83,226	8,485	1,221,931	135,770	7.18
June	312,855	33,883	466,275	225,991	190,446	425,038	124,525	26,186	7,268	1,812,467	201,385	10.65
July	147,042	27,589	322,055	385,620	345,570	185,816	22,312	13,143	3,424	1,452,571	161,397	8.53
August	102,393	51,636	173,476	193,110	310,492	63,163	37,095	18,696	1,434	951,495	105,722	5.59
September	94,689	37,529	362,158	225,061	343,586	106,233	40,785	46,250	679	1,256,970	139,663	7.38
October	28,999	25,461	473,368	156,408	117,007	92,525	62,659	41,117	20,110	1,017,654	113,073	5.98
November	94,308	366,197	461,626	251,652	498,031	38,370	69,354	256,704	487,159	2,523,401	280,378	14.83
December	35,691	65,295	222,848	292,216	223,071	130,523	127,666	135,023	181,507	1,413,840	157,093	8.31
Total	1,865,154	1,045,482	3,073,244	3,267,234	3,063,173	1,794,072	917,568	983,370	1,011,788	17,021,084	1,891,232	100.00

Table 6.35. Monthly trips with hard crab landings by year from single gear crab trawl trip tickets in North Carolina: 1994 - 2002.

	Year											Percent
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
January	21	65	6	100	85	131	20	47	23	498	55	1.79
February	137	50	35	310	169	258	194	176	115	1,444	160	5.19
March	560	376	131	729	684	385	348	320	198	3,731	415	13.41
April	506	302	599	570	745	503	170	505	138	4,038	449	14.52
May	624	245	683	811	617	556	365	522	85	4,508	501	16.21
June	636	154	623	664	585	591	366	201	58	3,878	431	13.94
July	232	140	338	338	578	276	63	79	35	2,079	231	7.47
August	209	146	245	222	573	105	97	88	15	1,700	189	6.11
September	210	106	453	253	515	138	123	102	7	1,907	212	6.86
October	88	80	506	252	264	123	163	65	25	1,566	174	5.63
November	125	204	323	183	281	68	71	128	130	1,513	168	5.44
December	67	49	115	156	205	107	75	106	71	951	106	3.42
Total	3,415	1,917	4,057	4,588	5,301	3,241	2,055	2,339	900	27,813	3,090	100.00

Table 6.36. Monthly hard crab CPUE (pounds/trip) by year from single gear crab trawl trip tickets in North Carolina: 1994-2002.

	Year									
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
January	83	659	246	1,289	1,097	428	281	416	595	729
February	1,282	470	351	1,327	806	437	401	395	703	762
March	690	610	333	841	439	447	570	463	892	608
April	573	337	642	260	430	414	178	249	222	406
May	314	165	219	290	300	366	332	159	100	271
June	492	220	748	340	326	719	340	130	125	467
July	634	197	953	1,141	598	673	354	166	98	699
August	490	354	708	870	542	602	382	212	96	560
September	451	354	799	890	667	770	332	453	97	659
October	330	318	936	621	443	752	384	633	804	650
November	754	1,795	1,429	1,375	1,772	564	977	2,006	3,747	1,668
December	533	1,333	1,938	1,873	1,088	1,220	1,702	1,274	2,556	1,487
Total	546	545	758	712	578	554	447	420	1,124	612

Table 6.37. Yearly shedder (peeler and soft blue crabs) landings* (pounds) and value for North Carolina: 1950 - 2002.

Year	Landings	Value	Year	Landings	Value
1950	208,800	$24,753	1977	16,000	$17,000
1951	167,000	$24,906	1978	46,826	$89,718
1952	124,200	$18,630	1979	80,367	$129,908
1953	167,800	$33,560	1980	87,482	$132,448
1954	95,100	$14,265	1981	77,748	$100,860
1955	25,800	$5,170	1982	147,959	$295,218
1956	71,000	$14,200	1983	87,101	$187,754
1957	63,600	$15,900	1984	199,771	$276,302
1958	75,600	$21,415	1985	326,163	$347,841
1959	124,400	$37,320	1986	595,468	$684,822
1960	90,900	$31,815	1987	660,791	$2,248,437
1961	100,800	$35,280	1988	468,191	$921,403
1962	97,700	$34,200	1989	788,681	$1,567,298
1963	83,400	$37,530	1990	1,085,122	$2,136,942
1964	69,700	$32,924	1991	755,613	$1,389,140
1965	237,000	$85,133	1992	560,959	$996,904
1966	125,600	$56,342	1993	805,623	$1,515,569
1967	86,100	$36,972	1994	1,253,007	$2,703,834
1968	83,500	$31,354	1995	1,409,997	$3,185,481
1969	93,400	$42,224	1996	1,397,698	$3,158,910
1970	59,800	$23,246	1997	1,736,564	$4,520,166
1971	48,900	$25,414	1998	1,673,838	$4,492,761
1972	50,000	$29,186	1999	1,452,585	$4,286,119
1973	45,100	$27,762	2000	1,749,111	$5,278,530
1974	33,300	$23,109	2001	2,240,896	$7,153,706
1975	20,100	$16,996	2002	1,274,384	$3,795,794
1976	20,000	$26,549	Average	442,388	$989,038

*Peeler and soft crab landings are usually reported by numbers. The Trip Ticket Program conversion of numbers to pounds for peeler and soft crabs is 0.33 (i.e., three peeler/soft crabs equal one pound).

Table 6.38. Monthly landings of shedders (peeler and soft crabs pounds combined) for North Carolina: 1994 - 2002

	Year											Percent
Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
January	368	14	130	58	208	725	11	51		1,566	174	0.01
February	3	9	153	20	41	288		44	116	673	75	0.00
March	12,319	13,704	5,368	10,386	5,201	4,840	16,710	2,377	5,688	76,593	8,510	0.54
April	184,179	150,916	68,360	58,578	172,857	122,127	120,049	110,129	416,647	1,403,841	155,982	9.89
May	700,052	818,115	759,680	1,034,296	837,954	709,287	670,068	1,256,834	336,522	7,122,809	791,423	50.20
June	194,888	214,993	366,700	321,143	302,406	337,289	163,524	398,576	229,511	2,529,031	281,003	17.83
July	53,852	47,780	66,961	133,314	106,360	122,259	109,260	119,070	81,722	840,577	93,397	5.92
August	45,012	99,951	105,257	111,960	138,279	120,114	479,527	233,601	151,890	1,485,590	165,066	10.47
September	56,781	55,304	23,299	57,438	95,780	27,531	145,131	101,908	42,633	605,804	67,312	4.27
October	4,952	8,601	1,691	9,158	14,127	7,470	43,361	17,771	5,191	112,323	12,480	0.79
November	586	605	93	211	546	375	442	506	4,462	7,825	869	0.06
December	17	4	4	2	82	279	1,030	29	1	1,448	161	0.01
Total	1,253,007	1,409,997	1,397,698	1,736,564	1,673,838	1,452,585	1,749,111	2,240,896	1,274,384	14,188,080	1,576,453	100.00

Table 6.39. Shedder (peeler and soft blue crabs combined) landings (pounds) from single gear trip tickets for North Carolina: 1994 – 2002.

	Year											Percent
Gear	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Crab pot	1,210,546	1,376,921	1,309,287	1,547,748	1,087,711	919,407	1,138,066	1,280,637	738,543	10,608,866	1,178,763	76.18
Peeler Pot	N/R	N/R	57,897	131,175	533,811	460,241	509,325	866,662	485,142	3,044,255	338,251	21.86
Crab Trawl	24,660	19,574	15,116	22,511	20,658	18,272	19,570	13,602	5,035	158,997	17,666	1.14
Shrimp trawl	4,315	3,416	6,712	12,417	3,192	5,102	11,309	1,538	3,781	51,781	5,753	0.37
Gill net set (sink)	463	978	2,574	6,883	4,640	6,516	8,817	7,015	5,359	43,245	4,805	0.31
Gill net set (float)	636	3,594	658	446	1,752	246	616	2,088	1,061	11,096	1,233	0.08
Skimmer trawl	N/R	46	807	1,736	1,487	8	3	146	30	4,263	474	0.03
Pound net	19	233	8	N/R	277	70	104	930	1	1,641	182	0.01
Crab dredge	N/R	6	N/R	N/R	N/R	N/R	N/R	N/R	710	715	79	0.01
Cast net	N/R	460	N/R	N/R	N/R	N/R	N/R	N/R	N/R	460	51	0.00
Trotline	60	N/R	N/R	N/R	N/R	139	124	34	96	454	50	0.00
By hand	N/R	298	N/R	N/R	N/R	N/R	N/R	N/R	N/R	298	33	0.00
Eel pot	N/R	N/R	16	9	28	2	15	33	N/R	102	11	0.00
Channel net	N/R	4	5	58	N/R	1	1	0	28	96	11	0.00
Haul seine	25	N/R	1	18	N/R	N/R	N/R	N/R	N/R	44	5	0.00
Gill net (runaround)	0	N/R	N/R	N/R	2	29	N/R	3	1	35	4	0.00
Oyster dredge	N/R	N/R	30	N/R	N/R	N/R	N/R	N/R	N/R	30	3	0.00
Fyke net	N/R	N/R	N/R	10	N/R	N/R	N/R	N/R	N/R	10	1	0.00
Rakes bull	N/R	6	2	N/R	N/R	N/R	N/R	N/R	N/R	8	1	0.00
Tongs, hand	N/R	4	N/R	N/R	N/R	N/R	N/R	N/R	N/R	4	0	0.00
Rakes hand	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Total	1,240,724	1,405,540	1,393,114	1,723,012	1,653,556	1,410,031	1,687,950	2,172,687	1,239,787	13,926,402	1,547,378	100.00

N/C=No landings collected; N/R= No landings reported.

Table 6.40. Monthly contribution of pot caught shedders from single gear trip tickets in North Carolina: 1994 – 2002.

	Crab pot		Peeler pot		Total pots	
Month	Pounds	% of total	Pounds	% of total	Pounds	% of total
January	782	0.01	726	0.02	1,508	0.01
February	495	0.00	0	0.00	495	0.00
March	16,813	0.16	2,524	0.08	19,337	0.14
April	942,660	8.89	392,080	12.88	1,334,739	9.78
May	5,025,708	47.37	1,919,173	63.04	6,944,881	50.87
June	2,068,425	19.50	378,595	12.44	2,447,020	17.92
July	750,642	7.08	51,322	1.69	801,965	5.87
August	1,194,441	11.26	215,815	7.09	1,410,256	10.33
September	502,045	4.73	74,489	2.45	576,534	4.22
October	100,181	0.94	8,088	0.27	108,269	0.79
November	6,101	0.06	572	0.02	6,673	0.05
December	573	0.01	870	0.03	1,443	0.01
Total	10,608,866	100.00	3,044,255	100.00	13,653,120	100.00

Table 6.41. Monthly contribution of trawl caught shedders from single gear trip tickets in North Carolina: 1994 – 2002.

	Crab trawl		Shrimp trawl		Skimmer trawl		Total trawls	
Month	Pounds	% of total	Pounds	% of total	Pounds	% of total	Pounds	% of total
January	0	0.00	8	0.02	0	0.00	8	0.00
February	156	0.10	22	0.04	0	0.00	178	0.08
March	52,032	32.73	367	0.71	3,412	80.04	55,810	25.95
April	31,204	19.63	432	0.83	583	13.68	32,219	14.98
May	29,562	18.59	1,939	3.74	146	3.42	31,646	14.72
June	25,169	15.83	5,568	10.75	0	0.00	30,737	14.29
July	6,765	4.25	15,215	29.38	9	0.21	21,989	10.23
August	9,661	6.08	23,237	44.88	36	0.84	32,934	15.32
September	4,086	2.57	4,229	8.17	28	0.67	8,343	3.88
October	363	0.23	673	1.30	48	1.11	1,084	0.50
November	0	0.00	87	0.17	1	0.03	89	0.04
December	0	0.00	5	0.01	0	0.00	5	0.00
Total	158,997	100.00	51,781	100.00	4,263	100.00	215,040	100.00

Table 6.42. Yearly landings (pounds) of shedders (peeler and soft blue crabs combined) for North Carolina waters: 1994 – 2002.

	Year											Percent
Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Albemarle Sound	201,065	337,744	392,223	344,756	356,870	394,276	605,423	765,213	431,913	3,829,482	425,498	26.99
Pamlico Sound	332,908	273,797	244,790	394,923	420,580	323,698	408,628	500,441	146,738	3,046,504	338,500	21.47
Roanoke Sound	235,636	231,981	189,242	358,468	317,515	239,479	293,540	377,060	275,072	2,517,995	279,777	17.75
Croatan Sound	201,969	293,300	192,898	296,498	184,527	146,048	118,911	213,159	115,224	1,762,535	195,837	12.42
Currituck Sound	40,170	55,409	68,699	69,194	119,261	49,659	48,996	111,532	89,280	652,199	72,467	4.60
Pamlico River	71,647	37,137	39,585	61,746	68,772	61,299	44,230	27,138	31,604	443,158	49,240	3.12
Neuse River	43,183	36,847	76,395	66,372	63,578	55,131	32,237	32,637	17,539	423,919	47,102	2.99
Core Sound	42,164	40,574	57,313	27,260	28,674	37,144	37,507	38,039	22,362	331,039	36,782	2.33
Alligator River	11,640	16,186	38,903	17,175	22,287	30,278	41,909	34,632	41,542	254,553	28,284	1.79
Newport River	20,075	19,973	24,506	20,182	14,801	23,892	21,566	28,390	18,972	192,358	21,373	1.36
Cape Fear River	13,660	14,169	15,526	17,293	20,857	17,559	21,266	30,091	22,704	173,125	19,236	1.22
Bay River	17,546	11,311	12,508	17,771	20,230	20,401	16,625	14,067	10,427	140,885	15,654	0.99
White Oak River	4,445	11,579	6,791	10,429	12,117	16,571	16,280	19,561	17,772	115,545	12,838	0.81
New River	4,845	9,579	3,041	7,875	3,292	5,048	6,973	13,124	7,280	61,057	6,784	0.43
Pungo River	N/C	2,737	4,206	9,838	7,880	7,323	7,998	3,919	9,055	52,955	5,884	0.37
North River	2,783	7,854	8,894	2,960	4,570	4,095	9,498	5,396	2,868	48,917	5,435	0.34
Pasquotank River	394	448	3,952	551	489	9,591	6,233	12,867	6,172	40,698	4,522	0.29
Bogue Sound	3,028	6,168	7,180	4,872	2,466	2,202	2,867	2,531	1,180	32,494	3,610	0.23
Stump Sound	2,701	1,370	5,141	3,170	2,220	4,031	3,910	4,479	2,822	29,844	3,316	0.21
Inland Waterway	1,580	224	2,876	3,040	1,950	1,823	2,760	3,441	1,273	18,967	2,107	0.13
Masonboro Sound	578	168	746	1,190	831	2,551	657	2,470	1,486	10,677	1,186	0.08
Topsail Sound	187	417	520	176	25	55	1,002	310	560	3,251	361	0.02
Shallotte River	218	583	511	523	33	N/R	N/R	311	387	2,565	285	0.02
Lockwood Folly	207	43	401	72	8	12	58	53	1	854	95	0.01
Chowan River	N/R	157	464	1	N/R	17	N/R	27	9	675	75	0.00
Perquimans River	249	81	26	N/R	N/R	N/R	28	3	140	528	59	0.00

Table 6.42. Continued

Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	Percent of total
Ocean less than 3 miles	129	159	11	N/R	N/R	94	N/R	1	N/R	394	44	0.00
Roanoke River	N/R	N/R	276	N/R	N/R	N/R	N/R	N/R	N/R	276	31	0.00
Ocean >3 mi, S.C.Hat.	N/R	N/R	71	180	2	12	5	N/R	1	271	30	0.00
Unknown	N/R	N/R	N/R	N/R	N/R	255	N/R	N/R	N/R	255	28	0.00
Ocean <3 mi, N.C.Hat.	N/R	N/R	N/R	N/R	N/R	41	N/R	N/R	N/R	41	5	0.00
Back Bay (VA)	N/R	N/R	N/R	36	N/R	N/R	N/R	N/R	N/R	36	4	0.00
Ocean <3 mi, S.C.Hat.	N/R	2	0	2	2	3	1	5	0	16	2	0.00
Ocean more than 3 miles	1	N/R	N/R	12	N/R	N/R	N/R	N/R	N/R	13	1	0.00
Grand Total	1,253,007	1,409,997	1,397,698	1,736,564	1,673,838	1,452,585	1,749,111	2,240,896	1,274,384	14,188,080	1,576,453	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.43. Yearly value of shedder (peeler and soft blue crabs combined) landings from North Carolina waters: 1994 – 2002.

Waterbody	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	Percent of total
Albemarle Sound	526,616	804,917	967,952	913,784	1,024,921	1,252,760	2,087,492	2,713,601	1,505,322	11,797,365	1,310,818	30.58
Roanoke Sound	639,700	545,932	554,007	1,234,061	1,087,928	886,068	1,142,965	1,438,626	960,111	8,489,397	943,266	22.01
Pamlico Sound	557,202	496,903	508,550	779,976	1,009,435	797,263	953,198	1,353,044	319,284	6,774,855	752,762	17.56
Croatan Sound	498,986	786,004	464,227	894,316	494,382	488,178	390,164	651,057	314,693	4,982,007	553,556	12.92
Currituck Sound	80,214	153,186	139,442	148,321	289,911	135,460	138,059	328,581	228,208	1,641,383	182,376	4.26
Neuse River	77,683	72,600	150,900	148,834	149,809	156,060	78,918	93,671	45,899	974,373	108,264	2.53
Pamlico River	108,635	67,091	59,961	130,728	139,205	140,894	88,154	65,310	67,163	867,142	96,349	2.25
Core Sound	60,980	71,970	71,936	51,282	57,123	80,994	74,209	90,198	47,632	606,324	67,369	1.57
Alligator River	14,281	27,501	59,668	30,904	50,057	78,890	84,250	81,571	85,806	512,927	56,992	1.33
Newport River	49,099	29,202	37,148	35,044	29,378	53,785	41,826	66,244	38,519	380,244	42,249	0.99
Cape Fear River	29,061	30,336	25,660	30,962	42,015	40,100	42,141	72,241	47,887	360,403	40,045	0.93

Table 6.43. Continued.

Waterbody	Year 1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	Percent of total
Bay River	21,334	16,495	19,902	31,472	40,194	46,119	34,824	32,935	21,712	264,986	29,443	0.69
White Oak River	5,708	18,753	14,723	18,460	24,056	37,339	31,597	45,650	36,544	232,829	25,870	0.60
New River	14,336	22,751	9,969	20,443	10,322	15,761	15,645	31,172	17,494	157,894	17,544	0.41
Pungo River	N/C	4,004	6,581	19,340	17,577	18,280	20,980	11,999	21,857	120,617	13,402	0.31
North River	5,914	20,545	28,928	5,593	9,110	9,390	18,422	12,590	6,310	116,802	12,978	0.30
Pasquotank River	1,209	1,192	9,111	1,380	1,048	22,166	12,139	30,032	12,539	90,816	10,091	0.24
Bogue Sound	4,565	10,621	14,721	8,489	5,185	4,951	5,567	7,152	2,397	63,650	7,072	0.17
Stump Sound	3,569	2,244	6,003	6,905	4,887	10,405	8,466	11,534	6,911	60,923	6,769	0.16
Inland Waterway	2,130	548	5,188	5,946	4,389	4,210	5,565	8,148	3,011	39,135	4,348	0.10
Masonboro Sound	736	247	1,517	2,107	1,670	5,791	1,753	6,562	4,156	24,538	2,726	0.06
Topsail Sound	235	666	844	367	53	169	1,957	822	1,209	6,321	702	0.02
Shallotte River	680	848	774	904	66	N/R	N/R	728	794	4,793	533	0.01
Lockwood Folly	338	65	611	128	29	47	126	142	5	1,489	165	0.00
Ocean less than 3 miles	296	504	38	N/R	N/R	212	N/R	2	N/R	1,052	117	0.00
Perquimans River	323	124	40	N/R	N/R	N/R	99	8	304	897	100	0.00
Unknown	N/R	N/R	N/R	N/R	N/R	573	N/R	N/R	N/R	573	64	0.00
Chowan River	N/R	229	58	4	N/R	68	N/R	64	24	447	50	0.00
Roanoke River	N/R	N/R	418	N/R	N/R	N/R	N/R	N/R	N/R	418	46	0.00
Ocean >3 mi, S.C.Hat.	N/R	N/R	33	325	6	18	10	N/R	3	395	44	0.00
Ocean <3 mi, N.C.Hat.	N/R	N/R	N/R	N/R	N/R	157	N/R	N/R	N/R	157	17	0.00
Back Bay (VA)	N/R	N/R	N/R	68	N/R	N/R	N/R	N/R	N/R	68	8	0.00
Ocean <3 mi, S.C.Hat.	N/R	3	1	5	7	11	5	21	1	55	6	0.00
Ocean more than 3 miles	3	N/R	N/R	21	N/R	N/R	N/R	N/R	N/R	24	3	0.00
Total	2,703,834	3,185,481	3,158,910	4,520,166	4,492,761	4,286,119	5,278,530	7,153,706	3,795,794	38,575,300	4,286,144	100.00

N/C=No landings data collected; N/R=No landings reported.

Table 6.44. Shedder (peeler and soft blue crabs combined) landings (pounds) by area for North Carolina: 1994 – 2002.

	Year											Percent
Area	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico	902,889	887,111	759,625	1,205,615	1,083,082	853,379	922,169	1,168,421	605,659	8,387,950	931,994	59.12
Albemarle	253,519	410,026	504,543	431,713	498,907	483,820	702,590	924,273	569,056	4,778,447	530,939	33.68
Core	68,049	74,568	97,894	55,275	50,511	67,333	71,439	74,356	45,382	604,808	67,201	4.26
Southern	28,420	38,131	35,553	43,768	41,334	47,649	52,906	73,840	54,285	415,886	46,210	2.93
Ocean	130	161	83	194	4	150	6	6	1	734	82	0.01
Unknown						255				255	28	0.00
Total	1,253,007	1,409,997	1,397,698	1,736,564	1,673,838	1,452,585	1,749,111	2,240,896	1,274,384	14,188,080	1,576,453	100.00

Table 6.45. Shedder (peeler and soft blue crabs combined) landings value by area for North Carolina: 1994 – 2002.

	Year											Percent
Area	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Pamlico	1,903,540	1,989,030	1,764,128	3,238,726	2,938,529	2,532,862	2,709,203	3,646,642	1,750,719	22,473,378	2,497,042	58.26
Albemarle	622,643	987,149	1,176,688	1,094,460	1,365,937	1,489,345	2,322,038	3,153,858	1,832,203	14,044,321	1,560,480	36.41
Core	120,559	132,338	152,734	100,408	100,796	149,120	140,025	176,184	94,858	1,167,021	129,669	3.03
Southern	56,793	76,458	65,288	86,221	87,485	113,821	107,249	176,999	118,011	888,326	98,703	2.30
Ocean	299	507	73	351	14	398	14	23	4	1,682	187	0.00
Unknown						573				573	64	0.00
Total	2,703,834	3,185,481	3,158,910	4,520,166	4,492,761	4,286,119	5,278,530	7,153,706	3,795,794	38,575,300	4,286,144	100.00

Table 6.46. Physical location and number of blue crab shedding operations in North Carolina: 2001 – 2003.

	Year					
	2001		2002		2003	
County	Number	Percent	Number	Percent	Number	Percent
Beaufort	17	5.43%	16	4.52%	17	4.83%
Brunswick	5	1.60%	6	1.69%	9	2.56%
Camden	14	4.47%	15	4.24%	16	4.55%
Carteret	44	14.06%	49	13.84%	53	15.06%
Craven	5	1.60%	7	1.98%	6	1.70%
Currituck	22	7.03%	30	8.47%	28	7.95%
Dare	122	38.98%	143	40.40%	140	39.77%
Greene	1	0.32%	1	0.28%	1	0.28%
Hyde	20	6.39%	19	5.37%	18	5.11%
New Hanover	5	1.60%	6	1.69%	7	1.99%
Onslow	7	2.24%	9	2.54%	6	1.70%
Pamlico	21	6.71%	20	5.65%	19	5.40%
Pasquotank	18	5.75%	19	5.37%	19	5.40%
Pender	2	0.64%	2	0.56%	2	0.57%
Perquimans	3	0.96%	4	1.13%	2	0.57%
Pitt	1	0.32%	2	0.56%	2	0.57%
Tyrrell	6	1.92%	6	1.69%	6	1.70%
Washington	0	0.00%	0	0.00%	1	0.28%
Total	313	100.00%	354	100.00%	352	100.00%

Table 6.47. Number of blue crab shedding tanks used in North Carolina: 2001 – 2003.

	Year											
	2001			2002			2003			Average		
PhysCounty	Flow through	Closed	Floating	Flow through	Closed	Floating	Flow through	Closed	Floating	Flow through	Closed	Floating
Beaufort	81	47	0	65	60	0	63	73	0	70	60	0
Brunswick	14	13	0	18	17	0	24	22	0	19	17	0
Camden	301.5	1	0	364	8	0	379.5	8	0	348	6	0
Carteret	254	212.5	16	277	182	17	343	145	27	291	180	20
Craven	18	35	0	21	35	0	15	32	0	18	34	0
Currituck	319	107	6	343	168	16	278	159	16	313	145	13
Dare	3,428	114	39	3,776	187	56	3,733	116	80	3,646	139	58
Greene	2	0	0	2	0	0	2	0	0	2	0	0
Hyde	719	232	0	750	278	0	720	158	0	730	223	0
New Hanover	18	12	0	20	18	0	22	16	0	20	15	0
Onslow	48	20	0	63	47	0	6	23	0	39	30	0
Pamlico	69	145	0	62	154	0	35	138	2	55	146	1
Pasquotank	321	21	0	398	26	0	329	41	0	349	29	0
Pender	19	0	0	21	0	0	21	0	0	20	0	0
Perquimans	23	16	0	33	24	1	25	0	0	27	13	0
Pitt	0	20	0	0	30	0	0	30	0	0	27	0
Tyrrell	20	63	0	20	64	0	20	64	0	20	64	0
Washington	0	0	0	0	0	0	0	10	0	0	3	0
Total	5,654.50	1,058.50	61	6,233	1,298	90	6,015.5	1,035	125	5,968	1,131	92

Table 6.48. Method of obtaining peeler crabs for blue crab shedding operations in North Carolina: 2001 - 2003.

	Year								
	2001			2002			2003		
	Purchase	Catch	Both	Purchase	Catch	Both	Purchase	Catch	Both
Beaufort	6	7	4	3	6	6	6	6	5
Brunswick	2	1	2	1	1	4	1	3	5
Camden	0	13	1	0	14	1	1	14	1
Carteret	5	33	6	3	40	3	1	42	6
Craven	1	3	1	1	6	0	0	2	1
Currituck	1	16	5	1	24	5	0	20	6
Dare	3	99	19	5	117	18	8	116	18
Greene	0	1	0	0	1	0	0	1	0
Hyde	9	2	9	9	2	8	5	2	8
New Hanover	0	4	1	0	4	2	0	6	1
Onslow	0	5	2	2	5	2	1	4	1
Pamlico	3	6	12	1	8	11	0	7	12
Pasquotank	3	12	3	1	12	6	2	13	4
Pender	0	0	2	0	0	2	0	0	2
Perquimans	1	1	1	1	2	1	0	1	1
Pitt	0	0	1	0	0	1	0	1	1
Tyrrell	0	0	6	0	0	6	0	0	6
Washington	0	0		0	0		0	0	1
Total	34	203	75	28	242	76	25	238	79

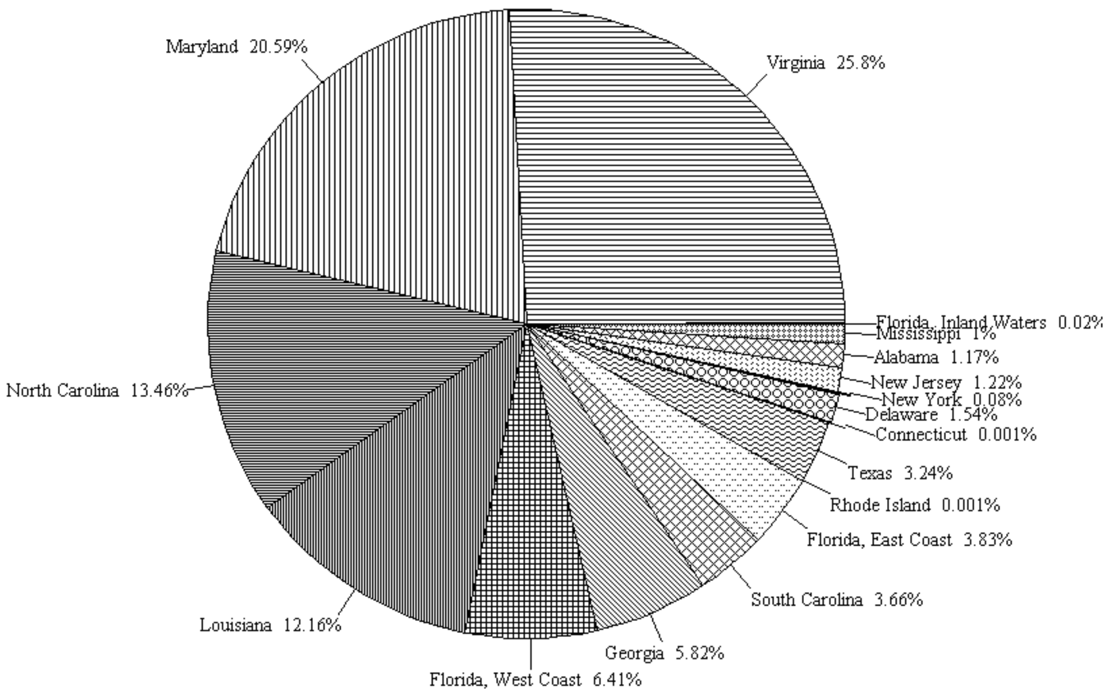

Figure 6.1. Contribution of blue crab producing states to total (hard, soft, and peeler) blue crab production: 1950 – 1993 (NMFS data).

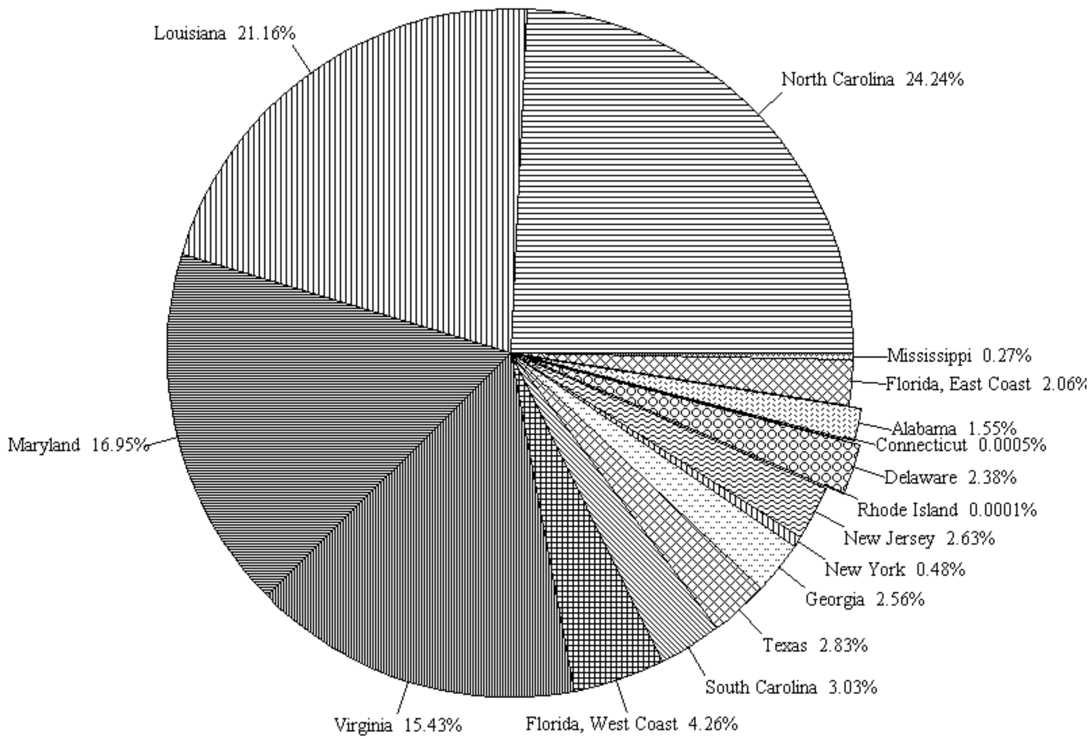

Figure 6.2. Contribution of blue crab producing states to total (hard, soft, and peeler) blue crab production: 1994 – 2002 (NMFS data).

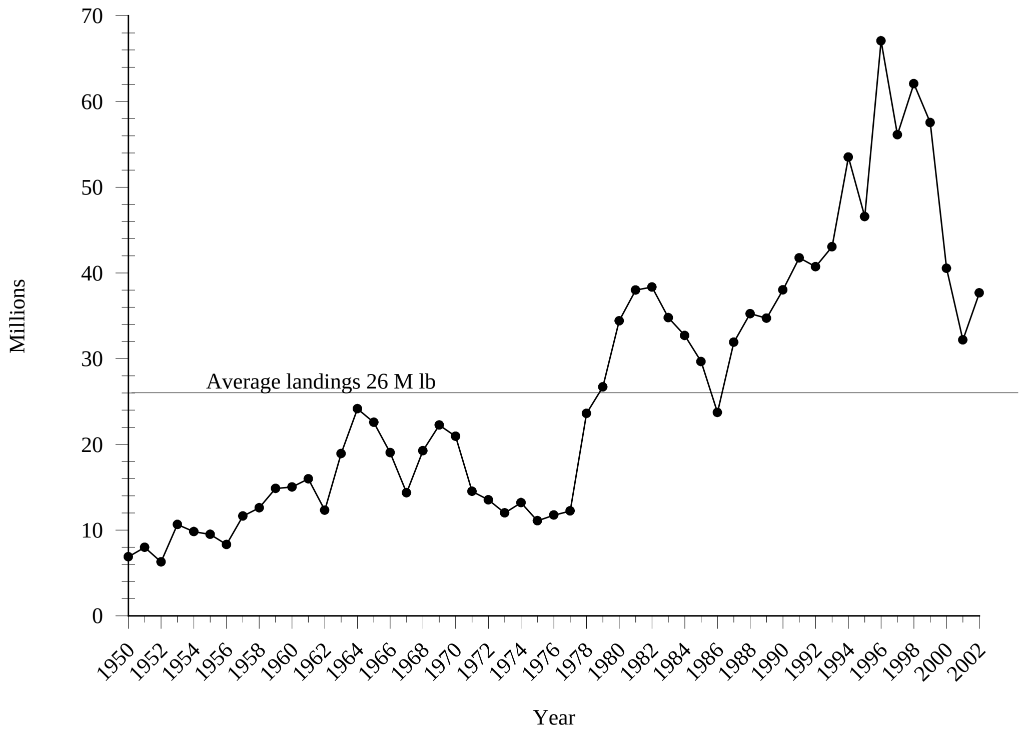

Figure 6.3. Total blue crab landings (hard, soft, and peeler pounds combined) for North Carolina: 1950 – 2002 (NMFS data 1950-1993; NCDMF Trip Ticket Data 1994 - 2002).

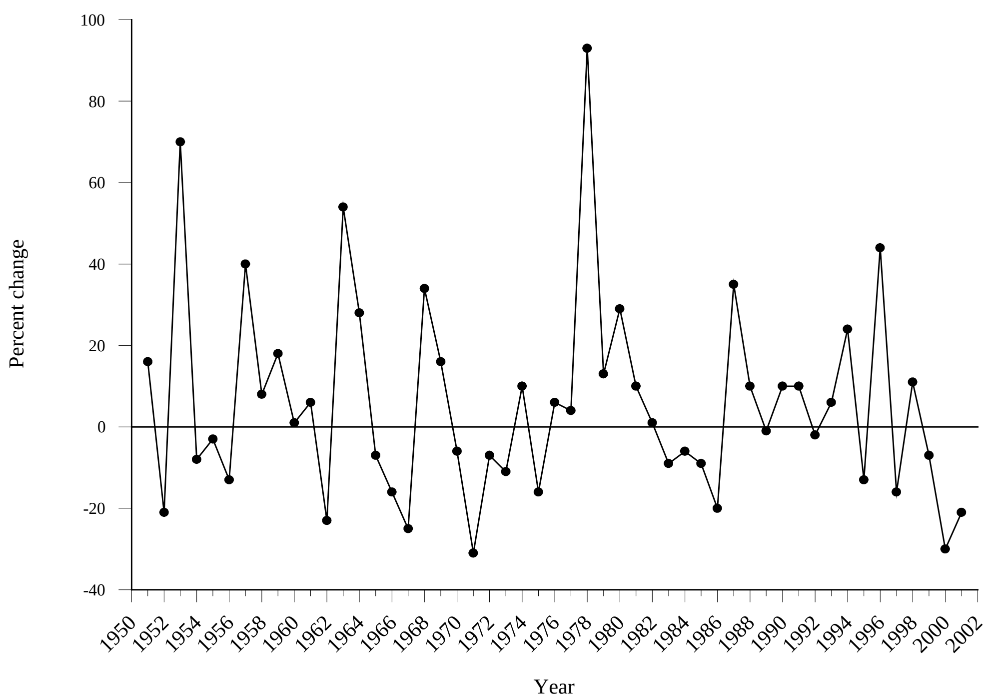

Figure 6.4. Percent change (year – $year_{+1}$) for blue crab landings (hard, soft, and peeler pounds combined) in North Carolina: 1950 – 2002 (NMFS data 1950-1993; NCDMF Trip Ticket Data 1994 - 2002).

Figure 6.5. Map of coastal North Carolina showing location of various waterbodies.

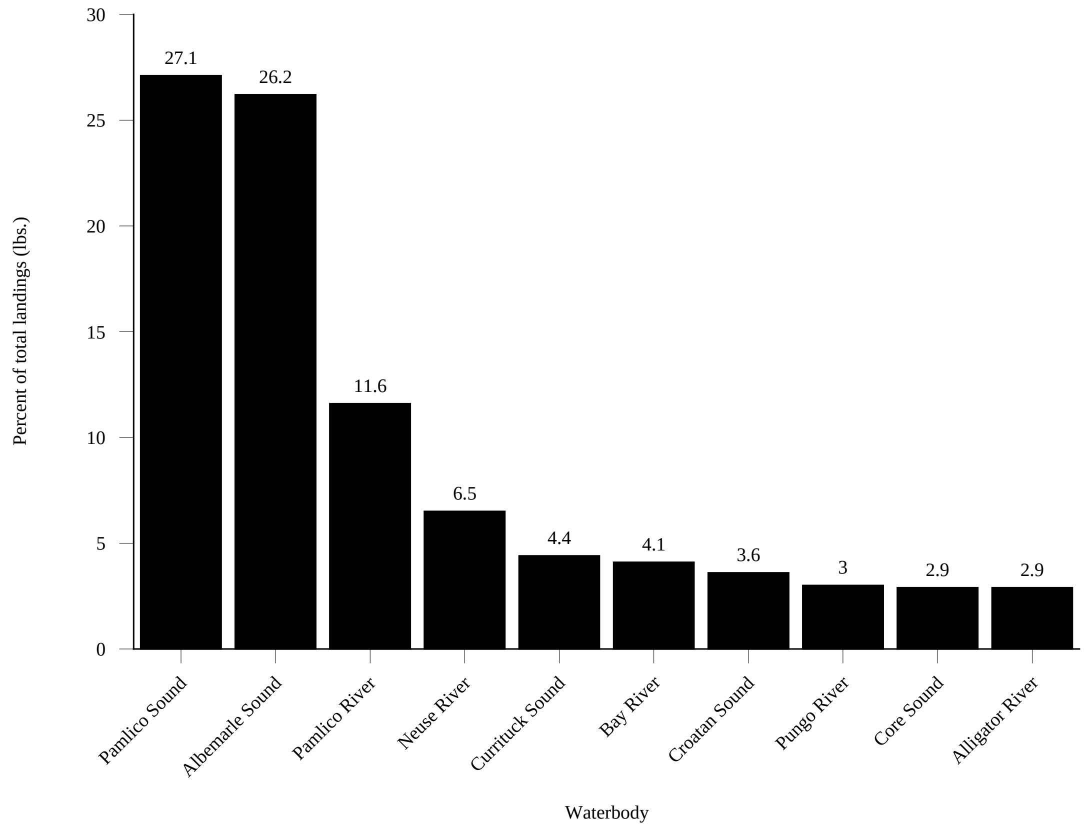

Figure 6.6. Top blue crab (hard, soft, and peeler pounds combined) producing waters for North Carolina: 1994 – 2002.

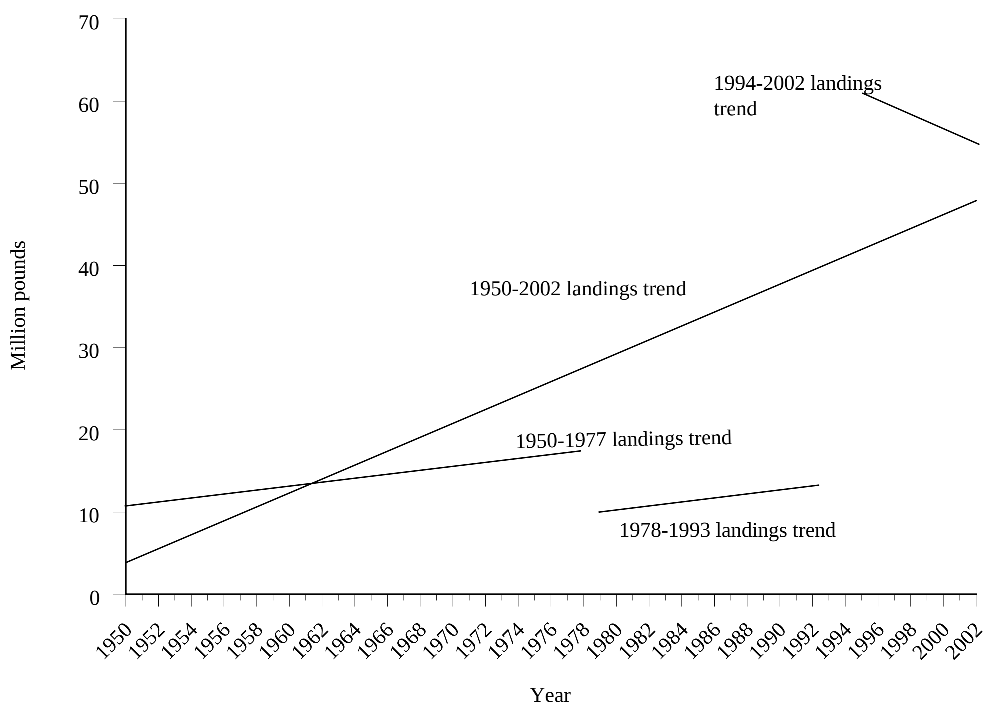

Figure 6.7. Trends in hard crab landings for various time periods in North Carolina: 1950 – 2002.

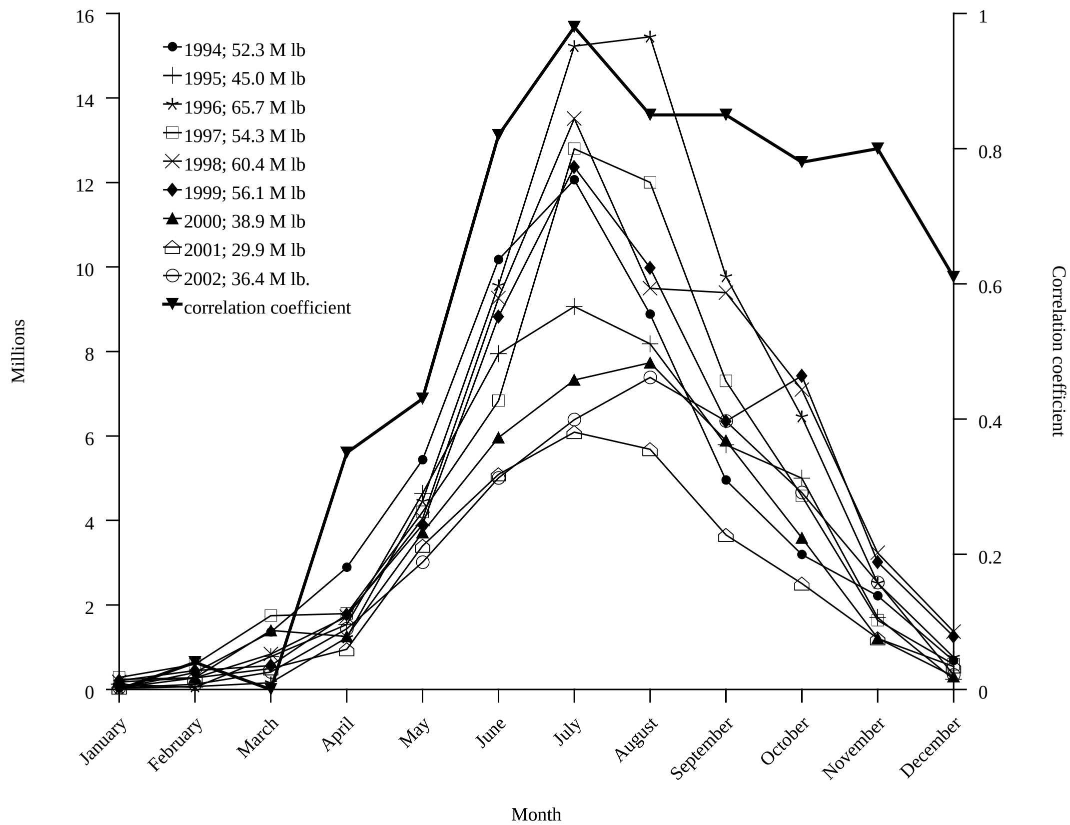

Figure 6.8. Monthly hard crab landings (pounds), and correlation to total landings for North Carolina: 1994 – 2002.

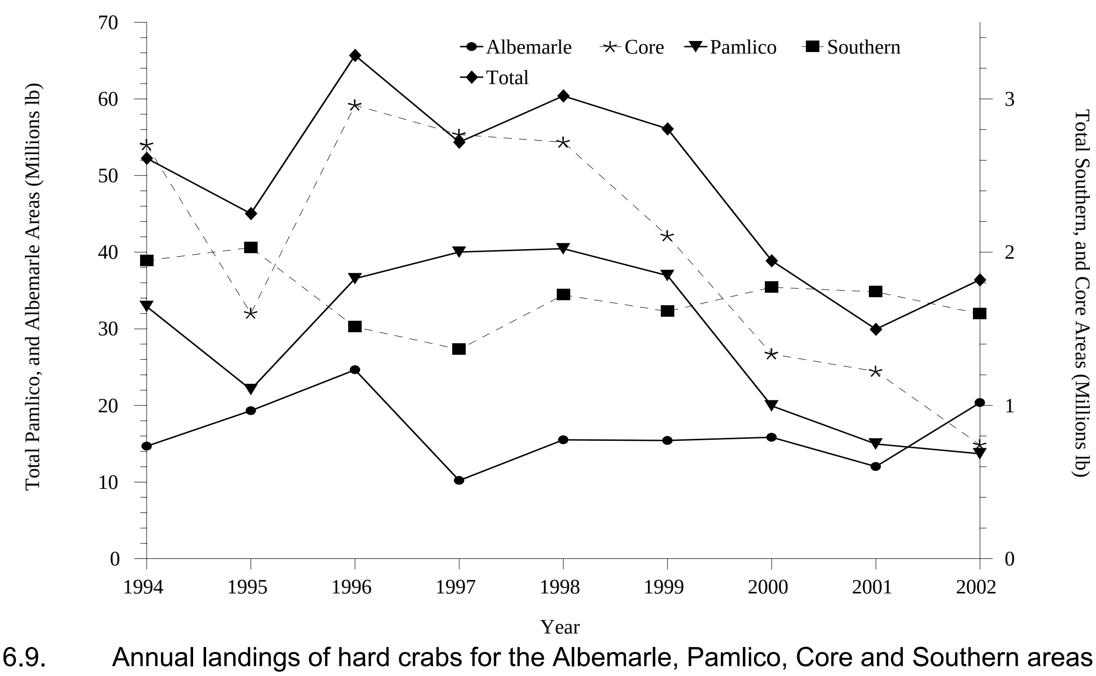

Figure 6.9. Annual landings of hard crabs for the Albemarle, Pamlico, Core and Southern areas of North Carolina: 1994 - 2002. Dashed lines are for the Southern and Core areas and are read off the y2 axis.

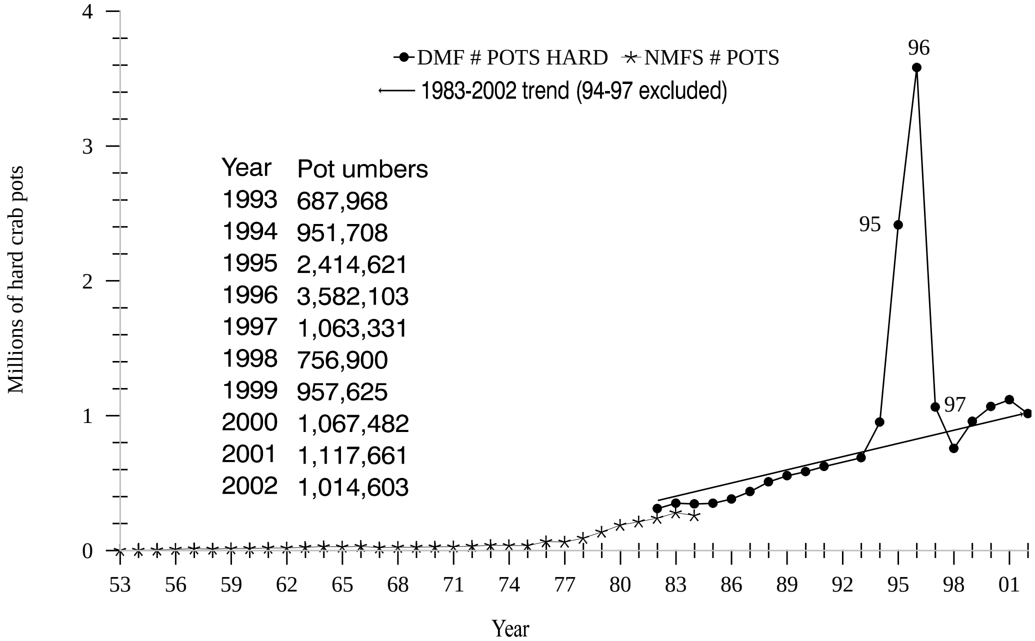

Figure 6.10. Number of operating units for the North Carolina blue crab pot fishery: 1953 – 2002.

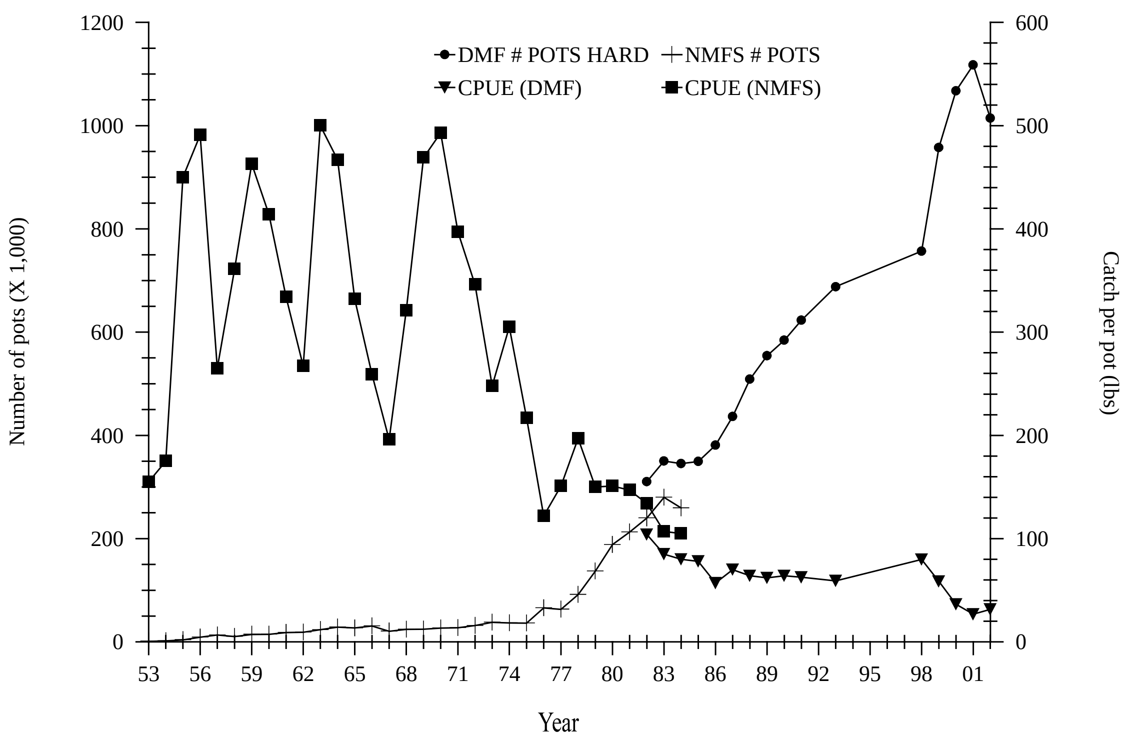

Figure 6.11. Catch per unit effort (pounds/pots) for North Carolina: 1953 – 2002.

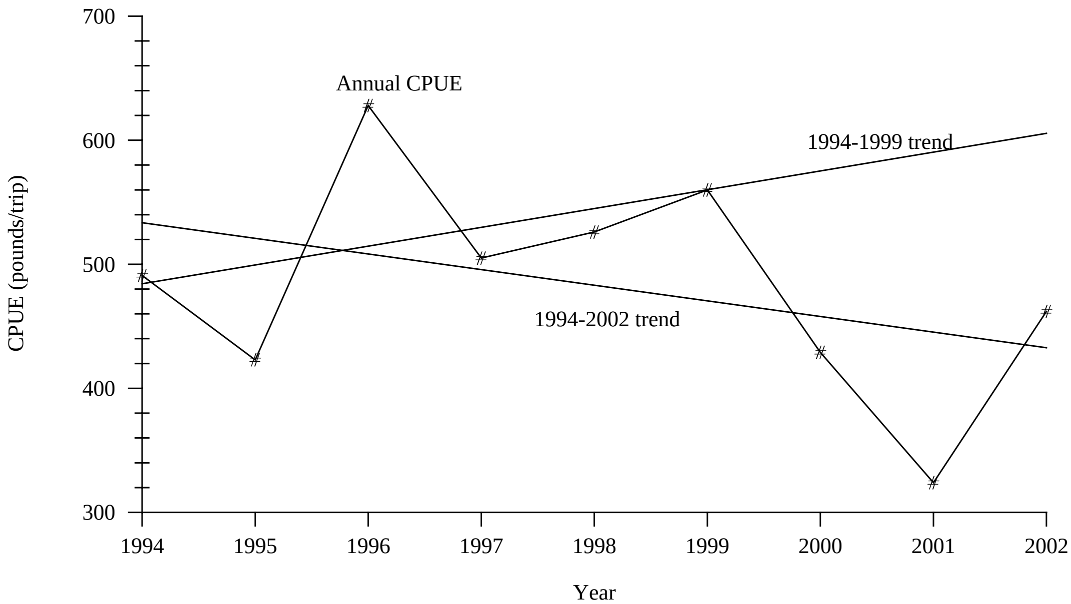

Figure 6.12. Trends in annual hard blue crab landings from single gear crab pot trips (pounds/trip) in North Carolina: 1994 - 2002.

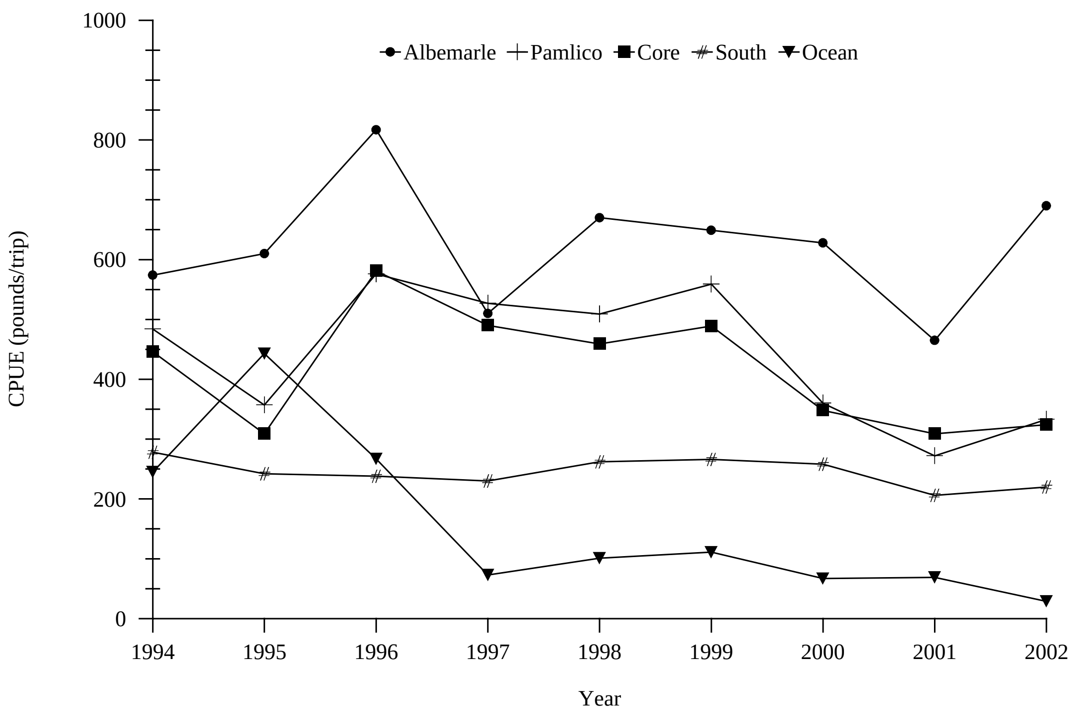

Figure 6.13. Annual hard crab CPUE (pounds/trip) from single gear crab pot trips for blue crab management areas in North Carolina: 1994 – 2002.

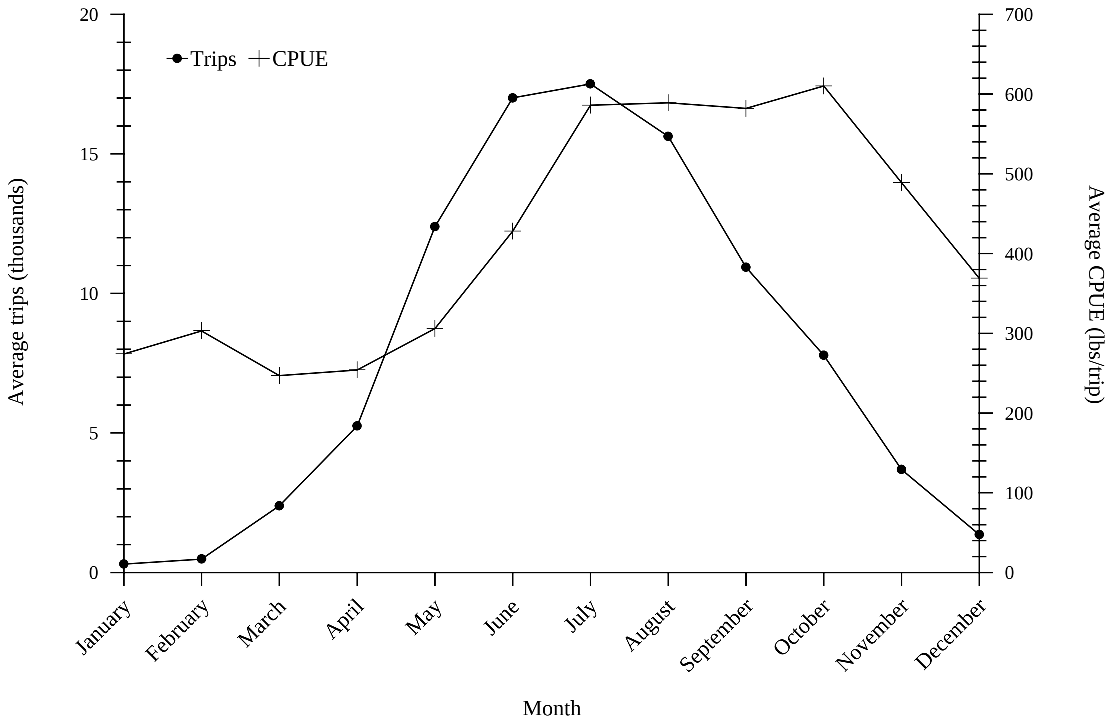

Figure 6.14. Average monthly CPUE (pounds/trip), and trips from single gear crab pot trip tickets for the North Carolina Blue Crab Pot Fishery: 1994 – 2002.

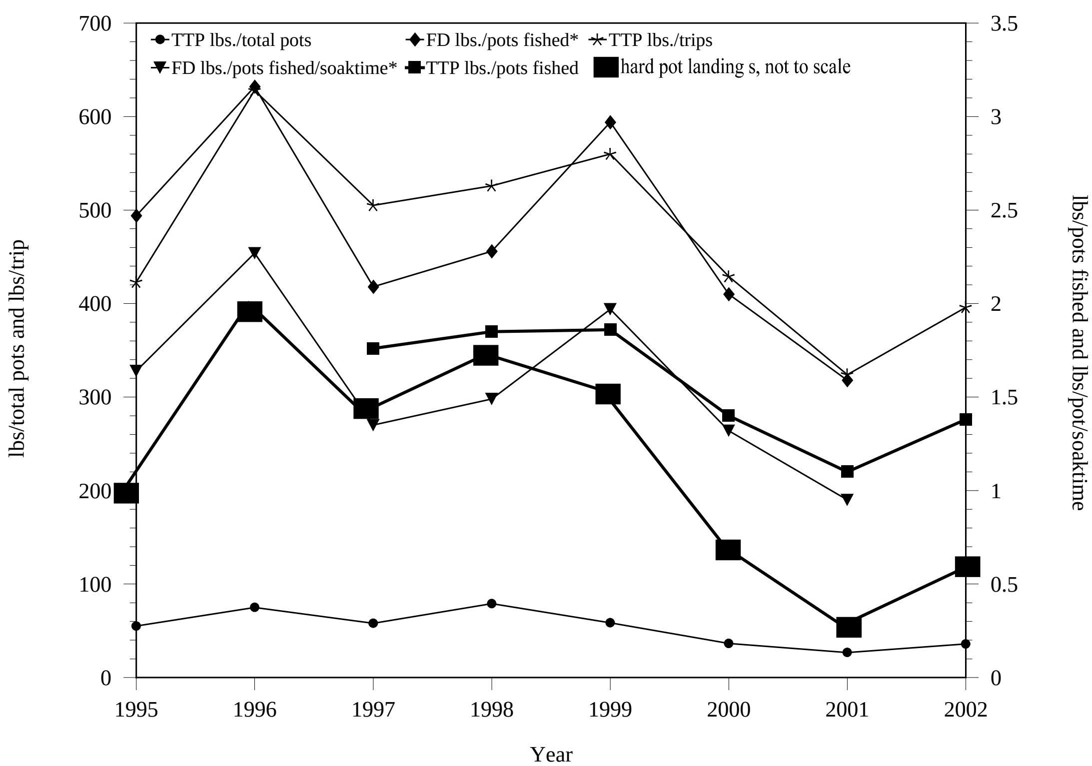

Figure 6.15. Comparisons of CPUE estimates for the North Carolina Blue Crab Pot Fishery: 1995 – 2002 (FD=Fishery Dependent Samples; TTP Trip Ticket Data).

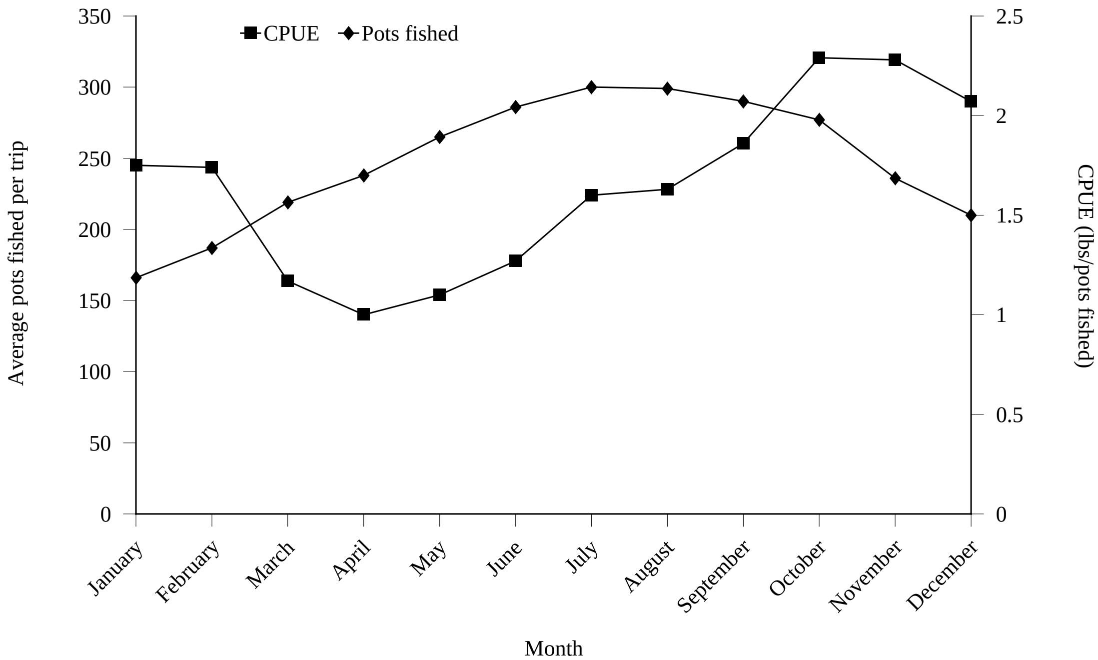

Figure 6.16. Monthly average number of pots fished, and CPUE (pounds/pots fished) from single gear crab pot trip tickets for North Carolina: 1997 – 2002.

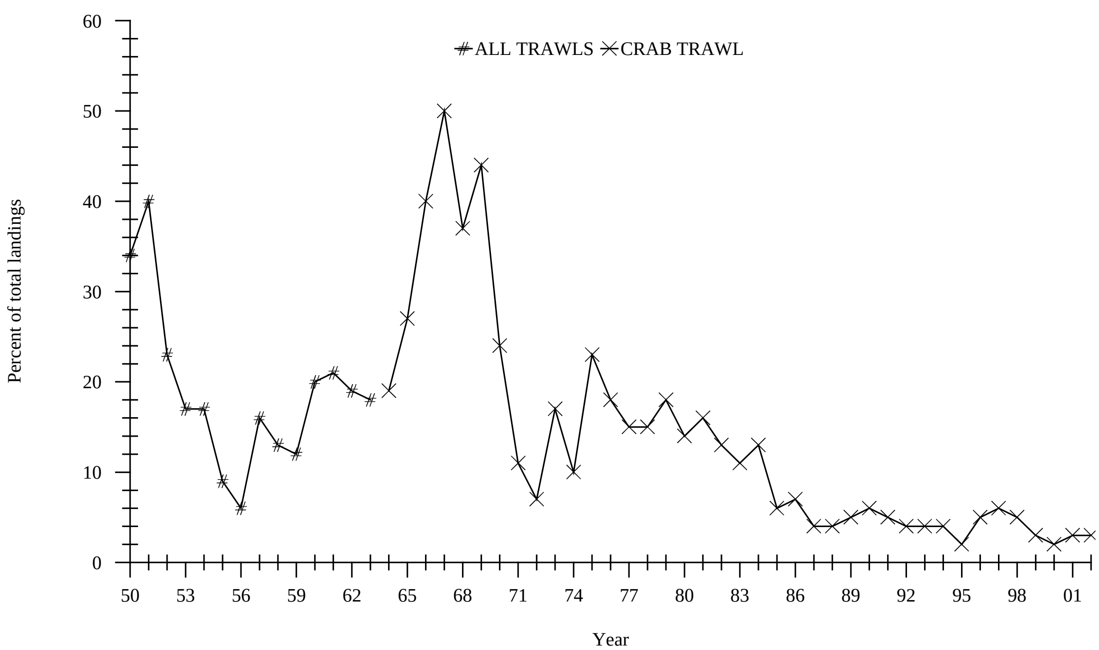

Figure 6.17. Hard crab landings from trawls for North Carolina: 1950 - 2002.

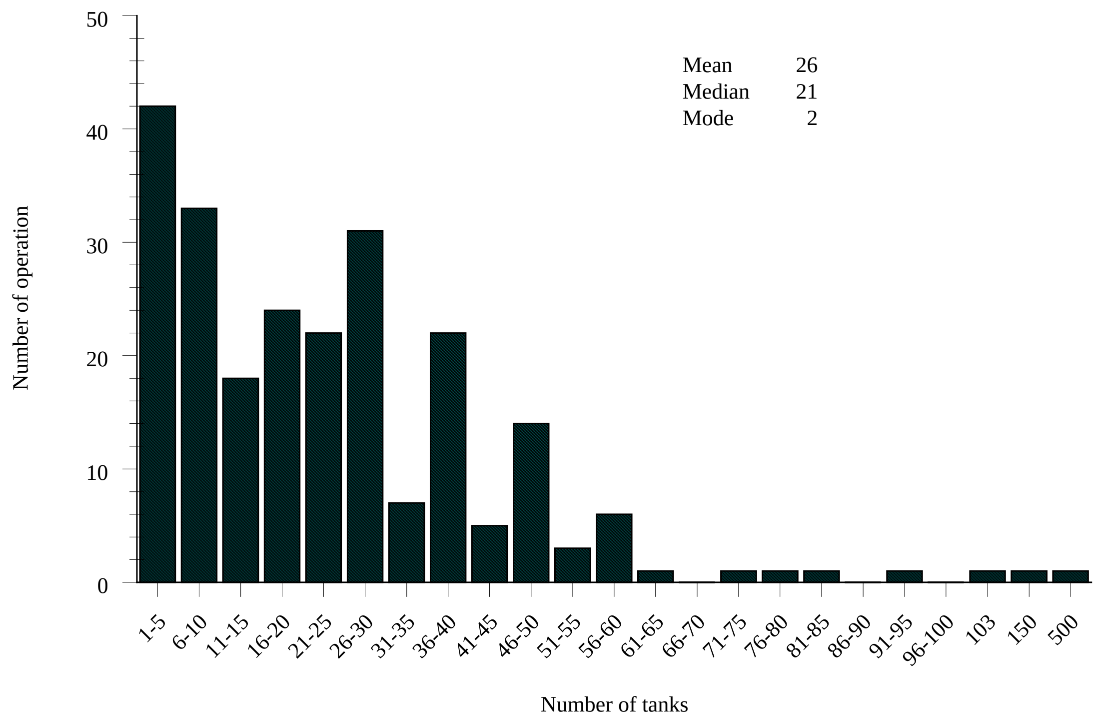

Figure 6.18. Frequency distribution of the number of flow-through blue crab shedding tanks being used in North Carolina in 2003.

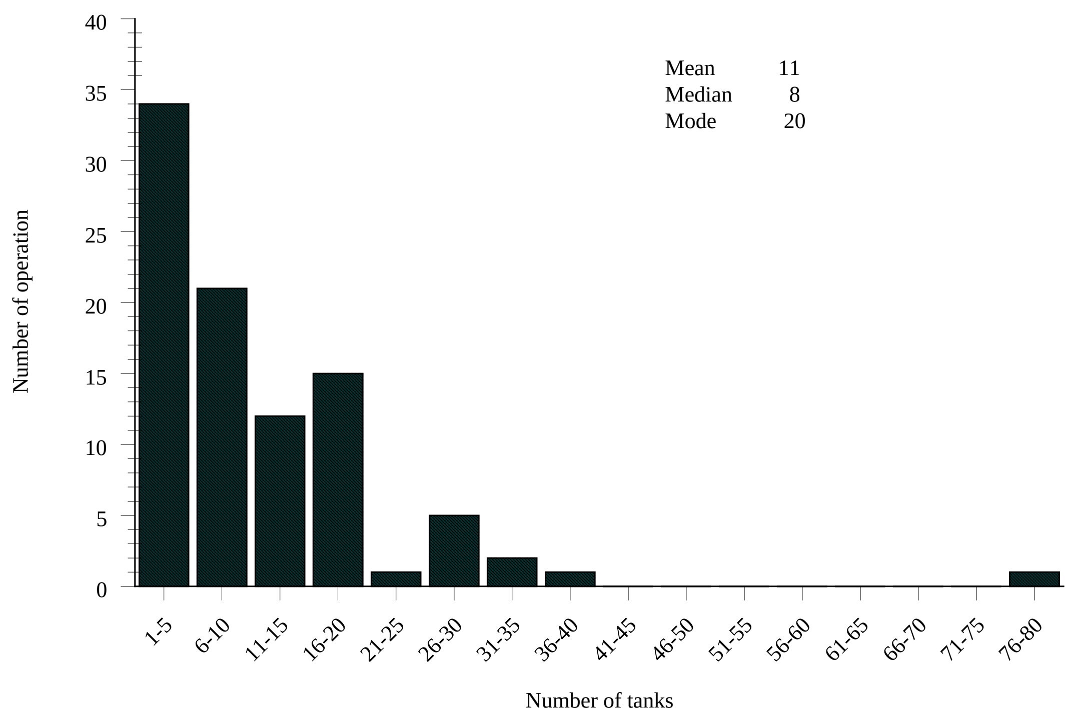

Figure 6.19. Frequency distribution of the number of closed blue crab shedding tanks being used in North Carolina in 2003.

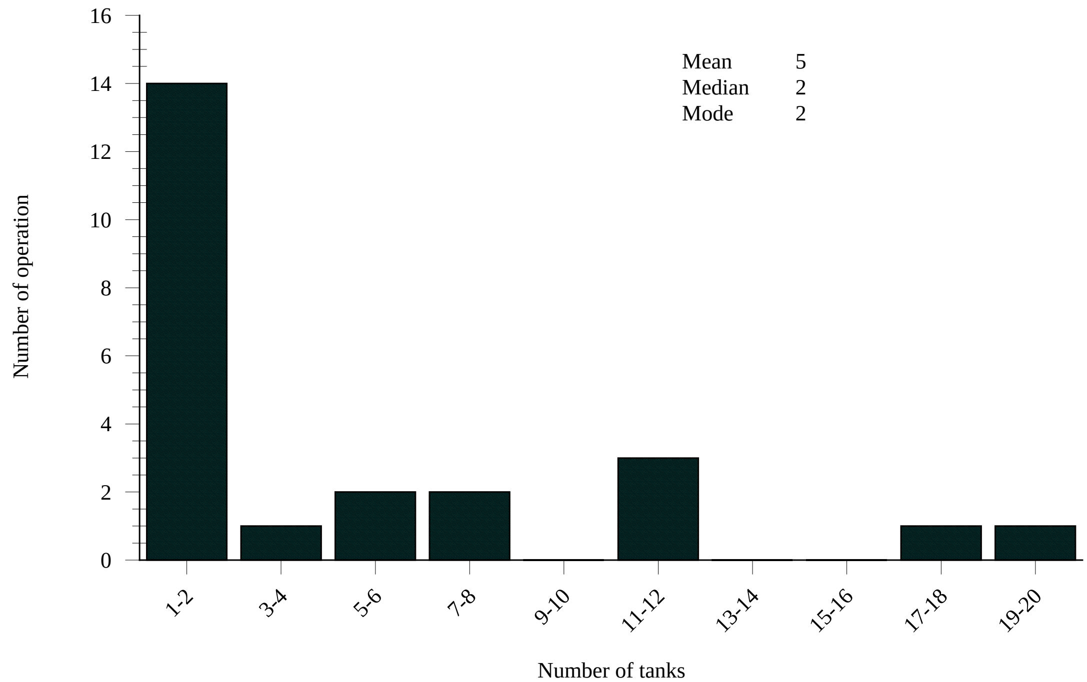

Figure 6.20. Frequency distribution of the number of floating blue crab shedding tanks being used in North Carolina in 2003.

7. ECONOMIC STATUS

7.1 COMMERCIAL FISHERY

7.1.1 Harvesting sector

7.1.1.1 Ex-vessel value and price

Hard blue crabs are the single, most important seafood product landed in North Carolina in terms of economic value. The percentage of total value of commercial landings attributable to hard crabs rose substantially from 1972 to 1998. From 1999 to 2001, the landings of blue crabs declined; however, they remained the most economically viable seafood product NC sends to market. Crabs rebounded slightly in 2002. In 1972, hard blue crabs represented 11% of the total value. By 1992, its share had doubled. By 1998, hard blue crabs accounted for 40% of the total seafood landed values. They declined to 31% of the total value by 2002 (Table 7.1).

The value of North Carolina's hard blue crab landings increased from $1.3 million in 1972 to a peak of nearly $40.5 million in 1998 (Table 7.2). The majority of increase in value was due to increased landings. Decreases in pounds of hard blue crabs landed in recent years are the cause of lower annual landings values.

The price paid to fishermen for hard blue crabs increased substantially between 1972 and 2001. In 1972, the average price was $0.10 per pound. By 1980, the price per pound had increased to $0.17. Between 1987 and 2001 the price fishermen received increased from $0.23 per pound to $0.84. When accounting for the effects of inflation, the real price per pound of hard blue crabs remained fairly constant from 1972 to 1993, roughly $0.10 in 1972 dollars. However, since 1993 the real price per pound has doubled to $0.20 per pound, the average amount received by fishermen in both 2000 and 2001. However, 2002 saw a drop in the "per pound" value. The average price per pound dropped $0.03 to $0.81 for hard crabs.

The value of peeler and soft crabs were relatively stable in the years 1972 to 1977. Beginning in 1978, the value of peelers and soft crabs has increased overall, from almost $90,000 to over $7.1 million in 2001 (Table 7.2). The value of peelers and soft crabs increased by 25% from 2000 to 2001, largely attributable to an increase in the numbers of peelers and soft crabs landed. In 2002, the value of peeler and soft crabs dropped by nearly half of the previous year, due largely to reduced landings.

Like most species, the price per pound of peeler and soft crabs has fluctuated. In 1972, peeler and soft crab fishermen received $0.59 per pound. By 1978, the price had tripled to $1.92. Overall, the price has increased to about $3.00 per pound in 2000, 2001 and 2002. In terms of real, inflation adjusted price per pound, the price per pound in recent years is about 50% higher than what it was in 1972. Yet, in 2002, the average price per pound for peelers and soft crabs dropped $0.06, from $0.75 to $0.69, equivalent to the price per pound paid in 1998.

Peeler and soft crabs landings have never amounted to more than 2% of the total annual landings (Table 7.1). However, their percentage of total value has increased disproportionately. Since 1990, the percentage of total landings value of peeler and soft crabs has been at least three times their average percentage of total annual landings in pounds.

Table 7.1. Landings and value of blue crabs as a percentage of the total landings in pounds and total value of all seafood landed in North Carolina, 1972 – 2002. (NCDMF Trip Ticket Program.)

	Total Landings		Hard Blue Crabs					Peeler and Soft Blue Crabs				
Year	Pounds (x 1,000)	Value (x $1,000)	Pounds (x 1,000)	% of Total Lbs.	Value (x $1,000)	% of Total Val.	Weight/ Price	Pounds (x 1,000)	% of Total Lbs.	Value (x $1,000)	% of Total Val.	Weight/ Price
1972	167,902	$ 11,799	13,479	8%	$ 1,345	11%	1.42	50	0%	$ 29	0%	8.25
1973	130,453	$ 15,955	11,963	9%	$ 1,537	10%	1.05	45	0%	$ 28	0%	5.09
1974	196,049	$ 17,324	13,163	7%	$ 1,373	8%	1.18	33	0%	$ 23	0%	7.89
1975	231,703	$ 19,453	11,072	5%	$ 1,454	7%	1.56	20	0%	$ 17	0%	10.12
1976	220,447	$ 27,409	11,732	5%	$ 2,406	9%	1.65	20	0%	$ 27	0%	10.86
1977	244,751	$ 28,374	12,221	5%	$ 2,148	8%	1.52	16	0%	$ 17	0%	9.17
1978	299,541	$ 40,609	23,559	8%	$ 4,326	11%	1.35	47	0%	$ 90	0%	14.12
1979	390,472	$ 58,454	26,624	7%	$ 4,623	8%	1.16	80	0%	$ 130	0%	10.85
1980	356,193	$ 68,784	34,323	10%	$ 5,975	9%	0.90	87	0%	$ 132	0%	7.86
1981	432,006	$ 57,520	37,928	9%	$ 8,172	14%	1.62	78	0%	$ 101	0%	9.73
1982	307,968	$ 63,824	38,206	12%	$ 7,185	11%	0.91	148	0%	$ 297	0%	9.68
1983	287,733	$ 57,425	34,689	12%	$ 8,445	15%	1.22	88	0%	$ 188	0%	10.70
1984	277,169	$ 57,263	32,491	12%	$ 6,665	12%	0.99	200	0%	$ 376	1%	9.10
1985	214,874	$ 64,593	29,330	14%	$ 6,090	9%	0.69	327	0%	$ 350	1%	3.56
1986	168,882	$ 63,231	23,160	14%	$ 5,430	9%	0.63	595	0%	$ 685	1%	3.07
1987	157,324	$ 65,707	31,760	20%	$ 7,345	11%	0.55	663	0%	$ 2,263	3%	8.17
1988	192,693	$ 77,757	35,136	18%	$ 10,212	13%	0.72	468	0%	$ 921	1%	4.88
1989	165,197	$ 73,958	33,936	21%	$ 8,790	12%	0.58	789	0%	$ 1,567	2%	4.44
1990	174,993	$ 70,692	36,985	21%	$ 9,156	13%	0.61	1,085	1%	$ 2,137	3%	4.88
1991	212,641	$ 66,788	41,074	19%	$ 9,154	14%	0.71	756	0%	$ 1,389	2%	5.85
1992	154,430	$ 58,025	40,507	26%	$ 12,837	22%	0.84	561	0%	$ 997	2%	4.73
1993	170,697	$ 64,604	42,867	25%	$ 14,262	22%	0.88	806	0%	$ 1,516	2%	4.97
1994	192,934	$ 91,421	52,260	27%	$ 26,898	29%	1.09	1,253	1%	$ 2,704	3%	4.55
1995	176,001	$110,767	45,034	26%	$ 33,054	30%	1.17	1,410	1%	$ 3,185	3%	3.59
1996	191,124	$105,695	65,683	34%	$ 39,874	38%	1.10	1,398	1%	$ 3,169	3%	4.10
1997	228,599	$109,181	54,354	24%	$ 33,166	30%	1.28	1,737	1%	$ 4,520	4%	5.45
1998	180,235	$101,055	60,402	34%	$ 40,467	40%	1.19	1,673	1%	$ 4,492	4%	4.79
1999	153,483	$ 99,076	55,918	36%	$ 33,418	34%	0.93	1,451	1%	$ 4,283	4%	4.57
2000	154,225	$108,311	38,890	25%	$ 32,155	30%	1.18	1,749	1%	$ 5,283	5%	4.30
2001	137,146	$ 88,072	29,939	22%	$ 25,079	28%	1.30	2,241	2%	$ 7,152	8%	4.97
2002	160,062	$ 94,651	36,435	23%	$ 29,339	31%	1.36	1,274	1%	$ 3,796	4%	5.04
Average	217,030	$ 65,735	34,036	17%	$ 13,948	18%	1.08	682	0%	$ 1,673	3%	6.75

Table 7.2. Commercial value of hard, peeler, and soft blue crab landings, North Carolina, 1972 – 2002. (NCDMF Trip Ticket Program).

	Hard Blue Crabs				Peeler and Soft Crabs			
Year	Current Value	Real Value*	Current Price/lb	Real Price/lb*	Current Value	Real Value*	Current Price/lb	Real Price/lb*
1972	$ 1,345,159	$ 1,345,159	$ 0.10	$ 0.10	$ 29,186	$ 29,186	$ 0.59	$ 0.59
1973	$ 1,536,873	$ 1,446,812	$ 0.13	$ 0.12	$ 27,762	$ 26,135	$ 0.61	$ 0.57
1974	$ 1,373,499	$ 1,164,590	$ 0.10	$ 0.08	$ 23,130	$ 19,612	$ 0.69	$ 0.59
1975	$ 1,454,456	$ 1,130,112	$ 0.13	$ 0.10	$ 16,996	$ 13,206	$ 0.84	$ 0.65
1976	$ 2,405,635	$ 1,767,179	$ 0.21	$ 0.15	$ 26,549	$ 19,503	$ 1.32	$ 0.97
1977	$ 2,148,346	$ 1,481,929	$ 0.18	$ 0.12	$ 17,000	$ 11,727	$ 1.06	$ 0.73
1978	$ 4,326,084	$ 2,773,452	$ 0.18	$ 0.12	$ 89,718	$ 57,518	$ 1.92	$ 1.23
1979	$ 4,622,539	$ 2,661,658	$ 0.17	$ 0.10	$ 129,908	$ 74,801	$ 1.62	$ 0.93
1980	$ 5,975,221	$ 3,031,230	$ 0.17	$ 0.09	$ 132,448	$ 67,191	$ 1.51	$ 0.77
1981	$ 8,172,428	$ 3,757,682	$ 0.22	$ 0.10	$ 100,860	$ 46,375	$ 1.30	$ 0.60
1982	$ 7,184,748	$ 3,112,433	$ 0.19	$ 0.08	$ 296,838	$ 128,590	$ 2.00	$ 0.87
1983	$ 8,444,863	$ 3,544,309	$ 0.24	$ 0.10	$ 188,223	$ 78,997	$ 2.15	$ 0.90
1984	$ 6,664,731	$ 2,681,221	$ 0.21	$ 0.08	$ 276,302	$ 111,156	$ 1.38	$ 0.56
1985	$ 6,089,982	$ 2,365,958	$ 0.21	$ 0.08	$ 350,373	$ 136,120	$ 1.07	$ 0.42
1986	$ 5,429,534	$ 2,070,824	$ 0.23	$ 0.09	$ 684,822	$ 261,191	$ 1.15	$ 0.44
1987	$ 7,345,210	$ 2,703,037	$ 0.23	$ 0.08	$ 2,263,437	$ 832,945	$ 1.91	$ 0.70
1988	$ 10,211,661	$ 3,607,780	$ 0.29	$ 0.10	$ 921,403	$ 325,532	$ 1.97	$ 0.70
1989	$ 8,790,304	$ 2,963,211	$ 0.26	$ 0.09	$ 1,567,298	$ 528,336	$ 1.99	$ 0.67
1990	$ 9,156,390	$ 2,928,214	$ 0.25	$ 0.08	$ 2,136,942	$ 683,394	$ 1.97	$ 0.63
1991	$ 9,154,358	$ 2,809,472	$ 0.22	$ 0.07	$ 1,389,140	$ 426,327	$ 1.84	$ 0.56
1992	$ 12,836,836	$ 3,824,093	$ 0.23	$ 0.07	$ 996,904	$ 296,978	$ 1.78	$ 0.53
1993	$ 14,262,152	$ 4,126,041	$ 0.33	$ 0.10	$ 1,515,569	$ 438,454	$ 1.88	$ 0.54
1994	$ 26,896,282	$ 7,587,441	$ 0.51	$ 0.15	$ 2,703,834	$ 762,751	$ 2.16	$ 0.61
1995	$ 26,296,509	$ 7,213,132	$ 0.58	$ 0.16	$ 2,361,562	$ 647,777	$ 1.67	$ 0.46
1996	$ 39,957,947	$ 10,644,797	$ 0.61	$ 0.16	$ 3,158,910	$ 841,534	$ 2.26	$ 0.60
1997	$ 33,165,872	$ 8,636,393	$ 0.61	$ 0.16	$ 4,520,166	$ 1,177,051	$ 2.60	$ 0.68
1998	$ 40,466,879	$ 10,375,708	$ 0.67	$ 0.17	$ 4,492,761	$ 1,151,944	$ 2.68	$ 0.69
1999	$ 33,525,159	$ 8,411,462	$ 0.60	$ 0.15	$ 4,286,532	$ 1,075,491	$ 2.95	$ 0.74
2000	$ 32,189,735	$ 7,812,449	$ 0.83	$ 0.20	$ 5,278,530	$ 1,281,099	$ 3.02	$ 0.73
2001	$ 25,095,797	$ 5,922,608	$ 0.84	$ 0.20	$ 7,153,706	$ 1,688,275	$ 3.19	$ 0.75
2002	$ 29,338,686	$ 6,818,311	$ 0.81	$ 0.19	$ 3,795,885	$ 882,164	$ 2.98	$ 0.69
Total (or Avg.)	$ 425,863,875	$ 130,718,700	$ 0.34	$ 0.12	$ 50,932,694	$ 14,121,359	$ 1.81	$ 0.68

* Based on the value of $1 in 1972

7.1.1.2 Fishing Income

Gross fishing income derived from crabbing (all gears) was estimated using landings from the Trip Ticket Program. Value data were derived from DMF surveys of ex-vessel prices received by fishermen at the point of initial sale to fish dealers. Gross income, as indicated in Table 7.3, varied substantially among fishermen and among segments within the blue crab fisheries. The total average gross fishing income reported for the 1,771 individual fishermen participating in the hard blue crab fishery in 2001 was $14,170. The average was $6,057 for the 1181 fishermen participating in the peeler and soft crab fishery.

Table 7.3. Reported income from blue crabs by individual NC commercial fishermen from 1994 – 2002 (NCDMF Trip Ticket Program).

		Year								
Crab Type		1994	1995	1996	1997	1998	1999	2000	2001	2002
Hard Crabs	Under $500	503	578	503	630	388	350	237	256	285
		24.6%	27.1%	22.5%	27.6%	19.8%	18.9%	14.0%	14.5%	18.3%
	$500.01 to $5,000	536	546	591	523	416	446	383	500	390
		26.2%	25.6%	26.5%	22.9%	21.2%	24.0%	22.6%	28.2%	25.0%
	$5,000.01 to $10,000	303	305	244	242	220	228	220	267	209
		14.8%	14.3%	10.9%	10.6%	11.2%	12.3%	13.0%	15.1%	13.4%
	$10,000.01 to $20,000	352	323	320	307	281	324	296	314	234
		17.2%	15.1%	14.3%	13.4%	14.3%	17.5%	17.5%	17.7%	15.0%
	$20,000.01 to $30,000	195	156	199	198	182	183	192	175	116
		9.5%	7.3%	8.9%	8.7%	9.3%	9.9%	11.4%	9.9%	7.4%
	$30,000.01 to $50,000	114	148	212	242	246	221	189	164	151
		5.6%	6.9%	9.5%	10.6%	12.6%	11.9%	11.2%	9.3%	9.7%
	More than $50,000	41	80	163	141	227	104	174	95	173
		2.0%	3.7%	7.3%	6.2%	11.6%	5.6%	10.3%	5.4%	11.1%
	Total Number of Fishermen	2044	2136	2232	2283	1960	1856	1691	1771	1558
		100%	100%	100%	100%	100%	100%	100%	100%	100%
Peeler and Soft Crabs	Under $500	494	615	688	669	517	476	483	482	452
		55.6%	58.2%	57.0%	49.8%	43.6%	40.6%	41.7%	40.8%	43.7%
	$500.01 to $5,000	264	331	363	488	455	478	454	417	395
		29.7%	31.3%	30.1%	36.3%	38.3%	40.8%	39.2%	35.3%	38.2%
	$5,000.01 to $10,000	51	43	66	73	95	120	97	91	84
		5.7%	4.1%	5.5%	5.4%	8.0%	10.2%	8.4%	7.7%	8.1%
	$10,000.01 to $20,000	43	43	50	53	64	63	64	82	53
		4.8%	4.1%	4.1%	3.9%	5.4%	5.4%	5.5%	6.9%	5.1%
	$20,000.01 to $30,000	25	16	28	24	33	18	26	41	30
		2.8%	1.5%	2.3%	1.8%	2.8%	1.5%	2.2%	3.5%	2.9%
	$30,000.01 to $50,000	7	6	9	27	18	12	21	42	17
		0.8%	0.6%	0.7%	2.0%	1.5%	1.0%	1.8%	3.6%	1.6%
	More than $50,000	4	3	3	9	5	5	14	26	4
		0.5%	0.3%	0.2%	0.7%	0.4%	0.4%	1.2%	2.2%	0.4%
	Total Number of Fishermen	888	1057	1207	1343	1187	1172	1159	1181	1035
		100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 7.3 shows the number of fishermen in each of seven income categories for the years 1994 to 2002. The percentages in each cell of the table represent the percent of fishermen whose total income matched the category for that year. Additionally, landings are reported separately for hard blue crabs and for peeler and soft crabs combined.

The overall trend has been towards fewer participants in the hard crab fishery from 1994 to 2002. However, with the exception of 2001 and 2002, on average, those who were in the hard crab fishery tended to make more money from it in each successive year. This can be seen by comparing the percentages in each income category from year to year. Nonetheless, more than 50% of the fishermen had $10,000 or less in annual income from hard blue crabs in 2000 to 2002.

The number of participants in the peeler and soft crab fisheries has remained stable from 1994 to 2001. However, 2002 saw a 12% drop in the number of participants. Again, except in 2002, there has been a general trend towards higher earnings for annual landings. More than 80% of all fishermen had $10,000 or less income from peeler and soft crabs in 2000 to 2002.

7.1.1.3 Employment

A total of 1,617 different individuals reported landings in the blue crab fishery in 2002 (NCDMF Trip Ticket Program). Members of the NC Marine Fisheries Commission's Crustacean Advisory Committee provided employment estimates, for those who actively participate in the blue crab fishery. These estimates are: for vessels of less than 18 feet, there is only one crewmember; two crewmembers for vessels of 19 – 38 feet; and three crewmembers for vessels greater than 38 feet. Based on average vessel sizes from previous years, we can estimate that approximately 2,656 individuals were directly engaged in blue crab harvesting activities in 2001, a decrease of over 1,000 individuals since 1997.

7.1.2 Distribution and processing sector

7.1.2.1 Unprocessed crab dealers

Blue crabs harvested in North Carolina are sold through licensed seafood dealers. This group includes fishermen reporting as dealers, wholesalers, processors, retailers, and restaurants. Figure 7.1 illustrates the flow of North Carolina blue crab products. Most of the harvest (80%) and value (83%) goes to local seafood dealers who sell directly to out-of-state dealers/processors, North Carolina dealers/processors, and retail markets. The other 20% of the harvest and 17% of the value goes directly to processors in North Carolina.

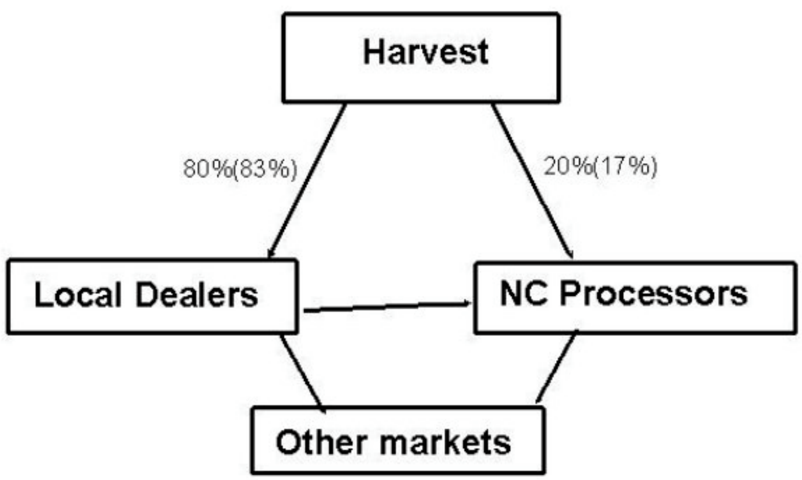

Figure 7.1. Flow of North Carolina blue crab harvest (value)

Source: NC DMF Trip Ticket Program.

The number of dealer licenses reporting landings of blue crabs generally increased in the early 1980's from approximately 150 to almost 220. There was a drop to fewer than 150 in 1984 then gradually increased to nearly 200 in 1992. The number of licenses sold in 1993 was 122. Since 1994, the number of dealers reporting crab landings has generally increased to well over 300 (see Table 7.4). Employment by unprocessed crab dealers is unknown and cannot be estimated.

Table 7.4. Number of dealers reporting landings of blue crabs in North Carolina, 1980 - 2002. (Courtesy NC DMF Trip Ticket Program)

Year	Number of Dealers Reporting Landings
1980	157
1981	189
1982	219
1983	218
1984	146
1985	147
1986	151
1987	157
1988	155
1989	170
1990	181
1991	196
1992	188
1993	122
1994	286
1995	303
1996	333
1997	346
1998	356
1999	396
2000	330
2001	337
2002	332

7.1.2.2 Processing

Processing is an important component of the blue crab fisheries. The number of processor licenses issued by NC DMF and the number of processing plants certified by the Shellfish Sanitation Program (North Carolina Division of Environmental Health) has fluctuated little from 1980 to 1997. The NC DMF stopped issuing crab-processing licenses in 1997 when the Fisheries Reform Act went into effect. The Shellfish Sanitation Program continues to certify processing plants.

The number of processing plants certified from 1998 through 2002 is shown in Table 7.5, which indicates there were roughly one-third fewer certified processing plants in 2002 as there were in 1998. The blue crab processing sector has faced increasing problems. The declining trend in the number of processing plants can be attributed to four factors:

(1) A lack of steady supplies from local fishermen due to an apparent shift to the live basket market;
(2) Competition from crabmeat imported from overseas;
(3) A large percentage of North Carolina crabs are shipped north for processing;
(4) Increases in federal HACCP requirements.

Steps to address these issues are needed if the processing industry is to remain competitive in the end.

Table 7.5. Number of blue crab processing plants certified by the NC Shellfish Sanitation Program from 1998 to 2002.

Year	Number of Plants Certified
1998	31
1999	27
2000	23
2001	21
2002	20

The number of daily pickers working for crab processing businesses in 2002 varied greatly. Four of the plants employed 25 or fewer pickers. Five employed between 26 and 50 pickers daily. Six employed more than 50 pickers daily. The remaining processors either do not pick daily, only repack crabmeat, or only process using a claw machine.

7.1.3 Economic impacts of the commercial fishery

The commercial fishery industry in North Carolina produces ripple effects in the state's economy. Each dollar earned within the industry generates a more vigorous economy by stimulating additional activity in the form of jobs, income, and output. In 2002, the commercial blue crab industry in North Carolina contributed, directly and indirectly, an estimated $53 million in sales (output), $32 million in total income, and 4,176 full and part-time jobs to the state's economy. As might be expected, most of the jobs were generated from harvesting and processing activities.

The estimates above are limited and must be viewed as conservative. These estimates do not include wholesale (seafood dealers), retail, and foodservice sectors because of a lack of economic data for those sectors.

7.2 RECREATIONAL FISHERY

Recreational Commercial Gear License (RCGL) fishermen land blue crabs primarily using four different gears: crab pots, shrimp trawl, gill nets, or trotline. A study of RCGL blue crab harvest (Nobles et al. 2002) estimated the commercial value of RCGL landings to be approximately $98,808 in 2001. However, since these fishermen by law, are not allowed to sell their catch, the true economic impact of RCGL fishing is in other sectors of the economy. In 2001, North Carolina began collecting socioeconomic data from fishermen who are licensed to use limited commercial gear.

Table 7.6 gives an indication of the economic impact of the recreational blue crab fishery by RCGL fishermen in 2002. The data are shown for those who made overnight trips compared to those who made day trips. The economic figures are based on an expansion of the actual values reported by RCGL fishermen and are considered the best available estimates. The economic impacts described below are solely due to crabbing. However, in many, if not most of the out of town trips, the fishermen and the non-fishers who accompanied them, engaged in other, non-fishing activities and some impacts such as the cost of lodging are prorated based on the percentage of people on the trip who actually fished.

Table 7.6. The economic impact of RCGL fishing for blue crabs in North Carolina, 2002 (NCDMF RCGL Program).

	Overnight	Day
Number of nights	3.15	
Miles traveled	145.93	54.82
# who fished	3.26	2.94
# who didn't fish	0.56	0.28
Total # of people/trip	3.82	3.22
Percent who fished	0.85	0.91
Lodging/night	$ 29.37	
Food/trip	$ 73.11	$ 3.70
Ice/trip	$ 10.16	$ 2.94
Bait/trip	$ 8.63	$ 25.27
Fuel and oil/trip	$ 75.32	$ 1.11
Equipment rental/trip	$ 6.34	$ -

Overnight trips averaged slightly over three nights and involved approximately 146 miles of travel. An average of four people went on the trip, with not all people participating in fishing. Not all overnight trips resulted in costs associated with paying for lodging, however, when averaged across all overnight trips, lodging per night was estimated to be nearly $30. Food expense for the trip was estimated at $73.11. A few trips required the rental of equipment and when averaged by all overnight trips, this cost was $6.34 per trip.

Day trips involved an average of 55 miles. Slightly fewer people went on day trips compared to overnight trips; however, of the people who went on day trips, a higher percent of the people participated in the fishing. Average trip costs tended to be less than for overnight trips. No day trip fisherman who landed blue crabs reported having rented equipment associated with the trip.

The economic impact of an average overnight trip was $230.73. For a day trip, the average economic impact was $32.60. Blue crabs were landed in 28,324 trips in 2002. Day trips accounted for 49% of the total number of trips taken. Blue crabs accounted for nearly 65% of the total by pounds of the species caught on all trips reporting blue crab landings. The total economic impact in 2002 for RCGL blue crab harvest is estimated to be $2,381,906.

8. SOCIOECONOMIC CHARACTERISTICS

8.1 COMMERCIAL FISHERY

8.1.1 Fishermen's profile

Commercial fishermen, who fish for blue crabs (Maiolo et al. 1985; Stroud 1996 and 1997), generally have demographic characteristics similar to most commercial fishermen in North Carolina (Diaby 1998 and 2000; Johnson and Orbach 1996).

Fishermen who harvest hard crabs tend to be younger than most commercial fishermen as a whole in North Carolina. Hard crabbers were between 14 and 74 years of age, with an average age of 36 years (Maiolo et al. 1985). In contrast, crab shedders averaged 49 years of age, with a range of 31 to 71 years (Diaby 1998). There are significant differences in average age between full and part-time fishermen and across areas for North Carolina's fishermen. For example, the average age ranged from a low of 41.2 years for full-timers in the Albemarle Sound area to a high of 55 years for part-timers in Dare County (Johnson and Orbach 1996).

With respect to years of experience in commercial fishing, hard crabbers were less experienced than other commercial fishermen in North Carolina. They averaged 14 years, compared to 22 years for crab shedders, ranging from a low of 13.7 years for full-timers in the inland (non-coastal) counties to a high of 30.7 years for part-timers in the western Pamlico Sound area for commercial fishermen.

Sixty-five percent of hard crabbers had a high school education or more. Relative to crab shedders and commercial fishermen as a whole, 70% and 68% graduated from high school, respectively; thus, the education level attained by hard crabbers is comparable to those of shedders and commercial fishermen.

No significant differences in marital status and gender exist across fisheries. Ninety-nine percent of hard crabbers were male, and 77% were married. A total of 96% of commercial fishermen were male, with 81% being married, while 91% of shedders were male and 98% were married.

8.1.2 Economic dependence on fishing and related activities

Fishermen engaged in the blue crab fisheries are in general dependent on the fisheries. Hard blue crabs are the most important source of income within the blue crab fisheries. The degree of dependence on crabbing varies with status of the fisherman (full-time vs. part-time). In 1996, 70% of crab potters surveyed fished full-time. The remaining 30%, part-timers, reported that some of their income came from non-fishing employment sources (Stroud 1997). Also, Maiolo et al. (1985) found that 58% of the full-time fishermen surveyed derived 100% of their total income from fishing activities, while fishing accounted for 40% of the part-timers' total income.

There is more economic dependence on fishing in rural areas than in urban areas. Johnson and Orbach (1996) showed that 75% of fishermen from the Albemarle Sound area, Dare County, and eastern Pamlico Sound area derived more than 50% of their income from commercial fishing, while in the southern coastal counties, commercial fishing accounted for less than 50% of commercial fishermen's income.

8.1.3 Employment opportunities and unemployment rates

Although commercial fishing is important to coastal local economies, all have some economic dependence on manufacturing, services, retail, etc. These industries provide employment opportunities for many communities when fishermen are not fishing. Employment opportunities for commercial fishermen in these non-fishing sectors are heavily dependent on the individual fisherman's skills and level of education.

Data available from the North Carolina Employment Security Commission indicate that coastal counties where blue crab fishing occurs are among those with the highest unemployment rates (Table 8.1). Only Currituck County had an unemployment rate that was lower than the state average. Some counties such as Beaufort, Tyrrell, and Washington had at least twice the unemployment rate as the rest of the state. Unemployment rates in many of these counties are quite seasonal as well, with more people being employed during warmer months than cooler months. This is particularly true in some fishing counties where the other major leading industries include tourism.

Table 8.1. Unemployment rates in North Carolina's commercial fishing counties, 2000. (NC Department of Commerce.)

County	**Annual Unemployment Rate (2000)**
Beaufort	9.6%
Brunswick	5.4%
Camden	3.4%
Carteret	4.9%
Chowan	5.0%
Craven	5.2%
Currituck	2.7%
Dare	6.4%
Hyde	6.9%
New Hanover	4.7%
Onslow	4.5%
Pasquotank	4.5%
Pender	6.1%
Perquimans	4.9%
Tyrrell	8.7%
Washington	7.2%
Statewide Average	**3.6%**

8.2 RECREATIONAL FISHERY

Data on socioeconomic characteristics of recreational crabbers is available only for those recreational fishermen who use a Recreational Commercial Gear License (RCGL). However, many recreational crabbers in North Carolina are "chicken neckers" or have only a single crab pot and therefore, are not licensed at all. There are no data available for these individuals.

The average RCGL fisherman has nearly 18 years experience fishing with commercial gear (see Table 8.2). Two thirds were born in North Carolina and the average age was 54 years old. Over 87% are currently married with over 5% who are divorced and 4% who have never married. This group of fishermen is overwhelmingly white (94%). The only other ethnic group with greater than 1% representation in the sample was Native Americans at 5%. A little over 94% of RCGL blue crab fishermen are male. Over 90% have at least a high school diploma. Almost one third have a college diploma. Over 80% of these fishermen have a total household income of greater than $30,000.

Table 8.2. Demographic characteristics of RCGL blue crab fishermen, North Carolina, 2001 (NC DMF RCGL Program).

	Category Values	Sample Size	Average/Percent
Years Experience Fishing Commercial Gear		1409	17.71
Born in NC		1400	65.90%
Age		1391	54.19
	< 16 years	6	0.43%
	17 to 25	19	1.37%
	26 to 40	212	15.24%
	41 to 60	636	45.72%
	> 60 years	518	37.24%
Marital Status		1384	
	Married	1209	87.36%
	Divorced	75	5.42%
	Widowed	31	2.24%
	Separated	13	0.94%
	Never Married	56	4.05%
Ethnic Group		1384	
	Hispanic/Latino	1	0.07%
	Caucasian/White	1305	94.29%
	Asian-Pacific Islander	4	0.29%
	African-American/Black	2	0.14%
	Native American	72	5.20%
Gender		1377	
	Male	1300	94.41%
	Female	77	5.59%
Education		1377	
	< High School	125	9.08%
	High School Diploma	325	23.60%
	Some College	499	36.24%
	College Diploma	428	31.08%
Total Household Income		1269	
	< $5,000	9	0.71%
	$5,001 to $15,000	37	2.92%
	$15,001 to $30,000	201	15.84%
	$30,001 to $50,000	318	25.06%
	$50,001 to $75,000	315	24.82%
	$75,001 to $100,000	201	15.84%
	> $100,000	188	14.81%

9. ENVIRONMENTAL FACTORS

9.1 INFLUENCES OF HABITAT AND WATER QUALITY

Habitat and water quality are critical elements linked in the ecology of estuarine systems. Degradation or improvement in one aspect of habitat or water quality may have a corresponding impact elsewhere. Maintenance and improvement of suitable estuarine habitat and water quality are probably the most important factors in providing a sustainable blue crab stock. Turner and Boesch (1987) noted evidence of a decrease in fishery production following wetland losses and stock increases following wetland gains. Steele and Perry (1990) suggested that habitat loss might be a significant factor in determining blue crab production.

According to Lindall et al. (1979), the major man-induced activities that affect the estuarine environment are the following:

1. Construction and maintenance of navigation channels;
2. Discharges from wastewater plants and industries;
3. Dredge and fill for land use development;
4. Agricultural runoff;
5. Ditching, draining, or impounding wetlands;
6. Oil spills;
7. Thermal discharges;
8. Mining, particularly for phosphate and petroleum;
9. Entrainment and impingement from electrical power plants;
10. Dams;
11. Marinas;
12. Alteration of freshwater inflows to estuaries;
13. Saltwater intrusion; and
14. Non-point-source discharges of contaminants.

Critical habitats may be impaired by freshwater drainage, land use changes, eutrophication (excessive nutrients), high organic loading, and physical destruction or disturbance by dredges, watercraft, and fishing practices. Changes in the amount and timing of freshwater inflow may have major effects on that segment of the blue crab life cycle taking place in the estuary (Steele and Perry 1990). Despite efforts to protect and restore wetland and stream functions on the part of NC Division of Water Quality (DWQ) and many other agencies and organizations in NC, there is still an annual net loss of wetlands and streams statewide (NCDENR 2002). Nursery areas are most threatened by non-point sources of pollution and development on nearby lands (Stanley 1992).

Other man-induced changes that may affect estuarine systems is the introduction of exotic species through ballast water discharges and excessive nutrient loading (eutrophication). In addition to man-induced changes, sea level rise, subsidence, storms, and erosion are natural processes responsible for loss of critical habitat (Steele and Perry 1990).

9.2 HABITAT

The blue crab life cycle consists of an offshore phase and an estuarine phase, and utilizes a wide range of habitats based on its life stage, sex, maturity, and associated salinity preferences. High salinity ocean waters provide habitat for spawning females as well as ensuring larval development and dispersal. Estuarine sounds, rivers and creeks have several different habitats which function as shelter and refuge for spawning, settlement, food and foraging.

Seasonal abundance of blue crabs for different habitat types in Core Sound, N.C. was documented by Dudley and Judy (1973). Juvenile blue crabs were most abundant from late fall through early spring in shallow soft-bottomed creeks bordered by marshlands. Peak juvenile abundance in shallow, sandy grass-bottomed areas at or near the mouths of small creeks occurred during the fall and again in spring. Samples from the ocean inlets during June, July, and August were composed mainly of mature females, most having either a sponge (egg mass on the abdomen) or remnant sponge (after the eggs have hatched).

The importance of these habitats varies with location along the coast. Shallow sand bottom, shell bottom and woody debris become more important along the southern coast where seagrasses are more seasonal, sparse or absent. Along the Cape Fear River, smaller crabs (juvenile and sub adult) are common just outside the inlet as well as in structural habitats and shallow areas of the estuary, probably reflecting the small size of the southern estuaries (Dr. Martin Posey, UNC-Wilmington, personal comment).

Fish Habitat Wetlands: Salt and Brackish Marshes

Salt and brackish marshes are tidal wetlands usually located in low energy environments where salinity is greater than 0.5 ppt. They are a complex ecosystem influenced by tide, salinity, temperature, and nutrients. Salinity in the marsh can vary because of evaporation and mixing of seawater and freshwater. It is a stressful environment for both plants and animals because of changes that occur in these variables. However, it is considered one of the most biologically productive ecosystems in the world. The high primary productivity that occurs in the marsh and the transfer of detritus into the estuary from the marsh provides the base of the food chain supporting many marine organisms including the blue crab.

Overall, North Carolina has approximately 212,800 acres of marsh habitat and is second to South Carolina in total acreage in the South Atlantic. In North Carolina, these salt marsh habitats are important nursery areas (Weinstein 1979). In general, juvenile blue crabs have wide distributions, but they are most abundant in middle and upper estuarine waters of low to intermediate salinity (Perret et al. 1971; Swingle 1971; Adkins 1972; Daud 1979; Perry and Stuck 1982). Optimum sediment for small crabs is detritus, mud, or mud-shell bottom (Adkins 1972). Subtidal sand and mud bottoms have been documented as overwintering habitat for juvenile blue crabs (Thomas et al. 1990). Small creeks and rivers in and around salt marshes provide shallow-water habitats for larger juveniles and mature crabs for feeding and refuge during molting (Orth and van Montfrans 1987; Hines et al. 1987; Thomas et al. 1990). Coarse woody debris (wood particles more than 2 centimeters or 0.8 inches in diameter) in shallow waters adjacent to forested riparian zones provides valuable shelter for large crabs, particularly during molting phases, when SAV is not present (Everett and Ruiz 1993; Wolcott and Hines 1989).

Habitat utilization by blue crabs within marshes may also differ. Recent work in Texas by Rozas and Zimmerman (2000) found that blue crabs preferred the low marsh edge dominated by salt marsh cord grass (*Spartina alternaflora)* or alkali bulrush (*Scirpus maritimus)* to the salt-meadow hay (*Spartina patens)* and needlerush (*Juncus sp.)* marsh found in high elevations as well as inner marsh areas. Within the inner marsh habitats, blue crabs preferred *Scirpus* to *S. alternaflora* in similar elevations.

Submerged Aquatic Vegetation (SAV)

Seagrass meadows are another complex ecosystem in that they provide primary productivity, structural complexity and are the preferred habitat for many species of finfish and crustaceans. There are approximately 200,000 acres of seagrasses in North Carolina consisting of three species of seagrasses in North Carolina. They are the shoal grass (*Halodule wrightii*), eel grass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) and are present throughout the year from the northern part of the state southward through Bogue Sound. However, in Bogue Sound, *Zostera* beds that are established in the cold months may be replaced by *Halodule* in the warm months. These seagrasses have very different structures and seine/trawl studies suggest they may be used differently by crustaceans (Dr. Martin Posey, UNC-Wilmington, personal comment). South of Bogue Sound to New River, seagrasses become seasonal. *Zostera* may form separate small patches in the cold months, but may be absent from some areas during warm winters as well as during late spring-fall. *Halodule*, uncommon in this area, forms small, widely spaced, isolated patches in summer in only a few locations. South of the New River area, seagrasses are not an important habitat, being absent entirely or present as isolated seedlings only during late winter (just north of Cape Fear). As seagrasses disappear, other habitats, especially intertidal oyster, marsh channel, and detritus/woody debris become more important as juvenile habitat.

Blue crabs use seagrasses during post-larval settlement, juvenile development and overwintering, as well as for protection during molting and soft shell phases of all size classes. Several studies have documented that post-larval and juvenile blue crabs prefer seagrasses and macroalgae over unvegetated shallow-water habitats (Chesapeake Bay Program 1997). Lipcius et al. (1995) noted that data collected over many years indicates that seagrass beds in Chesapeake Bay are of vital importance as settlement and nursery habitat for blue crabs during early growth stages. Lipcius et al. (1995) suggested that the Chesapeake Bay owes much of its blue crab productivity to the presence of vegetated habitats, and without them, the blue crab population would almost certainly experience a dramatic decline. In North Carolina, Etherington and Eggleston (2000) found that the majority of initial recruitment of blue crab occurs around Oregon Inlet within the extensive seagrasses located nearby. Much scientific evidence points to the importance of SAV in the blue crab life cycle. Growth of young crabs is faster in SAV; the survival of juvenile crabs is higher; the densities of crabs are substantially higher; and the abundance of juvenile crabs is higher in those years when SAV coverage is high (Chesapeake Bay Commission 1997). As juvenile crabs grow and disperse, they utilize other shallow-water habitats, as well as SAV (Chesapeake Bay Program 1997).

Tidal freshwater and aquatic freshwater grass beds are diverse communities with numerous plant species that vary in dominance because of the influence of salinity, turbidity and other environmental factors. These habitats are usually located in the uppermost portions of rivers and creeks and consist of several species of fresh/brackish water aquatic grasses such as widgeon grass (*R. maritima*), wild celery (*Vallisneria americana*), Eurasian watermilfoil (*Myriophyllum spicatum*), bushy pondweed (*Njas quadalupensis*), sago pondweed (*Potamogeton pectinatus*), and redhead grass (*Potamogeton perfoloiatus*). Most of these areas are located in Albemarle and Currituck Sounds. Within the Albemarle-Pamlico estuary, shallow detrital habitats and Eurasian watermilfoil are important alternative nursery habitats (Etherington and Eggleston 2000). Fully-grown adult male blue crabs and juvenile blue crabs also utilize Lake Mattamuskeet as well as other areas where there are aquatic freshwater beds. As with seagrasses, this habitat also provides primary productivity and structural complexity to the ecosystem.

Shell Bottom (oyster reefs and shell banks)

Oyster reefs are defined as natural structures composed of oyster shell, live oysters and other organisms that are discrete, contiguous and clearly distinguishable from scattered oysters in marshes and mudflats. Oyster reefs are found in both subtidal and intertidal zones of tidal creeks and estuaries of North Carolina and provide a three-dimensional structure that serves as protection and foraging habitat for blue crabs. In the Pamlico system, oysters occur in shallow subtidal regions with intertidal reefs present. From the White Oak River southward, there is a shift to predominantly mid intertidal reefs. These mid intertidal reefs along the southeastern coast are utilized as juvenile habitat by blue crabs and may form important habitat connections from subtidal areas to the intertidal marshes. The southern coastal area has greater tidal amplitude than the mid and northern coasts and oysters occupy a central location between subtidal channels and mid-upper intertidal marshes.

Blue crabs also recruit to oyster reefs that have been restored for oyster habitat. Studies of restored oyster reefs in the Neuse River demonstrated that restored oyster reefs provide important recruitment and foraging habitat for blue crabs (Hunter 1998). Those restored in shallow water as well as tall reefs in deep water provide refuge from low oxygen disturbances. Marshes and SAVs located near restored oyster reefs enhance movement of foraging blue crabs by providing a corridor for this movement (Micheli and Peterson 1999). In addition, the commercial value of blue crabs on restored oyster reefs was found to be higher than the value of those on nearby sand bottom.

Soft Bottom (riverine, intertidal, and subtidal bottom)

Intertidal mud flats provide nursery areas conducive for metamorphism of the blue crab from the planktonic stage to the benthic stage. During this phase in the life cycle of the blue crab, they become very vulnerable to predation and adverse physical conditions such as current. Mudflats provide an area of low energy, low predation, and a high amount of benthic prey that lives in or on the sediment. Grabowski et al. (2000) found that crabs would remain in structured habitat (seagrass, salt marsh, oyster rock) during the day, but would migrate onto mud flats at night where they could forage with less risk of becoming prey. Water depth appears to play a role in predation by limiting larger predators to deeper waters. It was noted in Ruiz et al. (1993) that larger predatory type fish and blue crabs stayed in deeper water (>70cm) probably to avoid avian and mammal type predation. They also noted that mortality rates of tethered juvenile blue crabs increased significantly as depth increased.

Although structured habitat such as marsh, SAVs, and shell bottom is continually demonstrated to have higher densities of blue crabs than unstructured riverine and subtidal soft bottoms, these also provide habitat to blue crabs. Proximity of soft bottoms to vegetation as well as water depth may influence use of these areas by blue crabs. Rozas and Zimmerman (2000) found that the nonvegetated areas adjacent to marshes contained higher densities of most animals, including blue crabs than shallow bay waters. In Chesapeake Bay, Pile et al. (1996) concluded that as small juvenile blue crabs increase in size to larger adult crabs, they move out of vegetated areas to non-vegetative areas. They found that the densities of 0+ year class crabs were significantly higher in vegetative habitats, while the density of 1+ year class crabs was significantly higher in nonvegetated habitats. This shift occurs when the risk of predation on the older crabs is higher than the energy value gained by remaining in the habitat. This move is probably associated with the antagonistic behavior of the older blue crab; thus reducing the risk of predation in these unvegetated areas (Pile et al. 1996). Subtidal sand and mud bottoms have also been documented as overwintering habitat for juvenile blue crabs (Thomas et al. 1990).

In a large-scale study of blue crab recruitment in the Croatan-Albemarle-Pamlico Estuarine System, Etherington and Eggleston (2000) found that the majority of initial recruitment occurred in the eastern region, especially around Oregon Inlet and the extensive seagrass beds located nearby. Also, in association with the passage of tropical storms and hurricanes, significant pulses of recruitment would occur along the mainland shoreline in areas of shallow detrital habitat. These shallow, low relief, intricate detrital habitats are primarily located on the western side of the sound in areas of moderate salinity and high energy. Densities of early juvenile crabs in these detritus habitats were similar to those found in seagrasses.

9.2.1 Habitat Protection

Presently, the MFC has authority for the following actions with regard to marine and estuarine resources: manage, restore, develop, cultivate, conserve, protect, and regulate. Marine and estuarine resources are: "All fish [including marine mammals, shellfish, and crustaceans], except inland game fish, found in the Atlantic Ocean and in coastal fishing waters; all fisheries based upon such fish; all uncultivated or undomesticated plant and animal life, other than wildlife resources, inhabiting or dependent upon coastal fishing waters; and the entire ecology supporting such fish, fisheries, and plant and animal life." (G.S. 113-129).

The MFC has the power and duty to: authorize, license, regulate, prohibit, prescribe, and restrict:

(A) All forms of marine and estuarine resources in coastal fishing waters with respect to: (1) Time, place, character or dimensions of any method or equipment that may be employed in taking fish, (2) Season for taking fish, and (3) Size limits on and maximum quantities of fish that may be taken.

(B) Possession, cultivation, transportation, importation, exportation and sale of all marine and estuarine resources and all related equipment and vessels.

The MFC also has authority to comment on State permit applications that may have an effect on marine and estuarine resources, regulate placement of fishing gear, develop and improve mariculture, regulate location and utilization of artificial reefs, and regulate the disposition of the young of edible fish. MFC authority is found at G.S. 143B-289.51 and 289.52.

In an effort to protect SAV and other habitats from bottom-disturbing fishing gears, the MFC prohibits the use of rakes and dredges of a specific weight and type in internal coastal waters (MFC 1997; 15A NCAC 3J .0303, 3K .0102, and 3K .0503), dredges/mechanical methods to take shellfish and crabs in certain areas (15A NCAC 3K .0204, 3R .0108, and 3I .0203), and trawl nets in certain areas [15A NCAC 3J .0104 (b) (4) and 3R .0106(2)]. Harvest methods for hard clams have been established in beds of submerged aquatic vegetation (15A NCAC 3K .0304), and the Fisheries Director has been granted proclamation authority to specify means and methods for mechanical harvest of shellfish by season and area (15A NCAC 3K .0302 and 3K .0501). The MFC has also provided habitat and fishery resource protection by prohibiting the use of various commercial gears in Primary Nursery Areas (PNAs) [15A NCAC 3N .0104 and 3R .0103], and prohibiting the use of trawl nets in Secondary Nursery Areas (15A NCAC 3N .0105, 3R .0104, and 3R .0105).

The MFC also has rules specific to the protection of oyster habitat and oyster management areas. Oyster dredges may weigh no more than 100 pounds, with only one oyster dredge per vessel (15A NCAC 3J. 0303). Oyster beds planted and posted by the state are protected from bottom disturbing gear (15A NCAC 3K. 0203). Certain areas of internal coastal waters are closed to mechanical harvest of oysters (15A NCAC 3K. 0204 and 15A NCAC 3R. 0108).

The NC Fishery Management Plan for Oysters (NCDMF 2001) also addresses the need for protecting oyster habitat. In 2002, criteria have been adopted to further designate areas to hand harvest methods only, reducing the amount of area open to mechanical harvest. The DMF is also increasing cultch plantings in hand harvest areas as well as maintaining cultch plantings in mechanical harvest areas. The plan also recommends the prohibition of trawling and long hauling on cultch and seed planting areas. Other recommendations include enhancing and expanding oyster sanctuaries.

Authority of Other Agencies

The North Carolina Division of Coastal Management (DCM) is responsible for development permits along the estuarine shoreline in 20 coastal counties. Wetland development activity throughout North Carolina is permitted through the United States Army Corps of Engineers (COE) and the North Carolina Division of Water Quality (DWQ; 401-certification program). Various federal and state environmental and resource agencies, including DMF, evaluate projects proposed for permitting and provide comments and recommendations to the DCM, DWQ, and COE on potential habitat and resource impacts. Habitat protection relies on enforcement, the efforts of commenting agencies to evaluate impacts, and the incorporation of recommendations into permitting decisions.

Coastal Habitat Protection Plan

The Fisheries Reform Act of 1997 (FRA 1997) mandated the Department of Environment and Natural Resources (DENR) to prepare a Coastal Habitat Protection Plan (CHPP -- G. S. 143B-279.8). The legislative goal for the CHPP is long-term enhancement of the coastal fisheries associated with coastal habitats and provides a framework for management actions to protect and restore habitats critical to North Carolina's coastal fishery resources. The Coastal Resources Commission, Environmental Management Commission, and the Marine Fisheries Commission must each approve the plan for it to become effective. These are the three Commissions that have regulatory jurisdiction over the coastal resources, water, and marine fishery resources. Actions taken by all three commissions pertaining to the coastal area, including rule making, are to comply, "to the maximum extent practicable" with the plan. The CHPP will help to ensure consistent actions among these three commissions as well as their supporting Department of Environment and Natural Resources agencies. The CHPP was approved in December 2004 and an implementation plan is to be developed by July 2005. The CHPP will be reviewed every five years.

The CHPP describes and documents the use of habitats by species supporting coastal fisheries, status of these habitats, and the impacts of human activities and natural events on those habitats (Figure 9.1)

As an organizational framework the CHPP program uses two basic categories to define habitat that supports coastal fisheries: 1) Fish Habitat, and 2) Strategic Habitat Areas. Fish Habitat (FH) is defined as freshwater, estuarine, and marine areas that support juvenile and adult populations of economically important fish, shellfish, and crustacean species (commercial and recreational), as well as forage species important in the food chain (Street et al. 2005). Fish Habitat also includes land areas that are adjacent to, and periodically flooded by riverine and coastal waters. The following six specific Fish Habitats have been designated based on distinctive physical properties, ecological functions, and habitat requirements for living components of the habitat: Wetlands, Submerged Aquatic Vegetation (SAV), Soft Bottom, Shell Bottom, Ocean Hard Bottom, and Water Column.

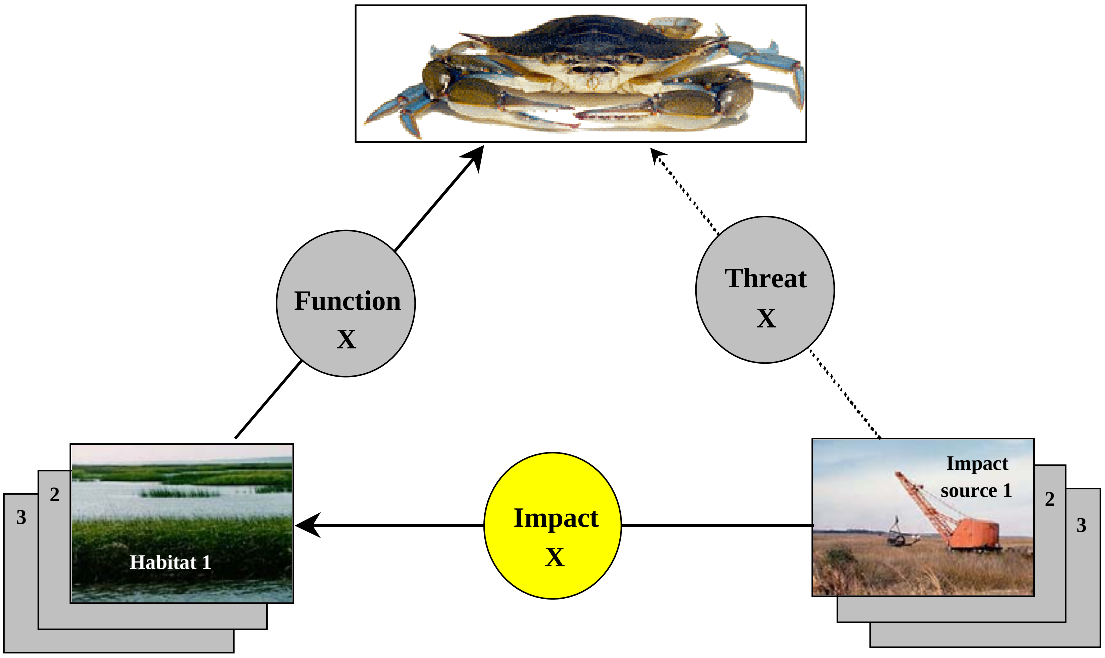

Figure 9.1 The figure illustrates the organization concept for presenting information needed to support management options affecting impact sources. Solid arrow = direct linkage, dashed arrow = indirect linkage.

A second category of habitat termed "Strategic Habitat Areas" (SHAs) is defined as specific locations of individual fish habitat or systems of habitat that have been identified to provide critical habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity. This concept recognizes that while all fish habitats are necessary for sustaining viable fish populations, some areas may be especially important to fish viability and productivity. Protection of these areas would therefore be a high priority (Street et al. 2005).

Critical Habitat Areas for Blue Crabs

The 'North Carolina Fisheries Rules for Coastal Waters' (MFC 2003 – 15A NCAC 3I .0101(20)) defines Critical Habitat Areas as the

> "fragile estuarine and marine areas that support juvenile and adult populations of economically important seafood species, as well as forage species important in the food chain. Critical habitats include nursery areas, beds of submerged aquatic vegetation, shellfish producing areas, anadromous fish spawning and anadromous fish nursery areas, in all coastal fishing waters as determined through marine and estuarine survey sampling. Critical habitats are vital for portions or the entire life cycle, including the early growth and development of important seafood species."

The definitions of habitats important to the blue crab (15A NCAC 3I) are:

- **Nursery areas**: those areas in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young finfish and crustaceans spend the major portion of their initial growing season.

- **Beds of submerged aquatic vegetation**: (Submerged aquatic vegetation) those habitats in public trust and estuarine waters vegetated with one or more species of submerged vegetation such as eelgrass (Zostera marina), shoal grass (Halodule wrightii) and widgeon grass (Ruppia maritima). The presence of aboveground leaves or the belowground rhizomes and propagules together with the sediment on which the plant grows define the bed.
- **Shellfish producing areas** (Shell bottom) those areas in which economically important shellfish, such as, but not limited to clams, oysters, scallops, mussels, and whelks, whether historically or currently, reproduce and survive because of such favorable conditions as bottom type, salinity, currents, cover, and cultch.
- **Intertidal Oyster Bed**: (Shell bottom) a formation of size or shape, formed of shell and live oysters of varying density.

Crab spawning sanctuaries located at Oregon Inlet, Hatteras Inlet, Ocracoke Inlet, Drum Inlet and Bardens Inlet are also considered important crab habitat for spawning, even though it is not recognized as a critical habitat area. These areas have extensive seagrass beds and are important areas for female blue crabs that have migrated there to spawn. These areas also provide habitats for larvae as well as a means of dispersal (Etherington and Eggleston 2000).

As illustrated in Figure 9.1, the CHPP focuses on fish habitat and threats to the habitat. This FMP documents habitat conditions or needs for the various life stages of the blue crab. The FRA 1997 gives precedent to the CHPP and stipulates that habitat and water quality considerations in the FMP should be consistent with the CHPP. Any recommendations will be considered and acted upon through the CHPP implementation process.

9.3 WATER QUALITY

9.3.1 Population growth and land use

Estuarine and coastal areas contain some of the Nation’s most densely populated and rapidly growing areas (Beach 2002). However, the highest-density areas in North Carolina were in the Piedmont region, suggesting that much of the problem from highly mobile pollutants can be traced upstream (Street et al. 2005). The North Carolina coast has a rapidly growing human population. The coastal counties in North Carolina experience tremendous population fluctuations due to the influx of seasonal visitors. In many of these counties, public facilities, including wastewater treatment, roads, and water supply systems are being taxed to the limit (Steel 1991). As population increases, so does the need for infrastructure (roads, schools, water and sewer facilities, power transmission lines, etc.) to support increasing numbers of people, resulting in loss of open areas such as forest and agricultural lands. Beach (2002) concluded that conversion of land in the coastal zone from open space (forest and agricultural uses) to urban/suburban uses was the primary threat to coastal water quality. As population density increases, so does the potential for degradation of the natural environment by human activities (Cairns and Pratt 1992).

9.3.2 Symptoms of declining water quality

The most common causes of use support impairment of North Carolina’s water quality classifications as documented in several coastal basinwide water quality management plans are oxygen-consuming wastes, nutrients, fecal coliform bacteria, metals/toxicants, sediment, and solids/turbidity (NCDEHNR 1997b). Nonpoint source pollution is identified as the major contributor to water quality impairment in the coastal river basins. Symptoms of declining water quality in North

Carolina's estuaries are the increased frequency of nuisance algal blooms, hypoxia, and fish kills.

Several of North Carolina's major coastal river basins, including the Chowan, Tar-Pamlico, Neuse, and Cape Fear, are designated as "nutrient sensitive". Eutrophication, or excessive nutrient loading, can create an ecological imbalance resulting in nuisance and frequent algal blooms (EPA and NCDEHNR 1994). A decline of SAV species in Chesapeake Bay during the late 1960's and early 1970's was attributed to increasing amounts of nutrients and sediments (Chesapeake Bay Program 1997).

Respiration and decomposition of algal blooms and organic loading can cause hypoxic (low levels of dissolved oxygen) and/or anoxic (absence of oxygen) conditions. Temperature and salinity stratification contributes to the formation and severity of hypoxic and anoxic events. In recent years there has been an increase in the number of coastal ecosystems worldwide that experience seasonal hypoxia and/or anoxic events (Sullivan and Gaskill 1999). These depressed (low) oxygen events themselves are also becoming larger and lasting longer as a result of eutrophic conditions exacerbated by anthropogenic nutrient loading to the coastal area (Breitberg 1992, Cooper and Brush 1991, Diaz and Rosenberg 1995, Lenihan and Peterson 1998, Paerl et al. 1998). Under very severe conditions (total anoxia or 2-3 weeks of sustained hypoxia), aquatic communities may experience complete defaunation and subsequent alterations in large-scale ecosystem function (Breitburg et al. 1997).

Benthic community composition and distribution is an important component of the trophic dynamics in estuaries. The blue crab can be and normally is a significant and integral component of the estuarine community. Hypoxic events can play a major role in determining benthic community structure and trophic dynamics in various systems (e.g. Tenore 1972; Falkowski et al. 1980; Santos and Simon 1980; Harper et al. 1991; Holland et al. 1987; Rosenberg et al. 1992; Rabalais et al. 1994). Direct or secondary effects of hypoxia and anoxia on crabs may include: reduced suitable habitat (Selberg et al. 2001); impeding or promoting movement (Pihl et al. 1991; Das and Stickle 1994; Eby and Crowder 2001); reduced feeding (Das and Stickle 1991; Taylor and Eggleston 2000; Bell et al. 2003), growth (Diaz and Rosenberg 1995); Sullivan and Gaskill 1999), and molting rate (Das and Stickle 1993); increased (Pihl et al. 1991 and 1992; Nesterode and Diaz 1998) or decreased nutrition (Noga et al. 1990; Pihl et al. 1991) due to prey availability; deteriorating body condition; increased environmental stress; increased species interaction and competition (Eby and Crowder 2001; Selberg et al. 2001);lower immunological competence (Noga et al. 1990) and increased susceptibility to disease; diminished reproductive capability; and mortality (Harper and Guillen 1989; Das and Stickle 1991 and 1993).

Oxygen deficient water and associated blue crab mortality has been reported in Mobile Bay, Alabama (May 1973; Tatum 1982), Chesapeake Bay (Carpenter and Cargo 1957; Van Engel 1982), Texas (More 1969), Louisiana (Guillory et al. 1996), and North Carolina (NCDEHNR 1997a; NCDENR 1997; 1999; 2000; 2001). Low levels of dissolved oxygen may restrict the use of otherwise suitable habitat and cause high local mortalities and influence the distribution or migration of blue crabs (Pihl et al. 1991; Das and Stickle 1994; Guillory et al. 1996; Selberg et al. 2001; Eby and Crowder 2001; Bell et al. 2003). Selberg et al. (2001) noted that blue crabs were present in Neuse River, NC where dissolved oxygen concentrations exceeded 2.4 mg/L, and generally absent from areas with lower oxygen concentrations. Crabbers in Chesapeake Bay have had to set traps progressively closer to shore because of hypoxic conditions in deeper water (Price et al. 1985). Crab potters in the Albemarle - Pamlico sound complex indicate that hypoxic and anoxic ("dead water") conditions can be frequent and widespread, resulting in significant trap mortalities and making vast areas unfishable. Sullivan and Gaskill (1999) in a Neuse River, NC study suggest that low dissolved oxygen can cause locally elevated mortality among crabs constrained by capture in pots. Neuse River crab potters indicated that low oxygen events cause them to move pots and alter fishing frequency. Adjustments in fishing activity were based on changing environmental observations and catch rates (Selberg et al. 2001). Conditions which suggest the presence of hypoxic and anoxic water conditions include: crabs swimming at or near the water's surface; crabs crawling out of the water on to shore; pot caught crabs clinging to the top of crab pots attempting to get out of the low oxygen water; weak crabs and reduced catches in pots; total mortality of potted crabs; and pots previously covered with aquatic organisms (marine fouling) suddenly appear clean.

Hypoxia or sediment contamination can cause large reductions in the benthic community density and diversity. Hackney et al. (1998) surveyed 165 sites within North Carolina's sounds and rivers during 1994-1997 to evaluate environmental conditions as part of the USEPA Environmental Assessment Program. Findings indicated benthic populations dominated by tolerant opportunistic species and low species richness. It was estimated that 13.4 percent of the estuarine bottoms were incapable of supporting benthic production. Contaminants surveyed included nickel, arsenic, DDT, PCBs, and mercury. The investigation found that 37.5 to 75.8% of the randomly selected stations had contaminated surface sediment, and 19 to 36% of the sites were highly contaminated. Fish sores and lesions were more prevalent at sites with high sediment contamination (up to 50% of examined fish), but sores were also found at less contaminated sites. Laboratory bioassays showed that sediments from many sites were toxic to biological organisms. This evidence suggests that a major portion of North Carolina's estuarine system may not fully support food chains that will support productive recreational and commercial fisheries (Hackney et al. 1998). However, because this study was limited in the number and frequency of sampling stations, additional sediment sampling is needed to more accurately assess the overall condition of soft bottom sediments in North Carolina.

Jordan et al. (1992; based on Funderburk et al. 1991) recommended a monthly average dissolved oxygen content of 5 mg/L for target species in Chesapeake Bay, including blue crabs. Blue crabs are tolerant of hypoxic (low oxygen) conditions (Lowery and Tate 1986); however, tolerance decreased with increasing temperature (deFur et al. 1990). Juvenile crabs may be less tolerant of hypoxia than adults (Stickle et al. 1989), and may require more oxygen than was recommended by Jordan et al. (1992).

Blue crab kills following excessive freshwater runoff and subsequent oxygen depletion due to rapid decomposition of organic matter were reported by Van Engel (1982). Changes in the amount and timing of freshwater inflow may have a major effect on that segment of the blue crab life cycle taking place in the estuary (Steele and Perry 1990). Adkins (1972) concluded that domestic, agricultural, and industrial pollution, as well as dredge and fill operations, have adversely affected blue crab populations in Louisiana. Although the exact mechanisms through which environmental pollutants affect blue crab production are poorly understood, evidence suggests that chemical pollution may be responsible for crab mortalities (Steele and Perry 1990). Chemical and biological pollutants, sediment, temperature, salinity, and low dissolved oxygen have been associated with crab mortalities (Van Engel 1982). Various organic compounds and inorganic contaminants have been found to be toxic to different blue crab life history stages (Millikin and Williams 1984). Crab mortalities in North Carolina have been documented in relation to severe runoff events, low dissolved oxygen levels, fish kills of unknown cause, and detergent spills (NCDEHNR 1997a; NCDENR 1997; 1999; 2000; 2001). Algal blooms and *Pfiesteria*-like organisms have been identified in some areas where crab kills were observed (NCDENR 1997). Toxic algae have caused blue crab mortalities in controlled laboratory tests (Burkholder et al. 1992).

9.3.3 Parasites and Disease

It has been suggested that changes and/or degradation of water quality is linked to the proliferation of parasites and disease. Many infections are contagious to other crabs and may be an indication of stress in a population. The relationship between stress and disease is a well-documented phenomenon. Sindermann (1989) found that the occurrence of disease was higher in stressed populations. Various sources suggest a link between poor water quality conditions, immunocompetence, and disease in crustaceans. Areas of high organic load and poor water quality generally contribute to an increase in bacteria numbers (Sindermann 1974). Blue crabs in these areas may be more prone to bacterial infections (shell disease). Noga et al. (1990) suggested the environment and not the presence of bacteria, as responsible for the induction and development of shell disease.

A variety of pathogens can affect crustaceans, including viruses, bacteria, fungi, protozoans, and helminths. Some pathogens may cause significant mortalities, reduced fecundity, and unattractive necrotic lesions on the shell or black/white pigmentation in the meat, rendering affected crabs unmarketable.

Diseases and parasites that have been observed in blue crabs from North Carolina include bacterial infections (shell disease), a dinoflagellate parasite *Hematodinium sp.,* an amoeba parasite *Paramoeba perniciosa* (gray crab disease), and a microsporidian parasite *Ameson michaelis* (cotton crab disease). In 1987, an extreme outbreak of shell disease was observed in the Pamlico River (McKenna et al. 1990). The chronic presence of shell disease was suggested as a possible factor contributing to a significant, progressive decline in blue crab landings in the Pamlico River during 1985-1989 (Noga et al. 1990). Gray crab disease has not been a major problem, though there have been periodic outbreaks causing localized mortalities (Mahood et al. 1970). Cotton crab disease was identified as the suspected cause of excessive mortality and weakened peelers and soft crabs in northern Outer Banks, NC shedding operations during 1999 (pers. comm. Dr. Ed Noga). A listing of potential parasites, diseases, symbionts, and other associated organisms reported from blue crabs is presented in Guillory et al. 2001.

Diseases and infections in the blue crab population can bring about wide and varied effects, both actual and perceived, on the blue crab and its industry. Even the perception of diseases and pathogens, once shared with the public, can have considerable effects on the industry and on management (Chesapeake Bay Program 1997). A toxic dinoflagellate bloom in Maryland during the summer of 1997 focused attention on similar water quality issues in North Carolina, affecting blue crab markets along the east coast.

9.3.4 Tropical Cyclones, Storms and Significant Weather Events

Tropical cyclones (hurricanes and storms) and other major weather events may have both significant short and long-term impacts on the blue crab resource and fishery. Hurricanes can play an important role in the water quality of the coastal area and are considered an important natural perturbation that is necessary for the long-term maintenance of estuarine systems (Meeder and Meeder 1989). Many of the weather related influences on the aquatic environment and resources can not be quantified with the existing levels of scientific sampling. Impacts on the blue crab resource and interdependent ecosystem can be either positive or negative. Also, these impacts can be quite different depending on the season, storm track, duration and physical characteristics of the storm, area of influence, and blue crab life stage. The storm's characteristics determine if the impacts are widespread or localized and beneficial or detrimental to aquatic resources and users. Widespread effects may significantly alter the fishery and population as a whole. Whereas, localized effects may have significant influence on individual participants in the fishery, but may not have a noticeable impact on the crab population and fishery.

Hurricanes Bertha and Fran dominated summer and fall weather patterns in 1996. These storms resulted in severe flooding of coastal areas, hypoxic and anoxic events, and multiple fish kills in both the Neuse and Pamlico rivers and Pamlico Sound (NCDENR 1998).

During September and October 1999, several noteworthy hurricanes (Dennis, Floyd, and Irene) combined to significantly impact North Carolina's weather, people, terrestrial and aquatic resources, and water quality. Heavy rainfall during a short time period was associated with each storm. Unprecedented rainfall was recorded in many parts of eastern and central North Carolina, yielding at least half the average annual rainfall during the 2 months (Bales et al. 2000). This rainfall resulted in massive amounts of runoff causing severe flooding in many streams and rivers for almost 2 months (Chowan, Cashie, Tar-Pamlico, Neuse, New, Cape Fear, Waccamaw, and Lumber river basins: Bales et al. 2000). This runoff and flooding delivered a massive load of organics, nutrients, and freshwater into the North Carolina estuarine system. Under normal conditions, inflow volume during September and October is about 13 percent of the volume of Pamlico Sound. The flooding during these 2 months resulted in an inflow volume equivalent to about 83 percent of the total sound volume (Bales et al. 2000). This large volume of inflow resulted in a tremendous dilution of potential problem constituents. The long-term effects on coastal water quality and aquatic life remain unknown.

The immediate obvious and measurable effects of this runoff on the estuaries were low dissolved oxygen levels, decreased salinity levels, and density/salinity stratification. Although dissolved oxygen levels were quite low in the upper river stations, the sustained hypoxic conditions associated with Hurricane Fran (Sept. 1996) floodwaters did not occur after Hurricane Floyd. Several factors may have contributed to the higher oxygen levels (e.g., cooler air temperatures, higher and sustained flows provided greater dilution of oxygen consuming wastes, slower recession of floodwaters and a gradual delivery of organic matter from the floodplain: Bales et al. 2000). Dissolved oxygen concentrations in the estuaries were also affected by the massive freshwater inflows, but persistent and extremely low oxygen conditions were not observed. Some data indicates that windy conditions associated with Hurricane Irene resulted in the beneficial mixing of estuarine waters which helped to reduce stratification and re-oxygenate low oxygen waters.

Impacts of the 1999 hurricanes on the blue crab resource are still unclear. Statewide blue crab landings during 2000 were down considerably compared with landings in the late 1990's. Lingering impacts on habitat and water quality, principally in the Pamlico estuary, associated with the flooding and massive freshwater inputs from the 1999 hurricanes likely contributed to the significant reduction in crab landings during 2000. Also, reduced crab catches in some areas resulted in lower overall effort and landings in the crab pot fishery as fishermen concentrated on other species. Landings in the Albemarle area and Southern District for 2000 were relatively normal compared to recent years.

9.3.5 Water Quality Protection

Federal and state laws mandate water quality protection activities through government commissions and agencies. Several divisions within the North Carolina Department of Environment and Natural Resources are responsible for providing technical and financial assistance, planning, permitting, certification, monitoring, and regulatory activities that have a direct or indirect impact on coastal water quality and habitat.

Various federal and state environmental and resource agencies, including DMF, evaluate proposed projects and provide comments and recommendations on potential water quality and resource impacts. Water quality protection relies on enforcement, the ability of commenting agencies to evaluate impacts, and whether recommendations are incorporated into permitting decisions.

An increase in population and land-based development, demands on water resources for various uses, and an inadequate understanding of impacts on estuaries have caused water quality degradation in spite of management efforts. The principal problems are a lack of strict pollutant standards, inadequate pollution abatement, and insufficient monitoring to protect water quality and the complex ecology of estuarine systems.

North Carolina has established a water quality classification and standards program for “best usage”. Recent water quality classifications and standards have been implemented to promote protection of surface water supply watersheds, high quality waters, ecosystem functions, and the protection of unique and special pristine waters with outstanding resource values. Classifications, particularly for High Quality Waters (HQW), Outstanding Resource Waters (ORW), Nutrient Sensitive Waters (NSW) and Water Supply (WS) waters, outline protective management strategies aimed at controlling point and nonpoint source pollution. Many water quality standards are based on potential impacts in the immediate receiving waters and do not factor in the cumulative and long-term effects to the complex functions that characterize estuarine systems. Standards should be based on the assimilative capacity of, and impacts to, the entire system. The Comprehensive Conservation and Management Plan of the Albemarle-Pamlico Estuarine Study (EPA and NCDEHNR 1994) and other earlier plans for water quality management have recommended strategies that need to be implemented to improve water quality. Many of these recommendations have not been accomplished. Achievement of basinwide water quality management planning by the DWQ will hopefully improve coastal water quality.

Various public agencies (state and federal) and private groups have established parks, refuges, reserves, sanctuaries, and natural areas that help to protect adjacent public trust estuarine water quality.

10. PRINCIPAL ISSUES AND MANAGEMENT OPTIONS

A summary of the major issues and management options identified during the development of the FMP are contained in this section. Each issue is briefly described along with potential management options, recommended strategies, and actions to be taken by the MFC, DMF, and others. An in-depth discussion of habitat and water quality is in Section 9 (Environmental Factors) while the remaining issues are discussed in Section 12 (Appendices).

10.1 ENVIRONMENTAL ISSUES

10.1.1 Habitat

10.1.1.1 Issue/ Purpose

Protect, enhance, and restore habitats utilized by the blue crab.

Suitable and adequate habitat is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of habitat may have a corresponding impact on water quality. Maintenance and improvement of suitable estuarine habitat and water quality are probably the most important factors in providing a sustainable blue crab stock.

10.1.1.2 Management Options

1. No regulatory action.
2. MFC rule changes to protect additional blue crab critical habitats.
3. Rule changes by other agencies (North Carolina Coastal Resources Commission, North Carolina Environmental Management Commission, and others) to protect blue crab critical habitats and water quality.

Option two would require rule changes by the MFC.

10.1.1.3 Recommended Management Strategy

Habitat protection, conservation, and restoration are essential to accomplish the goal and objectives of this plan. The MFC, North Carolina Coastal Resources Commission (CRC), and North Carolina Environmental Management Commission (EMC) should adopt rules to protect blue crab critical habitats as outlined in the Coastal Habitat Protection Plan (CHPP). The Department of Environment and Natural Resources (DENR) should develop a strategy to fully support the CHPP process with additional staff and funding. The MFC and DMF should continue to comment on activities that may impact aquatic habitats and work with permitting agencies to minimize impacts and promote restoration and research. Research must be conducted to investigate the impacts of trawling on various habitats. A strategy should be developed and adopted by the MFC and DENR to accomplish the actions outlined in Section 10.1.1.4. These strategies would address objectives 1, 3, 6, 7, and 8 of this plan.

10.1.1.4 Actions

Actions 1, 2, 3, 4, 7, and 12 would need to be implemented through the cooperate efforts of the N.C. General Assembly and/or several divisions within the Department of Environment and Natural Resources. The involvement of federal agencies and increased funding (state and federal) may be necessary to accomplish these actions.

Critical Habitat Areas

Action 1: The identification, maintenance, and enhancement of habitats critical to the life cycle of the blue crab should be a priority of efforts by the DENR and the MFC and its committees, in developing CHPPs as outlined in the Fisheries Reform Act of 1997.

Action 2: Management Actions as outlined in the Vital Habitats Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should receive priority for funding and be completed in a timely manner (see Appendix 3).

Action 3: Management Actions as outlined in the Vital Habitats Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should be expanded to all river basins that drain to North Carolina's coastal region (see Appendix 3).

Action 4: Advocate stronger regulatory programs and enforcement of regulations protecting blue crab critical habitat [marshes, SAVs, shell bottom, and soft bottom (riverine, subtidal and intertidal bottom)].

Action 5: Continue to make recommendations on all state, federal, and local permits to insure minimal impacts to critical habitat areas.

Action 6: Develop and maintain accurate maps and records of critical habitat areas for blue crabs (marshes, SAVs, shell bottom, and soft bottom (riverine, subtidal and intertidal bottom).

Action 7: Enhance existing efforts to restore the functions and values of degraded blue crab habitat (marshes, SAVs, shell bottom, and soft bottom (riverine, subtidal and intertidal bottom).

Action 8: Identify, research, and map shallow detrital areas important to blue crabs.

Nursery Areas

Action 9: Identify, research and designate additional areas as Primary Nursery Areas that may be important to blue crabs as well as other fisheries.

Submerged Aquatic Vegetation (SAV)

Action 10: Develop criteria to designate critical SAV habitat areas.

Action 11: Designate Critical SAV areas based on developed criteria.

Action 12: Request that EMC and CRC prohibit dredging or channelization in designated SAV areas.

Action 13: Complete mapping of SAVs throughout the state.

Action 14: Support follow-up mapping of previously mapped SAVs.

Shell bottom

Action 15: Solicit and acquire resources to update and complete shellfish bottom mapping of oyster reefs.

Action 16: Solicit and acquire resources to supplement resource enhancement for cultch plantings.

Action 17: Develop a protocol for identification and designation of oyster rock/shell bottom as critical fisheries habitat where fishing activities would be restricted.

Crab Spawning Sanctuaries

Action 18: Utilize the existing authority of the MFC for adoption of blue crab spawning areas as critical habitat.

Action 19: Develop criteria to be used to delineate crab spawning sanctuaries as critical habitat.

Action 20: Continue to support mapping of spawning sanctuaries through the Fisheries Resource Grant and Blue Crab Research Program.

Action 21: Support and conduct research and mapping of other inlet areas that may be significant to spawning.

10.1.2 Water Quality

10.1.2.1 Issue/ Purpose Protect, enhance, and restore estuarine water quality.

Suitable water quality is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of water quality may have a corresponding impact on habitat. Maintenance and improvement of suitable estuarine water quality and habitat are probably the most important factors in providing a sustainable blue crab stock.

10.1.2.2 Management Options

The MFC has no regulatory authority over water quality impacts. The MFC and DMF should highlight problem areas and advise other regulatory agencies (EMC, Division of Water Quality, Division of Environmental Health – Shellfish Sanitation, Division of Land Resources, US Army Corps of Engineers, and local governments) on preferred options and potential solutions.

10.1.2.3 Recommended Management Strategy

The MFC and DMF should continue to comment on activities (state, federal, and local permits) that may impact estuarine water quality and work with permitting agencies to minimize impacts. Additionally, the MFC and DMF should solicit and support Fishery Resource Grant (FRG) and Blue Crab Research Program (BCRP) projects that may provide information necessary for protection, management, and restoration of water quality. Water quality standards should be based on the assimilative capacity of, and impacts to, the entire system. Several plans for water quality management have recommended strategies that need to be implemented to improve water quality. A strategy should be developed and adopted by the MFC and DENR to accomplish the actions outlined in Section 10.1.2.4, and to assure that recommendations of existing and future water quality plans are addressed in a timely manner. The DENR should develop a strategy to fully support the CHPP process with additional staff and funding. Water quality protection and restoration are essential to accomplish the goal and objectives of this plan. This strategy would address objectives 1, 3, 6, 7, and 8 of this plan.

10.1.2.4 Actions

Actions would need to be implemented through the cooperate efforts of the N.C. General Assembly and several divisions within the Department of Environment and Natural Resources. The involvement of federal agencies and funding (state and federal) will be necessary to accomplish these actions.

Action 1: The identification, maintenance, and enhancement of water quality critical to the life cycle of the blue crab should be a priority of the NCDENR and the MFC and its committees, in developing Coastal Habitat Protection Plans as outlined in the Fisheries Reform Act of 1997.

Action 2: Management Actions as outlined in the Water Quality Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should receive priority for funding and be completed in a timely manner (see Appendix 3).

Action 3: Management Actions as outlined in the Water Quality Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should be expanded to all river basins that drain to North Carolina’s coastal region (see Appendix 3).

Action 4: Work with the permitting and commenting agencies to enhance protection of water quality. The MFC should fully utilize it's permit commenting authority outlined in G.S. 143B-289.52.
Action 5: Additional research is needed on the extent, causes, and impacts of hypoxia and anoxia on blue crab behavior and population abundance in North Carolina's estuarine waters.
Action 6: The MFC should strive for accomplishment of the management strategies as outlined in the coastal basinwide water quality management plans and water quality recommendations of the Fisheries Moratorium Steering Committee.
Action 7: Request that the North Carolina EMC review "Nutrient Sensitive Waters", "High Quality Waters", and "Outstanding Resource Waters" designations for the coastal river basins and implement additional strategies as needed.
Action 8: Conduct research on the water quality impacts of crab pot zincs, bait discard, and alternative crab baits in the pot fishery.
Action 9: Conduct education efforts on problems associated with the use of chlorine pot antifoulants (HTH®) and the surface water discharge of these solutions, which is prohibited by federal and state laws.
Action 10: Conduct additional research to document and quantify the influences of significant weather events on water quality and assess impacts on the blue crab resource and fishery.
Action 11: Conduct research on the interaction between water quality and habitat.

10.2 STOCK PROTECTION

10.2.1 Spawning Stock Management

10.2.1.1 Issue/ Purpose

Protect the reproductive potential of blue crabs.

With increasing concerns over fluctuating blue crab landings and increasing fishing effort, there have been numerous requests to further protect the spawning stock of blue crabs in North Carolina. Blue crab recruits in any given year rely, in part, on the size of the spawning stock from which the young originated. The spawning stock includes all female crabs that survive natural and fishing mortality to reproduce. Environmental conditions (winter mortality, drought, hypoxia, hurricanes, and human development effects), diseases, predation and cannibalism are natural mortality issues of concern. Fishery independent data suggests that the size of mature females in North Carolina has been decreasing in recent years. Possible causes for the declining size of mature females are: compensatory responses (maturing at smaller sizes due to low population abundance), phenotypic plasticity (changes caused by environmental or biotic conditions), and growth overfishing (removing larger individuals from the fishery). A spawning stock-recruitment relationship for the blue crab in North Carolina has been identified. The nature of the relationship dictates a risk adverse approach to the management of the spawning stock.

10.2.1.2 Management Options

1. No action.
2. Establish spawning sanctuaries around inlets in the southern coastal area.
3. Expand existing spawning sanctuaries (boundaries and/or time).
4. Reduce existing spawning sanctuaries (boundaries and/or time).
5. Establish a tolerance limit for certain sponge stages (e.g., brown or black sponge).
6. Reduce harvest of sponge crabs.
7. Repeal existing spawning sanctuary rules.
8. Prohibit harvest of all mature females.
9. Prohibit harvest of all sponge crabs.
10. Reduce harvest of mature females.

11. Establish a seasonal maximum size limit for mature females.

Option two through eleven would require rule changes by the MFC. See Appendix 4 for an in-depth discussion of the issue and management options.

10.2.1.3 Recommended Management Strategy

A seasonal (September - April) maximum size limit of 6.75 inches (with a 5 percent tolerance) for mature females is recommended, if the adjusted catch-per-unit-effort (CPUE - spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years (see Appendix 4 for additional information). These actions are recommended in combination with a similar proposal for the peeler segment of the fishery (see Section 10.2.2.3 and Appendix 5). This management measure could yield an increase in egg/larval production, and allow large females the opportunity to produce multiple broods over their lifetime. Sanctuaries afford the greatest protection to spawners, contribute to optimum yield of this resource, and have minimal impact on the majority of fishermen. Current sanctuary boundaries need to be modified to protect spawners. In establishing new sanctuary boundaries ease of identification and enforcement must be considered. This strategy would address objectives 1, 4, 6, and 8 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.2.1.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.2.1.4 Actions

Action 1: Establish a seasonal maximum size limit of 6.75 inches (with a 5 percent tolerance) for mature females from September 1 through April 30, if the adjusted CPUE (spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years

Action 2: Conduct surveys of existing sanctuary areas to determine population levels and to determine if these areas function as spawning grounds.

Action 3: Modify current sanctuary boundaries.

Action 4: Conduct tagging studies to determine exploitation rates of different life history stages, movement on and off the spawning grounds, and other life history parameters of female blue crabs.

10.2.2 Peeler/Soft Crab Harvest

10.2.2.1 Issue/ Purpose Impacts of peeler/soft blue crab harvest.

Increased effort and harvest in the peeler/soft blue crab fishery and reduced adult harvest has prompted concern about the impacts of peeler/soft crab harvest on the overall health of the fishery.

10.2.2.2 Management Options

1. No rule change.
2. Establish a minimum size limit for peelers and/or soft crabs.
3. Establish a seasonal minimum size limit for peelers and/or soft crabs.

4. Establish a seasonal maximum size limit for peelers and/or soft crabs.
5. Education efforts on the mortality associated with the shedding of peeler crabs.
6. Education efforts on peeler harvest, handling, and shedding practices.

Options two, three, and four would require rule changes by the MFC. See Appendix 5 for an in-depth discussion of the issue and management options.

10.2.2.3 Recommended Management Strategy

Considerable concern has been expressed about the need to provide additional protection to the spawning stock. A seasonal (September - April) maximum size limit of 5.25 inches with a 3 percent tolerance for female peeler crabs is recommended, if the adjusted catch-per-unit-effort (CPUE- spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years (see Appendix 5 for additional information). These actions are recommended in combination with a similar proposal for the mature female spawning stock segment of the fishery (see Section 10.2.1.3 and Appendix 4). This strategy should provide some conservation of potential spawners, while having a minimal impact on the shedder industry. Promoting educational efforts targeting harvesters/shedders on the mortality associated with the shedding of peeler crabs and peeler handling practices would help to further reduce mortality. This strategy would address objectives 1, 4, 6, 8, and 9 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.2.2.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.2.2.4 Actions

Action 1: Establish a seasonal maximum size limit of 5.25 inches (with a 3 percent tolerance) for female peeler crabs from September 1 through April 30, if the adjusted CPUE (spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years

Action 2: Determine shedding mortality rates by size, area, and season.

Action 3: Develop more effective harvest, handling, and shedding practices to minimize mortality.

Action 4: Promote educational efforts and information transfer for various issues impacting the shedder industry (i.e., peeler mortality, harvest, handling, and shedding practices.

Action 5: Evaluate the economic impact of implementing a minimum size limit.

Action 6: Determine peeler harvest rates by size, sex, area, and season.

10.3 WASTEFUL OR DAMAGING FISHING PRACTICES

10.3.1 White-Line Peeler Harvest

10.3.1.1 Issue/ Purpose

Reduce mortality of white-line peeler crabs.

White-line peelers held in shedding operations may experience relatively high mortality (over 50%) because of the length of time held until they molt. Some peeler and hard crab pot fishermen retain small hard crabs or “green hard crabs” calling them white-line peelers and, thereby use the peeler crab exemption to circumvent the minimum size limit and culling tolerance for hard crabs.

10.3.1.2 Management Options

1. No rule change.
2. Prohibit the possession of white-line peelers (remove white line from peeler crab definition).
3. Establish a season for the possession of white-line peelers.
4. Prohibit the sale of white-line peelers, but allow possession by the licensee/harvester for use in the licensee's permitted shedding operation. White-line peeler crabs must be separated from pink and red-line peeler crabs where taken and placed in a separate container.
5. Repeal the rule prohibiting the baiting of peeler pots, except with live male blue crabs.
6. Education efforts on the mortality associated with the shedding of white-line peeler crabs.
7. Education efforts on the handling of peelers.

Options two through five would require rule changes by the MFC. See Appendix 6 for an in-depth discussion of the issue and management options.

10.3.1.3 Recommended Management Strategy

Prohibiting or reducing the harvest of white-line peelers would minimize the harvest of “green” and white-line peelers in the peeler pot fishery, contribute to optimum yield of the resource, and have minimal impact on the majority of North Carolina's crab shedding operations. Research results and crabbers, who harvest and shed their own crabs, indicate that white-line peelers when handled properly can be shed successfully with minimal mortality. Therefore, the preferred option (option 4) is to prohibit the sale of white-line peelers, but allow possession by the licensee/harvester for use in the licensee's permitted shedding operation. White-line peeler crabs must be separated from pink and red-line peeler crabs where taken and placed in a separate container, with a of 5% tolerance allowed for white-line peelers in the pink/red-line peeler catch. Promoting educational efforts, targeting harvesters/shedders, on the mortality associated with the shedding of white-line peeler crabs and peeler handling practices would help to further reduce mortality. This strategy would address objectives 1, 2, 4, 6, 8, and 9 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.3.1.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.3.1.4 Actions

Action 1: Prohibit the sale of white-line peelers, but allow possession by the licensee/harvester for use in the licensee's permitted shedding operation. White-line peeler crabs must be separated from pink and red-line peeler crabs where taken and placed in a separate container, with a of 5% tolerance allowed for white-line peelers in the pink/red-line peeler catch.

Action 2: Increase education efforts, targeting harvesters/shedders, on the mortality associated with the shedding of white-line peeler crabs.

Action 3: Increase education efforts on the handling of peelers.

10.3.2 Ghost Pots

10.3.2.1 Issue/ Purpose

Reduce the bycatch and mortality of blue crabs and finfish in ghost (lost) pots.

Concern stems from the significant increase in the numbers of crab pots, the long life of vinyl coated pots, the pot's ability to continue to trap blue crabs and finfish, and mortality associated with prolonged entrapment.

10.3.2.2 Management Options

A. Options to minimize pot loss:

1. No action.
2. Harvest seasons by gear type (pot and trawl).
3. Area restrictions by gear type (pot and trawl).
4. Require reflective tape or paint on crab pot buoys.
5. Require the use of full size (5 inch X 11 inch vs. 5 inch x 5 inch) buoys on crab pots.
6. Shorten the attendance period for crab pots.
7. Extend pot clean-up period.
8. Allow other users to retrieve abandoned gear.
9. Require pots to be removed from the water prior to major storm events.
10. Structural modifications to pots.
11. Prohibit pots in certain areas.
12. Dockside disposal for old pots.

Options two through 10 would require rule changes by the MFC.

B. Options to minimize ghost pot fishing mortality:

1. No action.
2. Require biodegradable panels or devices on crab pots.

Option two would require a rule change by the MFC. See Appendices 7 and 8 for an in-depth discussion of the issue and management options.

10.3.2.3 Recommended Management Strategy

In the summer of 2002, this issue was clarified by Marine Patrol due to discussions generated by public concern. This clarification separates gear into two groups; abandoned and ghost. Abandoned pots are those that carry an owner's identification (marked buoy or tag), as the law requires, but their owners haven't checked them in seven days. Only the Marine Patrol or owner of the pots can remove abandoned pots. Ghost pots are those with no buoy or identifying tag attached to the pot. Any person can collect and possess ghost pots at any time. Marine Patrol should continue to document the number of abandoned pots collected during the pot clean-up period. DMF should educate fisherman and the general public about efforts to remove abandoned gear and encourage them to notify Marine Patrol of locations of said gear.

Other recommended strategies are: extend the pot cleanup period by nine days (January 15 through February 7), allow other users to retrieve ghost pots (see above), investigate the potential for dockside disposal of old pots, and shorten the attendance period from 7 to 5 days. Biodegradable panels will be considered for all hard and peeler crab pots, once necessary research is completed. This strategy would address objectives 1, 2, 5, 6, 7, 8, and 9 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.3.2.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.3.2.4 Actions

Action 1: Extend the pot cleanup period by nine days.
Action 2: Shorten the attendance period from 7 to 5 days.
Action 3: Investigate ways to provide for dockside disposal of old crab pots.
Action 4: Require biodegradable panels in crab pots, if warranted, once current studies are completed.
Action 5: Marine Patrol should continue to document the number of abandoned pots collected during the pot clean-up period.
Action 6: DMF should educate fisherman and the general public about efforts to remove abandoned gear and encourage them to notify Marine Patrol of locations of said gear.

10.3.3 Crab Pot Finfish Bycatch

10.3.3.1 Issue/ Purpose

Finfish bycatch in crab pots.

Document the species composition, fate, and quantity of finfish bycatch in hard and peeler pots.

10.3.3.2 Management Options

1. No action.
2. Require finfish escapement/release panels in hard and peeler crab pots.

Option two would require a rule change by the MFC. See Appendix 9 for an in-depth discussion of the issue and management options.

10.3.3.3 Recommended Management Strategy

Trip Ticket data indicates that landed marketable finfish bycatch in the crab pot fishery (hard and peeler pots) accounts for less than 1% of the total landings for each species, except catfish which comprises 3.6% of the total landings since 1996. Bycatch data from actively fished hard and peeler pots in the Neuse River indicates that, while flounder and other finfish species are captured in these gears, overall catch rates are low (4 organisms per trip and .007 per pot) and survival rates are high (70% hard crab pots; 99% peeler pots). These data suggest that no regulatory action is required to deal with the issue of finfish bycatch in actively fished pots, unless a specific species stock assessment indicates otherwise. This strategy would address objectives 6, 7, 8, and 9 of this plan.

10.3.3.4 Actions

No action is required for this issue.

10.3.4 Crab Trawl Bycatch

10.3.4.1 Issue/ Purpose

Bycatch in the crab trawl fishery.

Minimize sublegal blue crab and finfish bycatch in the crab trawl fishery. The crab trawl fishery has received a large amount of attention due to concerns over the bycatch and potential mortality of finfish and sublegal crabs.

10.3.4.2 Management Options

1. No rule change.
2. Increase tailbag mesh size (4 inch or 4.5 inch stretched mesh).
3. Increase crab trawl stretched mesh size to 4 inches throughout the net in the Pamlico-Pungo, Bay, and Neuse rivers.
4. Harvest seasons.
5. Area restrictions.
6. Ban crab trawling.

Options two through four, and six would require rule changes by the MFC. See Appendix 10 for an in-depth discussion of the issue and management options.

10.3.4.3 Recommended Management Strategy

To minimize waste in this fishery, a 4 inch stretched mesh tailbag should be required in the western portion of Pamlico Sound, including Pamlico, Pungo, Bay, and Neuse rivers (option 3). Additional data on harvest, bycatch, and economics should be collected from all trawl fisheries. Unless a specific species stock assessment indicates otherwise, this recommendation should address bycatch concerns. This strategy would address objectives 1, 2, 4, 6, and 8 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.3.4.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.3.4.4 Actions

Action 1: Require a 4 inch stretched mesh tailbag for crab trawls in western Pamlico Sound, including Pamlico, Pungo, Bay, and Neuse rivers.
Action 2: Collect fishery-dependent data from the peeler crab and shrimp trawl fisheries.
Action 3: Investigate the economic and social impacts of the crab trawl fishery.
Action 4: Separate hard and peeler crab trawl landings on trip tickets.

10.3.5 Protected Species Interactions with the Crab Fishery

10.3.5.1 Issue/ Purpose

Crab gear interactions with endangered, threatened, and species of special concern.

Crab pots and trawls utilized to harvest blue crabs in North Carolina have various levels of interactions with endangered and threatened species, and species of special concern. These species include bottlenose dolphins, sea turtles (Kemp's ridley, hawksbill, loggerhead, leatherback, and green), and diamondback terrapins.

10.3.5.2 Management Options

Bottlenose Dolphins:
1. No regulatory action.
2. Require the scope of crab pot lines be restricted to the minimum length necessary in order to reduce the overall length of line in the water column.

Option two would require rule changes by the MFC.

Sea Turtles:
1. No regulatory action.
2. Require Turtle Excluder Devices (TED's) in crab trawls.

Option two would require rule changes by the MFC.

Diamondback terrapins:
1. No regulatory action.
2. Require terrapin excluders and/or modifications to crab pots (hard and/or peeler) fished within a specified distance of shore during the spring, within specified areas.

Option two would require rule changes by the MFC. See Appendix 11 for an in-depth discussion of the issue and management options.

10.3.5.3 Recommended Management Strategy

With regard to bottlenose dolphin, fishermen should be educated on the potential problems of having too much free line in the water column. For sea turtle interactions with crab pots, research should be conducted on ways to minimize sea turtle damage to crab pots and the results made available to the industry (see education section for recommendations to disseminate information to members of the industry). Until more information is available on the extent of sea turtle bycatch in the crab trawl fishery, it is recommended that no state action be taken on this issue. The research outlined in section 10.3.5.4 (Actions 4, 5, 6, and 7) needs to be conducted prior to the passage of any new regulations to minimize diamondback terrapin bycatch. Additionally, the goals and objectives for the conservation of diamondback terrapins in North Carolina must be clearly defined. Current information on ways to eliminate diamondback terrapin bycatch in crab pots and current distribution in North Carolina needs to be made available to crab potters. This strategy would address objectives 4, 5, 7, and 9 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.3.5.4 need to be implemented.

10.3.5.4 Actions

Action 1: Test the effectiveness of inverted bait wells to alleviate the bait stealing behavior of bottlenose dolphin.
Action 2: Develop sea turtle proof crab pots.
Action 3: Determine the extent of sea turtle bycatch in crab trawls.
Action 4: Compile data on diamondback terrapin distribution.
Action 5: Problem assessment of crab pot diamondback terrapin bycatch and mortality by season, area, and gear (hard and peeler pots).
Action 6: Determine the effect that terrapin excluders have on peeler and terrapin catches in peeler pots.
Action 7: Test the effectiveness of cable ties for excluding terrapins from crab pots.
Action 8: Compile and distribute information on current distribution of diamondback terrapins and methods to eliminate diamondback terrapin bycatch in crab pots.

10.3.6 Channel Net Harvest of Blue Crabs

10.3.6.1 Issue/ Purpose Unlimited blue crab harvest from channel nets, especially of female "sponge" crabs.

Landings of hard crabs from channel nets in New River during 2001 dramatically increased to over 85,000 pounds from less than 1000 pounds/year (average 1995-1998). Increased harvest, especially of female "sponge" crabs, prompted concern among New River area crabbers for this perceived wasteful harvest of the spawning stock.

10.3.6.2 Management Options

1. No rule change.
2. Prohibit or limit the daily harvest of blue crabs from channel net operations, except as an incidental bycatch (proportion) of the shrimp harvest.
3. Make it unlawful to possess any "sponge" blue crab.

Options two and three would require rule changes by the MFC. See Appendix 12 for an in-depth discussion of the issue and management options.

10.3.6.3 Recommended Management Strategy

Allow blue crab harvest from channel nets as a limited incidental bycatch. This channel net proposal will be identical to the crab bycatch provisions for the shrimp trawl fishery (rule 15A NCAC 3J .0104), which provides that the weight of the crabs shall not exceed:

(A) 50 percent of the total weight of the combined crab and shrimp catch; or
(B) 300 pounds, whichever is greater.

This strategy would address objectives 2, 4, and 6 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.3.6.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.3.6.4 Actions

Action 1: Modify the CHANNEL NET rule (15A NCAC 3J .0106) to incorporate limited blue crab bycatch provisions identical to those for shrimp trawls (rule 15A NCAC 3J .0104 (f) (2) TRAWL NETS).

Action 2: Collect crab harvest data from channel nets.

10.4 COMPETITION AND CONFLICT WITH OTHER USERS

10.4.1 Conflict

10.4.1.1 Issue/ Purpose

Social and economic conflicts relating to the blue crab pot and trawl fisheries.

The increase in hard crab and peeler pot numbers has resulted in more frequent and severe conflicts over fishing space between crab potters (full and part-time), other commercial fisheries (trawlers, long haul seiners, etc.) and recreational activities (swimming, fishing, boating). Conflicts may arise from damage to vessels encountering gear, and may result in fishing gear being moved, damaged, destroyed or stolen. Also, theft of potted crabs has increased in some areas, as effort for and price of the commodity has increased.

10.4.1.2 Management options

1. Management areas.
2. Harvest seasons.

3. Gear restrictions/ reductions.
4. Time restrictions.
5. Catch limits.
6. Area restrictions.

Options one through six would require rule changes by the MFC. See Appendix 13 for an in-depth discussion of the issue and management options.

10.4.1.3 Recommended Management Strategy

Conflict issues in the blue crab fishery should be dealt with through regional/area management. The existing “User Conflict” rule (15A NCAC 3J .0301 (j) POTS) only allows the closure of an area to pots by proclamation authority of the Fisheries Director with the MFC’s approval. In an effort to further enhance the DMF’s, and MFC’s, ability to deal effectively with user conflicts, the current rule should be modified to allow various means and methods options to address area specific conflicts. Additionally, internal guidelines should be developed to resolve user conflict issues.

In an effort to address conflict issues and increasing effort associated with the crab pot fishery, a specific regional management proposal was developed and is presented in Appendix 14 (Regional Crab Pot Management). This proposal incorporates various open access management strategies into one comprehensive system of management that is specific to the crab pot fishery. These strategies are: (1) management areas, (2) gear restrictions (pot limits), (3) area restrictions, and (4) a permit system to participate in the fishery. Modifying the “User Conflict” rule to allow the use of any or a combination of the various options outlined in Section 10.4.1.2 and Appendix 13, and Appendix 14 (Regional Crab Pot Management) will broaden the suite of alternatives that may be utilized to deal with user conflicts.

To minimize conflicts, theft, and gear damage, and increase public trust utilization, the MFC needs to change the unattended pot rule from the existing 7 day period to 5 days, and support the establishment of boating safety courses. If this management strategy is adopted by the MFC, the actions in section 10.4.1.4 need to be implemented. This strategy would address objectives 5, 6, and 9 of this plan. Refer to Appendix 19 for proposed rule language.

10.4.1.4 Actions

Action 1: Shorten the unattended pot rule from 7 to 5 days.
Action 2: Modify the existing “User Conflict” rule to resolve user conflicts on a regional basis.
Action 3: Develop guidelines for the DMF, MFC, and regional advisory committees to assist in the resolution of user conflict issues.

10.4.2 Utilization of Non-Pot Areas by Proclamation

10.4.2.1 Issue/ Purpose

Open designated long haul areas to the use of crab pots by proclamation.

The NCDMF has received an increasing number of complaints from crab fishermen about lack of utilization of some of the non-pot (long haul) areas. Some crab potters feel reinstituting proclamation authority to designate some areas (particular ‘long haul’ sites in Hyde, Beaufort and Pamlico counties) would allow them to use this space when it is not needed by other fisheries (long haul, gill net and trawlers). Areas designated to address conflict between recreational users and crab potters will remain closed. This issue is a carry over from the 1998 Blue Crab FMP.

10.4.2.2 Management Options

1. No action
2. Open all designated long haul areas in Hyde, Beaufort, and Pamlico counties by proclamation during specified time periods.

Option two would require rule change by the MFC. See Appendix 15 for an in-depth discussion of the issue and management options.

10.4.2.3 Recommended Management Strategy

On March 14, 2001, the Central Regional Advisory Committee passed a motion that all designated long haul areas be managed by proclamation with preference for use given to long haulers. After numerous meetings and several motions on this issue the Crustacean Committee recommended leaving the long haul areas as they currently are (April 12, 2001). In June 2001, the Marine Fisheries Commission (MFC) voted to ask the DMF to draft language to amend the rules giving the DMF Director proclamation authority to open all long haul areas to crab potting. The strategy proposed in the draft rule would allow crab pots in all designated long haul areas in Hyde, Beaufort, and Pamlico counties during specified time periods. This strategy would address objectives 4, 5, and 6 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.4.2.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.4.2.4 Actions

Action 1: Take proposed rule change to public hearings.

10.4.3 Time Change for Placing Crab Pots in Designated Pot Areas

10.4.3.1 Issue/ Purpose

Modify dates when crab pots must be moved to designated pot areas.

Crab potters have requested the DMF/MFC to consider changing, through proclamation authority, the area restriction date from May-October to June-September in order to account for annual variations in crab distribution by water depth. Water temperature influences the depth at which crabs may be potted. The inside of the six foot depth contour line or specified distance from shore is used to designate pot areas during the current May-October time frame. If water temperatures remain cool past the May deadline, potters are required to move their pots into shallower areas which may be less productive for crabs. The May-October time frame was originally set to coincide with increased boating, and trawling in the vicinity. This issue is a carry over from the 1998 Blue Crab FMP.

10.4.3.2 Management Options

1. No action
2. Change time when pots must be moved to designated pot area from May 1 – October 31 to June 1 – September 30.
3. Change time when pots must be moved to designated pot area from May 1 – October 31 to June 1 – November 30.

Options two and three would require a rule change by the MFC. See Appendix 16 for an in-depth discussion of the issue and management options.

10.4.3.3 Recommended Management Strategy

The Crustacean Committee debated this issue during several meetings in 2000 and early 2001. On April 12, 2001, the committee passed a motion to change the dates for crab pot designated areas from May 1-October 31, to June 1-November 30. A similar motion was passed by the Central Advisory Committee on March 14, 2001. At it's June 2001 meeting, the MFC passed a motion asking the DMF to draft language to amend the rules for crab pot designated areas to June 1-November 30. This strategy would address objectives 4, 5, and 6 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.4.3.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.4.3.4 Actions

Action 1: Take proposed rule change to public hearings.

10.4.4 Designated Pot Areas

10.4.4.1 Issue/ Purpose

Compliance and ease of enforcement for the designated pot areas.

Fishermen have complained about the various depth and distance from shore regulations, for different designated pot areas (rule 15A NCAC 3R .0107), and have asked for a standard depth contour for all areas. Marine Patrol requested a change to depth contours for the designated pot areas, because depth would be easier to measure and enforce as compared to distance from shore.

10.4.4.2 Management Options

1. No action
2. Change designated pot area descriptions from distance from shore to a 6 foot depth contour.

Option two would require a rule change by the MFC. See Appendix 17 for an in-depth discussion of the issue and management options.

10.4.4.3 Recommended Management Strategy

The NCDMF and Crustacean Committee voted in November 2001 to take to public hearing changing designated pot areas to depth instead of distance from shore. The proposed strategy would change the designated pot area boundary descriptions to a standardized 6 foot depth contour in Hyde, Beaufort, Pamlico, and Craven counties. The MFC recommends that trawls be prohibited from these areas. This strategy would address objectives 4, 5, and 6 of this plan. If this management strategy is adopted by the MFC, the actions in Section 10.4.4.4 need to be implemented. Refer to Appendix 19 for proposed rule language.

10.4.4.4 Actions

Action 1: Take proposed rule changes to public hearings.

10.5 INSUFFICIENT ASSESSMENT DATA

10.5.1 Issue/ Purpose Data needed to accurately assess the blue crab stock and fishery.

Before 1995, DMF did not have a stock assessment program specifically for blue crabs, although limited information was collected through other programs. Realizing the increasing importance of the blue crab fishery to the coastal economy, crabbers petitioned the North Carolina General Assembly in 1994 to allocate funding specifically for a crab assessment project. The resulting program is focusing on the establishment of fishery-dependent and -independent databases coastwide.

10.5.2 Research needs

The following list of research needs was identified (DeLancey et al. 2003) at a recent meeting (November 2003) of blue crab managers from the Atlantic coast (NY to Fla.).

Maximum Age

Continue ongoing research to determine the maximum age of blue crabs, including:
1. encourage cooperation for expansion of lipofuscin research,
2. continue tagging methods with incorporation of verification,
3. evaluate use of historical methods using parasitic worms, and
4. conduct long-term holding experiments.

Variation in Natural Mortality (M)

Evaluate age-specific mortality rates and determination of more accurate estimates of natural mortality (M) possibly through the use of closed areas.

1. Evaluate geographic variation in M, and
2. Evaluate annual variations in M

Reproductive Biology

Conduct research to better understand the reproductive biology of blue crabs in more detail, including:

1. evaluate geographic variation in reproductive biology,
2. conduct field experiments to verify lab studies,
3. determine maturity at age, and
4. evaluate sperm limitation, fecundity schedule.

Predation and Cannibalism

There was agreement that predation occurs, but little scientific evidence that a single species is having a major impact on blue crab populations. However, the cumulative impacts of guilds of predators are unknown.

1. Encourage foodweb dynamics studies and continue current research activities involving modeling and diet studies.

Recruitment/Habitat Utilization

Identify specific habitats for each system within each state.

Dispersal

Evaluate the stock structure on the Atlantic and Gulf coasts, including:

1. evaluate the percentage of recruits from one bay system supporting other systems,
2. evaluate the magnitude of mixing between populations, especially at low abundance levels (metapopulations),
3. evaluate transport systems between estuaries,
4. conduct larval dispersal and recruitment studies, particularly in southern region, and
5. research where females go after spawning

Disease

1. More research is needed to evaluate the impacts that diseases are having on crab stocks.

Environmental Factors

Drought, Winter Mortality, and Hypoxia

The consequences of these factors affect the whole ecosystem, with some affects being positive and some being negative.

1. Evaluate the effects of environmental effects on the distribution of blue crabs and potential for increased mortality on a state-by-state basis since these effects will be unique to each system.

Hurricanes

Hurricanes have affected all east coast states at one time or another through direct and indirect effects. Effects depend on timing, where you are in relation to hurricane, tidal stage, etc.

1. Each state should quantify the direct and indirect impacts of hurricanes, and use this list as a tool for adaptive management.

Human Development Effects

1. Each state should evaluate the impacts of other indirect processes on blue crab populations, such as shoreline development, point and non-point source pollution, nutrient loading, and water control and utilization.

Recreational Landings

1. Each state should conduct a recreational survey at least once, with periodic updates if the percentage of total landings is high. Evaluate the addition of an add-on question to the MRFSS telephone survey to collect participation data.

Non-directed fisheries

1. Evaluate non-directed fisheries for bycatch of blue crabs (gill net and shrimp trawl fisheries).

Aquaculture

1. Continue small scale aquaculture activities, including continuation of ongoing research studies, improvements to collaborative efforts, and evaluation of feasibility as a large scale enhancement tool for blue crab management.

Monitoring Programs

1. Compile information on trawl efficiency for blue crab sampling.
2. States should continue to fund trawl and seine monitoring programs to support blue crab assessments.

10.5.3 Data needs

1. Collect necessary fishery independent and dependent data.

10.5.4 Recommended Management Strategy

The MFC and DMF should prioritize research needs and implement actions to accomplish the identified research and data needs. This strategy would address objectives 1, 2, 3, 7, and 8 of this plan.

10.5.5 Actions

Action 1: Prioritize research needs and implement actions to secure funding and accomplish research. Biological research needs are outlined in Section 10.5.2. Management and social and economic research needs are outlined in Sections 10.7.4, and 10.7.6.

10.6 PUBLIC EDUCATION

10.6.1 Issue/ Purpose

Promote public education and information transfer for blue crab resource issues.

10.6.2 Recommended Management Strategy

The MFC and DMF should collaborate with other agencies and groups to implement a program focused on enhancing public information and education for the blue crab resource. This program should heighten the public's awareness of the causes and nature of problems for the blue crab stock, its habitats and fisheries, and the rationale for management efforts to address these problems. A better understanding by resource users, of the blue crab's complex life history and strategies implemented by the state to regulate harvest and protect juveniles and spawning stock, is a key element in ensuring that this fishery is sustainable. This strategy would address objectives 2, 3, 5, 6, 7, 8, and 9 of this plan.

10.6.3 Actions

Action 1: Incorporate links from the DMF Web site to other blue crab websites maintained by other groups (i.e., Chesapeake Bay Foundation, Maryland Sea Grant, www.blue-crab.org).
Action 2: Work with agencies and groups such as NC Sea Grant, NC Wildlife Resources Commission, colleges and universities, to publish articles and place information on their website.
Action 3: Provide fact sheets about certain issues to fishermen when buying licenses (white bellies, protected species, escape rings, ghost pots, trip ticket data, shedding system mortality, and peeler handling).
Action 4: Develop an educational display spotlighting varying crabbing issues.
Action 5: Continue to send out news releases about various issues as needed.

See Appendix 18 for an in-depth discussion of the issue and management options.

10.7 SUMMARY OF MANAGEMENT ACTIONS

10.7.1 Rules (new, modifications, or technical changes)

See Appendix 19.

10.7.2 Legislative Action

No legislative action is required.

10.7.3 Processes

Sections of State government that will need to be involved in addressing these processes are noted in the parenthesis following each item. Abbreviations for the units of State government are: GA = NC General Assembly; DENR = Department of Environment and Natural Resources; MFC = Marine Fisheries Commission; and DMF = Division of Marine Fisheries.

1. The identification, maintenance, and enhancement of habitats critical to the life cycle of the blue crab should be a priority of efforts by the DENR and the MFC and its committees, in developing CHPPs as outlined in the Fisheries Reform Act of 1997 (GA, DENR, MFC, DMF).
2. Management Actions as outlined in the Vital Habitats Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should receive priority for funding and be completed in a timely manner (see Appendix 3) (GA, DENR, MFC, DMF).
3. Management Actions as outlined in the Vital Habitats Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should be expanded to all river basins that drain to North Carolina's coastal region (see Appendix 3) (GA, DENR, MFC, DMF).
4. Advocate stronger regulatory programs and enforcement of regulations protecting blue crab critical habitat [marshes, SAVs, shell bottom, and soft bottom (riverine, subtidal and intertidal bottom)] (GA, DENR, MFC, DMF).
5. Continue to make recommendations on all state, federal, and local permits to insure minimal impacts to critical habitat areas (MFC, DMF).
6. Develop and maintain accurate maps and records of critical habitat areas for blue crabs (marshes, SAVs, shell bottom, and soft bottom (riverine, subtidal and intertidal bottom) (DMF).

7. Enhance existing efforts to restore the functions and values of degraded blue crab habitat (marshes, SAVs, shell bottom, and soft bottom (riverine, subtidal and intertidal bottom) (GA, DENR, MFC, DMF).
8. Identify and map shallow detrital areas important to blue crabs (DMF).
9. Identify and designate additional areas as Primary Nursery Areas that may be important to blue crabs as well as other fisheries (DMF).
10. Develop criteria to designate critical SAV habitat areas (MFC, DMF).
11. Designate Critical SAV areas based on developed criteria (MFC, DMF).
12. Request that EMC and CRC prohibit dredging or channelization in designated SAV areas (DENR, MFC, DMF).
13. Complete mapping of SAVs throughout the state (DMF).
14. Support follow-up mapping of previously mapped SAVs (DMF).
15. Solicit and acquire resources to update and complete shellfish bottom mapping of oyster reefs (GA, DENR, MFC, DMF).
16. Solicit and acquire resources to supplement resource enhancement for cultch plantings (MFC, DMF).
17. Develop a protocol for identification and designation of oyster rock/shell bottom as critical fisheries habitat where fishing activities would be restricted (MFC, DMF).
18. Utilize the existing authority of the MFC for adoption of blue crab spawning areas as critical habitat (MFC).
19. Develop criteria to be used to delineate crab spawning sanctuaries as critical habitat (MFC, DMF).
20. Continue to support mapping of spawning sanctuaries through the Fisheries Resource Grant and Blue Crab Research Program (DMF).
21. Support research and mapping of other inlet areas that may be significant to spawning (DMF).
22. The identification, maintenance, and enhancement of water quality critical to the life cycle of the blue crab should be a priority of the NCDENR and the MFC and its committees, in developing Coastal Habitat Protection Plans as outlined in the Fisheries Reform Act of 1997 (GA, DENR, MFC, DMF).
23. Management Actions as outlined in the Water Quality Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should receive priority for funding and be completed in a timely manner (see Appendix 3) (GA, DENR, MFC, DMF).
24. Management Actions as outlined in the Water Quality Plan of the Albemarle - Pamlico Estuarine Study Comprehensive Conservation and Management Plan (EPA and DEHNR 1994) should be expanded to all river basins that drain to North Carolina's coastal region (see Appendix 3) (GA, DENR, MFC, DMF).
25. Work with the permitting and commenting agencies to enhance protection of water quality. The MFC should fully utilize it's permit commenting authority outlined in G.S. 143B-289.52 (MFC, DMF).
26. The MFC should strive for accomplishment of the management strategies as outlined in the coastal basinwide water quality management plans and water quality recommendations of the Fisheries Moratorium Steering Committee (MFC).
27. Request that the North Carolina EMC review "Nutrient Sensitive Waters", "High Quality Waters", and "Outstanding Resource Waters" designations for the coastal river basins and implement additional strategies as needed (MFC, DMF).
28. Conduct education efforts on problems associated with the use of chlorine pot antifoulants (HTH®) and the surface water discharge of these solutions, which is prohibited by federal and state laws (DENR, DMF).
29. Modify current sanctuary boundaries (MFC, DMF).
30. Develop more effective harvest, handling, and shedding practices to minimize mortality (DMF).

31. Promote educational efforts and information transfer for various issues impacting the shedder industry (i.e., peeler mortality, harvest, handling, and shedding practices (DMF).
32. Increase education efforts, targeting harvesters/shedders, on the mortality associated with the shedding of white-line peeler crabs (DMF).
33. Increase education efforts on the handling of peelers (DMF).
34. Investigate ways to provide for dockside disposal of old crab pots (MFC, DMF).
35. Marine Patrol should continue to document the number of abandoned pots collected during the pot clean-up period (DMF).
36. DMF should educate fisherman and the general public about efforts to remove abandoned gear and encourage them to notify Marine Patrol of locations of said gear (DMF).
37. Separate hard and peeler crab trawl landings on trip tickets (DMF).
38. Compile and distribute information on current distribution of diamondback terrapins and methods to eliminate diamondback terrapin bycatch in crab pots (DMF).
39. Develop guidelines for the DMF, MFC, and regional advisory committees to assist in the resolution of user conflict issues (MFC, DMF).
40. Incorporate links from the DMF Web site to other blue crab websites maintained by other groups (i.e. Chesapeake Bay Foundation, Maryland Sea Grant, www.blue-crab.org) (DMF).
41. Work with agencies and groups such as NC Sea Grant, NC Wildlife Resources Commission, colleges and universities, to publish articles and place information on their website (DMF).
42. Provide fact sheets about certain issues to fishermen when buying licenses (white bellies, protected species, escape rings, ghost pots, trip ticket data, shedding system mortality) (DMF).
43. Develop an educational display spotlighting varying crabbing issues (DMF).
44. Continue to send out news releases about various issues as needed (DMF).
45. Prioritize research needs and implement actions to secure funding and accomplish research (MFC, DMF).

10.7.4 Management Related Research (not ranked in order of priority)

1. Research shallow detrital areas important to blue crabs.
2. Research additional areas as Primary Nursery Areas that may be important to blue crabs as well as other fisheries.
3. Complete mapping of SAVs throughout the state.
4. Support follow-up mapping of previously mapped SAVs.
5. Conduct research and mapping of other inlet areas that may be significant to spawning.
6. Additional research is needed on the extent, causes, and impacts of hypoxia and anoxia on blue crab behavior and population abundance in North Carolina’s estuarine waters (DENR, MFC, DMF).
7. Conduct research on the water quality impacts of crab pot zincs, bait discard, and alternative crab baits in the pot fishery (DENR, DMF).
8. Conduct additional research to document and quantify the influences of significant weather events on water quality and assess impacts on the blue crab resource and fishery (DENR, DMF).
9. Conduct research on the interaction between water quality and habitat (DENR, DMF).
10. Conduct surveys of existing sanctuary areas to determine population levels and to determine if these areas function as spawning grounds.
11. Conduct tagging studies to determine exploitation rates of different life history stages, movement on and off the spawning grounds, and other life history parameters of female blue crabs.
12. Determine shedding mortality rates by peeler stage, size, area, and season.
13. Develop more effective harvest, handling, and shedding practices to minimize mortality.
14. Determine peeler harvest rates by peeler stage, size, sex, area, and season.

15. Test natural twine, and non-coated steel (24 gauge or less) across a wide range of salinities.
16. Determine the optimal escapement/release panel location for finfish and crab escapement from crab pots.
17. Determine minimum escapement/release panel size for blue crab and finfish escapement from crab pots.
18. Determine desired release time for blue crabs and finfish from ghost pots.
19. Require biodegradable panels in crab pots, if warranted, once current studies are completed.
20. Test effectiveness of large buoys, reflective tape (and/or paint), and larger or heavier irons to reduce pot loss.
21. Collect baseline data on the composition, quantity, and fate of unmarketable finfish bycatch in the crab pot (hard and peeler) fishery, by season and area.
22. Develop a bycatch reduction device for hard and peeler crab pots.
23. Collect fishery-dependent data from the peeler crab and shrimp trawl fisheries.
24. Test the effectiveness of inverted bait wells to alleviate the bait stealing behavior of bottlenose dolphin.
25. Develop sea turtle proof crab pots.
26. Determine the extent of sea turtle bycatch in crab trawls.
27. Compile data on diamondback terrapin distribution.
28. Problem assessment of crab pot diamondback terrapin bycatch and mortality by season, area, and gear (hard and peeler pots).
29. Determine the effect that terrapin excluders have on peeler and terrapin catches in peeler pots.
30. Test the effectiveness of cable ties for excluding terrapins from crab pots.
31. Collect crab harvest data from channel nets.

10.7.5 Biological Research Needs (not ranked in order of priority)

See Section 10.5.2 Research needs.

10.7.6 Social and Economic Research Needs (ranked in order of priority)

1. Determine the economic value of wholesale (seafood dealers), retail, and foodservice sectors.
2. Continue socioeconomic surveys of blue crab harvesters.
3. Continue Recreational Commercial Gear License (RCGL) survey.
4. Determine non-commercial landings of blue crabs by those other than RCGL holders.
5. Determine the economic effects of imported crabmeat, including the mixture of imported meat with local crabmeat, on processing and demand.
6. Determine the costs associated with crab processing. Identify the factors and their relative importance in predicting processor closures.
7. Determine the impact of value-added products to processors.
8. Seek data that will allow for historical cost analysis for doing business as a crab harvester.
9. Investigate the economic and social impacts of the crab trawl fishery.
10. Evaluate the economic impact of implementing a minimum size limit for peeler crabs.
11. Document the importance of white-line peelers to the economics of the fishery.

10.7.7 Data Needs

1. Collect necessary fishery independent and dependent data.

10.7.8 Education

1. Incorporate links from the DMF Web site to other blue crab websites maintained by other groups (i.e. Chesapeake Bay Foundation, Maryland Sea Grant, www.blue-crab.org).
2. Work with agencies and groups such as NC Sea Grant, NC Wildlife Resources Commission, colleges and universities, to publish articles and place information on their website.
3. Provide fact sheets about certain issues to fishermen when buying licenses (white bellies, protected species, escape rings, ghost pots, trip ticket data, shedding system mortality).
4. Develop an educational display spotlighting varying crabbing issues.
5. Continue to send out news releases about various issues as needed.

10.7.9 Rule Changes other agencies

None

10.7.10 Secure funding

Research needs as outlined in sections 10.7.4, 10.7.5, 10.7.6, and 10.7.8 should receive priority for funding (i.e., Blue Crab Research Program, Fishery Resource Grant Program) and be completed in a timely manner.

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12. APPENDICES

12.1 Appendix 1 SUMMARY OF ACTIONS TAKEN AS RECOMMENDED IN THE 1998 BLUE CRAB FISHERY MANAGEMENT PLAN

Section 5.5 of the Fishery Reform Act of 1997 specifically requires that the Marine Fisheries Commission "adopt a Fishery Management Plan (FMP) for the blue crab fishery" by January 1, 1999. The plan was adopted by the Marine Fisheries Commission on December 11, 1998.

Actions taken as a result of the recommendations outlined in the 1998 Blue Crab Fishery Management Plan (BCFMP - McKenna et al. 1998) are summarized below by section (see underlined text). Much of the funded research listed herein was conducted through the Fishery Resources Grant Program (FRG-year-project code-project number) or the Blue Crab Research Program (BCRP). Both grant programs are funded by the NC General Assembly and administered by the NC Sea Grant College Program.

10. PRINCIPAL ISSUES AND MANAGEMENT OPTIONS

10.1 ENVIRONMENTAL ISSUES

10.1.1 HABITAT (BCFMP 1998; page 29)

Recommended Management Strategy

The N.C. Marine Fisheries Commission (MFC), N.C. Coastal Resources Commission (CRC), and N.C. Environmental Management Commission (EMC) should adopt rules to protect blue crab critical habitats as outlined in the Coastal Habitat Protection Plans (CHPP), as those plans are prepared and approved. No Plans have been completed and approved.
The MFC and Division of Marine Fisheries (DMF) should continue to comment on activities that may impact aquatic habitats and work with permitting agencies to minimize impacts and promote restoration. Ongoing by DMF Staff and MFC Habitat/Water Quality Committee.
Research must be conducted to investigate the impacts of trawling on various habitats. See "Funded Research" below.

Funded Research:
"Study Utilization of Oyster Shell Planting Sites by Shrimp, Fishes, and Crabs."
FRG-96-FEG-104. Hunter Lenihan.

"The Biological and Economic Value of Restored Intertidal Oyster Reef Habitat to the Nursery Function of the Estuary." FRG-97-EP-06. Jonathan H. Grabowski.

"The Biological and Economic Value of Restored Intertidal Oyster Reef Habitat to the Nursery Function of the Estuary." FRG-98-EP-16. Jonathan Grabowski.

"Shrimp and Crab Trawling Impacts on Estuarine Soft-Bottom Organisms." FRG-98-EP-21. William Henry Daniels.

"A Comparison of Restored vs. Natural Oyster Reefs: Assessing Whether Restoring Oyster Reef Habitat Returns the Biological Functions and Economic Value Provided by Natural Reefs to the Estuary." FRG-00-EP-03. Jonathan Grabowski.

"Potential Impacts of Bottom Trawling on Water Column Productivity and Sediment Transport Processes." FRG-01-EP-04. Henry Daniels.

10.1.2 WATER QUALITY (BCFMP 1998; page 30)

Recommended Management Strategy

The MFC and DMF should continue to comment on activities that may impact estuarine water quality and work with permitting agencies to minimize impacts. <u>Ongoing</u>.

Water quality standards should be based on the assimilative capacity of, and impacts to, the entire system. <u>Standards are not based on assimilative capacity and impacts</u>.

Several plans for water quality management have recommended strategies that need to be implemented to improve water quality. <u>Many strategies have not been implemented</u>.

<u>Funded Research</u>:

“Effects of Anoxia on the Value of Bottom Habitat for Fisheries Production in the Neuse River Estuary.” FRG-98-EP-04. Elizabeth Thomson.

“Blue Crab Trophic Dynamics Project: Use of Stable Isotopes as Bio-Indicators of Anthropogenic Sources” BCRP-01-BIOL-06 and 02-BIOL-01. Steve Rebach and John Bucci.

“Impact of Salinity on Tolerance of Crustaceans to Nitrogenous Waste.” BCRP-03-BIOL-07. Dell Newman.

10.2 WASTEFUL or DAMAGING FISHING PRACTICES

10.2.1 SPAWNING STOCK MANAGEMENT (BCFMP 1998; page 31-32)

Recommended Management Strategy

Strengthening of spawning sanctuary rules should be accomplished by prohibiting all commercial gears, except attended gill nets (Action 4). <u>Existing rule was modified as follows</u>:

15A NCAC 3L .0205 CRAB SPAWNING SANCTUARIES (MFC 2003; page 60)

(a) It is unlawful to <u>set or</u> use ~~a trawl net~~ <u>trawls, pots, and mechanical methods for oysters or clams</u> or take crabs with the use of commercial fishing equipment from the crab spawning sanctuaries described in 15A NCAC 3R .0110 from March 1 through August 31.

Action 2: Survey sanctuary areas to determine functionality.

<u>Funded Research:</u>

NCDMF conducted a trawl survey of Oregon Inlet Sanctuary, 1999-2001 (trawl may not be an efficient sample gear in this habitat).

“Mapping of Geographic Features and their Attributes and Marking of Hazards In and Between the Ocracoke and Hatteras Inlet Blue Crab Sanctuaries.” FRG-98-FEG-31. Eugene Ballance.

“Reproductive Potential and Migratory Movements of Mature Female Blue Crabs.” BCRP-01-BIOL-05. Dan Rittschof, Earl Chadwick, Robert Cahoon, Lloyd Culpepper, Ray Golden, Anthony Sawyer, Dr. Richard Forward.

“Blue Crab Sampling in the Vicinity of the Hatteras and Ocracoke Spawning Sanctuaries Using Crab Pots.” BCRP-01-POP-04 and 02-POP-03. Eugene Ballance.

“Field Assessment of Spawning Sanctuaries and Possible Migration Corridors for the Blue Crab Spawning Stock in North Carolina." BCRP-01-POP-08. David Eggleston, Sean McKenna, Henry Daniels, Martin Posey, and Budd George.

"Tagging of Adult Female Blue Crabs to Study Migration Toward and Use of Spawning Sanctuaries." FRG-01-EP-06. Robin Doxey.

"Small Scale Movements and Protection of Brooding Female Blue Crabs Within a Spawning Sanctuary." BCRP 03-BIOL-02. Thomas Wolcott and Eugene Ballance.

10.2.2 GHOST POTS (BCFMP 1998; page 33)

Recommended Management Strategy

Sinking lines should be required on all crab (hard and peeler) pots. This restriction would not only reduce the number of new ghost pots each year but should significantly reduce conflicts. <u>Existing rule was modified to add new language as follows</u>**:**

15A NCAC 3J .0301 POTS (MFC 2003; pages 38-40)

(k) It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating.

Recommended Management Strategy

Biodegradable panels will be considered for all hard and peeler crab pots, once necessary research is completed. <u>Additional research was initiated in 2002 through the NCDMF Hurricane Crab Grant</u>. Conduct research on reflective tape for crab pot buoys. <u>No research to date</u>.

10.2.3 CRAB POT ESCAPE RING (BCFMP 1998; page 34)

Recommended Management Strategies

Data support the utility of escape rings as a viable management tool. The MFC should continue to require escape rings in hard crab pots. <u>No changes were recommended</u>.

Develop criteria for using proclamation authority to close or not require escape rings for mature females and peeler crab harvest. <u>Criteria have not been developed by NCDMF</u>.

10.2.4 CRAB TRAWL BYCATCH (BCFMP 1998; page 35)

Recommended Management Strategy

To minimize waste in this fishery, a 4 inch or 4.5 inch stretched mesh crab trawl should be considered in all coastal waters where crab trawling is allowed (Action 1). <u>No changes were implemented</u>.

<u>Funded Research:</u>

"Crab Trawl Tailbag Testing." FRG-98-FEG-10. Terry Hannah.

Recommended Management Strategy

Additionally, area restrictions need to be put in place during the summer months to prohibit trawling in areas that serve as critical habitat for the blue crab. <u>Trawling is currently prohibited in many areas of the State. No new critical habitat areas have been identified for protection</u>.

<u>Funded Research</u>:

"Study Utilization of Oyster Shell Planting Sites by Shrimp, Fishes, and Crabs." FRG-96-FEG-104. Hunter Lenihan.

"The Biological and Economic Value of Restored Intertidal Oyster Reef Habitat to the Nursery Function of the Estuary." FRG-97-EP-06. Jonathan H. Grabowski.

"The Biological and Economic Value of Restored Intertidal Oyster Reef Habitat to the Nursery Function of the Estuary." FRG-98-EP-16. Jonathan Grabowski.

"A Comparison of Restored vs. Natural Oyster Reefs: Assessing Whether Restoring Oyster Reef Habitat Returns the Biological Functions and Economic Value Provided by Natural Reefs to the Estuary." FRG-00-EP-03. Jonathan Grabowski.

"Use of Turtle Excluder Devices (TEDs) in Crab Trawl Fishery." FRG-02-FEG-21. Pamlico County School System.

Action 8: DMF should recommend a maximum allowable bycatch of crabs for shrimp trawls. <u>To reduce directed effort for crabs by shrimp trawlers, the DMF analyzed shrimp trawl bycatch data and recommended a maximum allowable bycatch of crabs per trip</u>. <u>Existing rule was modified to add a new section (f) as follows</u>:

15A NCAC 3J .0104 TRAWL NETS (MFC 2003; pages 26-27)

(f) It is unlawful to use shrimp trawls for the taking of blue crabs in internal waters, except that it shall be permissible to take or possess blue crabs incidental to shrimp trawling in accordance with the following limitations:

- (1) For individuals using shrimp trawls authorized by a Recreational Commercial Gear License, 50 blue crabs, not to exceed 100 blue crabs if two or more Recreational Commercial Gear License holders are on board.
- (2) For commercial operations, crabs may be taken incidental to lawful shrimp trawl operations provided that the weight of the crabs shall not exceed:
  - (A) 50 percent of the total weight of the combined crab and shrimp catch; or
  - (B) 300 pounds, whichever is greater.
- (3) The Fisheries Director may, by proclamation, close any area to trawling for specific time periods in order to secure compliance of this Paragraph.

Action 3: Collect fishery-dependent data from the peeler crab and shrimp trawl fisheries.
Action 4: Conduct tailbag mesh size studies in Pamlico Sound (work to be conducted during 1998 and 1999 through a grant funded by the Fisheries Resource Grant Program).
Action 5: Investigate the economic and social impacts of the crab trawl fishery).
Action 6: Separate hard and peeler crab trawl landings on trip tickets.
Action 7: Establish definitions for peeler and hard crab trawls and allow only these gears to direct for blue crab harvest
<u>No actions, research, or recommendations have been initiated for Action items 3-7</u>.

10.2.5 WHITE LINE PEELER HARVEST (BCFMP 1998; page 36)

Recommended Management Strategy

Prohibiting the baiting of peeler pots, except with live, legal male blue crabs would minimize the harvest of "green" and "white line" peelers in the peeler pot fishery, contribute to optimum yield of the resource, and have minimal impact on the majority of North Carolina's crab shedding operations. To address the minimum size limit exemption problem in the hard crab pot fishery, peelers should be culled from the catch were taken, and the possession of male "white line" peelers should be prohibited during June through September.
<u>Existing rule was modified as follows</u>:

15A NCAC 3L .0201 SIZE LIMIT AND CULLING TOLERANCE (MFC 2003; page 59)

(a) It is unlawful to possess blue crabs less than five inches from tip of spike to tip of spike except mature females, soft <u>and</u> peeler crabs <u>and from March 1 through October 31, male crabs to be used as peeler bait</u>. A tolerance of not more than 10 percent by number in any container shall be allowed.

(b) All crabs less than legal size, except mature female and soft crabs, shall be immediately returned to the waters from which taken. Peeler crabs shall be separated <u>where taken</u> ~~from the entire catch~~ and placed in a separate container ~~before reaching shore or dock~~. Those peeler crabs not separated ~~before reaching shore or dock~~ shall be deemed hard crabs and are not exempt from the size restrictions specified in Paragraph (a) of this Rule.

<u>Two new rules were implemented as follows</u>:

15A NCAC 3L .0206 PEELER CRABS (MFC 2003; page 61)

(a) It is unlawful to bait peeler pots, except with male blue crabs. Male blue crabs to be used as peeler bait and less than the legal size must be kept in a separate container, and may not be landed or sold.

(b) It is unlawful to possess male white line peelers from June 1 through September 1.

Action 4: Determine shedding mortality rates by peeler stage, area, and season.
Action 5: Determine the importance of "white line" peelers to the economics of the fishery and examine related enforcement issues.
Action 6: Develop and implement more effective shedding practices to minimize mortality.

<u>Funded Research</u>:

"Crab Shedding in Closed Recirculating Aquaculture Systems." FRG-97-AM-08. Norman Garry Culpepper.

"Assessing the Impact of Pesticide Use and Water Quality on the Blue Crab Survival in Soft Crab Shedding Operations." FRG-99-EP-16. Damian Shea.

"Development of a Simple Field Test to Assess the Health of Blue Crabs (Callinectes sapidus)." FRG-99-AM-01. Robin Doxey, and Edward D. Noga.

"Examine Mortality Rate in Crab Shedding Operations." FRG-00-AM-08. Donna Rose.

"Mortality and CPUE of the Blue Crab in North Carolina's Soft Shell Crab Industry." FRG-01-FEG-03. Juan Chavez.

"Comparison of Mortality Rates Among Male Peelers." BCRP-01-SHED-01. Dell Newman.

10.2.6 CRAB POT FINFISH BYCATCH (BCFMP 1998; page 37)

Recommended Management Strategy

No regulatory action should be taken at this time. Before this issue can be addressed, baseline information must be collected on the composition, quantity, and fate of unmarketable finfish bycatch in the crab pot (hard and peeler) fishery, by season and area.

<u>Funded Research</u>:
"Bycatch in the Crab Pot Fishery." FRG-99-FEG-45. Robin Doxey.

10.2.7 SMALL PEELER/ SOFT CRAB HARVEST (BCFMP 1998; pages 37-38)

Recommended Management Strategy

Currently, there is not sufficient information to indicate that there is a need to curtail the harvest of small peeler/soft crabs in an effort to protect the spawning stock. A minimum size limit would have a severe economic impact on the existing fishery practices and markets; therefore, no rule change is recommended. <u>No regulatory changes were initiated (recommended)</u>.

Action 2: Develop more effective shedding practices to minimize mortality.
Action 3: Examine the economic and biological issues involved and quantify the results.

Funded Research:

"Crab Shedding in Closed Recirculating Aquaculture Systems." FRG-97-AM-08. Norman Garry Culpepper.

"Assessing the Impact of Pesticide Use and Water Quality on the Blue Crab Survival in Soft Crab Shedding Operations." FRG-99-EP-16. Damian Shea.

"Development of a Simple Field Test to Assess the Health of Blue Crabs (Callinectes sapidus)." FRG-99-AM-01. Robin Doxey, and Edward D. Noga.

"Examine Mortality Rate in Crab Shedding Operations." FRG-00-AM-08. Donna Rose.

"Mortality and CPUE of the Blue Crab in North Carolina's Soft Shell Crab Industry." FRG-01-FEG-03. Juan Chavez.

"Comparison of Mortality Rates Among Male Peelers." BCRP-01-SHED-01. Dell Newman.

"Eliminating Bycatch in Peeler Pots." BCRP-02-STOK-04 and 03-STOK-01 Sam Marshall

10.2.8 DIAMONDBACK TERRAPIN BYCATCH and MORTALITY in CRAB POTS (BCFMP 1998; page 38)

Recommended Management Strategy

Additional research on potential options is warranted before regulatory action is taken on this issue. No regulatory changes were initiated.

Funded Research:

"Turtle Friendly Crab Pots." FRG-00-FEG-21. Joseph Benevides.

"Trying to Solve a Bycatch and Mortality Problem: Can We Exclude Diamondback Terrapins (Malaclemys terrapin) from Crab Pots Without Compromising Blue Crab (Callinectes sapidus) Catch." FRG-00-FEG-23. Larry Crowder.

"Evaluating the Efficiency and Necessity of Requiring Bycatch Reduction Devices on Pots in the Peeler Crab Fishery: Quantifying and Characterizing the Spatial and Temporal Overlap of Activities Between Diamondback Terrapins (*Malaclemys terrapin*) and the Commercial Fishery for Peeler Blue Crabs (*Callinectes sapidus*)." FRG-03-FEG-18. Robert Cahoon and Kristen Hart.

10.2.9 WHITE BELLY CRAB HARVEST (BCFMP 1998; page 39)

Recommended Management Strategy

No regulatory action should be taken on this issue at this time. No regulatory changes were initiated (recommended).

The crab industry should voluntarily reduce the harvest of white belly crabs or reduce the incentive for harvesting this low quality product. Information on the economics of this product should be collected and summarized and used in industry education efforts.

Funded Research:
"Pilot project to maximize the market potential of "white belly" crabs." FRG-99-FEG-17. Mark Hooper.

"Economic Implications of the Harvest of "White Belly" Blue Crabs." FRG-01-FEG-13. Mark Hooper.

"Economic Feasibility of Fattening Up White Belly Crabs." BCRP-01-BIOL-01. Willy Phillips.

"Feasibility and Economics of Holding and/or Selling White Belly Crabs." BCRP-01-ECON-04 and 02-ECON-03. Christopher Matthews, Russ Howell, and Gerry Howell.

10.3 COMPETITION and CONFLICT WITH OTHER USERS

10.3.1 CONFLICT (BCFMP 1998; page 40)

Recommended Management Strategy

The N.C. General Assembly needs to provide the Marine Patrol with statutory authority to deal with theft. G.S. 113-268 "Injuring, destroying, stealing, or stealing from nets, seines, buoys, pots, etc." was modified by inserting "steal" in subsection (c), effective Dec. 1, 1998.
The MFC needs to change the unattended pot rule from the existing 10 day period to seven days. Existing rule was modified as follows and Item 3 was added to deal with unforeseen events:

15A NCAC 3I .0105 LEAVING DEVICES UNATTENDED (MFC 2003; pages 10-11)

(b) It is unlawful to leave pots in any coastal fishing waters for more than ~~**ten**~~ seven consecutive days, when such pots are not being employed in fishing operations, except upon a timely and sufficient showing of hardship as defined in Subparagraph (b)(2) of this Rule or as otherwise provided by General Statute.
  (3) The Fisheries Director may, by proclamation, modify the seven day requirement, if necessary due to hurricanes, severe weather or other variable conditions.

Recommended Management Strategy

Modify existing crab pot areas using depth as the boundary instead of distance from shore. Crustacean Committee has recommended using the 6 foot depth contour to the MFC. The MFC has issued a subject matter notice for rule making (Jan. 2001).
Make it unlawful to use or set pots in any navigation channel marked by State or Federal agencies and in areas identified by the MFC. Existing rule was modified as follows:

15A NCAC 3J .0301 POTS (MFC 2003; pages 38-40)

(b) It is unlawful to use pots:
  (1) in any navigation channel ~~maintained and~~ marked by State or Federal agencies; or
  (2) in any turning basin maintained and marked by the North Carolina Ferry Division.

Recommended Management Strategy

Establish management areas. Five Regional Stakeholder Committees were established by the MFC in 1999 to assist with effort management deliberations. These groups were disbanded after recommendations on effort management were submitted to the MFC. Currently, there are no formal management areas to address crab resource issues.
Consider gear licenses or permits. Licenses and permits were considered and recommendations were made in conjunction with various open access and limited entry options that were explored during 1999 and 2000. However, no gear licenses or permits were implemented.
Consider a pot tagging system. Tagging was considered and recommendations were made in conjunction with various open access and limited entry options that were explored during 1999 and 2000. However, a pot tagging system was not implemented.

Develop guidelines to mediate user conflicts. Item (j) User Conflicts was added to the existing rules for POTS (see below).

15A NCAC 3J .0301 POTS (MFC 2003; pages 38-40)

(j) User Conflicts:

(1) The Fisheries Director may, with the prior consent of the Marine Fisheries Commission, by proclamation close any area to the use of pots in order to resolve user conflict. The Fisheries Director shall hold a public meeting in the affected area before issuance of such proclamation.

(2) Any person(s) desiring to close any area to the use of pots may make such request in writing addressed to the Director of the Division of Marine Fisheries. Such requests shall contain the following information:

(A) A map of the proposed closed area including an inset vicinity map showing the location of the proposed closed area with detail sufficient to permit on-site identification and location;

(B) Identification of the user conflicts causing a need for closing the area to the use of pots;

(C) Recommended method for resolving user conflicts; and

(D) Name and address of the person(s) requesting the closed area.

(3) Person(s) making the requests to close an area shall present their request at the public meeting.

(4) The Fisheries Director shall deny the request or submit a proposed proclamation granting the request to the Marine Fisheries Commission for their approval.

(5) Proclamations issued closing or opening areas to the use of pots under Paragraph (j) of this Rule shall suspend appropriate rules or portions of rules under 15A NCAC 3R .0107 as specified in the proclamation. The provisions of 15A NCAC 3I .0102 terminating suspension of a rule as of the next Marine Fisheries Commission meeting and requiring review by the Marine Fisheries Commission at the next meeting shall not apply to proclamations issued under Paragraph (j) of this Rule.

Recommended Management Strategy

Support the establishment of boating safety courses and boat operator licenses by the Wildlife Resources Commission (WRC). The MFC has not initiated any action on this recommendation. Re-examine the times when pots must be moved into designated crab pot areas. Crustacean Committee has recommended a time frame shift to the existing rule (1 May- 31 Oct.) to 1 June - 30 Nov. There will not be an increase or decrease in the total time the area is closed to crab potting. The MFC has issued a subject matter notice for rule making (Jan. 2001). Also, the Crustacean Committee has recommended a proposal to the MFC to open designated long haul areas to crab potting by proclamation. The MFC has issued a subject matter notice for rule making (Jan. 2001).

10.3.2 POTS IN INLAND WATERS (BCFMP 1998; page 41)

Recommended Management Strategy

The MFC and Wildlife Resources Commission (WRC) should work together to identify Inland Waters with historical crabbing activity and low recreational pressure. See WRC resolution below. The identification of inland waters that might be reclassified has not been initiated. Commercial crab potting should continue to be allowed in these selected waters. Historically, commercial crab potting was allowed in Inland Waters with a WRC Special Device License. This activity was prohibited by the WRC (see resolution below). Allowed crab pot use is noted in the resolution and a special device license is not required. Additionally, the commissions should work together to standardize rules for the crab fishery. The two commissions have not addressed standardized rules for the crab fishery.

RESOLUTION CONCERNING THE USE OF CRAB POTS IN INLAND WATERS

THAT WHEREAS, the Wildlife Resources Commission is responsible for managing the fishery resources of the inland waters of North Carolina, including the harvest of those resources by hook-and-line as well as special fishing devices;

AND WHEREAS, the use of crab pots in many inland waters presents a barrier to navigation and interferes with hook-and-line fishing;

AND WHEREAS, historically the use of crab pots has been restricted to joint and coastal waters where commercial fishing is controlled by the Marine Fisheries Commission;

AND WHEREAS, the Wildlife Resources Commission believes the continuation of this historical practice is in the best interests of the aquatic resources and the anglers who pursue those resources;

NOW, THEREFORE BE IT RESOLVED, that the North Carolina Wildlife Resources Commission meeting in official session on October 23, 1998 does hereby adopt the rule prohibiting the use of crab pots in inland waters, except that adjoining landowners may continue to set two crab pots that are attached to their property as prescribed in 15A NCAC 10C .0404(e);

AND BE IT FURTHER RESOLVED, that the staff of the Wildlife Resources Commission shall work with the staff of the Division of Marine Fisheries to identify specific inland waters that have blue crab populations in fishable numbers but lack substantial populations of inland sport fishes for the purpose of reclassifying such waters as either joint or coastal fishing waters.

10.4.2 RECREATIONAL COMMERCIAL GEAR LICENSE (RCGL) and EXEMPTION
(BCFMP 1998; pages 47-48)

Recommended Management Strategy

The specific number of pots allowed for RCGL-holders will be five per person or vessel.
<u>A new section of SUBCHAPTER 15A NCAC 3O was added to address rules associated with the “new” Recreational Commercial Gear License. Authorized gear types specific to the crab fishery are contained in the following rule</u>.

SECTION .0300 - RECREATIONAL COMMERCIAL GEAR LICENSES
15A NCAC 3O .0302 AUTHORIZED GEAR (MFC 2003; pages 102-103)

(a) The following are the only commercial fishing gear authorized (including restrictions) for use under a valid Recreational Commercial Gear License:…
  (3) With or without a vessel, five eel, fish, shrimp, or crab pots in any combination, except only two pots of the five may be eel pots. Peeler pots are not authorized for recreational purposes;
  (4) One multiple hook or multiple bait trotline up to 100 feet in length;

Recommended Management Strategy

Individuals (not possessing a RCGL) setting crab pots from privately owned shore or a pier will be limited to one pot per person and will be required to follow all gear marking requirements imposed on RCGL-holders. <u>Existing rule on “NON-COMMERCIAL USE OF POTS” was significantly modified and resulted in the following rule</u>.

15A NCAC 3J .0302 RECREATIONAL USE OF POTS (MFC 2003; page 40)

(a) It is unlawful to use pots for recreational purposes unless each pot is marked by attaching one floating buoy, any shade of hot pink in color, which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. The owner shall always be identified on the buoy using engraved buoys or by attaching engraved metal or plastic tags to the buoy. Such identification shall include the owner's last name and initials and if a vessel is used, one of the following:

(1) Gear owner's current motor boat registration number, or
(2) Owner's U.S. vessel documentation name.

(b) It is unlawful for a person to use more than one crab pot attached to the shore along privately owned land or to a privately owned pier without possessing a valid Recreational Commercial Gear License.

Recommended Management Strategy

Crab trawls should not be considered as a gear for RCGL-holders. Crab trawl was not allowed as an authorized gear type in Rule 3O .0302 AUTHORIZED GEAR (MFC 2003; pages 102-103).
Buoys for all recreational pots shall be hot pink and engraved with the full name of the fisher. DMF shall select a buoy shape for recreational gear. Marking and identification of recreational pots was addressed in the modification of Rule 3J .0302 (a) RECREATIONAL USE OF POTS (see rule above). DMF did not recommend a buoy shape for recreational gear. Also, a new rule was added to define the marking requirements for recreational trotlines (see below).

15A NCAC 3J .0305 TROTLINES (MULTIPLE HOOK OR MULTIPLE BAIT)
(MFC 2003; page 41)

It is unlawful to use multiple hook or multiple bait trotlines for recreational purposes unless such trotlines are marked by attaching to them at each end one floating buoy, any shade of hot pink in color, which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. The owner shall always be identified on the buoy by using an engraved buoy or by attaching engraved metal or plastic tags to the buoy. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:

(A) Gear owner's current motor boat registration number, or
(B) Owner's U.S. vessel documentation name.

Recommended Management Strategy

Define collapsible crab traps as non-commercial gear, and a RCGL would not be required. A definition for collapsible crab traps was added to the section of Rule 15A NCAC 3I .0101 DEFINITIONS (MFC 2003; page 2), which lists exceptions to those gears considered as commercial fishing equipment and gear.

15A NCAC 3I .0101 DEFINITIONS (MFC 2003; pages 2–8)

(b) The following additional terms are hereby defined:
(1) Commercial Fishing Equipment or Gear. All fishing equipment used in coastal fishing waters except:
(B) Collapsible crab traps, a trap used for taking crabs with the largest open dimension no larger than 18 inches and that by design is collapsed at all times when in the water, except when it is being retrieved from or lowered to the bottom;

Recommended Management Strategy

Existing non-commercial catch limits will apply to the recreational harvest of blue crabs. The current limit is 50 legal crabs per person per day, not to exceed 100 per vessel per day. Recreational harvest limits did not change and are contained in Rule 15A NCAC 3K .0105 HARVEST OF CRABS AND SHELLFISH (MFC 2003; pages 48-49).

10.5 INSUFFICIENT ASSESSMENT DATA (BCFMP 1998; page 49)

Recommended Management Strategy

The MFC and DMF should prioritize research needs and implement actions to accomplish the identified research and data needs. Many of the research needs were prioritized in BCFMP (1998) Sections 10.6.4, 10.6.5, 10.6.6, and 10.6.7. These research needs have been targeted by the commercial fishing and academic communities through FRG's, BCRP, and other grant programs.

Funded Research:

"Development of Two Simple Devices to Increase the Accuracy of Catch Per Unit Effort (CPUE) Data." FRG-98-FEG-08. Mark Hooper.

"The role of trawl discards in sustaining blue-crab fishery production." FRG-99-EP-07. Galen Johnson.

"Stock assessment of the blue crab (Callinectes sapidus) in North Carolina." FRG-99-FEG-10. David B. Eggleston, Joseph E. Hightower, and Eric G. Johnson.

"Population Dynamics and Stock Assessment of the Blue Crab (Callinectes sapidus) in North Carolina." FRG-00-FEG-11. David Eggleston.

"The Seasonal Food Habits of Striped Bass (Morone saxatilis) in the Albemarle." FRG-00-EP-14. Wesley Patrick.

"Survey of Catch/Effort Data from the Recreational Blue Crab Fishery." BCRP 01-POP-03. Jimmy Nobles, Lisa and Kim Nobles, Jeff Johnson, and Hans Vogelsong.

"Pilot Project to Improve the Accuracy of Catch Per Unit Effort (CPUE) Calculations in the Blue Crab Pot Fishery." BCRP-01-POP-06. Mark Hooper, and Royal Hooper.

"A New Method for the Evaluation of Spatial and Temporal Dispersal Patterns of Blue Crab (*Callinectes spp.*) Larvae in the Cape Fear River Plume." BCRP 01-BIOL-03. Ami Wilbur.

"Blue Crab (*Callinectes sapidus*) Culture for Stock Enhancement." BCRP 01-STOK-01. Joanne Harcke.

"Blue Crab Stock Enhancement Potential: Field Releases and Pond-Rearing." BCRP 01-STOK-03. G. Todd Kellison.

"Blue Crab Stock Enhancement Potential: Further Progress in Field Releases and Pond-Rearing." BCRP 02-STOK-02. G. Todd Kellison and David Eggleston.

"Artificial Manipulation of Critical Habitat for Alewife and Blue Crab in Pamlico Sound, North Carolina." FRG-02-EP-17 Roger Rulifson and Tommy Midgette.

"Blue Crab Attraction to Animal Processing Wastes: Chemoreception and Bait Potential." BCRP 02-BIOL-03. Daniel Rittschof and Joshua Osterberg.

"Migration and Reproductive Potential of Female Blue Crabs." BCRP 02-BIOL-04, Dan Rittschof.

"Pheromones from Male Crabs: Basic Properties and Bait Potential." BCRP 02-BIOL-05. Dell Newman.

"Evidence for Functional Sperm Limitation in NC Blue Crabs." BCRP 02-BIOL-07 and 03-BIOL-06. Donna Wolcott and Thomas Wolcott.

"High School Students and the Blue Crab: An Educational Outreach Program to Quantify Annual Recruitment Success." BCRP 02-POP-04. David Eggleston.

"Building the Pot Counter Network to Improve Calculation of CPUE (Catch Per Unit Effort) in the NC Crab Pot Fishery." BCRP 02-POP-06. Mark Hooper.

"Survey of Catch/Effort Data of Blue Crabs from the NC Coastal and Estuarine Landowners." BCRP 02-ECON-01. Hans Vogelsong and Jeffery Johnson.

"Trip Log and Socio-Economic Survey of North Carolina Commercial and Recreational Crab Potters." BCRP 02-ECON-02. Robin Doxey.

"Refinement of a Field Test to Assess the Health of Blue Crabs." BCRP 03-BIOL-01.
Edward Noga.

"Origin and Movement Patterns of Tar-Hens and Tar-Jimmys." BCRP 03-BIOL-04. Dan Rittschof.

"Fishing Baits from Poultry Production Wastes." BCRP 03-BIOL-05 Daniel Rittschof and Joshua Osterberg.

"A Dynamic View of North Carolina Blue Crab Stock Abundance and Distribution Generated from Fishery Dependent Data." BCRP 03-POP-02. Mark Hooper.

"Investigation of the Relationship Between Effort and Landings in the North Carolina Commercial Blue Crab (*Callinectes sapidus*) Pot Fishery." BCRP 03-POP-04. Teresa Thorpe, David Beresoff, and Mark Hooper.

"Crab Pot Cleaning Technique to Replace the Use of Toxic Chlorine." FRG-03-FEG-06.
Willy Phillips.

"Crab Pot Edge Guards." FRG-03-FEG-14. Edward Etheridge.

10.5 INSUFFICIENT ASSESSMENT DATA (continued) (BCFMP 1998; page 49)

Recommended Management Strategy

Licenses and/or permits should be implemented to identify participants and quantify activities and gear usage in the blue crab fisheries. <u>Licenses and permits for various activities were discussed in concert with several of the limited entry and open access effort management proposals</u>. <u>The MFC decided not to implement an effort management strategy for the crab fisheries; so additional licenses and permits for harvest or gear use were not pursued</u>. <u>Blue crab shedding was defined and a permit was implemented to identify individual blue crab shedding operations</u>. <u>The two new rules are presented below</u>.

15A NCAC 3I .0101 DEFINITIONS (MFC 2003; page 8)

(b) The following additional terms are hereby defined:

(50) Blue Crab Shedding. Shedding is defined as the process whereby a blue crab emerges soft from its former hard exoskeleton. A shedding operation is any operation that holds peeler crabs in a controlled environment. A controlled environment provides

and maintains throughout the shedding process one or more of the following: predator protection, food, water circulation, salinity or temperature controls utilizing proven technology not found in the natural environment. A shedding operation does not include transporting peeler crabs to a permitted shedding operation.

15A NCAC 3O .0503 PERMIT CONDITIONS; SPECIFIC (MFC 2003; page 117)

(c) Blue Crab Shedding Permit: It is unlawful to possess more than 50 blue crabs in a shedding operation without first obtaining a Blue Crab Shedding Permit from the Division of Marine Fisheries.

10.4 INCREASING FISHING EFFORT (BCFMP 1998; pages 42-47)

10.4.1 EFFORT MANAGEMENT

Recommended Management Strategy

It is likely that none of the traditional open-access management alternatives (for example seasons, time, and area restrictions) can significantly control or reduce the overall effort in the crab fishery without severely restricting individual landings or traditional fishing patterns. ******Therefore, some type of effort management system is needed to control and/or reduce effort in the crab fishery. ******No specific strategy for a continued open access or limited entry system to manage effort in the crab fishery is proposed at this time. The legislated time frame to develop the blue crab FMP did not allow for an effort management system to be fully developed for this fishery. ******Therefore, the crab licenses and license moratorium should be extended for one more year (until 1 July 2000) to allow for the development of an effort management system. ******Any option to reduce effort should provide an appropriate means to allow flexibility within the fishing community (future holders of the limited SCFL); minimize exclusive privileges and avoid monopolies; control or reduce effort in the crab fishery; and make management of the crab fishery more efficient and effective.

<u>The License moratorium and Crab License was scheduled to expire June 30, 1999. The expiration of this moratorium and the Crab License would allow anyone with an Endorsement to Sell License to purchase a Standard or Retired Commercial Fishing License and be eligible to participate in the crab fishery. The moratorium on new licenses and provisions of the Crab License had allowed only a limited number of license holders (3639 in Oct. 2000) to participate in the crab fishery. Once the moratorium and license expired, approximately 8830 (cap for year 2000) licensees would be eligible to participate in the crab fishery at any level of effort they chose. This increase would potentially more than double the number of participants. Therefore, a segment of the industry was concerned that increased participation, fishing effort, and gear use would escalate to the point that the resource and the economics of the fishery may collapse or would suffer from over capitalization</u>.

Action 3:
Crustacean and Blue Crab Advisory committees charged to evaluate effort management options. Final recommendation to MFC by 1 May 1999.
MFC to make a final recommendation on effort mgmt. for the crab fishery to the N.C. General Assembly by 1 July 1999 (General Assembly has the authority to limit entry).

In order to achieve “Action 3”, “Action 2” which was an “ongoing discussion of options” was implemented. Activity under “Action 2” are summarized below:

1. <u>Effort Management Workshop</u> held in January 1999. Five open access and 5 limited entry options evaluated. Three open and 3 limited considered viable.
2. <u>Two open access</u> and <u>2 limited entry</u> effort management options for the crab pot fishery presented at 5 public meetings in the coastal area (March 1999).

3. License moratorium and Crab License scheduled to expire on June 30, 1999. An Interim Crab License ("Action 1") was established by the N.C. General Assembly until October 1, 2000. This extension of the Crab License was granted to allow the industry, MFC, and DMF an opportunity to continue work on an effort management plan for the crab pot fishery.
4. To accomplish this plan the MFC established five regional crab pot management areas. A stakeholder advisory committee of commercial fishermen, dealers, recreational fishermen and boaters was appointed for each region. Due to the lack of consensus reached during prior effort management discussions, the need to allow new entrants into this fishery, and a desire to control overall pot numbers, the MFC directed these regional committees to assist in drafting an effort management plan for this fishery and to consider: 1) regional differences in the fishery; 2) market stability; and 3) also allow those involved to maintain operations similar to existing levels, while allowing flexibility for the entire fishing community to participate in the pot fishery.
5. MFC decided to pursue only open access options (Sept. 10, 1999).
6. The open access effort management plan considered for the crab pot fishery, included combining 3 elements of open access management into one system of management. These are (1) management areas, (2) gear restrictions (regional pot limits), and (3) a permit system to participate in the fishery.
7. Some of the committees identified a need to reduce effort in some areas and recommended pot limits. However, generally the Stakeholder Committees did not expect effort to increase significantly when the Crab License expired, and did not feel that pot limits were necessary, unless the primary purpose was to protect the blue crab population. Therefore, after almost 2 years of discussion, the MFC decided not to implement an effort management strategy for the crab pot fishery.

Literature Cited:

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MFC (North Carolina Marine Fisheries Commission). 2003. North Carolina Fisheries Rules for Coastal Waters 2003. NC Div. Mar. Fish., Morehead City, NC. 297p.

12.2 Appendix 2. SUMMARY OF BLUE CRAB REGULATIONS FROM OTHER STATES

Table 1. State comparisons of blue crab management actions for the 2003 commercial pot fishery. (Bolded text denotes a change from the 1998 BCFMP.)

Table 2. State comparisons of blue crab effort management actions for the 2003 commercial pot fishery. (Bolded text denotes a change from the 1998 BCFMP.)

Table 3. State comparisons of blue crab management actions for the 2003 recreational/ non-commercial pot fishery. (Bolded text denotes a change from the 1998 BCFMP.)

Table 1. State comparisons of blue crab management actions for the 2003 commercial pot fishery. (Bolded text denotes a change from the 1998 BCFMP.)

	Harvest restrictions				Gear restrictions			Size limits (inches)				Sponge crab	Effort	Pot
State	Season	Catch limits	Time	Days	Pots (max.)	Escape rings	Buoys	Hard	Soft	Peeler	Tolerance	protection	management	Attendance
NEW JERSEY	Apr. 16-Dec. 14 Delaware Bay Mar. 15-Nov. 30 Other waters	None	4:00am-9:00pm Bay, 24-hrs other waters	None	600 Delaware Bay 400 Other waters	None Terrapin excluder some areas Degradable panel	Reflective I.D. Sink Line	4.75* **4.5 non egg bearing female**	3.5	3	Zero	A	Yes	3 days
DELAWARE	Mar.1-Nov. 30	None	1 hr before sunrise-sunset	None	200 500/vessel	None	I.D. Color coded	5	3.5	3	5% by number	A	Yes	3 days
MARYLAND	Apr. 1- **Dec. 15**	None	**½ hr before sunrise – 7 ½ hrs after sunrise**	Prohibited either Sun. or Mon.	300 up to 900/ vessel w/ 2 crew	1 (2-3/16 in) 1 (2-5/16 in) may close for peelers	I.D.	5** Apr. 1-July 14	**3.5**	3.25** separate from catch	**5** hard crabs/ bushel or **13**/ barrel **10 peelers**	**A**	Yes effective 6/98	None
VIRGINIA	Apr. 1-Nov. 30	Apr. 1-May 31 51 bushels or 17 barrels/ vessel	**Set pots 1 hr. after 6am-2pm/Apr. Sept.-Nov. 5am-1pm/ May-Aug.**	Mon.-Sat. except peeler pots	**300** peeler 500 hard crab/ 300 tributaries 500 bay	1 (2-3/16 in) 1 (2-5/16 in)/ may close in some areas	I.D.	5	3.5	**3**	10 hard crabs/ bushel or 35/ barrel **10 peeler/ No soft**	B and C **Baywide Sanct. 35 ft. contour**	Yes	None
NORTH CAROLINA	None	None	1 hr before sunrise-1 hr after sunset	None	150 Newport River only	2 (2-5/16 in) may close in one area	I.D. **Sink Line**	5	None	None separate from catch	10% by number/ container	C	**Comm. License Cap**	7 days
SOUTH CAROLINA	None	None	5am-9pm 4/1-9/15 6am-7pm 9/16-3/31	None	None	2 (2-3/8 in) Jun. 1-Mar. 14 **Peeler pot may be baited. Bait not to exceed 3″ in any meas.**	I.D. with colors	5*	5*	None with peeler permit	Zero	**A and D**	None	5 days
GEORGIA	None	None	None	None	200/ includes peeler pots	2 (2-3/8 in)	I.D.	5	5	3	Zero	**A^ and D**	Yes	None
FLORIDA	None	None	1 hr before sunrise-1 hr after sunset	None	None	3 (2-3/8 in) Degradable panel	I.D.	5*	5	None separate from catch	5% by number/container except bait	A	**None develop by 12/2004**	None
ALABAMA	None	None	1 hr before sunrise-sunset	None	None	None	½ white	5*	None	5	Zero except bait	None	None	None
MISSISSIPPI	None	None	**½ hr before legal sunrise - ½ hr after legal sunset**	None	None	None	I.D. or color code	5*	None	None	Zero	A	None	None
LOUISIANA	None	None	½ hr before sunrise- ½ hr after sunset	None	None	2 (2-5/16 in) **Can be closed March - June Sept. - October**	I.D. on **metal** trap tag/ **plastic bait cov. Sink line**	5*	None	None separate from catch	10%by number in a 50 crab random sample	A 2% by number tolerance in work box only	**None**	None
TEXAS	**No pots 16 - 30 days in Feb. - March**	None	½ hr before sunrise-½ hr after sunset	None	200	2 (2-3/8 in) Degradable panel	White **gear tag - I.D.**	5*	5	5	5% by number in separate container for bait only	**A and D**	Yes effective 9/98	**30 day gear tag**

* Includes mature female

**** Split season size limits; minimum carapace width 5 ¼″ for hard male and 3 ½″ peeler crabs July 15 – December 15, 2003.** **A^ Prohibit sponge crabs until July 1, 2005. Reevaluate at that time.**

A = Unlawful to take, sell or possess sponge crabs; B = Prohibit brown/ black sponge with tolerance; C = Crab sanctuary to protect females; D = May sell or possess sponge crabs, if taken legally in another state.

Table 2. State comparisons of blue crab effort management actions for the 2003 commercial pot fishery. (Bolded text denotes a change from the 1998 BCFMP.)

			Crab License								
State	Commercial License Required	Crew License	Individual License	License Cap	Trap Permit	Pot Limit (maximum)	Transferable	Use or Lose Provision	Soft-shell Dealer License	Soft-shell Shedding License	Apprenticeship Program
NEW JERSEY	Yes	None	Yes	Yes (312)	None	600 Delaware Bay 400 Other waters	Yes Only Family	None	None	None	None
DELAWARE	Yes	None	Yes 50 pot increments	Yes Previous licensee (219)	None	200	Yes Family or Designee	None	None	None	None
MARYLAND (effective 6/98)	Yes Limited Entry	Fee for Crew	Yes	Yes Tied to Comm. Lic.	None	300 up to 900/ vessel with 2 crew	Yes with criteria	None	None	None	Yes with criteria
VIRGINIA	Yes 2 year delay	None	Yes 100, 300 or 500 pots	**Moratorium**	Peeler Hard	**300** peeler and500 hard/ 300 tributaries 500 bay	Yes **with boat or family**	None	None	Yes	None
NORTH CAROLINA	Yes **License cap**	None	**None Ended Oct. 2000**	**N/A Comm. License cap**	None	150 only in Newport River	**N/A**	None	None	No **Free permit required**	None
SOUTH CAROLINA	Yes	None	Yes \$25/50 pots \$1/pot over 50 pots	None	None	None	No	None	None	Yes	None
GEORGIA	Yes	Yes	Yes 50 pot increments	Yes **(159)** 1998/99 licenses	\$2/ pot	200/ includes peeler pots	Yes **with boat or family**	2 years	Yes	None	None
FLORIDA	Yes	Vessel license covers crew	Yes Income criteria	Yes **(4500) moratorium based on 1997/98 licenses** [1]	None	None	Yes Only Family	None	None	None	None
ALABAMA	Yes	None	Yes	None	None	None	No	None	None	None	None
MISSISSIPPI	Yes	None	Vessel	None	None	None	Yes	None	None	None	None
LOUISIANA	Yes	None	Yes	**None**	None	None	**No**	None	None	Yes	None
TEXAS (effective 9/98)	No	None	Yes	Yes Eligibility criteria	None	200	**Yes**	None	None	None	None

[1] Florida Crab License was extended and scheduled to expire 7/1/2005

Table 3. State comparisons of blue crab management actions for the 2003 recreational/ non-commercial pot fishery. (Bolded text denotes a change from the 1998 BCFMP.)

			Harvest restrictions				Gear restrictions			Size limits (inches)				
State	License	License exemption	Season	Daily catch limits	Time	Days	Pots (max.)	Escape rings	Buoys	Hard	Soft	Peeler	Tolerance	Effort management
NEW JERSEY	Yes No fee	None	None	1 bushel	4:00am- 9:00pm Bay, 24-hrs other waters	None	2	None terrapin excluder some areas	Reflective I.D. Sink line	4.5* prohibit sponge	3.5	3	Zero	None
DELAWARE	None		**March 1- Nov. 30**	1 bushel	None	None	2	None **terrapin excluder in inland bays**	I.D. white	5	3.5	3	5% by number	None
MARYLAND [1]	None		Apr. 1- **Dec. 15**	1 bushel 1 dozen peeler/ soft	**½ hr before sunrise – ½ hr before sunset**	None	2 Land owners only	1 (2-3/16 in) 1 (2-5/16 in)	I.D.	**5**** prohibit sponge	**4**	**3.5**	Zero	**Tribs. only**
VIRGINIA	Yes	2 pots 1 bushel and 24 peelers daily limit	Apr. 1- Nov. 30	None	**6am-2pm April/Sept.-Oct. 5am-1pm May-Aug.**	Mon.-Sat. with License	5	1 (2-3/16 in) 1 (2-5/16 in)/ may close in some areas	Marked with the letter "R"	5	3.5	**3**	10 crabs/ bushel or 35/ barrel **10 peeler/No soft**	None
NORTH CAROLINA	**Yes**	**One pot/person along privately owned shore or pier**	None	50 crabs 100/vessel	1 hr before sunrise- 1 hr after sunset	None	**5**	2 (2-5/16 in) may close in one area	I.D. **Hot Pink Sink line**	5	None	None	10% by number/ container	None
SOUTH CAROLINA	None		None	None	**None**	None	2	None	I.D. yellow	5*	5*	5	Zero	None
GEORGIA [2]	Yes Fishing Lic.	None	None	1 bushel 2 bushels/ vessel	None	None	6	2 (2- 3/8 in)	I.D.	5 **prohibit sponge**	5	3	Zero	None
FLORIDA	**Yes, If fishing from boat**		None	**10 gallons/ person**	1 hr before sunrise- 1 hr. after sunset	None	None	3 (2-3/8 in) Degradable panel	Marked with the letter "R"	**None*** prohibit sponge	None	**None**	5% by number/ container except bait	None
ALABAMA	None		None	None	None	None	5	None	**Orange, marked with letter "R"**	None	None	None	N/A	None
MISSISSIPPI	**Yes**		None	None	**30 min. before sunrise – 30 min. after sunset**	None	6/household	None	I.D.	5* prohibit sponge	None	None	Zero	None
LOUISIANA	Yes **If using traps**	None	None	**12 doz. per day per person**	½ hr before sunrise- ½ hr after sunset	None	10	2 (2-5/16 in) **Rings can be closed March-June, Sept.-Oct.**	I.D. on trap tag	None prohibit sponge	None	None	N/A	None
TEXAS	Yes Fishing Lic. & Saltwater Stamp		**No pots Feb. - March/ 16-30 Days**	None	½ hr before sunrise- ½ hr after sunset	None	6	2 (2-3/8 in) Degradable panel	white with color stripe gear tag- I.D. & date set	5* prohibit sponge	5	5	5% by number in separate container for bait only	None

* Includes mature female

**** Minimum carapace width 5 ¼ effective August 1, 2002.**

1 **Maryland's Noncommercial Crabbing License is not required for crab pots unless potter takes more than 2 doz. hard crabs/ 1 doz. soft crabs. With license can take 1 bushel hard crabs/ 2 doz. soft crabs.**

2 Georgia's ban on sponge crabs is until July 1st 2005. A reevaluation will be conducted at that time.

12.3 Appendix 3. SUMMARY OF VITAL HABITATS AND WATER QUALITY PLANS IN THE ALBEMARLE-PAMLICO ESTUARINE STUDY (APES) COMPREHENSIVE CONSERVATION AND MANAGEMENT PLAN (EPA and DEHNR 1994)

Vital Habitats Plan

Goal: Conserve and protect vital fish and wildlife habitats and maintain the natural heritage of the Albemarle-Pamlico region.

Objective A: Promote regional planning to protect and restore the natural heritage of the APES region.
Management Actions:
1. Develop ecosystem protection and restoration plans (basinwide ecosystem plans) for each river basin in the region. Individual basinwide ecosystem plans will be completed and implemented according to the schedule established for basinwide water quality management plans. (See Objective A in the Water Quality Plan.) Plans should establish coordinated priorities for protecting habitats and critical areas in each basin, and should target areas most vital to the survival of wildlife and fisheries and the protection of natural heritage.
2. Develop and maintain accurate maps and records of wetlands, fisheries habitats, federal and state endangered species and their habitats, natural areas, and natural communities.
3. Expand programs to identify wetlands on a regional scale and to evaluate and rank wetland function.

Objective B: Promote the responsible stewardship, protection, and conservation of valuable natural areas in the APES region.
Management Actions:
1. Bring areas identified as having the highest priority for protection into public ownership and/or management. Expand funding for public acquisition of park lands, gamelands, coastal reserves, and other natural areas.
2. Provide incentives and technical assistance for the protection of privately owned vital habitats.

Objective C: Maintain, restore, and enhance vital habitat functions to ensure the survival of wildlife and fisheries.
Management Actions:
1. Enhance the ability of state and federal agencies to enforce existing wetlands regulations by 1995.
2. Strengthen regulatory programs to protect vital fisheries habitats, which include submerged aquatic vegetation, shellfish beds, and spawning areas by 1995.
3. Enhance existing efforts to restore the functions and values of degraded wetlands and vital fisheries habitats. Develop and begin implementing an expanded program to restore wetlands.
4. Establish by 1995 a consistent and effective mitigation program to compensate for unavoidable permitted wetlands losses.

Water Quality Plan

Goal: Restore, maintain or enhance water quality in the Albemarle-Pamlico region so that it is fit for fish, wildlife and recreation.

Objective A: Implement a comprehensive basinwide approach to water quality management.
Management Actions:

1. Develop and begin implementing basinwide plans to protect and restore water quality in each basin according to the schedule established by the Division of Environmental Management's Water Quality Section. The plans would include provisions for basinwide wetland protection and restoration.
2. Establish total maximum daily loads (TMDLs) and associated control strategies for all impaired streams in the Albemarle-Pamlico region by 1999.
3. Renew all discharge permits in a river basin simultaneously by 1999.
4. Consider the potential for long-term growth and its impacts when determining how a basin's assimilative capacity will be used.
5. Improve the scientific models for understanding the estuarine system, the effects of human activities on the system, and the viability of alternative management strategies.
6. Continue long-term, comprehensive monitoring of water quality in the APES system, collecting data to assess general system health and target regional problems.

Objective B: Reduce sediments, nutrients and toxicants from nonpoint sources.
Management Actions:

1. For each river basin, develop and implement a plan to control non-point source pollution as part of the basinwide management plans.
2. Expand funding to implement nonpoint source pollution controls, particularly agricultural best management practices through the N.C. Agriculture Cost Share Program, and also to develop a broader Water Quality Cost Share Program. Expand the cost share programs to include wetlands restoration. Increase cost share funds to problem areas.
3. Continue to research and develop alternative septic systems and new best management practices to reduce nonpoint source pollution.
4. Strengthen current enforcement to detect and correct ground and surface water quality violations from non-point sources.
5. Strengthen implementation of forestry best management practices through training, education, technical assistance and enforcement.
6. Enhance stormwater runoff control by strengthening existing regulations and developing new ones, if needed, by 1995. Improve enforcement to ensure that stormwater management systems are properly installed and regularly maintained.
7. Implement an inter-agency state policy that addresses marina siting and integrates best management practices through permitting and better public education by 1995.

Objective C: Reduce pollution from point sources, such as wastewater treatment facilities and industry.
Management Actions:

1. Promote pollution prevention planning and alternatives to discharge, where feasible, for all point sources to reduce the volume and toxicity of discharges.
2. Expand and strengthen enforcement of National Pollutant Discharge Elimination System permits. Increase site inspections and review of self-monitoring data to improve facility compliance by 1995.

Objective D: Reduce the risk of toxic contamination to aquatic life and human health.
Management Actions:

1. Increase efforts to assess and monitor the extent of estuarine sediment contamination, fish and shellfish tissue contamination, and water quality violations, and to identify the causes and sources of these problems.

2. Continue to issue fish advisories as necessary to protect public health. Improve communication and education about the risks associated with eating contaminated fish and shellfish.

3. Remediate toxic contamination where necessary and feasible.

Objective E: Evaluate indicators of environmental stress in the estuary and develop new techniques to better assess water quality degradation.
Management Actions:

1. Continue to track and evaluate indicators of environmental stress, including algal blooms, fish kills, and fish and shellfish diseases.

2. Improve the techniques for evaluating the overall environmental health of estuarine waters.

3. Develop and adopt better indicators of shellfish contamination as soon as possible.

12.4 Appendix 4. SPAWNING STOCK PROTECTION

I. Issue:

Management measures needed to protect the reproductive potential of blue crabs.

II. Background:

With increasing concerns over fluctuating blue crab landings and increasing fishing effort, there have been numerous requests to further protect the spawning stock of blue crabs in North Carolina. Blue crab recruits in any given year rely, in part, on the size of the spawning stock from which the young originated (Chesapeake Bay Program 1997). The spawning stock includes all female crabs that survive natural and fishing mortality to reproduce. Recent analysis of data from the Chesapeake Bay has shown that there has been a rapid reduction (over 1 to 2 yr) in the spawning stock, recruitment, larval abundance, and female size of blue crabs in this system (Lipcius and Stockhausen 2002). These changes occurred in the early 1990's and this system has yet to recover. Lipcius and Stockhausen (2002) suggested that these trends will not turn around unless there is a significant reduction in fishing and natural mortality, along with enhanced environmental conditions conducive to successful recruitment. For the most part, all crab producing states along the east coast have shown a downward trend in larval, and spawner abundance over the last few years. Environmental conditions (winter mortality, drought, hypoxia, hurricanes, and human development effects), diseases, predation and cannibalism can exaggerate these problems. To fully understand spawning stock dynamics and effectively manage this portion of the blue crab population, information on the size structure of the stock, recruitment relationships, and abundance and movements of the spawning stock must be examined.

The protection of the spawning stock of various organisms is achieved through the establishment of minimum/maximum size limits and/or the protection of egg-bearing females. These methods are most effective when dealing with species that take a number of years to reach sexual maturity (i.e., lobster and striped bass). The protection of spawners has often been utilized by fisheries managers to protect declining stocks and/or stocks that are showing signs of growth or recruitment overfishing. Growth overfishing occurs when fish are harvested at sizes below those, which produce the maximum weight. Hence, there is a net loss of biomass from one year to the next (NMFS 1993), which is characterized by a decreasing proportion of older and larger individuals in the catch. This type of overfishing has been documented for male blue crabs in Maryland (Abbe 2002). While this example shows a reduction in yield-per-recruit, a similar pattern with females could lead to a reduction in egg production. Campbell and Robinson (1983) have shown that high exploitation of American lobsters can produce smaller lobsters and lowered larval output. Male reproductive capacity can have a significant effect on the lifetime reproductive success of females. Insemination rates of female crabs and the amount of sperm they receive from male crabs during mating may be dependent on the abundance and size of male crabs in the population. A small male may not be able to transfer enough sperm for the female to fertilize all of the eggs she is capable of producing. Consequently, it is important to consider not only the impact of growth overfishing in terms of yield-per-recruit but also it's potential effect on the reproductive capacity of the stock.

Recruitment overfishing is the rate of fishing above which recruitment to the exploitable stock is reduced. It is characterized by a reduced spawning stock and generally very low production of young, year after year (NMFS 1993). Excessive fishing pressure can result in recruitment overfishing. Conflicting views exist regarding the existence (Lipcius and Van Engle 1990; Lipcius and Stockhausen 2002, Eggleston et al. 2004) or absence (Pearson 1948; Sulkin et al.1983; Van Engel 1987) of a spawning stock-recruitment relationship for the blue crab. Most investigators state that annual fluctuations in blue crab populations are the result of environmentally-induced variations in recruitment. Although a definitive stock-recruitment relationship has not been identified for blue crabs, this does not mean that recruitment is independent of the size of the spawning stock. To manage a fishery based on the assumption that recruitment is independent of spawning stock size when this is not the case could lead to the decline of the population. In cases like this, the most appropriate management approach would be to protect some spawners until the dynamics of the population are better understood.

Concerns with protecting egg-bearing female blue crabs (sponge crabs) are complex, consisting of: economic factors (fewer pounds of meat can be picked from a given weight of sponge crabs than from the same weight of non-sponge crabs); biological considerations (recruitment overfishing); and personal opinions regarding “motherhood”. Currently, there are a number of states that prohibit the sale or possession of egg-bearing females (Table 1). Without exception, these states experience the same fluctuations in blue crab landings as seen in states that do not protect egg-bearing females. From the early 1920's until 1964, it was unlawful to harvest sponge crabs in North Carolina. When the sponge crab law was repealed in 1964, it was replaced with the establishment of Crab Spawning Sanctuaries [MFC (2003) rules 15A NCAC 3L .0205 and 3R .0110]. During the time frame that the sponge crab law was in effect in North Carolina, reported hard crab landings showed the same patterns in fluctuations as observed after its repeal.

Table 1. Summary of blue crab sponge and spawning sanctuary regulations (New Jersey to Texas).

State	Prohibit the sale or possession of sponge crabs	Have established crab spawning sanctuaries
Texas	Yes	No
Mississippi	Yes	No
Louisiana	Yes	No
Alabama	No	No
Florida	Yes	No
Georgia	Yes	No
South Carolina	Yes	No
North Carolina	No	Yes
Virginia	Yes1	Yes
Maryland	Yes	No
Delaware	Yes	No
New Jersey	Yes	No

[1] Minimum tolerance for brown and black sponge crabs

The utilization of marine protected areas is an effective management tool to conserve exploited species. Currently two states use this concept to protect the spawning stock of blue crabs (Table 1). North Carolina has five locations designated as Crab Spawning Sanctuaries through MFC (2003) Rule 15A NCAC 3L .0205 (see below IV. Current Regulations) and 3R .0110 (sanctuary boundary description). Approximate surface acreage for each of the sanctuaries is contained in Table 2.

Table 2. North Carolina blue crab spawning sanctuaries.

Location	Acreage
Oregon Inlet	5,787.5
Hatteras Inlet	4,444.0
Ocracoke Inlet	8,745.0
Drum Inlet	5,388.0
Bardens Inlet	4,610.0

III. Discussion:

Fishery independent data suggests that the size of mature females has been decreasing in recent years (Figure 1). Fishery dependent data shows the same trend for the Pamlico and southern areas of the state, however the trend is not as steep as seen in the independent data (Figure 2). Fishery dependent data from the Albemarle area shows an upward trend in carapace width for mature females (Figure 2). Possible causes for the declining size of mature females are: compensatory responses (maturing at smaller sizes due to low population abundance), phenotypic plasticity (changes caused by environmental or biotic conditions), and growth overfishing (removing larger individuals from the fishery). Lipcius and Stockhausen (2002) examined these causes in relation to the declining size of mature females in the Chesapeake Bay and suggested that a combination of all these factors contributed to the changes observed in this system. Furthermore these authors concluded that the use of escape rings is partly responsible for the reduction in smaller female sizes.

Since escape rings were required in North Carolina (February 1, 1989), some fishermen have suggested that escape rings were altering the genetic structure of the natural population and selecting for smaller size crabs. This was based on fishermen's personal observations of seeing more smaller mature females than in years past. For this assumption to be valid, we must assume that the ultimate size of the female is genetically controlled. Males continue to grow during their entire life, although molt increment lengthens as the size of the crab increases. After their terminal molt (from immature female to mature female), mature females generally do not shed again (there have been a few reports of mature females shedding). While there are no data available on the genetic control of size for blue crabs, data do exist for the effects of temperature and salinity on crab growth. Generally most investigations have noticed that females spending their entire life in high salinity water tend to be significantly smaller than females from lower salinity waters (phenotypic plasticity). Additionally an increase in abundance of smaller mature females could be an indicator of growth overfishing. Growth overfishing occurs as the result of size selective harvest of larger individuals. This selective harvest can occur at the time of capture, culling little females from the catch, or prior to harvest through gear modifications (escape rings). Data from commercial crab catches in the Albemarle and Pamlico areas (catches from these areas were combined since they all migrate to the Outer banks to spawn) suggest that growth overfishing might be occurring in North Carolina (Figure 3). Since mature females don't generally molt after their terminal molt, one would expect that the length frequencies of mature female and sponge crabs to be similar. However, this is not the case as shown in Figure 3. Part of this difference can be attributed to the use of escape rings, and part to the aforementioned factors. The 2 5/16 inch escape ring currently required in North Carolina allows smaller mature females to escape while retaining a larger percentage of larger females. However once a small female sponges, her body proportions (depth) change, and therefore, she is more vulnerable to capture. While some fishermen have suggested repealing the escape ring regulation, this would not solve the problem. Without escape rings there would be more mature females harvested than before which would further reduce the blue crabs reproductive potential. Additionally, the use of escape rings in crab pots has a number of important benefits: possible increase in legal crab catch, reduction in sublegal harvest, reduction in ghost pot fishing mortality, reduced culling time for fishermen, and reduced injuries, mortality, and/or physiological stress for sublegal crabs. Since larger crabs are more important to the overall egg production in a given year, steps should be taken to protect this portion of the spawning population (in a single brood a 180 mm crab will produce 3 times the number of eggs as compared to a 120 mm crab). A maximum size limit for mature females would protect these larger spawners. Since the peak spawning times for blue crabs in North Carolina are the spring and summer (Figure 4 and 5), the protection of larger crabs during late fall and early spring (September through April) would allow more of these individuals to enter the spawning population. The benefits of this management action would be; shifting the spawning size frequency to larger individuals (Figure 3); increase egg/larval production; allow larger females the opportunity to produce multiple broods over their lifetime; help conserve a natural size-at-age; and provide valuable information on longevity and maximum size. Figure 6 shows the estimated monthly contribution of males and females to the landed hard crab catch. During the proposed time period when larger females would have to be returned to the water, fishery dependent data shows that 38% of the catch from the Albemarle area is female, 33% from Pamlico Sound, 45% Core Sound, and 35% for the southern portion of the state. A seasonal (September – April) maximum size limit of 172 mm (6 ¾ inches) would reduce total annual landings by 0.66% (325,308 pounds) and protect approximately 975,923 large females (Table 3). A seasonal maximum size limit of 175 mm (6 7/8 inches) would reduce total annual landings by 0.39% (190,578 pounds) and protect approximately 571,733 large females (Table 4). A seasonal maximum size limit of 178 mm (7 inches) would reduce annual landings by 0.2% [99,011 pounds (Table 5)] and protect 297,032 large female crabs. While these reductions should not impose a economic burden to individual fishermen the impact that this proposed regulation would have on the picking houses is unknown. Fishery dependent data indicates that growth overfishing is not a concern for the male portion of the population (Table 6). The proportions of males in different size categories and areas have remained relatively stable since 1995. Since male reproductive capacity can have a significant effect on the lifetime reproductive success of females, it is important to protect a portion of this population. Males are most abundant in the mid and upper estuaries. Consequently, when inland waters were closed to crab potting in 1999 by the NC Wildlife Resources Commission, a portion of the male resource benefited by having inland sanctuaries. Unless current studies (sperm limitation, and egg viability) or trends dictate otherwise, no action is recommended for the male portion of the spawning population.

Juvenile abundance indices have shown a large amount of variation over time (Figure 7). There is no evidence to suggest that recruitment overfishing is occurring. Although a stock-recruitment relationship has been identified for North Carolina blue crabs, environmental and biotic conditions still play a large role in determining total production.

The underlying hypothesis of a prohibition on the harvest of sponge crabs is that by protecting the spawning stock (defined here as egg-bearing females), the fishery would benefit with more recruits to the fishery. The spawning stock of blue crabs is composed of all mature females, not just egg-bearing females. Studies conducted in South Carolina showed that over 98% of all mature females were fertile [carried a sperm plug (Dr. Elizabeth Wenner, personal communication)]. Hence, the current system (sanctuaries) affords protection to all spawners within the sanctuary; while prohibiting the harvest of sponge crabs would protect spawners only during the short time eggs are visible (approximately 14 days). If it's decided to prohibit the sale or possession of sponge crabs, additional measures to reduce their harvest are warranted to avoid injury to the egg mass (i.e., research needs to be conducted to develop an excluder for crab pots, and areas on the eastern side of the sound would have to be closed to trawling). Sponge crabs captured in crab pots have been observed destroying their egg mass (Dr. Dan Rittschof, Duke University, personal communication), possibly due to stress. Observations of trawl caught sponge crabs indicates that the trawling process damages the egg mass. It is unknown if stress affects the production of eggs, as well as how physical damage from culling and capture may affect egg viability. If these factors did affect egg viability, then the overall benefits of a sponge crab prohibition would be reduced. Prohibiting the harvest of sponge crabs would have a significant economic impact on the crab fisheries in some areas during certain periods. Over a two year sampling period, 27% of the crab catch in and around Ocracoke and Hatteras were sponge crabs (Ballance and Ballance 2004). Additionally, other fisheries (shrimp trawling and gill netting) would have to be restricted.

Spawning sanctuaries in North Carolina have been in place since the mid 1960's. The main assumption of this management concept is that mature females inhabit these areas prior to and during the sponge stage and will remain in these areas during the spawning season. Recent tagging data suggest that this is not the case in all areas. In Core Sound Rittschof (2003) observed that most tagged crabs migrate toward the inlets and many will release their first clutch of eggs prior to reaching the spawning grounds. Some crabs may reenter the fishery but most go out the inlet and move with currents up and down the coast. In Pamlico Sound sponge crabs are present on the spawning grounds from Spring-Fall, and mature females year round (Ballance and Ballance 2002, NCDMF unpublished tagging data 2003). Eggleston (2003) found no significant difference between mature female catches within the sanctuary versus an area 5 km outside of the sanctuary. Tag return data suggest that females tagged on the sanctuaries in Pamlico Sound are consistently caught up to 4 km surrounding the sanctuaries (Ballance and Ballance 2002, and NCDMF unpublished data).

No spawning sanctuaries have been established south of Cape Lookout, N.C. Local crabbers suggest that the deep fast flowing waters of the lower Cape Fear River "ship channel" provides a natural barrier to some crab harvesting practices and thus might serve as a sanctuary area for all crabs. Data from this portion of the state suggests that the lack of adequate juvenile habitat is the main limiting factor in this area (Dr. Martin Posey, UNC-Wilmington, personal communication). Designating spawning sanctuaries or prohibiting sponge crab harvest, as has been suggested by crabbers in the southern coastal area, would have negligible utility since the required habitat for juvenile crabs is limited. Spawning sanctuaries around the southern coastal inlets would prohibit commercial gears currently in use, forcing commercial harvesters into other areas, thereby increasing conflicts among all user groups.

IV. Current Authority:

15A NCAC 3L .0205

(a) It is unlawful to set or use trawls, pots, and mechanical methods for oysters or clams or take crabs with the use of commercial fishing equipment from the crab spawning sanctuaries described in 15A NCAC 03R .0110 from March 1 through August 31.

(b) From September 1 through February 28, the Fisheries Director may, by proclamation, close the crab spawning sanctuaries and may impose any or all of the following restrictions:
    (1) specify number of days;
    (2) specify areas;
    (3) specify means and methods which may be employed in the taking;

(4) specify time period; and
(5) limit the quantity.

V. Management Options/Impacts

(+ potential positive impact of action)
(- potential negative impact of action)

1. No action
   - \+ No rule changes
   - \+ Some level of protection for spawning stock
   - \- Doesn't maximize stock protection

2. Establish spawning sanctuaries around inlets in the southern coastal area.
   - \+ Spawning stock protection
   - \+ Reduce user conflict (navigation)
   - \+ Minimal economic impact as compared with prohibited harvest
   - \- Increase in user conflict (forcing commercial harvesters into other areas)
   - \- Close existing harvest areas
   - \- Decrease in harvest

3. Expand existing spawning sanctuaries (boundaries and/or time).
   - \+ Increase spawning stock protection
   - \+ Reduce user conflict (navigation and other fishing activity)
   - \+ Minimal economic impact as compared with prohibited harvest
   - \+ Ease enforcement burdens (new areas would be delineated to maximize enforcement capabilities)
   - \+ Larger areas would take into account annual variation in salinity
   - \- Increase in user conflict (forcing commercial harvesters into other areas)
   - \- Close existing harvest areas
   - \- Decrease in harvest

4. Reduce existing spawning sanctuaries (boundaries and/or time).
   - \+ Open additional harvest areas
   - \+ Increase in harvest
   - \- Increase in user conflict (navigation)
   - \- Increased potential for recruitment failure

5. Establish a tolerance limit for certain sponge stages (e.g., brown or black sponge).
   - \+ Spawning stock protection
   - \+ Increase in harvest (if sanctuaries rule is repealed)
   - \- Increased potential for recruitment failure
   - \- Possible impact on egg viability
   - \- Enforcement problems

6. Reduce harvest of sponge crabs.
   - \+ Spawning stock protection
   - \- Decrease in harvest
   - \- Increased management related activity (seasons, harvest allocation, opening/closing areas)

7. Repeal existing spawning sanctuary rules.
    + Open additional harvest areas
    + Increase in harvest
    - Increase in user conflict (navigation)
    - Increased potential for recruitment failure

8. Prohibit harvest of all mature females.
    + Increase spawning stock protection (year round)
    - Decrease in harvest (significant)
    - Increase pressure on other harvest segments (males, immature females, peelers)

9. Prohibit harvest of all sponge crabs.
    + Some spawning stock protection (seasonal and by area)
    + Increase in harvest area (if sanctuaries rule is repealed)
    - Decrease in harvest (seasonal and by area)
    - Only limited number of fishers contributing to protection

10. Reduce harvest of mature females.
    + Spawning stock protection
    - Decrease in harvest
    - Increased management related activity (seasons, harvest allocation, opening/closing areas)
    - Increased pressure on other harvest segments (males, immature females, peelers)

11. Establish a seasonal maximum size limit for mature females.
    + Spawning stock protection
    + All fishers would contribute to protection
    - Decrease in harvest
    - Increased enforcement related activity
    - Economic impact to picking houses

RECOMMENDATIONS:

A seasonal maximum size limit for mature females during September through April is recommended and could yield an increase in egg/larval production, and allow large females the opportunity to produce multiple broods over their lifetime (option 11).

DMF recommendation: 6.75 inches maximum size limit, with a 5 percent tolerance.

Crustacean Committee recommendation: 6 7/8 (6.875) inches maximum size limit, with a 5 percent tolerance (Table 4).

MFC recommendation: During a May 2004 MFC meeting, Dr. Dave Eggleston and Eric Johnson (NCSU) gave a presentation on their blue crab stock assessment. Subsequent to this presentation, the MFC discussed and recommended: (1) utilizing a measure of mature female abundance from the DMF Program 195 (Pamlico Sound Fishery Independent Trawl Survey) September survey as an indicator ("spawner index") of spawning stock health, and (2) to utilize the seasonal maximum size limit of 6.75 inches to protect the spawning stock, if female abundance declines below a specified level. Thus, the Program 195 September survey "spawner index" would be used as a trigger mechanism to implement the seasonal maximum size limit. The actual details of the "spawner index" and proposed rule were to be formulated by DMF staff and presented to the MFC for final approval. A "spawner index" was developed (see Attachment 1) with information and input (see Attachment 2) provided by Dr.

Eric Johnson (former NCSU graduate student) and Dr. Dave Eggleston and Dr. Joe Hightower (NCSU researchers).

The proposal developed by DMF is to: establish a seasonal maximum size limit of 6.75 inches (with a 5 percent tolerance) for mature females from September 1 through April 30, if the adjusted catch-per-unit-effort (CPUE - spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years. These actions are recommended in combination with a similar proposal for the peeler segment of the fishery (see Appendix 5).

Sanctuaries afford the greatest protection to spawners, contribute to optimum yield of this resource, and have minimal impact on the majority of fishermen. Current sanctuary boundaries need to be modified to protect spawners. In establishing new sanctuary boundaries ease of identification and enforcement must be considered.

VI. Research Needs:

1) Conduct surveys of existing sanctuary areas to determine population levels and to determine if these areas function as spawning grounds.
2) Conduct tagging studies to determine exploitation rates of different life history stages, movement on and off the spawning grounds, and other life history parameters of female blue crabs.

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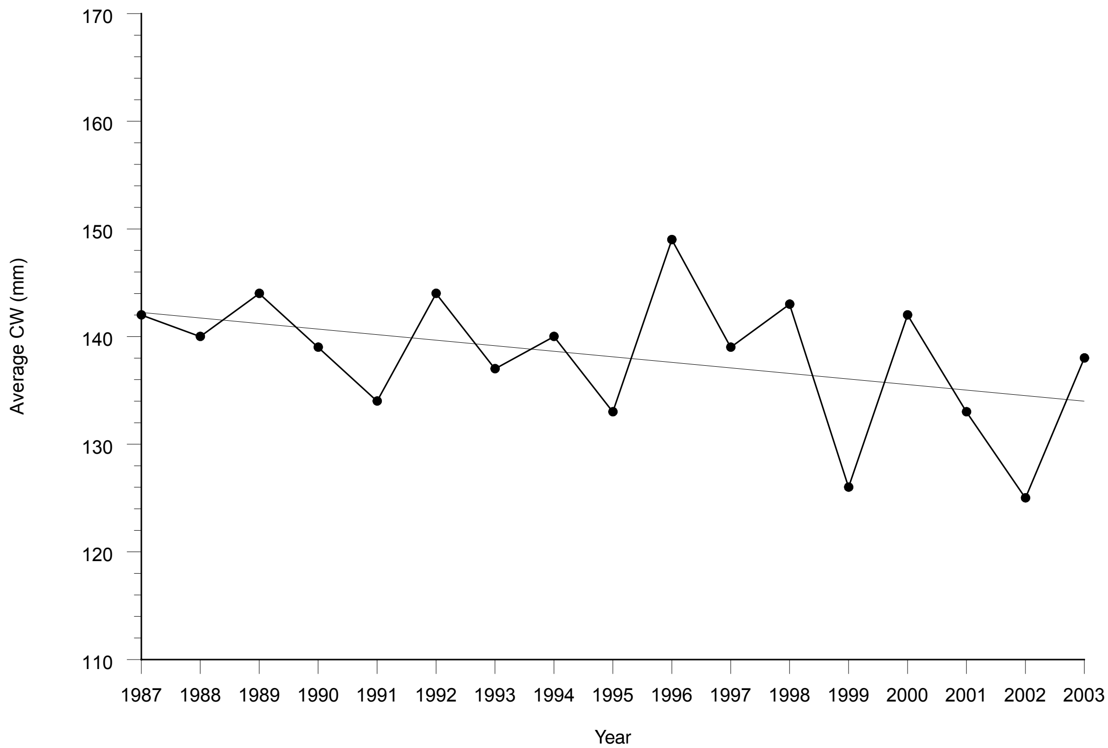

Figure 1. Average carapace width of mature female blue crabs captured in Pamlico Sound Survey: 1987 – 2003 (NCDMF fishery independent data, Program 195).

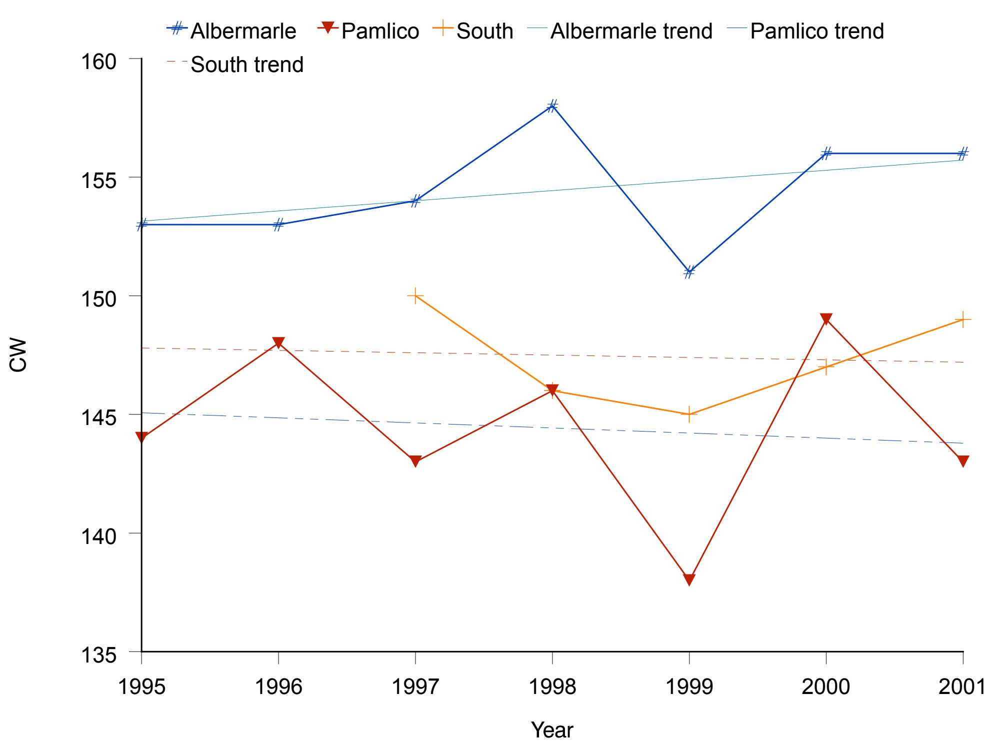

Figure 2. Average carapace width (mm) of mature females in commercial crab pot catches: 1995 – 2001 (data from NCDMF fishery dependent sampling, Program 436).

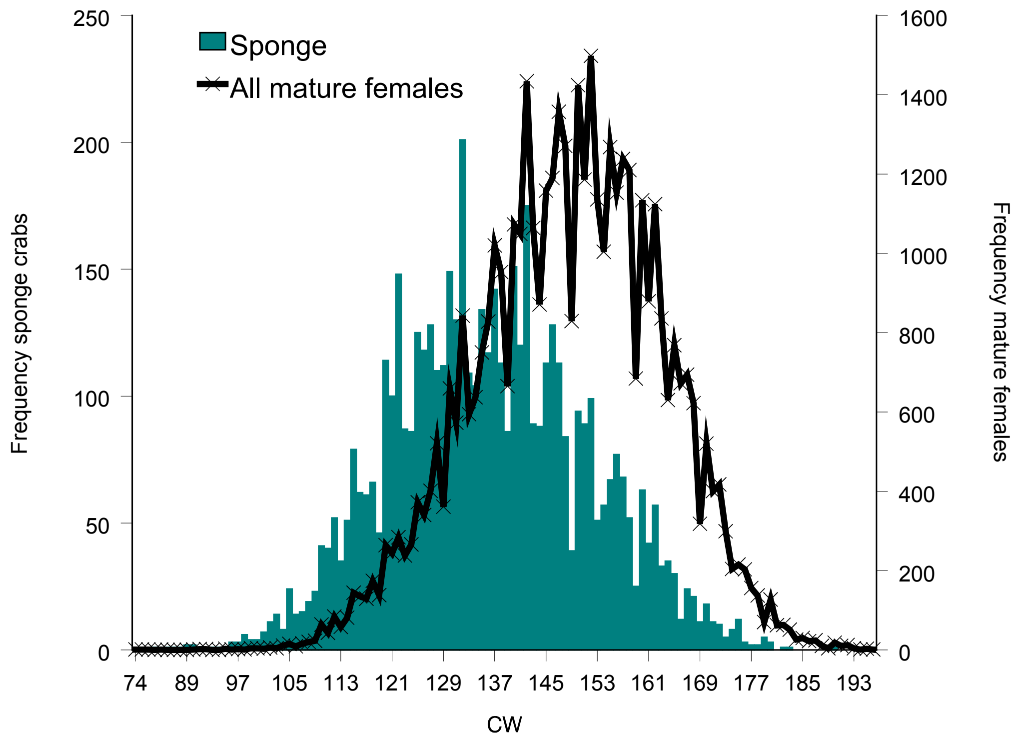

Figure 3. Carapace width (mm) of mature females and sponge crabs from commercial crab pot catches in the Albemarle, and Pamlico areas: 1995 – 2001 (data from NCDMF fishery dependent sampling, Program 436).

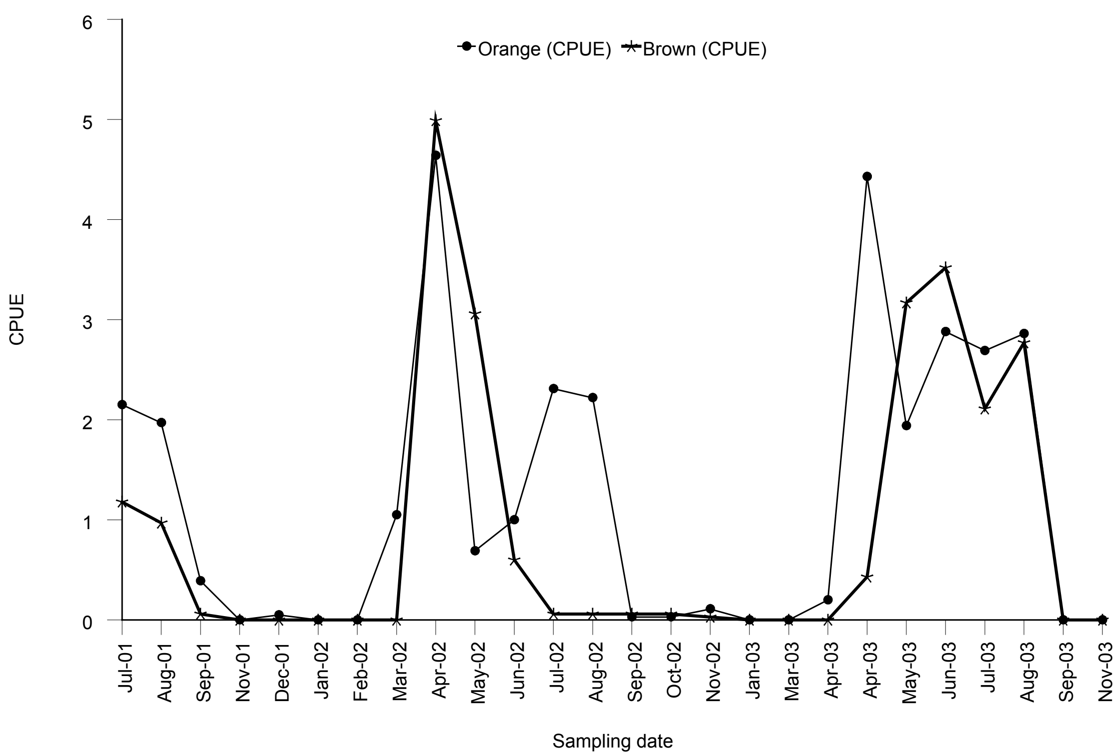

Figure 4. Monthly catch of sponge crabs around the Hatteras crab spawning sanctuary (data provided by Ballance and Ballance 2004).

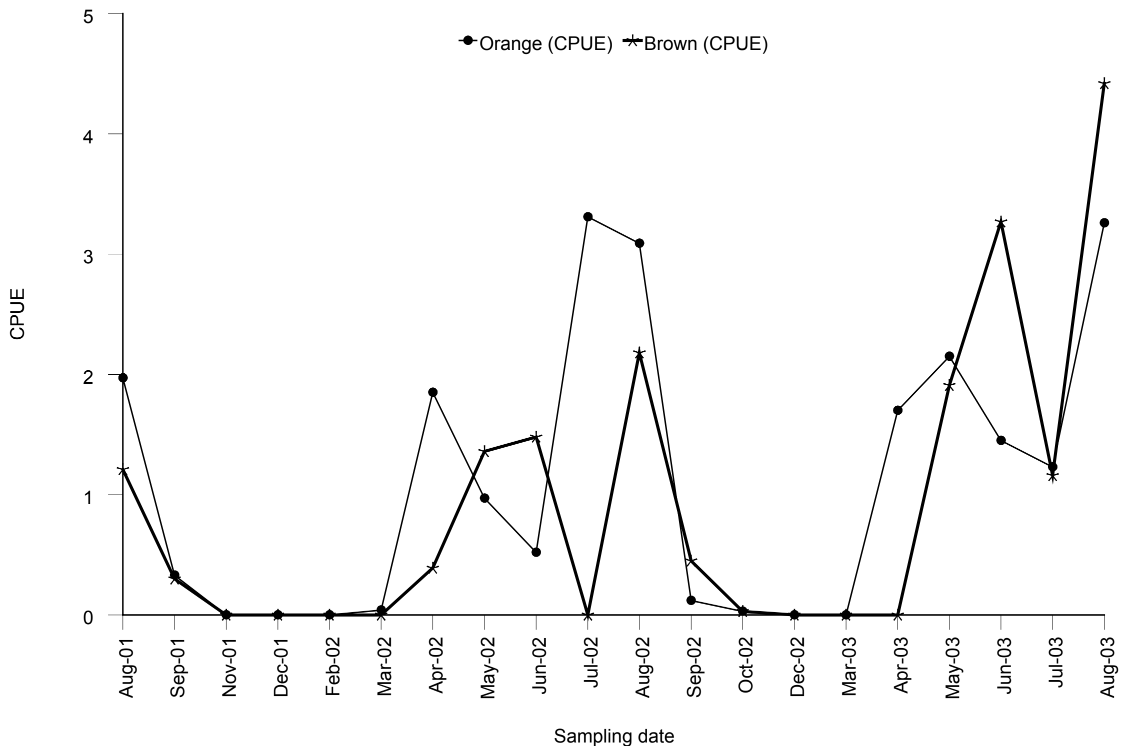

Figure 5. Monthly catch of sponge crabs around the Ocracoke crab spawning sanctuary (data provided by Ballance and Ballance 2004).

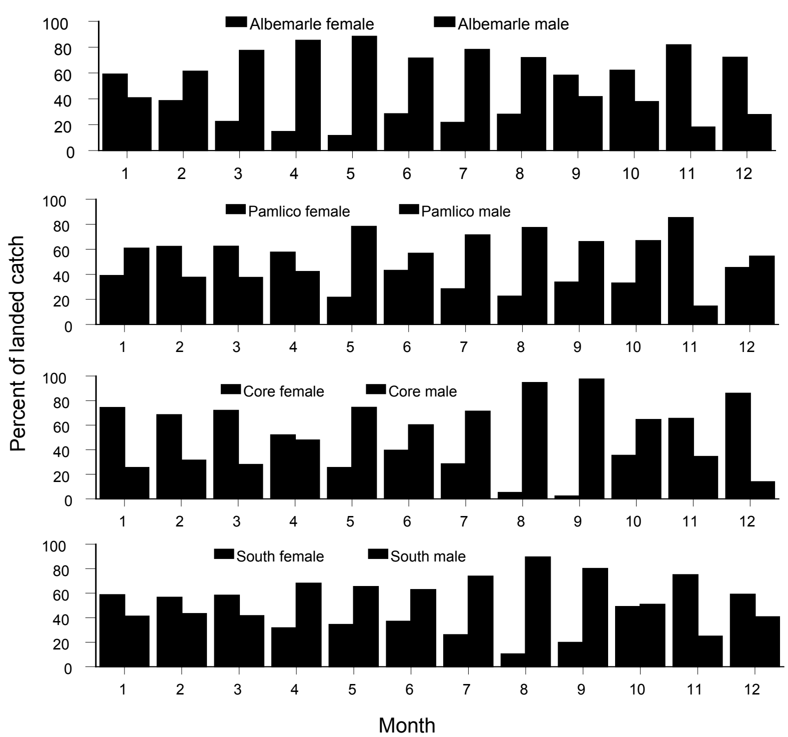

Figure 6. Monthly percent contribution of male and female blue crabs to the total commercial harvest in North Carolina: 1994 – 2002 (Trip Ticket Data).

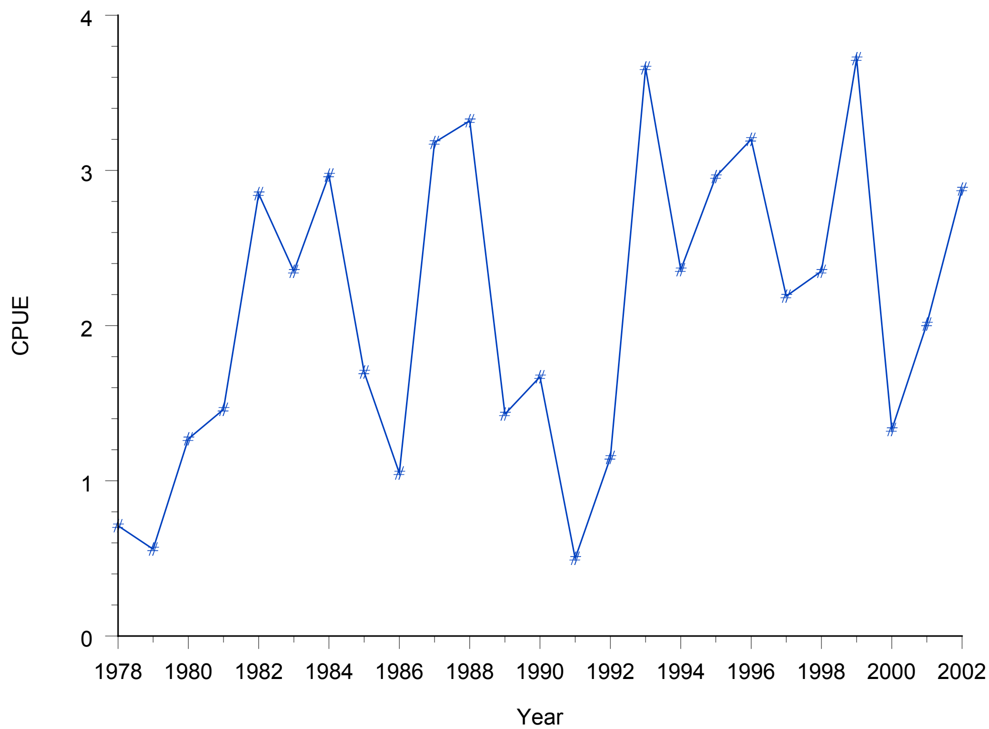

Figure 7. Statewide CPUE of blue crabs <=20mm for North Carolina: 1978 – 2002 (Data from NCDMF trawl surveys conducted in May and June, Program 120).

Table 3. Estimated reduction (pounds) of mature female hard crab landings with a 6.75 inch (172 mm) maximum size limit from September through April.

	Area				
1994 - 2002 landings	Albemarle	Core	Pamlico	Southern	Total
Total lbs.	147,992,325	18,149,907	257,605,429	15,298,165	439,045,825
Sept - April	56,347,747	8,165,817	83,400,050	6,879,615	154,793,229
% Sept - April	38.07	44.99	32.38	44.97	35.26
Total female lbs.	43,511,403	7,564,578	92,149,555	5,377,924	148,623,312
%female total	29.40	41.68	35.77	35.15	33.85
Sept - April (female)	34,434,726	4,304,215	38,635,114	3,285,450	80,670,250
% Sept-April females to total females	79.14	56.90	41.93	61.09	54.28
Total pounds #3's	19,324,829	612,968	21,375,390	1,738,134	43,052,511
Pounds #3's Sept - April	6,549,281	410,522	7,701,574	922,208	15,584,443
% Sept-April #3's to total #3's	33.89	66.97	36.03	53.06	36.20
% reduction with 6.75" maximum size limit*	5.67	2.1	2.1	2.24	
Reduction Sept - April (total female minus #3's)	1,581,105	81,768	649,604	52,937	2,365,413
Reduction Sept - April #3's	371,344	8,621	161,733	20,657	562,356
Total female reduction Sept - April	1,952,449	90,389	811,337	73,594	2,927,769
Yearly estimates					
Total female reduction Sept - April	216,939	10,043	90,149	8,177	325,308
Reduction Sept - April (total female minus #3's)	175,678	9,085	72,178	5,882	262,824
Reduction Sept - April #3's	41,260	958	17,970	2,295	62,484
Number of crabs	650,816	30,130	270,446	24,531	975,923
Percent reduction to average annual harvest	1.3	0.5	0.31	0.48	0.66

* Data from fish house samples

Table 4. Estimated reduction (pounds) of mature female hard crab landings with a 6 7/8 inch (175 mm) maximum size limit from September through April.

	Area				
1994 - 2002 landings	Albemarle	Core	Pamlico	Southern	Total
Total lbs.	147,992,325	18,149,907	257,605,429	15,298,165	439,045,825
Sept - April	56,347,747	8,165,817	83,400,050	6,879,615	154,793,229
% Sept - April	38.07	44.99	32.38	44.97	35.26
Total female lbs.	43,511,403	7,564,578	92,149,555	5,377,924	148,623,312
%female total	29.40	41.68	35.77	35.15	33.85
Sept - April (female)	34,434,726	4,304,215	38,635,114	3,285,450	80,670,250
% Sept-April females to total females	79.14	56.90	41.93	61.09	54.28
Total pounds #3's	19,324,829	612,968	21,375,390	1,738,134	43,052,511
Pounds #3's Sept - April	6,549,281	410,522	7,701,574	922,208	15,584,443
% Sept-April #3's to total #3's	33.89	66.97	36.03	53.06	36.20
% reduction with 6 7/8"" maximum size limit*	3.28	1.27	1.27	1.23	
Reduction Sept - April (total female minus #3's)	914,643	49,450	392,856	29,068	1,386,016
Reduction Sept - April #3's	214,816	5,214	97,810	11,343	329,183
Total female reduction Sept - April	1,129,459	54,664	490,666	40,411	1,715,200
Yearly estimates					
Total female reduction (lbs.) Sept - April	125,495	6,074	54,518	4,490	190,578
Reduction Sept - April (total female minus #3's)	101,627	5,494	43,651	3,230	154,002
Reduction Sept - April #3's	23,868	579	10,868	1,260	36,576
Number of crabs	376,486	18,221	163,555	13,470	571,733
Percent reduction to total annual harvest	0.76	0.3	0.19	0.26	0.39

* Data from fish house samples

Table 5. Estimated reduction (pounds) of mature female hard crab landings with a 7 inch (178 mm) maximum size limit from September through April.

	Area				
1994 - 2002 landings	Albemarle	Core	Pamlico	Southern	Total
Total lbs.	147,992,325	18,149,907	257,605,429	15,298,165	439,045,825
Sept - April	56,347,747	8,165,817	83,400,050	6,879,615	154,793,229
% Sept - April	38.07	44.99	32.38	44.97	35.26
Total female lbs.	43,511,403	7,564,578	92,149,555	5,377,924	148,623,312
%female total	29.40	41.68	35.77	35.15	33.85
Sept - April (female)	34,434,726	4,304,215	38,635,114	3,285,450	80,670,250
% Sept-April females to total females	79.14	56.90	41.93	61.09	54.28
Total pounds #3's	19,324,829	612,968	21,375,390	1,738,134	43,052,511
Pounds #3's Sept - April	6,549,281	410,522	7,701,574	922,208	15,584,443
% Sept-April #3's to total #3's	33.89	66.97	36.03	53.06	36.20
% reduction with 7" maximum size limit*	1.72	0.65	0.65	0.6	
Reduction Sept - April (total female minus #3's)	479,630	25,309	201,068	14,179	720,186
Reduction Sept - April #3's	112,648	2,668	50,060	5,533	170,910
Total female reduction Sept - April	592,277	27,977	251,128	19,713	891,096
Yearly estimates					
Total female reduction Sept - April	65,809	3,109	27,903	2,190	99,011
Reduction Sept - April (total female minus #3's)	53,292	2,812	22,341	1,575	80,021
Reduction Sept - April #3's	12,516	296	5,562	615	18,990
Number of crabs	197,426	9,326	83,709	6,571	297,032
Percent reduction to average annual harvest	0.4	0.2	0.1	0.1	0.2

* Data from fish house samples

Table 6. Percent contribution of various size groups of male blue crabs to total sampled catch: 1995 –2001 (data from NCDMF fishery dependent sampling, Program 436).

		Year							
Area	Size (mm)	1995	1996	1997	1998	1999	2000	2001	Total
Albemarle	126<	13.50%	9.23%	6.52%	1.46%	5.60%	6.95%	6.77%	9.53%
	127-140	37.20%	39.75%	35.45%	20.72%	30.85%	32.28%	37.84%	36.32%
	141-152	28.53%	31.47%	29.77%	36.43%	30.89%	32.74%	30.22%	30.25%
	153-165	15.65%	15.36%	17.21%	29.73%	23.70%	19.97%	17.95%	17.39%
	166-172	2.82%	2.53%	5.14%	7.83%	4.82%	4.05%	3.20%	3.45%
	173-178	1.33%	0.95%	2.41%	1.63%	1.84%	1.43%	1.86%	1.48%
	179>	0.97%	0.72%	3.50%	2.20%	2.29%	2.57%	2.16%	1.57%
Pamlico	126<	32.08%	13.60%	14.04%	14.56%	13.16%	15.98%	11.91%	16.41%
	127-140	42.23%	42.96%	43.23%	33.77%	46.42%	35.53%	47.50%	41.59%
	141-152	18.49%	26.95%	28.17%	27.15%	26.58%	26.25%	26.67%	26.09%
	153-165	5.66%	12.86%	11.43%	16.37%	10.63%	17.16%	10.22%	12.02%
	166-172	1.00%	2.23%	1.96%	4.63%	1.77%	3.27%	2.23%	2.36%
	173-178	0.40%	0.92%	0.66%	2.03%	0.55%	1.32%	0.61%	0.91%
	179>	0.13%	0.48%	0.51%	1.49%	0.89%	0.49%	0.85%	0.62%
Rivers	126<	4.26%	8.60%	11.18%	8.74%	11.25%	8.81%	4.38%	9.39%
	127-140	32.74%	44.14%	40.68%	26.51%	51.77%	28.30%	31.39%	38.50%
	141-152	34.53%	28.53%	29.47%	30.46%	25.58%	26.26%	33.58%	29.26%
	153-165	20.85%	14.49%	14.12%	21.88%	9.09%	25.47%	20.07%	16.44%
	166-172	5.16%	2.63%	2.77%	6.94%	1.08%	6.92%	6.20%	3.81%
	173-178	2.02%	0.91%	1.04%	3.10%	0.62%	2.83%	1.09%	1.50%
	179>	0.45%	0.70%	0.75%	2.37%	0.62%	1.42%	3.28%	1.11%
South	126<	ND	ND	5.24%	10.70%	8.27%	9.76%	11.05%	9.39%
	127-140	ND	ND	38.65%	40.65%	42.64%	40.71%	41.22%	41.06%
	141-152	ND	ND	33.11%	31.42%	28.73%	30.79%	30.13%	30.51%
	153-165	ND	ND	19.67%	15.29%	15.73%	15.79%	14.30%	15.77%
	166-172	ND	ND	2.05%	1.31%	2.91%	1.98%	1.79%	2.05%
	173-178	ND	ND	0.99%	0.48%	1.07%	0.72%	1.08%	0.85%
	179>	ND	ND	0.30%	0.16%	0.66%	0.25%	0.41%	0.37%

ND = no data collected

ATTACHMENT 1

Spawning Stock Trigger for Implementing Maximum Size Limits for Female Blue Crabs

12/3/04

Measures to protect the blue crab spawning stock [maximum size limit for mature females (6 ¾”) and female peeler crabs (5 ¼”) from September through April] will be implemented when the adjusted CPUE of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (LCL = 493) for two consecutive years (Figure 1). These management measures will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years. The maximum size limit rule will be managed through the proclamation authority of Fisheries Director.

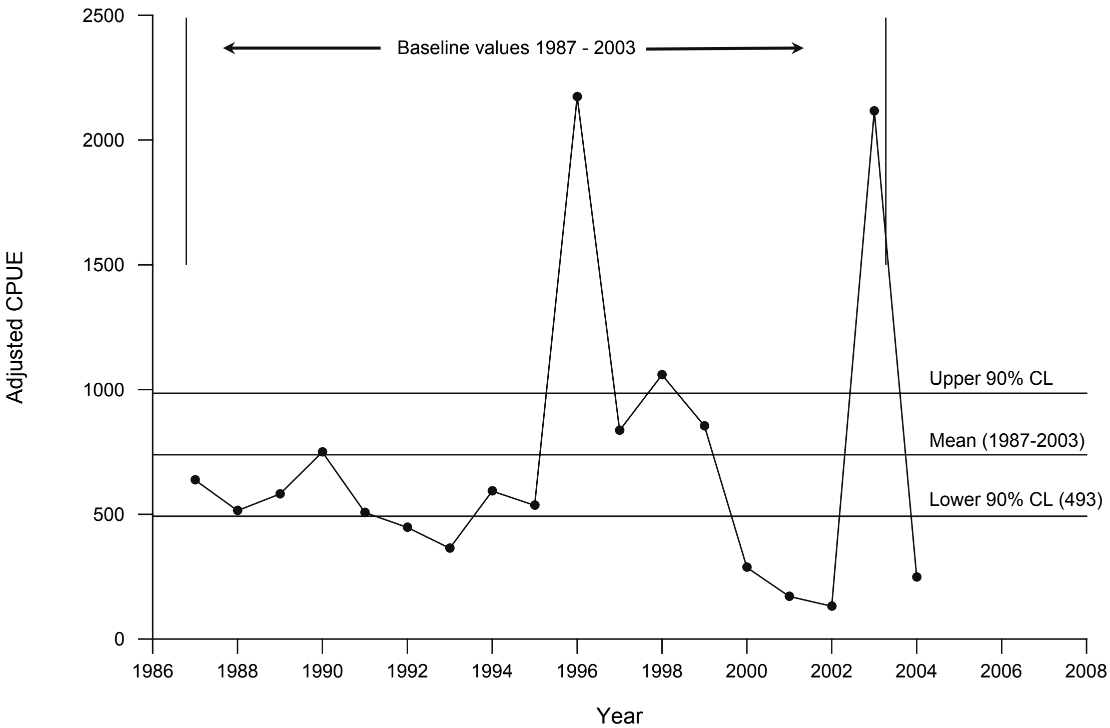

Figure 1. Adjusted CPUE (total carapace width (CW)/number of tows) for mature females collected in the Program 195 September cruise (1987-2004).

The reference baseline for the trigger is 1987 through 2003. Every five years when the plan is reviewed the baseline values will be updated. However, if the maximum size limit management measures are in place, the baseline update will be delayed until the measures are removed.

Adjusted CPUE is calculated by obtaining the sum of the carapace widths (CW) for mature female blue crabs collected during the Program 195 September cruise and dividing that value by the total number of tows (Figure 1). The CPUE adjusted by carapace width utilizes the size of females, similar to SSB estimates, as an indicator of spawning stock potential (egg production), with larger crabs contributing more than smaller individuals. The adjusted CPUE was chosen over the spawning stock biomass (SSB) estimate for three reasons:

1). The high correlation (r = 0.9969) between the two estimates (Figure 2);

2). The almost identical correlations between the two estimates and statewide hard crab landings from 1987-2003 (adjusted CPUE: r = 0.575 and SSB: r = 0.572), and good correlations with landings during the period from 1994-2002 (Figure 3; adjusted CPUE: r = 0.875 and SSB: r = 0.846); and

3). Ease of calculation.

   a). Carapace width is collected during the survey.

   b). Weight is not collected and must be estimated from a regression equation generated for blue crabs from the Chesapeake Bay.

The SSB adjusted for salinity was also examined. These values were correlated (r=0.76) with adjusted CPUE (Figure 4), and except in 1993, the general trends of the two estimates were the same. The same reasons for not using SSB apply to the adjusted SSB model. In addition, although salinity does affect female blue crab distribution (Eggleston et. al. 2004), other factors (such as water temperature, rainfall, storm events, etc.) also affect their distribution. Until these factors can be incorporated into the model the adjusted CPUE method appears to be the most appropriate measure of female spawning stock.

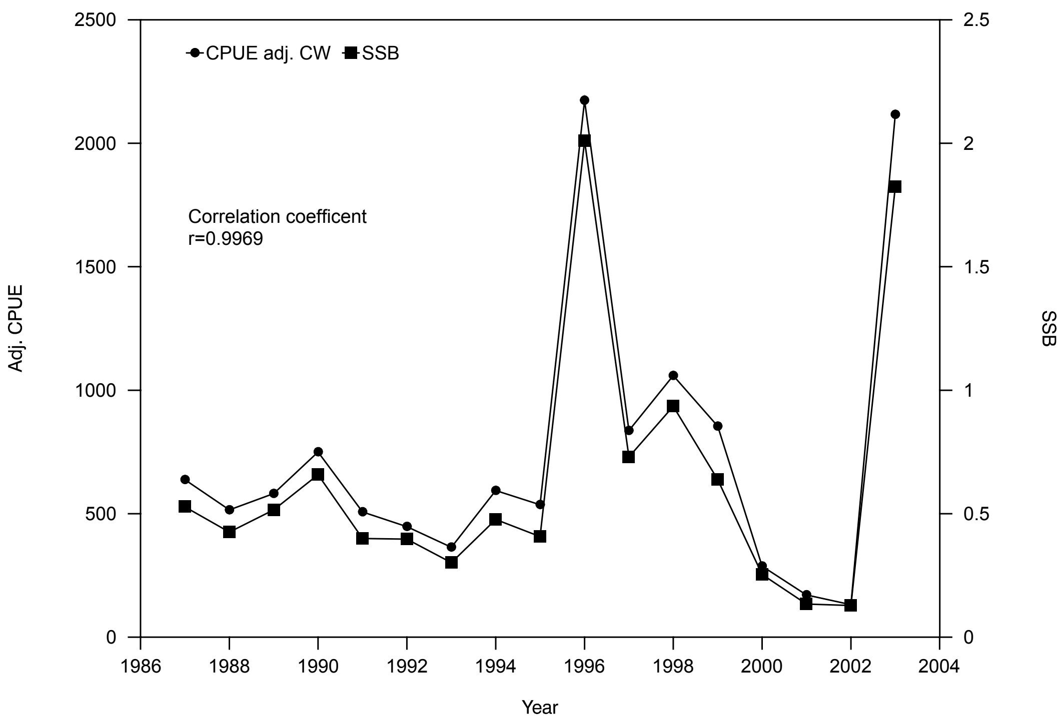

Figure 2. Comparison of adjusted CPUE and spawning stock biomass estimates of mature female blue crabs captured during the Program 195 September cruise (1987-2003).

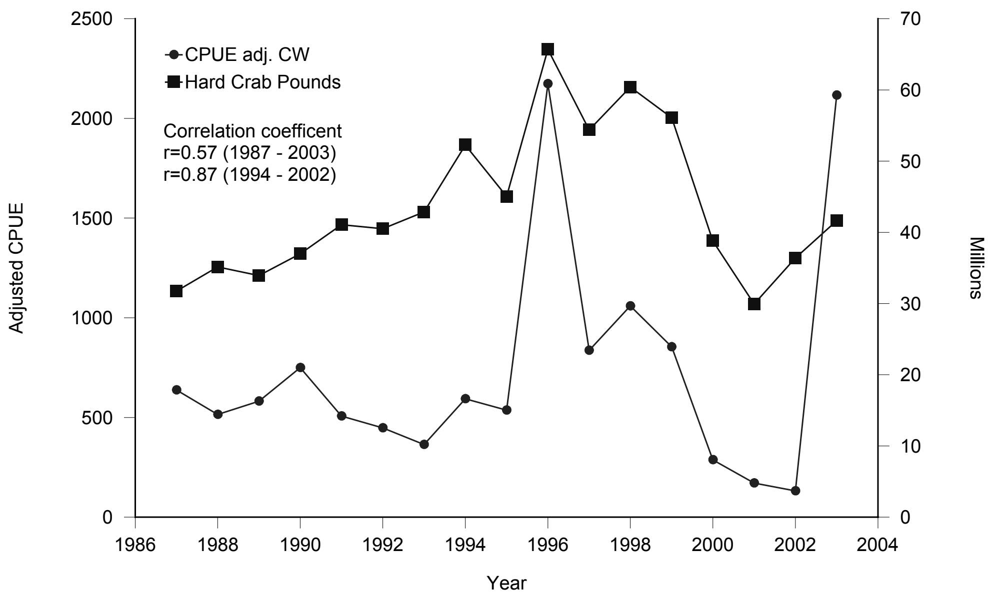

Figure 3. Correlation of adjusted CPUE and hard crab landings (1987-2003).

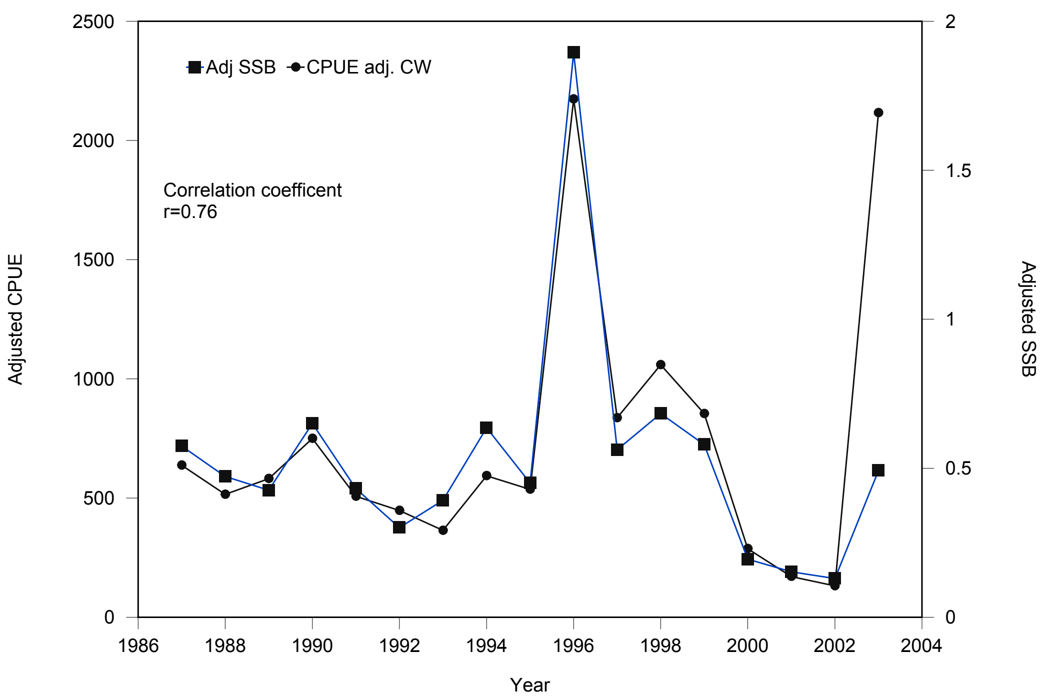

Figure 4. Comparison of adjusted CPUE and salinity adjusted spawning stock biomass estimates of mature female blue crabs captured during the Program 195 September cruise (1987-2003).

ATTACHMENT 2

Update to Salinity-Adjusted Indices of Blue Crab Spawning Stock Biomass and Scenarios to Trigger Management Options

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Rationale

This update was provided in response to Lynn Henry's (NC DMF) request for assistance in identifying scenarios that would trigger an upper size limit on mature female blue crabs as a means to conserve the spawning stock.

Methods

We requested and received data from Katy West for blue crabs from Program 195 for the period 1987-2003. This data was used to reanalyze the effects of salinity on our index of blue crab spawning stock biomass (Eggleston et al. 2004) using an ANCOVA. The ANCOVA approach, whereby each station in P195 was paired with bottom salinity measurements for that station, allowed us to present salinity-adjusted cpue indices of blue crab spawning stock biomass (i.e., the least-square means from the ANCOVA), rather than using the residuals of a regression between of annual indices of SSB and salinity, as was the case in our recent blue crab stock assessment (Eggleston et al. 2004).

After a revised, salinity-adjusted index of SSB was generated, we examined trends in this time series along with 95% confidence intervals in the context of scenarios that would trigger an upper size limit on the blue crab. We examined 4 scenarios that would trigger new regulations based on the current blue crab management plan, which states "if the September spawning stock biomass (Program 195) declines for 3 consecutive years, then the 6.75 inch maximum size on mature females (5% tolerance) and the 5.25 inch max. size on female peelers (3% tolerance) during Sept. - April would be triggered as a new regulation".

Results & Discussion

The annual trend in mean salinity-adjusted cpue of blue crab SSB indicates that the upper size limit management regulation, as described above and in the in the current blue crab FMP, would have been triggered 5 times since 1987 (Figure 1). Thus, given how the blue crab population has rebounded in 4 of the 5 cases (and possibly the fifth but it is too early to tell), the current wording for when to trigger the upper size limit seems too conservative. Several other triggering scenarios may be more preferable to the NC DMF, such as a combination of **(1) three consecutive years where the salinity-adjusted SSB declines, AND (2) three consecutive years below the mean cpue since 1987** (Table 1). The management regulation of an upper size limit could be relaxed after three consecutive years of increasing SSB cpue. Given that we do not know whether or not the overall average cpue will decline, increase, or remain the same, we suggest that the mean cpue which is used as a benchmark be re-calculated each year based on the most recent datum, but that this criteria of using a "moving average" be re-evaluated in the event that mean cpue is in continuous decline.

In terms of our revised, salinity adjusted SSB it is important to note that the trends in our original salinity-adjusted residuals of the relationship between SSB and salinity, and our new salinity-adjusted cpue indices are virtually the same (Figure 2). Thus, the major conclusions regarding trends in SSB based on our recent stock assessment (Eggleston et al. 2004) still hold.

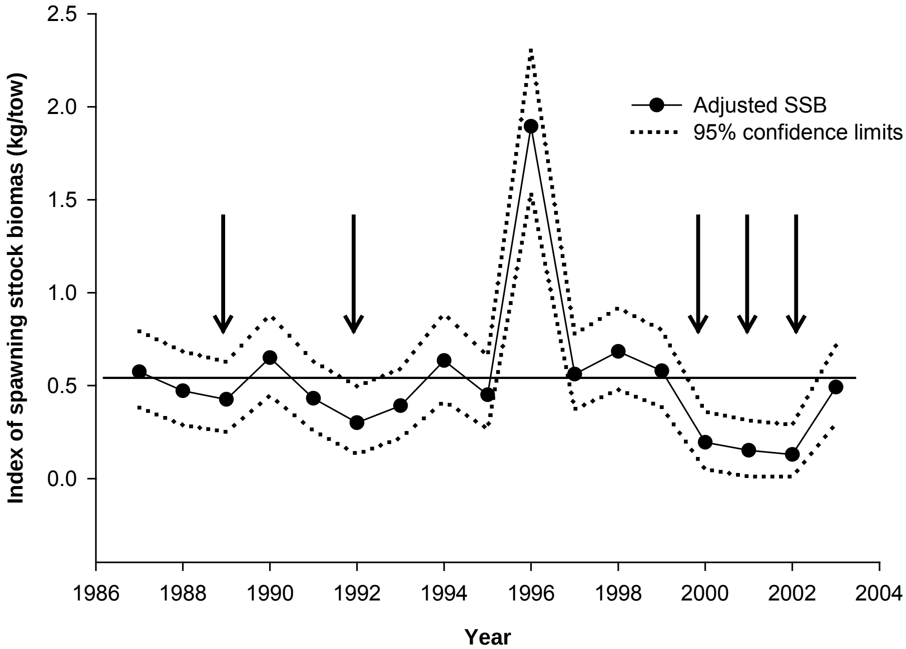

Figure 1. Annual adjuested mean trawl survey survey index of spawning stock biomass (SSB; kg/tow) collected in September from NC DMF Program 195 pooled across water bodies in North Carolina. Unadjusted SSB values were adjusted for the effect of salinity using an ANCOVA model. The dotted lines represent upper and lower 95% confidence limits. The solid horizontal line represents the average adjusted SSB for the time series. The black arrows represent years in which the criteria of three consecutive years of delcining SSB proposed by the NC DMF would have been met.

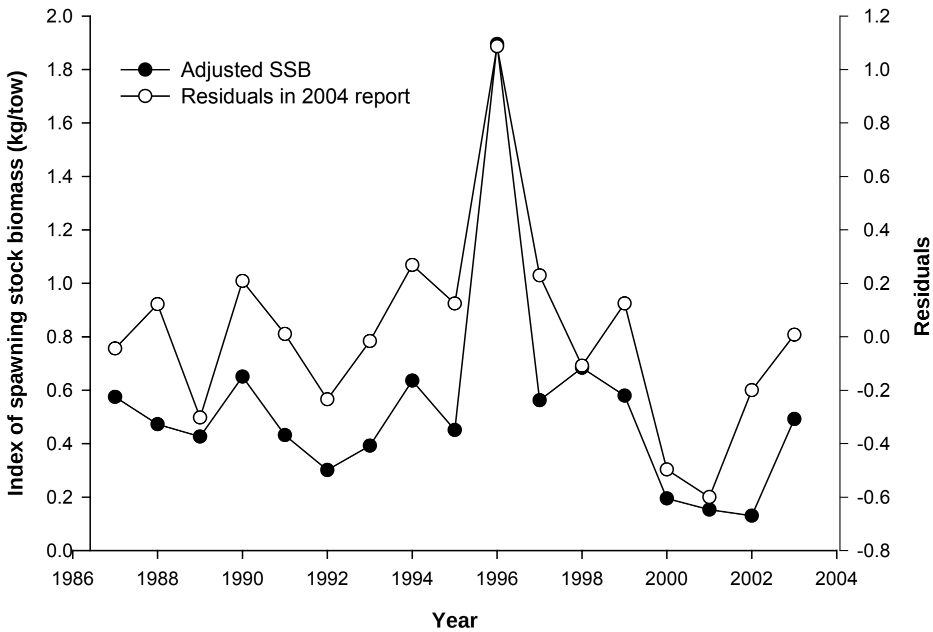

Figure 2. Annual adjusted mean trawl survey index of spawning stock biomass (**solid circles**) and residulals of a hyperbolic regression of salinity on SSB from the 2004 final report (**open circles**; see Eggleston et al. 2004 for details) collected in September from NC DMF Program 195 pooled across water bodies in North Carolina. Unadjusted SSB values were adjusted for the effect of salinity using an ANCOVA model.

Table 1. Years in which NC DMF regulation prohibiting harvest of mature females greater than 6.75" would have been triggered under varying triggering criterion scenarios. A bold X denotes that a selection criterion was used in a given scenario (labeled A-F).

Criterion triggering regulation	A	B	C	D	E
Three consecutive years of declining SSB	**X**	**X**		**X**	
Two of the three years below the long-term mean		**X**			
Three consecutive years below the long-term mean			**X**	**X**	
SSB declines by more than 50% over three year period					**X**
Years in which regulation would have been triggered					
1987					
1988					
1989	**X**	**X**			
1990					
1991					
1992	**X**	**X**			**X**
1993			**X**		
1994					
1995					
1996					
1997					
1998					**X**
1999					
2000	**X**				**X**
2001	**X**	**X**			**X**
2002	**X**	**X**	**X**	**X**	
2003			**X**		
Number of years regulation would be triggered (1987-2003)	**5**	**4**	**3**	**1**	**4**

12.5 Appendix 5. PEELER/SOFT CRAB HARVEST

I. Issue:

Increased effort and harvest in the peeler/soft blue crab fishery and reduced adult harvest has prompted concern about the impacts of peeler/soft crab harvest on the overall health of the fishery.

II. Background:

Peeler and soft crabs are exempt from the 5 inch minimum size limit [Rule 15A NCAC 3L .0201(MFC 2003)]. Law enforcement officers have found, in certain cases, that fishermen use the peeler crab exemption to circumvent the minimum size limit and culling tolerance. A peeler/soft crab size limit could allow more effective and efficient enforcement of the minimum size limit.

Molting (or shedding) is the process by which blue crabs shed their shells and grow. Before molting, a new shell is formed beneath the outer shell of the crab. Fishermen use color changes (signs) in the last two sections of the swimming legs to determine the time to next molt. Peeler crabs (hard crabs that exhibit signs of impending shedding or molting) are defined by Rule 15A NCAC 3I .0101 (b) (16) (MFC 2003) as: a blue crab that has a soft shell developing under a hard shell and having a definite pink, white, or red line or rim on the outer edge of the back fin or flipper. White-line peeler crabs are within two weeks of molt, pink-line crabs are within one week, and red-line crabs are within 1 - 3 days of shedding (Oesterling 1995). During their lifetime, a crab may molt 18 - 22 times. Within 12 hours after the molt, the shell is like parchment and will fully harden within 2 - 3 days. Crab shedding operations collect "peelers" and hold them in tanks until they molt to "soft" crabs.

Natural mortality of sublegal crabs (less than five inches) is in the range of 26 to 32% per year in Chesapeake Bay (Casey et al. 1992). Eggleston (1998) estimated an annual mortality rate of 50% for sub-adult and adult blue crabs in North Carolina. Chaves and Eggleston (2003) reported an average mortality of 23% for a typical 5-day shedding cycle, with crab size having no effect on mortality rates.

Current peeler fishing practices, employing live male crabs as an attractant or bait, target immature female peelers. Therefore, the vast majority of the peelers harvested are immature females that are approaching their terminal molt. Reducing fishing mortality on this segment of the population would contribute to efforts to protect the stock.

A Maryland DNR report noted that raising the peeler size limit would potentially provide an increase in spawning stock biomass by allowing more females to enter the spawning population, thereby reducing the potential for recruitment overfishing (Uphoff et al. 1993). The percent of mature females (assuming a 30% increase in size after the peeler sheds) rises rapidly with an increase in peeler minimum size from 3.0 inches (0%) to 3.5 inches (30-40%) or from 3.0 inches to 4.0 inches (80-90%; Rothschild et al. 1992). With a minimum size limit between 3.5 and 4.0 inches, female soft crabs must molt one or two more times to reach maturity. Approximately, 10% would be mature at 4.5 inches and nearly 90% would be mature at 5.0 inches (Rothschild et al. 1992).

Raising the size limit should also increase yield to the fishery (Uphoff et al. 1993). An increase of 0.5 inch to the minimum 3.0 inch peeler size increases the after-shedding weight of an individual crab by an additional 60% and an increase of 1.0 inch increases individual weight by 120%. The time interval between sheds of 3.0 or 3.5 inch crabs will generally be one to three months (Rothschild et al. 1992). The increase in yield from an increased peeler size limit would not be totally lost to natural mortality. Increasing the peeler size limit one half inch would result in a 9% drop in numbers and a

25% increase in yield by weight at 3.5 inches. Increasing from 3.0 to 4.0 inches decreases numbers by 18% and increases yield at the new minimum size by 49%. As the time between sheds increases with increasing size, the probability of capture of larger crabs at the peeler stage decreases.

No data are available on the peeler sizes that are harvested in North Carolina, however soft crab sales are recorded by market grade (size) through the NCDMF Trip Ticket Program. Soft crabs are normally graded by size (inches) into five market categories. These industry established soft crab market grades are:

1) Mediums	3.5 – 4.0 inches,
2) Hotels	4.0 – 4.5 inches,
3) Primes	4.5 – 5.0 inches,
4) Jumbos	5.0 – 5.5 inches, and
5) Whales/Slabs	5.5 inches and greater.

Extra small, small, large, and mixed were four additional grades that were recorded on DMF Trip Tickets. Discussion of the Trip Ticket data with several soft crab shedders indicated that the extra small and small categories were likely Mediums and the large were Jumbos. Trip Ticket data for soft crabs by market grade for the past three years (2000-2002) is summarized in Table 1 and Figure 1. In this summary, extra small and small are as reported and the large grade is assumed to be Jumbo. Soft shells that were reported in the mixed category could be any size. However, we assumed that the approximately 40% that were reported in the graded sizes provided a representative subsample of the mixed category (Table 2 and Figure 2). Based on the market grade soft shell data, small peeler harvest and the resulting soft shell crabs comprise a very small percentage (2.3%) of the overall harvest. Medium soft crabs, the smallest industry defined grade (3.0-4.0 inches), make up 3.2% of the harvest. Peelers yielding soft crabs in the x-small, small and Medium grades may not meet the established 3.0 inch minimum peeler size limit in most states. However, assuming an average 30% increase in size, a 2.75 inch peeler would yield a Medium 3.57 inch soft crab, with a 3.0 inch peeler producing a 3.9 inch soft shell. Overall the graded soft crab harvest is dominated (58%) by crabs in the Jumbo (5.0-5.5 inch) market grade. A 3.9 inch peeler would yield a Jumbo soft crab of approximately 5.07 inches.

Whale soft crabs, the largest industry defined grade (5.5 inches and greater), contribute approximately 27% of the total harvest. Assuming an average 30% increase in size, a 4.25 inch peeler would yield a 5.5 inch Whale soft crab and a 5.25 inch peeler would yield a 6.75 inch Whale soft crab. Various researchers, biologists, and crabbers have expressed concern about: 1) the potentially excessive fall harvest of mature female crabs, 2) a reduction in female size, and 3) the reduced abundance of large male and female crabs that potentially contribute to larger and more viable egg production. Reducing harvest on a portion of these larger peeler/soft crabs through a maximum size limit for peeler crabs would help to address these concerns by conserving a portion of the spawning stock. Affording protection to the larger crabs should yield the greatest conservation benefits as natural mortality is reduced on larger crabs. The estimated reduction in harvest with a 4.25 inch peeler maximum size limit during September – December is 2.7% (Table2). This reduction is based on eliminating the harvest of peeler crabs greater than 4.25 inches that would yield Whale soft crabs (5.53 inches) during September – December (Table2). The estimated reduction in harvest with a 5.25 inch peeler maximum size limit during September – April is 3.4% (Table2). This reduction is based on eliminating the harvest of peeler crabs greater than 4.25 inches that would yield Whale soft crabs (5.53 inches) during September – April (Table2). A reliable estimate for the percent reduction of 5.25 inch peelers can not be made, so the percent reduction was based on the elimination of all Whale soft crabs.

III. Discussion:

Several of the Atlantic and Gulf Coast States have minimum size limit restrictions on peeler and/or soft crab harvest. Minimum size limits (3 inches for peelers and 3.5 inches for soft crabs) in Maryland date back to 1929, and like many size limits of the time, probably reflected perceived marketability by seafood dealers (Uphoff et al. 1993). During 2002 in order to achieve a reduction in fishing mortality as recommended by the Chesapeake Bay Commission, Maryland increased it's minimum size limit for peelers to 3.25 inches (April 1-July 14) and to 3.5 inches (July 15-Dec. 15)]. Adopting a minimum size limit of 3 inches for peelers and/or 3.5 inches for soft crabs would address regulatory consistency among most Atlantic Coast States and foster interstate trade.

The overall value of the peeler/soft crab fishery might be enhanced by a size limit as larger soft crabs generally bring a higher price. A potential adverse impact on the soft crab fishery would be a decrease in market flexibility, particularly during the early spring when product availability is low and small peeler/soft crabs are in demand, bringing very high prices to fishermen. A size limit might increase handling mortality and waste in the fishery.

NC Trip Ticket market grade soft crab data suggest that the NC shedding industry is principally harvesting peelers in excess of the 3.0 inch minimum peeler size limit requirements in most states. Based on this market grade (size) distribution, natural mortality estimates for small crabs, and the potential for subsequent harvest after achieving legal size limits, the implementation of peeler/soft crab minimum size limits would not yield considerable benefits towards conservation of the spawning stock. Implementing minimum size limits would place an unjustified burden on the participants in the peeler/soft crab shedder fishery (Figure 3) and DMF enforcement. Consequently, a peeler minimum size limit does not appear to be justified at this time.

Considerable concern has been expressed about the need to provide additional protection to the spawning stock. During the fall season, when crabbing effort is already declining and crab prices are low, is the most opportune time to implement conservation measures. A maximum size limit of 5.25 inches for peeler crabs from September – April should provide some conservation of potential spawners, while having a minimal impact on the shedder industry.

IV. Current Authority:

15A NCAC 3L .0101 SIZE LIMIT AND CULLING TOLERANCE (MFC 2003)

(a) It is unlawful to possess blue crabs less than five inches from tip of spike to tip of spike except mature females, soft and peeler crabs and from March 1 through October 31, male crabs to be used as peeler bait. A tolerance of not more than 10 percent by number in any container shall be allowed.

(b) All crabs less than legal size, except mature female and soft crabs shall be immediately returned to the waters from which taken. Peeler crabs shall be separated where taken and placed in a separate container. Those peeler crabs not separated shall be deemed hard crabs and are not exempt from the size restrictions specified in Paragraph (a) of this Rule.

15A NCAC 3I .0101 DEFINITIONS (MFC 2003)

(a) All definitions set out in G.S. 113, Subchapter IV apply to this Chapter.

(b) The following additional terms are hereby defined:

(16) Peeler Crab. A blue crab that has a soft shell developing under a hard shell and having a definite pink, white, or red line or rim on the outer edge of the back fin or flipper.

(50) Blue Crab Shedding. Shedding is defined as the process whereby a blue crab emerges soft from its former hard exoskeleton. A shedding operation is any operation that holds peeler

crabs in a controlled environment. A controlled environment provides and maintains throughout the shedding process one or more of the following: predator protection, food, water circulation, salinity or temperature controls utilizing proven technology not found in the natural environment. A shedding operation does not include transporting peeler crabs to a permitted shedding operation.

V. Management Options/ Impacts:

(+ potential positive impact of action)
(- potential negative impact of action)

1. No rule change.
   - \+ Crab shedders have existing "peelers", as defined, to hold for producing soft crabs
   - \+ Allows for market flexibility
   - \+ Reduced handling mortality and waste
   - \- Fishermen may use peeler/soft crab exemption to exceed size tolerance
   - \- No protection for small peeler/soft crabs
   - \- Potential for increased harvest pressure on small peeler/soft crabs

2. Establish a minimum size limit for peelers and/or soft crabs.
   - \+ Enable better enforcement of size limit
   - \+ Protect small peeler/soft crabs
   - \+ Reduce harvest of small peeler/soft crabs
   - \+ Increase regulatory consistency among states
   - \+ Potential increase in spawning stock biomass
   - \+ Increased yield
   - \- Increased enforcement burden
   - \- Eliminate early high price market for small peeler/soft crabs
   - \- Potentially increase handling mortality and waste
   - \- Reduce existing peeler availability

3. Establish a seasonal minimum size limit for peelers and/or soft crabs.
   - \+ Enable better enforcement of size limit
   - \+ Protect small peeler/soft crabs
   - \+ Reduce harvest of small peeler/soft crabs
   - \+ Increase regulatory consistency among states
   - \+ Potential increase in spawning stock biomass
   - \+ Increased yield
   - \- Increased enforcement burden
   - \- Eliminate early high price market for small peeler/soft crabs
   - \- Potentially increase handling mortality and waste
   - \- Reduce existing peeler availability

4. Establish a seasonal maximum size limit for peelers and/or soft crabs.
   - \+ Protect large peeler/soft crabs
   - \+ Reduce harvest of large peeler/soft crabs
   - \+ Potential increase in spawning stock biomass
   - \+ Increased potential long-term yield
   - \- Increased enforcement burden
   - \- Potentially increase handling mortality and waste

- Reduce existing peeler availability
- Decreased short-term yield

Options two, three, and four would require a rule change by the MFC.

Recommendations:

Considerable concern has been expressed about the need to provide additional protection to the spawning stock. A maximum size limit of 5.25 inches for female peeler crabs from September through April with a 3 percent tolerance is recommended and should provide some conservation of potential spawners, while having a minimal impact on the shedder industry (option 4). Promoting educational efforts targeting harvesters/shedders on the mortality associated with the shedding of peeler crabs and peeler handling practices would help to further reduce mortality.

The Crustacean Committee's and DMF's preferred option is Option 4.

<u>MFC recommendation</u>: During a May 2004 MFC meeting, Dr. Dave Eggleston and Eric Johnson (NCSU) gave a presentation on their blue crab stock assessment. Subsequent to this presentation, the MFC discussed and recommended: (1) utilizing a measure of mature female abundance from the DMF Program 195 (Pamlico Sound Fishery Independent Trawl Survey) September survey as an indicator ("spawner index") of spawning stock health, and (2) to utilize the seasonal maximum size limit of 5.25 inches for female peeler crabs to protect the spawning stock, if female abundance declines below a specified level. Thus, the Program 195 September survey "spawner index" would be used as a trigger mechanism to implement the seasonal maximum size limit. The actual details of the "spawner index" and proposed rule were to be formulated by DMF staff and presented to the MFC for final approval. A "spawner index" was developed with information and input provided by Dr. Eric Johnson (former NCSU graduate student) and Dr. Dave Eggleston and Dr. Joe Hightower (NCSU researchers).

The proposal developed by DMF is to: establish a seasonal maximum size limit of 5.25 inches (with a 3 percent tolerance) for female peeler crabs from September 1 through April 30, if the adjusted catch-per-unit-effort (CPUE - spawner index) of mature females captured in Program 195 (Pamlico Sound Fishery Independent Trawl Survey) during the September cruise falls below the lower 90% confidence limit (CL) for two consecutive years. This management measure will be removed when the September adjusted CPUE of mature females rises above the lower 90% confidence limit for two consecutive years (see Appendix 4, Attachment 1). These actions are recommended in combination with a similar proposal for the mature female spawning stock segment of the fishery (see Appendix 4).

VI. Research Needs:

1) Shedding mortality rates by size, area, and season.
2) Develop more effective harvest, handling, and shedding practices to minimize mortality.
3) Economic impact of implementing minimum size limit.

VII. Literature Cited:

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Table 1. Percent of total soft crab market grades (inches) by month for 2000-2002; mixed category included (NCDMF Trip Ticket Program).

	Market Grade								
	Size ?	Size ?	3.5 - 4"	4 - 4.5"	4.5 - 5"	5 - 5.5"	5.5” & up	Size ?	
Month	X-small	Small	Medium	Hotel	Prime	Jumbo	Whale/Slab	Mixed	Total
January	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
March	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
April	0.00%	0.15%	0.14%	0.12%	0.38%	1.28%	0.27%	5.35%	7.68%
May	0.01%	0.25%	0.38%	0.37%	1.74%	8.37%	4.31%	31.54%	46.97%
June	0.00%	0.21%	0.25%	0.09%	0.44%	2.32%	1.50%	11.00%	15.81%
July	0.00%	0.19%	0.23%	0.03%	0.11%	1.04%	0.78%	1.60%	3.97%
August	0.00%	0.06%	0.16%	0.01%	0.12%	5.70%	2.70%	8.88%	17.62%
September	0.00%	0.01%	0.06%	0.01%	0.09%	1.98%	0.86%	2.66%	5.68%
October	0.00%	0.00%	0.01%	0.03%	0.02%	1.65%	0.10%	0.17%	1.98%
November	0.00%	0.00%	0.00%	0.00%	0.04%	0.05%	0.07%	0.06%	0.23%
December	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.05%
Total	0.01%	0.86%	1.24%	0.66%	2.93%	22.45%	10.58%	61.26%	100.00%

Table 2. Percent of total soft crab market grades (inches) by month for 2000-2002; mixed category omitted (NCDMF Trip Ticket Program).

	Market Grade							
	Size ?	Size ?	3.5 - 4"	4 - 4.5"	4.5 - 5"	5 - 5.5"	5.5” & up	
Month	X-small	Small	Medium	Hotel	Prime	Jumbo	Whale/Slab	Total
March	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.02%
April	0.00%	0.38%	0.37%	0.31%	0.98%	3.30%	0.69%	6.02%
May	0.04%	0.63%	0.99%	0.97%	4.49%	21.60%	11.12%	39.83%
June	0.00%	0.55%	0.65%	0.23%	1.13%	6.00%	3.86%	12.42%
July	0.00%	0.48%	0.60%	0.07%	0.27%	2.69%	2.00%	6.12%
August	0.00%	0.15%	0.41%	0.03%	0.32%	14.71%	6.97%	22.58%
September	0.00%	0.02%	0.17%	0.03%	0.24%	5.12%	2.22%	7.80%
October	0.00%	0.00%	0.02%	0.07%	0.04%	4.27%	0.27%	4.67%
November	0.00%	0.00%	0.00%	0.00%	0.10%	0.14%	0.19%	0.43%
December	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%	0.11%
Total	0.04%	2.22%	3.21%	1.70%	7.57%	57.94%	27.32%	100.00%

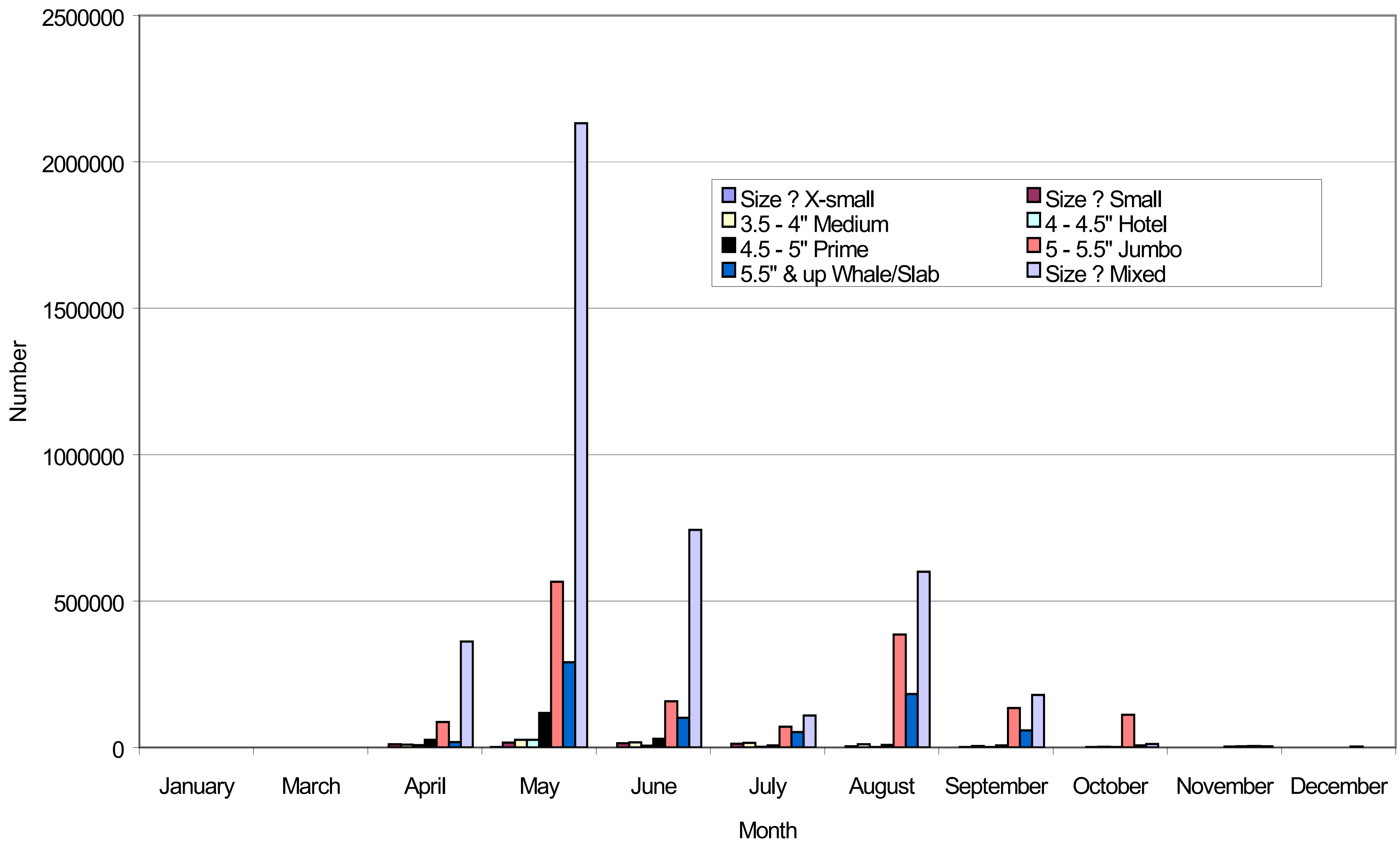

Figure 1. Soft blue crabs by market grade (inches) for 2000-2000 (mixed category included).

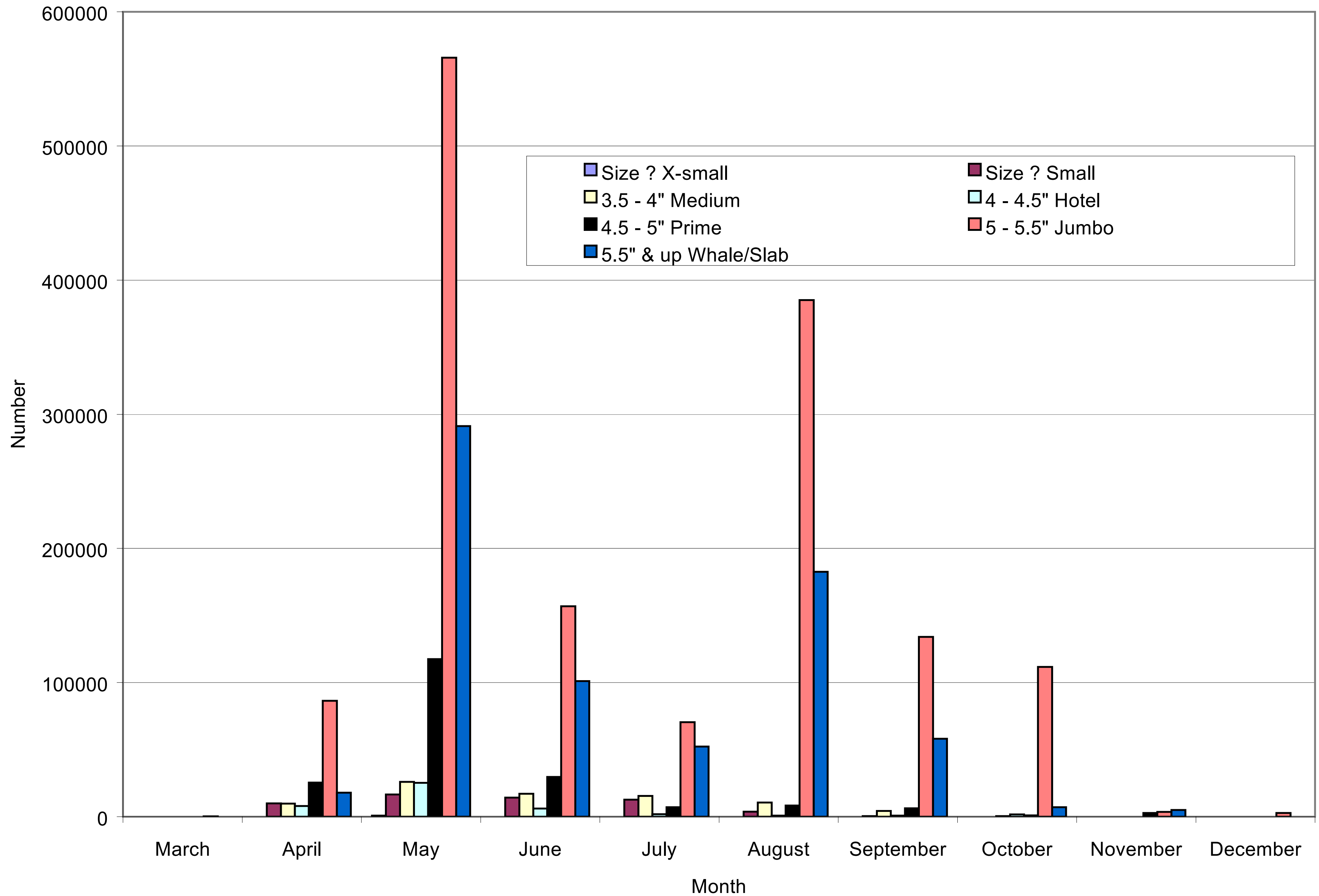

Figure 2. Soft blue crabs by market grade (inches) for 2000-2002 (mixed category omitted).

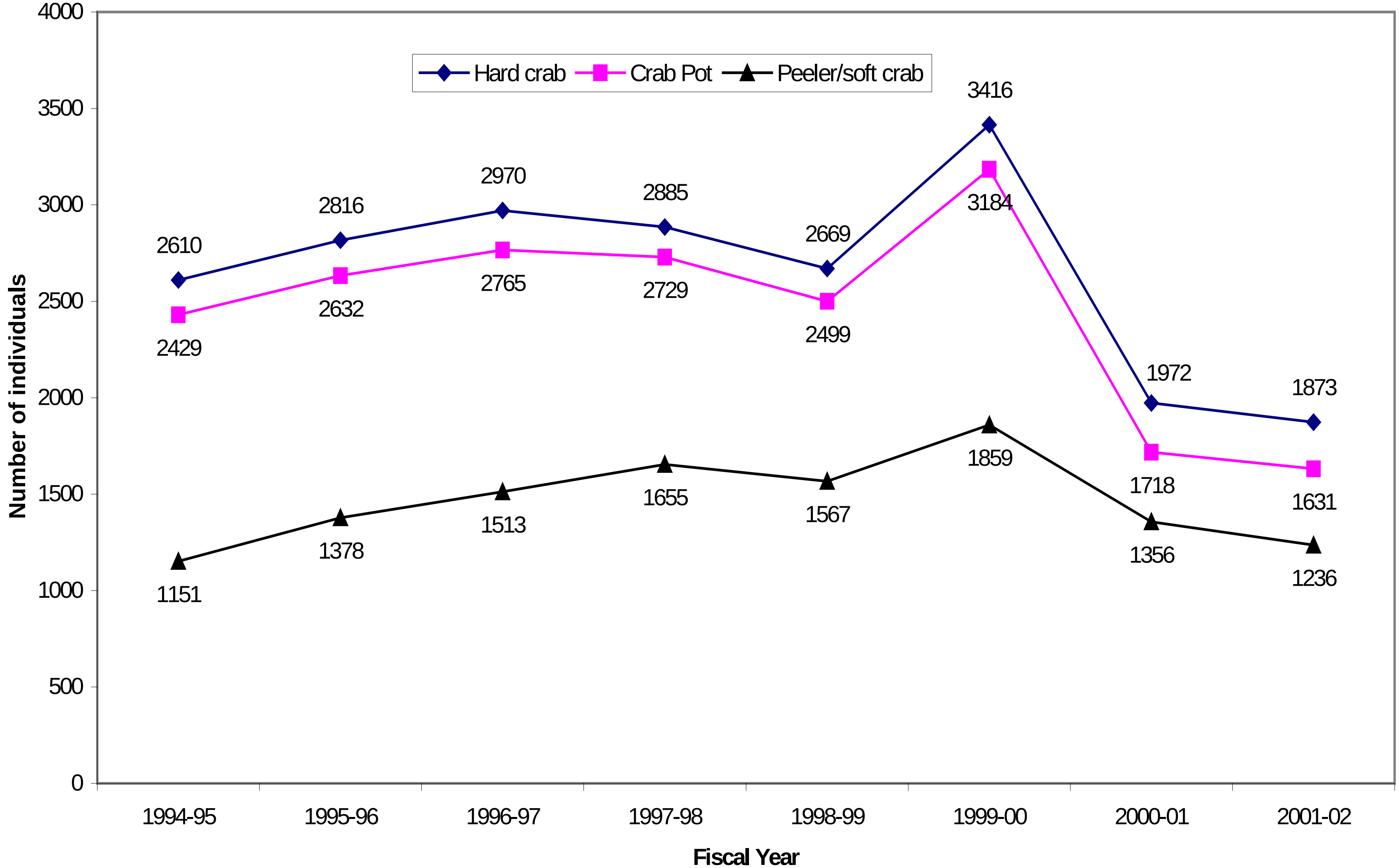

Figure 3. Number of individual participants with landings of hard and peeler/soft crabs for all gear types and by crab pot during fiscal years 1995-2002 [increase in 1999-2000 may be due to the change in licensing unit (vessel vs. individual)].

12.6 Appendix 6. HARVEST OF WHITE-LINE PEELER BLUE CRABS

I. Issues:

White-line peelers held in shedding operations may experience relatively high mortality because of the length of time held until they molt. Some peeler and hard crab pot fishermen retain small hard crabs or “green hard crabs” calling them white-line peelers and, thereby use the peeler crab exemption to circumvent the minimum size limit and culling tolerance for hard crabs.

II. Background:

Peeler crabs are exempt from the 5 inch minimum size limit [Rule 15A NCAC 3L .0201 (MFC 2003)]. Peeler crabs (crabs that exhibit signs of impending shedding or molting) are defined by Rule 15A NCAC 3I .0101 (b) (16) (MFC 2003) as: a blue crab that has a soft shell developing under a hard shell and having a definite pink, white, or red line or rim on the outer edge of the back fin or flipper.

Molting (or shedding) is the process by which blue crabs discard their older smaller shell in order to grow larger. Before molting, a new shell is formed beneath the outer shell of the crab. Fishermen use color changes (signs) in the last two sections of the swimming legs to determine the time to next molt. White-line peeler crabs are within two weeks of molt, pink-line crabs are within one week, and red-line crabs are within 1 - 3 days of shedding (Oesterling 1995). During their lifetime, a crab may molt 18 - 22 times. Within 12 hours after the molt, the shell is like parchment and will fully harden within 2 - 3 days. Crab shedding operations collect “peelers” and hold them in tanks until they molt to “soft” crabs. White-line peelers held in shedding operations may experience relatively high mortality (over 50%) because of the length of time held until they molt. Some shedders contend that this high shedding mortality is due to the inexperience of new people entering the shedding business.

The white-line stage is harder to distinguish than the other peeler stages, making the rule harder to enforce (i.e., same crab may be staged differently by different people). Law enforcement officers have found in certain cases that fishermen retain small hard crabs or “green hard crabs” calling them white-line peelers. This use of the peeler crab exemption circumvents the minimum size limit and culling tolerance for hard crabs. In spite of this, most states with a peeler definition include white-line in their definition.

Natural mortality of sublegal crabs (less than five inches) is in the range of 26 to 32% per year in Chesapeake Bay (Casey et al. 1992). Eggleston (1998) estimated an annual mortality rate of 50% for sub-adult and adult blue crabs in North Carolina. Uphoff et al. (1993) reported the following observations from a survey of Maryland crab shedding operations (June-Sept. 1990):

1) 5% to 80% peeler mortality (peeler stage was not reported);
2) 80% of responders reported between 10% and 50% peeler mortality; and
3) 38% mean mortality (weighted by number of shedding units and production).

Based on the survey of Maryland crab shedding operations, Uphoff et al. (1993) concluded that current industry practices are not sufficiently minimizing shedding mortality. Options outlined to address mortality in shedding operations were:

1) develop and enforce standards for shedding operations as part of licensing requirements;
2) prohibit the harvest of white-line peelers. (These crabs experience higher mortality due to more handling); and
3) conduct research to evaluate the conclusions reached in the shedding operation survey and develop more effective practices to minimize mortality.

Reducing waste is an objective of the DMF's overall management strategy for the blue crab. Currently, the largest area of waste in the peeler/soft crab fishery is the mortality of peelers in shedding systems. In a NC Sea Grant/Fishery Resource Grant (FRG) Project (01-FEG-03), Chaves and Eggleston (2003) found significantly higher mortality for white-line verses red-line peelers that were self-caught by the shedder operator. The report noted that the mortality of self-caught white-lines was similar to purchased red-line peelers (approximately 15% per day). However, Chaves and Eggleston (2003) expressed that cumulative mortality for white-line peelers would likely be higher than rates for red-line peelers (approximately 23% average mortality), because white-lines are generally held two to four times longer before molting. Study findings supported previous MFC rules prohibiting male white-line peeler harvest during the summer by documenting significantly higher mortality rates for male peelers when compared with female peelers, even though males had a significantly lower time to molt than females.

Chaves and Eggleston (2003) showed significantly higher mortality (11%) for all peeler stages that were purchased rather than self-caught by the shedders. However, they were unable to assess the effect of molt stage on purchased white-line peelers, because N.C. commercial shedders do not shed white-line peelers due to a fear of high mortality rates. This increased survival for self-caught peeler crabs was attributed to the extra attention to care and handling provided by the shedder operator/harvester, which highlights the importance of crab source and harvester care/handling as key factors influencing peeler mortality. Rose (2000; FRG 00-AM-08) reported a mortality rate of 7% for pink/red-line peelers, most of which were self-caught, during the late summer and fall season.

Other key findings outlined by Chaves and Eggleston (2003) were:
1) relatively high peeler mortality rates of 10-30% per shedding tank per day (average 15% mortality per day for an average mortality of 23% for a typical 5-day shedding cycle);
2) no effect of crab size on mortality rates;
3) no relationship between mortality and water quality parameters;
4) no significant differences in mortality between closed and open shedding systems;
4) no significant difference in mortality between crabs captured in hard or peeler crab pots;
6) decreasing peeler mortality with increasing density of peelers in shedding tanks;
7) no significant increase in male peeler mortality or time-to-molt in the presence of red-line females;
8) a significant decrease in a male red-line peeler's time-to-molt in the presence of a red-line female peeler and an intermolt (hard) male crab; and
9) reducing peeler mortality through the implementation of best management (harvesting and handling) practices could increase profits for crabbers who sell peelers and shedding system operators who purchase peelers.

Observations of North Carolina peeler crabbers indicate that peeler pots baited only with live male “jimmie” crabs catch fewer white-line peelers and small hard crabs than unbaited or fish and shrimp-baited pots. Maintaining the current North Carolina requirement that peeler pots be baited only with live male crabs will continue to reduce the potential for the harvest of white-line peelers. Virginia, South Carolina, Georgia, and Florida have rules which either: (1) define peeler pots as those pots baited with live male crabs, or (2) provide that peeler pots be baited only with live male crabs, or (3) exempt pots baited only with live male crabs from the escape ring requirement.

White-line peeler harvest has been reduced by the MFC’s requirement to bait peeler pots with a live male crab. Nevertheless, there continues to be a considerable number of small white-line peelers that are harvested from hard crab traps and naturally baited peeler pots (i.e., peeler pots that contain soft crabs and fish which attract other crabs). Data on white-line peeler catch rates in hard crab and peeler pots are not available. However, based on DMF fishery independent trawl data from the Hyde County bays, white-line peelers may comprise as much as 14.3 % of the crab population in some months and 12.5 % overall (Table 1 and Figure 1). Thus, prohibiting the harvest of white-line peelers will provide an estimated reduction in potential peeler catch of 12.5 % or less. These crabs would be available for subsequent harvest as they progress into the pink/red-line stages. Prohibiting white-line harvest could also significantly reduce injury and mortality of pink/red-line peelers during the handling and transport process. Other factors that affect the potential white-line peeler harvest are: area; season; harvest gear; bait type and source; market conditions; individual culling practices; and harvest restrictions. Therefore, the exact percentage reduction that might be attributed to a white-line peeler prohibition would vary.

Table 1. Blue crab shedding/peeler stages by month for the Hyde County bay area; 1987-89 (Program 120 DMF 20 ft. trawl)

	Month								
Shedding Stage	April	May	June	July	August	Sept.	October	Nov.	Grand Total
Hard/Green	69.50%	77.59%	65.53%	63.87%	68.66%	69.00%	79.41%	88.78%	69.23%
White-line	9.93%	8.25%	13.68%	14.06%	10.96%	14.27%	12.67%	7.82%	12.57%
Pink-line	7.09%	6.13%	7.34%	10.78%	8.61%	7.63%	3.17%	2.38%	7.69%
Red-line	1.42%	1.42%	2.88%	4.52%	6.25%	3.69%	0.79%	0.00%	3.49%
Buster	1.42%	0.47%	1.00%	0.95%	0.54%	0.86%	0.20%	0.00%	0.76%
Soft crab	4.26%	1.42%	3.52%	1.97%	1.99%	1.97%	2.38%	0.34%	2.36%
Paper shell	6.38%	4.48%	6.05%	3.86%	2.99%	2.58%	1.39%	0.68%	3.89%
Unknown	0.00%	0.24%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Grand Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

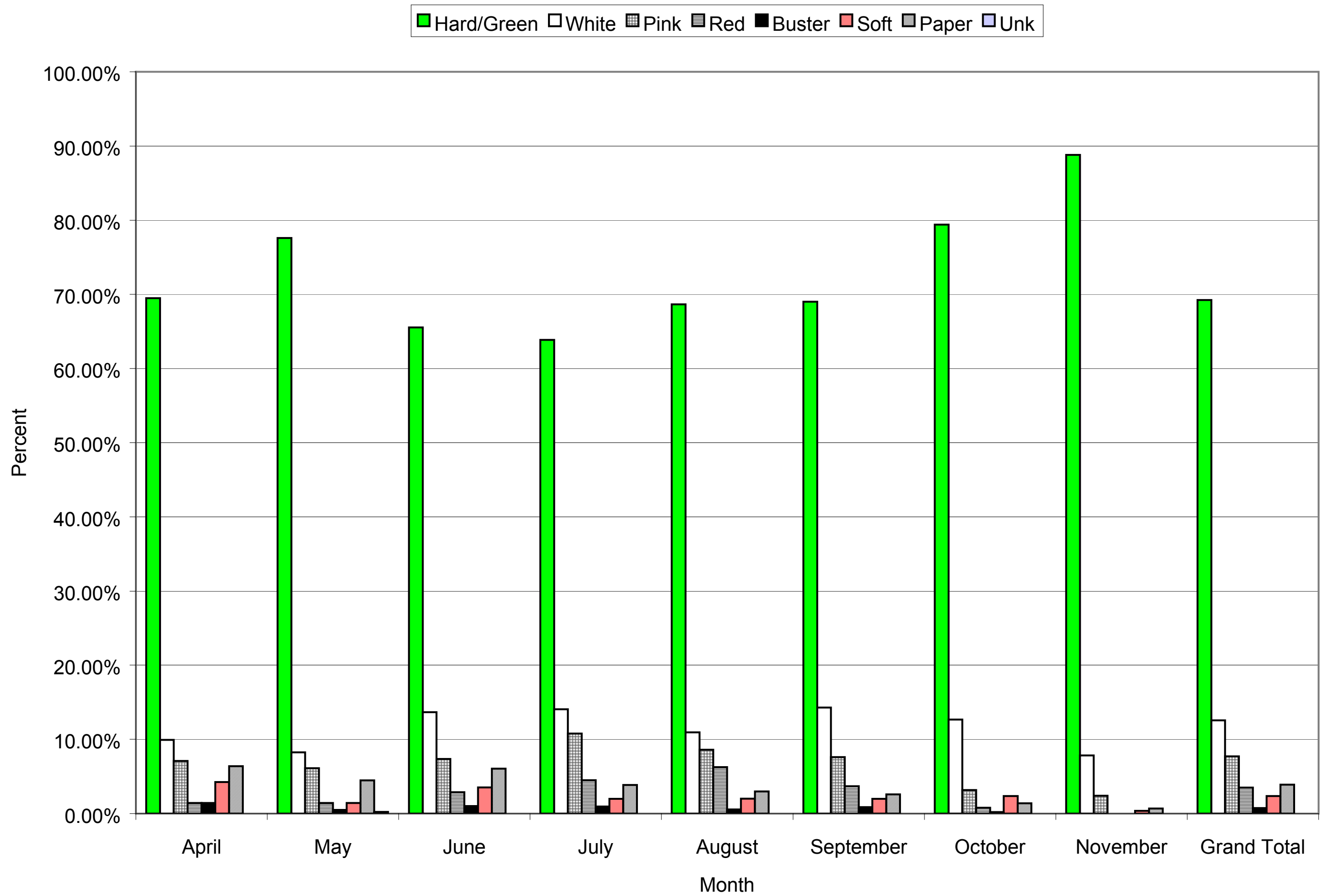

Figure 1. Blue crab shedding/peeler stages by month for Hyde Co. bay area; 1987-89 (Program 120 DMF 20 ft. trawl).

III. Discussion:

The DMF's continued concern with this issue is based on two main points: (1) the high shedding mortality of white-line peelers, and (2) law enforcement concerns with distinguishing the white-line peeler stage.

According to various N.C. shedders, Virginia and Maryland shedders provide the principle market for early season white-line peelers". High early season prices for live soft crabs yield ample profits, even with high white-line peeler mortalities. Therefore, as long as profits are achieved, significant mortality and waste is evidently an accepted standard within the out-of-state shedder industry.

The total prohibition of white-line peeler harvest was addressed by the MFC in 1994, with the MFC voting not to adopt a rule. Seasonal prohibition of white-line peeler harvest, from June 15 through December 31, was considered by the MFC in 1996; the proposed rule was not adopted. Both options were considered in the development of the 1998 Blue Crab Fishery Management Plan (BCFMP - McKenna et al. 1998), but were not recommended management strategies.

Prohibiting the possession of male white-line peelers from June – September was a recommended option in the 1998 BCFMP (McKenna et al. 1998) and was adopted in 1999.

Another recommended management strategy in the 1998 BCFMP was the requirement to use only live male “jimmie” crabs as bait in peeler pots. This was also adopted by the MFC in 1999. It was felt that these options would potentially reduce the harvest of white-line peelers and have a minimal affect on current fishing practices employed by the crabbing industry.

Current peeler fishing practices, employing live male crabs as an attractant or bait, target immature female peelers. Therefore, the vast majority of the peelers harvested are immature females that are approaching their terminal molt. Further reductions in fishing mortality on this white-line peeler segment of the population would contribute to efforts to protect the stock.

Prohibiting the harvest of white-line peelers would simplify enforcement of the peeler definition and further reduce the impacts of a continuing wasteful harvest practice that exists in the peeler/soft crab fishery. These crabs would most likely not be lost to the fishery and could be harvested later as a product with higher survival rates, profitability, and yield from the fishery.

IV. Current Authority:

15A NCAC 3I .0101 DEFINITIONS (MFC 2003)

(a) All definitions set out in G.S. 113, Subchapter IV apply to this Chapter.

(b) The following additional terms are hereby defined:

(16) Peeler Crab. A blue crab that has a soft shell developing under a hard shell and having a definite pink, white, or red line or rim on the outer edge of the back fin or flipper.

(50) Blue Crab Shedding. Shedding is defined as the process whereby a blue crab emerges soft from its former hard exoskeleton. A shedding operation is any operation that holds peeler crabs in a controlled environment. A controlled environment provides and maintains throughout the shedding process one or more of the following: predator protection, food, water circulation, salinity or temperature controls utilizing proven technology not found in the natural environment. A shedding operation does not include transporting peeler crabs to a permitted shedding operation.

15A NCAC 3L .0206 PEELER CRABS (MFC 2003)

(a) It is unlawful to bait peeler pots, except with male blue crabs. Male blue crabs to be used as peeler bait and less than the legal size must be kept in a separate container, and may not be landed or sold.

(b) It is unlawful to possess male white line peelers from June 1 through September 1.

V. Management Options/ Impacts:

(+ potential positive impact of action)
(- potential negative impact of action)

1. No rule change.
   - \+ Crab shedders have existing “peelers”, as defined, to hold for producing soft crabs
   - \+ Current definition is what fishermen coastwide mean when they refer to a peeler
   - \- Fishermen may use definition to exceed size tolerance
   - \- Wasteful, if white-line peelers die before shedding

2. Prohibit the possession of white-line peelers (remove white line from peeler crab definition).
   - \+ Allow more effective size limit enforcement
   - \+ Prevent a wasteful harvesting practice
   - \- Penalizes experienced shedders that can successfully shed white-line peelers
   - \- May make the term “peeler” ambiguous
   - \- Reduced income for some peeler crabbers and shedders

3. Establish a season for the possession of white-line peelers.
   - \+ Allow more effective size limit enforcement
   - \+ Reduce a wasteful harvesting practice
   - \- Penalizes experienced shedders that can successfully shed white-line peelers
   - \- Reduced income for some peeler crabbers and shedders

4. Prohibit the sale of white-line peelers, but allow possession by the licensee/harvester for use in the licensee’s permitted shedding operation. White-line peeler crabs must be separated from pink and red-line peeler crabs where taken and placed in a separate container.
   - \+ Allow more effective size limit enforcement
   - \- Reduce a wasteful harvesting practice
   - \- Penalizes experienced shedders who purchase crabs and can successfully shed white-line peelers
   - \- Reduced income for peeler crabbers who sell their catch

5. Repeal the rule prohibiting the baiting of peeler pots, except with live male blue crabs.
   - \+ Decreased enforcement burden
   - \+ Allows various bait options for the harvester
   - \- Increased catch of white-line peelers
   - \- Increases trap and handling mortality for white-line and “rank” peelers
   - \- Promotes a wasteful harvesting practice

6. Increase education efforts targeting harvesters/shedders on the mortality associated with the shedding of white-line peeler crabs.
   - \+ Reduced peeler mortality and resource waste
   - \+ Increased utilization of the resource
   - \+ Potential for increased profits for the shedder

7. Increase education efforts on the handling of peelers.
   + Reduced peeler mortality and resource waste
   + Increased utilization of the resource
   + Potential for increased profits for both the harvester and shedder

Options two through five would require rule changes by the MFC.

Recommendations:

The preferred option (option 4) is to prohibit the sale of white-line peelers, but allow possession by the licensee/harvester for use in the licensee's permitted shedding operation. White-line peeler crabs must be separated from pink and red-line peeler crabs where taken and placed in a separate container, with a of 5% tolerance allowed for white-line peelers in the pink/red-line peeler catch. Promoting educational efforts targeting harvesters/shedders on the mortality associated with the shedding of white-line peeler crabs and peeler handling practices would help to further reduce mortality (options 6 and 7).

VI. Research Needs:

1) Shedding mortality rates by peeler stage, area, and season.
2) Importance of white-line peelers to the economics of the fishery.
3) Peeler pot catch rates by peeler stage with various baiting methods.
4) Develop more effective harvest, handling, and shedding practices to minimize mortality.

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12.7 Appendix 7. GHOST POTS

I. Issue:

The bycatch and mortality of blue crabs and finfish in ghost (lost) pots.

II. Background:

A major issue specific to the blue crab pot fishery is “ghost pots”. These are pots that either through abandonment or loss (float lines cut by boats, storm events, etc.) continue to catch crabs and finfish. Concern stems from the significant increase in the numbers of crab pots, the long life of vinyl coated pots, and the pot’s ability to continue to trap crabs and finfish. The number of crab pots used in North Carolina has increased from 350,379 in 1983 to 1,285,748 in 2000. McKenna and Camp (1992) reported annual estimates of 14% crab pot loss for Pamlico and Pungo rivers, N.C. In a 1999 survey of crab license holders in North Carolina, statewide pot loss in 1998 for hard crab pots was 17% while peeler pot loss was reported at 11%. Total pot use for the same time frame was 853,766 hard crab pots and 163,151 peeler pots (DMF unpublished data, 1998). Estimated crab pot loss for 1998 was 145,140 hard crab pots and 17,947 peeler pots. Reported crab pot loss in N.C. due to Hurricanes Dennis and Floyd was 111,247 (DMF unpublished data from NC Hurricane Floyd Relief Program). Guillory (1993) estimated annual blue crab mortality at 25 crabs per ghost pot for Louisiana waters. In a study conducted in the Pamlico River in 1993, it was estimated that the annual mortality of legal blue crabs in ghost pots was 11.5 crabs per pot (DMF unpublished data, 1993). The difference in mortality estimates are due largely to the different escapement rates seen in the two studies, 45% in Louisiana and 64% in North Carolina.

Research conducted by High and Worlund (1978), suggests that the level of delayed mortality for crustaceans escaping from ghost pots may be high. While data exist on the fate and quantity of blue crabs in ghost pots little information is available on finfish bycatch since dead fish are quickly consumed by blue crabs, leaving only bones and fins (Guillory 1993; DMF unpublished data 1993). In a Louisiana ghost pot study, an average of 8.6 fish per trap-year was found (Guillory 1993). In the 1993 NC study, three species, southern flounder (n=11), Atlantic croaker (n=1), and white catfish (n=1) were captured and all were quickly consumed by blue crabs (DMF unpublished data, 1993).

The issue of ghost pots is a major concern in other pot fisheries: Caribbean spiny lobster (Seaman and Aska 1974); Dungeness crab (Breen 1987); American lobster (Sheldon and Dow 1975); snow crab (Gagnon and Boudreau 1991); and sablefish (Scarsbrook et al. 1988). For the most part, these fisheries now require that some sort of escape mechanism be incorporated into the various pot designs. In 1976, the state of Alaska passed legislation, which required all pots (crab and fish) to have a biodegradable termination device, which in time breaks down and allows crabs and fish to escape (Paul et al. 1993). Florida, Texas, and New Jersey are the only states that require biodegradable panels in blue crab pots.

III. Discussion:

Factors affecting ghost fishing include number of pots lost, pot type, location where lost, and target-species behavior (Smolowitz 1978). Significant reductions in ghost fishing mortality in blue crab pots could be achieved by minimizing pot loss and by incorporating design features into pots to prevent or reduce ghost fishing.

<u>POT LOSS</u>

Large areas of North Carolina waters are fished by both trawlers and potters. Sometimes trawlers inadvertently tow across areas containing pots and either sever the buoys, or drag the pot away from the line. Pots that are caught by trawlers are usually returned to the water. However, the new location of the pot is unknown to the owner and, unless notified by law enforcement or another fishermen, the pot is seldom retrieved. Harvest seasons for crab trawling and potting would eliminate crab pot loss by crab trawls. However, negative interactions would still occur between shrimp trawlers and potters. Other spatial conflicts exist between competing potters, recreational users, and other fishing activities. Some of these problems could be solved by a combination of seasonal and area restrictions. Currently, some user conflicts can be resolved by Rule 3J .0301 (j) which was adopted by the Marine Fisheries Commission (MFC) in 1999 as recommended by the 1998 North Carolina Blue Crab Fishery Management Plan (BCFMP - McKenna et al. 1998).

Historically, large numbers of pot buoy lines have been severed by boat propellers. Many crabbers rig their pots with buoy lines that match the deepest water fished. When pots were moved inshore to follow the crabs or to meet regulatory requirements, no change was made in the length of the buoy line. This extra line caused the buoy to float for a considerable area around the pot. Boaters unaware of the extra line just below the surface ended up cutting lines, inadvertently. In 1999, the MFC passed a temporary rule making it unlawful to take crabs with crab pots unless the line connecting the pot to the buoy is non-floating. This rule change was recommended by the 1998 BCFMP and became a permanent rule in August 2000. Other possible options to reduce loss through boat interactions include the use of full size buoys (5 inch by 11 inch) and/or reflective tape or paint on buoys. Although research on these topics was recommended in the 1998 BCFMP, none has been conducted to date.

Another source of pot loss is abandonment. Fishermen cut the buoys off older pots or simply leave the gear in the water. The MFC has two rules that address gear abandonment and attendance. One rule establishes that all pots shall be removed from internal waters from Jan. 24- Feb. 7 (pot clean-up period). This pot clean-up period makes it easier for law enforcement to find, retrieve, and issue citations for lost and/or abandoned pots. The other rule, which addresses unattended gear, was changed to require a shorter attendance period from 10 to 7 days as recommended by the 1998 BCFMP. Possible management options to further reduce abandonment losses are shortening the attendance period, providing dockside disposal for found gear (in 1995 NC Sea Grant conducted a gear recycling program approximately 4,600 pots were collected during a two week period), and extending the pot clean-up period by a week or more. In Texas, after the first week of their pot clean-up period, all pots left in the water are considered trash by law and may be removed by anyone. An additional 8,000 crab pots were removed from Texas waters after the first week in 1999 (Paul Hammerschmidt, Texas Parks & Wildlife, per. Comm.).

Storms events and water flow rates also contribute to pot loss. In 1999, 111,247 crab pots were reported lost due to Hurricanes Dennis and Floyd. Requiring fishermen to remove their gear from the water prior to major storm events would eliminate this problem. The National Weather Service is going to initiate a 10 day major storm warning timeframe in 2002. Pots move and/or become partially buried by sand or mud in areas with heavy currents and tides. Two potential management options to solve this problem are prohibiting pots in these areas, and requiring extra or a larger diameter iron on the pots.

Although the theft of crab pots is a serious problem, it does not contribute to ghost fishing since stolen pots are usually put into production or are sold. The willful destruction of fishing gear is currently prohibited by General Statute [G.S. 113-268 (b) and (c)]. The problem with this statute is that evidence has to be provided that the violator "willfully, wantonly, and unnecessarily" did injury or "willfully" destroyed fishing gear legally set.

<u>DESIGN FEATURES</u>

The mortality caused by ghost pots is directly related to the durability of the pot and its retention capability. The use of vinyl coated wire in crab pot construction has increased the life of crab pots. When lost, these pots do not degrade quickly, thereby increasing the potential for ghost fishing. The use of escape rings in hard crab pots significantly reduces ghost fishing mortality of sublegal blue crabs (Arcement and Guillory 1994). Since peeler pots are exempt from the escape ring requirement in North Carolina (Rule 3J .0303 (g)), this gear has a much greater potential for ghost fishing mortality than hard crab pots.

Biodegradable panels and galvanic time release (GTR) devices are used in many pot fisheries to minimize ghost pot fishing mortality. Biodegradable material can easily be incorporated into trap designs to provide an exit port for animals captured in ghost pots. Examples of these devices include: untreated wooden slats in lobster traps; escape panels constructed of natural twine; the use of untreated wire in certain sections of the pot; corrodible pot-lid hooks; and pot-lid hooks held in place by untreated wire or natural twine. GTR devices are composed of an active metal cylinder functioning as an anode, joining together two stable metal eyelets, which function as cathodes. When immersed in salt water, conductivity produces galvanic corrosion of the anode. When the anode disintegrates, the eyelets separate and release. These devices can be constructed to meet predetermined release times (i.e., 50 days, 100 days, etc.). Tests conducted in Alaska and Canada have shown that these devices are very predictable [+ or - a couple of days (Paul et al. 1993; Boudreau 1991)]. However, GTR devices are usually constructed to specific salinity ranges, and a device designed for high salinity sites would take longer to degrade in lower salinity areas. With many fishermen moving their pots to different areas and salinity ranges, the major advantage of GTR devices, their predictability, would be negated. Depending on the desired release time, the cost of GTR's for fishermen could be high. For example, a device that would release after 30 days would have to be replaced seven times a year in North Carolina (assuming 200 fishing days per year). At approximately $1.60 per device the cost per pot per year would be $11.20. This would cost a person fishing 300 pots an extra $3,360 per year.

Two natural twines (heavy duty jute and sisal) tested on exit ports in North Carolina broke, on average, in 47 and 53 days, respectively, at a low salinity site and 49 and 50 days in high salinity waters (DMF unpublished data, 1993). These twines were not as consistent in breaking time as GTRs. The range in breaking times for sisal was

35 to 77 days, and jute ranged from 28 to 63 days. The cost of this material is minimal, a 300 foot roll of sisal is about $1.50 and would be enough to rig about 600 pots. Hence, the cost for materials to a fishermen fishing 300 pots and making three or four changes per year would be approximately $2.25 to $3.00 per year.

Escapement mechanisms were evaluated by the DMF in 1993 and tested under commercial conditions in 1995 (Hooker 1996). These devices included the lid closure strap, an escapement panel, and an escape ring, all of which were held in place by natural twine. The lid closure strap was attached to a piece of natural twine located on top of the pot. In pots without a lip wire, the release of the strap would allow the top of the pot to open and all crabs to escape. The ability of crabs to escape through this opening was examined in 1993. In this study, all legal blue crabs (n=59) placed in test pots escaped in 48 hours (DMF unpublished data, 1993). No data were collected on finfish escapement. Under commercial evaluation, fishermen reported that this device was cumbersome to work with and could be expensive to maintain since the strap was lost when the device degraded.

The escape ring was held in place with two hog rings on the bottom and a piece of natural twine at the top. An extra mesh had to be cut to allow legal crabs to escape. The ability of crabs to escape through this opening was examined in 1993. In this study, all legal blue crabs (n=70) placed in test pots escaped in 72 hours (DMF unpublished data, 1993). Commercial fishermen testing this device felt that the hog rings interfered with the escapement of sublegal crabs through the escape ring (Hooker 1996). Additionally, fishermen were concerned with the inability of flounder and larger crabs to escape from this small opening when abandoned. Fishermen noted that blue crabs cut the string causing premature failure of the device.

The escapement panels were 4 1/2 inches by 3 inches made from 1/2 inch by 1 inch wire and were attached to the back of the pots. The bottom of the panel was held in place by three hog rings, while the top was secured at both corners and in the middle by twine. Fishermen preferred this larger device since it would allow larger crabs and flounder to escape from ghost pots (Hooker 1996).

Additional, regulatory measures to reduce pot loss and abandonment will not be sufficient to address crab and finfish mortality issues, particularly with respect to weather related pot loss. Therefore, more research on biodegradable escapement devices and the impact on the resource and industry are necessary. In 2002 and 2003, the NCDMF will be conducting studies to: 1) identify species composition in ghost blue crab pots; 2) determine the length of time that blue crabs can survive in ghost pots; 3) identify the method and placement of release sites on crab pots to minimize ghost fishing mortality; 4) find a degradable material that will allow for the escapement of blue crabs and finfish from crab pots after a predetermined length of time; and 5) test escapement panels and biodegradable material under commercial conditions.

IV. Current Authority:

SECTION 3I .0100 - GENERAL RULES
15A NCAC 3I .0105 LEAVING DEVICES UNATTENDED

(a) It is unlawful to leave stakes, anchors, nets, buoys, or floating devices in any coastal fishing waters when such devices are not being employed in fishing operations except as otherwise provided by rule or General Statute.

(b) It is unlawful to leave pots in any coastal fishing waters for more than seven consecutive days, when such pots are not being employed in fishing operations, except upon a timely and sufficient showing of hardship as defined in Subparagraph (b)(2) of this Rule or as otherwise provided by General Statute.

(1) Agents of the Fisheries Director may tag pots with a device approved by the Fisheries Director to aid and assist in the investigation and identification of unattended pots. Any such device attached to a pot by agents of the Fisheries Director must be removed by the individual utilizing the pot within seven days of attachment in order to demonstrate that the pot is being employed in fishing operations.

(2) For the purposes of Paragraph (b) of this Rule only, a timely and sufficient showing of hardship in a commercial fishing operation shall be written notice given to the Fisheries Director that a mechanical breakdown of the owner's vessel(s) currently registered with the Division of Marine Fisheries under G.S. 113-168.6, or the death, illness or incapacity of the owner of the pot or his immediate family, as defined in G.S. 113-168, prevented or will prevent employing such pots in fishing operations more than seven consecutive days. The notice, specifying the time needed because of hardship, shall be received by the Fisheries Director before any pot is left in coastal fishing waters for seven consecutive days without being employed in fishing operations, and shall state, in addition to the following, the number and specific location of the pots, and the date on which the pots will be employed in fishing operations or removed from coastal fishing waters:

(A) in case of mechanical breakdown, the notice shall state the commercial fishing vessel registration number, owner's N.C. motor boat registration number of the disabled vessel, date disabled, arrangements being made to repair the vessel or a copy of the work order showing the name, address and phone number of the repair facility; or

(B) in case of the death, illness or incapacity of the owner of the pot or his immediate family, the notice shall state the name of the owner or immediate family member, the date of death, the date and nature of the illness or incapacity. The Fisheries Director may require a doctor's verification of the illness or incapacity.

(3) The Fisheries Director may, by proclamation, modify the seven day requirement, if necessary due to hurricanes, severe weather or other variable conditions. Failure to employ in fishing operations or remove from coastal fishing waters all pots for which notice of hardship is received under this Rule within 14 days of the expiration of the hardship shall be violation of this Rule.

(c) It is unlawful to set or have any fishing equipment in coastal fishing waters in violation of this Section or which contains edible species of fish unfit for human consumption.

SECTION 3J .0300 – Pots, Dredges, and other fishing devices
15A NCAC 3J .0301 POTS

(a) It is unlawful to use pots except during time periods and in areas specified herein:

(1) From November 1 through April 30, except that all pots shall be removed from internal waters from January 24 through February 7. Fish pots upstream of U.S. 17 Bridge across Chowan River and upstream of a line across the mouth of Roanoke, Cashie, Middle and Eastmost Rivers to the Highway 258 Bridge are exempt from the January 24 through February 7 removal requirement. The Fisheries Director may, by proclamation, reopen various waters to the use of pots after January 28 if it is determined that such waters are free of pots.

(b) It is unlawful to use pots:

(1) in any navigation channel marked by State or Federal agencies; or

(2) in any turning basin maintained and marked by the North Carolina Ferry Division.

(c) It is unlawful to use pots in a commercial fishing operation unless each pot is marked by attaching a floating buoy which shall be of solid foam or other solid buoyant material and no less than five inches in diameter and no less than five inches in length. Buoys may be of any color except yellow or hot pink. The owner shall always be identified on the attached buoy by using engraved buoys or by engraved metal or plastic tags attached to the buoy. Such identification shall include one of the following:

(1) gear owner's current motorboat registration number; or

(2) gear owner's U.S. vessel documentation name; or

(3) gear owner's last name and initials.

(g) It is unlawful to use crab pots in coastal waters unless each pot contains no less than two unobstructed escape rings that are at least 2 5/16 inches inside diameter and located in the opposite outside panels of the upper chamber of the pot. Peeler pots with a mesh size less than 1 1/2 inches shall be exempt from the escape ring requirement. The Fisheries Director may, by proclamation, exempt the escape ring requirement in order to allow the harvest of peeler crabs or mature female crabs and may impose any or all of the following restrictions:

(1) Specify areas, and

(2) Specify time.

(j) User Conflicts:

(1) The Fisheries Director may, with the prior consent of the Marine Fisheries Commission, by proclamation close any area to the use of pots in order to resolve user conflict. The Fisheries Director shall hold a public meeting in the affected area before issuance of such proclamation.

(2) Any person(s) desiring to close any area to the use of pots may make such request in writing addressed to the Director of the Division of Marine Fisheries. Such requests shall contain the following information:

(A) A map of the proposed closed area including an inset vicinity map showing the location of the proposed closed area with detail sufficient to permit on-site identification and location;

(B) Identification of the user conflicts causing a need for closing the area to the use of pots;

(C) Recommended method for resolving user conflicts; and

(D) Name and address of the person(s) requesting the closed area.

(3) Person(s) making the requests to close an area shall present their request at the public meeting.

(4) The Fisheries Director shall deny the request or submit a proposed proclamation granting the request to the Marine Fisheries Commission for their approval.

(5) Proclamations issued closing or opening areas to the use of pots under Paragraph (j) of this Rule shall suspend appropriate rules or portions of

rules under 15A NCAC 3R .0107 as specified in the proclamation. The provisions of 15A NCAC 3I .0102 terminating suspension of a rule as of the next Marine Fisheries Commission meeting and requiring review by the Marine Fisheries Commission at the next meeting shall not apply to proclamations issued under Paragraph (j) of this Rule.

(k) It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating.

V. Management Options/Impacts:

(+ potential positive impact of action)
(- potential negative impact of action)

A. <u>Options to minimize pot loss</u>:

1. No action.
   + No new regulations
   - Continued problems with ghost pots (pot loss, mortality, spacial conflict)

2. Harvest seasons by gear type (pot and trawl).
   + Minimize interactions between crab trawlers and potters, thereby;
     a. Reducing pots lost to crab trawlers, and
     b. Reducing user conflicts.
   + More efficient law enforcement (able to concentrate on fewer fisheries at a time).
   - Lost revenue for fishermen.
   - Reduced flexibility for trawlers and potters.

3. Area restrictions by gear type (pot and trawl).
   + Minimize interactions between crab trawlers and potters, thereby;
     a. Reducing pots lost to crab trawlers, and
     b. Reducing user conflicts.
   + More efficient law enforcement (able to concentrate on fewer fisheries at a time).
   - Lost revenue for fishermen.
   - Reduced flexibility for trawlers and potters.

4. Require reflective tape or paint on crab pot buoys.
   + Reduce ghost pots.
   + Reduce user conflicts between boaters and potters.
   - Increased economic burden on pot fishermen (might be offset by having to replace fewer pots).

5. Require the use of full size (5 inch X 11 inch vs. 5 inch x 5 inch) buoys on crab pots.
   + Reduce ghost pots.
   + Reduce user conflicts between boaters and potters.
   - Increased economic burden on fishermen (might be offset by having to replace fewer pots).
   - Increase the number of ghost pots, because the increased buoyancy causes pots to move more readily during storms and periods of strong tides.

6. Shorten the attendance period for crab pots.
   + Reduce ghost pots.
   + Reduce user conflicts.
   + Reduce effort.
   - Burden to fishermen.
   - Cause inefficiency during certain times of the year.

7. Extend pot cleanup period.
   + Allow more gear to be removed from the water.
   + Give the resource a rest.
   - Lost revenue for fishermen.

8. Allow other users to retrieve abandoned gear.
   + Reduce the number of ghost pots.
   + More efficient law enforcement.

9. Dockside disposal for old pots.
   + Reduce the number of ghost pots.
   - Cost.

10. Require pots to be removed from the water prior to major storm events.
   + Reduce the number of ghost pots.
   + Fishermen save money by not having to replace lost pots.
   - Lost income due to days lost fishing.

11. Prohibit pots in certain areas.
   + Reduce the number of ghost pots.
   + Reduce user conflicts.
   - Lost income.
   - Increase conflicts among potters.

12. Structural modifications to pots.
   + Reduce the number of ghost pots.
   - Increased cost to fishermen.

Options two through eight and 10 and 12 would require rule changes by the MFC.

B. <u>Options to minimize ghost pot fishing mortality</u>:

1. No action.
   + No new regulations
   - Continued problem with ghost pot fishing mortality.

2. Require biodegradable panels or devices on crab pots.
   + Reduce waste of the blue crab resource.
   + Increase harvest of blue crabs.
   + Reduce finfish bycatch in ghost pots.
   - Possible loss of legal catch due to premature failure of panel.

Option two would require a rule change by the MFC.

Recommendations:

The Crustacean Committee, DMF, and MFC recommend extending the pot cleanup period by nine days (January 15 through February 7, allow other users to retrieve abandoned gear (see below), dockside disposal for old pots, and shorten the attendance period from 7 to 5 days. Take no action on minimizing ghost pot fishing mortality until DMF studies are complete.

The issue on retrieval of abandoned gear was further clarified by Marine Patrol, due to discussions generated in the summer of 2002 (see Appendix 8). This clarification separates gear into two groups; abandoned and ghost. Abandoned pots are those that carry an owner's identification (marked buoy or tag), as the law requires, but their owners haven't checked them in seven days. Only the Marine Patrol or owner of the pots can remove abandoned pots. Ghost pots are those with no buoy or identifying tag attached to the pot. Any person can collect and posses ghost pots at any time.

VI. Research Needs:

1. Test natural twine, and non-coated steel (24 gauge or less) across a wide range of salinities.
2. Determine the optimal panel location for finfish and crab escapement.
3. Determine minimum panel size for blue crab and finfish escapement.
4. Determine desired release time for blue crabs and finfish.
5. Test effectiveness of large buoys, reflective tape (and/or paint), and larger or heavier irons to reduce pot loss.

VII. Literature Cited:

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12.8 Appendix 8. RETRIEVAL OF ABANDONED AND/OR LOST CRAB POTS

I. Issue:

Retrieval of abandoned and/or lost crab pots by persons other than the gears owner.

II. Background:

One of the issues identified during the development of the revision of the Blue Crab Fishery Management Plan was ghost pots (see Appendix 7. Ghost Pots for a full discussion of issues). These are pots that either through abandonment or loss (float lines cut by boats, storm events, etc.) continue to catch crabs and finfish. Concern stems from the significant increase in the numbers of crab pots, the long life of vinyl coated pots, and the pot's ability to continue to trap crabs and finfish.

Historically, it was generally assumed that it was illegal to posses any gear that did not belong to you. In the summer of 2002, this issue was clarified by Marine Patrol due to discussions generated by the aforementioned issue paper. This clarification separates gear into two groups; abandoned and ghost. Abandoned pots are those that carry an owners identification (marked buoy or tag), as the law requires, but their owner's haven't checked them in seven days. Only the Marine Patrol or owner of the pots can remove abandoned pots. Ghost pots are those with no buoy or identifying tag attached to the pot. Any person can collect and possess ghost pots at any time.

The reported number of crab pots in North Carolina has increased from 350,379 in 1983 to 1,285,748 in 2000 (NCDMF Gear Survey). McKenna and Camp (1992) reported annual estimates of 14% crab pot loss for Pamlico and Pungo rivers, N.C. In a 1999 survey of crab license holders in North Carolina, statewide pot loss in 1998 for hard crab pots was 17%; while peeler pot loss was reported at 11%. Total pot use for the same time frame was 853,766 hard crab pots and 163,151 peeler pots (DMF unpublished survey data, 1998). Estimated crab pot loss for 1998 was 145,140 hard crab pots and 17,947 peeler pots. Reported crab pot loss in N.C. due to Hurricanes Dennis and Floyd in 1999 was 111,247 (DMF unpublished data from NC Hurricane Floyd Relief Program). Although it is unknown how many abandoned crab pots exist today, Marine Patrol identified 4,121 abandoned pots and 953 ghost pots during the 2003 clean-up period.

This issue has generated a copious amount of public interest. Staff have given over a dozen newspaper interviews and talked to representatives from saltwater fishing clubs, environmental groups, and many concerned citizens. All groups and individuals have expressed a willingness to assist in removing abandoned and ghost gear.

III. Discussion:

The original discussion of this issue was based on the premise that no gear could be retrieved by any person other than the gear's owner or Marine Patrol. From that discussion, several options were proposed:

1.) Shorten attendance period from seven to 5 days (supported by DMF and the Crustacean Committee).

2.) Extend pot cleanup period by nine days [current January 24 through February 7; proposed January 15 through February 7 (supported by DMF and the Crustacean Committee)].
3.) Allow other users, under the supervision of Marine Patrol, to remove abandoned crab pots from the waters during the pot cleanup period (supported by DMF and the Crustacean Committee).

In addition to these three recommendations, the question of how to get rid off collected pots was discussed. Possible solutions were the collection of a disposal fee from crabbers, and using grant monies to pay for disposal.

Given the new interpretation of the current rule; recommendation #3 needs to be revisited along with the question of pot disposal. The two most important issues that need to be addressed with regard to option 3 are: 1) how many abandoned pots are there in a given year; and 2) what effect would a rule change allowing pot retrieval by non-owners have on other law enforcement practices.

While someone can be prosecuted anytime of the year for failing to fish his/her crab pots at least every 7 days (5 days if the MFC adopts the rule change in the revised Blue Crab Fishery Management Plan), the true number of abandoned pots is most likely to be determined by the number of pots left in the water during the cleanup period. Determining the true number of abandoned pots is especially important since it will help define the extent of the problem. If the problem is serious enough to require a rule change allowing non-gear owners to collect and posses abandoned gear, even for a short time, it could negatively impact Marine Patrol's ability to deal with pot theft, which is a serious problem in this fishery. However, this concern is only valid if people were able to keep the gear they found. If all gear had to be turned over to Marine Patrol for disposal, the theft concern could be minimized. Another concern was that if someone had a legitimate emergency and had notified Marine Patrol that their pots were still in the water, then there was no way to prevent someone else from picking up their pots. This concern could be dealt with by, only allowing Marine Patrol to pick-up pots during the first two weeks and then allowing others to retrieve pots for the remainder of the time. Although there are problems that would have to be worked out with this option it seems that documenting the extent of the problem should be the first priority. Additionally, given the strong public support for wanting to help in solving this problem, efforts should be made to involve concerned citizens. This could be accomplished through news releases and information on the Division web page explaining the difference between ghost and abandoned pots and providing contact numbers to report locations of abandoned gear and means of disposal.

Since anyone may retrieve ghost pots, mechanisms need to be developed for pot disposal. While people may be willing to bring in ghost pots, they might not want to haul them to the dump and pay for their disposal. All contacted counties, with the exception of Beaufort, accept crab pots at their landfills or transfer stations. Brunswick and Pender counties do not charge for pot disposal (Table 1).

Table 1. County breakdown of pot disposal fees.

County	Disposal fee for pots	Notes
Perquimans	$64.00 a ton	
Chowan	$62.00 a ton	
Pasquotank	$53.00 a ton	
Camden	$53.00 a ton	
Currituck	$56.00 a ton	
Dare	$54.11 a ton	
Tyrrell	N/A	No transfer station in county, all waste disposed of in containers.
Washington	N/A	Same as Tyrrell Co.
Hyde	N/A	Same as Tyrrell Co.
Beaufort	Won't accept pots	
Pamlico	$46.50 a ton	
Craven	$34.00 a ton	
Onslow	$38.50 a ton	County residents only
Pender	No charge	County residents only
New Hanover	For business $30.00 a ton; non-business $10.00 pick-up load	
Brunswick	No charge	

Dockside disposal would allow for individuals to quickly dispose of ghost pots. Trawlers (crab and shrimp) catch large amounts of ghost pots and having disposal sites at fish houses would give them a place to dispose of this gear instead of throwing it back in the water. Many trawlers have expressed their willingness to dispose of this gear on land, if they had a convenient and free disposal site. Dumpster rental is not cheap. For example, one eight yard dumpster leased year round with weekly pick-up ranges from $112.11 a month to $139 a month. Dumpsters could be rented for shorter time periods (the first three weeks of shrimp season), but we still need to find a way to pay for them. Various grant programs (Fishery Resource Grant, Blue Crab Research Program, etc.) might be available for short term solutions, however a long term solution needs to be identified. Given the state budget crunch state funds are not available. Some have suggested that potters be charged a fee to help offset retrieval and disposal costs. Further discussion on this issue needs to take place (DMF, MFC, Crustacean Committee, etc.).

IV. Current Authority:

SECTION 3I .0100 - GENERAL RULES
15A NCAC 3I .0105 LEAVING DEVICES UNATTENDED

(a) It is unlawful to leave stakes, anchors, nets, buoys, or floating devices in any coastal fishing waters when such devices are not being employed in fishing operations except as otherwise provided by rule or General Statute.

(b) It is unlawful to leave pots in any coastal fishing waters for more than seven consecutive days, when such pots are not being employed in fishing operations, except upon a timely and sufficient showing of hardship as defined in Subparagraph (b)(2) of this Rule or as otherwise provided by General Statute.

(1) Agents of the Fisheries Director may tag pots with a device approved by the

Fisheries Director to aid and assist in the investigation and identification of unattended pots. Any such device attached to a pot by agents of the Fisheries Director must be removed by the individual utilizing the pot within seven days of attachment in order to demonstrate that the pot is being employed in fishing operations.

(2) For the purposes of Paragraph (b) of this Rule only, a timely and sufficient showing of hardship in a commercial fishing operation shall be written notice given to the Fisheries Director that a mechanical breakdown of the owner's vessel(s) currently registered with the Division of Marine Fisheries under G.S. 113-168.6, or the death, illness or incapacity of the owner of the pot or his immediate family, as defined in G.S. 113-168, prevented or will prevent employing such pots in fishing operations more than seven consecutive days. The notice, specifying the time needed because of hardship, shall be received by the Fisheries Director before any pot is left in coastal fishing waters for seven consecutive days without being employed in fishing operations, and shall state, in addition to the following, the number and specific location of the pots, and the date on which the pots will be employed in fishing operations or removed from coastal fishing waters:

(A) in case of mechanical breakdown, the notice shall state the commercial fishing vessel registration number, owner's N.C. motor boat registration number of the disabled vessel, date disabled, arrangements being made to repair the vessel or a copy of the work order showing the name, address and phone number of the repair facility; or

(B) in case of the death, illness or incapacity of the owner of the pot or his immediate family, the notice shall state the name of the owner or immediate family member, the date of death, the date and nature of the illness or incapacity. The Fisheries Director may require a doctor's verification of the illness or incapacity.

(3) The Fisheries Director may, by proclamation, modify the seven day requirement, if necessary due to hurricanes, severe weather or other variable conditions.

Failure to employ in fishing operations or remove from coastal fishing waters all pots for which notice of hardship is received under this Rule within 14 days of the expiration of the hardship shall be violation of this Rule.

(c) It is unlawful to set or have any fishing equipment in coastal fishing waters in violation of this Section or which contains edible species of fish unfit for human consumption.

SECTION 3J .0300 – Pots, Dredges, and other fishing devices

15A NCAC 3J .0301 POTS

(a) It is unlawful to use pots except during time periods and in areas specified herein:

(1) From November 1 through April 30, except that all pots shall be removed from internal waters from January 24 through February 7. Fish pots upstream of U.S. 17 Bridge across Chowan River and upstream of a line across the mouth of Roanoke, Cashie, Middle and Eastmost Rivers to the Highway 258 Bridge are exempt from the January 24 through February 7 removal requirement. The Fisheries Director may, by proclamation, reopen various waters to the use of pots after January 28 if it is determined that such waters are free of pots.

(c) It is unlawful to use pots in a commercial fishing operation unless each pot is marked by attaching a floating buoy which shall be of solid foam or other solid buoyant material and no less than five inches in diameter and no less than five inches in length. Buoys may be of any color except yellow or hot pink. The owner shall always be identified on the attached buoy by using engraved buoys or by engraved metal or plastic tags attached to the buoy. Such identification shall include one of the following:

(1) gear owner's current motorboat registration number; or
(2) gear owner's U.S. vessel documentation name; or
(3) gear owner's last name and initials.

(g) It is unlawful to use crab pots in coastal waters unless each pot contains no less than two unobstructed escape rings that are at least 2 5/16 inches inside diameter and located in the opposite outside panels of the upper chamber of the pot. Peeler pots with a mesh size less than 1 1/2 inches shall be exempt from the escape ring requirement. The Fisheries Director may, by proclamation, exempt the escape ring requirement in order to allow the harvest of peeler crabs or mature female crabs and may impose any or all of the following restrictions:

(1) Specify areas, and
(2) Specify time.

(j) User Conflicts:

(1) The Fisheries Director may, with the prior consent of the Marine Fisheries Commission, by proclamation close any area to the use of pots in order to resolve user conflict. The Fisheries Director shall hold a public meeting in the affected area before issuance of such proclamation.
(2) Any person(s) desiring to close any area to the use of pots may make such request in writing addressed to the Director of the Division of Marine Fisheries. Such requests shall contain the following information:
   (A) A map of the proposed closed area including an inset vicinity map showing the location of the proposed closed area with detail sufficient to permit on-site identification and location;
   (B) Identification of the user conflicts causing a need for closing the area to the use of pots;
   (C) Recommended method for resolving user conflicts; and
   (D) Name and address of the person(s) requesting the closed area.
(3) Person(s) making the requests to close an area shall present their request at the public meeting.
(4) The Fisheries Director shall deny the request or submit a proposed proclamation granting the request to the Marine Fisheries Commission for their approval.
(5) Proclamations issued closing or opening areas to the use of pots under Paragraph (j) of this Rule shall suspend appropriate rules or portions of rules under 15A NCAC 3R .0107 as specified in the proclamation. The provisions of 15A NCAC 3I .0102 terminating suspension of a rule as of the next Marine Fisheries Commission meeting and requiring review by the Marine Fisheries Commission at the next meeting shall not apply to proclamations issued under Paragraph (j) of this Rule.

(k) It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating.

V. Management Options/Impacts:

(+ potential positive impact of action)
(- potential negative impact of action)

1. No action.
   - + No new regulations
   - - Continued problems with abandoned pots (crab and finfish mortality, conflicts)

2. Document the number of abandoned pots collected during the pot cleanup period.
   - + Get accurate numbers on the amount of abandoned pots.
   - + Allow for informed management recommendations.
   - - Possible burden for law enforcement.

3. Educate fisherman and the general public about efforts to remove abandoned gear and encourage them to notify Marine Patrol of locations of said gear.
   - + Significantly increase the number of eyes looking for abandoned gear.
   - + Capitalize on strong public interest in helping to solve a problem and being part of the solution.
   - - Marine Patrol could be overwhelmed with reports.

4. Allow other users to retrieve abandoned pots.
   - + Reduce the number of abandoned pots.
   - - Reduce Marine Patrols ability to deal with pot theft.

Recommendations:

Marine Patrol should document the number of abandoned pots collected during the pot cleanup period. DMF should educate fisherman and the general public about efforts to remove abandoned gear and encourage them to notify Marine Patrol of locations of said gear.

VI. Literature Cited:

McKenna, S., and J. T. Camp. 1992. An examination of the blue crab fishery in the Pamlico River estuary. Albemarle-Pamlico Estuarine Study Rep. No. 92-08. 101p.

12.9 Appendix 9. CRAB POT FINFISH BYCATCH

I. Issue:

Finfish bycatch in crab pots.

II. Background:

Bycatch is defined as “the portion of a catch taken incidentally to the targeted catch because of non-selectivity of the fishing gear to either species or size differences” (ASMFC 1994). Bycatch can be divided into two components: incidental catch and discarded catch. Incidental catch refers to retained catch of non-targeted species. Discarded catch is that portion of the catch returned to the sea as a result of economic, legal, or personal considerations. The two management issues relating to finfish bycatch in crab pots are: 1) the composition, quantity, and fate of the marketable, and unmarketable discarded bycatch in actively fished pots; and 2) the composition, quantity, and fate of finfish bycatch in “Ghost pots” (see Appendix 7. Ghost Pots for discussion of this issue).

<u>MARKETABLE FINFISH BYCATCH</u>

Annual landings of the marketable portion of the incidental finfish bycatch from hard crab pots have averaged 52,185 pounds since 1996 (DMF Trip Ticket Program, 1996-2001, single gear trips; in 1994 and 1995 hard and peeler pot catches were combined). The top five finfish species or group of species landed from hard crab pots are; catfish [57% (bullheads, white, and channel)], flounder [25% (summer and southern)], white perch (3%), speckled trout (2%), and Atlantic Croaker [2% (Table 1)]. Although catfish landings from hard crab pots average 29,499 pounds per year, these landings only represent 3.6% of the average catfish landings by all gears [819,292 pounds per year (DMF Trip Ticket Program, 1996-2001)]. Average flounder landings from hard crab pots (13,007 lbs./year) represents 0.36% of the total state flounder landings. White perch (1,462 lbs./year), speckled trout (1,249 lbs.), and Atlantic croaker (1,165 lbs.) landings from crab pots account for 0.71%, 0.42%, and 0.01% of the total state landings for these species respectively.

Hard crab pot catches have been reported from 31 waterbodies, 28 of which also reported finfish landings (Table 2). Albemarle Sound yielded 39% of the finfish, followed by Currituck (22%), and Pamlico (8%) sounds and Alligator (7%), and Pamlico (7%) rivers (Table 2). Eighty-three percent of all finfish landed by hard crab pots come from these five areas. The Alligator River and Albemarle and Currituck sounds account for 91% of the catfish landings, 96% of the white perch and 71% of the Atlantic croaker landings (Table 3). Flounder landings from hard crab pots have been reported from 27 waterbodies. Albemarle Sound (29%), Pamlico River (12%), Pamlico Sound (10%), New River (9%), and Core Sound (6%) are the top five waters reporting flounder landings from crab pots and account for 67% of the landings. Speckled trout have been reported from 18 waterbodies. The top five areas for speckled trout landings are; Pamlico Sound (37%), Pamlico River (22%), Croatan Sound (11%), Albemarle Sound (7%), and Roanoke Sound (6%). Combined these areas account for 83% of the speckled trout landings.

The bulk of the finfish landings from hard crab pots occur from April through October, with October accounting for the largest percentage (17%) of the landings (Table 4). Seventy-three percent of the catfish landings occur in the fall (45%; Sept., Oct., and Nov.) and spring (28%; April, and May). Ninety-one percent of the flounder landings from crab pots occur from May through October. May, June, and July account for 57% of the white perch landings, 85% of the speckled trout landings, and 76% of the croaker landings.

On average 95,255 hard crab pot trips are reported each year (DMF Trip Ticket Program, 1996-2001, single gear trips). During 2% (1,991) of these trips, catfish are also landed from hard crab pots. Flounder landings from hard crab pots are reported from an average of 1,876 trips per year. White perch are reported from 634 trips, speckled trout from 279, and Atlantic croaker from 296 trips on average each year (DMF Trip Ticket Program, 1996-2001, single gear trips).

Reported average annual finfish landings from peeler pots are 1,002 pounds (DMF Trip Ticket Program, 1996-2001, single gear trips). American eels contribute 33% of the total followed by catfish (24%), and flounder (13% [Table 5]). Peeler pot catches have been reported from 21 waterbodies, 11 of which also reported finfish landings (Table 6). Albemarle Sound accounted for 33% of the finfish, followed by Roanoke (29%), and Currituck (27%) sounds (Table 6). Eighty two percent of the American eel landings from peeler pots are reported from Roanoke (36%), Currituck (31%), and Albemarle (15%) sounds (Table 7). These three waterbodies account for 98% of the catfish, 83% of the flounder, and 99% of the yellow perch and speckled trout landings from peeler pots (Table 7). Overall, 62% of all finfish landings from peeler pots occur in May (Table 8).

UNMARKETABLE BYCATCH

Two issues relating to finfish bycatch in crab pots are of concern to fishermen and managers alike. These issues are: 1) the composition, quantity, and fate of the unmarketable discarded bycatch in actively fished pots; and 2) the composition, quantity, and fate of marketable and unmarketable bycatch in “Ghost pots” (see Appendix 7. Ghost Pots for discussion of this issue). The 1998 NC Blue Crab Fishery Management Plan (BCFMP - McKenna et al. 1998) identified these two issues, as high priority research needs.

In 1999, a Fishery Resource Grant (FRG) was funded to examine bycatch in hard and peeler pots in the Neuse River, N.C. (Doxey 2000). Four crab pot fishermen kept records of bycatch in their hard and peeler pots from March through October 1999. Hard crab pot data was collected from 283 trips during which 149,649 hard crab pots were fished. Peeler pot data was collected from 11 trips taken in May during which 1,950 peeler pots were fished.

A total of 1,062 bycatch organisms [1,052 fish; 9 diamondback terrapin; and, 1 seahorse) was caught in hard crab pots. Flounder accounted for 34% of the total bycatch, followed by spot (15%), and pinfish [14% (Table 9)]. Other recreationally important species captured by this gear include speckled trout (9%), gray trout (6%), Atlantic croaker (4%), bluefish (3%), and red drum (1%). The Catch-per-Unit-Effort (CPUE) of all bycatch species was 4 per trip and .007 per pot (Table 9). Peeler pots captured 300 fish; of which white perch accounted for 50% of the total (Table 10). American eel accounted for 28% of the bycatch, followed by flounder (6%), menhaden (5%), gray trout and spot (4% each). For peeler pots, the CPUE per trip was 27, while pot CPUE was 0.15 (Table 10).

The highest monthly CPUE per trip (7.5) and per pot (0.02) in the hard crab pot fishery was during April (Table 11). This was followed by May, June, August, September, July, October, and March. Soak times for hard crab pots were highest in April (4 days) and lowest in September (1.5 days). Table 12 shows the monthly percent contribution by species in hard crab pots. All peeler pot trips occurred in May. All peeler pots had a soak time of one day.

Of the captured bycatch in hard crab pots, 70% were released alive, 22% were either dead, eaten, or injured, and 8% was used for bait (Table 13). In peeler pots 99.7% of the captured bycatch was released alive and 0.33% was used for bait (Table 14).

The average size of captured flounder in hard crab pots was 10 inches (Table 15). American eel lengths ranged from 7 to 20 inches and averaged 12 inches. In peeler pots, eels averaged 21 inches, while white perch and flounder averaged 6 inches (Table 16).

III. Discussion:

Information summarized herein indicates that landed marketable finfish bycatch in the crab pot fishery (hard and peeler pots) accounts for less than 1% of the total landings for each species except catfish which comprises 3.6% of the total landings since 1996. Preliminary bycatch data from actively fished hard and peeler pots in the Neuse River indicates that, while flounder and other finfish species are captured in these gears, overall catch rates are low (4 organisms per hard crab pot trip; 27 organisms per peeler pot trip) and survival rates are high (70% hard crab pots; 99% peeler pots). These data suggest that regulatory action is not required to deal with the issue of finfish bycatch in actively fished pots, unless a specific species stock assessment indicates otherwise.

Bycatch as noted in the documented landings can be significantly different by geographic area and season. Therefore, studies in other waterbodies need to be conducted to determine the fate, quantity, and composition of finfish bycatch (Neuse River contributes 1% of the hard crab pot finfish landings and 2.5% of the peeler pot finfish landings). The NCDMF will be conducting studies in different areas during 2002 and 2003 to examine various sizes of escapement openings and panels in crab pots (active and ghost pots) for their ability to release bycatch. This work coupled with stock assessments for various species should allow us to react to this issue, if it is shown to be a problem.

Overall, finfish bycatch does not appear to be a significant problem in the crab pot fishery. However, if it is shown that simple modifications can be incorporated into pots to reduce bycatch injury and waste of non-target species, then this would ultimately be of benefit to all the impacted resources and users.

IV. Current Authority:

3I .0105 LEAVING DEVICES UNATTENDED

(b) It is unlawful to leave pots in any coastal fishing waters for more than seven consecutive days, when such pots are not being employed in fishing operations, except upon a timely and sufficient showing of hardship as defined in Subparagraph (b)(2) of this Rule or as otherwise provided by General Statute.

3J. 0302 POTS

(g) It is unlawful to use crab pots in coastal waters unless each pot contains no less than two unobstructed escape rings that are at least 2 5/16 inches inside diameter and located in the opposite outside panels of the upper chamber of the pot. Peeler pots with a mesh size less than 1 1/2 inches shall be exempt from the escape ring requirement. The Fisheries Director may, by proclamation, exempt the escape ring requirement in order to allow the harvest of peeler crabs or mature female crabs and may impose any or all of the following restrictions:
  (1) Specify areas, and
  (2) Specify time.

(k) It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating.

V. Management Options/Impacts:

(+ potential positive impact of action)
(- potential negative impact of action)

1. No action.
   + No new regulations.
   - Potential waste of finfish resource.

2. Require finfish escapement/release panels in hard and peeler crab pots.
   + Reduce unmarketable finfish bycatch.
   - Reduction in marketable finfish bycatch.
   - Possible loss of legal crabs.

Recommendation:

The DMF, Crustacean Committee, and MFC recommend that no regulatory action be taken on this issue at this time.

VI. Research Needs:

1. Collect baseline data on the composition, quantity, and fate of unmarketable finfish bycatch in the crab pot (hard and peeler) fishery, by season and area.
2. Develop a bycatch reduction device for hard and peeler crab pots.
3. Test natural twine and non-coated steel (24 gauge or less) across a wide range of salinities.
4. Determine the optimal escapement/release panel location for finfish and crab escapement.
5. Determine minimum escapement/release panel size for blue crab and finfish escapement.
6. Determine desired release time for blue crabs and finfish.

VII. Literature Cited:

ASMFC (Atlantic States Marine Fisheries Commission). 1994. Acronyms, abbreviations, and technical terms used in ASMFC fishery management programs. Special Report No. 33 of the Atlantic States Marine Fisheries Commission, Washington DC. 22p.

Doxey, R. 2000. Bycatch in the Crab Pot Fishery. NC Sea Grant, Fishery Resource Grant Program (FRG) #99-FEG-45, Raleigh, NC.

McKenna, S., L.T. Henry, and S. Diaby. 1998. North Carolina Fishery Management Plan – Blue Crab (BCFMP). North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. Morehead City. 73p. + Appendices.

Table 1. Reported yearly finfish landings (lbs.) from hard crab pots* in North Carolina: 1996 - 2001.

	Year								Percent
	1996	1997	1998	1999	2000	2001	Total	Average	of total
Catfish	25,843	49,212	22,213	29,493	13,042	37,192	176,995	29,499	56.66
Flounders	16,008	14,922	7,314	13,192	16,356	10,251	78,043	13,007	24.98
White perch	641	1,100	669	2,846	1,638	1,876	8,770	1,462	2.81
Speckled trout	351	796	692	4,528	761	368	7,496	1,249	2.40
Atlantic croaker	1,713	419	226	1,011	806	2,818	6,993	1,166	2.24
Jumping mullets	957	532	127	2,466	1,453	372	5,907	985	1.89
Yellow perch	459	1,126	904	1,266	643	333	4,731	789	1.51
Spot	844	557	1,025	837	524	637	4,424	737	1.42
Eels	685	1,508	140	151	645	54	3,183	531	1.02
Puffer	1,625	158	465	252	160	66	2,726	454	0.87
Oyster toad	970	244	35	354	729	106	2,438	406	0.78
Gray trout	332	686	327	587	253	96	2,281	380	0.73
Bluefish	158	453	127	322	78	588	1,726	288	0.55
Black drum	803	380	6	397	55	54	1,695	283	0.54
Mullet (roundheads)	110	178	325	246	197	361	1,417	236	0.45
Fish, Mixed	458	138	8	3	123	46	776	129	0.25
Menhaden Bait (lb)	N/R	N/R	401	166	N/R	200	767	128	0.25
Sheepshead	36	80	117	282	112	43	670	112	0.21
Red drum	103	39	8	255	32	23	460	77	0.15
Large pigfish	27	80	54	60	29	14	264	44	0.08
Striped bass	30	40	5	57	N/R	N/R	132	22	0.04
Shad	4	17	50	N/R	20	4	95	16	0.03
Spanish mackerel	14	5	14	2	N/R	29	64	11	0.02
Gizzard shad	10	1	N/R	45	N/R	N/R	56	9	0.02
Triggerfish	2	23	1	N/R	8	20	54	9	0.02
Carp	N/R	11	N/R	N/R	39	N/R	50	8	0.02
Spadefish	5	4	N/R	21	2	5	37	6	0.01
Tautog	4	8	12	6	6	N/R	36	6	0.01
Pinfish	1	6	N/R	20	N/R	N/R	27	5	0.01
Black sea bass	11	2	4	6	N/R	N/R	23	4	0.01
Butterfish	1	9	4	4	N/R	1	19	3	0.01
Herring	13	2	N/R	N/R	N/R	N/R	15	3	0.00
Conger eel	7	N/R	8	N/R	N/R	N/R	15	3	0.00
Hickory shad	4	N/R	N/R	N/R	4	N/R	8	1	0.00
Pompano	1	N/R	4	N/R	N/R	3	8	1	0.00
Gars	N/R	N/R	3	N/R	N/R	N/R	3	1	0.00
Jack crevalle	2	1	N/R	N/R	N/R	N/R	3	1	0.00
Harvestfish	N/R	N/R	1	N/R	1	N/R	2	0	0.00
Sea robin	N/R	1	N/R	N/R	N/R	N/R	1	0	0.00
Cutlassfish	N/R	1	N/R	N/R	N/R	N/R	1	0	0.00
Kingfish	N/R	N/R	N/R	N/R	N/R	N/R	0	0	0.00
Total	52,229	72,736	35,284	58,872	37,715	55,558	312,394	52,066	100.00

*Only single gear trip tickets used (1994-1996 hard and peeler pot catches combined); N/R no landings reported.

Table 2. Total finfish landings from hard crab pots* in various waters of North Carolina: 1996 - 2001.

Waterbody	Total (lbs.)	Percent of total
Albemarle Sound	121,786.55	38.90
Currituck Sound	70,184.75	22.42
Pamlico Sound	24,909.91	7.96
Alligator River	21,130.58	6.75
Pamlico River	20,762.00	6.63
New River	8,167.01	2.61
Croatan Sound	7,869.50	2.51
Roanoke Sound	6,384.25	2.04
Core Sound	5,359.08	1.71
Inland Waterway	4,844.21	1.55
Pungo River	4,374.25	1.40
Neuse River	4,347.86	1.39
White Oak River	2,227.38	0.71
Pasquotank River	1,754.00	0.56
Bay River	1,690.00	0.54
Bogue Sound	1,568.87	0.50
Cape Fear River	1,487.17	0.47
Stump Sound	1,453.06	0.46
Topsail Sound	1,038.38	0.33
Masonboro Sound	735.17	0.23
Chowan River	366.00	0.12
Perquimans River	238.50	0.08
Back Bay (VA)	190.50	0.06
Lockwood Folly	124.85	0.04
North River	101.24	0.03
Ocean <3 mi, S.C.Hat.	10.00	0.00
Newport River	5.50	0.00
Shallotte River	1.50	0.00
Total	313,112.07	100.00

*Only single gear trip tickets used.

Table 3. Total landings of the top five finfish in the top five waters from hard crab pots* in North Carolina, 1996 - 2001.

		Waterbody					
		Albemarle Sound	Currituck Sound	Pamlico Sound	Alligator River	Pamlico River	Total top five areas
Catfish	Pounds landed	79,912	61,180	3,606	19,340	8,310	172,349
	% of all waters	45.15%	34.57%	2.04%	10.93%	4.70%	97.34%
Flounders	Pounds landed	22,324	2,861	7,972	792	9,434	43,382
	% of all waters	28.60%	3.67%	10.21%	1.01%	12.09%	55.58%
White perch	Pounds landed	5,879	1,723	150	813	33	8,598
	% of all waters	67.04%	19.65%	1.71%	9.27%	0.38%	98.05%
Speckled trout	Pounds landed	524	21	2,795	5	1,638	4,983
	% of all waters	6.99%	0.28%	37.29%	0.07%	21.85%	66.48%
Atlantic croaker	Pounds landed	4,697	211	620	70	202	5,799
	% of all waters	67.17%	3.02%	8.86%	1.00%	2.88%	82.93%
Total all species	Pounds landed	121,787	70,185	24,910	21,131	20,762	238,017
	% of all waters	38.90%	22.42%	7.96%	6.75%	6.63%	82.66%

*Only single gear trip tickets used.

Table 4. Total landings by month of the top five finfish species and all finfish species combined from hard crab pots* in North Carolina, 1996 - 2001.

		Month											
		1	2	3	4	5	6	7	8	9	10	11	12
Catfish	Total (lbs.)	359	305	7,229	25,800	23,368	11,564	11,655	14,776	24,239	39,936	15,378	2,386
	% of total	0.20%	0.17%	4.08%	14.58%	13.20%	6.53%	6.58%	8.35%	13.69%	22.56%	8.69%	1.35%
Flounders	Total (lbs.)	43	257	1,226	2,388	10,706	14,351	12,144	14,763	11,034	7,942	2,693	496
	% of total	0.06%	0.33%	1.57%	3.06%	13.72%	18.39%	15.56%	18.92%	14.14%	10.18%	3.45%	0.64%
White perch	Total (lbs.)	48	28	832	537	1,653	1,844	1,487	750	491	422	532	147
	% of total	0.55%	0.32%	9.49%	6.12%	18.85%	21.02%	16.95%	8.55%	5.60%	4.81%	6.07%	1.68%
Speckled trout	Total (lbs.)	102	6	63	99	880	3,990	1,481	450	103	140	143	40
	% of total	1.36%	0.08%	0.84%	1.31%	11.74%	53.23%	19.76%	6.00%	1.37%	1.86%	1.91%	0.53%
Atlantic croaker	Total (lbs.)	1	0	100	267	3,107	1,632	661	725	366	102	18	14
	% of total	0.01%	0.00%	1.42%	3.83%	44.43%	23.34%	9.45%	10.36%	5.24%	1.45%	0.26%	0.20%
Total all species	Total (lbs.)	762	1,197	11,189	32,486	46,585	38,724	29,167	33,412	40,057	53,504	22,459	3,571
	% of total	0.24%	0.38%	3.57%	10.38%	14.88%	12.37%	9.32%	10.67%	12.79%	17.09%	7.17%	1.14%

*Only single gear trip tickets used.

Table 5. Reported yearly finfish landings (lbs.) from peeler pots* in North Carolina: 1996 - 2001.

	Year								
	1996	1997	1998	1999	2000	2001	Total (lbs.)	Average	Percent of total
Eels	21	224	319	853	463	125	2,005	334	33.36
Catfish	9	426	328	327	74	267	1,431	239	23.81
Flounders		378	88	125	83	105	779	130	12.96
Yellow perch	1	53	60	250	92	59	515	86	8.56
Speckled trout		4	16	416	12	14	462	77	7.69
Atlantic croaker		1	4	113	91	163	372	62	6.19
Spot		1	11	124	4	13	153	26	2.55
White perch		13	44	28	11	8	104	17	1.73
Gray trout		1	3	38	14	2	58	10	0.96
Cutlassfish	45						45	8	0.75
Bluefish			1	5	4	12	22	4	0.37
Carp		20					20	3	0.33
Sheepshead			1	11	5		17	3	0.28
Black drum		14		1			15	3	0.25
Mullets				5		1	6	1	0.10
Red drum					3		3	1	0.05
Mixed fish		1		2			3	1	0.05
Sea mullet					1		1	0	0.02
Total	76	1,136	875	2,298	857	769	6,011	1,002	100.00

*Only single gear trip tickets used.

Table 6. Total finfish landings from peeler pots* in various waters of North Carolina, 1996 - 2001.

Waterbody	Total	Percent of total
Albemarle Sound	1,967	32.73%
Roanoke Sound	1,761	29.30%
Currituck Sound	1,620	26.94%
Croatan Sound	202	3.36%
Pasquotank River	176	2.93%
Neuse River	149	2.48%
Pamlico Sound	64	1.06%
Stump Sound	57	0.95%
New River	11	0.18%
Core Sound	3	0.05%
Cape Fear River	1	0.02%
Total	6,011	100.00%

*Only single gear trip tickets used.

Table 7. Total landings of the top five finfish by the top five waters from peeler pots* in North Carolina: 1996-2001.

		Waterbody					
		Albemarle Sound	Roanoke Sound	Currituck Sound	Croatan Sound	Pasquotank River	Total top five areas
Eels	Pounds landed	306	728	629	22	165	1,850
	% of all waters	15%	36%	31%	1%	8%	92%
Catfish	Pounds landed	555	286	554	21	8	1,424
	% of all waters	39%	20%	39%	1%	1%	100%
Flounders	Pounds landed	182	450	19	32	1	684
	% of all waters	23%	58%	2%	4%	0%	88%
Yellow perch	Pounds landed	131	20	362		2	515
	% of all waters	25%	4%	70%	0%	0%	100%
Speckled trout	Pounds landed	311	142	5	3		461
	% of all waters	67%	31%	1%	1%	0%	100%
Total all species	Pounds landed	1,967	1,761	1,620	202	176	5,726
	% of all waters	33%	29%	27%	3%	3%	95%

*Only single gear trip tickets used.

Table 8. Total landings by month of the top five finfish species and all finfish species combined from peeler pots* in North Carolina: 1996 - 2001.

		Month							
	Data	4	5	6	7	8	9	10	11
Eels	Total (lbs.)	456	1,257	155	23	15		99	
	% of total	22.74%	62.69%	7.73%	1.15%	0.75%	0.00%	4.94%	0.00%
Catfish	Total (lbs.)	181	1,022	54	105	57	1	11	
	% of total	12.65%	71.42%	3.77%	7.34%	3.98%	0.07%	0.77%	0.00%
Flounders	Total (lbs.)	15	483	93	11	122	39	12	4
	% of total	1.93%	62.00%	11.94%	1.41%	15.66%	5.01%	1.54%	0.51%
Yellow perch	Total (lbs.)	54	458	1		2			
	% of total	10.50%	88.92%	0.19%	0.00%	0.39%	0.00%	0.00%	0.00%
Speckled trout	Total (lbs.)	1	59	398	4				
	% of total	0.22%	12.77%	86.15%	0.87%	0.00%	0.00%	0.00%	0.00%
Total all species	Total (lbs.)	815	3,723	897	202	208	40	122	4
	% of total	13.56%	61.93%	14.92%	3.36%	3.46%	0.67%	2.03%	0.07%

*Only single gear trip tickets used.

Table 9. Catch numbers and Catch Per Unit Effort (CPUE) estimates for commercial hard crab pots sampled in the Neuse River, 1999*.

	Total number caught	Percent of total	CPUE trips	CPUE pots
Flounder	359	33.80	1.27	2.40E-03
Spot	159	14.97	0.56	1.06E-03
Pinfish	147	13.84	0.52	9.82E-04
Speckled trout	97	9.13	0.34	6.48E-04
American eel	66	6.21	0.23	4.41E-04
Gray trout	62	5.84	0.22	4.14E-04
Atlantic croaker	36	3.39	0.13	2.41E-04
Menhaden	31	2.92	0.11	2.07E-04
Bluefish	29	2.73	0.10	1.94E-04
Catfish	22	2.07	0.08	1.47E-04
Jumping mullet	15	1.41	0.05	1.00E-04
Red drum	11	1.04	0.04	7.35E-05
White perch	9	0.85	0.03	6.01E-05
Diamondback terrapin	9	0.85	0.03	6.01E-05
Sheepshead	5	0.47	0.02	3.34E-05
Yellow perch	1	0.09	0.00	6.68E-06
Hogfish	1	0.09	0.00	6.68E-06
Skate	1	0.09	0.00	6.68E-06
Seahorse	1	0.09	0.00	6.68E-06
Spanish mackerel	1	0.09	0.00	6.68E-06
Total	1,062		3.75	7.10E-03

*Raw data tabulated from Fishery Resource Grant 99FEG-45.

Table 10. Catch numbers and Catch Per Unit Effort (CPUE) estimates for commercial peeler pots sampled in the Neuse River, 1999*.

	Total number caught	Percent of total	CPUE trips	CPUE pots
White perch	150	50.00	13.64	0.077
American eel	84	28.00	7.64	0.043
Flounder	19	6.33	1.73	0.010
Menhaden	16	5.33	1.45	0.008
Gray trout	13	4.33	1.18	0.007
Spot	12	4.00	1.09	0.006
Jumping mullet	3	1.00	0.27	0.002
Speckled trout	2	0.67	0.18	0.001
Catfish	1	0.33	0.09	0.001
Total	300		27.27	0.154

*Raw data tabulated from Fishery Resource Grant 99FEG-45.

Table 11. Monthly statistics and catch rates for commercial hard crab pots sampled in the Neuse River, 1999*.

	Month								
	March	April	May	June	July	Aug.	Sept.	Oct.	Total
Number of trips	9	6	34	70	54	52	38	20	283
Number of pots examined	2,125	2,150	16,370	38,424	32,890	26,960	20,080	10,650	149,649
Average number of pots fished per trip	236.11	358.33	481.47	548.91	609.07	518.46	528.42	532.50	528.79
Average soak time (days)	3	4	2.5	2.2	1.9	1.7	1.5	1.8	2.0
Range soak time	1-5	3-7	1-12	1-7	1-11	1-6	1-3	1-6	1-12
Flounder	1	8	50	83	69	102	35	11	359
Spot	0	4	29	66	31	22	5	2	159
Pinfish	1	25	38	74	7	2	0	0	147
Speckled trout	0	3	16	25	19	10	21	3	97
American eel	0	0	0	21	16	21	5	3	66
Gray trout	0	1	7	7	8	14	18	7	62
Atlantic croaker	0	1	3	10	4	9	8	1	36
Menhaden	8	3	1	1	1	1	14	2	31
Bluefish	0	0	2	1	6	9	10	1	29
Catfish	0	0	1	1	0	2	6	12	22
Mullet	0	0	1	1	1	4	5	3	15
Red drum	0	0	0	1	3	3	4	0	11
White perch	0	0	1	0	0	0	8	0	9
Diamondback terrapin	0	0	0	4	4	1	0	0	9
Sheepshead	0	0	0	1	0	1	3	0	5
Yellow perch	0	0	1	0	0	0	0	0	1
Hogfish	0	0	0	0	1	0	0	0	1
Skate	0	0	0	0	1	0	0	0	1
Seahorse	0	0	0	0	1	0	0	0	1
Spanish mackerel	0	0	0	0	0	1	0	0	1
Total fish caught	10	45	150	295	173	201	139	45	1,058
CPUE trips	1.11	7.50	4.41	4.21	3.20	3.87	3.66	2.25	3.74
CPUE pot	0.005	0.021	0.009	0.008	0.005	0.007	0.007	0.004	0.007

*Raw data tabulated from Fishery Resource Grant 99FEG-45.

Table 12. Percent contribution of bycatch for hard crab pot catches sampled in the Neuse River, 1999*.

	Month							
	March	April	May	June	July	Aug.	Sept.	Oct.
Catfish	0.00	0.00	4.55	4.55	0.00	9.09	27.27	54.55
Atlantic croaker	0.00	2.78	8.33	27.78	11.11	25.00	22.22	2.78
American eel	0.00	0.00	0.00	31.82	24.24	31.82	7.58	4.55
Flounder	0.28	2.23	13.93	23.12	19.22	28.41	9.75	3.06
Gray trout	0.00	1.61	11.29	11.29	12.90	22.58	29.03	11.29
Menhaden	25.81	9.68	3.23	3.23	3.23	3.23	45.16	6.45
Mullet	0.00	0.00	6.67	6.67	6.67	26.67	33.33	20.00
Red drum	0.00	0.00	0.00	9.09	27.27	27.27	36.36	0.00
Sheepshead	0.00	0.00	0.00	20.00	0.00	20.00	60.00	0.00
Speckled trout	0.00	3.09	16.49	25.77	19.59	10.31	21.65	3.09
Spot	0.00	2.52	18.24	41.51	19.50	13.84	3.14	1.26
White perch	0.00	0.00	11.11	0.00	0.00	0.00	88.89	0.00
Yellow perch	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
Diamondback terrapin	0.00	0.00	0.00	44.44	44.44	11.11	0.00	0.00
Pinfish	0.68	17.01	25.85	50.34	4.76	1.36	0.00	0.00
Hogfish	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Skate	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Seahorse	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Bluefish	0.00	0.00	6.90	3.45	20.69	31.03	34.48	3.45
Spanish mackerel	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Total fish caught	0.94	4.24	14.12	27.87	16.20	19.02	13.37	4.24

*Raw data tabulated from Fishery Resource Grant 99FEG-45.

Table 13. Fate of captured individuals in commercial hard crab pots sampled in the Neuse River, 1999*.

	Total	Percent of total				
	number	Alive	Dead	Eaten	Bait	Injured
Flounder	216	75.46	1.85	12.50	0.00	10.19
Spot	104	61.54	1.92	18.27	10.58	7.69
American eel	63	100.00	0.00	0.00	0.00	0.00
Speckled trout	61	40.98	6.56	42.62	0.00	9.84
Gray trout	59	84.75	6.78	1.69	0.00	6.78
Pinfish	37	91.89	2.70	0.00	0.00	5.41
Atlantic croaker	32	46.88	3.13	34.38	9.38	6.25
Bluefish	27	14.81	0.00	0.00	85.19	0.00
Catfish	22	100.00	0.00	0.00	0.00	0.00
Menhaden	23	26.09	4.35	0.00	69.57	0.00
White perch	18	100.00	0.00	0.00	0.00	0.00
Mullet	15	100.00	0.00	0.00	0.00	0.00
Red drum	11	90.91	0.00	0.00	0.00	9.09
Diamondback terrapin	9	0.00	100.00	0.00	0.00	0.00
Sheepshead	6	100.00	0.00	0.00	0.00	0.00
Yellow perch	1	100.00	0.00	0.00	0.00	0.00
Hogfish	1	0.00	0.00	100.00	0.00	0.00
Skate	1	0.00	100.00	0.00	0.00	0.00
Seahorse	1	0.00	0.00	0.00	100.00	0.00
Spanish mackerel	1	0.00	100.00	0.00	0.00	0.00
Total bycatch	712	70.22	3.93	11.94	7.58	6.32

*Raw data tabulated from Fishery Resource Grant 99FEG-45.

Table 14. Fate of captured individuals in commercial peeler pots sampled in the Neuse River, 1999*.

	Total	Percent of total	
	number	Alive	Bait
White perch	150	100.00	0.00
American eel	84	100.00	0.00
Flounder	19	100.00	0.00
Menhaden	16	93.75	6.25
Gray trout	13	100.00	0.00
Spot	12	100.00	0.00
Mullet	3	100.00	0.00
Speckled trout	2	100.00	0.00
Catfish	1	100.00	0.00
Total bycatch	300	99.67	0.33

*Raw data tabulated from Fishery Resource Grant 99FEG-45.

Table 15. Average length of finfish caught in commercial hard crab pots sampled in the Neuse River, 1999*.

Species or group	Average length (inches)	Minimum length (inches)	Maximum length (inches)
Flounder	9.96	4.0	17.0
Spot	6.44	4.5	9.0
Speckled trout	13.20	5.0	18.0
American eel	11.66	7.0	20.0
Gray trout	11.37	7.0	16.0
Pinfish	4.03	3.0	6.0
Bluefish	13.43	7.0	16.5
Catfish	11.80	7.0	14.5
Atlantic croaker	7.50	4.5	14.0
Menhaden	6.81	4.5	12.0
Mullet	11.55	5.8	16.0
Red drum	11.09	8.0	14.0
Diamondback terrapin	8.33	7.0	12.0
Sheepshead	7.57	4.0	10.0
White perch	8.50	7.0	10.0
Gizzard shad	10.00	10.0	10.0
Yellow perch	6.00	6.0	6.0
Hogfish	4.50	4.5	4.5
Skate	10.00	10.0	10.0
Seahorse	3.00	3.0	3.0
Spanish mackerel	16.00	16.0	16.0

Raw data tabulated from Fishery Resource Grant 99FEG-45.

Table 16. Average length of finfish caught in commercial peeler pots sampled in the Neuse River, 1999*.

	Average length (inches)	Minimum length (inches)	Maximum length (inches)
American eel	21.36	17	22
White perch	6.14	4.5	8
Flounder	6.39	5	10
Gray trout	7.20	5.5	8
Menhaden	5.10	5	5.5
Spot	6.13	5	8
Mullet	7.00	6	8
Speckled trout	11.00	10	12
Catfish	8.00	8	8

*Raw data tabulated from Fishery Resource Grant 99FEG-45.

12.10 Appendix 10. CRAB TRAWL BYCATCH

I. Issue:

Bycatch in the crab trawl fishery.

II. Background:

Due to the non-selective nature of trawls, concerns have been raised about bycatch in the crab trawl fishery. The principle management issue in the crab trawl fishery is the composition, quantity, and fate of the marketable, and unmarketable bycatch. This bycatch can be divided into two components: incidental catch and discarded catch. Incidental catch refers to retained catch of non-targeted species. Discarded catch is that portion of the catch returned to the water as a result of economic, legal, or personal considerations.

In North Carolina's internal coastal waters, there are very few (less than 25) trawlers that harvest blue crabs exclusively. Since 1994, annual participation in the crab trawl fishery has ranged from 179 to 418 vessels, and averaged about 290 vessels (NCDMF Trip Ticket Program). The majority (60%) of the effort in the crab trawl industry, based on number of trips, occurs between March and June.

Crab trawl headrope lengths for double-rigged vessels range from 30 to 45 feet, while twin-rigged vessels usually pull four nets in the 30-foot range. Tow times vary depending on temperature and the amount of biomass encountered. Tow times generally decrease as biomass and/or temperature increases.

<u>Crab Trawl Landings</u>

Total annual landings in this fishery have averaged 2.0 million pounds, ranging from 1 to 3.4 million pounds (DMF Trip Ticket data 1994-2002). Blue crabs (hard, soft and peeler) account for 95% of the total landings; followed by finfish (4%), mollusks [0.45% (conchs/whelks, squid, and clams), and other invertebrates [0.68% (horseshoe crabs, stone crabs, and shrimp).

Overall hard crab landings from crab trawls account for 4% of the total statewide landings for this species (1994-2002 Trip Ticket Program). Since 1994, hard crab landings from crab trawls have averaged 1.8 million pounds annually and account for 94% of the total landings for this gear (Table 1). Hard crab landings are reported from every month with the highest percentage occurring in November (15%) and March [13% (Table 2)]. November and December have the highest CPUE (catch per trip) for hard crabs, 1,668 and 1,487 pounds respectively, while most trips occur in May (Table 2). Crab trawl landings have been reported from 22 waterbodies in the state (DMF Trip Ticket data 1994-2002). Pamlico Sound accounts for 47% of all hard crabs landed by crab trawls and 24% of all trips landing hard crabs (Table 3). Other areas with significant hard crab landings from crab trawl are Pamlico (17%), Neuse (9%), Pungo (9%), and Bay rivers (6%), and Croatan Sound (6%). Pamlico Sound has the highest CPUE (1,212 lbs. per trip) for hard crabs; followed by Bay River (653 lbs.), Croatan Sound (610 lbs.), and the Pamlico River (458 lbs. per trip).

Peeler crab landings from crab trawls represent 1.6% of the total statewide landings of peeler crabs. On average, 13,677 pounds of peeler crabs have been landed annually by crab trawls (Table 1). Sixty-two percent of the peeler crabs landed by crab trawls are caught in March and April (Table 4). The highest CPUE per trip was March with 92 pounds of peeler crabs; followed by April (60 lbs.) and August [43 lbs. (Table 4)]. Fifty-seven percent of all peeler crabs caught by crab trawls are harvested from Core Sound (Table 5). This area also has accounted for most of the tips (34%) and has the highest CPUE per trip of all waterbodies [83lbs. (Table 5)].

Finfish landings by crab trawls average 86,255 pounds per year (DMF Trip Ticket data 1994-2002). The main species landed is southern flounder accounting for 82% of the total finfish landed by crab trawls (Table 6). Southern flounder landings from crab trawls average 70,261 pounds per year and account for 2% of the total state landings for this species (Although both southern and summer flounder are caught in inside waters, DMF estimates that over 99% of the landed flounder from inside waters are southern.). On average, flounder are landed from 47% (average 1,442 trips out of 3,090 crab trawl trips per year) of the crab trawl trips each year. The months of February, March, and April account for 66% of the pounds and 48% of the trips landing flounder from crab trawls (Table 7). For all crab trawl trips, the average CPUE for flounder is 22.74 pounds per trip, for trips with flounder landings the CPUE is 48.74 pounds per trip. From late fall (November) through early spring (March) the CPUE's for flounder are 60 pounds or greater with March having the highest monthly CPUE [84 pounds/trip (Table 7)]. Flounder landings from crab trawls have been reported from 15 waterbodies. Eighty-nine percent of the flounder landed by crab trawls and 77% of the trips come from three areas: Pamlico Sound, Pamlico and Pungo rivers (Table 8). Pamlico Sound has the highest CPUE with 78 pounds of flounder landed per trip (Table 8). This is followed by Pamlico (48 lbs./trip), Neuse (38 lbs./trip), Bay (37 lbs./trip) and Pungo (28 lbs./trip) rivers (Table8).

Catfish are the next largest finfish component (10%) and average 8,628 lbs. per year (Table 6). Most catfish landings occur from February through April (Table 9). Pamlico River accounts for 83% of the catfish landings (Table 10). The remaining 8% of the finfish landed by crab trawls is shown in Table 6. Pamlico Sound accounts for 56% of the flounder, 7% of the catfish, 90% of the southern kingfish, and 37% of the gray trout landed by crab trawls (Table 10). The Pamlico River contributes, on average, 22% of the flounder, 83% catfish, 4% southern kingfish, and 39% gray trout to the total crab trawl finfish landings. Finfish landings from crab trawls in the Neuse River include, flounder 4%, catfish <1%, southern kingfish 1%, and gray trout 4%. Pungo River accounts for 12% of the flounder and 8% of the gray trout.

<u>Summary of Crab Trawl Characterization Studies</u>

The crab trawl fishery has received a large amount of attention due to concerns over the bycatch of finfish and sublegal crabs. In 1990 - 1991, a study was conducted by DMF in the Pamlico-Pungo river complex to examine this problem (McKenna and Camp 1992). During this study, 15 trips were made aboard commercial crab trawlers. The mean number of tows made during a trip was 3.3, and ranged from 1 to 5. Tow times ranged from 1 to 4 hours and averaged 2.87 hours. An average trip consisted of 9.46 hours of towing. On average, 181.55 lb of blue crabs (124.49 lb culls and 57.06 lb of basket crabs), and 131.15 lb of flounder were landed per trip.

<u>Finfish and Invertebrate Bycatch</u>

Species compositions were available for 14 of the 15 trips in the 1990-1991 study (McKenna and Camp 1992). Twenty-seven species of fish and eight invertebrate species were captured. Southern flounder were caught during every trip (15). Spot and Atlantic menhaden were caught in 10 of the 14 trips where species composition was recorded. Hogchokers occurred in eight of the trips; followed by Atlantic croaker (7), oyster toadfish (4), harvestfish (3), striped mullet (3), clearnose skates (2), pinfish (2), gizzard shad (2), bay whiff (2), and spotted seatrout (2). The remaining 14 species of finfish were observed only once. Blue crabs were the most frequently observed invertebrate per trip (15); followed by jellyfish (10), pink shrimp (7), lesser blue crab (5), mantis shrimp (3), iridescent swimming crab (2), horseshoe crab (1), and squid (1).

Of the 26 species of fish (excluding flounder) captured during the study, nine were of commercial importance (spot, Atlantic croaker, Atlantic menhaden, weakfish, harvestfish, striped mullet, sheepshead, spotted seatrout, and white catfish), and 11 are sought by recreational fishermen (pinfish, pigfish, brown bullhead, and all of the above except Atlantic menhaden). With the exception of spot, Atlantic croaker, Atlantic menhaden, harvestfish, and white catfish, the total weight of each species caught during the study (50 tows) was less than 1.1 lb. Due to the nonselective nature of trawls and the inherent variability of fish assemblages, bycatch in the crab trawl fishery will vary temporally and spatially. This variability was evident throughout this study with significant temporal and spatial differences being observed.

Southern flounder was the most abundant fish species by weight, accounting for 95% of the total fish weight and 47% of the total catch weight. Blue crabs accounted for 96% of the invertebrate weight and 33% of the total catch weight. The remaining percentage of the total catch weight was composed of miscellaneous material (16%), fish (3%), and invertebrates (1%).

On average, 13.2 lb of finfish (excluding flounder) were caught (3.9 lb per tow). Spot was the most abundant species by weight, accounting for 35% of the total finfish bycatch (excluding flounder). Atlantic croaker was the second most abundant species (26%); followed by clearnose skates (20%), harvestfish (4%), oyster toadfish (3%), white catfish (2%), Atlantic menhaden (2%), hogchoker (1%), and weakfish (1%). The remaining 6% of the bycatch weight was made up of 16 different species. More than 71% of the spot and 92% of the Atlantic croaker were caught on a single trip on November 14, 1990. This trip and the June 12, 1991 trip accounted for 78% of the total finfish bycatch, 49% and 29% respectively.

<u>Finfish Bycatch and Crab Trawl Tailbag Mesh Size</u>

Over 97% of the finfish bycatch (excluding flounder) was caught during trips in which a three-inch (stretched mesh) tailbag was used. However, as was the case above, 80% of this bycatch was caught during two trips (11/14/90 and 6/12/91). Twenty-two species of fish were caught in the three-inch tailbag, and eight species occurred in the four-inch (stretched mesh) tailbag. Spot and Atlantic croaker occurred in all of the three-inch tailbag trips for which data were available (7 of 8 trips), and accounted for 98% and 100% of the total catch weights for these species, respectively. Atlantic menhaden was the most frequently observed species in the four-inch tailbag, occurring in five of the seven trips, and accounting for 8% of the finfish bycatch for this gear. Redhorse suckers were the dominant species by weight (36%), but they only occurred in one trip. Spot was the second most abundant species in terms of frequency of occurrence and weight, 43% and 25%, respectively. The average catch of finfish bycatch in the three-inch tailbag was 24.16 lb (7.14 lb per tow) and 0.71 lb in the four-inch tailbag (0.21 lb per tow); this difference was significant at the p=0.001 level.

Flounder Bycatch and Mortality

Fifty-one percent of the southern flounder caught during this study were sublegal. For every pound of legal flounder landed, 1.04 lb of sublegal flounder (less than 13 inches) were culled from the catch. Mortality estimates for these sublegal fish were not determined. However, studies conducted by the DMF in January and February of 1991 showed that the survival rate of sublegal flounder held for 48 hours was greater than 95%. Tow times for these studies were two hours and the gears used were 30-foot crab trawls. The sample size for these studies was small (29 fish), and exact exposure times and scale loss estimates were not recorded (DMF unpublished data, 1991). In a crab trawl tailbag study conducted in Bay River during 1995 - 1996, Lupton (1996) found that nearly all of the sublegal southern flounder caught during the summer months were dead when returned to the water, while in the spring and winter little immediate mortality was observed.

Studies conducted in Long Island Sound, N.Y., estimated the survival of sublegal winter flounder caught in otter trawls at 60% for two hour tows and 75% for one hour tows (Simpson 1990). Critical factors affecting the survival of fish from trawl catches are tow duration, scale loss, total biomass, handling and sorting time, temperature and maximum depth fished (Jean 1963; Neilson et al. 1989; Wassenberg and Hill 1989; Simpson 1990).

Sublegal Blue Crab Bycatch

The overall percentage of sublegal crabs in the crab trawl catch (54%) was well above the legal tolerance (McKenna and Camp 1992). There was an apparent difference in the percentage of sublegal crabs retained in the two tailbag sizes sampled, 57% and 38% for the three- and four-inch (stretched mesh), respectively.

Blue Crab Bycatch Mortality

The incidence of physical injury to trawl and pot-caught crabs was similar in that the appendages were most frequently damaged (McKenna and Camp 1992). The chelipeds (pincher appendages) were the most frequently damaged appendage for both gear types; pot-caught crabs showed a greater loss than did trawl-caught crabs, 52% and 33%, respectfully. There were no differences between the survival rates of damaged crabs and undamaged crabs. These findings are in agreement with those of Smith and Howell (1987), who found the appendages were the most frequently damaged structure in pot and trawl-caught American lobsters in Long Island Sound, N.Y. Additionally, Wassenberg and Hill (1989) found that 99% of the trawl-induced damage to sand crabs was restricted to the appendages.

The only observed cases of immediate mortality in crab-trawl-caught crabs occurred in June (McKenna and Camp 1992). During this trip, a large number of paper shell and soft crabs were killed in the trawling process. These findings agree with those of other investigators who found that immediate mortality in trawl-caught crustaceans was almost entirely limited to soft or paper stage individuals (Smith and Howell 1987; Wassenberg and Hill 1989).

Factors affecting the level of delayed mortality in crustaceans are temperature, exposure time, amount and level of physical injury, and total catch biomass (Smith and Howell 1987; Wassenberg and Hill 1989). Overall a survival rate for trawl-caught crabs was 64%, while 93% of the crab pot crabs survived (McKenna and Camp 1992). The effects of temperature were readily apparent; survival rates for trawl-caught crabs during the winter months were 74%, while the individuals caught in June had a 20% survival rate.

Tailbag studies

Since the completion of the characterization study, which established that bycatch was an issue in the crab trawl fishery that needed to be addressed, three additional studies have been completed to determine the feasibility of reducing bycatch through the alteration of the mesh size within the tailbag. In lieu of more stringent regulations including quotas, limited entry, or spatial and temporal closures, the control of net selectivity is the preferred method for reducing incidental harvest. Minimum mesh size regulations for trawls are the principle approach taken to regulate fishing mortality on fish populations (Smolowitz 1983). The intent of mesh size regulation is to allow under-sized fish and invertebrates to escape from the tailbag and survive to contribute to the future spawning stock biomass. Studies on the survival of fish escaping from the tailbags of trawls support the use of minimum mesh sizes as a means of reducing fishing mortality on juvenile fish (Main and Sangster 1988, Simpson 1990). In contrast, fish and invertebrates discarded from the landed catch following the completion of a tow, have considerably lower survival rates (Jean 1963, Neilson et al 1989, Wassenberg and Hill 1989).

The first of the three studies (McKenna and Clark 1993) testing the effects of different tailbag mesh sizes on reducing bycatch was conducted immediately following the completion of the characterization study. This one-year study was performed by the NCDMF between November 1991 and November 1992. The testing was conducted in the Pamlico, Pungo, and Neuse rivers during the fall and winter and in Adam's Creek during the summer using 3-inch, 4-inch, and 4½-inch (stretched mesh) tailbags. Seventy-one tows were conducted aboard a research vessel towing two nets at a time, the control net with the 3-inch tailbag and the test net with either the 4-inch tailbag (31 tows) or 4½-inch tailbag (40 tows). Tow times were one hour at night during the winter and spring and 30 minutes during the day in the summer. All tows were pulled with the prevailing wind at a speed of 2.5 knots.

The second of the three studies (Lupton 1996) to determine the selectivity of different tailbag mesh sizes for crab trawls was conducted by the Pamlico County Schools between June 1995 and May 1996 through a Fishery Resource Grant (FRG). One objective of this study was to see if the results obtained in the comparison by McKenna and Clark (1993) would be the same with an increased amount of test tows. As with the NCDMF study, a 4-inch tailbag and a 4½-inch tailbag were tested against a 3-inch tailbag. Two hundred twenty tows were conducted during the day in the Bay River aboard a research vessel towing two nets at a time, the control net with the 3-inch tailbag and the test net with either the 4-inch tailbag (110 tows) or 4½-inch (110 tows) tailbag. Tow times were one hour during the winter and spring and 30 minutes in the summer. All tows were pulled at a speed of 2.5 knots.

The final study (Hannah and Hannah 2000) on mesh size selectivity was conducted by commercial fishermen through a FRG. The intent of the study was to evaluate whether an increase in the tailbag mesh size would yield the same reduction rates in the eastern Pamlico Sound as was found by McKenna and Clark (1993) and Lupton (1996) for the western Pamlico Sound. The study was conducted during 1998 and 1999 in both the eastern and the western potions of the Pamlico Sound; however, the eastern portion was only sampled during the winter and spring. The eastern areas of the Pamlico Sound included Stumpy Point Bay, Croatan Sound, Bluff Shoal, and the Outer Banks. The western Pamlico Sound areas were comprised of the Pamlico and Pungo rivers, Goose Creek, and Rose Bay. During each tow, two nets were fished, the control net with a 3-inch tailbag and a test net with either a 4-inch (39 tows) or a 4½-inch (41 tows) tailbag. All tows were an hour in duration, carried out between sunrise and sunset, and pulled at a vessel speed of 2.5 knots.

Sublegal Blue Crab Bycatch and Trawl Tailbag Mesh Size

During these studies, the number of sublegal blue crabs was reduced by 13% - 31% in the 4 inch tailbag and by 44% - 62% in the 4.5 inch tailbag, as compared to catches in a 3 inch tailbag (Tables 11 and 12). Also, the number of legal crabs was reduced by 0.21% - 7% in the 4 inch tailbag and by 17% - 26% in the 4.5 inch tailbag. Given the high percentage of sublegal blue crabs currently being harvested by the crab trawl fishery, an increase in the minimum tailbag mesh size should be implemented to reduce fishing mortality on this species. Increasing the mesh size to 4 inch would significantly reduce the harvest of sublegal crabs. Even though the 4 inch tailbag might also reduce the harvest of legal crabs these individuals would not necessarily be lost to the fishery. Except for the fall migration of mature females to the Outer Banks area, blue crabs exhibit very little long-range movement, and therefore should not be lost to future harvest. Additionally, the reduction of fishing mortality on sublegal crabs should make more individuals available for harvest at a future date.

Flounder Bycatch and Trawl Tailbag Mesh Size

Southern flounder are the most common finfish species landed by crab trawls (81%), averaging 70,261 lb per year (DMF trip ticket data 1994-2002). Over half of the southern flounder caught by commercial crab trawlers in the Pamlico River complex in 1990-1991 were sublegal (McKenna and Camp 1992). The two experimental tailbags tested (4 and 4.5") significantly reduced the number of sublegal southern flounder (less than 13 inches); 29% - 40% in the 4 inch tailbag and 49% - 82% in the 4.5 inch tailbag (Tables 11 and 12). Reduction rates in the 4 inch tailbag appear to be proportional throughout the sampled size range; whereas, the 4.5 inch tailbag almost totally eliminated the harvest of southern flounder below 9.8 inches.

Finfish Bycatch and Trawl Tailbag Mesh Size

Overall, finfish bycatch (excluding southern flounder) in the 3 inch tailbag averaged 3.90 lb per tow in the DMF study (McKenna and Clark 1993) and 1.55 lb per tow in the Lupton study (1996). This number compares favorably with estimates obtained from commercial samples of crab trawlers working the Pamlico River complex during the 1990-91 fishing season (2.75 lb per tow: McKenna and Camp 1992). Additionally, DMF tailbag studies have shown that the 3 inch tailbag reduces finfish bycatch by over 70% when compared to a 1.5 inch mesh tailbag (DMF unpublished data, 1985 and 1988). The 4 inch tailbag averaged 1.94 lb (McKenna and Clark 1993) and 1.14 lb (Lupton 1996) of finfish per tow, while 0.57 lb (McKenna and Clark 1993) and 0.21 lb (Lupton 1996) of finfish were caught, on average, in the 4.5 inch tailbag. Since the biomass of finfish (excluding southern flounder) caught in crab trawls is relatively small, the selection of a tailbag for its ability to cull finfish should be secondary to its culling ability for crabs and flounder.

III. DISCUSSION:

Based on the study by McKenna and Camp (1992), which characterized the level of crab trawl bycatch, it is evident that some measures need to be taken to reduce the levels of bycatch, particularly of sublegal flounder and crabs, that are occurring within the fishery. There are several methods by which bycatch can be reduced with varying degrees of success. The management options for achieving the goal of bycatch reduction are detailed below:

Increase in the Tailbag Mesh Size

In a multispecies fishery, such as the crab trawl fishery, determination of the best practical tailbag size may require accepting a design with less than optimal selection performance for some species. Although the crab trawl fishery primarily targets blue crabs, there is also the potential for unlimited harvest of sublegal southern flounder. Numerous other marketable species of finfish, including spot, croaker, and catfish, are also taken incidentally. The current industry standard for the mesh size in the tailbag of a crab trawl is 3 inches (stretched mesh). Increasing the mesh size to 4 or 4½ inches (stretched mesh) has been shown to have some success in reducing the amount of bycatch caught by the gear, particularly in the western portion of the Pamlico Sound (McKenna and Clark 1993, Lupton 1996, Hannah and Hannah 2000). If the only concern in the fishery was to reduce the amount of sublegal flounder taken as bycatch, this would typically be accomplished by setting the minimum mesh size requirement to match the mesh size at which a desired percentage of the catch would be sublegal. In the case of trawling, this percentage is usually set at 50%, or L_{50}. Based on a net mesh selectivity study conducted in North Carolina, to achieve an L_{50} of around 13 inches for flounder (the legal size limit in inshore waters), the mesh size of the tailbag would need to be between 5 and 5¼ inches (Gillikin et al. 1981). However, in the case of crab trawling, increasing the mesh size to that degree would be economically detrimental to the industry by allowing too much of the main product, crabs, to escape from the tailbag. Hence, a more moderate approach of a 4-inch or 4½-inch tailbag should be considered.

While the 4½-inch stretched mesh tailbag exhibits the greatest reduction in the take of undersized flounder (~50-82%), it also demonstrates a substantial loss of legal crabs (~17-26%; Table 12). These individuals, however, would remain available to the fishery in subsequent tows. In addition, the reduction of the fishing mortality on sublegal crabs (~44-62%) should increase the overall harvest of legal blue crabs, and therefore the amount of biomass landed. The initial burden on fishermen could be alleviated somewhat by opting to use a 4-inch tailbag rather than the 4½-inch. This size mesh was found to have little impact on the catch of legal crabs (a reduction of ~0-7%); however, a 4-inch tailbag would also have less of an impact on the reduction of sublegal flounder (~29-40%) and crabs (~13-31%), as well.

Harvest Seasons and Area Restrictions

Another option for managing the take of sublegal southern flounder and crabs in the crab trawl fishery would be to implement seasonal restrictions. According to Lupton (1996), fewer sublegal blue crabs and flounder are taken during the winter and spring than in the summer (Table 13). Lupton (1996) pointed out that nearly all of the southern flounder caught during the summer months were dead when returned to the water. In contrast, little immediate mortality was observed in the cooler months. A study conducted by the NCDMF during January and February of 1991 found that the survival rate for southern flounder caught in crab trawls and held for 48 hours was greater than 95% (NCDMF unpublished data). Other critical factors which affect the survival of fish from trawl catches include tow duration, scale loss, total biomass of catch, handling and sorting time, and maximum depth fished (Jean 1963, Neilson et al. 1989, Wassenburg and Hill 1989, Simpson 1990). Generally crab trawl effort declines during the summer and fall (Table 2), when crab trawlers switch to shrimp trawling. There is a significant negative correlation between shrimp landings and crab trawl landings during this time frame ($R = -0.61$; $p = 0.001$).

Area restrictions coupled with harvest seasons could minimize the extent of sublegal blue crab and southern flounder bycatch mortality. If an area or areas could be identified that are important summer habitats of blue crab and southern flounder; then these areas could be closed during the warmer months when trawl mortality is high.

Lupton (1996) recommended that a 4 inch tailbag be required in crab trawls. The 41/2 inch tailbag would put too much of an economic burden on crab trawlers, through the reduction of legal crab catch (Lupton 1996). Hannah and Hannah (2000) recommended that no change be made in the current regulation (3 inch tailbag). They agreed with Lupton (1996) in that a 41/2 inch tailbag would be an economic burden to crab trawlers. Additionally, these authors felt that a 4 inch tailbag would not work in the eastern and northeastern Pamlico Sound area during the fall and winter (loss of mature females) and crab trawlers would lose their peeler catch in the spring.

IV. Current Authority:

- ♦ It is unlawful to use trawl nets for the taking of finfish in internal waters, except that it shall be permissible to take or possess finfish incidental to crab or shrimp trawling in accordance with the following limitations: it is unlawful to possess more than 500 pounds of finfish from December 1 through February 28 and 1,000 pounds of finfish from March 1 through November 30. 15A NCAC 3J .0104 (a) (1)
- ♦ It is unlawful to use trawl nets from December 1 through February 28 from one hour after sunset to one before sunrise in portions of the Pungo, Pamlico, Bay, Neuse, and New rivers. 15A NCAC 3J .0104 (b) (5) (A) (B) 8 (D) (E)
- ♦ It is unlawful to use trawls within one-half mile of the ocean beach between the Virginia line and Oregon Inlet. 15A NCAC 3J .0202 (2)
- ♦ From December 1 through March 31 it is unlawful to possess finfish caught incidental to crab or shrimp trawling in the Atlantic Ocean unless the weight of the combined catch of shrimp and crabs exceeds the weight of finfish; except that crab trawlers working south of Bogue Inlet may keep up to 300 pounds of kingfish, regardless of their finfish or crab catch weight. 15A NCAC 3J .0202 (5) Temporary rule effective 12/97
- ♦ It is unlawful to trawl for crabs between one hour after sunset on any Friday and one hour before sunset on the following Sunday, except in the Atlantic Ocean. 15A NCAC 3L .0202 (d) and 3J .0104 (b) (1)
- ♦ It is unlawful to use trawl nets in Albemarle Sound and its tributaries. 15A NCAC 3J .0104 (b) (3)
- ♦ It is unlawful to use trawl nets in areas listed in 15A NCAC 3R .0106, except that certain areas may be opened to peeler trawling for single-rigged peeler trawls or double-rigged boats whose combined total headrope length does not exceed 25 feet. 15A NCAC 3R .0106
- ♦ It is unlawful to use any trawl net in any primary or secondary nursery area. 15A NCAC 3N .0104 and 3N .0105 (a)
- ♦ Special secondary nursery areas may be opened to shrimp and crab trawling from August 16 through May 14. 15A NCAC 3N .0105 (b)
- ♦ It is unlawful to take or possess crabs aboard a vessel in internal waters except in areas and during such times as the fisheries Director may specify by proclamation. 15A NCAC 3L .0202 (a)
- ♦ It is unlawful to take crabs with crab trawls with a stretched mesh less than 3 inches, except that the Director may, by proclamation, increase the minimum mesh length to no more than 4 inches. 15A NCAC 3L .0202 (b)

- ♦ It is unlawful to use trawls with a mesh length less than 2 inches (stretched mesh) or with a corkline exceeding 25 feet in length for taking soft or peeler crabs. 15A NCAC 3L .0202 (c)
- ♦ The Director may by proclamation, require bycatch reduction devices or codend modifications in trawl nets to reduce the catch of finfish that do not meet size limits or are unmarketable as individual foodfish by reason of size. 15A NCAC 3J .0104 (d)

V. Management Options/Impacts

(+ potential positive impact of action)
(- potential negative impact of action)

1. No rule change.
   - \+ No new regulations.
   - \- Continued biological concerns with finfish and sublegal crab bycatch.
   - \- Continued spacial conflicts.

2. Increase tailbag mesh size (4 inch or 4.5 inch stretched mesh).
   - \+ Reduce bycatch.
   - \+ Possibly increase numbers of legal crabs and southern flounder by delaying age at entry into the fishery.
   - \- Potential economic burden on fishermen.

3. Increase crab trawl stretched mesh size to 4 inches throughout the net in the Pamlico-Pungo, Bay, and Neuse rivers.
   - \+ Reduce bycatch.
   - \+ Possibly increase numbers of legal crabs and southern flounder by delaying age at entry into the fishery.
   - \- Maximum reduction benefits will not be achieved (area and gear).

4. Harvest seasons.
   - \+ Reduce bycatch mortality.
   - \+ Potential decrease in effort.
   - \+ Reduce/eliminate conflicts (crab trawl and crab potters).
   - \+ More efficient law enforcement.
   - \- Potential economic burden on fishermen.

5. Area restrictions.
   - \+ Reduce bycatch mortality.
   - \+ Protect critical habitats.
   - \+ Reduce effort.
   - \+ Reduce/eliminate user conflicts (shrimp and crab trawler vs. crab potters).
   - \- Potential economic burden on fishermen (reduction in catch).
   - \- Increased law enforcement duties.

6. Ban crab trawling.
   - \+ Eliminate trawl bycatch mortality.
   - \+ Reduce user conflicts (potters vs crab trawlers).
   - \+ Increased crab pot catches.
   - \- Economic hardship for trawlers.

Options two through four and six would require rule changes by the MFC.

Recommendations:

The MFC Crustacean Advisory Committee and Southern Flounder FMP Committee met on May 15, 2001 and made the following recommendation: Allow the Fisheries Director to specify a 4-inch (stretched mesh) crab trawl mesh size in western Pamlico Sound and tributaries and a 3-inch (stretched mesh) crab trawl tailbag mesh size on the eastern side of Pamlico Sound. A line dividing Pamlico Sound down the middle would be established by proclamation. The MFC endorsed the committees' recommendation on May 12, 2004. The NCDMF recommends a 4-inch (stretched mesh) tailbag in all areas of the state.

VI. Research Needs:

1) Collect fishery-dependent data from the peeler crab and shrimp trawl fisheries.

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Table 1. Yearly crab trawl landings (pounds) for North Carolina: 1994 - 2002.

	Year											Percent
	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Hard crabs	1,865,154	1,045,482	3,073,244	3,267,234	3,063,173	1,794,072	917,568	983,370	1,011,788	17,021,084	1,891,232	93.78
Flounders	104,251	58,468	84,704	78,411	92,395	69,917	61,592	52,208	30,408	632,351	70,261	3.48
Peeler crabs	17,977	15,512	11,775	17,523	14,941	10,547	18,140	11,794	4,885	123,095	13,677	0.68
Horseshoe crab	N/R	N/R	583	4,500	17,440	8,832	9,297	18,780	34,579	94,011	10,446	0.52
Catfish	7,687	3,227	14,689	14,061	14,226	16,615	2,902	1,136	3,109	77,651	8,628	0.43
Conchs/Whelk	3,210	34	28,362	15,291	8,858	4,572	1,828	9,157	34	71,346	7,927	0.39
Soft crabs	6,683	4,062	3,341	4,988	5,718	7,724	1,429	1,807	150	35,902	3,989	0.20
Shrimp	295	12,425	371	2,988	732	1,144	197	216	514	18,883	2,098	0.10
Croaker	768	298	1,073	1,659	512	2,524	1,740	6,586	350	15,510	1,723	0.09
Squid	8,156	138	15	288	193	N/R	130	1,149	N/R	10,069	1,119	0.06
Southern kingfish	933	1,165	781	1,521	1,526	795	316	1,424	693	9,152	1,017	0.05
Spot	551	117	2,403	319	1,487	432	391	1,884	629	8,212	912	0.05
Gray trout	573	325	694	2,916	873	517	181	280	81	6,438	715	0.04
Mixed fish	361	402	172	3,286	96	135	690	319	N/R	5,461	607	0.03
Speckled trout	345	1,511	370	140	294	634	2,019	43	15	5,370	597	0.03
Black drum	96	380	224	1,821	81	256	11	213	1,256	4,338	482	0.02
Bluefish	N/R	11	123	474	91	N/R	3,102	14	5	3,820	424	0.02
White perch	81	14	76	40	280	67	964	N/R	2	1,524	169	0.01
Bait	N/R	N/R	424	407	47	N/R	N/R	126	4	1,008	112	0.01
Puffer	N/R	3	N/R	526	88	N/R	N/R	180	10	807	90	0.00
Sheepshead	279	62	53	6	103	130	9	146	13	800	89	0.00
Mullet	31	312	89	70	89	16	104	22	27	760	84	0.00
Yellow perch	9	N/R	1	206	422	N/R	74	N/R	N/R	712	79	0.00
Smooth dogfish	N/R	78	58	412	N/R	N/R	N/R	N/R	N/R	548	61	0.00
Red drum	289	2	18	3	23	33	20	2	7	396	44	0.00
Striped bass	N/R	42	17	206	118	N/R	8	N/R	N/R	391	43	0.00
Butterfish	13	1	51	119	7	22	1	27	62	303	34	0.00
Monkfish	3	138	N/R	25	53	N/R	2	N/R	N/R	221	25	0.00
Stone crabs	155	N/R	N/R	65	N/R	N/R	N/R	N/R	N/R	220	24	0.00
Menhaden	N/R	N/R	N/R	N/R	40	N/R	N/R	86	N/R	126	14	0.00
Hakes	N/R	N/R	N/R	94	N/R	N/R	N/R	N/R	N/R	94	10	0.00
Harvestfish	4	15	4	N/R	40	1	16	3	N/R	83	9	0.00
Spiny dogfish	N/R	64	N/R	N/R	N/R	N/R	N/R	N/R	N/R	64	7	0.00
Hickory shad	N/R	N/R	N/R	5	20	32	N/R	2	N/R	59	7	0.00
Shad	5	18	2	N/R	N/R	N/R	N/R	N/R	N/R	25	3	0.00
Hard clam	N/R	7	N/R	12	N/R	N/R	N/R	N/R	N/R	19	2	0.00
Black sea bass	N/R	10	N/R	9	N/R	N/R	N/R	N/R	N/R	19	2	0.00

Table 1. Continued

	Year											Percent
	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Tautog	N/R	N/R	N/R	11	N/R	N/R	N/R	N/R	N/R	11	1	0.00
Pigfish	N/R	6	N/R	4	N/R	N/R	N/R	N/R	N/R	10	1	0.00
Carp	9	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	9	1	0.00
Spanish mackerel	N/R	N/R	8	N/R	1	N/R	N/R	N/R	N/R	9	1	0.00
Eels	N/R	N/R	N/R	N/R	N/R	N/R	N/R	5	N/R	5	1	0.00
Spadefish	N/R	3	N/R	N/R	N/R	N/R	N/R	N/R	N/R	3	0	0.00
Herring	N/R	N/R	N/R	N/R	3	N/R	N/R	N/R	N/R	3	0	0.00
Oyster toad	N/R	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	2	0	0.00
Skates	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	N/R	2	0	0.00
Pompano	N/R	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Total	2,017,916	1,144,330	3,223,725	3,419,640	3,223,968	1,919,016	1,022,730	1,090,977	1,088,621	18,150,924	2,016,769	100.00

N/R=No landings reported.

Table 2. Total monthly hard blue crab catches, trips, and CPUE for crab trawls in North Carolina: 1994 - 2002.

	Pounds			Trips			CPUE
Month	Total	Average	Percent	Total	Average	Percent	(lbs./trip)
January	363,108	40,345	2.13	498	55	1.79	729
February	1,100,072	122,230	6.46	1,444	160	5.19	762
March	2,267,730	251,970	13.32	3,731	415	13.41	608
April	1,639,846	182,205	9.63	4,038	449	14.52	406
May	1,221,931	135,770	7.18	4,508	501	16.21	271
June	1,812,467	201,385	10.65	3,878	431	13.94	467
July	1,452,571	161,397	8.53	2,079	231	7.47	699
August	951,495	105,722	5.59	1,700	189	6.11	560
September	1,256,970	139,663	7.38	1,907	212	6.86	659
October	1,017,654	113,073	5.98	1,566	174	5.63	650
November	2,523,401	280,378	14.83	1,513	168	5.44	1,668
December	1,413,840	157,093	8.31	951	106	3.42	1,487
Total	17,021,084	1,891,232	100.00	27,813	3,090	100.00	612

Table 3. Hard crab landings and CPUE for crab trawls for various waters in North Carolina: 1994 - 2002.

	Pounds			Trips			CPUE
Waterbody*	Total	Average	Percent	Total	Average	Percent	(lbs./trip)
Pamlico Sound	7,943,108	882,568	46.67	6,554	728	23.56	1,212
Pamlico River	2,817,316	313,035	16.55	6,158	684	22.14	458
Neuse River	1,509,773	167,753	8.87	3,764	418	13.53	401
Pungo River	1,485,376	165,042	8.73	4,837	537	17.39	307
Croatan Sound	1,076,058	119,562	6.32	1,763	196	6.34	610
Bay River	1,073,978	119,331	6.31	1,645	183	5.91	653
Core Sound	784,525	87,169	4.61	1,973	219	7.09	398
New River	160,455	17,828	0.94	682	76	2.45	235
Roanoke Sound	126,952	14,106	0.75	299	33	1.08	425
Newport River	10,973	1,219	0.06	47	5	0.17	233
North River	5,748	639	0.03	19	2	0.07	303
Ocean > than 3 miles	2,490	277	0.01	6	1	0.02	415
Inland Waterway	1,952	217	0.01	13	1	0.05	150
Ocean < than 3 miles	1,363	151	0.01	13	1	0.05	105
Bogue Sound	355	39	0.00	6	1	0.02	59
Grand Total (all 22 waterbodies reporting crab trawl landings)	17,021,084	1,891,232	100.00	27,813	3,090	100.00	612

*minimum of 5 trips to be included.

Table 4. North Carolina average monthly peeler crab catches and CPUE from crab trawls: 1994 - 2002.

	Pounds			Trips			CPUE
Month	Total	Average	Percent	Total	Average	Percent	(lbs./trip)
February	155	17	0.13	6	1	0.24	25.85
March	51,121	5,680	41.53	556	62	22.18	91.94
April	24,916	2,768	20.24	418	46	16.67	59.61
May	15,780	1,753	12.82	538	60	21.46	29.33
June	14,950	1,661	12.15	426	47	16.99	35.09
July	4,315	479	3.51	128	14	5.11	33.71
August	8,267	919	6.72	194	22	7.74	42.61
September	3,247	361	2.64	194	22	7.74	16.74
October	344	38	0.28	47	5	1.87	7.32
Total	123,095	13,677	100.00	2,507	279	100.00	49.10

Table 5. Peeler crab landings and CPUE for various waters in North Carolina:1994 - 2002.

	Pounds			Trips			CPUE
Waterbody	Total	Average	Percent	Total	Average	Percent	(lbs./trip)
Core Sound	69,889	7,765	56.78	841	93	33.55	83.10
Neuse River	17,040	1,893	13.84	523	58	20.86	32.58
Croatan Sound	16,459	1,829	13.37	546	61	21.78	30.15
Pamlico Sound	8,422	936	6.84	295	33	11.77	28.55
Roanoke Sound	4,735	526	3.85	105	12	4.19	45.09
Pamlico River	3,458	384	2.81	108	12	4.31	32.02
Bay River	1,484	165	1.21	44	5	1.76	33.74
New River	574	64	0.47	23	3	0.92	24.94
Pungo River	419	47	0.34	11	1	0.44	38.07
Total	123,095	13,677	100.00	2,507	279	100.00	49.10

*minimum of 5 trips to be included.

Table 6. Finfish landed by crab trawls in North Carolina: 1994 - 2002.

	Year											Percent
	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Flounders	104,251	58,468	84,704	78,411	92,395	69,917	61,592	52,208	30,408	632,351	70,261	81.46
Catfish	7,687	3,227	14,689	14,061	14,226	16,615	2,902	1,136	3,109	77,651	8,628	10.00
Croaker	768	298	1,073	1,659	512	2,524	1,740	6,586	350	15,510	1,723	2.00
Southern kingfish	933	1,165	781	1,521	1,526	795	316	1,424	693	9,152	1,017	1.18
Spot	551	117	2,403	319	1,487	432	391	1,884	629	8,212	912	1.06
Gray trout	573	325	694	2,916	873	517	181	280	81	6,438	715	0.83
Mixed fish	361	402	172	3,286	96	135	690	319	N/R	5,461	607	0.70
Speckled trout	345	1,511	370	140	294	634	2,019	43	15	5,370	597	0.69
Black drum	96	380	224	1,821	81	256	11	213	1,256	4,338	482	0.56
Bluefish	N/R	11	123	474	91	N/R	3,102	14	5	3,820	424	0.49
White perch	81	14	76	40	280	67	964	N/R	2	1,524	169	0.20
Bait	N/R	N/R	424	407	47	N/R	N/R	126	4	1,008	112	0.13
Puffer	N/R	3	N/R	526	88	N/R	N/R	180	10	807	90	0.10
Sheepshead	279	62	53	6	103	130	9	146	13	800	89	0.10
Mullet	31	312	89	70	89	16	104	22	27	760	84	0.10
Yellow perch	9	N/R	1	206	422	N/R	74	N/R	N/R	712	79	0.09
Smooth dogfish	N/R	78	58	412	N/R	N/R	N/R	N/R	N/R	548	61	0.07
Red drum	289	2	18	3	23	33	20	2	7	396	44	0.05
Striped bass	N/R	42	17	206	118	N/R	8	N/R	N/R	391	43	0.05
Butterfish	13	1	51	119	7	22	1	27	62	303	34	0.04
Monkfish	3	138	N/R	25	53	N/R	2	N/R	N/R	221	25	0.03
Menhaden	N/R	N/R	N/R	N/R	40	N/R	N/R	86	N/R	126	14	0.02
Hakes	N/R	N/R	N/R	94	N/R	N/R	N/R	N/R	N/R	94	10	0.01
Harvestfish	4	15	4	N/R	40	1	16	3	N/R	83	9	0.01
Spiny dogfish	N/R	64	N/R	N/R	N/R	N/R	N/R	N/R	N/R	64	7	0.01
Hickory shad	N/R	N/R	N/R	5	20	32	N/R	2	N/R	59	7	0.01
Shad	5	18	2	N/R	N/R	N/R	N/R	N/R	N/R	25	3	0.00
Black sea bass	N/R	10	N/R	9	N/R	N/R	N/R	N/R	N/R	19	2	0.00
Tautog	N/R	N/R	N/R	11	N/R	N/R	N/R	N/R	N/R	11	1	0.00
Pigfish	N/R	6	N/R	4	N/R	N/R	N/R	N/R	N/R	10	1	0.00
Carp	9	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	9	1	0.00

Table 6. Continued

	Year											Percent
	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Spanish mackerel	N/R	N/R	8	N/R	1	N/R	N/R	N/R	N/R	9	1	0.00
Eels	N/R	N/R	N/R	N/R	N/R	N/R	N/R	5	N/R	5	1	0.00
Spadefish	N/R	3	N/R	N/R	N/R	N/R	N/R	N/R	N/R	3	0	0.00
Herring	N/R	N/R	N/R	N/R	3	N/R	N/R	N/R	N/R	3	0	0.00
Oyster toad	N/R	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	2	0	0.00
Skates	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	N/R	2	0	0.00
Pompano	N/R	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	1	0	0.00
Total	2,017,916	1,144,330	3,223,725	3,419,640	3,223,968	1,919,016	1,022,730	1,090,977	1,088,621	776,295	86,255	100.00

Table 7. Average monthly flounder catches and CPUE from crab trawls in North Carolina: 1994 - 2002.

	Pounds			Trips			CPUE
Month	Total	Average	Percent	Total	Average	Percent	(lbs./trip)
January	26,185	2,909	4.14	327	36	2.52	80.07
February	75,762	8,418	11.98	981	109	7.56	77.23
March	223,278	24,809	35.31	2,673	297	20.60	83.53
April	117,192	13,021	18.53	2,531	281	19.51	46.30
May	22,044	2,449	3.49	1,548	172	11.93	14.24
June	10,333	1,148	1.63	936	104	7.21	11.04
July	3,205	356	0.51	351	39	2.71	9.13
August	2,156	240	0.34	300	33	2.31	7.19
September	13,399	1,489	2.12	722	80	5.56	18.56
October	23,122	2,569	3.66	849	94	6.54	27.23
November	64,939	7,215	10.27	1,077	120	8.30	60.30
December	50,738	5,638	8.02	680	76	5.24	74.61
Total	632,351	70,261	100.00	12,975	1,442	100.00	48.74

Table 8. Flounder landings and CPUE for various waters in North Carolina: 1994 - 2002.

	Pounds			Trips			CPUE
Waterbody*	Total	Average	Percent	Total	Average	Percent	(lbs./trip)
Pamlico Sound	353,111	39,235	55.84	4,505	501	34.72	78.38
Pamlico River	137,126	15,236	21.69	2,862	318	22.06	47.91
Pungo River	73,136	8,126	11.57	2,662	296	20.52	27.47
Neuse River	28,069	3,119	4.44	749	83	5.77	37.47
Croatan Sound	17,295	1,922	2.73	1,030	114	7.94	16.79
Bay River	9,738	1,082	1.54	261	29	2.01	37.31
Core Sound	6,844	760	1.08	531	59	4.09	12.89
New River	3,330	370	0.53	218	24	1.68	15.27
Roanoke Sound	2,046	227	0.32	122	14	0.94	16.77
Total (all 15 waters reporting flounder landings from crab trawls.)	632,351	70,261	100.00	12,975	1,442	100.00	48.74

*Minimum of 5 trips needed to estimate CPUE

Table 9. Monthly breakdown of crab trawl landings (pounds) for North Carolina: 1994 - 2002.

	Month												
	January	February	March	April	May	June	July	August	September	October	November	December	Total
Hard crabs	363,108	1,100,072	2,267,730	1,639,846	1,221,931	1,812,467	1,452,571	951,495	1,256,970	1,017,654	2,523,401	1,413,840	17,021,084
Flounders	26,185	75,762	223,278	117,192	22,044	10,333	3,205	2,156	13,399	23,122	64,939	50,738	632,351
Peeler crabs	N/R	155	51,121	24,916	15,780	14,950	4,315	8,267	3,247	344	N/R	N/R	123,095
Horseshoe crabs	1,458	21,480	18,358	4,872	96	N/R	3	N/R	N/R	609	22,040	25,095	94,011
Catfish	4,501	11,704	37,751	14,478	1,139	698	N/R	N/R	805	5,092	1,404	80	77,651
Conchs/Whelk	1,064	4,197	15,639	46,375	1,866	35	N/R	N/R	N/R	N/R	403	1,767	71,346
Soft crabs	N/R	1	911	6,288	13,782	10,218	2,450	1,394	839	19	N/R	N/R	35,902
Shrimp	421	138	1,608	2,867	1,459	1,295	9,209	1,497	N/R	153	133	105	18,883
Croaker	123	120	4,881	5,735	390	393	47	16	428	147	637	2,595	15,510
Squid	N/R	N/R	N/R	N/R	N/R	5	N/R	N/R	N/R	N/R	9,419	645	10,069
Southern kingfish	19	587	1,828	3,803	175	41	207	20	293	214	1,121	847	9,152
Spot	N/R	9	161	1,168	1,358	1,583	234	255	2,274	1,041	131	1	8,212
Gray trout	13	116	809	1,788	214	158	49	1,882	481	329	417	184	6,438
Mixed fish	N/R	48	989	457	276	230	5	5	3	23	3,198	227	5,461
Speckled trout	1,751	2,258	166	163	33	126	33	3	10	31	171	627	5,370
Black drum	139	384	486	358	4	N/R	N/R	1,786	29	309	649	194	4,338
Bluefish	N/R	115	402	68	39	4	N/R	N/R	11	7	30	3,144	3,820
White perch	798	444	118	16	N/R	33	N/R	N/R	12	44	10	49	1,524
Bait	N/R	N/R	580	N/R	N/R	424	N/R	N/R	N/R	N/R	N/R	4	1,008
Puffer	N/R	1	515	203	18	N/R	N/R	N/R	N/R	N/R	N/R	70	807
Sheepshead	3	12	N/R	200	8	79	N/R	9	74	315	95	6	800
Mullet	69	65	24	25	13	60	N/R	1	93	15	375	20	760
Yellow perch	12	17	415	126	74	1	N/R	N/R	N/R	N/R	5	62	712
Smooth dogfish	412	N/R	78	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	58	548
Red drum	32	230	25	42	N/R	22	18	N/R	12	7	9	N/R	396

Table 9. Continued.

	Month												
	January	February	March	April	May	June	July	August	September	October	November	December	Total
Striped bass	N/R	43	125	21	N/R	N/R	N/R	N/R	N/R	N/R	162	40	391
Butterfish	N/R	8	49	34	4	90	5	N/R	4	32	33	44	303
Monkfish	N/R	18	65	5	N/R	N/R	N/R	N/R	N/R	N/R	133	N/R	221
Stone crabs	N/R	N/R	65	N/R	155	N/R	N/R	N/R	N/R	N/R	N/R	N/R	220
Menhaden	N/R	N/R	N/R	86	13	27	N/R	N/R	N/R	N/R	N/R	N/R	126
Hakes	N/R	N/R	94	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	94
Harvestfish	N/R	N/R	N/R	N/R	N/R	6	1	N/R	43	2	15	16	83
Spiny dogfish	N/R	N/R	64	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	64
Hickory shad	N/R	20	37	2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	59
Shad	N/R	N/R	18	7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	25
Hard clam	2	10	7	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	19
Black sea bass	N/R	N/R	N/R	9	N/R	N/R	N/R	N/R	N/R	N/R	10	N/R	19
Tautog	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	11	11
Pigfish	N/R	N/R	2	N/R	2	N/R	N/R	N/R	N/R	N/R	6	N/R	10
Carp	N/R	N/R	N/R	N/R	9	N/R	N/R	N/R	N/R	N/R	N/R	N/R	9
Spanish mackerel	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	8	1	N/R	N/R	9
Eels	N/R	N/R	N/R	5	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	5
Spadefish	N/R	N/R	N/R	3	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	3
Herring	N/R	N/R	3	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	3
Oyster toad	N/R	N/R	N/R	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	N/R	2
Skates	N/R	N/R	N/R	N/R	2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	2
Pompano	N/R	N/R	N/R	N/R	1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	1
Total	400,109	1,218,013	2,628,398	1,871,155	1,280,883	1,853,279	1,472,350	968,784	1,279,032	1,049,508	2,628,944	1,500,469	18,150,924

Table 10. Percent contribution of various waters to finfish landings by crab trawls in North Carolina: 1994 - 2001.

	Waterbody																			
	Bay River	Bogue Sound	Chowan River	Core Sound	Croatan Sound	Inland Waterway	Lockwood Folly	Neuse River	New River	Newport River	North River	Ocean	Pamlico River	Pamlico Sound	Pungo River	Roanoke Sound	Topsail Sound	White Oak River	Unknown	Total
Bait	0.00%	0.00%	0.00%	0.00%	13.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.66%	82.24%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Black drum	0.02%	0.00%	0.00%	0.00%	9.11%	0.00%	0.00%	0.23%	0.12%	0.00%	0.00%	0.00%	41.72%	45.60%	0.07%	1.01%	0.00%	0.00%	2.12%	100.00%
Black sea bass	0.00%	0.00%	0.00%	48.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	51.95%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Bluefish	0.00%	0.00%	0.00%	0.08%	1.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.47%	88.09%	0.00%	0.00%	0.00%	0.00%	0.08%	100.00%
Butterfish	0.00%	0.00%	0.00%	1.32%	1.32%	0.00%	0.00%	0.00%	8.91%	0.00%	0.00%	0.00%	12.21%	75.58%	0.00%	0.33%	0.00%	0.00%	0.33%	100.00%
Carp	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Catfish	0.24%	0.00%	0.00%	0.00%	0.98%	0.00%	0.00%	0.43%	0.00%	0.00%	0.00%	0.00%	83.00%	7.01%	8.32%	0.02%	0.00%	0.00%	0.00%	100.00%
Hard clam	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Conchs/Whelk	0.00%	0.00%	0.02%	98.30%	0.00%	0.00%	0.00%	0.00%	0.01%	0.08%	0.00%	0.25%	0.00%	1.34%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Horseshoe crab	0.03%	0.00%	0.00%	0.15%	1.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.73%	97.54%	0.17%	0.34%	0.00%	0.00%	0.00%	100.00%
Croaker	1.02%	0.00%	0.00%	0.28%	7.32%	0.00%	0.00%	4.78%	0.00%	0.00%	0.00%	0.00%	4.90%	76.82%	4.57%	0.28%	0.00%	0.00%	0.04%	100.00%
Eels	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Flounders	1.54%	0.02%	0.00%	1.08%	2.73%	0.00%	0.00%	4.44%	0.53%	0.02%	0.01%	0.18%	21.69%	55.84%	11.57%	0.32%	0.00%	0.00%	0.04%	100.00%
Gray trout	3.33%	0.00%	0.00%	0.26%	7.17%	0.00%	0.00%	4.24%	0.00%	0.00%	0.00%	0.00%	38.90%	37.16%	8.09%	0.70%	0.00%	0.00%	0.14%	100.00%
Hakes	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Hard crabs	6.31%	0.00%	0.00%	4.61%	6.32%	0.01%	0.01%	8.87%	0.94%	0.06%	0.03%	0.02%	16.55%	46.67%	8.73%	0.75%	0.00%	0.00%	0.11%	100.00%
Harvestfish	0.00%	0.00%	0.00%	0.00%	53.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	45.78%	0.00%	1.20%	0.00%	0.00%	0.00%	100.00%
Herring	0.00%	0.00%	0.00%	0.00%	63.64%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	36.36%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Hickory shad	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	54.24%	11.86%	33.90%	0.00%	0.00%	0.00%	0.00%	100.00%
Menhaden	0.00%	0.00%	0.00%	0.00%	31.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	68.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Mixed fish	2.71%	0.00%	0.00%	1.15%	0.04%	0.00%	0.00%	8.96%	2.73%	0.00%	0.00%	0.00%	2.04%	81.20%	1.17%	0.00%	0.00%	0.00%	0.00%	100.00%
Monkfish	0.00%	0.00%	0.00%	20.86%	0.00%	0.00%	0.00%	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%	78.23%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Mullet	1.05%	0.00%	0.00%	0.00%	12.64%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	28.17%	18.30%	39.72%	0.00%	0.00%	0.00%	0.13%	100.00%
Oyster toad	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

Table 10. Continued.

	Waterbody																			
	Bay River	Bogue Sound	Chowan River	Core Sound	Croatan Sound	Inland Waterway	Lockwood Folly	Neuse River	New River	Newport River	North River	Ocean	Pamlico River	Pamlico Sound	Pungo River	Roanoke Sound	Topsail Sound	White Oak River	Unknown	Total
Peeler crabs	1.21%	0.32%	0.00%	56.78%	13.37%	0.00%	0.00%	13.84%	0.47%	0.00%	0.01%	0.01%	2.81%	6.84%	0.34%	3.85%	0.00%	0.00%	0.16%	100.00%
Pigfish	0.00%	0.00%	0.00%	10.53%	0.00%	0.00%	0.00%	10.53%	0.00%	0.00%	0.00%	0.00%	0.00%	78.95%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Pompano	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Puffer	0.00%	0.00%	0.00%	80.92%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	19.08%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Red drum	0.00%	0.00%	0.00%	0.00%	1.77%	0.00%	0.00%	1.58%	0.00%	0.00%	0.00%	63.09%	14.64%	17.92%	1.01%	0.00%	0.00%	0.00%	0.00%	100.00%
Shad	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	72.00%	0.00%	0.00%	0.00%	0.00%	0.00%	28.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Sheepshead	0.94%	0.00%	0.00%	26.13%	30.00%	0.00%	0.00%	0.44%	0.00%	0.00%	0.00%	0.00%	1.63%	29.75%	0.00%	11.13%	0.00%	0.00%	0.00%	100.00%
Shrimp	0.11%	0.00%	0.00%	6.49%	0.53%	0.00%	0.00%	4.58%	25.60%	0.23%	0.00%	0.00%	7.59%	54.82%	0.00%	0.06%	0.00%	0.00%	0.00%	100.00%
Skates	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Smooth dogfish	0.00%	0.00%	0.00%	85.77%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	14.23%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Soft crabs	0.27%	0.00%	0.00%	11.14%	3.50%	0.00%	0.00%	43.86%	0.18%	0.00%	0.00%	0.00%	12.74%	11.97%	5.87%	10.45%	0.00%	0.00%	0.02%	100.00%
Southern kingfish	0.56%	0.00%	0.00%	0.81%	3.27%	0.00%	0.00%	0.91%	0.00%	0.00%	0.00%	0.25%	3.70%	90.14%	0.16%	0.19%	0.00%	0.00%	0.01%	100.00%
Spadefish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Spanish mackerel	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	66.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Speckled trout	0.96%	0.00%	0.00%	0.45%	0.50%	0.00%	0.00%	0.17%	0.07%	0.00%	0.00%	2.57%	84.04%	6.43%	4.66%	0.07%	0.00%	0.00%	0.07%	100.00%
Spiny dogfish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Spot	0.67%	0.00%	0.00%	0.00%	41.29%	0.00%	0.00%	8.29%	2.34%	0.00%	0.00%	0.00%	8.94%	27.53%	3.95%	5.25%	0.00%	0.00%	1.73%	100.00%
Squid	0.00%	0.00%	0.00%	0.00%	1.33%	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.00%	0.10%	98.53%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Stone crabs	0.00%	0.00%	0.00%	29.55%	0.00%	0.00%	0.00%	0.00%	70.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Striped bass	0.00%	0.00%	0.00%	0.00%	57.36%	0.00%	0.00%	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%	37.39%	0.00%	4.35%	0.00%	0.00%	0.00%	100.00%
Tautog	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
White perch	0.00%	0.00%	0.00%	0.00%	5.97%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	82.90%	10.04%	1.08%	0.00%	0.00%	0.00%	0.00%	100.00%
Yellow perch	0.00%	0.00%	0.00%	0.00%	0.70%	0.00%	0.00%	0.42%	0.00%	0.00%	0.00%	0.00%	77.81%	16.71%	4.21%	0.14%	0.00%	0.00%	0.00%	100.00%
Total	5.98%	0.00%	0.00%	5.17%	6.17%	0.01%	0.01%	8.67%	0.94%	0.06%	0.03%	0.03%	16.76%	46.64%	8.65%	0.76%	0.00%	0.00%	0.11%	100.00%

Table 11. Comparison of the reduction rates for southern flounder and blue crabs from using a 4-inch tailbag versus a 3-inch tailbag in the Pamlico Sound and its tributaries.

	McKenna and Camp (1993)		Lupton (1996)		Hannah and Hannah (2000)	
	Weight	Numbers	Weight	Numbers	Weight	Numbers
Total flounder	-30.98%	-39.66%	-14.81%	-26.16%	-22.84%	-26.96%
Legal flounder	*	-41.18%	41.18%	34.37%	-19.96%	-11.83%
Sublegal flounder	*	-39.58%	-22.31%	-28.63%	-27.06%	-37.23%
Total blue crabs	-12.20%	-10.99%	-8.94%	-3.82%	-7.22%	-9.75%
Legal blue crabs	*	-7.27%	-3.57%	-5.97%	-4.14%	-0.21%
Sublegal blue crabs	*	-12.67%	-11.27%	-22.55%	-26.95%	-31.00%
Other finfish	-44.40%	*	-26.44	-36.14%	*	*

*Data not available for calculation of reduction rates.

Table 12. Comparison of the reduction rates for southern flounder and blue crabs from using a 41/2-inch tailbag versus a 3-inch tailbag in the Pamlico Sound and its tributaries.

	McKenna and Camp (1993)		Lupton (1996)		Hannah and Hannah (2000)	
	Weight	Numbers	Weight	Numbers	Weight	Numbers
Total flounder	-54.33%	-72.49%	-73.11%	-80.14%	-36.31%	-46.43%
Legal flounder	*	12.50%	-40.57%	-40.00%	-36.57%	-41.23%
Sublegal flounder	*	-75.87%	-80.00%	-82.35%	-35.93%	-49.48%
Total blue crabs	-35.81%	-42.08%	-34.47%	-34.39%	-38.83%	-36.70%
Legal blue crabs	*	-17.48%	-15.61%	-17.25%	-36.52%	-25.55%
Sublegal blue crabs	*	-52.68%	-46.35%	-44.21%	-54.11%	-61.84%
Other finfish	-80.00%	*	-86.30%	-85.40%	*	*

Table 13. The percent composition of the total catch of blue crabs and flounder that were sublegal for each tailbag mesh size tested (Lupton 1996).

	Winter/Spring		Summer	
Tailbag size	Blue crabs	Flounder	Blue crabs	Flounder
3 inch	23.98%	64.78%	69.28%	98.62%
4 inch	18.70%	56.63%	63.42%	98.66%
41/2 inch	23.14%	51.52%	58.65%	92.03%

12.11 Appendix 11. PROTECTED SPECIES INTERACTIONS WITH THE CRAB FISHERY

I. Issue:

Crab gear interactions with endangered, threatened, and species of special concern.

II. Background:

Crab pots and trawls utilized to harvest blue crabs in North Carolina have various levels of interactions with endangered and threatened species, and species of special concern. These species include bottlenose dolphins, sea turtles (Kemp's ridley, hawksbill, loggerhead, leatherback, and green), and diamondback terrapins.

The bottlenose dolphin (Tursiops truncates) inhabits temperate and tropical waters throughout the world. Bottlenose dolphin found in North Carolina are part of the western North Atlantic coastal stock. This stock inhabits coastal, nearshore and estuarine habitats along the U.S. Eastern seaboard. The western North Atlantic coastal stock of bottlenose dolphins is listed as depleted under the Marine Mammal Protection Act (MMPA). A species is designated as depleted when it falls below its optimum sustainable population. Bottlenose dolphins are active predators and eat a wide variety of fishes, squids, and crustaceans. Females reach sexual maturity at 5 to 12 years, while males attain sexual maturity at 10 to 12 years. Calves are primarily born in the spring or summer after a one year gestation period. Bottlenose dolphins have been observed throughout the year in North Carolina estuarine waters, but will migrate offshore when water temperatures fall below 10^{o} C. One of the requirements of the MMPA is that a Take Reduction Team, made up of fishermen, managers, scientists, and environmental groups, be convened to develop a Take Reduction Plan for this species. The goal of the Take Reduction Plan, as defined by the 1994 reauthorization of the MMPA, is a "seven-year goal for reducing incidental serious injury and mortality of marine mammals to insignificant levels approaching a zero mortality and serious injury rates".

Bottlenose dolphins are occasionally taken in various kinds of fishing gear including gill nets, seines, long-lines, shrimp trawls, and crab pot lines. Between 1994 and 1998, 22 bottlenose dolphin carcasses that displayed evidence of possible interaction with a trap/pot fishery (i.e., rope and/or pots attached, or rope marks) were recovered by the Stranding Network between North Carolina and Florida's Atlantic coast [2002 Bottlenose Dolphin Stock Assessment, National Marine Fisheries Service (NMFS)]. At least 5 other dolphins were reported to be released alive (condition unknown) from blue crab trap/pot lines during this time period. Reports of strandings with evidence of interactions between bottlenose dolphins and both recreational and commercial crab pot fisheries have been increasing in the Southeast Region in recent years.

The Kemp's ridley sea turtle (Lepidochelys kempii) was listed as endangered in 1970. The population status in North Carolina is unknown. Most Kemp's ridleys occur in the Gulf of Mexico, but they also occur along the Atlantic coast as far north as New England. The Kemp's ridley turtle is thought to be the most endangered sea turtle. Current population estimates for this species are unknown, however this species appears to be in the early stages of recovery. Juveniles occur year-round within the sounds, bays, and coastal waters of North Carolina. Adult Kemp's ridleys are generally restricted to more southern waters, particularly the Gulf of Mexico. The Kemp's ridley is primarily a bottom feeder, feeding on crabs, shrimp, urchins, starfish, jellyfish, clams, snails, and squid. They may also feed on small fish and limited amounts of marine vegetation.

Incidental take by shrimp trawls has been identified as the largest source of mortality with between 500 and 5,000 killed annually (NMFS 1993a). Manzella et al. (1988) estimated that 0.2% of the juvenile Kemp's ridleys killed by fishing gear were killed as a result of interaction with crab pots. In North Carolina 17% of the sea turtle strandings since 1990 were Kemp's ridleys (NC Wildlife Resource Commission Sea Turtle Stranding Data; 1990-2000).

The hawksbill sea turtle (Eretmochelys imbricata) was listed as endangered in 1970. Its population status in North Carolina is unknown. The hawksbill occurs in tropical and subtropical seas of the Atlantic, Pacific, and Indian oceans. In the Atlantic Ocean they occur from southern Brazil, throughout the Gulf of Mexico and Caribbean. Stragglers have been reported as far north as Massachusetts and as far south as northern Argentina. Sightings of this turtle north of Florida are considered rare. Hawksbill turtles have been reported off the coast of North Carolina during the months of June, July, October and November. This species of turtle prefers shallow coastal water with depths not greater than 66 feet. Preferred habitat includes rocky bottoms, reefs, and coastal lagoons. Hawksbills are omnivorous, preferring invertebrates. Identified food items include sponges, ectoprocts, urchins, algae, barnacles, mollusks, jellyfish, and fish. Hawksbills exhibit a wide tolerance for nesting substrate type and nests are typically placed under vegetation. Within the southeastern U.S., nesting occurs principally in Puerto Rico and the U.S. Virgin Islands. Within the continental U.S., nesting is restricted to the southeast coast of Florida and the Florida Keys.

The extent to which hawksbills are killed or debilitated after becoming entangled in marine debris has not been quantified, but it is believed to be a serious and growing problem. Hawksbills (predominantly juveniles) have been reported entangled in monofilament gill nets, fishing line, and synthetic rope. Hawksbills are incidentally taken by several commercial and recreational fisheries. Fisheries known or suspected to incidentally capture hawksbills include those using trawls, gill nets, traps, drift nets, hooks, beach seines, spear guns, and nooses (NMFS 1993b). No strandings of the hawksbill sea turtle have been reported for North Carolina since 1990 (NC Wildlife Resource Commission Sea Turtle Stranding Data; 1990-2000).

The leatherback sea turtle (Dermochelys coriacea) was listed as endangered in 1970. Leatherback turtles have a worldwide distribution in tropical and temperate waters. Concentrations of this species can be found during the summer months off Massachusetts and in the Gulf of Maine. Leatherbacks display a north-south migration pattern. Current estimates of the number of female leatherbacks worldwide range from 20,000 to 30,000 individuals. This species is found off the coast of North Carolina from April to October with occasional sightings into the winter. The main prey species of leatherbacks are jellyfish and tunicates. Other food items include urchins, squid, crustaceans, fish, seaweed, and blue-green algae. Nesting occurs on mainland beaches characterized by coarse sand free of large rocks or debris. There is one record of a nesting site at Cape Lookout in 1966 (Lee and Socci 1989), an additional nesting site was reported near Hatteras in 2000.

Leatherbacks become entangled fairly often in longlines, fish trap warps, buoy anchor lines, and other ropes and cables (NMFS 1992). Prescott (1988) implicated entanglement in lobster pot lines in 51 of 57 adult leatherback strandings in Cape Cod Bay, Massachusetts from 1977-1987. Since 1990 there have been 12 leatherback strandings in North Carolina, none from inside waters (NC Wildlife Resource Commission Sea Turtle Stranding Data; 1990-2000).

The green sea turtle (Chelonia mydas) was listed as threatened in 1978. This species has a circumglobal distribution in tropical and subtropical waters. In U.S. Atlantic waters, it occurs around the Virgin Islands and Puerto Rico and from Texas to Massachusetts. Total population estimates are unavailable. Current estimates of females nesting on U.S. beaches range from 200 to 1,100 individuals. Green turtles are sighted in oceanic waters and within the sounds of North Carolina during the period from May through October. Adults and juveniles have been reported in North Carolina waters. Green turtles are primarily herbivorous, feeding on various marine algae and seagrasses. Other prey items include sponges, jellyfish, crustaceans, and mollusks. Due to their food preference for submerged aquatic vegetation green turtles are normally found in lagoons, bays, and tidal inlets. No major nesting sites are located along the U.S. coastline. However, limited annual nesting occurs in Florida from April to July. There have been two reported (1987, Baldwin Island and 1989, Cape Hatteras) and one confirmed (1979, Camp Lejeune) nesting sites in North Carolina.

In the southeastern United States, the incidental capture and drowning in shrimp trawls is believed to be the largest single source of mortality on all life stages of this turtle (NMFS 1991a). Other trawl fisheries (flounder, whelk, crab, and croaker) are possible sources of mortality for this species (NMFS 1991a). Green sea turtles have been recovered entangled in trap lines with the trap in tow (NMFS 1991a). However, the overall impact of this gear on green turtle populations is unknown. Green turtles account for 18% of the sea turtle strandings in North Carolina (NC Wildlife Resource Commission Sea Turtle Stranding Data; 1990-2000).

The loggerhead sea turtle (Caretta caretta) was listed as threatened in 1978. Its population status in North Carolina is unknown. The geographic distribution of the loggerhead includes the subtropical (and occasionally tropical) waters and continental shelves and estuaries along the margins of the Atlantic, Pacific, and Indian oceans. It is rare or absent far from mainland shores. In the Western Hemisphere, it ranges as far north as Newfoundland and as far south as Argentina. The loggerhead turtle is present throughout the year in North Carolina with peak densities occurring from June to September. Loggerhead turtles are omnivorous. Their diet includes algae, seaweeds, horseshoe crabs, barnacles, various shellfish, sponges, jellyfish, squid, urchins, and fish. Nesting occurs along the U.S. Atlantic coast from New Jersey to Florida. However, the majority of nesting activity occurs from South Carolina to Florida. In North Carolina nesting activity has been reported from April to September. The highest nesting densities are reported south of Cape Lookout.

In the southeastern United States, the incidental capture and drowning in shrimp trawls is believed to be the largest single source of mortality on all life stages of this turtle (NMFS 1991b). Other trawl fisheries (flounder, whelk, crab, and croaker) are possible sources of mortality for this species (NMFS 1991b). While the impact of pot fisheries on loggerhead populations has not been quantified, this species may be particularly vulnerable since they feed on species caught in traps and on organisms growing on the traps, trap lines, and floats (NMFS 1991b). Loggerhead turtles account for 61% of the sea turtle strandings in North Carolina (NC Wildlife Resource Commission Sea Turtle Stranding Data; 1990-2000).

Diamondback terrapins are found throughout North Carolina's high salinity coastal marshes. In a South Carolina study (Bishop 1983), terrapins were captured in salinities ranging from 4.3 to 22 parts per thousand (ppt), with most captures in 10.1 to 15 ppt. Preferred habitats are the waters immediately adjacent to the marsh, small creeks, and mosquito control ditches. Terrapins are a long-lived species, probably surviving in excess of forty years. Females mature in 7 to 9 years, and fecundity is relatively low (Hildebrand 1932).

Populations of diamondback terrapins have declined throughout their range from Cape Cod, Massachusetts to southern Texas (Palmer and Cordes 1988, Seigal and Gibbons 1995). Possible reasons for this decline (Grant 1997) are: (1) degradation and loss of habitat, (2) mortality on roads (Wood 1995), (3) raccoon predation (Seigel 1980), and (4) incidental drowning in trawls, nets, and crab pots (Bishop 1983, Wood 1995). Blue crab pots may account for more adult diamondback terrapin mortalities than any other single factor (Bishop 1983). The diamondback terrapin is included on the North Carolina listing of "Endangered and Threatened Species" as a "Species of Special Concern." The status of "Special Concern" does not provide any special protection under the federal Endangered Species Act. The status may be upgraded to "Threatened" or deleted from the list as more information is collected on the species.

III. Discussion:

In 2001, a Take Reduction Team was established for the western North Atlantic coastal bottlenose dolphin. Recommendations from this group have been submitted to the NMFS for approval. For the crab pot fishery, the team developed a set of non-regulatory recommendations. The first recommendation encourages states to develop, implement, and enforce a program to remove derelict blue crab pots (ghost pots) and their lines from all waters frequented by bottlenose dolphins. The management measures outlined in the ghost pot section of this plan (see section 10.3.2) should address this recommendation (also see Appendices 7 and 8). The second recommendation has to do with gear modifications. The group recommended the use of sinking or negatively buoyant line, and that the scope of the line be restricted to the minimum length necessary in order to reduce the overall length of line in the water column. The first part of this recommendation was addressed in the 1998 Blue Crab Fishery Management Plan (BCFMP - McKenna et al. 1998) as a means of reducing ghost pots. After the BCFMP was adopted in 1998, a Marine Fisheries Commission (MFC) rule (NCAC 3J .0301 (k)) was passed that made it unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating. The final recommendations of the Take Reduction Team deal with areas where bottlenose dolphin are tipping and stealing bait from crab pots. It is recommended in areas where this is a problem that fishermen use inverted or modified bait wells. This technique has worked in Georgia, although the overall effectiveness has not been tested.

Sea turtles may be attracted to baited crab pots for food. Sea turtle entrapment in a pot or trap is not likely, but entanglement in the buoy lines of crab, lobster, and fish pots has been documented (Epperly et al. 2002). The entanglement of sea turtles in buoy lines is more problematic in pot fisheries that use bridles (lobster, and fish pots) as opposed to single line fisheries such as the North Carolina blue crab fishery (Cheryl Ryder personal communication NOAA/NMFS/NEFS). As sea turtle populations begin to recover, the rates of interactions also will increase. While there have been no reported strandings of sea turtles in North Carolina attributed to crab pots, there has been a major increase in crab pot damage caused by sea turtles. In the Core Sound area, fishermen have estimated that 62% of all crab pot damage, and 37% of lost crab catch, is due to sea turtles (Marsh 2002). Crab pot damage was also reported from the Outer Banks area in 2003. Crab pot damage occurs when the turtle overturns the pot and tears up the bottoms and sides trying to get at the bait and/or crabs. This damage results in higher operating costs and decreased catches. In 2001, Marsh (2002) tested a low profile crab pot designed to limit the ability of sea turtles to overturn crab pots. The overall dimensions were 34 x 24 x 13.5 inches. This pot was tested against standard hexagonal mesh (22 x 24 x 19 inches), and square mesh pots (24 x 24 x 21 inches). There was no difference between catch rates in the low profile pot and the square mesh pot, however there was a significant decrease in catch for the low profile pot compared to the hexagonal pot. However, this decrease in catch was only seen in one of the three lines of pots. Ten of each pot type was set in repeating order (low profile, square mesh, hexagonal) in three lines. Marsh (2002) suggested that the low profile crab pot has the potential to maintain crab catch and reduce gear replacement costs.

Although shrimp and flounder trawlers have been required to use Turtle Excluder Devices (TED's) for a number of years, no such regulation exists for the crab trawl fishery. Data on sea turtle and crab trawl interactions in North Carolina are limited. Of the 528 crab trawl tows examined (1,056 catches from individual nets) since 1990; 50 characterization (McKenna and Camp 1992), 101 TED testing (Morris 2002), and 378 tailbag testing (McKenna and Clark 1993, Lupton 1996, and Hannah and Hannah 2000) only one loggerhead sea turtle has been captured (released alive). The seasonality of turtle strandings in the Pamlico Sound complex (Pamlico, Roanoke, and Croatan sounds, and the Neuse, Bay, Pamlico, and Pungo rivers) along with trip data is given in Table 1. There is a non-significant negative correlation ($R = -0.47$, $p = 0.12$) between sea turtle strandings and crab trawl effort in the Pamlico Sound complex. The same type of correlation, although significant, is seen in the Core Sound area [$R = -0.63$, $p = 0.04$ (Table 2)]. One possible explanation for this relationship has to do with water temperature. The majority of crab trawl effort takes place in the winter/spring when water temperatures and turtle numbers are low compared to the rest of the year. Also, low water temperature increases the chance of survival of turtles after gear interactions. Additionally, crab trawl tows during the warmer months are usually less than ½ hour, as the crabs must be delivered to the dealer alive.

Morris (2002) tested two types of TED's, mini-super shooter and leatherback, in Bay River to determine the effect of TED's on crab catches in crab trawls. The mini-super shooter had a 14% reduction in the number of legal crabs (13% by weight), and a 31% reduction in sublegal crab weight. The leatherback TED showed a 23% reduction in legal crabs (24% by weight) and a 39% reduction of sublegal crabs. These significant reductions in legal crab catch would be detrimental to the crab trawl fishery.

Various studies in New Jersey (Wood 1995), Maryland (Roosenburg et al. 1997), North Carolina [Grant 1997; Crowder et al. 2002; NC Wildlife Resources Commission (WRC) unpublished; Tom Henson (WRC), pers. comm.], and South Carolina (Bishop

1983) have documented diamondback terrapin bycatch and mortality in crab pots. In South Carolina, few captured terrapins were drowned when crab pots were checked daily, and estimated capture mortality amounted to 10% (Bishop 1983). However, in a North Carolina study, Crowder et al. (2002) noted that terrapins can hold their breath for a maximum of 5 hours, and during the summer only 45 minutes. Of the 12 terrapins captured in the North Carolina study, 58% were dead [24 – 48 hour soak time (Crowder et al. 2002)]. Bishop (1983) noted that the occurrence of ghost pots is perhaps far more detrimental to terrapin populations than actively fished pots. Some observations suggest that once a terrapin is captured others may be attracted, particularly males to a female during the spring mating season.

Limiting factors affecting the catchability of terrapins in crab pots are:
(1) the abundance of terrapins,
(2) terrapin size (depth of shell),
(3) vertical height of the crab pot funnel,
(4) distance of the crab pot from shore, and
(5) season.

Each of these limiting factors and its relationship to crab pot catchability are discussed below.

Population size will influence catchability. Estimates of capture rates and population size, by Roosenburg et al. (1997); suggest that 15-78% of a local population may be captured annually. However, all coastal areas do not contain suitable terrapin habitat as outlined by Palmer and Cordes (1988).

Male terrapins do not grow as large (shell depth and length) as females, and may remain vulnerable to entrapment throughout their life. Female terrapins become too large to enter crab pots by the time they reach age eight (Roosenburg et al. 1997). However, small terrapins of either sex are vulnerable to capture.

Rectangular wire excluders, which restrict the vertical and horizontal dimensions of crab pot funnels, have been used to reduce or eliminate terrapin bycatch. A 90% reduction in terrapin captures and an increase in crab captures was reported by Wood (1995) in New Jersey for pots equipped with 2 X 4 inch excluders. Grant (1997) conducted a study of the impacts of crab pots with and without excluder devices in North Carolina's estuarine waters near Ocracoke, Sneads Ferry, and Wrightsville Beach. Each area contained small populations of terrapins and active commercial crab pot fisheries. The 2 X 4 inch excluder, tested in 1995-96, showed a 75.7% reduction in terrapin bycatch and a 19% reduction in legal-size crabs (Grant 1997). In an effort to further reduce small terrapin bycatch, Grant (1997) tested a more restrictive vertical dimension (1 5/8 X 4 3/4 inch) excluder in 1997. The 1 5/8 X 4 3/4 inch excluder eliminated all terrapin bycatch and reduced legal crab harvest by about 29%. In 2000 – 2001, Crowder et al. (2002) examined three sizes of excluders in Jarrett Bay, North Carolina (2 x 6 inch; 1 1/2 x 6 inch; and 1 3/4 x 6 inch). Excluders were tested in the entrance funnels (E) and in the internal entrances to the upper chamber of the pot (M). While catch rates were not given for this study the authors indicated that the M pots had the lowest catch rates for legal and sublegal male crabs. For legal sized males, only the spring 2001 tests showed a significant difference between the catch of E and M pots equipped with the 1 3/4 x 6 inch excluder (control pots caught more legal crabs by a factor of 1.064 for E pots and 1.158 for M pots). There were no significant differences in the catches of legal males between control and E, and M pots tested in the Spring of 2000 (2 x 6 inch), and Fall 2000 (2 x 6 inch). An alternative to excluders, a modified crab pot that maintains permanent access to air and prevents the drowning of terrapins, has been tested by Roosenburg et al. (1997) in Chesapeake Bay. Roosenburg et al. (1997) reported that the modified crab pot caught more crabs than standard pots.

Grant (1997) showed a significant reduction in terrapin captures as distance from shore increased. The majority of the terrapins (84.5%) were captured less than 27 yards from shore and 15.5% were taken between 28 and 55 yards offshore. No terrapins were captured in pots more than 55 yards from shore. He noted that few commercial crab pots are fished near-shore where most terrapins occur. Generally the water is too shallow near-shore for commercial crabbing operations, except in the deeper tidal creeks and along the Intracoastal Waterway (ICW). Most of the near-shore pots observed by Grant (1997) were along the edges of the ICW and within 22 yards of shore. No diamondback terrapins were observed in the surveyed area of the ICW, Stump Sound, N.C. In the Jarrett Bay study (Crowder et al. 2002), all terrapin captures were in the month of May and in pots set close to shore (depths and distance from shore was not given). No terrapins were captured in pots equipped with excluders in the entrance funnels.

Crab pot catch of terrapins was distinctly seasonal in South Carolina, with the majority of captures occurring during April and May. The elevated catches in April and May were probably associated with post hibernation feeding and reproduction activity (Bishop 1983). Pots may be concentrated in shallow near-shore waters, near terrapin habitat, during the spring to catch peeler crabs. Pots in these areas decline during June through August (Tom Henson, WRC, pers. comm.).

New Jersey is the only state that requires the use of terrapin excluders in crab pots. Other states may be considering terrapin excluders in the future. New Jersey's original rule (effective January 1, 1998) required that all commercial crab pots set in any body of water, less than 150 feet wide from shore to shore or any man-made lagoon, contain terrapin excluder devices attached to the inside of all pot entrance funnels which met the following criteria:

1) The terrapin excluder device shall be rectangular and no larger than four inches wide and two inches high;
2) The terrapin excluder device shall be securely fastened inside each funnel to effectively reduce the size of the funnel opening to no larger than four inches wide and two inches high; and
3) Any similar device may be approved by the Division after consultation at a regularly scheduled meeting of the Marine Fisheries Council.

In May 1998, New Jersey modified their rule to allow rectangular and diamond shaped excluder devices no larger than six inches wide and two inches high.

A workshop on the Ecology, Status and Conservation of Diamondback Terrapins will be held in the fall of 2004. One of the goals of this meeting is to develop a national Diamondback Terrapin Working Group and to begin to lay the foundation for a rangewide conservation plan. Once this plan is developed then the North Carolina Division of Marine Fisheries (NCDMF) and MFC will have a good idea on the direction to take on this issue.

IV. Current Rule:

NCAC 3J .0301 (k) It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating.

V. Management Options/ Impacts:

(+ potential positive impact of action)
(- potential negative impact of action)

Bottlenose Dolphins:

1. No regulatory action.
   + No additional regulations on fishery
   + No increased costs for crabbers to modify gear
   - Potential bottlenose dolphin mortality associated with crab pot lines

2. Require the scope of crab pot lines be restricted to the minimum length necessary in order to reduce the overall length of line in the water column.
   + Reduce potential bottlenose dolphin and crab pot line interactions
   - Reduce crabbers flexibility in moving gear
   - Increased enforcement burden

Sea Turtles:

1. No regulatory action.
   + No additional regulations on fishery
   + No increased costs for crabbers to modify trawls
   + No reduction in crab catch
   - Potential sea turtle bycatch and mortality in crab trawls

2. Require Turtle Excluder Devices (TED's) in crab trawls.
   + Reduce potential sea turtle bycatch in crab trawls
   - Significantly reduce legal blue crab catch

Option 2 would require rule changes by the MFC.

Diamondback terrapins:

1. No regulatory action.
   + No additional regulations on fishery
   + No increased costs for crabbers to modify pots
   + No reduction in crab catch
   - Continued uncontrolled terrapin bycatch and mortality

2. Require terrapin excluders and/or modifications to crab pots (hard and/or peeler) fished within a specified distance of shore during the spring, within specified areas.
   + Reduce terrapin bycatch and mortality
   - Additional pot regulations on fishery
   - Increased costs for crabbers to modify pots
   - Potential reduction in crab catch
   - Increased enforcement burden

Option 2 would require rule changes by the MFC.

Recommendations:

With regard to bottlenose dolphin, fishermen should be educated on the potential problems of having too much free line in the water column. For sea turtle interactions with crab pots, the research outlined in section VI (2 and 3) should be conducted and the results made available to the industry (see education section for recommendations to disseminate information to members of the industry). Until more information is available on the extent of sea turtle bycatch in the crab trawl fishery, it is recommended that no state action be taken on this issue. The research outlined in section VI (4, 5, and 6) needs to be conducted prior to the passage of any new regulations to minimize diamondback terrapin bycatch. Additionally, the goals and objectives for the conservation of diamondback terrapins in North Carolina must be clearly defined. Current information on ways to eliminate diamondback terrapin bycatch in crab pots and current distribution in North Carolina needs to be made available to crab potters. The DMF and Crustacean Committee support these recommendations.

VI. Research Needs:

1) Test the effectiveness of inverted bait wells to alleviate the bait stealing behavior of bottlenose dolphin.
2) Develop sea turtle proof crab pots.
3) Determine the extent of sea turtle bycatch in crab trawls.
4) Diamondback terrapin distribution.
5) Problem assessment of crab pot diamondback terrapin bycatch and mortality by season, area, and gear (hard and peeler pots).
6) Determine the effect that terrapin excluders have on peeler and terrapin catches in peeler pots.

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Table 1. Monthly breakdown of sea turtle strandings (1990 – 2000) and crab trawl effort (1994 – 2002) for the Pamlico Sound complex*.

	Crab trawl trips		Turtle strandings	
Month	Number	Percent	Number	Percent
January	283	1.27%	59	13.26%
February	662	2.97%	33	7.42%
March	2,451	11.00%	13	2.92%
April	2,922	13.11%	3	0.67%
May	3,690	16.55%	19	4.27%
June	3,552	15.94%	34	7.64%
July	1,953	8.76%	13	2.92%
August	1,586	7.12%	22	4.94%
September	1,798	8.07%	9	2.02%
October	1,474	6.61%	23	5.17%
November	1,204	5.40%	141	31.69%
December	715	3.21%	76	17.08%
Total	22,290	100.00%	445	100.00%

*Pamlico, Roanoke, and Croatan sounds and Pamlico, Pungo, Bay, and Neuse rivers.

Table 2. Monthly breakdown of sea turtle strandings (1990 – 2000) and crab trawl effort (1994 – 2002) for Core Sound.

	Crab trawl trips		Turtle strandings	
Month	Number	Percent	Number	Percent
January	144	5.87%	17	7.17%
February	422	17.19%	9	3.80%
March	1,029	41.91%	12	5.06%
April	614	25.01%	8	3.38%
May	108	4.40%	24	10.13%
June	25	1.02%	43	18.14%
July	1	0.04%	50	21.10%
August	5	0.20%	28	11.18%
November	49	2.00%	14	5.91%
December	58	2.36%	32	13.50%
Total	2,455	100.00%	237	100.00%

12.12 Appendix 12. CHANNEL NET HARVEST OF BLUE CRABS

I. ISSUE:

Currently, there are no limits on the amount of crabs that can be landed from channel nets. Landings of hard crabs by these nets in New River in 2000 and 2001 have dramatically increased from less than 1000 lbs/year to over 85,000 lbs.

II. BACKGROUND:

Hard crab catches in the past from channel nets in the New River area [New River, Stump Sound and adjacent Atlantic Intracoastal Waterway (ICW)] have been incidental and have been mostly discarded. By the year 2000, hard crabs became a significant portion of catches in this gear. The average total catch from 1995 - 1998 was 845 pounds. During 2000, the channel net catch increased dramatically to 37,474 lbs and catch more than doubled (85,785 lbs.; Table 1) in 2001.

Effective July 1, 2000, the entire blue crab fishery was opened to all Standard Commercial Fishing License (SCFL) holders, as the Crab License was scheduled to expire in October of 2000. Consequently, channel netters that had not previously held a Crab License were able to harvest and sell crabs. The ability of all SCFL holders to harvest and sell crabs likely contributed to the increase in channel net crab landings.

Shrimp landings in 2000 were 585,094 pounds; the highest in eight years. New River area fishermen experienced a sharp decline in shrimp landings in 2001; approximately half as many were landed (252,421 pounds) as compared to 2000 (Table 2). Most of this decline was in the shrimp and skimmer trawl catches. Channel net catches remained fairly level. Some of this decline can be attributed to the later opening (October 5) of New River to trawling in 2001.

While the number of trips made by channel netters has declined each year from 1999 – 2001, the amount of shrimp per trip has increased from 87.4 in 1999 to 117.4 lbs in 2001. Interesting is the increase in pounds of crabs caught per trip during these three years, an increase from 0.7 lbs/trip in 1999 to almost 67 lbs/trip in 2001 (Table 1).

Local markets opened up for the crabs because the crab landings in other states were in a slump. Because of this slump and the abundance of crabs in the New River area, Sneads Ferry dealers encouraged the harvest of these crabs caught by the channel nets.

Some crab fishermen from this area have voiced their concern over the large numbers of female "sponge" crabs that have been harvested and feel that channel netters should not be allowed to keep unlimited pounds of hard crabs. Rule 3J .0104 Trawl Nets sets a limit on the amount of crabs that can be harvested by shrimp trawls. Channel nets are not under this rule and catches are, therefore, limitless. Evidence of a stock-recruit relationship has been verified, as well as a drop in the spawning stock abundance index. Sponge crabs have a low market quality and value. Consequently, some area crabbers perceive sponge crab harvest as a wasteful harvest of the spawning stock. These crabbers feel that the fishery would yield greater long-term benefit by protecting the sponge crab portion of the spawning stock.

III. DISCUSSION

Any actions that can curtail or eliminate this perceived problem would require rule changes through the Marine Fisheries Commission. One proposal would be to only allow blue crab harvest from channel nets as an incidental bycatch. This proposal would be similar to the crab bycatch provisions in the shrimp trawl fishery (rule 15A NCAC 3J .0104; see below).

15A NCAC 3J .0104 TRAWL NETS (MFC 2003; pages 26-27)

(f) It is unlawful to use shrimp trawls for the taking of blue crabs in internal waters, except that it shall be permissible to take or possess blue crabs incidental to shrimp trawling in accordance with the following limitations:
- (1) For individuals using shrimp trawls authorized by a Recreational Commercial Gear License, 50 blue crabs, not to exceed 100 blue crabs if two or more Recreational Commercial Gear License holders are on board.
- (2) For commercial operations, crabs may be taken incidental to lawful shrimp trawl operations provided that the weight of the crabs shall not exceed:
  - (A) 50 percent of the total weight of the combined crab and shrimp catch; or
  - (B) 300 pounds, whichever is greater.
- (3) The Fisheries Director may, by proclamation, close any area to trawling for specific time periods in order to secure compliance of this Paragraph.

Another option would be to prohibit the possession of female "sponge" crabs altogether. This would eliminate the taking of female “sponge” crabs, but the harvest of males and non-sponge females would continue.

IV. CURRENT AUTHORITY:

15A NCAC 3J .0106 CHANNEL NETS (MFC 2003; pages 27-28)

(a) It is unlawful to use a channel net:
- (1) Until the Fisheries Director specifies by proclamation, time periods and areas for the use of channel nets and other fixed nets for shrimping.
- (2) Without yellow light reflective tape on the top portion of each staff or stake and on any buoys located at either end of the net.
- (3) With any portion of the set including boats, anchors, cables, ropes or nets within 50 feet of the center line of the Intracoastal Waterway Channel.
- (4) In the middle third of any navigation channel marked by Corps of Engineers and/or U.S. Coast Guard.
- (5) Unless attended by the fisherman who shall be no more than 50 yards from the net at all times.

(b) It is unlawful to use or possess aboard a vessel any channel net with a corkline exceeding 40 yards.

(c) It is unlawful to leave any channel net, channel net buoy, or channel net stakes in coastal fishing waters from December 1 through March 1.

(d) It is unlawful to use floats or buoys of metallic material for marking a channel net set.

(e) From March 2 through November 30, cables used in a channel net operation shall, when not attached to the net, be connected together and any attached buoy shall be connected by non-metal line.

(f) It is unlawful to leave channel net buoys in coastal fishing waters without yellow light reflective tape on each buoy and without the owner's identification being clearly printed on each buoy. Such identification must include one of the following:
  (1) Owner's N.C. motorboat registration number; or
  (2) Owner's U.S. vessel documentation name; or
  (3) Owner's last name and initials.

(g) It is unlawful to use any channel nets, anchors, lines, or buoys in such a manner as to constitute a hazard to navigation.

V. Management Options/Impacts/Proposed Authority Change

1. No rule change
   - \+ Channel netters would continue to harvest blue crab without restriction.
   - \- Harvest of mature females and sponge crabs would continue unabated.

2. Prohibit or limit the daily harvest of blue crabs from channel net operations, except as an incidental bycatch (proportion) of the shrimp harvest.
   - \+ The harvest of hard crabs would now be restricted to the same amounts as those allowed in shrimp trawls.
   - \+ Fishermen could still harvest the female "sponge" crabs.
   - \+ Large crab bycatch couldn't be harvested when the shrimp harvest was in decline.
   - \- Potential reduced harvest for channel netters.
   - \- Reduced income for channel netters.

3. Make it unlawful to possess any "sponge" blue crab.
   - \+ The entire female sponge crab population would now be protected.
   - \+ Enhance spawning stock protection.
   - \- The market would miss this segment of the hard crab harvest that normally goes to the picking houses.
   - \- Potential reduced harvest for all crab harvesters.
   - \- Reduced income for all crab harvesters.

Options two and three would require rule changes by the MFC. Option two is the Crustacean Committee’s and DMF’s preferred option. Specifically, the recommended option would only allow blue crab harvest from channel nets as a limited incidental bycatch. This channel net proposal would be similar to the crab bycatch provisions for the shrimp trawl fishery (rule 15A NCAC 3J .0104), which provides that the weight of the crabs shall not exceed:

  (A) 50 percent of the total weight of the combined crab and shrimp catch; or
  (B) 300 pounds, whichever is greater.

Recommendations:

Option two is the Crustacean Committee’s and DMF’s preferred option. Specifically, the recommended option would only allow blue crab harvest from channel nets as a limited incidental bycatch.

VI. Research Needs

1) Crab harvest data from channel nets.

VII. Literature Cited:

MFC (North Carolina Marine Fisheries Commission). 2003. North Carolina Fisheries Rules for Coastal Waters 2003. North Carolina Div. Mar. Fish., Morehead City, NC. 297p.

Table 1. Harvest data for shrimp and blue crabs from channel nets in New River, NC: 1999-2001 (NC Trip Ticket Program)

Year	No. of Trips	Pounds of Shrimp	Pounds of Crabs*	Pounds of Shrimp/Trip	Pounds of Crabs/Trip
1999	1689	147,694	1,240	87.4	0.73
2000	1542	176,432	37,474	114.4	24.30
2001	1285	150,916	85,785	117.4	66.76

*Average pounds of crabs from 1995-98 caught in channel nets was 845.3 pounds/year

Table 2. Shrimp landings (pounds) for New River area, 1999 - 2001.

1999	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTALS	by Gear
Shrimp Trawl*														
Inland Waterway		10	63	148	624	4526	6910	7965	1760	2493	3268	4417	32184	
New River			153	1328	1436	3354	5784	37171	20318	7351	1154		78049	126168
Stump Sound					190	382	776	5345	4456	2671	2115		15935	
Channel Net														
Inland Waterway					615	7760	3302	1231	4298	4425	592		22223	
New River					4329	18545	32967	9130	21329	25053	12917	460	124730	147909
Stump Sound						485				216	255		956	
Skimmer Trawl**														
Inland Waterway						460	2432	4110	374	511			7887	
New River				53	61	179	6761	14598	25991	16712	4459		68814	80332
Stump Sound								250	90	2398	893		3631	
OTHER***														
Inland Waterway						4091	152	32	3				4278	
New River					92			112		30			234	4512
Stump Sound													0	
TOTALS	0	10	216	1529	7347	39782	59084	79944	78619	61860	25653	4877	358921	

* includes crab trawl
** includes butterfly net
*** includes hand, cast net , fyke net, fish pot

2000	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTALS	
Shrimp Trawl*														
Inland Waterway	541			42	758	14451	10368	7540	11393	2842	7451	3197	58583	
New River				703	1548	3323	4912	1026	121283	23929	6628	290	163642	237865
Stump Sound					22	775	837	430	6413	5865	1298		15640	
Channel Net														
Inland Waterway					211	1839	1902	629	4976	2011	699		12267	
New River					1349	18554	24226	12361	59905	32352	14363		163110	176996
Stump Sound						40	382	137		1060			1619	
Skimmer Trawl**														
Inland Waterway						689	1557	1392	1903	1764	501		7806	
New River						1044	4424	2576	106313	36039	5553		155949	168382
Stump Sound									2970	1117	540		4627	
OTHER***														
Inland Waterway					238	24	303	209	31		2		807	
New River							19	86	900		39		1044	1851
Stump Sound													0	
TOTALS	541	0	0	745	4126	40739	48930	26386	316087	106979	37074	3487	585094	

2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTALS	
Shrimp Trawl*														
Inland Waterway				217	271	5309	11028	5899	6048	1594		26	30392	
New River				477	675	1446	3111	1220	779	7220			14928	55441
Stump Sound						180	759	1914	4534	2647	87		10121	
Channel Net														
Inland Waterway					77	5304	2260	812	1892	2245			12590	
New River					923	36173	56266	9502	15161	19213		358	137596	150916
Stump Sound						390		117	223				730	
Skimmer Trawl**														
Inland Waterway						6179	543	1162	221	332			8437	
New River						2729	9258	2542	6645	14570	300		36044	45381
Stump Sound								43	308	549			900	
OTHER***														
Inland Waterway					11	65	34	10					120	
New River					49	87	30		14	339			519	683
Stump Sound									10	29	5		44	
TOTALS	0	0	0	694	2006	57862	83289	23221	35835	48738	392	384	252421	

12.13 Appendix 13. CONFLICT

I. Issue:

Social and economic conflicts relating to the blue crab pot and trawl fisheries.

II. Background:

The first crab pot landings in North Carolina were in 1952 and by 1955 harvest seasons and a 100 pot limit were implemented to deal with user conflicts. The increase of crab pots, principally in the 1980's and 1990's has resulted in more frequent and severe conflicts over fishing space between crab potters (full and part-time), other fisheries (trawlers, haul seiners, etc.), and recreational activities [swimming, fishing, and boating access and navigation (Figure 1)]. Conflicts also arise from damage to vessels encountering gear, and may result in fishing gear being moved, damaged, destroyed, or stolen. In addition to social conflicts, the expansion of the blue crab fishery has caused economic conflicts between and among various user groups. The blue crab is a finite resource, and landings do not increase proportionally with effort. Theft of potted crabs and pots is reputed to have increased in some areas as effort and price of the commodity has increased.

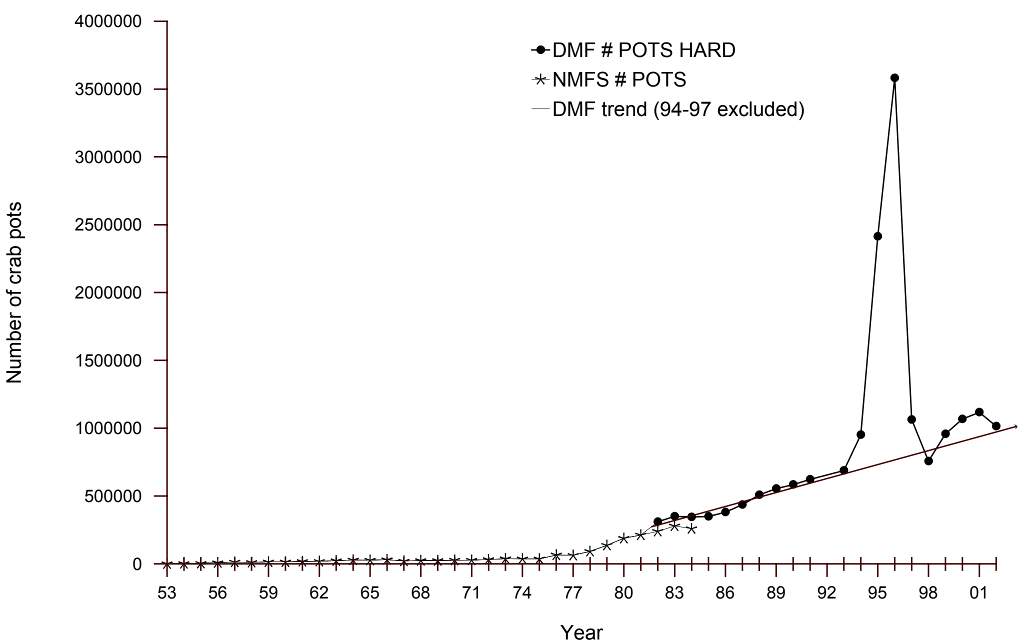

Figure 1. Number of Operating Units for the North Carolina blue crab pot fishery.

Coupled with the growth of the crab pot fishery a 25% increase in the number of motorized vessels registered in coastal NC counties since 1988 has been observed [26% state wide increase; North Carolina Wildlife Resources Commission data 1988-2001 (Figure 2)]. Additionally, the overall population in North Carolina increased by 24% from 1990-2000 (2000 US Census data). Five of the 18 coastal counties showed growth rates greater than 30% for the same time frame, and two had a reduction in population (Figure 2).

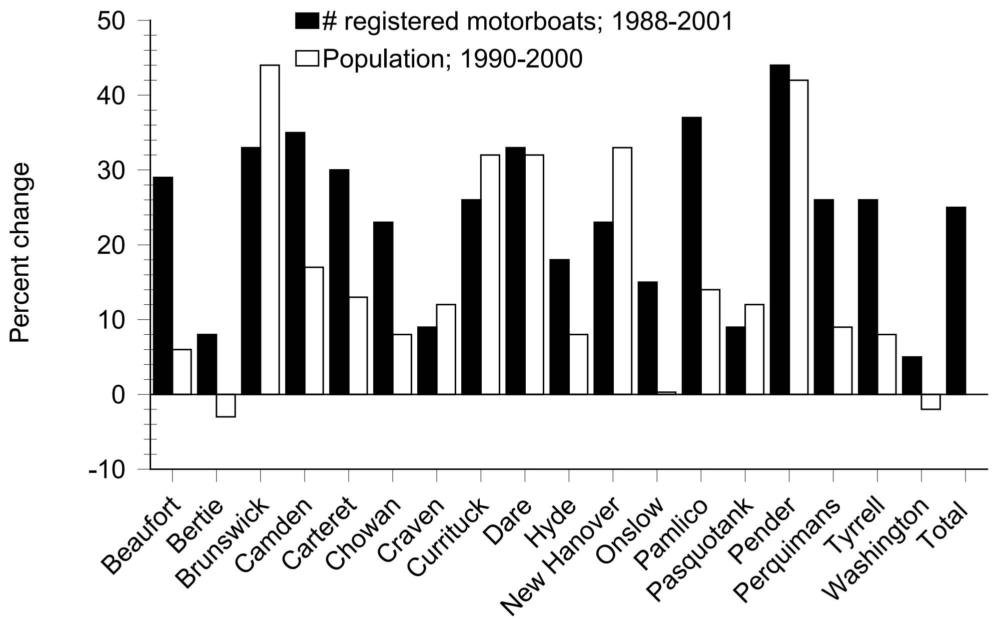

Figure 2. Increase in number of motorboat registrations and population for North Carolina coastal counties, 1988-2001 (NC Wildlife Resource Commission data, and U.S. Census data).

The number of crab potters and pots have increased dramatically, but crab pot catch-per-unit effort (CPUE) has declined. Information on blue crab pot use, number of fishermen, and harvest are available from landings and gear surveys conducted by the National Marine Fisheries Service [NMFS (early 1900's to 1977)] and the DMF (1978 to present). Gear survey data provides information on the type and amount of gear owned. These data do not indicate what is actively used; only what an individual says they own. However, over the long-term, these data are useful for examining gear trends.

The reported number of crab pots in North Carolina increased 97% from 1952 (1,200) to 1973 (380,060) and 96% from 1973 to 2002 [1,014,603 (1952 - 2002 NMFS and DMF gear survey data)]. From 1952 through 1973 CPUE varied from year to year without trend (Figure 3). Since 1973, there has been an inverse relationship between the average number of reported crab pots and the overall landings per pot. The average number of crab pots per fishermen in 1952 was 30, while the average CPUE/pot was 155 pounds. In 1973, the average number of crab pots was 89, and the CPUE/pot had increased to 248 pounds. While in 2001, the reported average number of crab pots per person was 342 and the CPUE/pot was 27 pounds. Data from other major blue crab producing states has shown the same trends as North Carolina with regard to increasing effort (pots and fishermen) and decreasing CPUE [Texas (Cody et al. 1991), Louisiana (Guillory et al. 1994), Alabama and the West Coast of Florida (Steele and Perry 1990), Georgia (Evans 1997), and Virginia and Maryland (Rugolo et al. 1997)].

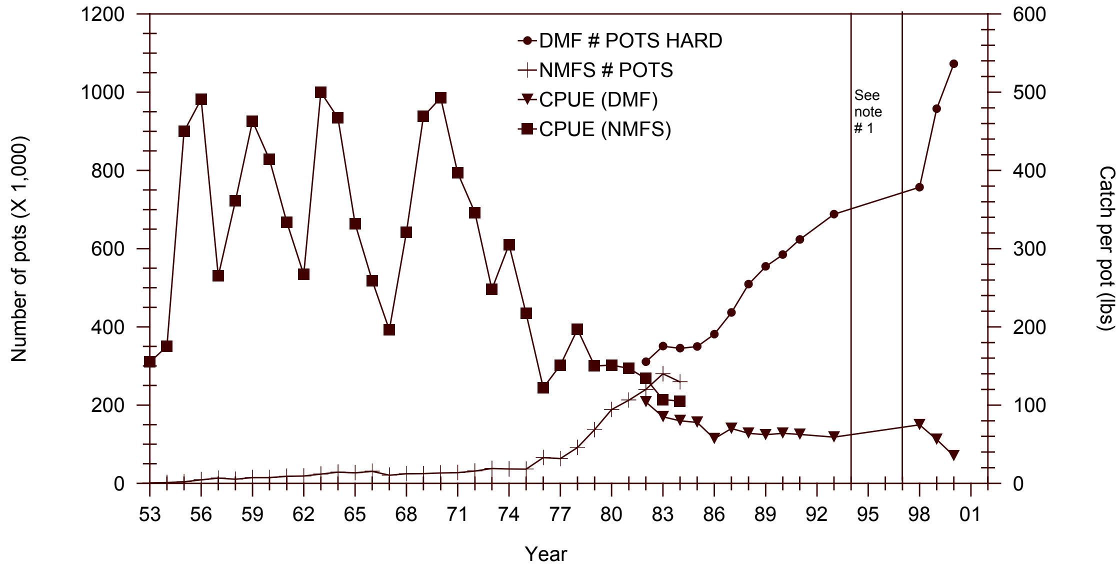

Figure 3. Number of Operating Units and CPUE for the North Carolina Blue Crab Pot Fishery. [Note: 1994 -1997 pot numbers not valid (see Figure 1)].

With the advent of the Trip Ticket Program in 1994, two other measures of effort are now available; the number of trips taken, and amount of gear fished. Additionally, fishery dependent sampling (1995-present) of crab catches provides estimates of the number of pots fished and the soaktime of those pots. The number of trips by gear is available for all gears since 1994. The amount of gear fished is only available for crab pots and started in 1996. Trip data show that the number of trips in the hard pot (R=0.55) and trawl fishery (R=0.77) are positively correlated with total blue crab landings, while peeler pot trips (R=-0.72) are negatively correlated with landings. The decline in the number of hard pot trips is viewed by some as an indication of declining effort. However, other indicators, the amount of pots (Figure 1) and the length of soaktime for hard crab pots are increasing (Figure 4). The downward trend in hard pot and crab trawl trips is more likely an indicator of declining landings (Table 1).

Table 1. Reported number of trips for crab trawls and crab pots (DMF trip ticket program, 1994 - 2002).

Year	Crab trawl trips	Hard crab pot trips	Peeler pot trips	Total blue crab landings
1994	3,888	114,063		53,513,175
1995	2,221	119,998		46,443,541
1996	4,344	115,995	135	67,080,197
1997	5,062	121,343	1,227	56,090,109
1998	5,718	128,050	4,571	62,076,170
1999	3,577	106,859	5,741	57,546,676
2000	2,306	106,781	5,788	40,638,384
2001	2,609	106,826	6,962	32,180,157
2002				

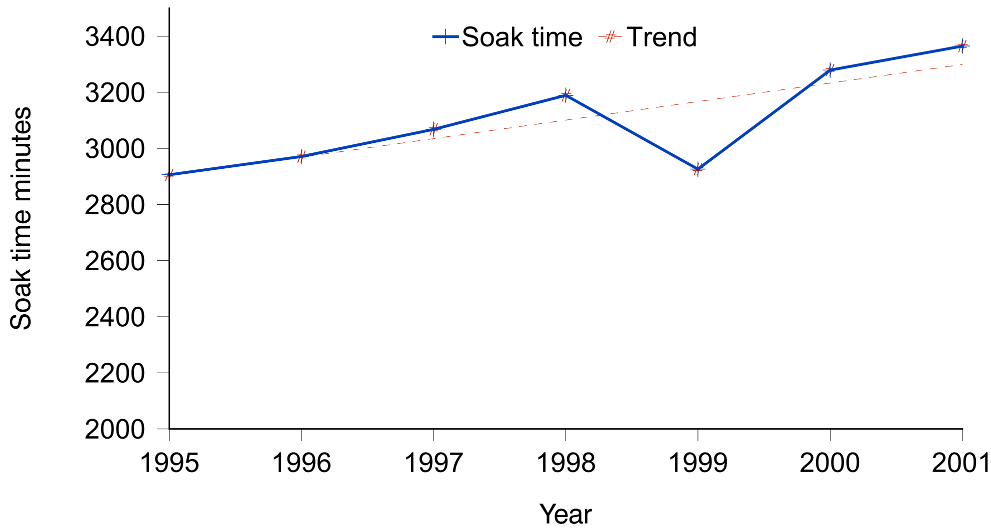

Figure 4. Average soak time (minutes) for blue crab hard pots in North Carolina (NCDMF unpublished data).

In a series of in-depth interviews with fishermen throughout North Carolina, Johnson and Orbach (1996) found that 58% of the full-time fishermen interviewed in the Albemarle area had conflicts over space. Forty-three percent of the full-time fishermen from the Pamlico area reported spacial conflicts, 35% in the Dare area, 34% from the Carteret area, and 33% from the Southern coastal area (Johnson and Orbach 1996). Except in the Carteret area, crab pots were the major gear involved in spacial conflicts among full-time fishermen; 82% Albemarle, 60% Pamlico, 50% Southern, and 43% Dare (Johnson and Orbach 1996). Spacial conflicts in the Carteret area were with trawls and pots (38% each) and channel nets (25%). In a survey sent to crabbers landing over 6,000 lbs of crabs, Stroud (1997 and 1998) found that 25% of the respondents reported conflicts with other crab potters in 1996 compared to 44% in 1997. In 1996, 16% of the respondents reported conflicts with recreational water users and 14% of the fishermen reported conflicts with other commercial fishermen (Stroud 1997). These numbers increased to 25% for both groups in 1997 (Stroud 1998). A social/economic study conducted in 1984 by Maiolo et al. (1985) in North Carolina indicated that 62% of the full-time crab fishermen and 35% of the part-time crab fishermen had problems with recreational fishermen. Space and gear conflicts were the main problem, with 41% of the crabbers stating that sports fishermen fish their pots (Maiolo et al. 1985). Seventy-five percent of the crab trawlers interviewed said that the presence of crab pots presented a problem (Maiolo et al. 1985). The main problem reported by crab trawlers (67%) was limited trawling area due to space conflicts with potters, while 33% complained that pots were drifting offshore and getting tangled in their nets (Maiolo et al. 1985). Only 42% of the crab potters interviewed said the presence of crab trawlers presented a problem (Maiolo et al. 1985). The major complaint by full (76%) and part-time (75%) crab potters was destruction of pots by trawls (Maiolo et al. 1985). The recent closure of waters off Goose Creek State Park and the Wildlife Resources Commission's closure of inland waters to commercial crab pots, exemplifies the conflicts between recreational water users and commercial fishermen.

Conflicts may result in gear being moved, damaged, destroyed, or stolen. Theft of potted crabs and pots has increased in some areas as effort and price of the resource has increased. Fishermen are setting more pots than can actively be fished. Pots may be set in several locations to hold fishing sites, while crabbing more productive areas. Additionally, pots may be left during unproductive times to pursue other activities (gill netting, trawling, hunting, etc.). Unattended pots continue to capture crabs and contribute to unnecessary mortality and waste of the fishery resource. These unattended pots cause conflicts with other water users, commercial and recreational.

North Carolina has an extensive history of activity, which has attempted to address competition, conflict, and effort concerns in the blue crab fishery. From the 1950's through the 1990's, the Marine Fisheries Commission (MFC) and the Division of Marine Fisheries (DMF) have dealt with spacial conflicts by:

1) Meeting with the various user groups to work out compromises;
2) Designating pot areas;
3) Restricting crab pot fishing times;
4) Implementing crab pot limits;
5) Harvest seasons; and
6) Increasing law enforcement.

The most recent (1993-2000) activities to address past and continuing concerns are presented in Attachment 1.

Possible management solutions to conflicts include:

1) Management areas;
2) Harvest seasons;
3) Gear restrictions/ reductions;
4) Time restrictions;
5) Catch limits; and
6) Area restrictions.

III. Discussion of Management options:

<u>Management areas</u>

Griffith (1996) found that the flexibility to move among and between fisheries is a hallmark of North Carolina fishermen. This movement is driven by regional/ecological factors, proximity to metropolitan areas, and by relationships to the marketing and processing sectors (Griffith 1996). Based on these findings, Griffith (1996) recommended that North Carolina consider creating management areas to allow for community-based fisheries management. Bennett (2000) noted that government willingness and ability to manage fisheries with the active participation of all stakeholders is a likely key to effective conflict management. Regional-based management was part of the overall management strategy in the 1998 Blue Crab Fishery Management Plan (BCFMP-McKenna et al. 1998).

This approach recognizes that too much management imposed from without is just as bad as too little. The state of North Carolina should allow as much flexibility as possible for fishermen to operate as they see fit. However, government has a responsibility to all citizens of the state to protect public resources. Cooperative management at the local level would allow management to be more responsive to local situations. Aubert (1963), Boulding (1966) and Powelson (1972) all differentiate between conflicts that are 'within consensus' and those that are 'over consensus'. In the former case, the parties agree about the conflict, but not about the means of achieving the solution. In the latter case the parties are unable to agree on the conflict, nor on how to solve it. The potential impact of conflict is thus dictated by the degree of consensual framework within which they are contested and the degree of conflict over basic consensus (Coser 1972). Therefore, a regional based mechanism to mediate local conflicts using existing MFC regional committees (Northern, Central, Southern, and Inland) would allow for "within consensus" deliberations. The various management options discussed below would benefit from a regional-based management approach that would allow a given management strategy to be tailored to the needs of each area.

PROS:
1) Flexibility of management options.
2) More public involvement.
3) Use established advisory committees to mediate user conflicts.
4) Fishermen get a felling of ownership and believe in the management system.

CONS:
1) Increased administrative cost?
2) Increased enforcement cost?
3) Might need to redraw enforcement lines to allow better enforcement.
4) Might need to redraw District lines to fully encompass management areas.

Harvest Seasons

The blue crab dredge fishery is currently the only blue crab fishery under seasonal restrictions (January 1 through March 1). From approximately 1955 through 1964, a crab pot harvest season prohibited crab potting in all areas of the state from May 1 through November 1, except for northern Pamlico Sound. In 1965 the Director of DMF was given proclamation authority to open closed areas from May 1 through November 1 (changed in 1966 to May 1 through September 1). This harvest season remained in place until 1984, when it was replaced with the current designated pot area rule (3R 0.017; MFC 2003). The intent of this harvest season was to reduce conflicts between crab potters and shrimp trawls. Implementing a harvest season similar to the one in place from the 50's to the early 80's would effectively eliminate conflicts and the crab fishery, as we now know it. The May – November period accounts for over 90% of the shrimp harvest and coincides with peak recreational water use. However, 90% of the crab pot harvest occurs during this time frame. To reduce conflicts using harvest seasons, the closed season must coincide with peak use by other user groups. In the case of the crab pot fishery, the peak season overlaps for all user groups. Hence from a conflict resolution standpoint, harvest seasons for the crab pot fishery are not economically practical.

A harvest season for crab trawls could reduce some of the conflict between this gear and crab pots (i.e., a summer closure). However, as was the case with pots a summer closure would negatively impact this fishery. Forty-eight percent of the crab trawl harvest and 59% of the trips occur from May through October. Additionally, a summer closure could affect the small resident trawl fleet since the crab trawl fishery is composed primarily of shrimp vessels in the 30-50 ft range, which convert to crab trawling during late fall and winter or during the summer in years of low shrimp abundance. Additionally, since the rivers are an important summertime crab trawling area, and these areas are currently managed using designated pot areas, most of the summertime conflict is already reduced.

PROS:
1) Significantly reduce user conflicts (trawler and recreational) with crab pots.

CONS:
1) Effectively eliminate the crab fishery, as we now know it.
2) Force crab fishermen (potters and/or trawlers) to other fisheries.
3) Negatively impact the small trawlers by reducing fishing options.

Gear Restrictions/ Reductions

Pots

Limits on the amount of gear that a fisherman may use have long been a stable management tool of resource managers. Limits are used to reduce conflicts, protect resources, and improve economics. Pot limits have been and are currently used in North Carolina as a means of conflict resolution. In the early 1950's, a 100 pot limit was imposed to reduce conflicts between trawlers and potters in North Carolina. This limit was repealed in 1967. In the mid 1980's, a 150 pot/vessel limit was established for the Newport River. This limit was implemented at the request of local fishermen in an effort to reduce conflict. Crab pot limits have been suggested as one way of reducing spacial conflicts, and improving economic efficiency in the crab pot fishery. A social/economic study conducted in 1984 by Maiolo et al. (1985) in North Carolina showed that 47% of all fishermen (52% full-time, and 38% part-time) supported a 250 pot limit. In a survey sent to crabbers landing more than 6,000 lbs of crabs, Stroud (1996 and 1997) found that 82% of the respondents supported pot limits in 1995, while in 1996 pot limits were supported by 71% of the fishermen. Suggested limits for both years are shown in Table 2.

PROS:
1). Would limit the amount of gear that a fisherman could use.
2). Could reduce the number of pots currently in the water.

CONS:
1) Increased administrative cost?
2) Increased enforcement cost?

Table 2. Suggested crab pot limits by category and year (data from Stroud 1996 and 1997)*.

Category	1995	1996
Full-time crab potter	426	443
Part-time crab potter, full-time commercial fishermen	332	403
Part-time crab potter, other major source of income	381	342
Overall average	403	424

*During development of the 1998 Blue Crab Fishery Management Plan, regional stakeholder groups were established to recommend pot limits for five areas of the state. The recommendations from these groups are in Attachment 2.

Trawls

The concept of limiting the headrope length of trawls in selected water bodies has been an issue among fishermen for many years (i.e., 1989 petition from Neuse River fishermen to limit total headrope length of shrimp trawls to 50 feet in this area). The main issue surrounding a headrope length limit is economic. Fishermen that are restricted to smaller bodies of waters because of their vessel size and individuals that are limited in the amount of net they are able to pull because of horsepower, frequently complain of unfair competition from bigger vessels. They feel that these individuals who are able to work in the open sound and ocean have an unfair advantage over them because they are able to work all open areas; whereas, the smaller boats are restricted to the smaller bodies of water due to the aforementioned limitations. Additionally these larger vessels are usually pulling four nets ranging in size from 30 to 60 feet each and occasionally larger. In these smaller areas, a large boat can usually fish out an area in a couple of passes; whereas, a smaller boat could work all day.

Headrope length limits could potentially allocate resources more equitably to alleviate conflicts between recreational and commercial trawlers, fixed gear and trawlers, and small and large commercial trawlers. In the smaller bodies of water, smaller headropes would allow the traditional small-medium trawl boats to operate more equally with the larger ocean vessels. Also, trawler potter conflicts could be reduced as a vessel towing smaller nets could more easily avoid crab pots.

PROS:
1) Reduce economic conflict between large and small trawlers.
2) Reduce trawler and potter conflicts.

CONS:
1) Increased cost to fishermen for new nets.
2) Decreased efficiency of larger vessels and lost income.

<u>Time Restrictions</u>

Three time restrictions currently pertain to the crab pot fishery (time limits on potting areas are considered in the area restrictions section). All crab pots must be removed from the water during a pot clean-up period between January 24 and February 7. Potting is prohibited from one hour after sunset to one hour before sunrise. There is also a 7 day abandoned gear rule. The pot clean-up period and the abandoned gear rule were implemented to reduce ghost pots. The prohibition on fishing time was an attempt to deal with the theft of crabs and pots.

Two regulations restrict fishing times in the crab trawl fishery. The first regulation closes trawling one hour after sunset on Friday to one hour before sunset on Sunday. The rivers (Pamlico, Pungo, Bay, and Neuse) are closed to nighttime trawling, one-hour after sunset to one hour before sunrise, from December 1 through February 28. Restrictions on weekend trawling were implemented to minimize conflicts with recreational fishermen and to reduce fishing effort. The nighttime closure was driven by resource and policy concerns, flounder bycatch, and retaining finfish caught in trawls.

Further restriction of fishing times (daylight hours only) and only allowing the unloading and/or possession of crabs before sunset could help deal with the continued problem of theft in this fishery. Various people have suggested that fishing time be restricted to a certain time frame (i.e., 6am until 2pm). The intent of this proposal is to eliminate those fishermen that work at other jobs and fish pots after work. Besides unfairly targeting a certain segment of the fishery, problems would be encountered by full-time fishermen working in tidal areas. Although, the latter problem could be resolved through regional management.

PROS:
1) Reduce theft.
2) Reduce pot numbers?

CONS:
1) Unfairly target a certain segment of the fishery.

<u>Catch Limits</u>

Catch limits attempt to reduce effort, and/or fishing mortality by limiting the daily (trip) catch of fishermen. The basic assumption of this management strategy is that by restricting catch fishermen will adjust their effort to maximize economic efficiency. However, this effort adjustment would vary from year to year depending on resource availability. In years of low crab abundance fishermen might put out more pots to harvest their limit. Additionally, catch limits could have a negative impact on crab processors, by creating uncertainty with regard to product availability.

PROS:
1) Could limit gear in years of high resource abundance.
CONS:
1) Gear use could expand during years of low abundance.
2) Could cause economic inefficiencies in the potting and processing sectors.
3) Would not reduce conflict.

<u>Area restrictions</u>

Crab pot areas, no trawl areas, and the crab dredge area are examples of area restrictions. These areas were set up to reduce user conflicts (crab pot areas), reduce environmental impacts (trawl and dredge areas), and to achieve biological objectives (trawl areas). While area restrictions have the potential to reduce conflict between crab potters and other user groups, they increase conflict among potters. However, for localized navigation and access conflicts this management strategy has the greatest potential to deal with these issues. The potential for success would be greatly increased, if it were tied to a regional management system.

PROS:
1) Reduce localized navigation and access conflicts.
2) Reduce conflicts between different fisheries.
3) Flexibility of management options.
4) More public involvement.
5) Establish advisory committees to mediate user conflicts.
6) Fishermen get a feeling of ownership and believe in the management system.

CONS:
1) Potentially increase conflict among potters.

IV. Recommendations:

Conflict issues in the blue crab fishery should be dealt with through regional/area management. The existing “User Conflict” rule (15A NCAC 3J .0301 (j) POTS) only allows the closure of an area to pots by proclamation authority of the Fisheries Director with the MFC’s approval. In an effort to further enhance the DMF’s and MFC’s, ability to deal effectively with user conflicts, the current rule should be modified to allow various means and methods options to address area specific conflicts. Additionally, internal guidelines should be developed to resolve user conflict issues.

In an effort to address conflict issues and increasing effort associated with the crab pot fishery, a specific regional management proposal was developed and is presented in Appendix 14 (Regional Crab Pot Management). This proposal incorporates various open access management strategies into one comprehensive system of management that is specific to the crab pot fishery. These strategies are: (1) management areas, (2) gear restrictions (regional pot limits), (3) area restrictions, and (4) a permit system to participate in the fishery. Modifying the “User Conflict” rule to allow the use of any or a combination of the various options outlined in Section 10.4.1.2 and Appendix 13, and Appendix 14 (Regional Crab Pot Management) will broaden the suite of alternatives that may be utilized to deal with user conflicts.

To minimize conflicts, theft, and gear damage, and increase public trust utilization, the MFC needs to change the unattended pot rule from the existing 7 day period to 5 days, and support the establishment of boating safety courses and boat operator licenses by the Wildlife Resources Commission (WRC). The MFC does not support a boat operator license.

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Attachment 1: History of Recent Competition/Conflict/Effort Management for the NC Blue Crab Fishery

<u>1993</u>

- Due to concern over the increase in pot numbers and threat of pot limits, crabbers met March 1993 and recommended a separate Crab License and a MFC Advisory Committee for the blue crab fishery. Provisions for a commercial Crab License were enacted by the N.C. General Assembly in July 1993; effective Jan. 1, 1994.

<u>1994</u>

- The new commercial Crab License was required to participate in the crab fishery on January 1, 1994.
- Crabbers concerned with the rapid increase in the number of crabbers and pots recommended a 2-year moratorium on Crab License sales (Jan. 29, 1994).
- With support from the majority of the fishing community the NC General Assembly put a moratorium on all new commercial fishing licenses; effective July 1, 1994.
- A License Appeals Panel is established to consider issuing new licenses during the moratorium for hardship cases that meet established criteria.
- The NC Fisheries Moratorium Steering Committee was established to explore and recommend changes to NC's fishery management system and various effort management options were discussed during this process.

<u>1995-1996</u>

- Researchers (Johnson and Orbach 1996) conducted a three part series of North Carolina Fisheries Moratorium Limited Entry Workshops. The purposes of these workshops were: 1) to discuss problems and issues in NC fisheries, 2) to discuss limited entry or access, 3) evaluate different alternatives for limited entry or access, and 4) present the results of evaluations and discuss further development of the concept of limited entry for NC's fisheries.

<u>1996</u>

- Crabbers from all regions of the coast were invited to a scoping meeting to review possible effort management options. A limited entry Gear Certificate option was accepted as the best management option for the blue crab pot fishery (March 1996 – Beaufort Community College).

<u>1997</u>

- Based on recommendations from the Moratorium Steering Committee, the Fisheries Reform Act (FRA 1997) implemented a cap on commercial licenses, restructured the licensing system (effective July 1, 1999), mandated Fisheries Management Plans (FMP), and required the first FMP to be for the blue crab fishery.

<u>1998</u>

- During development of the Blue Crab Fishery Management Plan (BCFMP - McKenna et al. 1998), a copious amount of time was spent discussing conflict/effort management, particularly for the crab pot fishery.Options considered and actions taken as recommended in Sections 10.3 and 10.4 of the 1998 BCFMP are summarized below.

1998 BLUE CRAB FISHERY MANAGEMENT PLAN (BCFMP - McKenna et al. 1998)

10.3 COMPETITION and CONFLICT WITH OTHER USERS (BCFMP 1998; pages 40-41)

10.3.1.2 Management options

1) Management areas;
2) Harvest seasons;
3) Gear restrictions/ reductions;
4) Time restrictions;
5) Catch limits;
6) Delayed entry;
7) Licenses;
8) Permits;
9) Area restrictions; and
10) Limited entry.

All options would require rule changes by the MFC. Options six, seven, and ten would require legislative action.

10.3.1.4 Actions (BCFMP 1998). Underlined text below denotes actions taken on the recommended "Actions" outlined in the 1998 BCFMP.

Action 1: Provide Marine Patrol with statutory authority to deal with theft.
G.S. 113-268 "Injuring, destroying, stealing, or stealing from nets, seines, buoys, pots, etc." was modified by inserting "steal" in subsection (c), effective Dec. 1, 1998.

Action 2: Change the unattended pot rule from the existing 10 day period to 7 days.
Existing rule (15A NCAC 3I .0105) was modified as follows and Item (b)(3) was added to deal with unforeseen events:

15A NCAC 3I .0105 LEAVING DEVICES UNATTENDED (MFC 2003; p. 10-11)
(b) It is unlawful to leave pots in any coastal fishing waters for more than ~~**ten**~~ seven consecutive days, when such pots are not being employed in fishing operations, except upon a timely and sufficient showing of hardship as defined in Subparagraph (b)(2) of this Rule or as otherwise provided by General Statute. [Item (b)(3)] The Fisheries Director may, by proclamation, modify the seven day requirement, if necessary due to hurricanes, severe weather or other variable conditions.

Action 3: Make it unlawful for pots (hard and/or peeler) to be used or set in any navigation channel marked by State or Federal agencies and in areas identified by the MFC. Existing rule (15A NCAC 3J .0301) was modified as follows:

15A NCAC 3J .0301 POTS (MFC 2003; p38-40)
(b) It is unlawful to use pots: In any navigation channel ~~maintained and~~ marked by State or Federal agencies; or In any turning basin maintained and marked by the North Carolina Ferry Division.

Action 4: Modify existing crab pot area regulations using depth as the boundary instead of distance from shore. Crustacean Committee has recommended using the 6 foot depth contour to the MFC. The MFC has issued a subject matter notice for rule making (Jan. 2001).

Action 5: Develop guidelines for the DMF and MFC to mediate user conflicts.
Item (j) User Conflicts was added to the existing rule (15A NCAC 3J .0301) for POTS (see below).

15A NCAC 3J .0301 POTS (MFC 2003; p35-37)

(j) User Conflicts:

(1) The Fisheries Director may, with the prior consent of the Marine Fisheries Commission, by proclamation close any area to the use of pots in order to resolve user conflict. The Fisheries Director shall hold a public meeting in the affected area before issuance of such proclamation.

(2) Any person(s) desiring to close any area to the use of pots may make such request in writing addressed to the Director of the Division of Marine Fisheries. Such requests shall contain the following information:

- (A) map of the proposed closed area including an inset vicinity map showing the location of the proposed closed area with detail sufficient to permit on-site identification and location;
- (B) Identification of the user conflicts causing a need for closing the area to the use of pots;
- (C) Recommended method for resolving user conflicts; and
- (D) Name and address of the person(s) requesting the closed area.

(3) Person(s) making the requests to close an area shall present their request at the public meeting.

(4) The Fisheries Director shall deny the request or submit a proposed proclamation granting the request to the Marine Fisheries Commission for their approval.

(5) Proclamations issued closing or opening areas to the use of pots under Paragraph (j) of this Rule shall suspend appropriate rules or portions of rules under 15A NCAC 3R .0107 as specified in the proclamation. The provisions of 15A NCAC 3I .0102 terminating suspension of a rule as of the next Marine Fisheries Commission meeting and requiring review by the Marine Fisheries Commission at the next meeting shall not apply to proclamations issued under Paragraph (j) of this Rule.

Action 6: Establish management areas to address user conflicts.
Five Regional Stakeholder Committees were established by the MFC in 1999 to assist with Effort Management deliberations. These groups were disbanded after recommendations on effort management were submitted to the MFC. Currently, there are no formal management areas to address crab resource issues.

Action 7: Consider gear licenses or permits for identification and inventory.
These items were considered and recommendations were made in conjunction with various open access and limited entry options that were explored during 1999 and 2000. However, no gear licenses or permits were implemented.

Action 8: Consider a pot tagging system for identification and inventory.
Tagging was considered and recommendations were made in conjunction with various open access and limited entry options that were explored during 1999 and 2000. However, a pot tagging system was not implemented.

Action 9: The MFC should support the establishment of boating safety courses and/or a boat operators license by the WRC for individuals operating any watercraft. The MFC has not initiated any action on this recommendation.

Action 10: Re-examine the times when pots must be moved into designated crab pot areas. Crustacean Committee has recommended a time frame shift to the existing rule (1 May- 31 Oct.) to 1 June - 30 Nov. There will not be an increase or decrease in the total time the area is closed to crab potting. The MFC has issued a subject matter notice for rule making (Jan. 2001). Also, the Crustacean Committee has recommended a proposal to the MFC to open designated long haul areas to crab potting by proclamation. The MFC has issued a subject matter notice for rule making (Jan. 2001). See Appendix 11 (1998 BCFMP: page 131) for an in-depth discussion of the issue and management options.

10.4 INCREASING FISHING EFFORT (BCFMP 1998; pages 42-47)

10.4.1 EFFORT MANAGEMENT

10.4.1.2 Management Options

10.4.1.2.1 Open Access

1) Management areas;
2) Harvest seasons;
3) Gear restrictions/ reductions (i.e., uniform pot limits);
4) Time restrictions;
5) Catch limits;
6) Delayed entry;
7) Licenses;
8) Permits; and
9) Area restrictions.

10.4.1.2.2 Limited entry

The license cap on Standard Commercial Fishing Licenses (SCFL), as enacted by the FRA (1997), established a limited entry system for North Carolina's commercial fishing industry (effective 1 July 1999). The MFC has no authority to limit entry in the blue crab fishery. The North Carolina General Assembly would have to enact legislation approving any further limited entry in the fisheries or delegate this authority to the MFC (1998 BCFMP). The following limited/restricted and non-limited entry options were considered for the crab fishery during development of the 1998 BCFMP. A description and evaluation of each option is contained in the 1998 BCFMP. The non-limited entry options did not provide further restriction on access to the crab fishery, but provided restrictions on participation through time limits, gear limits, or by choice.

1) Marketable Crab License Limitation (Limited Entry)
2) Transferable Two-Stage License Limitation (Limited Entry)
3) License Shares (Limited Entry)
4) Gear Certificates (Limited Entry)
5) The Status Quo (Non-Limited Entry) with the legislated cap on licenses and no Crab License
6) One-time Purchase Without Transfer (Limited Entry)
7) License Choice (Non-Limited Entry)
8) Time Slot Tag Purchase (Non-Limited Entry)
9) Uniform Two-Stage Limit on the Number of Pots per Fisherman (SCFL; Non-Limited Entry)

10) Gear Certificates Based on Historical Landings (Restricted Entry)

Different combinations of these alternatives would also be possible. For example, a license limitation system could be combined with a trap certificate system.
See Appendix 11 (BCFMP 1998: page 131) for an in-depth discussion of the issue and management options.

10.4.1.3 Recommended Management Strategy

It is likely that none of the traditional open-access management alternatives (for example seasons, time, and area restrictions) can significantly control or reduce the overall effort in the crab fishery without severely restricting individual landings or traditional fishing patterns. Therefore, some type of effort management system is needed to control and/or reduce effort in the crab fishery. No specific strategy for a continued open access or limited entry system to manage effort in the crab fishery is proposed at this time. The legislated time frame to develop the blue crab FMP did not allow for an effort management system to be fully developed for this fishery. Therefore, the crab licenses and license moratorium should be extended for one more year (until 1 July 2000) to allow for the development of an effort management system. Any option to reduce effort should provide an appropriate means to allow flexibility within the fishing community (future holders of the limited SCFL); minimize exclusive privileges and avoid monopolies; control or reduce effort in the crab fishery; and make management of the crab fishery more efficient and effective. Any strategy recommended should meet objectives 2, 3, 4, 5, 9, and 10 of this plan.

10.4.1.4 Actions

Action 1: Extension of the crab licenses and license moratorium until 1 July 2000.
Action 2: Ongoing discussion of options.
Action 3: The MFC Crustacean Committee and Blue Crab Advisory Committee are charged with continuing the discussion of effort management options for the blue crab fishery and making a final recommendation to the MFC by 1 May 1999. The MFC will make a final recommendation to the N.C. General Assembly on effort management as an amendment to the Blue Crab FMP on or before 1 July 1999.
The moratorium on new commercial fishing licenses and the Crab License were scheduled to expire on June 30, 1999. The expiration of this moratorium and the Crab License would allow anyone with an Endorsement to Sell License to purchase a Standard or Retired Commercial Fishing License (SCFL) and be eligible to participate in the crab fishery. The moratorium on new licenses and provisions of the Crab License had allowed only a limited number of license holders (3,639 in Oct. 2000) to participate in the crab fishery. Once the moratorium and license expired, approximately 8,830 (cap for 2000) licensees would be eligible to participate in the crab fishery at any level of effort they choose. This increase would potentially more than double the number of participants. Therefore, a segment of the industry was concerned that increased participation, fishing effort, and gear use would escalate to the point that the resource and the economics of the fishery may collapse or would suffer from over capitalization.

Consensus could not be reached on an appropriate effort management plan for the crab fishery. The committees and MFC recommended that the Crab License be extended to allow for continued discussion of an effort management plan by the industry, the MFC, and the DMF. Based on this recommendation, the N.C. General Assembly established an Interim Crab License effective July 1, 1999 until October 1, 2000. See highlights of the continued 1999-2000 conflict/effort management deliberations (below).

1999

- Effort Management Workshop was held for the Blue Crab FMP Advisory Committee to discuss options on January 12, 1999. Five open access (non-limited entry) and five limited entry options were evaluated. Three open access (#'s 1, 2, and 5.) and three limited entry options (#'s 6, 7, and 8.) were considered viable (see Supplement 1 for descriptions).
- The MFC Crustacean Committee met (February 11, 1999) to review and discuss results of the Effort Management Workshop.
- DMF staff presented two new "hybrid" effort management options that contained elements of several different options to the MFC Crustacean Committee (Feb. 11, 1999). One option was for open access (Permit Allocation System) and the other for limited entry (License Allocation System).
- The MFC Crustacean Committee evaluated and discussed, but made no formal recommendations on the effort options (Feb. 11, 1999).
- The MFC recommended four effort management options for the crab pot fishery, that would be presented at meetings coastwide to gather public input (Feb. 24, 1999).
- Two open access (1. Progressive Price per Pot and 2. Permit Allocation System) and two limited entry (3. License Allocation System and 4. Gear Certificates) effort management options for the crab pot fishery were presented at five public meetings in the coastal area (March 1999). Supplement 2, which was distributed prior to and at the meetings, contains a description of each option.
- MFC directed the DMF to develop Regional Stakeholder Advisory Committees for coastal areas with similar crab populations and fishing practices (March 13, 1999).
- In an attempt to develop an effort management option that would consider the vast differences in the pot fishery statewide and gain the support of the fishing community, the MFC established five regional crab pot management areas (see map; Figure 1) (May 1999).
- A Blue Crab Regional Stakeholder Advisory Committee of commercial fishermen, dealers, recreational fishermen and boaters was appointed to represent each region.
- Due to the lack of consensus reached during prior effort management discussions, the need to allow new entrants into this fishery, and a desire to control overall pot numbers, the MFC directed these regional committees to assist in the evaluation of an effort management plan for this fishery and to consider 1) regional differences in the fishery; 2) market stability; and 3) also allow those involved to maintain operations similar to existing levels, while allowing flexibility for the entire fishing community to participate in the pot fishery.
- License moratorium and Crab License were scheduled to expire on June 30, 1999.
- An Interim Crab License was established by the N.C. General Assembly effective July 1, 1999 until October 1, 2000.
- This extension of the Crab License was granted to allow the industry, MFC, and DMF an opportunity to continue work on an effort management plan for the crab pot fishery.
- An Amendment (effective July 1, 1998) to the FRA 1997 established that the MFC "may recommend that the General Assembly limit participation in a fishery only if the Commission (MFC) determines that optimal yield cannot otherwise be achieved". The amendment outlined stringent factors that were to be considered in making this

determination for any additional limits on participation in a fishery.

- Upon considering these criteria for limiting entry in the blue crab fishery, the MFC decided to pursue only open access options (Sept. 10, 1999).
- The regional open access effort management plan (option) developed by DMF (Supplement 3) and evaluated by the Regional Stakeholder Advisory Committee's for the crab pot fishery, included combining three elements of open access management into one system of management (October-November 1999). These elements are (1) management areas, (2) gear restrictions (regional pot limits), and (3) a permit system to participate in the fishery.
- Specifically, the MFC asked the Regional Stakeholder Advisory Committees to consider and make recommendations on regional pot limits, a permit system, pot tags, penalties for non-compliance, a pot reduction system (if deemed necessary), and conflict issues and methods to reduce conflicts with crab pot use (Supplement 3).

1999-2000

- The Regional Stakeholder Advisory Committees met independently to consider options and formulate recommendations (December 1999 – January 2000).
- Conflict issues and recommendations to resolve conflict identified by each regional committee and the MFC Crustacean Committee are summarized in Table 1.
- Attachment 2 summarizes all the recommendations from each Regional Stakeholder Committee and the MFC Crustacean Committee (February 8, 2000) for the regional open access crab pot fishery effort management plan.
- Some of the committees identified a need to reduce effort in some areas and recommended pot limits.
- However, generally the Regional Stakeholder Committees did not expect effort to increase significantly when the Interim Crab License expired, and did not feel that pot limits were necessary, unless the primary purpose was to protect the blue crab population.

2000

MFC Action on Recommendations for a Regional Open Access Crab Pot Fishery Effort Management Plan (February 18, 2000)

- Based on the recommendations of the Regional Stakeholder Committees and the Crustacean Committee and the lack of support from the fishing community, the MFC did not implement any aspect of the proposed regional effort management strategy for the crab pot fishery (i.e., pot limits, pot tags, a permit to participate in the fishery).
- The MFC also asked the N.C. General Assembly to allow all holders of the Standard Commercial Fishing License (SCFL) to participate in the crab fishery as soon as possible in the 2000 license year (effective July 1, 2000). (The N.C. General Assembly did not take any action on this recommendation.)
- Interim Crab License holders without a SCFL were encouraged to apply for a SCFL and allowed to continue participation in the fishery until the license expired on October 1, 2000.
- Assignability of the SCFL by individuals or corporations with several licenses and the potential increase in competition and effort that this could cause in the pot fishery was a major concern of the committees. To address this concern the MFC recommended that the N.C. General Assembly restrict the assignment of crabbing privileges when assigning the license. (The N.C. General Assembly did not take any action on this recommendation.)

- Some very good recommendations from the Regional Stakeholder Committees on managing social conflict in the crab pot fishery were referred by the MFC to the Crustacean Committee for further discussion and possible action (Table 1).

Table 1. Conflict issues and recommendations to resolve conflict identified by each Blue Crab Regional Stakeholder Committee and the MFC Crustacean Committee (December 1999 - February 2000).

Conflict Issues: (Identified by Regional Stakeholder Comm. 1999-2000)
Public trust issues, Regions 1,3 (property owners), 4, and 5 (recreational boaters).
Crab pots and navigation. Regions 1,2,3
Crabs, pots and potter concentrated in small areas. Regions 1,4 (bays)
Trawler and potter conflict. Regions 3,4
Too many pots in water. Region 5
Double rigged trawlers/potters. Region 2
Inability to see pot buoys. Region 5
Recommendations for conflict resolution: (Identified by Regional Stakeholder and Crustacean Comm. 1999-2000)
Establish marked navigation channels. Regions 1,2,3,4,5, and Crustacean.
Depth contours. Region 3 and Crustacean
Open haul net areas. Regions 3, and 4
Yardage setback for piers, by region. Region 3, and Crustacean
Deal with conflict at the lowest level possible. Region 1
Prohibit trawlers from pot areas. Region 3
Deal with problem fishermen. Region 4
Strengthen regional committees to address localized problems. Region 5
Distribute info on commercial gear identification. Region 5

Literature Cited:

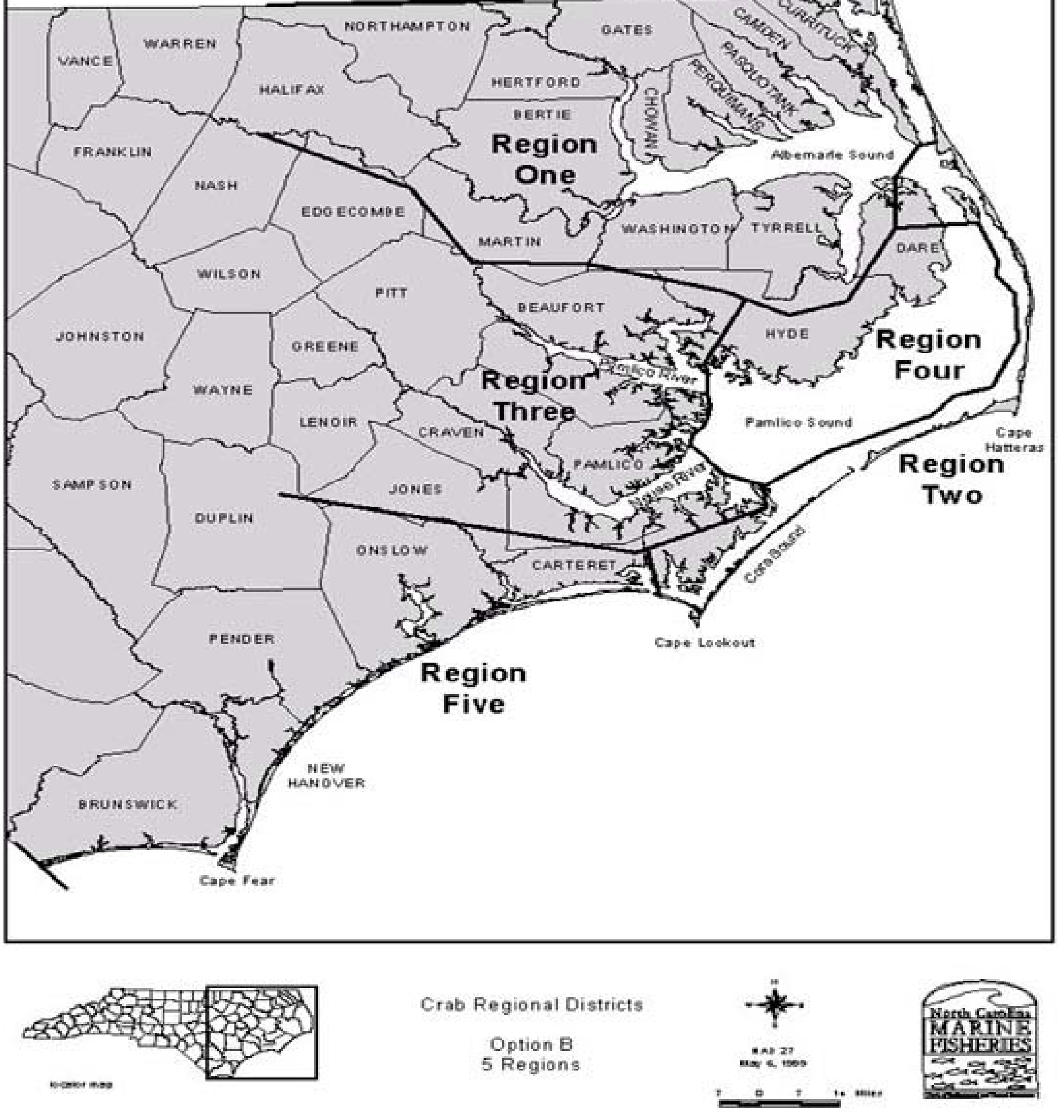
FRA (Fisheries Reform Act of 1997). 1997. An act to enact the Fisheries Reform Act of 1997 to protect, enhance, and better manage coastal fisheries in North Carolina. North Carolina General Assembly, 1997 Session, House Bill 1097. Raleigh, NC.

Johnson, J.C. and M.K. Orbach. 1996. Fisheries research reports to the fisheries moratorium steering committee, effort management in North Carolina fisheries: a total system approach. N.C. Sea Grant Rep. UNC-SG-96-08. 155p.

McKenna, S., L.T. Henry, and S. Diaby. 1998. North Carolina Fishery Management Plan – Blue Crab. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries. Morehead City. 73p. + Appendices.

MFC (North Carolina Marine Fisheries Commission). 2003. North Carolina Fisheries Rules for Coastal Waters 2003. NC. Div. Mar. Fish., Morehead City, NC. 297p.

Figure 1. Five Regional Crab Pot Management Units for North Carolina (1999-2000)



Supplement 1 DESCRIPTIONS OF EFFORT MANAGEMENT OPTIONS

OPEN ACCESS

1. Status Quo

This is the "no change" alternative, meaning that the management systems currently in place for the crab pot fishery would remain in effect with no changes, with one important note: *The moratorium, and the crab license, would no longer be in place*. At some point we either have to let the moratorium expire and go back to the open access situation (within the new limitations of the cap on SCFLs), or design a new system, which might more directly control access and effort.

2. Progressive Price Per Pot

This system incorporates a progressive fee per pot. The first 150 pots would cost $1.00/pot. The price increases to $2.00 for 151-300 pots, and $3.00 for any amount of pots over 300. There are no limits on the number of pots a fisher may purchase. All Standard Commercial Fishing License (SCFL) holders are eligible.

3. Time Restrictions

This system incorporates time as a limiting factor. This proposal would require pots be fished between one hour before sunrise and 2:00 pm daily with no fishing of pots on Sundays. Therefore fishing would cease Saturday at 2:00 pm and not resume until one hour before sunrise on Monday morning. Currently there are three time restrictions pertaining to the crab pot fishery. All crab pots must be removed from the water between Jan 24 and Feb 7, potting is prohibited from one hour after sunset to one hour before sunrise, and there is also a ten day abandoned-gear rule.

4. Pot Limits by Area

This system divides the coast into two sections: north of Core Sound and south of Core Sound including Core Sound. All marine and joint waterbodies from Core Sound south, would be allotted 300 pots per SCFL. Those areas north of Core Sound would be allowed 600 pots per SCFL.

5. Managed Growth System

All SCFL holders would be eligible for pot allotments based on a fisher's historic landings. This is a non-marketable system whereby all fishers would be allotted pots with an associated fee. Qualifying criteria for pots would be based on crab landings from crab pots only or seafood landings excluding crab pots. Those not qualifying with trip ticket landings would be allotted a minimum of 50 pots. This system would start January 2000 and would use the average landings from fiscal year (FY) 1997 and 1998 (FY=July 1 of the preceding year through June 30 of the noted year). Any fisher may apply to advance to a higher level based on an average of the previous two years. This system would be evaluated every three years

LIMITED ENTRY

6. Marketable Crab License Limitation

Under this alternative, licenses to participate in the crab fishery would be issued at the beginning of the system to a number of "initial qualifiers". Initial qualifiers might be those fishermen who had a valid ETS over a qualifying period of two years (FY 1997 and 1998). Qualifying criteria would be based on average crab landings from crab pots only or seafood landings excluding crab pots for these two years. After the initial issuance of licenses, the total number of licenses would remain the same; that is, they would not increase above the total number originally issued. Each licensee would be limited to 450 pots. These licenses would be marketable; that is, bought and sold among the fishers themselves

7. Transferable Two-Stage License Limitation

Under this system, the original distribution of licenses would be done through a one-time opportunity to purchase one of two kinds of licenses. The first, or "full time transferable" license, would be available for one-time purchase by any fisher who has landed an average of 7,001 pounds of crabs in FYs 1997 and 1998. These licenses would be transferable either a) with the sale of a boat; b) to the immediate family of the license holder; or c) by sale to the state separate from the boat. Holders of this license would be limited to 300 pots per licensee or 500 pots per licensee with an apprentice onboard.

The second, or "part time" license, would be available to any ETS holder who had landed at least 501 pounds in either year, 1997 or 1998. These licenses would be non-transferable; that is, when the holders of this license gave up fishing, the license would disappear. Thus, this system would eventually eliminate all of this type of license. Holders of this license would be limited to 125 pots per licensee.

New entrants would either have to purchase a boat and license from a licensed fisherman, or serve a two-year apprenticeship with a licensed fisherman. After this apprenticeship, the apprentice would be eligible to purchase a license from the state if any were available.

8. License Shares

Under this system each current crab license holder would be issued license shares in quarter-share increments of 150 pots. These quarter, half, three-quarter, and full shares would be issued to fishers based on their historic catch level. A full license (four quarter shares) would be limited to 600 pots, hard crab and peeler pots combined, in the water at any given time. The initial shares would be issued based either on crab landings from crab pots only in the qualifying period (FY 1997 and 1998), or based on seafood landings excluding crab pots. Thereafter, licenses would be marketable among the fishermen in quarter-share increments.

9. Gear Certificates (Based on Blue Crab Landings from Crab Pots)

Under this alternative, each fisherman would be issued pot certificates in increments based on a target number of pots statewide and a fisher's percentage of average blue crab landings from crab pots for fiscal year 1997 and 1998. A minimum of 50 pots and a maximum of 600 pots would be allocated under this option. These certificates would be marketable; that is, bought and sold among the fishers themselves.

10. Gear Certificates (Based on Crab/Seafood Landings)

Under this alternative, each commercial license holder would be issued pot certificates in increments based on individual overall average commercial Trip Ticket landings of: (1) crabs from pots or (2) all seafood excluding crabs from pots during a specific qualifying period (FY 1997 and 1998). The license holder would decide on the method of qualification (crab or seafood landings). An appropriate and equitable method of allocation could be based on an average daily catch-per-pot for the fishery statewide.

To recognize those licensees with a history of participation in the crab fishery, crab landings could qualify a license holder at a higher level than seafood landings. Certificates would be non-transferable and non-marketable among licensees. A maximum level could be placed on the units of gear used statewide and/or per license to address biological, social, and economic issues. A licensee could advance to a higher level based on an average of the previous two years landings, unless an overall gear cap is established. An entry level allocation would need to be addressed for new licensees.

Note: All preceding options may be modified by changing any qualifying criteria, number of pots per licensee, number of licensees, poundage categories, and even total number of pots.

Supplement 2. EFFORT MANAGEMENT OPTIONS FOR THE NORTH CAROLINA CRAB POT FISHERY

Prior to the 1994 moratorium on the sale of commercial fishing licenses, most fisheries in North Carolina were open access or open entry fisheries. Anyone who could afford a boat and the equipment could pursue a living by fishing. However, problems can develop when more fishermen enter a fishery than the resource can support. Many people felt that was occurring in the blue crab fishery as more and more people were fishing for crabs. That is one of the primary reasons the moratorium was put in place by the General Assembly.

During the moratorium, numerous studies were done and alternative fisheries management systems were reviewed and discussed to improve the state's management methods. In 1997, the state legislature passed the Fisheries Reform Act, which totally restructured North Carolina's fishery management system. The Act replaced the state's licensing system; required fishery management plans, which are long-term management strategies for North Carolina's most economically important fisheries; downsized the Marine Fisheries Commission; required the development of coastal habitat protection plans; and increased fines and penalties for fisheries violations.

Because of concerns about increased fishing pressure and the value of the blue crabs - the state's most lucrative fishery - the Fisheries Reform Act required that blue crabs be the focus of the first fishery management plan. The plan was completed in December 1998, with one of it's major recommendations being the development of a system to reduce effort in the blue crab fishery.

Listed below are four effort reduction recommendations developed by fishermen, the Division of Marine Fisheries, and the Marine Fisheries Commission. Two of the proposals are considered open access options; however, the system is not totally open to anyone - under the new licensing system which goes into effect on July 1, 1999, commercial fishing licenses are restricted to fishermen who have a current Endorsement-to-Sell License on June 30, 1999. The last two options are limited entry alternatives, which limit the number of participants in the crab fishery by either gear certificates or licenses.

<u>OPEN ACCESS OPTIONS</u>

Option 1: Progressive Price Per Pot

This option incorporates a progressive fee for each crab pot based on the number of pots a fisherman uses. There would be no limit on the number of pots that may be used by individuals who have a Standard Commercial Fishing License. In the future, the Marine Fisheries Commission may implement a cap on the total number of pots allowed under this plan. There would be approximately 8,785 fishermen qualified to harvest crabs with pots under this option.

The fee structure would be:

1 - 150 pots	$1.00 per pot
151 - 300 pots	$2.00 per pot
300 pots or more	$3.00 per pot

Option 2: Permit Allocation System

Anyone who holds a Standard Commercial Fishing License would be eligible for a crab pot permit or permits. Initially, fishermen would be allowed 50 crab pots per permit. In the future, the Marine Fisheries Commission may reduce or increase the number of crab pots allowed per permit to address biological, social, and economic issues that may be impacting the resource or fishery. There would be approximately 8,785 fishermen qualified to harvest crabs with pots under this option.

The number of permits issued to an individual is based on reported seafood landings during FY 96/97 and FY 97/98, with the greatest number of permits going to crab pot fishermen. Individuals who do not qualify with landings would be allowed one permit (50 pots). Each Standard Commercial Fishing License would be issued a minimum of one permit (50 pots), with a maximum of 16 permits (800 pots). An individual, operation, or corporation may not own or have interest in more than 30 permits (1500 pots).

Permits for fishermen with a history of crab pot landings:

CRAB POT LANDINGS*	PERMITS
Up to 5,000 lbs.	1 permit (50 pots)
Up to 10,000 lbs	2 permits (100 pots)
Up to 15,000 lbs	4 permits (200 pots)
Up to 35,000 lbs	6 permits (300 pots)
Up to 45,000 lbs	8 permits (400 pots)
Up to 55,000 lbs	10 permits (500 pots)
Up to 75,000 lbs	12 permits (600 pots)
Up to 100,000 lbs	14 permits (700 pots)
Over 100,000 lbs	16 permits (800 pots)

Potential Qualified Fishermen	Potential Number of Total Pots
3266	615,700

***Under this system, soft and peeler crabs would be valued as 1 lb. per crab.**

Permits for fishermen with no landings or a history of seafood landings - excluding crab pot landings:

SEAFOOD LANDINGS	PERMITS
0 - 5,000 lbs	1 permit (50 pots)
5,001-10,000 lbs	2 permits (100 pots)
10,001-20,000 lbs	4 permits (200 pots)
Over 20,000 lbs	6 permits (300 pots)

Potential Qualified Fishermen	Potential Number of Total Pots
5019	483,550

Permits for Standard Commercial Fishing License issued through Eligibility Pool:

Under the new licensing system that goes into effect July 1, 1999, a cap will be placed on the number of Standard and Retired Commercial Fishing Licenses based on the number of valid Endorsement-to-Sell Licenses on June 30, 1999. An additional 500 licenses will be placed in a “pool” and distributed by random drawing to persons meeting established criteria, including past involvement in commercial fishing, degree of reliance on commercial fishing for a living, and other factors. Fishermen who obtain a Standard Commercial Fishing License through the pool process would be eligible for one permit

(50 pots).

POTENTIAL QUALIFIED FISHERMEN	**NUMBER OF POTS**
500	25,000

Transfers and Assignments

Permits would be transferable and assignable among Standard Commercial Fishing License holders. Assignment of permits could only be made as part of a Standard Commercial Fishing License assignment. Transfer or assignment of the permit must be made through a Division of Marine Fisheries Office.

Pot Identification

A unique, sequentially numbered, Marine Fisheries Commission- approved identification marker (tag or sticker) must be attached to the crab pot or buoy. Crab pot identification markers must be purchased by the pot owner from a Commission-approved supplier.

Identification marker numbers and the owner's or previous owner's identification must be recorded on the transferred or assigned permit. Any permit or crab pot without the specified information would be void.

LIMITED ENTRY OPTIONS

Option 3: License Allocation System

Fishermen who have a Standard Commercial Fishing License and a history of crab pot landings or seafood landings in excess of 5,000 lbs. (excluding crab pot landings) for FY 96/97 and FY 97/98 would qualify for a crab pot license or licenses (50 crab pots per license). In the future, the Marine Fisheries Commission may reduce or increase the number of crab pots allowed per license to address biological, social, and economic issues that may be impacting the resource or fishery. There would be approximately 4,730 fishermen qualified to harvest crabs with pots under this option.

Each Standard Commercial Fishing License holder would be issued a minimum of one license (50 pots), with a maximum of 16 licenses (800 pots) for the initial allocation. An individual, operation, or corporation may not own or have interest in more than 30 licenses (1500 pots).

Licenses for fishermen with a history of crab pot landings:

CRAB POT LANDINGS*	LICENSE
Up to 5,000 lbs	1 license (50 pots)
Up to 10,000 lbs.	2 licenses (100 pots)
Up to 15,000 lbs	4 licenses (200 pots)
Up to 35,000 lbs	6 licenses (300 pots)
Up to 45,000 lbs	8 licenses (400 pots)
Up to 55,000 lbs	10 licenses (500 pots)
Up to 75,000 lbs	12 licenses (600 pots)
Up to 100,000 lbs	14 licenses (700 pots)
Over 100,000 lbs	16 licenses (800 pots)

Potential Qualified Fishermen	Potential Number of Total Pots
3,266	615,700

***Under this system, soft and peeler crabs would be equal to 1 lb. per crab.**

Licenses for fishermen with a history of seafood landings - excluding crab pot landings:

SEAFOOD LANDINGS	LICENSES
5,001-10,000 lbs	2 licenses (100 pots)
10,001-20,000 lbs	4 licenses (200 pots)
Over 20,000 lbs	6 licenses (300 pots)

Potential Qualified Fishermen	Potential Number of Total Pots
1,464	305,800

Transfers and Assignments

Licenses would be transferable and assignable among Standard Commercial Fishing License holders. Crab pot licenses could only be transferred to another Standard Commercial Fishing License holder. Assignment of crab pot licenses could only be made as part of an assignment of a Standard Commercial Fishing License. Transfer or assignment of the crab pot license must be made through a Division of Marine Fisheries Office.

Pot Identification

A unique, sequentially numbered Marine Fisheries Commission- approved identification marker (tag or sticker) must be attached to the crab pot or buoy. Crab pot identification markers must be purchased by the pot owner from a Commission-approved supplier.

Identification marker numbers and the owner's or previous owner's identification must be recorded on the transferred or assigned license. Any license or crab pot without the specified information would be void.

Option 4: Gear Certificates

Fishermen who have a Standard Commercial Fishing License and a history of landings from crab or peeler pots from 1994-1998 will be eligible for a one-time allocation of crab pot certificates. The number of certificates issued to a fisherman would be based on that fisherman's highest landings between 1994-1998. Fishermen would be issued one certificate per allowable crab pot. The total number of available certificates would be approximately 957,600. There would be approximately 3,266 fishermen qualified to harvest crabs with pots under this option.

CRAB POT LANDINGS	CERTIFICATES
1-5000 lbs	100
5,000-10,000 lbs	200
10,000-30,000 lbs	400
30,000-50,000 lbs	600
Over 50,000 lbs	900

Potential Qualified Fishermen	Potential Number of Total Pots
3266	957,600

***Under this system, soft and peeler crabs would be valued as 1 lb. per crab.**

An individual, operation, or corporation may not own or have interest in more than ¼ of 1 percent (approximately 2394 pots) of the total cap. These certificates will be marketable among Standard Commercial Fishing License holders once the initial allocation of gear certificates has been made. All sales transactions must be made through a Division of Marine Fisheries Office and a windfall surcharge may be required to avoid speculation marketing.

Transfers and Assignments

Permits would be transferable and assignable among Standard Commercial Fishing License holders. Assignment of certificates could only be made as part of a Standard Commercial Fishing License assignment. Transfer or assignment of the permit must be made through a Division of Marine Fisheries Office.

Pot Identification

A unique, sequentially numbered, Marine Fisheries Commission- approved identification marker (tag or sticker) must be attached to the crab pot or buoy. Crab pot identification markers must be purchased by the pot owner from a Commission-approved supplier. Identification marker numbers and the owner's or previous owner's identification must be recorded on the transferred or assigned permit. Any permit or crab pot without the specified information would be void.

Supplement 3. REGIONAL CRAB POT MANAGEMENT

November 28, 1999

Prepared by Lynn Henry and Sean McKenna

Issue:

Although the crab catch fluctuates with environmental conditions, the total number of crab pots and fishermen (total effort) in the crab pot fishery has been increasing at a rate much greater than the increase in the crab catch itself. The degree of increase varies from one part of the state to another, but some degree of economic inefficiency, social conflict, and possible biological and ecological impact appears to be present in the crab pot fishery throughout the state.

Any strategy to address effort in the crab pot fishery should meet objectives 2,3,4,5,9, and 10 of the N.C. Blue Crab Fishery Management Plan (BCFMP - McKenna et al. 1998) which are: 2) maintain a clear distinction between conservation goals and allocation issues; 3) minimize conflicts among user groups; 4) promote a program of education and public information to help the public understand the causes and nature of problems in the blue crab stock, its habitats and fisheries, and the rationale for management efforts to solve these problems; 5) develop a regulatory process that provides adequate resource protection, optimizes the harvest, provides sufficient opportunity for recreational crabbers, and considers the needs of other user groups; 9) initiate, enhance, and/or continue studies to collect and analyze economic, social, and fisheries data needed to effectively monitor and manage the blue crab fishery; and 10) maintain the blue crab fisheries as a major source of income for commercial fishermen in coastal North Carolina in a proportion similar to that which exists at the present time in the most efficient manner. Specific items outlined by the MFC that should also be considered in developing an effort plan for the pot fishery are: regional differences in the fishery; 2) market stability; and 3) allow those currently involved to maintain operations similar to existing levels, while allowing flexibility for the entire fishing community to participate in the pot fishery.

History:

Due to concerns over the increase in pot numbers and the threat of crab pot limits, a group of crabbers met in March of 1993 and recommended to the state the formation of a separate crab license and a blue crab advisory panel. The crab license was passed by the General Assembly in July 1993, and went on sale on January 1, 1994. On January 29, 1994, a group of crabbers met in Manteo to discuss the concept of a two-year moratorium on crab license sales. The concern of crabbers attending this meeting was the rapid increase in the number of crabbers and the subsequent build-up of pots. State officials expanded this concept to cover all commercial fishing licenses. With support from the majority of the commercial fishing community, the North Carolina General Assembly put a freeze on new licenses, effective July 1, 1994. During development of the N.C. Blue Crab Fishery Management Plan (FMP) in 1998, a copious amount of time was spent discussing effort management. However, consensus on an appropriate limited entry plan could not be reached. The license moratorium was scheduled to expire on June 30, 1999. However, the Crab License was extended until October 1, 2000 to allow the completion of an effort management plan by industry, the MFC, and the DMF. To accomplish this goal the MFC established five regional crab pot management areas. A stakeholder advisory committee of commercial fishermen, dealers, recreational fishermen and boaters was appointed for each region. Due to the lack of consensus reached during prior effort management discussions, the need to allow new entrants into this fishery, and a desire to control overall pot numbers, the MFC directed these regional committees to assist in drafting an open access plan for this fishery.

The most appropriate open access method to manage effort in the crab pot fishery is to implement pot limits. Pot limits have been suggested as one way of reducing spacial conflicts and improving economic efficiency in the crab pot fishery. Over the last 10 years, pot limits have been gaining support in the industry. A social/economic study conducted in 1984 by Maiolo et al. (1985) in North Carolina showed that 47% of all fishermen (52% full-time, and 38% part-time) supported a 250 pot limit. In a survey sent to crabbers landing more than 6,000 lbs of crabs, Stroud (1996 and 1997) found that 82% of the respondents supported pot limits in 1995, while in 1996 pot limits were supported by 71% of the fishermen. Additionally, pot limits will provide an initial means for achieving the strategy for effort management outlined in the Blue Crab FMP ("Any option to reduce effort should provide an appropriate means to allow flexibility within the fishing community; minimize exclusive privileges and avoid monopolies; control or reduce effort in the crab fishery; and make management of the crab fishery more efficient and effective").

Proposed Management Plan:

The development of this plan will occur in two phases. The first phase will provide the general framework of the plan (data needs and conceptual design of the plan and will be done by the DMF and MFC. The second phase will examine the specific design criteria (number of pots, penalties, type of permit, etc.) of the proposed plan. This phase will be conducted by the regional stakeholder committees. The following description of the proposed plan outlines the results of DMF's discussions on phase one and presents a proposed list of questions to be discussed by the regional committees.

I. Description of Regional Crab Pot Management

A. License and Crab Pot Permit

Goal: Inventory participants in the crab pot fishery and enhance enforcement capabilities.

1. Each Standard Commercial Fishing License (SCFL) or Retired Standard Commercial Fishing License (RSCFL) would be eligible to purchase a permit to crab pot.
2. Fee for the permit can only cover DMF's administrative costs and cannot exceed $50.
3. Transfer or assignment of the permit, only with the transfer or assignment of a SCFL or the transfer of a RSCFL.

B. Crab Pot Limits

Goal: Control or reduce effort in the crab pot fishery.

1 Pot limits by region.
2. Fishermen will be allowed to move between regions, but will be required to adhere to the pot limits in the region where they are crabbing.

3. Pot limits will be allocated by permit and SCFL or RSCFL up to the maximum per region.
4. Transfer or assignment of the permitted gear will be allowed, only with the transfer or assignment of a SCFL or with the transfer of a RSCFL.

C. Crab Pot Tags

Goal: Enhance enforcement capability and inventory potential pot use.

1. Pot tags will be needed to enforce gear limits.
2. Unique, sequentially numbered gear (buoy/pot) tags will be ordered and purchased from a DMF-approved supplier (cost = approximately $0.20 per tag).
3. Gear tags will be attached at the buoy marking each individual pot. When multiple pots are on a line, each pot not attached directly to the tagged buoy line must also be tagged. It will be unlawful to have more than one valid (current year) DMF-approved tag on the buoy/pot.
4. Pots attached to shore or a pier will be exempt from tagging requirements.
5. Tag loss:
    a. Replacement tags of up to 20% of the regional pot limit may be purchased from a DMF- approved supplier at the time of initial tag purchase.
    b. To address an individual's catastrophic gear tag loss:
        (1) the individual must petition the DMF for replacement tags,
        (2) replacement tags may be issued by DMF after a reasonable investigation of the circumstances involved with tag loss, and
        (3) fees for permits can only cover DMF's administrative costs and cannot exceed $50.
    c. To address major "multiple individual" gear losses due to storms, trawling, etc., the Fisheries Director could suspend the gear tag requirement by proclamation.
6. Gear tags will be legal for the calendar year of issue. Valid tags must be on pots set after February 7 (pot clean-up period).

II. Questions for Blue Crab Regional Stakeholder Committees

A. Crab Pot Limits

Goal: Control or reduce effort in the crab pot fishery.

1. Describe the aspects of the crab pot fishery in your region that makes it unique compared to the other regions. How would these unique aspects factor into controlling or reducing effort in North Carolina's crab pot fishery?

2. Can more pots and additional potters be allowed within your region or area without additional conflict or problems? What are the major conflict and effort issues? Recommendations to resolve conflicts and effort issues? What are the principle areas where conflicts occur (identify)?

3. Should hard crab and peeler pots be combined or separated when setting pot limits?

   Possible options:
   a. Overall combined hard crab and peeler pot limit
   b. Separate hard crab and peeler pot limits
   c. Overall combined hard crab and peeler pot limit with a springtime (2-3 month) exemption by region
   d. Other options

4. What is the maximum number of pots that would be allowed per Standard and Retired Commercial Fishing License (SCFL) in your region (no more than X pots) and maximum allowed statewide per license (see B. below)?
   What pot limits would allow crabbers to continue at levels similar to those that currently exist and allow some degree of flexibility?

5. Would daily fishing time restrictions or a shorter unattended pot period (currently 7 days) help to alleviate conflict and effort problems in your region?

B. Permit and Pot/Tag Limit Options

Goal: Inventory participants, limit potential crab pot effort, and enhance enforcement capabilities.

NOTE: Depending on the type of permit, pot limits, and how tags are allocated could make a big difference in total "potential" pot numbers.

1. Crab pot permit for each region?
   A permit for each region may be issued per SCFL.
   a. Number of pot tags = not to exceed XXXX (a number to be decided on)
   b. Number of pot tags = not to exceed the maximum for the highest regional pot limit statewide
   c. Number of pot tags = not to exceed the maximum for the highest one regional pot limit as indicated on the regional permits purchased
   d. Number of pot tags = not to exceed the sum of the regional pot limits for the regional permits purchased

2. Crab pot permit for each XXX pots (i.e., 100 pots)? A SCFL would be issued a permit for each XXX pots.

a. Number of pot tags = not to exceed XXXX (a number to be decided on)
b. Number of pot tags = not to exceed the maximum for the highest regional pot limit statewide

3. Crab pot permit for each XXX pots (i.e., 100 pots) by region? A SCFL would be issued a permit for each XXX pots for each region.
   a. Number of pot tags = not to exceed XXXX (a number to be decided on)
   b. Number of pot tags = not to exceed the maximum for the highest regional pot limit statewide
   c. Number of pot tags = not to exceed the maximum for the highest one regional pot limit as indicated on the regional permits purchased
   d. Number of pot tags = not to exceed the sum of the regional pot limits for the regional permits purchased

C. Penalties

Goal: Establish adequate penalties to deter violations.

1. Penalties for fishing crab pots without a permit or buoy/pot tag, or removing another fishermen's tags?
   a. Loss of crab pot permit?
   b. Other (list)?

NOTE: Severe penalties would be needed as a deterrent to deal with theft, vandalism, and crabbing too many pots.

D. Pot Reduction Plan

Goal: Stock protection and conflict resolution.

1. Pot reduction plan by region?
   a. Across the board reductions?
   b. Proportional reductions?
   c. Control date for participation to establish reduction?
   d. Justification and/or trigger for pot reduction?

NOTE: A pot reduction plan alone may not be sufficient for stock protection. Additional quota or catch limits may be necessary for adequate stock protection.

Literature Cited:

Maiolo, J., C. Williams, R. Kearns, H. Bean and H. S. Kim. 1985. Social and economic impacts of growth of the blue crab fishery in North Carolina. A report to the UNC-Sea Grant Program, NC State University. 39p.

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Attachment 2. Recommendations from the Blue Crab Regional Stakeholder Committees and the Crustacean Committee to the MFC on Open Access Effort Management in the Crab Pot Fishery

		RECOMMENDATIONS					
	Questions to Stakeholder Comm.	**Region 1**	**Region 2**	**Region 3**	**Region 4**	**Region 5**	**Crust.**
II. A.	**Crab Pot Limits**						
2.	Can more pots be allowed without additional conflict?	[1]	Yes	No	Yes	No	
3.	Should hard crab and peeler pots be combined or separated?	Separate	Separate	Combine	Separate	Separate	Combine
4.	Regional pot limit per SCFL?	None	None	[2]Yes	None	Yes	
	Hard crab pot	[3]	[4]800	600		500	
	Peeler pot	[3]	[4]800			500	
	Statewide pot limit per SCFL?	None	None	Yes		Yes	Yes
	Hard crab pot	[3]	[4]800	Highest 1		Highest 1	
	Peeler pot	[3]	[4]800	Reg. Limit		Reg. Limit	
	Combined						1,100
	Other Options						
a.	Pot limit is divided by number of regions actively fished			**X**			
5.	Would 1) daily fishing time restrictions, or	As is	As is	No	No	No	
	2) a shorter unattended pot period help with conflict and effort problems?	no less than 7 days	As is	5 days	5 days	No	5 days modified by Region
II. B.	**Permit and Pot/Tag Limit Options**						
	Regional Permit	No				No	
	Statewide Permit	No	Yes	Yes	[5]Yes	No	[6]Yes
	Pot Tags	No	No	Yes	No	No	No
II. C.	**Penalties**	[7]As is					stronger
	Loss of crab pot permit?		[8]Yes				penalties for
	Loss of SCFL?			[9]Yes		[11]Yes	fisheries
	Loss of replacement tags?			[10]Yes			violations
II. D.	**Pot Reduction Plan by Region**			Revisit			only if there
	Across the board reductions?	No	No	if a		No	is a biological
	Proportional reductions?	[3]Yes	[4]Yes	problem		Yes	need

(1) This question can not be answered because conflict is perceived differently from person to person.
(2) Each region should have a pot limit.
(3) Only, if there is a biological need.
(4) If a pot limit is deemed necessary by the MFC.
(5) If the MFC decides that some type of permit is needed.
(6) Crab permit/endorsement be nonassignable except in a hardship case.

(7) No specific penalties for crab violations; keep current Standard Operating Procedures; review and amend G.S. 113-268.
(8) First offense - 6 months; Second offense - 1 year; Fishing without permit - $5,000 fine; Grant more enforcement authority to Marine Patrol.
(9) For major infractions -- removing tags, theft, and fishing over the pot limit (5% or greater over the pot limit).
(10) For minor infractions -- pots without tags, and fishing over the pot limit (less than 5% over the limit).
(11) Make theft and vandalism punishable with severe penalties: Loss of license, minimum fine, and restitution.

Recommendations from the Blue Crab Regional Stakeholder Committees to the MFC on Open Access Effort Management in the Crab Pot Fishery

	II. A. 1. Unique regional aspects that should be considered in managing effort?	**II. A. 2.** Major conflict and effort issues?	Possible Solutions.	Recommendations.
Region 1	1. No trawling is allowed in this region. 2. Low fishery diversity (crab pots, pound nets, restricted gill nets) 3. The most productive region in landings and value of crabs	1. Crabbers, pots, crabs concentrated in small areas. 2. Crab pots and navigation. 3. Public trust issues. 4. Assignability of license may increase effort in pot fishery.	Establish a set distance between pots. Allow parties to work out problems without additional regulation.	Establish a marked navigational channel. User conflicts should be dealt with at lowest possible level. No assignment of license, one license per individual.
Region 2	1. Largest peeler pot fishery in NC 2. Dare Co. 2nd highest landings 3. Potters very mobile within region. 4. Large influx from other regions 5. Region 2 has a large diversity of commercial fishing opportunities	1. Double rigged trawlers/crabbers 2. Crab pots and navigation.	Allow single rigged trawlers, only.	Establish a marked navigational channel.
Region 3	1. Population densities in the river 2. Small area to crab in 3. Need to accommodate numerous fisheries in a small area	1. Trawler/Potter conflict 2. Crab pots and navigation. 3. Property owners	Prohibit trawls from pot areas Go to depth contours Open haul net areas Mark channels into all creeks Establish a proximity rule	
Region 4	1. Diverse physical nature 2. Crab pot fleet ranges in size from small boats to large operations 3. Crab potters are very mobile 4. Other fisheries are gill netting and trawling	1. Trawler/Potter conflict 2. Shallow water congestion 3. Recreational boaters 4. Crab potter vs. Crab potter	Deal with problem fishermen Open haul net areas Establish a marked navigational channel Change unattended pot period from 7 days to 5 days	
Region 5	1. Diverse physical nature 2. Large tidal differences 3. Heavily developed tourist area 4. Many diversified fisheries, hence there are few full time crabbers	1. Too many pots in water 2. Rec. Boaters vs. Crabbers 3. Inability to see crab pot buoys	No assignment of license, one license per individual. Establish a marked navigational channel. Place a white buoy beside normal pot or require a larger size buoy.	One license per individual. Strengthen regional committees to address localized problems. Establish marked Nav. Channels to boat landings/marinas Distribute info. packets at licensing locations and boat ramps on commercial gear identification.

Additional Recommendations from the Blue Crab Regional Stakeholder Committees to the MFC on Open Access Effort Management in the Crab Pot Fishery

New Entrants into the Crab Pot Fishery:

Region 2 ---- A 300 pot limit on all new entrants that did not previously hold a Crab License, with a 50 pot increase each year for 4 years. After that (6th year) they would be eligible to fish up to the maximum pot limit.

Region 3 ---- A "new fisherman" (no crab landings) get an allotment of 50% of the pot limit for the first year and the remaining pots will be given in increments of one-third over the next 3 years.

Pot Tags:

Region 3 ---- The first 300 pot tags should be free, a fisherman would pay an increasing fee for additional tags.

1 - 300	no cost
301 - 400	$2.00 per tag
401 - 500	$3.00 per tag
501 - 600	$4.00 per tag
601 - 700	$5.00 per tag
701 - 800	$6.00 per tag
801 - 900	$7.00 per tag
901 - 1000	$8.00 per tag
1001 - 1100	$9.00 per tag

Region 3 ----The purchase period for additional tags should be from January - March.

Realignment of Regional Boundaries:

Region 2 ----The Region 2 boundary line should be moved 5 miles west of "The Reef" off of Ocracoke Island and Hatteras Island up to Wanchese.

Region 2 ----The northern line separating Region 1 and Region 2 should be taken out.

Assignability / Transferability:

Region 1 ----No assignment of license; one license per individual.

Region 2 ----There should be no assignability of a SCFL or a crab permit.

Region 3 ----Crab permits should be limited to one per fisherman and they should be non-transferable.

Region 5 ---- One license per individual.

Property Owners:

Region 3 ----Allow property owners (no matter the number of household members) to set up to 5 crab pots from their property without an RCGL.

Miscellaneous:

Region 1 ----Agrees with relinquishment of the crab license after October 1, 2000.

--MFC and DMF staff recommendations should be included in proposals provided for public comment.

----MFC recommend to the General Assembly that reciprocal state licenses be defined to reflect each states' pot limits. NC's limit cannot be exceeded regardless of another states' pot limit.

Region 2 ----The Region 2 committee should stay together and meet once or twice a year to reevaluate statistics and information, and determine if there should be any further recommendations for the pot fishery.

Region 4 ----No action should be taken in Region 4 at this time.

Region 5 ----Some type of Managed Growth System should be considered by the MFC as another option.

12.14 Appendix 14. REGIONAL CRAB POT MANAGEMENT

April 2004

Prepared by NC Division of Marine Fisheries (NCDMF)

Proposed Management Plan:

This proposed plan has the potential to combine four methods of open access management into one comprehensive system of management that is specific to the crab pot fishery. These methods are (1) management areas, (2) gear restrictions (regional pot limits), (3) a license or permit system to participate in the fishery, and (4) area restrictions.

Management areas will allow the vast regional differences in the crab pot fishery to be considered when establishing restrictions.

Pot limits have been suggested as one way of reducing spacial conflicts and improving economic efficiency in the crab pot fishery. Over the last 10 years, pot limits have been gaining support in the industry. A social/economic study conducted in 1984 by Maiolo et al. (1985) in North Carolina showed that 47% of all fishermen (52% full-time, and 38% part-time) supported a 250 pot limit. In a survey sent to crabbers landing more than 6,000 lbs of crabs, Stroud (1996 and 1997) found that 82% of the respondents supported pot limits in 1995, while in 1996 pot limits were supported by 71% of the fishermen. Additionally, pot limits will provide an initial means for achieving the strategy for effort management outlined in the 1998 Blue Crab FMP (i.e., "Any option to reduce effort should provide an appropriate means to allow flexibility within the fishing community; minimize exclusive privileges and avoid monopolies; control or reduce effort in the crab fishery; and make management of the crab fishery more efficient and effective"; BCFMP - McKenna et al. 1998).

Area specific restrictions will likely yield the best potential solutions to deal with issues such as localized navigation and access conflicts. The existing regional advisory committees of the MFC (Northern, Central, Southern, and Inland) would mediate local user conflicts using current regulatory authority for conflict resolution, and make recommendations to the MFC concerning further time, season, area, and gear use restrictions for their respective areas.

A special permit to participate in the commercial crab pot fishery would allow identification of potential participants, establish regional pot limits, and enhance additional enforcement specific to this fishery. The basic elements of the proposed Regional Crab Pot Management Plan are outlined in the following description. A draft Permit for Crab Pots with more specific conditions is presented in Attachment 1.

Description of Regional Crab Pot Management

A. License Restrictions and Crab Pot Permit with Regional Pot Limits

Goal**:** Inventory participants in the commercial crab pot fishery and enhance enforcement capabilities specific to this fishery

1. A permit (Attachment 1) would be required to participate in the peeler and hard crab pot fishery. [The Fisheries Director may, by proclamation, require individuals taking marine and estuarine resources regulated by the Marine Fisheries Commission, to obtain a special permit (15A NCAC 3O .0506; MFC 2003).]
2. Each holder of a Retired Standard Commercial Fishing License, Standard Commercial Fishing License (R/SCFL) or an assigned license would be eligible for a permit to participate in the crab pot fishery.

3. A separate R/SCFL would be required for each permit issued. Each individual license, permit, and vessel will be linked for tracking and enforcement.
4. The permit cannot be transferred or assigned with the transfer or assignment of a SCFL or with the transfer of a RSCFL.
5. Pots attached to shore or a pier and pots used by holders of the Recreational Commercial Gear License are exempt from the permit requirement.

B. Vessel Use Restrictions

Goal: Restrict the number of permits and associated gear limits that can be used from a single vessel.

1. No more than two (2) vessels can be listed on one (1) Crab Pot Permit.
2. A vessel may not be listed on more than two (2) permits.
3. No more than two (2) permits and the associated pot limits may be used from an individual vessel (see Figure 1).
4. Permitted pots may only be fished from the vessel listed on the permit.
5. A change in the vessel listed on the permit must be transacted at a Division of Marine Fisheries (NCDMF) License Office.

NOTE: See Figure 1 for an illustration of the license, permit, and vessel use restrictions.

C. Regional Crab Pot Limits

Goal**:** Control or reduce conflict in the crab pot fishery.

1. Establish regional pot limits per permit and R/SCFL.
2. Pot limits will apply all year.
3. Fishermen will be allowed to move between regions, but will be required to adhere to the pot limits in the region where they are crabbing.
4. Pot limits will be for peeler and hard crab pots combined.

D. Crab Pot Buoy/Line "Gear" Tags

Goal: Inventory potential pot use and enhance enforcement capability.

1. Pot buoy/line tags will be needed to enforce gear limits.
2. Unique (R/SCFL number), sequentially numbered gear (buoy/line) tags will be ordered and purchased by the R/SCFL holder from a NCDMF-approved supplier (cost = approximately $0.20 per tag). Tags will have to be ordered 2 – 3 months in advance of when needed.
3. Gear tags will be attached at the buoy marking each individual pot in a manner where the tag is visible above the waters surface. It will be unlawful to have more than one valid (current year) NCDMF-approved tag attached at the buoy.
4. Gear tags will be valid for the fiscal year of issue from February 8 through February 7 of the following year. Valid tags must be on gear set after February 7 (end of pot clean-up period).
5. It will be unlawful to buy, sell, trade, borrow, barter or exchange tags from or to another individual.
6. Tag loss:
    a. Replacement tags of up to 20% of the established pot limit may be purchased from a NCDMF- approved supplier at the time of initial tag purchase.
    b. To address an individual's catastrophic gear tag loss:
        (1) the individual must petition the NCDMF for replacement tags, and
        (2) replacement tags may be issued by NCDMF after a reasonable investigation of the circumstances involved with tag loss.
    c. To address major "multiple individual" gear losses due to storms, trawling, etc., the Fisheries Director could suspend the gear tag requirement by proclamation

for a specific area or statewide.

E. Hardship Situations

Goal: Allow permitted crab pots to be used or fished by a permit designee during hardship situations encountered by the permittee.

1. Pots may only be fished by the permittee, except pots may be fished by another designated individual (designee) during hardship situations.
2 Designee is defined as “any person who is under the direct control of the permittee or who is employed by or under contract to the permittee for the purposes authorized by the permit” [NCAC 3I. 0101 (49); MFC 2003].
3. The permit holder may list designees on the permit. Designee listing must be transacted at a Division of Marine Fisheries (NCDMF) License Office.
4. Designee must hold an individual SCFL or RSCFL or assigned license when acting as the permit designee.
5. The permit designee shall abide by all the conditions of the permit.
6. The designee may use a vessel other than the vessel listed on the permit, as long as the vessel to be used is also listed on the written approval or notice to the Fisheries Director from the permittee.
7. The permit holder can not be engaged in another permitted crab pot fishing operation during the period in which one of his/her permits has been designated under a hardship.

   a. Short-term Hardship Provisions [a single period of no more than seven (7) consecutive days]
      (1) The permit holder shall not allow an individual designee to engage in the permitted activity for no more than seven consecutive days, unless the permittee or his immediate family has complied with the permit conditions regarding a timely and sufficient showing of a long-term hardship in a commercial fishing operation (see long-term conditions below).
      (2) Designee must have written and dated approval from the permit holder when acting as the permit designee. To be valid, written approval shall identify the permittee and any individual acting as the permit designee (including name, participant I.D. and R/SCFL number, physical and mailing address, and telephone number), reason for the hardship, permit number, the number and specific location of the pots, and the dates (beginning and end) that the pots will be employed in the permit designee’s fishing operations.
      (3) The permit designee has the authority to engage in the privileges allocated by the permit for no more than seven consecutive days.

   b. Long-term Hardship Provisions [more than seven (7) consecutive days]
      (1) The permit holder shall not allow an individual designee to engage in the permitted activity for more than seven consecutive days, unless the permittee or his immediate family has complied with the permit conditions regarding a timely and sufficient showing of a long-term hardship in a commercial fishing operation.
      (2) A timely and sufficient showing of a long-term hardship in a commercial fishing operation shall be written notice given to the Fisheries Director that a mechanical breakdown of the owner's vessel(s) currently registered with the Division of Marine Fisheries under G.S. 113-168.6, or the death, illness or incapacity of the owner of the pots or his immediate family, as defined in G.S. 113-168, prevented or will prevent employing such pots in

fishing operations for more than seven consecutive days. The notice, specifying the time needed because of hardship, shall state, in addition to the following, the permittee and any individual acting as the permit designee (including name, participant I.D. and R/SCFL number, physical and mailing address, and telephone number), permit number, the number and specific location of the pots, and the date on which the pots will be employed in the permittee's or permit designee's fishing operations or removed from coastal fishing waters:

(A) in case of mechanical breakdown, the notice shall state the Commercial Fishing Vessel Registration number, owner's NCWRC Vessel Registration or US Coast Guard Vessel Documentation Number of the disabled vessel, date disabled, arrangements being made to repair the vessel or a copy of the work order showing the name, address and phone number of the repair facility; or

(B) in case of the death, illness or incapacity of the owner of the pots or his immediate family, the notice shall state the name of the owner or immediate family member, the date of death, the date and nature of the illness or incapacity. The Fisheries Director may require a doctor's verification of the illness or incapacity.

(3) These hardship provisions may not extend beyond 15 days for each specific incidence, without the Fisheries Director's approval. Failure to employ in fishing operations or remove from coastal fishing waters all pots within 5 days of the expiration of a specific hardship shall be violation of this permit.

F. Penalties

Goal: Establish adequate penalties to deter violations.

1. Establish a new crab pot permit with strict and immediate permit suspension or revocation penalties for violations of permit conditions.
2. Current citation and license revocation process for some violations.

Literature Cited:

Maiolo, J., C. Williams, R. Kearns, H. Bean and H. S. Kim. 1985. Social and economic impacts of growth of the blue crab fishery in North Carolina. A report to the UNC-Sea Grant Program, NC State University. 39p.

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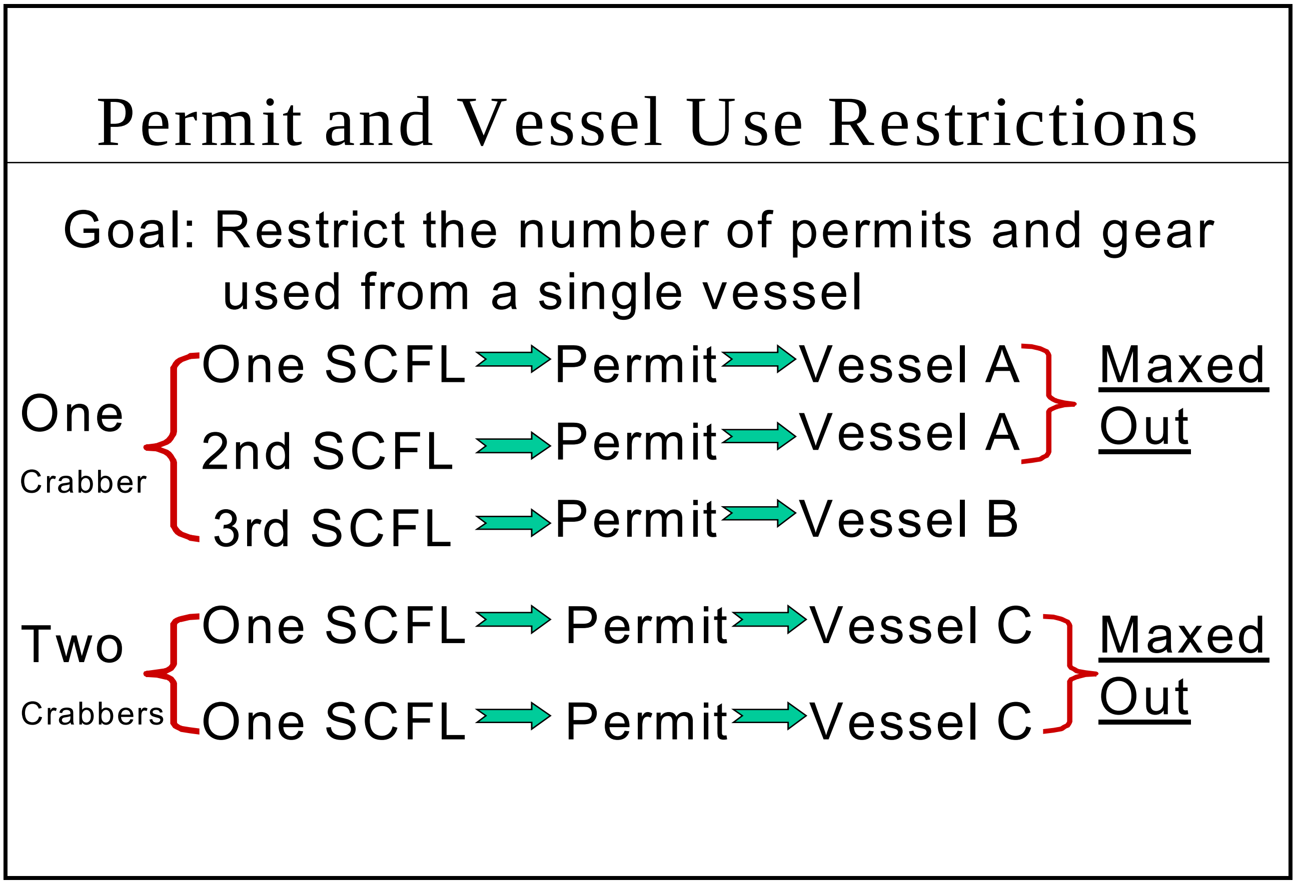
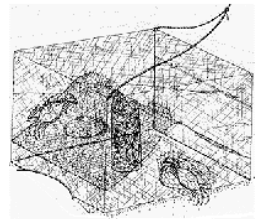


Figure 1. Example of the license, permit, and vessel use restrictions associated with the Crab Pot Permit.

ATTACHMENT 1.



North Carolina Division of Marine Fisheries (NCDMF)
Permit for Crab Pots

Rule Authority (15A NCAC 3O.0506):

The Fisheries Director may, by proclamation, require individuals taking marine and estuarine resources regulated by the Marine Fisheries Commission, to obtain a special permit.

Specific Permit Conditions

A Crab Pot Permit is required to lawfully use crab pots (hard crab and/or peeler pots).

An individual must hold or be assigned a Standard Commercial Fishing License (SCFL) or a Retired Standard Commercial Fishing License (RSCFL) to obtain a Crab Pot Permit. Only one permit may be obtained per license. When a SCFL is assigned, the Crab Pot Permit will be issued in the name of the assignee. The permittee shall have the Crab Pot Permit in possession at all times while on the water.

<u>Vessel Use Restrictions</u>

The vessel used in the commercial fishing operation must be identified on the Crab Pot Permit by a valid NCDMF Commercial Fishing Vessel Registration and the NC Wildlife Resources Commission (NCWRC) Vessel Registration or US Coast Guard Vessel Documentation Number.

No more than two (2) vessels shall be listed on one (1) Crab Pot Permit.

It is unlawful to list a vessel on more than two (2) permits.

It is unlawful to use more than two (2) permits and associated gear limits from the same vessel.

It is unlawful to fish permitted pots from a vessel not listed on the permit.

A change in vessel must be transacted at a Division of Marine Fisheries (NCDMF) License Office.

<u>Crab Pot Limits</u>

It is unlawful for the permittee to set more than the specified number of crab pots per permit (includes hard crab and peeler pots combined). Failure to comply with this provision will result in the revocation of the permit.

<u>Crab Pot Buoy Tags</u>

It is unlawful to use any crab pots without a valid (current year) NCDMF-approved crab pot buoy tag attached near the buoy.

It is unlawful to attach crab pot buoy tags in a manner where the tag is not readily visible above the waters surface.

It is unlawful to attach or display invalid (not current year) crab pot tags on buoys in use.

Tags are valid from February 8 through February 7 of the following year.

Tags can only be purchased from a NCDMF-approved vendor.

It is unlawful to buy, sell, trade, borrow, barter or exchange tags.

Replacement tags of up to 20% of the established pot limit may be purchased from a NCDMF- approved supplier at the time of initial tag purchase. The permit holder may obtain additional replacement tags by filing a NCDMF-approved tag replacement form with a NCDMF license agent. It is unlawful to file a false tag replacement form.

Short-term Hardship Provisions

Pots may only be fished by the permittee, except pots may be fished by another designated individual during hardship situations that are short-term (a single period of no more than seven consecutive days). The permit holder may list individuals on the permit to act as permit designees during hardship situations. Designee listing must be transacted at a Division of Marine Fisheries (NCDMF) License Office. Minimum requirements for listed designees are: name, physical and mailing address, and telephone number.

It is unlawful for the designee to engage in the permitted activity without holding an individual SCFL or RSCFL or assigned license

The designee must have written approval from the permit holder when acting as the permit designee. To be valid, written approval shall identify the permittee and any individual acting as the permit designee (including name, participant I.D. and R/SCFL number, physical and mailing address, and telephone number), reason for the hardship, permit number, the number and specific location of the pots, and the dates (beginning and end) that the pots will be employed in the permit designee's fishing operations. The designee may use a vessel other than the vessel listed on the permit, as long as the vessel to be used is also listed on the written approval from the permittee.

The permit designee has the authority to engage in the privileges allocated by the permit for no more than seven consecutive days.

The permit designee shall abide by all the conditions of the permit.

The permit holder can not be engaged in another permitted crab pot fishing operation during the period in which one of his/her permits has been designated under a hardship.

The permit may not be designated to an individual for more than seven consecutive days, unless the permittee has complied with the permit conditions regarding a timely and sufficient showing of a long-term hardship in a commercial fishing operation (see conditions below).

Long-term Hardship Provisions

Pots may only be fished by the permittee, except pots may be fished by another designated individual during hardship situations that are long-term (more than seven consecutive days). A timely and sufficient showing of a long-term hardship in a commercial fishing operation shall be written notice given to the Fisheries Director that a mechanical breakdown of the owner's vessel(s) currently registered with the Division of Marine Fisheries under G.S. 113-168.6, or the death, illness or incapacity of the owner of the pots or his immediate family, as defined in G.S. 113-168, prevented or will prevent employing such pots in fishing operations. The notice, specifying the time needed because of hardship, shall be received by the Fisheries Director before any pot is left in coastal fishing waters for five consecutive days without being employed in fishing operations, and shall state, in addition to the following, the permittee and any individual acting as the permit designee (including name, participant I.D. and R/SCFL number, physical and mailing address, and telephone number), permit number and the number and specific location of the pots, and the date on which the pots will be employed in the permittee's or permit designee's fishing operations or removed from coastal fishing waters:

(A) in case of mechanical breakdown, the notice shall state the Commercial Fishing Vessel Registration number, owner's NCWRC Vessel Registration or US Coast Guard Vessel Documentation Number of the disabled vessel, date disabled, arrangements being made to repair the vessel or a copy of the work order showing the name, address and phone number of the repair facility; or

(B) in case of the death, illness or incapacity of the owner of the pots or his immediate family, the notice shall state the name of the owner or immediate family member, the date of death, the date and nature of the illness or incapacity. The Fisheries Director may require a doctor's verification of the illness or incapacity.

These hardship provisions may not extend beyond 15 days for each specific incidence, without the Fisheries Director's approval. Failure to employ in fishing operations or remove from coastal fishing waters all pots for which notice of hardship is received under this Rule within 5 days of the expiration of the hardship shall be violation of this permit.

General Permit Conditions:

The following conditions apply to all permits issued by the Division of Marine Fisheries:

It is unlawful to operate under the permit except in areas, at times, and under conditions specified on the permit.

It is unlawful to operate under a permit without having the permit or copy thereof in possession of the permittee or their designees at all times of operation and must be ready at hand for inspection, except for Pound Net Permits.

It is unlawful to operate under a permit without having a current picture identification in possession and ready at hand for inspection.

It is unlawful to refuse to allow inspection and sampling of a permitted activity by

an agent of the Division.

It is unlawful to fail to provide complete and accurate information requested by the Division in connection with the permitted activity.

It is unlawful to hold a permit issued by the Division of Marine Fisheries when not eligible to hold any license required as a condition for that permit as stated in 15A NCAC 3O.0501.

It is unlawful to fail to provide reports within the timeframe required by the specific permit conditions.

It is unlawful to fail to keep such records and accounts as may be required by the Division for determination of conservation policy, equitable and efficient administration and enforcement, or promotion of commercial or recreational fisheries.

It is unlawful to assign or transfer permits issued by the Division, except Pound Net Permits as authorized by 15A NCAC 3J .0107(d).

The Fisheries Director, or his agent, may, by conditions of the permit, specify any or all of the following for the permitted purposes:

Species,	**Means and methods,**
Quantity or size,	**Disposition of resources,**
Time period,	**Marking requirements, or**
Location,	**Harvest conditions**

Unless specifically stated as a condition on the permit, all statutes, rules and proclamations apply to the permittee and their designees,
As a condition of accepting the permit from the Division of Marine Fisheries, the permittee agrees to abide by all conditions of the permit and agrees that if specific conditions of the permit, as identified on the permit are violated or if false information was provided in the application for initial issuance, renewal or transfer, the permit any be suspended or revoked by the Fisheries Director.

Rule Conditions in BOLD lettering above or items HIGHLIGHTED on the permit if violated may result in suspension or revocation of the permit.

12.15 Appendix 15. UTILIZATION OF NON-POT AREAS BY PROCLAMATION

I. Issue:

Open designated long haul areas to the use of crab pots by proclamation.

II. Background:

Crab pot areas were first designated by proclamation during 1977/1978. Areas were primarily designated in Hyde, Beaufort and Pamlico counties to alleviate social concerns about competition for space between crab potters, long haulers, and shrimp/crab trawlers. Areas were designated in other areas such as those in mid-Neuse River, to address competition between recreational users versus crab potting. Areas were last designated by proclamation in 1983 and have since been designated by regulation.

Since 1984, long haul fishing activity has decreased in some of the designated non-crab pot areas, especially during the last five years in Hyde, Beaufort and Pamlico counties. These areas were originally designated to allow long haul fishermen to gather up their seines in recognized "footing" areas. Due to a decline in numbers of long haul fishermen and a shift in the fishery to more productive fishing grounds in northern Pamlico Sound, several non-crab pot areas are not presently utilized by long haulers. The Division of Marine Fisheries (DMF) has received an increasing number of complaints from crab fishermen about lack of utilization of some of the non-pot (long haul) areas. Some crab potters feel reinstituting proclamation authority to designate some areas (particular 'long haul' sites in Hyde, Beaufort and Pamlico counties) would allow them to use this space when it is not needed by other fisheries (long haul, gill net and trawlers). Areas designated to address competition between recreational users versus crab potters will remain closed.

In 1994, the Director of DMF was given proclamation authority to open 11 long haul areas in Hyde, Beaufort and Pamlico counties (3J .0301 (a)(2)(B) and 3R .0107 (b)). Since that date, these areas have been opened every year by proclamation from May 1 through October 31 without incidence. These areas can be closed in 48 hours, if long haulers want to haul those areas and potters do not voluntarily move their pots.

III. Discussion:

After numerous meetings and several motions on this issue the Crustacean Committee recommended leaving the long haul areas as they currently are (April 12, 2001). On March 14, 2001, the Central Regional Advisory Committee passed a motion that all designated long haul areas be managed by proclamation with preference for use given to long haulers. In June 2001, the Marine Fisheries Commission (MFC) voted to ask the DMF to draft language to amend the rules giving the DMF Director proclamation authority to open all long haul areas to crab potting.

IV. Current Regulation:

SUBCHAPTER 3J - NETS, POTS, DREDGES, AND OTHER FISHING DEVICES
SECTION .0300 - POTS, DREDGES, AND OTHER FISHING DEVICES

.0301 POTS

(a) It is unlawful to use pots except during time periods and in areas specified herein:

(1) From November 1 through April 30, except that all pots shall be removed from internal waters from January 24 through February 7. Fish pots upstream of U.S. 17 Bridge across Chowan River and upstream of a line across the mouth of Roanoke, Cashie, Middle and Eastmost Rivers to the Highway 258 Bridge are exempt from the January 24 through February 7 removal requirement. The Fisheries Director may, by proclamation, reopen various waters to the use of pots after January 28 if it is determined that such waters are free of pots.

(2) From May 1 through October 31, north and east of the Highway 58 Bridge at Emerald Isle:

(A) In areas described in 15A NCAC 3R .0107(a);

(B) To allow for the variable spatial distribution of crustacea and finfish, the Fisheries Director may, by proclamation, specify time periods for or designate the areas described in 15A NCAC 3R .0107(b); or any part thereof, for the use of pots.

SUBCHAPTER 3R - DESCRIPTIVE BOUNDARIES

.0107 DESIGNATED POT AREAS

(a) As referenced in 15A NCAC 3J .0301, it is unlawful to use pots north and east of the Highway 58 Bridge at Emerald Isle from May 1 through October 31, except in areas described below:

(1) In Albemarle Sound and tributaries.

(2) In Roanoke Sound and tributaries.

(3) In Croatan Sound and tributaries.

(4) In Pamlico Sound and tributaries, except the following areas and areas further described in Paragraphs (5), (6), and (7) of this Rule:

(A) In Wysocking Bay:

(i) Bound by a line beginning at a point on the south shore of Lone Tree Creek 35° 25’ 05” N - 76° 02’ 05” W running 239° (M) 1000 yards to a point 35° 24’ 46” N - 76° 02’ 32” W; thence 336° (M) 2200 yards to a point 35° 25’ 42” N - 76° 03’ 16” W; thence 062° (M) 750 yards to a point on shore 35° 25’ 54” N - 76° 02’ 54” W; thence following the shoreline and the Lone Tree Creek primary nursery area line to the beginning point;

(ii) Bound by a line beginning at a point on the south shore of Mt. Pleasant Bay 35° 23’ 07” N - 76° 04’ 12” W running 083° (M) 1200 yards to a point 35° 23’ 17” N - 76° 03’ 32” W; thence 023° (M) 2400 yards to a point 35° 24’ 27” N - 76° 03’ 12” W; thence 299° (M) 1100 yards to a point on shore 35° 24’ 38” N - 76° 04’ 48” W; thence following the shoreline and the Browns Island and Mt. Pleasant Bay primary nursery area line to the beginning point; except pots may be set no more than 50 yards from the shoreline.

(B) In Juniper Bay bound by a line beginning at a point on Juniper Bay

Point 35° 20' 18" N - 76° 13' 22" W running 275° (M) 2300 yards to a point 35° 20' 15" N - 76° 14' 45" W; thence 007° (M) 2100 yards to Daymarker No. 3; thence 040° (M) 1100 yards to a point on shore 35° 21' 45" N - 76° 14' 24" W; thence following the shoreline and the Buck Creek and the Laurel Creek primary nursery area line to the beginning point.

(C) In Swanquarter Bay, bound by a line beginning at a point on the north shore of Caffee Bay 35° 21' 57" N - 76° 17' 44" W; running 191° (M) 800 yards to a point on the south shore 35° 21' 35" N - 76° 17' 45" W; thence following the shoreline to a point on shore 35° 21' 37" N - 76° 18' 22" W; thence running 247° (M) 1300 yards to a point 35° 21' 17" N - 76° 19' 03" W; thence 340° (M) 1350 yards to a point 35° 21' 51" N - 76° 19' 27" W; thence 081° (M) 1150 yards to a point on the north shore 35° 22' 02" N - 76° 18' 48" W; thence following the shoreline and the primary nursery area line to the beginning point.

(D) In Deep Cove east of a line beginning at a point on the south shore 35° 20' 33" N - 76° 22' 57" W, running 021° (M) 1800 yards to a point on the north shore 35° 21' 55" N - 76° 22' 43" W and west of a line beginning at a point on the south shore 35° 20' 44" N - 76° 22' 05" W running 003° (M) 1400 yards to a point on the north shore 35° 21' 26" N - 76° 22' 11" W.

(E) Off Striking Bay bound by a line beginning at a point on the west shore of Striking Bay 35° 23' 20" N - 76° 26' 59" W running 190° (M) 1900 yards to a point 35° 22' 23" N - 76° 27' 00" W; thence 097° (M) 900 yards to Beacon No. 2; thence 127° (M) 1600 yards to a point 35° 21' 55" N - 76° 25' 43" W; thence following the shoreline to a point 35° 22' 30" N - 76° 25' 14" W; thence 322° (M) 2200 yards to a point 35° 23' 17" N - 76° 26' 10" W; thence following the shoreline to a point 35° 23' 19" N - 76° 26' 24" W; thence 335° (M) 900 yards to a point 35° 23' 40" N - 76° 26' 43" W; thence 059° (M) 500 yards to a point 35° 23' 30" N - 76° 26' 58" W; thence following the shoreline to the beginning point.

(F) In Rose Bay bound by a line beginning at a point southwest of Swan Point 35° 23' 56" N - 76° 23' 39" W running 288° (M) 1500 yards to a point on shore 35° 24' 03" N - 76° 24' 33" W; thence 162° (M) 1650 yards to a point 35° 23' 19" N - 76° 24' 04" W; thence 084° (M) 1350 yards to a point on shore 35° 23' 29" N - 76° 23' 17" W; thence following the shoreline to the beginning point.

(G) In Spencer Bay bound by a line beginning at a point on shore at Willow Point 35° 22' 26" N - 76° 28' 00" W running 059° (M) 1700 yards to a point 35° 22' 57" N - 76° 27' 13" W; thence 317° (M) 1500 yards to a point 35° 23' 25" N - 76° 27' 57" W; thence 243° (M) 1300 yards to a point on shore 35° 23' 02" N - 76° 28' 35" W; thence following the shoreline and the unnamed primary nursery area line to the beginning point.

(H) In Big Porpoise Bay bound by a line beginning at a point on shore 35° 15' 58" N - 76° 29' 10" W running 182° (M) 750 yards to Sage Point 35° 15' 36" N - 76° 29' 06" W; thence 116° (M) 850 yards to a point 35° 15' 28" N - 76° 28' 36" W; thence 023° (M) 700 yards to a point on shore 35° 15' 48" N - 76° 28' 30" W; thence following the shoreline to the beginning point.

(I) In Middle Bay bound by a line beginning at Middle Bay Point 35° 14’ 53” N - 76° 28’ 41” W; running 210° (M) 3650 yards to Sow Island Point 35° 13’ 09” N - 76° 29’ 28” W; thence following the shoreline of Middle Bay to Big Fishing Point 35° 14’ 05” N - 76° 29’ 52” W; thence 008° (M) 1100 yards to a point on the north shore 35° 14’ 31” N - 76° 29’ 52” W; thence following the shoreline to the point of beginning.

(J) In Jones Bay bound by a line beginning at a point on Sow Island Point 35° 13’ 09” N - 76° 29’ 28” W running 204° (M) 2600 yards to Green Flasher No. 5; thence 322° (M) 2450 yards to a point 35° 12’ 48” N - 76° 30’ 58” W; thence 217° (M) 1200 yards to a point on shore 35° 12’ 20” N - 76° 31’ 16” W; thence 284° (M) 740 yards to a point on shore 35° 12’ 26” N - 76° 31’ 46” W; thence following the shoreline to a point 35° 12’ 36” N - 76° 32’ 01” W; thence 051° (M) 600 yards to a point 35° 12’ 52” N - 76° 31’ 45” W; thence parallel with the shoreline no more than 600 yards from shore to a point 35° 13’ 11” N - 76° 32’ 07” W; thence 038° (M) to a point 600 yards from the north shore 35° 13’ 39” N - 76° 31’ 54” W; thence parallel with the shoreline no more than 600 yards from shore to a point 35° 13’ 09” N - 76° 30’ 48” W; thence 009° (M) 600 yards to a point on shore 35° 13’ 26” N - 76° 30’ 47” W; thence following the shoreline to the beginning point.

(K) In an area bound by a line beginning at Boar Point 35° 12’ 07” N - 76° 31’ 04” W running 106° (M) 2000 yards to Green Flasher No. 5; thence 200° (M) 2200 yards to a point 35° 10’ 56” N - 76° 30’ 10” W; thence 282° (M) 2350 yards to Bay Point 35° 11’ 02” N - 76° 31’ 35” W; thence following the shoreline to the beginning point.

(5) In Pamlico River west of a line from a point on Pamlico Point 35° 18’ 42” N - 76° 28’ 58” W running 009° (M) through Daymarker No. 1 and Willow Point Shoal Beacon to a point on Willow Point 35° 22’ 23” N - 76° 28’ 48” W pots may be used in the following areas:

(6) In Bay River west of a line beginning at a point on Maw Point 35° 09’ 02” N - 76° 32’ 09” W running 022° (M) to a point on Bay Point 35° 11’ 02” N - 76° 31’ 34” W, pots may be used in the following areas:

(7) In the Neuse River and West Bay Area south and west of a line beginning at a point on Maw Point 35° 09’ 02” N - 76° 32’ 09” W, running 137° (M) through the Maw Point Shoal Day Marker No. 2 and through the Neuse River Entrance Light to a point at the mouth of West Bay 35° 02’ 09” N - 76° 21’ 53” W, pots may be set in the following areas:

(8) Core Sound, Back Sound and the Straits and their tributaries.

(9) North River:

(10) Newport River:

(11) Bogue Sound:

(12) Designated primary nursery areas in all coastal fishing waters which are listed in 15A NCAC 3R .0103, except Burton Creek off Lower Broad Creek in Pamlico County.

(13) West and south of the Highway 58 Bridge at Emerald Isle from May 1 through October 31 in areas and during such times as the Fisheries Director shall designate by proclamation.

(b) It is unlawful to use pots from May 1 through October 31 in the areas described in Subparagraphs (b)(1) through (6) of this Rule except in accordance with 15A NCAC 3J .0301(a)(2)(B):

(1) In Wysocking Bay:

(A) Bound by a line beginning at a point on the south shore of Lone Tree Creek 35° 25' 05" N - 76° 02' 05" W running 239° (M) 1000 yards to a point 35° 24' 46" N - 76° 02' 32" W; thence 336° (M) 2200 yards to a point 35° 25' 42" N - 76° 03' 16" W; thence 062° (M) 750 yards to a point on shore 35° 25' 54" N - 76° 02' 54" W; thence following the shoreline and the Lone Tree Creek primary nursery area line to the beginning point;

(B) Bound by a line beginning at a point on the south shore of Mt. Pleasant Bay 35° 23' 07" N - 76° 04' 12" W running 083° (M) 1200 yards to a point 35° 23' 17" N - 76° 03' 32" W; thence 023° (M) 2400 yards to a point 35° 24' 35" N - 76° 04' 00" W; thence 299° (M) 1100 yards to point on shore 35° 24' 38" N - 76° 04' 48" W; thence following the shoreline and the Browns Island and Mt. Pleasant Bay primary nursery area line to the beginning point; except pots may be set no more than 50 yards from the shoreline;

(2) In Juniper Bay bound by a line beginning at a point on Juniper Bay Point 35° 20' 18" N - 76° 13' 22" W running 275° (M) 2300 yards to a point 35° 20' 15" N - 76° 14' 45" W; thence 007° (M) 2100 yards to Daymarker No. 3; thence 040° (M) 1100 yards to a point on shore 35° 21' 45" N - 76° 14' 24" W; thence following the shoreline and the Buck Creek primary nursery area line to the beginning point;

(3) In Rose Bay bound by a line beginning at a point southwest of Swan Point 35° 23' 56" N - 76° 23' 39" W running 288° (M) 1500 yards to a point 35° 24' 03" N - 76° 24' 33" W; thence 162° (M) 1650 yards to a point 35° 23' 19" N - 76° 24' 04" W; thence 084° (M) 1350 yards to a point on shore 35° 23' 29" N - 76° 23' 17" W; thence following the shoreline to the beginning point;

(4) In Spencer Bay bound by a line beginning at a point on shore at Willow Point 35° 22' 26" N - 76° 28' 00" W running 059° (M) 1700 yards to a point 35° 22' 57" N - 76° 27' 13" W; thence 317° (M) 1500 yards to a point 35° 23' 25" N - 76° 27' 57" W; thence 243° (M) 1300 yards to a point on shore 35° 23' 02" N - 76° 28' 35" W; thence following the shoreline to the beginning point;

(5) In Bay River, beginning at a point on shore at Moore Creek 35° 08' 51" N - 76° 40' 14" W; running 296° (M) to a point 35° 08' 59" N - 76° 50' 19" W; thence no more than 150 yards from shore to a point 35° 09' 43" N - 76° 40' 06" W; thence running 134° (M) to a point on shore west of Bell Point 35° 09' 40" N - 76° 40' 00" W;

(6) In Neuse River:

(A) Beginning at a point on shore north of Swan Creek 35° 07' 17" N - 76° 33' 26" W running 115° (M) to a point near the six foot depth contour 35° 07' 15" N - 76° 33' 16" W; thence running 074° (M) to Beacon No. 2 at Maw Point Shoal; thence running 294° (M) to a point on shore 35° 08' 30" N - 76° 32' 36" W; thence following the shoreline to the beginning point 35° 07' 17" N - 76° 33' 26" W;

(B) Beginning at a point on shore north of Gum Thicket Creek 35° 04' 40" N - 76° 35' 38" W; thence running 129° (M) to a point 35° 04'

12” N - 76° 34’ 37” W; thence running 355° (M) to Beacon No. 1 in Broad Creek; thence running the six foot contour line to Green Marker No. 3;

(C) Beginning at a point on the eastern tip of Cockle Point 35° 03’ 20” N - 76° 38’ 27” W; thence running 100° (M) to a point 35° 03’ 18” N - 76° 37’ 53” W; thence running 005° (M) to a point on shore 35° 03’ 38” N - 76° 37’ 54” W; thence following the primary nursery area line to the beginning point 35° 03’ 20” N - 76° 38’ 27” W;

(D) Beginning at a point on shore on the eastern side of the MBYB channel 34° 58’ 16” N - 76° 49’ 05” W running 186° (M) to a point on the six foot depth contour 34° 58’ 07” N - 76° 49’ 05” W; thence following the six foot depth contour to a point 34° 58’ 24” N - 76° 46’ 34” W; thence running 351° (M) to a point on shore 34° 58’ 32” N - 76° 46’ 38” W;

(E) Beginning at a point on shore at Beards Creek 35° 00’ 08” N - 76° 52’ 13” W; thence running 209° (M) to a point 34° 59’ 52” N - 76° 52’ 20” W; thence running along the six foot depth contour to a point 34° 59’ 25” N - 76° 51’ 14” W; thence running 043° (M) to a point on shore at Mill Creek 34° 59’ 34” N - 76° 51’ 06” W.

VI. Management Options/Impacts:

1. No regulatory action.
2. Open all designated long haul areas in Hyde, Beaufort, and Pamlico counties by proclamation during specified time periods.

Recommendations:

On March 14, 2001, the Central Regional Advisory Committee passed a motion that all designated long haul areas be managed by proclamation with preference for use given to long haulers. After numerous meetings and several motions on this issue the Crustacean Committee recommended leaving the long haul areas as they currently are (April 12, 2001). In June 2001, the Marine Fisheries Commission (MFC) voted to ask the DMF to draft language to amend the rules giving the DMF Director proclamation authority to open all long haul areas to crab potting. The strategy proposed in the draft rule (Appendix 19) would allow crab pots in all designated long haul areas in Hyde, Beaufort, and Pamlico counties during specified time periods.

12.16 Appendix 16. TIME CHANGE FOR PLACING CRAB POTS IN DESIGNATED POT AREAS

I. Issue:

Modify dates when crab pots must be moved to designated pot areas.

II. Background:

During 1 May -31 October north and east of the Emerald Isle Highway 58 bridge, setting of crab pots is restricted to designated areas. During development of the 1998 Blue Crab Fishery Management Plan (BCFMP), crab potters asked the DMF/MFC to consider changing, through proclamation authority, the area restriction date from May-October to June-September in order to account for annual variations in crab distribution by water depth. Water temperature influences the depth at which crabs may be potted. The inside of the six foot depth contour line or specified distance from shore is used to designate pot areas during the current May-October time frame. If water temperatures remain cool past the May deadline, potters are required to move their pots into shallower areas which may be less productive for crabs. The May-October time frame was originally set to coincide with increased boating and trawling in the vicinity. Rule 15A NCAC 3J requires pots to be moved into designated areas (6-foot contours or specified distance from shore).

III. Discussion:

One of the 1998 North Carolina Blue Crab Fishery Management Plan recommendations was to re-examine the times when pots must be moved into designated crab pot areas (Section 10.3 COMPETITION and CONFLICT WITH OTHER USERS, Action #10 in section 10.3.1.4). The Crustacean Committee debated this issue during several meetings in 2000 and early 2001. On April 12, 2001, the committee passed a motion to change the dates for crab pot designated areas from May 1-October 31 to June 1-November 30. A similar motion was passed by the Central Advisory Committee on March 14, 2001. At it's June 2001 meeting, the MFC passed a motion asking the DMF to draft language to amend the rules for crab pot designated areas to June 1-November 30. The front end this time change would not affect shrimp trawlers, as May only accounts for 0.45% of all shrimp landed from these areas (Table 1). Crab trawlers might be affected, since 14% of the total river crab harvest occurs in May (Table 2). On the backside, neither trawl gear would be affected negatively with a possible gain to the crab trawlers (Table 1 and 2).

IV. Current Regulation:

SUBCHAPTER 3J - NETS, POTS, DREDGES, AND OTHER FISHING DEVICES
SECTION .0300 - POTS, DREDGES, AND OTHER FISHING DEVICES

15A NCAC 3J .0301 POTS

(a) It is unlawful to use pots except during time periods and in areas specified herein:

(1) From November 1 through April 30, except that all pots shall be removed from internal waters from January 24 through February 7. Fish pots upstream of U.S. 17 Bridge across Chowan River and upstream of a line across the mouth of Roanoke, Cashie, Middle and Eastmost Rivers to the Highway 258 Bridge are exempt from the January 24 through February 7 removal requirement. The Fisheries Director may, by proclamation,

reopen various waters to the use of pots after January 28 if it is determined that such waters are free of pots.

(2) From May 1 through October 31, north and east of the Highway 58 Bridge at Emerald Isle:
   (A) In areas described in 15A NCAC 3R .0107(a);
   (B) To allow for the variable spatial distribution of crustacea and finfish, the Fisheries Director may, by proclamation, specify time periods for or designate the areas described in 15A NCAC 3R .0107(b); or any part thereof, for the use of pots.

(3) From May 1 through October 31 in the Atlantic Ocean and west and south of the Highway 58 Bridge at Emerald Isle in areas and during time periods designated by the Fisheries Director by proclamation.

SUBCHAPTER 3R - DESCRIPTIVE BOUNDARIES

SECTION .0100 - DESCRIPTIVE BOUNDARIES

15A NCAC 3R .0107 DESIGNATED POT AREAS

(a) As referenced in 15A NCAC 3J .0301, it is unlawful to use pots north and east of the Highway 58 Bridge at Emerald Isle from May 1 through October 31, except in areas described below:
   (13) West and south of the Highway 58 Bridge at Emerald Isle from May 1 through October 31 in areas and during such times as the Fisheries Director shall designate by proclamation.

(b) It is unlawful to use pots from May 1 through October 31 in the areas described in Subparagraphs (b)(1) through (6) of this Rule except in accordance with 15A NCAC 3J .0301(a)(2)(B):

VI. Management Options/Impacts:

1. No regulatory action.
2. Change the dates for crab pot designated areas from May 1-October 31 to June 1-November 30

Recommendations:

The Crustacean Committee debated this issue during several meetings in 2000 and early 2001. On April 12, 2001, the committee passed a motion to change the dates for crab pot designated areas from May 1-October 31 to June 1-November 30. The Central Advisory Committee passed a similar motion on March 14, 2001. At it’s June 2001 meeting, the MFC passed a motion asking the DMF to draft language to amend the rules for crab pot designated areas from June 1-November 30.

Table 1. Total shrimp landings from shrimp trawls for selected waterbodies, 1994-2001*.

	River									
	Pamlico		Pungo		Bay		Neuse			
Month	Landings pounds	Percent of total	Landings pounds	Percent of total	Landings pounds	Percent of total	Landings pounds	Percent of total	Total pounds	Percent of total
1	1,747	0.66	0	0.00	0	0.00	0	0.00	1,747	0.13
2	1,041	0.39	0	0.00	0	0.00	0	0.00	1,041	0.08
3	0	0.00	0	0.00	0	0.00	326	0.03	326	0.02
4	127	0.05	0	0.00	12	0.01	17	0.00	156	0.01
5	1,309	0.50	0	0.00	96	0.08	4,878	0.50	6,283	0.45
6	10,451	3.96	4,566	19.92	24,622	20.74	100,060	10.19	139,699	10.07
7	85,701	32.45	4,333	18.91	72,618	61.16	491,437	50.04	654,089	47.13
8	70,627	26.74	8,032	35.05	15,861	13.36	150,385	15.31	244,905	17.65
9	29,383	11.13	5,987	26.12	2,826	2.38	127,147	12.95	165,343	11.91
10	27,084	10.26	0	0.00	2,363	1.99	80,648	8.21	110,095	7.93
11	29,901	11.32	0	0.00	325	0.27	26,421	2.69	56,647	4.08
12	6,710	2.54	0	0.00	10	0.01	722	0.07	7,442	0.54
	264,081		22,918		118,733		982,041		1,387,773	

*2001 landings preliminary

Table 2. Total crab landings from crab trawls for selected waterbodies, 1994-2001*.

	River									
	Pamlico		Pungo		Bay		Neuse			
Month	Landings pounds	Percent of total	Landings Pounds	Percent of total	Landings pounds	Percent of total	Landings pounds	Percent of total	Total pounds	Percent of total
1	20,020	0.71	1,012	0.07	564	0.05	187	0.01	21,783	0.32
2	120,030	4.25	8,083	0.55	13	0.00	34,968	2.27	163,094	2.36
3	209,518	7.42	70,587	4.80	20,886	1.95	92,477	5.99	393,468	5.70
4	162,548	5.76	103,945	7.07	33,115	3.09	181,712	11.77	481,320	6.97
5	268,977	9.53	230,609	15.68	189,834	17.70	260,179	16.86	949,599	13.75
6	557,770	19.76	221,550	15.07	361,924	33.75	341,932	22.15	1,483,176	21.47
7	400,300	14.18	263,694	17.93	236,618	22.06	385,909	25.00	1,286,521	18.62
8	399,973	14.17	232,666	15.82	83,840	7.82	144,861	9.39	861,340	12.47
9	424,531	15.04	184,647	12.56	100,300	9.35	74,547	4.83	784,025	11.35
10	174,119	6.17	105,435	7.17	43,431	4.05	15,464	1.00	338,449	4.90
11	50,069	1.77	35,095	2.39	1,865	0.17	4,666	0.30	91,695	1.33
12	34,390	1.22	13,151	0.89	0	0.00	6,524	0.42	54,065	0.78
	2,822,245		1,470,474		1,072,390		1,543,426		6,908,535	

*2001 landings preliminary

12.17 Appendix 17. DESIGNATED POT AREAS

I. Issue:

Compliance and ease of enforcement.

II. Background:

Crab pot areas were first designated by proclamation during 1977/1978. Areas were primarily designated in Hyde, Beaufort and Pamlico counties to alleviate social concerns about competition for space between crab potters, long haulers, and shrimp/crab trawlers. Areas were designated in other locations, such as those in mid-Neuse River, to address competition between recreational users versus crab potting. Areas were last designated by proclamation in 1983 and have since been designated by regulation.

In the Pamlico, Pungo, Bay and Neuse rivers, these areas are designated based on a combination of distance from shore and water depth. Fishermen have complained about the various depth and distance from shore regulations, for different designated pot areas (rule 15A NCAC 3R .0107), and have asked for a standard depth contour for all areas. Marine Patrol requested a change to depth contours for the designated pot areas, because depth would be easier to measure and enforce as compared to distance from shore.

III. Discussion:

One of the 1998 North Carolina Blue Crab Fishery Management Plan recommendations was to modify existing crab pot area regulations using depth as the boundary instead of distance from shore (Section 10.3 COMPETITION and CONFLICT WITH OTHER USERS, Action #4 in section 10.3.1.4).

IV. Current Authority:

15A NCAC 03J .0301 POTS

(a) It is unlawful to use pots except during time periods and in areas specified herein:

(1) From November 1 through April 30, except that all pots shall be removed from internal waters from January 24 through February 7. Fish pots upstream of U.S. 17 Bridge across Chowan River and upstream of a line across the mouth of Roanoke, Cashie, Middle and Eastmost Rivers to the Highway 258 Bridge are exempt from the January 24 through February 7 removal requirement. The Fisheries Director may, by proclamation, reopen various waters to the use of pots after January 28 if it is determined that such waters are free of pots.

(2) From May 1 through October 31, north and east of the Highway 58 Bridge at Emerald Isle:

- (A) In areas described in 15A NCAC 03R .0107(a);
- (B) To allow for the variable spatial distribution of crustacea and finfish, the Fisheries Director may, by proclamation, specify time periods for or designate the areas described in 15A NCAC 03R .0107(b); or any part thereof, for the use of pots.

15A NCAC 03R .0107 DESIGNATED POT AREAS

(a) As referenced in 15A NCAC 03J .0301, it is unlawful to use pots north and east of the Highway 58 Bridge at Emerald Isle from May 1 through October 31, except in areas described below:

(1) In Albemarle Sound and tributaries.

(2) In Roanoke Sound and tributaries.

(3) In Croatan Sound and tributaries.

(4) In Pamlico Sound and tributaries, except the following areas and areas further described in Paragraphs (5), (6), and (7) of this Rule:

(A) In Wysocking Bay:

(i) Bound by a line beginning at a point on the south shore of Lone Tree Creek 35° 25’ 05” N - 76° 02’ 05” W running 239° (M) 1000 yards to a point 35° 24’ 46” N - 76° 02’ 32” W; thence 336° (M) 2200 yards to a point 35° 25’ 42” N - 76° 03’ 16” W; thence 062° (M) 750 yards to a point on shore 35° 25’ 54” N - 76° 02’ 54” W; thence following the shoreline and the Lone Tree Creek primary nursery area line to the beginning point;

(ii) Bound by a line beginning at a point on the south shore of Mt. Pleasant Bay 35° 23’ 07” N - 76° 04’ 12” W running 083° (M) 1200 yards to a point 35° 23’ 17” N - 76° 03’ 32” W; thence 023° (M) 2400 yards to a point 35° 24’ 27” N - 76° 03’ 12” W; thence 299° (M) 1100 yards to a point on shore 35° 24’ 38” N - 76° 04’ 48” W; thence following the shoreline and the Browns Island and Mt. Pleasant Bay primary nursery area line to the beginning point; except pots may be set no more than 50 yards from the shoreline.

(B) In Juniper Bay bound by a line beginning at a point on Juniper Bay Point 35° 20’ 18” N - 76° 13’ 22” W running 275° (M) 2300 yards to a point 35° 20’ 15” N - 76° 14’ 45” W; thence 007° (M) 2100 yards to Daymarker No. 3; thence 040° (M) 1100 yards to a point on shore 35° 21’ 45” N - 76° 14’ 24” W; thence following the shoreline and the Buck Creek and the Laurel Creek primary nursery area line to the beginning point.

(C) In Swanquarter Bay, bound by a line beginning at a point on the north shore of Caffee Bay 35° 21’ 57” N - 76° 17’ 44” W; running 191° (M) 800 yards to a point on the south shore 35° 21’ 35” N - 76° 17’ 45” W; thence following the shoreline to a point on shore 35° 21’ 37” N - 76° 18’ 22” W; thence running 247° (M) 1300 yards to a point 35° 21’ 17” N - 76° 19’ 03” W; thence 340° (M) 1350 yards to a point 35° 21’ 51” N - 76° 19’ 27” W; thence 081° (M) 1150 yards to a point on the north shore 35° 22’ 02” N - 76° 18’ 48” W; thence following the shoreline and the primary nursery area line to the beginning point.

(D) In Deep Cove east of a line beginning at a point on the south shore 35° 20’ 33” N - 76° 22’ 57” W, running 021° (M) 1800 yards to a point on the north shore 35° 21’ 55” N - 76° 22’ 43” W and west of a line beginning at a point on the south shore 35° 20’ 44” N - 76° 22’ 05” W running 003° (M) 1400 yards to a point on the north shore 35° 21’ 26” N - 76° 22’ 11” W.

(E) Off Striking Bay bound by a line beginning at a point on the west shore of Striking Bay 35° 23’ 20” N - 76° 26’ 59” W running 190° (M) 1900 yards to a point 35° 22’ 23” N - 76° 27’ 00” W; thence 097° (M) 900 yards to Beacon No. 2; thence 127° (M) 1600 yards to a point 35° 21’ 55” N - 76° 25’ 43” W; thence following the shoreline to a point 35° 22' 30" N - 76° 25' 14" W; thence 322° (M) 2200 yards to a point 35° 23' 17" N - 76° 26' 10" W; thence following the shoreline to a point 35° 23' 19" N - 76° 26' 24" W; thence 335° (M) 900 yards to a point 35° 23' 40" N - 76° 26' 43" W; thence 059° (M) 500 yards to a point 35° 23' 30" N - 76° 26' 58" W; thence following the shoreline to the beginning point.

(F) In Rose Bay bound by a line beginning at a point southwest of Swan Point 35° 23' 56" N - 76° 23' 39" W running 288° (M) 1500 yards to a point on shore 35° 24' 03" N - 76° 24' 33" W; thence 162° (M) 1650 yards to a point 35° 23' 19" N - 76° 24' 04" W; thence 084° (M) 1350 yards to a point on shore 35° 23' 29" N - 76° 23' 17" W; thence following the shoreline to the beginning point.

(G) In Spencer Bay bound by a line beginning at a point on shore at Willow Point 35° 22' 26" N - 76° 28' 00" W running 059° (M) 1700 yards to a point 35° 22' 57" N - 76° 27' 13" W; thence 317° (M) 1500 yards to a point 35° 23' 25" N - 76° 27' 57" W; thence 243° (M) 1300 yards to a point on shore 35° 23' 02" N - 76° 28' 35" W; thence following the shoreline and the unnamed primary nursery area line to the beginning point.

(H) In Big Porpoise Bay bound by a line beginning at a point on shore 35° 15' 58" N - 76° 29' 10" W running 182° (M) 750 yards to Sage Point 35° 15' 36" N - 76° 29' 06" W; thence 116° (M) 850 yards to a point 35° 15' 28" N - 76° 28' 36" W; thence 023° (M) 700 yards to a point on shore 35° 15' 48" N - 76° 28' 30" W; thence following the shoreline to the beginning point.

(I) In Middle Bay bound by a line beginning at Middle Bay Point 35° 14' 53" N - 76° 28' 41" W; running 210° (M) 3650 yards to Sow Island Point 35° 13' 09" N - 76° 29' 28" W; thence following the shoreline of Middle Bay to Big Fishing Point 35° 14' 05" N - 76° 29' 52" W; thence 008° (M) 1100 yards to a point on the north shore 35° 14' 31" N - 76° 29' 52" W; thence following the shoreline to the point of beginning.

(J) In Jones Bay bound by a line beginning at a point on Sow Island Point 35° 13' 09" N - 76° 29' 28" W running 204° (M) 2600 yards to Green Flasher No. 5; thence 322° (M) 2450 yards to a point 35° 12' 48" N - 76° 30' 58" W; thence 217° (M) 1200 yards to a point on shore 35° 12' 20" N - 76° 31' 16" W; thence 284° (M) 740 yards to a point on shore 35° 12' 26" N - 76° 31' 46" W; thence following the shoreline to a point 35° 12' 36" N - 76° 32' 01" W; thence 051° (M) 600 yards to a point 35° 12' 52" N - 76° 31' 45" W; thence parallel with the shoreline no more than 600 yards from shore to a point 35° 13' 11" N - 76° 32' 07" W; thence 038° (M) to a point 600 yards from the north shore 35° 13' 39" N - 76° 31' 54" W; thence parallel with the shoreline no more than 600 yards from shore to a point 35° 13' 09" N - 76° 30' 48" W; thence 009° (M) 600 yards to a point on shore 35° 13' 26" N - 76° 30' 47" W; thence following the shoreline to the beginning point.

(K) In an area bound by a line beginning at Boar Point 35° 12' 07" N - 76° 31' 04" W running 106° (M) 2000 yards to Green Flasher No. 5; thence 200° (M) 2200 yards to a point 35° 10' 56" N - 76° 30' 10" W; thence 282° (M) 2350 yards to Bay Point 35° 11' 02" N - 76° 31' 35" W; thence following the shoreline to the beginning point.

(5) In Pamlico River west of a line from a point on Pamlico Point 35° 18' 42" N - 76° 28' 58" W running 009° (M) through Daymarker No. 1 and Willow

Point Shoal Beacon to a point on Willow Point 35° 22’ 23” N - 76° 28’ 48” W pots may be used in the following areas:

(A) In that area bound by a line beginning at a point on the line from Pamlico Point to Willow Point 35° 19’ 24” N - 76° 28’ 56” W running westerly parallel to the shoreline at a distance of no more than 1000 yards to Green Flasher No. 1 at the mouth of Goose Creek; thence 248° (M) parallel to the ICWW to a point off Fulford Point 35° 19’ 59” N - 76° 36’ 41” W; thence 171° (M) to a point on Fulford Point 35° 19’ 41” N -76° 36’ 34” W.

(B) All coastal waters and tributaries of Oyster Creek, James Creek, Middle Prong and Clark Creek.

(C) All coastal waters of Goose Creek:

  (i) In that area bound by a line beginning at a point on Reed Hammock 35° 20’ 24” N - 76° 36’ 51” W running 171° (M) 300 yards to a point 35° 20’ 16” N - 76° 36’ 48” W; thence parallel with the shoreline no more than 300 yards from shore to a point 35° 20’ 09” N - 76° 37’ 10” W; thence 302° (M) 300 yards to a point on shore 35° 20’ 13” N - 76° 37’ 19” W.

  (ii) In that area bound by a line beginning at a point on shore 35° 19’ 58” N - 76° 37’ 33” W; running 291° (M) 300 yards to a point 35° 19’ 57” N - 76° 37’ 21” W; thence parallel to the shoreline no more than 300 yards from shore to a point 35° 18’ 16” N - 76° 37’ 16” W; thence 292° (M) to a point on the north shore of Snode Creek 35° 18’ 15” N - 76° 37’ 27” W.

  (iii) In that area bound by a line beginning at a point at the mouth of Goose Creek 35° 19’ 59” N - 76° 36’ 41” W; running 348° (M) to Green Daymarker No. 5; thence south parallel to the shoreline no more than 300 yards from shore to a point 35° 18’ 12” N - 76° 37’ 07” W; thence 112° (M) to Store Point 35° 18’ 09” N - 76° 36’ 57” W.

  (iv) Between the line from Store Point to Snode Creek and a line beginning at a point on Long Neck Point running 264° (M) through Beacon No. 15 to Huskie Point from the shoreline to no more than 150 yards from shore.

  (v) All coastal waters southeast of the line from Long Neck Point through Beacon No. 15 to Huskie Point.

  (vi) Campbell Creek - west of a line from a point on Huskie Point 35° 17’ 00” N - 76° 37’ 06” W running 004° (M) to Pasture Point 35° 17’ 20” N - 76° 37’ 08” W, to the Inland-Commercial line.

(D) All coastal waters bound by a line beginning on Reed Hammock 35° 20’ 24” N -76° 36’ 51” W running 171° (M) to a point 35° 20’ 16” N - 76° 36’ 47” W; thence 100° (M) 800 yards to Red Daymarker No. 4; thence 322° (M) 1200 yards to a point 35° 20’ 40” N - 76° 36’ 48” W; thence westerly parallel to the shoreline at a distance of 300 yards to a point in Bond Creek 35° 20’ 40” N - 76° 41’ 37” W; thence 199° (M) to a point on the south shore of Muddy Creek 35° 20’ 18” N - 76° 41’ 34” W, including all waters of Muddy Creek up to the Inland-Coastal boundary line.

(E) Along the west shore of Bond Creek from Fork Point to the Coastal-Inland boundary line from the shoreline to no more than 50 yards from shore.

(F) All coastal waters of South Creek upstream of a line beginning at a point on Fork Point 35° 20’ 45” N - 76° 41’ 47” W running 017° (M) to a point on Hickory Point 35° 21’ 44” N - 76° 41’ 36” W.

(G) In that area bound by a line beginning at a point at the six foot depth contour south of Hickory Point 35° 21’ 33” N - 76° 41’ 39” W; thence easterly following the six foot depth contour to a point off the east end of Indian Island 35° 21’ 42” N - 76° 38’ 04” W; thence 270° (M) to a point on the east end of Indian Island 35° 21’ 38” N - 76° 38’ 36” W; thence following the shoreline of Indian Island to a point on the west end 35° 21’ 37” N - 76° 39’ 40” W; thence 293° (M) toward Daymarker No. 1 to a point at the six foot depth contour 35° 21’ 46” N - 76° 40’ 16” W; thence following the six foot depth contour in a westerly direction to a point off Long Point 35° 22’ 42” N - 76° 42’ 44” W; thence 233° (M) to a point on shore 35° 22’ 24” N - 76° 43’ 05” W.

(H) Beginning at a point on shore near Long Point 35° 22’ 29” N - 76° 43’ 25” W, running 001° (M) to a point 300 yards offshore 35° 22’ 39” N - 76° 43’ 26” W; thence westerly parallel to the shoreline at a distance of 300 yards to a point 35° 22’ 39” N - 76° 43’ 59” W; thence 209° (M) to a point on shore 35° 22’ 30” N - 76° 44’ 03” W.

(I) Beginning at a point on shore 35° 22’ 30” N - 76° 44’ 27” W, running 355° (M) to a point offshore 35° 22’ 40” N - 76° 44’ 31” W; thence westerly parallel to the shoreline at a distance of 300 yards to a point 35° 22’ 53” N - 76° 45’ 00” W; thence running 251° (M) to a point on shore 35° 22’ 46” N - 76° 45’ 14” W.

(J) Beginning at a point on shore 35° 22’ 54” N - 76° 45’ 43” W; running 003° (M) to a point offshore 35° 23’ 03” N - 76° 45’ 43” W; thence westerly parallel to the shoreline at a distance of 300 yards to the intersection of a line beginning on the north shore at Gum Point 35° 25’ 09” N - 76° 45’ 33” W; running 210° (M) to a point on the south shore 35° 23’ 28” N - 76° 46’ 26” W.

(K) All coastal waters west of a line beginning on the north shore at Gum Point 35° 25’ 09” N - 76° 45’ 33” W running 210° (M) to a point on the south shore 35° 23’ 28” N - 76° 46’ 26” W.

(L) On the north side of Pamlico River bound by a line beginning at the intersection of the line from Gum Point to the south shore 500 yards from shore 35° 24’ 55” N - 76° 45’ 39” W running easterly parallel to the shoreline at a distance of 500 yards to a point at the six foot contour near Adams Point 35° 23’ 08” N - 76° 35’ 59” W.

(M) All waters and tributaries of North Creek except the marked navigation channel.

(N) In that area bound by a line beginning at a point at the six foot contour near Adams Point 35° 23’ 08” N - 76° 35’ 59” W running westerly following the six foot depth contour to a point off Wades Point 35° 23’ 28” N - 76° 34’ 09” W.

(O) Pungo River:

(i) Bound by a line beginning at Wades Point 35° 23’ 16” N - 76° 34’ 30” W running 059° (M) to a point at the six foot depth contour, 35° 23’ 28” N - 76° 34’ 09” W; thence northerly following the six foot depth contour to a point near Beacon No. 3 35° 25’ 44” N - 76° 34’ 46” W; thence 272° (M) 950 yards to a point on shore 35° 25’ 41” N - 76° 35’ 22” W.

(ii) Bound by a line beginning at a point on shore 35° 25’ 50” N - 76° 35’ 37” W running 050° (M) 1150 yards to a point at 35° 26’ 17” N - 76° 35’ 10” W; thence northerly following the six foot depth contour to a point 35° 26’ 54” N - 76° 36’ 09” W; thence 314° (M) 350 yards to a point on shore 35° 27’ 00” N - 76° 36’ 20” W.

(iii) Bound by a line beginning at a point on shore 35° 27’ 14” N - 76° 36’ 26” W running 077° (M) 800 yards to a point 35° 27’ 23” N - 76° 36’ 02” W; thence northerly following the six foot depth contour to a point off Windmill Point 35° 30’ 50” N - 76° 38’ 09” W; thence 076° (M) to a point 200 yards west of Daymarker No. 3 35° 31’ 21” N - 76° 36’ 37” W; thence 312° (M) to a point at the “Breakwater” 35° 31’ 36” N - 76° 37’ 05” W.

(iv) All coastal waters bound by a line beginning at a point at the “Breakwater” 200 yards northeast of Beacon No. 6 35° 31’ 47” N - 76° 36’ 51” W running 132° (M) to a point 200 yards from Daymarker No. 4 35° 31’ 31” N - 76° 36’ 21” W; thence running 102° (M) to a point 35° 31’ 28” N - 76° 35’ 59” W; thence running 010° (M) to Beacon No. 1; thence running 045° (M) 700 yards to a point on shore 35° 32’ 22” N - 76° 35’ 42” W.

(v) All coastal waters north and east of a line beginning at a point on shore west of Lower Dowry Creek 35° 32’ 25” N - 76° 35’ 07” W running 177° (M) 1950 yards to a point 200 yards north of Daymarker No. 11 35° 31’ 31” N - 76° 35’ 06” W; thence easterly parallel to the marked navigation channel at a distance of 200 yards to a point on the shore northwest of Wilkerson Creek 35° 33’ 13” N - 76° 27’ 36” W.

(vi) All coastal waters south of a line beginning on shore south of Wilkerson Creek 35° 33’ 02” N - 76° 27’ 20” W running westerly parallel to the marked navigation channel at a distance of 200 yards to a point southeast of Daymarker No. 14 35° 31’ 05” N - 76° 32’ 34” W; thence running 208° (M) to a point on shore 35° 30’ 28” N - 76° 32’ 47” W.

(vii) All coastal waters bound by a line beginning on shore east of Durants Point 35° 30’ 29” N - 76° 33’ 25” W running 347° (M) to a point southwest of Daymarker No. 12 35° 31’ 08” N - 76° 33’ 53” W; thence westerly parallel to the marked navigation channel at a distance of 200 yards to a point south of Beacon No. 10 35° 31’ 08” N - 76° 35’ 35” W; thence running 185° (M) to a point at the six foot depth contour between Beacon No. 8 and the eastern shore of Pungo River 35° 30’ 08” N - 76° 35’ 28” W; thence following the six foot depth contour to a point 35° 28’ 09” N - 76° 33’ 43” W; thence 127° (M) to a point on shore 35° 28’ 00” N - 76° 33’ 25” W; thence 159° (M) to a point at the six foot depth contour 35° 27’ 40” N - 76° 33’ 12” W including the waters of Slades Creek and its tributaries; thence 209° (M) to a point on shore 35° 27’ 22” N - 76° 33’ 21” W; thence 272° (M) to a point at the six foot depth contour 35° 27’ 18” N - 76° 33’ 53” W; thence southerly following the six foot depth contour to a point south of Sandy Point 35° 26’ 35” N - 76° 33’ 50” W; thence 087° (M) to a point on shore 35° 26’ 38” N - 76° 33’ 34” W.

(viii) In that area bound by a line beginning at a point on shore 35° 26’ 20” N - 76° 33’ 18” W running 176° (M) to a point at the six foot depth contour 35° 26’ 05” N - 76° 33’ 13” W; thence southerly following the six foot depth contour throughout Fortescue Creek to a point off Fortescue Creek 35° 25’ 44” N - 76° 32’ 09” W; thence 145° (M) to a point on shore 35° 25’ 36” N - 76° 32’ 01” W.

(ix) In that area bound by a line beginning at a point on shore 35° 25’ 20” N - 76° 32’ 01” W running 258° (M) to a point at the six foot depth contour 35° 25’ 17” N - 76° 32’ 18” W; thence following the six foot depth contour to the intersection of the line from a point 500 yards west of Currituck Point 35° 24’ 30” N - 76° 32’ 42” W; thence southeasterly parallel to the shoreline and including Abel Bay at a distance of 500 yards to a point at the intersection of the line from Pamlico Point to Willow Point 35° 22’ 09” N - 76° 28’ 48” W.

(6) In Bay River west of a line beginning at a point on Maw Point 35° 09’ 02” N - 76° 32’ 09” W running 022° (M) to a point on Bay Point 35° 11’ 02” N - 76° 31’ 34” W, pots may be used in the following areas:

(A) In that area beginning at a point on Maw Point 35° 09’ 02” N - 76° 32’ 09” W; running 018° (M) to Green Daymarker No. 1; thence 223° (M) to a point on shore in Fisherman Bay 35° 09’ 18” N - 76° 32’ 23” W.

(B) In Fisherman Bay bound by a line beginning at a point on the shore west of Maw Point 35° 09’ 18” N - 76° 33’ 02” W; thence 351° (M) 3200 yards to lighted Beacon No. 3 in Bay River; thence 230° (M) 1200 yards to a point on the shore 35° 10’ 24” N - 76° 34’ 00” W.

(C) In that area bound by a line beginning at a point on the east shore at the mouth of Bonners Bay 35° 10’ 05” N - 76° 35’ 18” W; thence 306° (M) 300 yards to a point in Bay River, 35° 10’ 10” N - 76° 35’ 30” W; thence parallel to the shoreline no more than 300 yards from shore to a point in Bay River 35° 10’ 40” N - 76° 34’ 42” W; thence 188° (M) to a point on shore 35° 10’ 27” N - 76° 34’ 42” W.

(D) In Bonner Bay bound by a line beginning at a point on the east shore 35° 10’ 05” N - 76° 35’ 18” W running 306° (M) 200 yards to a point 35° 10’ 09” N - 76° 35’ 25” W; thence parallel to the shoreline no more than 200 yards offshore to a point 35° 09’ 16” N - 76° 35’ 18” W; thence 097° (M) 200 yards to a point on shore 35° 09’ 16” N - 76° 35’ 13” W.

(E) In Bonner Bay, Spring Creek and Long Creek south of a line beginning at a point on the east shore 35° 09’ 16” N - 76° 35’ 13” W running 274° (M) to a point on the west shore 35° 09’ 14” N - 76° 35’ 43” W.

(F) In Bonner Bay bound by a line beginning at a point on the west shore 35° 09’ 14” N - 76° 35’ 44” W running 094° (M) 100 yards to a point 35° 09’ 13” N - 76° 35’ 39” W; thence parallel to the shoreline no more than 100 yards offshore to a point in Riggs Creek 35° 09’ 15” N - 76° 36’ 08” W; thence 142° (M) to a point on shore 35° 09’ 13” N - 76° 36’ 08” W.

(G) In that area bound by a line beginning on the south shore of Bay River west of Bell Point 35° 09’ 40” N - 76° 40’ 00” W, running 314° (M) to a point 200 yards offshore 35° 09’ 43” N - 76° 40’ 06” W; thence no more than 200 yards from the shoreline to a point

35° 09’ 53” N - 76° 36’ 45” W; thence 102° (M) to a point 35° 09’ 50” N - 76° 35’ 54” W; thence 181° (M) to a point 35° 09’ 36” N - 76° 35’ 51” W; thence 237° (M) to a point in Riggs Creek 35° 09’ 18” N - 76° 36’ 12” W; thence 322° (M) to a point on shore at the mouth of Riggs Creek 35° 09’ 21” N - 76° 36’ 18” W.

(H) In that area on the south side of Bay River bound by a line beginning at a point on shore at the confluence of Bay River and Trent Creek 35° 08’ 27” N - 76° 43’ 12” W running 016° (M) 150 yards to a point 35° 08’ 31” N - 76° 43’ 11” W; thence no more than 150 yards from shore to a point 35° 08’ 57” N - 76° 40’ 19” W; thence 116° (M) to a point on shore at Moores Creek 35° 08’ 57” N - 76° 40’ 14” W.

(I) In Bay River and Trent Creek west of a line beginning at a point on the south shore 35° 08’ 27” N - 76° 43’ 12” W running 016° (M) to a point on the north shore 35° 08’ 41” N - 76° 43’ 09” W.

(J) In that area on the north shore of Bay River bound by a line beginning at a point west of Vandemere Creek 35° 10’ 53” N - 76° 39’ 42” W running 135° (M) 150 yards to a point 35° 10’ 52” N - 76° 39’ 39” W; thence no more than 150 yards from shore to a point at the confluence of Bay River and Trent Creek 35° 08’ 37” N - 76° 43’ 10” W; thence to a point on the north shore 35° 08’ 39” N - 76° 43’ 09” W.

(K) In Vandemere Creek northeast of a line beginning at a point on the east shore 35° 11’ 04” N - 76° 39’ 22” W running 315° (M) to a point on the west shore 35° 11’ 12” N - 76° 39’ 36” W.

(L) In that area bound by a line beginning at a point at the mouth of Vandemere Creek 35° 11’ 04” N - 76° 39’ 22” W, running 216° (M) 200 yards to a point in Bay River 35° 10’ 58” N - 76° 39’ 25” W; thence parallel to the shoreline no more than 200 yards from shore to a point in Bay River northwest of Beacon No. 4 35° 10’ 40” N - 76° 36’ 38” W; thence 344° (M) 200 yards to a point on shore 35° 10’ 45” N - 76° 36’ 42” W.

(M) In that area bound by a line beginning at a point on Sanders Point 35° 11’ 19” N - 76° 35’ 54” W; running 067° (M) 200 yards to a point 35° 11’ 23” N - 76° 35’ 47” W; thence following the shoreline no more than 200 yards from shore to a point in Bay River northwest of Beacon No. 4 35° 10’ 40” N - 76° 36’ 38” W; thence 344° (M) 200 yards to a point on the shore 35° 10’ 45” N - 76° 36’ 42” W.

(N) In that area beginning at a point on shore 35° 11’ 53” N - 76° 35’ 54” W of a line running 170° (M) to a point 35° 11’ 40” N - 76° 35’ 51” W; thence parallel to the shoreline no more than 500 yards from shore to a point 35° 11’ 57” N - 76° 35’ 05” W; thence running 344° (M) to a point on shore at the mouth of Gales Creek 35° 12’ 10” N - 76° 35’ 12” W.

(O) In that area bound by a line beginning at a point on shore at the mouth of Gale Creek 35° 12” 08” N - 76° 34’ 52” W, running 278° (M) 200 yards to a point in Bay River 35° 12’ 08” N - 76° 35’ 02” W; thence running parallel to the shoreline at a distance of 200 yards to a point in Bay River 35° 11’ 32” N - 76° 33’ 24” W; thence running 352° (M) 200 yards to a point on shore at Dump Creek 35° 11’ 39” N - 76° 33’ 25” W.

(P) In Gale Creek except the Intracoastal Waterway north of a line beginning at a point on the west shore 35° 12’ 08” N - 76° 35’ 12” W running 098° (M) to a point on the west shore 35° 12’ 08” N - 76° 34’ 52” W.

(Q) In an area bound by a line beginning at a point on the eastern shore at the mouth of Rockhole Bay 35° 11’ 06” N - 76° 32’ 11” W; thence 180° (M) 600 yards to a point in Bay River 35° 10’ 49” N - 76° 32’ 09” W; thence east with the five foot curve 1100 yards to a point 35° 10’ 36” N - 76° 31’ 30” W; thence 000° (M) 850 yards to a point on Bay Point 35° 11’ 02” N - 76° 31’ 34” W.

(7) In the Neuse River and West Bay Area south and west of a line beginning at a point on Maw Point 35° 09’ 02” N - 76° 32’ 09” W, running 137° (M) through the Maw Point Shoal Day Marker No. 2 and through the Neuse River Entrance Light to a point at the mouth of West Bay 35° 02’ 09” N - 76° 21’ 53” W, pots may be set in the following areas:

(A) All coastal fishing waters northwest of a line beginning at a point at the mouth of Slocum Creek 34° 57’ 02” N - 76° 53’ 42” W, running 029° (M) to a point at the mouth of Beards Creek 35° 00’ 08” N - 76° 52’ 13” W. Pots may also be set in coastal fishing waters of Goose Bay and Upper Broad Creek.

(B) In that area bound by a line beginning at a point on the north shore at Mill Creek 34° 59’ 34” N - 76° 51’ 06” W; thence running 223° (M) approximately 300 yards into the river to a point 34° 59’ 25” N - 76° 51’ 14” W; thence along the six foot depth curve southeast to a point at the rock jetty 34° 58’ 06” N - 76° 49’ 14” W; thence 016° (M) approximately 300 yards to a point on the shore 34° 58’ 17” N - 76° 49’ 12” W.

(C) In that area bound by a line beginning at a point on the north shore approximately 500 yards west of Pierson Point 34° 58’ 32” N - 76° 46’ 38” W; thence running 171° (M) approximately 300 yards into the river to a point 34° 58’ 24” N - 76° 46’ 34” W; thence east and northeast along the six foot curve to a point in the river 34° 58’ 47” N - 76° 45’ 39” W; thence 330° (M) approximately 700 yards to a point on the shore 50 yards west of an existing pier 34° 59’ 04” N - 76° 45’ 54” W.

(D) In that area bound by a line beginning at a point on the north shore east of Dawson Creek Bridge 34° 59’ 34” N - 76° 45’ 12” W; thence running 244° (M) approximately 500 yards to Day Marker No. 4 (entrance to Dawson Creek Channel); thence running east 117° (M) to a point 34° 59’ 22” N - 76° 45’ 19” W; thence east and northeast along the six foot curve to a point 50 yards west of Day Marker No. 3 (channel to Oriental) 35° 01’ 02” N - 76° 41’ 51” W; thence 303° (M) approximately 600 yards to a point on the eastern tip of Windmill Point 35° 01’ 10” N - 76° 42’ 08” W.

(E) In Greens Creek (Oriental) west of a line at the confluence of Greens and Kershaw Creeks beginning at a point on the south shore 35° 01’ 28” N - 76° 42’ 55” W running 005° (M) to a point on the north shore 35° 01’ 38” N - 76° 42’ 54” W, no more than 75 yards from the shoreline east of this line to the Highway 55 bridge.

(F) In that area bound by a line beginning at a point on Whittaker Point 35° 01’ 37” N - 76° 40’ 56” W; thence running 192° (M) approximately 500 yards to a point in the river 35° 01’ 23” N - 76° 40’ 57” W; thence along the six foot depth curve northeast to a point in the river off Orchard Creek 35° 03’ 18” N - 76° 37’ 53” W; thence 280° (M) approximately 900 yards to a point on the eastern tip of Cockle Point 35° 03’ 20” N - 76° 38’ 27” W.

(G) In that area bound by a line beginning at a point on the north shore near the mouth of Orchard Creek 35° 03’ 38” N - 76° 37’

54” W running 177° (M) approximately 400 yards to a point 35° 03’ 27” N - 76° 37’ 54” W; thence along the six foot depth curve to a point eastward; thence 174° (M) 600 yards to a point on the north shore 35° 03’ 56” N - 76° 36’ 42” W.

(H) In that area bound by a line beginning at a point on the north shore approximately 400 yards south of Gum Thicket Creek 35° 04’ 12” N - 76° 36’ 11” W; thence running 132° (M) approximately 600 yards to a point 35° 03’ 55” N - 76° 35’ 48” W; thence along the six foot depth curve eastward to a point 35° 04’ 10” N - 76° 34’ 37” W; thence 304° (M) to a point on the shore 400 yards north of Gum Thicket Creek 35° 04’ 38” N - 76° 35’ 42” W.

(I) In Lower Broad Creek west of a line running 188° (M) through Red Day Marker No. 4. No more than 150 yards from shore between a line running 188° (M) through Red Day Marker No. 4 and a line running 228° (M) through Green Marker No. 3. Pots may not be set in Burton Creek.

(J) Piney Point Shoal Area, in that area bound by a line beginning at a point on the north side of a creek (locally known as Wadin or Persimmon Creek) 35° 07’ 17” N - 76° 33’ 26” W running 115° (M) approximately 300 yards to a point near the six foot depth curve 35° 07’ 15” N - 76° 33’ 16” W; thence south and southeast along the six foot depth curve to a point east of the old lighthouse 35° 05’ 17” N - 76° 32’ 42” W; thence 288° (M) through the old lighthouse to a point on shore north of Red Day Marker No. 2 at the mouth of Broad Creek 35° 05’ 42” N - 76° 35’ 18” W.

(K) In that area bound by a line beginning at a point on the south shore of Maw Bay 35° 08’ 32” N - 76° 32’ 38” W; thence running 114° (M) to Maw Point Shoal Day Marker No. 2; thence 317° (M) to Maw Point 35° 08’ 55” N - 76° 32’ 11” W.

(L) In that area east of Slocum Creek bound by a line beginning at a point 34° 57’ 02” N - 76° 53’ 42” W; thence running 029° (M) approximately 1100 yards to a point 34° 57’ 32” N - 76° 53’ 28” W; thence along the six foot curve to a point 34° 56’ 34” N - 76° 49’ 38” W; thence 176° (M) approximately 300 yards to a point 34° 56’ 26” N - 76° 49’ 35” W.

(M) In that area bound by a line beginning at a point 34° 56’ 22” N - 76° 49’ 05” W, running 057° (M) approximately 1100 yards to Day Marker “2” off Cherry Point; thence 097° (M) approximately 200 yards to a point 34° 56’ 42” N - 76° 48’ 27” W; thence along the six foot curve to a point 34° 55’ 10” N - 76° 45’ 40” W; thence 187° (M) approximately 400 yards to a point on Temple Point 34° 54’ 58” N - 76° 45’ 40” W.

(N) In that area southeast of a line beginning at a point at the mouth of Clubfoot Creek 34° 55’ 20” N - 76° 45’ 09” W running 076° (M) to a point on shore 34° 55’ 37” N - 76° 44’ 23” W.

(O) In Clubfoot Creek south of a line beginning at a point on the east shore 34° 54’ 30” N - 76° 45’ 26” W, running 284° (M) to a point on the west shore 34° 54’ 33” N - 76° 45’ 43” W. Pots may be set 50 yards from shore north of this line.

(P) In that area bound by a line beginning at the western tip of Great Island 34° 55’ 47” N - 76° 44’ 50” W; thence running 275° (M) approximately 500 yards to a point 34° 55’ 46” N - 76° 45’ 07” W; thence 029° (M) approximately 1400 yards to a point 34° 56’ 24” N - 76° 44’ 48” W; thence 120° (M) to a point 34° 56’ 06” N - 76° 43’ 59” W; thence 232° (M) to a point on Great Island 34° 55’ 50” N - 76° 44’ 17” W.

(Q) In that area bound by a line beginning at a point west of Long Creek 34° 55’ 38” N - 76° 44’ 18” W running 064° (M) to a point 34° 55’ 57” N - 76° 43’ 43” W; thence 138° (M) to a point on shore at the mouth of Great Neck Creek 34° 55’ 50” N - 76° 43’ 25” W.

(R) In that area bound by a line beginning at a point at the mouth of Great Neck Creek 34° 55’ 50” N - 76° 43’ 25” W, running 318° (M) 750 yards to a point 34° 56’ 04” N - 76° 43’ 47” W; thence following the shoreline no more than 750 yards from shore to a point 34° 56’ 50” N - 76° 43’ 11” W; thence 116° (M) 750 yards to a point on shore at Courts Creek 34° 56’ 42” N - 76° 42’ 46” W.

(S) In that area bound by a line beginning at a point on Courts Creek 34° 56’ 42” N - 76° 42’ 46” W, running 296° (M) 1000 yards to a point 34° 56’ 52” N - 76° 43’ 20” W; thence parallel with the shoreline no more than 1000 yards to a point 34° 57’ 53” N - 76° 41’ 59” W; thence 190° (M) 1000 yards to a point on shore 34° 57’ 24” N - 76° 42’ 00” W.

(T) In that area bound by a line beginning at a point on shore, 34° 57’ 24” N - 76° 42’ 00” W, running 010° (M) 500 yards to a point 34° 57’ 38” N - 76° 42’ 00” W; thence running parallel to the shoreline no more than 500 yards from shore to a point 34° 57’ 33” N - 76° 41’ 00” W; thence 179° (M) to a point 34° 57’ 23” N - 76° 40’ 58” W; thence 260° (M) to a point on shore at the mouth of Adams Creek 34° 57’ 22” N - 76° 41’ 10” W.

(U) In that area bound by a line beginning at a point on the northeast side of Adams Creek 34° 57’ 30” N - 76° 40’ 36” W; thence 278° (M) 225 yards offshore to a point 34° 57’ 30” N - 76° 40’ 45” W; thence 359° (M) to a point off Winthrop Point 34° 58’ 26” N - 76° 40’ 56” W; thence running 056° (M) to a point off Cedar Point 34° 59’ 07” N - 76° 40’ 04” W; thence 140° (M) to the shoreline on Cedar Point 34° 58’ 50” N - 76° 39’ 41” W.

(V) In that area bound by a line beginning at a point on Cedar Point 34° 58’ 50” N - 76° 39’ 41” W, running 320° (M) 750 yards to a point 34° 59’ 05” N - 76° 40’ 01” W; thence parallel to the shoreline no more than 750 yards from shore to a point 34° 59’ 16” N - 76° 39’ 31” W; thence 167° (M) to a point on shore 34° 58’ 56” N - 76° 39’ 21” W.

(W) In that area bound by a line beginning at a point on shore 34° 58’ 56” N - 76° 39’ 21” W running 347° (M) to a point 34° 59’ 03” N - 76° 39’ 24” W; thence parallel to the shoreline no more than 200 yards from shore to a point 34° 59’ 08” N - 76° 38’ 47” W; thence 184° (M) to a point on shore 34° 59’ 01” N - 76° 35’ 25” W.

(X) In that area bound by a line beginning at a point west of Garbacon Creek 34° 59’ 01” N - 76° 38’ 43” W, running 004° (M) 750 yards to a point 34° 59’ 23” N - 76° 38’ 46” W; thence parallel with the shoreline no more than 750 yards from shore to a point off Browns Creek 35° 00’ 20” N - 76° 33’ 45” W; thence 172° (M) to the shoreline on the west side of Browns Creek 34° 59’ 57” N - 76° 33’ 35” W.

(Y) In that area bound by a line beginning at a point on shore at the mouth of Browns Creek 34° 59’ 55” N - 76° 33’ 29” W, running 352° (M) 750 yards to a point on 35° 00’ 22” N - 76° 33’ 34” W; thence parallel to the shoreline no more than 750 yards from shore to a point 35° 01’ 45” N - 76° 29’ 51” W; thence 162° (M) 750 yards to a point on shore north of Cedar Bay Point 35° 01’ 22” N - 76° 29’ 34” W.

(Z) In that area bound by a line beginning on the north side of Rattan Bay at a point on the shoreline 35° 03’ 45” N - 76° 28’ 32” W; thence running 316° (M) 600 yards offshore to a point 35° 03’ 54” N - 76° 28’ 52” W; thence running parallel with the shoreline 600 yards offshore to a point 35° 04’ 09” N - 76° 26’ 44” W; thence 239° (M) 600 yards to a point on shore 35° 04’ 57” N - 76° 27’ 00” W.

(AA) In Adams Creek:

(i) Between a line running 080° (M) through Red Flasher No. 4 at the mouth of Adams Creek and a line beginning at a point on the south shore of Cedar Creek 34° 55’ 52” N - 76° 38’ 49” W, running 297° (M) to a point on the west shore of Adams Creek 34° 56’ 03” N - 76° 39’ 27” W, no more than 200 yards from shore.

(ii) Between a line beginning at a point at the mouth of Cedar Creek 34° 55’ 52” N - 76° 38’ 49” W; running 297° (M) to a point on the west shore of Adams Creek 34° 56’ 03” N - 76° 39’ 27” W, and a line beginning at a point on the east shore 34° 54’ 55” N - 76° 39’ 36” W; running 280° (M) to a point on the west shore 34° 54’ 55” N - 76° 40’ 01” W; no more than 300 yards from the west shore and 200 yards from the east shore.

(iii) South of a line beginning at a point on the east shore 34° 54’ 55” N - 76° 39’ 36” W, running 280° (M) to a point on the west shore 34° 54’ 55” N - 76° 40’ 01” W, except in the marked navigation channel.

(BB) In South River:

(i) Southeast of a line beginning at a point on the southwest shore 34° 58’ 35” N - 76° 35’ 25” W, running 049° (M) through Red Flasher No. 2 to a point on the northeast shore 34° 59’ 07” N - 76° 34’ 52” W, no more than 200 yards from the shoreline.

(ii) That area bound by a line beginning at a point on the southwest shore 34° 58’ 35” N - 76° 35’ 25” W, running 049° (M) to Red Flasher No. 2; thence running 207° (M) to a point north of Hardy Creek 34° 58’ 13” N - 76° 35’ 22” W; thence following the shoreline to the point of beginning.

(CC) In Turnagain Bay:

(i) Between a line running 077° (M) through Green Flasher No. 1 and a line beginning at a point on the east shore 34° 59’ 04” N - 76° 29’ 01” W; running 276° (M) to a point on the west shore 34° 59’ 03” N - 76° 29’ 28” W, no more than 300 yards on the east shore and 100 yards on the west shore.

(ii) Between a line beginning at a point on the east shore 34° 59’ 04” N - 76° 29’ 01” W, running 276° (M) to a point on the west shore 34° 59’ 03” N - 76° 29’ 28” W, and a line beginning at a point on the east shore 34° 57’ 56” N - 76° 29’ 25” W, running 275° (M) to a point on the west shore 34° 57’ 58” N - 76° 29’ 44” W, no more than 150 yards from shore.

(DD) In West Bay - North Bay area:

(i) In that area bound by a line beginning at a point 35° 02’ 32” N - 76° 22’ 27” W; thence southwest 220° (M) to Marker No. 5 WB; thence southeast 161° (M) to a point in West Bay 35° 00’ 34” N - 76° 21’ 50” W; thence southwest 184° (M) to Deep Bend Point 34° 58’ 36” N - 76° 21’ 48” W; thence following the shoreline of West Bay and North Bay to a point 35° 02’ 09” N - 76° 21’ 53” W; thence 317° (M) to the beginning point.

(ii) In West Bay bound by a line beginning at a point on shore 35° 03’ 34” N - 76° 26’ 24” W, running 033° (M) 100 yards to a point 35° 03’ 38” N - 76° 26’ 23” W; thence parallel to the shoreline no more than 100 yards from shore to a point 35° 00’ 06” N - 76° 25’ 24” W, running 278° (M) to a point on shore 35° 00’ 06” N - 76° 25’ 28” W.

(iii) In West Bay bound by a line beginning at a point 35° 00’ 06” N - 76° 25’ 28” W, running 098° (M) 500 yards to a point 35° 00’ 06” N - 76° 25’ 12” W; thence 171° (M) 2800 yards to a point 34° 58’ 45” N - 76° 24’ 42” W; thence 270° (M) 1400 yards to a point on shore 34° 58’ 39” N - 76° 25’ 22” W.

(EE) In West Thorofare Bay and Merkle Bay south and southeast of a line beginning at a point in West Bay at Tump Point 34° 58’ 42” N - 76° 22’ 49” W; thence southwest 258° (M) to Marker F1 R15 ft. 3M 8 WB; thence southwest 203° (M) to Long Bay Point 34° 57’ 52” N - 76° 24’ 12” W.

(FF) In Long Bay:

(i) In that area bound by a line beginning at a point on the south side of Stump Bay in Long Bay 34° 57’ 13” N - 76° 27’ 12” W; running northeast 077° (M) across Stump Bay to a point 34° 57’ 39” N - 76° 25’ 51” W; thence 032° (M) to a point 34° 58’ 39” N - 76° 25’ 22” W, following the shoreline to the beginning point.

(ii) Southwest of a line beginning on the west shore 34° 57’ 13” N - 76° 27’ 12” W, running 134° (M) to a point on the east shore at Swimming Point 34° 56’ 46” N - 76° 26’ 26” W.

(iii) In the area bound by a line beginning at a point on shore at Swimming Point 34° 56’ 46” N - 76° 26’ 26” W, running 314° (M) 300 yards to a point 34° 56’ 52” N - 76° 26’ 33” W; thence parallel to the shoreline no more than 300 yards from shore to a point 34° 58’ 03” N - 76° 24’ 10” W; thence 203° (M) to Long Bay Point 34° 57’ 52” N - 76° 24’ 12” W.

(GG) Raccoon Island, on the northeast shore between a point on the northwest shore 35° 04’ 27” N - 76° 26’ 16” W and a point on the southwest shore 35° 04’ 00” N - 76° 25’ 33” W from the shoreline no more than 150 yards from shore; on the south and west shores, no more than 50 yards from the shoreline.

(8) Core Sound, Back Sound and the Straits and their tributaries.

(9) North River:

(A) In that area bound by a line beginning at a point on the shore on the east side of North River south of Goose Bay 34° 43’ 35” N - 76° 34’ 55” W; thence running 252° (M) to a point in the river 34° 43’ 28” N - 76° 35’ 14” W; thence running 355° (M) to a point in the river 34° 45’ 20” N - 76° 35’ 45” W; thence running 060° (M) to a point in the river 34° 45’ 45” N - 76° 35’ 04” W; thence running 165° (M) to a point on the shore at the mouth of South Leopard Creek 34° 45’ 36” N - 76° 34’ 59” W; thence with the shoreline to the point of beginning.

(B) In that area bound by a line beginning at a point on the west side of North River near Steep Point 34° 43’ 40” N - 76° 37’ 20” W; thence running 040° (M) to a point 34° 44’ 35” N - 76° 36’ 36” W; thence running 291° M 300 yards to a point 34° 44’ 37” N - 76° 36’ 45” W; thence running 219° (M) to a point 34° 44’ 13” N - 76° 37’ 05” W; thence running 307° (M) to a point 34° 44’ 16” N - 76° 37’ 12” W; thence running 018° (M) to a point 34° 45’ 20” N - 76° 36’ 56” W following the shoreline to the beginning point.

(C) In that area of the North River marshes bound by a line beginning at Red Flasher No. “6” running 038° (M) along the southeast side of Steep Point Channel through Red Day Marker No. “8” to a point 34° 44’ 08” N - 76° 36’ 52” W; thence 125° (M) to a point 34° 43’ 48” N - 76° 36’ 08” W; thence 144° (M) to a point 34° 43’ 30” N - 76° 35’ 47” W; thence 188° (M) to a point 34° 42’ 23” N - 76° 35’ 47” W; thence 221° (M) to Red Flasher No. “56”; thence 278° (M) to a point 34° 42’ 14” N - 76° 36’ 43” W; thence 346° (M) to a point 34° 42’ 45” N - 76° 36’ 58” W; thence 008° (M) to a point 34° 43’ 14” N - 76° 36’ 58” W; thence 318° (M) to the beginning point.

(D) In the area north of a line beginning on the east shore at 34° 46’ 11” N - 76° 35’ 13” W; thence running 270° (M) to a point on the west shore at 34° 46’ 11” N - 76° 37’ 01” W.

(10) Newport River:

(A) In that area east and south of a line beginning at a point on the south shore 34° 45’ 30” N - 76° 43’ 10” W; thence running 026° (M) to a point on the north shore Newport River near Oyster Creek; thence following the shoreline to a point on the west bank of Core Creek at 34° 47’ 05” N - 76° 41’ 14” W; thence running 099° (M) through Marker "21" to a point on the east shore at 34° 47’ 05” N - 76° 41’ 10” W; thence following the shoreline southward to Gallant Point at 34° 44’ 00” N - 76° 40’ 19” W; thence running 271° (M) to Marker "2" at 34° 43’ 58” N - 76° 40’ 32” W; thence running 148° (M) to a point at 34° 43’ 42” N - 76° 40’ 05” W; thence running 182° (M) to a point at 34° 43’ 21” N - 76° 40’ 11” W at the Beaufort Causeway; thence running west with U.S. Highway 70 and the shoreline as the southern border to the point of beginning.

(B) In that area north and east of a line beginning at Penn Point 34° 45' 44" N - 76° 43' 35" W; thence running 022° (M) to a point on the north shore 34° 46' 47" N - 76° 43' 15" W near White Rock.

(11) Bogue Sound:

(A) In that area bound by a line beginning at a point 34° 40’ 33” N - 77° 00’ 48” W on the south shore of Bogue Sound at Archer Point running 014° (M) to Channel Marker No. 37 at 34° 41' 15" N - 77° 00' 43" W and in the east by the Atlantic Beach Bridge.

(B) In that area north of the Intracoastal Waterway beginning at the Atlantic Beach Bridge and running parallel with the Intracoastal Waterway to the Highway 58 Bridge.

(C) In that area east of the Atlantic Beach Bridge at 34° 43’ 08” N – 76° 44’ 12” W; thence 119° (M) to a point at Tar Landing Bay 34° 42’ 30” N – 76° 42’ 12” W; thence 191° (M) to a point on Bogue Banks 34° 42’ 00” N – 76° 42’ 15” W; thence back to the Atlantic Beach Bridge.

(12) Designated primary nursery areas in all coastal fishing waters which are listed in 15A NCAC 03R .0103, except Burton Creek off Lower Broad Creek in Pamlico County.

(13) West and south of the Highway 58 Bridge at Emerald Isle from May 1 through October 31 in areas and during such times as the Fisheries Director shall designate by proclamation.

V. Management Options/ Impacts:

1. No action
2. Change designated pot area descriptions from distance from shore to a 6 foot depth contour.

Recommendations:

The NCDMF and Crustacean Committee voted in November 2001 to take to public hearing changing designated pot areas to depth instead of distance from shore. The proposed strategy would change the designated pot area boundary descriptions to a standardized 6 foot depth contour in Hyde, Beaufort, Pamlico, and Craven counties. On May 12, 2004, the MFC recommended that trawls be prohibited from these areas.

12.18 Appendix 18. PUBLIC EDUCATION

I. Issue:

Blue crabs have become North Carolina's most economically important fishery. As concerns are raised about the viability of the stock, it is essential to instill a conservation ethic regarding the harvest of these crustaceans, as well as raising the awareness level of the general public. A better understanding by commercial and recreational fishermen, of the blue crab's complex life history and strategies implemented by the state to regulate harvest and protect juveniles and spawning stock, is a key element in ensuring this fishery is sustainable.

II. Background:

The North Carolina Division of Marine Fisheries has always been proactive in getting important information out to the fishermen, as well as to the public. This is done in several different ways through news releases, proclamations, brochures, newspaper, magazines, local radio and television stations, as well as through an award winning website that is accessed by 1.8 million Internet users. The division's public information officer (PIO) works with PIOs from other agencies to ensure information important to the citizens of NC is available. Presently, there is life history and stock status information about blue crabs on the website, as well as commercial landing information and a link to a video produced by a fishery resource grant. In recent years, the crab harvest is always prominently featured in the annual release on landings. In addition, to raise the awareness level on the ghost pot issue, a news release was sent out to over 1500 media outlets and interested parties.

III. Discussion:

As the Blue Crab FMP is reviewed, and as the knowledge about blue crabs expands, there are several issues that should be explored to determine what, if any, educational/outreach needs exist. Items selected for consideration by the DMF staff and the Crustacean Committee include findings from recent research on white belly crabs, soft crab shedding system mortality, ghost pots, information about protected species, escape rings in pots, as well as information on the trip ticket program.

<u>White Belly Crabs.</u> Results from recent research on the economic feasibility of retaining white bellies need to be made available to the public. This may be accomplished by working collaboratively with N.C. Sea Grant communications and extension staff to present the findings in *Coastwatch*, as well as sending out a news release to statewide media outlets. A fact sheet on white bellies, advocating crabbers to release them in the spring to allow time for them to grow and be more valuable to the fishery in the fall, could be developed. Photos showing a white belly, compared to crabs that are ready for harvest, would be a key element in educating the public on how to identify these crabs. Facts sheets can be posted on the Web site, handed out at license offices, and distributed at educational exhibits.

<u>Shedding System Mortality.</u> Soft crab shedding has become an increasingly important segment of the blue crab fishery in recent years. Peeler mortality continues to be a principle-limiting factor. Improved survival will translate directly to increased profit and reduced waste of the resource. A joint effort between N.C. Sea Grant and DMF to

publicize methods to reduce mortality through articles and fact sheets would help to address this issue. Publishing a contact list containing N.C. Sea Grant and DMF staff with knowledge of shedding system technology could assist shedders in troubleshooting mortality problems. Additionally, workshops fostering a forum for information transfer among peeler harvesters, shedders, Sea Grant, DMF staff, and researchers may be beneficial to highlight existing knowledge and future research needs. Facts sheets and the contact list could be posted on the Web site, handed out at license offices, and distributed at educational exhibits.

Ghost Pots. This issue has already received considerable public attention through a statewide news release issued in July 2002. More information may be made available to the public as well as to fishermen by placing information about how to minimize the potential of a pot becoming a ghost pot. A fact sheet could be handed out to both commercial and recreational fishermen when they get their licenses. Information about biodegradable panels could be made available to the public and pot manufacturers via fact sheets. The public could also be encouraged to remove ghost pots from the water, but clear directions must be given on the differences between ghost pots and abandoned gear.

Escape Rings. There does not appear to be a compliance problem with escape ring regulations, which require no less than two unobstructed escape rings that are at least 2 5/6 inches inside diameter and located in the opposite outside panels of the upper chamber of the pot. However, crabbers' awareness could be raised about utilizing various escape ring sizes for different waterbodies, as long as the rings met the minimum state requirement.

Protected Species. The state continues to work collaboratively with federal agencies, primarily the National Marine Fisheries Service (NMFS), to get information out to crabbers regarding protected species. The division has worked with NMFS in targeting mailings and developing fact sheets for fishermen about protected species rules, as well as background information about protected species.

Trip Ticket Program. The DMF trip ticket program has been collecting commercial landings data by trip since 1994 and is considered one of the best commercial data sets on the Atlantic coast. This program also collects number of crab pots fished for each crab pot trip. These data have provided valuable information on catch per unit effort in the crab pot fishery as well as trends of pot use by coastal waterbodies throughout NC. This data set is only as good as the data collected and it must be stressed that accurate reporting on trip tickets is essential. News releases and fact sheets could be made available to fishermen and dealers stressing the need and use of this valuable information.

IV. Current Authority:

There are no rules regarding education of the public.

V. Management Options:

1. Expand existing information on DMF website on blue crabs.

2. Incorporate links from the DMF website to other blue crab websites maintained by other groups (i.e., Chesapeake Bay Foundation, Maryland Sea Grant, www.blue-crab.org).

3. Work with agencies and groups such as NC Sea Grant, NC Wildlife Resources Commission, colleges and universities, to publish articles and place information on their websites.

4. Provide fact sheets about certain issues to fishermen when buying licenses (white bellies, protected species, cull rings, ghost pots, trip ticket data, shedding system mortality).

5. Develop an educational display spotlighting varying crabbing issues.

6. Continue to send out news releases about various issues as needed.

VI. Recommendations:

Incorporate links from the DMF Web site to other blue crab websites maintained by other groups (i.e. Chesapeake Bay Foundation, Maryland Sea Grant, www.blue-crab.org).

Work with agencies and groups such as NC Sea Grant, NC Wildlife Resources Commission, colleges and universities, to publish articles and place information on their website.

Provide fact sheets about certain issues to fishermen when buying licenses (white bellies, protected species, escape rings, ghost pots, trip ticket data, shedding system mortality).

Develop an educational display spotlighting varying crabbing issues.

Continue to send out news releases about various issues as needed.

12.19 Appendix 19. PROPOSED RULES

Underlined text in the following rules denotes proposed new language. Strike through text denotes proposed deletions to the rule.

15A NCAC 03I .0101 DEFINITIONS

(a) All definitions set out in G.S. 113, Subchapter IV apply to this Chapter.

(b) The following additional terms are hereby defined:

(1) Commercial Fishing Equipment or Gear. All fishing equipment used in coastal fishing waters except:

(A) Seines less than 30 feet in length;

(B) Collapsible crab traps, a trap used for taking crabs with the largest open dimension no larger than 18 inches and that by design is collapsed at all times when in the water, except when it is being retrieved from or lowered to the bottom;

(C) Spears, Hawaiian slings or similar devices which propel pointed implements by mechanical means, including elastic tubing or bands, pressurized gas or similar means;

(D) A dip net having a handle not more than eight feet in length and a hoop or frame to which the net is attached not exceeding 60 inches along the perimeter;

(E) Hook-and-line and bait-and-line equipment other than multiple-hook or multiple-bait trotline;

(F) A landing net used to assist in taking fish when the initial and primary method of taking is by the use of hook and line;

(G) Cast Nets;

(H) Gigs or other pointed implements which are propelled by hand, whether or not the implement remains in the hand; and

(I) Up to two minnow traps.

(2) Fixed or stationary net. A net anchored or staked to the bottom, or some structure attached to the bottom, at both ends of the net.

(3) Mesh Length. The diagonal distance from the inside of one knot to the outside of the other knot, when the net is stretched hand-tight.

(4) Possess. Any actual or constructive holding whether under claim of ownership or not.

(5) Transport. Ship, carry, or cause to be carried or moved by public or

private carrier by land, sea, or air.

(6) Use. Employ, set, operate, or permit to be operated or employed.

(7) Purse Gill Nets. Any gill net used to encircle fish when the net is closed by the use of a purse line through rings located along the top or bottom line or elsewhere on such net.

(8) Gill Net. A net set vertically in the water to capture fish by entanglement by the gills in its mesh as a result of net design, construction, mesh size, webbing diameter or method in which it is used.

(9) Seine. A net set vertically in the water and pulled by hand or power to capture fish by encirclement and confining fish within itself or against another net, the shore or bank as a result of net design, construction, mesh size, webbing diameter, or method in which it is used.

(10) Internal Coastal Waters or Internal Waters. All coastal fishing waters except the Atlantic Ocean.

(11) Channel Net. A net used to take shrimp which is anchored or attached to the bottom at both ends or with one end anchored or attached to the bottom and the other end attached to a boat.

(12) Dredge. A device towed by engine power consisting of a frame, tooth bar or smooth bar, and catchbag used in the harvest of oysters, clams, crabs, scallops, or conchs.

(13) Mechanical methods for clamming. Includes, but not limited to, dredges, hydraulic clam dredges, stick rakes and other rakes when towed by engine power, patent tongs, kicking with propellers or deflector plates with or without trawls, and any other method that utilizes mechanical means to harvest clams.

(14) Mechanical methods for oystering. Includes, but not limited to, dredges, patent tongs, stick rakes and other rakes when towed by engine power and any other method that utilizes mechanical means to harvest oysters.

(15) Depuration. Purification or the removal of adulteration from live oysters, clams, and mussels by any natural or artificially controlled means.

(16) Peeler Crab. A blue crab that has a soft shell developing under a hard shell and having a definite ~~pink, white, or red line~~ <u>white, pink, or red-line</u> or rim on the outer edge of the back fin or flipper.

(17) Length of finfish.

(A) Total length is determined by measuring along a straight line the distance from the tip of the snout with the mouth closed to the tip of the compressed caudal (tail) fin.

(B) Fork length is determined by measuring along a straight line the distance from the tip of the snout with the mouth closed to the middle of the fork in the caudal (tail) fin.

(C) Fork length for billfish is measured from the tip of the lower jaw to the middle of the fork of the caudal (tail) fin.

(18) Licensee. Any person holding a valid license from the Department to take or deal in marine fisheries resources.

(19) Aquaculture operation. An operation that produces artificially propagated stocks of marine or estuarine resources or obtains such stocks from authorized sources for the purpose of rearing in a controlled environment. A controlled environment provides and maintains throughout the rearing process one or more of the following: predator protection, food, water circulation, salinity, or temperature controls utilizing technology not found in the natural environment.

(20) Critical habitat areas. The fragile estuarine and marine areas that support juvenile and adult populations of fish species, as well as forage species utilized in the food chain. Critical habitats include nursery areas, beds of submerged aquatic vegetation, shellfish producing areas, anadromous fish spawning and anadromous fish nursery areas, in all coastal fishing waters as determined through marine and estuarine survey sampling. Critical habitats are vital for portions, or the entire life cycle, including the early growth and development of fish species.

(A) Beds of submerged aquatic vegetation are those habitats in public trust and estuarine waters vegetated with one or more species of submerged vegetation such as eelgrass (Zostera marina), shoalgrass (Halodule wrightii) and widgeongrass (Ruppia maritima). These vegetation beds occur in both subtidal and intertidal zones and may occur in isolated patches or cover extensive areas. In either case, the bed is defined by the presence of above-ground leaves or the below-ground rhizomes and propagules together with the sediment on which the plants grow. In defining beds of submerged aquatic vegetation, the Marine Fisheries

Commission recognizes the Aquatic Weed Control Act of 1991 (G.S. 113A-220 et. seq.) and does not intend the submerged aquatic vegetation definition and its implementing rules to apply to or conflict with the non-development control activities authorized by that Act.

(B) Shellfish producing habitats are those areas in which shellfish, such as, but not limited to clams, oysters, scallops, mussels, and whelks, whether historically or currently, reproduce and survive because of such favorable conditions as bottom type, salinity, currents, cover, and cultch. Included are those shellfish producing areas closed to shellfish harvest due to pollution.

(C) Anadromous fish spawning areas are those areas where evidence of spawning of anadromous fish has been documented by direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae.

(D) Anadromous fish nursery areas are those areas in the riverine and estuarine systems utilized by post-larval and later juvenile anadromous fish.

(21) Intertidal Oyster Bed. A formation, regardless of size or shape, formed of shell and live oysters of varying density.

(22) North Carolina Trip Ticket. Multiple-part form provided by the Department to fish dealers who are required to record and report transactions on such forms.

(23) Transaction. Act of doing business such that fish are sold, offered for sale, exchanged, bartered, distributed or landed. The point of landing shall be considered a transaction when the fisherman is the fish dealer.

(24) Live rock. Living marine organisms or an assemblage thereof attached to a hard substrate including dead coral or rock (excluding mollusk shells). For example, such living marine organisms associated with hard bottoms, banks, reefs, and live rock may include, but are not limited to:

(A) Animals:

(i) Sponges (Phylum Porifera);

(ii) Hard and Soft Corals, Sea Anemones (Phylum Cnidaria):

(I) Fire corals (Class Hydrozoa);

(II) Gorgonians, whip corals, sea pansies, anemones, Solenastrea (Class Anthozoa);

(iii) Bryozoans (Phylum Bryozoa);

(iv) Tube Worms (Phylum Annelida):

(I) Fan worms (Sabellidae);

(II) Feather duster and Christmas tree worms (Serpulidae);

(III) Sand castle worms (Sabellaridae).

(v) Mussel banks (Phylum Mollusca:Gastropoda);

(vi) Colonial barnacles (Arthropoda: Crustacea: Megabalanus sp.).

(B) Plants:

(i) Coralline algae (Division Rhodophyta);

(ii) Acetabularia sp., Udotea sp., Halimeda sp., Caulerpa sp. (Division Chlorophyta);

(iii) Sargassum sp., Dictyopteris sp., Zonaria sp. (Division Phaeophyta).

(25) Coral:

(A) Fire corals and hydrocorals (Class Hydrozoa);

(B) Stony corals and black corals (Class Anthozoa, Subclass Scleractinia);

(C) Octocorals; Gorgonian corals (Class Anthozoa, Subclass Octocorallia):

(i) Sea fans (Gorgonia sp.);

(ii) Sea whips (Leptogorgia sp. and Lophogorgia sp.);

(iii) Sea pansies (Renilla sp.).

(26) Shellfish production on leases and franchises:

(A) The culture of oysters, clams, scallops, and mussels, on shellfish leases and franchises from a sublegal harvest size to a marketable size.

(B) The transplanting (relay) of oysters, clams, scallops and mussels from designated areas closed due to pollution to shellfish leases and franchises in open waters and the natural cleansing of those shellfish.

(27) Shellfish marketing from leases and franchises. The harvest of oysters,

clams, scallops, mussels, from privately held shellfish bottoms and lawful sale of those shellfish to the public at large or to a licensed shellfish dealer.

(28) Shellfish planting effort on leases and franchises. The process of obtaining authorized cultch materials, seed shellfish, and polluted shellfish stocks and the placement of those materials on privately held shellfish bottoms for increased shellfish production.

(29) Pound Net Set. A fish trap consisting of a holding pen, one or more enclosures, lead or leaders, and stakes or anchors used to support such trap. The lead(s), enclosures, and holding pen are not conical, nor are they supported by hoops or frames.

(30) Educational Institution. A college, university or community college accredited by a regional accrediting institution.

(31) Long Haul Operations. A seine towed between two boats.

(32) Swipe Net Operations. A seine towed by one boat.

(33) Bunt Net. The last encircling net of a long haul or swipe net operation constructed of small mesh webbing. The bunt net is used to form a pen or pound from which the catch is dipped or bailed.

(34) Responsible party. Person who coordinates, supervises or otherwise directs operations of a business entity, such as a corporate officer or executive level supervisor of business operations and the person responsible for use of the issued license in compliance with applicable laws and regulations.

(35) New fish dealer. Any fish dealer making application for a fish dealer license who did not possess a valid dealer license for the previous license year in that name or ocean pier license in that name on June 30, 1999. For purposes of license issuance, adding new categories to an existing fish dealers license does not constitute a new dealer.

(36) Tournament Organizer. The person who coordinates, supervises or otherwise directs a recreational fishing tournament and is the holder of the Recreational Fishing Tournament License.

(37) Holder. A person who has been lawfully issued in their name a license, permit, franchise, lease, or assignment.

(38) Recreational Purpose. A fishing activity has a recreational purpose if it is

not a commercial fishing operation as defined in G.S. 113-168.

(39) Recreational Possession Limit. Includes, but is not limited to, restrictions on size, quantity, season, time period, area, means, and methods where take or possession is for a recreational purpose.

(40) Attended. Being in a vessel, in the water or on the shore immediately adjacent to the gear and immediately available to work the gear and within 100 yards of any gear in use by that person at all times. Attended does not include being in a building or structure.

(41) Commercial Quota. Total quantity of fish allocated for harvest taken by commercial fishing operations.

(42) Recreational Quota. Total quantity of fish allocated for harvest taken for a recreational purpose.

(43) Office of the Division. Physical locations of the Division conducting license transactions in the cities of Wilmington, Washington, Morehead City, Columbia, Wanchese and Elizabeth City, North Carolina. Other businesses or entities designated by the Secretary to issue Recreational Commercial Gear Licenses are not considered Offices of the Division.

(44) Land:

(A) For purposes of trip tickets, when fish reach a licensed seafood dealer, or where the fisherman is the dealer, when the fish reaches the shore or a structure connected to the shore.

(B) For commercial fishing operations, when fish reach the shore or a structure connected to the shore.

(C) For recreational fishing operations, when fish are retained in possession by the fisherman.

(45) Master. Captain of a vessel or one who commands and has control, authority, or power over a vessel.

(46) Regular Closed Oyster Season. The regular closed oyster season occurs from May 15 through October 15, unless amended by the Fisheries Director through proclamation authority.

(47) Assignment. Temporary transferral to another person of privileges under a license for which assignment is permitted. The person assigning the license delegates the privileges permitted under the license to be exercised by the assignee, but retains the power to revoke the

assignment at any time, is still the responsible party for the license.

(48) Transfer. Permanent transferral to another person of privileges under a license for which transfer is permitted. The person transferring the license retains no rights or interest under the license transferred.

(49) Designee. Any person who is under the direct control of the permittee or who is employed by or under contract to the permittee for the purposes authorized by the permit.

(50) Blue Crab Shedding. The process whereby a blue crab emerges soft from its former hard exoskeleton. A shedding operation is any operation that holds peeler crabs in a controlled environment. A controlled environment provides and maintains throughout the shedding process one or more of the following: predator protection, food, water circulation, salinity or temperature controls utilizing proven technology not found in the natural environment. A shedding operation does not include transporting pink or red-line peeler crabs to a permitted shedding operation.

(51) Fyke Net. An entrapment net supported by a series of internal or external hoops or frames, with one or more lead or leaders that guide fish to the net mouth. The net has one or more internal funnel-shaped openings with tapered ends directed inward from the mouth, through which fish enter the enclosure. The portion of the net designed to hold or trap fish is completely enclosed in mesh or webbing, except for the openings for fish passage into or out of the net (funnel area).

(52) Hoop Net. An entrapment net supported by a series of internal or external hoops or frames. The net has one or more internal funnel-shaped openings with tapererd ends directed inward from the mouth, through which fish enter the enclosure. The portion of the net designed to hold or trap the fish is completely enclosed in mesh or webbing, except for the openings for fish passage into or out of the net (funnel area).

History Note: Authority G.S. 113-134; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. March 1, 1995; March 1, 1994; October 1, 1993; July 1, 1993;

Recodified from 15A NCAC 03I .0001 Eff. December 17, 1996;
Amended Eff. April 1, 1999; August 1, 1998; April 1, 1997;
Temporary Amendment Eff. May 1, 2000; August 1, 1999; July 1, 1999;
Amended Eff. August 1, 2000;
Temporary Amendment Eff. August 1, 2000;
Amended Eff. April 1, 2003; April 1, 2001.

15A NCAC 03I .0105 LEAVING DEVICES UNATTENDED

(a) It is unlawful to leave stakes, anchors, nets, buoys, or floating devices in any coastal fishing waters when such devices are not being employed in fishing operations except as otherwise provided by rule or General Statute.

(b) It is unlawful to leave pots in any coastal fishing waters for more than ~~seven~~ five consecutive days, when such pots are not being employed in fishing operations, except upon a timely and sufficient showing of hardship as defined in Subparagraph (b)(2) of this Rule or as otherwise provided by General Statute.

(1) Agents of the Fisheries Director may tag pots with a device approved by the Fisheries Director to aid and assist in the investigation and identification of unattended pots. Any such device attached to a pot by agents of the Fisheries Director must be removed by the individual utilizing the pot within ~~seven~~ five days of attachment in order to demonstrate that the pot is being employed in fishing operations.

(2) For the purposes of Paragraph (b) of this Rule only, a timely and sufficient showing of hardship in a commercial fishing operation shall be written notice given to the Fisheries Director that a mechanical breakdown of the owner's vessel(s) currently registered with the Division of Marine Fisheries under G.S. 113-168.6, or the death, illness or incapacity of the owner of the pot or his immediate family , as defined in G.S. 113-168, prevented or will prevent employing such pots in fishing operations more than ~~seven~~ five consecutive days. The notice, specifying the time needed because of hardship, shall be received by the Fisheries Director before any pot is left in coastal fishing waters for seven consecutive days without being employed in fishing operations, and shall state, in addition to the following, the number and specific location of the pots, and the date on which the pots will be employed in fishing operations or removed from coastal fishing waters:

(A) in case of mechanical breakdown, the notice shall state the commercial fishing vessel registration number, owner's N.C. motor boat registration number of the disabled vessel, date disabled, arrangements being made to repair the vessel or a copy of the work order showing the name, address and phone number of the repair facility; or

(B) in case of the death, illness or incapacity of the owner of the pot or his immediate family, the notice shall state the name of the owner or immediate family member, the date of death, the date and nature of the illness or incapacity. The Fisheries Director may require a doctor's verification of the illness or incapacity.

(3) The Fisheries Director may, by proclamation, modify the ~~seven~~ five day requirement, if necessary due to hurricanes, severe weather or other variable conditions. Failure to employ in fishing operations or remove from coastal fishing waters all pots for which notice of hardship is received under this Rule within 14 days of the expiration of the hardship shall be violation of this Rule.

(c) It is unlawful to set or have any fishing equipment in coastal fishing waters in violation of this Section or which contains edible species of fish unfit for human consumption.

History Note: Authority G.S. 113-134; 113-137; 113-182; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. March 1, 1996;
Recodified from 15A NCAC 03I .0005 Eff. December 17, 1996;
Amended Eff. April 1, 1997;
Temporary Amendment Eff. July 1, 1999;
Amended Eff. August 1, 2000.

15A NCAC 3J .0104 TRAWL NETS

(a) It is unlawful to possess aboard a vessel while using a trawl in internal waters more than 500 pounds of finfish from December 1 through February 28 and 1,000 pounds of finfish from March 1 through November 30.

(b) It is unlawful to use trawl nets:

(1) In internal coastal waters, from 9:00 p.m. on Friday through 5:00 p.m. on Sunday, except that in the areas listed in Subparagraph (b)(5) of this Rule, trawling is prohibited from December 1 through February 28 from one hour after sunset on Friday to one hour before sunrise on Monday.

(2) For the taking of oysters;

(3) In Albemarle Sound and its tributaries;

(4) In the areas described in 15A NCAC 03R .0106, except that the Fisheries Director may, by proclamation, open the area designated in Item (6) of 15A NCAC 03R .0106 to peeler crab trawling; ~~and~~

(5) From December 1 through February 28 from one hour after sunset to one hour before sunrise in the following areas:

(A) In Pungo River, north of a line beginning on Currituck Point at a point 35° 24.5833' N-76° 32.3166' W; running southwesterly to Wades Point to a point 35° 23.3062' N-76° 34.5135' W;

(B) In Pamlico River, west of a line beginning on Wades Point at a point 35° 23.3062' N – 76° 34.5135' W; running southwesterly to Fulford Point to a point 35° 19.8667' N – 76° 35.9333' W;

(C) In Bay River, west of a line beginning on Bay Point at a point 35° 11.0858' N – 76° 31.6155' W; running southerly to Maw Point to a point 35° 09.0214' N – 76° 32.2593' W;

(D) In Neuse River, west of a line beginning on the Minnesott side of the Neuse River Ferry at a point 34° 57.9116' N – 76° 48.2240' W; running southerly to the Cherry Branch side of the Neuse River Ferry to a point 34° 56.3658' N – 76° 48.7110' W; and

(E) In New River, all waters upstream of the N.C. Highway 172 Bridge when opened by ~~proclamation.~~ proclamation; and

(6) In designated pot areas opened to the use of pots by 15A NCAC 03J .0301 (a)(2) and described in 15A NCAC 03R .0107(a)(5), (a)(6), and (a)(7), except subparagraphs (A) and (B).

(c) Minimum mesh sizes for shrimp and crab trawls are presented in 15A NCAC 03L .0103 and .0202.

(d) The Fisheries Director may, with prior consent of the Marine Fisheries Commission, by proclamation, require bycatch reduction devices or codend modifications in trawl nets to reduce the catch of finfish that do not meet size limits or are unmarketable as individual foodfish by reason of size.

(e) It is unlawful to use shrimp trawls for recreational purposes unless the trawl is marked by attaching to the codend (tailbag), one floating buoy, any shade of hot pink in color, which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. The owner shall always be identified on the buoy by using an engraved buoy or by attaching engraved metal or plastic tags to the buoy. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:

(1) Gear owner's current motor boat registration number; or

(2) Owner's U.S. vessel documentation name.

(f) It is unlawful to use shrimp trawls for the taking of blue crabs in internal waters, except that it shall be permissible to take or possess blue crabs incidental to shrimp trawling in accordance with the following limitations:

(1) For individuals using shrimp trawls authorized by a Recreational Commercial Gear License, 50 blue crabs, not to exceed 100 blue crabs if two or more Recreational Commercial Gear License holders are on board.

(2) For commercial operations, crabs may be taken incidental to lawful shrimp trawl operations provided that the weight of the crabs shall not exceed:

(A) 50 percent of the total weight of the combined crab and shrimp catch; or

(B) 300 pounds, whichever is greater.

(g) The Fisheries Director may, by proclamation, close any area to trawling for specific time periods in order to secure compliance with this Rule.

History Note: Authority G.S. 113-134; 113-173; 113-182; 113-221; 143B-289.52;
Eff. February 1, 1991;
Amended Eff. August 1, 1998; May 1, 1997; March 1, 1994; February 1, 1992;

Temporary Amendment Eff. July 1, 1999;
Amended Eff. August 1, 2004; August 1, 2000.

15A NCAC 03J .0106 CHANNEL NETS

(a) It is unlawful to use a channel net:

(1) Until the Fisheries Director specifies by proclamation, time periods and areas for the use of channel nets and other fixed nets for shrimping.

(2) Without yellow light reflective tape on the top portion of each staff or stake and on any buoys located at either end of the net.

(3) With any portion of the set including boats, anchors, cables, ropes or nets within 50 feet of the center line of the Intracoastal Waterway Channel.

(4) In the middle third of any navigation channel marked by Corps of Engineers and/or U.S. Coast Guard.

(5) Unless attended by the fisherman who shall be no more than 50 yards from the net at all times.

(b) It is unlawful to use or possess aboard a vessel any channel net with a corkline exceeding 40 yards.

(c) It is unlawful to leave any channel net, channel net buoy, or channel net stakes in coastal fishing waters from December 1 through March 1.

(d) It is unlawful to use floats or buoys of metallic material for marking a channel net set.

(e) From March 2 through November 30, cables used in a channel net operation shall, when not attached to the net, be connected together and any attached buoy shall be connected by non-metal line.

(f) It is unlawful to leave channel net buoys in coastal fishing waters without yellow light reflective tape on each buoy and without the owner's identification being clearly printed on each buoy. Such identification must include one of the following:

(1) Owner's N.C. motorboat registration number; or

(2) Owner's U.S. vessel documentation name; or

(3) Owner's last name and initials.

(g) It is unlawful to use any channel nets, anchors, lines, or buoys in such a manner as to constitute a hazard to navigation.

(h) It is unlawful to use channel nets for the taking of blue crabs in internal waters, except that it shall be permissible to take or possess blue crabs incidental to channel net operations in accordance with the following limitations:

(1) Crabs may be taken incidental to lawful channel net operations provided that the weight of the crabs shall not exceed:

(A) 50 percent of the total weight of the combined crab and shrimp catch; or

(B) 300 pounds, whichever is greater.

(2) The Fisheries Director may, by proclamation, close any area to channel net use for specific time periods in order to secure compliance with this Paragraph.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. January 1, 1991.

15A NCAC 03J .0301 POTS

(a) It is unlawful to use pots except during time periods and in areas specified herein:

(1) ~~From~~ In Coastal Fishing Waters from ~~November 1~~ December 1 through ~~April 30,~~ May 31, except that all pots shall be removed from internal waters from ~~January 24~~ January 15 through February 7. Fish pots upstream of U.S. 17 Bridge across Chowan River and upstream of a line across the mouth of Roanoke, Cashie, Middle and Eastmost Rivers to the Highway 258 Bridge are exempt from the January 24 through February 7 removal requirement. The Fisheries Director may, by proclamation, reopen various waters to the use of pots after ~~January 28~~ January 19 if it is determined that such waters are free of pots.

(2) From ~~May 1~~ June 1 through ~~October 31~~, November 30, north and east of the Highway 58 Bridge at Emerald Isle:

(A) In areas described in 15A NCAC 03R .0107(a);

(B) To allow for the variable spatial distribution of crustacea and finfish, the Fisheries Director may, by proclamation, specify time periods for or designate the areas described in 15A NCAC 03R .0107(b); or any part thereof, for the use of pots.

(3) From May 1 through ~~October 31~~ November 30 in the Atlantic Ocean and west and south of the Highway 58 Bridge at Emerald Isle in areas and during time periods designated by the Fisheries Director by proclamation.

(b) It is unlawful to use pots:

(1) in any navigation channel marked by State or Federal agencies; or

(2) in any turning basin maintained and marked by the North Carolina Ferry Division.

(c) It is unlawful to use pots in a commercial fishing operation unless each pot is marked by attaching a floating buoy which shall be of solid foam or other solid buoyant material and no less than five inches in diameter and no less than five inches in length. Buoys may be of any color except yellow or hot ~~pink.~~ pink or any combination of colors that include yellow or hot pink. The owner shall always be identified on the attached buoy by using engraved buoys or by engraved metal or plastic tags attached to the buoy. Such identification shall include one of the following:

(1) gear owner's current motorboat registration number; or

(2) gear owner's U.S. vessel documentation name; or

(3) gear owner's last name and initials.

(d) Pots attached to shore or a pier shall be exempt from Subparagraphs (a) (2) and (a) (3) of this Rule.

(e) It is unlawful to use shrimp pots with mesh lengths smaller than one and one-fourth inches stretch or five-eights inch bar.

(f) It is unlawful to use eel pots with mesh sizes smaller than one inch by one-half inch unless such pots contain an escape panel that is at least four inches square with a mesh size of 1 inch by one-half inch located in the outside panel of the upper chamber of rectangular pots and in the rear portion of cylindrical pots, except that not more than two eel pots per fishing operation with a mesh of any size may be used to take eels for bait.

(g) It is unlawful to use crab pots in coastal fishing waters unless each pot contains no less than two unobstructed escape rings that are at least 2 5/16 inches inside diameter and located in the opposite outside panels of the upper chamber of the pot. Peeler pots with a mesh size less than 1 1/2 inches shall be exempt from the escape ring requirement. The Fisheries Director may, by proclamation, exempt the escape ring requirement in order to allow the harvest of peeler crabs or mature female crabs and may impose any or all of the following restrictions:

(1) Specify areas, and

(2) Specify time.

(h) It is unlawful to use more than 150 pots per vessel in Newport River.

(i) It is unlawful to remove crab pots from the water or remove crabs from crab pots between one hour after sunset and one hour before sunrise.

(j) User Conflicts:

(1) ~~The Fisheries Director may, with the prior consent of the Marine Fisheries Commission, by proclamation close any area to the use of pots in order to resolve user conflict.~~ In order to address user conflicts, the Fisheries Director may by proclamation impose any or all of the following restrictions:

(A) Specify time period;

(B) Specify areas;

(C) Specify means and methods; and

(D) Specify time period.

The Fisheries Director shall hold a public meeting in the affected area before issuance of such proclamation.

(2) Any person(s) desiring ~~to close any area to the use of pots~~ user conflict resolution may make such request in writing addressed to the Director of the Division of Marine Fisheries. Such requests shall contain the following information:

(A) A map of the ~~proposed closed~~ affected area including an inset vicinity map showing the location of the ~~proposed closed~~ area with detail sufficient to permit on-site identification and location;

(B) Identification of the user ~~conflicts~~ conflict causing a need for ~~closing the area to the use of pots;~~ user conflict resolution;

(C) Recommended ~~method~~ solution for resolving user ~~conflicts;~~ conflict; and

(D) Name and address of the person(s) requesting ~~the closed area.~~ user conflict resolution.

(3) ~~Person(s) making the requests to close an area for user conflict mediation shall present their request at the public meeting.~~ Upon the requestor's demonstration of a user conflict to the Fisheries Director and within 90 days of the receipt of the information required in subparagraph (j) (2), the Fisheries Director shall issue a public notice of intent to address a user conflict. A public meeting shall be held in the area of the user conflict. The requestor shall present their request at the public meeting, and other parties affected may participate.

(4) The Fisheries Director shall deny the request or submit a ~~proposed~~ proclamation that addresses the results of the public meeting ~~granting the request~~ to the Marine Fisheries Commission for their approval.

(5) Proclamations issued ~~closing or opening areas to the use of pots~~ under ~~Paragraph~~ subparagraph (j) (1) of this Rule shall suspend appropriate rules or portions of rules under 15A NCAC ~~3R~~ 03R .0107 as specified in the proclamation. The provisions of 15A NCAC ~~3I~~ 03I .0102 terminating suspension of a rule as of the next Marine Fisheries Commission meeting and requiring review by the Marine Fisheries Commission at the next meeting shall not apply to proclamations issued under ~~Paragraph~~ subparagraph (j) (1) of this Rule.

(k) It is unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating.

History Note: Authority G. S. 113-134; 113-173; 113-182; 113-221; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. August 1, 1998; May 1, 1997; March 1, 1996; March 1, 1994; October 1, 1992; September 1, 1991;
Temporary Amendment Eff. July 1, 1999;
Amended Eff. August 1, 2000;
Temporary Amendment Eff. September 1, 2000;
Amended Eff. August 1, 2004; August 1, 2002.

15A NCAC 03L .0201 SIZE LIMIT AND CULLING TOLERANCE

(a) It is unlawful to possess blue crabs less than five inches from tip of spike to tip of spike except mature females, soft and peeler crabs and from March 1 through October 31, male crabs to be used as peeler bait. A culling tolerance of not more than 10 percent by number in any container shall be allowed.

(b) All crabs ~~less than~~ <u>not of</u> legal size, except mature female and soft crabs shall be immediately returned to the waters from which taken. Peeler crabs shall be separated where taken and placed in a separate container. <u>White-line peeler crabs shall be separated from pink and red-line peeler crabs where taken and placed in a separate container. A culling tolerance of not more than five percent by number shall be allowed for white-line peelers in the pink and red-line peeler container.</u> Those peeler crabs not separated shall be deemed hard crabs and are not exempt from the size restrictions specified in Paragraph (a) of this Rule.

(c) <u>The Director, may by proclamation, impose the following restrictions when spawning stock biomass falls below the spawner index as defined in the Blue Crab Fishery Management Plan:</u>

<u>(1) It is unlawful to possess mature female blue crabs greater than 6¾ inches from tip of spike to tip of spike from September 1 through April 30. A culling tolerance of not more than five percent by number in any container shall be allowed.</u>

<u>(2) It is unlawful to possess female peeler crabs greater than 5¼ inches from tip of spike to tip of spike from September 1 through April 30.</u>

History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. April 1, 1997; July 1, 1993;
Temporary Amendment Eff. July 1, 1999;
Amended Eff. August 1, 2000.

15A NCAC 03L .0202CRAB TRAWLING

(a) It is unlawful to take or possess aboard a vessel crabs taken by trawl in internal waters except in areas and during such times as the Fisheries Director may specify by proclamation.

(b) It is unlawful to use any crab trawl with a mesh length less than three inches for taking hard crabs, except that the Fisheries Director may, by proclamation, increase the minimum mesh length to ~~not~~ no more than four ~~inches.~~ inches, and specify areas for crab trawl mesh size use.

(c) It is unlawful to use trawls with a mesh length less than two inches or with a combined total headrope length exceeding 25 feet for taking soft or "peeler" crabs.

History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;
Eff. February 1, 1991;
Amended Eff. August 1, 2004; March 1, 1994; September 1, 1991.

15A NCAC 03L .0206PEELER CRABS

(a) It is unlawful to bait peeler pots, except with male blue crabs. Male blue crabs to be used as peeler bait and less than the legal size ~~must~~ shall be kept in a separate container, and may not be landed or sold.

(b) It is unlawful to possess male white line peelers from June 1 through September 1.

(c) It is unlawful to sell white-line peelers.

(d) It is unlawful to possess white-line peelers unless they are to be used by the harvester in the harvester’s permitted blue crab shedding operation.

(e) Peeler crabs shall be separated where taken and placed in a separate container.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Temporary Adoption Eff. July 1, 1999;
Eff. August 1, 2000.

15A NCAC 03R .0107 DESIGNATED POT AREAS

~~(a) As referenced in 15A NCAC 03J .0301, it is unlawful to use pots north and east of the Highway 58 Bridge at Emerald Isle from May 1 through October 31, except in areas described below:~~

~~(1) In Albemarle Sound and tributaries.~~

~~(2) In Roanoke Sound and tributaries.~~

~~(3) In Croatan Sound and tributaries.~~

~~(4) In Pamlico Sound and tributaries, except the following areas and areas further described in Paragraphs (5), (6), and (7) of this Rule:~~

~~(A) In Wysocking Bay:~~

~~(i) Bound by a line beginning at a point on the south shore of Lone Tree Creek 35° 25' 05" N - 76° 02' 05" W running 239° (M) 1000 yards to a point 35° 24' 46" N - 76° 02' 32" W; thence 336° (M) 2200 yards to a point 35° 25' 42" N - 76° 03' 16" W; thence 062° (M) 750 yards to a point on shore 35° 25' 54" N - 76° 02' 54" W; thence following the shoreline and the Lone Tree Creek primary nursery area line to the beginning point;~~

~~(ii) Bound by a line beginning at a point on the south shore of Mt. Pleasant Bay 35° 23' 07" N - 76° 04' 12" W running 083° (M) 1200 yards to a point 35° 23' 17" N - 76° 03' 32" W; thence 023° (M) 2400 yards to a point 35° 24' 27" N - 76° 03' 12" W; thence 299° (M) 1100 yards to a point on shore 35° 24' 38" N - 76° 04' 48" W; thence following the shoreline and the Browns Island and Mt. Pleasant Bay primary nursery area line to the beginning point; except pots may be set no more than 50 yards from the shoreline.~~

~~(B) In Juniper Bay bound by a line beginning at a point on Juniper Bay Point 35° 20' 18" N - 76° 13' 22" W running 275° (M) 2300 yards to a point 35° 20' 15" N - 76° 14' 45" W; thence 007° (M) 2100 yards to Daymarker No. 3; thence 040° (M) 1100 yards to a point on shore 35° 21' 45" N - 76° 14' 24" W; thence following the shoreline and the Buck Creek and the Laurel Creek primary nursery area line to the beginning point.~~

~~(C) In Swanquarter Bay, bound by a line beginning at a point on the north shore~~

~~of Caffee Bay 35° 21’ 57” N - 76° 17’ 44” W; running 191° (M) 800 yards to a point on the south shore 35° 21’ 35” N - 76° 17’ 45” W; thence following the shoreline to a point on shore 35° 21’ 37” N - 76° 18’ 22” W; thence running 247° (M) 1300 yards to a point 35° 21’ 17” N - 76° 19’ 03” W; thence 340° (M) 1350 yards to a point 35° 21’ 51” N - 76° 19’ 27” W; thence 081° (M) 1150 yards to a point on the north shore 35° 22’ 02” N - 76° 18’ 48” W; thence following the shoreline and the primary nursery area line to the beginning point.~~

~~(D) In Deep Cove east of a line beginning at a point on the south shore 35° 20’ 33” N - 76° 22’ 57” W, running 021° (M) 1800 yards to a point on the north shore 35° 21’ 55” N - 76° 22’ 43” W and west of a line beginning at a point on the south shore 35° 20’ 44” N - 76° 22’ 05” W running 003° (M) 1400 yards to a point on the north shore 35° 21’ 26” N - 76° 22’ 11” W.~~

~~(E) Off Striking Bay bound by a line beginning at a point on the west shore of Striking Bay 35° 23’ 20” N - 76° 26’ 59” W running 190° (M) 1900 yards to a point 35° 22’ 23” N - 76° 27’ 00” W; thence 097° (M) 900 yards to Beacon No. 2; thence 127° (M) 1600 yards to a point 35° 21’ 55” N - 76° 25’ 43” W; thence following the shoreline to a point 35° 22’ 30” N - 76° 25’ 14” W; thence 322° (M) 2200 yards to a point 35° 23’ 17” N - 76° 26’ 10” W; thence following the shoreline to a point 35° 23’ 19” N - 76° 26’ 24” W; thence 335° (M) 900 yards to a point 35° 23’ 40” N - 76° 26’ 43” W; thence 059° (M) 500 yards to a point 35° 23’ 30” N - 76° 26’ 58” W; thence following the shoreline to the beginning point.~~

~~(F) In Rose Bay bound by a line beginning at a point southwest of Swan Point 35° 23’ 56” N - 76° 23’ 39” W running 288° (M) 1500 yards to a point on shore 35° 24’ 03” N - 76° 24’ 33” W; thence 162° (M) 1650 yards to a point 35° 23’ 19” N - 76° 24’ 04” W; thence 084° (M) 1350 yards to a point on shore 35° 23’ 29” N - 76° 23’ 17” W; thence following the shoreline to the beginning point.~~

~~(G) In Spencer Bay bound by a line beginning at a point on shore at Willow Point 35° 22’ 26” N - 76° 28’ 00” W running 059° (M) 1700 yards to a point 35° 22’ 57” N - 76° 27’ 13” W; thence 317° (M) 1500 yards to a point 35° 23’ 25” N - 76° 27’ 57” W; thence 243° (M) 1300 yards to a point on shore 35° 23’ 02” N - 76° 28’ 35” W;~~

~~thence following the shoreline and the unnamed primary nursery area line to the beginning point.~~

~~(H) In Big Porpoise Bay bound by a line beginning at a point on shore 35° 15' 58" N - 76° 29' 10" W running 182° (M) 750 yards to Sage Point 35° 15' 36" N - 76° 29' 06" W; thence 116° (M) 850 yards to a point 35° 15' 28" N - 76° 28' 36" W; thence 023° (M) 700 yards to a point on shore 35° 15' 48" N - 76° 28' 30" W; thence following the shoreline to the beginning point.~~

~~(I) In Middle Bay bound by a line beginning at Middle Bay Point 35° 14' 53" N - 76° 28' 41" W; running 210° (M) 3650 yards to Sow Island Point 35° 13' 09" N - 76° 29' 28" W; thence following the shoreline of Middle Bay to Big Fishing Point 35° 14' 05" N - 76° 29' 52" W; thence 008° (M) 1100 yards to a point on the north shore 35° 14' 31" N - 76° 29' 52" W; thence following the shoreline to the point of beginning.~~

~~(J) In Jones Bay bound by a line beginning at a point on Sow Island Point 35° 13' 09" N - 76° 29' 28" W running 204° (M) 2600 yards to Green Flasher No. 5; thence 322° (M) 2450 yards to a point 35° 12' 48" N - 76° 30' 58" W; thence 217° (M) 1200 yards to a point on shore 35° 12' 20" N - 76° 31' 16" W; thence 284° (M) 740 yards to a point on shore 35° 12' 26" N - 76° 31' 46" W; thence following the shoreline to a point 35° 12' 36" N - 76° 32' 01" W; thence 051° (M) 600 yards to a point 35° 12' 52" N - 76° 31' 45" W; thence parallel with the shoreline no more than 600 yards from shore to a point 35° 13' 11" N - 76° 32' 07" W; thence 038° (M) to a point 600 yards from the north shore 35° 13' 39" N - 76° 31' 54" W; thence parallel with the shoreline no more than 600 yards from shore to a point 35° 13' 09" N - 76° 30' 48" W; thence 009° (M) 600 yards to a point on shore 35° 13' 26" N - 76° 30' 47" W; thence following the shoreline to the beginning point.~~

~~(K) In an area bound by a line beginning at Boar Point 35° 12' 07" N - 76° 31' 04" W running 106° (M) 2000 yards to Green Flasher No. 5; thence 200° (M) 2200 yards to a point 35° 10' 56" N - 76° 30' 10" W; thence 282° (M) 2350 yards to Bay Point 35° 11' 02" N - 76°~~

~~31’ 35” W; thence following the shoreline to the beginning point.~~

~~(5) In Pamlico River west of a line from a point on Pamlico Point 35° 18’ 42” N - 76° 28’ 58” W running 009° (M) through Daymarker No. 1 and Willow Point Shoal Beacon to a point on Willow Point 35° 22’ 23” N - 76° 28’ 48” W pots may be used in the following areas:~~

~~(A) In that area bound by a line beginning at a point on the line from Pamlico Point to Willow Point 35° 19’ 24” N - 76° 28’ 56” W running westerly parallel to the shoreline at a distance of no more than 1000 yards to Green Flasher No. 1 at the mouth of Goose Creek; thence 248° (M) parallel to the ICWW to a point off Fulford Point 35° 19’ 59” N - 76° 36’ 41” W; thence 171° (M) to a point on Fulford Point 35° 19’ 41” N -76° 36’ 34” W.~~

~~(B) All coastal waters and tributaries of Oyster Creek, James Creek, Middle Prong and Clark Creek.~~

~~(C) All coastal waters of Goose Creek:~~

~~(i) In that area bound by a line beginning at a point on Reed Hammock 35° 20’ 24” N - 76° 36’ 51” W running 171° (M) 300 yards to a point 35° 20’ 16” N - 76° 36’ 48” W; thence parallel with the shoreline no more than 300 yards from shore to a point 35° 20’ 09” N - 76° 37’ 10” W; thence 302° (M) 300 yards to a point on shore 35° 20’ 13” N - 76° 37’ 19” W.~~

~~(ii) In that area bound by a line beginning at a point on shore 35° 19’ 58” N - 76° 37’ 33” W; running 291° (M) 300 yards to a point 35° 19’ 57” N - 76° 37’ 21” W; thence parallel to the shoreline no more than 300 yards from shore to a point 35° 18’ 16” N - 76° 37’ 16” W; thence 292° (M) to a point on the north shore of Snode Creek 35° 18’ 15” N - 76° 37’ 27” W.~~

~~(iii) In that area bound by a line beginning at a point at the mouth of Goose Creek 35° 19’ 59” N - 76° 36’ 41” W; running 348° (M) to Green Daymarker No. 5; thence south parallel to the shoreline no more than 300 yards from shore to a point 35° 18’ 12” N - 76° 37’ 07” W; thence 112°~~

~~(M) to Store Point 35° 18’ 09” N - 76° 36’ 57” W.~~

~~(iv) Between the line from Store Point to Snode Creek and a line beginning at a point on Long Neck Point running 264° (M) through Beacon No. 15 to Huskie Point from the shoreline to no more than 150 yards from shore.~~

~~(v) All coastal waters southeast of the line from Long Neck Point through Beacon No. 15 to Huskie Point.~~

~~(vi) Campbell Creek - west of a line from a point on Huskie Point 35° 17’ 00” N - 76° 37’ 06” W running 004° (M) to Pasture Point 35° 17’ 20” N - 76° 37’ 08” W, to the Inland-Commercial line.~~

~~(D) All coastal waters bound by a line beginning on Reed Hammock 35° 20’ 24” N -76° 36’ 51” W running 171° (M) to a point 35° 20’ 16” N - 76° 36’ 47” W; thence 100° (M) 800 yards to Red Daymarker No. 4; thence 322° (M) 1200 yards to a point 35° 20’ 40” N - 76° 36’ 48” W; thence westerly parallel to the shoreline at a distance of 300 yards to a point in Bond Creek 35° 20’ 40” N - 76° 41’ 37” W; thence 199° (M) to a point on the south shore of Muddy Creek 35° 20’ 18” N - 76° 41’ 34” W, including all waters of Muddy Creek up to the Inland-Coastal boundary line.~~

~~(E) Along the west shore of Bond Creek from Fork Point to the Coastal-Inland boundary line from the shoreline to no more than 50 yards from shore.~~

~~(F) All coastal waters of South Creek upstream of a line beginning at a point on Fork Point 35° 20’ 45” N - 76° 41’ 47” W running 017° (M) to a point on Hickory Point 35° 21’ 44” N - 76° 41’ 36” W.~~

~~(G) In that area bound by a line beginning at a point at the six foot depth contour south of Hickory Point 35° 21’ 33” N - 76° 41’ 39” W; thence easterly following the six foot depth contour to a point off the east end of Indian Island 35° 21’ 42” N - 76° 38’ 04” W; thence 270° (M) to a point on the east end of Indian Island 35° 21’ 38” N - 76° 38’ 36” W; thence following the shoreline of Indian Island to a point on the west end 35° 21’ 37” N - 76° 39’ 40” W; thence 293° (M) toward Daymarker No. 1 to a point at the six foot depth~~

~~contour 35° 21' 46" N - 76° 40' 16" W; thence following the six foot depth contour in a westerly direction to a point off Long Point 35° 22' 42" N - 76° 42' 44" W; thence 233° (M) to a point on shore 35° 22' 24" N - 76° 43' 05" W.~~

~~(H) Beginning at a point on shore near Long Point 35° 22' 29" N - 76° 43' 25" W, running 001° (M) to a point 300 yards offshore 35° 22' 39" N - 76° 43' 26" W; thence westerly parallel to the shoreline at a distance of 300 yards to a point 35° 22' 39" N - 76° 43' 59" W; thence 209° (M) to a point on shore 35° 22' 30" N - 76° 44' 03" W.~~

~~(I) Beginning at a point on shore 35° 22' 30" N - 76° 44' 27" W, running 355° (M) to a point offshore 35° 22' 40" N - 76° 44' 31" W; thence westerly parallel to the shoreline at a distance of 300 yards to a point 35° 22' 53" N - 76° 45' 00" W; thence running 251° (M) to a point on shore 35° 22' 46" N - 76° 45' 14" W.~~

~~(J) Beginning at a point on shore 35° 22' 54" N - 76° 45' 43" W; running 003° (M) to a point offshore 35° 23' 03" N - 76° 45' 43" W; thence westerly parallel to the shoreline at a distance of 300 yards to the intersection of a line beginning on the north shore at Gum Point 35° 25' 09" N - 76° 45' 33" W; running 210° (M) to a point on the south shore 35° 23' 28" N - 76° 46' 26" W.~~

~~(K) All coastal waters west of a line beginning on the north shore at Gum Point 35° 25' 09" N - 76° 45' 33" W running 210° (M) to a point on the south shore 35° 23' 28" N - 76° 46' 26" W.~~

~~(L) On the north side of Pamlico River bound by a line beginning at the intersection of the line from Gum Point to the south shore 500 yards from shore 35° 24' 55" N - 76° 45' 39" W running easterly parallel to the shoreline at a distance of 500 yards to a point at the six foot contour near Adams Point 35° 23' 08" N - 76° 35' 59" W.~~

~~(M) All waters and tributaries of North Creek except the marked navigation channel.~~

~~(N) In that area bound by a line beginning at a point at the six foot contour near Adams Point 35° 23' 08" N - 76° 35' 59" W running westerly following the six foot depth contour to a point off Wades Point 35° 23' 28" N - 76° 34' 09" W.~~

~~(O) Pungo River:~~

~~(i) Bound by a line beginning at Wades Point 35° 23' 16" N - 76° 34' 30" W running 059° (M) to a point at the six foot depth contour, 35° 23' 28" N - 76° 34' 09" W; thence northerly following the six foot depth contour to a point near Beacon No. 3 35° 25' 44" N - 76° 34' 46" W; thence 272° (M) 950 yards to a point on shore 35° 25' 41" N - 76° 35' 22" W.~~

~~(ii) Bound by a line beginning at a point on shore 35° 25' 50" N - 76° 35' 37" W running 050° (M) 1150 yards to a point at 35° 26' 17" N - 76° 35' 10" W; thence northerly following the six foot depth contour to a point 35° 26' 54" N - 76° 36' 09" W; thence 314° (M) 350 yards to a point on shore 35° 27' 00" N - 76° 36' 20" W.~~

~~(iii) Bound by a line beginning at a point on shore 35° 27' 14" N - 76° 36' 26" W running 077° (M) 800 yards to a point 35° 27' 23" N - 76° 36' 02" W; thence northerly following the six foot depth contour to a point off Windmill Point 35° 30' 50" N - 76° 38' 09" W; thence 076° (M) to a point 200 yards west of Daymarker No. 3 35° 31' 21" N - 76° 36' 37" W; thence 312° (M) to a point at the "Breakwater" 35° 31' 36" N - 76° 37' 05" W.~~

~~(iv) All coastal waters bound by a line beginning at a point at the "Breakwater" 200 yards northeast of Beacon No. 6 35° 31' 47" N - 76° 36' 51" W running 132° (M) to a point 200 yards from Daymarker No. 4 35° 31' 31" N - 76° 36' 21" W; thence running 102° (M) to a point 35° 31' 28" N - 76° 35' 59" W; thence running 010° (M) to Beacon No. 1; thence running 045° (M) 700 yards to a point on shore 35° 32' 22" N - 76° 35' 42" W.~~

~~(v) All coastal waters north and east of a line beginning at a point on shore west of Lower Dowry Creek 35° 32' 25" N - 76° 35' 07" W running 177° (M) 1950 yards to a point 200 yards north of Daymarker No. 11 35°~~

~~31’ 31” N - 76° 35’ 06” W; thence easterly parallel to the marked navigation channel at a distance of 200 yards to a point on the shore northwest of Wilkerson Creek 35° 33’ 13” N - 76° 27’ 36” W.~~

~~(vi) All coastal waters south of a line beginning on shore south of Wilkerson Creek 35° 33’ 02” N - 76° 27’ 20” W running westerly parallel to the marked navigation channel at a distance of 200 yards to a point southeast of Daymarker No. 14 35° 31’ 05” N - 76° 32’ 34” W; thence running 208° (M) to a point on shore 35° 30’ 28” N - 76° 32’ 47” W.~~

~~(vii) All coastal waters bound by a line beginning on shore east of Durants Point 35° 30’ 29” N - 76° 33’ 25” W running 347° (M) to a point southwest of Daymarker No. 12 35° 31’ 08” N - 76° 33’ 53” W; thence westerly parallel to the marked navigation channel at a distance of 200 yards to a point south of Beacon No. 10 35° 31’ 08” N - 76° 35’ 35” W; thence running 185° (M) to a point at the six foot depth contour between Beacon No. 8 and the eastern shore of Pungo River 35° 30’ 08” N - 76° 35’ 28” W; thence following the six foot depth contour to a point 35° 28’ 09” N - 76° 33’ 43” W; thence 127° (M) to a point on shore 35° 28’ 00” N - 76° 33’ 25” W; thence 159° (M) to a point at the six foot depth contour 35° 27’ 40” N - 76° 33’ 12” W including the waters of Slades Creek and its tributaries; thence 209° (M) to a point on shore 35° 27’ 22” N - 76° 33’ 21” W; thence 272° (M) to a point at the six foot depth contour 35° 27’ 18” N - 76° 33’ 53” W; thence southerly following the six foot depth contour to a point south of Sandy Point 35° 26’ 35” N - 76° 33’ 50” W; thence 087° (M) to a point on shore 35° 26’ 38” N - 76° 33’ 34” W.~~

~~(viii) In that area bound by a line beginning at a point on shore 35° 26’ 20” N - 76° 33’ 18” W running 176° (M) to a point at the six foot depth contour~~

~~35° 26’ 05” N - 76° 33’ 13” W; thence southerly following the six foot depth contour throughout Fortescue Creek to a point off Fortescue Creek 35° 25’ 44” N - 76° 32’ 09” W; thence 145° (M) to a point on shore 35° 25’ 36” N - 76° 32’ 01” W.~~

~~(ix) In that area bound by a line beginning at a point on shore 35° 25’ 20” N - 76° 32’ 01” W running 258° (M) to a point at the six foot depth contour 35° 25’ 17” N - 76° 32’ 18” W; thence following the six foot depth contour to the intersection of the line from a point 500 yards west of Currituck Point 35° 24’ 30” N - 76° 32’ 42” W; thence southeasterly parallel to the shoreline and including Abel Bay at a distance of 500 yards to a point at the intersection of the line from Pamlico Point to Willow Point 35° 22’ 09” N - 76° 28’ 48” W.~~

~~(6) In Bay River west of a line beginning at a point on Maw Point 35° 09’ 02” N - 76° 32’ 09” W running 022° (M) to a point on Bay Point 35° 11’ 02” N - 76° 31’ 34” W, pots may be used in the following areas:~~

~~(A) In that area beginning at a point on Maw Point 35° 09’ 02” N - 76° 32’ 09” W; running 018° (M) to Green Daymarker No. 1; thence 223° (M) to a point on shore in Fisherman Bay 35° 09’ 18” N - 76° 32’ 23” W.~~

~~(B) In Fisherman Bay bound by a line beginning at a point on the shore west of Maw Point 35° 09’ 18” N - 76° 33’ 02” W; thence 351° (M) 3200 yards to lighted Beacon No. 3 in Bay River; thence 230° (M) 1200 yards to a point on the shore 35° 10’ 24” N - 76° 34’ 00” W.~~

~~(C) In that area bound by a line beginning at a point on the east shore at the mouth of Bonners Bay 35° 10’ 05” N - 76° 35’ 18” W; thence 306° (M) 300 yards to a point in Bay River, 35° 10’ 10” N - 76° 35’ 30” W; thence parallel to the shoreline no more than 300 yards from shore to a point in Bay River 35° 10’ 40” N - 76° 34’ 42” W; thence 188° (M) to a point on shore 35° 10’ 27” N - 76° 34’ 42” W.~~

~~(D) In Bonner Bay bound by a line beginning at a point on the east shore 35° 10’ 05” N - 76° 35’ 18” W running 306° (M) 200 yards to a point 35° 10’ 09” N - 76° 35’ 25” W; thence parallel to the shoreline no more than 200 yards~~

~~offshore to a point 35° 09’ 16” N - 76° 35’ 18” W; thence 097° (M) 200 yards to a point on shore 35° 09’ 16” N - 76° 35’ 13” W.~~

~~(E) In Bonner Bay, Spring Creek and Long Creek south of a line beginning at a point on the east shore 35° 09’ 16” N - 76° 35’ 13” W running 274° (M) to a point on the west shore 35° 09’ 14” N - 76° 35’ 43” W.~~

~~(F) In Bonner Bay bound by a line beginning at a point on the west shore 35° 09’ 14” N - 76° 35’ 44” W running 094° (M) 100 yards to a point 35° 09’ 13” N - 76° 35’ 39” W; thence parallel to the shoreline no more than 100 yards offshore to a point in Riggs Creek 35° 09’ 15” N - 76° 36’ 08” W; thence 142° (M) to a point on shore 35° 09’ 13” N - 76° 36’ 08” W.~~

~~(G) In that area bound by a line beginning on the south shore of Bay River west of Bell Point 35° 09’ 40” N - 76° 40’ 00” W, running 314° (M) to a point 200 yards offshore 35° 09’ 43” N - 76° 40’ 06” W; thence no more than 200 yards from the shoreline to a point 35° 09’ 53” N - 76° 36’ 45” W; thence 102° (M) to a point 35° 09’ 50” N - 76° 35’ 54” W; thence 181° (M) to a point 35° 09’ 36” N - 76° 35’ 51” W; thence 237° (M) to a point in Riggs Creek 35° 09’ 18” N - 76° 36’ 12” W; thence 322° (M) to a point on shore at the mouth of Riggs Creek 35° 09’ 21” N - 76° 36’ 18” W.~~

~~(H) In that area on the south side of Bay River bound by a line beginning at a point on shore at the confluence of Bay River and Trent Creek 35° 08’ 27” N - 76° 43’ 12” W running 016° (M) 150 yards to a point 35° 08’ 31” N - 76° 43’ 11” W; thence no more than 150 yards from shore to a point 35° 08’ 57” N - 76° 40’ 19” W; thence 116° (M) to a point on shore at Moores Creek 35° 08’ 57” N - 76° 40’ 14” W.~~

~~(I) In Bay River and Trent Creek west of a line beginning at a point on the south shore 35° 08’ 27” N - 76° 43’ 12” W running 016° (M) to a point on the north shore 35° 08’ 41” N - 76° 43’ 09” W.~~

~~(J) In that area on the north shore of Bay River bound by a line beginning at a point west of Vandemere Creek 35° 10’ 53” N - 76° 39’ 42” W running 135° (M) 150 yards to a point 35° 10’ 52” N - 76° 39’ 39” W; thence no more than 150 yards from shore to a point at the confluence of Bay River and Trent Creek 35° 08’ 37” N - 76° 43’ 10” W; thence to a point on the north shore 35° 08’ 39” N - 76° 43’ 09” W.~~

~~(K) In Vandemere Creek northeast of a line beginning at a point on the east~~

~~shore 35° 11’ 04” N - 76° 39’ 22” W running 315° (M) to a point on the west shore 35° 11’ 12” N - 76° 39’ 36” W.~~

~~(L) In that area bound by a line beginning at a point at the mouth of Vandemere Creek 35° 11’ 04” N - 76° 39’ 22” W, running 216° (M) 200 yards to a point in Bay River 35° 10’ 58” N - 76° 39’ 25” W; thence parallel to the shoreline no more than 200 yards from shore to a point in Bay River northwest of Beacon No. 4 35° 10’ 40” N - 76° 36’ 38” W; thence 344° (M) 200 yards to a point on shore 35° 10’ 45” N - 76° 36’ 42” W.~~

~~(M) In that area bound by a line beginning at a point on Sanders Point 35° 11’ 19” N - 76° 35’ 54” W; running 067° (M) 200 yards to a point 35° 11’ 23” N - 76° 35’ 47” W; thence following the shoreline no more than 200 yards from shore to a point in Bay River northwest of Beacon No. 4 35° 10’ 40” N - 76° 36’ 38” W; thence 344° (M) 200 yards to a point on the shore 35° 10’ 45” N - 76° 36’ 42” W.~~

~~(N) In that area beginning at a point on shore 35° 11’ 53” N - 76° 35’ 54” W of a line running 170° (M) to a point 35° 11’ 40” N - 76° 35’ 51” W; thence parallel to the shoreline no more than 500 yards from shore to a point 35° 11’ 57” N - 76° 35’ 05” W; thence running 344° (M) to a point on shore at the mouth of Gales Creek 35° 12’ 10” N - 76° 35’ 12” W.~~

~~(O) In that area bound by a line beginning at a point on shore at the mouth of Gale Creek 35° 12” 08” N - 76° 34’ 52” W, running 278° (M) 200 yards to a point in Bay River 35° 12’ 08” N - 76° 35’ 02” W; thence running parallel to the shoreline at a distance of 200 yards to a point in Bay River 35° 11’ 32” N - 76° 33’ 24” W; thence running 352° (M) 200 yards to a point on shore at Dump Creek 35° 11’ 39” N - 76° 33’ 25” W.~~

~~(P) In Gale Creek except the Intracoastal Waterway north of a line beginning at a point on the west shore 35° 12’ 08” N - 76° 35’ 12” W running 098° (M) to a point on the west shore 35° 12’ 08” N - 76° 34’ 52” W.~~

~~(Q) In an area bound by a line beginning at a point on the eastern shore at the mouth of Rockhole Bay 35° 11’ 06” N - 76° 32’ 11” W; thence 180° (M) 600 yards to a point in Bay River 35° 10’ 49” N - 76° 32’ 09” W; thence east with the five foot curve 1100 yards to a point 35° 10’ 36” N - 76° 31’ 30” W; thence 000° (M) 850 yards to a point on Bay Point 35° 11’ 02” N - 76° 31’ 34” W.~~

~~(7) In the Neuse River and West Bay Area south and west of a line beginning at a point on Maw Point 35° 09' 02" N - 76° 32' 09" W, running 137° (M) through the Maw Point Shoal Day Marker No. 2 and through the Neuse River Entrance Light to a point at the mouth of West Bay 35° 02' 09" N - 76° 21' 53" W, pots may be set in the following areas:~~

~~(A) All coastal fishing waters northwest of a line beginning at a point at the mouth of Slocum Creek 34° 57' 02" N - 76° 53' 42" W, running 029° (M) to a point at the mouth of Beards Creek 35° 00' 08" N - 76° 52' 13" W. Pots may also be set in coastal fishing waters of Goose Bay and Upper Broad Creek.~~

~~(B) In that area bound by a line beginning at a point on the north shore at Mill Creek 34° 59' 34" N - 76° 51' 06" W; thence running 223° (M) approximately 300 yards into the river to a point 34° 59' 25" N - 76° 51' 14" W; thence along the six foot depth curve southeast to a point at the rock jetty 34° 58' 06" N - 76° 49' 14" W; thence 016° (M) approximately 300 yards to a point on the shore 34° 58' 17" N - 76° 49' 12" W.~~

~~(C) In that area bound by a line beginning at a point on the north shore approximately 500 yards west of Pierson Point 34° 58' 32" N - 76° 46' 38" W; thence running 171° (M) approximately 300 yards into the river to a point 34° 58' 24" N - 76° 46' 34" W; thence east and northeast along the six foot curve to a point in the river 34° 58' 47" N - 76° 45' 39" W; thence 330° (M) approximately 700 yards to a point on the shore 50 yards west of an existing pier 34° 59' 04" N - 76° 45' 54" W.~~

~~(D) In that area bound by a line beginning at a point on the north shore east of Dawson Creek Bridge 34° 59' 34" N - 76° 45' 12" W; thence running 244° (M) approximately 500 yards to Day Marker No. 4 (entrance to Dawson Creek Channel); thence running east 117° (M) to a point 34° 59' 22" N - 76° 45' 19" W; thence east and northeast along the six foot curve to a point 50 yards west of Day Marker No. 3 (channel to Oriental) 35° 01' 02" N - 76° 41' 51" W; thence 303° (M) approximately 600 yards to a point on the eastern tip of Windmill Point 35° 01' 10" N - 76° 42' 08" W.~~

~~(E) In Greens Creek (Oriental) west of a line at the confluence of Greens and Kershaw Creeks beginning at a point on the south shore 35° 01' 28" N - 76° 42' 55" W running 005° (M) to a point on the north shore 35° 01' 38" N~~

~~- 76° 42' 54" W, no more than 75 yards from the shoreline east of this line to the Highway 55 bridge.~~

~~(F) In that area bound by a line beginning at a point on Whittaker Point 35° 01' 37" N - 76° 40' 56" W; thence running 192° (M) approximately 500 yards to a point in the river 35° 01' 23" N - 76° 40' 57" W; thence along the six foot depth curve northeast to a point in the river off Orchard Creek 35° 03' 18" N - 76° 37' 53" W; thence 280° (M) approximately 900 yards to a point on the eastern tip of Cockle Point 35° 03' 20" N - 76° 38' 27" W.~~

~~(G) In that area bound by a line beginning at a point on the north shore near the mouth of Orchard Creek 35° 03' 38" N - 76° 37' 54" W running 177° (M) approximately 400 yards to a point 35° 03' 27" N - 76° 37' 54" W; thence along the six foot depth curve to a point eastward; thence 174° (M) 600 yards to a point on the north shore 35° 03' 56" N - 76° 36' 42" W.~~

~~(H) In that area bound by a line beginning at a point on the north shore approximately 400 yards south of Gum Thicket Creek 35° 04' 12" N - 76° 36' 11" W; thence running 132° (M) approximately 600 yards to a point 35° 03' 55" N - 76° 35' 48" W; thence along the six foot depth curve eastward to a point 35° 04' 10" N - 76° 34' 37" W; thence 304° (M) to a point on the shore 400 yards north of Gum Thicket Creek 35° 04' 38" N - 76° 35' 42" W.~~

~~(I) In Lower Broad Creek west of a line running 188° (M) through Red Day Marker No. 4. No more than 150 yards from shore between a line running 188° (M) through Red Day Marker No. 4 and a line running 228° (M) through Green Marker No. 3. Pots may not be set in Burton Creek.~~

~~(J) Piney Point Shoal Area, in that area bound by a line beginning at a point on the north side of a creek (locally known as Wadin or Persimmon Creek) 35° 07' 17" N - 76° 33' 26" W running 115° (M) approximately 300 yards to a point near the six foot depth curve 35° 07' 15" N - 76° 33' 16" W; thence south and southeast along the six foot depth curve to a point east of the old lighthouse 35° 05' 17" N - 76° 32' 42" W; thence 288° (M) through the old lighthouse to a point on shore north of Red Day Marker No. 2 at the mouth of Broad Creek 35° 05' 42" N - 76° 35' 18" W.~~

~~(K) In that area bound by a line beginning at a point on the south shore of Maw Bay 35° 08' 32" N - 76° 32' 38" W; thence running 114° (M) to Maw~~

~~Point Shoal Day Marker No. 2; thence 317° (M) to Maw Point 35° 08' 55" N - 76° 32' 11" W.~~

~~(L) In that area east of Slocum Creek bound by a line beginning at a point 34° 57' 02" N - 76° 53' 42" W; thence running 029° (M) approximately 1100 yards to a point 34° 57' 32" N - 76° 53' 28" W; thence along the six foot curve to a point 34° 56' 34" N - 76° 49' 38" W; thence 176° (M) approximately 300 yards to a point 34° 56' 26" N - 76° 49' 35" W.~~

~~(M) In that area bound by a line beginning at a point 34° 56' 22" N - 76° 49' 05" W, running 057° (M) approximately 1100 yards to Day Marker "2" off Cherry Point; thence 097° (M) approximately 200 yards to a point 34° 56' 42" N - 76° 48' 27" W; thence along the six foot curve to a point 34° 55' 10" N - 76° 45' 40" W; thence 187° (M) approximately 400 yards to a point on Temple Point 34° 54' 58" N - 76° 45' 40" W.~~

~~(N) In that area southeast of a line beginning at a point at the mouth of Clubfoot Creek 34° 55' 20" N - 76° 45' 09" W running 076° (M) to a point on shore 34° 55' 37" N - 76° 44' 23" W.~~

~~(O) In Clubfoot Creek south of a line beginning at a point on the east shore 34° 54' 30" N - 76° 45' 26" W, running 284° (M) to a point on the west shore 34° 54' 33" N - 76° 45' 43" W. Pots may be set 50 yards from shore north of this line.~~

~~(P) In that area bound by a line beginning at the western tip of Great Island 34° 55' 47" N - 76° 44' 50" W; thence running 275° (M) approximately 500 yards to a point 34° 55' 46" N - 76° 45' 07" W; thence 029° (M) approximately 1400 yards to a point 34° 56' 24" N - 76° 44' 48" W; thence 120° (M) to a point 34° 56' 06" N - 76° 43' 59" W; thence 232° (M) to a point on Great Island 34° 55' 50" N - 76° 44' 17" W.~~

~~(Q) In that area bound by a line beginning at a point west of Long Creek 34° 55' 38" N - 76° 44' 18" W running 064° (M) to a point 34° 55' 57" N - 76° 43' 43" W; thence 138° (M) to a point on shore at the mouth of Great Neck Creek 34° 55' 50" N - 76° 43' 25" W.~~

~~(R) In that area bound by a line beginning at a point at the mouth of Great Neck Creek 34° 55' 50" N - 76° 43' 25" W, running 318° (M) 750 yards to a point 34° 56' 04" N - 76° 43' 47" W; thence following the shoreline no more than 750 yards from shore to a point 34° 56' 50" N - 76° 43' 11" W;~~

~~thence 116° (M) 750 yards to a point on shore at Courts Creek 34° 56' 42" N - 76° 42' 46" W.~~

~~(S) In that area bound by a line beginning at a point on Courts Creek 34° 56' 42" N - 76° 42' 46" W, running 296° (M) 1000 yards to a point 34° 56' 52" N - 76° 43' 20" W; thence parallel with the shoreline no more than 1000 yards to a point 34° 57' 53" N - 76° 41' 59" W; thence 190° (M) 1000 yards to a point on shore 34° 57' 24" N - 76° 42' 00" W.~~

~~(T) In that area bound by a line beginning at a point on shore, 34° 57' 24" N - 76° 42' 00" W, running 010° (M) 500 yards to a point 34° 57' 38" N - 76° 42' 00" W; thence running parallel to the shoreline no more than 500 yards from shore to a point 34° 57' 33" N - 76° 41' 00" W; thence 179° (M) to a point 34° 57' 23" N - 76° 40' 58" W; thence 260° (M) to a point on shore at the mouth of Adams Creek 34° 57' 22" N - 76° 41' 10" W.~~

~~(U) In that area bound by a line beginning at a point on the northeast side of Adams Creek 34° 57' 30" N - 76° 40' 36" W; thence 278° (M) 225 yards offshore to a point 34° 57' 30" N - 76° 40' 45" W; thence 359° (M) to a point off Winthrop Point 34° 58' 26" N - 76° 40' 56" W; thence running 056° (M) to a point off Cedar Point 34° 59' 07" N - 76° 40' 04" W; thence 140° (M) to the shoreline on Cedar Point 34° 58' 50" N - 76° 39' 41" W.~~

~~(V) In that area bound by a line beginning at a point on Cedar Point 34° 58' 50" N - 76° 39' 41" W, running 320° (M) 750 yards to a point 34° 59' 05" N - 76° 40' 01" W; thence parallel to the shoreline no more than 750 yards from shore to a point 34° 59' 16" N - 76° 39' 31" W; thence 167° (M) to a point on shore 34° 58' 56" N - 76° 39' 21" W.~~

~~(W)In that area bound by a line beginning at a point on shore 34° 58' 56" N - 76° 39' 21" W running 347° (M) to a point 34° 59' 03" N - 76° 39' 24" W; thence parallel to the shoreline no more than 200 yards from shore to a point 34° 59' 08" N - 76° 38' 47" W; thence 184° (M) to a point on shore 34° 59' 01" N - 76° 35' 25" W.~~

~~(X) In that area bound by a line beginning at a point west of Garbacon Creek 34° 59' 01" N - 76° 38' 43" W, running 004° (M) 750 yards to a point 34° 59' 23" N - 76° 38' 46" W; thence parallel with the shoreline no more than 750 yards from shore to a point off Browns Creek 35° 00' 20" N - 76° 33' 45" W; thence 172° (M) to the shoreline on the west side of Browns Creek~~

~~34° 59’ 57” N - 76° 33’ 35” W.~~

~~(Y) In that area bound by a line beginning at a point on shore at the mouth of Browns Creek 34° 59’ 55” N - 76° 33’ 29” W, running 352° (M) 750 yards to a point on 35° 00’ 22” N - 76° 33’ 34” W; thence parallel to the shoreline no more than 750 yards from shore to a point 35° 01’ 45” N - 76° 29’ 51” W; thence 162° (M) 750 yards to a point on shore north of Cedar Bay Point 35° 01’ 22” N - 76° 29’ 34” W.~~

~~(Z) In that area bound by a line beginning on the north side of Rattan Bay at a point on the shoreline 35° 03’ 45” N - 76° 28’ 32” W; thence running 316° (M) 600 yards offshore to a point 35° 03’ 54” N - 76° 28’ 52” W; thence running parallel with the shoreline 600 yards offshore to a point 35° 04’ 09” N - 76° 26’ 44” W; thence 239° (M) 600 yards to a point on shore 35° 04’ 57” N - 76° 27’ 00” W.~~

~~(AA) In Adams Creek:~~

~~(i) Between a line running 080° (M) through Red Flasher No. 4 at the mouth of Adams Creek and a line beginning at a point on the south shore of Cedar Creek 34° 55’ 52” N - 76° 38’ 49” W, running 297° (M) to a point on the west shore of Adams Creek 34° 56’ 03” N - 76° 39’ 27” W, no more than 200 yards from shore.~~

~~(ii) Between a line beginning at a point at the mouth of Cedar Creek 34° 55’ 52” N - 76° 38’ 49” W; running 297° (M) to a point on the west shore of Adams Creek 34° 56’ 03” N - 76° 39’ 27” W, and a line beginning at a point on the east shore 34° 54’ 55” N - 76° 39’ 36” W; running 280° (M) to a point on the west shore 34° 54’ 55” N - 76° 40’ 01” W; no more than 300 yards from the west shore and 200 yards from the east shore.~~

~~(iii) South of a line beginning at a point on the east shore 34° 54’ 55” N - 76° 39’ 36” W, running 280° (M) to a point on the west shore 34° 54’ 55” N - 76° 40’ 01” W, except in the marked navigation channel.~~

~~(BB) In South River:~~

~~(i) Southeast of a line beginning at a point on the southwest shore 34° 58’ 35” N - 76° 35’ 25” W, running 049° (M) through Red Flasher No. 2 to a point on the northeast shore 34° 59’ 07” N - 76° 34’ 52” W, no more than 200 yards from the shoreline.~~

~~(ii) That area bound by a line beginning at a point on the southwest shore 34° 58’ 35” N - 76° 35’ 25” W, running 049° (M) to Red Flasher No. 2; thence running 207° (M) to a point north of Hardy Creek 34° 58’ 13” N - 76° 35’ 22” W; thence following the shoreline to the point of beginning.~~

~~(CC) In Turnagain Bay:~~

~~(i) Between a line running 077° (M) through Green Flasher No. 1 and a line beginning at a point on the east shore 34° 59’ 04” N - 76° 29’ 01” W; running 276° (M) to a point on the west shore 34° 59’ 03” N - 76° 29’ 28” W, no more than 300 yards on the east shore and 100 yards on the west shore.~~

~~(ii) Between a line beginning at a point on the east shore 34° 59’ 04” N - 76° 29’ 01” W, running 276° (M) to a point on the west shore 34° 59’ 03” N - 76° 29’ 28” W, and a line beginning at a point on the east shore 34° 57’ 56” N - 76° 29’ 25” W, running 275° (M) to a point on the west shore 34° 57’ 58” N - 76° 29’ 44” W, no more than 150 yards from shore.~~

~~(DD) In West Bay - North Bay area:~~

~~(i) In that area bound by a line beginning at a point 35° 02’ 32” N - 76° 22’ 27” W; thence southwest 220° (M) to Marker No. 5 WB; thence southeast 161° (M) to a point in West Bay 35° 00’ 34” N - 76° 21’ 50” W; thence southwest 184° (M) to Deep Bend Point 34° 58’ 36” N - 76° 21’ 48” W; thence following the shoreline of West Bay and North Bay to a point 35° 02’ 09” N - 76° 21’ 53” W; thence 317° (M) to the beginning point.~~

~~(ii) In West Bay bound by a line beginning at a point on shore 35° 03’ 34” N - 76° 26’ 24” W, running 033° (M) 100 yards to a point 35° 03’ 38” N - 76° 26’ 23” W; thence parallel to the shoreline no more than 100 yards from shore to a point 35° 00’ 06” N - 76° 25’ 24” W, running 278° (M) to a point on shore 35° 00’ 06” N - 76° 25’ 28” W.~~

~~(iii) In West Bay bound by a line beginning at a point 35° 00' 06" N - 76° 25' 28" W, running 098° (M) 500 yards to a point 35° 00' 06" N - 76° 25' 12" W; thence 171° (M) 2800 yards to a point 34° 58' 45" N - 76° 24' 42" W; thence 270° (M) 1400 yards to a point on shore 34° 58' 39" N - 76° 25' 22" W.~~

~~(EE) In West Thorofare Bay and Merkle Bay south and southeast of a line beginning at a point in West Bay at Tump Point 34° 58' 42" N - 76° 22' 49" W; thence southwest 258° (M) to Marker F1 R15 ft. 3M 8 WB; thence southwest 203° (M) to Long Bay Point 34° 57' 52" N - 76° 24' 12" W.~~

~~(FF) In Long Bay:~~

~~(i) In that area bound by a line beginning at a point on the south side of Stump Bay in Long Bay 34° 57' 13" N - 76° 27' 12" W; running northeast 077° (M) across Stump Bay to a point 34° 57' 39" N - 76° 25' 51" W; thence 032° (M) to a point 34° 58' 39" N - 76° 25' 22" W, following the shoreline to the beginning point.~~

~~(ii) Southwest of a line beginning on the west shore 34° 57' 13" N - 76° 27' 12" W, running 134° (M) to a point on the east shore at Swimming Point 34° 56' 46" N - 76° 26' 26" W.~~

~~(iii) In the area bound by a line beginning at a point on shore at Swimming Point 34° 56' 46" N - 76° 26' 26" W, running 314° (M) 300 yards to a point 34° 56' 52" N - 76° 26' 33" W; thence parallel to the shoreline no more than 300 yards from shore to a point 34° 58' 03" N - 76° 24' 10" W; thence 203° (M) to Long Bay Point 34° 57' 52" N - 76° 24' 12" W.~~

~~(GG) Raccoon Island, on the northeast shore between a point on the northwest shore 35° 04' 27" N - 76° 26' 16" W and a point on the southwest shore 35° 04' 00" N - 76° 25' 33" W from the shoreline no more than 150 yards from shore; on the south and west shores, no more than 50 yards from the shoreline.~~

~~(8) Core Sound, Back Sound and the Straits and their tributaries.~~

~~(9) North River:~~

~~(A) In that area bound by a line beginning at a point on the shore on the east side of North River south of Goose Bay 34° 43' 35" N - 76° 34' 55" W; thence running 252° (M) to a point in the river 34° 43' 28" N - 76° 35' 14"~~

~~W; thence running 355° (M) to a point in the river 34° 45' 20" N - 76° 35' 45" W; thence running 060° (M) to a point in the river 34° 45' 45" N - 76° 35' 04" W; thence running 165° (M) to a point on the shore at the mouth of South Leopard Creek 34° 45' 36" N - 76° 34' 59" W; thence with the shoreline to the point of beginning.~~

~~(B) In that area bound by a line beginning at a point on the west side of North River near Steep Point 34° 43' 40" N - 76° 37' 20" W; thence running 040° (M) to a point 34° 44' 35" N - 76° 36' 36" W; thence running 291° M 300 yards to a point 34° 44' 37" N - 76° 36' 45" W; thence running 219° (M) to a point 34° 44' 13" N - 76° 37' 05" W; thence running 307° (M) to a point 34° 44' 16" N - 76° 37' 12" W; thence running 018° (M) to a point 34° 45' 20" N - 76° 36' 56" W following the shoreline to the beginning point.~~

~~(C) In that area of the North River marshes bound by a line beginning at Red Flasher No. "6" running 038° (M) along the southeast side of Steep Point Channel through Red Day Marker No. "8" to a point 34° 44' 08" N - 76° 36' 52" W; thence 125° (M) to a point 34° 43' 48" N - 76° 36' 08" W; thence 144° (M) to a point 34° 43' 30" N - 76° 35' 47" W; thence 188° (M) to a point 34° 42' 23" N - 76° 35' 47" W; thence 221° (M) to Red Flasher No. "56"; thence 278° (M) to a point 34° 42' 14" N - 76° 36' 43" W; thence 346° (M) to a point 34° 42' 45" N - 76° 36' 58" W; thence 008° (M) to a point 34° 43' 14" N - 76° 36' 58" W; thence 318° (M) to the beginning point.~~

~~(D) In the area north of a line beginning on the east shore at 34° 46' 11" N - 76° 35' 13" W; thence running 270° (M) to a point on the west shore at 34° 46' 11" N - 76° 37' 01" W.~~

~~(10) Newport River:~~

~~(A) In that area east and south of a line beginning at a point on the south shore 34° 45' 30" N - 76° 43' 10" W; thence running 026° (M) to a point on the north shore Newport River near Oyster Creek; thence following the shoreline to a point on the west bank of Core Creek at 34° 47' 05" N - 76° 41' 14" W; thence running 099° (M) through Marker "21" to a point on the east shore at 34° 47' 05" N - 76° 41' 10" W; thence following the shoreline southward to Gallant Point at 34° 44' 00" N - 76° 40' 19" W; thence running 271° (M) to Marker "2" at 34° 43' 58" N - 76° 40' 32" W; thence~~

~~running 148° (M) to a point at 34° 43' 42" N - 76° 40' 05" W; thence running 182° (M) to a point at 34° 43' 21" N - 76° 40' 11" W at the Beaufort Causeway; thence running west with U.S. Highway 70 and the shoreline as the southern border to the point of beginning.~~

~~(B) In that area north and east of a line beginning at Penn Point 34° 45' 44" N - 76° 43' 35" W; thence running 022° (M) to a point on the north shore 34° 46' 47" N - 76° 43' 15" W near White Rock.~~

~~(11) Bogue Sound:~~

~~(A) In that area bound by a line beginning at a point 34° 40' 33" N - 77° 00' 48" W on the south shore of Bogue Sound at Archer Point running 014° (M) to Channel Marker No. 37 at 34° 41' 15" N - 77° 00' 43" W and in the east by the Atlantic Beach Bridge.~~

~~(B) In that area north of the Intracoastal Waterway beginning at the Atlantic Beach Bridge and running parallel with the Intracoastal Waterway to the Highway 58 Bridge.~~

~~(C) In that area east of the Atlantic Beach Bridge at 34° 43' 08" N – 76° 44' 12" W; thence 119° (M) to a point at Tar Landing Bay 34° 42' 30" N – 76° 42' 12" W; thence 191° (M) to a point on Bogue Banks 34° 42' 00" N – 76° 42' 15" W; thence back to the Atlantic Beach Bridge.~~

~~(12) Designated primary nursery areas in all coastal fishing waters which are listed in 15A NCAC 03R .0103, except Burton Creek off Lower Broad Creek in Pamlico County.~~

~~(13) West and south of the Highway 58 Bridge at Emerald Isle from May 1 through October 31 in areas and during such times as the Fisheries Director shall designate by proclamation.~~

~~(b) It is unlawful to use pots from May 1 through October 31 in the areas described in Subparagraphs (b)(1) through (6) of this Rule except in accordance with 15A NCAC 03J .0301(a)(2)(B):~~

~~(1) In Wysocking Bay:~~

~~(A) Bound by a line beginning at a point on the south shore of Lone Tree Creek 35° 25' 05" N - 76° 02' 05" W running 239° (M) 1000 yards to a point 35° 24' 46" N - 76° 02' 32" W; thence 336° (M) 2200 yards to a point 35° 25' 42" N - 76° 03' 16" W; thence 062° (M) 750 yards to a point on shore 35° 25' 54" N - 76° 02' 54" W; thence following the shoreline and~~

~~the Lone Tree Creek primary nursery area line to the beginning point;~~

~~(B) Bound by a line beginning at a point on the south shore of Mt. Pleasant Bay 35° 23’ 07” N - 76° 04’ 12” W running 083° (M) 1200 yards to a point 35° 23’ 17” N - 76° 03’ 32” W; thence 023° (M) 2400 yards to a point 35° 24’ 35” N - 76° 04’ 00” W; thence 299° (M) 1100 yards to point on shore 35° 24’ 38” N - 76° 04’ 48” W; thence following the shoreline and the Browns Island and Mt. Pleasant Bay primary nursery area line to the beginning point; except pots may be set no more than 50 yards from the shoreline;~~

~~(2) In Juniper Bay bound by a line beginning at a point on Juniper Bay Point 35° 20’ 18” N - 76° 13’ 22” W running 275° (M) 2300 yards to a point 35° 20’ 15” N - 76° 14’ 45” W; thence 007° (M) 2100 yards to Daymarker No. 3; thence 040° (M) 1100 yards to a point on shore 35° 21’ 45” N - 76° 14’ 24” W; thence following the shoreline and the Buck Creek primary nursery area line to the beginning point;~~

~~(3) In Rose Bay bound by a line beginning at a point southwest of Swan Point 35° 23’ 56” N - 76° 23’ 39” W running 288° (M) 1500 yards to a point 35° 24’ 03” N - 76° 24’ 33” W; thence 162° (M) 1650 yards to a point 35° 23’ 19” N - 76° 24’ 04” W; thence 084° (M) 1350 yards to a point on shore 35° 23’ 29” N - 76° 23’ 17” W; thence following the shoreline to the beginning point;~~

~~(4) In Spencer Bay bound by a line beginning at a point on shore at Willow Point 35° 22’ 26” N - 76° 28’ 00” W running 059° (M) 1700 yards to a point 35° 22’ 57” N - 76° 27’ 13” W; thence 317° (M) 1500 yards to a point 35° 23’ 25” N - 76° 27’ 57” W; thence 243° (M) 1300 yards to a point on shore 35° 23’ 02” N - 76° 28’ 35” W; thence following the shoreline to the beginning point;~~

~~(5) In Bay River, beginning at a point on shore at Moore Creek 35° 08’ 51” N - 76° 40’ 14” W; running 296° (M) to a point 35° 08’ 59” N - 76° 50’ 19” W; thence no more than 150 yards from shore to a point 35° 09’ 43” N - 76° 40’ 06” W; thence running 134° (M) to a point on shore west of Bell Point 35° 09’ 40” N - 76° 40’ 00” W;~~

~~(6) In Neuse River:~~

~~(A) Beginning at a point on shore north of Swan Creek 35° 07’ 17” N - 76° 33’ 26” W running 115° (M) to a point near the six foot depth contour 35° 07’~~

~~15” N - 76° 33’ 16” W; thence running 074° (M) to Beacon No. 2 at Maw Point Shoal; thence running 294° (M) to a point on shore 35° 08’ 30” N - 76° 32’ 36” W; thence following the shoreline to the beginning point 35° 07’ 17” N - 76° 33’ 26” W;~~

~~(B) Beginning at a point on shore north of Gum Thicket Creek 35° 04’ 40” N - 76° 35’ 38” W; thence running 129° (M) to a point 35° 04’ 12” N - 76° 34’ 37” W; thence running 355° (M) to Beacon No. 1 in Broad Creek; thence running the six foot contour line to Green Marker No. 3;~~

~~(C) Beginning at a point on the eastern tip of Cockle Point 35° 03’ 20” N - 76° 38’ 27” W; thence running 100° (M) to a point 35° 03’ 18” N - 76° 37’ 53” W; thence running 005° (M) to a point on shore 35° 03’ 38” N - 76° 37’ 54” W; thence following the primary nursery area line to the beginning point 35° 03’ 20” N - 76° 38’ 27” W;~~

~~(D) Beginning at a point on shore on the eastern side of the MBYB channel 34° 58’ 16” N - 76° 49’ 05” W running 186° (M) to a point on the six foot depth contour 34° 58’ 07” N - 76° 49’ 05” W; thence following the six foot depth contour to a point 34° 58’ 24” N - 76° 46’ 34” W; thence running 351° (M) to a point on shore 34° 58’ 32” N - 76° 46’ 38” W;~~

~~(E) Beginning at a point on shore at Beards Creek 35° 00’ 08” N - 76° 52’ 13” W; thence running 209° (M) to a point 34° 59’ 52” N - 76° 52’ 20” W; thence running along the six foot depth contour to a point 34° 59’ 25” N - 76° 51’ 14” W; thence running 043° (M) to a point on shore at Mill Creek 34° 59’ 34” N - 76° 51’ 06” W.~~

(a) The pot areas referenced in 15A NCAC 03J .0301 (a) (2) (A) are delineated in the following coastal fishing waters:

(1) In Albemarle and Currituck sounds and tributaries.

(2) In Roanoke Sound and tributaries.

(3) In Croatan Sound and tributaries.

(4) In Pamlico Sound and tributaries, except areas further described in subparagraphs (a)(5), (a)(6), and (a)(7) of this Rule. Pots shall not be set within the following area described by lines:

(A) Striking Bay - beginning on shore at a point 35° 23.7003' N - 76° 26.6951' W; running southeasterly to shore at a point 35° 23.3580' N - 76° 26.3777' W; running easterly along shore to Long Point to a point 35° 23.3380' N - 76° 26.2540' W; running southeasterly to Drum Point to a point 35° 22.4830' N - 76° 25.1930' W; running southerly along shore to Point of Narrows to a point 35° 21.9240' N - 76° 25.4080' W; running northwesterly near Marker “2” to a point 35° 22.4166' N - 76° 26.4833' W; running westerly to a point 35° 22.3833' N - 76° 27.0000' W; running northerly to Short Point to a point 35° 23.3831' N - 76° 26.9922' W; running northerly along shore to a point 35° 23.5000' N - 76° 26.9666' W; running northeasterly to the beginning point.

(5) In the Pamlico River and its tributaries west of a line beginning on Willow Point at a point 35° 22.3741' N - 76° 28.6905' W; running southerly to Pamlico Point to a point 35° 18.5882' N - 76° 28.9625' W; pots may be used within an area bound by the shoreline to the depth of six feet, except areas listed in paragraph (b) of this rule that may be opened to the use of pots by proclamation and except;

(A) Pots shall not be set within the following areas described by lines:

(i) Lupton Point - beginning on Lupton Point at a point 35° 25.6012' N - 76° 31.9641' W; running northwesterly to a point 35° 25.7333' N - 76° 32.1500' W; running southerly along the six foot depth to a point 35° 25.2833' N - 76° 32.3000' W; running northeasterly to shore to a point 35° 25.3389' N - 76° 31.9592' W; running northerly along shore to the beginning point.

(ii) Green Point - beginning on shore at a point 35° 26.6478' N - 76° 33.5008' W; running westerly to a point 35° 26.5833' N - 76° 33.8333' W; running southeasterly along the six foot depth to a point 35° 26.0833' N - 76° 33.2167' W; running northerly to shore to a point 35° 26.4216' N - 76° 33.2856' W; running northwesterly along the shore to the beginning point.

(iii) July Point - beginning on shore at a point 35° 27.3667' N - 76° 33.3500' W; running northeasterly to a point 35° 27.5166' N - 76° 33.3000' W; running westerly along the six foot depth to a point 35° 27.3000' N - 76° 33.8833' W;

running easterly to the beginning point.

(iv) Manley Point - beginning on shore at a point 35° 28.0171' N - 76° 33.3144' W; running northwesterly to a point 35° 28.1500' N - 76° 33.7167' W; running southeasterly along the six foot depth to a point 35° 27.6667' N - 76° 33.2000' W; running northwesterly to the beginning point.

(v) Durants Point - beginning on shore east of Durants Point at a point 35° 30.4660' N - 76° 33.4513' W; running northwesterly to a point 35° 30.7666' N - 76° 33.6500' W; running easterly along the six foot depth to a point 35° 30.8347' N - 76° 32.6529' W; running southwesterly to shore to a point 35° 30.4400' N - 76° 32.7897' W; running westerly along shore to the beginning point.

(vi) Lower Dowry Point - beginning on shore west of Lower Dowry Creek at a point 35° 32.4334' N - 76° 35.6647' W; running southwesterly to a point 35° 32.2333' N - 76° 35.8500' W; running easterly along the six foot depth to a point 35° 32.1166' N - 76° 35.1166' W; running northerly to shore to a point 35° 32.4740' N - 76° 35.1017' W; running westerly along shore to the Inland/Coastal line on the east shore of Lower Dowry Creek; running westerly along the Inland/Coastal line to the west shore of Lower Dowry Creek; running westerly along shore to the beginning point.

(vii) Schrams Beach - beginning on shore at a point 35° 27.2222' N - 76° 36.4662’ W; running northeasterly to a point 35° 27.2988' N - 76° 36.2600' W; running southerly along the six foot depth to a point 35° 26.9000' N - 76° 36.1500' W; running northwesterly to shore to a point 35° 27.0418' N - 76° 36.3767' W; running northerly along shore to the beginning point.

(viii) Grassy Point - beginning on shore at a point 35° 25.8333' N - 76° 35.6167' W; running northeasterly to a point 35° 25.9846' N - 76° 35.4654' W; running southerly along the six foot depth to a point 35° 25.7333' N - 76° 34.7667' W;

running westerly to shore to a point 35° 25.6787' N - 76° 35.4654' W; running northwesterly along shore to the beginning point.

(ix) Long Point - beginning on shore at a point 35° 22.4833' N - 76° 43.4167' W; running northwesterly to a point 35° 22.6500' N - 76° 43.4333' W; running easterly along the six foot depth to a point 35° 22.7333' N - 76° 42.7333' W; running to shore to a point 35° 22.4000' N - 76° 43.0833' W; running westerly along shore to the beginning point.

(x) Pamlico River Mainstream Channel - beginning at a point 250 yards north of Marker "7" at a point 35° 27.2953' N - 76° 55.1351' W; running westerly to a point near Marker "8" at a point 35° 27.4217' N - 76° 56.0917' W; running westerly along the north side of the marked channel to a point 100 yards north of Marker "9" at a point 35° 27.7472' N - 76° 57.5392' W; running westerly along the north side of the marked channel to a point near Marker "16", north of Whichard's Beach at a point 35° 30.4750' N - 77° 01.2217' W; running southwesterly across the channel to a point 35° 30.4373' N - 77° 01.2614' W; running southeasterly along the south side of the marked channel at a distance of 100 yards from the north side of the marked channel to a point near Marker "7" at a point 35° 27.1722' N - 76° 55.1380' W; running northerly to the beginning point.

(xi) Chocowinity Bay Channel - beginning at a point near the Wildlife Resources Commission (WRC) red marker in Chocowinity Bay at a point 35° 29.5501' N - 77° 01.4335' W; running easterly to the south side of the marked navigation channel in Pamlico River, at a point 35° 29.0408' N - 76° 59.5437' W; running southeasterly to a point 35° 28.9236' N - 76° 59.3109' W; running westerly to the WRC green buoy in Chocowinity Bay at a point 35° 29.5004' N - 77° 01.4339' W; running northerly to the beginning point.

(xii) Whichards Beach Channel - beginning on shore at a point 35° 30.2364’ N - 77° 01.3679’ W; running easterly to the south side of the marked navigation channel in Pamlico River at a point 35° 30.1952’ N - 77° 01.0252’ W; running southeasterly to a point 35° 30.1373’ N - 77° 00.9685’ W; running westerly to shore at a point 35° 30.2002’ N - 77° 01.4518’ W, running northeasterly to the beginning point.

(xiii) Broad Creek Channel - beginning near Marker “3” in Broad Creek at a point 35° 29.0733’ N - 76° 57.2417’ W; running southwesterly near Marker “1” at a point 35° 28.8591’ N - 76° 57.3823’ W; running southerly to the marked navigation channel in Pamlico River at a point 35° 27.8083’ N - 76° 57.6250’ W; running southeasterly to a point 35° 27.7344’ N - 76° 57.4822’ W; running northerly to the six foot depth at a point 35° 28.5779’ N - 76° 57.2924’ W; running northerly to the six foot depth at a point 35° 28.7781’ N - 76° 57.3508’ W; running northerly along the six foot depth to a point near Marker “4” at a point 35° 29.0933’ N - 76° 57.1967’ W; running southwesterly to the beginning point.

(xiv) Blounts Bay - from June 1 through September 15, on the south side of Pamlico River beginning near Marker “7” at a point 35° 27.1722’ N - 76° 55.1381’ W; running westerly and along the south side of the marked navigation channel to a point near Marker “9” at a point 35° 27.7070’ N - 76° 57.5739’ W; running northwesterly along the south side of the marked channel to the intersection of the Chocowinity Bay Channel at a point 35° 28.9236’ N - 76° 59.3109’ W; running westerly along the south side of the Chocowinity Bay Channel to a point 35° 29.0206’ N - 76° 59.6678’ W; running southerly to the eight foot depth at a point 35° 28.6667’ N - 76° 59.6667’ W; running southeasterly along the eight foot depth to a point 35° 27.0833’ N - 76° 55.1667’ W; running northerly to the beginning point.

(B) Pots may be set within the following areas described by lines:

(i) Durants Point - beginning on Durants Point at a point 35° 30.5197' N - 76° 35.1521' W; running northwesterly to a point 35° 31.1333' N - 76° 35.5833' W; running northeasterly 200 yards south of Marker "10" to a point 35° 31.2032' N - 76° 35.5558' W; running easterly parallel to the marked navigation channel at a distance of 200 yards to a point southwest of Marker "12" to a point 35° 31.1492' N - 76° 33.8997' W; running southeasterly to shore to a point 35° 30.4660' N - 76° 33.4513' W; running westerly along shore to the beginning point.

(ii) South shore, upper Pungo River - beginning on shore west of Durants Point at a point 35° 30.4400' N - 76° 32.7897' W; running northeasterly to a point southeast of Marker "14" to a point 35° 31.0833' N - 76° 32.5667' W; running easterly parallel to the marked navigation channel at a distance of 200 yards to the shore south of Wilkerson Creek to a point 35° 33.0493' N - 76° 27.2752' W; running southerly and westerly along the shoreline and following the Inland/Coastal lines of Horse Island, Tarklin, Scranton, and Smith Creeks to the beginning point.

(iii) North shore, upper Pungo River - beginning on shore east of Lower Dowry Creek at a point 35° 32.4740' N - 76° 35.1017' W; running southerly to a point 35° 31.5167' N - 76° 35.1000' W; running easterly parallel to the marked navigation channel at a distance of 200 yards to the north shore of Wilkerson Creek to a point 35° 33.2339' N - 76° 27.5449' W; running northwesterly along the shoreline to the east end of the US 264 bridge; running westerly along the bridge and following the Inland/Coastal line to the western shore; running southerly and westerly along the shoreline and following the Inland/Coastal lines of Crooked Creek and Upper Dowry Creek to the beginning point.

(iv) Tooleys Point - beginning at the “Breakwater” 200 yards northeast of Beacon “6”, at a point 35° 31.7833' N - 76° 36.8500' W; running southeasterly to a point 200 yards from Marker “4” at a point 35° 31.5167' N - 76° 36.3500' W; running easterly to a point 35° 31.4667' N - 76° 35.9833' W; running northerly near Beacon “1” to a point 35° 32.1100' N - 76° 35.9817' W; running northeasterly to shore to a point 35° 32.4334' N - 76° 35.6647' W; running westerly and along the shoreline of Battalina and Tooley Creeks; running along the river shore to the “Breakwater” to a point 35° 31.9908' N - 76° 36.6105' W; running southwesterly along the “Breakwater” to the beginning point.

(v) Pungo Creek - beginning on Windmill Point at a point 35° 30.7444' N - 76° 38.2869' W; running northeasterly to a point 200 yards west of Marker “3” to a point 35° 31.3500' N - 76° 36.6167' W; running northwesterly to the “Breakwater” to a point 35° 31.6296' N - 76° 37.1201' W; running westerly along the “Breakwater” to shore to a point 35° 31.5653' N - 76° 37.3832' W; running westerly along shore and into Pungo Creek following the shoreline and the Inland/Coastal lines of Vale, Scott, and Smith creeks to the north end of the NC 92 bridge over Pungo Creek; running southerly along the bridge and following the Inland/Coastal line to the southern shore; running easterly along shore to the beginning point.

(vi) Upper Pamlico - in coastal fishing waters west of a line beginning on the north shore of Gum Point at a point 35° 25.1699' N - 76° 45.5251' W; running southwesterly to a point on the south shore of Pamlico River to a point 35° 23.4453' N - 76° 46.4346' W, except as described in subparagraphs (a)(5)(A)(x)-(xiv).

(vii) South Creek - in coastal fishing waters of South Creek and tributaries west of a line beginning on Hickory Point at a point 35° 21.7385' N - 76° 41.5907' W; running southerly to Fork Point to a point 35° 20.7534' N - 76° 41.7870' W.

(6) In Bay River west of a line beginning on Bay Point at a point 35° 11.0750' N - 76° 31.6080' W; running southerly to Maw Point to a point 35° 09.0407' N - 76° 32.2348' W; pots may be used within an area bound by the shoreline to the depth of six feet, except areas listed in Paragraph (b) of this rule that may be opened to the use of pots by proclamation, and pots shall not be set within the following areas described by lines:

(A) Vandemere - beginning on the west shore of Vandemere Creek at a point 35° 11.2280' N - 76° 39.6046' W; running southeasterly to the east shore to a point 35° 11.0920' N - 76° 39.3240' W; running southerly to a point 35° 10.9390' N - 76° 39.4426' W; running southwesterly to a point 35° 10.8567' N - 76° 39.6212' W; running northwesterly to shore west of Vandemere Creek to a point 35° 10.8983' N - 76° 39.7307' W; running northerly along shore to the beginning point.

(B) Moore Bay - beginning on shore west of Bell Point at a point 35° 09.6712' N - 76° 39.9651' W; running northwesterly to a point 35° 09.7331' N - 76° 40.0928' W; running southerly along the six foot depth to a point 35° 09.0045' N - 76° 40.3141' W; running southeasterly to the north shore of Moore Creek to a point 35° 08.9640' N - 76° 40.2000' W; running northerly along shore to the beginning point.

(7) In the Neuse River and Point of Marsh area south and west of a line beginning on Maw Point at a point 35° 09.0407' N – 76° 32.2348' W; running southeasterly near the Maw Point Shoal Marker "2" to a point 35° 08.1250' N - 76° 30.8532' W; running southeasterly near the Neuse River Entrance Marker "NR" to a point 35° 06.6212' N – 76° 28.5383' W; running southeasterly to a point 35° 04.7670' N – 76° 25.7920' W; running southwesterly to shore to a point 35° 03.9387' N – 76° 27.0466' W; pots may be used in coastal fishing waters bound by the shoreline to the depth of six feet, except areas listed in Paragraph (b) of this rule that may be opened to the use of pots by proclamation and except;

(A) Pots shall not be set within the following areas described by lines:

(i) Oriental - in that area including Greens Creek and tributaries downstream of the bridge on State Secondary Road 1308, and Whittaker Creek north of a line beginning on the west shore at the Whittaker Creek primary nursery area (PNA) line; running easterly along the Whittaker Creek PNA line to the east shore; running southerly to a point 35° 01.3833' N – 76° 40.9500' W; running westerly following the six foot depth to a point 35° 01.1666' N – 76° 41.8833' W; running southerly across the channel to a point 35° 01.1339' N – 76° 41.9589' W; running westerly to Windmill Point to the south shore of the Shop Gut Creek PNA line; running northerly along the Shop Gut Creek PNA line to the north shore of the Shop Gut Creek PNA line.

(ii) Greens Creek - more than 75 yards from shore in the area beginning on the south shore of Greens Creek primary nursery area (PNA) line; following the PNA lines of Greens Creek and Kershaw Creek to the east shore of Kershaw Creek; running easterly along the shore of Greens Creek, and running along the shore of Smith Creek and its tributaries to the bridge on State Secondary Road 1308; running southwesterly along the bridge to the south shore of Greens Creek; running westerly along the shore to the beginning point.

(iii) Wilkerson Point - beginning on the west side of the Minnesott Beach Yacht Basin Channel at a point 34° 58.2682' N – 76° 49.1903' W; running southerly to a point 34° 58.1403' N – 76° 49.2253' W; running easterly along the six foot depth to a point 34° 58.4000' N – 76° 46.5667' W; running northerly to shore to a point 34° 58.5333' N – 76° 46.6333' W; running westerly along shore to the beginning point.

(iv) Beard Creek - beginning on shore west of Beard Creek at a point 35° 00.1902' N – 76° 52.2176' W; running southerly to a point 34° 59.8883' N – 76° 52.3594' W; running easterly along the six foot depth to a point 34° 59.4167' N – 76° 51.2333' W; running northeasterly to shore to a point 34° 59.5989' N – 76° 51.0781' W; running westerly along shore to the Beard Creek tributary primary nursery area (PNA) line; running northeasterly along the PNA line to the Inland/Coastal line in Beards Creek; running westerly along the Inland/Coastal line to the western shore; running southerly along shore to the beginning point.

(v) Clubfoot Creek - more than 50 yards from shore in the area south of a line beginning at a point 34° 54.9327' N - 76° 45.6506' W on the west shore; running northerly to a point 34° 55.1501' N - 76° 45.6221' W; running northeasterly to a point 34° 55.1812' N - 76° 45.5172' W near Marker "5"; running northeasterly to a point 34° 55.2994' N - 76° 45.1180' W on the east shore and north of line beginning at a point on the west shore 34° 54.5424' N - 76° 45.7252' W; running easterly to a point 34° 54.4853' N - 76° 45.4022' W on the east shore.

(B) Pots may be set in coastal fishing waters west of a line beginning on shore west of Beards Creek at a point 35° 00.1902' N – 76° 52.2176' W; running southwesterly to shore west of Slocum Creek to a point 34° 57.0333' N – 76° 53.7252' W.

(8) In the West Bay and Long Bay area south and west of a line beginning on shore at a point 35° 03.9387' N – 76° 27.0466' W; running northeasterly to a point 35° 04.7670' N – 76° 25.7920' W; running southeasterly to the eastern shore of West Bay to a point 35° 02.1203' N - 76° 21.8122' W; areas described by lines:

(A) Raccoon Island, northern shore - beginning at the western point at a point 35° 04.3696' N – 76° 26.1815' W; running southeasterly along the north shore to a point 35° 03.9814' N - 76° 25.5862' W; running easterly 150 yards to a point 35° 03.9777' N - 76° 25.4910' W; running northwesterly at a distance of 150 yards from shore to a point 35° 04.4417' N - 76° 26.2150' W; running easterly to the beginning point.

(B) Raccoon Island, southern shore - beginning at the western point at a point 35° 04.3696’ N – 76° 26.1815’ W; running southeasterly along the south shore to a point 35° 03.9814’ N – 76° 25.5862’ W; running easterly 50 yards to a point 35° 03.9800’ N - 76° 25.5513’ W; running westerly at a distance of 50 yards from shore to a point 35° 04.3955’ N - 76° 26.1934’ W; running easterly to the beginning point.

(C) West Bay:

(i) Point of the Narrows; beginning on shore at a point 35° 03.5421’ N – 76° 26.3909’ W; running northeasterly to a point 35° 03.5980’ N – 76° 26.3894’ W; running southeasterly parallel to shore at a distance of 100 yards to a point 35° 02.4740’ N – 76° 26.1280’ W; running northwesterly to shore to a point 35° 02.5440’ N – 76° 26.1486’ W; running northerly along shore to the beginning point.

(ii) Point of Island Bay, Dowdy Bay; beginning on shore at a point 35° 01.5271’ N – 76° 26.2836’ W; running southeasterly to a point 35° 01.4684’ N - 76° 26.2450’ W; running southeasterly parallel to shore at a distance of 100 yards to a point 35° 00.0701’ N - 76° 25.4414’ W; running southerly to a point 35° 00.0620’ N - 76° 25.5074’ W on Dowdy Point; running westerly and northerly along shore to the beginning point.

(iii) Beginning on Dowdy Point at a point 35° 00.0620’ N – 76° 25.5074’ W; running easterly to a point 35° 00.1000’ N – 76° 25.2000’ W; running southerly to a point 34° 58.7500’ N – 76° 24.7000’ W; running westerly to Jack’s Bay Point to a point 34° 58.6886’ N - 76° 25.3683’ W; running northerly along shore to the beginning point.

(D) Long Bay:

(i) Jack’s Bay, Stump Bay; beginning on Jack’s Bay Point at a point 34° 58.6886’ N – 76° 25.3683’ W; running southwesterly to a point 34° 57.6500’ N – 76° 25.8500’ W; running westerly to shore to a point 34° 57.2089’ N – 76° 27.2292’ W; running northerly along shore to the boundary of the military restricted area (having its center at a point 34° 58.8000’ N – 76° 26.2000’ W) in Jack’s Bay to a point 34° 58.4208’ N – 76° 25.9417’ W; running northeasterly along the boundary of the military restricted area to a point 34° 58.7746’ N – 76° 25.6733’ W; running easterly along shore to the beginning point.

(ii) Long Bay; beginning on the east point of the southern shore of Stump Bay at a point 34° 57.2089’ N – 76° 27.2292’ W; running southeasterly to Swimming Point to a point 34° 56.7619’ N – 76° 26.3838’ W; running southerly along shore to the head of Long Bay; running northerly along the west shore to the beginning point.

(iii) Owens Bay; beginning on Swimming Point at a point 34° 56.7619’ N – 76° 26.3838’ W; running northwesterly to a point 34° 56.8470’ N – 76° 26.5363’ W; running northeasterly parallel to shore at a distance of 300 yards to a point 34° 57.9394’ N – 76° 24.1326’ W; running southwesterly to Long Bay Point at a point 34° 57.7863’ N – 76° 24.1837’ W; running southwesterly along shore to the beginning point.

(E) West Thorofare Bay, Merkle Bay; beginning on Long Bay Point at a point 34° 57.7863’ N – 76° 24.1837’ W; running northeasterly near Marker “8WB” to a point 34° 58.4600’ N – 76° 23.9600’ W; running easterly to Tump Point to a point 34° 58.7000’ N – 76° 22.8166’ W; running southerly along the shore of Merkle Bay and West Thorofare Bay back to the beginning point.

(F) West Bay, North Bay; beginning on the eastern shore of West Bay at a point 35° 02.1203’ N – 76° 21.8122’ W; running northwesterly to a point 35° 02.5412’ N - 76° 22.4445’ W; running southwesterly near Marker “5WB” to a point 35° 02.0798’ N - 76° 22.8729’ W; running southerly to a point 35° 00.5666’ N – 76° 21.8333’ W;

running southerly to Deep Bend Point to a point 34° 58.5923' N – 76° 21.7325' W; running easterly and northerly along shore to the beginning point.

(9) Core Sound, Back Sound and the Straits and their tributaries.

(10) North River:

(A) Goose Bay; beginning on shore west of South Leopard Creek at a point 34° 45.4517' N – 76° 35.1767' W; running northerly to a point 34° 45.6409' N – 76° 35.2503' W; running southwesterly to a point 34° 45.3333' N – 76° 35.7500' W; running southerly to a point 34° 43.4667' N – 76° 35.2333' W; running easterly to shore at a point 34° 43.5833' N – 76° 34.9167' W; running northerly along shore to the beginning point.

(B) Ward Creek; coastal fishing waters north and east of a line beginning on the north shore at a point 34° 46.2667' N – 76° 35.4933' W; running southerly to south shore to a point 34° 45.4517' N – 76° 35.1767' W.

(C) Upper North River; coastal fishing waters north of a line beginning on the west shore at a point 34° 46.0383' N – 76° 37.0633' W; running easterly to shore to a point 34° 46.2667' N – 76° 35.4933' W.

(D) Newby Creek, Gibbs Creek; beginning on Marsh Hen Point at a point 34° 45.2004' N – 76° 37.0639' W; running southwesterly to a point 34° 44.5833' N – 76° 36.6000' W; running southeasterly to shore near Holland's Rocks to a point 34° 43.6667' N – 76° 37.3333' W; running northerly along shore to the beginning point.

(E) North River Marshes; beginning near Marker "6" at a point 34° 43.4833' N – 76° 37.3500' W; running northeasterly to a point 34° 44.1333' N – 76° 36.8667' W; running southeasterly to a point 34° 43.8000' N – 76° 36.1333' W; running southeasterly to a point 34° 43.5000' N – 76° 35.7833' W; running southerly near Marker "56"to a point 34° 42.2391' N – 76° 35.8498' W; running westerly to a point 34° 42.2333' N – 76° 36.7167' W; running northerly to a point 34° 42.7500' N – 76° 36.9667' W; running northerly to a point 34° 43.2333' N – 76° 36.9667' W; running northwesterly to the beginning point.

(11) Newport River:

(A) Lower portion; beginning on shore east of Penn Point at a point 34° 45.4397’ N – 76° 43.0638’ W; running northeasterly to shore east of Oyster Creek to a point 34° 46.5480’ N – 76° 41.9910’ W; running easterly along shore to a point on the western shore of Core Creek to a point 34° 47.0816’ N – 76° 41.2605’ W; running easterly to the eastern shore at a point 34° 46.9867’ N – 76° 41.0437’ W; running southerly along shore to Gallant Point to a point 34° 43.9911’ N – 76° 40.2762’ W; running westerly near Marker “2” to a point 34° 44.0031’ N – 76° 40.5038’ W; running southeasterly near Marker “4” to a point 34° 43.7064’ N – 76° 40.1627’ W; running southerly to the west side of Gallant’s Channel at the drawbridge to a point 34° 43.3500’ N – 76° 40.1833’ W; running westerly along the US 70 and the US 70 bridge to its terminus at the State Port Terminal; running westerly and northerly along the western shore of Newport River and its tributaries to the beginning point.

(B) Upper portion; the coastal fishing waters west of a line beginning on shore east of Harlowe Creek at a point 34° 46.5730’ N – 76° 42.6350’ W; running southerly to shore east of Penn Point to a point 34° 45.6970’ N - 76° 43.5180’ W.

(12) Bogue Sound:

(A) South of the IWW; beginning on Archer Point at a point 34° 40.5500’ N – 77° 00.8000’ W; running northerly near Marker “37” to a point 34° 41.2500’ N – 77° 00.7167’ W; running easterly along the south side of the IWW channel to the Atlantic Beach bridge to a point 34° 43.0320’ N – 76° 44.1300’ W; running easterly to the northeastern shore of Tar Landing Bay to a point 34° 42.5000’ N – 76° 42.2000’ W; running easterly along shore to a point 34° 42.1990’ N - 76° 41.3873’ W; running southeasterly to a point 34° 42.1631’ N - 76° 41.3491’ W; running southeasterly and westerly along shore to the beginning point.

(B) North of the IWW; beginning on the north shore at the NC 58 bridge at a point 34° 40.7780' N - 77° 04.0010' W; running southerly along the bridge to the north side of the IWW channel to a point 34° 40.4640' N – 77° 03.9090' W; running easterly along the north side of the IWW channel to the Atlantic Beach bridge to a point 34° 43.0620' N – 76° 44.1240' W; running northerly along the bridge to shore to a point 34° 43.2780' N – 76° 44.0700' W; running westerly along shore to the beginning point.

(13) Designated primary nursery areas in all coastal fishing waters which are listed in 15A NCAC 03R .0103, except Burton Creek off Lower Broad Creek in Pamlico County.

(b) The pot areas referenced in 15A NCAC 03J .0301 (a) (2) (B) to be opened by proclamation are delineated in the following coastal fishing waters:

(1) Wysocking Bay:

(A) Lone Tree Creek - beginning on shore at a point 35° 25.9705' N - 76° 02.7799' W; running easterly along the shoreline to the primary nursery area (PNA) line on the north shore of Lone Tree Creek; running southeasterly along the PNA line to the south shore; running southwesterly to a point 35° 24.7666' N - 76° 02.5333' W; running northwesterly to a point 35° 25.7000' N - 76° 03.2666' W; running northeasterly to the beginning point.

(B) Mt. Pleasant Bay - beginning on shore west of Green Point at a point 35° 24.6160' N - 76° 03.9690' W; running easterly to a point 35° 24.4500' N - 76° 03.2000' W; running southerly to a point 35° 23.2833' N - 76° 03.5333' W; running southwesterly to shore to a point 35° 23.1166' N - 76° 04.2000' W; running westerly and northerly along shore to the primary nursery area (PNA) line on the western shore of Hickory Creek Bay; running northeasterly along the PNA line to Browns Island; running along the eastern shore of Browns Island to the PNA line on the south shore of Old Hill Bay; running northerly along the PNA line to shore; running northeasterly along shore to the beginning point.

(2) Juniper Bay - beginning on shore at a point 35° 21.7957' N - 76° 14.3545' W; running southeasterly along shore to the primary nursery area (PNA) line on the western shore of Buck Creek; running southeasterly along the

PNA line to the eastern shore; running southeasterly along shore to the PNA line on the north shore of Laurel Creek; running southerly to the south shore; running southerly along shore to Juniper Bay Point to a point 35° 20.4420' N - 76° 13.2680' W; running westerly to a point 35° 20.2500' N - 76° 14.7500' W; running northerly near Marker "3" to a point 35° 21.5360' N - 76° 14.8040' W; running northeasterly to the beginning point.

(3) Swanquarter Bay - beginning in Caffee Bay on the north shore at a point 35° 21.9928' N - 76° 17.6720' W; running southerly to the south shore at a point 35° 21.5240' N - 76° 17.8130' W; running westerly along shore to Drum Point to a point 35° 21.5920' N - 76° 18.3560' W; running westerly to a point 35° 21.2833' N - 76° 19.0500' W; running northwesterly to a point 35° 21.8500' N - 76° 19.4500' W; running easterly to Sandy Point to a point 35° 22.1080' N - 76° 18.7440' W; running easterly along shore and following the PNA line of the northern tributary in Caffee Bay to the beginning point.

(4) Deep Cove - beginning on the north shore at a point 35° 21.5784' N - 76° 22.7505' W; running easterly along shore to a point 35° 21.5002' N - 76° 22.1112' W; running southerly to shore to a point 35° 20.6851' N - 76° 22.0524' W; running westerly along shore to a point 35° 20.5390' N - 76° 22.7790' W; running northerly to the beginning point.

(5) Rose Bay - beginning on shore south of Swan Point at a point 35° 23.9650' N - 76° 23.5530' W; running southeasterly along shore to a point 35° 23.5060' N - 76° 23.2090' W; running westerly to a point 35° 23.3166' N - 76° 24.0666' W; running northwesterly to a point 35° 24.0500' N - 76° 24.5500' W; running easterly to the beginning point.

(6) Spencer Bay - beginning on Roos Point at a point 35° 22.3590' N - 76° 28.1850' W; running northeasterly to a point 35° 22.9500' N - 76° 27.2166' W; running northwesterly to a point 35° 23.4166' N - 76° 27.9500' W; running southwesterly to shore to a point 35° 23.0209' N - 76° 28.5060' W; running southeasterly along shore and the primary nursery area line of the unnamed western tributary of Spencer Bay to the beginning point.

(7) Pamlico River:

(A) Lee Creek - beginning on shore at a point 35° 22.8779' N - 76°

45.7149' W; running northerly to a point 35° 23.1011' N - 76° 45.7371' W; running easterly along the six foot depth to a point 35° 22.9450' N - 76° 44.8403' W; running southwesterly to shore to a point 35° 22.7667' N - 76° 45.2333' W; running westerly along shore to the beginning point.

(B) Huddy Gut - beginning on shore at a point 35° 22.5000' N - 76° 44.4500' W; running northerly to a point 35° 22.7166' N - 76° 44.5000' W; running easterly along the six foot depth to a point 35° 22.7170' N - 76° 43.9500' W; running southwesterly to shore to a point 35° 22.4657' N - 76° 44.0536' W; running westerly along shore to the beginning point.

(C) Indian Island - beginning on shore at the west end of Indian Island at a point 35° 21.6240' N - 76° 39.4090' W; running westerly to a point 35° 21.7667' N - 76° 40.2667' W; running easterly along the six foot depth to a point 35° 21.6107' N - 76° 38.2202' W; running westerly to the east end of Indian Island to a point 35° 21.6100' N - 76° 38.6290' W; running westerly along the northern shore to the beginning point.

(D) Old Field Point, Goose Creek - beginning on shore at a point 35° 20.2297' N - 76° 37.3456' W; running southeasterly to a point 35° 20.1500' N - 76° 37.1000' W; running southerly along the six foot depth to a point 35° 19.9031' N - 76° 37.2308' W; running westerly to shore to a point 35° 19.9812' N - 76° 37.4917' W; running northerly along shore to the beginning point.

(8) Big Porpoise Bay - beginning on the north shore at a point 35° 16.0028' N - 76° 29.1708' W; running southerly to Sage Point at a point 35° 15.5930' N - 76° 29.1270' W; running easterly to a point 35° 15.4660' N - 76° 28.6000' W; running northerly to shore to a point 35° 15.8120' N - 76° 28.4270' W; running westerly along shore to the beginning point.

(9) Middle Bay - beginning on Middle Bay Point at a point 35° 14.8310' N - 76° 28.7500' W; running southerly to Sow Island Point at a point 35° 13.2876' N - 76° 29.5585' W; running westerly along shore to Big Fishing Point at a point 35° 14.0285' N - 76° 29.9336' W; running northerly to Oyster Creek Point at a point 35° 14.6042' N - 76° 29.8544' W; running

easterly along shore to the beginning point.

(10) Jones Bay - beginning on Sow Island Point at a point 35° 13.1811' N - 76° 29.6096' W; running southerly near Marker "3" to a point 35° 12.0250' N - 76° 29.9660' W; running northwesterly to a point 35° 12.8000' N - 76° 30.9666' W; running southwesterly to shore at the east shore of the Little Drum Creek primary nursery area (PNA) line; running westerly along the PNA line to the west shore of the Little Eve Creek PNA; running westerly along shore to a point 35° 12.6000' N - 76° 32.0166' W; running northeasterly to a point 35° 12.8666' N - 76° 31.7500' W; running northwesterly to a point 35° 13.1833' N - 76° 32.1166' W; running northerly to a point 35° 13.6500' N - 76° 31.9000' W; running southeasterly to a point 35° 13.1500' N - 76° 30.8000' W; running northerly to shore at a point 35° 13.4886' N - 76° 30.7785' W; running easterly along shore to the beginning point.

(11) Bay Point - beginning on Boar Point at a point 35° 12.1450' N - 76° 31.1150' W; running easterly near Marker "5" to a point 35° 12.0250' N - 76° 29.9660' W; running southerly to a point 35° 10.9333' N - 76° 30.1666' W; running westerly to Bay Point to a point 35° 11.0750' N - 76° 31.6080' W; running northerly along shore to the beginning point.

(12) Bay River:

(A) Rockhole Bay - beginning on the western shore of Dump Creek at a point 35° 11.6708' N - 76° 33.4359' W; running southerly to a point 35° 11.3833' N - 76° 33.3166' W; running southeasterly along the six foot depth to a point 35° 10.8333' N - 76° 32.1333' W; running northerly to shore at a point 35° 11.1250' N - 76° 32.1340' W; running northwesterly along shore to the southeast shore of the Rockhole Bay PNA line; running northwesterly along the PNA line to the western shore; running westerly along shore to the east shore of PNA line in Dump Creek; running southwesterly along the PNA line to the western shore; running southerly along shore to the beginning point.

(B) Hogpen Creek - beginning on shore north of Bonner Bay at a point 35° 10.4174' N - 76° 34.7041' W; running northerly to a point 35° 10.7500' N - 76° 34.7333' W; running easterly along the six foot depth to a point southwest of Marker “3" to a point 35° 10.8137' N - 76° 33.5120' W; running southwesterly to shore to a point 35° 10.3195' N - 76° 34.0876' W; running westerly along shore to the beginning point.

(C) Fisherman Bay - beginning on the western shore of Fisherman Bay at a point 35° 09.2345' N - 76° 33.0199' W; running northwesterly to a point 35° 09.9892' N - 76° 33.2213' W; running easterly along the six foot depth to a point southwest and near Marker “1” to a point 35° 09.7951' N - 76° 32.0099' W; running southwesterly to shore to a point 35° 09.2668' N - 76° 32.3668' W; running westerly along shore to the beginning point.

(13) Neuse River:

(A) Swan Creek - beginning at a point on shore south of Maw Bay at a point 35° 08.5760' N - 76° 32.6320' W; running southerly along shore to a point north of Swan Creek to a point 35° 07.3182' N - 76° 33.4620' W; running southeasterly to the six foot depth to a point 35° 07.2524' N - 76° 33.2078' W; running northeasterly along the six foot depth to a point 35° 08.3214' N - 76° 31.9971' W; running westerly to the beginning point.

(B) Broad Creek - beginning on Tonney Hill Point at a point 35° 05.5505' N - 76° 35.7249' W; running southeasterly along shore and following the primary nursery area line of Cedar Creek; running southerly along shore to a point north of Gum Thicket Creek to a point 35° 04.6741' N - 76° 35.7051' W; running southeasterly to a point 35° 04.5786' N - 76° 35.4808' W; running northerly near Marker “1” to a point 35° 05.4809' N - 76° 34.9734' W; running westerly along the six foot depth near Marker “3” to a point 35° 05.6400' N - 76° 35.6433' W; running southwesterly to the beginning point.

(C) Gum Thicket Shoal - beginning on shore west of Gum Thicket Creek at a point 35° 04.2169' N - 76° 36.2119' W; running southwesterly along shore to a point 35° 04.0634' N - 76° 36.6548' W; running southerly to a point 35° 03.6833' N - 76° 36.7166' W; running easterly along the six foot depth to a point 35° 03.9166' N - 76° 35.8000' W; running northwesterly to the beginning point.

(D) Orchard Creek - beginning on the eastern shore at and running southwesterly along the Orchard and Old House Creeks primary nursery area line to Cockle Point; running easterly to a point 35° 03.3000' N - 76° 37.8833' W; running northerly to the beginning point.

(E) Dawson Creek - beginning on the eastern shore of Dawson Creek at a point 34° 59.5863’ N – 76° 45.3907’ W; running westerly along the bridge to the western shore to a point 34° 59.5994’ N – 76° 45.4624’ W; running southwesterly along shore to a point 34° 59.0667’ N – 76° 45.9000’ W; running southeasterly to a point 34° 58.7833’ N – 76° 45.6500’ W; running northerly along the six foot depth to a point 34° 59.3666’ N – 76° 45.3166’ W; running northwesterly near Marker “4” to a point 34° 59.4430’ N – 76° 45.4521’ W; running northerly to the beginning point.

(F) Pine Cliff Recreation Area - beginning on shore at a point 34° 56.4333’ N – 76° 49.5833’ W; running easterly along shore to a point 34° 56.3422’ N – 76° 49.1158’ W; running northeasterly near Marker “2” to a point 34° 56.7650’ N – 76° 48.5778’ W; running northerly to a point 34° 56.8333’ N – 76° 48.6000’ W; running southwesterly along the six foot depth to a point 34° 56.6067’ N – 76° 49.6190’ W; running southerly to the beginning point.

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12.20 Appendix 20. STOCK ASSESSMENT

Population Dynamics and Stock Assessment of the Blue Crab in North Carolina

Final Report for Contracts 99-FEG-10 and 00-FEG-11 to the North Carolina Fishery Resource Grant Program, North Carolina Sea Grant, and the North Carolina Department of Environmental Health and Natural Resources, Division of Marine Fisheries

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ABSTRACT

The blue crab (*Callinectes sapidus*) is an ecologically important estuarine predator and represents North Carolina's most important commercial fishery. Recent fishery-dependent and –independent data suggest the population is declining. The goal of this study was to increase our understanding of the status and population dynamics of the blue crab in North Carolina by addressing the following objectives: (1) estimate population demographics of blue crabs in salt marsh creeks, (2) construct a discontinuous model of blue crab using growth rates estimated from free-ranging blue crabs, and (3) provide a comprehensive stock assessment for the blue crab in North Carolina. A series of complimentary laboratory and field studies assessed the nursery role of salt marsh habitats for the blue crab (*Callinectes sapidus*). Population demographics and movement patterns of juvenile and adult blue crabs were quantified in two tidal salt marsh creeks (Prytherch Creek, PC; Haystacks, HS) near Beaufort, North Carolina, USA during June – October 2001. While there are many studies that report estimates of population density, mortality rates, or movement rates for blue crabs, this study represents one of the first attempts to estimate all quantities concurrently. Juvenile crabs were mobile within the interstices of the marsh canopy during flood tide, and were equally distributed buried in intertidal marsh and adjacent mud areas during ebb tide. Juvenile crabs may experience a spatial refuge from cannibalism in the marsh canopy since adult conspecifics are physically impeded by dense vegetation and rarely move far into marsh habitats. This spatial refuge in the vegetated marsh surface may be significant, since cannibalism represents a large source of mortality for this species. The relatively high use of the marsh surface by juvenile blue crabs, combined with a general lack of sampling these complex habitats, suggest that crab densities may be even higher in salt marsh systems than previously thought.

Growth models commonly used in fisheries and ecological modeling assume growth is a continuous function of age. While this approach is appropriate for finfish, the validity of these models for crustacean species, which grow discontinuously, has been questioned. There is a critical need to compare the predictions of discontinuous and continuous models simultaneously to identify if potential biases are introduced by the assumption of continuous growth. The blue crab stock in North Carolina currently sustains heavy exploitation by the commercial fishery, and information on the recreational fishery is generally lacking. There has been a systematic increase in commercial landings from 1987-1999, followed by a period of reduced landings from 2000-2002, and gradual increase in landings in 2003. Fishery-independent indices of abundance, such as spawning stock biomass, remained somewhat stable during 1987-1995, increased sharply in 1996, and declined steadily from 1996 to 2002, followed by another sharp increase in 2003. Since 1987, there as been a 12% decline in the average size of mature female blue crabs, and an increasing frequency of mature "pygmy" females (< 100 mm CW) in the fisheries independent indices of abundance. Declines in spawning stock biomass (SSB) and the average size of mature females are of concern because of we detected a significant spawning stock-recruit relationship for the blue crab in NC, such that declines in abundance and average size of mature females should lead to reduced recruitment in the same or a subsequent year. The average size of a mature crab and the overall population distribution pattern of blue crabs in Pamlico Sound respond to salinity fluctuations such that crabs are larger, on average in wet than dry years, and are more available to the NC DMF trawl survey gear in wet than dry years. When we accounted for the annual effects of salinity on crab abundance and average size-at-maturity, the most noteworthy findings were that (1) 2000-01 represented the two lowest SSB values on record,

(2) the decline in average size of mature females is even more pronounced and statistically significant, and (3) SSB during 2002-03 appears to be returning to average levels. The low SSB during 2000-01 was due to the interacting effects of hurricane floodwaters in fall 1999 and overfishing of hyper-aggregations of crabs that had migrated in masse downriver to Pamlico Sound. Although there is uncertainty with predictions from fishery models, biomass-based models indicated that, through 2002, relative crab biomass was declining and relative fishing mortality was increasing. Given the significant stock-recruit relationship for the blue crab in North Carolina and the decline in average size of mature females, we recommend that fishery managers strive to increase the average size-at-maturity of female blue crabs, and closely monitor the SSB with management measures in place to reduce fishing mortality on female blue crabs if SSB successively falls below acceptable levels. We encourage decision makers to use the information and recommendations in this report to manage the blue crab fishery in NC in a sustainable manner. Given the interest by fishery managers in this report, an executive summary for the stock assessment (chapter 3) follows this abstract.

EXECUTIVE SUMMARY FOR STOCK ASSESSMENT (Chapter 3)

The primary stock assessment portion of this report is located in chapter 3. An initial assessment of the population dynamics of the blue crab in North Carolina was provided in 1998 (Eggleston 1998). This report builds on the previous assessment by incorporating six additional years of data (1998 – 2003), generating objective indices of annual fishery-independent blue crab abundance using length-based models, using additional modeling techniques, incorporating the uncertainty involved with fisheries data and model outputs, and incorporating additional information on postlarval abundance. The goal of the stock assessment was to increase our understanding of the status and population dynamics of the blue crab in North Carolina by addressing the following objectives: (1) identify temporal variation in commercial effort and landings, (2) identify long-term trends in blue crab abundance as measured with fishery-independent research surveys; (3) describe the relationship between fisheries-independent catch-per-unit-effort (CPUE) and commercial harvest; (4) identify potential relationships between stock and recruitment, as well as between different cohorts (Age 0, Age 1, Age 2); (5) estimate historical biomass and fishing mortality rates; (6); estimate fisheries management targets such as Maximum Sustainable Yield (MSY); and (7) generate biological reference points using yield-per-recruit (YPR) and spawning stock biomass-per-recruit (SSBR) analyses.

1. Identify temporal variation in commercial effort and landings

Total annual hard crab landings in North Carolina steadily increased from 1953-1997, with peak landings of approximately 65 million pounds in 1996. This general increase in landings was most likely due to increased effort, landings, and reporting in Albemarle and Croatan Sounds, rather than an increase in stock size. Recent increases in landings in Pamlico Sound were likely due to new, more rigorous commercial landings reporting requirements initiated in 1994 by the NC DMF. Although there is no statistical evidence of a decreasing trend in landings, commercial landings for the blue crab for 2000-2002 were the lowest in the last 10 years. A concomitant reduction in commercial effort also occurred over this same period (2000-2002). Commercial effort, which was relatively stable and low from 1953-1975, showed a sharp increase from 1976-2000. During 1976-2000, effort has been increasing at an average annual rate of 17%. Commercial effort has leveled off during 2001-2002, potentially in response to lowered catch rates in the fishery during this period.

2. Identify long-term trends in blue crab abundance as measured with fishery-independent research surveys

We examined two fishery-independent trawl survey time series of blue crab catch-per-unit-effort (CPUE) collected by the NC DMF: juvenile trawl survey Program 120 (P120), for the period 1987-2002; and adult trawl survey Program 195 (P195), for the period 1987-2003, to provide a first order approximation of the status of juvenile and adult blue crab stocks in North Carolina. Overall, there was a general lack of coherence in trends among survey indices of blue crab abundance creating considerable uncertainty regarding current stock status. Due to this uncertainty, we considered all indices of abundance in our analyses. Because of the up-estuary nature of sampling, P120 was biased against sampling mature females since females tend to mate in the mesohaline zone of estuaries, and then migrate seaward to inlets to spawn. The CPUE of mature female crabs captured in P195 in September provided a useful index of spawning stock abundance (see section on Index of Spawning Stock Biomass). Evidence from this index of relative SSB indicates that spawner abundance has declined in recent years (although not significantly according to statistical models) and reached historically low levels during 2000-2001. When adjusted for the effects of salinity on cpue, SSB during 2002-30 appears to be rising from historic lows observed during 200-01 to average levels. Any decline in SSB is especially troubling considering the concurrent decrease in average size of mature females, the positive relationship between spawning stock and recruitment for the blue crab in North Carolina, and the possibility of recruitment overfishing.

3. Relationship between fisheries-independent catch-per-unit-effort (CPUE) and commercial harvest

There was no relationship between research survey indices of abundance for Age 0 crabs and commercial landings one year later. There was, however, a significant relationship between the CPUE of Age 2 crabs from P195 in September and commercial landings in the same year. Both linear and hyperbolic statistical regression models adequately described the relationship between the abundance of Age 2 crabs and commercial landings. There was also a significant relationship between the CPUE of Age 0 and 1 crabs from P120 in June and commercial landings in the same year. Although several indices were significantly correlated with landings in the same year, none of the indices were able to predict future landings. The inability to forecast landings in advance using fishery survey data was likely due to the uncertainty of estimated indices of abundance. This uncertainty in estimated indices of abundance may be due to annual changes in availability of crabs to NC DMF trawl surveys due to fluctuations in salinity, and to changes in the magnitude of commercial landings data due to fishing effort rather than abundance.

4. Identify potential relationships between stock and recruitment, as well as between different cohorts (Age 0, Age 1, Age 2)

There was a relatively strong and highly significant spawning stock-recruit relationship using an index of relative SSB from P195 in September, and an index of recruits based on the CPUE of small crabs (< 60mm CW) from P195 in September of the same year. Additionally, a significant stock-recruit relationship was identified using our index of relative SSB from P195 in September and an index of recruits based on the CPUE of Age 0 crabs from P120 surveys in May and June in the following year. Statistically significant stock-recruit relationships were identified using both parametric (Ricker, Beverton-Holt, and linear models) and non-parametric methods. The Ricker function provided the best fit to observed stock-recruit data in both cases. Other potential measures of recruitment failed to produce significant fits. Correlation analyses on survey indices at appropriate lags (e.g., Age 0 in year t vs. Age 1 in year t + 1) were used to determine the extent to which surveys were able to track cohorts through successive years. Cohorts could only be tracked in the P195 survey in June. In this survey, Age 0 crabs in June were positively correlated with Age 1 crabs in the following year. No other survey programs were able to follow cohorts at appropriate lags.

5. Estimate historical biomass and fishing mortality rates

Based on a maximum age (t_{max}) of 5 years from tagging studies in North Carolina (Fischler 1965), M was estimated to be 0.87 using a regression equation developed by Hoenig (1983). While we believe t_{max} = 5 to be the best estimate for blue crabs in North Carolina, a wide range of reported values for t_{max} have been used in previous assessments (ranging from 3 to 8; Rugolo et al. 1997, 1998, Helser and Kahn 1999). To address this uncertainty, we also calculated estimates of M using Hoenig's equation (1983) based on $t_{\max}$ values of 3 and 8. Thus, three estimates of M (0.55, 0.87, and 1.44) based on $t_{\max}$ values of 8, 5, and 3, respectively, were used in subsequent analyses.

Annual total instantaneous mortality rates (Z) were estimated with length-based methods (Hoenig 1987). Length-based estimates of mean total instantaneous annual (Z) crab mortality from P195 during 1987-2003 were 1.03 (range: 0.91 – 1.22). These estimates are similar to Zs reported for the blue crab in Chesapeake Bay (~1.0-1.5; Rugolo et al. 1998), but lower than estimates from Delaware Bay (1.19-2.90; Helser and Kahn 1999). Length-based estimates of Z were generally considerably lower than annual Zs estimated from Collie-Sissenwine modeling over the same period (1987-2001; 1.04-2.90). There was no significant increase in mortality observed over time. Length-based estimates of Z were not generated using P120 data because the shallow water emphasis of this survey resulted in very few large crabs being captured. Although the sampling gear used in P120 can effectively sample larger crabs if they are present, this survey selects against large crabs by sampling in habitats (depth strata) in which relatively few large crabs are present.

6. Estimate fisheries management targets such as Maximum Sustainable Yield (MSY)

We used a non-equilibrium, biomass-based stock assessment model to estimate historical biomass (B) and fishing mortality rates (F), as well as Maximum Sustainable Yield (MSY). To address the uncertainty in MSY generated from inherent variability in CPUE data, we fitted one fishery-dependent and two fishery-independent time series separately and in combination. The CPUE of legal-sized blue crabs (crabs > 127 mm CW) from P195 in June and September, and NC DMF commercial pot CPUE (Landings/# NC DMF pots) were selected as the most reliable measures of crab abundance and were fitted to the biomass-based models. Estimates of MSY ranged from a minimum of 27.9 million pounds to a maximum of 51.7 million pounds. Average landings were near or above estimated MSY from 1994-1999 (e.g., 65 million pounds in 1996). During 1996-2002, relative blue crab biomass declined steadily while fishing mortality increased sharply. Relative fishing mortality rates above 1 are inefficient and may lead to a decline in the resource; current fishing mortality rates are likely above this threshold (e.g., estimated F in 2002 was between 0.87 and 3.01). Our estimates of relative F_{MSY} and B_{MSY} indicate that the stock is currently overfished and at a low stock size (B_{2002}/B_{MSY} range: 0.43 – 0.81), and that the fishery has operated above F_{MSY} during 1996-2002. Given: (1) the known limitations of surplus production models; (2) uncertainty associated with landings prior to 1994; (3) inherent variability in CPUE data; and (4) the difficulty obtaining biologically reasonable model fits with many time series, a cautionary approach should be taken to the interpretation of biomass-based modeling results. These difficulties are not surprising, as biomass-based models have historically been applied to long-lived species, and can be unreliable for species which exhibit high rates of intrinsic population growth (Punt and Hilborn 1996). The results, however, do suggest that the blue crab stock is currently at low biomass, and current fishing pressure likely exceeds that required to produce MSY, leading to reduced yields.

Additionally, we employed a two-stage population model (C-S; Collie and Sissenwine 1983) that has proven very useful for crustacean assessments (see Smith and Addison (2003) and references therein). The model has been used to describe blue crab population dynamics in Delaware Bay (Helser and Kahn 1999; Helser and Kahn 2001) and in Chesapeake Bay (L. Fegley, MD Department of Natural Resources, personal communication). The C-S model estimates recruit and fishable population size, as well as annual harvest and fishing mortality (F) rates. Predicted numbers of legal-sized crabs were higher in the early 1990s due to estimated strong year classes and lower Fs; crab numbers then generally declined from 1992 through 2002. The estimated harvest or exploitation rate generally increased over time, although values were substantially lower and showed less of a trend for the highest M. The 10-20% exploitation rates for an assumed M of 1.44 seem unlikely, and we suspect that the M=0.55 and 0.87 cases are more realistic. For those two Ms, exploitation rates ranged from about 0.2 in 1989 to 0.50-0.75 during 1995-2001. Estimated Fs in 1995-2001 for Ms of 0.55 and 0.87 ranged from about 1.0 to 1.5.

7. Generate biological reference points using yield-per-recruit (YPR) and spawning stock biomass-per-recruit (SSBR) analyses

Yield-per-recruit modeling suggests that current fishing mortality rates in North Carolina exceed the conservative biological reference point, $F_{0.1}$, and exceed F_{MAX} under likely values of assumed M (0.55 and 0.87). A fishing target between $F_{0.1}$ and F_{MAX} has been recommended for blue crabs in Delaware Bay (Helser and Kahn 1999). When the most conservative approach of M = 0.55 is used, the analyses yields a target F between 0.36 ($F_{0.1}$) and 0.51 (F_{MAX}), which suggests a reduction in fishing effort should be implemented, since current estimated Fs ($F_{1995\text{-}2001}$ = 1.28) from C-S models exceed this value. Under the assumption of M = 0.87, which we believe to be the best estimate of M, a target F would be somewhere between 0.45 ($F_{0.1}$) and 0.64 (F_{MAX}). Estimates of F from C-S models exceed F_{MAX} from 1994-2001 and range from 0.68 to 2.03. At levels of F that exceed F_{MAX}, the fishery is considered to be growth overfished. Mace and Sissenwine (1993) have advocated the use of $F_{20\%}$ (fishing mortality rate at which the SSBR is 20% of the unexploited SSBR) as a recruitment overfishing threshold. Current estimated Fs ($F_{1995\text{-}2001} = 0.90$) from C-S models exceed $F_{20\%}$ (0.81) in North Carolina for M = 0.55, but not M = 0.87 ($F_{20\%} = 1.12$). Particular concern regarding the status of the spawning stock is warranted, since female blue crabs are harvested at the beginning of their sexual maturity (peeler fishery) and mature females have no size protection in the hard crab fishery. Given the uncertain status of the blue crab spawning stock in North Carolina, a reduction in fishing pressure on mature females may be warranted. Further, non-parametric stock-recruit models estimate that levels of recruitment are generally greater (up to ~ 4 times greater) when relative SSB is above the median value. With the exception of 2003, relative SSB has been below the median since 1999, suggesting levels of recruitment may be inadequate replenish the SSB.

8. Conclusions

There was a systematic increase in commercial landings from 1987-1998, followed by a period of decreased landings from 2000-2002. Overall, fishery-independent indices of abundance are conflicting regarding whether or not a decline in the blue crab stock has occurred. Some indices suggest that the stock has not declined, while others suggest a decline has occurred. Noteworthy, is the decline in SSB to historic low levels during 2000-01, and the apparent return to average levels in 2002-03. In no cases, did we find a significant increasing trend in survey indices, suggesting a conservative, risk-averse management approach to this fishery.

Key findings that should be considered in terms of effort management for the blue crab fishery in North Carolina include: (1) a general lack of coherence among survey indices of abundance resulting in considerable uncertainty regarding current stock status; (2)

extremely low estimates of relative SSB during 2000-2001, although an increase in relative SSB in 2003 suggests a recovery of SSB to average levels; (3) the major role that environmental variation due to rainfall and wind-stress appear to play in annual postlarval recruitment of the blue crab, as well as crab availability to fishery-independent trawl surveys and vulnerability to fishing; (4) a significant spawning stock-recruitment relationship with certain indices of recruitment; (5) generally increased recruitment when levels of relative SSB are above the median value; (6) females are harvested at the beginning of their sexual maturity (peeler fishery) and mature females have no size protection in the hard crab fishery; (7) a decreasing size of mature females and increasing proportion of small (< 100 mm CW) females; (8) the range of best estimates of MSY for the blue crab in North Carolina was 27.9 to 51.7 million lbs, and landings were at or above this level from 1994-1999; (9) steadily decreasing biomass and sharply increasing fishing mortality rates (0.87-3.01 times levels at MSY); (10) decreasing numbers of legal-sized crabs from 1992-2002, concurrent with a generally increasing exploitation rate over the same period; and (11) biological reference points from YPR and SSBR that suggest a reduction in fishing mortality may be warranted due to growth and recruitment overfishing concerns.

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CHAPTER 1

POPULATION DEMOGRAPHICS AND MOVEMENT OF BLUE CRABS IN SALT MARSH CREEKS

ABSTRACT: A series of complimentary laboratory and field studies assessed the nursery role of salt marsh habitats for the blue crab (*Callinectes sapidus*). Population demographics and movement patterns of juvenile and adult blue crabs were quantified in two tidal salt marsh creeks (Prytherch Creek, PC; Haystacks, HS) near Beaufort, North Carolina, USA during June – October 2001. While there are many studies that report estimates of population density, mortality rates, or movement rates for blue crabs, this study represents one of the first attempts to estimate all quantities concurrently. Approximately 1,100 blue crabs were tagged internally with individually coded microwire tags. A Jolly-Seber capture-recapture model was used to estimate population density as well as survival and capture probabilities. Mean crab density in PC was 1.2 crabs/m^2, which was an order of magnitude larger than crab density estimates from HS (0.10 crabs/m^2). Mean daily survival probabilities for crabs residing in PC were 0.98 d $\pm$ 0.08, and 0.96 d $\pm$ 0.03 for crabs in HS. To examine patterns of movement within a salt marsh and to quantify emigration rates from our study areas, crabs were tracked for 24-h using individually numbered floating tags that were affixed to the carapace of juvenile crabs. These independent estimates of emigration allowed us to partition crab loss from salt marshes into mortality and emigration. Juvenile crabs exhibited a high degree of site fidelity to a given marsh creek during summer-fall, suggesting that losses are due more to mortality than emigration, and help to understand site-specific differences in mean density. Juvenile crabs were mobile within the interstices of the marsh canopy during flood tide, and were equally distributed buried in intertidal marsh and adjacent mud areas during ebb tide. Juvenile crabs may experience a spatial refuge from cannibalism in the marsh canopy since adult conspecifics are physically impeded by dense vegetation and

rarely move far into marsh habitats. This spatial refuge in the vegetated marsh surface may be significant, since cannibalism represents a large source of mortality for this species. The relatively high use of the marsh surface by juvenile blue crabs, combined with a general lack of sampling these complex habitats, suggest that crab densities may be even higher in salt marsh systems than previously thought.

INTRODUCTION

Estuaries are comprised of a mosaic of habitats that are among the most productive ecosystems on Earth. Within estuaries, salt marshes composed mainly of *Spartina alterniflora* and associated tidal creeks and marsh pools are among the most conspicuous habitats. Due to high densities of fish and crustaceans, salt marsh ecosystems are generally recognized as important nursery areas for many species, and support many lucrative coastal fisheries (Nixon 1980, Boesch & Turner 1984, Zimmerman et al. 2000). The nursery role of estuarine habitats is of special importance to conservation and management issues, and has received increasing attention in light of recent U. S. federal regulations that mandate the identification of Essential Fishery Habitat (EFH) for all federally managed fishery species. Nurseries are those habitats that allow for greater juvenile production as a result of a combination of factors such as increased (1) density, (2) growth, (3) survival, (4) efficient movement to adult habitats (Beck et al. 2001). A comparison of all of these factors across different habitats is ideal, and may aid in determining which habitats serve as key nurseries, as well as the underlying ecological processes responsible.

The blue crab (*Callinectes sapidus*) is a key benthic predator in the ecology of estuarine and nearshore coastal habitats of the Eastern United States and Gulf of Mexico, capable of regulating populations of many benthic and infaunal invertebrate species on which it feeds (Eggleston et al. 1992, Seitz et al. 2001). The blue crab supports some of the most economically important fisheries on the east and gulf coasts of the U.S. Recent declines in blue crab stocks in Chesapeake Bay (Miller & Houde 1998, Lipcius et al.

2002), Delaware Bay (Helser & Kahn 1999) and North Carolina (this report) have been attributed to overfishing and habitat loss. Habitat management plans attempt to protect vital nursery areas for the blue crab and other species from degradation. These plans require information on key nursery habitats for conservation.

Although seagrass beds have generally been considered the primary nursery areas for juvenile blue crabs because of relatively high crab abundances in these habitats (Orth & van Montfrans 1987, Etherington & Eggleston 2000, Etherington & Eggleston 2003), a suite of alternative complex nursery habitats such as salt marsh and shallow detrital habitats have also been identified (Etherington & Eggleston 2001, Minello et al. 2003). The overall objective of this study was to quantify population demographics and movement patterns of juvenile and adult blue crabs in two tidal salt marsh habitats. This study used capture-recapture methodologies that allowed for identification of individually tagged crabs, and included covariates into analyses that traditionally do not include them, which allowed assessment of the relationship between survival, capture probability and crab size. The results are used to assess the nursery role (*sensu* Beck et al. 2001) of tidal salt marshes for blue crabs.

MATERIALS AND METHODS

Study sites

Local population demographics of juvenile blue crabs were studied in two tidal marsh creeks, Prytherch Creek (PC) and Haystacks (HS), located in the Newport River estuary near Beaufort, North Carolina, USA (Fig. 1). Intertidal zones within the study sites were composed mainly of *Spartina alterniflora*, while the subtidal areas consisted of muddy substrate and small patches of oyster, *Crassostrea virginica*. The study sites were well suited for an intensive capture-recapture study of mobile crabs because of the (1) relatively high densities (0.1 - 1.2 crabs/m^2) of juvenile blue crabs, (2) relatively small size of the study areas (PC = 1,625 m^2, HS = 2,028 m^2), which facilitated intensive sampling, and (3) constricted entrance to the study sites, which likely reduced emigration. The upstream boundaries of the study areas were defined by the intertidal marsh, which were generally inaccessible to sampling, and the downstream boundaries were defined by an imaginary line transecting the creek mouth. The estimated total drainage of marsh area into each study area was significantly larger (PC 3,275 m^2, HS 8,270 m^2) than the actual area sampled.

Population sampling

During June-October 2001, PC was sampled on 10 occasions (mean sampling interval 4 days), while HS was sampled on six occasions (mean sampling interval 7.8 days). A 2-m beam trawl (0.76 cm mesh; 0.38 cm mesh cod-end) was used to collect juvenile and adult blue crabs (22 – 153 mm CW). The beam trawl provides an efficient means of sampling blue crabs from shallow water habitats because the width of the net is fixed, allowing for relatively accurate measures of animal densities, and the relatively small size of the net and frame allowed manual towing immediately adjacent to the intertidal marsh in shallow water (<1 m) water. A total of 1,376 individual crabs were captured from PC over 10 sampling intervals and 1,110 individuals from HS over 6 sampling intervals (Appendix Table 1). Of these, 795 individuals were tagged and released in PC, and 347 individuals were tagged and released in HS. Three factors precluded the tag and release of all captured crabs: (1) many crabs were smaller than the lower limit imposed by our tagging gear (22 mm), (2) crabs sustained recent damage from capture or subsequent interaction with conspecifics, (3) recaptured crabs were necessarily sacrificed to obtain the coded microwire tag (CWT), which coded for the initial date of capture and allowed identification of an individual (see below). Captured crabs were sorted approximately by size (mm CW) and stored in dark holding containers filled with water to minimize agonistic encounters. Additionally, containers were supplied with aeration to minimize physiological stress following capture. Both total and internal CW (Olmi & Bishop 1983), as well as sex, were recorded for each crab; however, only crabs greater than 22 mm CW were considered in analyses due to limitations of the internal microwire tagging method (see below). Crabs showing obvious recent damage were not tagged and were returned to the population.

Crabs were tagged using stainless steel CWTs (Northwest Marine Technologies, Inc. Shaw Island, WA 98286), which are laser-etched with a sequential numeric code and individually identifiable. CWT's have been used to quantify blue crab demographics such as population size and apparent survival in estuarine systems (van Montfrans et al. 1991, Fitz & Wiegert 1992a,b). Additional laboratory studies (Fitz & Wiegert 1991, van Montfrans et al. 1986, this study) demonstrated that CWT's have negligible effects on mortality and growth. The CWT's were magnetized at the time of injection, which allows for later detection of tags in the field at the time of recapture using a magnetic detection system, and then injected into the basal muscle of the 5^{th} periopod, and were completely internal and retained through molting. To ensure that crabs received a full CWT, a blank tag was cut and saved following each tagging of an individual crab. This procedure was necessary to keep a reference of the numeric sequence to which CWT's recovered from recaptured crabs could be compared to identify unique individuals. After data collection and tagging, each individual crab was scanned using a magnetic moment detector to check for successful tagging and released into the study site in the approximate area of capture. During recapture efforts, captured crabs were checked for CWT's using a magnetic moment detector (Northwest Marine Technologies). Crabs with CWT's were not released, but were sacrificed to obtain the CWT for individual identification; a procedure that is required to obtain the original date of capture. During each recapture event, untagged crabs were tagged and released to the study site as described above. Individual capture-recapture histories were then used to generate Jolly-Seber (JS) summary statistics for PC and HS (Appendix Tables 1a, b).

Mark-recapture analysis

Population abundance and maximum-likelihood estimates (MLE's) of apparent survival (ϕ) and recapture (p) probabilities were generated from individual capture-recapture histories using the JS model framework (Cormack 1964, Jolly 1965, Seber 1965). The stochastic JS model does not assume population closure (closure = no additions or deletions from the population), and is therefore useful for demographically open populations in which mortality, migration, and recruitment occur (Manly 1984). Following standard JS notation, ϕ_i is the probability of not dying or emigrating from the study site between periods i and i + 1, and p_i is the probability of being captured during period i. Estimates of population size ($\hat{N}_i$) for each sampling interval i were calculated as

$$\hat{N}i = n_i / \hat{p}_i,$$

where n_i was the total number of individuals captured in period *i*, and $\hat{p}_i$ the probability of capture from JS modeling as described above. The assumptions of the JS model are: (1) all individuals in the populations at a given sampling time have an equal probability of capture (this value can change over time), (2) every tagged individual in the population has the same probability of survival, (3) tags are neither lost nor overlooked, (4) the duration of the sampling period must be short relative to the time between samples, and (5) animals are released immediately after sampling (Lancia et al. 1994). Variation in survival or capture probability among individuals (heterogeneity) can lead to both positive and negative bias in estimates of population size (Pollock et al. 1990). The assumptions of homogeneity of survival and capture probabilities were addressed by goodness of fit (GoF) testing and through the inclusion of covariates, which can account for potential size-specific differences in survival (ϕ) and recapture rates (p). Although often ignored, tag loss can impart significant bias to survival estimates, and reduces the effective recapture rate resulting in a loss of precision. To account for bias due to tag loss and tag induced mortality, estimates of tag retention and mortality due to tagging were generated from a laboratory tagging study and used to correct survival estimates following the procedure of Arnason and Mills (1983). The assumption that sampling is instantaneous was met to the degree possible based on logistical constraints, by relatively short sampling duration (~ 4 hours) and sampling intervals (minimum 4 days).

Goodness-of-fit and model selection

All JS capture-recapture modeling used the computer software program MARK (White and Burnham 1999) for parameter estimation and model selection. GoF tests insured that the JS model provided an adequate fit to the data, and were conducted with the computer program RELEASE (Burnham et al. 1997). GoF testing is important as a significant lack of fit may indicate that assumptions underlying the model have been violated. Presently, there is no adequate method for assessing GoF with models containing covariates; therefore GoF tests were performed on the most general model of time-varying survival and capture probabilities, with covariates omitted as recommended by Cooch and White (2001). To adjust for lack of fit, overdispersion in the data was quantified using c-hat (χ^2/df) from GoF testing (Lebreton et al. 1992), and, if necessary, used to transform Akaike's Information Criterion (AIC) values to quasi-likelihood adjusted Akaike's Information Criterion ($QAIC_c$). Although the preferred method to estimate c-hat is parametric bootstrapping (Cooch & White 1999), this statistical technique was infeasible due the experimental protocol in which animals were sacrificed at recapture.

Once an adequate fit to the fully time-dependent (ϕ_t,p_t) JS model was established through GoF testing, reduced parameter models (ϕ,p ; ϕ,p_t ; ϕ_t,p ; model notation follows the convention of Lebreton et al. (1992), and uses the subscript t to denote that a parameter can vary over time), holding ϕ and p constant over all sampling intervals, were fitted to capture-recapture histories to determine the most parsimonious model that still provided a good fit to the recapture data. Additionally, since individual crab size may affect the probability of capture and survival, length (CW) was tested as a model covariate. Survival and capture probabilities were constrained to linear and quadratic functions of CW. Individual covariates were converted to standardized values ($(x - \bar{x})/SD_x$), and estimators (ϕ, p) were related to CW using a logit function with beta parameters estimated from MARK. The use of standardized covariates helped insure that numerical optimization routines arrived at correct parameter estimates (Evan and Cooch 1999).

JS model selection was based on $QAIC_c$, which was adjusted using c-hat values generated from GoF testing. This is generally the preferred method for model selection, as it allows for comparison of a large number of candidate models without an inflation of experiment-wise error, and performs well when assumptions may be violated (Burnham et al. 1995). In general, models with $\Delta QAIC_c < 7$ are considered plausible, and models with a $\Delta QAIC_c < 2$ have approximately equal weight (Cooch and White 2001). Maximum likelihood estimates and standard errors of survival and capture probabilities were derived from model averaging of reasonably likely models ($\Delta QAIC_c < 2$) for PC and HS.

Laboratory estimation of tag retention and tag-induced mortality

To determine the extent to which certain model assumptions may have been violated, a 37 d laboratory experiment (August 8 – September 12, 2002) tested the effects of CWT's on blue crab mortality and rates of tag retention (θ). A 2-m trawl was used to collect juvenile blue crabs ranging from 22.7 to 35.1 mm CW from PC. This size range was predominant within both study areas, and was representative of the majority of the study population. Fifteen crabs were randomly selected and subsequently received a CWT using the tagging procedure described above. An equal number of crabs were not tagged and served as a control treatment. Crabs were sexed and measured (mm CW) prior to being randomly assigned to individual plastic containers, which prevented cannibalism and allowed individual crabs to be tracked throughout the duration of the experiment. Crabs in containers were placed into a water table supplied with flow-through seawater and supplemental aeration. Initial size of crabs did not differ significantly (student's t-test, *df* = 28, p = 0.78) among tagged (27.58 mm CW $\pm$ 1.16 mm) and control (27.99 mm CW $\pm$ 0.88) treatments (Table 1). Crabs were fed to satiation at 1-2 day intervals with snails (*Littorina irroratta*) and fish, principally pinfish (*Lagodon rhomboides*) and killifish (*Fundulus sp.*) collected from local marsh creeks. Crabs were checked daily for mortality and molting. Recently molted crabs were allowed 1 - 2 d to harden prior to being measured and checked for tag retention. A student's t-test was used to test whether or not tagging affected (1) time-to-first-molting (days), (2) molt interval between first and second molts (days), (3) survival, and (4) mean percent increase in CW per molt (%). The mean percent increase in size (i.e., (postmolt CW – premolt CW)/ premolt CW) was calculated following each molt event. The assumption that variances were homogeneous was verified using Levene's test of equality of variances. A Chi-square test was used to assess the effects of tagging on mortality.

Field movement rates, emigration and habitat utilization.

One disadvantage of the JS model is the inability to separate the probability of loss (1 - ϕ) into its component processes, mortality and emigration, without additional information (Pollock et al. 1990). To complement the mark-recapture analysis and quantify emigration rates of juvenile crabs within the marsh creeks, as well as provide information on daily patterns of movement and distribution, individual crabs were tagged and tracked within PC and HS. Juvenile crabs (35 - 62 mm CW) were collected from the study sites and fitted with individually numbered floats attached to the lateral spines by a short metal leader and 1 m of monofilament line. Due to the small size of these juvenile crabs, it was not feasible to use ultrasonic telemetry as a study technique (e.g., Bell et al. 2003) because of the large size of the transmitters relative to the crabs.

Crabs were observed to be quite mobile in pilot trials in the tidal creek systems suggesting that the float did not significantly hamper movement. While movement was not hampered in unvegetated habitats, crabs occasionally became tangled within the interstices of the marsh and the tagging method likely limited the distance to which crabs could enter the marsh. The experiment was conducted in four batch releases (two each at PC and HS). Each release consisted of 24 individually tagged crabs, and the interval between trials at each site was no more than 4 days. Tagged crabs were released at flood tide and at random starting locations within the study site boundaries, and allowed a period of four hours to acclimate prior to tracking. Crabs were relocated visually every 1 – 2 h for a period of 24 h. Nighttime tracking was accomplished using a combination of ambient moonlight and a flashlight, and was aided by the reflective surface of the floats. To track movement distance and direction over time, the location of each crab was plotted onto site maps relative to natural landmarks and PVC-pipe stakes that were placed at 10 m distances apart. Two metrics were used to quantify movement distance within tidal creeks: (1) the total distance traveled, defined as the sum of the linear distances between all relocation observations, and (2) the net distance traveled, defined as the linear distance between the initial and final relocation observations. An index of meander was also calculated using the ratio of the net distance to the total distance traveled. This value can range between 0 and 1, with 0 indicating random movement and 1 indicating directed movement. Estimates of emigration rates were calculated as the proportion of crabs leaving the study area over 24 h. To determine microhabitat utilization, the habitat type (marsh vs. mud) was recorded for each individual at each resighting, and observations were stratified into two subsets defined by tidal height relative to the marsh surface (flooded vs. exposed). The proportion of time spent in each microhabitat for individual crabs was then calculated separately for periods when the marsh was flooded and when the marsh was exposed at low tide. We tested separately whether or not the mean proportion of time spent in mud versus intertidal marsh varied for periods when the marsh was flooded or exposed using student's t-tests.

RESULTS

Population structure

The population of crabs within replicate tidal marsh creeks consisted mainly of small individuals ranging from 6 - 79 mm CW, and contained few crabs greater than 120 mm CW (Fig. 2). The size structure of crabs was similar between study sites, with small (0-39 mm CW) to medium (40 –79 mm CW) sized crabs dominating both populations throughout the study duration, composing 95% (range: 88 – 98%) of the total population in PC, and 93% (range: 88 – 97%) in HS. Sex ratios (M:F) were 0.94 at PC and 1.03 at HS, and did not differ significantly from 1:1 at either PC ($\chi^2 = 0.859$, $df = 1$, $p = 0.35$) or HS ($\chi^2 = 0.16$, $df = 1$, $p = 0.69$).

Goodness of fit and capture-recapture model selection

No significant lack of fit to the fully time-dependent JS model was observed for crab recapture data at either PC ($\chi^2 = 18.37$, $df = 11$, $p = 0.07$) or HS ($\chi^2 = 0.86$, $df = 3$, $p = 0.83$), indicating that model assumptions were probably met, and that the JS model framework was appropriate for both populations. Estimates of c-hat generated from GoF testing were 1.39 for PC and 0.34 for HS, and were used to calculate the $QAIC_c$. Since correcting for underdispersion (c-hat < 1) is not suggested, a c-hat of 1.0 was used for HS.

The full JS model allowing varying survival and capture probabilities over time, as well as reduced parameter models, were fitted to the capture-recapture histories of crabs for PC and HS separately. $QAIC_c$ values for PC and HS were then used to rank the models from the candidate model set (Appendix Table 2a, b). More complex models including covariates were then fitted to the capture-recapture data. The smallest $QAIC_c$ for PC was for a model with constant survival and time-specific probability of capture, where p was modeled as a quadratic function of length (CW) for the PC population (Appendix table 2a). Despite the lower $QAIC_c$ values for the models with covariates included, we chose to use the best fitting base model (ϕ, p_t) for the following reasons: (1) estimates of ϕ and p were similar in models with and without covariates (Appendix Table 3), (2) the relationships between size (CW) and model parameter estimates (ϕ, p) differed by study site (Appendix Fig. 1) and the predicted relationships could not be explained biologically, and (3) limitations of the data set in which sufficient recapture data for a relatively large size range of crabs was lacking. For example, the majority of captured crabs (88-98%) were within a size range of 22 and 80 mm CW, resulting in a lack of data for both very small (crabs < 22 mm CW) and larger individuals (crabs > 80 mm CW). Thus, the relationships between estimated model parameters (ϕ, p) and size (CW) were poorly defined over a large range of sizes and did not justify using complex models including covariates. Because no single model clearly fitted the data better than another (Appendix table 3), model averaging was used to generate apparent survival and capture probabilities. For the HS population, the model with the best $QAIC_c$ assumed constant survival and time-specific capture probability, where survival was modeled as a linear function of CW, and probability of capture was modeled as a quadratic function of length

(CW; Appendix Table 2b, Appendix Fig. 1). As with PC, models with and without covariates generated similar estimates of survival and capture probability (Appendix Table 4) and the base model with the lowest $QAIC_c$ assumed constant survival and time-specific capture probability. Because the base model (ϕ, p_t) was strongly supported by the data (ΔQAICc values > 2 for all other models; Appendix table 2), model averaging was not required for HS.

Population size and demographic rates

Mean population size in PC ranged from 1,085 – 5,096 crabs over the course of the study (Table 2a), which was an order of magnitude larger than population estimates from HS (range: 102 – 270 crabs). Mean crab density at PC was 1.2 crabs/m^2 and ranged from 0.7 to 3.3 crabs/m^2 over time. Mean crab density at PC was an order of magnitude higher than HS (HS: mean = 0.10 crabs/m^2 and ranged from a minimum of 0.05 to a maximum of 0.13 crabs/m^2).

Mean apparent survival probabilities (ϕ) for crabs residing in PC were 0.80 $\pm$ 0.06 (Table 2a), and 0.74 $\pm$ 0.03 (Table 2b) for crabs in HS. Estimates of tag retention (?) were used to correct estimates of survival (ϕ^c) and SEs for bias due to tag loss, and to calculate unbiased estimates of survival probabilities ($\phi^c = \phi / \theta$). After correction, daily survival probabilities increased to 0.91 $\pm$ 0.08 for crabs at PC (Table 2a) and 0.84 $\pm$ 0.03 for crabs at HS (Table 2b). For comparison with estimated emigration rates (see below), which were daily probabilities, daily crab survival (ϕ_d) was calculated as $\phi_i = (\phi_d)^d$, where d is the time between sampling events in days. Mean daily survival probabilities corrected for tag loss were 0.98 d^{-1} $\pm$ 0.08 ($0.91 = 0.98^4$) for crabs at PC and 0.96 d^{-1} $\pm$ 0.03 ($0.84 = 0.96^4$) for crabs at HS. Coefficients of variation (CV = SE/estimate), which describe the precision of survival estimates, were 0.09 for PC and 0.04 for HS, indicating relatively precise parameter estimates despite a low capture probability for PC (see below). Following correction for tag loss, apparent survival (ϕ^c = 1 – (mortality + emigration)) was partitioned using estimates of emigration from free-ranging blue crabs (see below) to calculate mortality.

The estimated emigration rate from PC was 0 individuals d^{-1}, and was 0.02 individuals d^{-1} in HS, resulting in roughly equal estimated survival rates for both creeks (PC = 0.98 + 0.0 = 0.98; HS = 0.96 + 0.02 = 0.98), since the probability of loss includes mortality and emigration. Estimates of capture probabilities were ~ 8 fold larger in HS, and were more precise at HS (CV range: 0.09 – 0.19) than at PC (CV range: 0.30 – 0.75). For example, mean recapture probability in PC was 0.06 $\pm$ 0.02 per sampling period, and was time-specific, ranging from 0.02 to 0.17 among sampling intervals for PC (Table 2a). Mean recapture probability in HS was 0.46 $\pm$ 0.10 per sampling period (Table 2b), and ranged from 0.15 to 0.73.

Tag retention and tag-induced mortality

Proportional mortality of juvenile blue crabs in the laboratory was low in both tagged (7%) and control (13%) treatments, and was not significantly different between treatments (χ^2 = 0.28, *df* = 1, p = 0.60). Of the 15 tagged individuals, 13 retained the tag through the entire experiment (37 d) for an overall tag retention of 88% (Table 1). In both cases in which tags were shed, tag loss occurred during the first molt following tagging. All crabs that retained the tag through the first molt retained the tag through all subsequent molts. Mean time to first molt was not significantly different (student's t-test, t = 0.08, *df* = 28, p = 0.77) between tagged (5.9 d $\pm$ 0.5) and control (6.1 d $\pm$ 0.5) treatments. The intermolt period between first and second molts was also not significantly different (student's t-test, t = 1.41, *df* = 1,17, p = 0.25) between tagged (12.7 d ± 0.8) and control (14.3 d ± 1.1) treatments. Proportional size increases were not significantly different between tagged and control treatments after the first molt (student's t-test, t = 0.35, *df* = 1,28, p = 0.56), but marginally significant after the second molt (student's t-test, t =3.61, *df* = 1,17, p = 0.08; Table 1), with size increases in the tagged treatment being higher than in the control. This result is likely spurious since tagging would likely have a negative impact on growth.

Movement in the field

Emigration rates of crabs from tidal creeks was extremely low (0.02 crabs d^{-1}, for HS, and 0 crabs d^{-1} for PC), indicating high site fidelity of juvenile crabs to individual tidal marsh creeks during summer. The mean total distance that crabs moved in tidal marsh creeks was 19 m for PC (range: 6 – 48 m) and 25 m for HS (range 4 – 50 m). Mean net movement was 12 m for PC (range: 6 – 23 m) and 18 m for HS (range: 4 – 37 m). The index of meander was 0.68 for PC, and 0.73 for HS, indicating juvenile crabs exhibited relatively directed movement over a period of one day. Movement speeds were slow, and averaged 0.77 m h^{-1} and 1.09 m h^{-1} for PC and HS, respectively, and reflected the tendency of crabs to bury into the mud during ebb tide.

Relocation observations were also used to calculate the proportion of time individual crabs spent in either the *Spartina alterniflora* marsh surface or unvegetated muddy creek during flood vs. ebb tidal stages. When the marsh was flooded at high tide, crabs utilized the vegetated marsh surface significantly more often than the adjacent muddy creek habitats in both PC (student's t-test, t = 5.09, *df* = 29, p < 0.001) and HS (student's t-test, t = 3.862, *df* = 34, $p < 0.001$) (Fig. 3). When the marsh was exposed at low tide, there was no significant difference in the proportion of time crabs spent in the marsh versus muddy creek bottom (Fig 3), indicating that ~50% of the tagged crabs remained buried in mud within the vegetated marsh surface at low tide.

DISCUSSION

Capture-recapture techniques using microwire tags are a powerful tool for estimating demographic rates and habitat use of mobile animals, information that is essential to identifying the nursery role of a given estuarine habitat. The key findings from these complementary field and laboratory experiments were: (1) mean density of juvenile blue crabs was an order of magnitude higher at Prytherch Creek than the Haystacks salt marsh creek, (2) survival was similar between sites, and subtle differences in daily probabilities of loss only partially explained the order of magnitude differences in mean crab density (see below), (3) microwire tagging had negligible effects on crab growth and mortality, (4) juvenile crabs displayed very little emigration from a given salt marsh creek, and (5) crabs took refuge in the vegetated marsh surface during flood tide and often buried in mud during exposure of the marsh at during ebb tide. The results from this study indicate relatively high survival of juvenile blue crabs in salt marsh creeks, but it appears that the same habitat type can harbor strikingly different densities of crabs. This might be due to differences in proximity to sources of postlarval and early juvenile recruits ingressing through nearby Beaufort Inlet (Fig. 1), as well as to tidal creek morphology, which provided more marsh edge at PC than HS (see below). The extent of potential differences in crab density in similar marsh habitats is still not clear since inferences from this study are based on only two replicate creeks. While there are many studies that report estimates of population density, mortality rates, or movement rates for blue crabs, this study represents one of the first attempts to estimate all quantities concurrently. Concurrent estimates of the probability of loss and emigration allowed for survival to be explicitly estimated in this study. It is also one of several studies to apply capture-recapture techniques to juvenile blue crabs, and the first to allow for the identification of individual crabs, as well as accounting for size-specific variation in capture and loss probabilities. Identification of individual animals is necessary for incorporating covariates into capture-recapture models.

Assumptions of the Jolly-Seber model

Meeting the assumptions of capture-recapture models is critical to ensuring unbiased parameter estimates, and is requisite to designing capture-recapture experiments (Pollock & Mann 1983). Below, we consider the assumptions of the JS capture-recapture model (see Methods) employed in this study, and the degree to which these assumptions may have been violated. If tagged individuals are more likely to be captured than untagged individuals, these individuals will be more likely to be subsequently recaptured, which will lead to an underestimation of population size since tagged individuals constitute a greater proportion of recaptured individuals than in the overall population under study. Conversely, if tagged individuals are less likely to be recaptured than untagged individuals, then population size will be overestimated. In the present study, we used a beam trawl to capture crabs within each study site. It is unlikely that the capture probabilities of tagged and untagged individuals differed because the efficiency of capture by actively trawling should be independent of tag status. Additionally, the shortest interval between sampling periods was 4 d, which should have been sufficient to allow for mixing of tagged and untagged individuals. A previous tagging study using blue crabs reported adequate mixing after only several days (Fitz & Wiegert 1992).

Although the presence or absence of a tag is unlikely to affect capture rates, aspects of the ecology of blue crabs and large variations in size likely generated heterogeneous capture probabilities. Larger blue crabs are capable of faster movement rates, and may be more likely to evade sampling by the beam trawl than smaller crabs. This assertion was supported by field observations in which net avoidance by larger individuals was observed. Similarly, the smallest crab sizes are not sampled as effectively as larger crabs by trawl gear (Orth and van Montfrans 1987), leading to reduced capture probabilities for the smallest crabs. We attempted to address differences in capture probabilities by including length as a covariate, which would allow explicit estimation of capture probabilities as a function of length. The relationship of length and capture probability was best described by a quadratic function in both study populations (Appendix fig. 1), but was generally an increasing function of size (CW) at PC and generally decreasing with size (CW) at HS (Appendix Fig. 1). We could find no biological justification for the different observed patterns between capture probability and size at PC and HS, and lacked sufficient data for both small (<22 mm CW) and large (>80 mm CW) crabs to adequately model this complex relationship. Although our data did not justify the inclusion of covariates, factors such as body size may affect capture probabilities, and we encourage the use of covariates to investigate this potential relationship in future studies whenever feasible.

Survival rates are assumed constant for each tagged animal in the population. If tagging causes reduced survival of tagged animals, then survival rates will be underestimated. Laboratory studies (van Montfrans et al. 1986, Fitz & Wiegert 1991, this study) demonstrated that microwire tagging has negligible effects on survival. Mortality rates are likely to vary as a function of body size since larger individuals attain a relative refuge from predation with size (Hines & Ruiz 1995). Smaller individuals also molt more frequently than larger crabs, and are particularly vulnerable to increased predation immediately following molting while in a soft-shell state (Ryer et al. 1997). Conversely, survival of large crabs may be underestimated since large crabs are capable of relatively large daily movements (e.g. mean 131 m d^{-1}; range: 0 – 569 m d^{-1} ; Wolcott & Hines 1990), and are more likely to emigrate from study populations than smaller crabs. While we used body size as a covariate to assess size-specific differences in survival, a decrease in mortality with size may be balanced by an increase in emigration with size. The loss rates estimated in this study likely represent mainly mortality, however, since smaller crabs composed 88 – 98% of the study populations, and emigration rates for these sizes were extremely low. As with capture probabilities, our data did not justify the inclusion of covariates to explain the relationship between size (CW) and survival.

The effects of tag loss include both direct and indirect consequences on parameter estimation. Most important is that tag loss will result in fewer recaptures, and consequently survival will be underestimated. Our estimate of tag retention (88%) was similar to rates reported by van Montfrans (1986), but lower than those (96 - 98%) obtained by Fitz & Wiegert (1991). High tag retention (Fitz & Wiegert 1991) was likely a factor of the larger size of crabs used in their experiment (46.4 mm CW) versus this study (27.6 mm CW). Both cases of tag loss in the present study were associated with the first molt following tagging, and occurred in the smallest individuals. In this study, most tagged crabs were less than 40 mm CW and therefore survival estimates were corrected for tag loss (Arnason and Mills 1981).

Population size and demographic rates

Mean densities of blue crabs in this study (0.7 – 3.3 crabs m^{-2} for PC and 0.04 – 0.10 crabs m^{-2} for HS) were generally similar to estimates from other salt marsh systems along the U.S. east coast during summer-fall: 0.4 – 4.8 crabs m^{-2} (Orth & van Montfrans 1987), 0.08 – 0.15 crabs m^{-2} (van Montfrans et al. 1991), and 0.2 crabs m^{-2} (Fitz & Wiegert 1992). Estimates of population densities are often difficult to obtain because they require that the sampling efficiency and selectivity of the sampling gear be known for a given species. Assuming catch efficiencies less than 100% (i.e., not all animals present are captured), densities will be underestimates of true abundance. Catch efficiency for the blue crab has been estimated for dredges (Voelstad et al. 2000), trawls (Orth & van Montfrans 1987) and suction sampling (Orth and van Montfrans 1987), but interactions between gear type (Kneib 1997, Rozas and Minello 1997), habitat (Rozas and Minello 1997), and tidal stage (Kneib & Wagner 1994) make direct comparisons difficult. JS models allow for estimation of capture efficiency and provide an alternative method for estimating density.

The populations in both PC and HS were consistently dominated by smaller size classes (0-39 mm CW). This is in contrast to patterns of relative abundance reported for blue crab populations elsewhere, in which larger crabs were most common. In salt marsh habitats in Georgia, crab sizes ranging from 51 - 125 mm CW predominated (Fitz & Wiegert 1992a,b), and in Chesapeake Bay crab sizes ranging from 50 - 99 mm CW were most abundant (van Montfrans et al. 1991). Differences in sampling regimes likely explain the differences in relative abundance observed in the present study versus the previous studies (van Montfrans et al. 1991, Fitz & Wiegert 1992b). In contrast to Fitz & Wiegert (1992b), who sampled exclusively in subtidal habitats (minimum depth 1.5 m), and van Montfrans (1991), who used block nets to capture crabs before they buried at low tide and uncovered buried crabs by hand at low tide, we sampled areas immediately adjacent to the marsh edge, and continuously sampled shallow habitats (<0.1 m) until the study sites had completely drained of water at low tide. This method of sampling appeared to preferentially catch smaller crabs found in these shallow areas. For example, our continuous tracking of individual crabs found smaller crab size classes utilized intertidal habitats almost exclusively, and that these small size-classes rarely moved into subtidal areas. Furthermore, an inverse relationship between crab size and distance from unvegetated habitats was reported by Arnold & Kneib (1983), with smaller individuals concentrated on the marsh surface relative to large crabs that were restricted mainly to the marsh edge at high tide (Kneib 1995).

One striking feature of our blue crab density estimates was that those in HS were an order of magnitude lower than those in PC. This pattern of abundance may be explained by several factors affecting additions and losses to the local population. The most parsimonious explanation was the higher probability of loss for HS relative to PC. Overall, daily probabilities of loss between sites were similar (PC = 0.98 vs HS = 0.96), but could lead to differences in local population size over relatively short time scales. For instance, assuming no recruitment, a cohort at PC would be reduced to 55% of initial abundance after one month (0.98^{30}), whereas an identical cohort at HS would be reduced to 29% (0.96^{30}) over 30 days. This roughly two-fold expected difference in crab abundance between PC and HS after 30 days, however, is not sufficient to explain the order of magnitude difference in crab density observed between PC and HS. Differential recruitment between sites may also explain the observed differences in density between PC and HS. PC is located closer to Beaufort Inlet (Fig.1), the likely source of emigrating megalopae to both study areas, and in close proximity to a high flow channel (Hettler and Chester 1990). Differences in the spatial scale and morphology of the tidal creeks may have also led to increased densities at PC relative to HS. The PC site was smaller, composed of many pools and rivulets, and had a greater percentage of edge microhabitat relative to HS. Survival of blue crabs is higher along marsh edge microhabitats than the central channel of tidal creeks, and higher in a small tidal creeks compared to a large ones (Ryer et al. 1997).

The probability of crab loss (mortality + emigration) observed in our study (2 – 4% crabs d^{-1}) was similar to previous reported estimates for blue crabs using mark-recapture techniques in Chesapeake Bay during summer (van Montfrans et al. 1991; 5.7 – 8.2% d^{-1}), and to the highest loss rates observed in Georgia (Fitz & Wiegert 1992b; 40% biweekly ≈ 3% daily). Loss probabilities for blue crabs in tidal marsh creeks in this study indicate that loss is relatively constant over summer and early fall (June – October), as seems to be the case in Chesapeake Bay tidal creeks (van Montfrans et al. 1991, Ryer et al. 1997). Juvenile crabs in this study displayed a high degree of site fidelity to individual tidal creek systems during summer. Although movement rates of crabs in this study were lower than those reported previously (Wolcott & Hines 1990, Hines et al.1995), it was not surprising given the relatively small size of individuals in this study.

The low rates of emigration for juvenile blue crabs (35 – 67 mm CW) observed in this study contrast with the density-dependent and very rapid emigration rates of early juvenile blue crabs (2.1 – 9.1 mm CW) from seagrass beds near Oregon Inlet, NC (Etherington et al. 2003, Reyns and Eggleston 2004). Ontogenetic changes in blue crab behavior likely explain the lower rates of emigration observed in this study compared to those in Reyns and Eggleston (2004). For example, density-dependent emigration of early juvenile benthic instars (J1-J2) was observed at 1-1.2 crabs/m^2 (Reyns and Eggleston 2004), which is similar to densities in this study but using larger sized crabs. Alternatively, emigration rates may be lower in salt marsh (this study) than seagrass systems where studies by Etherington et al. (2003) and Reyns and Eggleston (2004) were conducted.

Utilization of marsh habitats

Juvenile crabs moved onto the marsh surface at high tide, a pattern consistent with earlier observations of habitat utilization in this species (Kneib & Arnold 1983, Fitz & Wiegert 1991, Kneib 1995). Crabs in this study were found in association with the marsh edge, and rarely traveled more than 3 m into the marsh. While the method of tagging crabs using floats attached to the dorsal carapace likely impeded travel through the heavily vegetated marsh, Kneib (1995) found that crabs rarely migrated far onto the marsh surface. Additional evidence that blue crabs migrate only partially into the marsh vegetation during high tide comes from data on predation rates by blue crabs on ribbed mussels (*Geukensia dismissa*; Stiven & Gardner 1992) and periwinkle snails (*Littorina irrorata*; Lewis & Eby 2002), which decreased with intertidal elevation. Several authors have recognized the value of salt marshes as a refuge for juvenile fishes and crustaceans from predators (Boesch & Turner 1983, Zimmerman & Minello 1984, Rozas & Zimmerman 2000, Minello et al. 2003). Juvenile crabs may experience a spatial refuge from cannibalism in the vegetated marsh since adult conspecifics are physically impeded by dense vegetation and rarely move far into marsh habitats (Arnold & Kneib 1983, Kneib 1995, Kneib 1997). This spatial refuge in the vegetated marsh surface from larger conspecifics may be significant, since a majority of blue crab mortality in previous studies has been attributed to cannibalism (Dittel et al. 1995, Hines & Ruiz 1995, Ryer et al. 1997). The marsh surface may also provide refuge to juvenile crabs by the exclusion of transient finfish predators that are known to invade inundated marsh creeks at high tide (Helfman et al. 1983, Rountree & Able 1992, Szedlmayer & Able 1993).

As the marsh became exposed at low tide, crabs buried within the marsh and unvegetated creek bottom. Burying behavior has been described for various life stages of the blue crab (Wilson et al. 1987, van Montfrans 1991, Tankersley & Forward 1994). This behavior may represent a trade-off between predation risk and foraging behavior (Gilliam & Fraser 1987, Dahlgren & Eggleston 2000). Risk of predation in subtidal areas is likely increased, since greater densities of crabs are concentrated in subtidal habitats at low tide. Since crabs cannot actively forage while buried, the decreased risk of predation associated with burial may outweigh the benefits of continuous feeding. The ecological processes underlying size- and tide-specific habitat use of the marsh surface by juvenile crabs is unknown.

The patterns of high survival and densities of blue crabs within tidal salt marsh creeks reported here are consistent with the conclusions of Minello et al. (2003), who found salt marshes to be important nursery areas for decapod crustaceans, and this study provides additional information on the demographic processes underlying the importance of salt marshes as nurseries for estuarine-dependent species. Moreover, relatively high use of the vegetated marsh surface by juvenile blue crabs, combined with a general lack of sampling these complex habitats, suggest that crab densities may be even higher in salt marsh systems than previously thought.

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Table 1. Mean (± SE) initial and final juvenile blue crab carapace width, mortality, tag retention estimates, and first and second molt increments for tagged and untagged (control) crabs using coded microwire tags in a laboratory experiment. N = 15 crabs tagged and 15 crabs untagged (control). Overall tag retention was not applicable (N/A) to control groups since they did not receive a microwire tag.

	Tagged	Control
Initial CW (mm)	27.58 ± 1.16	27.99 ± 0.88
Final CW (mm)	41.28 ± 1.64	39.86 ± 1.95
Mortality (%)	7	13
Time to first molt (d)	5.93 ± 0.53	6.13 ± 0.46
(Overall tag retention (%))	88	N/A
Time between first and second molts (d)	12.70 ± 0.84	14.33 ± 1.11
(Tag retention between first and second molts (%))	100.00	N/A
Size increase at first molt (%)	26.7 ± 0.9	25.8 ± 1.2
Size increase at second molt (%)	28.9 ± 0.9	26.4 ± 1.0

Table 2. Estimates and approximate standard errors of juvenile blue crab population size (N), survival (ϕ), and capture probabilities (p) for populations in Prytherch Creek (A) and Haystacks (B) using Jolly-Seber capture-recapture models. Estimates of tag retention (?) were used to correct estimates of survival and SEs for bias due to tag loss, and calculate unbiased estimates ($\phi_i^c = \phi_i / \theta$).

A.) Prytherch Creek

Date	Period	N_i	SE	ϕ_i	SE	ϕ_i^c	SE	p_i	SE
June 11	1								
June 15	2	1,085						0.17	0.05
June 19	3	1,968						0.05	0.02
June 23	4	1,447						0.10	0.03
June 27	5	1,216		0.80	0.06	0.91	0.08	0.05	0.02
July 1	6	1,866						0.04	0.02
July 5	7	1,402						0.03	0.02
July 9	8	1,548						0.03	0.02
July 13	9	5,096						0.02	0.01
July 17	10	2,265						0.03	0.02
	$\bar{x}$			0.80	0.06	0.91	0.08	0.06	0.02

B.) Haystacks

Date	Period	N_i	SE	ϕ_i	SE	ϕ_i^c	SE	p_i	SE
August 22	1								
August 28	2	270						0.54	0.10
August 31	3	260		0.74	0.03	0.84	0.03	0.32	0.05
September 7	4	228						0.15	0.05
September 18	5	152						0.55	0.14
October 1	6	102						0.73	0.20
	$\bar{x}$			0.74	0.03	0.84	0.03	0.50	0.05

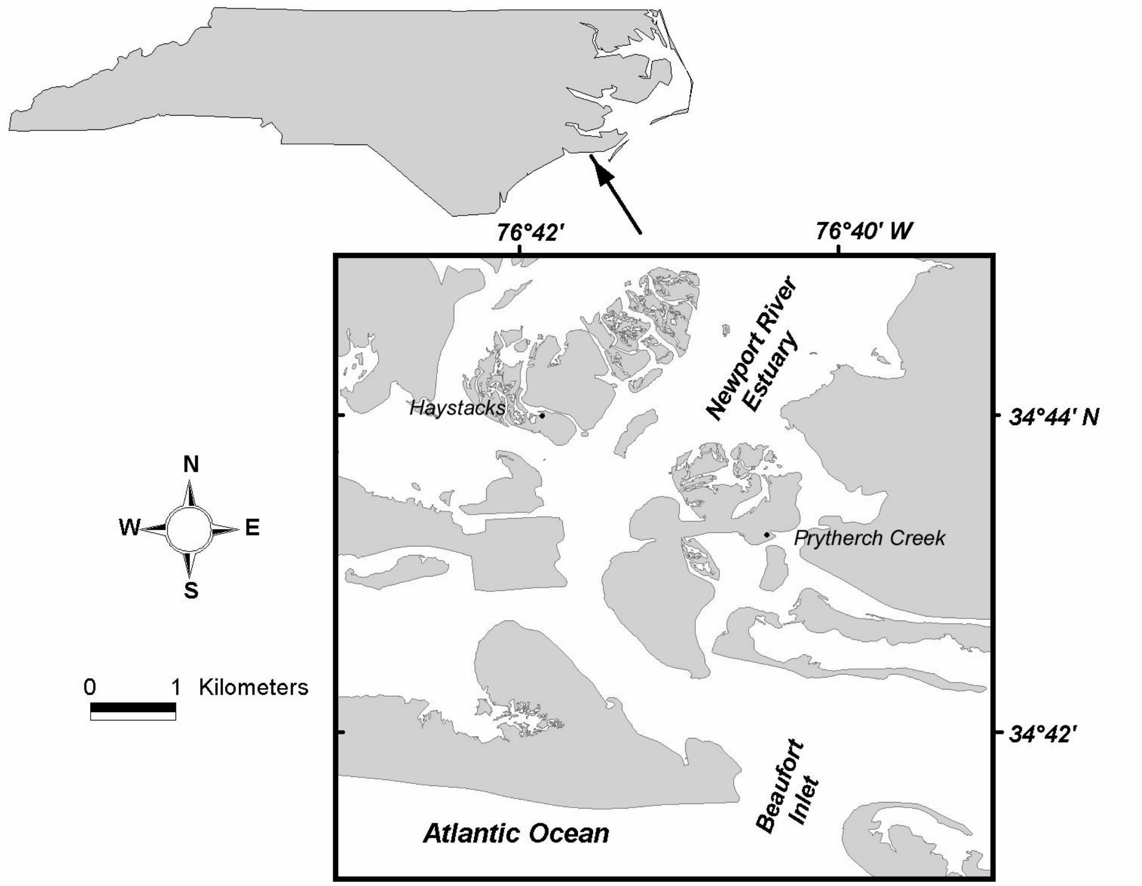


Figure 1. Locations of salt marsh creek study sites at Prytherch Creek (PC) and Haystacks (HS) near Beaufort Inlet, North Carolina, USA.

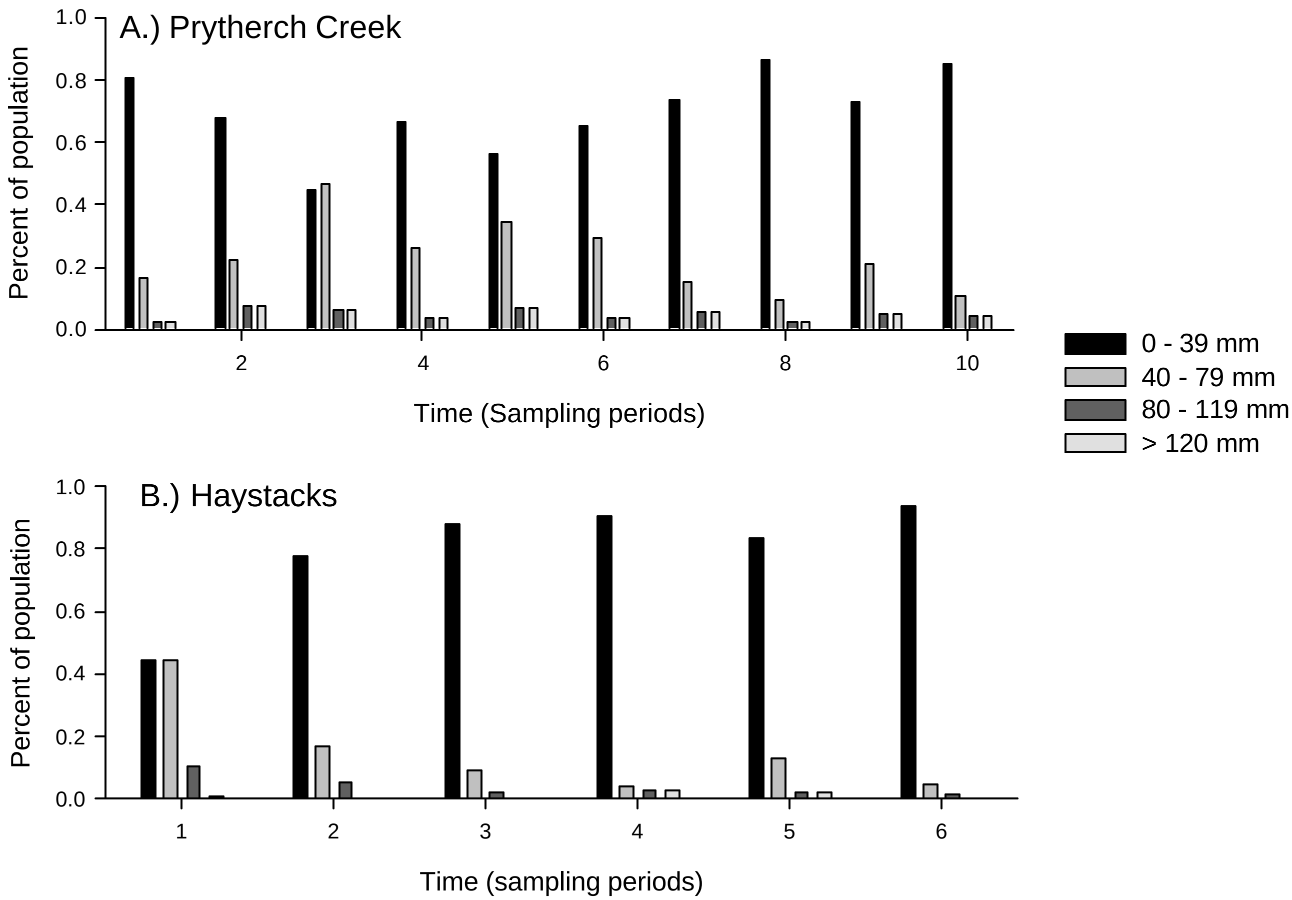


Figure 2. Proportional abundance of four size classes of blue crabs in both Prytherch Creek (A) and Haystacks (B) study sites for each sampling period. The duration between sampling periods averaged 4 d for Prytherch Creek and 7.8 d for Haystacks.

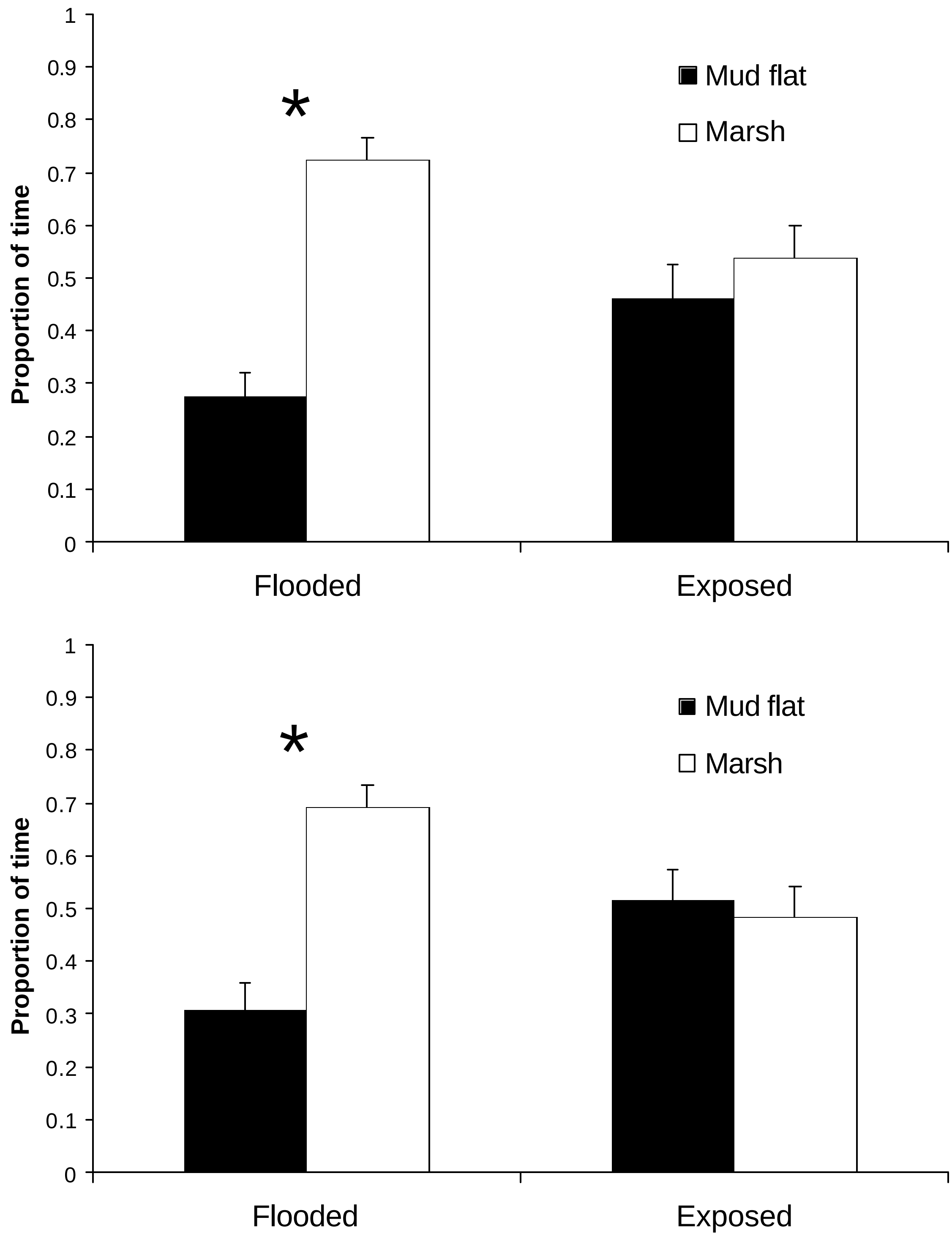


Figure 3. The mean proportion ± SE of time spent in microhabitat types (marsh and mud) during periods in which the marsh was tidally flooded or exposed at Prytherch Creek (A) and Haystacks (B) study sites.

Appendix Table 1. Capture-recapture summary statistics for populations of blue crabs at Prytherch Creek (A) and Haystacks (B) from June to October 2001, following standard Jolly-Seber capture-recapture notation (Jolly 1965): n_i is the number of crabs captured in the ith sample; m_i is the number of tagged blue crabs captured in the ith sample; R_i is the number of crabs captured in i and released; r_i is the number of crabs released at i and subsequently recaptured; z_i is the number of crabs captured before i, but not at i, that are subsequently recaptured.

A.) Prytherch Creek

Date	Period	n_i	m_i	R_I	r_i	z_i
June 11	1	115		115	31	
June 15	2	188	16	172	21	15
June 19	3	100	10	90	17	26
June 23	4	138	21	107	10	22
June 27	5	65	13	52	7	19
July 1	6	83	10	73	4	16
July 5	7	49	8	41	3	12
July 9	8	52	7	45	1	8
July 13	9	104	4	100	3	5
July 17	10	78	8	70		

B.) Haystacks

Date	Period	n_i	m_i	R_I	r_i	z_i
August 22	1	79		79	24	
August 28	2	145	21	124	41	3
August 31	3	82	33	49	7	11
September 7	4	34	8	26	8	10
September 18	5	83	14	69	15	4
October 1	6	74	19	55		

Appendix Table 2. Quasi-adjusted Aikaike's Information Criterion (QAICc), ? $QAIC_c$, Aikaike's weights, and number of parameters (*Np*) from JS capture-recapture models for Prytherch Creek (A) and Haystacks (B) sampling sites. Models are grouped into those that did not incorporate covariates (base models) and those that included covariates. Models were sorted by QAICc with best fitting models having the lowest $QAIC_c$ values. The model used for each site is bolded. While many models including covariates produced lower QAICc values, these models were not selected due to limitations in size range of crabs in the data set.

A.) Prytherch Creek

Model	Survival (ϕ)	Recapture (p)	$QAIC_c$	? $QAIC_c$	$QAIC_c$ weight	Model likelihood	Np	Qdeviance
I. Base models								
1	**Constant**	**Time**	**624.8**	**3.4**	**0.06**	**0.17**	**10**	**604.6**
2	Time	Constant	626.5	5.1	0.03	0.08	8	610.3
3	Constant	Constant	628.1	6.7	0.01	0.03	2	624.1
4	Time	Time	638.2	16.8	0.00	0.00	18	601.3
II. Models including covariates								
5	Constant	Time; quadratic	621.4	0	0.35	1	12	597.0
6	Constant	Time; linear	622.1	0.7	0.24	0.69	11	599.8
7	Constant; linear	Time; quadratic	623.4	2	0.13	0.37	13	596.9
8	Constant; quadratic	Time; quadratic	623.9	2.5	0.1	0.29	14	595.3
9	Constant; linear	Time; linear	624.2	2.8	0.09	0.25	12	599.8

B.) Haystacks

Model	Survival (ϕ)	Recapture (p)	$QAIC_c$	? $QAIC_c$	$QAIC_c$ weight	Model likelihood	Np	Qdeviance
I. Base models								
1	**Constant**	**Time**	**527.3**	**5.2**	**0.03**	**0.07**	**6**	**515.1**
2	Time	Time	531.0	8.8	0.00	0.01	10	510.3
3	Time	Constant	531.8	9.7	0.00	0.00	6	519.6
4	Constant	Constant	544.2	22.1	0.00	0.00	2	544.2
II. Models including covariates								
5	Constant; linear	Time; quadratic	522.2	0	0.4	1	9	503.6
6	Constant	Time; quadratic	522.9	0.7	0.27	0.69	8	506.5
7	Constant; quadratic	Time; quadratic	524.1	1.9	0.15	0.39	10	503.4
8	Constant	Time; linear	524.2	2	0.14	0.36	7	509.9

Appendix Table 3. Apparent survival (ϕ) and capture probabilities (p) from Jolly-Seber (JS) capture-recapture models for Pytherch Creek. Models are grouped into those that did not incorporate covariates (base models) and those that included covariates. The descriptors in parenthesis indicate whether a parameter was held constant (c) or allowed to vary (t) over time, and whether a parameter was a linear or quadratic function of size (carapace width; mm). No values for ϕ and p are presented for the final period (i = 10) since these values are confounded and can not estimated individually (see Lebreton et al. 1992).

Base models (no covariates)

phi (c), p (c)					phi (c), p (t)					phi (t), p (c)					phi (t), p (t)				
Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE
2	0.70	0.04	0.08	0.01	2	0.80	0.06	0.17	0.05	2	1.00	0.00	0.08	0.01	2	1.00	0.00	0.14	0.04
3					3			0.05	0.02	3	0.56	0.13			3	0.57	0.16	0.07	0.03
4					4			0.10	0.03	4	1.00	0.00			4	1.00	0.00	0.09	0.03
5					5			0.05	0.02	5	0.51	0.15			5	0.57	0.24	0.07	0.04
6					6			0.04	0.02	6	0.81	0.27			6	1.00	0.00	0.05	0.02
7					7			0.03	0.02	7	0.52	0.20			7	0.72	0.49	0.04	0.03
8					8			0.03	0.02	8	0.74	0.31			8	1.00	0.00	0.03	0.02
9					9			0.02	0.01	9	0.49	0.24			9	0.62	0.59	0.02	0.02
10					10			0.03	0.02	10	0.59	0.27			10				

Models including covariates

phi (c), p (t; quadratic)					phi (c), p (t; linear)					phi (c, linear), p (t, quadratic)					phi (c; quadratic), p (t; quadratic)				
Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE
2	0.82	0.06	0.19	0.05	2	0.81	0.06	0.19	0.05	2	0.82	0.07	0.19	0.05	2	0.81	0.07	0.19	0.05
3			0.05	0.02	3			0.05	0.02	3			0.05	0.02	3			0.05	0.02
4			0.09	0.03	4			0.09	0.03	4			0.09	0.03	4			0.09	0.03
5			0.05	0.02	5			0.05	0.02	5			0.05	0.02	5			0.05	0.02
6			0.04	0.02	6			0.04	0.02	6			0.04	0.02	6			0.04	0.02
7			0.03	0.01	7			0.03	0.02	7			0.03	0.02	7			0.03	0.02
8			0.03	0.02	8			0.03	0.02	8			0.03	0.02	8			0.03	0.02
9			0.02	0.01	9			0.02	0.01	9			0.02	0.01	9			0.02	0.01
10			0.03	0.01	10			0.03	0.02	10			0.03	0.01	10			0.03	0.02

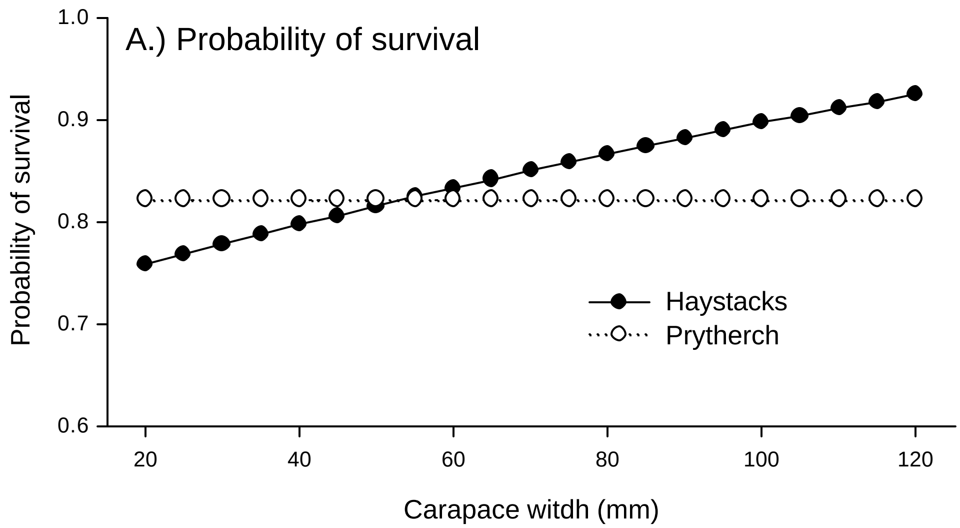
Appendix Table 4. Apparent survival (phi) and capture probabilities (p) from Jolly-Seber (JS) capture-recapture models for Haystacks. Models are grouped into those that did not incorporate covariates (base models) and those that included covariates. The descriptors in parenthesis indicate whether a parameter was held constant (c) or allowed to vary (t) over time, and whether a parameter was a linear or quadratic function of size (carapace width; mm). No values for ϕ and p are presented for the final period (i = 6) since these parameters are confounded and can not be estimated individually (see Lebreton et al. 1992).

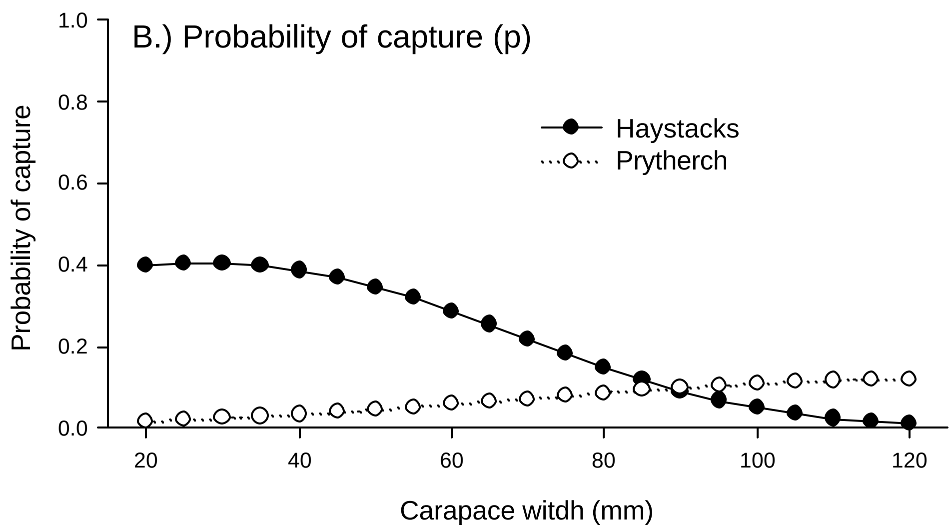
Base models (no covariates)

phi (c), p (c)					phi (c), p (t)					phi (t), p (c)					phi (t), p (t)				
Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE
2	0.77	0.03	0.34	0.05	2	0.74	0.03	0.54	0.10	2	0.72	0.07	0.39	0.06	2	0.62	0.06	0.70	0.13
3					3			0.32	0.05	3	0.61	0.11			3	0.83	0.26	0.30	0.10
4					4			0.15	0.05	4	0.62	0.06			4	0.65	0.11	0.20	0.09
5					5			0.55	0.14	5	0.92	0.06			5	0.85	0.09	0.43	0.15
6					6			0.73	0.20	6	0.84	0.06			6				

Models including covariates

phi (c; linear), p (t; quadratic)					phi (c), p (t; quadratic)					phi (c, quadratic), p (t; quadratic)					phi (c), p (t; linear)				
Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE	Period	phi	SE	p	SE
2	0.73	0.025	0.628	0.118	2	0.728	0.032	0.599	0.133	2	0.723	0.027	0.629	0.114	2	0.72	0.028	0.642	0.116
3			0.287	0.051	3			0.295	0.051	3			0.293	0.053	3			0.311	0.052
4			0.138	0.051	4			0.142	0.052	4			0.141	0.052	4			0.147	0.054
5			0.577	0.14	5			0.573	0.152	5			0.592	0.142	5			0.598	0.143
6			0.877	0.151	6			0.825	0.288	6			0.919	0.157	6			0.905	0.226





Appendix Figure 1. Relationships between blue crab carapace width and Cormack-Jolly-Seber estimates of survival (A), and capture probabilities (B) for both Prytherch Creek and Haystacks study sites. Survival probabilities (A) were modeled as linear functions of CW, and capture probabilities (B) were best described by quadratic functions. See text for justification for fitting linear and quadratic functions.

CHAPTER 2

A STOCHASTIC, DISCONTINUOUS GROWTH MODEL FOR BLUE CRABS

ABSTRACT: Growth models commonly used in fisheries and ecological modeling assume growth is a continuous function of age. While this approach is appropriate for finfish, the validity of these models for crustacean species, which grow discontinuously, has been questioned. There is a critical need to compare the predictions of discontinuous and continuous models simultaneously to identify if potential biases are introduced by the assumption of continuous growth. A lack of long-term studies, including both field-tagging efforts and controlled laboratory experiments, has been cited as a contributing factor to the poor quantitative understanding of crustacean growth. We used complementary laboratory and field experiments to examine growth of blue crabs (*Callinectes sapidus*). Our laboratory experiment provided observations of (1) molt increment (MI) in mm carapace width (CW), (2) exact intermolt period (IP) in days, and (3) the time to first molt (days), and allowed for a direct comparison with free-ranging individuals from field experiments. Furthermore, the rate of tag loss was explicitly estimated in laboratory experiments. Growth of free-ranging blue crabs varying in initial size from 23.2 – 107.3 mm CW was quantified in two tidal salt marsh creeks in the Newport River estuary, Beaufort, North Carolina, USA during June – October 2001. Growth in crustaceans is discontinuous, since they must periodically molt to grow. The discontinuous nature of crustacean growth was modeled as the combination of two functions describing (1) molt increment (MI; i.e. growth-per-molt), and (2) the intermolt period (IP; i.e. time between successive molts). A positive and highly significant ($r^2 = 0.98$, $p = 0.0001$) relationship between premolt-CW and postmolt-CW was identified using linear regression, and a cubic model was used to describe the positive and significant ($r^2 = 0.67$, $p = 0.04$) relationship between premolt-CW and IP. Simulated growth trajectories for 500 individuals were generated from the model and provided estimates of mean growth and

variability in individual growth rates. The results were compared to predictions from a traditional growth model (von Bertalanffy growth function; VBGF) commonly used in fishery stock assessments that assumes growth is a continuous function of age. A VBGF predicted the mean size-at-age from the discontinuous model simulations very well ($r^2 = 0.99$, $p < 0.0001$), suggesting that continuous growth models can adequately predict the growth of blue crabs. The results from our study support the applicability of continuous growth models in fishery stock assessments and ecological modeling of blue crab population dynamics.

INTRODUCTION

Accurate growth data are necessary for modeling the demographics of a given species and, in the marine realm, are required for comprehensive fishery stock assessments. Information on growth is also critical for more ecologically based models such as individual-based, population simulation models and matrix models (Rice et al. 1993, Caswell 1999). Broadly defined, growth is the change (increase) in some measure of size (length, weight, carapace width, etc.) over time. Traditionally, length has been used as the measure of body size in most fisheries modeling efforts (von Bertalanffy 1938, Schnute 1981), due in large part to the ease of collecting length measurements. For crustaceans, length measurements are almost always used because precise aging techniques are generally not available (Ju et al. 2001, 2003, Miller and Smith 2003). The growth process of crustaceans precludes the use of aging techniques that are frequently applied to finfish (i.e., otolith, scales, spines) because all hard parts are shed during the molting process. An approach for aging blue crabs using lipofuscin, a compound which accumulates in nervous tissue with age, has been developed (Ju et al. 2001, 2003); however, estimates of age from this technique are imprecise (Miller and Smith 2003). Field tagging studies are a common source of growth information for animals, and are advantageous because they are conducted in natural conditions. The lack of such long-term studies for crustaceans, including both field-tagging efforts and controlled laboratory experiments, has been cited as main factor in the poor quantitative understanding of crustacean growth (Smith 1997, Miller and Smith 2003).

Traditional growth models most commonly used in fishery stock assessments (von Bertalanffy 1938, Schnute 1981) assume growth to be a continuous function of age. While these approaches may be valid for finfish, the application of these models to crustacean species, which grow discontinuously, has been questioned (Miller and Smith 2003). Thus, there is a critical need to compare the predictions of discontinuous and continuous models fit to observed growth data simultaneously. Such analyses (e.g., Restrepo 1989) can identify potential biases, if any, introduced by the assumption of continuous growth for an animal that grows incrementally via molting.

Despite the ecological importance of the blue crab (*Callinectes sapidus*) as an estuarine predator, as well as its commercial importance along the Atlantic and Gulf coasts of the United States, there are no growth estimates from free-ranging natural populations of individually tagged blue crabs. Since growth is examined under natural conditions, field studies of free-ranging individuals represent the best estimates of growth. Growth has been estimated primarily from studies of blue crabs held in captivity (Gray and Newcombe 1938, Newcombe et al. 1949). Many of these studies have focused on the effects of environmental factors, such as salinity and temperature on growth (Holland 1971, Leffler 1972, Cadman and Weinstein 1988), and have been mainly qualitative in nature. The quantitative aspect of blue crab growth under laboratory conditions was described by Fitz and Wiegert (1991); however, their study focused primarily on juvenile crabs (29 – 67 mm CW) and used a batch tagging protocol, which did not allow for unique identification of individual crabs. Additionally, Smith (1997) described a discontinuous model of blue crab growth using estimates of growth from laboratory data, but did not compare discontinuous model results with those of continuous models, which are traditionally used in fishery and ecological modeling. Tagatz (1968) examined the growth of blue crabs held in floating cages in the field. The crabs were exposed to natural environmental conditions, but confined to individual compartments and were fed artificial diets. Application of growth rates estimated from laboratory or field caging studies to natural populations is problematic. For example, risk of predation (Hines and Ruiz 1989, Ryer et al. 1997) and the unavailability of the marsh surface to blue crabs at low tide (Chapter 1 in this report, Ryer 1987) may limit the growth potential of wild crabs relative to laboratory individuals, which are not subject to predation and are often fed to satiation.

The overall objectives of this study were to: (1) estimate growth rates of free-ranging juvenile and adult blue crabs in tidal salt marsh habitats using capture-recapture techniques, (2) compare growth rates of free-ranging blue crabs to individuals held under laboratory conditions, (3) use the estimates of growth to construct a stochastic, discontinuous growth model, and (4) compare growth trajectories predicted from our discontinuous growth model with a more commonly used approach (von Bertalanffy 1953) that assumes continuous growth. The results are then used to assess the applicability of continuous growth models in stock assessments of the blue crab and other commercially important crustacean fishery species. The present capture-recapture study is novel in that (1) the growth rates of blue crabs were examined under natural conditions (free-ranging), (2) blue crabs were individually identifiable (uniquely coded microwire tags), and (3) the growth of a broad range of size classes (early juveniles-adults) was investigated.

MATERIALS AND METHODS

Laboratory tagging

A 37 d laboratory experiment (August 8 – September 12, 2002) tested the effects of tagging using CWT's on blue crab growth and mortality, and allowed the rate of tag retention (θ) to be estimated directly (see Chapter 1 for a detailed description of methods). Crabs were checked daily for mortality and molting. Recently molted crabs were allowed ~ 1-2 d to harden prior to being measured and checked for tag retention, which allowed for tag loss to be explicitly estimated. Tag loss around the time of molting would result in a decreased estimate of the proportion of molted animals since they are effectively removed from the population and overestimate the intermolt period (IP; see below) in the field. An estimate of the rate of tag loss, and whether the rate of tag loss increases during molting, allows for biases in IP to be corrected (Restrepo and Hoenig 1988).

Traditional analyses of growth in fishery species have relied upon various models (von Bertalnaffy 1938, Schnute 1981) that describe the relationship between length and age. These models inherently assume that growth is a continuous process. Growth measured as carapace width (CW) in crustaceans is discontinuous, as crabs must periodically molt to grow. The discontinuous nature of crustacean growth can be more adequately modeled as the combination of two functions describing (1) molt increment (MI; i.e. growth-per-molt), and (2) the intermolt period (IP; i.e. time between successive molts). MI can be described using a Hiatt diagram (Hiatt 1948) which examines the relationship between premolt-CW and postmolt-CW, and the IP for a range of size classes can be estimated by examining the relationship between IP and premolt-CW. The two functional relationships described above can be combined to construct a growth trajectory (Hiatt 1948, Caddy 1987, Smith 1997).

Our laboratory experiment also provided (1) 46 observations of molt increment (MI; postmolt-CW – premolt-CW), (2) 29 observations of exact intermolt period (IP), and (3) 30 observations of the time-to-first-molt in captivity, and allowed for a direct comparison of MI and IP with free-ranging individuals from field experiments (see below). A two-way, fixed factor analysis of covariance (ANCOVA) model using tag status and sex as factors, and premolt CW as a covariate, was used to test whether or not the response variables (MI, IP, and time to first molt) were significantly different between tag and no-tag treatments.

Analysis of laboratory growth data

The relationship between and pre- and postmolt CW varies by crustacean species (Botsford 1985), and has been described using both linear (Kurata 1962, Somerton 1980) and hyperbolic (Mauchline 1976) models. We compared the fit of a (1) linear regression, and (2) a non-linea,r hyperbolic model (Mauchline 1976) to observed laboratory blue crab growth data using Akaike's Information Criterion (AIC; Akaike 1975; Table 2). AIC is a commonly employed maximum-likelihood approach that incorporates a penalty for over-parameterization and provides an objective method for selecting the most parsimonious model from a candidate set that adequately explains the observed data (Akaike 1975).

We estimated the IP for blue crabs in the laboratory by allowing each animal to molt once, then recording the time until the second molt. This procedure allowed for exact measurements of IP from laboratory crabs. Three models were fitted to the observed relationship between premolt-CW and IP from laboratory experiments: (1) linear, (2) a cubic, and (3) an exponential (Table 2) since the relationship varies in different species (Hartnoll 1982). Models were selected based on their previous application in crustacean growth studies (Mauchline 1977, Restrepo 1989), and the ability to biologically describe growth dynamics. Growth in crustaceans generally follows the simple allometric relationship ($y = a*x^b$; Hartnoll 1978). For example, as an individual blue crab increases in length (one-dimensional), the concurrent increase in body volume (three-dimensional) is proportionally larger (Olmi and Bishop 1983, Rothchild et al. 1991). A simple, intuitive biological explanation is that successive molts allow for increasing growth capacity (volume) and increase the time necessary to acquire sufficient food resources for the next successive molt if a large increase in foraging efficiency does not occur. Thus, as size increases, IP will become longer. Both the exponential and cubic models adequately described the relationship between premolt-CW and IP. Model fits were compared using AIC.

Field tagging

Growth of free-ranging juvenile blue crabs was studied in two tidal marsh creeks, Prytherch Creek (PC) and Haystacks (HS), located in the Newport River estuary near Beaufort, North Carolina, USA during June-October 2001 (see Chapter 1 for a detailed description of methods). The field tagging data yielded individual records of sex, carapace widths (CW; mm) at initial release and recapture, and the time (days) at liberty. A total of 155 recaptures obtained from tagging were used to estimate growth of free-ranging blue crabs, varying in initial size from 23.2 – 107.3 mm CW.

Analysis of field growth data

Similar to the analysis of laboratory data, we compared the fit of (1) one-phase (simple) linear and (2) a hyperbolic model (Mauchline 1976) to the observed relationship between and MI from the free-ranging crabs in the field using AIC (Akaike 1975; Table 2). Because the field data for MI was available for a wider range of size classes than in the laboratory experiments, we also fitted a two-phase (segmented) linear regression ("bent-line") model (Gray and Newcombe 1938; Table 2). This model allows for possible changes in the slope of the relationship between pre- and postmolt-CW that may accompany the onset of sexual maturity as somatic growth declines and energy resources are diverted into reproduction. This ontogenetic shift in growth has been reported in many crustacean species (Restrepo 1989, Wainwright and Armstrong 1993), including blue crabs (Gray and

Newcombe 1938).

Prior to fitting models to the relationship between premolt-CW and MI, a two-way analysis of covariance (ANCOVA) using site (PC vs. HS) and sex as factors, and premolt-CW as a covariate was applied to field data from recaptured blue crabs, and tested whether or not MI was significantly different between factors (site & sex), and varied significantly with premolt-CW.

The relationship between premolt-CW and IP for blue crabs was estimated from field observations of molting from free-ranging blue crabs. Unlike laboratory methods that allow for daily monitoring and exact measurements of IP, IP must be estimated from field tagging experiments since exact times of molting are unknown. To identify the functional relationship between premolt-CW and IP from field tagging data, we first grouped individual recaptured blue crabs into size classes. Crabs were assigned to size bins using 10 mm intervals. For example, all crabs between 20 and 30 mm CW were assigned to the 25 mm size class. For each size class (i), the daily probability of molting (Pm) was calculated as:

$$\frac{\text{Observed number of crabs molting in size class } i}{\text{Total number of days at large in size } i} \tag{1}$$

For each size class, the approximate IP was determined by dividing 1 by the P_m. Similar to previous methods for estimating IP (Munro 1974, 1983), this method assumes that there is no synchronicity in molting (i.e., the probability of molting for individual crabs is independent). A significant bias can be introduced if tag loss primarily occurs at the time of molting. Tag losses were estimated to be12% from laboratory experiments, and were similar to earlier reported estimates (van Montfrans 1987; Fitz and Wiegert 1992) using microwire tags. Two tags were lost, both during the first molt following tagging. To correct for biased estimates of IP due to tag loss, we applied the following correction as suggested by Restrepo and Hoenig (1988):

$$IP_{correct} = IP_{uncorrected} * (1 + PRT)/2 \qquad (2),$$

where PRT is the proportion of crabs that retain their tags.

As with laboratory data, three models were fitted to field observations of IP to describe the relationship between premolt-CW and IP for free-ranging crabs: (1) linear model, (2) a cubic model, and (3) exponential model (Table 2), and model fits were compared using AIC.

Construction of growth trajectories from field capture-recapture data

The relationships between MI, IP, and premolt-CW were combined to generate a discontinuous model of blue crab growth. Data from the field CWT tagging study were chosen over laboratory data for this analysis because: (1) growth rates of blue crabs were examined under natural conditions (free-ranging) and represent the best estimates for growth in the wild, (2) this data set contained growth information for a wider range of sizes (23.2 – 107.3 mm CW) than examined in the laboratory, (3) of the longer duration of the field study (143 d) as opposed to 37 d in the laboratory experiment, and (4) of the larger sample size (n = 155 for field vs. 46 for laboratory). Despite the large size range of blue crabs for which information on MI and IP was available, the lack of data for MI and IP for very small individual blue crabs (CW < 23 mm) and large blue crabs (CW > 107.3 mm) required extrapolation of growth predictions to these size ranges. Limitations of the tagging method precluded using CWTs to examine MI and IP for small crabs (< 22 CW), and information for the MI and IP of large crabs was difficult to obtain due to the longer IP of these individuals.

We constructed a discontinuous model of blue crab growth to describe size-at-age using a combination of the linear model for MI and the cubic model for IP. The initial size of blue crabs was assumed to be 2.5 mm CW (Newcombe et al. 1949), corresponding to the mean size at the first benthic instar. All subsequent sizes were determined using a linear model to relate premolt-CW to postmolt-CW:

$$CW_{POST} = a*CW_{PRE} - b + \varepsilon \qquad (3)$$

The error term (ε) was assumed to be normally distributed ($\varepsilon \sim N(0, 2.58)$. The magnitude of the error term was based on the fit of equation (1) to the observed field data (See below). Thus, the model was able to incorporate stochasticity explicitly, and provide information on the mean size-at-age, as well as the distribution of sizes at a given age. The relationship between premolt-CW and IP was described using a cubic model:

$$IP = a + b*(CW_{PRE})^3 + \varepsilon \qquad (4)$$

When combined, equations (3) and (4) can be used to describe the growth trajectory of an individual blue crab as a discontinuous function resembling a staircase. We simulated growth trajectories for 500 individuals. Individual growth trajectories provided estimates of variability in individual growth rates, and were used to calculate mean and 95% confidence intervals for size-at-age. Although growth of crustaceans is an inherently discontinuous process, most fishery models used in stock assessments rely on growth described as a continuous function of time (Rugolo et al. 1997, 1998, Miller and Houde 1999, Helser and Kahn 1999, 2001). Therefore, we fitted a von Bertalanffy growth function (VBGF) to predicted mean size-at-age from our discontinuous growth model. The VBGF is the most commonly used model for predicting growth. Further, the VBGF has been used to describe growth in numerous stock assessments for the blue crab (Rugolo et al. 1997, Helser and Kahn 1999, Miller and Houde 1999). The VBGF (von Bertalanffy 1953) is defined by the following equation:

$$L_t = L_{inf}\,(1 - e^{\,k(t-t0)}) \qquad (5)$$

where Lt is the length at time t, k is the curvature (Brody growth coefficient) and L_{inf} = asymptotic maximum size, and t0 is the theoretical age at length 0. Assessing the ability of the continuous functions (VBGF) to predict simulated mean size-at-age from a discontinuous model will address whether or not these models may be appropriate for use in stock assessment modeling of animals which inherently grow discontinuously, such as crustaceans.

RESULTS

Effects of tagging on growth, tag retention and tag-induced mortality

Proportional mortality of juvenile blue crabs in the laboratory was low in both tagged and control treatments, and was not significantly different between treatments ($\chi^2 = 0.28$, $df = 1$, $p = 0.60$; Table 1). Of the 15 tagged individuals, 13 retained the tag through the entire experiment (37 d) for an overall tag retention of 88%. In both cases in which tags were shed, tag loss occurred during the first molt following tagging. All crabs that retained the tag through the first molt, retained the tag through all subsequent molts. Mean time to first molt was not significantly different (ANCOVA, F = 0.009, *df* = 1, 28 p = 0.93) between tagged and control treatments or between sexes (ANCOVA, F = 0.004, *df* = 1, 28 p = 0.95; Table 1). Premolt-CW, included in the model as a covariate, had a significant effect on time to first molt (ANCOVA, F = 15.35, *df* = 1, 28 p = 0.03). The relationship between time to first molt and premolt-CW was positive. The IP between first and second molts was also not significantly different (ANCOVA, F = 0.05, *df* = 1,17, p = 0.83) between tagged and control treatments or between sexes (ANCOVA, F = 1, 17 p = 0.73). Premolt-CW was included in the ANCOVA model as a covariate and had a significant effect on the intermolt period (ANCOVA, F = 4.99, df = 1,17 p = 0.04). The relationship between time to first molt and premolt-CW was positive, indicating that IP increases with crab size. Differences in proportional size increases were not significant between tagged and control treatments after the first molt (student's t-test, t = 0.35, *df* = 1,28, p = 0.56; Table 1), but marginally significant after the second molt (student's t-test, t =3.61, *df* = 1,17, p = 0.08; Table 1), with size increases in the tagged treatment being higher than in the control. This result is likely spurious since tagging would likely have a negative impact on growth.

Relationship between postmolt- and premolt-CW from laboratory data

Linear and hyperbolic regression models (Mauchline 1976) were fitted to the laboratory observations of the relationship between premolt and postmolt CW. Although both models produced good fits to the data, AIC (Akaike 1973) indicated the linear model provided the best fit to the data (AIC = 66.95, AIC weight = 0.99) as compared to a hyperbolic model (AIC = 79.3, AIC weight = 0.01). A positive and highly significant (r^2 =

0.97, $p = 0.0001$) relationship premolt- versus postmolt-CW was identified using linear regression (Figure 1).

Relationship between premolt-CW and intermolt period from laboratory data

We estimated the IP for blue crabs in the laboratory by allowing each animal to molt once and recording exact measurements of IP, and subsequently plotting IP as a function of premolt-CW (Figure 2). Although the linear model produced the lowest AIC, all models produced good fits to the data and no single model was clearly favored as the best fit to the data (Linear: AIC = 8.10, AIC weight = 0.35; Cubic: AIC = 8.24, AIC weight = 0.31; Exponential: AIC = 8.17, AIC weight = 0.33). The AIC weights ($0.35 \approx 0.31 \approx 0.33$) indicated that all models were approximately equally likely to best describe the relationship between premolt-CW and IP. The similar fit of both linear and non-linear models to observed IP in the laboratory may be a result of the relatively small size ranges of blue crabs (22.8 – 44.0 mm CW) for which data was available. Since all models produced similar fits, we chose the simplest model (linear) to describe the positive and significant ($r^2 = 0.32$, $p = 0.007$) relationship between premolt-CW and IP (Figure 2).

Effects of site and sex on molt increment of blue crabs in the field

Mean MI was not significantly different (ANCOVA, $F = 0.022$, *df* = 1, 62 $p = 0.88$) between the PC (10.71 mm $\pm$ 0.85) and HS (10.21 mm $\pm$ 0.99) study sites or between sexes (males = 10.47 mm $\pm$ 0.92 versus females = 10.16 d $\pm$ 1.46; ANCOVA, $F = 0.004$, *df* = 1, 62 $p = 0.95$). The interaction between site and sex was not significant ($p > 0.05$). Premolt-CW, included in the model as a covariate, had a highly significant effect on MI (ANCOVA, $F = 21.82$, *df* = 1, 62 $p < 0.0001$). The relationship between time to first molt and premolt-CW was positive, indicating that MI increases with size

Relationship between premolt- and postmolt-CW from field data

Simple and "bent-line" linear models, as well as the hyperbolic regression model (Mauchline 1976), were fitted to the field observations of the relationship between premolt- and postmolt-CW (Table 2). AIC indicated the one-phase linear model provided the best fit to the observed pre- vs. postmolt-CW data (AIC = 62.95, AIC weight = 0.99) as compared to either a two-phase linear (AIC = 76.40, AIC weight ≈ 0) or hyperbolic (AIC = 79.82, AIC weight ≈ 0) model. A positive and highly significant ($r^2 = 0.98$, $p = 0.0001$) relationship was identified using a simple linear regression (Figure 3) and was defined by the following equation:

$$CW_{POST} = 1.18 * CW_{PRE} + 1.43 + \varepsilon \qquad (6)$$

The error term (ε) was assumed to be normally distributed ($\varepsilon \sim N(0, 2.58)$. The magnitude of the error term was based on the fit of equation (6) to the observed field data (See below).

Relationship between premolt-CW and intermolt period from field data

We estimated the IP for blue crabs from field recapture data for both sites (PC and HS) combined. In total, field recaptures yielded information for 155 individual blue crabs. Eighty-three of the 155 recaptured individuals had molted, and in total recaptured individuals spent 1677 days-at-large. Individual recaptures were pooled by 10 mm CW size classes using observed premolt-CW, and the number of molts and days-at-large for each size class were used to calculate the probability of molting (P_m) and IP. (Table 3). The cubic model produced the lowest AIC, but only marginally (linear: AIC = 5.63, AIC weight = 0.29; cubic: AIC = 5.33, AIC weight = 0.38; exponential: AIC = 5.51, AIC weight = 0.32). The AIC weights (0.39 ≈ 0.32 ≈ 0.29) indicated substantial support for all models. We chose the following cubic model to describe the positive and significant ($r^2 = 0.67$, $p = 0.04$) relationship between premolt-CW and IP (Figure 4):

$$IP = 17.67 + 0.0001{*}CW_{PRE}3 + \varepsilon \qquad (7)$$

Similar to equation (3), error was assumed to be normally distributed ($\varepsilon \sim N(0, 5.43)$, and the magnitude of the error was based on the fit of the cubic regression model (Fig. 4) to observed field data for IP.

Comparison of laboratory and field data

To investigate potential differences between MI of blue crabs under laboratory and field conditions, we used a two-factor ANCOVA using environmental condition (laboratory vs. field) and sex as fixed factors, and premolt-CW as a covariate. Because there was no significant difference in blue crab MI between sites, we pooled MI data from PC and HS for this analysis. Mean MI was not significantly different (ANCOVA, $F = 0.334$, $df = 1, 108$ $p = 0.57$) between laboratory (10.12 mm $\pm$ 0.92) and field (8.15 mm $\pm$ 0.39) conditions or between sexes (males = 9.81 mm $\pm$ 0.61 versus females = 9.15 mm $\pm$ 0.54; ANCOVA, $F = 0.071$, $df = 1, 108$ $p = 0.79$). The interaction between site and sex was not significant ($p > 0.05$). Premolt-CW, included in the model as a covariate, had a highly significant effect on MI (ANCOVA, $F = 39.61$, $df = 1, 108$ $p < 0.0001$). Formal statistical analysis to test for differences in IP between field and laboratory blue crabs was not feasible since field data were pooled to estimate IP for a given size range. Nevertheless, the IP for laboratory crabs was generally lower than the IP for free-ranging crabs for a given size (Fig.4), and suggests that blue crabs held in laboratory conditions molt more frequently than free-ranging individuals.

Construction of growth trajectories from field tagging data

The relationships between premolt-CW, MI, and IP (Figs. 3, 4) from field data were used initially to construct a deterministic growth trajectory for the blue crab (Figure 5a). Because the deterministic model provides no information on the variability of individual blue crabs about a given mean size, we used a random number generator and estimates of variability (σ) from model regressions to simulate growth trajectories for 500 individual blue crabs. This allowed for the quantification of variability in length for a given size (Figure 5b).

A von Bertalanffy growth function (VBGF) was fitted to the simulated mean size-at-age data and resulted in estimates of L_{inf} = 237.7 mm CW, k = 0.74, and t_0 = 0.02 months, obtained from a non-linear regression model (Figure 6). The VBGF provided a good first order approximation to the simulated mean length-at-age data (Figure 6), but examination of the residuals suggested that predicted values were underestimated at intermediate ages, and overestimated at older ages--the magnitude of these errors, however, were small. Regardless, the fit of the VBGF predicted the mean size-at-age from the model simulation extremely well ($r^2 = 0.99$, $p < 0.0001$), suggesting that continuous growth models can adequately predict the growth of blue crabs, and potentially other crustaceans.

DISCUSSION

Capture-recapture studies using microwire tags are extremely valuable in estimating growth of animals under natural environmental conditions. The important findings of this study were: (1) blue crab growth was similar across two independent salt marsh creek systems during summer-fall (Prytherch Creek and Haystacks) (2) tag retention was high

(88%), and tag loss was associated with the first molt following tagging (3) MI was similar between animals held under laboratory and field conditions, (4) blue crabs held in the laboratory molted more frequently than free-ranging individuals of similar size, (5) tag retention was high (88%), and tag loss was associated with the first molt following tagging, and (6) continuous and discontinuous growth models yielded similar predictions for size-at-age. This capture-recapture study illustrates the utility of CWTs to investigate the growth of crustacean species for which many conventional tagging methods can not be applied.

Assumptions of the tagging method

Capture-recapture experiments provide a powerful tool for estimating growth, however, these methods are based on several assumptions: (1) the tagging process does not adversely effect growth, (2) mortality and tag loss are not associated with the molting process, and (3) no synchrony in molting in the population (i.e., the probability of molting for each individual is independent). Estimated growth rates from free-ranging, tagged blue crabs can be applied to wild populations only if the tagging process does not alter natural growth patterns. Laboratory studies (van Montfrans et al. 1986, Fitz and Wiegert 1991, this study) demonstrated that microwire tagging has negligible effects on growth in blue crabs. In this study, MI, time to first molt, and IP were similar for tagged and untagged individuals.

Tag loss and mortality result in a positive bias for estimates of IP if these processes are associated with the time of molting. This occurs because the observed proportion of animals molting will be lower than the actual proportion since molting individuals are effectively removed from the population when they lose their tags (Restrepo and Hoenig 1988). Both cases of tag loss in the present study occurred during the first molt following tagging. The estimate of IP can be corrected, however, if tag loss and mortality can be quantified. We estimated tag loss to be 12%, and corrected estimates of IP following the method of Restrepo and Hoenig (1988). Mortality at the time of molting is also likely to be increased; blue crabs are particularly vulnerable to predation immediately following molting while soft (Ryer et al. 1997). Since the magnitude of mortality associated with molting was unknown, we were unable to correct IP for this bias, however, estimates of IP have been demonstrated to be robust to the failure of this assumption (Restrepo and Hoenig 1988).

Molting of blue crabs is assumed to be asynchronous. Blue crabs held under laboratory conditions in this study did not appear to molt synchronously. While molting is likely asynchronous for our study population of crabs in the Newport River estuary during summer and fall, estimation of IP from mature females during the spring may be difficult. For example, in the U.S. mid-Atlantic, prepubertal female blue crabs exhibit an annual period of synchronous molting to sexual maturity in the spring. This “peeler” fishery in North Carolina targets these molting females and captures 51% of the annual peeler catch during the month of May (NC DMF 1998). Thus, whether or not the assumption of asynchrony is violated must be considered based on crabs size and sex in future studies when calculating IP from capture-recapture data.

Comparison of laboratory and free-ranging blue crabs

Growth rates of animals estimated from laboratory studies are frequently used to make inferences about growth rates in natural populations (Restrepo 1989, Wainwright and Armstrong 1993, Smith 1997). The extension of laboratory results to describe growth of wild individuals is often required for crustaceans because of the difficulty in estimating MI and IP in the field relative to the laboratory (Miller and Smith 2003). The application of growth rate estimates obtained from laboratory experiments assumes growth to be similar to individuals in natural populations. While potential differences in growth rates between laboratory and free-ranging individuals is generally acknowledged in studies which extrapolate laboratory growth to natural populations (Hoenig and Restrepo 1989, Restrepo 1989, Wainwright and Armstrong 1993), data are frequently not available to test for violations of this assumption.

The simultaneous field and laboratory components in this study allowed for a direct test of the relationship between premolt-CW and MI in free-ranging versus laboratory-held blue crabs. The relationship between premolt CW and MI in blue crabs in this study was similar for laboratory and field individuals, as has been found in other crustaceans (Restrepo 1989), suggesting that estimates of MI for blue crabs from laboratory studies are applicable to free-ranging populations. Our study suggests, however, that blue crabs in the laboratory molted more frequently than similar sized individuals in the field. These differences may be explained by environmental variables or differences in diet, since IP in crustaceans is often influenced by temperature, salinity and diet (Hartnoll 1982). For example, IP is negatively correlated with temperature in blue crabs (Tagatz 1969, Holland et al. 1971, Leffler 1972, Cadman and Weinstein 1984), and growth throughout the U.S. mid-Atlantic ceases during winter months at low temperatures (Smith 1997, Miller and Smith 2003). Our laboratory experiment was conducted in close proximity to field sites and utilized a continuous flow-through design that supplied water from nearby Core Sound, North Carolina. As a result, water temperatures were similar between field and laboratory blue crabs, and were probably not responsible for observed differences in IP. Longer IPs for blue crabs in the field may be the result of decreased feeding rates relative to laboratory crabs that were fed to satiation daily. For example, blue crabs in salt marshes bury within the marsh and unvegetated creek bottom when exposed at low tide (see Chapter 1). Since crabs are unable to actively forage while buried, food intake of blue crabs in the field was probably reduced relative to laboratory individuals. Gut fullness of blue crabs in a Chesapeake Bay marsh creek was greatest when captured during high tide and lowest just prior to the beginning of ebb tide, indicating blue crabs were utilizing the vegetated marsh surface to forage (Ryer et al. 1987). Moreover, the amount of energy expended for blue crabs in the field may have been increased relative to individuals in the laboratory that did not actively forage and had reduced movement rates. The exact mechanism underlying the shorter IP in blue crabs in the laboratory study, relative to those in the field is not clear. Nevertheless, the results of our concurrent laboratory and field studies suggest that estimates of IP for blue crabs derived from laboratory experiments may differ from those of individuals in the wild. Estimated growth rates of blue crabs held in the laboratory may impart significant bias when these estimates are extrapolated to natural populations. Advances in tagging technology (i.e., uniquely identifiable CWTs) have eliminated many of the difficulties associated with estimating growth rates from free-ranging animals. We recommend that, when and wherever feasible, studies aimed at quantifying blue crab and crustacean growth rates be conducted in the field. When field estimates of crustacean growth rates are unavailable, we recommend that extrapolation of laboratory results to growth models be considered carefully.

Application of capture-recapture estimates to natural populations

The observed IPs in this study probably represent maximum molt frequencies attainable during summer and fall, and likely overestimate growth rates during colder winter months when IP is longer (Tagatz 1968, Leffler 1972, Smith 1997). The present study was conducted during June-October, a period when water temperatures are at or near their annual maximum in North Carolina. Our estimates of growth indicate that blue crabs in North Carolina grow to a legally harvestable size (CW > 127 mm) at approximately 1.2 years of age. Estimated von Bertalanffy parameters (L_{inf} = 237.7, k = 0.74) from this study were similar to those reported for blue crabs in Delaware Bay (L_{inf} = 234.7, k = 0.75; Helser and Kahn 1999) and Chesapeake Bay (L_{inf} = 262.5, k = 0.59, Rugolo et al. 1997), but were considerably higher than values for North Carolina derived from length-based modeling of length-frequency data (L_{inf} = 216.9, k = 0.47; see Chapter 3 in this report). The higher growth rates in this capture-recapture study may be a result of the summer-early fall timing of this study. Blue crabs grow faster at increased temperatures as a result of shorter IPs (Tagatz 1968, Winget et al. 1976).

Lowered growth rates as a result of decreased MI often accompany the onset of sexual maturity, as somatic growth declines and energy resources are diverted into reproduction. This drop in growth rate has been reported in many crustacean species (Restrepo 1989, Wainwright and Armstrong 1993), including blue crabs (Gray and Newcombe 1938). While this change in growth rate can be adequately modeled using a two-phase regression model, we lacked sufficient information on large crabs to justify fitting such a model. As a result, model estimates based on our capture-recapture data may overestimate the MI of large crabs, and could partially account for the greater predicted size-at-age relative to estimates from length-based modeling of length-frequency data (see this study, Chapter 3). For the reasons above, growth rates in this study are probably overestimated relative to wild populations that experience large annual fluctuations in growth rates with seasonal changes in water temperature. Nevertheless, this study provides important information on the growth of free-ranging blue crabs during summer-fall, and allows for a comparison of predictions of size-at-age from discontinuous and continuous models.

Comparison of predicted size-at-age from discontinuous and continuous models

The mean sizes-at-age predicted from the VBGF were very similar to simulated growth trajectories from the discontinuous model (Fig. 6a). Similar to Restrepo (1988), a plot of residuals (Fig. 6b) suggested that the VBGF underestimated the size of intermediate age crabs (0.3 – 1.2 years) and overestimated the size of older crabs (1.2 – 3 years) relative to simulated data. The differences between the predictions from the VBGF and the discontinuous model were relatively small, and likely would not introduce a significant bias into stock assessment models. While discontinuous models provide a more realistic representation of crustacean growth by implicitly considering the molting process, the VBGF has several advantages: (1) it is considerably simpler, (2) is less data intensive, and (3) is integrated into current stock assessment analysis software. Thus, the results from our study support the current practice of using continuous growth models in fishery stock assessments, as well as more ecologically based modeling (i.e., IBMs and matrix models) of the blue crab and other commercially important crustacean fishery species.

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Table 1. Mean (± SE) initial and final juvenile blue crab carapace width, mortality, tag retention estimates, and first and second molt increments for tagged and untagged (control) blue crabs using coded microwire tags in a laboratory experiment. N = 15 crabs tagged and 15 crabs untagged (control). Overall tag retention was not applicable (N/A) to control groups since they did not receive a microwire tag.

	Tagged	Control
Initial CW (mm)	27.58 ± 1.16	27.99 ± 0.88
Final CW (mm)	41.28 ± 1.64	39.86 ± 1.95
Mortality (%)	6.70	13.33
Time to first molt (d)	5.93 ± 0.53	6.13 ± 0.46
(Overall tag retention (%))	87.67	N/A
Time between first and second molts (d)	12.70 ± 0.84	14.33 ± 1.11
(Tag retention between first and second molts (%))	100.00	N/A
Molt increment (mm)	8.17 ± 0.39	8.14 ± 0.41
Size increase at first molt (%)	26.7 ± 0.9	25.8 ± 1.2
Size increase at second molt (%)	28.9 ± 0.9	26.4 ± 1.0

Table 2. Functional relationships between molt increment (MI) and intermolt period (IP) (Y in the equations below) to premolt carapace width (X in the equations below).

Model	Equation		Source
Molt increment			
Linear	$Y = a + b*X + \varepsilon$		Hiatt (1948)
Bent-line model	$Y = a + b*X + \varepsilon$	$x \leq X_0$	Somerton (1980)
	$Y = a + b*X + c(X - X_0) + \varepsilon$	$x \geq X_0$	
Hyperbolic	$Y = K/(X - X_0) + Y_0 + \varepsilon$		Mauchline (1976)
Intermolt period			
Linear	$Y = a + b*x + \varepsilon$		Mauchline (1977)
Cubic	$Y = a + b*X^3$		Kurata (1962)
Exponential	$Y = a*e^{b*X}$		Mauchline (1977)

Table 3. Size class (mm), days-at-large, number of crabs molting, Pm (daily probability of molting), and uncorrected and corrected IP for recaptured free-ranging blue crabs in North Carolina. Corrected IP was calculated using the procedure of Restrepo and Hoenig (1988).

Size class (mm)	Days-at-large	No. of crabs molting	P_m	$IP_{uncorrected}$	$IP_{corrected}$
25	591	39	0.07	15.15	14.17
35	362	18	0.05	20.11	18.80
45	263	9	0.03	29.22	27.32
55	187	9	0.05	20.78	19.43
65	80	3	0.04	26.67	24.93
75	194	5	0.03	38.80	36.28

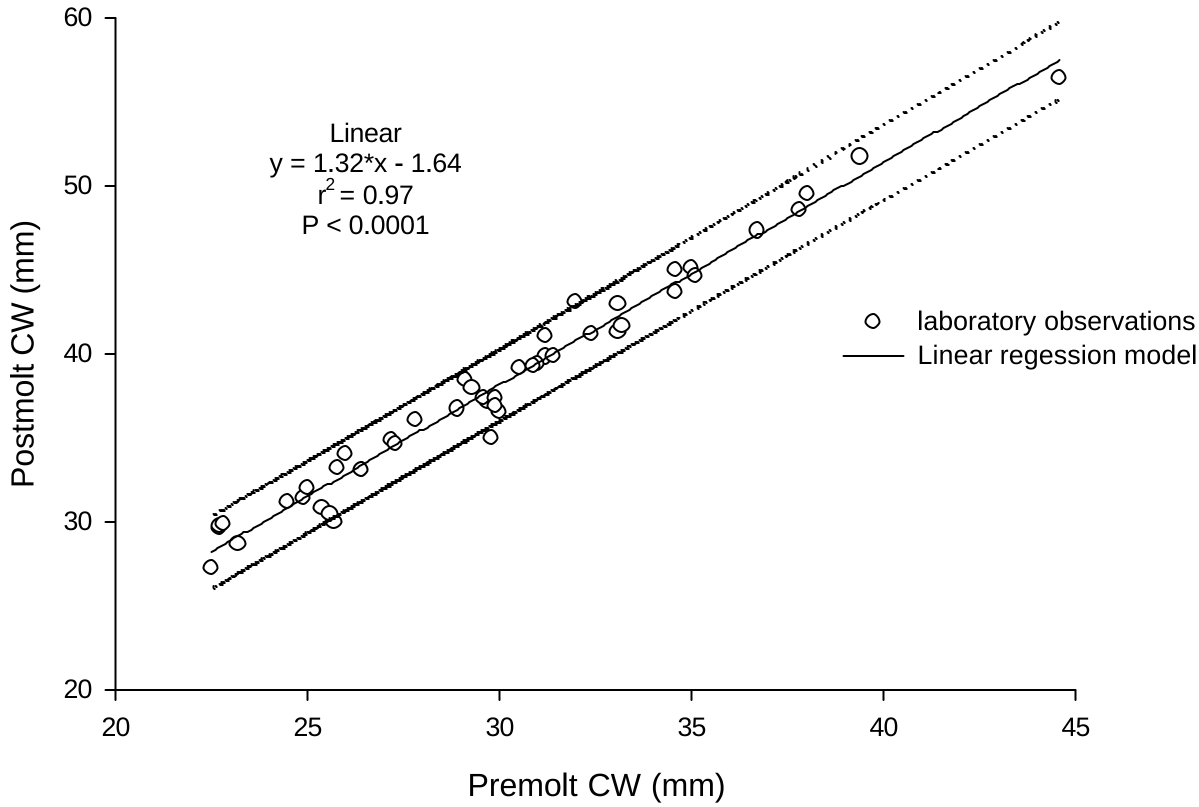

Figure 1. The relationship between premolt and postmolt carapace width (CW) for tagged and untagged juvenile blue crabs in a laboratory experiment. Molt increment for tagged and untagged crabs did not differ statistically (see text for results of statistical tests), and results were pooled for both treatments. The solid black line corresponds to a linear regression and dotted lines represent 95% confidence intervals (n = 46).

Carapace width (mm)

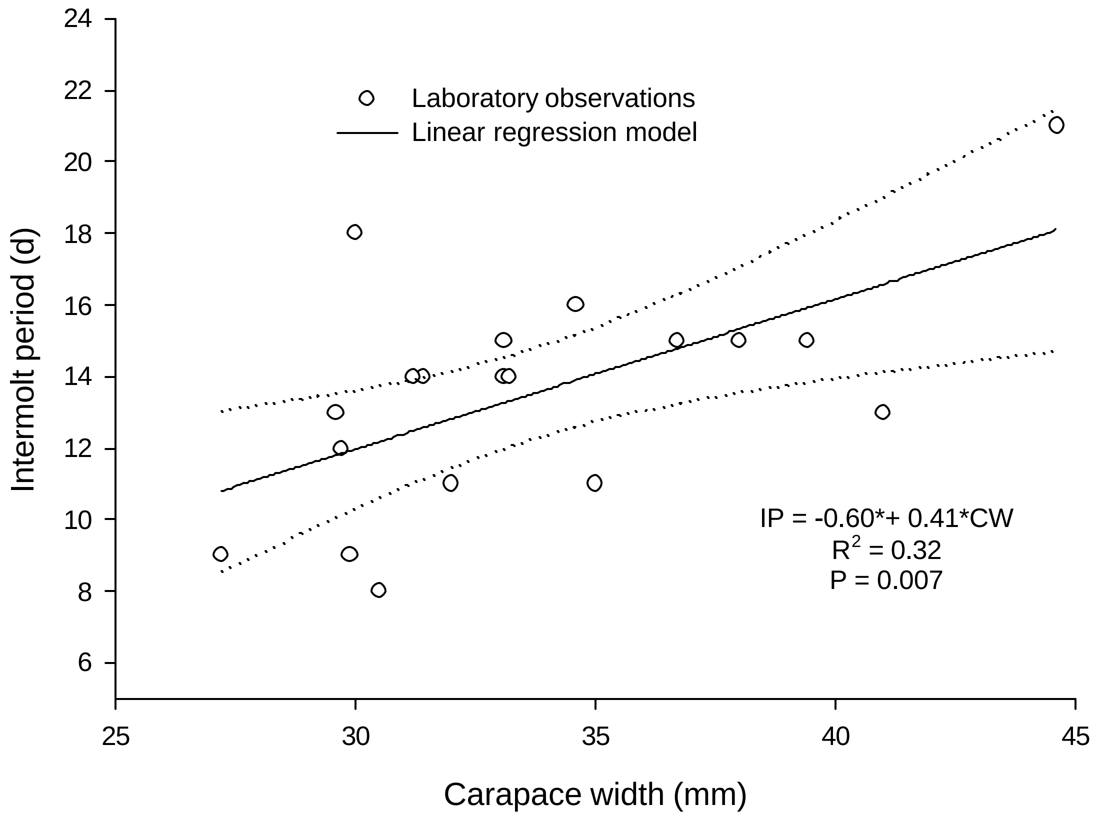

Figure 2. Relationship between premolt carapace width (CW) and exact intermolt period (IP) in days for juvenile blue crabs in a laboratory experiment. IP for tagged and untagged crabs did not differ statistically (see text for results of statistical tests), and results were pooled for both treatments. The solid black line corresponds to a linear regression and dotted lines represent 95% confidence intervals (n = 30).

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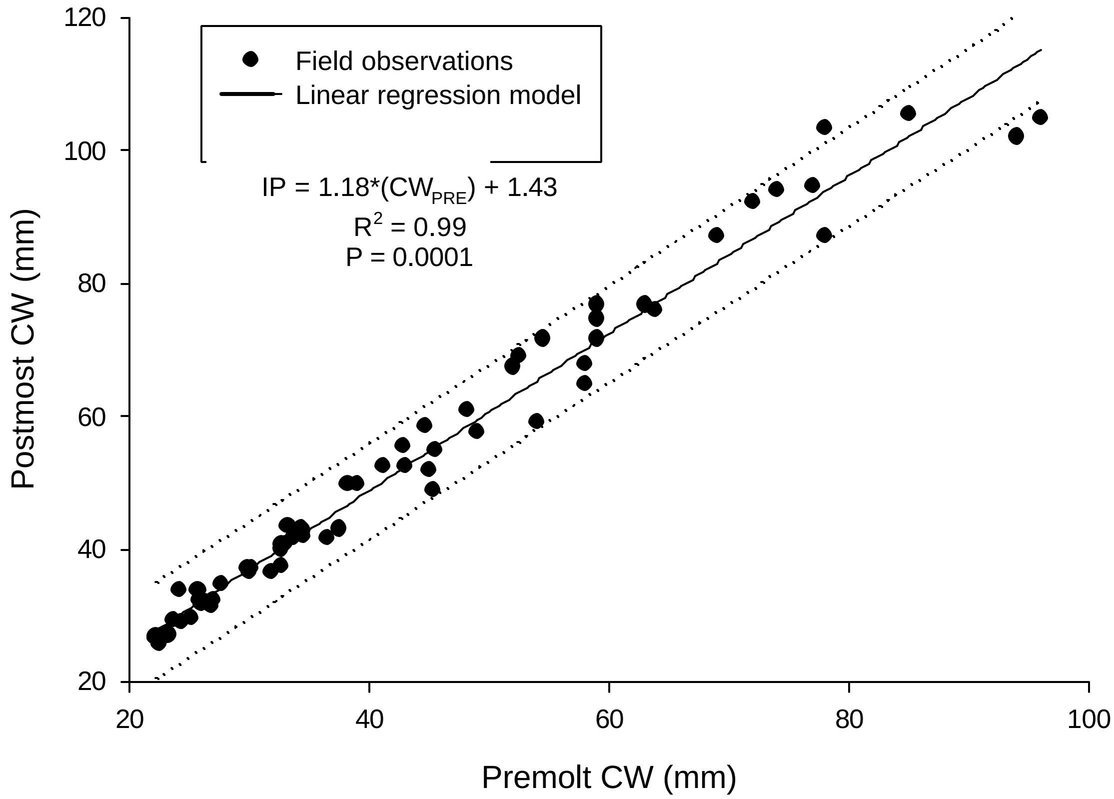

Figure 3. The relationship between premolt and postmolt carapace width (CW) for free-ranging blue crabs in the field. Molt increment for two field sites did not differ and results were pooled for both locations (PC and HS). The solid black line corresponds to a linear regression and dotted lines represent 95% confidence intervals (n = 66).

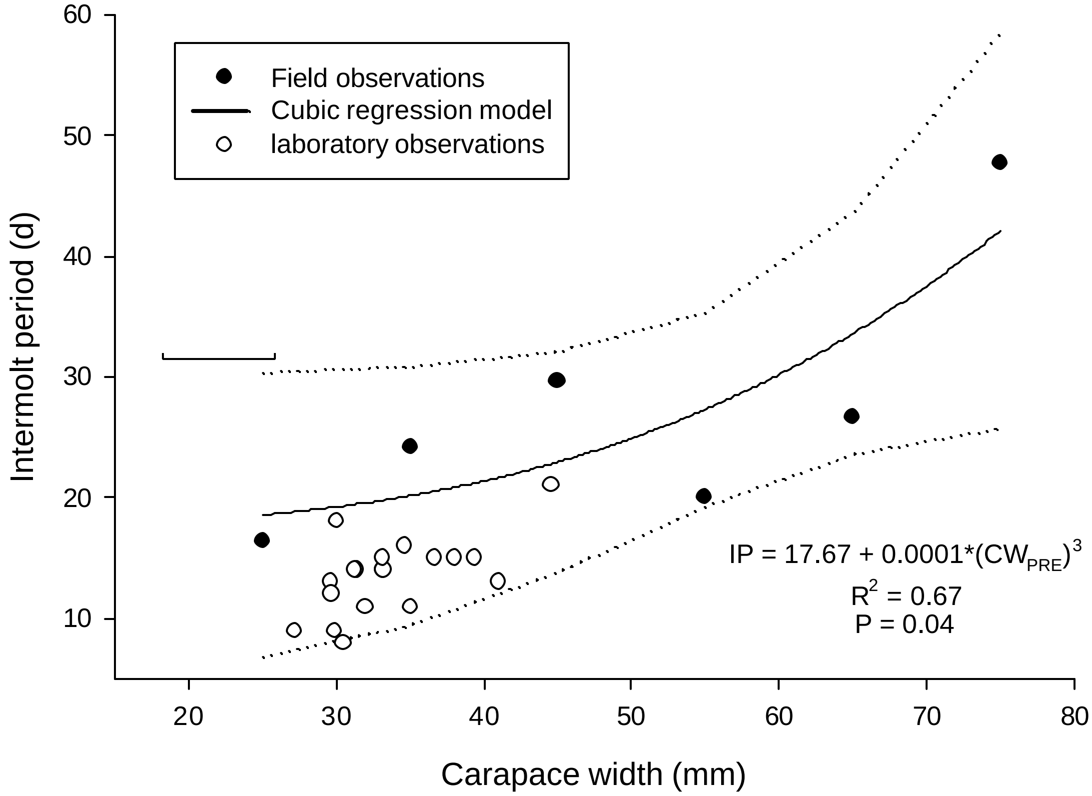

Figure 4. Relationship between premolt carapace width (CW) and estimated intermolt period (IP) for blue crabs under laboratory and free-ranging conditions. Individual data points represent the pooling of data for each size class (n = 155; see text for details.). The solid black line corresponds to a cubic regression and dotted lines represent 95% confidence intervals (n = 6).

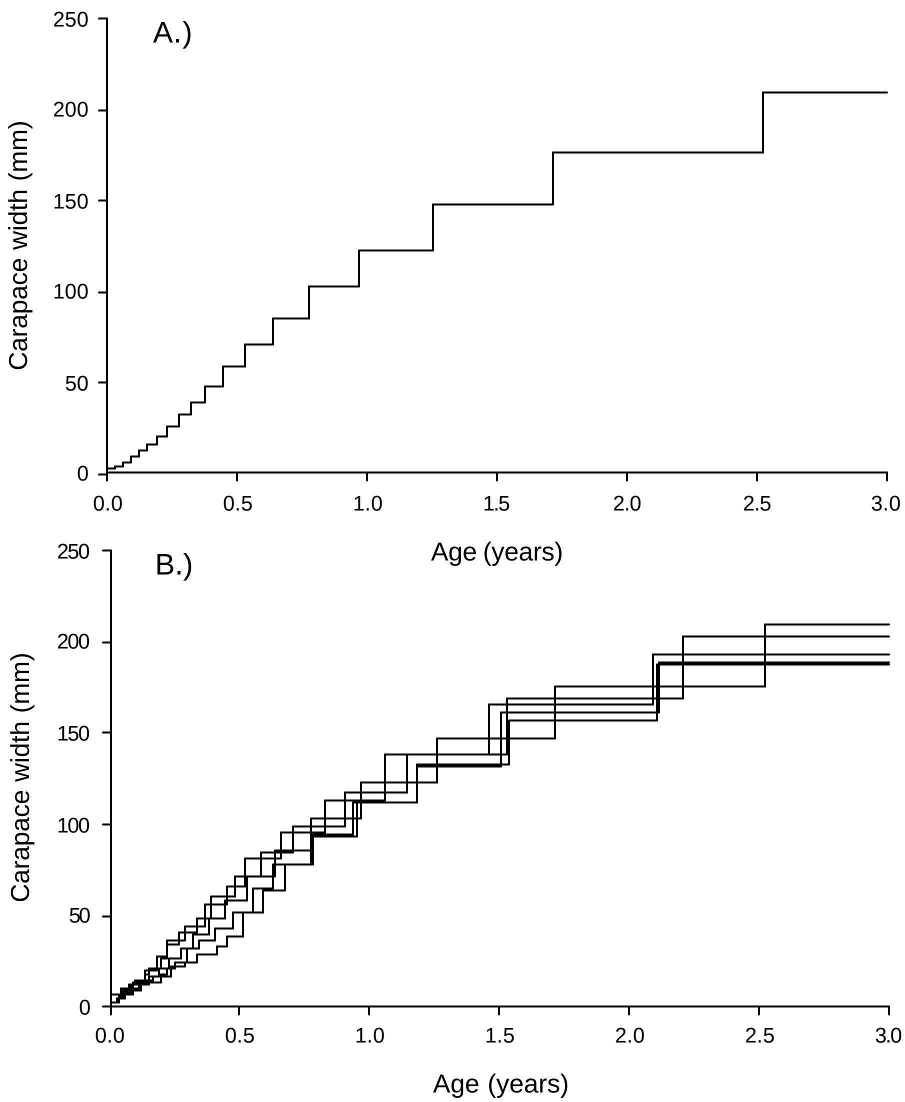

Figure 5. Simulated growth trajectories for A.) a single individual blue crab using a deterministic discontinuous growth model, and B.) five individual blue crabs using a stochastic, discontinuous growth model. The magnitude of variability was estimated from relationships of premolt-CW to MI and IP from field data. See text for model details.

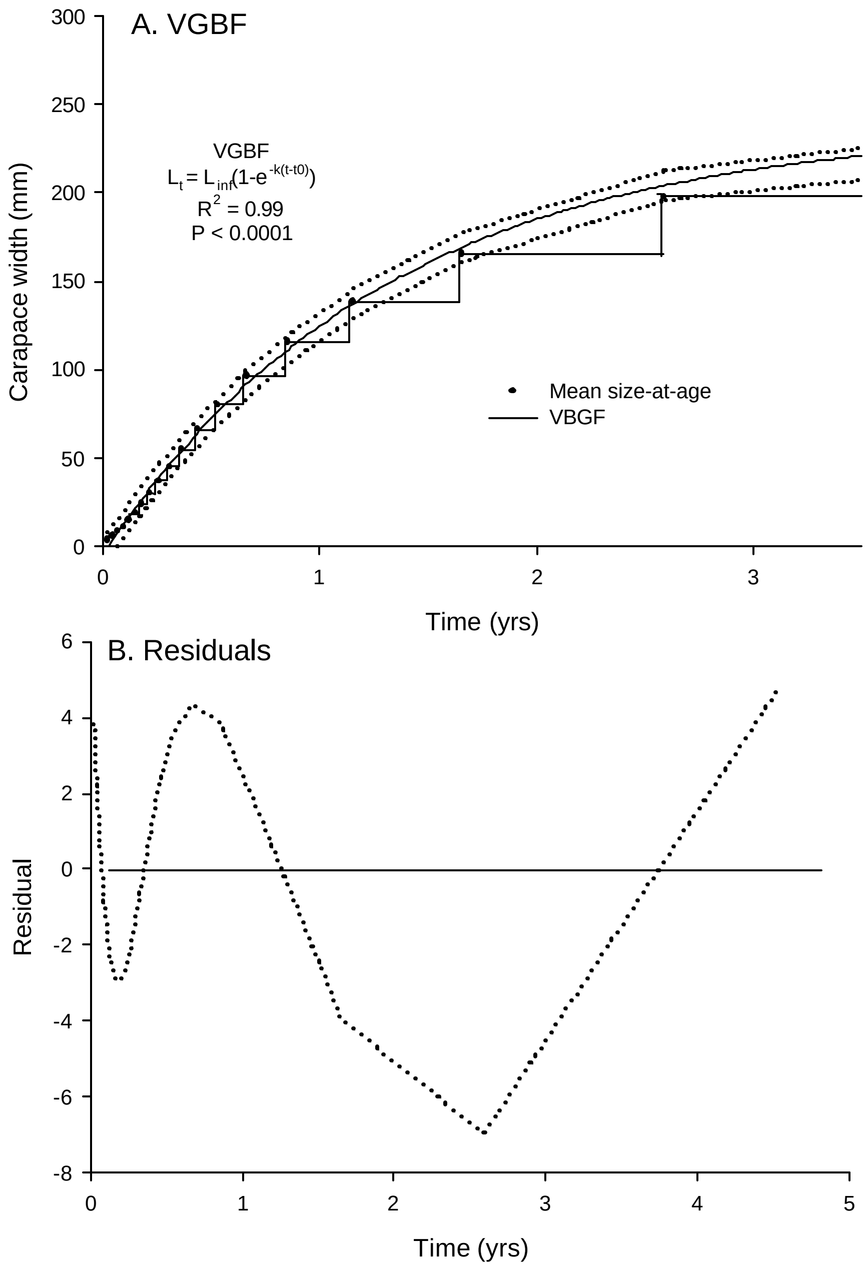

Figure 6. A.) A von Bertalanffy growth function fit to simulated mean size-at-age values from 500 simulations using the discontinuous growth model (this study). The solid black stairstep represents growth of an individual crab from the deterministic growth model (this study). The solid black curve represents the fit of the VBGF to the mean size-at-age. Dotted lines are 95% confidence for the VBGF predictions. B.) Plot of residuals (simulated mean size – VBGF prediction) for all ages.

CHAPTER 3

STOCK ASSESSMENT OF THE BLUE CRAB IN NORTH CAROLINA

ABSTRACT: The blue crab (*Callinectes sapidus*) is an ecologically important estuarine predator and represents North Carolina's most important commercial fishery. Recent fishery-dependent and –independent data suggest the population is declining. An initial description of the population dynamics of the blue crab in North Carolina was provided in 1998 (Eggleston 1998). The present report builds on the previous assessment by incorporating six additional years of data (1998-2003), generating objective indices of annual blue crab abundance using length-based models, using additional modeling techniques, incorporating the uncertainty involved with fisheries data and model outputs, and incorporating additional information on postlarval abundance. The goal of the stock assessment was to increase our understanding of the status and population dynamics of the blue crab in North Carolina by addressing the following objectives: (1) identify temporal variation in commercial effort and landings, (2) identify long-term trends in blue crab abundance as measured with fishery-independent research surveys; (3) describe the relationship between fisheries-independent catch-per-unit-effort (CPUE) and commercial harvest; (4) identify potential relationships between stock and recruitment, as well as between different cohorts (Age 0, Age 1, Age 2); (5) estimate historical biomass and fishing mortality rates; (6); estimate fisheries management targets such as Maximum Sustainable Yield (MSY); and (7) generate biological reference points using yield-per-recruit (YPR) and spawning stock biomass-per-recruit (SSBR) analyses. There has been a systematic increase in commercial landings from 1987-1999, followed by a period of reduced landings from 2000-2002, and gradual increase in landings in 2003. Fishery-independent indices of abundance, such as spawning stock biomass, remained somewhat stable during 1987-1995, increased sharply in 1996, and declined steadily from 1996 to

2002, followed by another sharp increase in 2003. Since 1987, there as been a 12% decline in the average size of mature female blue crabs, and an increasing frequency of mature "pygmy" females (< 100 mm CW) in the fisheries independent indices of abundance. Declines in spawning stock biomass (SSB) and the average size of mature females are of concern because of we detected a significant spawning stock-recruit relationship for the blue crab in NC, such that declines in abundance and average size of mature females should lead to reduced recruitment in the same or a subsequent year. The average size of a mature crab and the overall population distribution pattern of blue crabs in Pamlico Sound respond to salinity fluctuations such that crabs are larger, on average in wet than dry years, and are more available to the NC DMF trawl survey gear in wet than dry years. When we accounted for the annual effects of salinity on crab abundance and average size-at-maturity, the most noteworthy findings were that (1) 2000-01 represented the two lowest SSB values on record, (2) the decline in average size of mature females is even more pronounced and statistically significant, and (3) SSB during 2002-03 appears to be returning to average levels. The low SSB during 2000-01 was due to the interacting effects of hurricane floodwaters in fall 1999 and overfishing of hyper-aggregations of crabs that had migrated in masse downriver to Pamlico Sound. Although there is uncertainty with predictions from fishery models, biomass-based models indicated that, through 2002, relative crab biomass was declining and relative fishing mortality was increasing. Given the significant stock-recruit relationship for the blue crab in North Carolina and the decline in average size of mature females, we recommend that fishery managers strive to increase the average size-at-maturity of female blue crabs, and closely monitor the SSB with management measures in place to reduce fishing mortality on female blue crabs if SSB successively falls below acceptable levels. We encourage decision makers to use the information and recommendations in this report to manage the blue crab fishery in NC in a sustainable manner.

INTRODUCTION

Due to the decline in fisheries resources and concomitant increase in fishing effort in North Carolina over the past decade, a moratorium was placed on the issuance of additional commercial fishing licenses in 1994. The North Carolina General Assembly then charged the NC Sea Grant College Program to conduct comprehensive studies of the fishing industry to supplement information needed by a Moratorium Steering Committee, which was responsible for making changes in fisheries management and legislation. As a part of this effort, Eggleston and McKenna (1996) evaluated fisheries resource data collection, analysis and availability for the blue crab (*Callinectes sapidus*) in North Carolina. Key information gaps identified through their study, which are relevant to this report, included a lack of information on: (1) long-term trends in blue crab abundance as measured with fishery-independent research surveys; (2) the relationship between fisheries-independent catch-per-unit-effort (CPUE) and commercial harvest; (3) spawning stock biomass; (4) stock-recruit and recruit-juvenile-adult relationships; (5) historical biomass and fishing mortality rates; and (6) fisheries management targets such as Maximum Sustainable Yield (MSY; Eggleston and McKenna 1996). In 1998, an initial assessment of the blue crab stock and population dynamics was undertaken (Eggleston 1998), the principal goals of which were to address the information gaps identified in Eggleston and McKenna (1996) by analyzing long-term fisheries data generated by the North Carolina Department of Marine Fisheries (NC DMF). One of the key findings from the initial study by Eggleston (1998) was that annual harvest of the blue crab during 1994-1997 was above levels deemed sustainable; however, there was considerable uncertainty in estimates of MSY that necessitated a more rigorous and comprehensive stock assessment (Eggleston 1998). This more comprehensive stock assessment should help produce an efficient and cost-effective stock-assessment program in the future, facilitate forecasting of year-class strength and setting biologically-based management targets, and increase our understanding of blue crab population dynamics in North Carolina. Better information on the stock status of the blue crab in NC is urgently needed given that the moratorium on the issuance of new crab licenses was lifted in 2000, and commercial landings declined 35% from 1998-2002. This report builds on the previous assessment (Eggleston 1998) by generating age-specific indices of relative stock abundance for the blue crab using statistical length-based models, incorporating six additional years of data (Program 195: 1998-2003; Program 120: 1998-2002), including information on postlarval abundance, using additional modeling techniques, and incorporating the uncertainty involved with the fisheries data.

1. Description of the Fishery

The blue crab supports North Carolina's most valuable commercial fishery in terms of total landings, the amount of gear used, employment, and value (both dockside and post-processing). For example, landings in 1996 were 65 million pounds (Table 1, Fig. 1) with a value exceeding $40 million. Processed crab products annually range in value from $25-$50 million; this value is in addition to the harvest dockside value.

Historically, many types of harvest gear have been used in North Carolina's commercial blue crab fishery, including trotlines, dredges, crab pots, and trawls. The use of crab pots has steadily increased since the 1950s (Fig. 1). Since 1994, the crab pot has accounted for, on average, 95% of the total hard blue crab harvest (Table 1; McKenna et al. 1998). The peak months of pot landings in North Carolina are May through October, which contain, on average, 89% of the total landings (Fig. 2; NC DMF Trip Ticket Data 1994-2002), with a relatively small percentage of annual landings taken from November through April (Fig. 2).

Peeler crabs are harvested through peeler pots, directed peeler trawling, or as bycatch associated with trawling for hard blue crabs and shrimp. Peelers are held in onshore-shedding systems until the crabs complete the molting cycle. Soft crabs are shipped alive or cleaned and frozen. The recent development of onshore-shedding systems and peeler pots has contributed to the steady growth in this segment of the fishery during the 1980s-2000 (McKenna et al. 1998, Chaves and Eggleston 2003). Nevertheless, the peeler and soft crab fishery accounts for, on average, only 3-4% of the total blue crab harvest in North Carolina (McKenna et al. 1998, and see section on Fishery-Dependent Data). For example, annual peeler and soft crab landings have averaged 0.93 million and 0.68 million pounds, respectively since 1994 (Table 1, Fig. 3; NC DMF Trip Ticket data, 1994-2002). Prior to 1994, annual peeler and soft crab landings were not separated, and landings data for these segments of the fishery are available only as the sum of peeler and soft crab landings (Table 1). The impact of the peeler fishery may be underestimated (Chaves and Eggleston 2003), however, as many crabs that die in shedding operations are not sold to dealers and therefore are not reported. Nevertheless, the fishery-dependent data used in this study focused on hard blue crabs landed by crab pots, since pots have accounted for 95% of the total NC landings since 1994 and have the longest time series (see section on Fishery-Dependent Data).

Blue crabs are harvested recreationally in North Carolina with crab pots (rigid and collapsible), trawls (crab and shrimp), hand lines, and dip nets (McKenna et al. 1998). Currently, there is no license required to harvest blue crabs recreationally, unless a vessel is used. The bag limit on recreationally caught crabs is 50 crabs per person per day, not to exceed 100 per vessel. Although estimates of recreational harvest for North Carolina are unavailable, this unaccounted segment of the fishery could be significant. For example, estimates of the Maryland recreational harvest of blue crabs in 1990 were 11.5 million pounds, whereas the commercial harvest was approximately 30 million pounds (Rugolo et al. 1997). The absence of landings data for the recreational fishery in North Carolina could bias population estimates based solely on commercial landings data.

METHODS & RESULTS

1. Fishery-Dependent Data

North Carolina commercial hard crab landings have averaged 21.5 million pounds during 1953-2002 (Table 1, Fig. 1). The U.S. National Marine Fisheries Service collected commercial effort statistics for the blue crab in NC until 1984 (Fig. 1). The NC DMF initiated and augmented the collection of hard blue crab landings data in 1982 as a part of the NMFS/North Carolina Cooperative Statistics Program (Fig. 1). Both programs were based entirely upon voluntary reporting. In 1994, the NC DMF implemented a mandatory Trip Ticket program, which records landings for each commercial harvest trip. During 1994, 131 seafood dealers who had not previously reported hard blue crab landings under the voluntary collection program reported approximately 14 million pounds (26% of the total landings; McKenna et al. 1998). Thus, reliable fishery-dependent data for landings are only available since 1994. One potential solution to correct for underreporting in commercial landings was to adjust commercial landings upwards by 26% prior to 1994. While this option was considered, it was concluded that although 26% of landings in 1994 came from dealers that did not report in 1993, this value would likely result in the over-inflation of catches prior to 1993 (S. McKenna, NC DMF, pers. comm.). Thus, unadjusted landings were used throughout this report, as they were considered to be a more accurate estimate of catch over the entire time series than were adjusted landings. The use of historical landings data in this report should be viewed cautiously and only as a general indicator of fishing trends, since they are influenced by different data collection methods, market demand, price, fishing effort, weather, availability of alternate species, regulations, and stock abundance.

Commercial crab pot landings have been reported from all coastal waters of North Carolina. The major water bodies of pot-caught hard crabs from 1994 through 2001 were Pamlico Sound (28%), Albemarle Sound (25%), Pamlico River (11%), Neuse River (7%), and Croatan Sound (5%). Although total catch for 2002 was known at the time of this report, regional landings were not. Since 1978, when a standardized fishery-independent survey of juvenile blue crabs was initiated (see section on Fishery-Independent Research Survey Indices, A. Juvenile Survey (NC DMF Program 120)), hard blue crab landings have steadily increased in Albemarle and Croatan sounds (Fig. 3), most likely due to rapidly increasing fishing effort in this region (S. McKenna, NC DMF, pers. comm.). Although mean landings for the period 1978-2002 was approximately 4 million pounds in both the Neuse and Pamlico rivers, the patterns of annual landings differed between rivers. Annual landings for the Neuse and Pamlico rivers were among the most variable of all the major water bodies in North Carolina (Fig. 3). For example, with the exception of 1984, annual landings for the Pamlico River were at or below average from 1978 to 1993, above average from 1994-99, but decreased sharply in 2000-2002 (Fig. 3). Sharp increases in landings in the Pamlico River beginning in 1994 most likely reflect the NC DMF mandatory trip-ticket reporting procedures initiated in 1994. The below average landings from 1986 to 1993 (Fig. 3) in the Pamlico River may reflect increasing water quality problems rather than increased crab trawling-induced mortality rates (McKenna and Camp 1992). The period of relatively low crab landings observed in the Pamlico River during 1978-93 were not observed in the Neuse River (Figure 3). Blue crab landings in the Neuse River during 2000 and 2001 are the lowest catches since 1978, and likely represent a large-scale decrease in abundance rather than a trend specific to the Neuse River (see Index of spawning stock biomass below). Annual landings in Pamlico Sound were also somewhat variable, with a steady decline from 1980 to 1986, a period of relatively constant and high landings from 1987 to 1994, followed by extremely low landings in 1995 (Fig. 3). Total annual hard crab landings from the five major water bodies combined show steadily increasing landings from 1986 to 1999, with highest landings of 65 million pounds recorded in 1996, followed by a sharp decline from 2000 to 2002 (Table 1, Fig. 1). The general increase in total annual landings was most likely due to increased effort and landings in Albemarle and Croatan sounds, as described above, rather than an increase in stock size (except for 1996, which was also a year of high relative abundance as measured by fishery-independent data), while the relatively low landings since 1999 reflect a lowered population size. Although soft crabs generally contributed only 3-4% to the total annual landings, they accounted for approximately 20% of the total annual landings in Croatan Sound in 1997 (Fig. 3). We re-emphasize the need for better reporting statistics on commercial effort for hard blue crabs, as well as more reliable data on landings, effort, mortality during shedding for the peeler fishery, soft crabs landed, and the recreational harvest.

2. Fishery-Independent Research Survey Indices

A. Juvenile Survey (NC DMF Program 120)

NC DMF Program 120 (P120) was initiated in 1970 as a shallow water (< 2 m) juvenile survey in primary nursery habitats, which are defined by the North Carolina Marine Fisheries Commission (NC MFC) as those areas in the estuarine system where initial post-larval development occurs. The principal goal of P120 is to develop indices of abundance for a number of recreationally, commercially, and ecologically important species, including the blue crab. Although data generated through P120 was standardized in 1978, we present data beginning in 1987 to remain consistent with the available data from P195 data which was initiated in 1987 (see this section, B. Adult survey (NC DMF Program 195)). The gear in P120 is standardized to a 4-m otter-trawl with 0.64 cm mesh, and a towing distance of ~ 75 m. Blue crabs are separated by sex and maturity, and stations subject to commercial trawling are identified. Initially, selection of station locations was haphazard, however, since 1978 sampling stations were stratified according to eight water bodies: (1) Croatan Sound; (2) Northwest Pamlico Sound (Stumpy Pt. Bay to Abel's Bay); (3) Pamlico and Pungo rivers; (4) Southwest Pamlico Sound (Pamlico Pt. to Cedar Pt.); (5) Neuse River; (6) Outer Banks (Oregon Inlet to Ocracoke Inlet); (7) Core and Bogue sounds (Cedar Island to Bouge Inlet); and (8) Southern area (Bogue Inlet to S. Carolina line) (Table 2, Fig. 4). The number of stations has ranged from 48-109 since 1978. Presently, there are 109 core stations for this sampling program (Table 2, Fig. 4). P120 represents a relatively reliable 16-year data set (1987-2002); although the survey occurs predominantly in May-June, prior to the major recruitment period for blue crabs in NC. Thus, indices of Age 0 blue crabs generated from NC DMF P120 generally reflect both spring recruitment, as well as recruitment from the previous fall. Data for NC DMF P120 were not available for 2003 for inclusion in this report.

B. Adult Survey (NC DMF Program 195)

NC DMF Program 195 (P195) was initiated in 1987 as a deep-water (> 2m), survey of adult blue crabs in North Carolina. The gear used is a 9.1 m "Mongoose" trawl with a 1.9 cm cod-end. This is a stratified random sampling scheme based on area, with a total of 54 stations that were initially sampled in March, June, September and December of each year. In 1990, the sampling frequency was reduced to twice per year (June and September). Presently, there are 54 core stations (Table 3, Fig. 5); the number of sampling sites within a station has ranged from 1-341 (Fig. 6). The spatial coverage of sampling is very comprehensive for Pamlico Sound, and ranges geographically from the mouth of Albemarle Sound to the Southwest portion of Pamlico Sound, as well as the Neuse and Pamlico rivers (Fig. 6). Most of the sampling effort for P195 has been concentrated in Pamlico Sound (Table 3, Fig. 6). Similar to P120, the data for P195 were divided into eight major water bodies: (1) Albemarle Sound (Camden Point to Ned Bees Point); (2) Croatan Sound (Caroon Point to Croatan Sound); (3) Northwest Pamlico Sound (off Stumpy Point to Rose Bay); (4) Outer Banks (Gull Island to Howard Reef); (5) Pamlico River (Sandy Point to upstream of Maules Point); (6) Pamlico Sound (Long Shoal to west of Bluff Shoal); (7) Southwest Pamlico Sound (Bay River to West Bay), and the Neuse River (Gum Thicket Shoal to South River) water bodies (Table 3).

C. Calculation of Annual Indices of Blue Crab Abundance

Blue crab catch-per-unit-effort (CPUE) from P120 and P195 were used as relative indices of stock abundance and in various population models. Although techniques for aging blue crabs are being developed (Ju et al. 2002, 2003), direct aging of blue crabs with precision is not possible at this time. Past assessments have assigned crabs to age classes using size class proxies based on carapace-width (CW mm) increments (Rugolo et al. 1997, Helser and Kahn 1999). The size-specific indices of blue crab abundance used by Rugolo et al. (1997) and Helser and Kahn (1999) were: 0-60 mm CW; 60-120 mm CW; and > 120 mm CW, and represented Age 0, Age 1, and Age 2 crabs in the Chesapeake Bay stock assessment, respectively (Rugolo et al. 1997), or as young-of-the-year (YOY), medium crabs, and large crabs in the Delaware Bay stock assessment, respectively (Helser and Kahn 1999). While these conventions may be appropriate for the Chesapeake and Delaware Bay stocks of blue crab, application of these size/age classes to the North Carolina blue crab stock is problematic given potential differences in the timing of spawning, individual growth rates, and extended growing season. To address this concern, the catch data from the NC DMF survey programs were used to calculate age-specific indices of relative stock abundance for the blue crab using a statistical length-based model.

The length-based model estimated the proportion of crabs in each age class for each year using a maximum likelihood approach to fit a predicted length-frequency distribution to the observed fishery-independent data (P120 and P195). The predicted length-frequency distribution was generated from three von Bertalanffy growth function (VBGF) parameters, L_∞, k, t_0, as well the standard deviation of crab CW (s). We assumed a single VBGF described the pattern of blue crab growth for all years; however, the model allowed for year-specific estimation of proportions in each age class for each survey program (P120 and P195) and month (May, June, September). All model parameters were allowed to vary without constraint, with the exception of L_{inf}. We fixed L_{inf} at 216.9 mm CW based on an average of previous estimates of L_{inf} (187.0, 200.3, 200.6, 235.7, and 262.5; mean = 216.9 mm CW) from earlier stock assessments (Rothschild et al. 1991, Rugolo et al. 1997, Helser and Kahn 1999). Setting $\mathrm{L_{inf}}$ was required since in this heavily exploited fishery, the fishery-independent surveys captured very few large, older individuals. Consequently, P120 and P195 surveys lacked sufficient information about maximum size, and did not produce biologically reasonable estimates of L_{inf} when this parameter was allowed to vary. Since k and L_{inf} were inversely related, this resulted in similar model fits over a wide range of values. Similar difficulties estimating L_{inf} (values as high as several thousand mm CW) for the blue crab were encountered in Delaware Bay (Helser and Kahn 1999) using MULTIFAN (Fournier et al. 1990).

We used the Akaike Information Criterion (AIC; Akaike 1973) to determine the best fitting length-based model from our candidate set of models. The AIC is a commonly used approach, which provides an objective method for selecting the most parsimonious model that still provides an adequate fit to the observed data. The model makes several assumptions regarding the length distribution of crabs: (1) the CWs of the crabs in each age class are distributed normally; (2) the mean CW of each age class can be described using the VBGF; and (3) the dispersion of the carapace widths of each age class about the mean length is described by the standard deviation (σ). All crabs were assumed to be born on September 15th of a given year based on life history information (see section on Index of Spawning Stock Biomass), and fishery-independent trawl surveys were assumed to occur at the mid-point of each month (i.e. for May all trawls were assumed to occur on May 15th). Additionally, the number of age classes in the population must be assumed *a priori*; in all cases we assumed two age classes were present. The assumption of two age classes was based on the visual examination of the observed length-frequency distributions from fishery-independent trawl survey data (P120 and P195) in which two distinct modes were generally present. While it is likely that older age classes are present in the population, given the heavy exploitation in this fishery these ages represent a small fraction of the population and do not produce a distinct mode in the data. Similar data fits to the length-based models over a wide range of assumed ages are common when these older age classes do not represent a large portion of the population and do not exhibit distinct modes in the observed length-frequency distribution (Fournier et al. 1990).

Four sets of indices of annual abundance were generated based on data collected by P120 and 195 during 1987-2003: (1) P120 data collected from tows conducted in May; (2) P120 data collected in June; (3) P195 data collected in June; and (4) P195 data collected in September. Thus, indices of Age 0 and Age 1 were generated for each trawl survey program (P120 and 195) and for each month (P120: May and June; P195 June and September (Age 1 only in Sept., see below). For example, since a September 15th birthdate is assumed for all crabs, Age 0 crabs in May are 0.66 years old (241d / 365d = 0.66), and Age 1 crabs were 1.66 years old. The only exception was P195 in September in which only indices of Age 1 and Age 2 crabs were generated. No index of abundance for Age 0 crabs was available for this time series because of the timing of the survey (September 15th) relative to the assumed crab birthdate of September 15th (See section on Index of Spawning Stock Biomass for justification of Sept. 15 birthdate), and the deep water focus of this trawl program failed to capture large numbers of Age 0 crabs. Thus, the first mode in the observed length-frequency for P195 in September is crabs that are effectively one year old (see section on Fishery-Independent Research Surveys, B. Adult Survey (NC DMF Program 195)). Since a September 15th birthdate was assumed for all crabs, and surveys are assumed to occur at the mid-point of each month (i.e. September 15th), Age 1 crabs in the P195 September survey are ~1.0 year old (365d / 365d = 1.0), and Age 2 crabs were ~2.0 years old. A single growth curve was fitted to the P120 data from both months (May and June) simultaneously. The joint analysis of two points in time (May and June) should capture additional information on growth based on the shift in size modes from May to June within a given year. Similarly, a single growth curve was fit simultaneously to P195 data in June and September.

In general, the length-based model provided a reasonable fit to the observed length-frequency data from the trawl surveys in most years (Figs. 7-10). AIC values were used to select the best fitting model for each trawl survey program and sampling month. Model parameters from best fitting model runs (Tables 4, 5) were used to estimate size/age classes for a given year, and to estimate growth rates of blue crab in North Carolina (Tables 4, 5; for details see section on Life History Characteristics, 3. Estimation of Growth Rates).

D. Correlation Analyses of Length-Based Indices of Blue Crab Abundance

We conducted correlation analyses on our annual length-based estimates of blue crab abundance for three purposes: (1) to determine whether the multiple indices of abundance for a given year class covaried (i.e., Do the indices of Age 0 abundance from P120 trawls in May, P120 trawls in June, and P195 trawls June, and Age 1 abundance from P195 show similar patterns within a given year?); (2) to determine whether individual cohorts could be tracked over successive years (i.e., Does Age 0 abundance in a given survey in year t predict Age 1 abundance in year t + 1?); and (3) to determine whether indices of abundance for all age classes were correlated within a single year (i.e., Do the indices provide an accurate estimation of abundance, or do they reflect changes in the annual availability of blue crabs to the survey gear?).

To determine the extent to which different indices of abundance (Table 6) covaried, we conducted correlation analyses for all survey indices within the same year. If the indices of abundance for Age 0, Age 1 and Age 2 crabs from the different survey programs and months were significantly correlated within years, it would provide a greater level of confidence in survey data. Given the timing of the survey programs, the estimates of P120 Age 0 crabs in May (0.66 years), P120 and P195 Age 0 crabs in June (0.75 years) and P195 Age 1 crabs in September (1.0 years) were considered to represent a single age class over time and used for within year calculations. Similarly, P120 Age 1 in May and June, P195 Age 1 in June and P195 Age 2 crabs in September were also considered for within year analyses. The results indicated that only indices of Age 0 crabs for P120 May and P120 June were positively correlated ($r = 0.485$, $P = 0.028$; Table 7). Indices of Age 1 crabs for P120 May and P120 June were positively correlated, but the correlation was only marginally significant ($r = 0.403$, $P = 0.061$; Table 7). No other indices of Age 0, Age 1 or Age 2 abundance were significantly correlated (Table 7), indicating considerable variation within annual estimates of abundance. Due to this uncertainty, we considered all indices of abundance in further analyses.

Correlation analyses on survey indices at appropriate lags (e.g. Age 0 in year t vs. Age 1 in year t + 1) were used to determine the extent to which surveys were able to track cohorts through successive years. Cohorts could only be tracked in the P195 survey in June. In this survey, Age 0 crabs in June were positively correlated ($r = 0.537$, $P = 0.016$) with Age 1 crabs in the following year (Table 7). The relationship between P195 June Age 0 and Age 1 blue crabs was described by a statistically significant linear regression model (Fig. 11). No other survey programs were able to follow cohorts at appropriate lags (Table 7). The inability of P120 in both May and June to track cohorts may be a result of the timing and spatial coverage of this survey. The length-frequency data from P120 suggests that this survey collects a large abundance of small crabs (CW < 20 mm, Figs. 7, 8) in the spring. These crabs are too small to have recruited to the estuary in the fall, and these indices are partially tracking recruitment of juvenile crabs from spring spawning females. Data also suggests that the offshore concentration of megalopae in the late summer and fall is much greater than in the spring (see section on Index of Spawning Stock Biomass, 2. Relative abundance of blue crab larvae and megalopae), suggesting that the primary recruitment of blue crabs into the estuary occurs in the fall. Thus, the index of Age 0 crabs from P120 surveys seem to partially reflect the abundance of spring spawned crabs, but also effectively captures larger Age 0 crabs (40 – 80 mm CW) that presumably resulted from the fall spawn of the previous year.

We also tested for correlations between indices of abundance for all age classes within the same year. If indices are an accurate measure of abundance, one would expect to see a high correlation between age classes in successive years, but not in the same year. High correlation between different age classes within a single year may be a result of changing availability to the survey gear due to environmental factors that result in large or small numbers of all age classes of crabs being available to the survey gear. Similar to analyses from Chesapeake Bay (Rugolo et al. 1997), we found a high level of correlation between age classes within years (Table 8), suggesting that certain survey indices may better reflect availability of crabs to the survey gear than relative abundance. The correlation between indices of Age 0 and Age 1 crabs in the same year for P120 in May was not significant. P120 indices of blue crab abundance in June for Age 0 and Age 1 crabs, however, were significantly and positively correlated ($r = 0.74$, $P < 0.001$, Table 8). P195 indices of blue crab abundance in June were also significantly correlated between Age 0 and Age 1 ($r = 0.581$, $P = 0.01$). P195 September indices of Age 1 and Age 2 crabs were not significantly correlated (Table 8). These results suggest that certain P120 and P195 blue crab trawl survey indices reflect availability to the survey gear to an extent, and annual availability to NC DMF survey gear may mask any cohort signal over time. This finding underscores the need to examine the effect of environmental factors on the distribution and abundance of blue crabs in North Carolina relative to the current spatial coverage of current NC DMF survey programs, and how this environmental variation drives crab availability to the surveys. An initial evaluation of the role of salinity on availability of blue crabs to the NC DMF trawls surveys is described in the Conclusion section of this report.

E. Trends in Indices of Blue Crab Abundance

1. Size-frequency analysis of Program 120 data

Carapace width-frequency distributions were prepared for each survey program (sexes combined). Crabs were pooled by CW into 5-mm groups. From 1987-2002, P120 in May (Fig. 7) and June (Fig. 8) collected early juvenile through adult stages of blue crabs ranging in size from 5 to 200 mm CW. As intended, however, P120 captured primarily small juvenile crabs less than 40 mm CW (Figs. 7, 8). The general increase in size frequency of juvenile crabs to a peak of approximately 20-40 mm CW (Figs. 7, 8) suggests that crabs were not fully recruited to the sampling gear used in P120 until this size, and suggests that these surveys are primarily tracking the abundance of a spring cohort. This survey, however, may also effectively track the abundance of fall spawned Age 0 crabs, since it collects larger Age 0 crabs as well (40 – 80 mm CW). Crabs of this size (40-80 mm CW) presumably resulted from the fall spawn of the previous year. The P120 survey is not as effective at capturing larger individuals as P195, probably because larger crabs occupy deeper waters (> 2m) and are not available to the P120 survey.

2. Trends in the Program 120 indices of abundance

Overall, mean juvenile CPUE in May was higher for Age 0 blue crabs (mean = 6.34 crabs per tow) than for Age 1 (mean = 1.17 crabs per tow) crabs (Table 6, Figs. 12, 13). No long-term pattern in the time series of Age 0 crabs from P120 May was observed between 1987 and 2002 (Fig. 12), and linear regression revealed no significant trends. The abundance of Age 0 crabs in May for the most recent year for which data was available (2002) was similar to the long-term (16 year) average (Table 6, Figs. 12, 13). Similar to the May time series, the mean CPUE for P120 in June was higher for Age 0 crabs (mean = 5.46 crabs per tow) than for Age 1 (mean = 3.22 crabs per tow; Table 6, Fig. 12); however, the June time series was slightly more variable (coefficient of variation (CV) = 0.44) than the May series (CV = 0.36; Table 6). This increased variation in crab abundance from May to June is largely a result of the large CPUE value in 1998 (Fig. 12). No long-term pattern in the time series of Age 0 crabs from P120 June (Fig. 12) was identified using linear regression models, and the abundance of Age 0 crabs in June 2002 was just below the long-term (16 year) average (Fig. 12). Similarly, the index of Age 1 crabs from P120 May did not show any statistical trends in abundance over time (Fig. 12), and abundance of Age 1 crabs in 2002 is just above the long-term average (Fig. 12). The index of Age 1 crabs from P120 June was also trendless, but exhibited a large spike in 1998 (Table 6, Fig. 12). Overall, no trends in abundance were evident over time for Age 0 or Age 1 blue crabs from the P120 May or June surveys (Fig. 12), and abundance in 2002 appears to be at or near the long-term average.

3. Size-frequency analysis of Program 195 data

The size frequency of blue crabs captured in P195 ranged from 20-200 mm CW, and was skewed towards larger sized crabs (> 60 mm CW, Figs. 9, 10). In most years, length-frequency distributions exhibit clear modes suggesting the existence of individual cohorts (e.g. Fig. 9, 1987, Fig. 10, 1996). Although crabs > 127 mm CW are harvested by the fishery, relatively large numbers of crabs above this size class were captured in most years (Figs. 9, 10).

4. Trends in Program 195 indices of abundance

Overall, mean CPUE from P195 June was higher for Age 0 crabs (mean = 34.56 crabs per tow) than for Age 1 (mean = 14.04 crabs per tow) crabs. (Table 6, Figs. 14, 15). No long-term pattern in the time series of Age 0 crabs from P195 June (Fig. 14) was evident, and a linear regression model revealed no significant trends. The abundances of Age 0 crabs in June of 2002 and 2003 were well above the long-term (17 year) average and the second and third highest on record, respectively (Table 6, Fig. 14). A statistically significant ($r^2 = 0.28$, $P = 0.03$) decline in the abundance of P195 June Age 1 crabs, however, was identified using linear regression (Fig. 14), and current abundance was estimated to be well below the long-term average (2003 = 4.47 vs. mean = 12.12; Fig. 14). Mean CPUE from P195 September was lower for Age 1 blue crabs (mean = 5.27 crabs per tow) than for Age 2 (mean = 6.31 crabs per tow) crabs (Table 6, Fig. 14). Linear regression identified a significant ($r^2 = 0.37$, $P = 0.01$) decline in CPUE of Age 1 blue crabs from P195 September (Fig. 14). The mean CPUE of P195 September Age 2 crabs did not exhibit a trend over time, and abundance in 2003 was the highest observed between 1987 and 2003 (Fig. 14).

Overall, there was a general lack of coherence in trends among survey indices of blue crab abundance suggesting considerable uncertainty regarding current stock status. P120 surveys for Age 0 and Age 1 crabs indicate that population size has remained at or near a long-term average. It should be recognized, however, that these surveys were not designed to target Age 1 and Age 2 blue crabs and may not provide the best estimates of larger individuals. In some cases, P195 data exhibited a statistically significant trend toward declining population abundance over time (P195 June Age 1, September Age 1; Fig. 14). The 2003 values for blue crabs captured in P195 June Age 0 and P195 September Age 2 (Fig. 14) were well above the long-term average, but were not consistent with a single strong year class. For example, the record CPUE value for Age 2 crabs in September 2003 should be evident as a very large peak in Age 1 CPUE in June, which was not the case. The CPUE values for P195 June Age 0 and September Age 2 were well above the long-term average (Age 2 crabs in P195 September were the highest on record; Fig. 14). Overall, indices of relative abundance are conflicting between P120 and P195 regarding whether or not a decline in stock abundance has occurred. Nevertheless, in no case did we find a significant increasing trend in survey indices, suggesting that a conservative, risk-averse management strategy would be advisable.

F. Relationship Between Survey Indices and Landings

Identifying the relationship between research survey indices of blue crab abundance and commercial landings is essential for forecasting fishery year class strength. The abundance of blue crab recruits from fishery-independent surveys has been used to predict harvest for both the Chesapeake and Delaware Bays (Speir et al. 1995). The CPUE of mature crabs (> 4.7 inches or 120 mm CW) is positively correlated with commercial landings and effort in Chesapeake Bay (Lipcius and Van Engel 1990, Speir et al. 1995). Conversely, in North Carolina, McKenna and Camp (1992) did not find a correlation between the CPUE of juvenile crabs in the Pamlico River and subsequent commercial landings.

We used correlation analyses, as well as linear and non-linear regression procedures, to identify possible relationships between blue crab fishery-independent CPUE estimates generated from length-based models for NC DMF P120 and 195, and commercial landings. For P120 in May, there was no relationship between the CPUE of Age 0 or Age 1 blue crabs and commercial landings with or without annual lags (Table 9). Conversely, there was a positive and statistically significant relationship between all P120 June indices of crab abundance (Age 0 and 1) and landings the same year (Table 9). The relationship between P120 Age 1 blue crabs in June and commercial landings the same year was described by a non-linear (hyperbolic) regression model (Fig. 16) when all years were considered. The relationship between P120 Age 1 crabs in June and commercial landings was described by linear model when data from 1998, which appears as an outlier (Fig. 16a), was removed (Fig 16). The relationship between P120 Age 0 blue crabs in June and commercial landings in the same year is likely spurious; a result of autocorrelation of the Age 0 and Age 1 indices due to availability to the survey gear (see section on Fishery-Independent Research Survey Indices, D. Correlation analyses of length-based indices of abundance). There was no relationship between P120 indices of blue crab abundance in June and landings lagged by one or two years (Table 9). For

P195 June, there was no relationship between the relative abundance of Age 0 and 1 blue crabs and landings with or without an annual lag (Table 10). Conversely, there was a positive and statistically significant relationship between P195 September Age 2 crabs and commercial landings the same year; none of the other P195 September indices were correlated with landings (Table 10). The relationship between P195 Age 2 blue crabs in September and commercial landings the same year was described equally well by linear and non-linear regression models (Fig. 17). Thus, although several fishery-independent indices of blue crab abundance are correlated with landings the same year, none of the indices are capable of predicting landings 1 to 2 years in advance.

G. Index of Spawning Stock Biomass

There are two primary fishery-independent surveys in NC (P120 and P195), each of which includes several monthly sampling events, and 2-size/age classifications, providing a number of potential indices of spawning stock at various points in time. Both crab sex and maturation stage are recorded in the NC blue crab surveys. Thus, rather than use a size-based proxy to estimate abundance of mature females, we used a direct measure, which avoided underestimating the spawning stock size given an apparent decline in mean size at maturity (see section on Trends in Spawning Stock Biomass and Size of Mature Females). The relative abundance of mature females was converted to relative spawning stock biomass (SSB) to better capture the decline in mean size-at-maturity (see below). Conversions from crab size (mm CW) to biomass are described in the yield-per-recruit section below (see section on Biological Reference Points, 1. Yield- and spawning stock biomass-per-recruit analyses).

We used CPUE data from P195 in September for our index of spawning stock based on biological evidence that the offshore larval concentrations and subsequent poastlaval recruitment to Pamlico Sound are highest in August and September, respectively, and that relative abundance of mature females on the major inlet spawning sanctuaries in NC is relatively high in August. Moreover, P195 uses sampling gear that targets adult crabs in Pamlico Sound, as opposed to P120, which uses gear and samples in shallow areas to target juveniles. In addition, indices of mature females in September from P195 should better reflect the abundance of mature females available to spawn in late summer/early fall than the abundance of mature females measured in June, the only other month P195 samples. Moreover, given the intense nature of the fishery in NC, the relative abundance of mature blue crabs declines greatly from June to September (Eggleston 2003). Lastly, there is a significant spawning stock-recruit relationship using P195 September spawners, but not using June spawners (see section on Spawning stock-recruit relationships, 1. Parametric stock-recruit relationships). In the sections below, we provide information in support of our decision to use September P195 data for an index of blue crab spawning stock in NC.

1. Relative abundance of mature females on spawning sanctuaries.

Newly inseminated female blue crabs either migrate to seaward inlets in NC or the lower Chesapeake Bay during summer, or migrate in fall, overwinter, and then spawn the following year (Van Engel 1958; Tagatz 1968; S. McKenna, NC DMF, unpubl. data). The collective evidence from published and unpublished data indicates that egg-bearing female blue crabs are present and spawn on the inlet sanctuaries from spring through fall in NC, and during this same time in Chesapeake Bay (Dudley and Judy 1971; Prager et al. 1990; Ballance and Ballance 2002; Eggleston 2003; Lipcius et al. 2003; Medici 2004). Peak abundance of mature female crabs in the major NC inlets occurs in May and August (Dudley and Judy 1971, Ballance and Ballance 2002, Eggleston 2003). For example, Eggleston's (2003) trawl surveys at all of the inlet spawning sanctuaries in NC in 2002 indicated similar relative abundance of mature females within the sanctuary versus a ~ 5 km distance away from the sanctuary (inshore & offshore) during June-September, with peak abundance in August (Fig. 18). Fishery-independent crab pot surveys from Ocracoke Inlet indicate peak abundance of mature female blue crabs in May and August, with peak abundance of egg-bearing females in May (Ballance and Ballance 2002). Thus, the collective evidence (Balance and balance 2002, Eggleston 2003) suggests that peak abundance of mature females on NC inlet spawning sanctuaries occurs in May and August.

2. Relative abundance of blue crab larvae and megalopae.

Nichols and Keney (1963) found peak concentrations of blue crab larvae and megalopae off North Carolina in August compared to other months (Fig. 19). Dudley and Judy (1971) found highest larval concentrations in June-August, with highest megalopal concentrations in September-November. Similarly, Eggleston (unpubl. data) identified a relatively weak pulse of blue crab megalopae that settled to artificial settlement substrates near Oregon Inlet in spring, followed by a major pulse in fall (Fig. 20). The fall recruitment pulse of megalopae to Pamlico Sound has been observed annually since 1996 (Etherington and Eggleston 2003, Eggleston unpubl. data). Thus, irrespective of the origin of blue crab larvae to Pamlico Sound, or the fact that mature, egg-bearing female crabs are present on the spawning grounds throughout the summer, the main recruitment period of blue crabs to Pamlico Sound appears to be late summer-early fall. Given that the larval duration of the blue crab is documented at ~ 30 d (Van Engel 1958; McConaugha et al. 1983), the blue crab spawning stock sampled by P195 in September appears to better reflect the relative abundance of those crabs available to spawn in August compared to the relative abundance of mature females surveyed by P195 in June, since the abundance of crabs sampled in June declines greatly during the summer (Fig. 21). It remains to be determined if the relatively high blue crab larval concentrations offshore of NC and SC in August and subsequently high megalopal settlement in Pamlico Sound in September is due to (1) peak spawning of blue crabs in Pamlico Sound in August, or (2) continual spawning of blue crabs during spring-fall with oceanographic conditions most favorable for inshore transport only during early fall. Mechanisms underlying #2 could involve both active (delayed metamorphosis) or passive (storm-driven transport) recruitment processes.

H. Trends in Relative Spawning Stock Biomass (SSB) and Size of Mature Females

1. Spawning stock biomass. No statistically significant decline in SSB was observed from 1987-2003 (Fig. 22). The mean index of SSB from 2000-2002, however, declined 72% from the previous 10-year average, and produced the three lowest recorded values for SSB since P195 was initiated in 1987 (Fig. 22). Following this period of low abundance, SSB has appeared to rebound in 2003, and was the second highest value recorded since 1987 (Fig. 22). While the 2003 index of spawning stock may indeed reflect an increase in SSB from low levels, a precautionary approach is warranted when interpreting the 2003 value because crabs blue crabs shift their distribution within

Pamlico Sound depending on salinity, which determines their availability to P195 surveys. For example, we suggest that blue crabs shift their distribution downstream during wet years as was the case following hurricane floodwaters in 1999 (Fig. 23), which makes them more available to P195. Conversely, blue crabs likely shift their distribution upstream during dry years (S. McKenna, NC DMF pers. comm.), which would make blue crabs less available to P195 surveys. To determine the extent to which availability of mature females to the P195 trawl survey was driven by annual fluctuations in salinity, we examined the relationship between our index of SSB and mean annual salinity. We fit both linear and hyperbolic regression models to the relationship between the index of SSB and mean salinity from P195. A statistically significant ($r^2 = 0.49$, $P = 0.008$) relationship was identified using non-linear hyperbolic regression (Fig. 24a) and provided the best fit to the observed data. We then examined the residuals (i.e., observed SSB – predicted SSB) from the regression of salinity on relative SSB to examine the trend over time while controlling for the effects of salinity (Fig 23b). The residuals from regression models are used frequently in statistical analyses to remove the confounding effects of variables (Garcia-Berthou 2001, Freckleton 2002). Although multiple regression and ANCOVA are recommended as more powerful techniques that control for autocorrelation (Garcia-Berthou 2001, Freckleton 2002), these approaches were precluded due to the summary of data into annual means. Nevertheless, our approach is valid since no autocorrelation existed between salinity and year. Two major differences are apparent in the patterns of the residuals when the effects of salinity are removed, (1) SSB was underestimated by P195 in 2002, and (2) SSB was overestimated by P195 in 2003 (compare Figs. 22 and 24b). Thus, it appears that the large increase in relative SSB in the P195 September survey in 2003 (Fig. 22) reflects both an actual increase in spawning stock from historic lows observed during 2000-2001 to average levels, and an increase in availability of mature females to survey gear due to low salinity. P195 surveys were conducted in October rather than September 2003 due to delays from the passage of hurricane Isabel in mid-September. The pattern of lowest SSB on record during 2000-01 was unchanged after adjusting for salinity (compare Figs. 22 and 24b).

2. Size of mature females. Concurrent with the observed decline in SSB from 1996 to 2002 are two related trends: (1) a declining trend in the average size of mature females from 1987-2002, and (2) an increasing proportion of extremely small mature females (CW < 100 mm CW) in the spawning stock (Fig. 25). Mature females were identified using the semi-circular morphology of the female abdominal apron that is characteristic of maturity. The average carapace width of mature females over time was variable, potentially due to annual fluctuations in salinity. Blue crabs mature at a smaller size as temperature and salinity increase (Fisher 1999). Although untested, a negative correlation between size and salinity was suggested for blue crabs in Chesapeake Bay (Tagatz 1968), and results of laboratory experiments suggest blue crabs will achieve maximum size in low salinity waters at high temperatures (Cadman and Weinstein 1988). The physiological mechanism for crabs achieving a relatively large size at low salinities is unknown.

To determine if annual fluctuations in salinity affected the mean size of mature females in NC, we examined the relationship between mean CW of mature females and salinity from the P195 trawl survey. A marginally significant ($r^2 = 0.18$, $P = 0.10$)

relationship was identified using linear regression (Fig. 26a). We then examined the residuals (i.e., observed CW– predicted CW) from the regression of salinity on mean CW of mature female blue crabs to determine if there was still a decline in mean size over time (Fig. 26b). A linear regression on the residuals identified a statistically significant ($r^2 = 0.37$, $p = 0.01$) decline in mean size of mature female blue crabs over time after removing the effects of salinity (Fig 26b). There also appears to be an increasing and marginally significant ($r^2 = 0.23$, $P = 0.06$) trend in the proportion of small (CW < 100 mm) mature females in the population (Fig. 25b).

This decline in mean size of mature females be the result of the implementation of cull rings, mandated by NC DMF in 1989, leading to an increasing proportion of escapement from crab pots by small females (< 127 mm CW), although cull rings have been exempted by proclamation in the Outer Banks area of NC since 1994. A decline in average size-at-maturity may also reflect a compensatory response by the population to reproduce as soon as possible under intense exploitation rates (Bertelsen and Cox 2001). A similar pattern of concurrent decline in spawning stock abundance and average size has been documented for the blue crab in Chesapeake Bay (Lipcius and Stockhausen 2002). Similar to the North Carolina fishery, crab pots in both the Maryland and Virginia waters of Chesapeake Bay must have at least 2 cull rings (one at least 2 3/16" and a second at least 2 5/16"); however, cull rings may be closed on the seaside of the eastern shore of Virginia within areas open to crab dredging. Because blue crab fecundity increases with size (Prager et al. 1990), a simultaneous decline in both spawning stock abundance and size-at-maturity will produce a synergistic reduction in spawning potential.

Overall, the evidence from trends in the index of SSB and size-at-maturity for female blue crabs indicates that spawner abundance and biomass declined to historic low levels during 2000-2001, but increased during 2002-2003 to near the long-term (17 year) average (Fig. 24b). We believe the low SBB values from 2000-2001 accurately reflect a low abundance in spawning stock during this period because: (1) intense, localized fishing of crabs migrating to high salinity waters following multiple hurricanes in 1999 (Dennis, Floyd, and Irene; Fig. 23) resulted in an increase in state-wide catch-efficiency during Fall 1999 that was 369% above the average from 1987 – 1998 (Fig 27), and (2) there were concurrent declines in varying life history stages of the blue crab in 2000-2001 (e.g., decline in Age 1 crabs shown in Fig. 14, and decline in postlarval crabs shown in Fig. 28a). Thus, it appears that the blue crab spawning stock is susceptible to overfishing and recruitment failure (Etherington and Eggleston 2003) during extreme flooding events, as observed in 1999, and the large increase in relative SSB in 2003 reflects both an actual increase in spawning stock from historic lows observed during 2000-2001 to near average levels, and an increase in availability of mature females to survey gear due to annual changes in salinity.

I. Spawning Stock-Recruitment Relationships

1. Parametric stock-recruitment relationships

The relationship between spawner abundance and subsequent recruitment is one of the most fundamental issues in fisheries management because in the absence of a stock-recruit relationship, managers would only be concerned with maximizing yield-per-recruit (YPR; Hilborn and Walters 1992). The goal of stock-recruit analyses in this study was to determine if a fishery-independent index of spawning stock abundance (Relative spawning stock biomass of mature females collected in Program 195 September trawls; SSB) and several potential indices of recruitment could be described with standard stock-recruit functions (Ricker, Beverton-Holt), as well as non-parametric methods (Myers and Barrowman 1996). Specifically, we examined the relationship between relative SSB in year t and six potential indices of recruitment: (1) postlarval index of abundance in year t; (2) P195 CPUE of crabs 0 – 60 mm CW collected in September of year t; (3) P195 CPUE of Age 0 crabs collected in June of year t + 1; (4) P120 CPUE of Age 0 crabs collected in May of year t + 1; (5) P120 CPUE of Age 0 crabs collected in June of year t + 1; and (6) P120 CPUE of Age 0 crabs collected in May and June in year t + 1 combined. The Ricker stock-recruitment model (Ricker 1954) is one of the two most commonly used models. According to this model, maximum recruitment is at an intermediate stock size and declines in a density-dependent manner towards zero as spawning stock size increases. The equation relating recruitment (R) to spawning stock size (S) is:

$$R = aS * e^{(-bS)}$$

where a and b are model parameters. Some possible biological mechanisms for the density-dependence assumed in Ricker's (1954) model include (1) cannibalism of early juvenile crabs by older juveniles and adults (Lipcius and Van Engle 1990, Hines and Ruiz 1995), and (2) density-dependent mortality of early juvenile crabs (Pile et al. 1996, Etherington and Eggleston 2000; Etherington 2001).

The Beverton-Holt (B-H) model (Beverton and Holt 1957) has also been widely used to fit stock-recruitment data. According to this model, recruitment is essentially constant over a wide range of spawning stock levels. The equation relating recruitment (R) to spawning stock size (S) is:

$$R = \frac{1}{(a + b/S)}$$

where a and b are model parameters.

Ricker, B-H, and linear stock-recruit models were fitted to the various indices of blue crab recruitment and the index of relative SSB (Figs. 28, 29). There was a relatively strong and highly significant spawning stock-recruit relationship using an index of relative SSB from P195 in September, and an index of recruits based on the CPUE of small crabs (< 60mm CW) from P195 in September of the same year. Although Ricker, B-H, and linear relationships all produced significant fits, we used the Akaike Information Criterion (AIC; Akaike 1973) to determine the best fitting model from our candidate set (Ricker, B-H and linear). Using this AIC selection criterion, the Ricker model generated the best fit to the data (AIC weight = 0.51). A good model fit was also generated using the B-H stock-recruit function (AIC weight = 0.44) indicating that the Ricker and B-H models were both able to adequately describe the observed stock-recruit relationship. The linear model generated a much poorer fit to the entire data series (AIC weight = 0.05). A significant stock-recruit relationship was also identified using our index of relative SSB from P195 in September and an index of recruits based on the CPUE of Age 0 crabs from P120 surveys in May and June in the following year. We chose to model the stock-recruit relationship of the blue crab in NC using a Ricker model because it produced the lowest AIC value for both indices of recruitment (P195 September crab < 60 mm CW and P120

Age 0 crabs in May and June), and because of known density-dependent mortality in this species (Pile at al. 1996, Etherington and Eggleston 2000, Etherington 2001).

Since the index of SSB varied with annual changes in salinity (compare Figs 22 and 24b), we examined the relationship between relative SSB adjusted for salinity in year t and two potential indices of recruitment: (1) P195 CPUE of crabs 0 – 60 mm CW collected in September of year t, and 2) P120 CPUE of Age 0 crabs collected in May and June in year t + 1 combined (Fig 30). The significant stock-recruit relationships identified earlier (Figs 28, 29) were also identified using our salinity-adjusted index of relative SSB from P195 in September (Fig. 30).

A significant relationship between spawning stock abundance of blue crabs and recruit abundance (i.e., Ricker S-R function) has been identified for the blue crab in Chesapeake and Delaware Bays (Tang 1985, Lipcius and van Engel 1990, Helser and Kahn 1999). We detected a significant stock-recruit relationship in two of six potential indices of recruitment.

2. Non-parametric stock-recruitment relationships

Several researchers have promoted the use of non-parametric stock-recruit models when dealing with noisy stock-recruit data (Getz and Swartzman 1981; Hilborn and Walters 1992). These approaches can be advantageous because they allow for a greater variety of functional forms (Getz and Swartzman 1981, Rothschild and Mullen 1986, Hilborn and Walters 1992), and can be useful in management because they lack assumptions about the underlying relationship between spawning stock and recruitment (Miller and Houde 1999). We employed a simple, non-parametric method (Myers and

Barrowman 1996) to further investigate the stock-recruit relationship for the blue crab in North Carolina. This method provides answers to three simple questions: (1) Does the highest recruitment occur at high levels of spawner abundance?; (2) Does the lowest recruitment occur at low levels of spawner abundance?; and (3) Is recruitment higher if spawner abundance is above historic median levels rather than below the median? (Myers and Barrowman 1996).

To determine whether the largest recruitment was associated with the highest levels of spawning stock abundance (i.e., Question 1 above), we followed the procedure of Myers and Barrowman (1996) and computed a relative rank, $r_{\mathrm{max}} = (\mathrm{rank}(SR_{\mathrm{max}}) - 1)/(n - 1)$, where SR_{max} is the spawning stock abundance that produced the maximum subsequent recruitment, and n is the number of observations in the stock-recruit series. The value of r_{max} can take values between 0 and 1, with $r_{\mathrm{max}} = 0$ implying that the highest level of recruitment is produced from the lowest level of spawning stock abundance, and conversely $r_{\mathrm{max}} = 1$ implies that the highest level of recruitment is associated with the highest level of spawner abundance. The average value of r_{max} for our six stock-recruitment time series was 0.74, and ranged from 0.36 to 1.0 (Figs. 31, 32). To determine whether the smallest recruitment was associated with the lowest levels of spawning stock abundance (i.e., Question 2 above), we computed a relative rank, $r_{\mathrm{min}} = (\mathrm{rank}(SR_{\mathrm{min}}) - 1)/(n - 1)$, where SR_{min} is the spawning stock abundance that produced the minimum subsequent recruitment, and n is the number of observations in the stock-recruit series. The value of r_{min} can take values between 0 and 1, with $r_{\mathrm{min}} = 0$ implying that the lowest level of recruitment is produced from the lowest level of spawning stock abundance, and conversely $r_{\mathrm{min}} = 1$ implies that the highest level of recruitment is associated with the lowest level of spawner abundance. The average value of r_{min} for our six stock-recruitment time series was 0.24, and ranged from 0.07 to 0.67 (Figs. 31, 32). Thus, overall the largest observed recruitment in each time series tends to be associated with larger values of SSB, and the lowest observed recruitment tends to be associated with lower values of SSB. The results suggest a qualitative positive relationship between SSB and recruitment, such that low levels of SSB produce low subsequent recruitment.

To determine whether mean recruitment was higher at larger spawning stocks (i.e., Question 3 above), we split each stock-recruitment data series into two subsets divided by the median spawning stock (Figs. 31, 32). One group contained all the values of the spawning stock larger than the median, and the other group contained all values below the median. The mean recruitment for each group was then calculated. We followed the notation of Myers and Barrowman (1996) and denote the mean recruitment below the median spawning stock as R_{below}, and the mean recruitment above the median spawning stock as R_{above}, and then calculated the ratio of the two values ($R_{\text{above}}/R_{\text{below}}$). When mean recruitment does not differ between the groups this ratio is near 1. This ratio for our postlarval index of abundance in year t was 3.87, indicating that mean recruitment resulting from spawning stock sizes above the median is on average 3.87 times greater than mean recruitment resulting from lower stock sizes (Fig. 31). Similar values calculated for P195 CPUE of crabs 0 – 60 mm CW in year t and P195 CPUE of Age 0 crabs in June of t + 1, were 1.68 and 0.96, respectively (Fig. 31). For P120, values of $R_{\text{above}}/R_{\text{below}}$ for P120 CPUE of Age 0 in May, June, and May and June combined of year t + 1, were 0.92, 1.21, 1.39, respectively (Fig 32). In four of the six recruitment series, recruitment is higher when SSB is above the median value. This result suggests that maintaining spawning stock above median levels will result in greater overall recruitment of blue crabs in North Carolina.

J. Life History Characteristics

1. Estimation of natural mortality

The natural mortality rate (M) is a critical parameter for fishery stock assessments, yet this parameter is among the most difficult to estimate. A lack of direct estimates of M for the blue crab has hampered stock assessment efforts for the blue crab, and necessitated the use of rules of thumb to estimate M. Given the lack of a direct estimate of M, previous stock assessments for the blue crab (Rugolo et al. 1997, 1998; Helser and Kahn 1999) have estimated M using the convention of M = 3/maximum age (t_{max}). Following this convention, M is estimated as the value that results in 5% of the individuals in a cohort surviving to their maximum age. Based on tagging data (McConaugha 1991), the maximum age for blue crabs in Chesapeake Bay was assumed to be 8 years (Rugolo et al. 1997), resulting in an estimate of M = 0.375 ($3/t_{max} = 8$). Helser and Kahn (1999) noted that blue crabs in Delaware Bay are near the northern most extent of the species distribution, and suggest a lower maximum age of 3-4 years is appropriate for blue crabs in Delaware Bay. Thus, M for blue crabs in Delaware Bay was estimated to be between 0.75 and 1.0 ($3/t_{max}$ = 4 and 3, respectively). Tagging studies suggest the maximum age of blue crabs in North Carolina is 5 years (Fischler 1965), and would result in M = 0.60 ($3/t_{max} = 5$).

Unlike previous assessments, however, we have chosen not to adopt the $3/t_{max}$ convention based on recent criticisms of the method (Hewitt and Hoenig *in review*).

Rather, we estimate M using Hoenig's (1983) regression estimator. This method (Hoenig 1983) uses the following regression:

$$\ln(Z) = 1.44 - 0.982*\ln(t_{max})$$

to predict Z from the maximum age (t_{max}) and is based on empirical data from 134 fishery stocks. This method has been recommended (Hewitt and Hoenig *in review*) to replace the $3/t_{max}$ convention when direct estimates of M are not available. The regression is based on lightly exploited fish stocks so that $Z \approx M$. Based on a t_{max} of 5 years estimated from tagging studies in North Carolina (Fischler 1965), M was estimated as 0.87 using Hoenig's equation (Hoenig 1983). We believe $t_{max} = 5$ to be the best estimate for blue crabs in North Carolina, and represent a good estimate of maximum age under light exploitation. A wide range of reported values of t_{max} have been used in previous assessments ranging from 3 to 8 (Rugolo et al. 1997, 1998, Helser and Kahn 1999). To address the uncertainty regarding estimates of M, we also calculated estimates of M using Hoenig's equation (1983) based on t_{max} values of 3 and 8. Thus, three estimates of M (0.55, 0.87, and 1.44) based on t_{max} values of 8, 5, and 3, respectively, were used in subsequent analyses.

2. Length-based estimation of total mortality rates

The goal of these analyses was to derive estimates of total instantaneous mortality (Z) for the North Carolina blue crab population using length-based methods. Both Beverton and Holt (1957) and Hoenig (1987) have developed approaches for estimating Z from the mean size in the catch (mean length) and the VBG parameters for growth rate and asymptotic size. Hoenig (1987), however, argues that the Beverton and Holt (1957) formulation induces bias in the estimate of Z when mean size approaches the length of full recruitment to the fishing gear (CW_{FR}). For this reason, and as a means for comparison with similar estimates from Chesapeake Bay (Rugolo et al. 1997, Miller and Houde 1998) and Delaware Bay (Helser and Kahn 1999), we used the Hoenig (1987) length-based approach for estimating Z of blue crabs in North Carolina:

$$Z = \log_e \left[\frac{(e^{-k} * (\overline{CW} - CW_{\inf})) + CW_{\inf} - CW_{FR}}{(\overline{CW} - CW_{FR})} \right]$$

where, k = the curvature (Brody growth coefficient) and $CW_{\inf} = L_{\inf}$ = maximum carapace width parameters from the VBG model; $\overline{CW}$ = mean CW (mm) of crabs from the P195 survey that are larger than the size at full recruitment to the fishery (CW_{FR}). CW_{FR} was 127 mm, the legal minimum size for hard crabs in North Carolina. The total mortality rate (Z) for crabs > 127 mm would include both fishing and natural mortality. Natural mortality is assumed to be constant over time. Estimates of k and $L_{\inf}$, 0.47 and 216.9, respectively, were derived from length-based modeling of P195 length frequency data in June and September (see section on Life history characteristics, 3. Estimation of growth rates). Because estimates of Z are highly dependent on assumptions of growth, estimates of Z were also obtained using growth parameters from previously published stock assessments for the blue crab in Chesapeake Bay (Rugolo et al. 1997) and Delaware Bay (Helser and Kahn 1999). Length-based estimates of Z were not generated using P120 data because the shallow water emphasis of this survey resulted in very few large crabs being captured.

Caution has been advised when interpreting the results of this length-based model, because large variations in recruitment can impact the estimates of Z (Helser and Kahn 1999). For example, a large recruitment year class will have the effect of reducing average size in the population resulting in a larger estimated value for Z. We investigated the relationship of the annual index of P195 Age 0 blue crabs in North Carolina and Z using linear regression analysis, but did not detect any significant relationships.

Based on growth parameters from this study, estimates of Z from P195 June length-frequency data ranged from 0.91 to 1.22 (Table 11, Fig. 33), and averaged 1.03 with no apparent trend in mortality over time (Table 11, Fig. 33). These estimates are similar to Zs reported for the blue crab in Chesapeake Bay (~1.0-1.5; Rugolo et al. 1998), but lower than estimates from Delaware Bay (1.19-2.90; Helser and Kahn 1999). Length-based estimates of Z were generally considerably lower than annual Zs (1.04-2.90) estimated from Collie-Sissenwine modeling from over the same period (1987-2001; see section on Collie-Sissenwine modeling).

3. Estimation of growth rates.

Accurate growth data are a necessary component of many fishery modeling techniques. Broadly defined, growth is the change (increase) in some measure of size (length, weight, carapace width, etc.) over time. Traditionally, length has been used as the measure of body size in most fisheries modeling efforts (von Bertalanffy 1938; Schnute 1981), due in large part to the ease of collecting length measurements. For crustaceans, length measurements are necessitated due to the current lack of precise aging techniques (Ju et al. 2001, 2003). Growth measured as CW in blue crabs is discontinuous, as crabs must periodically molt to grow. Most attempts to model blue crab growth have assumed continuous growth and fitted various forms of the von Bertalanffy growth function (VGBF; Rothschild et al. 1991, Rugolo et al 1997, Helser and Kahn 1999). Attempts have been made to model growth as a discontinuous process (Grey and Newcombe 1938, Newcombe et al. 1949, Smith 1997), but that approach has not been incorporated into stock assessments. Previous estimates of growth rates have been variable. Rothschild et al. (1991) used a modified version of the VBGF adjusted for molting to produce a growth trajectory defined by k = 0.51 and L_{inf} of 186 mm CW. In a recent stock assessment for the blue crab in Chesapeake Bay, Rugolo et al. (1997) predicted growth using k = 0.59 and L_{inf} = 262.5 mm CW. Helser and Kahn (1999) used MULTIFAN (Fournier et al. 1990) to estimate blue crab growth in Delaware Bay, resulting in estimates of k = 0.75 and L_{inf} = 234.7 mm CW.

We employed the length-based model described above (see section on Fishery-independent research surveys, C. Calculation of age-specific annual indices of abundance) to generate VBG parameters from P195 June and P195 September trawl survey data from 1987-2002. The estimate of L_{inf} was fixed to 216.9 mm CW. A single VBGF was assumed to describe growth in all years, and estimates of k and t_0 from P195 June (Fig. 9) and September (Fig. 10) length-frequency data were 0.47 and 0.02, respectively (Fig 34). The estimate of k (k = 0.51) from the analysis of P120 length-frequency data was similar to that of P195 (k = 0.47); however, the estimate t_0 (t_0 = 0.41) was very different than P195 estimates (t_0 = 0.02). Differences in estimates of t_0 between P120 and P195 were probably due to a violation of the assumed September 15th birthdate of blue crabs in the P120 survey data. The initial mode in the length-frequency data from P120 is at 10-20 mm CW, representing crabs that were recruiting in the spring, not the fall. Thus, growth estimates derived from P195 survey data are a more accurate reflection of growth in NC and were used in length-based estimates of total instantaneous annual mortality rates (Hoenig 1987), as well as yield-per-recruit (YPR) and spawning stock biomass-per-recruit (SSBR) analyses.

K. Surplus Production Modeling

1. Relative biomass, fishing mortality, and MSY

Biomass-based models are one of several approaches for analyzing fishery data to estimate historical abundance and mortality. Unlike age-structured models that track population numbers by age and describe population change in terms of growth, recruitment, and mortality, biomass-based models describe stock dynamics strictly in terms of biomass. Biomass-based models are among the simplest and most commonly used stock assessment method, and have proven valuable in cases where fisheries species are difficult or impossible to age (e.g., crustaceans), or where sufficient age data are not yet available. Biomass-based and age-structured models may perform equally well and often result in similar management recommendations (Hilborn and Walters 1992). Thus, the additional effort required to obtain age data and fit more complex models may not be justifiable in certain fisheries.

We used a non-equilibrium biomass-based model to estimate relative fishing mortality and biomass over time for the blue crab in North Carolina, as well as estimate Maximum Sustainable Yield (MSY). This model, which is given in Hilborn and Walters (1992), consisted of three equations:

$$B_{y+1} = B_y + rB_y\,(1\text{-}B_y/K) - C_y,$$

$$U_y = qB_y,$$

For the first equation, B = biomass, r = the intrinsic rate of population growth, K = carrying capacity (the unfished stock size), and C = catch. This difference equation describes how the change in biomass from year to year depends on the magnitude of surplus production versus catch. The second equation relates the model for biomass to the observed CPUE from fishery-independent and -dependent indices of abundance (Table 6, Fig. 1). CPUE (U) is assumed to be directly proportional to population biomass. We used a maximum likelihood approach to estimate r, K, B_1, and q, so that the sum of squared differences ($\Sigma(U_y - \hat{U}_y)^2$) between observed and predicted CPUE was minimized. The parameters r and K were used to estimate MSY ($rK/4$, Hilborn and Walters 1992). Since MSY is the product of r and K, this value tends to be more reliably estimated than the individual model parameters themselves (Prager 1993).

We fitted the non-equilibrium, biomass-based model described above to three different time series (1) CPUE of legal-sized crabs (crabs > 127 mm CW) from P195 in June for the period 1987-2002; (2) CPUE legal-sized crabs (crabs > 127 mm CW) from P195 in September for the period 1987-2002; and (3) NC DMF commercial pot CPUE (Commercial landings / NC DMF pot numbers) for the period 1953-2002 (Fig. 1). CPUE was generated from fishery-independent trawl survey data from P195 in all cases except the use of NC DMF commercial crab pot CPUE series, which is a fishery-dependent measure of abundance. In 1994, the NC DMF instigated a mandatory reporting program for the blue crab fishery resulting in a 26% increase in landings from dealers that had not previously reported. As discussed earlier (see section on Description of the fishery), it was concluded that although 26% of landings in 1994 came from dealers that did not report in 1993, this value would likely result in the over-inflation of catches prior to 1993 (S. McKenna, NC DMF, pers. comm.). Thus, unadjusted landings were used, as they were considered to be a more accurate estimate of catch over the entire time series than were adjusted landings (S. McKenna, NC DMF, pers. comm.). Model fits were produced using only the NC DMF commercial crab pot time series (Table 12), and also by fitting the three time series simultaneously (Table 13). We chose to fit the NC DMF commercial pot CPUE, mean CPUE of crabs > 127 mm CW from P195 in June and September, as these time series provided: (1) a long-term data set 1953 – 2002 (commercial crab pot CPUE); and (2) the most reliable estimates of adult abundance available based on targeted sampling of large crabs in deep water habitats. The NC DMF commercial pot CPUE was also fit separately without the fishery-independent data because this data series represents a much longer time series (50 years vs. 16 years).

Our first model run included only the NC DMF commercial pot effort series for the period 1953-2002. Model fitting began by allowing all model parameters (r, K, and B_1) to vary simultaneously. These model fits were difficult to obtain, were extremely sensitive to initial values of B_1 and K, and often resulted in a failure to generate reasonable model parameter values. To avoid these problems, we assumed that the starting model biomass (B_1) was equal to K. This assumption is likely valid for this model given that it estimates starting biomass in 1953, when extremely low fishing pressure was placed on the stock (1953 pot landings = 185,700 lbs vs. 1996 pot landings 61,800,000 lbs.). Despite this simplifying assumption, model fits were still difficult to obtain. To generate an estimate of model parameters over a wide range of possible *r* and *K* values, we fixed *r* at values between 0.2 and 2.0, and allowed the model to obtain a best fit by varying *K* (Table 12). This fitting also generated a likelihood profile, which can provide information for selecting the best fitting model (Punt and Hilborn 1996; Figure 35). Estimates of MSY varied widely and ranged from 26.3 to 51.1 million pounds (Table 12). The model fit was essentially the same for a large range of biologically reasonable values of *r* and *K* (Table 12). Additional management benchmarks from this biomass-based model were estimates of relative fishing mortality (F) and biomass (B) (Table 12). The ratio estimates such as $Biomass_{year}$/MSY Biomass (B_y/B_{MSY}) and Fishing $Mortality_{year}$/MSY Fishing Mortality (F_y/F_{MSY}) are more precise estimates than absolute biomass and fishing mortality (Prager et al. 1996). For an assumed r of 1.0, annual biomass of crabs was high and relatively stable through 1978, then began a decline that continues until present (Figs. 36, 37). Since 1995, concurrent with increased commercial landings from 1995 – 1999, relative biomass has steadily declined to values below B_{MSY} while relative fishing mortality has sharply increased (Fig. 37). For any plausible values of r, relative fishing mortality (F_y/F_{MSY}) values were greater than or equal to 1 (e.g., F_{2002}/F_{MSY} = 2.08 – 6.45 in 2002; Table 12). Values greater than 1 are inefficient and produce a level of harvest less than the MSY. Relative stock biomass values for 2002 (B2002 / BMSY) were substantially less than 1 for all assumed values of r (Table 12).

Given the important management implications of the previous findings regarding estimates of relative B and F, as well as MSY, it is critical to assess the reliability of the model results. We used the log-likelihood profile described above (Table 12, Fig. 35), and two additional indicators of the reliability of model results, including indices of (1) nearness and (2) coverage (Prager et al. 1996). “Nearness” (N) ranges from 0 (least reliable) to 1 (most reliable) and indicates how closely a modeled stock has approached the biomass level producing B_{MSY}:

$$\hat{N} = 1 - \frac{|\hat{B}_{MSY} - \hat{B}*|}{\hat{B}_{MSY}}$$

where B_{MSY} is the biomass at MSY and B* is the smaller value of K or the estimated biomass closest to MSY. “Coverage” ranges from 0 (least reliable) to 2 (most reliable), and indicates how widely stock biomass has varied between 0 and K:

$$C = \frac{\hat{B}^{+} - \hat{B}^{-}}{\hat{B}_{MSY}}$$

where B^{+} is the lesser value of K or the largest estimated biomass, and B^{-} is the smallest estimated stock size. The rationale for these indices is that B_{MSY} will be estimated more reliably if estimated biomass has gone from above B_{MSY} to below (or vice versa). In our case, “nearness” and “coverage” were 1.0 and 1.73, respectively. MSY values from likelihood profiling varied from 26.3 to 51.1 million pounds as F_{MSY} ranged from 0.10 to 1.0 (Table 14). While there was considerable uncertainty regarding model fits, in all cases the model suggests that the stock is currently at low levels of biomass (B_{2002}/B_{MSY} = 0.21 to 0.34) and that the stock is heavily exploited (F_{2002}/F_{MSY} = 2.08 – 6.45).

Our second model run was fit to the NC DMF commercial pot effort series (1953-2002), P195 crabs > 127 mm CW in June, and P195 crabs > 127 mm CW in September. Similar to our first run, model fits were difficult to obtain, and were extremely sensitive to initial values of B_1 and K; often resulting in a failure to generate reasonable model parameter values even after assuming $B_1 = K$. As above, we estimated model parameters over a wide range of possible r and K values by constraining r to values between 0.2 and 2.0 and allowing the model to vary K (Table 13). This fitting procedure also generated a likelihood profile, which can provide information in selecting the best fitting model (Punt and Hilborn 1996; Fig. 38). Estimates of MSY varied widely and ranged from 27.9 to 51.7 million pounds (Table 13). Annual biomass of crabs was high and relatively stable through 1978, then began a decline that continues until present (Figs. 39, 40). From 1979 through 2000, relative biomass steadily declined to values below B_{MSY} while relative fishing mortality has sharply increased (Fig. 40), however, the population stopped declining and showed possible increases in 2001-2002 concurrent with reduced harvest (average landings 2000-2002 ~ 35 million lbs.; Table 1). Relative fishing mortality (F_y/F_{MSY}) values were greater than or equal to 1 in 2002 for most values of r and K (e.g., F_{2002}/F_{MSY} = 0.87 - 3.01; Table 13). For all model runs, however, the relative biomass in 2002 was below 1.0 (0.43-0.81; Table 13), suggesting the stock is currently below the MSY level.

Estimates of annual MSY from all surplus production models ranged widely from 26.3-51.7 million pounds (Tables 12, 13). Average landings were near or above the largest estimated value for MSY of 51.7 million pounds from 1994-1999 (e.g., 65 million pounds in 1996). Since 1996, relative crab biomass has declined steadily while fishing mortality has increased sharply (Figs. 37, 40). Relative fishing mortality rates above 1 result in annual yields less than MSY; most current fishing mortality rates are estimated to be above this threshold (e.g., F in 2002 = 0.87 – 6.45 times F_{MSY}, Tables 12, 13). Our estimates of relative F_{MSY} and B_{MSY} indicate that the stock is currently overfished and at low stock size (e.g. $B_{2002} < B_{MSY}$), and that the fishery has operated near or above F_{MSY} since 1996 (Figs. 37, 40). Given: (1) the known limitations of surplus production models; (2) uncertainty associated with landings prior to 1994; (3) inherent variability in CPUE data; (4) uncertainty in fishery-independent surveys (see section on Fishery-independent research survey indices D.) Correlation analyses of length-based indices of abundance), and (5) the difficulty of obtaining biologically reasonable model fits with many time series (likely caused by lack of contrast in data sets), a cautionary approach should be taken to the interpretation of these results. The results, however, do suggest that the blue crab stock is currently at low biomass, and current fishing pressure is resulting in reduced yields.

L. Collie-Sissenwine Modeling

Collie and Sissenwine (1983) developed a two-stage population model (herein referred to as the "C-S model") that has proven very useful for crustacean assessments (see Smith and Addison 2003 and references therein). The C-S model has been used to describe blue crab population dynamics in Delaware Bay (model referred to as modified DeLury: Helser and Kahn 1999; Helser and Kahn 2001) and in Chesapeake Bay (L. Fegley, MD Department of Natural Resources, personal communication). Another regional application of the model is for white perch in the Choptank River, MD (P. Piavis, MD Department of Natural Resources). The model requires catch data, survey indices for legal-sized and undersized animals, and an external estimate or assumed value for natural mortality (M).

For the simplest case where harvest is assumed to occur in mid-year (Smith and Addison 2003), the population of legal-sized animals in year y+1 (N_{y+1}) is defined as

$$N_{y+1} = \left[\left(N_y + R_y\right)e^{-0.5M} - C_y\right]e^{-0.5M}$$

The population at the start of year y is made up of legal-sized individuals (N_y) plus incoming recruits that will reach legal size within the next year (R_y). This total population size at the start of year y ($N_y + R_y$) decreases due to natural mortality for one-half year (i.e., a rate of 0.5M), at which time the catch is removed. After the catch is subtracted, the remaining population decreases due to natural mortality for the remaining half-year (at rate 0.5M). For the more general case where the fishery occurs at time T (ranging between 0 and 1), the total population declines due to natural mortality for time T, then the catch is removed, then the remaining population declines due to natural mortality for the remainder of the year (1 - T).

Because population size is generally not known, the above equation is rewritten in terms of abundance indices representing the legal-sized animals and recruits:

$$n_y = q_n N_y$$

and

$$r_y = q_r R_y$$

where n_y is the abundance index for legal-sized individuals, r_y is the index for recruits, q_n is the catchability coefficient for adults, and q_r is the catchability coefficient for recruits.

An important advantage of this model compared to a biomass-based (surplus production) model is that recruitment can vary annually, such as due to environmental factors. Thus, the C-S model can account for an unusually large (or small) year class as long as it is evident in the recruitment index. In contrast, the biomass-based model assumes that all population changes can be accounted for by the annual harvest and logistic population growth. The biomass-based model works best for longer-lived stocks where fishable biomass changes gradually in response to fishing (Punt and Hilborn 1996). The biomass-based model would not be expected to work well for short-lived species for which incoming recruits have a substantial effect on population size, which appears to be the case for the blue crab in NC (Etherington and Eggleston 2003).

Following the approach used by Helser and Kahn (1999), we assumed that September P195 surveys provide a useful index of legal-sized and recruit categories for the following year. The primary spawning period for NC blue crabs is during fall, and recruits detected in the September P195 survey would be expected to attain legal size over the next year. Also, most of the harvest in NC occurs during May-October (Figure 2), so September indices should be related to abundance the following January. For example, the September 1987 P195 CPUE for recruits and legal-sized blue crabs were used as indices of relative blue crab abundance in January 1988. Survey data for 1987-2001 were used to estimate population size between 1988 and 2002.

Helser and Kahn (1999) defined recruit and fully recruited blue crabs to be less than and greater than 120 mm, respectively based on a legal minimum size of 120 mm for New Jersey and 127 mm for Delaware. For NC, the legal minimum size is 127 mm, which was used as the dividing line between recruits and legal-sized blue crabs in this study. Following Helser and Kahn (1999), we assumed that legal-sized and recruiting blue crabs were equally vulnerable to the trawl survey gear ($q_n/q_r = 1$).

The model requires an assumed value for M and we considered three values: 0.55, 0.87, and 1.44. These values are obtained using the regression equation relating maximum age and Z, and the total instantaneous mortality rate (Hoenig 1983). We fitted an observation error model, which assumes that differences between predicted and observed CPUE are due to variability in survey catches rather than to a mis-specified population model. Parameter estimates were obtained by minimizing ln-scale differences between observed and predicted CPUE.

The C-S model fitted the survey relative abundance data for legal-sized crabs reasonably well (see results for M=0.87, Figure 41). The model was less successful in fitting CPUE of recruits, because of the lack of an apparent connection between incoming recruits and subsequent numbers of legal-sized blue crabs. For example, the high recruit CPUE value for 1997 did not result in a large increase in legal-sized blue crabs, nor did the low recruit CPUE value for 2001 result in a large decrease in legal-sized blue crabs in 2002 (Fig. 41). Because there was no obvious trend in recruitment over time, the model attributed the decrease in relative abundance of legal-sized blue crabs mostly to an increasing rate of fishing.

When results from all three assumed natural mortality rates were compared, specific values depended on M but the trends were similar (Table 14, Figs. 42, 43). Predicted numbers of recruits varied without obvious trend between 1988 and 2002, except for higher estimated recruitment in 1989 and 1991 Figs. 42, 43). Predicted numbers of legal-sized crabs were higher in the early 1990s, due to those estimated strong year classes in 1989 and 1991, and lower Fs, then generally declined from 1992 through 2002 (Table 14, Fig. 42). The estimated harvest or exploitation rate generally increased over time, although values were substantially lower and showed less of a trend for the highest M (Table 14, Fig. 43). The 10-20% exploitation rates for an assumed M of 1.44 seem unlikely, and we suspect that the M=0.55 and 0.87 cases are more realistic. For those two Ms, exploitation rates ranged from about 0.2 in 1989 to 1995-2001 levels of about 0.50-0.75 (Fig. 43). Estimated Fs in 1995-2001 for Ms of 0.55 and 0.87 ranged from about 1.0 to 1.5 (Table 14, Fig. 43).

The specific values obtained depended on the assumed value for M. For the lowest assumed value for M (0.55), blue crab abundance was lower than when using higher values of M, and more of the total mortality was attributed to fishing (higher Fs). At higher assumed Ms, abundance was higher but Fs were lower because more of the total mortality was assumed to be due to natural causes.

M. Biological Reference Points

1. Yield- and spawning stock biomass-per-recruit analyses

Yield-per-recruit analyses (YPR) have been conducted to estimate the appropriate level of fishing mortality for the blue crab in Chesapeake Bay (Rugolo et al. 1997, Miller and Houde 1999) and Delaware Bay (Helser and Kahn 1999). YPR analysis is an optimization in time between two opposing effects: (1) increasing weight of crabs due to growth, and (2) decreasing population size due to mortality. Ideally, the fishery should wait until the maximum YPR value, and catch every individual instantaneously at that time. Although theoretically possible, this strategy poses obvious practical impossibilities for the fishery, and disregards the potential problems from a flood of the fishery product into a market driven economic system (decreased product value following increased market supply; Sissenwine 1981).

A recognized weakness of the YPR model is that it is ignorant of recruitment overfishing, in which overfishing a stock leads to future recruitment being lowered (Hilborn and Walters 1992). Therefore, spawning stock biomass-per-recruit (SSBR) is also considered. SSBR is a related approach to YPR, which examines the effects of fishing on the spawning stock. The two analyses (YPR and SSBR) are used to generate several important biological reference points (BRPs) such as F_{MAX} (fishing mortality rate at which yield-per-recruit is maximized), $F_{0.1}$ (Fishing mortality rate at which the slope of the YPR curve is 10% of the slope at the origin; Gulland and Boerema 1973, Deriso 1987), and $F_{30\%}$ and $F_{20\%}$ (fishing mortality rate at which the SSBR is 30% and 20% of the virgin or unexploited SSBR, respectively).

We conducted both YPR and SSBR analyses for the North Carolina blue crab stock. These models require numerous inputs: (1) information on size-at-age, (2) relationship between size (CW) and weight, (3) a schedule of partial recruitment to the fishery, (4) relationship between size and maturity, and (5) an estimate of natural mortality. Model inputs were estimated using data from North Carolina whenever possible. In cases where estimates were not available, we relied upon previously published information from earlier stock assessments for the blue crab in Chesapeake and Delaware Bays (Rothschild et al. 1991, Miller and Houde 1999).

The relationship between size and age was described using a VBGF generated from length-based modeling of length-frequency data from P195 trawl surveys (see section on Life history characteristics, 3. Estimation of growth rates). The growth equation was generated from the length-frequency data from P195 June and September (Figs. 9, 10), and was used to conduct YPR and SSBR analyses. The following equations described the change in mean length with age for our YPR analysis:

$$L_t = 216.9(1 - e^{(-0.47(t - 0.02)})$$

The relationship between blue crab length and weight was described using the equation Rothschild et al. (1991) generated for blue crabs in Chesapeake Bay, as this information is not available for North Carolina. Since the commercial catch is comprised of both males and females, we used parameters that relate weight (g) to CW (mm) for both sexes combined for YPR analyses (Rothschild et al. 1991):

$$W_g = 0.001089 * CW^{(2.363)}$$

For SSBR analyses, we used a different weight to CW relationship that was specific to females (Miller and Houde 1998), since spawning stock is composed of only female crabs:

$$W_g = 0.003486 * CW^{(2.1165)}$$

We calculated the partial recruitment (PR) of crabs of various age classes to the fishery using the predicted length-frequency of crabs at age from NC DMF P195 trawl surveys, the size-specific fishery regulations for North Carolina, and the relative contribution of various fishery sectors to the overall landings. Specifically, we considered three distinct sectors of the blue crab fishery in North Carolina when calculating age-specific PR: (1) soft/peeler crab fishery; (2) hard crab fishery for mature females; and (3) hard crab fishery for males and immature females > 127 mm CW. Currently, there is no minimum size regulation for soft/peeler crabs allowing for all ages of crabs (including Age 0 crabs) to be taken in this fishery. Since 1978, the soft/peeler crab fishery has averaged approximately 3-4% of total landings, and the fishery has comprised nearly 5% of total landings since 1994 (Table 1, McKenna et al. 1998). For these analyses, we assumed that 4% of crabs in each age class had recruited to the soft/peeler fishery and were susceptible to harvest. Hard crabs in North Carolina must measure at least 127 mm CW (5 in.) to be legally harvested, however, this regulation does not apply to mature females which can currently be legally harvested at any size. To account for the PR of mature females to the hard crab fishery, we first estimated the percentage of females that are mature at a given age, as these individuals can be legally harvested and are recruited to the fishery. We used the VBGF parameters and maturity ogive (Fig. 44, see below) to estimate the percentage of crabs that are mature in each age class. We estimated that 4.4% of female crabs are mature by the end of their first year, 67% of crabs are mature by the end of their second year, and the remainder will mature before age 3. Assuming a sex ratio of 1:1 (M:F), and adjusting for the percentage of females captured in the soft/peeler fishery, approximately 4.2% (4.4% * 0.96) of female crabs are mature and have recruited to the hard crab fishery by the end of age 0, and 64% (67% * 0.96) have recruited by the end of Age 1. All female crabs are assumed recruited to the fishery by the end of Age 2. In addition to mature females, hard crabs greater than 127 mm CW can be legally harvested.

To estimate age-specific PR for this fishery, we estimated the proportion of male and immature females at each age that have attained 127 mm CW. The proportion of crabs > 127 mm CW in each age class was calculated by assuming that CW followed a normal distribution defined by a mean size-at-age from the VBGF and a standard deviation from the length-based modeling of observed length-frequency data (see section on Fishery-independent research survey indices, C. Calculation of annual indices of abundance). We estimate that 0.82% of crabs have attained a size of 127 mm CW or greater by the end of their first year, and 77% are greater than 127 mm CW by their second year, and all crabs are greater than 127 mm CW by the end of Age 3. By summing the contribution of each fishery to the PR, we estimate that 7% (4% soft/peeler + 2.2% (4.4%/2) mature females + 0.82% of male and immature female crabs greater than 127 mm CW) of crabs are susceptible to the fishery by the end of their first year (Age 0). We estimate 77% of crabs are recruited to the fishery by the end of their second year (Age 1). All crabs are recruited to the fishery by the third year (Age 2).

The previously described relationship between size and maturity was used in SSBR analyses. We estimated that 4.4% of females in North Carolina are mature by the end of their first year, and that 67% of females are mature by the second year. Females Age 3 and above were assumed to all be mature for the SSBR analysis. We assumed a flat-topped maturity ogive such that there was no reduction in fecundity with age, similar to assumption made by Helser and Kahn (1999) for blue crabs in Delaware Bay .

Given the sensitivity of YPR models to assumptions regarding M, we conducted the analysis using three different values of M. Estimates of M (0.55, 0.87, and 1.44) were chosen based on Hoenig's method (1983; see section on Life history characteristics, 1.

Estimation of natural mortality), and correspond to maximum ages of 8, 5, and 3 years, respectively.

YPR estimates were generated for length-based estimates of growth parameters and estimates varied predictably with M values (Table 15, Fig. 45). F_{MAX} ranged from 0.51 to greater than 0.93 as M increased, and resulted in lower absolute values of YPR (Table 15 Fig. 45). For the fishery, this translates to increasing fishing mortality rates (i.e., increasing F_{MAX} and $F_{0.1}$) to catch individuals before they are removed from the system by natural mortality. $F_{0.1}$ ranged from 0.36 to greater than 0.62 with increasing M (Table 15, Fig. 45). Our values of $F_{0.1}$ are similar to those reported by Miller and Houde (1999) for the blue crab in Chesapeake Bay (range $F_{0.1}$ = 0.35 to 0.47), and for Delaware Bay (range $F_{0.1}$ = 0.60 – 0.70; Helser and Kahn 1999). While F_{MAX} produces the highest value of YPR, $F_{0.1}$ is a more conservative reference point, and consistent with risk-averse management. A fishing target between $F_{0.1}$ and F_{MAX} has been recommended for blue crabs in Delaware Bay (Helser and Kahn 1999). The use of $F_{0.1}$ also increases economic efficiency, and is less likely to lead to declines in spawning stock abundance (Miller and Houde 1999).

Historical fishing mortality rates from length-based modeling were compared to BRPs from YPR analysis to evaluate the status of the blue crab fishery in NC and the concern of growth overfishing under three different assumptions regarding the value of M (M = 0.55, 0.87, 1.44). Although results are presented for all values of M, estimated exploitation rates from C-S modeling for an assumed M of 1.44 seem unlikely, and we suspect that the M=0.55 and 0.87 cases are more realistic (see section on Collie-Sissenwine modeling). For M = 0.55 and 0.87, the stock would be considered growth overfished and the fishery operating inefficiently when current Fs (1995-2001) are considered ($F_{1995\text{-}2001} > F_{\text{MAX}}$; Table 15). We believe the most reasonable estimate of M is 0.87. Using this natural mortality rate, recent estimated Fs exceed $F_{0.1}$, and F_{MAX}.

Because YPR analysis does not account for declines in spawning stock due to fishing that may result in potential reductions in recruitment, SSBR was also considered. Fishery benchmarks from SSBR are generally reported as percentages of the maximum spawning potential that would result, theoretically, in the absence of all fishing pressure. We calculated the following reference values: $F_{30\%}$ and $F_{20\%}$, which represent the fishing mortality rates which result in a reduction of the spawning stock to 30% and 20% of the unfished value of SSB. When M is assumed to be 0.87, the values of $F_{30\%}$ and $F_{20\%}$ are 0.72 and 1.10, respectively (Table 15). The average estimated F from 1995-2001 from C-S modeling was 0.91 (Table 15), which exceeded $F_{30\%}$, but not $F_{20\%}$.

The results of YPR models suggest that current fishing mortality rates in North Carolina exceed the conservative fishery benchmark, $F_{0.1}$, and exceed F_{MAX}, under reasonable assumptions for M (M = 0.55 and 0.87). When considering the results of similar analyses for Delaware Bay, Helser and Kahn (1999) suggested a target value for F somewhere between $F_{0.1}$ and F_{MAX}. Under the assumption of M = 0.87, a target F would be somewhere between 0.45 and 0.64 with the estimated current F for 1995-2001 higher than either target level. Current estimated Fs (1995-2001) from C-S modeling exceeded $F_{30\%}$, but not $F_{20\%}$, indicating the potential for recruitment overfishing. Mace and Sissenwine (1993) have advocated the use of $F_{20\%}$ as a recruitment overfishing threshold.

DISCUSSION AND CONCLUSIONS

The blue crab stock in North Carolina currently sustains heavy exploitation by the commercial fishery, with additional (generally undocumented) pressure from the recreational fishery. There has been a systematic increase in commercial landings from 1987-1999, followed by a period of reduced landings from 2000-2002. Although recent landings are reduced from the peak landings from 1994-1999 (mean = 52.8 million lbs.), landings from 2000-2002 (mean = 34.6 million lbs.) were similar to catches prior to 1994 (mean landings 1987-1993 = 36.0 million lbs.). Effort, however, during 2000-2002, (NC DMF number of pots) was 1.8 times greater than from 1987-1993. During 1987-2003, fishery-independent indices of blue crab abundance have either remained stable, or have shown significant declines. In no case do any fishery-independent indices of blue crab abundance show an increasing trend. The relative abundance of Age 1 blue crabs and relative SSB in the P195 trawl survey during 1999-2001 were at the lowest levels recorded since 1987 (Figs. 14, 22), however the index of SSB appeared to rebound in 2003 . While the 2003 index of spawning stock may indeed reflect an increase in SSB from low levels, a precautionary approach is warranted when interpreting the 2003 value because crabs blue crabs shift their distribution within Pamlico Sound depending on salinity, which determines their availability to P195 surveys. For example, we suggest that blue crabs shift their distribution downstream during wet years as was the case following hurricane floodwaters in 1999 (Fig. 23) and the wet year of 2003, which makes them more available to P195. Conversely, blue crabs likely shift their distribution upstream during dry years (S. McKenna, NC DMF pers. comm.), which would make blue crabs less available to P195 surveys, as appeared to be the case in 2002. To determine the extent to which availability of mature females to the P195 trawl survey was driven by annual fluctuations in salinity versus actual abundance, we examined the relationship between our index of SSB and mean annual salinity. Two major differences are apparent in the patterns of the residuals when the effects of salinity are removed: (1) SSB was underestimated by P195 in 2002, and (2) SSB was overestimated by P195 in 2003 (compare Figs. 22 and 24b). Thus, it appears the large increase in relative SSB in the P195 September survey in 2003 (Fig. 22) reflects both an actual increase in spawning stock from historic lows observed during 2000-2001, to average levels, and an increase in availability of mature females to survey gear due to low salinity. Any decline in the index of SSB would be especially troubling given (1) the potential influence of spawning stock on subsequent recruitment detected for North Carolina (Figs. 28, 29, 30); (2) a concurrent decrease in the mean size of mature females over time (Fig. 25, 26b); and (3) that female blue crabs have no size protection in from the peeler fishery, nor any protection as sponge crabs.

Estimates of annual MSY from all surplus production models ranged widely from 26.3 to 51.7 million pounds (Tables 12, 13). Average landings were near or above the maximum estimated MSY of 51.7 million pounds from 1994 – 1999 (e.g., 65 million pounds in 1996). The models suggest that since 1996, biomass has declined steadily while fishing mortality has increased sharply (Figs. 32, 35). Relative fishing mortality rates above 1 result in annual yields less than MSY, and current fishing mortality rates are estimated to be generally above this threshold (e.g., F in 2002 = 0.87 – 6.45 times F_{MSY}, Tables 12, 13). Our estimates of relative F_{MSY} and B_{MSY} suggest that the stock is currently overfished and at low stock size (e.g. $B_{2002} < B_{MSY}$), and that the fishery has operated near or above F_{MSY} since 1996 (Figs. 32, 35). Results from the biomass-based model incorporating both fishery-independent (P195 June and September crabs > 127 CW indices of abundance) and fishery-dependent (NC DMF commercial pot CPUE) suggest that while population biomass remains low, it has stopped declining following low landings in 2000-2002 (mean landings = 34.6 million lbs.), and may be increasing (Figs. 39, 40).

YPR modeling suggests that current fishing mortality rates in North Carolina exceed the conservative fishery benchmark, $F_{0.1}$, and exceed F_{MAX} under reasonable assumptions for M. Helser and Kahn (1999) advocate a target F between $F_{0.1}$ and F_{MAX} for the Delaware Bay blue crab fishery. Current Fs exceed values of $F_{30\%}$, but not $F_{20\%}$ for North Carolina (Table 15), indicating conservation of the spawning stock in NC is critical. Given the uncertain status of the blue crab spawning stock in North Carolina, however, a reduction of fishing pressure on mature females is suggested. Further, non-parametric stock-recruit models estimate that levels of recruitment are generally greater when spawning stock abundance is above the median value. With the exception of 2003, relative SSB has been below the median since 1999. Key management recommendations should include conservation of the spawning stock as an urgent and critical goal.

Numerous biological patterns identified in this study should be considered in terms of effort management for the blue crab fishery in North Carolina, and include: (1) a general lack of coherence among survey indices of abundance resulting in considerable uncertainty regarding current stock status; (2) current spawning stock size has been extremely low in recent years, but appears to be returning to average levels in 2003; (3) a significant spawning stock-recruitment relationship with some indices of recruitment; (4)

generally increased recruitment at levels of relative SSB above the median value; (5) females are harvested at the beginning of their sexual maturity (peeler fishery) and mature females have neither size protection, nor protection as sponge crabs in the hard crab fishery; (6) a decreasing size of mature females and increasing proportion of small (< 100 mm CW) females with a resultant decrease in fecundity; (7) the range of best estimates of MSY for the blue crab in North Carolina was 27.9 to 51.7, and landings were at or above this level from 1994-1999; (8) steadily decreasing biomass and sharply increasing fishing mortality rates, the latter of which are ~ 0.87-3.01 times levels at MSY; (9) predicted numbers of legal-sized crabs from C-S modeling were higher in the early 1990s, then generally declined from 1992 through 2002, concurrent with a generally increasing exploitation rate over the same period; and (10) biological reference points from YPR and SSBR that suggest a reduction in fishing mortality would be warranted due to growth and recruitment overfishing concerns.

RECOMMENDATIONS

1. Data Collection

A. Of the two NC DMF fishery-independent research survey programs (P120 and 195), P195 provides the most useful information in terms of tracking population trends and estimating population and stock assessment parameters for the blue crab. The timing and deep-water sampling protocol of the P195 survey permitted us to successfully fit spawning stock-recruit, C-S models, and to a lesser extent, biomass-based stock assessment models to the fishery-independent data. Moreover, P120 was biased against sampling female crabs because of the up-estuary nature of the sampling stations. Data generated from P120, however, may be useful in examining historical relationships between water quality in primary nursery habitats and relative abundance of Age 0 blue crabs (e.g., Neuse and Pamlico Rivers), as well as environmentally-driven recruitment variation in Age 0 crabs. Given the length-frequency of blue crabs captured in P120, this survey appears to track recruitment of a cohort spawned in early spring (small crabs < 20 mm CW), as well as larger crabs (40-80 mm CW) that were likely spawned in the fall of the previous year. To the extent possible, NC DMF should consider re-initiating P120 sampling in the fall (October or November) to observe annual recruitment of the fall spawn of blue crabs to juvenile habitats prior to their overwintering. For example, consideration of replacing the current sampling protocol of NC DMF P120 from May, June and July to sampling in April, July, and October to better measure recruitment and abundance of early juveniles. If only two months can be effectively sampled due to budgetary or time constraints, the NC DMF may consider sampling in May and October. The NC DMF should re-initiate sampling in Albemarle Sound by P195 because this region represents a significant percentage (25% of hard crab landings from 1994-2001) of annual landings in NC. If a redirection in current research survey effort was required to resume sampling in Albemarle Sound due to budgetary constraints, then one viable option would be to reduce the number of stations in P195 by treating the Outer Banks, Northwest Pamlico Sound, and Southwest Pamlico Sound as a single water body, and redirecting this effort to Albemarle Sound.

B. All crabs captured in each tow should be measured and sexed to facilitate more straightforward data reduction and decreased uncertainty in estimates from trawl catches that were sub-sampled. Moreover, gear efficiency studies should be conducted to assess potential habitat-specific gear biases. Such information would aid in using CPUE survey data to make inferences concerning juvenile habitat requirements.

C. We re-emphasize the critical need for reliable catch and effort data for commercial landings, and catch and effort data for the soft crab and recreational fishery. Currently, the impact of the peeler fishery on the blue crab population may be underestimated, as many crabs that die in shedding operations are not sold to dealers and therefore not reported in landings data. This information is even more critical given the targeting of pre-pubertal females by this fishery--these females are captured just prior to entering the spawning stock. Reliable data for effort and catch for the recreational blue crab fishery is currently lacking in NC, and the magnitude of the recreational catch is unknown. The impact of the recreational fishery may be significant. For example, the recreational component of the Chesapeake Bay fishery accounted for 11.5 to 41.2 million lbs in the three years (1983, 1988, 1990) for which data was available (Rugolo et al. 1997). Moreover, estimates of the Maryland recreational harvest of blue crabs in 1990 were 11.5 million pounds, whereas the commercial harvest was approximately 30 million pounds (Rugolo et al. 1997). Data on all components of the blue crab fishery in NC may allow for more effective modeling of the fishery, and will increase confidence in fishery model outputs.

D. Environmental variation due to rainfall, hurricanes, wind-stress and temperature appears to play a major role in annual postlarval recruitment success of the blue crab (Etherington and Eggleston 2003, Eggleston unpubl. Data), as well as crab availability to fishery-independent trawl surveys, and vulnerability to fishing. It is critical that fishery-independent trawl surveys continue to collect abiotic data, and that future stock assessments and investigations of blue crab population dynamics in NC assess the relative importance of abiotic variation and fishing pressure on the population.

E. Critical data on the spatial and temporal abundance of mature females within North Carolina is lacking. Information of the spatial dynamics of the spawning stock of blue crabs in NC is urgently needed to aid management in rebuilding the potentially depleted spawning stock.

2. Conservation of the Spawning Stock

A. Options - Although each of the major inlets in NC (Oregon, Hatteras, Ocracoke, Drum) serves as a spawning sanctuary for the blue crab, declines in the fishery-independent index of SSB from 2000-2002 show that these sanctuaries may fail to maintain the spawning stock at a level that ensures sufficient recruitment under intense fishing pressure. Moreover, based on tagging and telemetry data, Medici (2004) concluded that due to the small size of the current sanctuaries in NC relative to the movement patterns of mature females, the sanctuaries offer minimal protection to the spawning stock as implemented. Possible solutions may be found in current management practices in Chesapeake Bay. The blue crab spawning stock in Chesapeake Bay has also declined precipitously since 1992, prompting the following management actions in Chesapeake Bay: (1) creation of a marine protected area and corridor (MPAC) that covers an area of 935 mi^2 and primarily in water > 33 ft. (10 m) deep from June 1 - September 15, which allows females to migrate to the bay mouth to spawn; (2) 8 hour fishing day (dawn-2PM); (3) 3 inch CW size limit on peelers; (4) protection of dark sponge crabs (brown to black sponge); (5) 5 ¼ inch CW size limit on hard crabs, and (6) pot limits. If NC considers implementing a MPAC, then it is critical that future research quantify mature female and sponge crab distribution and abundance patterns over time to select the best places and times to establish no take zones. Alternative methods to conserve the spawning stock in NC include: (1) an upper size limit on mature females; and (2) increasing the size of current inlet spawning sanctuaries and enforcing the sanctuary boundaries.

B. Establish upper size limit on females - The fecundity of female blue crabs increases in a linear, statistically significant manner with carapace width (Prager et al. 1990). For example, an 180 mm CW female blue crab produces broods 3 times as large as a 120 mm CW crab does. The first benefit of establishing an upper size limit would be a sharp increase in egg/larval production per crab. The second benefit would be to allow large females the opportunity to produce multiple broods over their lifetime. Presently, fishing mortality rates on legal-sized crabs is so high that their overall lifetime fecundity must be greatly reduced compared to the relatively small mature females, the latter of which escape fishing mortality through cull rings or the crab pot wire. The third benefit to an upper size limit on the harvest of mature female blue crabs is that it would help conserve a "natural" size-at-age. For example, increasing the lifetime fecundity of relatively large females would help ensure that their genes are maintained in the population. The fourth benefit is that an upper size limit on females has a much lower economic impact to crabbers than an upper size limit to males. For example, a size of 6.5 inch CW and greater male blue crabs sell for ~$4.75/crab compared to ~$1.83 for similar sized females (http://www.angelfire.com/f14/overtoncrabcompany1
/bluecrab.html). Thus, since mature female blue crabs are generally not graded by size, protection of large females has less economic impacts than an upper size limit for males.

The current system of harvesting most of the large females before they reproduce or after they reproduce once, and allowing an increasing proportion of relatively small mature females to reproduce, may partially explain the observed decline in the mean size of mature female blue crabs in NC and Chesapeake Bay.

To protect large mature females, the NC MFC considered a maximum size limit of 6 ¾" (172 mm) CW be implemented for mature female blue crabs captured in the hard crab fishery from September – April (NC MFC meeting, New Bern, NC, 12 May 2004. We support this recommendation as a step toward increased conservation of the blue crab spawning stock in North Carolina, although year round protection or an annual total allowable catch would afford greater protection and less risk to the spawning stock given the heavy exploitation rates of the fishery during (May-August). Maximum size limits for mature females in NC has also been recommended by Medici (2004). Protection of relatively large mature females may buffer the population from a potential decrease in size-at-age from genetic selection that is occurring as the likely result of cull rings (i.e., increased escapement from crab pots by small females < 127 mm CW). Although this regulation would offer protection to only a small fraction of the spawning stock, it would preserve larger, more fecund (Prager et al. 1990) individuals. Moreover, because the regulation protects a small fraction of the total biomass available to the fishery, a minimal impact is expected to the fishery. For example, trawl surveys at all of the inlet spawning sanctuaries in NC in 2002 (Eggleston 2003) indicate that mature females > 6 ¾" (172 mm) CW comprise less than 1% (Table 16) of the total number of legal hard crabs (crabs > 127 mm CW + mature females) captured within ~ 5 km distance of the inlet spawning sanctuaries in NC. Similarly, P195 trawls in 2002 suggest that mature females > 6 ¾" comprise less than 1% (Table 16) of the fishable population in Pamlico Sound. The percentage of mature females > 6 ¾" in trawls surveys in the Cape Fear River and surrounding waters in 2002, however, comprised 16.3% (Table 16) of the legal hard crabs, and suggest that the magnitude of the economic impact of an upper size limit on mature females may vary regionally. Mature female blue crabs in the Cape Fear River estuary were 22% larger (152.23 vs. 124.36 mm CW) than those in Pamlico Sound in 2002. The smaller size of mature females in Pamlico Sound may be due to regional differences in salinity, or a result of heavier exploitation rates in Pamlico Sound. Although data from 2002 was highlighted because of the large spatial coverage of sampling that year (Eggleston 2003), the percentage of mature females > 6 ¾" in the P195 trawl survey during 1987-2002 was never greater than 2% of the total number of legal hard crabs captured in the P195 trawl surveys (Table 16). Although we support an upper size limit on mature female blue crabs as one means of conserving the spawning stock and as a way to help increase mean size-at-age, we are concerned that any tolerance of bycatch of large, protected females would very detrimental given that this management action would only protect ~ 2% of the adult population. Thus, if there is any tolerance in bycatch of large, protected female crabs, then we advocate an annual, total allowable catch of mature females as a means of conserving blue crab SSB in NC.

C. Increase the area of the spawning sanctuaries and enforce the boundaries - Unpublished data from Balance & Balance (2002), Eggleston (2003), and Medici (2004) indicate that mature, egg-bearing females are present on the inlet spawning grounds in NC from spring-fall. Eggleston's (2003) trawl surveys at all of the inlet spawning sanctuaries in NC in 2002 indicated equal numbers of mature females within the sanctuary versus an area 5 km outside of the sanctuary (inshore & offshore) from June-September. Similarly, Medici (2004) and Balance & Balance (2002) found that mature females tagged in the Ocracoke Inlet sanctuary are consistently caught in crab pots up to 4 km surrounding the sanctuary. The benefit of increasing the area of the spawning sanctuaries is that for inseminated females that manage to migrate successfully to inlet sanctuaries, it would provide a more effective sanctuary to release multiple broods than the present system, particularly if the sanctuary boundaries are enforced. For example, over a 6 d period in 2003, Medici (2004) reported up to 176 illegal crab pots within the Ocracoke Inlet spawning sanctuary that were actively being fished.

IMPACTS AND BENEFITS

The impacts of this fishery resource grant project are enormous because the findings and recommendations not only impact the livelihood of fishermen, seafood processors and dealers, and fishery managers of the largest fishery in the state of North Carolina, but help provide a roadmap for conservation of one of the most ecologically important species in North Carolina's estuaries, and a North Carolina cultural resource. The results from this study can improve existing and future management practices in NC by (1) refining the space/time scales of NC DMF fishery trawl survey programs 120 and 195, (2) highlighting the most profitable indices of blue crab relative abundance and spawning stock biomass to enable managers to track annual trends in abundance, (3) highlighting the most profitable fishery modeling approaches for determining the status of the blue crab stock in NC, (4) identifying data gaps that are essential to management (e.g., recreational and peeler fisheries), (5) identifying the nursery role of salt marshes for juvenile blue crabs, and (6) highlighting the need to consider environmental variables such as salinity when interpreting fishery data. The data generated from this study on blue crab growth will help reduce uncertainty in fishery and ecological modeling efforts concerning the blue crab, ranging from the application of continuous growth models to blue crab growth, to the best indices for assessing the relationship between spawning stock biomass and subsequent recruitment. Lastly, the main results of this study were central to the recent Marine Fisheries Commission deliberations on potential revisions to the fishery management plan for the blue crab in NC (NC MFC meeting, New Bern, NC, 12 May 2004).

EXTENSION OF RESULTS

We have actively communicated the findings from this study throughout its evolution. This communication has taken place primarily through presentations and question/answer sessions at various meetings hosted by the NC Crustacean Commission or NC Marine Fisheries Commission, the NC Commercial Fishing Show, scientific conferences, and university seminars. We have also communicated the results of this study to the general public via interviews with newspaper reporters and National Public Radio, phone conversations and e-mail correspondence with the general public as well as crabbers and conservation groups, and have conducted presentations to coastal county public schools (grades 5-12). We have also provided drafts of this report to NC DMF staff, as well interested scientists and fishermen, and have worked in a responsive and enthusiastic manner with NC DMF staff to address any concerns or recommendations they had to our ongoing efforts. Lastly, the initial mark-recapture study of blue crabs in the Neuse River was a collaborative effort between our research group at NC State University and commercial crabbers (Robin Doxey & family, Merritt NC). A list of presentations and publications resulting from this work follows below. We anticipate numerous additional publications from this work once the various data sets have been isolated into discrete, publishable units.

1. Formal Presentations

1. Eggleston, D. B., E. G. Johnson and J. Hightower. 2004. Population dynamics and stock assessment of the blue crab in North Carolina. NC Marine Fisheries Commission meeting, New Bern, NC, May 2004.

2. Eggleston, D. B., E. G. Johnson and J. Hightower. 2004. Population dynamics and stock assessment of the blue crab in North Carolina. NC Commercial Fishing Show, New Bern, NC, February 2004.

3. Eggleston, D. B., E. G. Johnson, L. L. Etherington, S. McKenna. 2004. The interactive effects of hurricane floodwaters and overfishing cause population decline in the blue crab. Duke University, Durham, NC, February 2004.

4. Eggleston, D. B., E. G. Johnson and J. Hightower. 2004. Population dynamics and stock assessment of the blue crab in North Carolina. NC Crustacean Commission, Washington, NC, January 2004.

5. Eggleston, D. B., E. G. Johnson, L. L. Etherington, S. McKenna. 2003. The interactive effects of hurricane floodwaters and overfishing cause population decline in the blue crab. NC State University, Department of Marine, Earth & Atmospheric Sciences, Raleigh, NC, Sept. 2003.

6. Eggleston, D. B., E. G. Johnson, L. L. Etherington, S. McKenna. 2003. The interactive effects of hurricane floodwaters and overfishing cause population decline in the blue crab. The Crustacean Society annual meeting, Williamsburg, VA, June 2003

7. Johnson, E. G**.** and D. B. Eggleston. 2003. Population dynamics and movement patterns of blue crabs in estuarine salt marshes. The Crustacean Society annual meeting, Williamsburg, VA, June 2003

8. Eggleston, D. B., E. G. Johnson, L. L. Etherington, S. McKenna. 2003. The interactive effects of hurricane floodwaters and overfishing cause population decline in the blue crab University of Washington, Seattle, WA, May 2003.

9. Eggleston, D. B., E. G. Johnson, L. L. Etherington, S. McKenna. 2003. The interactive effects of hurricane floodwaters and overfishing cause population decline in the blue crab. Chesapeake Biological Laboratory, Solomons MD, April 2003.

10. Eggleston, D. B., E. G. Johnson, L. L. Etherington, S. McKenna. 2003. The interactive effects of hurricane floodwaters and overfishing cause population decline in the blue crab. North Carolina State University, Department of Zoology, Raleigh, NC, April 2003.

11. Johnson, E. G**.** and D. B. Eggleston. 2002. Population dynamics and movement patterns of blue crabs in estuarine salt marshes. Benthic Ecology Meetings. Orlando, Florida. March, 2002.

12. Eggleston, D.B., E.G. Johnson, L.L. Etherington and S. McKenna. 2002. The interactive effects of humans and nature on marine populations: hurricanes and fishing contribute to population decline in the blue crab. Benthic Ecology Meetings, Orlando, Florida, March, 2002

13. Eggleston, D. B., E. G. Johnson and J. Hightower. 2002. Population dynamics and stock assessment of the blue crab in North Carolina. NC Commercial Fishing Show. New Bern, NC, March, 2002.

14. Eggleston, D. B., E. G. Johnson and J. Hightower. 2002. Population dynamics of the blue crab, *Callinectes sapidus*, in North Carolina. NC Marine Fisheries Commission – Crustacean Advisory Committee, Washington, NC. February, 2002.

15. Eggleston, D. B., E. G. Johnson and J. Hightower. 2001. Stock assessment of the blue crab in North Carolina. Duke University Marine Laboratory, Beaufort, NC, November, 2001.

16. Johnson, E.G. and D.B. Eggleston. 2001. Biology of the blue crab. Blue Crab Research Program workshop, NC Aquarium at Roanoke Island, Manteo, NC. October, 2001.

17. Eggleston, D. B., E. G. Johnson and J. Hightower. 2001. Stock assessment of the blue crab in North Carolina. NC Commercial Fishing Show. New Bern, North Carolina. February, 2001.

18. Eggleston, D. B., E. G. Johnson, J. Hightower. 2001. Population dynamics of the blue crab, *Callinectes sapidus*, in North Carolina. North Carolina Marine Fisheries Commission Meeting. Greenville, North Carolina. January, 2001.

19. Eggleston, D. B., E. G. Johnson, and J.E. Hightower. 2000. Population dynamics and density-dependence in the blue crab in NC. Blue Crab Symposium, Wilmington, North Carolina. March, 2000.

20. Johnson, E.G., D.B. Eggleston, and J.E. Hightower. 2000. Spatiotemporal variability in abundance of the blue crab in North Carolina. Blue Crab Symposium, Wilmington, NC. March, 2000.

21. Eggleston, D. B., E. G. Johnson and J. Hightower. 2000. Stock assessment of the blue crab in North Carolina. NC Commercial Fishing Show. New Bern, NC. February, 2000.

2. Publications

1. Johnson, E. G. and D. B. Eggleston. (in review). Population demographics and movement of blue crabs in salt marsh creeks. Marine Ecology Progress Series.

2. Johnson, E. G. and D. B. Eggleston. (in review). A stochastic, discontinuous growth model for blue crabs. Canadian Journal of Fishery and Aquatic Sciences.

3. Burkholder, J., D. Eggleston, H. Glasgow, C. Brownie, R. Reed, G. Janowitz, M. Posey, G. Melia, C. Kinder, R. Corbet, D. Toms, T. Alphin, N. Deamer, J. Springer. (2004). Comparative impacts of two major hurricaneseasons on the Neuse River and western Pamlico Sound ecosystems. Proceedings of the National Academy of Sciences (in press).

3. Integrations with Related Studies

This report has benefited from related data on the blue crab in NC generated with funding from the following agencies:

1. *NC Sea Grant/Blue Crab Fishery Resource Grant Program* to D.B.E. (01-POP-08) – provided additional information on the use of spawning sanctuaries by mature female blue crabs, as well as distribution and abundance patterns of mature female blue crabs in Pamlico Sound and the Cape Fear River, NC.

2. *NC Sea Grant/Blue Crab Fishery Resource Grant Program* to D.B.E. (02-POP-04) – provided data on blue crab postlarval supply, which was used as one measure of recruits in stock-recruit modeling, and to understand the impact of hurricanes in 1999 on crab recruitment failure.

3. *NSF Biological Oceanography* to D.B.E. (OCE 97-34472) - provided data on blue crab postlarval supply, which was used as one measure of recruits in stock-recruit modeling, and to understand the impact of hurricanes in 1999 on crab recruitment failure.

4. North Carolina Sea Grant to D.B.E. (NA46RG0087) - provided data on blue crab postlarval supply, which was used as one measure of recruits in stock-recruit modeling, and to understand the impact of hurricanes in 1999 on crab recruitment failure.

STUDENTS

Johnson, E. G. 2004. Population dynamics and stock assessment of the blue crab in North Carolina. Doctoral dissertation, NC State University, Department of Marine, Earth and Atmospheric Sciences, Raleigh, NC 27695-8208, 215 p.

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Table 1. Commercial hard crab, peeler, and soft crab landings (lbs.) for the North Carolina blue crab fishery.

Year	Hard Crab	Peeler	Soft Crab	Total landings
1978	23,558,546	46,826 *		23,605,372
1979	26,623,723	80,367 *		26,704,090
1980	34,322,937	87,482 *		34,410,419
1981	37,927,573	77,748 *		38,005,321
1982	38,206,327	148,364 *		38,354,691
1983	34,689,455	87,570 *		34,777,025
1984	32,490,769	199,771 *		32,690,540
1985	29,329,547	326,978 *		29,656,525
1986	23,159,779	595,468 *		23,755,247
1987	31,760,413	663,191 *		32,423,604
1988	35,136,232	468,191 *		35,604,423
1989	33,935,992	788,681 *		34,724,673
1990	36,985,206	1,085,122 *		38,070,328
1991	41,074,063	755,613 *		41,829,676
1992	40,507,415	560,959 *		41,068,374
1993	42,867,109	805,623 *		43,672,732
1994	52,260,188	642,238	610,769	53,513,195
1995	45,033,543	724,442	685,555	46,443,540
1996	65,682,738	878,382	519,316	67,080,436
1997	54,472,171	1,022,695	713,898	56,208,764
1998	60,397,141	975,781	697,741	62,070,663
1999	55,917,857	923,650	510,363	57,351,870
2000	38,794,370	998,971	750,140	40,543,481
2001	29,938,956	1,319,202	921,693	32,179,851
2002	36,401, 654**	555,532**	718,894**	37,712,571**
Average	39,378,002	935,670	676,184	39,915,287

* Prior to 1994 peeler and soft crab landings were not tabulated separately. Asterisked values represent the sum of peeler and soft crab landings.

** Landings for 2002 are estimates and subject to change prior to official release.

Table 2. Summary of water bodies, sampling areas, and station numbers of a fisheries-independent trawl survey (i.e., Program 120) of juvenile crabs conducted by the North Carolina Division of Marine Fisheries. Station numbers correspond to those shown on Figure 4.

Water Body	Sampling Area	Station Number
Northwest Pamlico Sound	Stumpy Point Bay	1
	Deep Creek	2
	Pains Bay	3
	Broad Creek	4
	Otter Creek	5
	Far Creek	6
	Middletown Creek	7
	Wysocking Bay	8
	Douglas Bay	9
	Harbor Creek	10
	Northwest Creek	11
	Oyster Creek	12
	Shingle Creek	13
	Striking Bay	14
	Unnamed Western	15
	Tooley Creek	16
	Unnamed North	17
	Box Creek	18
Pamlico and Pungo Rivers	Warner Creek	19
	Wood Creek	20
	Spring Creek	21
	Bradley Gut	22
	East Fork	23
	Mixon Creek	24
	Bath Creek	25
	Porter Creek	26
	Tooley Creek	27
	Jacobs Creek	28
	South Creek	29
	Muddy Creek	30
	East Prong	31
	Betty Creek	32
	Mallard Creek	33

Table 2 (continued).

Water Body	Sampling Area	Station Number
Southwest Pamlico Sound	Long Creek	34
	Clark Creek	35
	Porpoise Creek	36
	Upper Jones Bay	37
	Ditch Creek	38
	Dump Creek	39
	Riggs Creek	40
	Long Creek	41
	Smith Creek	42
	Chapel Creek	43
	Moore Creek	44
	Simpson Creek	45
	Bryan Creek	46
	Dipping Vat Creek	47
	Green Creek	48
	Parson’s Creek	57
	Fur Creek	58
	Golden Creek	59
	Codduggen Creek	60
Neuse River	Upper Broad Creek	49
	Bright Creek	50
	Pierce Creek	51
	Kershaw Creek	52
	Clubfoot Creek	53
	Jonaquin Creek	54
	Big Creek	55
	Horton Bay	56
Core and Bogue Sounds	Southwest Prong	61
	Cedar Island Bay	62
	E. Thorofare Creek	63
	Oyster Creek	64
	Great Island Bay	65
	Smyrna Creek	66
	Horsepen Point	67
	Core Banks Area	68
	North River Narrows	69
	North River Below	70
	Cross Rock	71

Table 2 (continued).

Water Body	Sampling Area	Station Number
Southern Area	New River	72
	New River	73
	Northeast Creek	74
	French's Creek	75
	Mill Creek	76
	Snead's Bay	77
	Alligator Bay	78
	Turkey Creek	79
	Spicer's Bay	80
	Permuda Island	81
	Virginia Creek	82
	Smith Creek	83
	Cape Fear River	84
	Toomer's Creek	85
	North of Snow's	86
	North of Snow's	87
	North of Snow's	88
	Shallotte River	89
	Shallotte River	90
	Shallotte River	91
	Shallotte River	92
Outer Banks	Hatteras Island	93
	Hatteras Island	94
	Hatteras Island	95
	Hatteras Island	96
	Blossie Creek	97
Croatan Sound	Broad Creek	96
	Cuttthrough	98
	Roanoke Sound	99
	Dough Creek	101
	Dough Creek	102
	Scarboro Creek	103
	Buzzard Bay	104
	Kitty Hawk Bay	105
	Peter Mashoes	106
	Spencer Creek	107

Table 3. Summary of water bodies, sampling areas, station numbers, and number of sites sampled at each station of a fisheries-independent trawl survey (i.e., Program 195) of adult blue crabs conducted by the North Carolina Division of Marine Fisheries. Station numbers correspond to those shown on Figure 5.

Water Body	Sampling Area	Station Number	Number of Sampling Sites
Albemarle	Camden Pt.	1	8
Sound	Long Shoal Pt.	2	6
	Powell's Pt.	3	3
	Ned Bees Pt.	4	10
Croatan Sound	Caroon Pt.	5	11
	Croatan Sound	6	24
Neuse River	Gum Thicket Shoal	48	3
	Cherry Pt/Wiliknninson Pt.	49	11
	Mouth to Cherry Pt.	50	52
	South River	51	2
Northwest	Off Stumpy Pt.	8	7
Pamlico Sound	Off Sandy Pt.	9	1
	Long Shoal	10	5
	Long Shoal River	11	2
	Pingleton Shoal	12	7
	Gibbs Shoal	13	2
	Middleton Anchorage	14	2
	Wysocking Bay	18	3
	Outfall Canal	20	1
	East Bluff Bay	21	2
	Bluff Shoal	22	11
	West Bluff Bay	23	1
	Juniper Bay	36	1
	Great Island	37	9
	Swanquarter Bay	38	2
	Deep Cove	39	1
	Rose Bay	41	3

Table 3 (continued).

Water Body	Sampling Area	Station Number	Number of Sampling Sites
Outer Banks	Gull Island	17	4
	Clam Shoal	26	4
	Offshore Oliver	27	1
	Legged Lump	28	1
	Portsmouth Island	29	1
	Howard Reef	30	3
Pamlico River	Sandy Pt./Old Field Pt.	42	6
	Upstream of Durant	43	5
	Durant/Pungo Pt.	44	8
	Gum Pt./Garrison	45	39
	Upstream of Maules Pt.	46	3
Pamlico Sound	Long Shoal/Rodan.	7	86
	Mauls Pt./Rugged Pt.	15	10
	East of Bluff Shoal	16	341
	Gull Shoal	19	4
	Outer Banks	24	1
	Seven Foot Patch	25	3
	Royal Shoal	31	6
	Lower Middle Grounds	32	1
	Inner Middle Grounds	33	4
	Brant Island Shoal	34	13
	Upper Middle Shoal	35	4
	West of Bluff Shoal	40	198
Southwest Pamlico Sound	Bay River	47	3
	Point of Marsh	52	1
	West Bay	53	2
	West Bay	54	2

Table 4. Maximum likelihood estimates of model parameters from length-based modeling of observed blue crab length frequencies from NC DMF Program 120 trawls in May and June from 1987-2002. Growth was assumed to be described by a single von Bertalanffy growth function (VBGF) for all years. VBGF parameters (t0, Linf and k) and standard deviation (StDev) were constant among all years. The Estimated values for t0 (0.41), Linf (216.90), k (0.51), and StDev (21.25) were generated from length-based modeling (see text for details). The proportion of blue crabs in each age class (Prop Age 0, Prop Age 1) were allowed to vary among years.

	May			June		
Year	*N*	*Prop Age 0*	*Prop Age 1*	*N*	*Prop Age 0*	*Prop Age 1*
1987	987	0.93	0.07	954	0.80	0.20
1988	1230	0.89	0.11	913	0.85	0.15
1989	451	0.80	0.20	472	0.88	0.12
1990	884	0.80	0.20	674	0.70	0.30
1991	594	0.70	0.30	496	0.61	0.39
1992	495	0.78	0.22	415	0.70	0.30
1993	893	0.91	0.09	631	0.84	0.16
1994	903	0.90	0.10	710	0.79	0.21
1995	925	0.89	0.11	698	0.81	0.19
1996	1328	0.92	0.08	1460	0.74	0.26
1997	1097	0.87	0.13	825	0.80	0.20
1998	642	0.81	0.19	3800	0.33	0.67
1999	952	0.85	0.15	1048	0.63	0.37
2000	421	0.69	0.31	494	0.69	0.31
2001	886	0.87	0.13	564	0.73	0.27
2002	958	0.86	0.14	813	0.69	0.31
Mean		0.85	0.15		0.72	0.28

Table 5. Maximum likelihood estimates of model parameters from length-based modeling of observed blue crab length frequencies from NC DMF Program 195 trawls in June and September from 1987-2003. Growth was assumed to be described by a single von Bertalanffy growth function (VBGF) for all years. VBGF parameters (t0, Linf and k) and standard deviation (StDev) were constant among all years. The Estimated values for t0 (0.02), Linf (216.90), k (0.47), and StDev (19.53) were generated from length-based modeling (see text for details). The proportion of blue crabs in each age class (Prop Age 0, Prop Age 1, Prop Age 2) were allowed to vary among years.

	June			September		
Year	*N*	*Prop Age 0*	*Prop Age 1*	*N*	*Prop Age 1*	*Prop Age 2*
1987	3062	0.57	0.43	853	0.57	0.43
1988	737	0.59	0.41	603	0.62	0.38
1989	3300	0.69	0.31	489	0.68	0.32
1990	6239	0.75	0.25	625	0.58	0.42
1991	6810	0.62	0.38	687	0.63	0.37
1992	2019	0.44	0.56	422	0.30	0.70
1993	2301	0.67	0.33	579	0.64	0.36
1994	1244	0.68	0.32	639	0.52	0.48
1995	859	0.57	0.43	226	0.22	0.78
1996	525	0.90	0.10	1450	0.36	0.64
1997	1720	0.74	0.26	560	0.43	0.57
1998	944	0.59	0.41	601	0.32	0.68
1999	1911	0.65	0.35	599	0.58	0.42
2000	796	0.82	0.18	204	0.51	0.49
2001	1540	0.72	0.28	257	0.46	0.54
2002	5179	0.85	0.15	247	0.53	0.47
2003	4140	0.95	0.05	1315	0.14	0.86
Mean		0.69	0.31		0.48	0.52

Table 6. Summary of mean annual trawl survey indices of abundance (catch-per-unit-effort;CPUE) for blue crabs (NC DMF Programs 120 and 195) by age, based on surveys conducted in May, June and September from 1987-2003. CPUE values were generated using the length-based model descibed in the text.

	Program 195				**Program 120**			
	June Age 0	June Age 1	Sept Age 1	Sept Age 2	May Age 0	May Age 1	June Age 0	June Age 1
1987	33.56	25.30	9.42	6.98	7.75	0.70	7.08	1.88
1988	8.48	5.96	7.35	4.47	9.24	1.24	6.97	1.26
1989	45.66	20.31	6.69	3.09	3.05	0.87	3.82	0.55
1990	86.41	29.06	6.75	4.82	5.99	1.70	4.28	1.97
1991	79.12	49.32	8.14	4.83	3.51	1.72	2.78	1.88
1992	16.76	21.32	2.36	5.61	3.31	1.05	2.52	1.12
1993	28.65	13.94	6.82	3.90	7.43	0.77	4.87	0.98
1994	16.03	7.43	6.32	5.73	7.14	0.84	4.76	1.31
1995	9.36	7.16	0.98	3.37	7.26	1.01	4.88	1.20
1996	9.10	0.99	10.08	17.80	10.45	1.04	9.22	3.43
1997	24.12	8.31	4.52	6.04	8.19	1.36	6.08	1.60
1998	10.62	7.52	3.72	7.84	4.60	1.19	11.62	25.00
1999	22.89	12.48	6.41	4.68	7.00	1.39	6.12	3.72
2000	12.38	2.64	1.97	1.88	2.83	1.40	3.53	1.65
2001	20.89	8.15	2.23	2.62	6.57	1.15	3.76	1.46
2002	83.34	14.32	2.49	2.17	7.09	1.25	5.10	2.43
2003	80.19	4.47	3.42	21.38				
Mean	34.56	14.04	5.27	6.31	6.34	1.17	5.46	3.22
s.d.	28.96	12.12	2.77	5.29	2.28	0.30	2.39	5.87
C.V.	0.84	0.86	0.53	0.84	0.36	0.26	0.44	1.83

Table 7. Correlations between mean annual indices of abundance for Age 0, Age 1, and Age 2 crabs from Programs 120 and 195 at appropriate lags. For example, Age 0 crabs in a given year are correlated with Age 1 crabs the following year, and correlated to Age 2 crabs at a lag of two years. Each entry represents the Pearson correlation coefficient, significance level, and the number of observations (N). Significant correlations are shown in bold.

	Program 195				**Program 120**			
	June Age 0	June Age 1	Sept Age 1	Sept Age 2	May Age 0	May Age 1	June Age 0	June Age 1
Program 195								
	1.000	**0.537***	0.076	0.324	-0.243	0.422	-0.373	-0.069
June Age 0	.	**0.016**	0.386	0.111	0.182	0.058	0.077	0.403
	17	**16**	17	16	16	15	16	15
		1.000	0.245	-0.291	-0.305	0.403	-0.232	-0.156
June Age 1		.	0.180	0.137	0.125	0.061	0.193	0.289
		16	16	16	16	16	16	15
			1.000	-0.384	0.380	0.218	0.285	-0.175
September Age 1			.	0.071	0.074	0.218	0.142	0.266
			17	16	16	15	16	15
				1.000	0.189	-0.152	-0.016	0.257
September Age 2				.	0.242	0.287	0.476	0.178
				17	16	16	16	15
Program 120								
					1.000	-0.043	**0.485***	0.206
May Age 0					.	0.440	**0.028**	0.231
					16	15	**16**	15
						1.000	0.218	0.403
May Age 1						.	0.218	0.061
						16	15	15
							1.000	0.120
June Age 0							.	0.335
							16	15
								1.000
June Age 1								.
								16

Table 8. Correlations between mean annual indices of abundance for Age 0, Age 1, and Age 2 crabs from Programs 120 and 195 within years. Each entry represents the Pearson correlation coeffcient, significance level, and the number of observations (N). Significant correlations are shown in bold.

	Program 195				**Program 120**			
	June Age 0	June Age 1	Sept Age 1	Sept Age 2	May Age 0	May Age 1	June Age 0	June Age 1
Program 195								
June Age 0	1.000 . 17	**0.581*** **0.007** **17**	0.076 0.386 17	0.125 0.316 17	-0.243 0.182 16	**0.478*** **0.031** **16**	-0.373 0.077 16	-0.191 0.239 16
June Age 1		1.000 . 17	0.346 0.087 17	-0.275 0.143 17	-0.413 0.056 16	0.403 0.061 16	**-0.435*** **0.046** **16**	-0.166 0.270 16
September Age 1			1.000 . 17	0.251 0.017 17	0.380 0.740 16	-0.099 0.358 16	0.285 0.142 16	-0.113 0.339 16
September Age 2				1.000 . 17	**0.486*** **0.028** **16**	-0.152 0.287 16	**0.621*** **0.005** **16**	0.248 0.177 16
Program 120								
May Age 0					1.000 . 16	-0.244 0.181 16	**0.485*** **0.028** **16**	-0.146 0.295 16
May Age 1						1.000 . 16	-0.175 0.259 16	0.068 0.401 16
June Age 0							1.000 . 16	**0.736*** **0.001** **16**
June Age 1								1.000 . 16

Table 9. Correlations between mean annual indices of abundance for Age 0 and Age 1 crabs from Program 120 and commercial hard crab landings within years and at various annual lags. For example, each index in a given year is correlated to landings in the same year (t), and the following year (t + 1). Each entry represents the Pearson correlation coefficient, significance level, and the number of observations (N). Significant correlations are shown in bold.

Program 120 May trawls

	Landings	Landings (t + 1)	landings (t + 2)
Age 0	0.311 0.121 16	0.349 0.101 15	0.294 0.154 14
Age 1	0.029 0.457 16	-0.151 0.296 15	-0.271 0.174 14

Program 120 June trawls

	Landings	Landings (t + 1)	landings (t + 2)
Age 0	**0.614*** **0.006** **16**	0.380 0.081 15	-0.059 0.420 14
Age 1	**0.479*** **0.030** **16**	0.296 0.142 15	-0.191 0.257 14

Table 10. Correlations between mean annual indices of abundance for Age 0, Age 1, and Age 2 crabs from Program 195 and commercial hard crab landings within years and at various annual lags. For example, each index in a given year is correlated to landings in the same year (t), the following year (t + 1),. Each entry represents the Pearson correlation coefficient, significance level, and the number of observation (N). Significant correlations are shown in bold.

Program 195 June trawls

	Landings	Landings (t + 1)	landings (t + 2)
Age 0	-0.393 0.066 16	-0.246 0.188 15	-0.247 0.197 14
Age 1	-0.380 0.074 16	-0.262 0.173 15	-0.266 0.179 14

Program 195 September trawls

	Landings	Landings (t + 1)	landings (t + 2)
Age 1	0.167 0.268 16	-0.187 0.252 15	-0.095 0.373 14
Age 2	**0.679*** **0.002** **16**	0.358 0.095 15	0.407 0.075 14

Table 11. Summary of length-based estimates of blue crab mortality (Z) for sexes combined from NC DMF Program 195 using the Hoenig (1987) approach with three previously published growth trajectories (Rugolo et al. 1998, Helser and Kahn 1998), and two growth trajectories generated from length-based modeling in the present study.

			Total Instantaneous mortality (Z)				
			Previous growth estimates			Present Assessment	
Year	N	Mean CW (mm)	K = 0.59 L_{inf} = 262.5	K = 0.93 L_{inf} = 200.3	K = 0.75 L_{inf} = 235.7	K = 0.47 L_{inf} = 216.9	Average
1987	1081	142.70	1.48	1.17	1.42	1.02	1.27
1988	309	143.00	1.47	1.15	1.40	1.01	1.26
1989	643	141.62	1.54	1.23	1.48	1.08	1.33
1990	916	142.56	1.49	1.18	1.43	1.03	1.28
1991	1078	139.19	1.71	1.39	1.64	1.22	1.49
1992	815	141.93	1.53	1.21	1.46	1.06	1.32
1993	545	141.68	1.54	1.23	1.48	1.07	1.33
1994	428	141.51	1.55	1.24	1.49	1.08	1.34
1995	283	141.60	1.55	1.23	1.48	1.08	1.33
1996	800	143.00	1.47	1.15	1.40	1.01	1.26
1997	440	141.84	1.53	1.22	1.47	1.06	1.32
1998	445	144.78	1.37	1.06	1.31	0.92	1.17
1999	324	141.86	1.53	1.22	1.47	1.06	1.32
2000	158	144.95	1.37	1.05	1.30	0.92	1.16
2001	300	144.48	1.39	1.08	1.32	0.94	1.18
2002	468	145.06	1.36	1.05	1.29	0.91	1.15
2003	1036	143.62	1.43	1.12	1.37	0.98	1.22
Mean	1092	142.61	1.49	1.18	1.43	1.03	1.28
s.d.		1.58	0.09	0.09	0.09	0.08	0.09

Table 12. Estimates of carrying capacity (K), first-year biomass (B_1), maximum sustainable yield (MSY), biomass at MSY (B_{MSY}), fishing mortality at MSY (F_{MSY}), and relative biomass (B_{2002}/B_{MSY}), fishing mortality rates (F_{2002}/F_{MSY}) for 2002, and maximum log likelihood (-2ln(L) for the blue crab stock in NC generated from fixing the population growth rate (r) and fitting the remaining model parameters simultaneously to the commercial crab pot CPUE time series from 1953 - 2002. B_1 was constrained to be equal to K.

	r									
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
K	526.60	347.97	263.29	213.19	179.70	155.62	137.40	123.20	111.71	102.29
B_1	526.60	347.97	263.29	213.19	179.70	155.62	137.40	123.20	111.71	102.29
MSY	26.30	34.78	39.49	42.64	44.90	46.69	48.10	49.30	50.27	51.15
B_{MSY}	263.30	173.99	131.64	106.60	89.90	77.82	68.70	61.60	55.86	51.15
F_{MSY}	0.10	0.20	0.3	0.40	0.50	0.60	0.70	0.80	0.90	1.00
F_{2002}/F_{MSY}	6.45	4.36	3.52	3.05	2.74	2.53	2.37	2.25	2.15	2.08
B_{2002}/B_{MSY}	0.21	0.24	0.26	0.28	0.30	0.31	0.32	0.33	0.34	0.34
- 2(ln)L	49.50	51.13	52.08	52.69	53.10	53.43	53.70	53.90	54.01	54.14

Table 13. Estimates of carrying capacity (K), first-year biomass (B_1), maximum sustainable yield (MSY), biomass at MSY (B_{MSY}), fishing mortality at MSY (F_{MSY}), and relative biomass (B_{2002}/B_{MSY}), fishing mortality rates (F_{2002}/F_{MSY}) for 2002, and maximum log likelihood (-2ln(L) for the blue crab stock in NC generated from fixing the population growth rate (r) and fitting the remaining model parameters simultaneously to Program 195 June and September indices (crabs > 127 mm CW; 1987 – 2002) and commercial crab pot CPUE time series (1953 – 2002). B_1 was constrained to be equal to K.

	r									
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
K	557.62	364.57	273.77	220.23	184.61	159.14	140.00	125.10	113.17	103.41
B_1	557.62	364.57	273.77	220.23	184.61	159.14	140.00	125.10	113.17	103.41
MSY	27.88	36.46	41.06	44.05	46.15	47.74	49.00	50.04	50.93	51.71
B_{MSY}	278.81	182.28	136.88	110.12	92.31	79.57	70.00	62.55	56.59	51.71
F_{MSY}	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
F_{2002}/F_{MSY}	3.01	1.96	1.56	1.34	1.20	1.09	1.02	0.96	0.91	0.87
B_{2002}/B_{MSY}	0.43	0.51	0.57	0.62	0.66	0.70	0.73	0.76	0.78	0.81
- 2(ln)L	82.48	83.57	84.15	84.46	84.63	84.73	84.80	84.85	84.89	84.94

Table 14. Estimates of absolute recruit (crabs < 127 mm CW) and fishable (crabs > 127 mm CW) abundance in millions , annual harvest rate and fishing mortality for the blue crab stock in North Carolina generated from a Collie-Sissenwine model fit to observed relative abundance data , at varying assumed natural mortality rates (M) of 0.55, 0.87, 1.44.

	M = 0.55				**M = 0.87**				**M = 1.44**			
	Absolute abundance				Absolute abundance				Absolute abundance			
Year	Recruits	Fishable	Harv Rate	Est F	Recruits	Fishable	Harv Rate	Est F	Recruits	Fishable	Harv Rate	Est F
1988	141.6	200.9	0.47	0.63	247.9	360.2	0.34	0.41	1610.9	2446.0	0.08	0.08
1989	779.6	104.8	0.18	0.19	1500.0	169.1	0.12	0.13	10584.4	886.9	0.03	0.03
1990	26.1	420.7	0.38	0.48	43.0	616.6	0.33	0.39	259.5	2646.1	0.11	0.12
1991	649.8	160.1	0.23	0.26	1334.5	186.2	0.16	0.17	8885.8	610.2	0.04	0.04
1992	27.8	358.8	0.48	0.65	46.2	537.0	0.40	0.52	284.5	2163.0	0.15	0.16
1993	332.8	116.1	0.44	0.57	604.6	145.6	0.33	0.40	3906.7	494.3	0.09	0.09
1994	228.6	145.7	0.64	1.02	382.5	209.8	0.51	0.72	2207.0	952.1	0.15	0.16
1995	253.7	77.9	0.62	0.97	411.5	120.7	0.49	0.68	2305.9	638.0	0.14	0.15
1996	252.9	72.4	0.92	2.58	327.1	113.2	0.87	2.03	1236.0	602.3	0.32	0.38
1997	446.8	14.2	0.54	0.78	793.0	24.3	0.39	0.49	5913.3	296.7	0.08	0.08
1998	253.4	122.5	0.74	1.33	390.9	209.9	0.59	0.88	2445.8	1356.4	0.14	0.15
1999	296.2	57.3	0.73	1.30	465.1	104.4	0.57	0.85	2954.1	773.1	0.13	0.14
2000	205.2	55.8	0.68	1.15	329.7	101.9	0.52	0.74	2032.6	764.5	0.12	0.13
2001	187.5	47.9	0.58	0.87	289.4	86.0	0.46	0.62	1439.2	580.5	0.13	0.14
2002		56.8				84.3				415.3		
	Mean (1987-2001)		0.54	0.91			0.43	0.65			0.12	0.13
	Mean (1995-2001)		0.69	1.28			0.56	0.90			0.15	0.17

Table 15. Fishery management benchmarks resulting from YPR and SSBR analyses, and estimates of the average instantaneous total and fishing mortality from Collie-Sissenwine modeling from two time periods (1987-2001 and 1995-2001) for the North Carolina blue crab. The values for F were calculated by subtracting M from Z. Reference points were calculated from a growth trajectory generated from statistical length-based modeling and using three estimates of natural mortality. F values which exceed benchmark values are shown in bold.

		Instantaneous mortality rates (Z and F)			
	Benchmark	Z (1987-2001)	F (1987-2001)	Z (1995-2001)	F (1995-2001)
M = 0.55					
F_{MAX}	0.51	1.46	**0.91**	1.83	**1.28**
$F_{0.1}$	0.36	1.46	**0.91**	1.83	**1.28**
$F_{30\%}$	0.56	1.46	**0.91**	1.83	**1.28**
$F_{20\%}$	0.81	1.46	**0.91**	1.83	**1.28**
		Z (1987-2001)	F (1987-2001)	Z (1995-2001)	F (1995-2001)
M = 0.87					
F_{MAX}	0.64	1.52	**0.65**	1.77	**0.90**
$F_{0.1}$	0.45	1.52	**0.65**	1.77	**0.90**
$F_{30\%}$	0.78	1.52	0.65	1.77	**0.90**
$F_{20\%}$	1.12	1.52	0.65	1.77	0.90
		Z (1987-2001)	F (1987-2001)	Z (1995-2001)	F (1995-2001)
M = 1.44					
F_{MAX}	0.93	1.57	0.13	1.61	0.17
$F_{0.1}$	0.62	1.57	0.13	1.61	0.17
$F_{30\%}$	1.07	1.57	0.13	1.61	0.17
$F_{20\%}$	1.55	1.57	0.13	1.61	0.17

Table 16. Percent of mature females greater than 6 ¾" of the total crabs legal (crabs > 127 mm CW and mature females) to be harvested in the hard crab fishery from P195 trawl surveys between 1987 and 2002, and trawls surveys conducted in the inlet sanctuaries (Barden's, Drum, Hatteras, Ocracoke, Oregon) and Cape Fear River in 2002.

	Program 195		Inlet Sanctuaries		Cape Fear River	
Year	N	%	N	%	N	%
1987	1148	0.52				
1988	316	0.32				
1989	786	0.51				
1990	825	0.49				
1991	944	0.21				
1992	717	0.84				
1993	541	0.74				
1994	376	0.80				
1995	267	1.12				
1996	764	0.65				
1997	412	0.73				
1998	422	1.66				
1999	319	1.57				
2000	150	2.00				
2001	177	1.13				
2002	750	0.67	215	0.93	1179	16.28
Mean		0.87		0.93		16.28

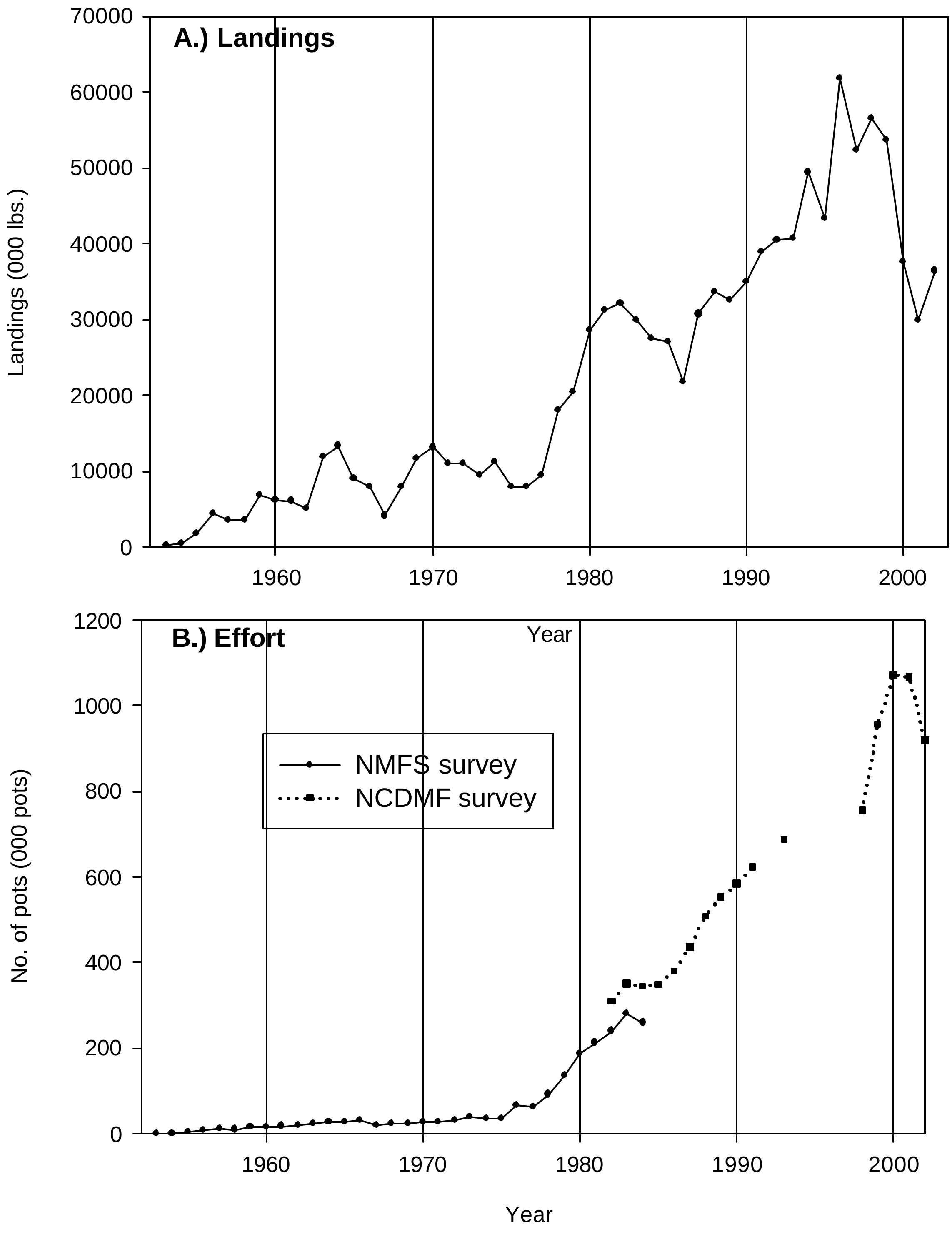


Figure 1. A.) Commercial landings in North Carolina from 1953 - 2002, and B.) National Marine Fisheries Service (NMFS) and North Carolina Division of Marine Fisheries (NC DMF) estimates of effort for the North Carolina Blue Crab pot fishery from 1953 - 2002. Fishing effort from 1994-1997 was removed because of problems with assumed over reporting in response to perceived pot limit legislation (S. McKenna, NC DMF, pers. comm.).

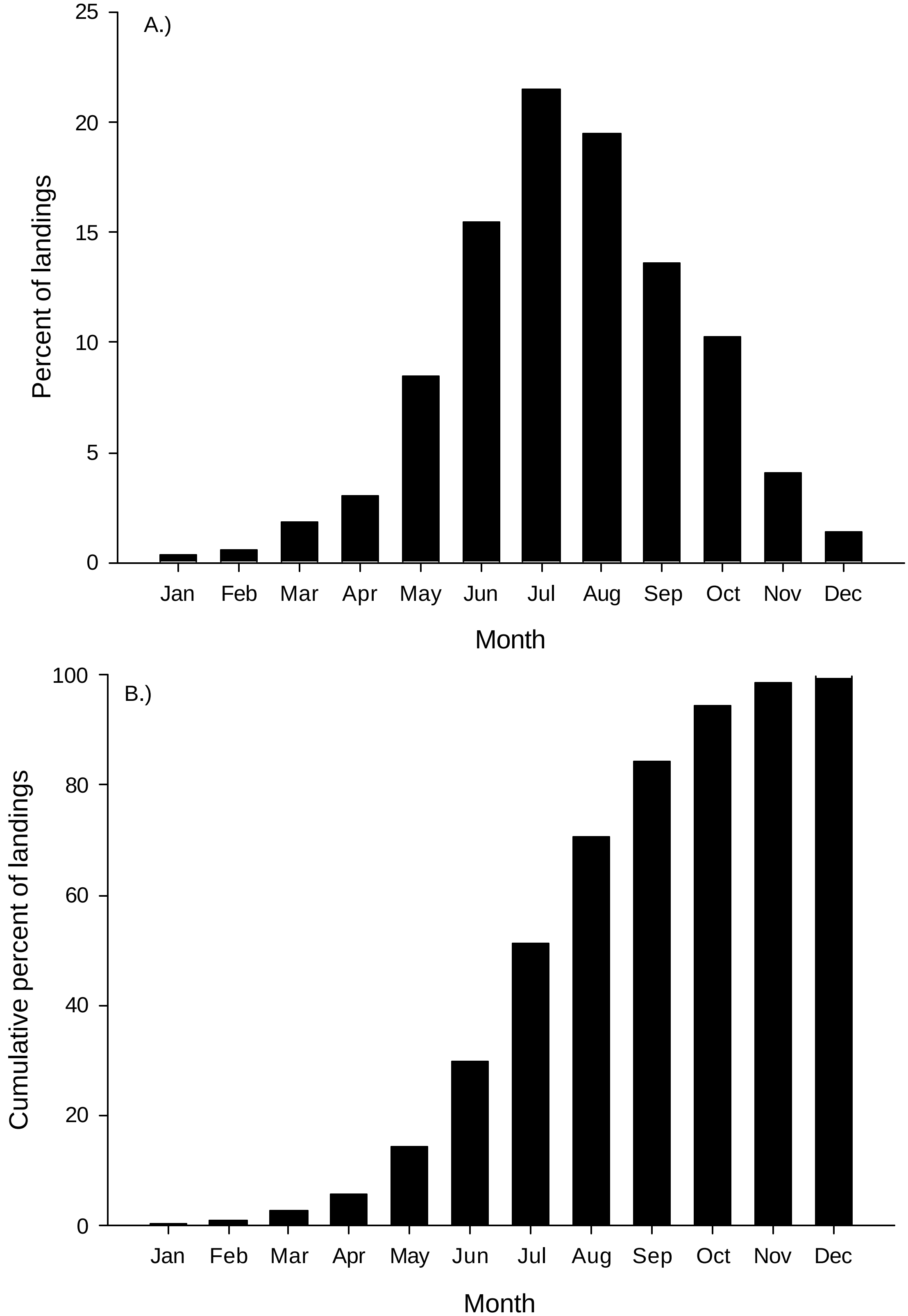


Figure 2. North Carolina commercial landings averaged by month from 1987 - 2002 A.) percentage of landings by month, and B.) cumulative percentage of annual commercial landings.

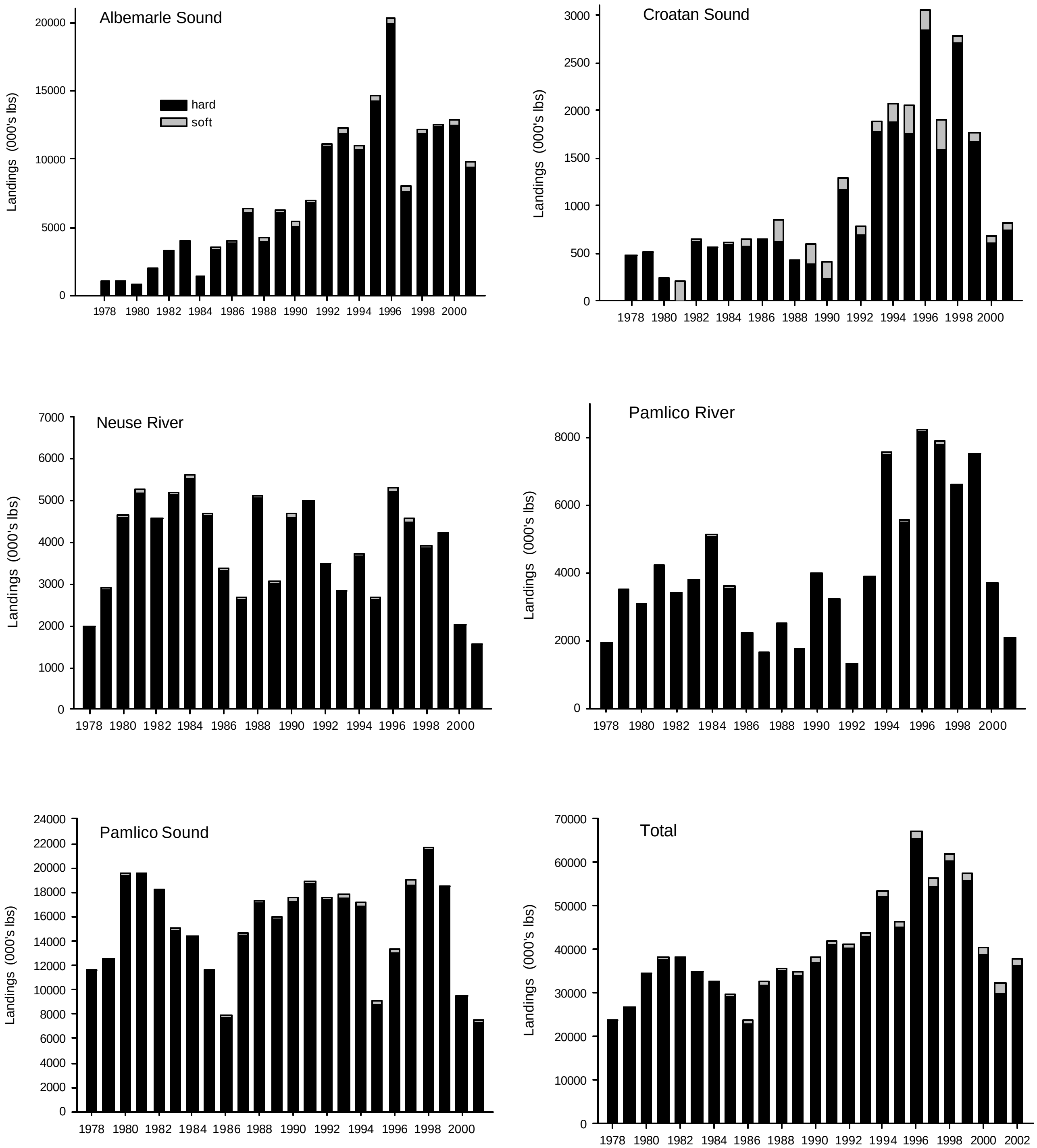


Figure 3. Commercial landings of hard and soft blue crabs in North Carolina by water body and year (1978-2001). These years were chosen as a comparison with blue crab trawl survey data collected by the NC DMF from 1978-2002 (Program 120 and Program 195). The landings for all five water bodies pooled equals total landings.

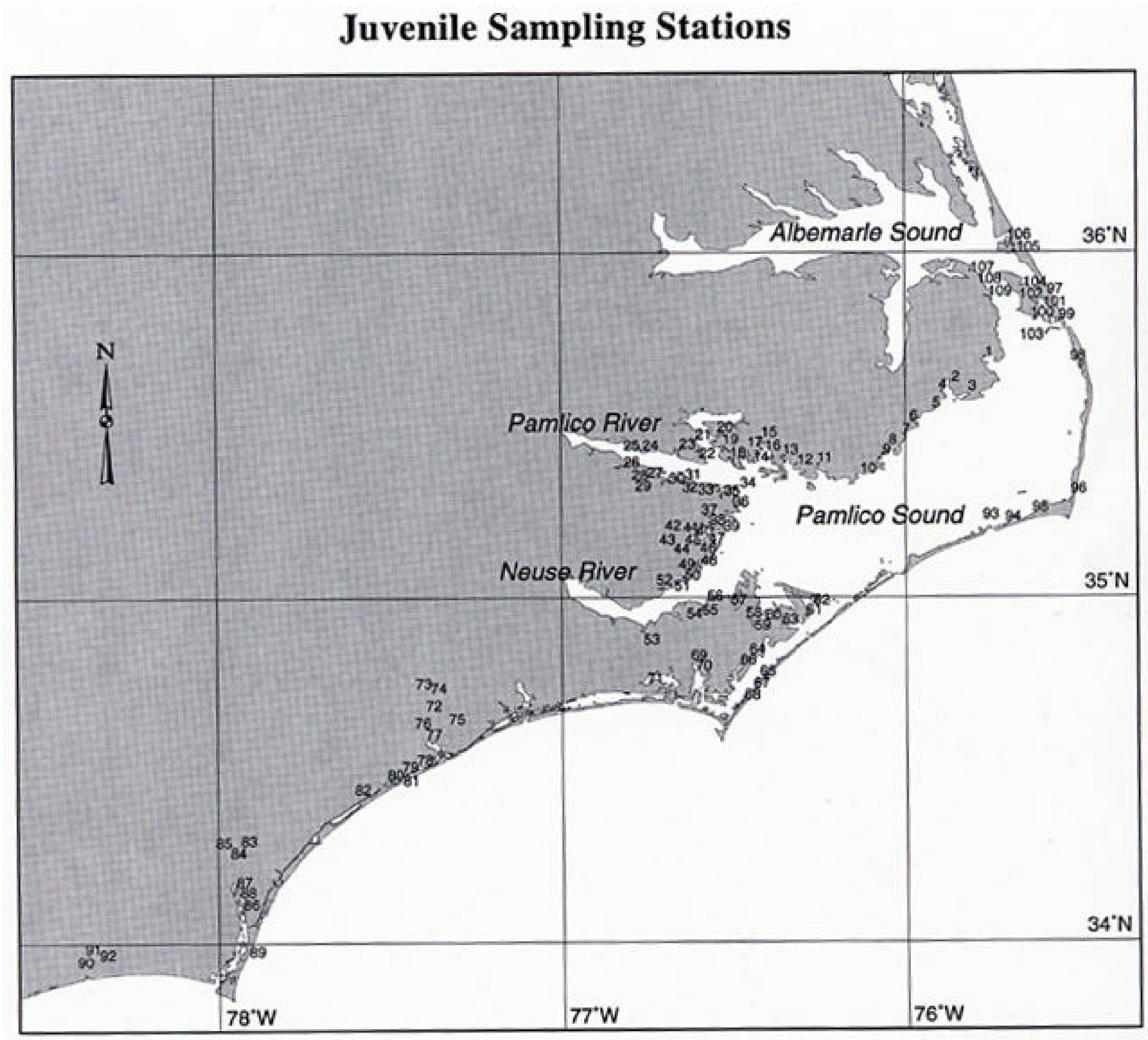


Figure 4. Locations of trawl survey sampling stations for juvenile blue crabs conducted by the North Carolina Division of Marine Fisheries (NC DMF Program 120). See Table 2 for the water body and sampling area for a given station number.

Adult Sampling Stations

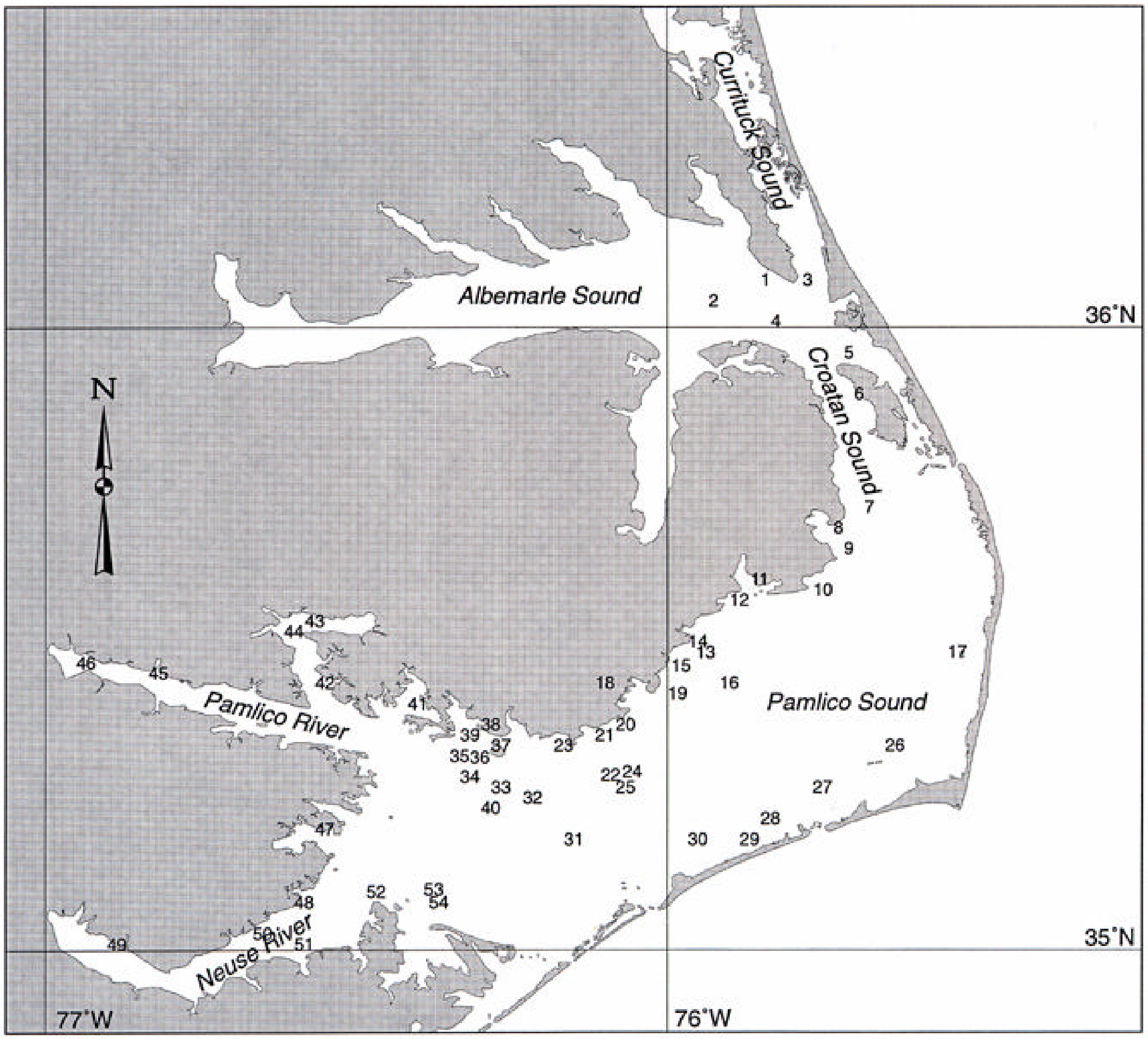


Figure 5. Locations of trawl survey core sampling stations for adult blue crabs conducted by the North Carolina Division of Marine Fisheries (NC DMF Program 195). See Table 3 for the water body and sampling area for a given station number.

Adult Sampling Sites within Stations

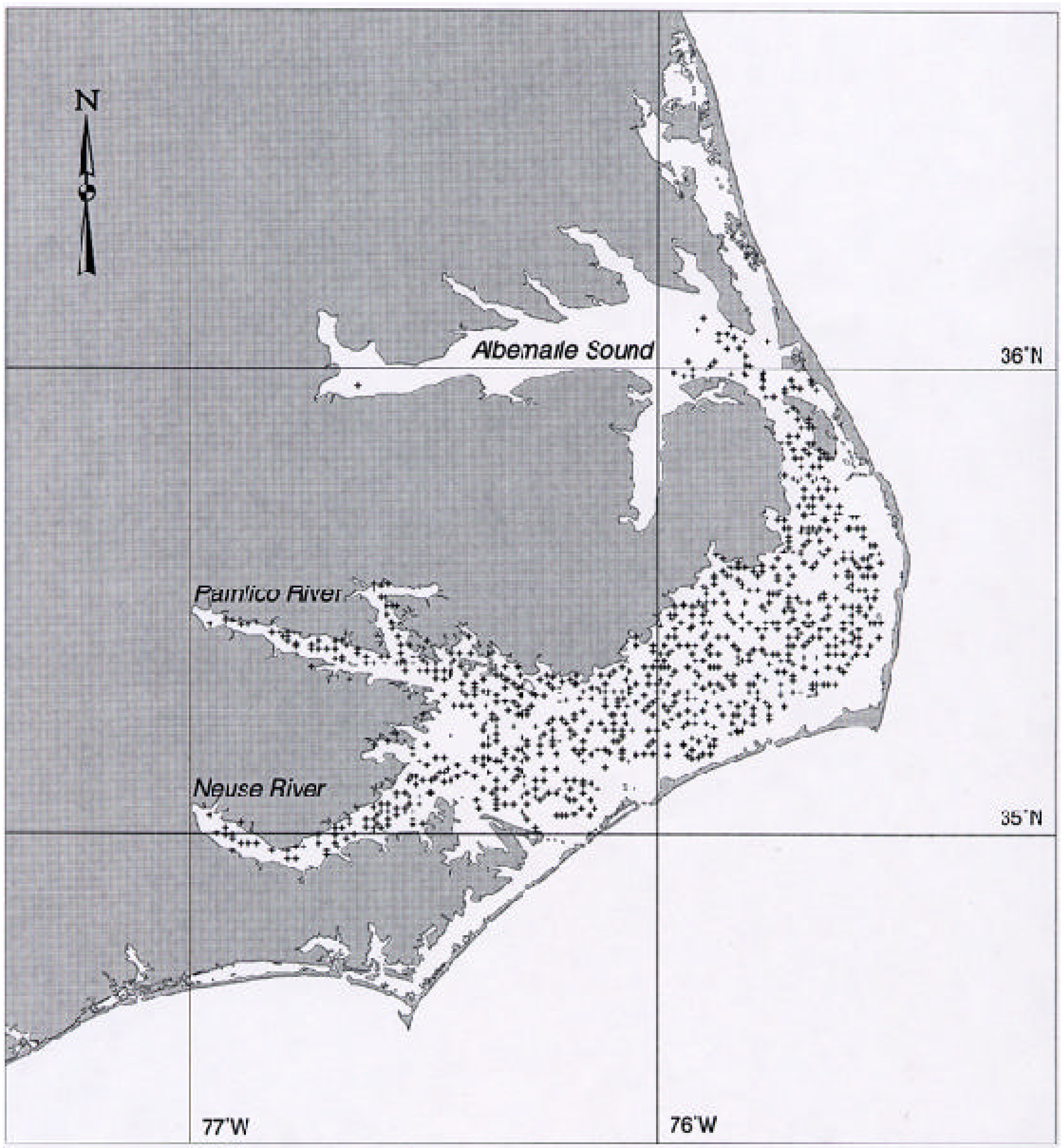


Figure 6. Locations of trawl survey sampling sites within core sampling stations (Fig. 5) for adult blue crabs conducted by the North Carolina Division of Marine Fisheries (NC DMF Program 195).

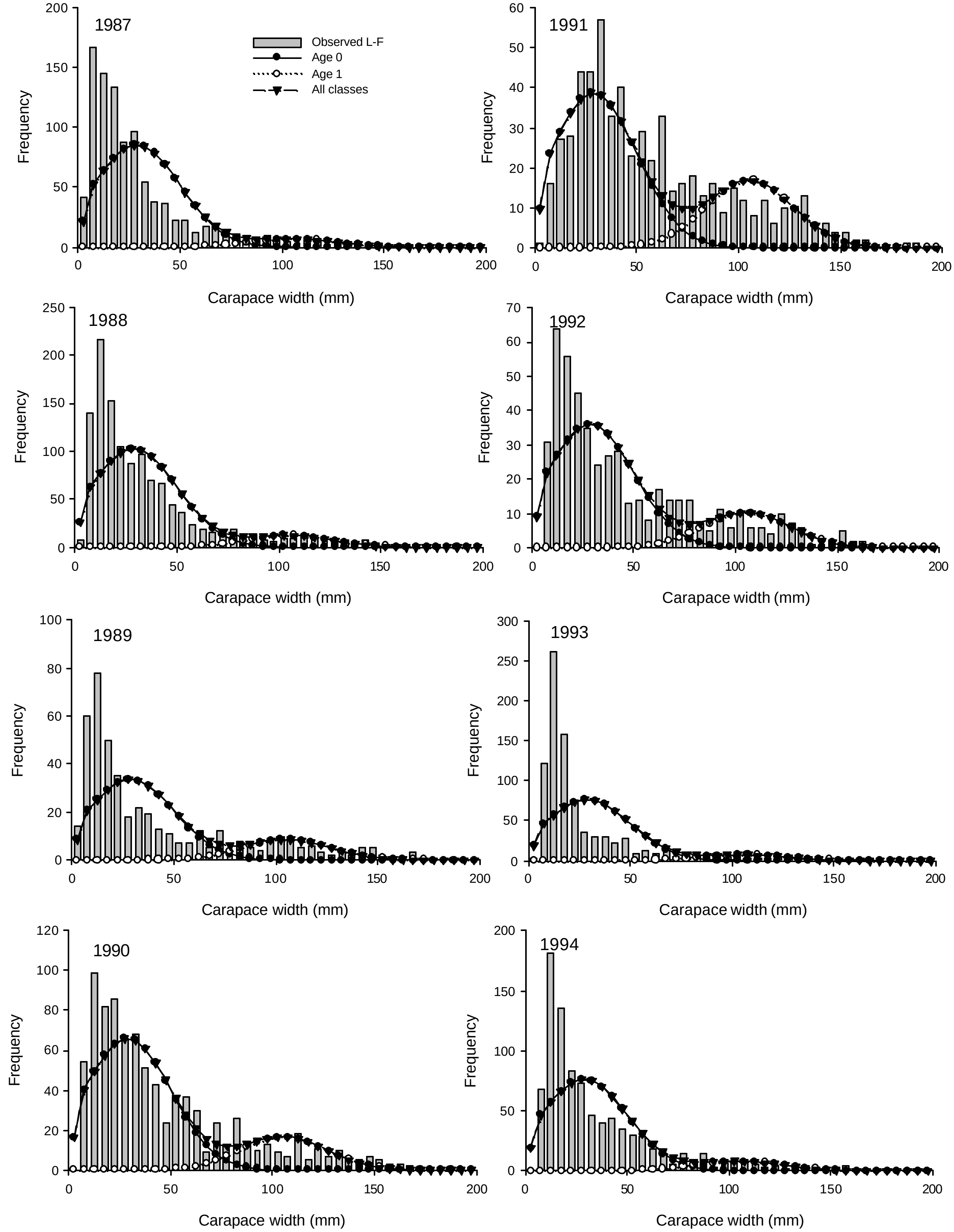


Figure 7. The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 120 in May from 1987 – 2002 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

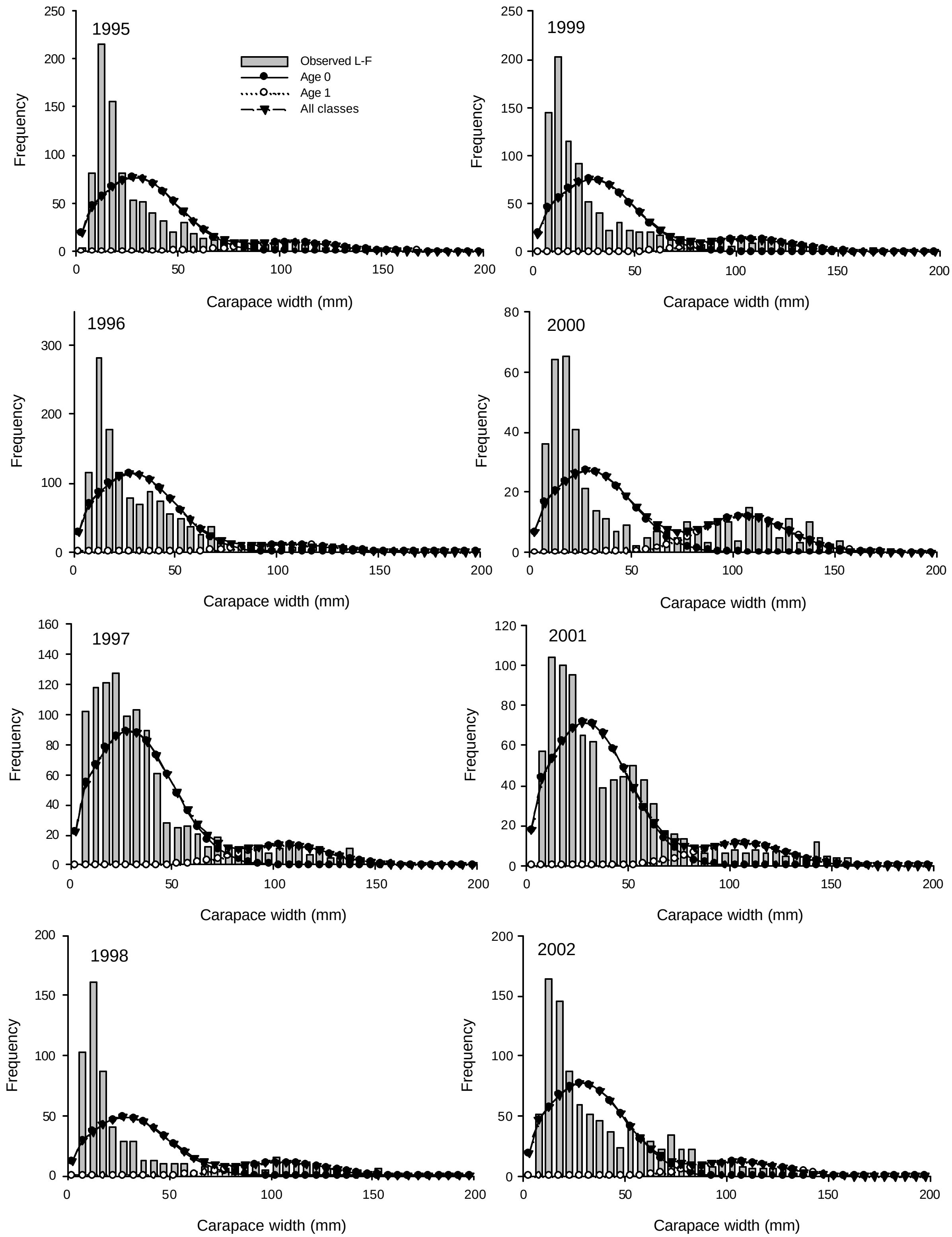


Figure 7 (continued). The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 120 in May from 1987 – 2002 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

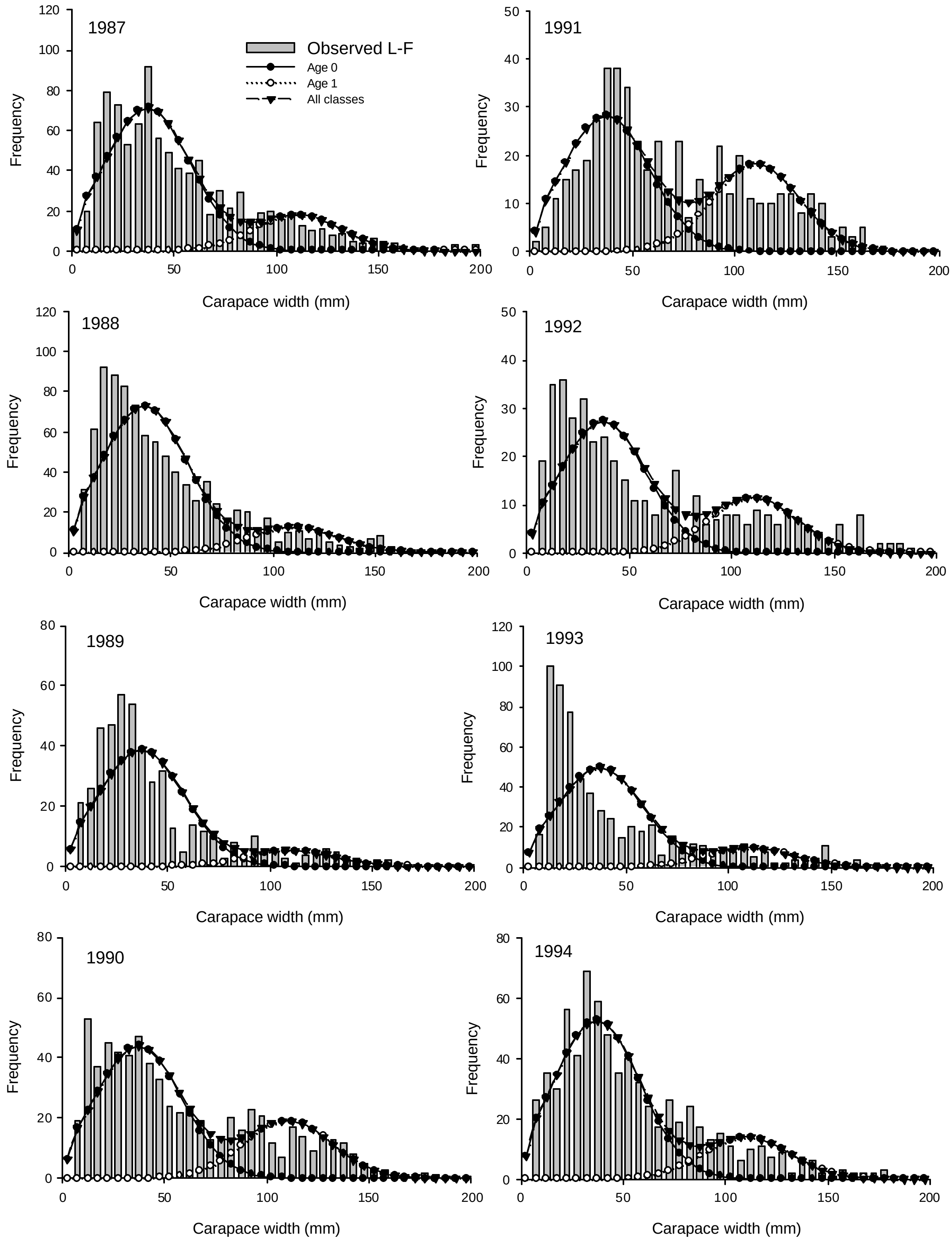


Figure 8. The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 120 in June from 1987 – 2002 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

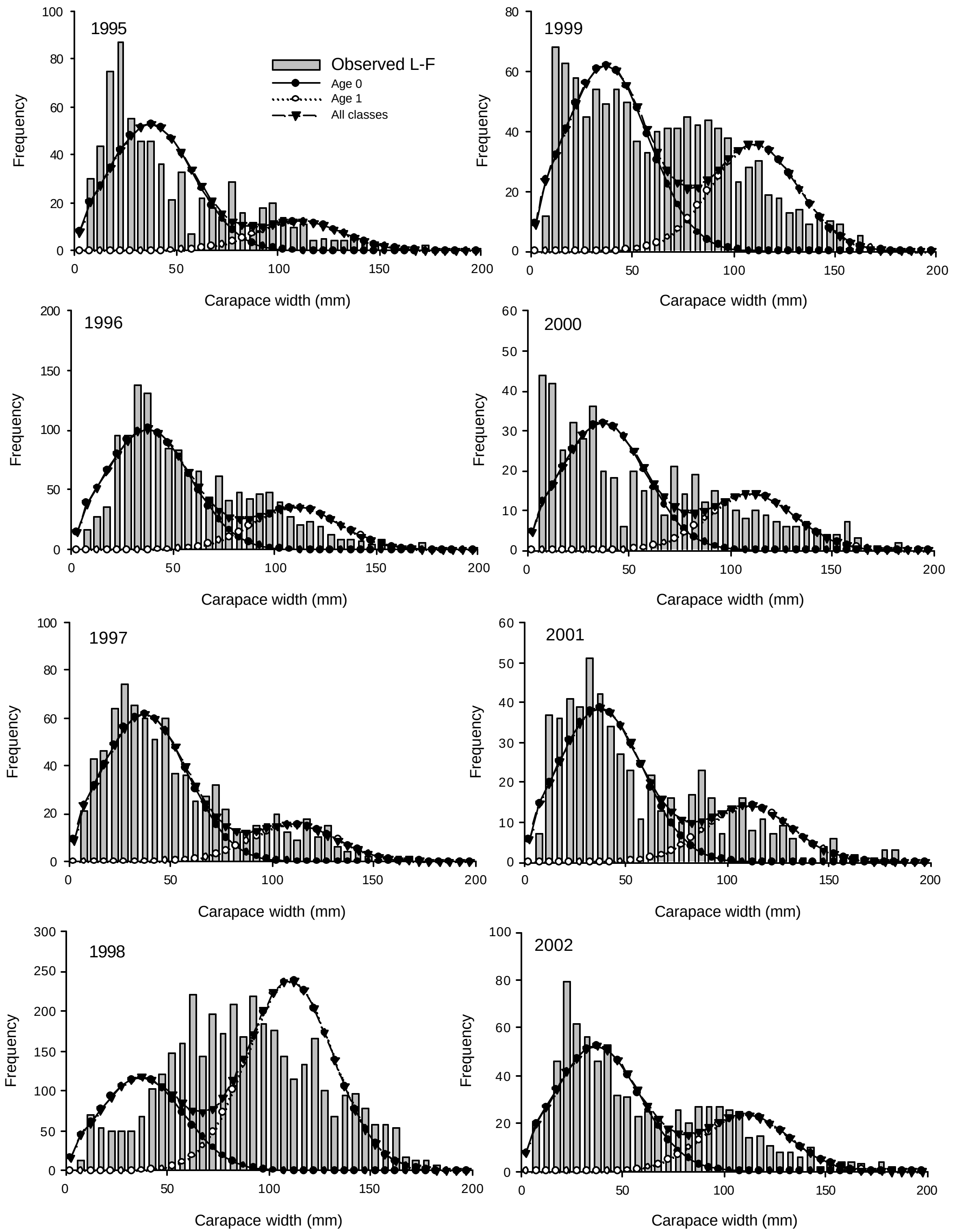


Figure 8 (continued). The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 120 in June from 1987 – 2002 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

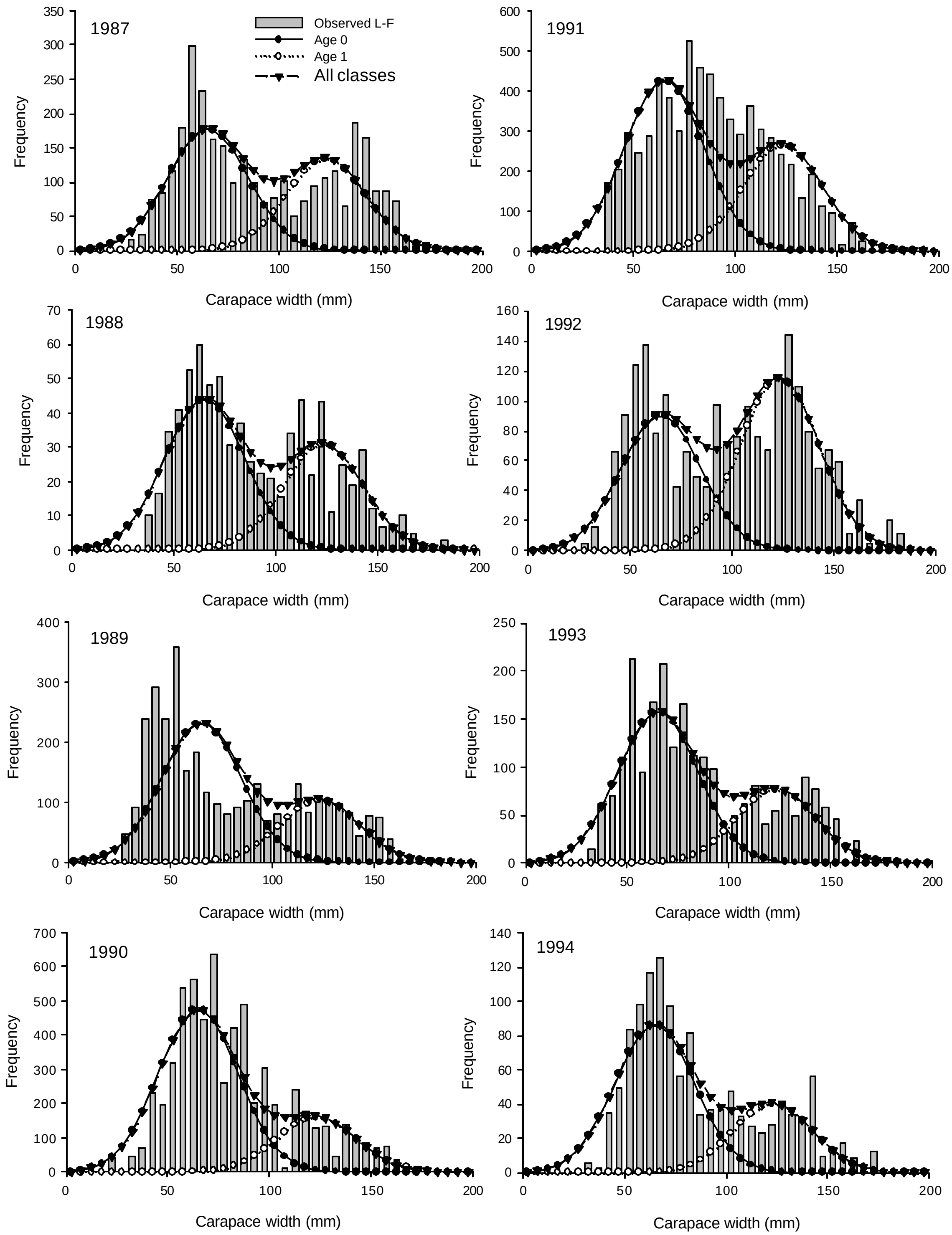


Figure 9. The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 195 in June from 1987 – 2003 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

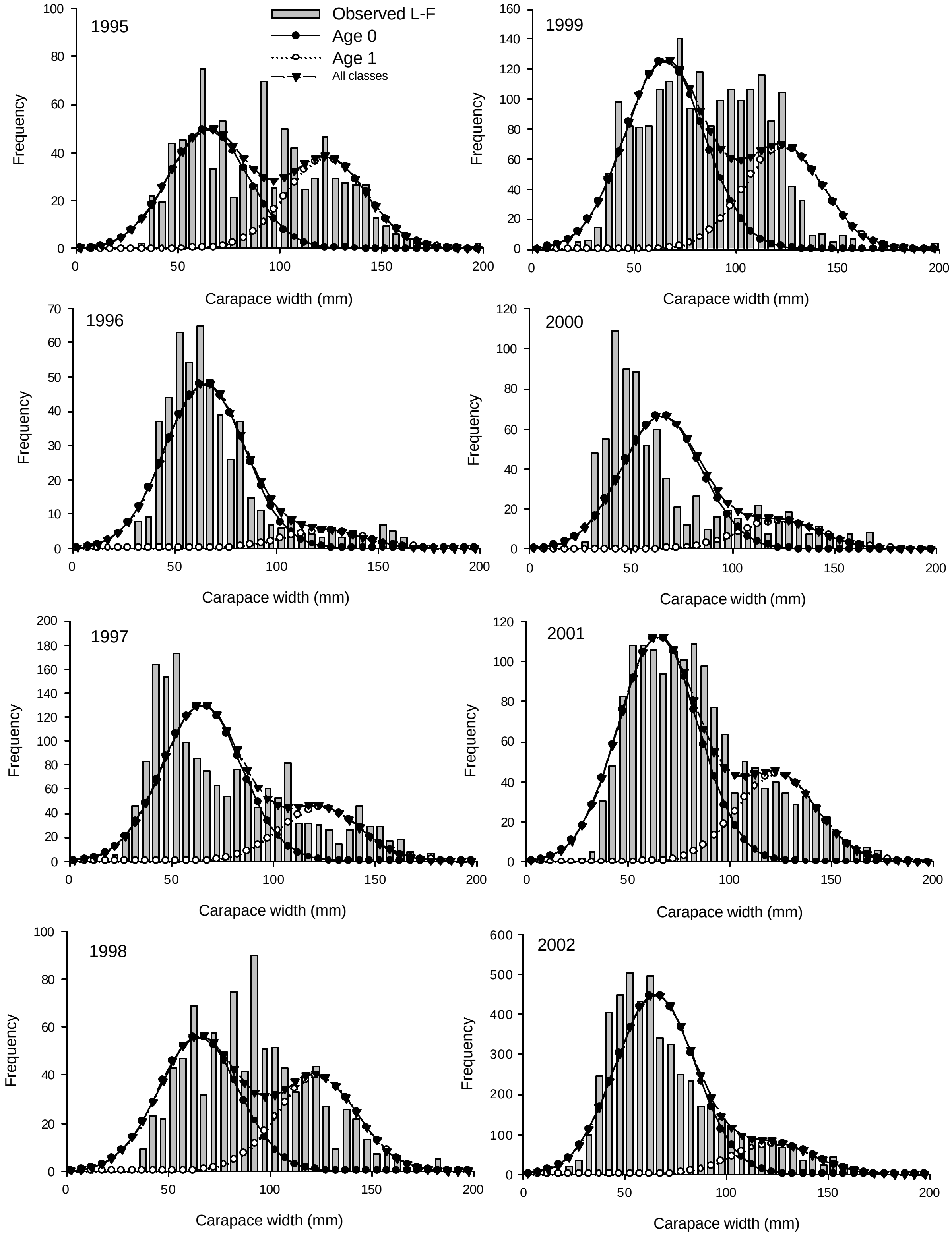


Figure 9 (continued). The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 195 in June (except 1999 which occurred in July) from 1987 – 2003 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

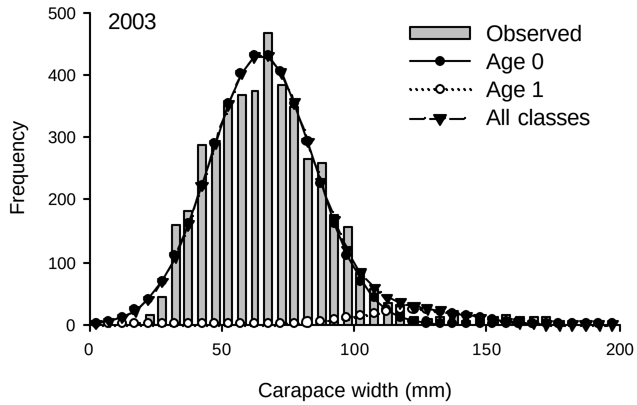


Figure 9 (continued). The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 195 in June from 1987 – 2003 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

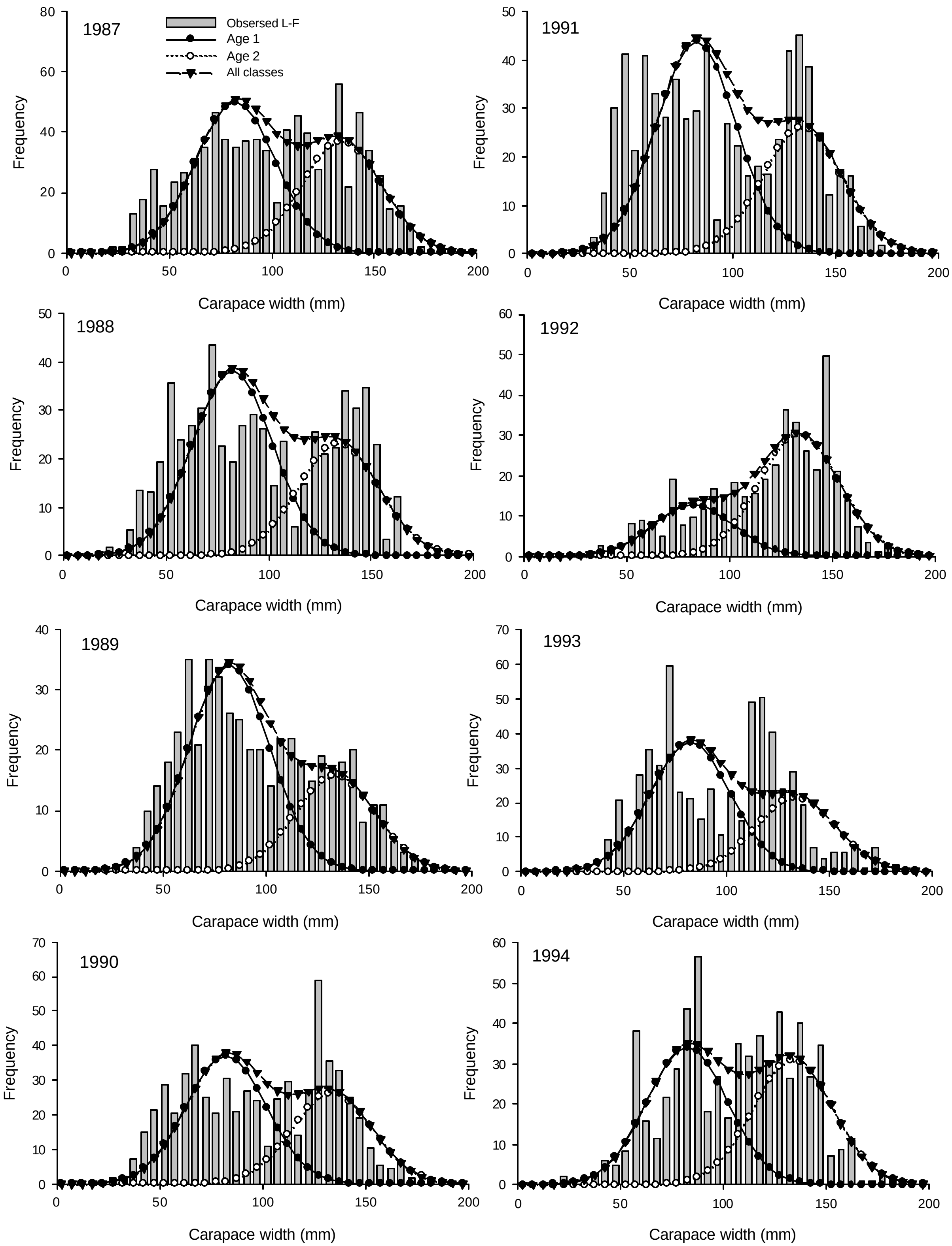


Figure 10. The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 195 in September from 1987 – 2003 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

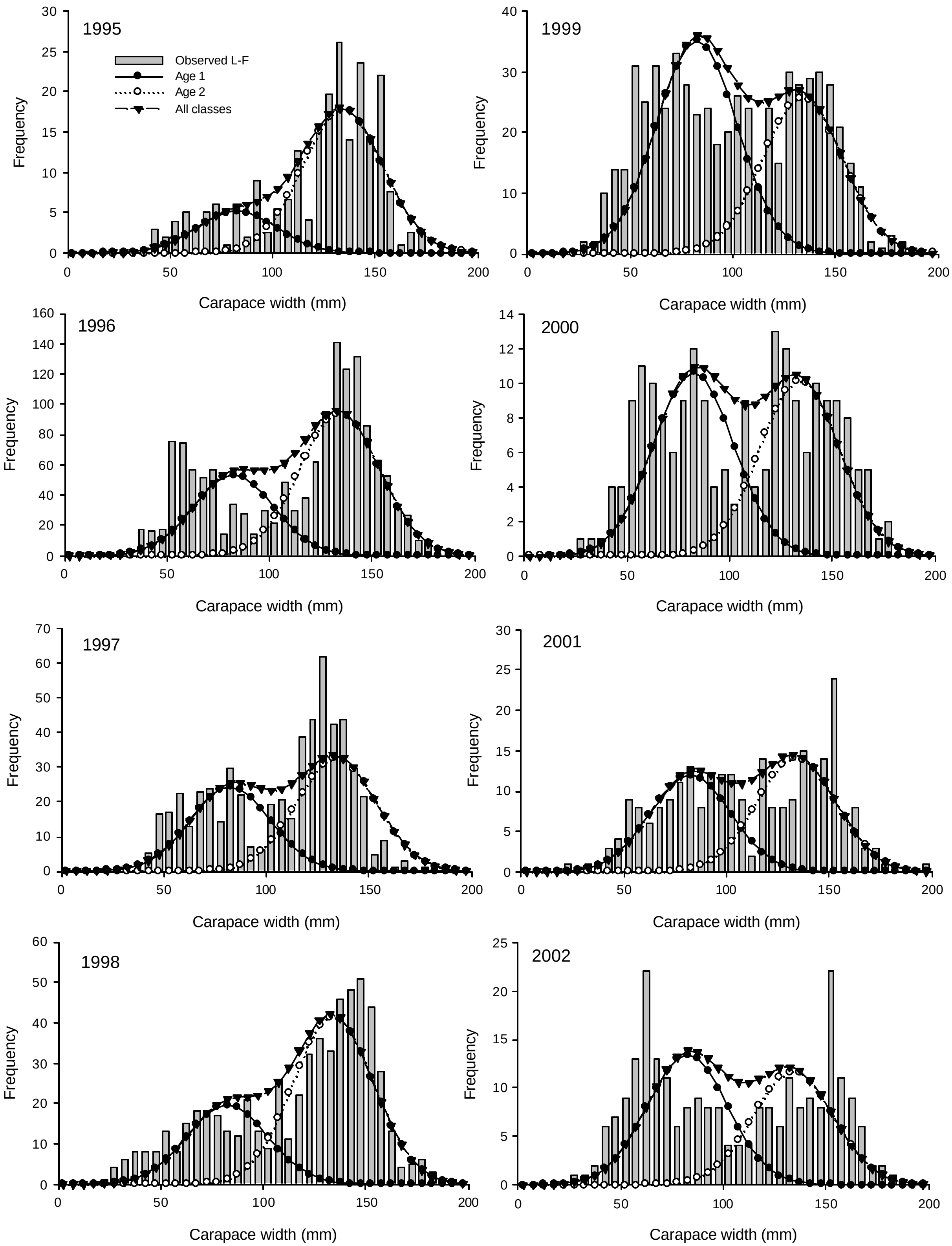


Figure 10 (continued). The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 195 in September (except 1999 in which surveys were conducted in October) from 1987 – 2003 pooled across all water bodies. The predicted fits shown were produced by minimizing a log-likelihood length-based model.

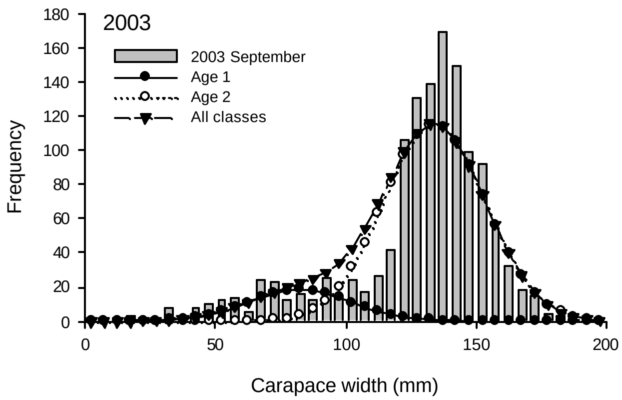


Figure 10 (continued). The observed (histograms) and predicted (symbols) size frequency of blue crabs by year collected in NC DMF Program 195 in September from 1987 – 2003 pooled across all water bodies The predicted fits shown were produced by minimizing a log-likelihood length-based model.

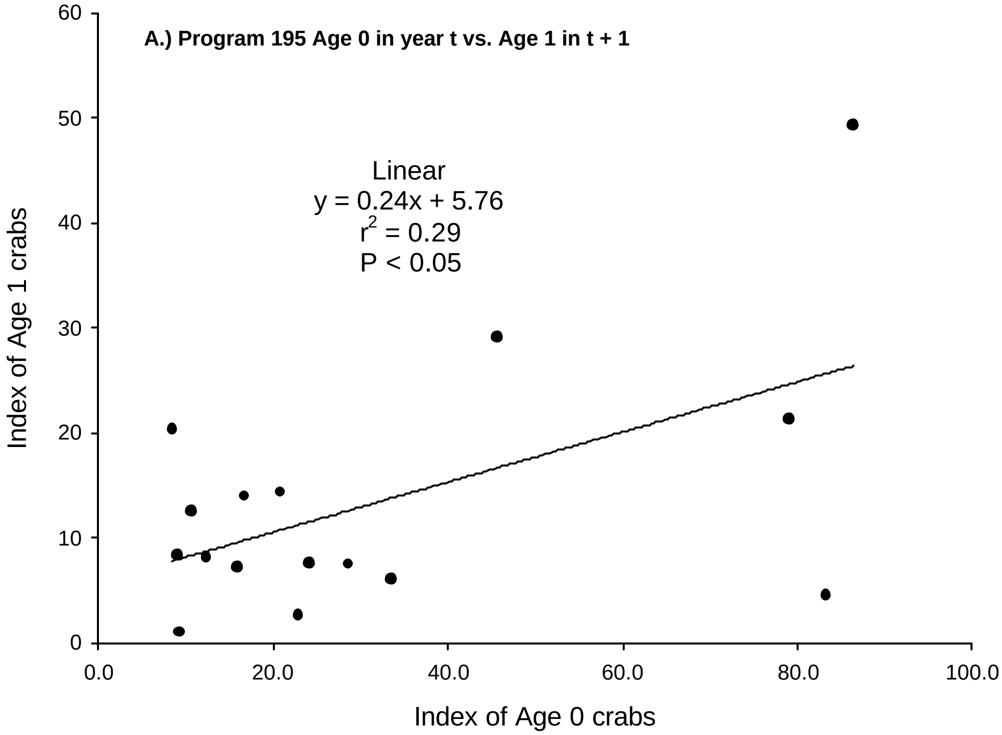


Figure 11. Relationship between mean indices of abundance from NC DMF trawl surveys for A.) Indices of Program 195 June Age 0 crabs in year t and Age 1 crabs in year t + 1.

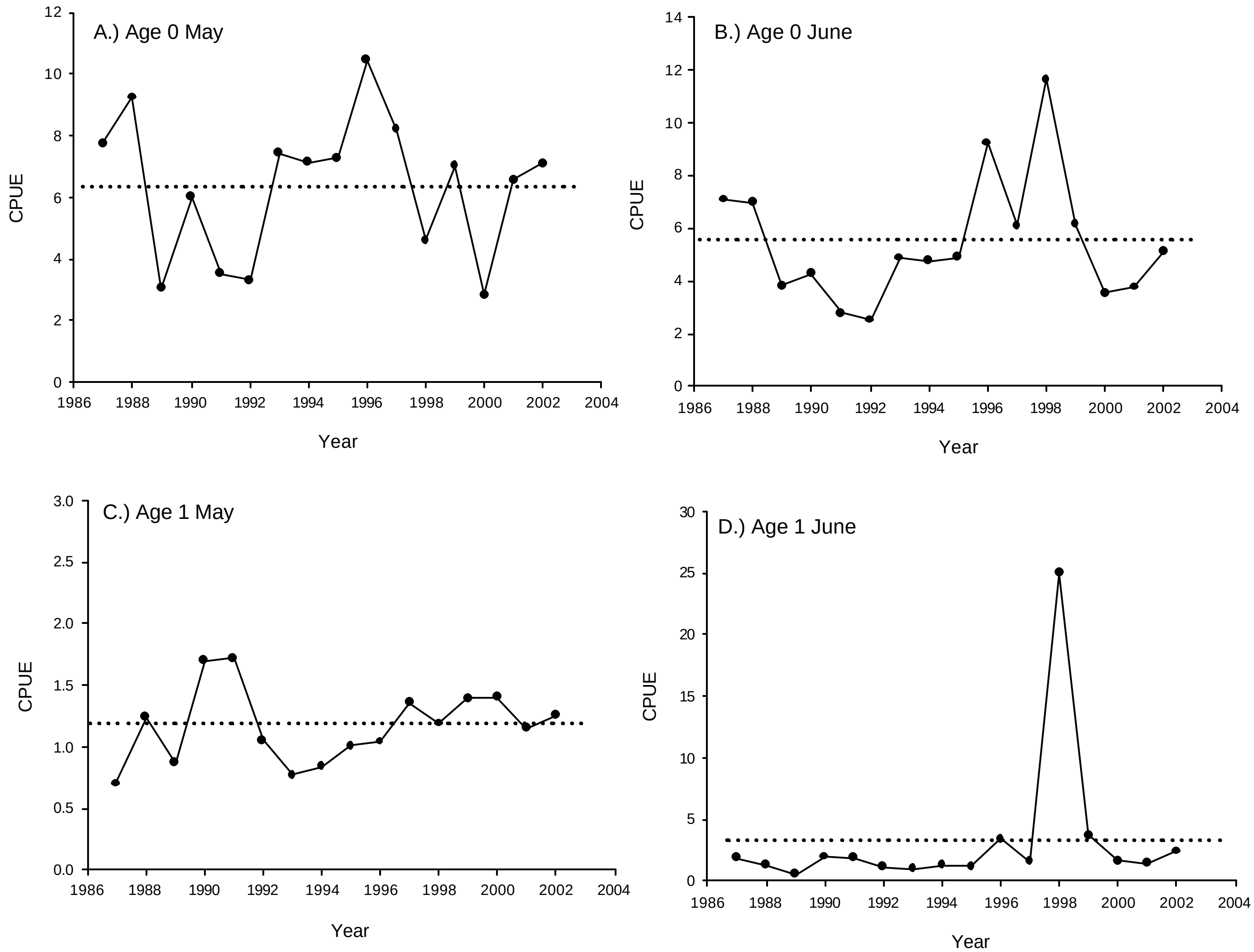


Figure 12. Annual mean trawl survey index of abundance (CPUE) pooled across water bodies in North Carolina collected in Program 120 tows 1987 - 2002 for May (panels A and C) and June (panels B and D). The dotted line indictaes the mean CPUE for the entire time series.

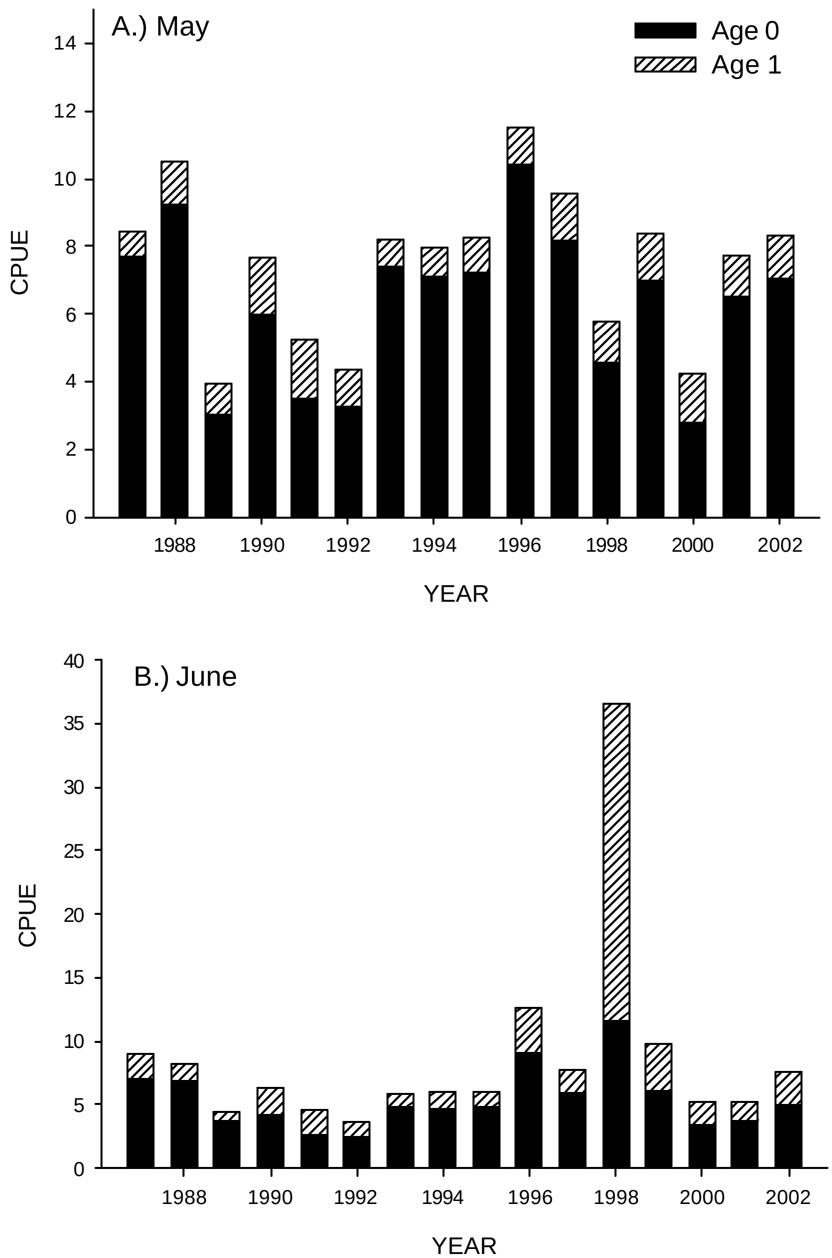


Figure 13. Mean catch-per-unit-effort of blue crabs from Program 120 (May and June) by year, and age class. The CPUE for all eight water bodies pooled equals the total CPUE.

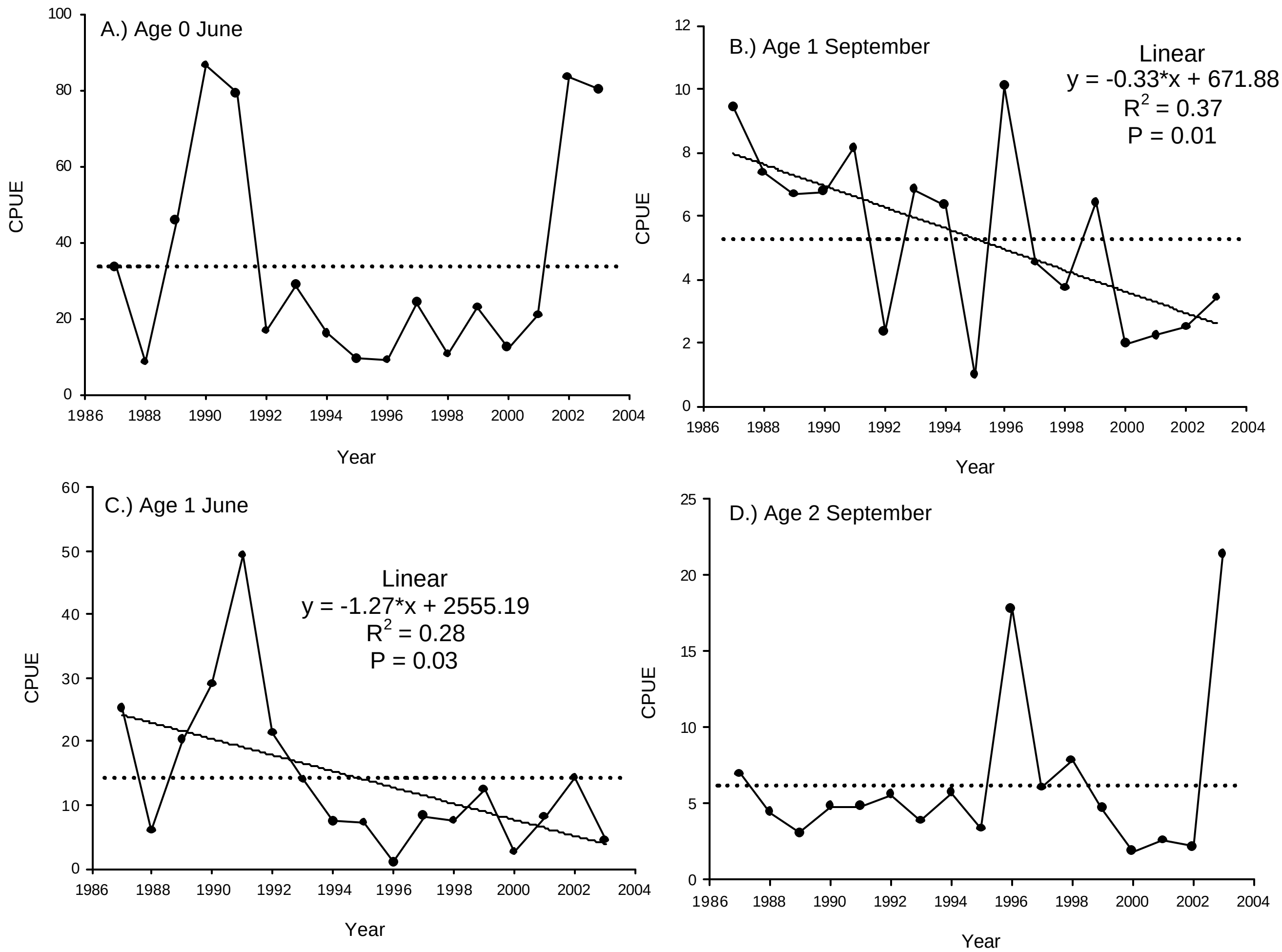
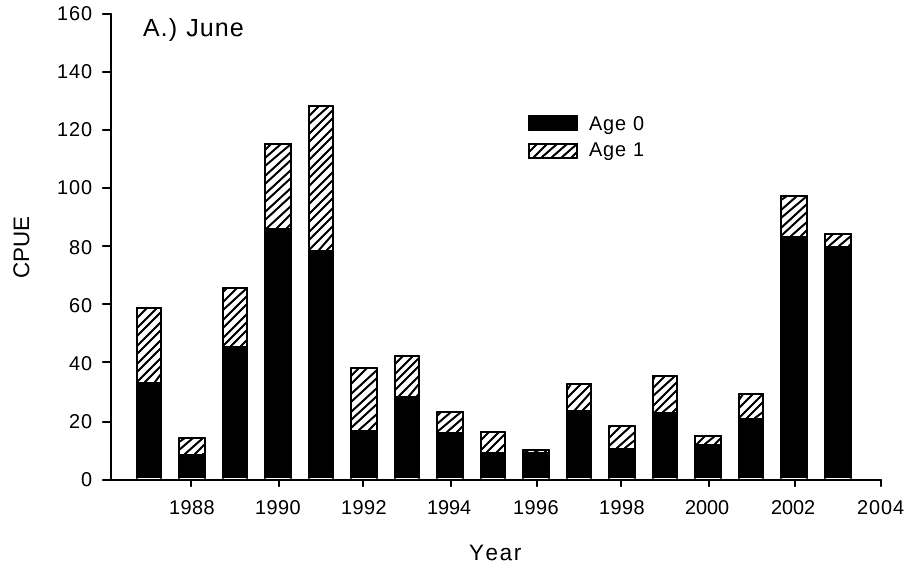


Figure 14. Annual mean trawl survey index of abundance (CPUE) pooled across water bodies in North Carolina collected in Program 195 tows 1987 - 2002. The dotted line indicates the mean CPUE for the entire time series. Linear regression models were fit to the data, and significant regressions are shown. Plots are shown in chronological order and assume a September 15th birth date for a given year class (see text for justification). For example, Age 0 crabs sampled in June are 0.75 years of age, calculated by dividing the 273 days between the assumed birthdate (September 15th) and the timing of sampling assumed to be the mid-point of each sampling month (June 15th), by the 365 days in a calender year. Similarly, Age 1 crabs sampled in September were assumed to be collected on their birthday and be exactly one year old.



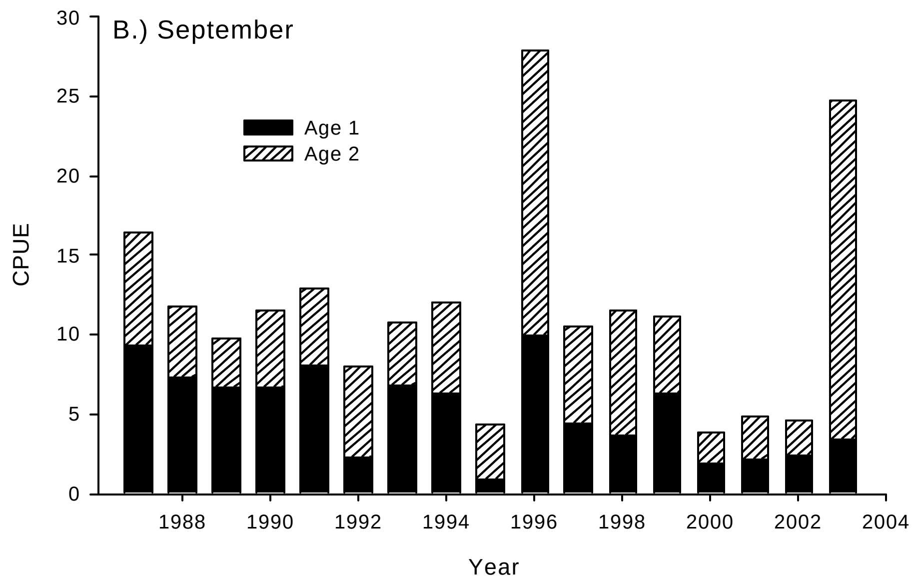


Figure 15. Mean catch-per-unit-effort of blue crabs from Program 195 (June and September) by water body, year, and age class. Note y-axes differ.

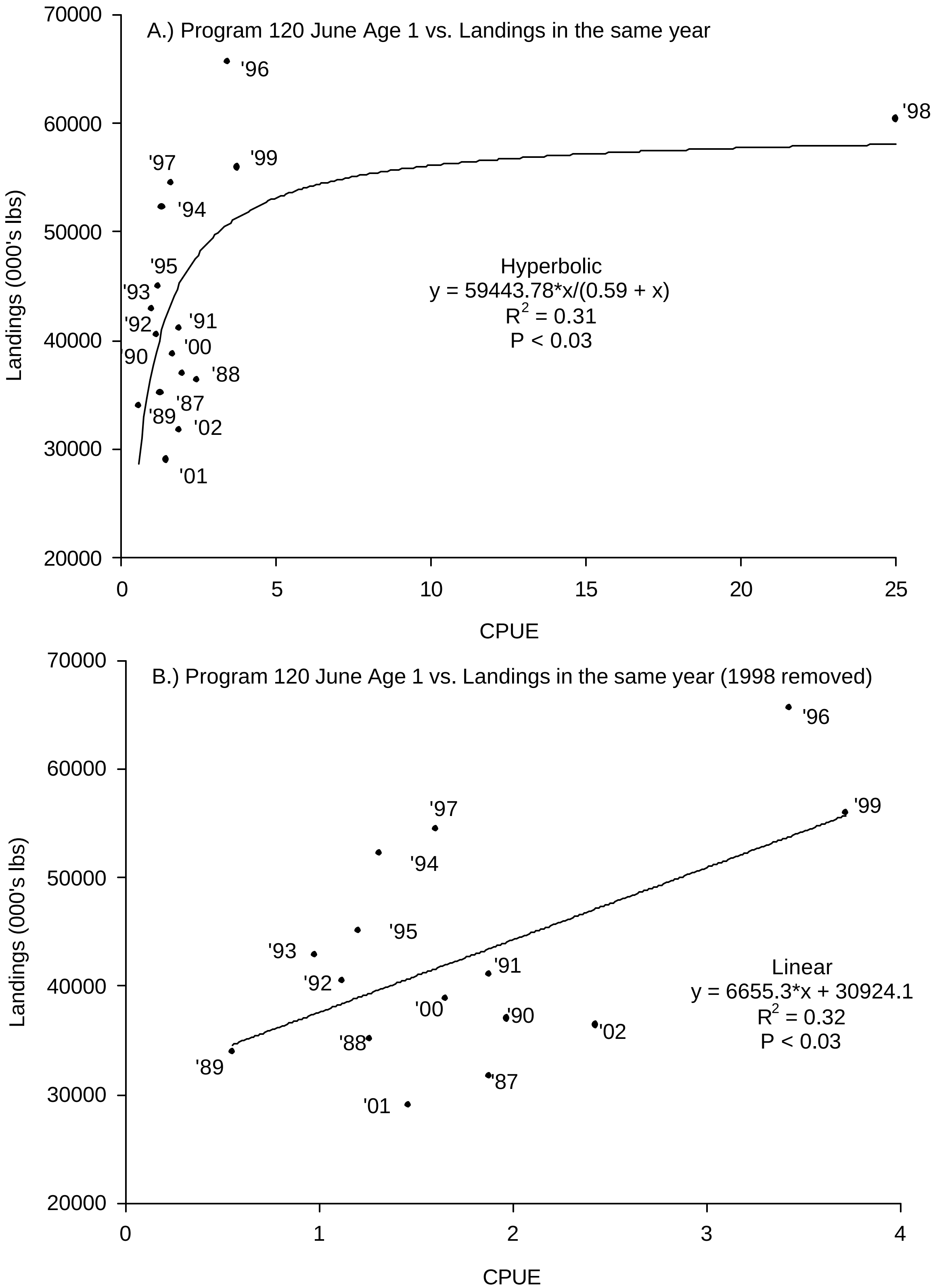


Figure 16. Relationship between A.) mean annual CPUE of Age 1 crabs from Program 120 June and commercial landings from 1987 - 2002, and B.) mean annual CPUE of Age 1 crabs from Program 120 June and commercial landings with 1998 data removed.

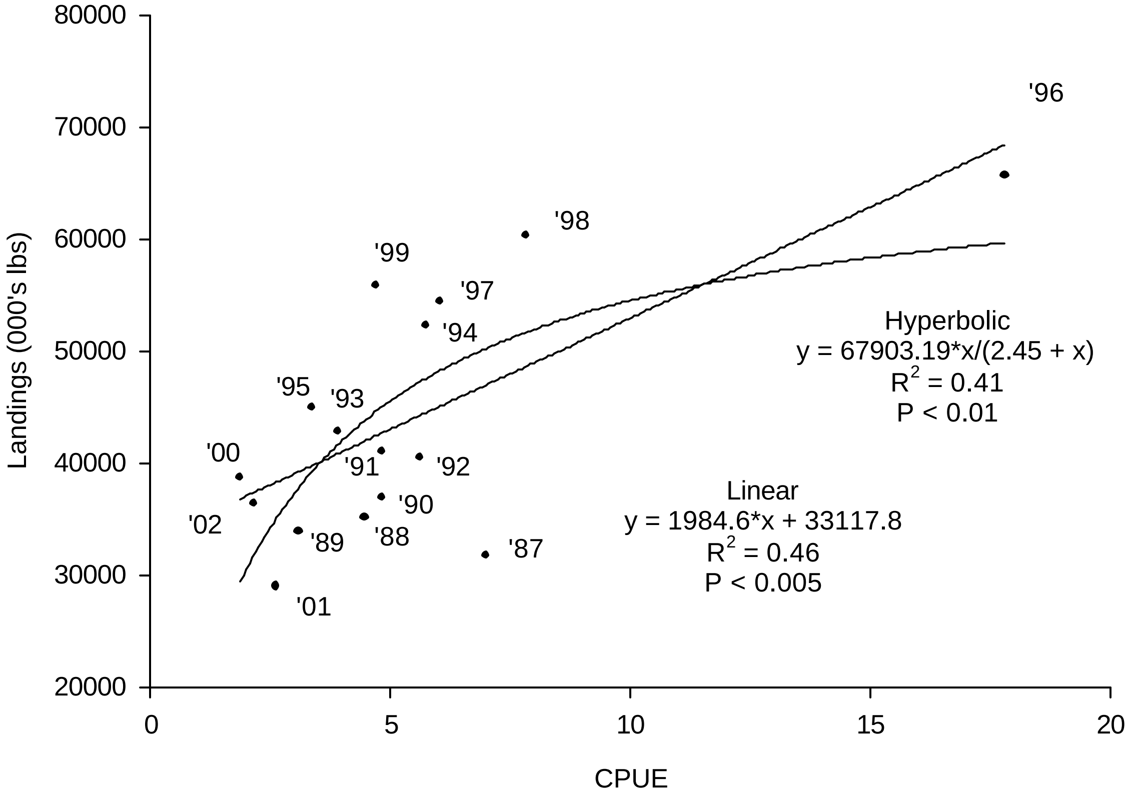


Figure 17. Relationship between mean annual CPUE of Age 2 crabs from Program 195 September and commercial landings from 1987 - 2002.

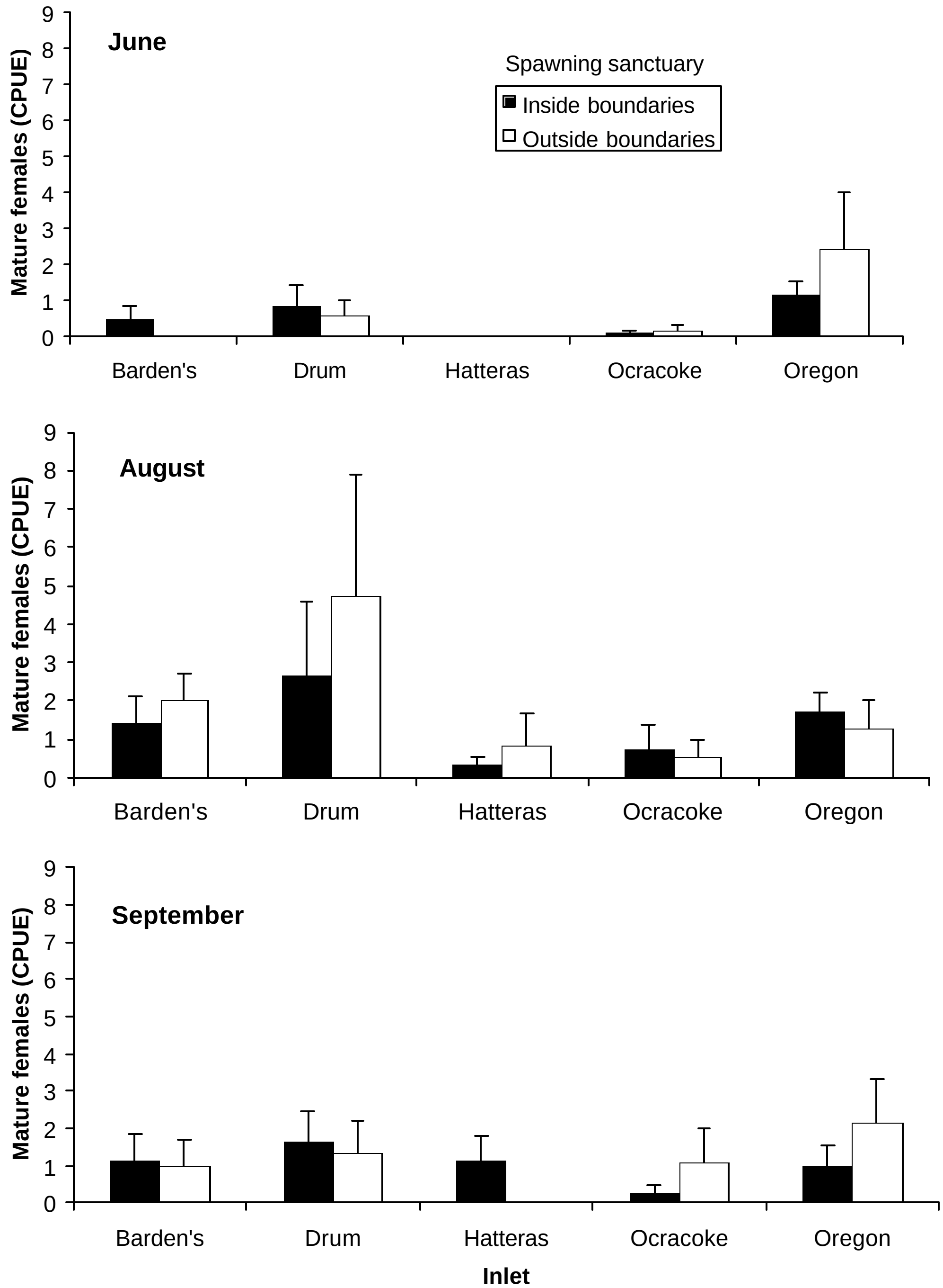


Figure 18. Mean (± SE) catch-per-unit-effort of mature female blue crabs as a function of month (June, August, September), inlet (Barden's, Drum, Hatteras, Ocracoke, Oregon), and within versus outside of blue crab spawning sanctuary boundaries. Statistical analysis of the data indicate that there was no difference in mean crab CPUE within versus outside sanctuary boundaries, higher CPUE in August and September than June, and lowest CPUE in Hatteras and Ocracoke Inlets (adapted from Eggleston 2003).

Relative abundance of larval and megalopal blue crabs off NC & SC

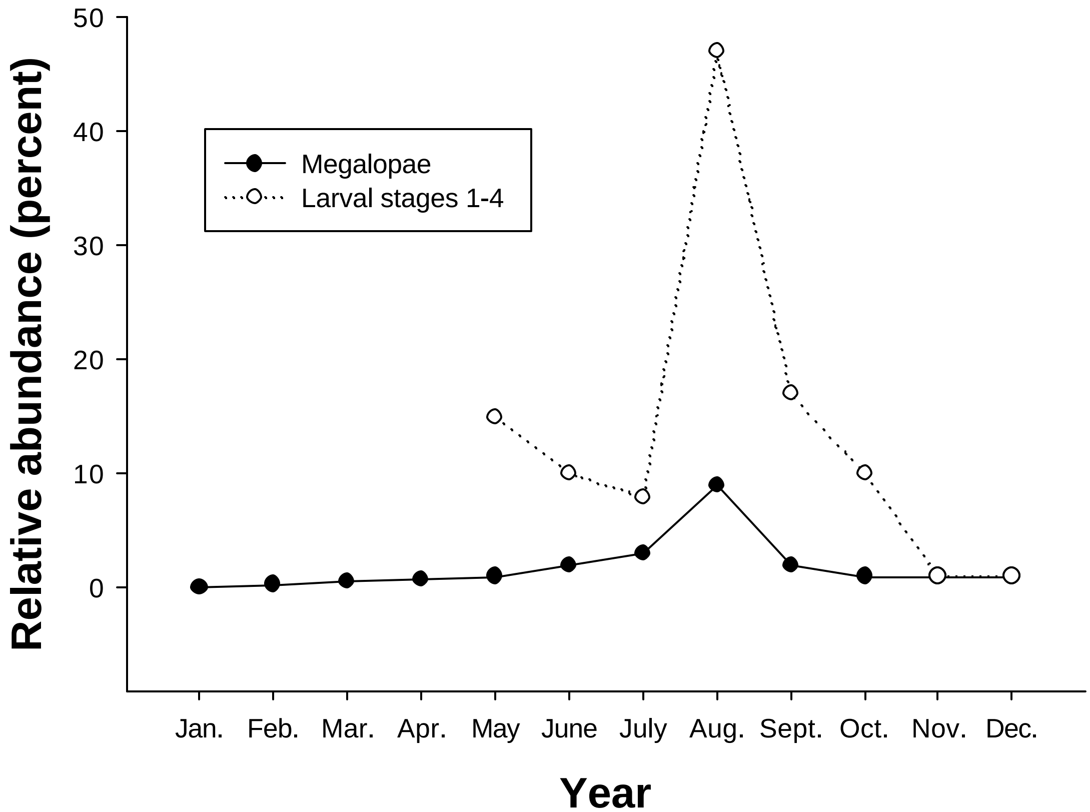


Figure 19. Relative abundance of early stage zoeae and megalopae of the blue crab by month in plankton samples collected on the continental shelf off North and South Carolina during 1953-54 (adapted from Nichols and Keney 1963).

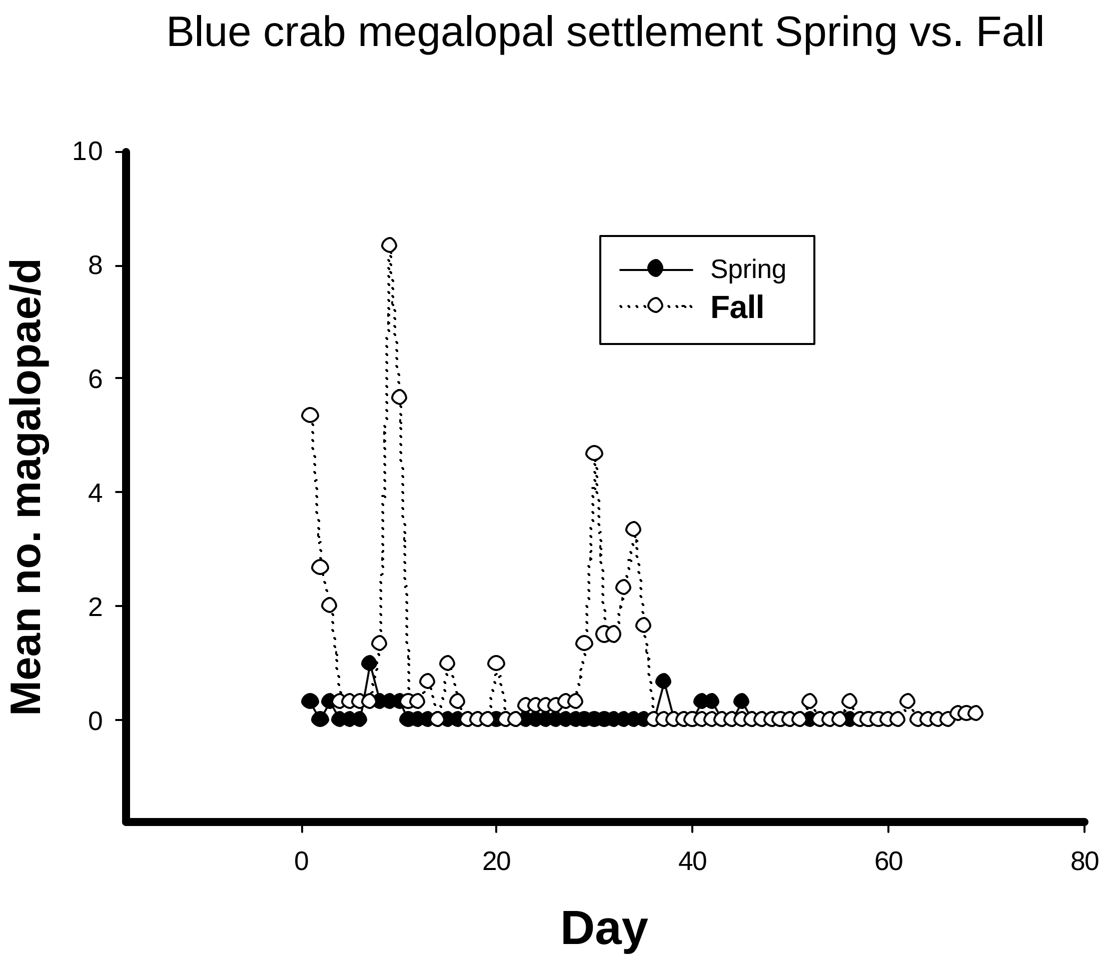


Figure 20. The relative abundance of blue crab megalopae collected on floating, artificial settlement substrates (N = 3) moored on the US Coast Guard dock at Oregon Inlet, NC. During Spring, artificial settlement substrates were checked daily from April 8-June 4, 2002. During late summer-early Fall, artificial substrates were checked daily from August 1-October 31, 2002 (from D. Eggleston, unpubl. data).

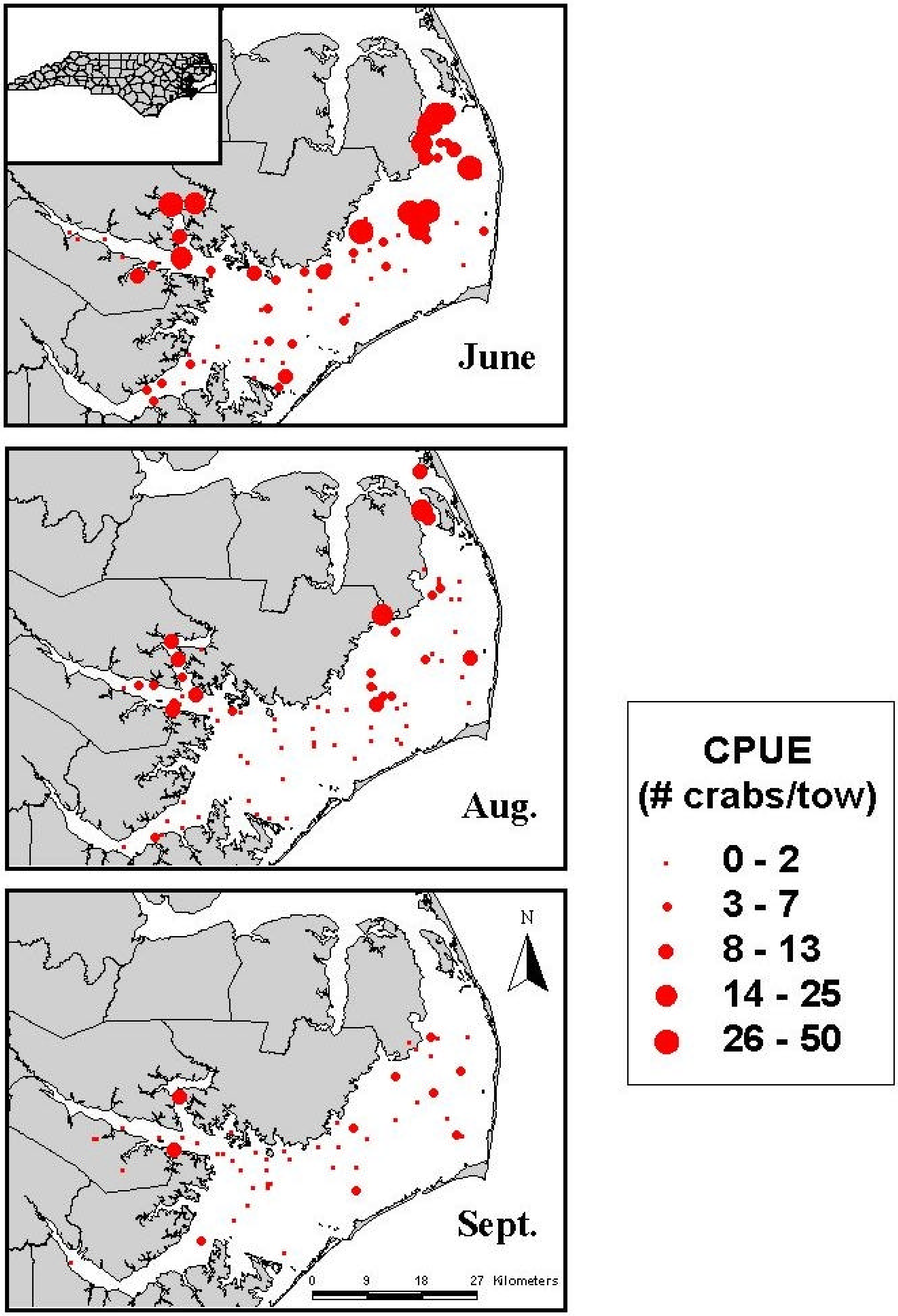


Figure 21. Catch-per-unit-effort of mature female blue crabs from NC DMF Program 195 and supplemental stations (75 stations per month) during 2002. Note decline in relative abundance (CPUE) from June to September (from Eggleston 2003).

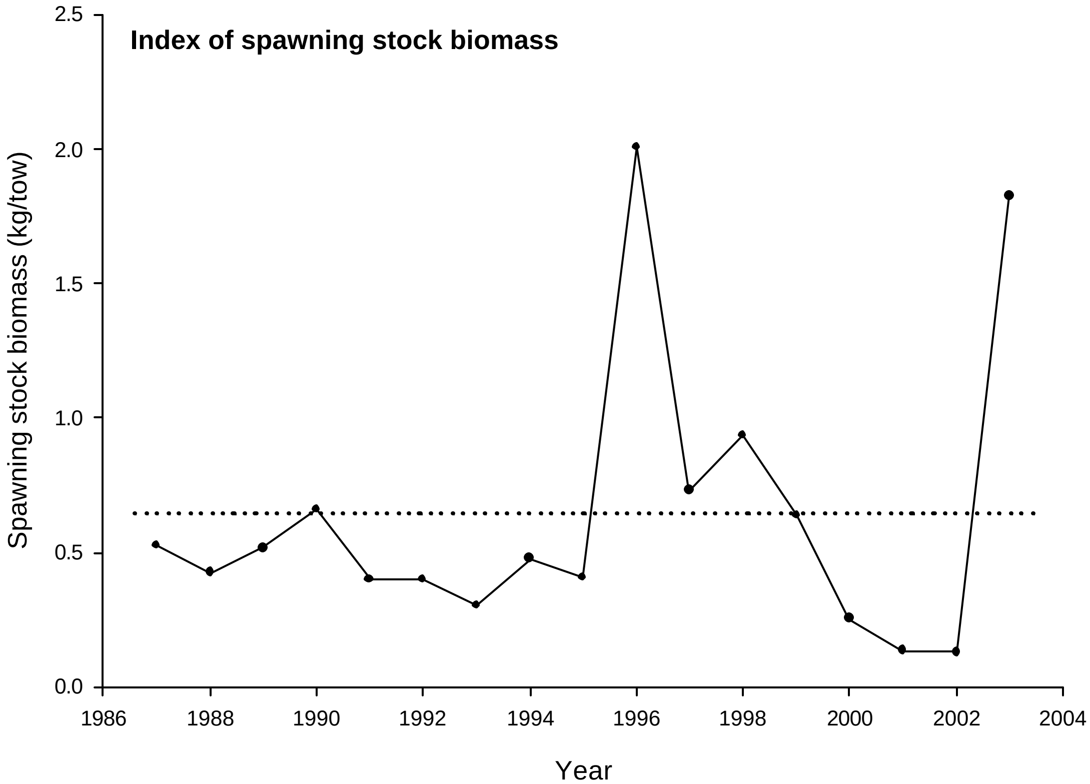


Figure 22. Annual mean trawl survey index of spawning stock biomass (SSB; kg/tow) collected in September from NC DMF Program 195 pooled across water bodies in North Carolina. The dotted line represents the average SSB for the time series.

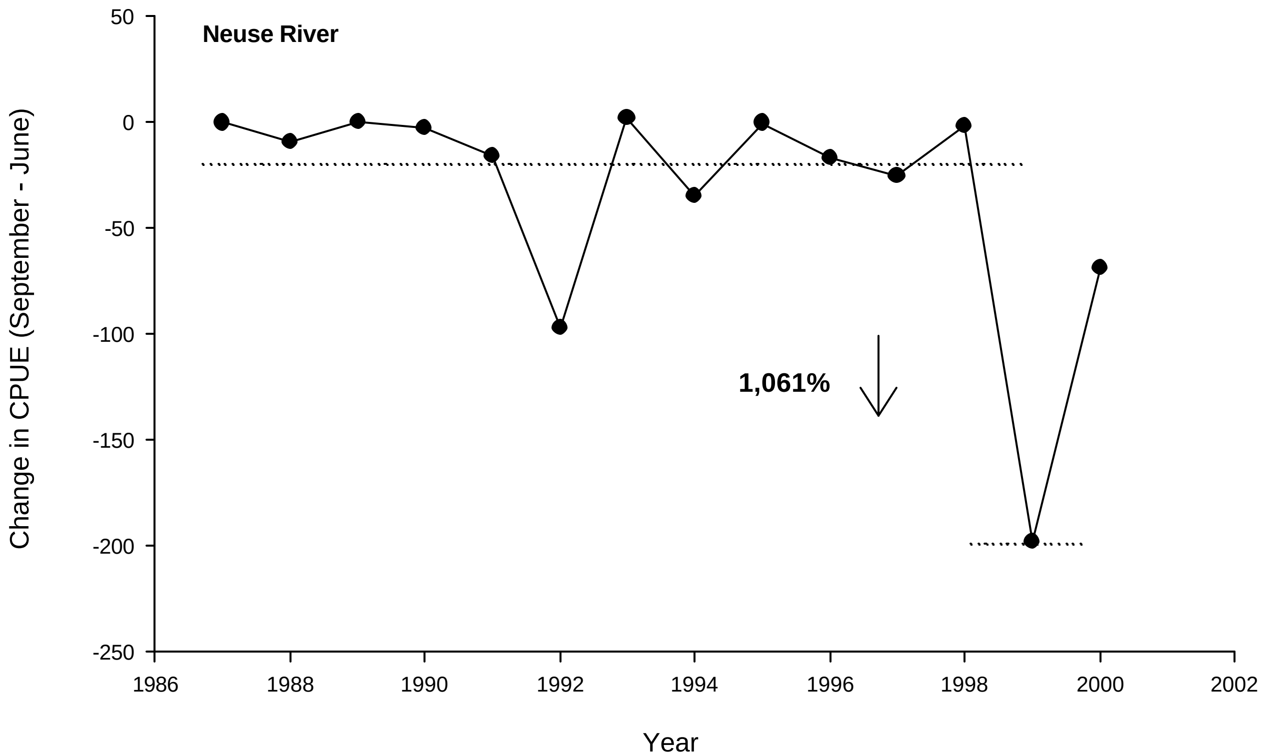


Figure 23. Index of loss of adult blue crabs in the Neuse River, a tributary of Pamlico Sound, calculated by subtracting the June cpue from NC DMF Program 195 from the September cpue. The index of loss should be negative since the abundance of crabs is expected to decline during summer (June-August) due to fishing and natural mortality, as well as migration of inseminated females to seaward inlets to spawn. This data illustrates the behavioral response by blue crabs to hurricane floodwaters during September 1999, whereby crab migrated in masse downriver to Pamlico Sound.

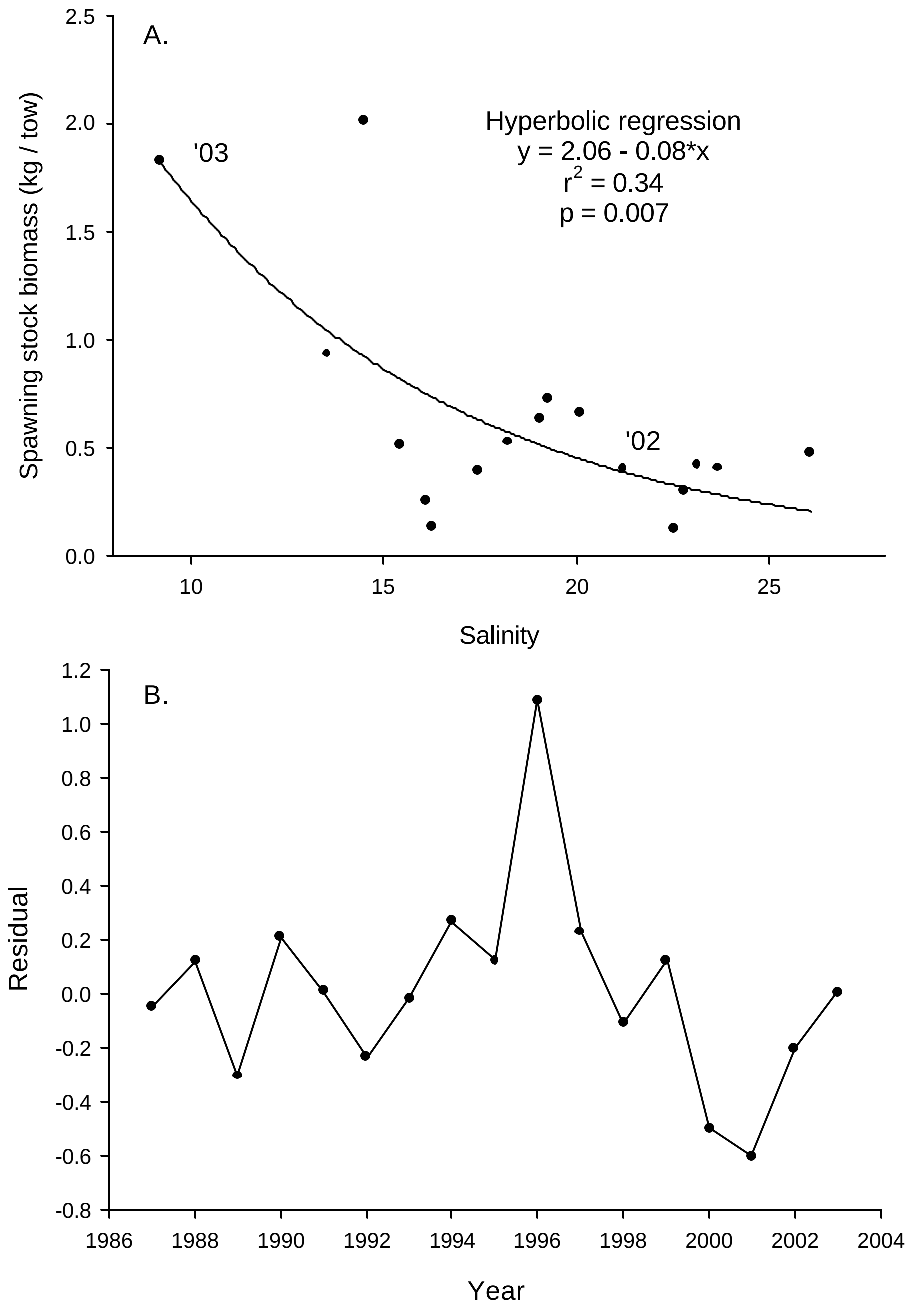


Figure 24. A.) Relationship between the annual mean trawl survey index of spawning stock biomass (SSB; kg/tow) collected in September and mean salinity from NC DMF Program 195 pooled across all water bodies and the mean salinity B.) Residuals from the fit of the regression model (exponential decay) shown in panel A.

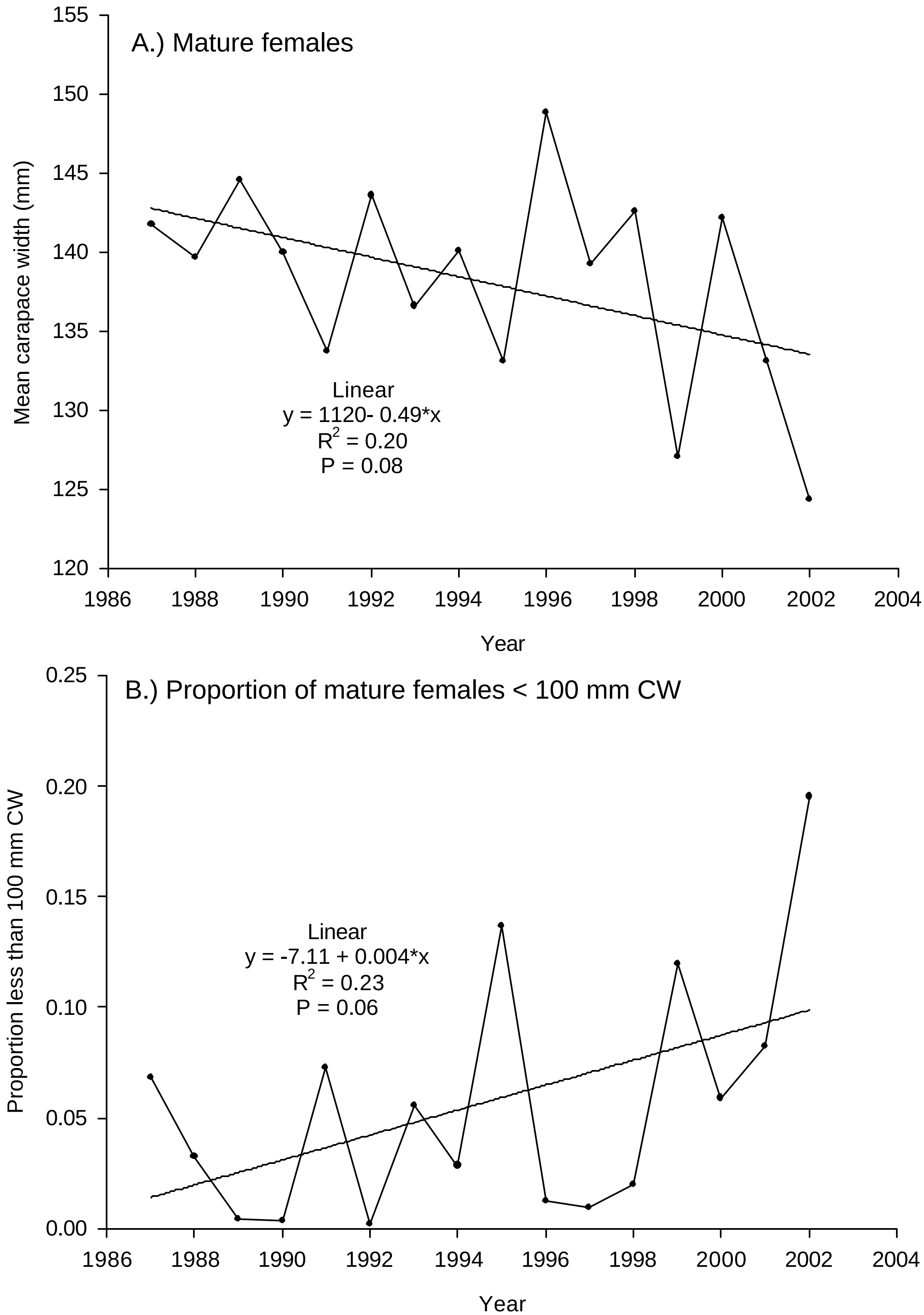


Figure 25. Relationships of mature female size over time A.) mean carapace width of mature females from Program 195 trawl surveys from 1987 - 2003, and B.) annual proportion of mature females less than 100 mm carapace width.

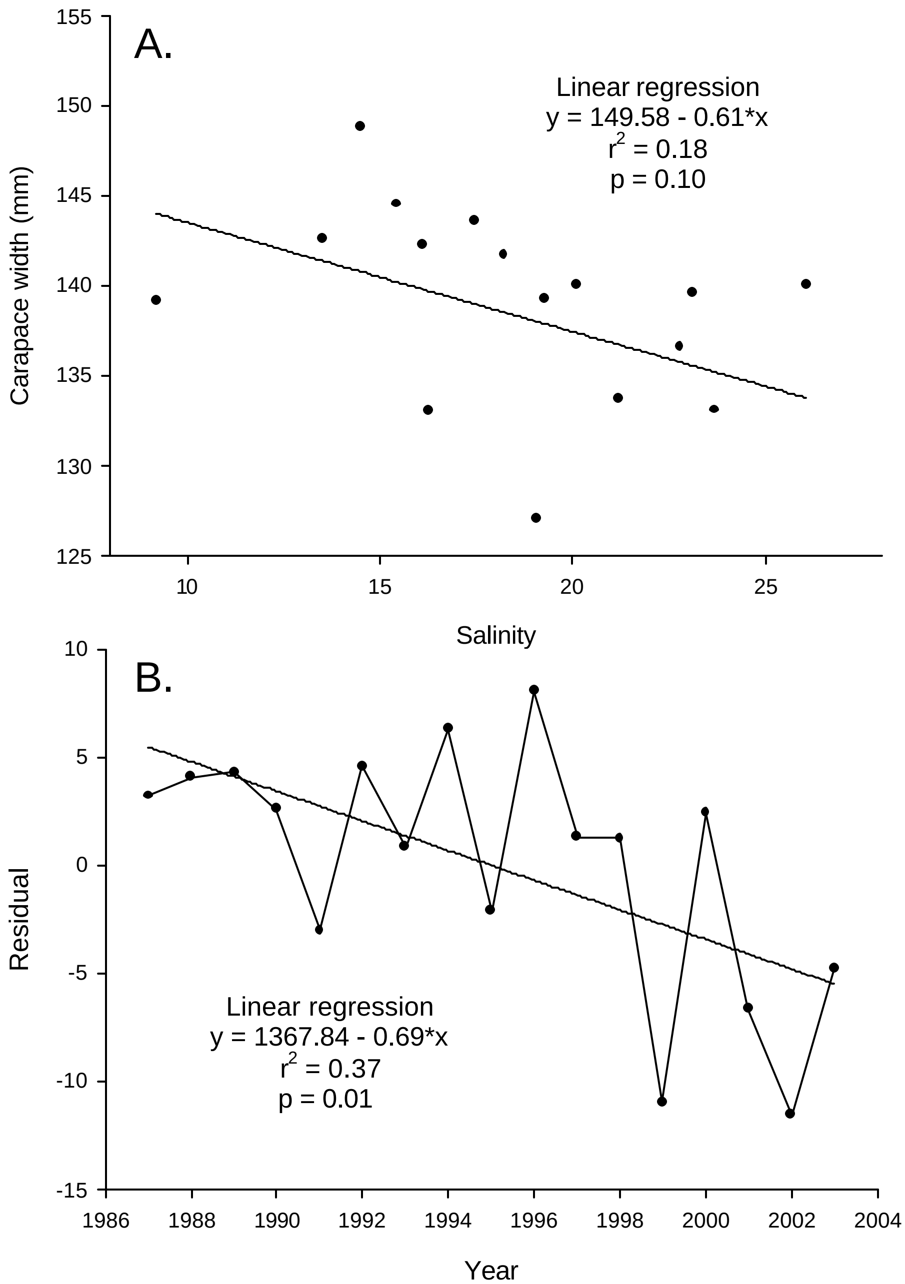


Figure 26. A.) Relationship bewteen annual mean carapace width (mm) of mature females and salinity from NC DMF Program 195 trawl surveys from 1987-2003. B.) residuals from the fit of the linear regression model shown in panel A.

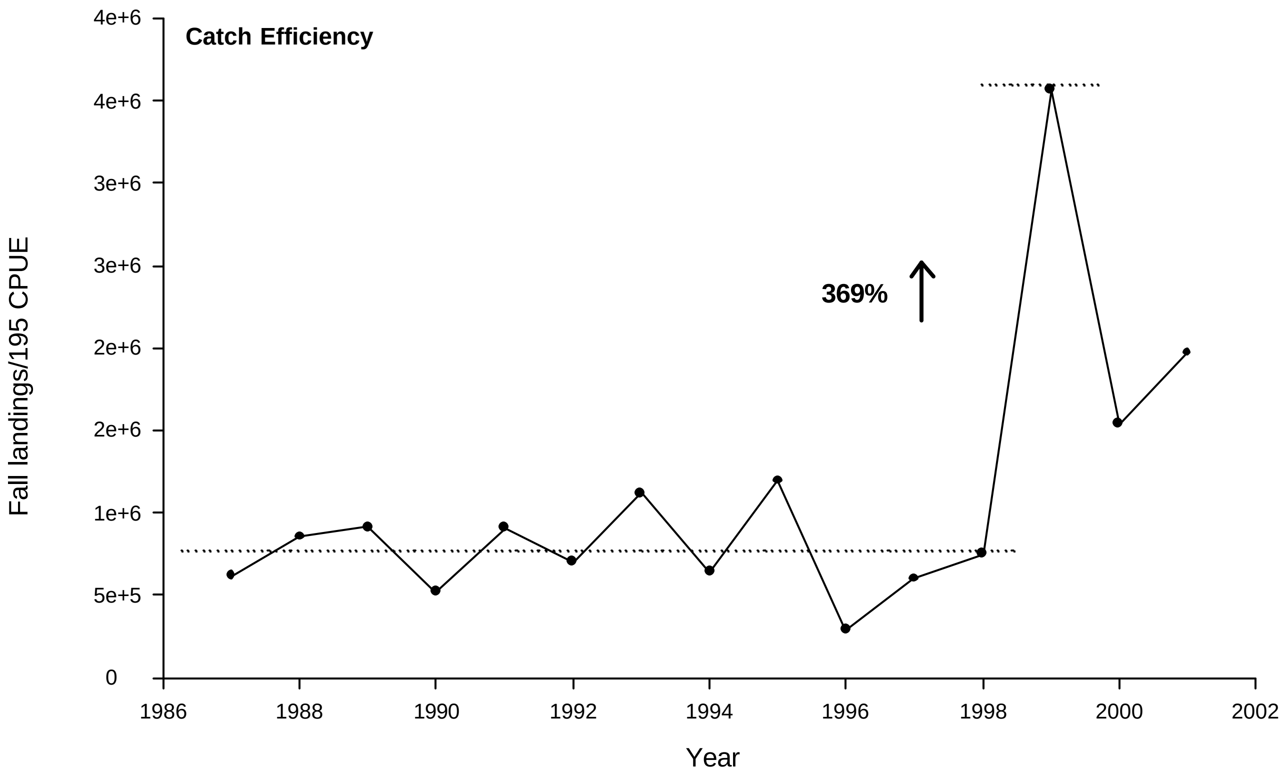


Figure 27. Annual changes in mean state-wide catch efficiency, estimated by dividing crab landings from Fall (Sept.-Nov.) each year by the nominal population size determined from index of Age 2 crabs for September from NC DMF Program 195. The horizontal lines represent the average prior to 1999.

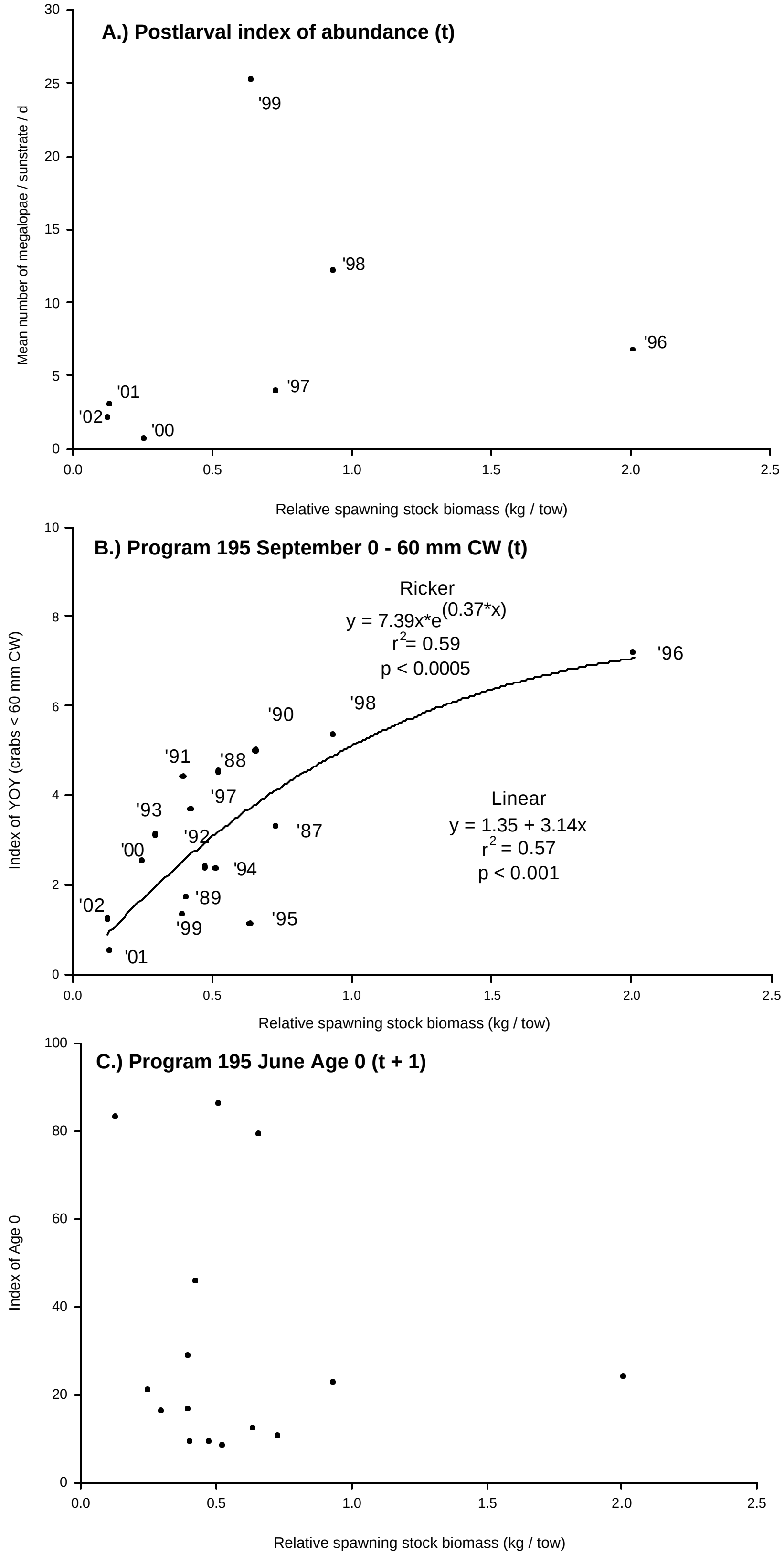


Figure 28. The relationship between the relative spawning stock biomass in September of year t and A.) postlarval settlement (mean number of blue crab megalopae/substrate/d collected from Oregon and Hatteras inlets from August - October) from in year t, B.) Program 195 crabs less than 60 mm CW and C.) Program 195 Age 0 CPUE from trawls in June in year t + 1.

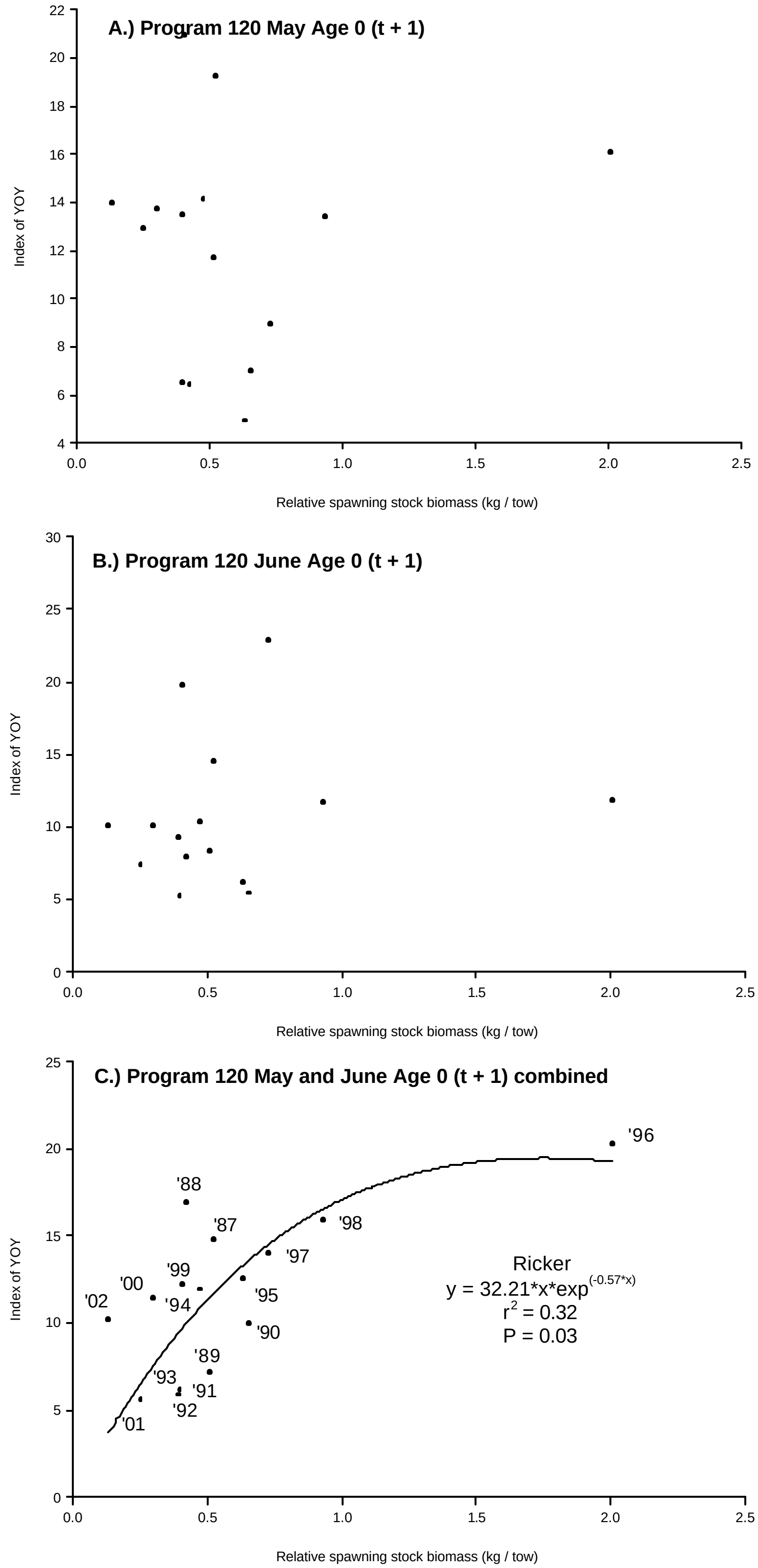


Figure 29. The relationship between the relative spawning stock biomass in September of year t and A.) Program 120 Age 0 CPUE from trawls taken in May of year t + 1, B.) Program 120 Age 0 CPUE from trawls taken in June of year t + 1 and C.) Program 120 Age 0 CPUE from trawls taken in May and June of year t + 1 averaged.

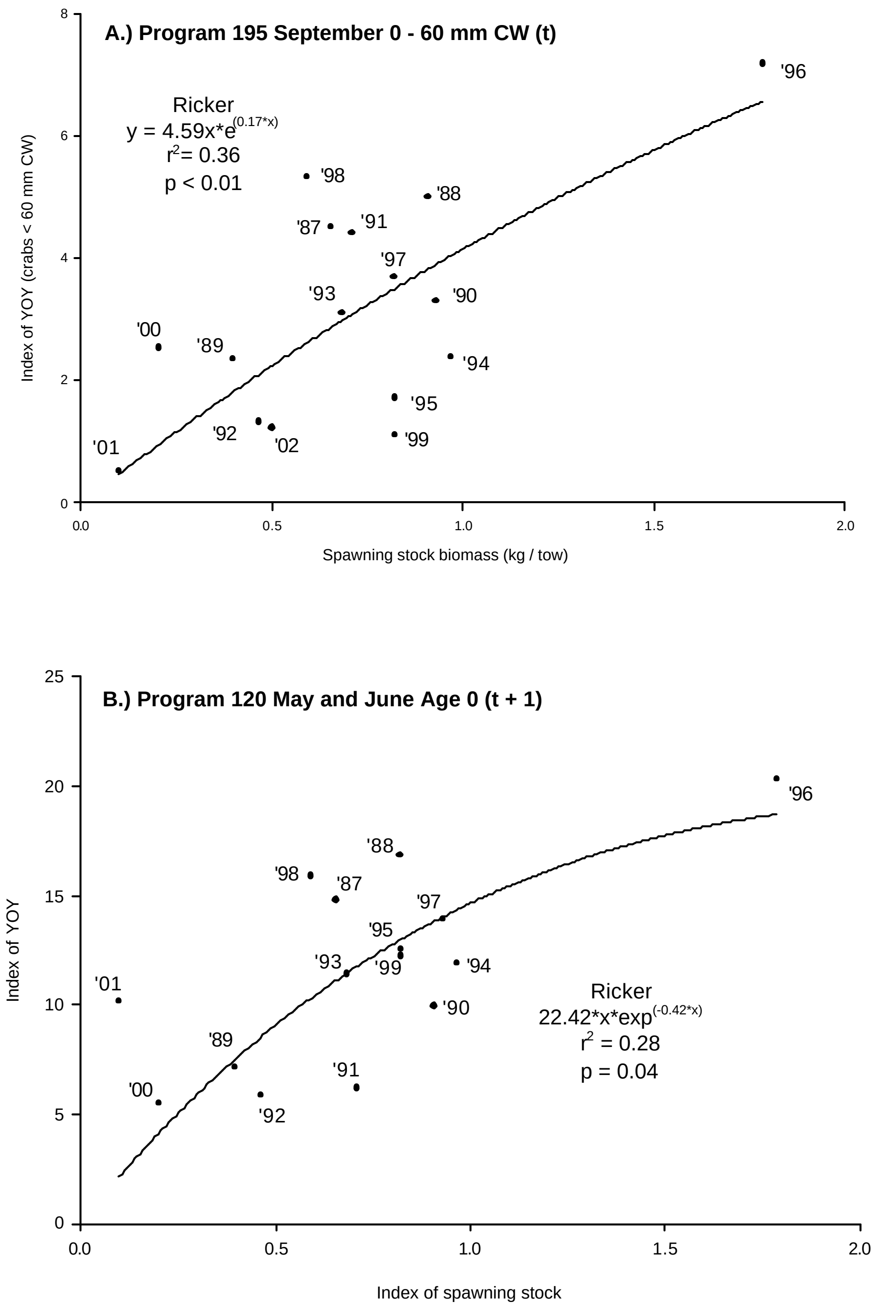


Figure 30. The relationship between the relative spawning stock biomass (SSB; kg/tow) adjusted for mean annual salinity (see figure 23 and text for details) in September of year t and A.) Program 195 crabs less than 60 mm CW in September of year t and B.) Program 120 Age 0 CPUE from trawls in May and June combined in year t + 1.

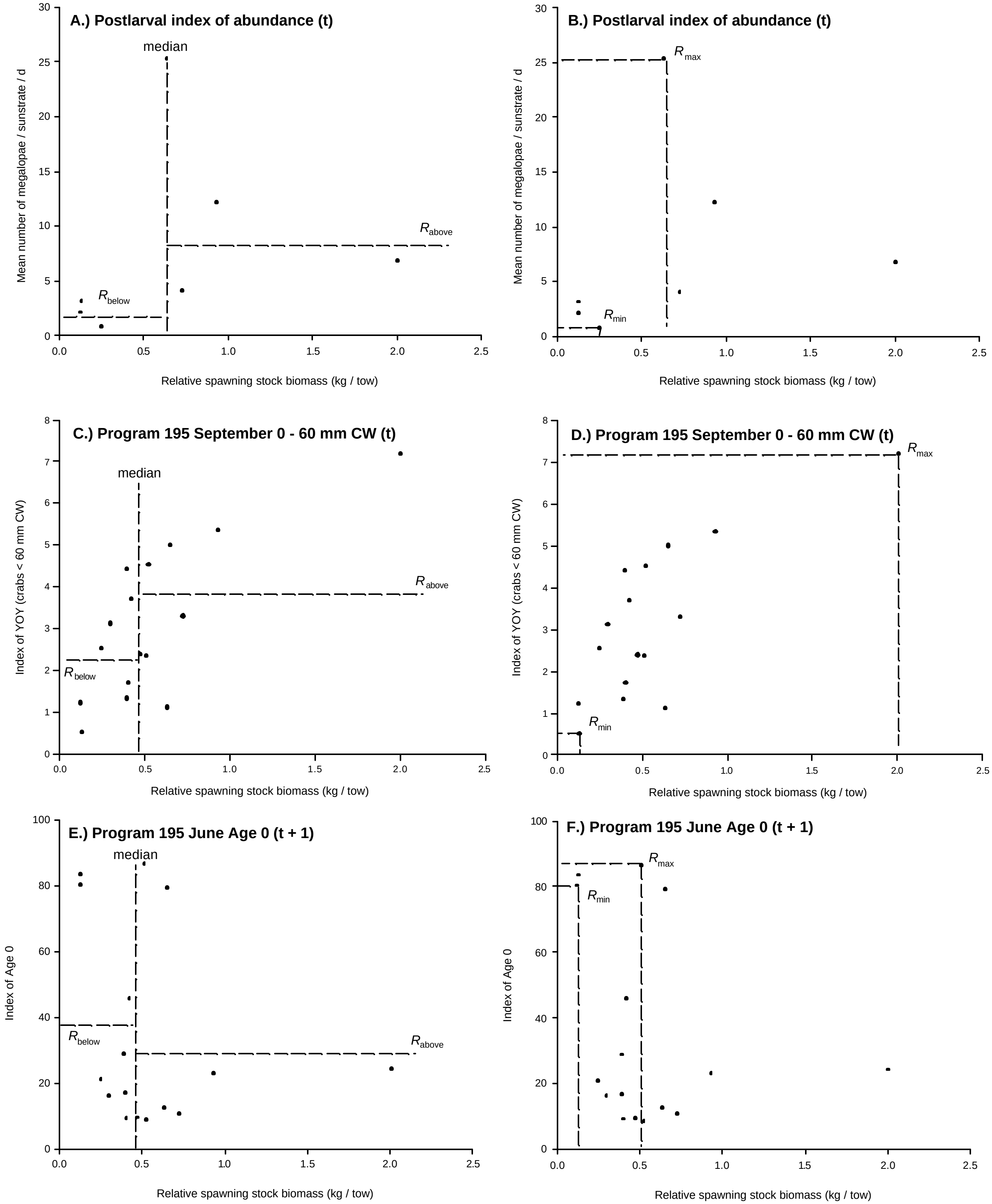


Figure 31. The relationship between the relative spawning stock biomass (mean kg/tow collected Program 195 in September) and various indices of recruit abundance. Non-parametric methods (Myers and Barrowman 1996) were fitted to the data to investigate the strength of the spawner-recruit relationship with postlarval settlement in year t (A and B), Program 195 crabs less than 60 mm CW in year t (C and D), and Program 195 Age 0 crabs in June of year t+1 (E and F). The vertical dashed line represents the median spawner abundance. R_{above} is the mean recruitment for spawner abundance greater than the median and R_{below} is the mean recruitment for spawner abundance lower than the median. r_{max} shows the maximum observed recruitment and the SSB that produced it (this value is associated with the rank

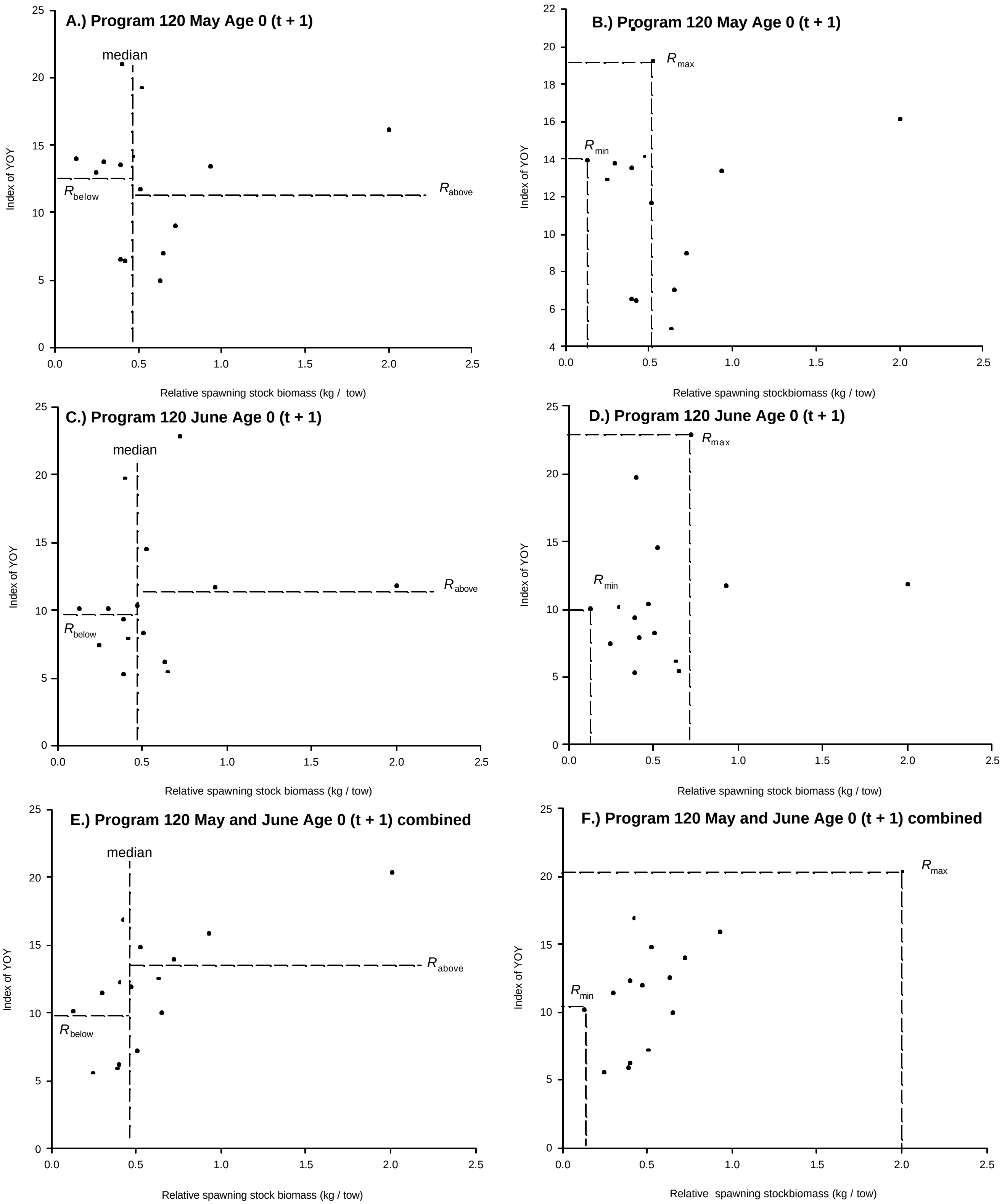


Figure 32. The relationship between the relative spawning stock biomass (mean kg/tow collected Program 195 in September) and various indices of recruit abundance. Non-parametric methods (Myers and Barrowman 1996) were fitted to the data to investigate the strength of the spawner-recruit relationship with Program 120 Age 0 crabs in May of year t + 1 (A and B), Program 120 crabs in June of year t + 1 (C and D), and Program 120 Age 0 crabs in May and June averaged of year t+1 (E and F). The vertical dashed line represents the median spawner abundance. R_{above} is the mean recruitment for spawner abundance greater than the median and R_{below} is the mean recruitment for spawner abundance lower than the median. r_{max} shows the maximum observed recruitment and the SSB that produced it (this value is associated with the rank value R_{max}) and r_{min} is the minimum observed recruitment and the SSB that produced it (this value is associated with the rank value R_{min}).

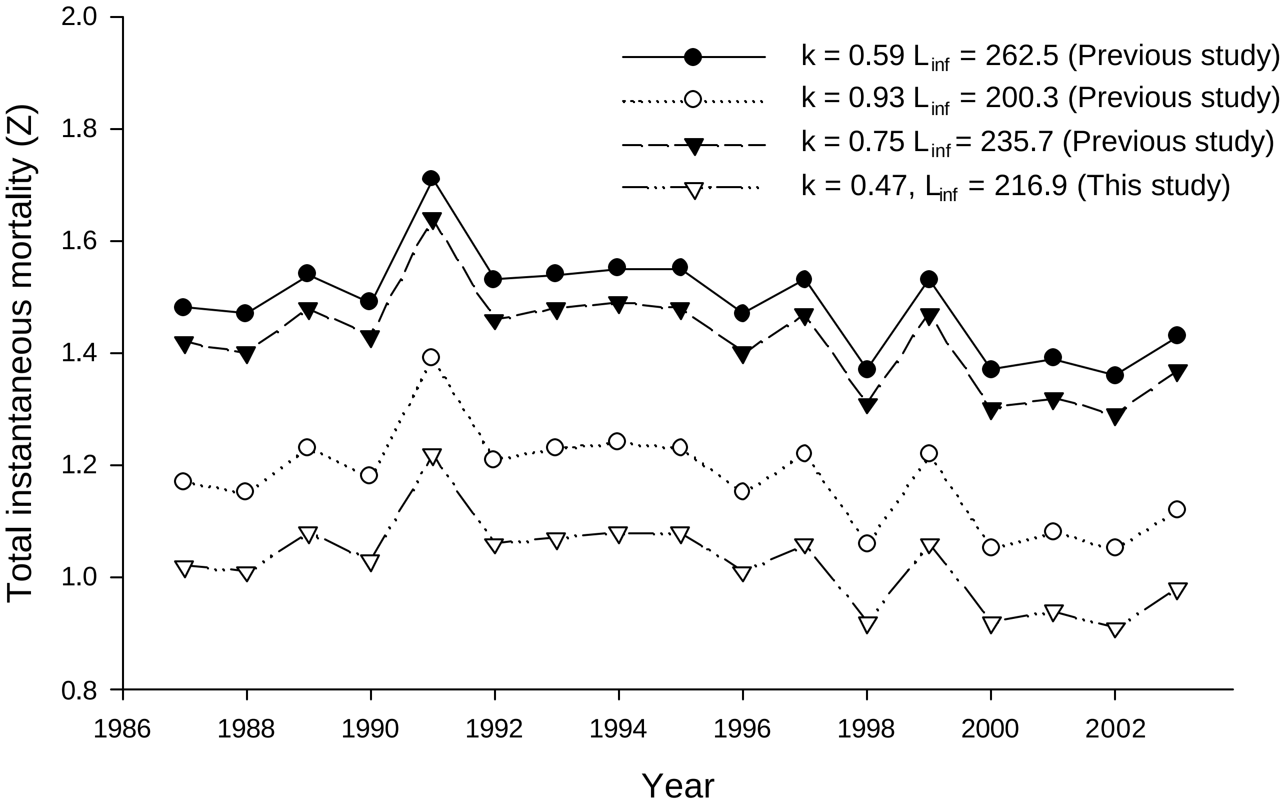


Figure 33. Length-based estimates of blue crab mortality rates (Z) for sexes combined from NC DMF trawl survey data for Program 195 using the approach of Hoenig (1987). Since estimates are highly dependent on growth rate estimates, mortality is shown for five different sets of von Bertalanffy parameters: three from previous published work (see text) and one fit from the present study.

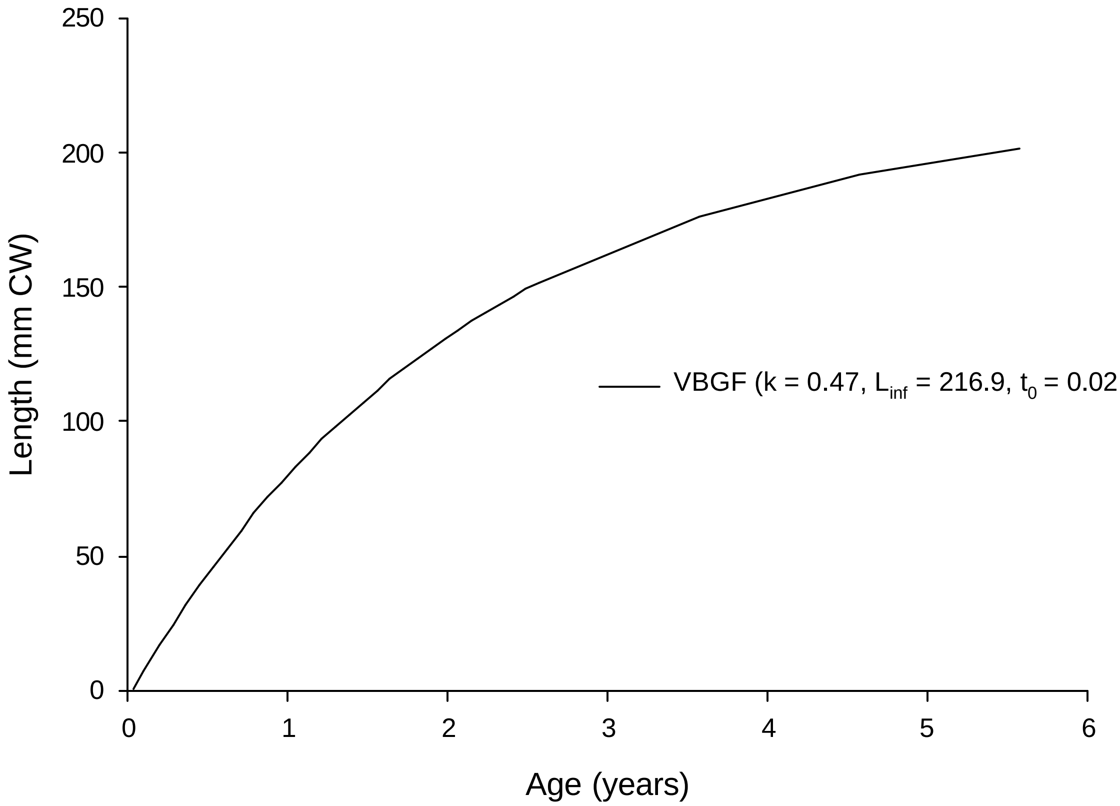


Figure 34. Von Bertalanffy growth trajectories fit to blue crab length frequency data from NC DMF adult (Program 195) trawl survey data from June and September. A length-based model was fit to the observed data (see text for details on model fitting).

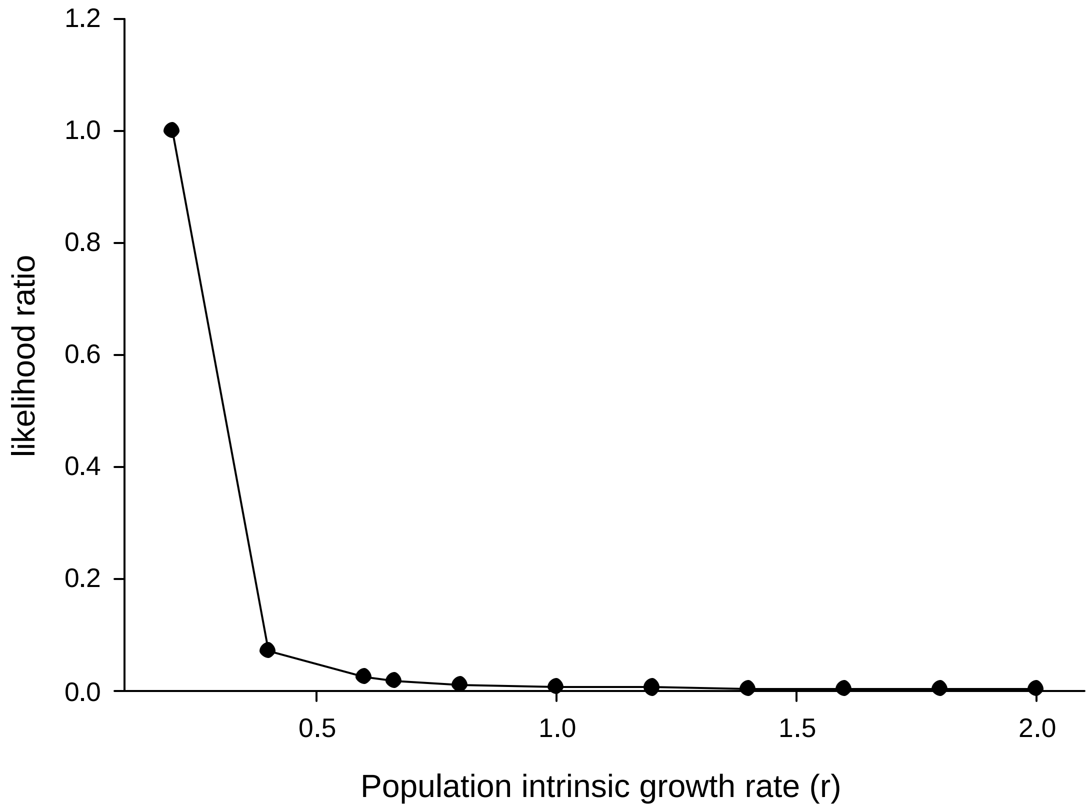


Figure 35. Likelihood profile from a non-equilibrium surplus production model that was fitted to the commercial pot CPUE data series for the period 1953-2002. Values were generated by fixing the intrinsic population growth rate (r) and fitting the remaining model parameters (K) using a maximum likelihood approach B_1 was assumed to be equal to K for model runs. A value of 1.0 indicates the most likely fit, values near 0 indicate poorer fits.

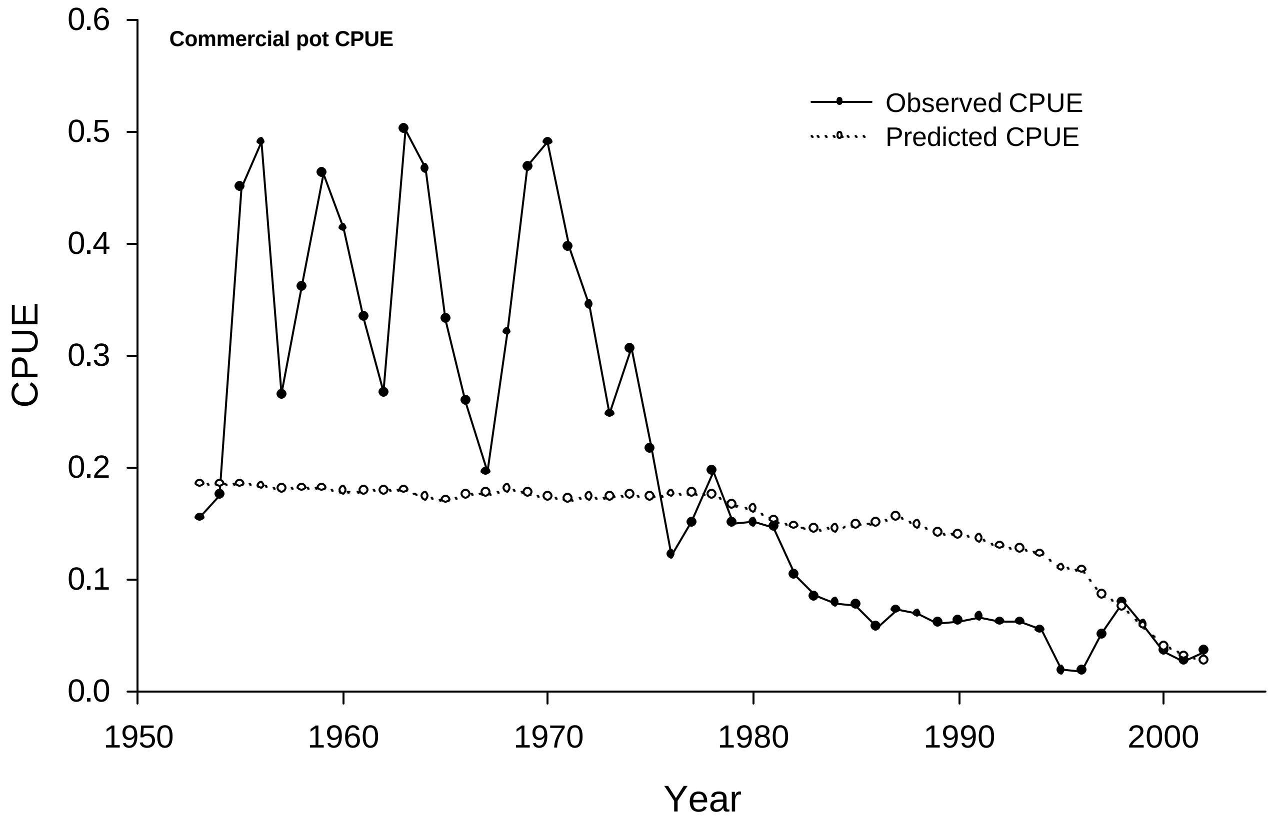


Figure 36. Relationship between observed and predicted mean CPUE from 1953 - 2002 as described by a non-equilibrium surplus production model with mean CPUE of commercial pots. The fit shown was for a fixed r = 1.0.

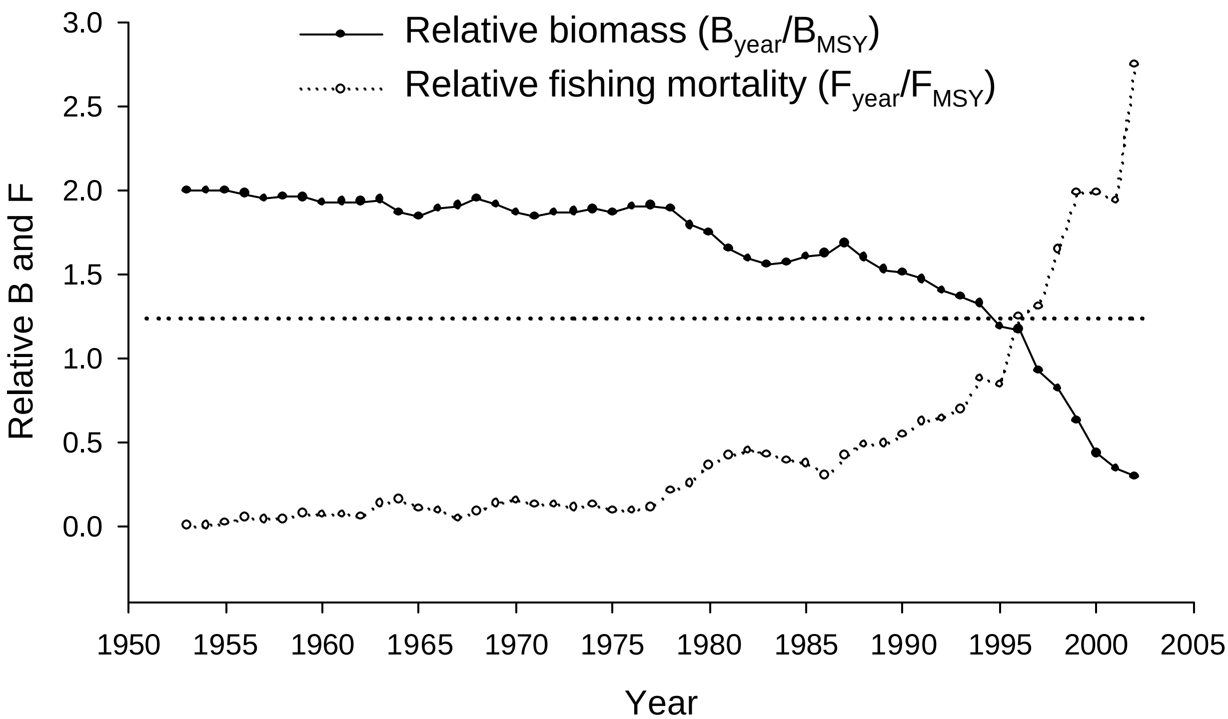


Figure 37. Historical relationship between relative biomass (Relative B = B_{year}/B_{MSY}) and fishing mortality (Relative F = F_{year}/F_{MSY}) generated by a non-equilibrim surplus production model fitted to observed CPUE of crab from commercial pots. The "nearness" index, which ranges from 0 (least reliable) to 1 (most reliable), indicates how closely a modeled stock has approached the biomass level producing B_{MSY}. " Coverage" ranges from 0 (least reliable) to 2 (most reliable), and indicates how widely stock biomass has varied between 0 and K. The rationale for these indices is that MSY will be estimated more reliably if estimated biomass has gone from above B_{MSY} to below (or vice versa). In this case,"nearness" 1 was and "coverage" was 1.73, respectively. The fit shown is for r fixed at 1.0.

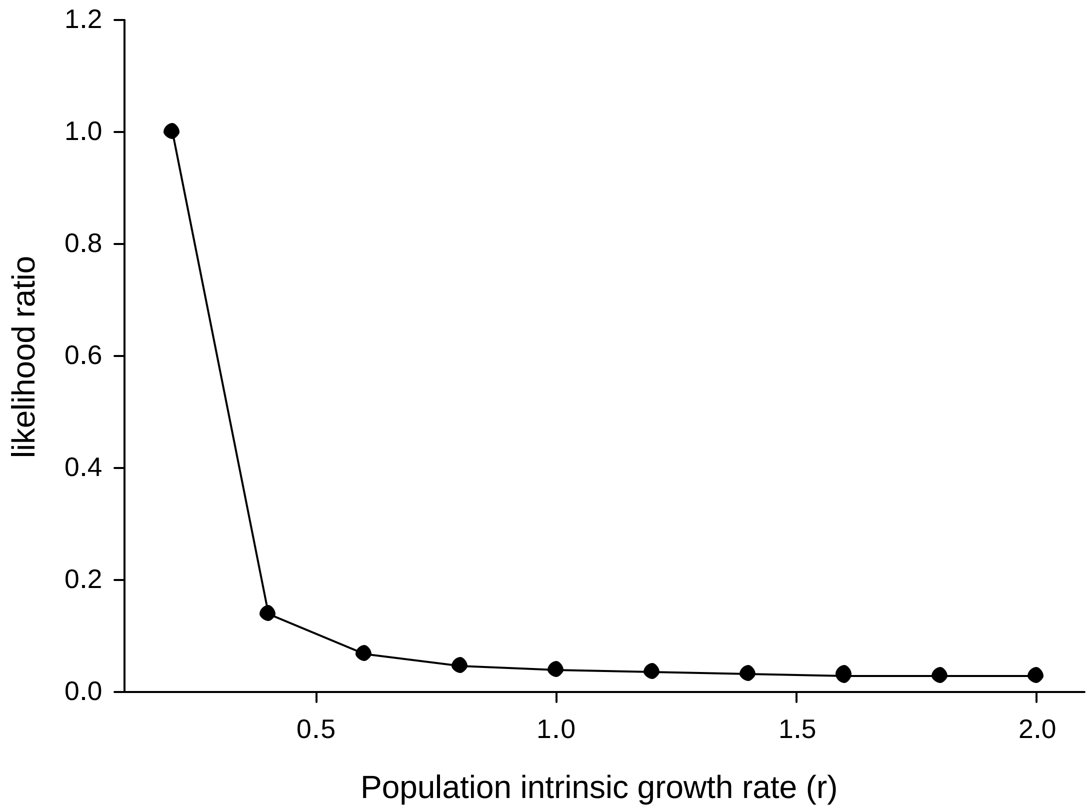


Figure 38. Likelihood profile from a non-equilibrium surplus production model that was fitted to Program 195 June and September indices of abundance (crabs > 127 mm CW) and commercial pot CPUE data series simultaneously. Values were generated by fixing the intrinsic population growth rate (*r*) and fitting the remaining model parameters (*K*) using a maximum likelihood approach. B_1 was assumed to be equal to K for model runs.

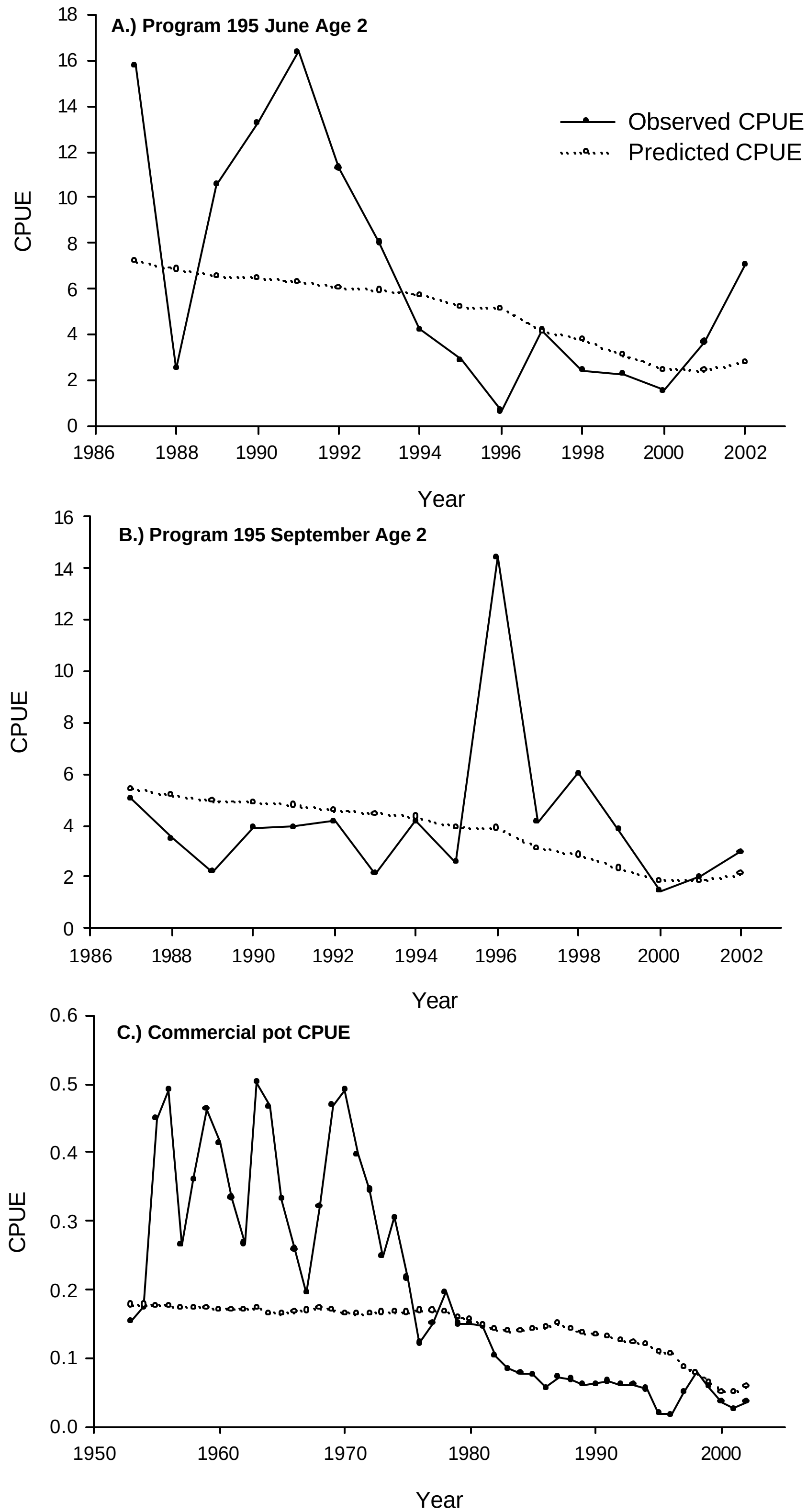


Figure 39. Relationship between observed and predicted mean CPUE from 1953 - 2002 as described by a non-equilibrium surplus production model with A.) Program 195 June index of abundance (crabs > 127 mm CW), B.) Program 195 September index of abundance (crabs > 127 mm CW), and C.) mean CPUE of commercial pots. The model fits shown are for r fixed at 1.

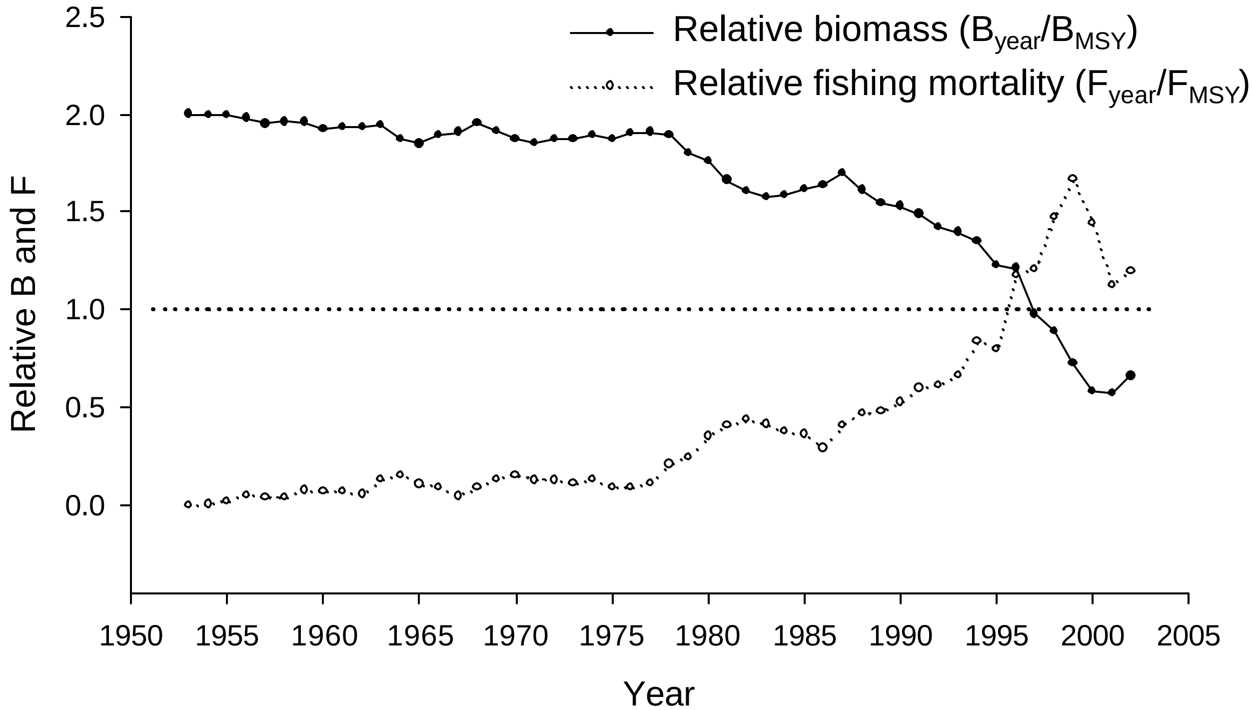


Figure 40. Historical relationship between relative biomass (Relative B = B_{year}/B_{MSY}) and fishing mortality (Relative F = F_{year}/F_{MSY}) generated by a non-equilibrim surplus production model fitted to observed CPUE of crabs > 127 mm CW from Program 195 June and September indices of abundance and commercial pots. The "nearness" index, which ranges from 0 (least reliable) to 1 (most reliable), indicates how closely a modeled stock has approached the biomass level producing B_{MSY}. " Coverage" ranges from 0 (least reliable) to 2 (most reliable), and indicates how widely stock biomass has varied between 0 and K. The rationale for these indices is that MSY will be estimated more reliably if estimated biomass has gone from above B_{MSY} to below (or vice versa). In this case,"nearness" 1 was and "coverage" was 1.44, respectively. The fit shown is for r fixed at 1.0.

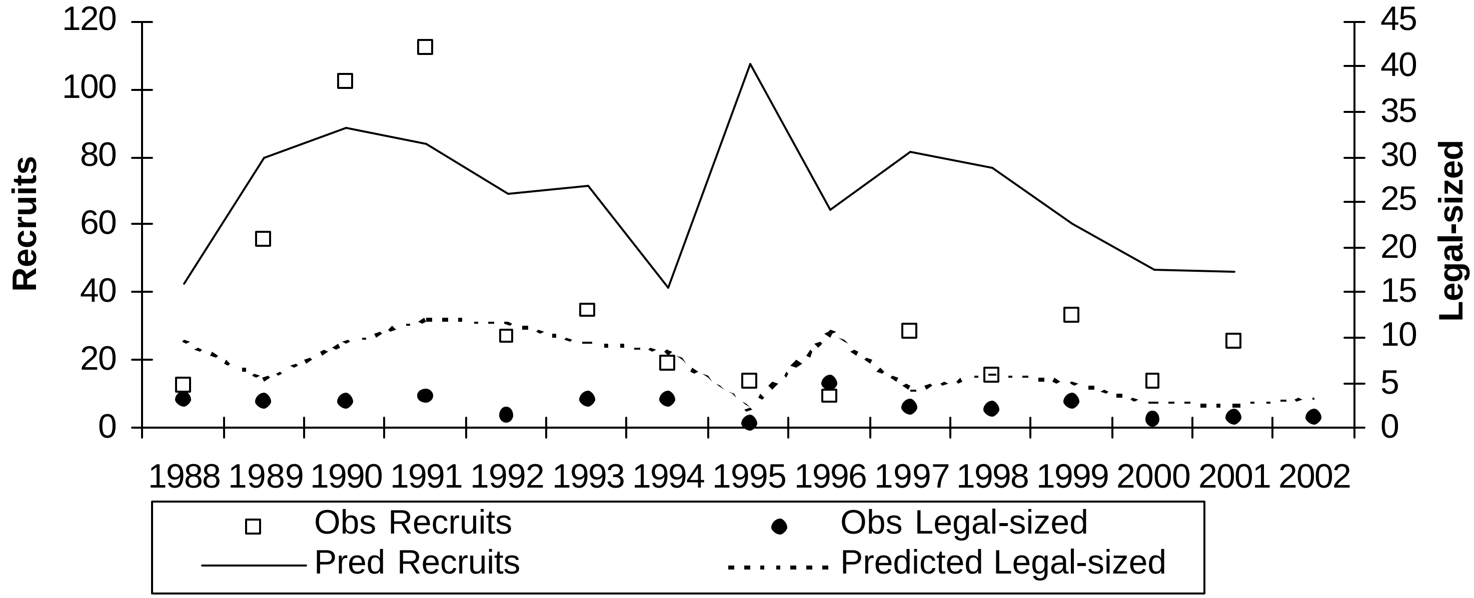


Figure 41. Example of a Collie-Sissenwine model fitted to observed relative abundance data for recruits (<127 mm CW) and legal-sized (127 mm and greater CW) blue crabs, at an assumed natural mortality rate (M) of 0.87. Survey data are from the September P195 surveys

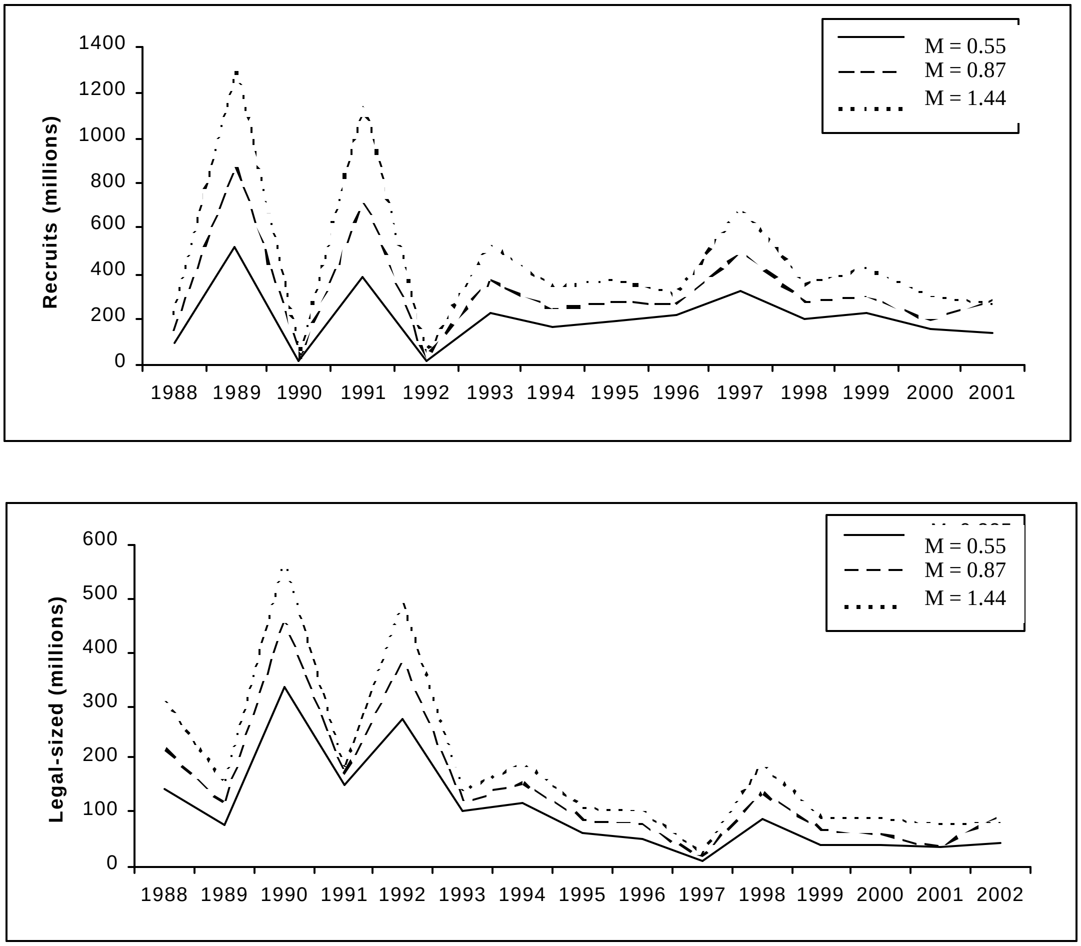


Figure 42. Estimated abundance (number in millions) for recruit (<127 mm CW, upper panel) and legal-sized (127 mm and greater CW, lower panel) blue crabs, based on a Collie-Sissenwine model and one of three assumed natural mortality rates (M).

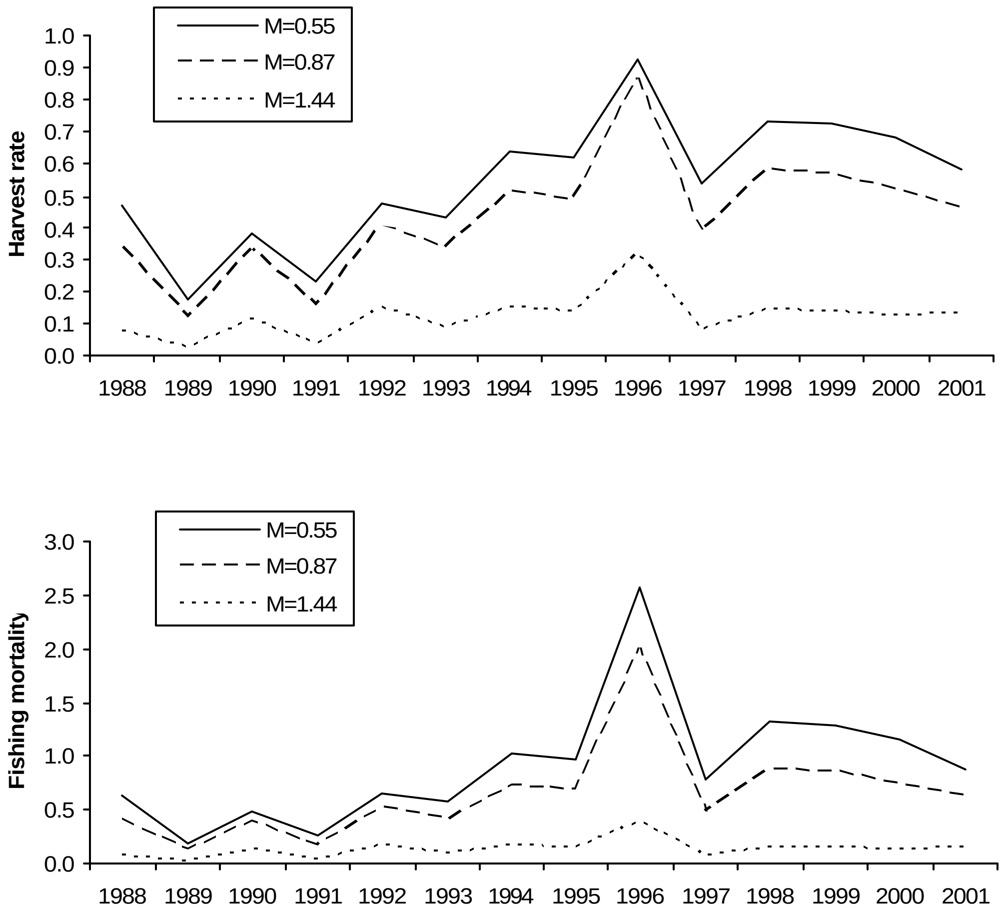


Figure 43. Estimated exploitation rate (upper panel) and instantaneous fishing mortality rate (lower panel), based on a Collie-Sissenwine model and one of three assumed natural mortality rates (M).

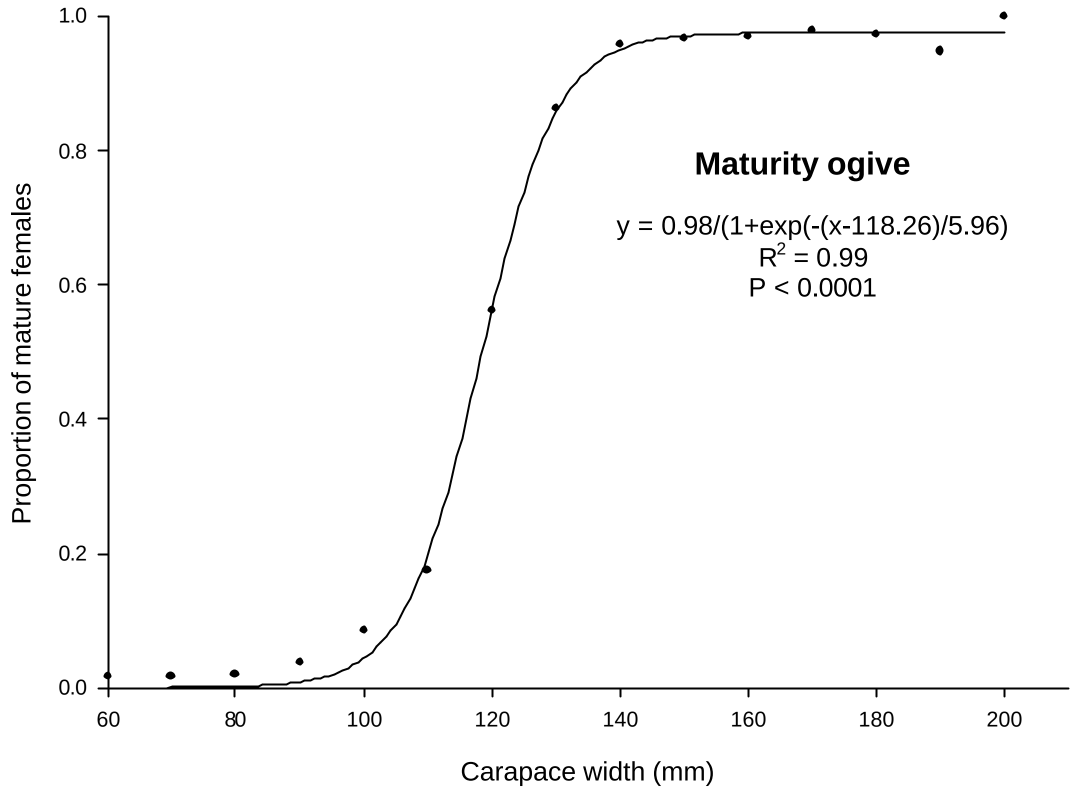


Figure 44. Proportion of mature females by size class from NC DMF Program 195 trawl surveys. A sigmoidal relationship was fitted to the data (n = 16,620 crabs) for the years 1987 - 2002.

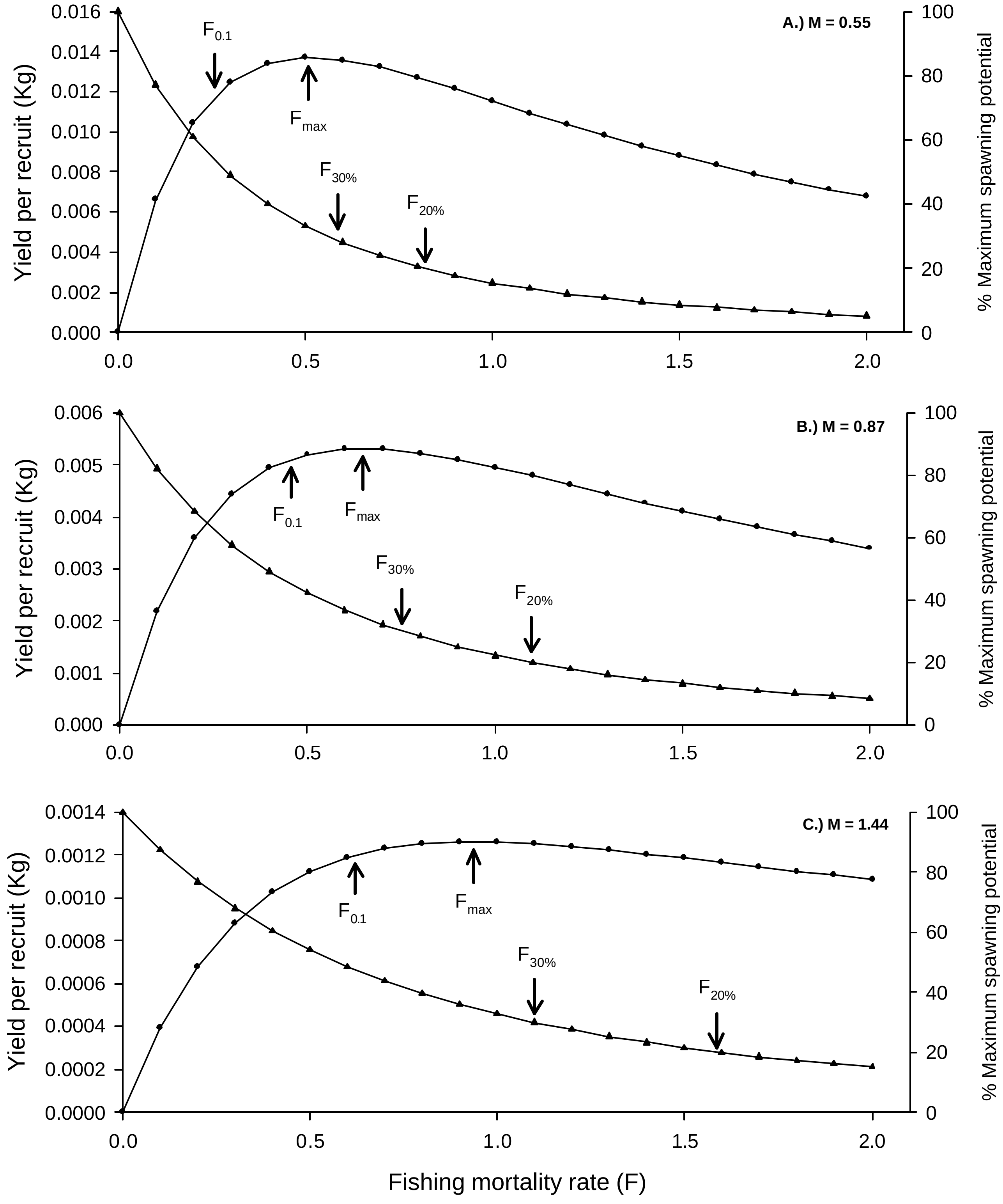


Figure 45. Results of Yield-per-recruit (YPR) and Spawning stock biomass-per recruit (SSBR) analysis for three different assumed natural mortality rates: A.) M = 0.55, B.) M = 0.87, and C.) M = 1.44. Growth was described by the von Bertalanffy growth equation generated from length-based modeling of Program 195 June and September trawl data (k = 0.47, L_{inf} = 216.9).