ECOSYSTEM AND FISHERY IMPACTS

Habitat use patterns of southern flounder vary over time and space by life stage. The growth and survival of southern flounder within the habitats used are maximized when water quality parameters, such as temperature, salinity, and dissolved oxygen, are within optimal ranges. For further information on habitat use by life stage and optimal water quality parameters see *Description of Stock Section.* Additional information on the habitats discussed below, threats to these habitats, and water quality degradation, as well as how these topics relate to fisheries can be found in the North Carolina Coastal Habitat Protection Plan and various Division of Water Resources publications (NCDWQ 2000, 2008; NCDEQ 2016) and in the representation as shown in Figure 6.1 .

While southern flounder can be found in both the estuaries and the ocean, more is known in the estuary. This section will focus on the importance of the estuarine habitats used by southern flounder and the broad effects of the southern flounder fishery on the habitat and ecosystem in these areas.

HABITAT DEGRADATION AND LOSS

Southern flounder migrate through the coastal ecosystem over their life cycle using multiple habitats. Submerged aquatic vegetation, wetlands, shell bottom, and soft-bottom, including inlets and ocean bottom, are particularly important as nursery, refuge, forage, and corridor. These and other potentially important flounder habitats are described in detail in the North Carolina Coastal Habitat Protection Plan (CHPP) (NCDEQ 2016). Additionally, research is underway by the division and universities to identify spawning areas and associated habitats for southern flounder in the ocean.

Portions of these habitats have been degraded or lost over time by a variety of anthropogenic (human caused) sources. It is difficult to quantify how habitat degradation may alter southern flounder population dynamics, but it is important to understand how habitat loss and condition controls the growth and survival of estuarine fish species. Protection and enhancement of these areas may be particularly important for growth and survival of juveniles to adult southern founder. Key habitats for juvenile southern flounder's time in the estuaries for foraging, refuge, and their growth to adults include: submerged aquatic vegetation, wetlands, shell bottom, and soft bottom (Table 6.1; Rozas and Odum 1987; Burke et al. 1991; Mitsch and Gosselink 1993; Walsh et al. 1999; Graff and Middleton 2001; Nañez-James et al. 2009; Meyer 2011; Furey 2012; Furey and Rooker 2013; Scyphers et al. 2015; Dance and Rooker 2015). (1,2)

Inlets are critical corridors and as the southern flounder reach spawning sizes both inlets and ocean bottoms become critical habitats. Adults move to offshore spawning grounds during the fall and winter in the ocean to complete their lifecycle. Larvae spawned offshore migrate into the estuarine system by transport on nearshore and tidal currents through the inlet before settling in preferred estuarine habitats. It is believed that some adult southern flounder return through the inlets to the estuaries and rivers after spawning; however, some adult flounder are thought to remain in the ocean after spawning (Watterson and Alexander 2004; Taylor et al. 2008). The proportion of the adult spawning stock remaining in the ocean and the proportion of those

returning to the estuaries is unknown. For further information on the impact inlets may have on the southern flounder populations see *Inlet Corridors Issue Paper*.

WATER QUALITY DEGRADATION

Good water quality is essential for supporting the various life stages of southern flounder (Table 6.1) and maintaining their habitats. Naturally occurring and human caused activities can alter the preferred salinity or temperature conditions, elevate toxins, nutrients, turbidity, as well as lower dissolved oxygen levels which can degrade water quality. (3)

More detailed information on water quality degradation, including the topics of hypoxia, toxins, and temperature, in North Carolina and the effect on fish stocks can be found through the North Carolina Division of Water Resources guides (NCDWQ 2000, 2008) and the Coastal Habitat Protection Plan (NCDEQ 2016). (4)

GEAR IMPACTS ON HABITAT

Bottom disturbing fishing gear can impact ecosystem function through habitat degradation, bycatch, and derelict gear. Static (or non-mobile) gear used in a fishery tends to have a lesser impact on habitat compared to mobile gear, as the area affected by the static gear tends to be insignificant when compared to that of the mobile gear (Rogers et al. 1998).

The primary gears used in the southern flounder commercial fishery are pound nets, gill nets, and gigs; in the recreational fishery they are hook-and-line and gigs. Other gears that may harvest southern flounder as incidental catch include hard crab and peeler pots, crab and shrimp trawls, channel nets, fyke nets, and haul seines. Most gears that interact with southern flounder are considered static gear (Barnette 2001; NCDEQ 2016), thus in general fishing gear targeting flounder have little impact habitat.

BYCATCH AND DISCARDS OF NON-TARGET SPECIES

Finfish and shellfish species may be caught as incidental bycatch in fisheries targeting southern flounder and may be retained or discarded as a result of economic, regulatory, or personal considerations. For discussion on bycatch and discards of southern flounder from the commercial and recreational fisheries, in targeted and non-targeted commercial fisheries see *Description of the Fisheries Section*.

Other Finfish Species

From 2013 to 2017, southern flounder gill net trips landed 162,141 pounds (24%) of fish other than flounder (incidental catch), while these same trips averaged 520,227 pounds (76%) of southern flounder annually. Four species, or groups of species, comprised over 77% of the incidental catch by weight: red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), catfishes, and sheepshead (*Archosargus probatocephalus)*. Over 40 additional species, including spotted seatrout (*Cynoscion nebulosus*), bluefish (*Pomatomus saltatrix*), striped mullet (*Mugil cephalus*), and striped bass (*Morone saxatilis*) comprised the remaining 23% of the catch.

Six species comprised approximately 76% of the observed discards (live and dead; by number): Atlantic menhaden (*Brevoortia tyrannus*), blue crab (*Callinectes sapidus*), common carp (*Cyprinus carpio*), cownose rays (*Rhinoptera bonasus*), red drum, and Atlantic stingrays (*Dasyatis sabina*). Additionally, southern flounder make up 10% of the overall discards from the gill net fishery (for further discussion see *Description of the Fishery* section). An additional 135 species make up the remaining 14% of discarded catch, including bluefish, Atlantic croaker (*Micropogonias undulates*), and horseshoe crab (*Limulus polyphemus*). From June through October greater than 75% of all gill net trips made were targeted flounder trips.

Over 70% of the landings from flounder pound nets were southern flounder from 2013 to 2017. Summer and Gulf flounders comprised approximately 2% of the harvest during the same time frame. Other species commonly captured included black drum, harvest fish (*Peprilus alepidotus*), and red drum. More than thirty additional species including sheepshead, butterfish (*P. triacanthus*), and catfish made up the remaining catch; with none of these species individually exceeded 1% of the total catch. Mortality of non-target species discarded from pound nets is likely minimal, provided fishing practices are such that non-harvested fish are handled carefully and released immediately.

Gigging for southern flounder results in very little bycatch of non-flounder species; fish are gigged by sight and are therefore targeted. Other flounder species, such as gulf flounder and summer flounder, are subject to the same size restrictions and may be taken in fishing operations targeting southern flounder. Giggers in both the recreational and commercial fisheries can be prone to gig undersized flounder, resulting in some regulatory discards of these other flounder species.

Protected Species

Protected species (sometimes referred to as "protected resources") is a broad term that encompasses a range of organisms that are protected by federal or state statutes because their populations are at risk or are vulnerable to risk of extinction. Federal statutes include the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and the Migratory Bird Treaty Act (MBTA). Of federally protected species, the following are known or suspected to be incidentally taken in the southern flounder fishery: sea turtle species, sturgeon species, common bottlenose dolphin, and various seabird species. There may be additional protected species that occasionally occur in estuarine waters and rarely interact with the southern flounder fisheries. The division currently has two Incidental Take Permits (ITP) (Section 10(a)(1)(B) of the ESA) that establish legal take thresholds for sea turtles and Atlantic sturgeon in estuarine gill nets (NMFS 2013, 2014). As part of the ITPs, the division operates an observer program to monitor take levels and implement adaptive management measures based on those levels (for the most recent annual reports see Byrd et al. 2020a, 2020b).

The common bottlenose dolphin (*Tursiops truncatus*; hereafter, bottlenose dolphin) is the predominant marine mammal in North Carolina estuarine waters (Hayes et al. 2018). Incidental takes of bottlenose dolphins in ocean gill nets have been documented by federal fisheries observers (Lyssikatos and Garrison 2018) and from estuarine and ocean strandings (Byrd et al. 2014; Byrd and Hohn 2017). However, the level of bycatch in estuarine gill nets is unknown. During the years of state-wide observer coverage of estuarine gill nets (ITP year 2014-present),

only one incidental take of a bottlenose dolphin (small-mesh) has been documented (McConnaughey et al. 2019). Entanglement of bottlenose dolphins in North Carolina pound nets is thought to be uncommon, but the NMFS recovered one dead bottlenose dolphin entangled in a pound net during 2008 (Byrd et al. 2014).

North Carolina has a great diversity of birds, including migratory waterbirds (Potter et al. 1980). Within North Carolina estuarine waters, there are several species of birds that may be unintentionally caught in the southern flounder gill net fishery. Bycatch estimates for the estuarine gill net fishery are not available, though Warden (2010) documented bycatch of common loons (*Gavia immer)* and red-throated loons (*G. stellate)* in ocean-side and estuarine gill nets operating from Maine to North Carolina. Gill net interactions with waterbirds have been documented in several division sampling programs. However, in-depth studies are needed to determine quantifiable bycatch estimates in the estuarine gill net fishery and the levels of impact.

CLIMATE CHANGE AND RESILIENCY

Extreme weather events have always occurred, but scientists from across the state agree that the changes to North Carolina's climate in this century will be larger than anything experienced in the historical past (Kunkel et al. 2020). It is predicted that average annual temperatures will continue to increase, sea level will continue to rise, the intensity of hurricanes will increase, total annual precipitation from hurricanes and severe thunderstorms will increase resulting in increased flooding events while severe droughts will also likely increase due to higher temperature (Kunkel et al. 2020). Flood events can flush contaminated runoff into the estuary causing degraded water quality, hypoxia resulting in fish kills, alter the salinity regime, and erode shorelines resulting in habitat loss of important coastal habitats, such as submerged aquatic vegetation (SAV), shell bottom, and wetlands, that are critical to southern flounder throughout their life history. This could have an inverse effect on the recruitment and survival of southern flounder in the estuarine system.

The increasing temperatures will also impact the distribution of finfish and invertebrate populations and they coastal habitats they use. It has been predicted that hundreds of finfish and invertebrate species will be forced to move northward due to increasing temperatures caused by climate change (Morley et al. 2018). North Carolina already exhibits one of the greatest northward shifts in commercial fishing effort, with average vessel landings occurring 24km further north each year (Dubik et al. 2019). Studies have shown that the sex determination of southern flounder is sensitive to the water temperatures during larval development. When southern flounder were grown in high and low water temperatures a higher proportion of males were produced while a midrange water temperature produced a sex ratio closer to 1:1 (Luckenbach et al. 2003, 2009; Montalvo et al. 2012). Honeycutt et al. (2019) found the more southerly habitats of North Carolina exhibited warmer temperatures and consistently produced higher proportions of males in wild populations (up to 94%), indicating latitudinal variation in sex ratios. With trends in increasing water temperatures, this is an important factor in the understanding of population dynamics of southern flounder. (5)

The repeated impacts and compounding losses from the effects of climate change can be catastrophic not only to the coastal communities, but to the coastal habitats and the fisheries they support. While the risks and hazards associated with climate change and extreme weather events

cannot be completely eliminated, the affects can be decreased by increasing coastal resilience, which can be broken down into two parts: 1) community resiliency – the ability of a community to withstand, respond to, and recover from a disruption, and 2) ecosystem resiliency – the ability of the natural environment to withstand, respond to, and recover from a disruption, such as hurricanes, tropical storms, and flooding. A resilient ecosystem is able to bounce back from disturbances over time while resistant ecosystems may withstand a disturbance or two but over time the ecosystem function is lost and unable to recover. Building a more resilient coastal community and ecosystem will help ensure the coastal habitats critical to the life history of southern flounder and may other species will be able to persist (NCDEQ 2016, 2020).

HABITAT AND WATER QUALITY PROTECTION

The FRA statutes requires that a Coastal Habitat Protection Plan (CHPP) be drafted by the Department of Environmental Quality (DEQ) and reviewed every five years (G.S. 143B 279.8). The CHPP is intended as a resource and guide compiled by DEQ staff to assist the division, Environmental Management, and Coastal Resources commissions in the development of goals and recommendations for the continued protection and enhancement of fishery habitats of North Carolina. The amended Plans focus on current priority habitat issues while the CHPP Source Document summarizes the economic and ecological value of coastal habitats to North Carolina, their status, and the potential threats to their sustainability (NCDEQ 2016). Habitat recommendations related to fishery management can be addressed directly by the MFC. The MFC has passed rules that provide protection for southern flounder habitat. Some rules prohibit bottom disturbing gear in specific areas, others designate sensitive fish habitat such as nursery areas and SAV beds, with applicable gear restrictions. Habitat recommendations not under MFC authority (e.g., water quality management, shoreline development) can be addressed by the other commissions through the CHPP process. The CHPP helps to ensure consistent actions among these commissions as well as their supporting NCDEQ divisions.

The Coastal Habitat Protection Plans and Source Document can be viewed and downloaded from: http://portal.ncdenr.org/web/mf/habitat/chpp/downloads. For an overview of additional habitat management roles in North Carolina from other state and federal agencies see E-doc.

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Table 6.1. Water quality parameters required by and habitats associated with different life stages of southern flounder.

Life Stage	Salinity (ppt)	Temp (°C)	DO (mg/L)	Associated Habitats	Related literature
Adult	0-36	4-35	Greater than 5.0	Entire estuary and ocean	Reagan and Wingo 1985; Farmer et al. 2013; NCDEQ 2016
Larvae	9-36	16-35	Greater than 3.7	Inlet and ocean water column, estuarine soft bottom	Williams and Duebler 1968; Reagan and Wingo 1985; Burke et al. 1991; Moustakas et al. 2004; NCDEQ 2016
Juveniles	0.02-35	16-35	Greater than 3.7	Wetlands, SAV, shell bottom, soft bottom	Reagan and Wingo 1985; Taylor et al. 2000; Taylor and Miller 2001; Del Toro-Silva et al. 2008; Nañez-James et al. 2009; Lowe et al. 2011; Farmer et al. 2013; NCDEQ 2016

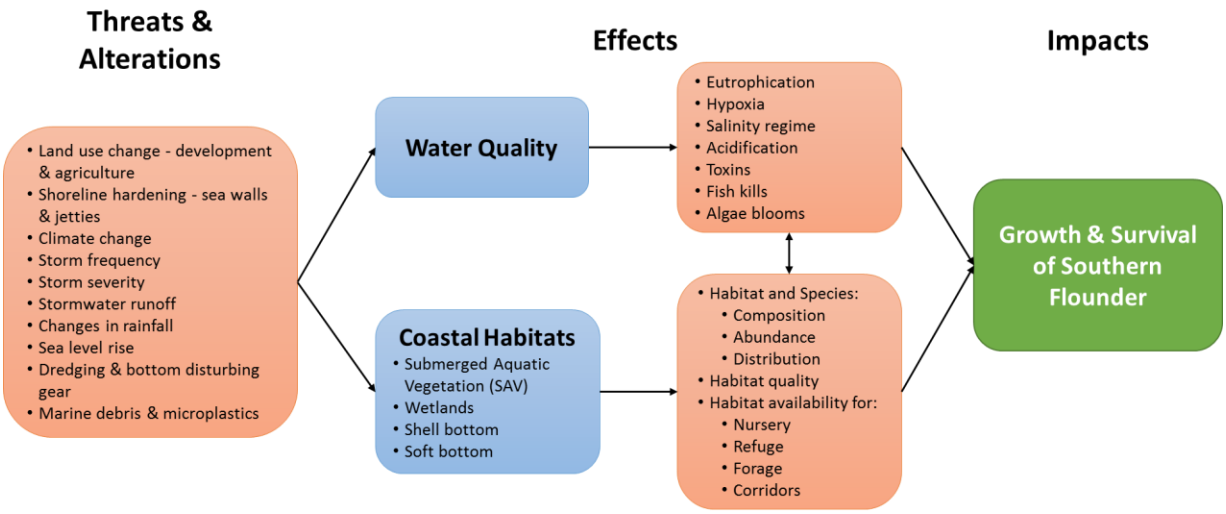

Figure 6.1. Effects of threats and alterations on water quality and coastal habitats and their ultimate impact on the growth and survival of southern flounder.

Text Boxes and Images

1. Text Box: Higher abundances of southern flounder are associated with SAV. Seagrass beds function as important nursery areas by providing a complex structure for juvenile southern flounder for predator avoidance while supplying accessible prey.

2. Text Box: Meyer (2011) found a negative correlation between abundance of southern flounder and conversion of wetlands/undeveloped forest to agriculture/development areas (where the development change was greater than 21%). **OR** Scyphers et al. (2015) found living shorelines supported a greater abundance and diversity of aquatic life, with flounder species 79% more abundant.

3. Picture of flounder jubilee
   Text Box: Dissolved oxygen depletion in the water column occurs most often in summer. These conditions can result in flounder "jubilees" that have been known to occur in the northern Gulf of Mexico and North Carolina's estuarine waters. Under low oxygen conditions, flounder will suddenly aggregate along the water's edge in an attempt to escape the hypoxic water.

4. Text Box: EMERGING ISSUES
   There are several water quality issues of increasing importance that may affect flounder (and human health) in the future. These include, but are not limited to, microplastics and PFAS and other emerging compounds. For further information see https://deq.nc.gov/news/key-issues/emerging-compounds/emerging-compounds-resources or https://www.nccoast.org/wp-content/uploads/2020/01/N.C.-Marine-Debris-Action-Plan.pdf.

5. Text Box: North Carolina is not the only state where warming water temperatures seem to effect the southern flounder population. Anecdotal information from Texas indicates that winters with above normal temperatures can lead to poor recruitment the following year.