NORTH CAROLINA

MANAGEMENT PLAN

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AQUATIC NUISANCE SPECIES MANAGEMENT PLAN

Prepared by the NC Aquatic Nuisance Species Management Plan Committee
October 1, 2015

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Aerial photo of Hydrilla verticillata in Lake Gaston North Carolina - Steve Hoyle, NCSU Crop Science

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We would also like to dedicate this plan to the memory of our friend and colleague, Rick Iverson, whose work on the issue of aquatic nuisance species continues to be a source of inspiration and guidance.

EXECUTIVE SUMMARY

The purpose of the North Carolina Aquatic Nuisance Species Management Plan (NCANSMP) is to improve the state's ability to address aquatic invasive and aquatic nuisance species with the goal of preventing and controlling their introduction, spread, and negative impacts.

North Carolina is fortunate to have abundant and diverse water resources, and protection of them is important to support the state's unique biological attributes and growing population and economy. There are 17 major river basins with over 37,000 miles of freshwater streams that support thousands of aquatic species and provide drinking water for almost 9 million citizens. NC coastal fisheries are among the most productive in the U.S. because of the diversity of habitats available in the largest estuarine system (2.3 million acres) of any single Atlantic coastal state (Deaton et al. 2010). These waters are home to a variety of marine species that support the recreational and commercial livelihood for residents and delight millions of visitors to the state every year. An estimated 1.5 million freshwater and saltwater anglers fished in North Carolina during 2011 spending an estimated $1.65 billion with an economic ripple effect of $2.71 billion (Southwick Associates 2012). Recreational saltwater fishing alone brings in over $1.6 billion each year to the state's economy (Crosson 2010). Given the significance of these water resources, it is critical to address current threats to the integrity of aquatic systems, as well as potential problems before they arise. The purpose of the North Carolina Aquatic Nuisance Species Management Plan (NCANSMP) is to improve the state's ability to address aquatic invasive and aquatic nuisance species with the goal of preventing and controlling their introduction, spread, and negative impacts.

The problem of aquatic invasive species (AIS) and aquatic nuisance species (ANS) is not a new one in North Carolina, but one whose impacts have historically not been researched extensively or clearly understood. Meanwhile, those impacts have continued to threaten, and in some cases degrade, the very water resources that the state is dependent on. Data focused on the specific economic impact and cost for addressing ANS in North Carolina are severely lacking, but a recent national study noted that loses attributed to the presence of just three aquatic nuisance plant species were in excess of $800 million per year (CAST 2014). For that reason, a multi-agency committee was formed in 2014 and charged with developing a plan for management of ANS. Members of the committee were appointed by their respective agencies with the goal of preventing and controlling the spread and negative impacts of ANS in North Carolina. The committee worked together to document current rules and policies, identify potential gaps or areas needing more attention, and collectively agree on action steps to address the ANS issue in a more comprehensive way. The committee met regularly and conferred with other professionals to develop the peer-reviewed plan prior to its release for comment from the general public and the availability of the draft plan and related information on a prepared webpage. Finally, this plan was drafted in accordance with the National Invasive Species Act of 1996, which encouraged individual states to create their own ANS plans and also established a federal-level Aquatic Nuisance Species Task Force to review and approve state plans. Section one of the plan provides information about the differences between AIS and ANS, how the plan was developed, and an overview of general economic and ecologic impacts relying on the little data that are currently available. The planning committee felt strongly that not every nonnative aquatic species is a problem, and the terms aquatic invasive species and aquatic nuisance species should not be used interchangeably. An AIS is a nonnative species found outside of its historic range that is likely to cause ecological or economic harm. An ANS is a nonnative species that has been introduced and is known to be causing ecological or economic harm. This section also provides information about other plans in North Carolina that reinforce the need for monitoring and control of ANS and offer opportunities for partnerships and information sharing. The potential for collaborative efforts among agencies and other organizations may also enable leveraging of funds available for plan implementation.

Section two provides information about the problem of aquatic nuisance species throughout the state in both freshwater and marine environments. In order to show that the problem is a statewide issue, case studies from the eastern region (Lake Waccamaw in Columbus County and the Chowan River in Chowan County), the central region (Lake Gaston in Halifax, Northampton, and Warren Counties), and the western region (Lake James in Burke and McDowell Counties) illustrate the environmental implications and mounting monetary costs associated with the control of ANS.

Section three is an overview of where ANS originate and how they are introduced into the state's waters. Nearly three-quarters of the ANS species in North Carolina have been introduced from other areas of North America. Humans play a key role in these introductions, either through unintentional or deliberate actions. For example, over one-half of ANS fish species known to be in the state were introduced by intentional stocking

or bait release. Additional pathways include cultivated species that escaped captivity, "hitchhiking" on recreational or commercial watercraft, and aquarium releases. Existing regulations help to minimize potential problems associated with the aquaculture trade, such as genetic mixing with native species.

Section four provides detailed information about ANS species of concern. The committee used the lists of known noxious, prohibited, injurious, and invasive species and classified them into categories for invasive and nuisance aquatic species. An additional category was created to highlight "high risk" ANS: those that are not known to be in the state at this time, but that could potentially have severe negative impacts (such as Zebra Mussels). One-page fact sheets for many of these species are included and can be used by interested groups and members of the public for dissemination of public information regarding specific threats. A complete list of species is provided in Appendix D, including information about nonnative species that are not causing significant impacts, and species that are native to one part of the state and only become a problem when they are moved to another part of the state.

Section five of the plan provides summary information about the various agencies with statutory regulatory responsibilities regarding ANS. Four primary state entities currently have such duties: the NC Department of Agriculture and Consumer Services (NCDA&CS), the NC Wildlife Resources Commission (NCWRC), the NC Division of Marine Fisheries (NCDMF), and the NC Division of Water Resources (NCDWR). The four entities all address various issues associated with ANS, though they are not redundant as they regulate different species or industries and practices. Other state agencies also are involved to a lesser extent as their budgets allow. A number of federal agencies are also involved in regulating and overseeing the ANS issue in North Carolina, including the U.S. Department of Agriculture (USDA), the U.S. Fish and Wildlife Service (USFWS), the U.S. Army Corps of Engineers, the U.S. Coast Guard, and others. Their roles are defined in federal policy approved by Congress and implemented through local field offices. Private sector companies and organizations are also playing a critical role in addressing the ANS issue in various parts of the state. A case study about a private utility and control of Hydrilla is provided as an example.

Section six provides an overview of current gaps in the state's response to ANS, including a general lack of both spatial and biological information about existing ANS and their impacts, no systematic reporting mechanisms or monitoring procedures in place, little available research on the economic implications of ANS introduction and proliferation, and fragmented control efforts. For these reasons, the committee has recommended that a standing Aquatic Nuisance Species Task Force (ANSTF) be established to coordinate reporting, control, and monitoring of existing and new ANS occurrences. Implementation tables are provided with associated timelines. The committee did not feel that they were prepared to assign dollar values to the activities and preferred to be specific about financial considerations after implementation steps were considered and prioritized by the ANSTF.

The proposed ANSTF will be the lead entity to develop a "rapid response" strategy for newly identified ANS occurrences, create and implement a comprehensive public outreach effort, establish reporting and monitoring procedures, and identify topics needing additional research and observation. Communication channels can be enhanced among regulators, academia, and interested members of both public and private sectors by having regular meetings and joint activities focused on a common topic of concern. In a time of constrained financial resources, leveraging of funding opportunities can be more fruitful with a broad base of support that such a committee could cultivate and serve.

Though much about the ANS issue in North Carolina is unknown, there is clearly a certainty that the issue is having many negative impacts and is a growing threat to the environmental and economic well-being of the state. Effective partnerships, shared learning, and timely proactive management strategies are necessary to meet the goal of controlling the incidence and spread of ANS in North Carolina. The North Carolina Aquatic Nuisance Species Management Plan provides a road map for that coordination to occur more comprehensively and effectively.

I. INTRODUCTION

North Carolina stretches across three geographic regions including the Mountains, the Piedmont, and the Coastal Plain and provides a variety of aquatic habitats including creeks, rivers, reservoirs, ponds, natural lakes, wetlands, and estuaries. There are 17 major river basins located wholly or partially within the state (Figure 1). Unique characteristics of aquatic habitats across the state support a diverse natural heritage that in some areas has become threatened by introduced species. International commerce involving movement of goods and material has brought with it unintentional consequences. Wildlife, plants, and other organisms are collected from one corner of the world, then transported and introduced to other locations where native populations are often adversely affected. Similarly, relocating animals and plants from one area of the state to another can also pose a significant risk to established aquatic communities. It is estimated that introduced nuisance species, both aquatic and terrestrial, cost the United States an estimated $120 billion a year in total damage and control costs. (Pimentel et al. 2005). Recreationists, hobbyists, and commercial activities are all contributing to the large-scale movement of species. It is a complex problem imposing significant ecological and economic impacts to North Carolina, a problem that demands coordinated, timely, and effective responses. Invasive species are particularly difficult to manage in aquatic resources because they spread easily through the water, are difficult to chemically control, and often cross jurisdictional boundaries. Regulatory agencies, academic researchers, and both public and private sectors in North Carolina must identify ways to more effectively communicate and implement efforts to prevent the introduction and spread of aquatic invasive species before more of those species become a nuisance.

NORTH CAROLINA RIVER BASINS

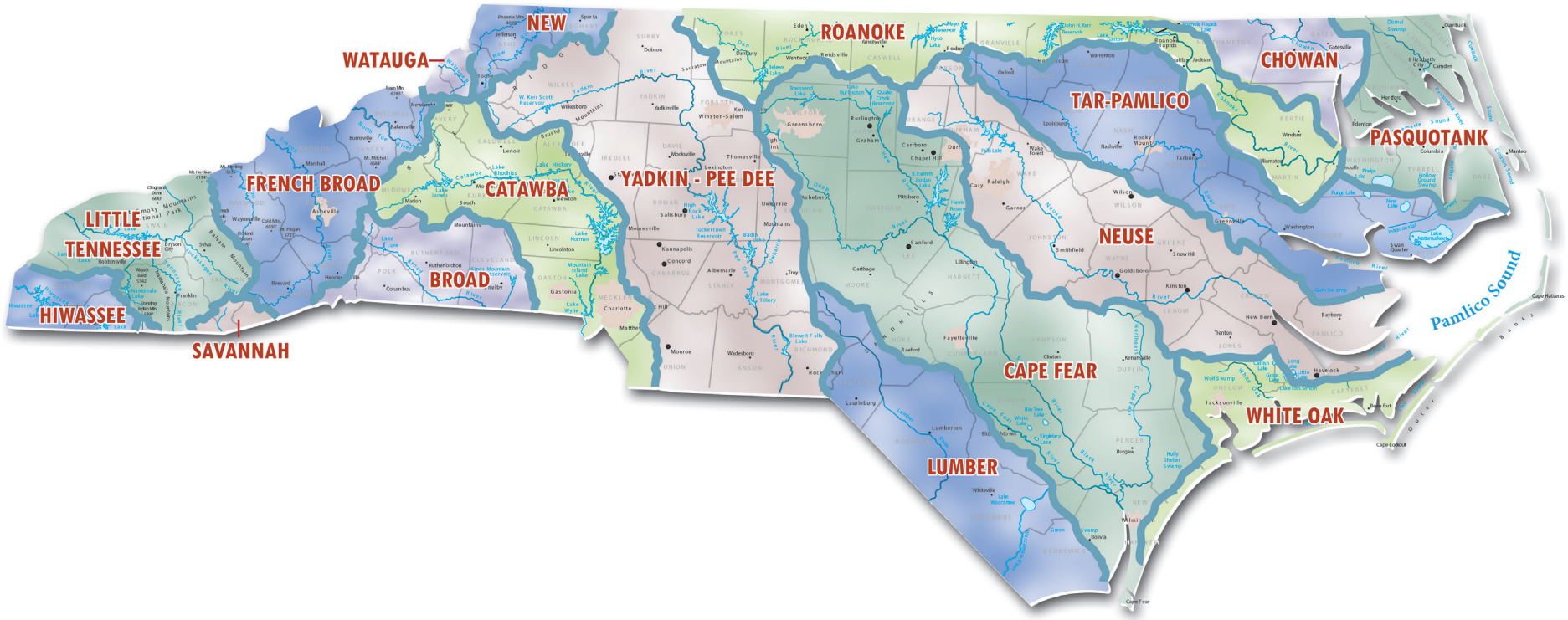


Figure 1. Map of river basins in North Carolina (www.ncwildlife.org)
N.C. WILDLIFE RESOURCES COMMISSION. BASE MAP COPYRIGHT JOHN FELS, 1997

The 17 river basins and their geographic size within the state are (from east to west):

Albemarle Sound / Pasquotank: This basin drains over 18,000 square miles (mostly in southern Virginia). The North Carolina portion is 3,906 square miles in size and includes the Albemarle Sound, Currituck Sound, Croatan Sound, Roanoke Sound, and a portion of Pamlico Sound along the Outer Banks to Ocracoke Inlet, and the outlets of the Pasquotank, Chowan, and Roanoke Rivers. Extensive planning and management partnerships are formed between the states and the U.S. Environmental Protection Agency through the Albemarle-Pamlico National Estuary Partnership.

Tar Pamlico: This basin drains 5,375 square miles and lies entirely within North Carolina. It includes the Tar River and Fishing Creek, which converge to form the Pamlico River; an ecologically important wetland and estuary area.

Neuse: This basin drains approximately 6,225 square miles of the piedmont and central coastal plain of North Carolina and includes the Neuse, Eno, Flat, and Trent Rivers which becomes an estuary of the Pamlico Sound. The Falls Lake impoundment on the Neuse River is the primary water supply for the City of Raleigh.

White Oak: Located on the eastern coastal plain, this basin drains approximately 910 acres and includes White Oak River, Newport River, and North River. It also includes the waters of Bogue Sound and Core Sound. Almost half of the basin is classified as open water, and most of the balance is forested area, including the Croatan National Forest.

Chowan: This basin drains approximately 4,973 square miles, mostly within southeastern Virginia. The lowest quadrant of the basin (487 square miles) is located within North Carolina. It begins at the convergence of the Nottoway and Blackwater Rivers which then become the Chowan River that drains to the Albemarle Sound. The Chowan Basin is part of the Albemarle-Pamlico estuarine system, the second largest estuarine system in the United States.

Roanoke: Though the Roanoke basin comprises over 10,000 square miles, only 3,530 of them are located in northern central North Carolina and includes the south-flowing Roanoke River, and portions of the Dan and Hyco Rivers. The basin includes hydropower facilities on Kerr Lake, Roanoke Rapids Lake, and Lake Gaston before regaining river characteristics on the north eastern coastal plain.

Cape Fear: Located entirely within North Carolina and is the state's largest drainage basin, encompassing 9,149 square miles. It includes the Cape Fear River, the Haw River (impounded by the B. Everett Jordan Dam), and the Deep River.
Lumber: This basin is actually an uppermost composite of three larger basins that are mostly located in South Carolina, and one small basin in eastern North Carolina. The three uppermost reaches include the Lumber, Big Shoe Heel Creek, and the Waccamaw, and all of them ultimately become part of the Great Pee Dee Basin. The fourth sub-basin includes the Shallotte River and Lockwood's Folly River that eventually flow into the Atlantic Ocean.

Yadkin Pee Dee: This area is the northern-most portion of a large basin that extends from mountainous headwater areas through the central piedmont of North Carolina and into South Carolina. It includes the Yadkin River and its confluence with the Uwharrie River which forms the Pee Dee River and its confluence with the Rocky River. There are impoundments located at W. Kerr Scott Lake, High Rock Lake, Tuckertown Reservoir, Baden Lake, Lake Tillery, and Blewett Falls Lake before the Pee Dee runs into South Carolina. The portion of the basin in North Carolina covers approximately 2,723 square miles.

Catawba: Located in western North Carolina and drains 3,343 square miles of high elevation and piedmont lands. It contains the Catawba River which has 7 impounded lakes formed by Duke Energy hydropower facilities, and eventually flows into South Carolina just below the densely-populated City of Charlotte.

New: The New River basin includes 754 square miles in north western North Carolina that drain the western slope of the Eastern Continental Divide. It is comprised of the North and South forks of the Toe River which converge to form the New River that flows north to Virginia. Portions of the South Fork and New River have been designated as National Wild & Scenic River and State Natural and Scenic River.

Broad: Mostly located in South Carolina, the 1,511 square miles of this basin are primarily undeveloped headwater streams that drain some of the eastern slope of the Blue Ridge.

Watauga: The entire basin is 883 square miles. Though largely located in eastern Tennessee, approximately 206 square miles are located in mountainous northwestern North Carolina and includes the Elk and Watauga Rivers. Land in this sparsely-populated portion of the basin is predominantly forested area and pasture.

French Broad: The main rivers included in this basin include the French Broad, the Pigeon, and the Nolichucky, all of which drain the western slope of the Blue Ridge and are part of the Mississippi River system ultimately emptying in the Gulf of Mexico. The basin encompasses 2816 square miles in western North Carolina and 1500 square miles in eastern Tennessee. The three rivers converge in eastern Tennessee where they are impounded just upstream of Douglas Lake. Much of this basin lies in undeveloped land within the Pisgah and Cherokee National Forests.

Little Tennessee: Two primary rivers in this basin are the Little Tennessee and the Tuckasegee on the western slope of the Blue Ridge. The basin begins in northern Georgia and extends through just over 2,300 square miles into North Carolina and eastern Tennessee. Much of this basin is comprised of Tennessee Valley Authority hydropower facilities at Fontana Lake and forested land.

Savannah: Only a very small portion (172 square miles) of this basin exists in southwestern North Carolina that includes headwater areas for the Savannah River which flows through South Carolina and Georgia before entering the Atlantic Ocean. This is a very steep area that is almost exclusively within the boundaries of the Nantahala National Forest and receives an average annual rainfall of over 100 inches.

Hiawassee: This basin encompasses 2,099 square miles in Georgia, North Carolina, and Tennessee. Approximately 641 square miles of it is located in two mountainous counties in far western North Carolina, predominantly within the Nantahala National Forest. The entire river is managed by the Tennessee Valley Authority for hydropower production, and three impoundments are located on the river reach within North Carolina.

North Carolina‘s coastal ocean includes the convergence between two major oceanic currents: the warm, north-flowing Gulf Stream and the cool, south-flowing Virginia coastal current (also called the Labrador Current). The Gulf Stream current moves within 10 – 12 mi (16.1 – 19.3 km) of the coast at Cape Hatteras before turning northeast toward Europe, bringing southern native and non-native species to North Carolina‘s ocean and estuarine waters. The Virginian (Labrador) Current ends at the Gulf Stream, supplying northern oceanic native and non-native species to North Carolina (Deaton et al. 2010).

AIS or ANS

What is the difference between Aquatic Invasive Species (AIS) and Aquatic Nuisance Species (ANS)?

Although some groups and documents use AIS and ANS interchangeably, for this document we have classified introduced aquatic species into three general groups:

Aquatic nonnative species are organisms that have been moved to a place, drainage system, ecosystem, or any aquatic system outside of their historic range;

Aquatic invasive species **(AIS)** are aquatic organisms that are likely to cause negative ecological and/or economic impacts when moved outside of their historical range;

Aquatic nuisance species **(ANS)** are aquatic invasive organisms that have been introduced and are causing ecological and/or economic harm.

Plan Purpose, Scope, and Development

The North Carolina Aquatic Nuisance Species Management Plan (NCANSMP) addresses both aquatic invasive species and aquatic nuisance species. Examples of AIS that have been found in North Carolina include Tiger Shrimp (*Paneaus monodon*) and Giant Salvinia (*Salvinia molesta*). Examples of ANS include Lionfish (*Pterois volitans*), Flathead Catfish (*Pylodictis olivaris*), Hydrilla (*Hydrilla verticillata*), Alligatorweed (*Alternanthera philoxeroides*), and Nutria (*Myocastor coypus*). For the remainder of this section the term "invasive" refers to any organism that falls in the invasive species category or the nuisance species category. The designation of current species in this document are defined based on existing knowledge and monitoring of these species within the extent of North Carolina. Annual reviews of the NCANSMP species list will allow for changes in the prioritization and designation of individual species.

The purpose of the NCANSMP is to improve the State's ability to address aquatic invasive and nuisance species issues. In order to have measurable and meaningful results (i.e. curbing the impact of aquatic invasive species), multiple approaches will be needed. This plan makes specific recommendations that will create a framework to guide coordinated statewide actions. This plan aims to help improve current management by identifying potential strategies for coordination among agencies and other organizations, to raise awareness and enhance cooperation on aquatic invasive species issues. Expected outcomes are to effectively identify and prioritize aquatic invasive species threats, to identify and prioritize vectors, and to minimize the impacts of aquatic invasive species that are causing harm to the ecology and economy of North Carolina. Another expected outcome of the plan is to educate and engage the public in assisting agencies in identifying and addressing aquatic invasive species throughout the state. This plan is in alignment with general guidance provided by the national Aquatic Nuisance Species Task Force (ANSTF).

The NCANSMP was developed by a steering committee representing multiple state and federal agencies, including the U.S. Fish and Wildlife Service (USFWS), the NC Division of Water Resources (NCDWR), the NC Department of Agriculture and Consumer Services (NCDA&CS), the NC Division of Marine Fisheries (NCDMF), the NC Wildlife Resources Commission (NCWRC), the NC Division of Coastal Management (NCDCM), the NC Office of Land and Water Stewardship and faculty of North Carolina State University (NCSU). Starting in 2014, the NCANSMP steering committee met regularly as a think tank, identifying and discussing current aquatic invasive species management efforts, reviewing materials, and drafting plan components. The working draft was then circulated to peer reviewers for further refinement. Once the draft was completed, the steering committee publicized and posted it on a Department of Environmental Quality (NCDEQ) webpage for dissemination to the public and solicited comments. Comments received were considered and a final draft was prepared for executive review and approval in 2015.

This plan is limited to aquatic invasive species problems within the state of North Carolina but it is implicit that management activities be coordinated with our neighboring states to help reach our goal of minimizing new introductions. Congress authorized the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) in 1990 with the goal of addressing specific ANS problems in the Great Lakes region of the country. By 1996, NANPCA was reauthorized and renamed the National Invasive Species Act, which established a national goal of eliminating and preventing new introductions of all AIS. This act authorized every state to develop a comprehensive management plan to deal with the multitude of problems that are attributed to AIS. States with approved plans are eligible for federal financial assistance to help implement their management objectives.

Some viruses and diseases could be considered aquatic invasive species. While it is recognized that they cause harm to native wildlife as well as people and that these microorganisms have aquatic relevance, they are beyond the scope of this plan. However, they may be addressed in future iterations of the NCANSMP.

It is important to note that not all exotic or nonnative aquatic species are predisposed to become a nuisance in North Carolina. Statistically, only a small percentage of all exotics that are able to survive or even naturalize in North Carolina will become aquatic nuisance species. ANS cause problems when there are few or no native predators or biological controls to keep the growth and reproduction of those specific organisms in check.

Aquatic Invasive Species Vectors and Impacts

Aquatic invasive species can be moved from one system to another through a variety of pathways or vectors (e.g. stocking, bait release, aquarium release, relocation by "hitchhiking" on boating or fishing equipment or any other equipment exposed to aquatic systems, aquaculture escapement, aquarium and water garden trade, or in the ballast water of ships). It is important to note that not all exotic or nonnative aquatic species are predisposed to become a nuisance in North Carolina. Statistically, only a small percentage of all exotics that are able to survive or even naturalize in North Carolina will become aquatic nuisance species. ANS cause problems when there are few or no native predators or biological controls to keep the growth and reproduction of those specific organisms in check.

ANS often have unintended, negative consequences, which can alter the existing aquatic community permanently. Quantifying the ecological impacts of ANS is often difficult. Introduced animals can feed on eggs, fry, or adults of existing animals; compete with existing animals for food and habitat; introduce diseases and parasites; interbreed with existing species, diluting the native gene pool; and degrade habitat and water quality. Similarly, introduced plants compete with existing plants for nutrients, light, and habitat; impact water quality; and alter existing habitat. Some impacts may be indirect and others may not yet be known. Unfortunately, once established, ANS are nearly impossible to eradicate. Strategies to evaluate and manage the unintended impacts of ANS are difficult to implement, often ineffective, and costly. Furthermore, the harm caused by ANS is not limited to the waters where they are introduced because these species inevitably move downstream or are transferred to adjacent basins. ANS will often outcompete native organisms and can ultimately lead to a condition of reduced biodiversity. There are obvious challenges with assigning a dollar value to ecological function and biodiversity. Environmental impacts and economic impacts are often tightly linked, yet the specifics of the relationships can be elusive.

Often it is the economic and social impacts that are more effectively quantified and articulated. The value of real property that is affected by aquatic nuisance species can be more easily determined. The impacts to direct water use and recreation can be measured. The direct economic impact of ANS on commercially important fish or shellfish industries can be calculated. Noxious aquatic weeds are ANS that have caused numerous problems across the state and have been investigated specifically to determine negative economic impacts in North Carolina. In 1995 the North Carolina General Assembly directed the NCDWR to study aquatic weed infestations on a statewide basis. The NCDWR was to identify research; assess environmental and economic impacts; assess impact of federal regulations; and discuss management, eradication, enforcement and funding mechanism options. A report titled "Economic & Environmental Impacts of N.C. Aquatic Weed Infestations" was released in April 1996. The report specifically highlighted Hydrilla, Alligatorweed, and Eurasian Watermilfoil (*Myriophyllum spicatum*). Hydrilla grows as a submersed plant and forms thick mats which directly impact recreation activities and can impede water withdrawal (municipal supply, irrigation and industrial). Hydrilla can outcompete beneficial native submerged aquatic vegetation and alter the function or structure of the habitat it invades (Langeland, K.A. et al. 1996.).

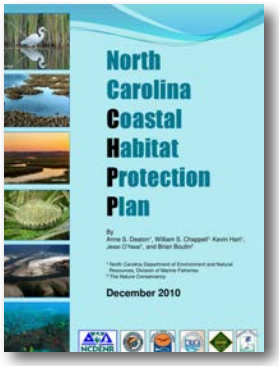
Hydrilla verticillata wrapped around a boat prop can be a source of contamination in new water bodies.

Interactions with Other Plans

Albemarle-Pamlico Comprehensive Conservation and Management Plan

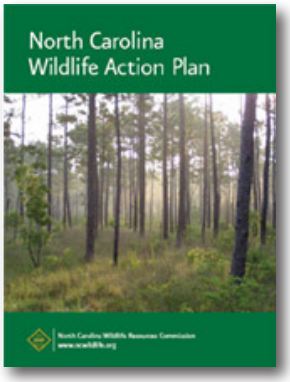
The Albemarle-Pamlico National Estuary Partnership (APNEP) is a cooperative effort jointly sponsored by the NCDEQ and the U.S. Environmental Protection Agency (USEPA) with support from the Commonwealth of Virginia. The mission of APNEP is to identify, protect and restore the significant resources of the Albemarle-Pamlico estuarine system. The program area extends across most of the Albemarle-Pamlico watershed, which falls in SE Virginia and the eastern part of North Carolina. APNEP currently has in place its Comprehensive Conservation and Management Plan 2012-2022. This plan identifies three primary goals and lists specific ecosystem outcomes for each goal. Goal number 2 states "A region where aquatic, wetland and upland habitats support viable populations of native species" and one of the outcomes is "Nonnative invasive species do not significantly impair native species' viability or function, nor impair habitat quality, quantity and the processes that form and maintain habitats." (APNEP Policy Board 2012).

Coastal Habitat Protection Plan



Recognizing the need to both protect habitat and prevent overfishing, the North Carolina General Assembly passed the Fisheries Reform Act in 1997. Part of that act charged the NCDMF with writing a Coastal Habitat Protection Plan (CHPP). The CHPP includes a section on threats to coastal fish habitat and specifically lists "Introduced or Nuisance Species." The CHPP states "Introduced species can compete with natives for space, light and nutrients and displace natives with species of lower value to native fish utilization." One of the goals of the 2010 CHPP is to "Improve Effectiveness of Existing Rules and Programs Protecting Coastal Fish Habitats," which includes enhancing and expanding educational outreach on the value of fish habitat, threats from human activities, effects of nonnative species, and reasons for management measures (Deaton et al. 2010). The CHPP is updated every 5 years and is currently under its 2015 revision.

North Carolina Wildlife Action Plan



The North Carolina Wildlife Action Plan (WAP) is a comprehensive management tool developed by the NCWRC and more than 50 partners to help conserve and enhance the state's full array of fish and wildlife species and their habitats. The WAP describes 17 river basins and 23 types of habitats that are found across the state. The plan matches each priority species to the habitat type or river basin where it is found, identifies the most important threats facing each habitat, including invasive species, and details the critical actions required to protect and conserve these habitats. The plan was originally developed in 2005 and is currently undergoing a 2015 revision (NC Wildlife Resources Commission 2005).

River Basin Water Resources Plans

The NCDWR is in the process of developing river basin water resources plans for each of the 17 river basins in North Carolina. A component of these plans is to identify and catalog aquatic weed problems within each basin. These plans will provide recommendations to the Environmental Management Commission (EMC) to ensure the quality and quantity of surface water and groundwater (North Carolina Division of Water Resources website, http://portal.NCDEQ.org/web/wq/ps/bpu.).

Adjoining State ANSMPs

North Carolina shares borders with four other states that have already adopted plans to address aquatic nuisance species: the Virginia Invasive Species Management Plan (2005), the Tennessee Aquatic Nuisance Species Management Plan (2008), and the South Carolina Aquatic Invasive Species Management Plan (2008), and the Georgia Aquatic Nuisance Species Management Plan (2009). Each of these states has emphasized ways to prevent the introduction of AIS that are also noted in the North Carolina Plan. Coordination between states to prevent the introduction of AIS into shared waters can be further enhanced by establishing regular communications between state AIS program coordinators, participation in National ANS Task Force conferences and events, and through the implementation of other existing interstate aquatic management plans such as the Albemarle-Pamlico Comprehensive Conservation and Management Plan. Additionally, continued participation in regional ANS efforts through the Southeast Aquatic Resources Partnership (SARP), the Southeastern Association of Fish & Wildlife Agencies (SEAFWA), and the Gulf and South Atlantic Regional Panel on Aquatic Invasive Species enhances information exchange and can provide a forum for identifying partnerships for future initiatives and joint activities to address shared objectives.

II. PROBLEM DESCRIPTION

The direct and indirect negative impacts of ANS are increasing noticeably, affecting the survival and diversity of our native plants and animals; disrupting natural ecosystem functions; and impairing the valuable use of our waterways for recreational, commercial, and industrial activities.

Background

As our economy has become more global, aquatic plants and aquatic animals are being moved around at an increased rate. These organisms are being moved to areas outside of their native ranges, both within and from outside of the United States. Not all nonnative aquatic species are predisposed to cause problems or are considered threats to the state's environment or economy; however, a handful do constitute a significant risk in one or both of these categories. The direct and indirect negative impacts of ANS are increasing noticeably, affecting the survival and diversity of our native plants and animals; disrupting natural ecosystem functions; and impairing the valuable use of our waterways for recreational, commercial, and industrial activities. While not always a true measure of ecological health, species biodiversity is one metric that can be helpful to natural resource managers when assessing ecological conditions of specific habitats.

Aquatic animal species introductions have greatly increased in North Carolina since the 1950s (Figure 2). North Carolina does not have a current or complete record of when each of the known introduced species first arrived into our state, nor do we know the definite geographical extent of each species. These gaps in data will hopefully be addressed in the near future as education and awareness are increased about the impacts some of these species can cause both ecologically and economically to our state. As recently as 2014 it was estimated that there are 130 different nonnative aquatic species in our waterways (Figure 2).

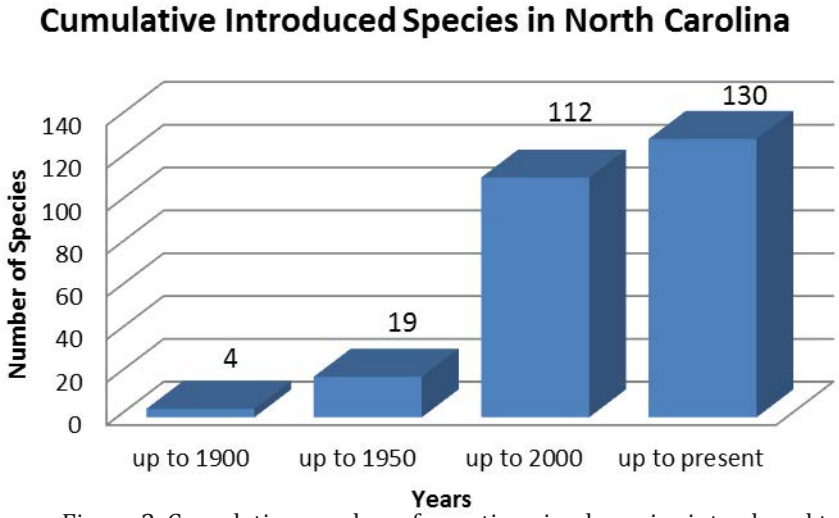


Figure 2. Cumulative number of aquatic animal species introduced to North Carolina waters. Data accessed on 11/20/2014 by United States Geological Survey.

North Carolina has a diverse distribution of both freshwater and marine resources. Within the 17 major river basins, there are over 37,000 miles of freshwater rivers and streams. There are 58 major reservoirs (>250 acres) in North Carolina, ranging in size from 272 to 32,510 acres, with a combined total surface area of 218,505 acres (McRae 2015). Coastal waters include the extensive Albemarle and Pamlico estuarine systems which are separated from the Atlantic Ocean by 300 miles of coastline. The waters' features and the surrounding wetlands provide important habitat for fish and other wildlife at various stages of their life cycles. North Carolina provides terrestrial and aquatic habitat for over 4,131 species including vascular plants, native vertebrate animal species (excluding marine fishes), and native species in the following invertebrate groups: freshwater mussels; freshwater snails; crayfishes; large branchiopods; butterflies and skippers; underwing moths; tiger beetles; and dragonflies and damselflies and ranks number 9 in the nation for species diversity. North Carolina also ranks number 1 for amphibian diversity with 84 species (Stein 2002). Approximately 40% of freshwater fish in North America are considered imperiled (Jelks et al. 2008) and 70% of freshwater mussels are at risk (Stein et al. 2000). In North Carolina 13.6% of our 206 freshwater fish species are considered "at risk" (Stein 2002). These waters continually provide the public with a wide range of recreational activities, supporting the tourism industry and local economies throughout North Carolina.

Ecological Impacts

North Carolina has many native species that are declining and nonnative nuisance species are one of the major causes. It is estimated that 42% of Federally Threatened or Endangered species are significantly impacted by nonnative nuisance species across the nation and nuisance species are significantly impeding recovery efforts for them in some way (Stein and Flack 1996).

There are many areas across the state of North Carolina where ANS have invaded aquatic communities; are competing with native species for food, light, or breeding and nesting areas; and are impacting biodiversity. Biodiversity refers to all of the organisms (plants, animals, fungi, bacteria, etc.) and ecosystems that can be found in a region. Generally, a high level of biodiversity indicates

North Carolina has many native species that are declining and nonnative nuisance species are one of the major causes.

that natural systems are in balance and that the environment is healthy. When an AIS is introduced it may have many advantages over native species, such as easy adaptation to varying environments and a high tolerance of living conditions that allows it to thrive in its nonnative range. There may not be natural predators to keep the invasive species in check; therefore, it can potentially live longer and reproduce more often, further reducing the biodiversity in the system. The native species may become an easy food source for invasive species, or the invasive species may carry diseases that wipe out populations of native species.

Aquatic nuisance species that disrupt coastal and ocean waterways around North Carolina can affect various life history stages of native species. Species such as the Australian Spotted Jellyfish, the Asian Tiger Shrimp, and the Lionfish are known to be voracious predators, eating or impacting food sources for native species and are not known to have natural predators in North Carolina waters. These coastal and marine ANS are currently tracked through NCDMF annual and seasonal surveys and through validation of local reports.

These are just a few examples, but there are many more direct and indirect ecological impacts that can be anticipated with continued introductions of nuisance species in our state.

CASE STUDY: Lake Waccamaw and Hydrilla

Lake Waccamaw in Columbus County is the most biologically diverse lake in North Carolina and one of the most species-rich lakes in the Western hemisphere. Unfortunately, the ecology of the lake has become threatened by ANS (Figure 3): specifically an aquatic weed known as Hydrilla (*Hydrilla verticillata*). Native to Asia, Hydrilla was introduced to North Carolina waters more than 30 years ago. This plant readily reproduces by fragmentation, where a small fragment can grow into a whole new plant. This form of asexual reproduction (including tubers) can quickly lead to the development of a large colony of plants capable of impeding a waterway, damaging fisheries, and displacing native plants by filling the water column with vegetation.

Lake Waccamaw has 52 fish species, 11 species of snails, and 15 species of mussels and clams, many of them endemic to the lake, meaning they have been found nowhere else on earth. Some of the species found in this lake are extremely rare and under state or federal protection. The Waccamaw Silverside (*Menidia extensa*) is listed as a Federally Threatened species and the Waccamaw Fatmucket (*Lampsilis fullerkati*) and Carolina Pygmy Sunfish (*Elassoma boehlkei*) are being considered for federal listing. There are several other rare, endemic species in the lake, including: Waccamaw Killifish (*Fundulus waccamensis*), Waccamaw Darter (*Etheostoma perlongum*), Waccamaw Spike (*Elliptio waccamawensis*), Waccamaw Snail (*Amnicola sp.*) and Waccamaw Siltsnail (*Cincinnatia sp.*).

The introduction of Hydrilla to this important biological resource was alarming to many natural resource managers and stakeholders. Because of this one ANS, Lake Waccamaw's rare native species are under careful watch by biologists and natural resource managers who are working to address the Hydrilla problem and the threats it currently imposes on this uncommonly rich natural resource. NCDEQ, in cooperation with other state entities and local governments, began a Hydrilla eradication project in 2013. The entire infestation was treated with herbicide at a cost of $401,000 and the associated field work (monitoring and survey) was completed for an additional cost of approximately $15,000. In 2014 the treatment cost was slightly less at $367,000 plus associated field work. The treatment is highly influenced by rainfall; unfavorable weather conditions would have resulted in an addition $97,000 herbicide cost in 2014. The Lake Waccamaw Technical Advisory Committee estimates that costs will be on average approximately $500,000 annually through 2020 to completely remove Hydrilla from Lake Waccamaw. The time and money used to monitor Hydrilla and its impact on native species illustrates the complexity of invasive species management and eradication efforts. The very high costs associated with these management activities emphasizes why prevention of these invasions are so critical to the North Carolina environment and economy (Emens 2015).

Figure 3. An estimated 608 acre area of Hydrilla infestation (highlighted in red) on Lake Waccamaw. *Courtesy of North Carolina State University Department of Crop Science*

CASE STUDY: Lake James and White Perch, Blueback Herring, and Alewife

Lake James, located in Burke and McDowell counties, is the uppermost reservoir on the Catawba River chain of Duke Energy lakes. Impounded in 1923, the reservoir supports recreational fisheries for Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), sunfish (*Lepomis sp.*), Walleye (*Sander vitreus*), White Bass (*Morone chrysops*), and crappie (*Pomoxis sp.*). However, invasive species have been introduced into the reservoir and have been implicated in the decline of sport fish populations, most notably Walleye. Walleye were introduced into the reservoir in the 1950s and have since supported a very popular fishery.

In 2008, White Perch (*Morone americana*) were first verified in Lake James by NCWRC biologists. White Perch are known to consume eggs and compete with some sport fish during specific life stages and can have negative impacts on the population dynamics of popular fisheries (Feiner 2011). In 2009, Blueback Herring (*Alosa aestivalis*) and Alewife (*A. pseudoharengus*) were first discovered in the reservoir. These two fish are also known to negatively impact some sport fisheries. A recent study on Hiwassee reservoir demonstrated a strong negative effect from Blueback Herring on Walleye recruitment (Wheeler et al. 2004). After the initial discovery of these species, NCWRC biologists collected in 2012 an abundance of all three species during Walleye broodstock surveys in Catawba and Linville rivers, tributaries to the reservoir. As of March 2012 all three species appeared to be well established in Lake James.

Concurrent with invasive species establishment there were numerous complaints from anglers concerning low catch rates of Walleye. NCWRC biologists verified a lack of reproduction during 2011 and 2012. Surveys conducted annually from 1999-2008 indicated the Lake James Walleye population was composed of multiple year classes maintained through annual natural reproduction, albeit moderately erratic from year to year. The percentage of age-0 and 1 Walleye was lower in the 2012 survey than any reported value since annual surveys were initiated in 1999. These results were evidence that invasive species may be impacting spawning success of Walleye in Lake James and an immediate management action was necessary. Consequently, NCWRC began stocking Walleye at the historical rate of 30,000 fish/year to offset future recruitment failures. NCWRC biologists plan to continue stocking efforts and evaluate the contribution of stocked fingerlings to the Lake James Walleye fishery by utilizing modern population genetic techniques. The genetic evaluation will be conducted over a several year period costing approximately $10,000 per year. The annual cost of producing and stocking of Walleye to maintain a fishery is estimated at $6,500. However, it will require a more significant effort to restore the fishery to levels observed before White Perch, Blueback Herring and Alewife were introduced.

Economic Impacts

Nationwide it is estimated that nonnative, aquatic, and terrestrial nuisance species cost the United States economy $120 billion dollars annually in lost production, control costs and environmental damage (Pimentel et al. 2005). An additional study has estimated that the introduction of 15 recent species alone could cost the U.S. $134 billion by 2050 (U.S. Congress 1993). While North Carolina's total economic and environmental impact costs are not well known or clearly defined, it is clear that costs continue to rise as more nonnative species make their way into our state. Potential costly impacts from ANS that are more measurable include reduced waterfront property values when desirable water bodies become infested by invasive aquatic plants; the costs associated with maintaining blocked water intakes; and the cost of contaminated water used for municipal, industrial, and agricultural purposes. Duke Energy estimates that they have spent approximately $400,000 over the past five years to manage ANS such as Hydrilla at their facilities in North Carolina. This cost includes herbicides, triploid Grass Carp, surveys, equipment, travel costs, and staff time (Manuel 2015). Duke Energy, in cooperation with the state, has successfully managed Hydrilla throughout the Catawba and elsewhere over the last twenty years. Many home and business owners face real costs associated with ANS across the state on an increasing basis.

Impeded flow patterns and nuisance plant infestations create optimal breeding conditions for mosquitos and provides these pests with food and shelter from predators that would normally help naturally control them. Because of this nuisance aquatic plant–mosquito association, many of the early aquatic plant control programs were initiated by mosquito control districts (Gallagher and Haller 1990). Local governments and public health officials incur increasing costs for managing mosquitos and other pests that live and multiply in standing water; these costs could be passed along to the local residents.

Some of the most widely used public lakes in North Carolina are managed by the U.S. Army Corps of Engineers (USACE) in cooperation with the NC Division of Parks and Recreation (NCDPR) and NCWRC. Managing these lakes for ANS is a joint effort that is an ongoing, time consuming, and expensive task. Current cooperative management efforts include aquatic vegetation surveys that are done at known ANS locations, point surveys over an entire lake yearly, triploid Grass Carp stocking, and herbicide applications where

deemed appropriate. These multiple agency collaborations have improved the success of invasive species removals and increased data sharing among partners across the state.

B. Everett Jordan, Falls of the Neuse and John H. Kerr reservoirs are USACE owned properties that have Hydrilla issues to varying degrees. In addition to Hydrilla other invasive aquatic plants include Brittle Naiad and Parrotfeather at B. Everett Jordan Reservoir; Brittle Naiad and Alligatorweed at John H. Kerr Reservoir; and Parrotfeather, Alligatorweed and Creeping Water Primrose at Falls of Neuse Reservoir. The USACE implemented an Aquatic Vegetation Management Program (AVMP) for John H. Kerr Reservoir in 2012. The 2014 aquatic vegetation survey results estimated that approximately 1,274 acres of Hydrilla were in the lake, mainly on the North Carolina section of the lake. USACE funded surveys and control measures including stocking of triploid Grass Carp at John H. Kerr Reservoir have cost in excess of $185,000 since 2011 (Hosey 2015). Survey results since 2011 and the Kerr AVMP can be accessed on the USACE John H. Kerr Reservoir website: (http://www.saw.usace.army.mil/Locations/DistrictLakesandDams/JohnHKerr/NaturalResources/AquaticVegetationManagement.aspx).

The recreation and tourism industry also has the potential to see the economic impacts of these aquatic nuisance species if water bodies are not able to be used by boaters for fishing and other water sports. Many commercial, recreation, and tourism jobs across the state depend on our rivers, lakes and other water features. If these waterways are unusable for recreation due to ANS, boating, watersports and fishing will become much more difficult and frustrating and recreationists may choose to visit or vacation elsewhere.

CASE STUDY: Lake Gaston

The story of Hydrilla at Lake Gaston serves as an example of how a single nuisance species can lead to tremendous management costs. Lake Gaston is a 20,000-acre reservoir located on the North Carolina-Virginia border. In 1989 approximately 25 acres of Hydrilla were identified. By 1992 it spread to more than 500 acres and 200 of those acres were treated with herbicide. Despite efforts to control its spread, by 1994 more than 2,500 acres were infested. From 1995 through 2012 approximately 3,000 acres of the lake were infested with Hydrilla. Large-scale herbicide applications and triploid Grass Carp stockings over that entire period (19 years) eventually led to a reduction of Hydrilla. Management costs exceeded 1 million annually in the late 2000s (Figure 4).

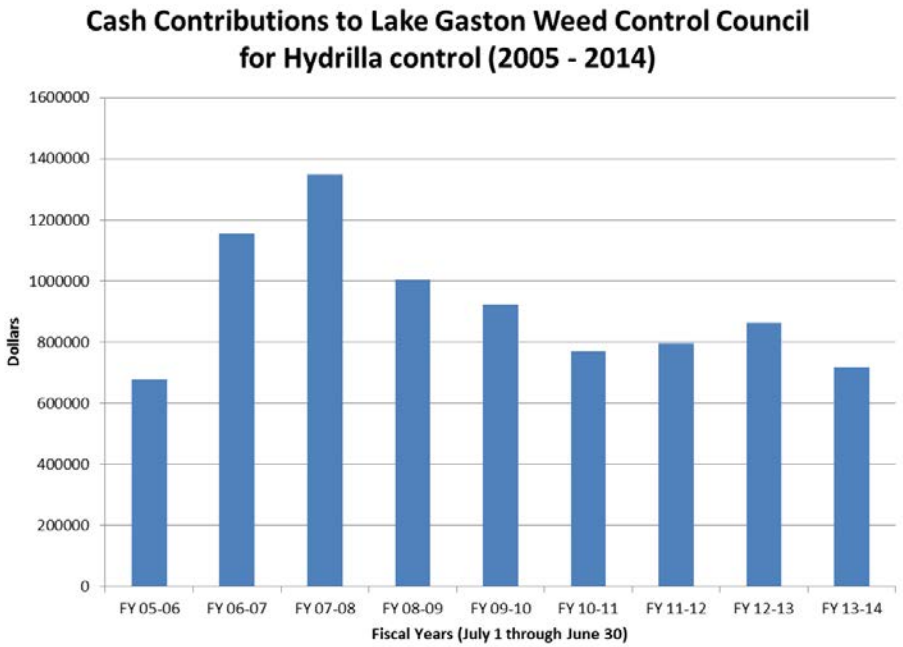


Figure 4. The following data were extracted from the "Cash Contributions Paid to LGWCC" reports; produced by Lake Gaston Weed Control Council.

In terms of management dollars spent, Hydrilla is currently the most costly ANS that infests North Carolina waterways. Once introduced and established in an area, Hydrilla is difficult and expensive to eradicate. Over the last few years, approximately $1.5 million dollars of public funds are spent annually on Hydrilla management across the state, and additional funding comes from private entities, utilities, and non-profit organizations. However, the need for treatment far exceeds available funds (Emens 2015). Eradicating the plant through the use of herbicides or by using triploid Grass Carp is an expensive and lengthy process that can also impact native species in the area. Hydrilla has been a serious problem at Lake Gaston since the 1990s. It began to infest the Catawba chain of lakes in 1999 and management heavily relied on stocking triploid Grass Carp, although rapid response herbicide treatments were applied prior to the approval of the use of triploid Grass Carp. Despite the coordinated effort to control its growth and spread, Hydrilla has continued to infest waterways in more counties and is now spreading to areas which are even more challenging to manage. Hydrilla currently infests the Eno River, Cape Fear River, the Chowan River basin and is beginning to colonize the shoreline along the Albemarle Sound. Biologists fear that it could find its way into pristine lakes such as those in and around Pocosin Lakes and Mattamuskeet National Wildlife Refuges.

Case Study of Economic Impacts: Chowan County

Local communities have begun to identify the need for action on invasive and nuisance species. Chowan County Soil and Water Conservation District and their local community members have collaborated to fund over $25,000 in the past seven years to treat the Chowan River for Hydrilla infestations (Alons 2014). Disruptions in boating traffic, aesthetics and general concern for the spread of invasive species have ignited this county into action. In 2014 Chowan County, in cooperation with NCDWR, treated approximately 15 acres of shoreline in the Chowan River; however, an organized volunteer survey of river shoreline identified additional infested areas that have yet to be treated. Overall, the lack of a broader management plan and funding have led to a patchwork of treatments that have not controlled the spread of Hydrilla into other areas of the river. This results in greater economic impacts and control costs. Local stakeholders are continuing to survey for the presence of Hydrilla to coordinate a unified response.

The story of Giant Salvinia (*Salvinia molesta*) is an example of how the power of partnerships and well-coordinated efforts can lead to excellent results. This story shows that ANS can be managed and even eradicated with Early Detection and Rapid Response (EDRR). Giant Salvinia is a Federally Listed Noxious Aquatic Weed. A one-page fact sheet on this plant is included in this document. Entering the state as a contaminant in water garden plants, Giant Salvinia was unintentionally shipped into North Carolina in 1997. The aquatic plant nursery in Beaufort that received the shipment did not know what the plant was. Giant Salvinia spread within the nursery and contaminated most of their water garden stock. As they continued sales of water garden plants, Giant Salvinia was distributed further. Some of the plants were discovered at the North Carolina State Fair in October 1998 and were found by an NCSU aquatic weed specialist. NCDA&CS was informed and the noxious weeds were traced back to the nursery in Beaufort. Sales records from that nursery helped discover other sites where Giant Salvinia had been introduced. All locations were examined and control/eradication efforts were undertaken. NCSU, NCDA&CS, and NCDWR cooperated in all efforts. Alerts were sent to agricultural extension agents and other state agencies, resulting in several additional infested sites being detected, most of them less than 1 acre in size, and Giant Salvinia was removed from them within a year or two. In 2000, the Southeast North Carolina Giant Salvinia Task Force was formed after a large infestation was discovered in Pender County. The Task Force, composed of twelve partners from federal, state and local agencies, was developed with an explicit mission to detect and eradicate Giant Salvinia from southeastern North Carolina. A rapid response program was put in place so that potential locations were confirmed and evaluated, and control measures were initiated in a timely manner. By 2001, Giant Salvinia had been detected in 9 counties in Eastern North Carolina with all the smaller locations having been eradicated. One site proved to be challenging: a 40 acre hardwood swamp adjacent to the Cape Fear River in Pender County. The task force partnership, with funding support from the National Fish and Wildlife Foundation Pulling Together Initiative grant program, addressed the management challenges of the Pender County site and the last bit of Giant Salvinia was removed from the state in 2009 (Emens and Hoyle 2015).

Control methods:

The use of herbicide was the primary method of control across all known sites. An experimental release of the Salvinia weevil was done at the River Bend site in Pender County. The weevils were released onto a pond which is separate from the hardwood swamp site. The insects were provided to the state by the USDA APHIS program. The weevils controlled the growth of Salvinia to some degree however it became apparent that they were not going to remove Salvinia entirely. Ultimately the pond was treated with herbicide to remove the remaining Salvinia. The most challenging site to remove Salvinia from was the hardwood swamp in River Bend. For several years the approach was to use foliar applications of diquat and/or fluridone, whereas staff waded through with backpack sprayers and towed small kayaks that carried battery-powered spray rigs. Each year Salvinia was partially controlled but also continued to spread and re-infest previously controlled areas. It became apparent this strategy was not going to successfully eradicate the invasive aquatic fern. The management approach shifted to a site-wide herbicide treatment using fluridone. Approximately 2 consecutive years of fluridone pressure successfully removed Salvinia from the site. The trees were not injured and native aquatic plants naturally repopulated the swamp without the need of a revegetation program.

Scott Robinson, Georgia Department of Natural Resources, Bugwood.org

III. PATHWAYS OF INTRODUCTION

Nearly 74% of the 95 introduced aquatic animal species come from elsewhere in North America (Figure 5). Humans have played a key role in introducing the majority of these nonnative species over the years, either unintentionally or deliberately.

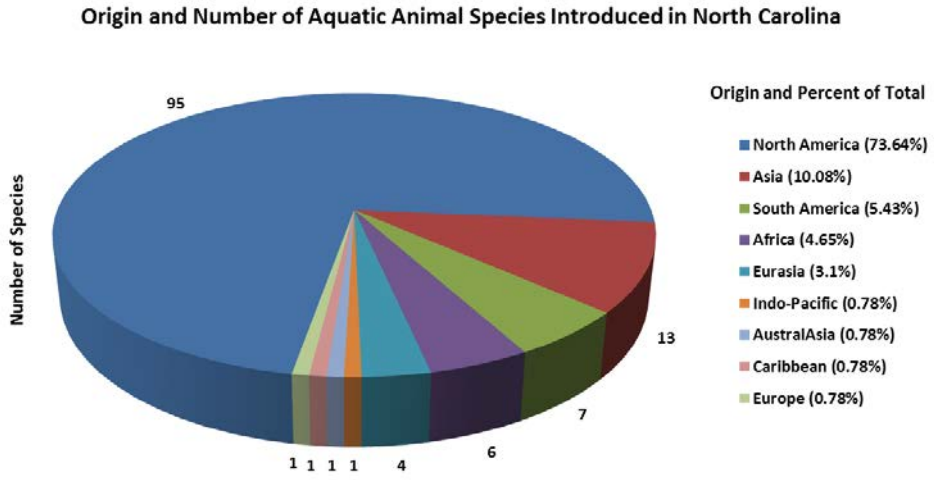


Figure 5. Origin and number of nonnative aquatic animals introduced in North Carolina. Data gathered on 11/20/2014 from the United States Geological Survey.

We have defined ANS as a nonnative species that lives most or all of its life in aquatic environments and is causing negative ecologic and/or economic impacts in North Carolina. It is important to understand how these species enter and invade nonnative ranges in order to educate the public about ways to reduce future harmful introductions. Species have been found outside of their native ranges from other parts in North Carolina, the United States, or even from around the world. Nearly 74% of the 95 introduced aquatic animal species come from elsewhere in North America (Figure 5). Humans have played a key role in introducing the majority of these nonnative species over the years, either unintentionally or deliberately. Introduction pathways are defined as natural or manmade means by which species are physically relocated to areas outside of their native range. Introduction pathways are also referred to as introduction mechanisms or vectors.

Introductions can be unintentional or deliberate and can include many activities, media and occurrences. North Carolina has the potential to be more vulnerable to ANS due to interconnected systems which may allow easier inland access to our rivers and streams for species transportation.

In the Southeast, Florida and North Carolina have the most introduced and established fish species; however, the dominant pathway in each state is different. For example, the majority of Florida's introductions are related to the aquarium trade while North Carolina's are mainly the result of stocking for sportfishing, either by intentional historic resource agency stockings or unauthorized releases by anglers. An average of 72% of all fish species introduced in the Southeast have become established (Benson et al, 2001).

In North Carolina, many species have been introduced from outside of the state. However, a substantial number of species have also been transplanted from one North Carolina waterway where they are native to another waterway outside of their native range. For example, North Carolina has a large number of native minnow species that are thought to have been introduced into previously unoccupied areas as the result of bait releases. Just like exotic species, these species when introduced into new areas of the state can have negative ecological and/or economic impacts.

There are many introduction pathways for ANS species to enter North Carolina. Based upon the information collected and analyzed in the United States Geological Survey (USGS) Nonindigenous Aquatic Species (NAS) database (which excludes plants), the top five most commonly occurring known aquatic pathways in North Carolina are intentional stocking (38%), bait release (25%), aquarium release (9.33%), hitchhiker (4%) and aquaculture (3%)(Figure 7). A more detailed look into some of these pathways is discussed below.

Additionally, ANS species are vectored by several different methods. One example would be through seed/seedling movement on migrating animals. Another vector would be through human movement, and lack of sanitation on shoes, boat trailers, tractor tires, and new planting materials. It is important to distinguish between vectors and pathways as they contribute to the introduction and spread of ANS species.

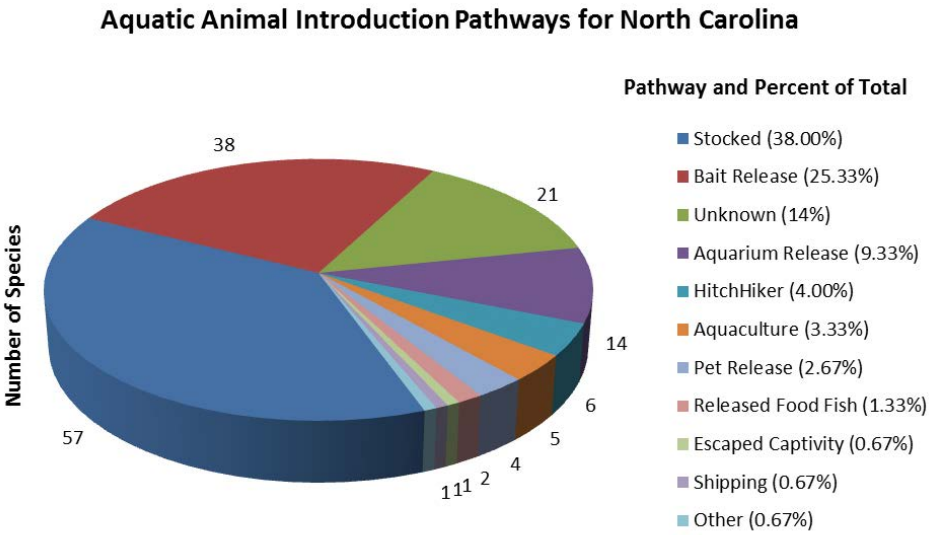


Figure 6. Introduction pathways for aquatic animals in North Carolina. Each category includes all species introduced via that pathway. A single species can be introduced by more than one pathway and may therefore be counted more than once. Data gathered on 12/1/2014 from the United States Geological Survey.

Stocking

Historically, most federal and state government fish and wildlife agencies routinely stocked game fish for recreational purposes and North Carolina was no different. In fact, North Carolina ranks stocking as the primary introduction pathway in the state with 38% to date (Figure 7). Many stockings during the late 1800s and much of the 1900s involved sport fish such as Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*), both of which are not native to the state. Other sport fish stocked extensively included species native to only a part of the state, such as Largemouth Bass (*Micropterus salmoides*), Channel Catfish (*Ictalurus punctatus*), White Bass (*Morone chrysops*), and many sunfish (*Lepomis spp.*). The potential impact the historical stockings had upon native fishes and other aquatic organisms was not known at the time, nor was it considered in the ways it is today. Stocking still occurs, but state and federal fish and wildlife agencies are much more conscious of the potential ecological consequences. The focus is often on restoring rare species to their native range.

Intentional release by anglers and hunters can be another avenue in which ANS can be introduced into previously uninhabited waters. Some anglers and hunters have the opinion that releasing or introducing species will improve the sport by increasing the stock and variety of fish or improving habitat for fish and waterfowl. Species such as Hydrilla and Brazilian Elodea (*Egeria densa*) have been introduced by a few anglers and hunters in North Carolina with hopes of increasing habitat for their target species, such as bass and various waterfowl (Waters 2015). Consequently, these species begin to spread into the waters and become a nuisance species to the existing natives. Prime examples for North Carolina include the intentional unauthorized release of Flathead Catfish (*Pylodictis olivaris*), Blue Catfish (*Ictalurus furcatus*), White Perch and Spotted Bass (*Micropterus punctulatus*) that have been illegally introduced to numerous waters for sport fishing. The two catfish species grow very large and can outcompete native species in the waters where they are released. Biologists have noted that native sunfish, madtoms and bullheads disappear in areas where the Flathead Catfish are introduced.

In North Carolina Flathead Catfish are opportunistic feeders that eat whatever becomes available, which can include native species (Pine 2005). Both Flathead and Blue Catfish species have been documented to consume river herring in coastal rivers where they are depleted (Schloesser et al. 2011).

Bait Release

The transport and release of live bait by both fresh and saltwater anglers in North Carolina waters may pose a nuisance species risk. Bait releases consisting primarily of minnow species make up approximately 25% of all introductions in North Carolina (Figure 7). Some bait species native to coastal rivers, such as Blueback Herring and Alewife, can pose a great nuisance risk if released intentionally or accidentally in inland reservoirs. Walleye fishing in most mountain reservoirs has been seriously degraded by the release of these species by anglers. Other species of bait, including fish and crayfish, may be brought into North Carolina by anglers from nearby states, or imported from outside the state and then introduced into our waters. Bait, such as nonnative shrimp, may carry diseases or parasites which could impact our native species.

More discussion has begun to circulate on this issue with introduction of the Eel Swimbladder Nematode (*Anguillicoloides crassus*) into the United States. This introduction poses a significant risk to the native American eel (*Anguilla rostrata*). The nematode is native to Southeast Asia and its native host is the Japanese eel (*Anguilla japonicas*). Releasing unused bait from another water body increases the risk

of introducing nonnative species into areas they weren't previously known to exist.

Additional NCWRC and NCDMF rules and other agency jurisdiction information on bait release can be found in Section V of this document.

Aquarium and Pet Release

Aquarium releases can be a considerable source of invasive species introduction into native waters (Padilla and Williams 2004). In North Carolina, aquarium and pet release makes up approximately 12% of all nonnative fish introductions in the state (Figure 7). No statistics are available regarding nonnative plant species introductions. In general, the majority of plant and animal species sold in aquarium and pet stores are nonnative, diverse in selection, and easily available for consumers to purchase either in stores or online. Aquarium species are usually medium to large in size, which, if released, have a greater probability of surviving and reproducing in their new environment, especially if the water temperature range is suitable. Some introduced species can survive through the cold winters by inhabiting a warm water outlet from industrial companies or power plants.

Releases usually occur when an aquarium or pet owner has a fish or plant that has gotten too large for the tank or for a backyard water feature. In some cases, the owner decides they don't want to care for the species any longer. The public does not always understand the invasive qualities for certain aquatic species, but feel that "freeing" the fish or plant species into the wild is preferable to other methods of disposal. The owners may release the pet or dump the entire aquarium (nonnative animals, plants and pathogens) and contaminated water into a water body, storm drain, or sewer system when they are finished with the aquarium, which has the potential to cause disease in native organisms.

Plant species such as Eurasian Watermilfoil (*Myriophyllum spicatum*) and Brazilian Elodea have been found in stores that carry aquarium merchandise, and others can be acquired through various e-commerce sites (Reichard and White 2001). All nurseries and garden centers that sell aquatic plants are regularly inspected by NCDA&CS employees for Federal and State Noxious Weeds.

There is no current comprehensive information available on the distribution of aquarium species in North Carolina waters, but there are a number of examples of aquarium releases that have been documented in the state. Lionfish (*Pterois miles*) have been one of the more commonly caught nuisance fish species in North Carolina and locations southward in the Eastern Atlantic Ocean (Morris and Akins 2009). Additionally, species such as the Oscar (*Astronotus ocellatus*), Pacu (*Colossoma spp. and Piaractus spp.*), Oriental Weatherfish (*Misgurnus anguillicaudatus*) and Piranha (*Pygocentrus spp., Rooseveltiella spp. and Serrasalmus spp.*) are occasionally found in North Carolina freshwater systems (North Carolina Museum of Natural Sciences unpublished data; NCWRC unpublished data). It is suspected that some species, such as Mysterysnails (*Cipangopaludina spp.*), are intentionally placed in aquatic systems to grow and multiply for later harvest.

Relocation by "Hitchhiking"

Hitchhiking is considered here as the unintentional movement of non-native species from one location to another. It is the pathway through which 4% (Figure 7) of invasive animal species have entered or spread throughout North Carolina waterways, but plants also are introduced to new water via this mechanism. Boat and trailer transportation between the state's infested and clean water bodies presents a risk of invasive species introduction through hull fouling; entanglements; and water discharge from bilge pumps, live-wells, and bait buckets. Equipment such as life jackets, fishing tackle and nets, watersport accessories such as tubes or skis, waterfowl hunting gear, and even the family dog may have ANS hitchhikers that could be transported unknowingly if not properly inspected. The vegetation may itself be an ANS or harbor other ANS, such as nonnative snails.

When boat owners do not thoroughly wash and inspect boats and boat trailers, they can easily transport aquatic weeds, such as Hydrilla, from one water body to another. Educating boaters about the importance of inspecting and cleaning their boats and trailers is critical to reducing the unwanted introduction of these nuisance species in our state. Many public boat ramps and marinas across the state post educational boards at the docks or ramps to increase education and awareness. This information can be found at the National ANSTF website and campaign for http://anstaskforce.gov/campaigns.php.

Importation of cultured species into North Carolina, even those that are legal, can bring unwanted species along as hitchhikers. For example, a shipment of fish to stock a private pond may contain invasive species, such as other fish, crayfish, snails, mussels, plants, or diseases.

Aquaculture

North Carolina has a diverse aquaculture industry (freshwater and marine), which is one of the largest in the Southeast. This industry is also a pathway that makes up approximately 3% of our state's invasive species introductions (Figure 7). Saltwater aquaculture operations include the production of hard clams, oysters and soft shell crabs. Freshwater aquaculture operations include Hybrid Striped Bass (*Morone chrysops x saxatilis*), Rainbow Trout, Channel Catfish, freshwater prawns and various Tilapia (*Oreochromis spp.*), many of which are nonnative. In addition, there are several crayfish operations in North Carolina that raise Red Swamp Crawfish (*Procambarus clarkii*). Concerns about this pathway include the escape and reproduction of nonnative aquaculture species in North Carolina waters, potential genetic mixing of native species with highly inbred production stocks, and the introduction of various finfish and shellfish diseases that may cause negative impacts to native species. Industry precautions and aquaculture regulations are in place to help prevent these problems.

Additional Pathways of Introduction

There are many other pathways in which species may make their way into North Carolina waters. The above sections focus on the top five introduction pathways in our state. Additional pathways that contribute to North Carolina's species introductions include shipping, released food fish, escaped captives, aquascaping and strong storms.

Although our neighboring state South Carolina has ranked shipping as their fifth highest introduction pathway, very little data are available for this pathway in North Carolina, where it is currently ranked tenth (Figure 7). North Carolina has ports in Wilmington, Morehead City, and along the Intracoastal Waterway where there are military operations, but gaps in invasive species monitoring on shipping vessels and their ballast waters at these ports has resulted in the shipping pathway being ranked lower than it realistically would be for North Carolina. This is a data gap that needs to be addressed in order to more accurately account for and manage the aquatic invasive species entering our state's waterways.

The water garden and nursery trades have historically been sources of purposeful plant introductions that later become classified as noxious (Williams 1980). In recent years the water garden industry has grown as more homeowners build backyard ponds and water features on their property. Stormwater retention ponds have also been constructed on many commercial properties, and wetland plants are utilized for soil stabilization and nutrient filtering purposes. NCDA&CS' Plant Industry Division reports 49 nurseries that carry aquatic plants for sale in 2015. These nurseries are inspected yearly by NCDA&CS personnel, and nursery owners are informed of laws and guidelines regarding invasive aquatic plants. Ongoing educational efforts are necessary to reduce the number of accidental releases and to advise homeowners of proper disposal mechanisms.

Occasionally, noxious weeds such as Hydrilla have been found as contaminants in aquatic plants for sale at nurseries and garden centers, and stop-sale orders are issued by the appropriate regulatory authorities. Internet sales of federal and state noxious weed species are monitored by United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Plant Protection and Quarantine officers and intercepted when possible. Sales by individuals at flea markets and through unlicensed nurseries can circumvent the state and federal oversight of invasive species.

Several species of aquatic plants are commonly used in the trade because of their attractive flowers and foliage. One such example is Water Hyacinth (*Eichhornia crassipes*). Although it not considered invasive in North Carolina because it can rarely survive the low winter temperatures, it is regulated in South Carolina due to warmer weather. Growing Water Hyacinth in a container will prevent this plant from spreading and is preferable to releasing it into a large water body where it might grow unchecked.

Hurricanes and other strong storms can spread invasive species by changing and disrupting the normal flow patterns of Atlantic coast currents, pushing invasive species into new areas. This disruption in the currents traditional flow pattern allows an opening for invasive to spread their distribution to areas previously uninhabited. In North Carolina, storms, such as hurricane Fran, can effect more than just the ocean currents. Hurricane Fran caused a decrease in the height of forest canopies. This reduction allowed more light to penetrate the understory and increases the resource and microhabitat variability that enhanced colonizing species to establish in disturbed areas, including potentially invasive weeds (Boutet and Weishampel 2003).

IV. AQUATIC NUISANCE SPECIES OF CONCERN

The Steering Committee developed lists of known or potential aquatic invasive and aquatic nuisance species (Appendix D) in a stepwise manner. North Carolina and federal prohibited, noxious, injurious or invasive species lists were compiled in addition to the lists from aquatic nuisance management plans of adjacent states. This master list was then pared down by removing duplicates and those species not pertinent to North Carolina. Additions were then made of known invasive or nuisance species in the state. All species were then reviewed for accuracy and adjusted based on current knowledge since some of the original lists were 5-10 years old.

The master list was used to create the individual tables in Appendix D. Tables 1 and 2 are lists of invasive and nuisance species (as defined in this document) currently known to exist in North Carolina. Table 3 contains those species not currently known to be present in North Carolina, but are considered "high risk" of becoming a nuisance should they arrive in the state. An example of a high risk ANS is the Zebra Mussel. Table 4 is similar to Table 3 in that the species are not currently present in the state, but the risk is lower of them becoming a nuisance. Table 5 includes those nonnative species already found in North Carolina but whose presence has not caused significant or widespread impacts or have been a part of the ecological landscape for many decades (e.g., Rainbow Trout). Tables 6 and 7 are lists of species that are native to part of the state but have been moved outside their native range and are considered either invasive (Table 6) or nuisance (Table 7) in the introduced waters. Finally, Table 8 contains species that have one or more questions concerning their origin (i.e., cryptogenic species), their presence in North Carolina, or their potential for becoming a nuisance.

Priority ANS Species:

Nuisance species were ranked to provide an indication of those species that should receive the most attention for action upon plan approval. Rankings were provided by members of the Steering Committee using the following criteria:

1. **Ecological Impacts** – potential to impact aquatic ecosystems based on literature, discussions with colleagues, field observations and personal experience;
2. **Current Distribution and Status** – documented current distribution in North Carolina;
3. **Trend in Distribution and Abundance** – anticipated spread of this species in the state within the next ten years;
4. **Management Difficulty** – difficulty in controlling this species including availability of proven management techniques and a need for repetitive and ongoing treatments;
5. **Economic Impact** – ability or potential to negatively impact the economy based on historical information from within the state or other states.

Each species was given a relative numerical ranking of 1, 2 or 3 for each of the five criteria with 1 being the lowest impact and 3 being the highest impact. The committee members ranked each species independently for each criterion. A mean for the independent rankings was then calculated for each criterion and the five means (i.e., one for each criterion) for each species was summed to give a composite score. The resulting scores were then ordered from high to low to provide an overall ranking. The following table indicates how the ANS species identified by the committee are ranked based on this methodology:

Prioritization of ANS Species currently found in North Carolina. Species in bold have commercial or recreational value

Higher Priority | Medium Priority | Lower Priority

Scientific Name	Common Name	Taxa Group	Habitat	Rank
Hydrilla verticillata	Hydrilla	Plant	Freshwater	1
Pterois miles	Lionfish; Devil Firefish	Fish	Marine	2
Pterois volitans	Red Lionfish	Fish	Marine	2
Nymphoides peltata	Yellow Floating Heart	Plant	Freshwater	4
Phragmites australis australis	European Common Reed	Plant	Freshwater-Brackish	4
Orconectes rusticus	Rusty Crayfish	Crayfish	Freshwater	6
Procambarus clarkii	**Red Swamp Crawfish**	Crayfish	Freshwater	6
Alternanthera philoxeroides	Alligatorweed	Plant	Freshwater	6
Orconectes virilis	Virile Crayfish	Crayfish	Freshwater	9
Ictalurus furcatus	**Blue Catfish**	Fish	Freshwater	10
Lyngbya wollei	Musty black mat algae	Cyanobacterium	Freshwater	11
Cipangopaludina chinensis malleata	Chinese Mysterysnail	Gastropod	Freshwater	12
Cipangopaludina japonica	Japanese Mysterysnail	Gastropod	Freshwater	12
Anguillicoloides crassus (= Anguillicola crassus)	Eel Swimbladder Nematode	Nematode	NA	12
Myriophyllum spicatum	Eurasian Watermilfoil	Plant	Freshwater	12
Myocaster coypus	Nutria	Mammal	Freshwater	16
Corbicula fluminea	Asian Clam	Bivalve	Freshwater	17
Micropterus punctulatus	Spotted Bass	Fish	Freshwater	17
Phyllorhiza punctata	Australian Spotted Jellyfish	Coelenterate	Marine	19
Lythrum salicaria	Purple Loosestrife	Plant	Freshwater	19
Lythrum spp.	Purple Loosestrife (any not native to NC)	Plant	Freshwater	19
Murdannia keisak	Marsh Dewflower; Asian Spiderwort	Plant	Freshwater	19
Ludwigia hexapetala (L. uruguayensis)	Uruguay Waterprimrose	Plant	Freshwater	23
Myriophyllum aquaticum	**Parrotfeather**	Plant	Freshwater	23
Polysiphonia breviarticulata	a red algae	Algae	Marine	25
Egeria densa	Brazilian Elodea	Plant	Freshwater	25
Najas minor	Brittle Naiad	Plant	Freshwater	25
Triadica sebifera	Chinese Tallow Tree	Plant	Freshwater	25
Tilapia zillii	**Redbelly Tilapia**	Fish	Freshwater	29
Ludwigia peploides peploides	Creeping Water Primrose	Plant	Freshwater	29
Codium fragile tomentosoides	Green Sea Fingers	Algae	Marine	31
Carcinus maenas	European Green Crab	Crab	Marine	31
Oreochromis aureus	**Blue Tilapia**	Fish	Freshwater	31
Eichhornia crassipes	**Water Hyacinth**	Plant	Freshwater	31
Ludwigia peploides montevidensis	Creeping Water Primrose	Plant	Freshwater	31
Pistia stratiotes	**Water Lettuce**	Plant	Freshwater	31
Potamogeton crispus	Curly Pondweed	Plant	Freshwater	37
Nasturtium officinale	Watercress	Plant	Freshwater	38

The following page lists species that are particularly problematic in North Carolina. Expanded information about each of these can be found in Appendix H. The list is not all-inclusive of all invasive species in North Carolina, but they were chosen in order to highlight some of the more commonly discussed nuisance and invasive species found across the state. Additional information is also included for several "high risk" species that are not currently in North Carolina, but could have potentially devastating impacts if they were to be introduced.

Freshwater Plants:

Alligatorweed (*Alternanthera philoxeroides*)
Brazilian Elodea (*Egeria densa*)
Brittle Naiad (*Najas minor*)
Curly Pondweed (*Potamogeton crispus*)
Eurasian Watermilfoil (*Myriophyllum spicatum*)
European Common Reed (*Phragmites australis australis*)
Hydrilla (*Hydrilla verticillata*)
Marsh Dayflower (*Murdannia kiesak*)
Parrotfeather (*Myiophyllum aquaticum*)
Purple Loosestrife (*Lythrum salicaria*)
Watercress (*Nasturtium officinale*)
Water Hyacinth (*Eichornia crassipes*)
Water Primrose (*Ludwigia grandiflora*)
Water Lettuce (*Pistia statiodes*)
Yellow Crested Heart (*Nymphoides peltata*)
Floating Crested Heart (*N. cristata*)

High Risk Species Not Currently in NC:

Apple Snail (*Pomacea insularum* and *P. canaliculata*)
Giant Salvinia (*Salvinia molesta*)
Marbled Crayfish, Marmokrebs (*Procambarus fallax virginalis)*
Silver Carp (*Hypophthalmichthys molitrix*)
and Bighead Carp (*H. nobilis*)
Snakeheads (*Channa spp.*)
Zebra Mussel (*Dreisenna polymorpha*)

Freshwater Animals:

Alewife (*Alosa pseudoharengus*) and
Blueback Herring (*A. aestivalis*)
(when introduced into reservoirs)
Asian Clam (*Corbicula fluminea*)
Blue Catfish (*Ictalurus furcatus*)
Blue Tilapia (*Oreochromis aureus*) and
Redbelly Tilapia (*Tilapia zilli*)
Chinese Mysterysnail (*Cipangopaludina malleata*) and
Japanese Mysterysnail (*C. japonica*)
Flathead Catfish (*Pylodictis olivaris*)
Nutria (*Myocastor coypus*)
Red Swamp Crawfish (*Procambarus clarkia*)
Rusty Crayfish (*Orconectes rusticus*) and
Virile Crayfish (*O. virilis*)
Spotted Bass (*Micropterus punctulatus*)
White Perch (*Morone Americana*)
(when introduced into reservoirs)

Marine/Estuarine Species:

Australian Spotted Jellyfish (*Phyllorhiza punctate*)
Eel Swimbladder Nematode (*Anguillicoloides crassus* or *Anguillicola crassus*)
Lionfish (*Pterois miles* or *Pterois volitans*)

V. JURISDICTIONS & RESPONSIBILITIES

In North Carolina aquatic nuisance species are managed by state and federal agencies. The North Carolina state agencies that have some authority include the Department of Environmental Quality (NCDEQ), NCDWR and NCDMF, NCWRC and NCDA&CS. The United States Fish and Wildlife Service (USFWS), the United States Department of Agriculture (USDA), the United States Coast Guard (USCG) and National Marine Fisheries Service also have some authority in North Carolina.

State Entities

NC Department of Agriculture and Consumer Services

The NC Aquaculture Development Act designates the NCDA&CS as the lead state agency in matters pertaining to aquaculture and grants the NCDA&CS the authority for registration and licensing of freshwater aquaculture facilities (§ 106-761). In addition, the Act states that NCDA&CS authority shall be limited to commercially reared fish and does not include authority over wild fishery resources managed under the authority of the NCWRC. Under this statute, production of any species not listed as an approved species in the Aquaculture Development Act is "prohibited from propagation and production unless the applicant for the permit first obtains written permission from the Wildlife Resources Commission." Table 1 identifies the species that do not require individual approval from the NCWRC. If the species is found on this list, the NCDA&CS is able to register and license the facility. If the species is not listed, the applicant is responsible for obtaining written permission from the NCWRC. Furthermore, the statute makes it unlawful to willfully release domestically raised fish into waters of the state, other than in private ponds, without written permission of the NCWRC or NCDMF. For NCDA&CS licensing program information visit http://www.ncagr.gov/markets/aquaculture/license.htm. The statute specifically states that nothing in the Act shall apply to the aquarium or ornamental trade in fish.

Table 1: Approved Species for Aquaculture Production

Common Name	Scientific Name
Bluegill [1]	*Lepomis macrochirus*
Redear Sunfish [1]	*Lepomis microlophus*
Redbreast Sunfish [1]	*Lepomis auritus*
Green Sunfish [1]	*Lepomis cyanellus*
Black Crappie	*Pomoxis nigromaculatus*
White Crappie	*Pomoxis annularis*
Largemouth Bass	*Micropterus salmoides* (northern strain)
Smallmouth Bass	*Micropterus dolomieu*
White Catfish	*Ictalurus catus*
Channel Catfish	*Ictalurus punctatus*
Golden Shiner	*Notemigonus crysoleucas*
Fathead Minnow	*Pimephales promelas*
Goldfish	*Carassius auratus*
Rainbow Trout	*Oncorhynchus mykiss*
Brown Trout	*Salmo trutta*
Brook Trout	*Salvelinus fontinalis*
Common Carp	*Cyprinus carpio*
Crayfish	*Procambarus* species
Hybrid Striped Bass [2]	*Morone chrysops* × *Morone saxatilis*
Yellow Perch	*Perca flavenscens* [3]

1. Including any hybrids using these four species of the genus Lepomis
2. Production, propagation, and holding facilities in the Neuse, Roanoke, or Tar/Pamlico River basins for hybrid Striped Bass shall comply with additional escapement prevention measures prescribed by the NCWRC
3. A letter of approval from the NCWRC is required before Yellow Perch may be raised at a facility located west of Interstate Highway 77

The NCDA&CS is responsible for developing and implementing a fish disease management plan to prevent the introduction of fish diseases through aquaculture facilities. This plan is to be created with the assistance of the NCWRC (§ 106-762). To satisfy the requirement of the statue the NCDA&CS and NCWRC must work together to develop the fish disease management plan.

The NCDA&CS Noxious Weed Regulations, adopted under authority of the NC Plant Pest Law (N.C.G.S. 106 Article 36), were established to prevent the widespread establishment of harmful nonnative plants. This list is comprised of all weeds that are found on the Federal Noxious weed list (http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/weedlist.pdf) as well as several additional species that are state noxious weeds and are approved by the NC Board of Agriculture. Any plant on the state or federal noxious weed list that does not already occur in the state is prohibited in the state without a permit. Plants on the noxious weed list that are already present in the state (but are found in less than 20 counties) are quarantined to those counties where they are known to exist. Movement of the plant outside of those quarantine counties is prohibited. In addition to the plant itself, articles that could contain noxious weed propagules, such as soil or hay, are also regulated. In addition, the sale of noxious weeds is prohibited unless exempted by provisions of the Noxious Weed Regulations. The list of NCDA&CS noxious weeds that are considered to be aquatic plants is provided in Table 2.

Table 2: NCDA&CS Noxious Weed List (Aquatic)

Common Name	Scientific Name
Mosquito Fern	*Azolla pinnata*
Caulerpa [Killer Algae (Mediterranean Strain)]	*Caulerpa taxifolia*
Rooted Water Hyacinth	*Eichhornia azurea*
Hydrilla	*Hydrilla verticillata*
Miramar Weed	*Hygrophila polysperma*
Water Spinach	*Ipomoea aquatic*
African Oxygen Weed; African Elodea	*Lagarosiphon major*
Ambulia, Asian Marshweed	*Limnophila sessiliflora*
Uruguay Waterprimrose	*Ludwigia hexapetala*
Water Primrose	*Ludwigia uruguayensis*
Purple Loosestrife	*Lythrum salicaria*
Loosestrife species (any not native to NC)	Lythrum spp.
Broadleaf Paper Bark Tree	*Melaleuca quinquenervia*
Arrowleaf False Pickerelweed	*Monochoria hastate*
Heartshape False Pickerelweed	*Monochoria vaginalis*
Eurasian Watermilfoil	*Myriophyllum spicatum*
Crested Floating Heart	*Nymphoides cristata*
Water Snowflake	*Nymphoides indica*
Yellow Floating Heart	*Nymphoides peltata*
Duck Lettuce	*Ottelia alismoides*
Arrowhead	*Sagittaria sagittifolia*
Giant Salvinia	*Salvinia auriculata*
Giant Salvinia	*Salvinia biloba*
Giant Salvinia	*Salvinia herzogii*
Giant Salvinia	*Salvinia molesta*
Wetland Nightshade	*Solanum tampicense*
Exotic Bur Reed	*Sparganium erectum*

North Carolina
Wildlife Resources Commission

The NCWRC has the authority for conservation of wildlife resources and all the activities that are connected with the conservation and regulation of wildlife resources (G.S. 113-132). This includes management authority for aquatic nuisance species when introduced into inland fishing waters and shared management authority with NCDMF for joint fishing waters. The NCWRC has authority based on G.S. 113-274 and G.S. 113-292 to regulate and permit the transportation, purchase, possession, sale or stocking of species within its jurisdiction. It is illegal to stock fish into public waters or for any person, firm, or corporation to transport live freshwater nongame fishes, or live game fishes in excess of the possession limit, or fish eggs without a permit from the NCWRC (15A NCAC 10C .0209). The NCWRC also prohibits the possession of certain exotic species (15A NCAC 10C .0211) (Table 3). Triploid grass carp may be bought, possessed and stocked only for the purpose of controlling aquatic vegetation under a NCWRC permit. Regulations also allow hunting for invasive species including Nutria and Mute Swans, as long as all other local laws and bag limits are obeyed.

The Aquaculture Development Act (G.S. Chapter 106 Article 63) provides a list of species that can be propagated and produced with a NCDA&CS Aquaculture License. The NCWRC can only place restrictions on the listed species when there is a disease concern. All other species are prohibited from propagation and production unless the applicant for the permit first obtains written authorization from the NCWRC. In the past the NCWRC has reviewed requests for species that spend any portion of their life in freshwater even though they may spend a majority of their life in estuarine or marine environments. Propagation and production of species on the NCWRC prohibited species list (Table 3) are not allowed.

Table 3: NCWRC Prohibited Species List

Common Name	Scientific Name
Piranha	*Pygocentrus nattereri*
Walking Catfish	*Clarias batrachus*
Snakehead Fish	from the Family *Channidae*, formerly *Ophiocephalidae*
Black Carp	*Mylopharyngodon piceus*
Bighead Carp	*Hypophthalmichthys nobilis*
Silver Carp	*Hypophthalmichthys molitrix*
Rudd	*Scardinius erythropthalomus*
Round Goby	*Neogobius melanostomus*
Tubenose Goby	*Proterorhinus marmoratus*
Ruffe	*Gymnocephalus cernuus*
Japanese Mysterysnail	*Cipangopaludina japonica*
Chinese Mysterysnail	*Cipangopaludina chinensis malleata*
Red-rim Melania	*Melanoides tuberculatus*
Virile Crayfish	*Orconectes (Gremicambarus) virilis*
Rusty Crayfish	*Orconectes (Procericambarus) rusticus*
Australian Red Claw Crayfish or red claw	*Cherax quadricarinatus* or *Cherax genus*
White Amur or Grass Carp	*Ctenopharyngodon idella*
Swamp or "rice" Eel	*Monopterus albus*
Red Shiner	*Cyprinella lutrensis*
Zebra Mussel	*Dreissena polymorpha*
Quagga mussel	*Dreissena rostriformis bugensis* or any mussel in the family *Dreissenidae*

North Carolina
Division of Marine Fisheries

The North Carolina Marine Fisheries Commission has jurisdiction over the conservation of marine and estuarine resources (G.S. 113-132) and oversees NCDMF, which has regulatory authority over aquaculture facilities that cultivate or rear marine or estuarine resources through an Aquaculture Operation Permit (AOP). In order to operate an aquaculture facility that deals with estuarine or marine species the facility must obtain a permit from the NCDMF director (15A NCAC 03O .0501). If the applicant is collecting wild fish for the aquaculture facility NCDMF has regulatory authority over how the fish are collected.

Under regulatory authority (15A NCAC 03I .0104) it is illegal to introduce any living marine or estuarine nonnative species into state waters without obtaining a permit from NCDMF. This permit regulates the ability to place live marine and estuarine organisms not native to North Carolina into coastal waters, to place live marine and estuarine organisms native to North Carolina that originated outside of the State's boundaries, to hold or maintain any live marine or estuarine organism imported into the state in a quarantine or isolation system for live bait or use in an aquaculture operation, or to sell for bait in any live marine or estuarine organism imported into the state. NCDMF is also given the authority to regulate the release of domestically raised fish into waters of the state other than in private ponds as defined by G.S. 113-129 (§ 106-762).

NCDMF continues to monitor species that occur in NC estuaries and sounds through continuous monitoring of its fishery surveys and mapping of sub-tidal estuarine habitat. NCDMF employees participate on the federal aquatic invasive species boards and the state aquatic weed control board to ensure the most up to date information is identified.

North Carolina
Division of Water Resources

The Aquatic Weed Control Act of 1991 empowers the NCDEQ Secretary to designate plant organisms as noxious aquatic weeds and to direct the control, eradication and regulation of those noxious aquatic weeds. Furthermore, the Weed Control Act provides the NCDEQ Secretary authority to control, remove, or destroy any noxious aquatic weed located in the waters of the state. A key operational component of the Act allows the Department to coordinate management activities and enter into cost-share agreements with local governments. The Secretary assigned the NCDWR to formalize an aquatic weed control program in order to implement the Act. Previous to the Act an interagency committee coordinated aquatic weed control activities with NCDWR as the lead agency. That committee became the NC Aquatic Weed Control Council (NCAWCC). The NCAWCC is a standing voting committee that determines the distribution of state-appropriated funds that are used to treat nuisance species. The NCDWR coordinates aquatic weed control projects. The NCDA&CS has the authority to regulate the importation, sale, use, culture, collection, transportation and distribution of noxious aquatic weeds, as described in the NC Plant Pest Law and rules subsequently adopted by the NC Board of Agriculture.

Ducks in Spotted Duckweed, Shutterstock

Aquatic nuisance species are often managed with pesticides. The Clean Water Act has been interpreted such that any pesticide applied to, over, or near waters of the United States requires a National Pollutant Discharge Elimination System (NPDES) permit. As is the case with many states, the EPA has authorized North Carolina to administer its own NPDES permit program. North Carolina established threshold criteria so that a general permit would cover small-scale pesticide treatments. If a pesticide application is expected to exceed any threshold, then an application for an NPDES permit must be obtained from the NCDEQ so pesticides can be used. For a full list of the pesticide thresholds please see the entire NCDWR NCG560000 permit.

Other State Entities

Other state agencies, (e.g. North Carolina Division of Coastal Management, North Carolina Department of Transportation (NCDOT) and North Carolina Forest Service) will treat for aquatic nuisance species as funds are available. NCDOT actively controls Japanese Knotweed and Alligatorweed when they pose a threat to the structural integrity of bridges and roadways (D. Smith, 2015). In addition to treatment around roadways, the NCDOT controls nuisance species if they are found on mitigation sites.

Recent and Proposed Legislation

Since 2010 very few bills related to ANS have been introduced in North Carolina. The Appropriations Act of 2013 (Session Law 2013-360) appropriated $250,000 to control Hydrilla in Lake Waccamaw. The Appropriations Act of 2014 (Session Law 2014-100) limited to $500,000 the amount of the Shallow Draft Navigation Channel Dredging and Lake Maintenance Fund that could be used for aquatic weed control.

In the 2015 session of the General Assembly there are two identical bills (House Bill 430 and Senate Bill 422) that, if passed, would direct the Environmental Review Commission to study issues relating to statewide approaches to control invasive aquatic noxious weeds in the state's waters, including funding needed to support statewide control.

The Lacey Act

The Lacey Act [18 USC 42-43; 16 USC 3371-3378 (50 CFR 16)] was created in 1900, giving the Secretary of the Interior the authority to regulate the importation and transport of species, including offspring and eggs, determined to be injurious to the health and welfare of humans, the interests of agriculture, horticulture or forestry, and the welfare and survival of wildlife resources of the U.S. Wild mammals, wild birds, fish, mollusks, crustaceans, amphibians and reptiles are the only organisms that can be added to the injurious wildlife list. Species that have been listed as injurious cannot be imported or transported between states, the District of Columbia, the Commonwealth of Puerto Rico or any territory or possession of the U.S. by any means without a permit issued by the USFWS. A permit may be granted for importation or the transportation of listed injurious species for scientific, medical, educational, or zoological purposes.

Nonindigenous Aquatic Nuisance Prevention and Control Act

The NANPCA {(Nonindigenous Aquatic Nuisance Prevention and Control Act, reauthorized as the National Invasive Species Act (NISA) in 1996)} was primarily created in response to the Zebra Mussel invasion of the Great Lakes, where ballast water introduction had caused serious ecological and socioeconomic impacts. Although the zebra mussel invasion of the Great Lakes has played a central role in prompting passage of the federal legislation, NANPCA has been established to prevent the occurrence of all new ANS introductions and to limit the dispersal of all ANS already in U.S. waters.

The Act, established for the prevention and control of the unintentional introduction of nonindigenous aquatic nuisance species, is based on the following five objectives as listed in Section 1002 of NANPCA:

- To prevent further unintentional introductions of nonindigenous aquatic nuisance species.
- To coordinate federally funded research, control efforts and information dissemination.
- To develop and carry out environmentally sound control methods to prevent, monitor and control unintentional introductions.
- To understand and minimize economic and ecological damage.
- To establish a program of research and technology development to assist state governments.
- The primary components of the Act:
- Required vessels entering ports on the Great Lakes to exchange ballast water and meet other requirements, with voluntary guidelines for similar actions on other waters of the U.S.
- Authorized a number of studies and monitoring programs to assess the spread of AIS and develop methods for controlling them.
- Required the development of Armed Services ballast water programs as well as the establishment of the Ballast Water Management Demonstration Program.
- Authorized the establishment of the Aquatic Nuisance Species Task Force.
- Established a mechanism for regional collaboration and coordination through the establishment of the ANSTF Regional Panels.
- Authorized the development of an AIS Program to be housed within the USFWS.
- Established the State/Interstate ANS Management Plan Grant program managed by the USFWS, through which states can develop and implement a comprehensive state management plan for the prevention and control of aquatic nuisance species.

NISA amended NANPCA "To provide for ballast water management to prevent the introduction and spread of nonindigenous species into the waters of the United States, and for other purposes." NISA authorized:

- The production of guidelines for how to guard against the introduction and dispersal of invasive species.
- Regulations for vessel operations and crew safety, and education and training programs to promote compliance.
- Funding for research on environmentally sound methods to control the spread of invasive species.
- Ecological surveys for certain environmentally sensitive regions of the country.
- The establishment of the National Ballast Information Clearinghouse to provide data about ballasting practices and compliance with guidelines.

Executive Order 13112 of February 3, 1999

The purpose of Executive Order 13112 is to outline the duties and responsibilities of federal agencies to prevent the introduction and spread of aquatic invasive species and provide for their control and impact minimization. It enables federal agencies to develop prevention and rapid response protocols, conduct monitoring and restoration activities, and to promote public education and research on invasive species. It also prohibits agencies from conducting activities that would enable the introduction and spread of invasive species unless the benefits of such activities "outweigh" the potential harm.

Another directive of this executive order is the establishment of the Invasive Species Council, an interagency to advise and provide recommendations for federal invasive species activities, develop an Invasive Species Management Plan for federal agency efforts, and work with other state, tribal, regional local, and ecosystem-level organizations to coordinate responses on invasive species issues.

United States
Department of Agriculture

The Plant Protection Act (7 U.S.C. 7701 et seq.) gives the Secretary of Agriculture the authority to prohibit or restrict the importation, entry, exportation or movement in interstate commerce of any plant, plant product, biological control organism, noxious weed, article or means of conveyance if the Secretary determines that the prohibition or restriction is necessary to prevent the introduction of a plant pest or noxious weed into the United States. The Secretary of Agriculture was also given the authority to designate noxious weeds and prohibit them from interstate or foreign commerce under the Federal Noxious Weed Act (7 U.S.C. 2801). This Act also authorizes the USDA Secretary to inspect, seize, and destroy products and to quarantine areas, to prevent the spread of noxious weeds. The 2014 Farm Bill allocated $62.5 million annually for the Plant Pest and Disease Management programs for fiscal years 2014 through 2017 then the funding will increase to $75 million annually.

United States
Fish and Wildlife Service

The mission of the USFWS is to work with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. Because of their responsibilities, the USFWS is very concerned about the impacts that invasive species are having across the Nation. The USFWS addresses invasive species issues through a variety of programs and partnerships. The USFWS' invasive species efforts take proactive approaches to address intentional and unintentional introductions, combat the spread of existing invaders on and off USFWS lands, and maintain the USFWS as a leader in invasive species prevention and control.

Fisheries and Aquatic Conservation

The USFWS' Aquatic Invasive Species Program is housed within the Fisheries and Habitat Conservation Program's Division of Fisheries and Aquatic Conservation. The Branch of Aquatic Invasive Species essentially houses three functions:

- The USFWS Aquatic Invasive Species Program – The AIS Program seeks to prevent the introduction and spread of AIS, rapidly respond to new invasions, monitor the distribution of and control established invaders, and foster responsible conservation behaviors through its national public awareness campaigns (Stop Aquatic Hitchhikers and Habitattitude).
- Administration of Aquatic Nuisance Species Task Force – This Branch of AIS builds capacity, coordinates, and implements AIS prevention and control activities authorized under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA, as amended by the National Invasive Species Act (NISA) of 1996), including: cochairing and administering the ANSTF, supporting Regional Panels, providing grants for State/Interstate ANS Management Plans, and implementing a National AIS program.
- Injurious Wildlife Evaluations and Listings – The AIS Program supports the Injurious Wildlife Provisions of the Lacey Act through an ongoing process of evaluating species and possibly listing them as injurious through the rulemaking process.

The AIS Program has worked to prevent populations of invasive species from entering or spreading into the United States. Priority containment (boat inspection and decontamination), early detection and rapid response (snakehead eradication and Chicago Sanitary Shipping Canal), interjurisdictional coordination and planning (Quagga/Zebra Mussel Action Plan and 100th Meridian), and regulatory (injurious wildlife listing of Black and Silver Asian Carp) and nonregulatory actions (Stop Aquatic Hitchhikers!) have occurred across many jurisdictions. Through the actions of the AIS program, a national AIS network has been built – including 42 states, 6 Regional panels, over 1,000 participants in two national public awareness campaigns and many other partners – that has planned, directed and accomplished significant regional and landscape-level invasive species prevention and management resource outcomes. The AIS Program serves as the nation's front line for prevention of new aquatic invasive species by regulating imports of injurious wildlife, facilitating behavioral change and managing pathways to limit the introduction and spread of invasives (awareness campaigns and ballast water), and developing monitoring programs for invasion hotspots to facilitate early detection and rapid response.

The Service's Fisheries and Conservation Program maintains one facility in North Carolina: the Edenton National Fish Hatchery.

The USFWS is also responsible for certifying Grass Carp hatcheries to ensure triploidy. Grass Carp are regularly used by the public and government agencies to control aquatic nuisance species (e.g., Hydrilla). The USFWS subsample these facilities to determine that these fish will not be able to breed, once released, in the wild. If triploidy is not observed these fish will not be certified for resale.

National Wildlife Refuge System

The USFWS also manages more than 561 refuges, encompassing more than 150 million acres of wildlife habitat, within its National Wildlife Refuge System. According to 2013 data, more than 2.4 million acres of the Refuge System are impacted by invasive plants. In addition, there are approximately 1,715 invasive animal populations residing on refuge lands.

There are 10 National Wildlife Refuges in North Carolina: Alligator River, Cedar Island, Currituck, Mackay Island, Mattamuskeet, Pea Island, Peedee, Pocosin Lakes, Roanoke River, and Swanquarter National Wildlife Refuges.

Endangered Species

The ultimate goal of the Endangered Species Act [ESA - (16 U.S.C. § 1531 et seq.)] is the recovery (and long-term sustainability) of endangered and threatened species and the ecosystems on which they depend. Recovery is the process by which the decline of an endangered or threatened species is arrested or reversed, and threats removed or reduced so that the species' survival in the wild can be ensured. The goal of the ESA is the recovery of listed species to levels where protection under the ESA is no longer necessary.

In many instances these threats may be caused by invasive species. They may either directly harm the species by causing mortality or may threaten a species by modifying or destroying the habitat or food source on which that species depends. A variety of methods and procedures are used to recover listed species, such as reduction of threats (including invasive species), protective measures to prevent extinction or further decline, consultation to avoid adverse impacts of federal activities, habitat acquisition and restoration, and other on-the-ground activities for managing and monitoring endangered and threatened species.

National Oceanic and Atmospheric Administration (NOAA)

The National Oceanic Atmospheric Administration (NOAA) is responsible for the stewardship of the nation's ocean resources and their habitat. NOAA provides vital services for the nation: productive and sustainable fisheries, safe sources of seafood, the recovery and conservation of protected resources, and healthy ecosystems—all backed by sound science and an ecosystem-based approach to management. NOAA has responsibility for prevention, monitoring, control, education, and research to prevent future introductions and the spread of ANS. NOAA provides staff support for engagement and activities related to its leadership role as the co-chair of both the National Invasive Species Council (representing the Department of Commerce) and the ANS Task Force-two interagency organizations that coordinate and ensure complementary, cost-efficient, and effective federal activities regarding invasive species. Additionally, NOAA's Sea Grant program and program offices have been actively involved in research and outreach regarding ANS, as well as restoration of habitat that benefits native species by removal of invasive organisms.

The Monitor National Marine Sanctuary (MNMS or Sanctuary), located 16 miles south-southeast of Cape Hatteras, was designated in 1975 to protect the wreck of the famed vessel. Since designation, the Sanctuary has started to expand its research and monitoring of resources beyond maritime heritage resources to include biological resources as well. Fundamental to this change is the basic requirements to inventory and characterize invasive species that live in and around the MNMS. With this information MNMS will be better informed and able to assess the status of invasive species living in the Sanctuary, make more informed management decisions, and take action as needed.

National Park Service

Along with Executive Order 13112, the National Park Service (NPS) works to manage invasive species on park lands through national and local programs. These programs have strategies that include cooperation and collaboration, inventory and monitoring, prevention, early detection and rapid response, treatment and control, and restoration.

United States Army Corps of Engineers

The USACE Wilmington District has four reservoirs and three locks and dams in North Carolina. The USACE has authority under 36 CFR 327.12 to post restrictions on the use of a project or portion of a project by reason of public health, public safety, maintenance, resource protection or other reason in the public interest. The USACE Wilmington District Commander has implemented a posted restriction to address the spread of aquatic nuisance species: "Stop Invasive Species – Before launching and leaving, you must remove visible mud, plants, and animals from vessels, trailers, and other equipment." B. Everett Jordan, Falls of the Neuse, and John H. Kerr reservoirs are USACE-owned properties that have Hydrilla issues. In B. Everett Jordan Reservoir the USACE has worked with the NCWRC, NCDPR and other partners to perform annual surveys to determine invasive species locations. Hydrilla in the Weaver Creek section of B. Everett Jordan Reservoir has been managed with triploid Grass Carp. In Falls of the Neuse Reservoir, the USACE has worked with NCWRC, NCDPR, City of Raleigh and Wake County to perform annual surveys that have identified Hydrilla, Parrot Feather, Alligatorweed and Creeping Primrose. The USACE is working to develop an Aquatic Vegetation Management Program for Falls of the Neuse Reservoir. The City of Raleigh, which has a water intake on Falls of the Neuse Reservoir, has been surveying and treating nuisance aquatic

species in the reservoir proper and the Beaverdam Subimpoundment for many years. Hydrilla, Alligatorweed, and Brittle Naiad have been documented in John H. Kerr Reservoir. Since 2012, the USACE has implemented an Aquatic Vegetation Management Program, which includes annual aquatic vegetation surveys and stocking of triploid Grass Carp: http://www.saw.usace.army.mil/Locations/DistrictLakesandDams/JohnHKerr/NaturalResources/AquaticVegetationManagement.aspx (Accessed January 2015). These surveys estimated 1,274 acres of Hydrilla in 2014. The USACE, shoreline permit holders and NCDPR have performed spot treatments for invasive species.

United States Coast Guard

The United States Coast Guard (USCG) is responsible for management of ballast water regulations. In 2012, regulations were modified to respond to concerns that invasive species found in ballast water could have ecological, economic, or potential health threats. These new management regulations include mandatory ballast water management practices for all vessels that operate in United States waters and additional practices for vessels entering United States waters as well as record keeping and reporting of ballast operations by all large commercial vessels.

Environmental Protection Agency (EPA)

The EPA's NPDES vessels program regulates incidental discharges from the normal operations of vessels consistent with Clean Water Act Section 402 http://water.epa.gov/polwaste/npdes/vessels/index.cfm (Accessed January 2015). Through this program the EPA has a Vessel General Permit (VGP) that covers incidental discharges and ballast water for commercial vessels greater than 79 feet in length and operating as a means of transportation. Ballast water discharges for vessels less than 79 feet in length are covered by the EPA's Small Vessels General Permit.

U.S. Forest Service

The mission of the USFS is to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations. The USFS strives nationally, regionally, and locally to reduce, minimize, or eliminate the potential for introduction, establishment, spread, and impact of aquatic and terrestrial invasive species (including plants, pathogens, vertebrates, invertebrates, fungi, algae, etc.) across all landscapes and ownerships. The Forest Service plays an important national and regional role with the Aquatic Nuisance Species Task Force, including serving on several Regional ANS Panels. USFS invasive species management specialists are stationed at national, regional, and local offices throughout the country. The USFS National Invasive Species Management Policy (Forest Service Manual – FSM 2900) provides direction to all National Forests and Grasslands to work with local, state, tribal, and other partners to address aquatic and terrestrial invasive species threats. This national policy emphasizes the importance of integrating USFS invasive species activities to expand prevention, early detection and rapid response, control, restoration, cooperation, education and awareness, and mitigation activities across all National Forest System program areas. Among other requirements, the policy directs all National Forests and Grasslands to cooperate with state governments and tribes to implement and enforce applicable regulations, plans, and guidance on invasive species management on National Forests and Grasslands, including but not limited to:

a) State regulations related to prevention and control of aquatic and terrestrial invasive species (including noxious weeds).
b) State regulations associated with utilizing, storing, transporting, or certifying invasive-species-free (and/or noxious weed-free) straw, hay, mulch, gravel, forage, seed, or other materials.
c) Statewide aquatic nuisance species management plans, fish and wildlife management plans, early detection and rapid response plans, or other statewide or region-wide invasive species management plans.

Other Entities

Utility Companies

Duke Energy has an in-house aquatic invasive management team that manages 43 waterbodies. These water bodies, located in the Carolinas, are prioritized and surveyed by the team on a two to three year rotation. The Duke Energy team's focus is on invasive submerged aquatic vegetation (SAV) that may become a problem for recreation (boating, swimming, fishing, shoreline esthetics, etc.) and municipal and industrial water withdrawals. When invasive SAV is observed Duke Energy quickly moves to implement a management plan, usually in cooperation with relevant stakeholders and natural resource agencies.

Nongovernment Organizations

Nongovernment organizations such as The Nature Conservancy (TNC) who own large areas of land are responsible for the management of invasive species on their property. TNC will manage invasive species by herbicide treatment to restore native species. For more information see (http://www.nature.org/ourinitiatives/habitats/forests/howwework/protecting-native-plants-and-animals-taking-on-the-invaders.xml)

CASE STUDY SUCCESS: Lake Norman and Mountain Island Lake Hydrilla

In Lake Norman and Mountain Island Lake on the Catawba River, Hydrilla has successfully been eliminated for almost ten years. Lake Norman, at 32,500 acres, is the largest water body in the state. Although significantly smaller at 3,280 acres, Mountain Island Lake supplies most of the drinking water for more than 1.2 million citizens in the metropolitan Charlotte area. Both reservoirs are operated by Duke Energy Corporation for power generation.

The management strategy used was: (1) early detection of Hydrilla, (2) early use of registered herbicides for plant suppression along with stocking triploid Grass Carp, and (3) maintenance stocking of triploid Grass Carp to prevent Hydrilla regrowth from tubers (Manuel et al. 2013).

Following this strategy, Hydrilla standing biomass was quickly removed in the water bodies in one to two growing seasons following the introduction of triploid Grass Carp. This suggests that integrating herbicide applications with stocking triploid Grass Carp may largely eliminate the multi-year lag effect normally associated with using triploid Grass Carp alone. Sustaining a maintenance density of triploid Grass Carp in the reservoirs prevented Hydrilla regrowth. This management approach proved successful when Hydrilla coverage was as little as one to three percent of the reservoir's surface area. Detecting and controlling Hydrilla early during the infestation should reduce the cost of management and perhaps minimize some adverse impacts associated with the use of triploid Grass Carp.

Partners for these two successful Hydrilla management projects included Duke Energy Corporation, Lake Norman Marine Commission, Charlotte Mecklenburg Utilities Department, Mountain Island Marine Commission, Gastonia Water Supply, NCDEQ, and NCWRC.

Other Aquatic Nuisance Species Regulatory Points to Note

Often there are multiple state and/or federal agencies that are involved when it comes to aquatic nuisance species. There may be overlap in jurisdictions leading to confusion for the general public. These overlaps often occur when discussions include, but are not limited to aquaculture, aquatic weed authority, aquarium and ornamental fish trade and water garden industries and importation of aquatic species into North Carolina. These jurisdiction questions are often handled on a case by case basis by the agencies that are involved.

Aquaculture

Although laws defining the jurisdictions between freshwater and marine/estuarine species exist, there can be confusion as to which agency has jurisdiction if a permit applicant is proposing to produce a species that may be found in freshwater for a portion of its life while the rest of its life is in estuarine or marine waters. In this instance, all three agencies would have jurisdiction and the applicant could be required to obtain an aquaculture license from the NCDA&CS, written permission from the NCWRC and an aquaculture operations permit from the NCDMF. However, this is not how the process generally works. For example, although flounders are found in freshwater they spend a majority of their life in marine and estuarine waters; therefore NCDMF has issued flounder aquaculture permits, while NCWRC has not issued authorization and NCDA&CS has not permitted the facilities. However, if a species spends a majority of its life within freshwater or the facility is in NCWRC inland water jurisdiction, the NCWRC and NCDA&CS have been taking the lead. In recent years there has been an informal process between NCWRC and NCDMF to determine who is responsible for authorizing or permitting a facility in instances where jurisdiction is unclear. There has been open communication prior to the permitting of a facility based on the potential risks to all native fishes. At times, after discussion amongst the agencies, one agency will take the lead and process the aquaculture application with comments provided by the other agency. The agencies have been conducting business this way to aid the applicants by providing one point of contact during the review. Although there has been open communication among the agencies, this process can be confusing to permit applicants. In order to alleviate this confusion, the agencies responsible for authorizing these facilities should attempt to provide permit applicants with additional guidance regarding the appropriate agency to contact to obtain a permit. This informal process should be documented and be made available to the public on each agency's web site.

Aquatic Weed Authority

The Aquatic Weed Control Act of 1991 provides authority to both NCDEQ and NCDA&CS. With regards to NCDEQ, the Act states "The Secretary shall direct the control, eradication and regulation of noxious aquatic weeds," and with regards to NCDA&CS, "The Commissioner of Agriculture may regulate the importation, sale, use, culture, collection, transportation and distribution of a noxious aquatic weed as a plant pest under Article 36 of Chapter 106 of the General Statutes." Both agencies have listed specific invasive plants and there is a significant amount of overlap between the two, however they are not identical (Table 4).

Table 4: Agency oversight regulating specific invasive aquatic plant species in North Carolina. Species highlighted in the color grey are listed on the Federal Noxious Weed List[1].

	NCDA & CS[2]	NC DENR[3]	PPQ-APHIS[4]
African Elodea (*Lagarosiphon* spp.)	X	X	X
Alligatorweed (*Alternanthera philoxeroides*)		X	
Ambulia (*Limnophila sessiliflora*)	X	X	X
Anchored Water Hyacinth (*Eichhornia azurea*)	X	X	X
Arrowhead (*Sagittaria sagittifolia*)	X	X	X
Arrowleaf False Pickerelweed (*Monochoria hastata*)	X	X	X
Brazilian Elodea (*Egeria densa*)		X	
Brittleleaf Niad (*Najas minor*)		X	
Broadleaf Paperbark Tree (*Melaleuca quinquenervia*)	X	X	X
Common Reed (*Phragmites australis australis*)		X	
Crested Floating Heart (*Nymphoides cristata*)	X		
Duck lettuce (*Ottelia alismoides*)	X		X
Eurasian Watermilfoil (*Myriophyllum spicatum*)	X_a	X	
Exotic Bur Reed (*Sparganium erectum*)	X	X	X
Giant Salvinia (*Salvinia auriculata*)	X	X	X
Giant Salvinia (*Salvinia biloba*)	X	X	X
Giant Salvinia (*Salvinia herzogii*)	X	X	X
Giant Salvinia (*Salvinia molesta*)	X	X	X
Heartshape False Pickerelweed (*Monochoria vaginalis*)	X	X	X
Hydrilla (*Hydrilla verticillata*)	X	X	X
Killer Algae (*Caulerpa taxifolia*)	X		X
Miramar Weed (*Hygrophila polysperma*)	X	X	X
Mosquito Fern (*Azolla pinnata*)	X	X	X
Parrotfeather (*Myriophyllum aquaticum*)		X	
Purple Loosestrife (*Lythrum salicaria*)	X_a	X	
Swamp Stonecrop (*Crassula helmsii*)	X	X	
Uruguay Waterprimrose (*Ludwigia uruguayensis*)		X	
Water Chestnut (*Trapa* spp.)	X	X	
Water Hyacinth (*Eichhornia crassipes*)		X	
Water Lettuce (*Pistia stratiodes*)		X	
Water Snowflake (*Nymphoides indica*)	X		
Water Spinach (*Ipomoea aquatica*)	X	X	X
Wetland Nightshade (*Solanum tampicense*)	X		X
Water Fern (*Salvinia* spp.)	X	X	
Yellow Floating Heart (*Nymphoides peltata*)	X	X	

[1]Federal Noxious Weed List. Last updated Dec 10, 2010. https://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/weedlist.pdf Last accessed Sept 19, 2015.

[2]NC Noxious Weed List (North Carolina Department of Agriculture and Consumer Services). Last updated Dec 10, 2010. http://www.ncagr.gov/plantindustry/plant/weed/noxweed.htm Last accessed Sept 19, 2015.

[3]Noxious Aquatic Weed List (North Carolina Department of Environmental Quality). Last updated April 1, 2006. http://www.ncwater.org/files/awc/noxious_weeds.pdf Last accessed Sept 19, 2015.

[4]Noxious Weed Regulations (Animal and Plant Health Inspection Service – United States Department of Agriculture). Last updated November 10, 2010. https://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/7cfr360-11.pdf Last accessed Sept 19, 2015.

Aquarium and Ornamental Fish Trade and Water Garden Industries

Most fish, crayfish, mollusks, aquatic snails, and aquatic plants found in the aquarium, ornamental fish trade and water garden industries can be legally possessed, imported, produced, transported, bought and sold, unless their possession is specifically prohibited by the NCWRC or the NCDA&CS.

Although the Aquaculture Development Act does not apply to the aquarium or ornamental fish trade, the Act does grant the NCWRC authority to "identify species for which possession in the State is prohibited [§ 106-761(h)]." The NCWRC has prohibited the possession of 21 species of fish, crayfish, mollusks and aquatic snails (Table 3). Live individuals of these species may not be transported, purchased, possessed, sold or stocked in the public or private waters of North Carolina. The NCDA&CS regulates 27 species of aquatic plants through the Noxious Weed List under authority of the N.C. Plant Pest Law. The sale or distribution of all noxious aquatic weeds identified by the NCDA&CS is prohibited unless a permit is issued by NCDA&CS.

The major risk associated with the aquarium and ornamental fish trade and water garden industries is the introduction of nuisance aquatic species into public waters. Introductions can occur through intentional releases or escapement. The NCWRC and NCDMF prohibit the release of fish, crayfish, mollusks and aquatic snails into public waters without a permit. Unless specifically allowed by permit or regulation, the import, possession, sale or distribution of aquatic plants is prohibited for those species identified by the NCDA&CS as noxious weeds. This prohibition precludes the release of these aquatic plants into public waters.

Importation of Aquatic Animal Species into North Carolina

The importation of fish, crayfish, mollusks and aquatic snails, into North Carolina is not directly regulated as an independent activity. The NCWRC and NCDMF have statutory authority to regulate importation for their respective jurisdictions, but have not fully promulgated rules to directly address this issue.

Currently the transport of aquatic animal species into the state is regulated by NCWRC, NCDMF and USFWS under certain circumstances. NCWRC requires a transportation permit for wild-caught fish, crayfish, mollusks and aquatic snails when transported in excess of daily creel limits. In addition, NCWRC prohibits the possession, including importation, of 21 species of fish, crayfish, mollusks, and aquatic snails as noted in Table 3. NCDMF restricts the introduction, transfer and holding of imported marine and estuarine organisms without first obtaining a permit or without obtaining them from a permit holder. The NCDMF permits are limited to the activities of placing live marine and estuarine organisms not native to the state into coastal fishing waters, placing live marine and estuarine organisms which are native but which originated outside the state's boundaries into coastal fishing waters, holding or maintaining any live marine or estuarine organism imported into the state in a quarantine or isolation system for live bait or use in an aquaculture operation, or selling for bait any live marine or estuarine organism imported into the state. The USFWS restricts the importation of some species under the authority of the Lacey Act. The Act prohibits import and interstate transport of any live specimen of a species listed as "injurious" without a permit from the USFWS. Species listed as "injurious" have been deemed to be harmful "to human beings, to the interests of agriculture, horticulture, forestry, or to wildlife or the wildlife resources of the United States."

VI. MANAGEMENT GOALS AND OBJECTIVES

*The overall goal of the North Carolina Aquatic Nuisance Species Plan is "**to prevent and control the introduction, spread and negative impacts of aquatic nuisance species in North Carolina.**" Currently gaps in ANS management within the state include: the lack of a comprehensive policy statement on ANS, the lack of a centralized decision making framework, inadequate statewide monitoring and reporting procedures, no centralized reporting system, a lack of biological and economic data, insufficient mapping, no rapid response plans, limited resources for enforcement, no comprehensive public education strategy, and limited coordination of partnerships with nonstate agencies and entities.*

In order to address these deficiencies, several primary objectives have been identified to improve prevention and management programs and minimize adverse impacts of ANS populations on North Carolina's public waters. Those primary objectives are:

PRIMARY OBJECTIVES

1. Increase the coordination of aquatic nuisance species prevention and management activities.
2. Educate public and private stakeholders on the impacts of aquatic nuisance species.
3. Review existing federal and state legislation and regulations to identify inconsistencies and gaps.
4. Identify and secure new funding for aquatic nuisance species activities.
5. Monitor occurrence and spread of aquatic nuisance species.
6. Manage populations of aquatic nuisance species and manage other aquatic invasive species as appropriate to prevent their establishment and spread.
7. Identify and implement needed research on impacts and control of aquatic nuisance species.

OBJECTIVES, STRATEGIES, & ACTIONS

The following is a list of recommended strategies and action items to help accomplish each objective.

1. Increase the coordination of ANS prevention and management activities.

The challenges ANS bring to the state requires the collaboration and expertise of a variety of different governmental agencies and non-governmental organizations. In order to control or manage ANS, improved coordination will require ongoing communication and coordination among all entities.

a. Develop a formal agreement (e.g., MOU) for improved coordination between NCDA&CS, NCDEQ and NCWRC to clearly identify roles of each agency in addressing and regulating ANS in North Carolina.
   - Draft MOU to emphasize mutual support and secure signatures from agency leadership.
   - Develop and distribute informational material to agency staff and interested stakeholders to clearly articulate specific roles and contact information.

b. Establish a North Carolina Aquatic Nuisance Species Task Force to lead plan implementation
   - Recruit representation / participation from various government agencies, industries, non-governmental organizations, and universities.
   - Determine meeting schedule, communication channels, and task force leadership (chair, co-chair, etc.)
   - Provide participants with relevant information, such as copies of the NCANSMP and adjoining state ANS plans, required to establish an annual program of work initially focused on high priority tasks.

c. Establish Early Detection Rapid Response (EDRR plans to address new introductions that have the potential for significant negative impacts such as encroachment into sensitive habitat areas, rapid spread into surrounding areas, and potential damage to infrastructure.
   - Utilize information about "high risk" ANS species

that are identified in the NCANSMP to establish early detection and response protocol and circulate to agency staff.
- Develop taxa-specific protocols when establishing species specific plans is not feasible.
- Distribute information about ANS to relevant stakeholders and request reporting of species observations and distributions.
- Establish communication channel with adjoining states to monitor ANS species distribution in surrounding areas, and include them in development of the EDRR plan.

d. Develop management plans for prevention, control and eradication of specific ANS.
- Establish a schedule for plans to be developed and prioritize them based on level of impact and rate of spread as part of annual work plan development.
- Collect and review relevant scientific information and stay current on emerging control methods.
- Map and monitor known populations of ANS.
- Identify potential unaffected habitats that ANS populations are likely to impact in the future.
- Recommend specific control measures and / or eradication techniques.

e. Participate on regional and national ANS panels and organizations.
- Maintain membership and participation in the regional and national aquatic nuisance species task forces and working groups.
- Secure necessary membership and travel funds through agency budgeting processes.

f. Coordinate ANS prevention and management activities with bordering states (VA, SC, TN, GA).
- Review current ANS plans of adjoining states.
- Develop / Maintain communication channels with relevant staff in adjoining states.
- Stay apprised of existing ANS policy and proposed changes in adjoining states.

g. Establish an ANS coordinator to provide staff support for NCANSTF.
- Review existing NCDEQ positions and identify 1 FTE coordinator and funding streams.
- Accommodate coordinator duties into work plan and schedule.

2. Educate the public and private stakeholders on ANS.
Improving educational understanding and programs for public and private stakeholders on ANS will assist in the early detection and prevention of the introduction and spread of ANS. Promoting ANS management through interagency cooperation will provide a centralized partnership for participation by local and private entities.

a. Develop interagency plan for outreach: prioritize audiences, list specific materials to be developed, conduct workshops as needed.
- Inventory and assess existing public information materials for consistency.
- Target audiences such as boaters, fishermen, lake homeowners associations and communities, aquaculture professionals, aquarium hobbyists, school children, college students, landscaping professionals, and agencies' staff and partners.
- Incorporate ANS prevention information into existing activities such as vessel registration and titling, boater safety checks, boating education courses, issuance of fishing licenses, development f stocking permits, issuance of aquaculture licenses, fishing education events, and master gardener programs.
- Review and utilize resources available through other existing programs such as Stop Aquatic Hitchhikers (SAH) – Protect Your Waters, a national public awareness campaign that empowers citizens and others to help prevent the spread of AIS, and Habitattitude, a national public awareness campaign on responsible pet use and not releasing pets into the wild.

b. Develop and maintain NCANS Management Plan webpage.
- Organize existing ANS webpage to accommodate NCANSTF documents and announcements.
- Provide link to ANS webpage to agency webpages and partner organizations.
- Post one-page info sheets from the NCANSMP to the webpage for the public and interested parties to download and circulate through their own education initiatives.

c. Develop and maintain an electronic information sharing process and database of ANS species and locations.
- Investigate opportunity to utilize existing NCDEQ database to accommodate ANS information.
- Engage university to discuss utilization of a common data base.
- Investigate geospatial data sharing compatibility issues with other systems. (Ex: USGS NAS database, EDDmaps)

d. Cultivate additional partnerships to collect and disseminate information to technical and non technical audiences, coordinate prevention activities, and identify and leverage funding opportunities.
- Invite relevant non-governmental organizations, utilities, and professional organizations such as Sea Grant and local citizen-led lake and river groups to participate on the NCANSTF.
- Enhance ANS education and information in existing agency programs and publications such as river basin management plans, published fishing regulations, and agency publications for broader dissemination.

e. Develop and adopt a recognizable slogan, logo, or brand.
- Work with state agencies graphic design and public information staff to develop logo and branding materials

f. Improve communication with state and federal law

enforcement and natural resources management officials regarding ANS.
- Maintain involvement in regional and national ANS-focused organizations such as the National ANS Task Force, Southeast Aquatic Resources Partnership (SARP), and the Southeastern Association of Fish & Wildlife Agencies (SEAFWA)
- iShare relevant information through web postings, listserves, and social media channels.

3. Review existing federal and state legislation and regulations to identify inconsistencies and gaps.
A periodic review of existing and proposed legislation will help ensure effective and efficient management of ANS throughout the state. Improved legislation could assist in the coordination of these state agencies as they monitor and respond to ANS issues throughout the state.

a. Assess legislation and regulations periodically, as required.
   - Monitor federal policies and legislation for changes that may impact North Carolina.
   - Monitor adjoining states policies and rules for changes that may impact North Carolina.
   - Review NC legislative initiatives involving ANS as they arise during annual sessions of the NC General Assembly.
   - Determine if any future proposed rules or regulations are in conflict with existing agency policies and / or existing state or federal laws.

4. Identify and secure new funding for ANS activities.
Monetary needs will increase with the implementation of ANS rapid response plans and additional monitoring. Leveraging existing funding sources and seeking new funding sources is critical for the state to successfully become more proactive in managing ANS.

a. Identify existing funding of cooperating NCANSTF agencies that is dedicated to or can be used for ANS activities.
   - Review agency budgets to assess existing funding for ANS-related activities to identify any redundancies or leveraging opportunities.

b. Identify new funding and grant opportunities (federal, state, local, private industry, nonprofit, etc.).
   - Review non-state agency funding for ANS-related activities by other NCANSTF members to identify leveraging opportunities and / or matching funds.

c. Seek recurring funding via legislative action in state agency budgets.
   - Budget priorities will be determined by individual agencies.

5. Monitor occurrence and spread of ANS.
Currently there is limited data collected on ANS in North Carolina. Establishing statewide monitoring and data reporting guidelines with centralized data storage will help address the lack of data currently available to state agencies working with ANS. A program to centralize data will allow agencies to map and understand ANS movements throughout the state. This will also help to prioritize key ANS species that are of the most concern for the state of North Carolina.

a. Identify all existing monitoring efforts and critical data gaps.
   - Compile list of all geospatial data sets containing ANS in North Carolina and assess for compatibility and comprehensiveness.
   - Document the method of data collection and storage.
   - Develop early detection networks for ANS and AIS.

b. Standardize monitoring and reporting guidelines.
   - Create a list of necessary data to collect for each ANS sighting (i.e. GPS coordinates, date found, photographic evidence of ANS in situ, known control efforts, etc)
   - Create inventory of ANS species already in existing databases such as APNEP and EDDmapS

c. Develop comprehensive mapping efforts.
   - Establish and coordinate surveys and monitoring of aquatic habitats for ANS occurrence.
   - Consider data formatting that is compatible with existing data sets such as USGS NAS, the NC Conservation Planning Tool, and the North Carolina One Map for ease of transferability and incorporation.

d. Centralize data storage and sharing.
   - Integrate proposed existing GIS maps and data on the state and federal level for compatibility.
   - Create AIS/GIS working group to compile data.
   - Establish protocol for distribution of information.

e. Long term: Identify and monitor areas of greatest vulnerability to specific ANS infestations.
   - Compile information / assessment on the ANS-related impacts on native species and habitats.
   - Identify opportunities for university research.
   - Focus on areas with high levels of environmental vulnerability, such as Lake Waccamaw; potential for significant difficulties in ANS containment and treatment, such as the Eno River, and areas with importance for public needs, such as near recreational access points, hydropower facilities and public drinking water supplies and infrastructure.

6. Manage populations of ANS and AIS as appropriate to prevent their establishment and spread.
Establishing and initiating protocols to respond to prioritized threats will reduce the spread of these species into other areas of the state, and potentially prevent their establishment within North Carolina.

a. Eradicate discreet populations of ANS including those recently introduced, relatively small, isolated, and poorly established.

- Develop and update prioritized list of ANS and AIS, incorporating risk analyses methods and outcomes.
- Implement rapid response procedures, as outlined in management plans for new introductions that have the potential for high levels of negative impact.
- Identify and implement accepted protocols as outlined for eradication operations on private property.
- Implement accepted protocols as outlined within management plans developed by the regional panels of the ANSTF or by the NCANSTF.
- Conduct follow-up monitoring to determine efficacy of management activities.

b. Manage/eradicate ANS according to accepted protocols as outlined within management plans developed by Regional Panels of the ANSTF or by the NCANSTF. Conduct follow-up monitoring to determine efficacy of management activities.

c. Identify ways to enhance the effectiveness and efficiency of management treatments.
   - Investigate and develop programmatic Environmental Assessments and Environmental Impact Statements for ANS control to facilitate rapid response as needed.
   - Investigate the feasibility of alternative prevention and management methods.

7. Identify and implement needed research on impacts and management of ANS

Continual research on all ANS including those that are currently in and could potentially threaten North Carolina is necessary to understand how they are affecting or may impact our aquatic systems. Improved research on life histories, environmental factors and management and control alternatives will contribute to North Carolina's ability to prevent and manage the spread of ANS, as well as to increase coordination with governmental and private entities throughout the region.

a. Study life histories of ANS that occur in or threaten North Carolina.
   - Compile existing information and identify research gaps.
   - Coordinate with colleges and universities to develop ANS research agenda
   - Identify and investigate environmental tolerances of ANS
   - Compile existing and proactively develop risk assessments for ANS

b. Study environmental and economic impacts of high priority ANS.
   - Compile existing information and identify research gaps.
   - Coordinate with colleges and universities and relevant private sector entities to develop research agenda.
   - Targeted organizations with specific research agendas focused on High Priority ANS and high risk species.

c. Identify research priorities by NCANSTF coordination with regional organizations (i.e., GSARP, SARP) and share priority lists with funding agencies such as NC Water Resources Research Institute, SeaGrant, and others.

d. Evaluate platforms to serve as a clearinghouse for ANS research in North Carolina.
   - Disseminate information gained through research conducted on ANS in NC through professional organizations such as the National ANS Task Force.

e. Consider expansion of ANS species list to include those pathogens that pose a threat specific to human health.

Implementation Tactics Tables

In order to implement action items, it is necessary to have a timeline with guidelines for accomplishment. The following implementation tables will provide road marks for implementing action items and meeting plan objectives. Implementation tactics were originally identified by the NCANSMP steering committee and are intended to be revised and improved by the NCANSTF. The steering committee has made the recommendation that the main vector to implement many of the objectives be driven by the NCANSTF, however if the task force is not created then the objectives could be completed through inter-agency and external partner cooperation. Examples of partnerships and cooperators are not inclusive of those listed below. Additionally, action items have each been assigned a priority level (high, medium, or low) to indicate which activities should be initiated earlier than others. When assigning the priority level, the planning committee considered various factors, such as available or projected funding, severity of the ecological and / or economic impact, and sequencing of necessary steps in the processing of specific activities.

Objective 1: Increase the coordination of ANS prevention and management activities.

Tactic	Description	Lead Agency	Cooperators	Funding Sources	Priority Level	Planned Effort			
						FY16	FY17	FY18	FY19
1A	Improve coordination between NCWRC, NCDENR and NCDA&CS	NCWRC, NCDEQ and NCDA&CS	NCANSTF	None required	Medium	X			
1B	Establish ANS Task Force	NCWRC, NCDEQ and NCDA&CS	various government agency staff, utilities, NGO's, academics, etc.	None required	High	X			
1C	Establish rapid response procedure for new introductions that have the potential for high levels of negative impact	NCANSTF	TBD – by organism and location	TBD – by organism and location	High	X	X	X	X
1D	Develop management plans for prevention, control, eradication of specific ANS	NCWRC, NCDEQ and NCDA&CS	NCANSTF	Internal	High	X	X	X	X
1E	Participate on regional and national ANS panels and organizations	NCWRC, NCDEQ, and NCDA&CS	NCANSTF	Agency budgets	Medium	x	x	x	x
1F	Coordinate ANS prevention and management with border states	NCWRC, NCDEQ and NCDA&CS	NCANSTF	Internal and external	Medium	X	X	X	X
1F	Establish an ANSTF coordinator position	NCDEQ	NCDEQ, NCANSTF	Internal and external	High	X	~~X~~		

Objective 2: Educate the public and private stakeholders on ANS.

Tactic	Description	Lead Agency	Cooperators	Funding Sources	Priority Level	Planned Effort			
						FY16	FY17	FY18	FY19
2A	Develop interagency plan for outreach	ANSTF	TBD	Internal and external	High	X			
2B	Develop and maintain ANS plan webpage	NCDEQ	NCDA&CS and NCWRC	Internal	Medium	X			
2C	Develop electronic information sharing process and database	NCANSTF	TBD		Medium	X	X	X	X
2D	Cultivate additional partnerships	ANSTF	TBD	Internal and external	Medium	X			
2E	Developing or adopting recognizable slogan, logo, or brand	ANSTF	TBD	Internal and external	Low			X	
2F	Improve communication with state, federal law enforcement officials and natural resource managers re: ANS.	NCWRC, NCDEQ and NCDA&CS	Federal and state law enforcement agencies, NCANSTF	Internal and external	Medium	X	X	X	X

Objective 3: Review existing federal and state legislation and regulations to identify inconsistencies and gaps.

Tactic	Description	Lead Agency	Cooperators	Funding Sources	Priority Level	Planned Effort			
						FY16	FY17	FY18	FY19
3A	Assess legislation and regulations as needed.	NCWRC, NCDEQ and NCDA&CS	NCANSTF	TBD	Low	X	X	X	X

Objective 4: Identify and secure funding for ANS activities.

Tactic	Description	Lead Agency	Cooperators	Funding Sources	Priority Level	Planned Effort			
						FY16	FY17	FY18	FY19
4A	Identify existing funding in cooperating NCANS taskforce entities that is dedicated to ANS activities.	NCANSTF	NCAWCC, NCDEQ, NCWRC, NCDA&CS	Internal and external	High	X	X	X	X
4B	Identify new funding and grant opportunities (federal, state, local, private industry, nonprofit)	NCANSTF	NCAWCC	Internal and External	High	X	X	X	X
4C	Seek recurring funding via legislative action in state agency budgets.	NCWRC, NCDEQ and NCDA&CS	NCANSTF, NCAWCC	Internal	Medium		X	X	X

Objective 5: Monitor occurrence and spread of ANS.

Tactic	Description	Lead Agency	Cooperators	Funding Sources	Priority Level	Planned Effort			
						FY16	FY17	FY18	FY19
5A	Identify all existing monitoring efforts and data gaps	NCANSTF	NCWRC, NCDEQ and NCDA&C	Internal and external	High	X	X	X	X
5B	Standardize monitoring and reporting guidelines	ANSTF	NCWRC, NCDEQ and NCDA&C	Internal and external	High	X			
5C	Develop comprehensive mapping efforts	ANSTF	NCWRC, NCDEQ and NCDA&C	Internal and external	High	X			
5D	Centralize data storage and sharing - Integrate existing GIS maps and data on the state and federal level.	ANSTF	NCWRC, NCDEQ and NCDA&C	Internal and external	Medium	X			
5E	Long term: Identify and monitor areas of greatest vulnerability to individual ANS infestations	ANSTF	NCWRC, NCDEQ and NCDA&C	Internal and external	Low			X	

Objective 6: Manage populations of ANS and AIS as appropriate to prevent their establishment and spread.

Tactic	Description	Lead Agency	Cooperators	Funding Sources	Priority Level	Planned Effort			
						FY16	FY17	FY18	FY19
6A	Eradicate discreet populations of ANS and AIS included small and isolated occurrences	ANSTF	All	Internal	High	X	X	X	X
6B	Manage established populations of ANS and AIS to minimize their expansion and impact.	NCWRC, NCDEQ and NCDA&C	ALL	Internal	High	X	X	X	X
6C	Identify ways to enhance the effectiveness and efficiency of management treatments.	NCDA, NCDEQ, NCWRC	NCANSTF	Internal and external	Medium	X			

Objective 7: Identify and implement needed research on impacts and management of ANS.

Tactic	Description	Lead Agency	Cooperators	Funding Sources	Priority Level	Planned Effort			
						FY16	FY17	FY18	FY19
7A	Study life histories of ANS that occur in or threaten NC	TBD based on organism or location	NCANSTF	Internal and external	Medium	X	X	X	X
7B	Study environmental and economic impacts of high priority ANS.	TBD based on organism or location	NCANSTF	Internal and external	High	X	X	X	X
7C	Identify research priorities by NCANSTF and share priorities with funding agencies such as NCWRRI, SeaGrant, etc	NCANSTF	TBD based on organism and location	Internal and external	High	X	X	X	X
7D	Evaluate platforms to serve as clearinghouse for ANS research in NC.	NCANSTF	University system, non-state agencies	Internal and external	Medium	X	X	X	X
7F	Consider expansion of ANS species list to include those pathogens that pose a threat specific to human health	NCANSTF	Public health agencies	Internal and external	Low			x	X

Monitoring & Evaluation

Regular and systematic monitoring of progress on the goals and objectives of the NCANSMP will be critical to determine the success of implementation priorities, selection of future action steps and the ongoing efforts to prevent and manage ANS and AIS species in North Carolina.

Regular and systematic monitoring of progress on the goals and objectives of the NCANSMP will be critical to determine the success of implementation priorities, selection of future action steps and the ongoing efforts to prevent and manage ANS and AIS species in North Carolina.

As outlined in the previous tables, the NCANSTF, composed of members representing agencies, academia, industry, and non-governmental organizations involved in ANS management and research, will be charged with oversight of the NCANSMP, including enhancing the coordination of monitoring efforts and establishing a statewide database that will be regularly updated with current information about the type and spread of ANS occurrences, based on a standardized reporting process. Metrics concerning impacts on other species will also be developed by the task force. This will require a centralized GIS database that can be shared with governmental and nongovernmental partners utilizing an established protocol. Success of the NCANSMP will be evaluated each year by the NCANSTF, based on progress in meeting the seven objectives, as measured by assessing the degree of completion of associated action items. The ongoing progress of implementing the NCANSMP will be evaluated through regular annual work

plan updates which may add or delete objectives and action items as needed by the NCANSTF. Their findings will be used to establish their next steps and priorities for the coming year. This evaluation will be posted on the NCANSMP webpage and circulated to interested parties. The Implementation Tactics Tables will be updated based on this information and will also be available on the NCANSMP webpage.

A critical first step towards successful implementation of the plan will be establishing the ANS coordinator position to provide staff support for the NCANSTF. A second critical step will be to obtain seed money that will allow the NCANSTF to begin plan implementation. Though much of the early high priority action items outlined in Section VI of this plan mostly require the time and effort of the NCANSTF members, some items will require funding and that is the primary obstacle for plan success at this point. Early successes can raise the program profile and potentially attract additional funding for implementing additional components.

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VIII. GLOSSARY OF TERMS AND ACRONYMS

Aquatic – relating to fresh or saltwater ecosystems including wetlands and open waters.

Aquaculture – a multimillion dollar industry, primarily consisting of marine and freshwater finfish and shellfish production.

Aquaculture Development Act – state law that regulates commercial production and sale of freshwater finfish and shellfish in North Carolina. See G.S. 106-759 – 106-764.

Aquatic invasive species – a nonnative species that lives most or all of its life in aquatic environments and has the potential to, or is likely to, cause harm to the ecosystem and/or the economy.

Aquatic nuisance species – a nonnative species that lives most or all of its life in aquatic environments and is causing negative ecological and/or economic impacts in North Carolina.

Aquatic Weed Control Act (1991) – authorizes the DEQ Secretary to designate plant organisms as noxious aquatic weeds and to direct the control, eradication and regulation of those noxious aquatic weeds.

Ballast water – any water that is placed in the hold of a ship or vessel for the purpose of providing stability to said ship or vessel.

Biodiversity – the total number of all organisms (plants, animals, fungi, bacteria, etc.) and ecosystems that can be found in a region.

Control – using biological, chemical, or mechanical methods to limit the spread and abundance of organisms.

Cryptogenic – unknown origin.

Discreet species – a population that is localized in a small area or system and could be targeted for eradication.

Endemic – a species that can only be found in a particular place.

Eradicate – to eliminate a species or population entirely from an ecosystem or geographic area.

Exotic species – a species that is not native to the state of North Carolina and the United States. Because some exotic species may be harmful or invasive while others are not, this term should be used with great care.

Extant – existing or still exists.

Freshwater species – aquatic species native to freshwater.

Habitat – area where a species has the necessary food, water, shelter and space to live and reproduce.

Historic range – those geographic areas the species was known or believed to occupy in the past.

Hitchhiker – an invasive species that is moved inadvertently from one place to another by being attached to or carried on equipment (such as a boat, trailer, heavy machinery, waders, or other gear).

Introduced species – an organism that is not native to a designated ecosystem or geographic area.

Invasive Species – an exotic or nonnative species that has the potential to, or is likely to, cause harm to the ecosystem and/or the economy.

Marine species – aquatic species native to saline (or brackish) waters. Synonym includes saltwater species.

Monitor – to test for compliance within certain limits or guidelines, to look for changes in the environment and to determine whether predictions may fall within expected ranges.

Native species – organisms naturally occurring in a specific geographic area or ecosystem.

Native range – the geographical area within which that species can be found.

Naturalization – to introduce organisms into a region and to cause them to flourish as if native.

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 – established a broad new Federal program to prevent introduction of and to control the spread of introduced aquatic nuisance species and the brown tree snake.

Nonindigenous species – synonymous with nonnative species.

Nonnative species – an organism in the wrong place, drainage system, ecosystem, or aquatic system outside its historical range.

Noxious aquatic weed – According to N.C.G.S. 113A-222, any plant organism which: (1) Grows in or is closely associated with the aquatic environment, whether floating, emersed, submersed, or ditch-bank species, and including terrestrial phases of any such plant organism; (2) Exhibits

characteristics of obstructive nature and either massive productivity or choking density; and (3) Is or may become a threat to public health or safety or to existing or new beneficial uses of the waters of the State.

Noxious weed – any noxious weed that is not native to the state, not currently known to occur in the state and poses a threat to the state (02 NCAC 48A .1701).

Nuisance species – an exotic or nonnative species that has been introduced into a new ecosystem and is now causing biological, physical, cultural, or economic harm to the ecosystem and/or the economy.

Parasite – an organism living in or on another organism.

Pathogen – a specific agent causing disease. May be a bacteria, virus, or fungus.

Pathway – natural or manmade means by which species are physically transported from one location to new areas which are outside of their native range. Interchangeable words used include vectors and mechanisms.

Plant Pest Law (Amendment 2013) – state law that states any insect or other invertebrate, disease, noxious weed, plant product, or article exposed to a plant pest can be considered a "plant pest." Board of Agriculture shall have the sole authority to prohibit the planting, cultivation, harvesting, disposal, handling, or movement of plants within this law.

Rapid response – a timely systematic effort to eradicate, contain, or control a potentially invasive nonnative species introduced into an ecosystem while the infestation is still localized.

Regulation – a law, rule, or order prescribed by authority

Saltwater species – aquatic species native to saltwater, spending any or all portions of its life cycle in saltwater.

Species – a fundamental category of taxonomy, ranking below genus and subgenus, consisting of related organisms capable of interbreeding.

Stocking – to add organisms or species to an ecosystem to achieve a certain population.

Taxa – taxonomic category, such as a species or genus.

Terrestrial species – organisms living primarily on land.

Triploid – Having three times the haploid number of chromosomes in the cell nucleus, resulting in a sterile organism

Vector – transportation of a species on or in a media or through a pathway.

Watershed – a geographic area that encompasses lakes, streams, rivers and/or estuary drainage areas that drain into a single water body or hydrologic unit.

Zero Tolerance Species – species that, if found, would trigger an immediate rapid response plan

List of Acronyms

AIS – Aquatic Invasive Species
AISP – Aquatic Invasive Species Program
APHIS – Animal and Plant Health Inspection Service
ANS – Aquatic Nuisance Species
ANSTF – Aquatic Nuisance Species Task Force (National)
AOP – Aquaculture Operation Permit
EDRR – Early Detection and Rapid Response
GIS – Geographic information system
GSARP – Gulf and South Atlantic Regional Panel on Aquatic and Invasive Species
NANPCA – Nonindigenous Aquatic Nuisance Prevention and Control Act
NCANSMP – North Carolina Aquatic Nuisance Species Management Plan
NCANSTF – North Carolina Aquatic Nuisance Species Task Force
NCAWCC – North Carolina Aquatic Weed Control Council
NCDA&CS – North Carolina Department of Agriculture and Consumer Services
NCDEQ – North Carolina Department of Environmental Quality
NCDMF – North Carolina Division of Marine Fisheries
NCDWR – North Carolina Division of Water Resources
NCNHP – North Carolina Natural Heritage Program
NCSU – North Carolina State University
NCWRC – North Carolina Wildlife Resources Commission
NCWRRI – North Carolina Water Resources Research Institute
NISC – National Invasive Species Council
NOAA – National Oceanic and Atmospheric Administration
NPDES – National Pollutant Discharge Elimination System
MOU – Memorandum of Understanding
SARP – Southeast Aquatic Resources Partnership
USACE – United States Army Corps of Engineers
USCG – United States Coast Guard
USDA – United States Department of Agriculture
USFS – United States Forest Service
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey

IX. APPENDICES

Appendix A:
Members of the NC Aquatic Nuisance Species Management Plan Steering Committee

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Rob Emens, NCDEQ - Division of Water Resources
Chris Goudreau, NCWRC – Habitat Conservation Program
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Appendix B:
NCDA&CS Noxious Weed List (Aquatic)

Mosquito Fern	*Azolla pinnata*
Caulerpa [Killer Algae (Mediterranean strain)]	*Caulerpa taxifolia*
Rooted Water Hyacinth	*Eichhornia azurea*
Hydrilla	*Hydrilla verticillata*
Miramar Weed	*Hygrophila polysperma*
Water Spinach	*Ipomoea aquatica*
African Oxygen Weed; African Elodea	*Lagarosiphon major*
Ambulia, Asian Marshweed	*Limnophila sessiliflora*
Uruguay Waterprimrose	*Ludwigia hexapetala*
Water Primrose	*Ludwigia uruguayensis*
Purple Loosestrife	*Lythrum salicaria*
Purple Loosestrife (any not native to NC)	*Lythrum spp.*
Broadleaf Paper Bark Tree	*Melaleuca quinquenervia*
Arrowleaf False Pickerelweed	*Monochoria hastata*
Heartshape False Pickerelweed	*Monochoria vaginalis*
Eurasian Watermilfoil	*Myriophyllum spicatum*
Crested Floating Heart	*Nymphoides cristata*
Water Snowflake	*Nymphoides indica*
Yellow Floating Heart	*Nymphoides peltata*
Duck Lettuce	*Ottelia alismoides*
Arrowhead	*Sagittaria sagittifolia*
Giant Salvinia	*Salvinia auriculata*
Giant Salvinia	*Salvinia biloba*
Giant Salvinia	*Salvinia herzogii*
Giant Salvinia	*Salvinia molesta*
Wetland Nightshade	*Solanum tampicense*
Exotic Bur Reed	*Sparganium erectum*

Appendix C:
Federal Noxious Weed List (Aquatic)

Mosquito Fern	*Azolla pinnata*
Caulerpa [Killer Algae (Mediterranean strain)]	*Caulerpa taxifolia*
Rooted Water Hyacinth	*Eichhornia azurea*
Hydrilla	*Hydrilla verticillata*
Miramar Weed	*Hygrophila polysperma*
Water Spinach	*Ipomoea aquatica*
African Oxygen Weed; African Elodea	*Lagarosiphon major*
Ambulia, Asian Marshweed	*Limnophila sessiliflora*
Broadleaf Paper Bark Tree	*Melaleuca quinquenervia*
Arrowleaf False Pickerelweed	*Monochoria hastate*
Heartshape False Pickerelweed	*Monochoria vaginalis*
Duck Lettuce	*Ottelia alismoides*
Arrowhead	*Sagittaria sagittifolia*
Giant Salvinia	*Salvinia auriculata*
Giant Salvinia	*Salvinia biloba*
Giant Salvinia	*Salvinia herzogii*
Giant Salvinia	*Salvinia molesta*
Wetland Nightshade	*Solanum tampicense*
Exotic Bur Reed	*Sparganium erectum*

Appendix D:
Species Tables

Table 1. **Invasive** species currently found in North Carolina. Species in bold have commercial or recreational value in North Carolina.

Scientific Name	Common Name	Taxa Group	Habitat
Gracilaria vermiculophylla	a red macroalga (seaweed)	Algae	Marine
Osteopilus septentrionalis	Cuban Treefrog	Amphibian	Freshwater-Brackish
Diplosoma listerianum	Lister's Encrusting Tunicate	Ascidian	Marine
Styela canopus	Rough Sea Squirt	Ascidian	Marine
Styela plicata	Pleated Sea Squirt	Ascidian	Marine
Cygnus olor	Mute Swan	Bird	Freshwater
Rangia cuneata	Atlantic Rangia	Bivalve	Marine
Zoobotryon verticillatum	Spaghetti Bryozoan	Bryozoan	Marine
Blackfordia virginica	Black Sea Jellyfish	Coelenterate	Freshwater-Marine
Cordylophora caspia	Freshwater Hydroid	Coelenterate	Freshwater-Marine
Craspedacusta sowerbyi	Freshwater Jellyfish	Coelenterate	Freshwater
Drymonema dalmatinum	Pink Meanie	Coelenterate	Marine
Garveia franciscana	Rope Grass	Coelenterate	Freshwater-Marine
Haliplanella lineata	Orange-striped Green Anemone	Coelenterate	Marine
Maeotias marginata	Black Sea Jellyfish	Coelenterate	Freshwater-Marine
Moerisia lyonsi	a hydroid	Coelenterate	Marine
Elaphoidella bidens bidens	a copepod	Copepod	Freshwater
Callinectes bocourti	Bocourt Swimming Crab; Red Blue Crab	Crab	Marine
Callinectes exasperatus	Rugose Swimming Crab	Crab	Marine
Charybdis hellerii	an Indo-Pacific crab	Crab	Marine
Astronotus ocellatus	Oscar	Fish	Freshwater
Carassius auratus	**Goldfish**	Fish	Freshwater

Table 1. **Invasive** species currently found in North Carolina. Species in bold have commercial or recreational value in North Carolina. (continued)

Scientific Name	Common Name	Taxa Group	Habitat
Chitala ornata	Clown Knifefish	Fish	Freshwater
Ctenopharyngodon idella	**Grass Carp**	Fish	Freshwater
Cyprinella lutrensis	Red Shiner	Fish	Freshwater
Cyprinus carpio	Common Carp	Fish	Freshwater
Dorosoma petenense	Threadfin Shad	Fish	Freshwater-Marine
Ictiobus cyprinellus	Bigmouth Buffalo	Fish	Freshwater
Lepomis cyanellus	Green Sunfish	Fish	Freshwater
Morone americana x saxatilis	Hybrid White Perch	Fish	Freshwater
Morone chrysops x saxatilis	**Hybrid Striped Bass**	Fish	Freshwater-Marine
Pterygoplichthys pardalis	Amazon Sailfin Catfish	Fish	Freshwater
Melanoides tuberculata	Red-rim Melania	Gastropod	Freshwater
Ligia exotica	Wharf Roach	Isopod	Marine
Arundo donax	**Giant Reed**	Plant	Freshwater-Brackish
Azolla pinnata	Mosquito Fern	Plant	Freshwater
Colocasia esculenta	Wild Taro	Plant	Freshwater
Iris pseudacorus	Pale Yellow Iris	Plant	Freshwater
Landoltia (Spirodela) punctata	Dotted Duckweed	Plant	Freshwater
Marsilea minuta	Dwarf Waterclover	Plant	Freshwater
Nelumbo nucifera	Sacred Lotus	Plant	Freshwater
Nymphoides cristata	Crested Floating Heart	Plant	Freshwater
Panicum repens	Torpedo Grass	Plant	Freshwater
Sagittaria montevidensis	Giant Arrowhead	Plant	Freshwater
Salvinia minima	Common Salvinia; Water Spangles	Plant	Freshwater
Tamarix gallica	French Tamarisk; Salt Cedar	Plant	Terrestrial
Haplosporidium nelsoni	MSX (Oyster) Disease	Protist	Marine
Perkinsus marinus	Dermo Disease	Protist	Marine
Pelodiscus sinensis	**Chinese Softshell Turtle**	Reptile	Freshwater
Penaeus monodon	Asian Tiger Shrimp	Shrimp	Marine
Largemouth bass virus (a species in the *Iridoviridae* family)	Largemouth Bass Virus	Virus	Freshwater
Rhabdovirus carpio	Spring Viraemia of Carp	Virus	Freshwater

Table 2. **Nuisance** species currently found within North Carolina. Species in bold have commercial or recreational value in North Carolina.

Scientific Name	Common Name	Taxa Group	Habitat
Codium fragile tomentosoides	Green Sea Fingers	Algae	Marine
Polysiphonia breviarticulata	a red algae	Algae	Marine
Corbicula fluminea	Asian Clam	Bivalve	Freshwater
Phyllorhiza punctata	Australian Spotted Jellyfish	Coelenterate	Marine
Carcinus maenas	European Green Crab	Crab	Marine
Orconectes rusticus	Rusty Crayfish	Crayfish	Freshwater
Orconectes virilis	Virile Crayfish	Crayfish	Freshwater
Procambarus clarkii	**Red Swamp Crawfish**	Crayfish	Freshwater
Lyngbya wollei	Giant Lyngbya	Cyanobacterium	Freshwater
Ictalurus furcatus	**Blue Catfish**	Fish	Freshwater
Micropterus punctulatus	Spotted Bass	Fish	Freshwater
Oreochromis aureus	**Blue Tilapia**	Fish	Freshwater
Pterois miles	Lionfish; Devil Firefish	Fish	Marine
Pterois volitans	Red Lionfish	Fish	Marine
Tilapia zillii	**Redbelly Tilapia**	Fish	Freshwater
Cipangopaludina chinensis malleata	Chinese Mysterysnail	Gastropod	Freshwater
Cipangopaludina japonica	Japanese Mysterysnail	Gastropod	Freshwater
Myocaster coypus	Nutria	Mammal	Freshwater
Anguillicoloides crassus (= Anguillicola crassus)	Eel Swimbladder Nematode	Nematode	NA
Alternanthera philoxeroides	Alligatorweed	Plant	Freshwater
Egeria densa	Brazilian Elodea	Plant	Freshwater
Eichhornia crassipes	**Water Hyacinth**	Plant	Freshwater
Hydrilla verticillata	Hydrilla	Plant	Freshwater
Ludwigia hexapetala (L. uruguayensis)	Uruguay Waterprimrose	Plant	Freshwater
Ludwigia peploides montevidensis	Creeping Water Primrose	Plant	Freshwater
Ludwigia peploides peploides	Creeping Water Primrose	Plant	Freshwater
Lythrum salicaria	Purple Loosestrife	Plant	Freshwater
Lythrum spp.	Purple Loosestrife (any not native to NC)	Plant	Freshwater
Murdannia keisak	Marsh Dewflower; Asian Spiderwort	Plant	Freshwater
Myriophyllum aquaticum	**Parrotfeather**	Plant	Freshwater
Myriophyllum spicatum	Eurasian Watermilfoil	Plant	Freshwater
Najas minor	Brittle Naiad	Plant	Freshwater
Nasturtium officinale	Watercress	Plant	Freshwater
Nymphoides peltata	Yellow Floating Heart	Plant	Freshwater
Phragmites australis australis	European Common Reed	Plant	Freshwater-Brackish
Pistia stratiotes	**Water Lettuce**	Plant	Freshwater
Potamogeton crispus	Curly Pondweed	Plant	Freshwater
Triadica sebifera	Chinese Tallow Tree	Plant	Freshwater

Table 3. Species not currently found within North Carolina but considered a **high risk** of becoming a **nuisance** species. Species in bold have commercial or recreational value in North Carolina.

Scientific Name	Common Name	Taxa Group	Habitat
Caulerpa taxifolia	Caulerpa [Killer Algae (Mediterranean strain)]	Algae	Marine
Codium fragile scandinavicum	Green Sea Fingers	Algae	Marine
Bufo marinus	Cane Toad	Amphibian	Freshwater
Eleutherodactylus planirostris	Greenhouse Frog	Amphibian	Terrestrial
Xenopus laevis	African Clawed Frog	Amphibian	Freshwater
Renibacterium salmoninarum	Bacterial Kidney Disease (BKD)	Bacterium	Freshwater
Crassostrea ariakensis	Asian Oyster; Suminoe Oyster	Bivalve	Marine
Dreissena bugensis	Quagga Mussel	Bivalve	Freshwater
Dreissena polymorpha	Zebra Mussel	Bivalve	Freshwater
Dreissena spp.	Dreissenid mussels	Bivalve	Freshwater
Musculista senhousia	Asian Date Mussel	Bivalve	Marine
Mytella charruana	Charrua Mussel	Bivalve	Marine
Mytilopsis sallei	Black-striped Mussel	Bivalve	Marine
Mytilus galloprovincialis	Mediterranean Mussel	Bivalve	Marine
Perna perna	Brown Mussel	Bivalve	Marine
Perna viridis	Green Mussel	Bivalve	Marine
Bythotrephes longimanus	Spiny Waterflea	Cladoceran	Freshwater
Cercopagis pengoi	Fishhook Waterflea	Cladoceran	Freshwater
Eurytemora affinis	a copepod	Copepod	Freshwater-Marine
Eriocheir sinensis	Chinese Mitten Crab	Crab	Marine
Eriocheir spp.	Mitten Crab	Crab	Marine
Petrolisthes armatus	Green Porcelain Crab	Crab	Marine
Orconectes palmeri creolanus	Creole Painted Crayfish	Crayfish	Freshwater
Orconectes placidus	Bigclaw Crayfish	Crayfish	Freshwater
Procambarus fallax virginalis	Marbled Crayfish; Marmorkrebs	Crayfish	Freshwater
Cyanobacterium sp.	Avian Vacuolar Myelopathy (AVM)	Cyanobacterium	Freshwater
Didymosphenia geminata	Didymo	Diatom	Freshwater
Anguilla mossambica	African Longfin Eel; Madagascar Eel	Fish	Freshwater-Marine
Channa argus	Northern Snakehead	Fish	Freshwater
Channa maculata	Blotched Snakehead	Fish	Freshwater
Channa spp.	Snakehead	Fish	Freshwater
Channallabes spp.	Walking Catfish	Fish	Freshwater
Clarias spp.	Walking Catfish	Fish	Freshwater
Gymnallabes spp.	Walking Catfish	Fish	Freshwater
Gymnocephalus cernuus	Ruffe	Fish	Freshwater
Heterobranchus spp.	Walking Catfish	Fish	Freshwater
Heteropneustea spp.	Walking Catfish	Fish	Freshwater
Hypophthalmichthys molitrix	Silver Carp	Fish	Freshwater
Hypophthalmichthys nobilis	Bighead Carp	Fish	Freshwater
Mylopharyngodon piceus	Black Carp	Fish	Freshwater
Neogobius melanostomus	Round Goby	Fish	Freshwater
Oreochromis mossambicus	Mozambique Tilapia	Fish	Freshwater-Brackish
Oreochromis niloticus	**Nile Tilapia**	Fish	Freshwater
Parachanna spp.	Snakehead	Fish	Freshwater
Proterorhinus marmoratus (= P. semilunaris)	Tubenose Goby; Western Tubenose Goby	Fish	Freshwater
Pygocentrus spp.	Piranha	Fish	Freshwater
Rooseveltiella spp.	Piranha	Fish	Freshwater
Scardinius erythrophthalmus	Rudd	Fish	Freshwater
Serrasalmus spp.	Piranha	Fish	Freshwater
Microtralia ovula (= M. occidentalis)	a pulmonate snail	Gastropod	Brackish-Marine

Table 3. Species not currently found within North Carolina but considered a **high risk** of becoming a **nuisance** species. Species in bold have commercial or recreational value in North Carolina. (continued)

Scientific Name	Common Name	Taxa Group	Habitat
Myosotella myosotis (= Ovatella myosotis)	Mouse-ear Snail	Gastropod	Brackish-Marine
Pomacea canaliculata	Channeled Applesnail	Gastropod	Freshwater
Pomacea maculata (= P. insularum)	Giant Applesnail; Island Applesnail	Gastropod	Freshwater
Pomacea paludosa	Florida Applesnail	Gastropod	Freshwater
Potamopyrgus antipodarum	New Zealand Mudsnail	Gastropod	Freshwater
Rapana venosa	Rapa Whelk	Gastropod	Marine
Viviparus georgianus	Banded Mysterysnail	Gastropod	Freshwater
Viviparus subpurpureus	Olive Mysterysnail	Gastropod	Freshwater
Carcinoscorpius rotundicauda	Mangrove Horseshoe Crab	Merostome	Marine
Tachypleus gigas	Indo-Pacific Horseshoe Crab	Merostome	Marine
Myxobolus cerebralis	Whirling Disease	Myxosporean	Freshwater
Crassula helmsii	Swamp Stonecrop	Plant	Freshwater
Eichhornia azurea	Rooted Water Hyacinth	Plant	Freshwater
Hygrophila polysperma	Miramar Weed	Plant	Freshwater
Ipomoea aquatica	Water Spinach	Plant	Freshwater
Lagarosiphon major	African Oxygen Weed; African Elodea	Plant	Freshwater
Lagarosiphon spp.	African Elodea	Plant	Freshwater
Limnophila sessiliflora	Ambulia; Asian Marshweed	Plant	Freshwater
Melaleuca quinquenervia	Broadleaf Paperbark Tree	Plant	Freshwater
Monochoria hastata	Arrowleaf False Pickerelweed	Plant	Freshwater
Monochoria vaginalis	Heartshape False Pickerelweed	Plant	Freshwater
Nymphoides indica	Water Snowflake	Plant	Freshwater
Ottelia alismoides	Duck Lettuce	Plant	Freshwater
Sagittaria sagittifolia	Arrowhead	Plant	Freshwater
Salvinia auriculata	Eared Watermoss	Plant	Freshwater
Salvinia biloba	Lobed Salvinia	Plant	Freshwater
Salvinia herzogii	Giant Salvinia	Plant	Freshwater
Salvinia molesta	Giant Salvinia	Plant	Freshwater
Salvinia spp. (all except S. rotundifolia)	Water Fern	Plant	Freshwater
Solanum tampicense	Wetland Nightshade	Plant	Freshwater
Sparganium erectum	Branched Burreed	Plant	Freshwater
Stratiotes aloides	Crabs Claw; Water Aloe	Plant	Freshwater
Trapa natans	Water Chestnut	Plant	Freshwater
Trapa spp.	Water Chestnut	Plant	Freshwater
Mikrocytos mackini	Oyster Mikrocytosis	Protist	Marine
Perkinsus olseni	Clam and Cockle Perkinsus	Protist	Marine
Infectious hematopoietic necrosis virus (a species of *Novirhabdovirus*)	Infectious Hematopoietic Necrosis (IHN)	Virus	Freshwater
Epizootic hematopoietic necrosis virus (a species of *Ranavirus*)	Epizootic Hematopoietic Necrosis (EHN)	Virus	Freshwater
Viral hemorrhagic septicemia virus (a species of *Novirhabdovirus*)	Viral Hemorrhagic Septicemia (VHS)	Virus	Freshwater-Marine
Infectious hypodermal and hematopoietic necrosis virus	Shrimp parvovirus; IHHN	Virus	Marine

Table 4. Species not currently found within North Carolina but considered a **lower risk** of becoming a **nuisance** species.

Scientific Name	Common Name	Taxa Group	Habitat
Caprella scaura	a caprellid amphipod	Amphipod	Marine
Stenothoe gallensis	an amphipod	Amphipod	Marine
Bothriocephalus opsarichthydis	Great Asian Tapeworm	Cestode	Freshwater
Cardisoma guanhumi	Blue Land Crab	Crab	Brackish-Marine
Cambarus cumberlandensis	Cumberland Crayfish	Crayfish	Freshwater
Cherax quadricarinatus	Australian Redclaw Crayfish	Crayfish	Freshwater
Cherax spp.	"giant" crayfish	Crayfish	Freshwater
Astyanax mexicanus	Mexican Banded Tetra	Fish	Freshwater
Colossoma macropomum	Tambaqui (Pacu)	Fish	Freshwater
Colossoma spp.	Pacu	Fish	Freshwater
Culaea inconstans	Brook Stickleback	Fish	Freshwater
Electrophorus electricus	Freshwater Electric Eel	Fish	Freshwater
Esox lucius	Northern Pike	Fish	Freshwater
Jordanella floridae	Flagfish	Fish	Freshwater
Leuciscus idus	Ide	Fish	Freshwater
Monopterus albus	Asian Swamp Eel	Fish	Freshwater
Morone mississippiensis	Yellow Bass	Fish	Freshwater
Osmerus mordax	Rainbow Smelt	Fish	Freshwater-Marine
Piaractus brachypomus	Red-bellied Pacu	Fish	Freshwater
Piaractus spp.	Pacu	Fish	Freshwater
Pterygoplichthys disjunctivus	Vermiculated Sailfin Catfish	Fish	Freshwater
Salmo salar	Atlantic Salmon	Fish	Freshwater-Marine
Tinca tinca	Tench	Fish	Freshwater
Vandellia cirrhosa	Carnero; Candiru Catfish	Fish	Freshwater
Creedonia succinea	a pulmonate snail	Gastropod	Brackish-Marine
Sphaeroma terebrans	an isopod	Isopod	Brackish-Marine
Synidotea laticauda	an isopod	Isopod	Brackish-Marine
Urochloa (Brachiaria) mutica	Para Grass	Plant	Freshwater
Ficopomatus miamiensis	a tube-building worm	Polychaete	Marine
Hydroides elegans	a tubeworm	Polychaete	Marine
Litopenaeus stylirostris	Blue Shrimp	Shrimp	Marine
Litopenaeus vannamei	Pacific White Shrimp; Whiteleg Shrimp	Shrimp	Marine
Macrobrachium olfersii	Bristled River Shrimp	Shrimp	Freshwater-Marine
Sinelobus stanfordi	a tanaid	Tanaid	Marine

Table 5. **Nonnative** species currently found within North Carolina, but that pose low risk. Species in bold have commercial or recreational value in North Carolina.

Scientific Name	Common Name	Taxa Group	Habitat
Daphnia lumholtzi	a waterflea	Cladoceran	Freshwater
Lepomis microlophus	**Redear Sunfish**	Fish	Freshwater
Lucania goodei	Bluefin Killifish	Fish	Freshwater
Misgurnus anguillicaudatus	Oriental Weatherfish	Fish	Freshwater
Oncorhynchus mykiss	**Rainbow Trout**	Fish	Freshwater-Marine
Oncorhynchus nerka	Sockeye Salmon (Kokanee)	Fish	Freshwater-Marine
Pimephales promelas	**Fathead Minnow**	Fish	Freshwater
Salmo trutta	**Brown Trout**	Fish	Freshwater-Marine
Batrachochytrium dendrobatidis	Amphibian Chytrid Fungus	Fungus	Freshwater
Oryza sativa	Rice	Plant	Freshwater
Apalone ferox	Florida Softshell Turtle	Reptile	Freshwater
Trachemys scripta elegans	Red-eared Slider	Reptile	Freshwater

Table 6. Species native to a portion of North Carolina that may be **invasive** outside their native range. Species in bold have commercial or recreational value in North Carolina.

Scientific Name	Common Name	Taxa Group	Habitat
Morone chrysops	**White Bass**	Fish	Freshwater-Marine
Cabomba pulcherrima	Purple Cabomba	Plant	Freshwater
Phalaris arundinacea	Reed Canarygrass	Plant	Freshwater

Table 7. Species native to a portion of North Carolina that are a **nuisance** outside their native range. Species in bold have commercial or recreational value in North Carolina.

Scientific Name	Common Name	Taxa Group	Habitat
Alosa aestivalis	**Blueback Herring**	Fish	Freshwater-Marine
Alosa pseudoharengus	**Alewife**	Fish	Freshwater-Marine
Ictiobus bubalus	Smallmouth Buffalo	Fish	Freshwater
Morone americana	**White Perch**	Fish	Freshwater
Pylodictis olivaris	**Flathead Catfish**	Fish	Freshwater
Procambarus acutus	**White River Crawfish**	Crayfish	Freshwater

Table 8. Species with one or more questions as to native range (cryptogenic), presence in North Carolina or degree of threat (i.e., invasive or nuisance).

Cryptogenic species				
Scientific Name	**Common Name**	**Taxa Group**	**Habitat**	**Other Question**
Lyngbya spp.	Blue-green Algae; Black Mat Algae	Cyanobacterium	Freshwater-Marine	
Salmincola edwardsii	gill lice	Copepod	Freshwater	Degree of threat
Molgula manhattensis	a sea grape	Ascidian	Marine	
Nematostella vectensis	Starlet Sea Anemone	Coelenterate	Marine	
Gyrodactylus anguillae	gill worm fluke on eels	Fluke	Freshwater-Marine	
Fabricia stellaris	a polychaete worm	Polychaete	Marine	Present in NC?
Baculovirus penaei	Baculovirus of Shrimp	Virus	Marine	Present in NC?
Coronoviridae	Yellow Head Virus (of shrimp)	Virus	Marine	Present in NC?
Picornaviridae	Taura Syndrome Virus (of shrimp)	Virus	Marine	Present in NC?
Whispovirus	White Spot Disease (of shrimp)	Virus	Marine	Present in NC?
Species presence in NC is unknown				
Scientific Name	**Common Name**	**Taxa Group**	**Habitat**	**Other Question**
Paradella dianae	an isopod	Isopod	Marine	Degree of threat
Pseudodactylogyrus anguillae	gill worm fluke on eels	Fluke	Freshwater-Marine	
Pseudodactylogyrus bini	gill worm fluke on eels	Fluke	Freshwater-Marine	
Species present in NC but degree of threat is unknown				
Scientific Name	**Common Name**	**Taxa Group**	**Habitat**	**Other Question**
Amphibalanus amphitrite	Striped Barnacle; Purple Acorn Barnacle	Barnacle	Marine	
Balanus trigonus	Purple Striped Barnacle	Barnacle	Marine	
Loxothylacus panopaei	a parasitic barnacle	Barnacle	Marine	
Megabalanus coccopoma	Titan Acorn Barnacle	Barnacle	Brackish-Marine	
Megabalanus tintinnabulum (= M. antillensis)	Giant Purple Barnacle	Barnacle	Marine	
Teredo navalis	Naval Shipworm	Bivalve	Marine	
Lernaea cyprinacea	Anchor Worm	Copepod	Freshwater	
Skistodiaptomus pallidus	a copepod	Copepod	Freshwater	
Hemigrapsus sanguineus	Asian Shore Crab	Crab	Marine	
Synidotea laevidorsalis	an isopod	Isopod	Marine	
Ficopomatus enigmaticus	Australian Tubeworm	Polychaete	Marine	Present in NC?

Appendix E:
Summary of North Carolina State Laws, Programs and Regulations Relevant to Aquatic Invasive Species

Statute	Agency	Summary
§ 106-761 Aquaculture facility registration and licensing.	NCDA&CS	Registration and licensing of freshwater aquaculture facilities. The NCDA&CS have the ability to license facility if a species is on the Clean list. If the species are not on the list they must get prior approval from the NCWRC.
§ 106-762 Fish disease management	NCDA&CS	Development of a fish disease management plan with assistance from the NCWRC. Makes it unlawful to willfully release domestically raised fish into waters of the State, other than in private ponds without written permission from the NCWRC or NCDMF.
§ 106 article 36 Plant pests	NCDA&CS	NC Plant Pest Law to prevent the spread of nonnative plants from the noxious weed list. This law prohibits transportation of noxious weeds into NC and within the state.
§ 113-274	NCWRC	Regulates and permits the transportation, purchase, possession, sale or stocking of wildlife species within NCWRC jurisdiction.
§ 113-292 Authority of the Wildlife Resources Commission in regulation of inland fishing and the introduction of exotic species	NCWRC	Authorize, license, regulate, prohibit, prescribe, or restrict all fishing in inland fishing waters and the introduction of exotic species.
15A NCAC 10C .0209 Transportation of live fish	NCWRC	Illegal to transport freshwater non-game fishes or live game fishes in excess of possession limits. Makes it unlawful to stock any life stage of any species of fish in inland fishing waters without a stocking permit from the NCWCRC.
15A NCAC 10C .0211 Possession of certain fishes	NCWRC	Prohibits the possession of exotic species found on the NCWRC prohibited list.
§ 113-132 Jurisdiction of fisheries agencies	NCWRC NCDMF	Gives the MFC jurisdiction over the conservation marine and estuarine resources and NCWRC jurisdiction of the conservation of wildlife including the hunting of invasive species. Statute also divides the state's waters into NCMFC and NCWRC jurisdiction based on the fishes present.
15A NCAC 03O .0501	NCDMF	Marine and estuarine aquaculture operation permit and regulatory authority.
15A NCAC 03I .0104 Introduce, transfer or hold imported marine estuarine organisms	NCDMF	Illegal to introduce living marine or estuarine nonnatives into North Carolina waters without a permit from NCDMF.
113 Article 15 Aquatic Weed Control Act	NCDEQ	Aquatic Weed Control Act gives NCDEQ the authority to designate and control aquatic noxious weeds. This also gives the Commissioner of Agriculture the ability to regulate the importation, sale, use, culture, collection, transportation, and distribution of noxious weeds.
NCG560000	NCDWR	Pesticide National Pollutant Discharge Elimination System General Permit to use pesticides for mosquito and other flying insect pest control, aquatic weed and algae control, aquatic animal pest control, forest canopy pest control and intrusive vegetation control.

Appendix F:
Summary of Federal and International Laws and Treaties Relevant to Aquatic Invasive Species

Statute	Agency	Summary
16 USC 4702 Aquatic nuisance species prevention and control	USFWS	Gives the USFWS Invasive Species Branch the authority to manage the ANSTF and Aquatic Nuisance Species Program.
Executive Order 13112	Federal Agencies	Coordinated federal agency responses to address terrestrial and aquatic invasive species and created the National Invasive Species Council. The Order also directed federal agencies to not authorize, fund, or carry out actions that would promote the introduction or spread of invasive species in the United States.
18 USC 42-43	DOI	Lacey Act. The Act gave the Secretary of the Interior authority to regulate the importation and transport of species including offspring and eggs that are injurious.
16 USC 3371-3378	DOI	Secretary of the Interior authority to regulate the importation and transport of species including offspring and eggs that are injurious.
33CFR 151.2025 Ballast Water Management Requirements	USCG	Ballast Water Discharge requirements to respond to concerns that invasive species found in ballast water could have ecological, economic, or potential health threats.
7 USC 7701 Plant Protection	USDA	Secretary of Agriculture the authority to prohibit or restrict the importation, entry, exportation or movement of in interstate commerce of any plant, plant product, biological control organism, noxious weed, article or means of conveyance if the Secretary determines that the prohibition or restriction is necessary to prevent the introduction of a plant pest or noxious weed into the United States.
7 USC 2801	USDA	Secretary of Agriculture the ability to designate federally listed noxious weeds.

Appendix G:
Public Comments Received and Responses

The draft North Carolina Aquatic Nuisance Species Management Plan was available for comment by the general public from May 1-31, 2015 on a specially-created webpage. Visitors to the site were able to submit comments online through the webpage or send comments to a staff member whose contact information was provided on the webpage. Notification of the public comment period was posted in the North Carolina Register. Additionally, an announcement of the public comment period was posted on department webpages with links to the comment webpage and information about the plan and the comment period was circulated on various social media platforms such as Facebook and Twitter, and posted on relevant list serves. Various formatting and technical writing corrections were made after a thorough professional editing review.

The ANSMP Committee reviewed the comments and incorporated a number of changes based on the information they received. Here is a list of summarized comments from the general public and the responses from the committee:

Based on my experience in research involving aquatic nuisance species, I think these species categorizations seem reasonable. I believe Red Shiner should be included, and also Redbelly Tilapia.

Red Shiner is included in Appendix D, Table 1 as an invasive species. Redbelly Tilapia?

Very pleased to see this plan. Please make this correction in the Chowan case study: the exact size of the new infested area is still undetermined.

Text clarified to indicate that the size of the area is undetermined and is not being treated at this time.

This plan needs to include small ponds and lakes in the county where I live. Many of them have too many weeds for fishing.

The plan recognizes the need for a more comprehensive inventory of the current locations where aquatic nuisance species occur. The plan (Section VI, Objective 2) recommends that a database for professionals and the public be established to centralize information about the whereabouts of ANS throughout the state.

Please correct photo credit of golf course.

Correction made to credit Steve Hoyle from NCSU.

Salvinia is misspelled in various sections of the plan.

Spelling corrections made.

Letter from the North Carolina Chapter of the American Fisheries Society supports the draft plan and offered 2 suggestions: include New Zealand Mud Snail Potamopyrgus antipodarum as a high risk species due to its established populations in other states transported by anglers, and include Smallmouth Buffalo Ictiobus bubalus which is already established in NC piedmont rivers and is known to dominate the biomass of fishes in those areas.

New Zealand Mudsnail is included on Appendix D, Table 3 as a High Risk Species. Added Smallmouth Buffalo to Appendix D, Table 7.

Appendix H:
Aquatic Nuisance Species of Concern Information Sheets

Alligatorweed
(Alternanthera philoxeroides)

Taxa Group: Plant

Size: Stems 6-10 inches long. Leaves 1-3 inches long.

Distinctive Physical Characteristics: A perennial that forms large dense mats and is invasive to many agricultural and aquatic communities.

Habitat: Generalist, preferring full sun; grows rampantly in canals, ditches, wetlands, and slow moving streams and rivers.

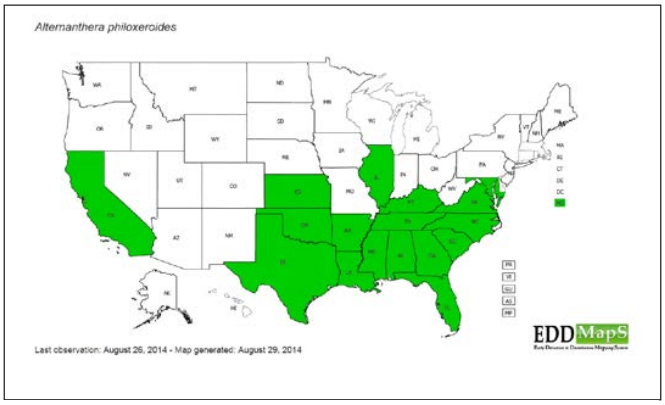
Native Range: South America.

NC History: Management since 1980s.

Current NC Distribution: Coastal Plain and into the Piedmont.

Pathway of Introduction: Fragmentation, and possibly seed distribution.

Management and Control: Primarily herbicides. Limited biological control using the Aligatorweed flea beetle (*Argasicles hygrophila*). In NC, the flea beetle cannot survive winter temperatures, and populations will only persist in extreme southeastern counties.



Introduced Distribution of Alligatorweed (EDDMapS, 2015)

Alligatorweed clogging a drainage canal. (©Bridget Lassiter)

Impacts and Uses of Alligatorweed in NC

Ecological: Creates dense floating mats which shade out submersed vegetation.

Economic: Alligatorweed has proved to be problematic in drainage ditches and canals, used in Eastern NC to drain agricultural and urban areas following heavy rains. It impacts recreational activities such as swimming, wading, paddling, and fishing.

Sources:

Aulback-Smith, C.A. and S. de Kozlowski. 1999. Aquatic and Wetland Plants of South Carolina. SC Dept. of Nat. Resources

Buckingham, G. R. Alligatorweed. In: Van Driesche, R., *et* al., 2002, Biological Control of Invasive Plants in the Eastern United States, USDA Forest Service Publication FHTET-2002-04, 413 p. Available : (https://dnr.state.il.us/Stewardship/cd/biocontrol/1Alligato rweed.html)

Lassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas, NC Cooperative Extension.

EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=2779. Acc. 9-19-15.

Brazilian Elodea
(Egeria densa)

Taxa Group: Plant

Size: Stems 1/15th inch in diameter, but can grow to lengths of 6 feet. Leaves 1-1.25 inches long.

Distinctive Physical Characteristics: A branched, submersed, dioecious perennial found rooted or free-floating in water. Can be double-noded. Roots can form at any branching point. White flowers; somewhat showy and occurring in spring and early summer.

Habitat: Thrives in ponds, lakes, streams and rivers.

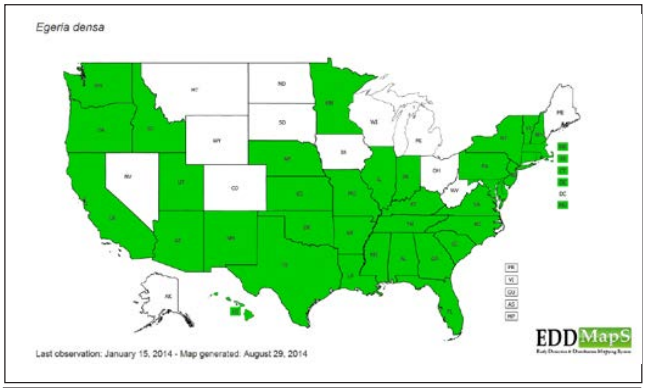
Native Range: South America

NC History: Management from mid 1990s.

Current NC Distribution: Scattered counties across the Coastal Plain and some Piedmont counties.

Pathway of Introduction: Fragmentation. A popular aquarium plant typically sold under the name "Anacharis."

Management and Control: Herbicide use and triploid grass carp.



Introduced Distribution of Brazilian Elodea (EDDMapS, 2015)

Brazilian Elodea leaves and flower. (©Bridget Lassiter)

Impacts and Uses of Brazilian Elodea in NC

Ecological: Alters habitat by forming dense canopies which displaces and/or suppresses native submersed aquatic plants.

Economic: Restricts water movement and has potential to clog intakes. It affects recreational activities such as swimming, wading, paddling, and fishing.

Human Health or Human use: Creates stagnant water which increases mosquito breeding habitat

Sources:

Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.

Lassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas, NC Cooperative Extension.

EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/uscounty.cfm?sub=3019. Acc. 9-19-15.

Brittle Naiad
(Najas minor)

Taxa Group: Plant

Size: Grows in masses that can be 4 feet+ tall. Leaves are ~1 inch long.

Distinctive Physical Characteristics: An annual aquatic plant with brittle shoots. Parts of the plant readily fragment, which facilitates its spread. Leaves are linear and opposite. Bright green or reddish with rough serrations on margins. Always submersed, and typically stacked with shorter internodes at stem tips.

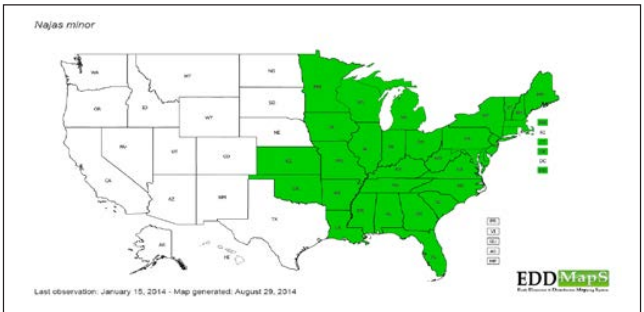
Habitat: Rarely occurs as a monoculture, often associated with other aquatic weeds such as hydrilla.

Native Range: Europe.

NC History: State-agency-level management began in 1989, however limited to few sites. Since then State-agency level management projects occur infrequently and are relatively small scale (<5 acre).

Current NC Distribution: Piedmont. Insufficient monitoring data for Coastal Plain and Mountains to determine distribution.

Pathway of Introduction: Reproduces by seed and fragmentation. Seed dispersal by water flow and wildlife. Recreationists serve as a hitchhiker vector for both seed and fragments.



Introduced Distribution of Brittle Naiad. (EDDMapS, 2015)

Brittle Naiad. (© Bridget Lassiter)

Management and Control: Herbicides and triploid grass carp.

Impacts and Uses of Brittle Naiad in NC

Ecological: Alters habitat. Out-competes native submersed vegetation.
Economic: Impedes navigation in waterways, impacts recreation activities, and fouls water intakes.
Human health or Human Use: Creates stagnant water which increases mosquito breeding habitat.

Sources: Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
Lassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas, NC Cooperative Extension.
EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=3056. Acc. 9-19-15.

Brittle Naiad growing on surface of water, Burlington, NC, 2005. (© Rob Emens)

Curly Pondweed
(Potamogeton crispus)

Taxa Group: Plant

Size: 1 foot to 12 feet long.

Distinctive Physical Characteristics: A perennial that can grow in water as deep as 15 ft. The plants are highly branched, with zigzag brittle stems. All leaves are submerged.

Habitat: Can form large, dense infestations, especially in cool climate zones. Tolerant of brackish water environments.

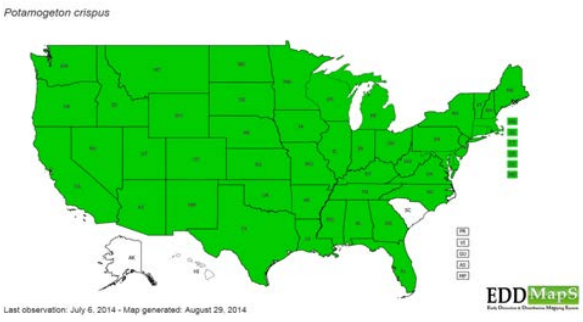
Native Range: Europe.

NC History: Unknown.

Current NC Distribution: Statewide.

Pathway of Introduction: Propagates via seed and turions.

Management and Control: Herbicide



Introduced Distribution of Curly Pondweed. (EDDMapS, 2015)

Curly Pondweed Infestation, (EDDMapS, 2015)

Impacts and Uses of Curly Pondweed in NC

Ecological: Can form large, dense populations that severely impair recreation and other water activities.

Economic: Severely impairs waterways, impacts recreation activities and fouls water intakes.

Human Health or Human use: None known.

Close-up image of Curly Pondweed, (EDDMapS, 2015)

Sources:

Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.

EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=6219. Acc. 9-19-15.

Eurasian Watermilfoil
(Myriophyllum spicatum)

Taxa Group: Plant

Size: Stems can be 4 feet+ long. Leaves are ~1 inch.

Distinctive Physical Characteristics: Completely submerged except for the floral spike. Leaves are whorled and finely divided resembling a bird's feather. Leaves are flimsy and collapse when removed from the water. Flowers are tiny, inconspicuous, and borne in the leaf axils of emergent spikes.

Habitat: Thrives in cool water. Will "top out" during peak growth periods with majority of biomass concentrated near the water surface. Forms dense, impenetrable mats.

Native Range: Europe, Asia, N. Africa.

NC History: Extensively infested the Currituck Sound during the mid-20th century.

Current NC Distribution: Widespread throughout the Albemarle Sound and Currituck Sound and Roanoke Rapids Lake. Insufficient data for Piedmont & Mountains to determine distribution.

Pathway of Introduction: Recreationists serving as a hitchhiker vector.

Management and Control: Herbicide.

Introduced Distribution of Eurasian Watermilfoil. (USDA Plants Database, 2015)

Eurasian Watermilfoil. © Bridget Lassiter

Impacts and Uses of Eurasian Watermilfoil in NC

Ecological: An introduced species with enormous potential for invasiveness. Alters habitat and water quality.

Economic: Hydroelectric operations, irrigation and municipal water intakes, clogs trash racks and impedes recreational activities.

Human Health or Human use: Creates stagnant water which increases mosquito habitat and leads to increased frequency of mosquito-borne illness.

Eurasian Watermilfoil collecting on a boat ramp, Kitty Hawk Bay, NC, 2007. (© Rob Emens)

Sources:

Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
USDA Plants Database Citation: http://plants.usda.gov/core/profile?symbol=MYSP2. Acc. 9-18-15.

European Common Reed *(Phragmites australis ssp. australis)*

Taxa Group: Plant

Size: Can grow to 12 feet+ tall.

Distinctive Physical Characteristics: A stout perennial grass with creeping rhizomes and stolons. Nonnative biotypes are highly invasive due to prolific growth habits and difficulty in management. Stem is round and hollow. The seedhead is a terminal panicle, plumelike and brown to purple in color. Length ranges from 6 to 16 inches. The roots are stout and very difficult to pull out of the ground.

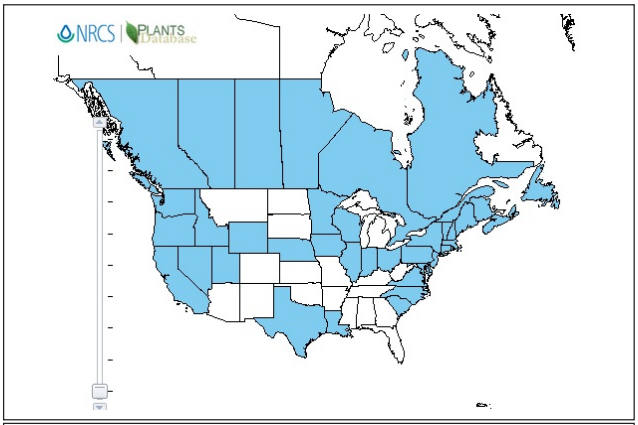
Habitat: Forms dense homogeneous stands in fresh or brackish marshy areas.

Native Range: Europe.

NC History: Has largely gone unmanaged.

Current NC Distribution: Coastal Plain. Large areas in the lower Cape Fear Basin.

Pathway of Introduction: Spreads by runners and seed. Phragmites is likely to invade and colonize disturbed areas if seed is present. Contaminated equipment, like heavy machinery, is a likely vector.



Distribution of invasive strain of phragmites. (USDA, PLANTS Database, 2015)

European Common Reed seedhead. (© Bridget Lassiter)

Management and Control: Cutting and mowing regularly provides some control. Herbicides are often used. Phragmites is difficult to control.

Impacts and Uses of European Common Reed in NC

Ecological: Reduces biodiversity by forming mono-culture.

Economic: Reduces aesthetic value of waterfront properties.

Human Health or Human use: Native strain was used by American Indians to make arrows. No known human health concerns.

Sources:

Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.

USDA Plants Database Citation: http plants.usda.gov/core/profile?symbol=PHAUA7. Acc. 9-18-15.

European Common Reed, Alligator River, 2009 (© Rob Emens)

Hydrilla
(Hydrilla verticillata)

Taxa Group: Plant

Size: Depending on depth and water quality (a few inches to 8 feet+). Up to 20 feet in some reservoirs.

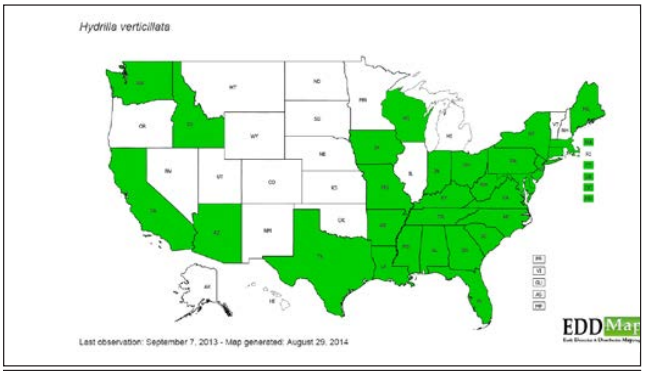
Distinctive Physical Characteristics: A submersed, rooted perennial with a very fast growth rate. Plants persist through the winter as subterranean tubers which sprout in the spring. Shoots grow laterally and vertically, often reaching the surface by late summer. Hydrilla is one of the most invasive plants found in NC. Leaves are oblong, sessile and whorled in groups of 4-8 around the stem. Leaf margins are serrated. Flowers are small, delicate and inconspicuous, often forming in late summer or autumn.

Habitat: Freshwater areas around the state, including rivers, lakes, and ponds.

Native Range: Asia

NC History: First discovered in 1980 in Wake County. From mid 1980s to late 1990s it spread to many Piedmont reservoirs where management was primarily done with triploid grass carp. Only recently has it become widespread in many of the water systems of the state.

Current NC Distribution: Statewide, from Mountains to Coastal Plain.



Introduced Distribution of Hydrilla. (EDDMapS, 2015)

Hydrilla. (©Bridget Lassiter)

Tar River Reservoir, NC. 2006. (©Rob Emens)

Pathway of Introduction: Boaters and other recreationists and waterfowl/wildlife.

Management and Control: Herbicides and biological control with triploid grass carp.

Impacts and Uses of Hydrilla in NC

Ecological: Alters habitat by forming dense colonies which displaces and/or suppresses native submersed aquatic plants. Decrease in water flow contributes to sediment buildup. Extensive growth provides substrate for the causative agent of Avian vacuolar myelinopathy (AVM) that kills waterfowl and bald eagles.

Economic: Impedes navigation in waterways, impacts recreation activities and fouls water intakes and hydroelectric dams.

Human Health or Human use: Limited distribution as a nutritional supplement. Creates stagnant water which increases mosquito breeding habitat.

Sources:
Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
Lassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas, NC Cooperative Extension.
EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=3028. Acc. 9-19-15.

Marsh Dayflower (*Murdannia kiesak*)

Taxa Group: Plant

Size: Grows in mats with stems that are 12-30 inches long. Leaves are ~3 inches long.

Distinctive Physical Characteristics: A perennial plant with prostrate stems and bluish-purple or pink flowers. Leaves are alternate and lance shaped.

Habitat: Grows in dense mats along edges of freshwater structures and marshes. Often grows immersed.

Native Range: Temperate and tropical Asia.

NC History: Unknown.

Current NC Distribution: Statewide.

Pathway of Introduction: Rice seed.

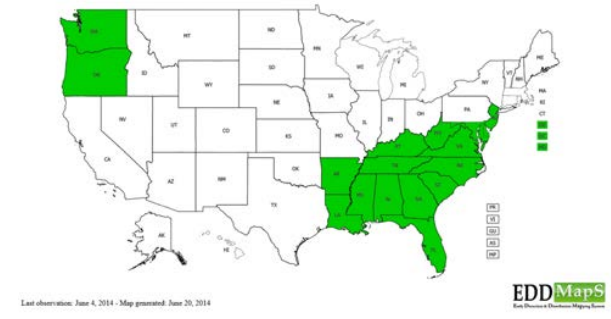
Management and Control: Herbicide.

Impacts and Uses of Marsh Dayflower in NC

Ecological: Alters native habitat by outcompeting native emerged vegetation.

Economic: Can inhibit shoreline access for recreation, and impede water intakes. Impedes navigation in waterways; impacts recreational activities and fouls water intakes .

Human Health or Human use: None known.



Introduced Distribution of Marsh Dayflower. (EDDMapS, 2015)

Marsh Dayflower. (©invasive.org)

Sources:
Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
Laassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas. NC Cooperative Extension.
EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=3053. Acc. 9-19-15.

Marsh Dayflower growing near surface of water, (© oak.ppws.vt.edu)

Parrotfeather
(Myriophyllum aquaticum)

Taxa Group: Plant

Size: Stems are 4– 6 inches long. Leaves are 0.5 to 2 inches long.

Distinctive Physical Characteristics: As a member of the milfoil family this plant roots into the bottom has a floral spike which emerges from the water. Leaves are whorled and grey-green in color. This plant derives its common name from the featherlike leaves. The stems are elongated and strong. The floral spikes will die back to the surface of the water during winter, but submersed parts continue winter growth in moderate climates. Reproduction is through fragmentation.

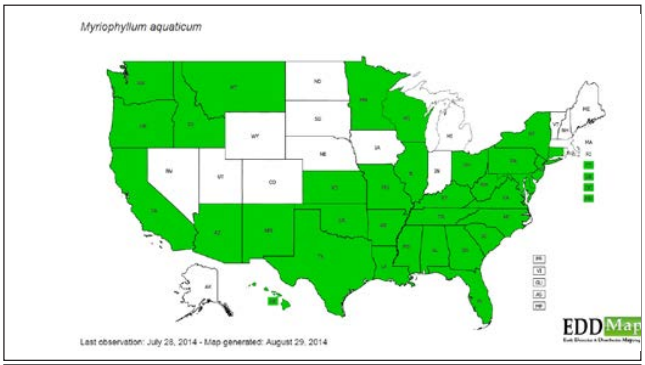
Habitat: Generalist, preferring full sun; can tolerate a wide variety of conditions (lakes, ponds, wetlands, streams, and river margins).

Native Range: South America.

NC History: Few and isolated historical incidents where this plant required large-scale management. Lookout Shoals reservoir became heavily infested circa 2000. High stocking rates of triploid grass carp effectively controlled the growth of this noxious weed at that site.

Current NC Distribution: Statewide.

Pathway of Introduction: Water garden trade and recreationists serving as a hitchhiker vector.



Introduced Distribution of Parrotfeather. (EDDMapS, 2015)

Parrotfeather. (© Rob Emens)

Management and Control: Physical removal possible for relatively small and confined sites (<0.25 acre). Herbicide applications to larger sites. Triploid grass carp at high stocking rates.

Impacts and Uses of Parrotfeather in NC

Ecological: Alters habitat by forming dense canopies which displaces and/or suppresses native submersed aquatic plants.

Economic: Impedes recreation activities (swimming, boating and fishing).

Human Health or Human use: Creates stagnant water which increases mosquito breeding habitat.

Sources:

Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.

Laassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas. NC Cooperative Extension.

EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=3054. Acc. 9-19-15.

Parrotfeather infesting a Raleigh Parks and Recreation pond. 2002 (© NC Aquatic Weed Program)

Purple Loosestrife
(Lythrum salicaria)

Taxa Group: Plant

Size: Grows in dense stands with stalks up to 6 feet tall leaves are 1.5-4 inches long.

Distinctive Physical Characteristics: Emergent perennial with pink, purple, magenta, or white flower spikes and square purple stems that arise from a common root mass. Leaves are opposite or whorled and lance-shaped.

Habitat: Grows in a variety of habitats ranging from moist soil to shallow water. It prefers freshwater wetlands but can also thrive in brackish waters.

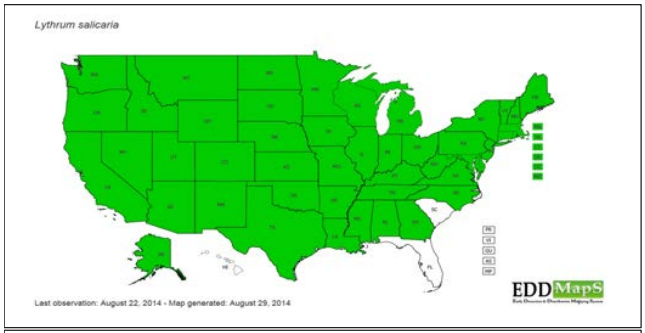
Native Range: Europe, Asia.

NC History: First found in NC in late 1980's

Current NC Distribution: Infrequent, but scattered across 15 counties in NC from Dare County on the east to Henderson County on the west.

Pathway of Introduction: Intentionally introduced in early 1800s for ornamental and medicinal purposes. Spreads through nursery trade and dispersal of seeds through water and mud.

Management and Control: Herbicides, mechanical removal/disruption and biocontrol.



Introduced Distribution of Purple Loosestrife. (EDDMapS, 2015)

Purple Loosestrife © John D. Byrd, Mississippi State University, Bugwood.org

Impacts and Uses of Purple Loosestife in NC

Ecological: Supresses native plant species, decreases biodiversity, alters water chemistry and hydrological functioning.

Economic: Invades irrigation systems, wetlands, and agricultural crop stand such as wild rice; impedes recreation activities.

Human Health or Human use: Used as ornamental plant and by beekeepers.

Sources:

Gettys, Lyn A., William T. Haller, and David G. Petty. *Biology And Control Of Aquatic Plants: A Best Management Practices Handbook*. 3rd ed. Marietta, Georgia: Aquatic Ecosystem Restoration Foundation, 2014. Web. 6 Feb. 2015.
EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=3047. Acc. 9-19-15.

Purple Loosestrife Infestation. © Linda Haugen, USDA Forest Service, Bugwood.org

Watercress
(Nasturtium officinale)

Taxa Group: Plant

Size: Grows in masses several feet in length. Flowers are ~0.2 inches. Fruit range from 0.4-0.6 inches. Leaves are 2-6 inches long.

Distinctive Physical Characteristics: A nonnative, invasive aquatic species with oval shape leaflets. Stems will float on the water surface and root freely from the nodes. Older leaflets are compound, with wavy-edged oval leaflets growing from a central stalk.

Habitat: Lakes, ponds, rivers, streams, moist soil. Gnetly flowing, shallow freshwater.

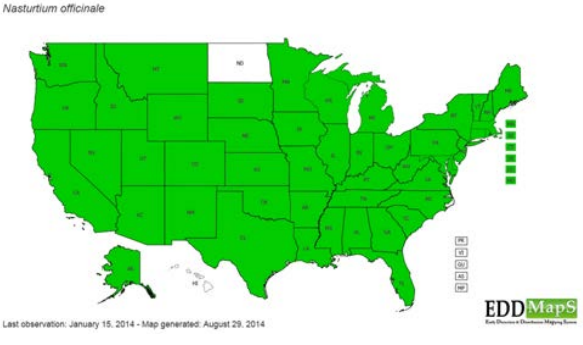
Native Range: Europe.

NC History: First known introduction in the late 1960s.

Current NC Distribution: Statewide.

Pathway of Introduction: Propagates via seed and adventitious rooting from stem nodes.

Management and Control: Herbicide.



Introduced Distribution of watercress. (EDDMapS, 2015)

Watercress growing on pond surface, (©sewisc.org)

Impacts of Uses of Watercress in NC

Ecological: Can outcompete native aquatic species.

Economic: Impedes waterways, impacts recreation activities and fouls water intakes.

Human Health or Human use: No human risks known; can be eaten for food or medicine.

Sources:
Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=14217. Acc. 9-19-15.

Watercress flowering, ©plants.usda.gov

Water Hyacinth
(Eichhornia crassipes)

Taxa Group: Plant

Size: Stems are up to 3 feet long. Leaves can be 4-7 inches across.

Distinctive Physical Characteristics: A floating perennial with attractive purple flowers. Leaves are waxy, rounded and elevated by long, inflated, spongy petioles. The flowers are showy (purple with yellow spots) and borne upon a spike with 5 to 20 individual flowers. Roots are fibrous and black to purplish in color. Roots form a dense feather mat beneath the plant.

Habitat: Spreads rapidly in slow-moving waters. May overwinter in USDA hardiness zone 7b or warmer climates.

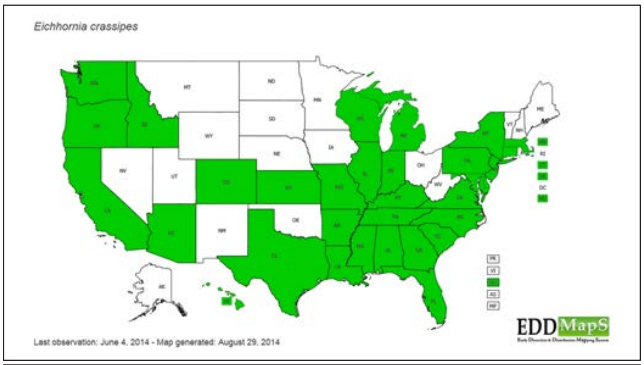
Native Range: Brazil.

NC History: Isolated and relatively small-scale incidents have occurred where control efforts were needed. NCDENR listed this species as a noxious aquatic weed in 2006, however it is not a regulated species.

Current NC Distribution: Populations outside of cultivation have been observed to persist only in the Coastal Plain.

Pathway of Introduction: Water garden trade.

Management and Control: Physical or mechanical removal. Herbicide applications.



Introduced Distribution of Water Hyacinth. (EDDMapS, 2015)

Water Hyacinth leaves and flowers. (©Bridget Lassiter)

Dense mat of Water Hyacinth. (©Bridget Lassiter)

Impacts of Water Hyacinth in NC

Ecological: Alters habitat by forming dense colonies which displace and/or suppress native submersed aquatic plants.

Economic: Rapid growth and reproductive ability. Forms dense growth. This plant poses a serious economic threat to waterways in the Southeastern U.S. In 1902, the U.S. Congress amended the Rivers and Harbors Act, allowing for the 'extermination' of water hyacinth by any means (U. of FL. IFAS).

Human Health or Human use: A popular specimen in the water garden trade. Considered as a means of removing nutrients from water. Creates stagnant water which increases mosquito breeding habitat.

Sources:

"A Brief History of Aquatic Herbicide Use." Plant Management in Florida Waters. University of Florida IFAS, 28 November 2011. WEB. 29 January 2015.

Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.

Lassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas. NC Cooperative Extension.

EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=3020. Acc. 9-19-15.

Water Primrose
(Ludwigia grandiflora)

Taxa Group: Plant

Size: Stems 10-15 inches long. Leaves 2-3 inches long.

Distinctive Physical Characteristics: A perennial that forms large dense mats and is invasive to many agricultural and aquatic communities.

Habitat: Grows rampantly in quiescent waters (canals, ditches, reservoirs, rivers, etc.) and wetlands.

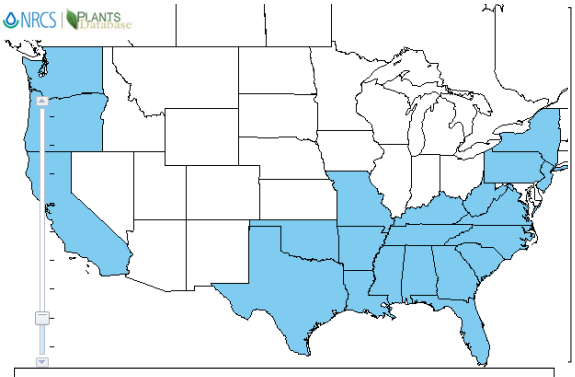
Native Range: Native to the coast of South America, from Venezuela to Buenos Aires. Reported in the Amazon River basin. Naturalized to the Southeastern U.S.

NC History: Listed as a Noxious Aquatic Weed. State agency began managing sites (<5 acres) in 1990s. Agency began managing larger sites (<30 acres) which appeared in 2000s.

Current NC Distribution: Coastal Plain and into the Piedmont.

Pathway of Introduction: Seed dispersal. Boaters and other recreationists and wildlife sometimes transport pleant fragments.

Management and Control: Physical removal possible for relatively small and confined sites (<0.25 acre). Herbicide applications to larger sites.



Introduced Distribution of Water Primrose. (USDA Plants Database, 2015)

Water Primrose. (©Rob Emens)

Impacts and Uses of Water Primrose in NC

Ecological: Alters habitat by forming dense colonies which displaces and/or suppresses native submersed aquatic plants. Deoxygenation of water can suppress fish populations.

Economic: Impedes recreation activities (swimming, boating and fishing).

Human Health or Human use: None known.

Sources:
Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
USDA Plants Database Citation: http plants.usda.gov/core/profile?symbol=LUGR9. Acc. 9-18-15.

Water Primrose in Foreground. Greensboro, NC. 2006. (©Rob Emens)

Water Lettuce
(Pistia stratiotes)

Taxa Group: Plant

Size: Rosettes are 6 to 8 inches long.

Distinctive Physical Characteristics: A floating stoloniferous plant usually found *en masse*. The rosettes are made up of pale green fan-shaped leaves. The leaves are sessile, and the leaf blades are simple, ribbed, and covered in many short hairs. The roots make up a fibrous mat beneath the rosette.

Habitat: Tends to form floating mats that clog waterways. Prefers shallow, protected waterways. Unlikely to overwinter in climates colder than USDA hardiness zone 8a.

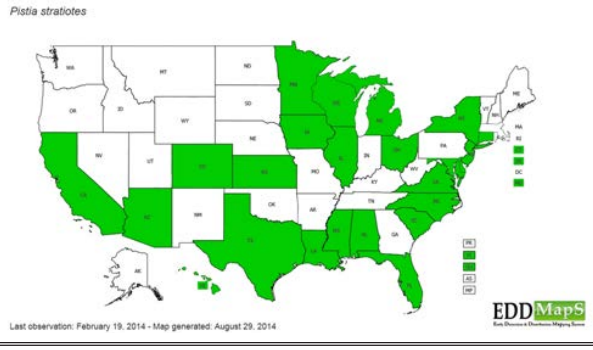
Native Range: Uncertain; Africa or South America.

NC History: No persistent infestations are known. No agency-level management projects have occurred.

Current NC Distribution: Coastal Plain.

Pathway of Introduction: Water garden and aquarium trade. Potential spread by hitchhiking on boats, trailers, or livewells.

Management and Control: Mechanical harvestors and chopping machines. Insect biocontrols and herbicides.



Introduced Distribution of Water Lettuce. (EDDMapS, 2015)

Water Lettuce. © Bridget Lassiter

Impacts and Uses of Water Lettuce in NC

Ecological: Mats can prevent atmospheric oxygen from entering water. Competition with native plants reduces biodiversity.

Economic: Impact recreation activities (wading, fishing, swimming, boating, etc.) and aesthetics.

Human Health or Human use: Creates stagnant water which increases mosquito breeding habitat.

Sources:
Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
Lassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas. NC Cooperative Extension.
EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=3064. Acc. 9-19-15.

Water Lettuce. © Bridget Lassiter

Yellow and Crested Floating Heart *(Nymphoides peltata & N. cristata)*

Taxa Group: Plant

Size: Leaves 4-6 inches long.

Distinctive Physical Characteristics: Perennial aquatic plants with rhizomes and leaves attached to a long, petiole-like stem. Leaves are heart shaped and attached by a short petiole to a long stem. Undersides are smooth (no raised veins). The fruit is an oblong capsule that contains rounded and smooth seeds. The flowers are white or yellow with wide margins. Petals are ruffled on the edges, and there is a crest on the flower. Blooms from summer to fall.

Habitat: A blackwater species found in canals, lakes and ponds.

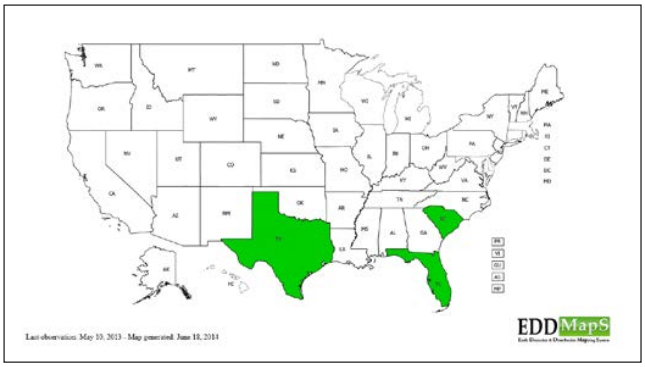
Native Range: Asia.

NC History: First discovered in June 2014 in the NC Piedmont.

Current NC Distribution: Mountains, Piedmont and Coastal Plain.

Pathway of Introduction: Nursery and water garden industry; Propagates via fragmentation and seed.

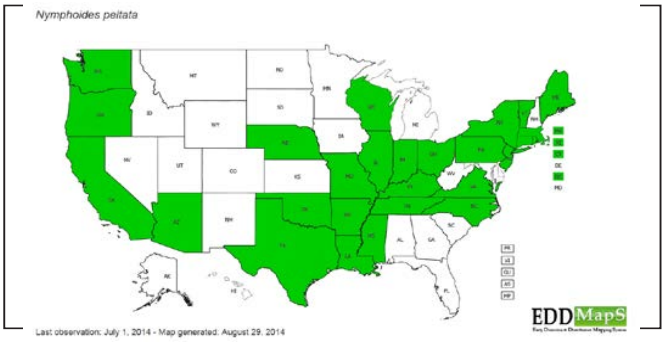
Management and Control: Herbicide



Yellow Floating Heart. © Bridget Lassiter

Crested Floating Heart. © www.aquarius-systems.com

Sources:
Aulback-Smith, C. A. and S. J. de Kozlowski. Aquatic and Wetland Plants of South Carolina. 1996. SC DNR and SCAPMS.
Lassiter, B., R. Richardson, and G. Wilkerson. 2008. Aquatic Weeds: A Pocket Identification Guide for the Carolinas. NC Cooperative Extension.
EDDMapS. 2015. Early Detection & Distribution Mapping System. The University of Georgia Center for Invasive Species and Ecosystem Health. http:www.eddmaps.org/distribution/usstate.cfm?sub=11616 and 12805. Acc. 9-19-15.



Introduced Distribution of Crested (Left) and Yellow (Above) Floating Heart. (EDDMapS, 2015)

Alewife (*Alosa pseudoharengus*) Blueback Herring (*Alosa aestivalis*)

When Introduced into Reservoirs

Taxa Group: Fish

Size: In reservoirs, up to 10 inches.

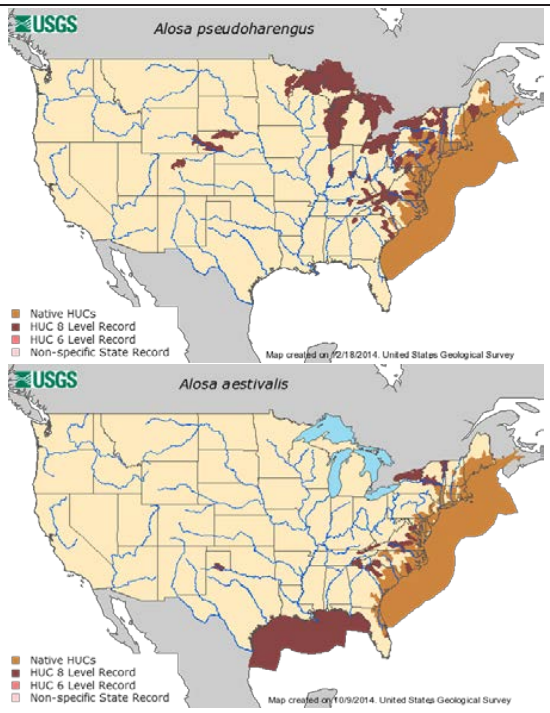
Distinctive Physical Characteristics: Both species are small herring with a dark dorsal side, bluish to greenish, and light sides with horizontal darker stripes. They are distinguished from other inland shad by the lack of an elongated posterior dorsal ray.

Habitat: Collectively referred to as "river herring," both species have anadromous spawning runs in coastal rivers and streams. Reservoir populations also use tributary streams for spawning. Both species prefer cooler water in summer in reservoirs.

Native Range: Atlantic coastal rivers and streams.

NC History: Native anadromous runs in coastal rivers; landlocked populations introduced in various reservoirs 1970-present.

Current NC Distribution: Widespread in impoundments of Atlantic Slope rivers throughout North Carolina. Blueback Herring have also been introduced in all major impoundments of the Hiwassee River and in Glenville Reservoir on the West Fork Tuckasegee River.



Native and Introduced Ranges of Alewife and Blueback Herring (U.S. Geological Survey)

Top – Alewife (Illustration by Duane Raver)
Bottom – Blueback Herring (Illustration by Duane Raver)

Pathway of Introduction: Bait bucket/live well transfer; some populations established by stocking.

Management and Control: None, once established; public education and signage have been used to discourage further introductions in reservoirs.

Impacts and Uses of Alewife and Blueback Herring

Ecological: Establishment of reservoir populations of river herring has been linked to recruitment failure of river-spawning sport fish, particularly Walleye.

Economic: River herring are an important fishery in their native range. In reservoirs they provide forage for larger fish and bait for anglers. However, they have a costly impact on Walleye fisheries that must be supported by hatchery culture and stocking once river herring become established.

Human Health or Human use: Native coastal river runs are harvested as food fish; in reservoirs, river herring are highly prized as bait fish for Striped Bass and other sport fish.

Sources:

Fuller, P., E. Maynard, D. Raikow, J. Larson, A. Fusaro, and M. Neilson. 2015. *Alosa pseudoharengus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=490 Revision Date: 10/17/2012.

Fuller, P., G. Jacobs, J. Larson, A. Fusaro, and M. Neilson. 2015. *Alosa aestivalis*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=488 Revision Date: 6/14/2013.

Asian clam
(Corbicula fluminea)

Taxa Group: Mollusk - Bivalve

Size: Juveniles are only 1 mm long when released from adult. At maturity (~4 yrs), they are about 1 cm long. Adults can reach a length of ~ 5 cm.

Distinctive Physical Characteristics: Small, light-colored with shell ornamented by distinct, concentric ridges, anterior and posterior lateral teeth with many fine serrations. Dark shell morphs exist but are limited to the southwestern United States. The light-colored shell morph has a yellow-green to light brown periostracum and white to light blue or light purple nacre while the darker shell morph has a dark olive green to black periostracum and deep royal blue nacre.

Habitat: Aquatic. Rivers and streams.

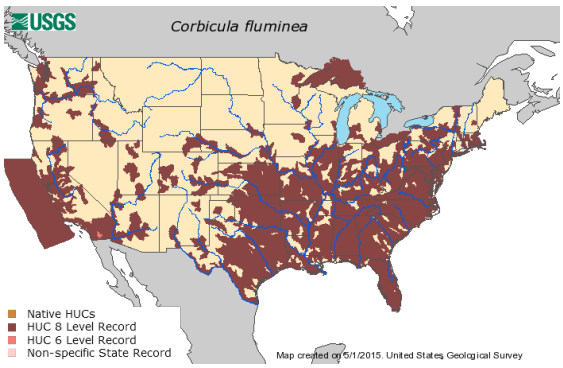
Native Range: Temperate to tropical southern Asia west to the eastern Mediterranean; Africa, except in the Sahara desert; southeast Asian islands south into central and eastern Australia.

NC History: The first collection of Asian clams in the United States occurred in 1938 along the banks of the Columbia River near Knappton, Washington, and was first documented in North Carolina in 1970.

Current NC Distribution: Ubiquitous in most streams and rivers throughout NC.

Pathway of Introduction: Thought to have entered the United States as a food item used by Chinese immigrants or with the importation of the Giant Pacific oyster from Asia. Current methods of introduction include bait bucket introductions, accidental introductions associated with imported aquaculture species, and intentional introductions by people who buy them as a food item in markets.

Management and Control: Eradication of Asian clams from infested open waters is unlikely – emphasis is generally on preventing further spread.



Corbicula midden (© michelgeven.zenfolio.com)

Corbicula fluminea (© 2014 Wikipedia)

Impacts and Uses of Asian clams

Ecological: The most prevalent environmental effect of the introduction of the Asian clam into the United States has been alteration of benthic substrates and competition with native species for limited resources. Asian clams are consumed mainly by fish and crayfish.

Economic: In the United States, Asian Clams have caused millions of dollars worth of damage to intake pipes used in the power and water industries. Large numbers, either dead or alive, clog water intake pipes and the cost of removing them is estimated at over a billion U.S. dollars each year. Juveniles get carried by water currents into condensers of electrical generating facilities where they attach themselves to the walls via byssus threads, growing and ultimately obstructing the flow of water. Several nuclear reactors have had to be closed down temporarily in the U.S. for the removal of *Corbicula* from the cooling systems.

Human Health or Human Use: Food item.

Sources:

U.S. Geological Survey. 2014. Nonindigenous Aquatic Species Database. Gainesville, Florida, http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=92. Accessed 12/23/2014.

Blue Catfish (*Ictalurus furcatus*)

Taxa Group: Fish

Size: Commonly reaches 36 inches and 20 pounds and the world record Blue Catfish, caught in 2011 from Kerr Reservoir on the NC/VA border, was 57 inches and 143 pounds.

Distinctive Physical Characteristics: Blue Catfish have a deeply forked tail and typically has a bluish-gray body above, fading to white on its sides and belly. Small Blue Catfish are sometimes mistaken for Channel Catfish, but Blue Catfish do not have spots. The anal fin of a Blue Catfish has a straight outer edge and 30–36 rays, whereas the anal fin of a Channel Catfish is rounded with 24–29 rays.

Habitat: Deep channels and pools in large rivers. Often prefers areas with swift current. Also thrives in reservoirs and can occur in estuaries up to 11.4 ppt salinity.

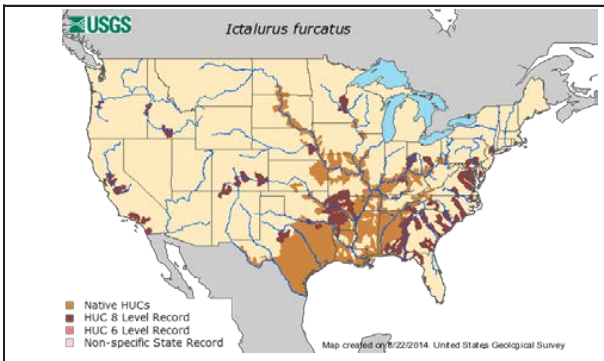
Native Range: Mississippi River basin and Gulf slope.

NC History: Blue Catfish were introduced in North Carolina reservoirs in the mid-1960s through NCWRC stocking efforts.

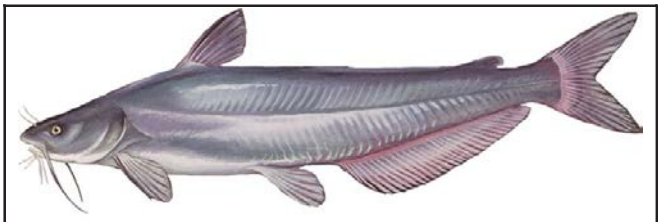
Current NC Distribution: Present in nearly all major river basins in the Piedmont and Coastal Plain.

Pathway of Introduction: Intentional stocking by resource agencies and suspected angler relocations.

Management and Control: Blue Catfish are considered nongame fish by NCWRC and NCDMF. There are currently no limits on recreational and commercial harvest, except for the one-fish daily creel limit for Blue Catfish greater than 32 inches on Badin Lake and Lake Norman and the six-fish daily creel limit on forked tail catfishes in ponds managed under NCWRC game lands and Community Fishing Program regulations.



Native and Introduced Range of Blue Catfish (U.S. Geological Survey)



Blue Catfish (Illustration by Duane Raver)

Impacts and Uses of Blue Catfish

Ecological: Problems could arise due to competition with game fish species, such as striped bass, for shad and other prey species. Blue Catfish may potentially displace native catfishes.

Economic: Popular recreational and commercial fisheries have developed for Blue Catfish. In a 2011 survey of recreational anglers, Blue Catfish were the second most popular ictalurid species targeted by catfish anglers.

Human Health or Human Use: Biomagnification of methylmercury presents concerns with human consuption and consumption advisories are often necessary with this species.

Sources:

Fuller, P. and M. Neilson. 2015. *Ictalurus furcatus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=740 Revision Date: 1/15/2014.

Jenkins, R.E., and N.M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Duda, M.D. 2012. North Carolina catfish anglers' participation in catfishing and their opinions on management of catfish. Responsive Management Final Report. Harrisonburg, VA.

NCWRC biologists with a large Blue Catfish collected from the Roanoke River in 2014. (Bennett Wynne)

Blue Tilapia (*Oreochromis aureus*)
Redbelly Tilapia (*Tilapia zillii*)

Taxa Group: Fish

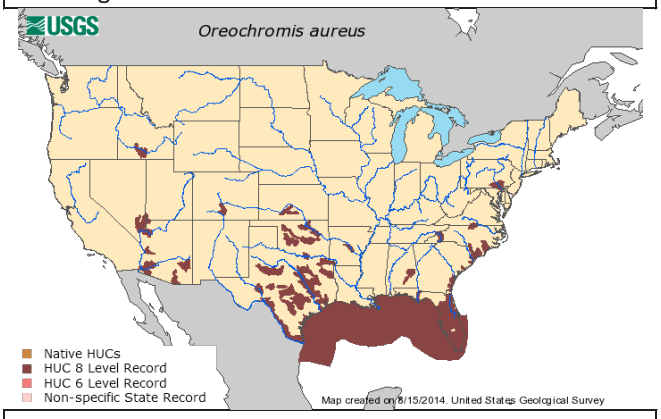
Size: Blue tilapia have maximum length of 20 inches and average weight of 2–4 pounds. Redbelly tilapia have a maximum size of 11 inches.

Distinctive Physical Characteristics: Color of adult blue tilapia is blue-gray with white belly, borders of dorsal and caudal fins with red to pink borders. Redbelly tilapia are dark to light olive with 6 to 7 poorly defined vertical bars. During spawning condition fish have a red throat and belly.

Habitat: Reservoirs and warmwater streams. Both species can be tolerant of saltwater. Both species feed on plankton, detritus and aquatic macrophytes.

Native Range: Tropical and subtropical Africa, and Middle East.

Current NC Distribution: Established populations of Blue Tilapia occur in Hyco Reservoir (Person Co.) and Lake Julian (Buncombe Co.). Redbelly Tilapia are also established in Hyco Reservoir.These species are essentially limited to waters receiving heated discharges.



Introduced Range of Blue and Redbelly Tilapia (U.S. Geological Survey)

Top – Blue tilapia (Univ. of Florida Aquaculture Dept.)
Bottom – Redbelly tilapia (U.S. Army Corps of Engineers)

Pathway of Introduction: Blue tilapia were introduced into Lake Julian in the mid-1960s to control vegetation. Both species were introduced into Hyco Reservoir in 1984.

Management and Control: No effective management or control strategies are known.

Impacts and Uses of Blue and Redbelly Tilapia

Ecological: Tilapia are considered a competitor with native species for spawning areas, food, and space. Fish community structure has been known to change due to tilapia introductions. Aquatic macrophyte abundance declines when tilapia are introduced.

Economic: Economic impacts in NC due to Tilapia introductions are not known. Tilapia are produced by private aquaculture facilities in NC mainly for food production, but also stocking for vegetation control.

Sources:

Nico, L., M. Neilson, and P. Fuller. 2015. *Oreochromis aureus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=463 Revision Date: 6/9/2013.

Nico, L., M. Neilson, and B. Loftus. 2015. *Tilapia zillii*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=485 Revision Date: 2/27/2013.

Chinese Mysterysnail *(Cipangopaludina chinensis malleata)* Japanese Mysterysnail *(Cipangopaludina japonica)*

Taxa Group: Snails

Size: About 2 inches.

Distinctive Physical Characteristics: Chinese – Light coloration as a juvenile and olive green, greenish brown, brown or reddish brown as an adult. Japanese – Light colored as a juvenile and dark brown as an adult. Japanese is more elongate than Chinese.

Habitat: Lakes and reservoirs with silt, sand, and mud substrate, although it can survive in slower regions of streams as well.

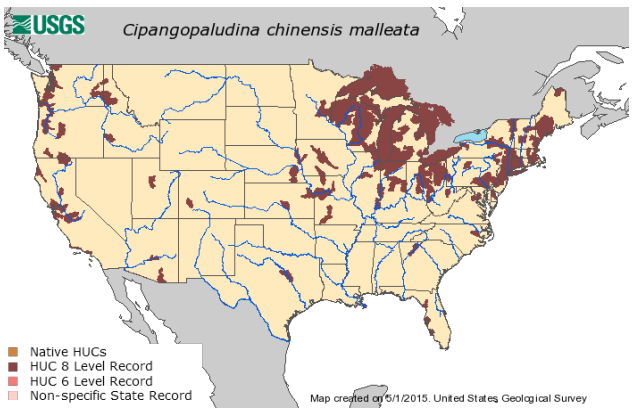
Native Range: Chinese – Southeast Asia to Russia. Japanese – Japan, Korea, Taiwan.

NC History: Introduced to U.S. in late 1800s. Collected in northeastern states in 1910s through 1940s.

Current NC Distribution: Lakes Gaston, Hickory, Jordan, Norman, and Wylie. Neuse, Yadkin, and Pee Dee rivers.

Pathway of Introduction: Likely introduced as a source for Asian food markets.

Management and Control: Specific control methods for mystery snails have yet to be developed. Copper compounds are sold as mollascides but they are usually not selective in the snails they kill. With mystery snails possessing the ability to "close up," more damage would probably occur to native snails in the treatment area than to the target pest.



Left – Chinese Mysterysnail (Amy Benson, USGS)
Right – Japanese Mysterysnail (Amy Benson, USGS)

Impacts and Uses of Mystery Snails

Ecological: To date, these species have exerted no recorded impacts in the Great Lakes and are considered relatively "benign" with respect to their potential to greatly change or influence ecosystems and native species. Negative interactions with native gastropods are also possible.

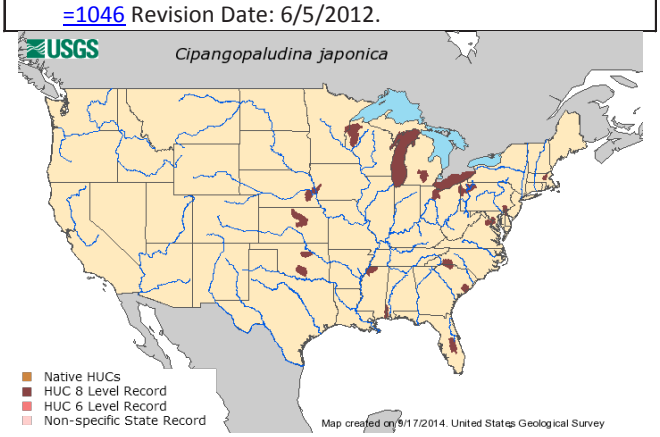
Economic: Known to clog screens of water intake pipes and heat exchangers in power plants. Large numbers known to affect commercial fishing in Lake Erie by clogging seine hauls.

Human Health or Human Use: Have the potential to be vectors for the transmission of parasites and diseases. Used as food source by Asian peoples.

Sources:

Kipp, R.M., A.J. Benson, J. Larson, and A. Fusaro. 2014. *Cipangopaludina chinensis malleata*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1045 Revision Date: 6/26/2014.

Kipp, R.M., A.J. Benson, J. Larson, and A. Fusaro. 2014. *Cipangopaludina japonica*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1046 Revision Date: 6/5/2012.



Flathead Catfish (*Pylodictis olivaris*)

Taxa Group: Fish

Size: Up to 61 inches, 123 pounds.

Distinctive Physical Characteristics: Wide, flat head; projecting lower jaw. Slender, compressed body. Nonforked caudal fin. 14-17 anal fin rays.

Habitat: Pools with logs and other debris in low- to moderate-gradient, small to large rivers; lakes and reservoirs. Can tolerate elevated salinity levels.

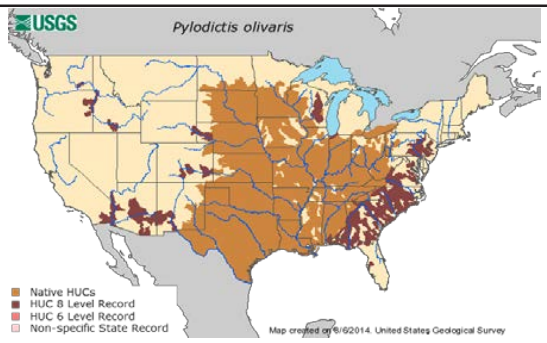
Native Range: Native to lower Great Lakes and Mississippi River basins from western Pennsylvania to White-Little Missouri River system in North Dakota, and south to Louisiana in the USA; Gulf Slope from Mobile Bay drainage in Georgia and Alabama, USA to Mexico. Introduced elsewhere.

NC History: NC Museum specimens archived from Tennessee River basin (Nolichucky River) in 1968.

Current NC Distribution: Little Tennessee (native range) and outside its native range in the Cape Fear, Tar, Neuse, Catawba, and Yadkin river basins and associated reservoirs; Roanoke River basin above Roanoke Rapids Dam; Sutton Lake, Lake Waccamaw

Pathway of Introduction: Intentional stocking of 11 Flathead Catfish in the Cape Fear River basin in 1966; unauthorized stockings by private individuals.

Management and Control: Flathead Catfish are considered nongame fish by NCWRC and NCDMF. There are currently no limits on recreational and commercial harvest.



Native and Introduced Range of Flathead Catfish (U.S. Geological Survey)

Flathead Catfish (Illustration by Duane Raver)

Impacts and Uses of Flathead Catfish

Ecological: Flathead Catfish are primarily obligate piscivores and an apex predator in any aquatic ecosystem. Flathead Catfish are known to influence sunfish and bullhead populations as well as prey upon resident and diadromous fishes within occupied range.

Economic: Recreational and tournament anglers across North Carolina spend copious amounts of money fishing for Flathead Catfish due to their strong fight and palatability. In a 2003-2004 creel survey on the Cape Fear River, catfish anglers spent an estimated $118,428; 30% of total estimated expenditures for that creel survey where catfish were the most targeted species by Cape Fear River anglers.

Human Health or Human Use: Biomagnification of methylmercury presents concerns with human consumption and consumption advisories are often necessary with this species.

Sources:

Ashley, K. W., and R. T. Rachels. 2005. Cape Fear River Basin Recreational Creel Survey, 2003-2004. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Guier, C. R., L. E. Nichols, and R. T. Rachels. 1984. Biological investigations of flathead catfish in the Cape Fear River. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 35(1981):607-621.

Page, L.M., and B.M. Burr. 2011. A field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Harcourt Company, New York. 637 p.

U.S. Geological Survey. 2015. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [1/6/2015]. nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=750

Nutria
(Myocastor coypus)

Taxa Group: Mammal

Size: Adults are typically 10–20 pounds in weight, and 16–24 inches in body length. Tail is 12–18 inches.

Distinctive Physical Characteristics: Large rodent, resembling beavers and muskrats. The Nutria has a long, thin round tail which distinguishes it from the beaver which has a flat tail and the muskrat which has a laterally flattened tail. They have coarse, darkish brown outer fur with soft dense grey under fur, also called the nutria. Orange-yellow incisors are also distinctive.

Habitat: Semi-aquatic. Rivers, streams and wetlands.

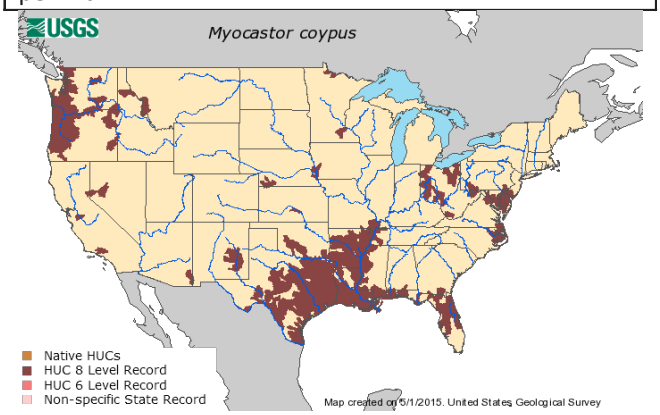
Native Range: South America

NC History: Nutria were originally introduced into the U.S. in Louisiana for fur farming in the 1938. They were stocked in other states and had become established in North Carolina by the 1970s.

Current NC Distribution: Known populations in Bertie, Dare, Hyde, and Washington counties. Likely also occurs in many other coastal counties.

Pathway of Introduction: Human introduction and natural expansion.

Management and Control: In addition to education and awareness programs to reduce their spread, Nutria are controlled by hunting and trapping. Nutria may be hunted year-round with a hunting license. Nutria may be trapped year-round East of I-77 with a trapping license. In both cases there is no closed season and no bag limit. Nutria may also be taken with a depredation permit.



Nutria (© 2014 Encyclopædia Britannica, Inc)

Impacts and Uses of Nutria

Ecological: Nutria are opportunistic feeders and eat approximately 25% of their body weight daily. Most damage is from feeding or burrowing. At high densities and under certain conditions, foraging Nutria can significantly impact natural plant communities. They compete with native muskrats.

Economic: Nutria sometimes burrow into the styrofoam flotation under boat docks and wharves, causing these structures to lean and sink. They may burrow under buildings, which may lead to uneven settling or failure of the foundations. Burrows can weaken roadbeds, stream banks, dams, and dikes, which may collapse.

Human Health and Human Use: Mainly fur pelts, although the use of nutria meat is being promoted.

Sources:

http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=1089

www.ces.ncsu.edu/nreos/wild/pdf/wildlife/nutria.pdf

http://www.basic.ncsu.edu/ncgap/sppreport/amafk01010.html

Nutria showing white muzzle and orange incisors. (©Moment in der Natur; www.vorbusch.de)

Red swamp crawfish *(Procambarus clarkii)*

Taxa Group: Crayfish

Size: Up to 5 inches long.

Distinctive Physical Characteristics: Juveniles are usually striped or plain; adults are dark red (nearly black) and conspicuously granular (rough), have narrow, long pincers, and a black wedge-stripe on underside.

Habitat: Prefers flowing to nonflowing water streams and ditches with mud or sand bottoms and plenty of organic debris. Vegetation not a necessity.

Native Range: Gulf coastal plain from the Florida panhandle to Mexico; southern Mississippi River drainage to Illinois.

Current NC Distribution: Widely introduced species occurs in Piedmont and coastal plain systems in the Broad, lower Cape Fear, Catawba, French Broad, Lumber, Neuse, Pasquotank, Tar-Pamlico, and Yadkin-Pee Dee basins.

Pathway of Introduction: Probable aquaculture introduction.

Management and Control: Trapping can reduce crayfish numbers but is not likely to eradicate them

No chemicals are registered for crayfish control.

Red Sawmp Crawfish (Photo taken by Mike Murphy, Wikipedia 2006)

Red Swamp Crawfish (©fr.wikipedia.org/wiki/Utilisateur:Duloup)

Impacts and Uses of Red Swamp Crawfish

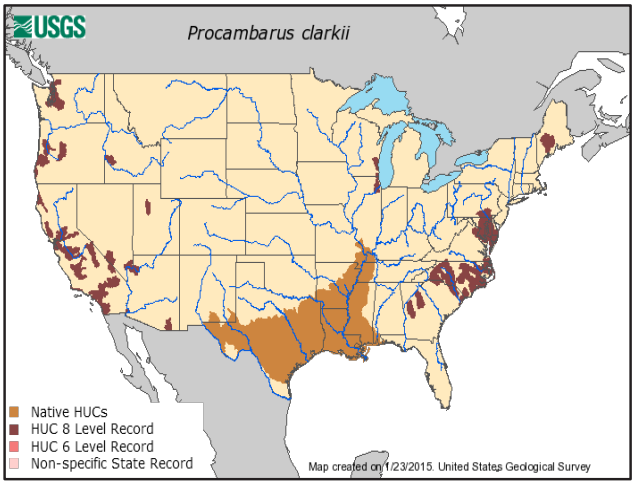
Ecological: The burrowing activities of the red swamp crawfish can lead to damage to water courses and to crops, particularly rice, and its feeding can disrupt native ecosystems. It may displace native crayfish species, and is a vector for the crayfish plague fungus *Aphanomyces astaci*, for crayfish virus vibriosis, and a number of worms that are parasitic on vertebrates.

Human Health or Human use: An important aquaculture species.

Sources:

Missouri Dept of Conservation. 2015. Field Guide. http://mdc.mo.gov/node/6366. Accessed 1/7/2015.

U.S. Geological Survey. 2014. Nonindigenous Aquatic Species Database. Gainesville, Florida, http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=217. Accessed 12/23/2014.



Rusty Crayfish *(Orconectes rusticus)*
Virile Crayfish *(Orconectes virilis)*

Taxa Group: Crayfish

Size: Rusty – up to 4 inches; Virile – up to 5 inches.

Distinctive Physical Characteristics: Rusty – Reddish patch on side and black tips on claws. Virile - Reddish-brown or green color without prominent markings. Pincers are green with orange tips and in adults are conspicuously studded with whitish knobs.

Habitat: Streams, lakes, and ponds with varying substrates from silt to rock and plenty of debris for cover.

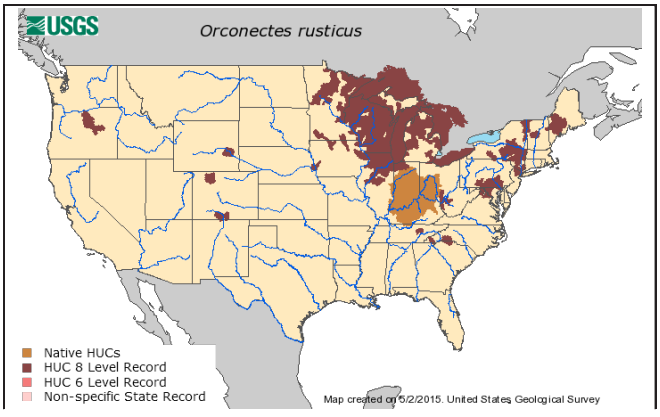
Native Range: Rusty – Ohio, Indiana, Kentucky. Virile – Canada, northern U.S.

NC History: Rusty – First collected in 1999. Virile – First collected in 1993. Original source of both species is unknown.

Current NC Distribution: Rusty – Broad River (Rutherford Co.), Catawba and North Fork Catawba rivers (McDowell Co.). Virile – Linville River and White Cr. (Burke Co.), Beaverdam Cr. (Gaston Co.), Catawba River (McDowell Co.), Kerr Reservoir (Granville and Vance Co.), Gaston Reservoir (Northampton and Warren Co.), Grassy Cr. (Granville Co.), Castle Cr. and Mayo Cr. (Person Co.).

Pathway of Introduction: Most likely bait bucket. The introduction of one female carrying viable sperm could start a new population.

Management and Control: Trapping can reduce crayfish numbers but is not likely to eradicate them. No chemicals are registered for crayfish control.



Top – Rusty Crayfish (Brian Roth)
Bottom – Virile Crayfish (Chris Lukhaup)

Impacts and Uses of Rusty and Virile Crayfish

Ecological: Displace native crayfish; destruction of plant bed abundance and diversity.

Human health or Human use: May be used as bait in some areas.

Sources:

http://www.seagrant.umn.edu/ais/rustycrayfish_invader

Amy Benson. 2014. *Orconectes virilis*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=215 Revision Date: 8/23/2011.

Spotted Bass (*Micropterus punctulatus*)

Taxa Group: Fish

Size: Up to 24 inches.

Distinctive Physical Characteristics: Lower portion of its body usually has dark blotching (spots). Has a rectangular, sandpaper-like tooth patch on the tongue. Rear of the jaw does not extend behind the eye. Juveniles have a series of dark blotches along sides. Species is often confused with Largemouth Bass.

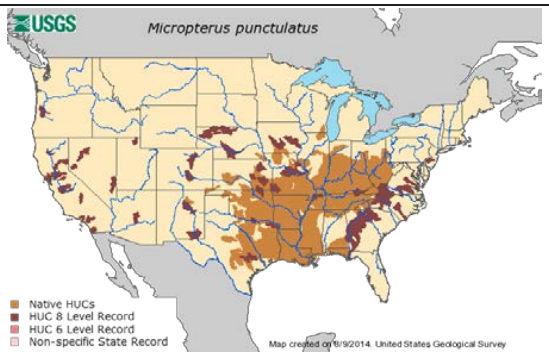
Habitat: Slow moving portions of streams and rivers. Common in reservoirs.

Native Range: Illinois, Missouri and Ohio, southward to eastern Texas and the Gulf, covering major drainages of the Mississippi River.

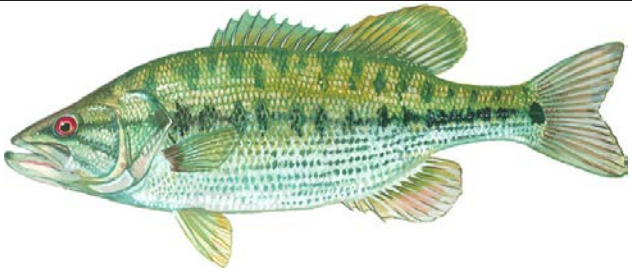
Current NC Distribution: Spotted Bass have been documented in the following river basins: Yadkin, Catawba, Little Tennessee, Hiwassee, French Broad, Broad, Cape Fear, Lumber, Tar, and Watauga.

Pathway of Introduction: Human introduction and natural expansion.

Management and Control: Game fish size and creel limits. Public education has been used to discourage further introductions.



Native and Introduced Range of Spotted Bass (U.S. Geological Survey)



Spotted Bass (Illustration by Duane Raver)

Impacts and Uses of Spotted Bass

Ecological: Competition and hybridization with other black basses. Of particular concern is genetic introgression with current Largemouth and Smallmouth Bass populations.

Human Health and Human Use: Recreational fishing and food.

Sources:

Etnier, D., and W. Starnes. The Fishes of Tennessee. 1993. The University of Tennessee Press, Knoxville.

Fuller, P., M. Cannister, and M. Neilson. 2015. *Micropterus punctulatus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=397 Revision Date: 11/05/2012.

North Carolina Wildlife Resources Commission. Spotted Bass. Sport Fish Profiles. http://www.ncwildlife.org/Portals/0/Fishing/documents/Spotted_Bass_profile.pdf Revision Date: 05/2010.

White Perch (*Morone americana*)
When Introduced into Reservoirs

Taxa Group: Fish

Size: Up to 20–24 inches.

Distinctive Physical Characteristics: A thin, deep-bodied fish with sides that are predominantly silver, but sometimes golden or olive colored. White perch do not have dark lines running the length of the body or a tooth patch. Both occur in other moronids such as white bass and striped bass.

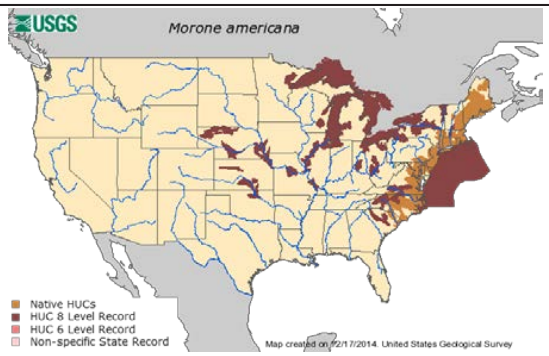
Habitat: Prefer low-salinity estuaries but frequently inhabit coastal rivers and lakes. They are also found in reservoirs where they have been introduced. Foods include eggs of other fish, aquatic macroinvertebrates, zooplankton, worms, and fish.

Native Range: Atlantic slope drainages from St. Lawrence River, Canada to the Pee Dee River, South Carolina.

NC History: White Perch are native to the coastal rivers of NC. Introductions of white perch to Piedmont and mountain reservoirs have occurred.

Pathway of Introduction: Fish have been introduced to reservoirs via angler introductions.

Management and Control: Biological, chemical, and physical control have been tried for White Perch with limited success. The only management recommendation is unlimited harvest of White Perch.



Native and Introduced Range of White Perch (U.S. Geological Survey)


White Perch (Illustration by Duane Raver)

Impacts and Uses of White Perch

Ecological: Fish eggs are an important component of the diet of White Perch especially during spring spawning activities. White Perch have been known to prey on eggs of walleye, white bass and other game species. The collapse of the walleye fishery in the Bay of Quinte coincided with the increase in the white perch population. (Schaeffer and Margraf 1987). The Lake James (NC) walleye population decline may be attributed to the introduction of White Perch.

Human Use: When they reach harvestable size , White Perch are a popular food source for anglers. They are also used for bait by some anglers.

Sources:

Fuller, P.F., E. Maynard, D. Raikow, J. Larson, A. Fusaro, and M. Neilson. 2015. *Morone americana*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=777 Revision Date: 6/23/2014.

N.C. Wildlife Resources Commission. 2015. http://www.ncwildlife.org/Portals/0/Fishing/documents/White_perch_profile.pdf. North Carolina Sport Fish Profiles: White Perch. Revision Date: May 2010.

Schaeffer, J.S., and F.J. Margraf. 1987. Predation on fish eggs by white perch, *Morone americana*, in western Lake Erie. Environmental Biology of Fishes 18(1):77–80.

Australian Spotted Jellyfish *(Phyllorhiza punctata)*

Taxa Group: Coelenterate

Size: 18–20 inches (45-50 cm in bell diameter)

Distinctive Physical Characteristics: Round and flattened bell which appears clear or light brown in color and contains refractive spots. Eight oral arms protrude from the mouth area with brown nematocysts (stinging cells) attached to the ends.

Habitat: Prefers the warm, temperate waters in estuaries and the open sea and is not extremely tolerant of low salinity conditions.

Native Range: Australia and South Pacific and Indian Ocean.

NC History: First known records in NC were from Bogue Sound in 2006.

Current NC Distribution: Unknown.

Pathway of Introduction: Possible hitchhiker, as polyps, on the hull of a ship.

Control: Early detection is key to preventing the spread and establishment of this species and regional/local monitoring or surveillance is essential.

Australian Spotted Jellyfish (*Phullorhiza punctata)*
Photo credit: Micha L. Rieser, Berlin Zoo

Australian Spotted Jellyfish (*Phyllorhiza punctata)*
Photo credit: Monterey Bay Aquarium, 2006. Wikimedia Commons.

Impacts and Uses of the Australian Spotted Jellyfish in NC

Ecological: Australian Spotted Jellyfish consume plankton and the eggs and larvae of important species (e.g. fish, crabs, and shrimp), ingesting the plankton that native species need.

Economic: Studies have found that jellyfish are opportunists, moving in and taking over regions of the sea that humans overfish. This could pose an issue in NC if fishing pressure and stock abundances are not maintained properly.

Human Health or Human use: Only mildly venomous and do not pose a threat to humans.

Sources:

J. Masterson. 2014. *Phyllorhiza punctate.* Smithsonian Marine Station. http://www.sms.si.edu/IRLSpec/Phyllorhiza_punctata.htm. Revision Date: 6/13/2007.

Eel Swimbladder Nematode
(Anguillicoloides crassus or *Anguillicola crassus)*

Taxa Group: Nematode

Size: Males measure 20-60mm while females measure 47-71.5 mm

Distinctive Physical Characteristics: The adult nematode is covered by a soft wrinkled outer cuticle. The mouth has a circular opening surrounded by 4 cephalic papillae and 2 lateral amphids. Males have 6 pairs of caudal papillae. Females possess white housing copious numbers of eggs.

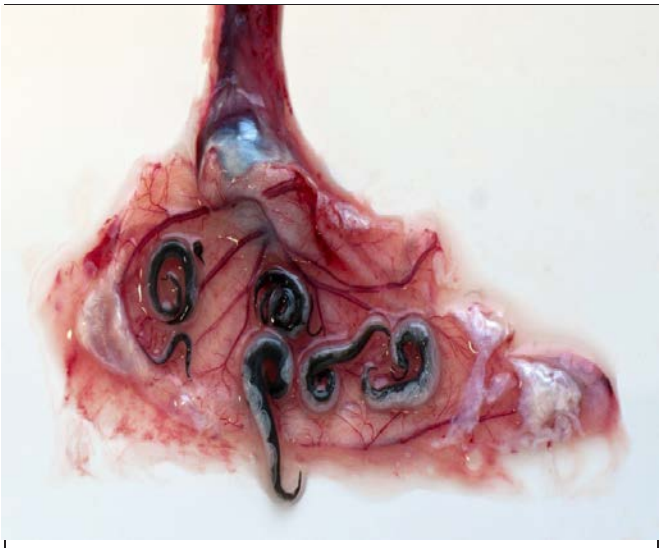
Habitat: The Nematode can remain viable in seawater at the adult and egg stage, but hatching is reduced from increased salinity. This Nematode has the highest rate of survival in freshwater environments and higher temperatures. Studies have shown significant decline in growth rate of larvae and increase mortality of adult worms in colder water.

Native Range: Southeast Asia.

Current NC Distribution: The majority of NC river basins have this nematode present.

Pathway of Introduction: Introduction into the United States is thought to have come in the form of a live eel shipment to a Texas aquaculture facility from Japan and has since spread up the eastern Atlantic Coast into Canada affecting the American Eel (*Anguilla rostrata*). Direct introduction into North Carolina is not known, but suspected to be through eel importation or infected eels making their way from an infected South Carolina river.

Management and Control: The main vector of dispersal has been identified as humans. It is important to monitor and quarantine eel farms to prevent further spread of this nematode. Providing information and awareness is the only current method of management. If an infection is suspected it is important to notify local authorities and prevent uncontrolled migration when possible.



Anguillicoloides crassus. © Senckenberg. http://www.senckenberg.de/root/index.php?page_id=5206&year=2015&kid=2&id=3490. Acc. 9/28/15.

Impacts and Uses of the Eel Swimbladder Nematode

Ecological: The American Eel (*Anguilla rostrate),* a Federal Species of Concern, can be infected with *A. crassu* as early as the glass eel stage, resulting in acute inflammatory reactions. Scar tissue build up causes constriction of the intestine and can lead to rupture of the swimbladder and bacterial infection, resulting in increased mortality rate. With the American eel population already declining, the introduction of this nematode may have a large negative impact on the survival of this species. Reduced swimming ability from infection may render the eel vulnerable to predators.

Human use: American Eel aquaculture facilities may suffer losses if largely infected by the nematode. Moralities have been reported in eel farms in addition to reduced growth rate, which has a large impact on economic output of the eel farm.

Sources:
Invasive Species Compendium. Anguillicoloides crassus datasheet. Mod. 1-5-12. www.cabi.org/isc/datasheet/93709#20023079170. Acc. 5-12-15.
Moser ML, Patrick WS, Crutchfield JU Jr, 2001. Infection of American eels, *Anguilla rostrata*, by an introduced nematode parasite, *Anguillicola crassus*, in North Carolina. Copeia, No.3:848-853.
Texas Invasive Species Institute. 2014. Eel Swimbladder nematode. www.stoppinginvasives.org/home/database/anguillicola-crassus. Acc. 5-11-15.
tsusinvasives.org/database/eel-swimbladder-namatode.html#sthash.80YrLOUs.dpuf.

Lionfish
(Pterois miles and *Pterois volitans)*

Taxa Group: Fish

Size: 18–20 inches (45-50 cm in diameter).

Distinctive Physical Characteristics: Lionfish have a white or cream colored body with red/brownish vertical stripes and elongated dorsal fin spines.

Habitat: A reef dwelling fish, found to inhibit areas between 10 – 175 meters.

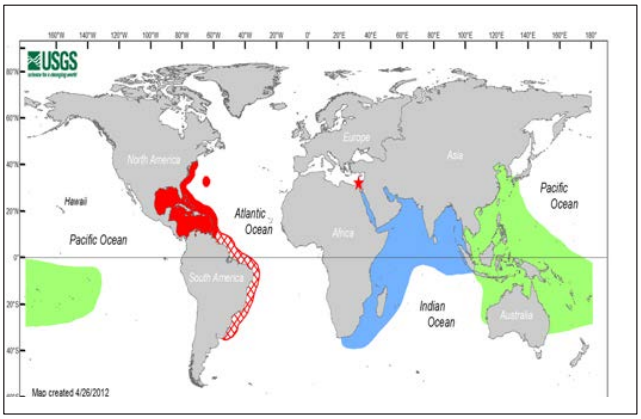
Native Range: *P. volitans* – Pacific Ocean*, P. miles* – Indian Ocean and Red Sea.

NC History: First known records were reported in two different shipwrecks off the coast of North Carolina in early 2000.

Current NC Distribution: Along the entire coastline, in offshore shelf habitats.

Pathway of Introduction: Possible aquarium releases.

Management and Control: Sport fishing.



Map of native range of *P. volitans* (green) and *P. miles* (blue), nonnative range (red). Red hatched area is predicted future distribution; red star shows migration through the Suez Canal. Lionfish World Distribution. USGS. Mod. 6-14-13. Acc. 4-22-15. http:// nas.er.usgs.gov/taxgroup/fish/maps/lionfishr angemap.gif.

Lionfish (*Pterois volitans)* Photo credit: Don DeMaria, http://nas.er.usgs.gov/queries/FactSheet.aspx?species ID=963

Impacts and Uses of Lionfish in NC

Ecological: Lionfish have few natural enemies and have the potential to outcompete and prey upon native species. Lionfish have also been found to reduce the recruitment of native reef fish larvae.

Economic: Impacts include potential loss in economic returns for commercial fisheries, as well as recreational divers and snorkelers.

Human Health or Human use: Lionfish possess venomous spines which are intended to discourage predators. The spines will injure humans, causing very painful puncture wounds. Symptoms of the sting may include extreme pain, swelling, nausea, and many other symptoms.

Sources:

Schofield, PJ, JA Morris, JN Langston, and PL Fuller. 2012. *Pterois volitans/miles*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/factSheet.aspx?speciesI D=963. Revision Date: 9/18/2012. Accessed April 22, 2015.

Apple Snail (*Pomacea insularum* and *Pomacea canaliculata*)

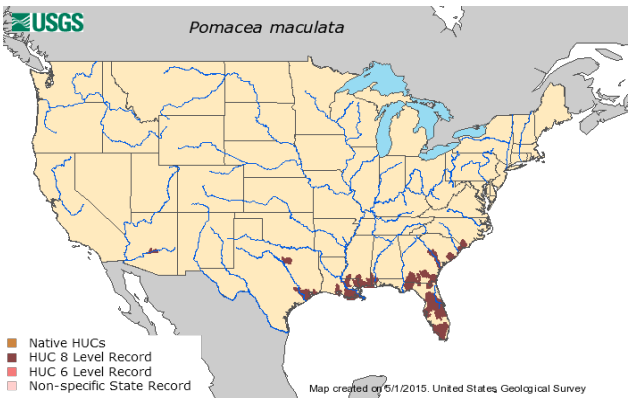
Taxa Group: Gastropod

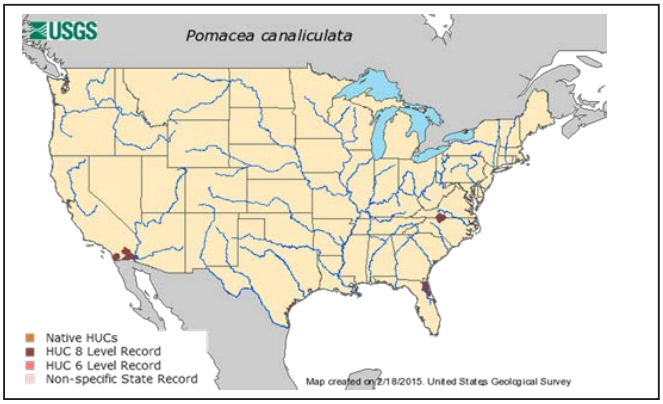
Distinctive Physical Characteristics: Apple snails are round and much larger than any snail native to North Carolina. Adults commonly reach over 3 inches in width. Apple snails have large pink egg masses.

Native Range: Freshwater wetlands of South America. Introduced populations occur throughout the Southeastern United States from South Carolina to Texas. No documented occurrences of Apple Snails in North Carolina have been recorded.

Pathway of Introduction: Introductions likely occurred through the aquarium trade. Once established the apple snail reproduces rapidly and matures quickly allowing for rapid establishment and expansion.

Management and Control: Currently apple snails can be controlled using chemical applications of copper sulfate and chelated copper. Egg removal and spraying eggs with oil are also methods for control. A commercial snail trap is also available but is likely more useful for measuring abundance than for control.





Apple Snails and Two Egg Masses (Ben Ricks)

Impacts and Uses of Apple Snails

Ecological: Once apple snails become established detrimental effects to natural resources include heavy predation on native aquatic macrophytes, aquatic habitat degradation, and direct competition with native species. Furthermore, once apple snails become established in an area dispersal along North Carolina's waterways would easily enable expansion. There are no known native predators of apple snails in North Carolina.

Economic: In some countries apple snails have been introduced as a food source. However in the United States no known benefits of apple snails have been identified.

Human Health or Human Use: Apple snails can serve as disease vectors as they can harbor potentially harmful nematodes and trematodes that have potential to pose human health risks. The primary health risks are *Angiostongylus cantonensis* (rat ringworm), *Echinostoma ilocanum* (intestinal fluke), and *Eosinophilic meningoencephalitis* (infections caused by human endoparasite rat lungworm).

Sources:

Burlakova, L. E. et. al. 2008. Wetland restoration and invasive species: Apple snail (*Pomacea insularum*) feeding on native and invasive aquatic plants. Restoration Ecology 1-8.

Joshi, R. C. 2005. The golden apple snail: Raiders of the rice fields. Outlooks on Pest Management. 23-26.

Ramakrishnan, V. 2007. Salinity, pH, temperature, desiccation and hypoxia tolerance in the invasive freshwater apple snail, *Pomacea insularum*. Ph.D. Dissertation. University of Texas at Arlington, Arlington, Texas. 245pp.

Giant Salvinia
(Salvinia molesta)

Taxa Group: Plant

Size: 2-3 inches long.

Distinctive Physical Characteristics: Floating fern. An identifying feature on the leaves is the presence of egg-beater shaped leaf hairs on the upper surface of each leaf. Located beneath the green floating leaves are dark brown feathery appendages resembling roots that are actually modified leaves.

Habitat: Found in still water (drainage ditches, canals, ponds and lakes).

Native Range: Brazil and Argentina.

NC History: Introduced circa 1998 as a contaminant in a water garden plant shipment. Eradicated from the state in 2009.

Current NC Distribution: None known.

Pathway of Introduction: Water garden trade.

Management and Control: Herbicides.

Golf Course Pond Covered in Giant Salvinia, New Hanover county, NC. Circa 2000. (Steve Hoyle)

Giant Salvinia. (© Bridget Lassiter)

Impacts and Uses of Giant Salvinia in NC

Ecological: An extremely invasive plant and Federally Listed as a "noxious aquatic weed." Alters habitat. A free-floating fern, giant salvinia can double its biomass in ~10 days and can form thick (>3feet) floating mats. Prevents atmospheric oxygen from entering water.

Economic: Impedes boat navigation and recreation activities. Blocks movement of water which may lead to flooding.

Human Health or Human Use: Leads to stagnant water and increased mosquito breeding area.

Egg-beater Shaped Hairs on Leaves of Giant Salvinia. (© Bridget Lassiter)

Marbled Crayfish, Marmokrebs *(Procambarus fallax virginalis)*

Taxa Group: Crayfish

Size: Up to 3 inches.

Distinctive Physical Characteristics: Brownish appearance with darker brown mottling. The color can change depending on diet, occasionally showing slight blues or greens.

Habitat: Freshwater streams and lakes.

Native Range: None. This is not a naturally occurring species, but a parthenogenetic crayfish that was discovered in the pet trade in Germany in the 1990s. It is closely related to the Slough Crayfish (*Procambarus fallax*) which is native to Georgia and Florida. No natural populations of Marbled Crayfish are known.

Current NC Distribution: Not currently known to occur in NC. Populations have become established across Europe, with isolated populations in Japan and Madagascar.

Pathway of Introduction: Aquarium releases.

Management and Control: They should not be used for bait or released from aquaria. Missouri has added Marbled Crayfish to its list of prohibited species.

Marbled Crayfish

Impacts and Uses of Marbled Crayfish

Ecological: Unknown. They have recently been shown to be carriers of crayfish plague.

Human Health or Human use: Available via aquarium trade from numerous sources. Since this species reproduces by cloning, there is some use of it in various research circles.

Sources:
http://faculty.utpa.edu/zfaulkes/marmorkrebs/

High Risk Species Not Currently in NC:

Silver Carp *(Hypophthalmichthys molitrix)*
Bighead Carp *(Hypophthalmichthys nobilis)*

Taxa Group: Fish

Size: Adults are 10-20 pounds, but can exceed 60 pounds.

Distinctive Physical Characteristics: Both species have deep bodies and are laterally compressed with eyes low on the head. Adult Silver Carp is olive green on the back and silver sides, while juveniles are completely silver. The Bighead Carp is darker and covered with many dark gray to black blotches.

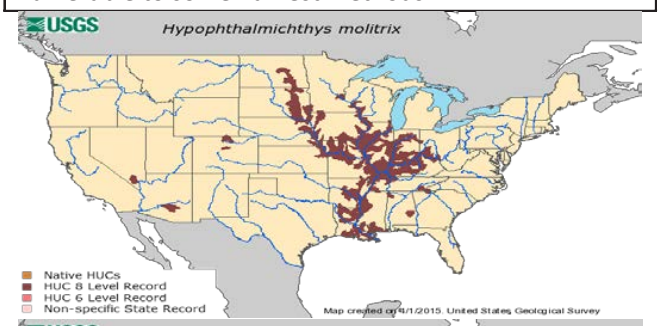
Habitat: Large rivers, reservoirs.

Native Range: Asia.

Current NC Distribution: Neither species is believed to be extant in North Carolina waters, although there is a 2011 record of bighead carp in Chowan River.

Pathway of Introduction: Introduced in the 1970s in Arkansas aquaculture to control algae, they spread throughout the Mississippi and Upper Tennessee River drainages.

Management and Control: Management is difficult because their filter-feeding habits do not make them vulnerable to some harvest methods.



Top – Silver Carp (Great Lakes Fishery Commission)
Bottom – Bighead Carp

Impacts and Uses of Silver and Bighead Carp

Ecological: In large numbers, these species have the potential to cause enormous damage to native species because they feed on plankton required by larval fish, native mussels and some adult fish. Asian carps have been shown to affect zooplankton communities and can alter fish community structure.

Economic: In locations where they have become abundant, these species can affect gillnet fisheries and recreation. These species have been declared injurious species under the Lacey Act.

Human Health or Human Use: When frightened by motorboats Silver Carp are known to jump out of the water and injure people.

Sources:

Ross, S.z. 2001. The Inland Fishes of Mississippi.

Leo Nico and Pam Fuller. 2014. *Hypophthalmichthys molitrix*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=549 Revision Date: 4/26/2013

Leo Nico and Pam Fuller. 2014. *Hypophthalmichthys nobilis*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=551 Revision Date: 4/26/2013

Snakeheads
(Channa spp.)

Taxa Group: Fish. Species include Northern (*C. argus*), Blotched (*C. maculata*), Bullseye (*C. marulius*) and Giant (*C. micropeltes*).

Size: Up to 33-36 inches.

Distinctive Physical Characteristics: Similar to the native Bowfin. Snakeheads can be distinguished from Bowfin by the position of pelvic fins (directly behind pectoral fins in snakeheads, farther back on body in Bowfin) and the size of the anal fin (elongate and similar in size to dorsal fin in snakeheads, short and much smaller than dorsal fin in Bowfin).

Habitat: Prefers stagnant shallow ponds, swamps and slow streams with mud or vegetated substrate. Snakeheads are highly piscivorous, with fishes comprising >97% of its diet.

Native Range: Asia.

NC History: Two Northern Snakeheads were reportedly caught by anglers in 2002 from Lake Wylie. In 2007, a large adult was caught by a fisherman in Lake Wylie but subsequent sampling has not captured any other specimens. A specimen collected from Lake Wylie in 2009 was originally identified as Northern Snakehead, but later genetic work combined with a closer morphological analysis determined the specimen to be Blotched Snakehead.

Current NC Distribution: Not considered established.

Pathway of Introduction: These fish are popular in the Asian food market and most introductions were likely released for this purpose.

Management and Control: New introductions may be eradicated using rotenone or electrofishing.

Top – Northern Snakehead
Bottom – Blotched Snakehead

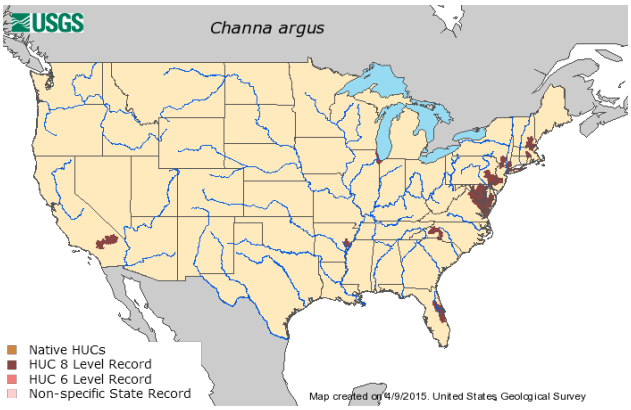
Impacts and Uses of Snakeheads

Ecological: These predatory fishes may compete with native species, including Largemouth Bass, for food and habitat. Juveniles eat zooplankton, insect larvae, small crustaceans, and the fry of other fish.

Human Health or Human Use: Popular food fish in Asian communities. Not common in aquarium trade.

Sources:

Fuller, P.F., A.J. Benson, and M.E. Neilson. 2014. *Channa argus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=2265 Revision Date: 5/2/2013



High Risk Species Not Currently in NC:

Zebra Mussel *(Dreisenna polymorpha)*

Taxa Group: Mollusk - Bivalve

Size: < 50mm.

Distinctive Physical Characteristics: Small freshwater bivalve mollusk that exhibits many different morphs

Habitat: Freshwater rivers, lakes, and reservoirs.

Native Range: Zebra Mussels are native to the Black, Caspian, and Azov Seas.

NC History: Zebra Mussels were first discovered in North America in 1988 in the Great Lakes. The first account of an established population came from Canadian waters of Lake St. Clair.

Current NC Distribution: Not present.

Pathway of Introduction: Introduction into the Great Lakes appears to be the result of ballast water discharge from transoceanic ships that were carrying veligers, juveniles, or adult mussels. Rapid dispersal throughout the Great Lakes and major river systems is due to the passive drifting of the larval stage (the free-floating or "pelagic" veliger), and the ability of the mussels to attach to boats navigating these lakes and rivers.

Management and Control: Total eradication of widespread populations is considered impossible with current technologies. No control methods are currently available for open water applications. Control efforts focus primarily on protection of human infrastructure (such as water intakes) and along vectors of spread (such as boats, trailers, gear, etc).

Zebra Mussels (©U.S. Fish and Wildlife Service)

Zebra Mussel Infestation of Native Freshwater Mussel (©theriverwhisperer.blogspot.com)

Impacts and Uses of Zebra Mussels

Ecological: Zebra Mussels can have profound effects on the ecosystems they invade by removing substantial amounts of phytoplankton, zooplankton and suspended particulates from the water, altering the system's food web. Impacts associated with the filtration of water include increases in water transparency, decreases in chlorophyll concentrations, and accumulation of pseudofeces. Water clarity increases light penetration causing a proliferation of aquatic plants that can change species dominance and alter the entire ecosystem. The pseudofeces create a foul environment. As the waste particles decompose, oxygen is used up, the pH lowers and toxic byproducts are produced. The mussels accumulate organic pollutants within their tissues, increasing wildlife exposure to organic pollutants through the food chain. Effects may continue through the food web to fish. Reductions in zooplankton biomass may cause increased competition, decreased survival and decreased biomass of planktivorous fish, as well as behavioral shifts from pelagic to benthic-feeding.

Economic: The ability of Zebra Mussels to rapidly colonize hard surfaces such as boats, docks and bulkheads causes serious economic problems. These organisms can also clog water intake structures, such as pipes and screens, therefore reducing pumping capabilities for power and water treatment plants, costing industries, companies, and communities.

Sources:

U.S. Geological Survey. 2014. Nonindigenous Aquatic Species Database. Gainesville, Florida, http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=5; http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=95. Accessed 12/23/2014.