

Delaware's Aquatic Invasive Species Management Plan

Delaware Department of Natural Resources and Environmental Control
Division of Fish and Wildlife
2024



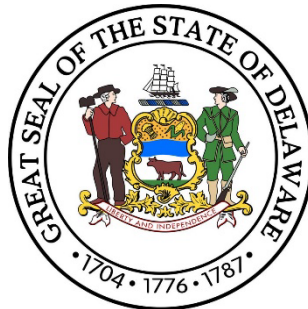
Delaware's Aquatic Invasive Species Management Plan was developed by Delaware Division of Fish and Wildlife, with cooperation from other Delaware agencies and organizations with a vested interest in aquatic invasive species management, including the general public.

State of Delaware
John Carney, Governor

Department of Natural Resources and Environmental Control
Shawn M. Garvin, Secretary

Division of Fish and Wildlife
Pat Emory, Director

Drafted by:
Michael Steiger
Environmental Scientist III
Aquatic Invasive Species
3002 Bayside Drive
Dover, DE 19901
(302) 735-2966



John C. Carney

Sept. 12, 2024

Approved by John Carney, Governor

Date

(Cover photos courtesy of Division of Fish and Wildlife staff)

Acknowledgements

Delaware's Aquatic Invasive Species Management Plan was greatly improved through comments, suggestions, and guidance provided by State and Federal agencies, Sandra Keppner, Don MacLean, Dr. Kimberly Holzer, The Mid-Atlantic Panel on Aquatic Invasive Species, Delaware Invasive Species Council, the Aquatic Nuisance Species Task Force, and the general public.

Delaware's Aquatic Invasive Species Management Plan

Executive Summary

An invasive species is a non-native species whose introduction causes or is likely to cause economic or environmental harm or harm to human health according to the National Invasive Species Management Plan (NISC 2016). Many non-native aquatic species have been introduced into Delaware waters, but not all survive, and even fewer are considered invasive. There are 82 introduced and established aquatic species listed in the United States Geological Survey (USGS) Nonindigenous Aquatic Species Database (NAS) that were documented in Delaware. Only 23 of the 82 species listed in the NAS are currently recognized as invasive species by Delaware Invasive Species Council (DISC) or are listed in state regulations.

AIS can be introduced to Delaware waterways via numerous pathways including ballast, biofouling, boating and fishing gear, live bait, aquarium trade, authorized and illegal stocking, aquaculture, and interstate waterbody connectivity. Many of these pathways are partially controlled by State or Federal laws and regulations, however, gaps do exist. To help address these pathways Division of Fish and Wildlife staff are actively involved in numerous State and Federal task forces, councils, and committees, as well as regional Aquatic Invasive Species (AIS) groups.

Seven of the 23 invasive species listed in Delaware are currently considered a priority, including: Northern Snakehead, Blue Catfish, Flathead Catfish, Hydrilla, Creeping Water Primrose, and Phragmites. These species are a high priority because of the potential to impact native species and ability to spread quickly. While these are the highest priority species currently, this list will change over time to address new or changing AIS threats.

Four objectives, six strategies, and 22 actions are included to guide implementation of this plan. Due to a lack of resources, not all of these objectives, strategies, and actions can be implemented within the next five years. Therefore, 10 actions were prioritized based on available funds, staff time, and impact on invasive species. The priority actions may change over time as objectives are met or other threats arise.

Ongoing efforts throughout the state to manage and control AIS lack a clear strategy and data collection on occurrences is not well coordinated. The Delaware Division of Fish and Wildlife (DFW) has no inspection authority to monitor or survey for invasive species on private lands, nor emergency authority to force treatment or eradication of an invasive species on private property. DFW has regulations in place that limit the purchase and stocking of AIS, but there are enough gaps and loopholes to leave Delaware at risk for invasion and spread of AIS. A 2005 plan developed by the Delaware Invasive Species Council (DISC) provides a baseline for AIS management, but the plan only addresses issues related to terrestrial plants. A Delaware AIS management plan approved by the Aquatic Nuisance Species Task Force (ANSTF), would allow Delaware to apply for funds that will be used to support a scientist to gather baseline

information, engage with partner agencies, eliminate duplicate efforts, and coordinate the implementation of the comprehensive plan state-wide.

The data and analysis that result from completing the actions outlined in this plan will be included in Federal aid grant reports, presented to the councils and committees that address invasive species issues, and shared with other jurisdictions. Feedback will aid in streamlining the plan and guiding implementation so that Delaware can more effectively combat issues caused by AIS.

This plan will be implemented under the direction of the Department of Natural Resources and Environmental Control (DNREC), Division of Fish and Wildlife, and through collaboration amongst State, Federal, and academic partners as well as numerous counsels and committees.

Goal

This management plan is a guide for the detection and monitoring of AIS throughout the State so that efforts to prevent their introduction, rapidly respond to their introduction, and control their spread will be more effective. The goal is to prevent new introductions into Delaware waters and to limit the spread of AIS that are already established.

Purpose

- Facilitate funding from various sources for the prevention, management, research, and control of AIS in the State of Delaware.
- Create a network of local, State, and Federal agencies, and public collaborators to devise solutions for cost-effective AIS management measures.
- Develop and maintain tools for natural resource managers and the public in Delaware for rapid detection and response to intentional and unintentional AIS introductions.

Objectives

- Prevent new introductions and reduce the spread of AIS in Delaware waters.
- Continue to improve and maintain early detection methods and develop rapid response protocols that contain and/or eradicate newly introduced species.
- Research the environmental and economic impact of AIS introductions and evaluate control methods that reduce the spread of AIS in Delaware waters.

Priorities for Action

- Foster stronger relationships with MAPAIS, ANSTF, surrounding states, and interested parties within Delaware. (Action 1.A.1).
- Continue to suggest species suitable for vetting through DISC's invasive species matrix to assess their potential for listing by DISC. The aquatic invasive species list in

Delaware's AIS management plan should match DISC's Invasive Species List, but also include species listed in State or Federal regulations (1.A.2).

- Assess current laws and regulations to determine effectiveness at stopping the introduction and spread of AIS. Input should be gathered from the Advisory Council on Tidal Finfisheries, the Advisory Council on Wildlife and Freshwater Fish, the Council on Shell Fisheries, and DNREC's Natural Resources Police to ensure laws and regulations are easily understood by the public as well as enforceable (1.B.1).
- Develop a detailed rapid response plan for Delaware. The plan will include the names and phone numbers of response staff as well as an organizational structure. Supplies needed to launch a response will be kept in specified locations to ease retrieval. The plan will be updated on an annual basis to ensure all names and contact information is current (2.A.1).
- Develop and conduct personnel training, inventory equipment needs, and identify storage locations to support implementing the rapid response plan (2.A.2).
- Develop a list of strategies to control high- priority AIS. Cost effectiveness, and practicality should be taken into consideration when developing these strategies (3.A.2).
- Continue to monitor and control invasive aquatic plants such as Hydrilla and Creeping Water Primrose that occur in Delaware's public ponds (3.A.6).
- Continue to use various methods to control Phragmites in Delaware's public waterways and wetlands (3.A.7).
- Establish long-term studies that determine biomass or estimate population abundance. The results of these studies can be used to assess if control methods are impacting AIS populations (4.A.1).
- Support research necessary to control, manage, and assess the status of AIS in Delaware by providing funding and dedicated staff (4.A.4).

Table of Contents

Executive Summary	4
Table of Contents	7
Glossary	9
Acronyms	10
Introduction	11
Problem Definition	13
High Priority Pathways	13
High Priority Aquatic Invasive Species	16
Existing Delaware Authorities and Programs	21
Current Impacts	22
Current Programs and Activities	25
Gaps in AIS Prevention, Response, and Management	28
Objectives, Strategies, and Actions	30
1. Prevent new AIS introductions into Delaware waters and detect introductions early	30
1.A Anticipate future invaders and their potential impacts	
1.B Take action to prevent or minimize the chance of AIS introduction via identified pathways	
1.C Identify new and use existing outlets to conduct outreach and education to raise public awareness and inform various industries on the consequences of AIS introduction	
2. Rapid Response to an Introduction	32
2.A Develop a rapid response system to contain or eradicate an AIS introduction	
3. Control and Management of Aquatic Invasive Species	33
3.A When possible, control aquatic invasive species that have significant impacts in Delaware through various removal and control methods including integrated pest management strategies. Reduce harmful effects of AIS through management when eradication is not possible	

4. Research and Restoration	34
4.A Research the effects aquatic invasive species are having on native plant and animal communities and possible control measures to alleviate these affects.	
Implementation Table	35
Priorities For Action	38
Program Monitoring and Evaluation	40
Public Comment Period	41
Literature Cited	42
Appendices	45

Glossary

Anadromous Alosines: For the purpose of this plan, the species defined are American Shad, Blueback Herring, and Alewives.

Aquaculture: The rearing of aquatic animals or the cultivation of aquatic plants for food.

Aquatic Species: All animals and plants as well as pathogens or parasites of aquatic animals and plants totally dependent on aquatic ecosystems for at least a portion of their life cycle. Bacteria, viruses, parasites, and other pathogens of humans are excluded (ANSTF 1994).

Aquatic Nuisance Species and Invasive Species: Means a nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters (ANSTF 1994). The term ANS is synonymous with aquatic invasive species (AIS) the preferred term used in this plan.

Baitfish: Fish species commonly sold for use as bait for recreational fishing.

Ballast water: Any water and associated sediments used onboard a ship to manipulate the trim and stability of a vessel.

Control: To reduce the incidence or severity of invasive species to innocuous levels.

Ecosystem: The complex of a community of organisms and their environment.

Eradicate: The act or process of eliminating an aquatic invasive species.

Introduction: The intentional or unintentional escape, release, dissemination, or placement of a species into an ecosystem as a result of human activity.

Pathways: Natural and human connections that allow the movement of organisms or their reproductive materials, such as seeds, spores, or eggs, from place to place.

Phragmites: Includes European reed and Common Reed (*Phragmites australis subsp. Australis*).

Rapid Response: A systematic effort to identify, eradicate, or contain aquatic nuisance species while infestations are still localized (NISC 2001).

Species: A group of organisms all of which have a high degree of physical and genetic similarity, generally interbreed only among themselves, and show persistent differences from members of allied groups of organisms.

Stakeholder: A person or organization with an interest in something.

Watershed: The geographic area that drains to a single water body or hydrographic unit such as a lake, stream reach, or estuary.

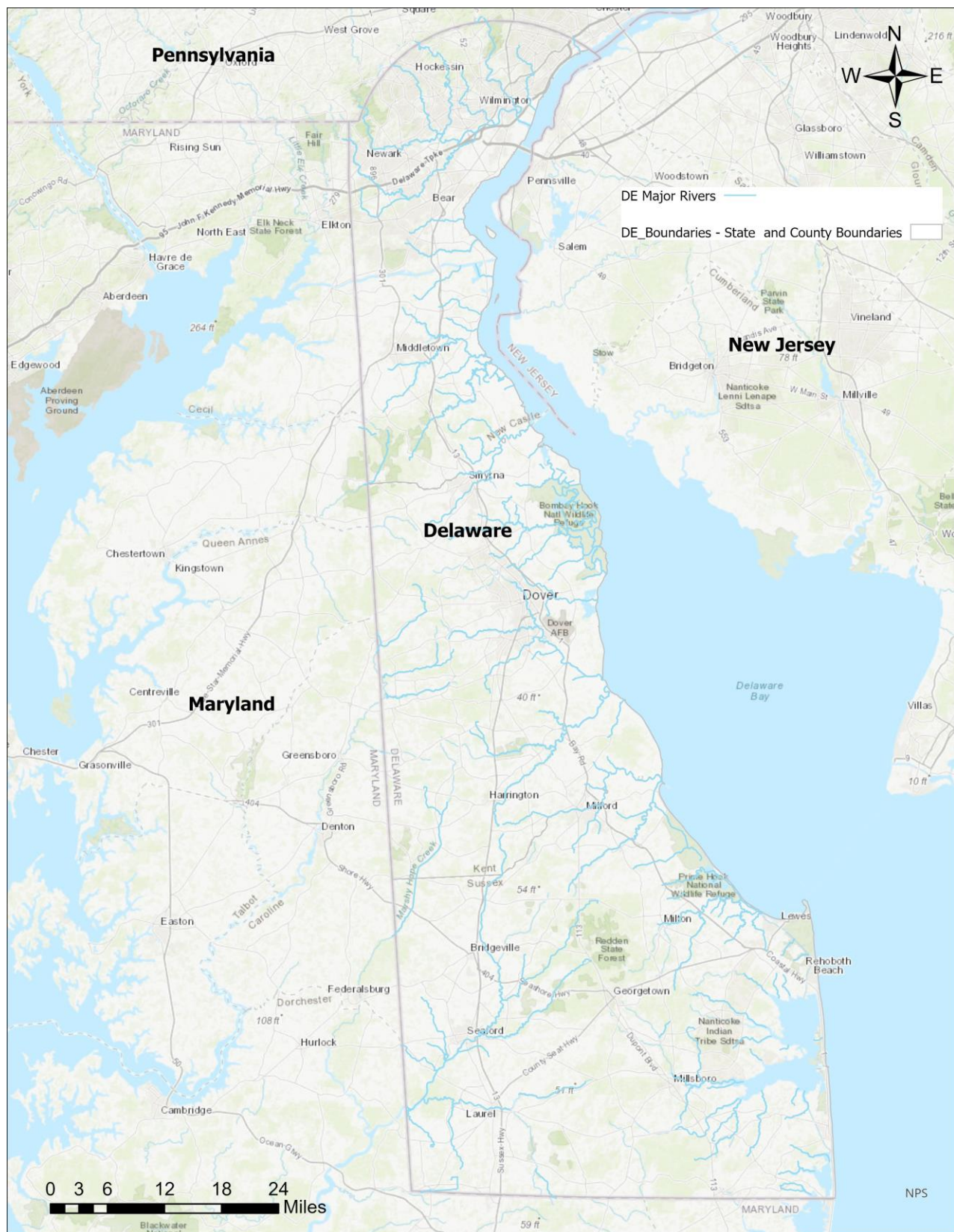
ACRONYMS

AIS	Aquatic Invasive Species
APAIS	Access Point Angler Intercept Survey
ANSTF	Aquatic Nuisance Species Task Force
BC	Blue Catfish (<i>Ictalurus furcatus</i>)
C&D Canal	Chesapeake and Delaware Canal
DDA	Delaware Department of Agriculture
DEGA	Delaware General Assembly
DEMCC	Delaware Environmental Monitoring Coordination Council
DelDOT	Delaware Department of Transportation
DESG	Delaware Sea Grant
DFW	Delaware Division of Fish and Wildlife
DISC	Delaware Invasive Species Council
DNERR	Delaware National Estuarine Research Reserve
DNREC	Delaware Department of Natural Resources and Environmental Control
DOD	Department of Defense
DPR	Delaware Department of Parks and Recreation
ESA	Endangered Species Act
FC	Flathead Catfish (<i>Pylodictis olivaris</i>)
MAPAIS	Mid-Atlantic Panel on Aquatic Invasive Species
NAS	USGS Nonindigenous Aquatic Species Database
NISA	National Invasive Species Act
NOAA	National Oceanographic and Atmospheric Administration
NSH	Northern Snakehead (<i>Channa argus</i>)
UD	University of Delaware
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Introduction

“An invasive species is a non-native species whose introduction causes or is likely to cause economic or environmental harm or harm to human health” according to the National Invasive Species Management (2001). The ability to manage and control the spread of Aquatic Invasive Species (AIS) in Delaware has implications not only within the state, but in the region. Northern Snakehead (*Channa argus*) (NSH) and Blue Catfish (*Ictalurus furcatus*) (BC) are just two examples of a species spreading into Delaware via waterbodies with interstate connections. Currently, the status and distribution of many AIS are largely unknown, and additional species may be discovered too late for early management or eradication. The development of this State-wide comprehensive AIS plan allows Delaware to shift to a proactive rather than a reactive approach to AIS issues. The result will be an increased capability to monitor, rapidly detect, and minimize the introduction and spread of AIS.

Over 82 potential aquatic invasive species have been identified in Delaware. At just over 1,981 square miles, Delaware is the second smallest state in the USA and smallest state in the Mid-Atlantic region. Delaware is ‘water-rich’ with 4,470 linear miles of river/streams/canals/ditches, 11,491 acres of lakes/ponds, 296,351 acres of tidal/non-tidal wetlands, 841 square miles of estuarine waters, and 25 miles of coastal waters (State of Delaware 2020). The northern part of the state is in the Piedmont region, whereas the central and southern part of the state is classified as Coastal Plains. Many Chesapeake Bay and Delaware Estuary tributaries are partly or entirely in Delaware, including the headwaters where rare plant and animal species often occur. Wilmington is a major international port and the first port on the Delaware River, just 63 miles from the Atlantic Ocean. The state borders Maryland, Pennsylvania, and New Jersey. The Delaware River and C&D Canal connect Delaware waters to New Jersey, Pennsylvania, and Maryland. The Nanticoke River and Marshyhope Creek connect Delaware to southern Chesapeake Bay (Figure 1). These connections allow for the movement of AIS across the waters of multiple states. Pennsylvania and Maryland have ANSTF accepted plans, while New Jersey’s plan is currently in development as of Fall 2023. These states are all members of the Mid-Atlantic Panel on Aquatic Invasive Species (MAPAIS). During regular meetings of MAPAIS, coordination across joint jurisdictions is discussed. Also, Delaware participates in the Chesapeake Bay Northern Snakehead Plan Working Group, which produced the Northern Snakehead Control and Management Plan for the Chesapeake Bay Watershed in May 2023. However, other pathways and species are not regulated in the same manner across jurisdictions. Aquatic invasive species threaten the diversity of Delaware’s native species, the ecological integrity of infested waters, and impact valuable commercial and recreational activities.



Problem Definition

Delaware is experiencing a constant influx of new residents and visitors, and this brings an increased probability for the introduction of aquatic AIS through various pathways. There are many ways organisms may be transported and introduced into coastal or inland waterways. An example is the introduction of various invasive aquatic plants such as Hydrilla (*Hydrilla verticillata*) by the movement of recreational vessels and trailers from one water body to another. ‘Stop Aquatic Hitchhikers!’¹ signage was used to address the recreational boating pathway of Hydrilla spread, with varying levels of success. Other pathways of introduction include aquaculture, aquarium trade, ballast water discharge and vessel biofouling, illegal stocking, and natural movement from other states via canals and shared waterbodies. Some pathways, such as shellfish aquaculture, have an extensive body of regulations limiting the possibilities of AIS introduction. Others have little to no regulations or precautions in place. Efforts throughout the state to manage and control AIS are ongoing but there is not a clear strategy or coordinated data collection on occurrences. The Delaware Division of Fish and Wildlife has no inspection authority to monitor or survey for invasive species on private lands, nor the emergency authority to force the treatment or eradication of an invasive species introduction on private property. A state management plan is needed to guide the detection and monitoring of AIS throughout the state so that efforts to prevent introductions, rapidly respond, and control the spread can be more effective. A 2005 plan supported by the Delaware Invasive Species Council (DISC) provides a baseline, but the plan only addresses issues related to terrestrial plants. Time utilized to incorporate input from a diverse set of partner agencies, stakeholders and the public will result in a plan that is credible, reasonable, and more likely to be implemented. This process will also identify key partners and their capabilities to share resources and support AIS efforts in a variety of ways within the state. The rapid response part of the plan and long-term strategies for reducing the impact of AIS in Delaware will also reduce the threat of spread into other jurisdictions in the Mid-Atlantic region. Blue Catfish and NSH invaded Delaware waters via Chesapeake Bay tributaries. Tidal rivers, such as the Nanticoke River, flow from Delaware and empty into the Chesapeake Bay. This provides a perfect conduit for the movement of aquatic invasive species into Delaware. The interconnectivity of this water body with multiple states illustrates the necessity of interstate communication to slow or prevent the spread of AIS.

The priority actions in this Plan will be amended by DFW as new information, priorities, or threats arise. Updates to this plan and its goals and associated actions will mirror the research priorities set forth by ANSTF.

High Priority Pathways

The following is a list of pathways that are responsible for non-native species introduction including some AIS into Delaware. These pathways are the most obvious, however, other less obvious pathways may also contribute to the spread of AIS.

Ship ballast: This is a primary pathway for the long-distance movement of non-native aquatic organisms. Aquatic organisms ranging from microscopic (plankton) to large fish can be

¹ <https://stopaquatichitchhikers.org/>

transported to new areas through the release of ballast water. Ballast water discharge has been responsible for the establishment of over a third of marine AIS worldwide (Hewitt and Campbell 2007). This pathway is particularly relevant to Delaware because of the Port of Wilmington (formerly Wilmington Marine Terminal), a deep-water port located at the confluence of the Christina River and the Delaware River in Wilmington, Delaware. The port has been ranked as the top North American port for imports of fresh fruit, bananas, and juice concentrate, and as having the largest dockside cold storage facility.

The United States Coast Guard (USCG) regulates ballast water via the United States Final Ballast Water Rule which was adopted in 2012. This rule established discharge standards and concentrations of organisms in ships' ballast water. Because of this rule, the USCG regulates ballast water in Delaware.

Hull biofouling: Aquatic organisms of all shapes and sizes can attach to the bottom of any vessel and be transported long distances and drop off at any time. Biofouling control can be obtained by using anti-fouling paints and hull treatments. Anti-fouling paints and hull treatments are not regulated in Delaware and are commonly used on recreational vessels.

Boating gear: Various aquatic organisms can be transported in or on boats, motors, trailers, and associated equipment. Recreational boaters may inadvertently collect AIS on a boat trailer, bilge, or live well in one water body and transport it to another. This is likely how Hydrilla was transported throughout the state and led to its introduction into many waterbodies in Delaware. The State has 32 non-tidal and 27 tidal public fishing access areas that contain boat ramps or access points. Due to the popularity of freshwater and marine recreational angling in Delaware, education and outreach will be Delaware's best tool in combating the spread of AIS via this pathway.

Live bait pathway: The movement and eventual discarding of live fish and invertebrates, including various worm species, by anglers can introduce these organisms, and possibly the pathogens they may be carrying, into new bodies of water. Live bait may be purchased from a bait vendor or captured legally within the state to use for fishing. There are 13 bait and tackle shops throughout Delaware that participate as weight stations for Delaware's Sportfish Tournament. Although 7 DE Admin. Code 3308 prohibits stocking any fish species in non-tidal public waters without written authorization from the Division of Fish and Wildlife, this regulation does not prohibit stocking in tidal waters of the state and does not address the discard of live bait other than fish. Baitfish imported from outside sources is also a concern. Live bait named the "black salty," a hybrid goldfish imported from a southern state, was being sold as bait in the Mid-Atlantic region. This fish is super-hardy, saltwater resistant, and is touted as the ultimate baitfish for both fresh and saltwater. This topic was discussed by the Northeast Fisheries Administrators Association and other fisheries groups searching for more effective ways to enforce illegal bait introductions. Introduction through the live bait pathway is extremely difficult to enforce since the person needs to be caught in the act. Throughout Delaware, there are only a few local governments and municipalities that regulate live bait via ordinances and special policies. For example, it is unlawful for any person to use or have in his or her possession any live fish, as bait, while fishing on Lake Como, a public lake owned in the town of Smyrna. However, there are few regulations that address the legality of stocking non-native or invasive

species in private water bodies (other than species prohibited by 7 DE Admin. Code 3545: Invasive Finfish).

Aquarium/Pet pathway: The aquarium and pet trades present multiple pathways for introducing AIS to Delaware waters. The sale of invasive and non-native aquatic species is difficult to regulate and hard to enforce in Delaware. The trading of invasive and non-native species amongst hobbyists is very difficult to monitor or regulate and could be a pathway for introductions from other states or countries. The intentional release of pets is a common way various species are introduced into Delaware waters. Goldfish, Koi, Oscar, Piranha, and Pacu are fish species that have been documented in recent years in Delaware's public waters. Members of the public can stock their private ponds with any number of exotic/invasive fish species as long as they are not prohibited by regulation. These fish species can then escape via flooding or outflow pipes into public waters. In 2021, Zebra Mussels were detected within a variety of moss ball products designed for use in aquariums and water gardens. Examples of these products are "Betta Buddy Marimo Balls" or "Marimo Balls". These pathways in particular are an area where guidelines and/or regulations could be added to limit the accidental introduction of exotic/invasive species.

Authorized stocking pathway- The transport, possession, purchase, sale, and stocking of live Grass Carp in Delaware is illegal without a permit signed by the DFW Director (7 Del C. § 942 (b), 7 DE Admin. Code 3545). To legally stock Grass Carp, pond and lake owners must fill out an application and agree to a site inspection to ensure the situation meets DFW policy criteria. Criteria contained in the policy include adequate water quality, 40 percent coverage of an aquatic plant or algae known to be consumed by Grass Carp, and a barrier on outlet pipes or water control structures to prevent the escape of stocked fish into adjacent water bodies. This legal pathway can lead to the unintentional escape of this species into public waters through failure of these barriers. After the barrier failed on Collins Pond, a 35.6 ha private pond with a dam on Gravelly Branch, and potentially allowed 1,800 stocked Grass Carp to escape into the Nanticoke River watershed, a moratorium was placed on stocking carp in water bodies with a direct connection to any Chesapeake Bay tributary. Also, a 100 percent triploidy check is required to stock Grass Carp in water bodies with a direct connection to a Delaware Bay tributary. Since 2002, 59 permits were issued for stocking Grass Carp in Delaware, totaling 2,450 individual fish. Although all permits were issued with the stipulation that DFW had the right to inspect the barriers at any time, inspections rarely took place due to staff time constraints. Since 2019, more effort was expended by DFW to inspect the barriers, including a required three-year inspection schedule to ensure compliance and to evaluate vegetation control.

Illegal stocking pathway- Every year there are multiple reports of AIS in locations that have no natural connection to known AIS populations. For example, the occurrence of NSH into closed-system water bodies with no connection to known locations indicates that anglers are likely moving them to expand fishing opportunities. Except for invasive finfish prohibited by regulation (7 DE Admin. Code 3545), there are few regulations that restrict stocking tidal water or private waters. It is illegal to stock non-tidal public waters without a permit from the DFW Director. Enforcement of illegal stocking regulations requires an eyewitness; thus, outreach and education are likely more effective at preventing the intentional spread of AIS.

Aquaculture pathway- The aquaculture pathway pertains to both fish and shellfish in Delaware waters. Delaware has a shellfish aquaculture program that allows aquaculturists to grow oysters out in public waters in the Inland Bays. There is a strict set of regulations that were developed by DNREC staff to prevent the importation of non-native species of oysters and to limit the importation of diseases and oyster seedlings that could be carrying diseases. Other forms of aquaculture are governed by the Delaware Department of Agriculture (DDA). The current policy allows an invasive/ non-native species to be raised in a closed system at an aquaculture facility if it is not specifically prohibited by the policy. Red Swamp Crayfish (*Procambarus clarkia*) were introduced in Delaware through this pathway. They were legally raised in an aquaculture facility and escaped into the wild and spread from there. This highlights a potential loophole that needs to be addressed through tighter control to help combat the unintentional introduction of aquaculture species into public waters.

Waterbody connectivity pathway- The state of Delaware is situated between two major watershed basins, Delaware Bay, and Chesapeake Bay. The Delaware River connects Delaware Bay and its tributaries to New Jersey and Pennsylvania. There are multiple ports and anchorages in the river which opens Delaware up to the ship biofouling, ballast, and boating gear pathways. With multiple state borders, ports, and anchorages, the Delaware River is an accessible pathway for the introduction of invasive species into Delaware waters.

The Chesapeake Bay watershed is shared by New York, Pennsylvania, Maryland, Virginia, West Virginia, and Delaware. Blue Catfish and NSH invaded Delaware waters via Chesapeake Bay tributaries. Tidal rivers, such as the Nanticoke River, flow from Delaware and empty into the Chesapeake Bay. This provides a perfect conduit for the movement of aquatic invasive species into Delaware. The interconnectivity of this water body with multiple states illustrates the necessity of interstate communication to slow or prevent the spread of AIS.

The Chesapeake and Delaware Canal (C&D Canal) is a 14-mile-long canal that connects the Chesapeake Bay to the Delaware River. The canal is used by commercial and recreational boats as well as fish for passage between these two large bodies of water. Activities related to the passage of these vessels facilitates AIS invasion into Delaware, and some AIS also utilize the canal as a migratory pathway. For example, on May 11th, 2022, a NSH was tagged by staff with the Fish and Wildlife Service in the vicinity of Elk River Park near Elkton, Maryland. On May 23rd, 2022, a fly fisherman reported catching the NSH from Darby Creek, Pennsylvania in John Heinz National Wildlife Refuge. To reach that location the fish moved through the C&D canal into the Delaware River and upstream to Darby Creek (Joshua Newhard, USFWS personal communication). This highlights how quickly an invasive species can move from one state to another. That fish traveled between the water bodies of three states in just 12 days highlighting the need for constant contact between state and Federal agencies to control and manage the interstate spread of invasive species.

High Priority Aquatic Invasive Species

Delaware's Invasive Species Council created a list of invasive species known to be problematic in Delaware (Reilly 2005), however, the list primarily included terrestrial plants. In 2019, the

plant list was updated and invasive species from other taxa were included (Appendix 1). Taxa included on the list were assessed by protocols DISC developed based on NatureServe methodology (DISC, in-house unpublished document). Each species being considered for listing was vetted through a ranked scoring matrix that assessed, categorized, and evaluated potential invasiveness based on ecological impact, current distribution and abundance, trends in distribution and abundance, and management difficulty. Aquatic species experts from government, non-government organizations, and academic institutions were contacted and asked to complete the assessment in an online format. A list of species was provided to each expert who then applied the ranking protocol to the species they were most familiar with. Experts completing the assessment did so independently and were unable to view answers input by other species reviewers. Five months were provided to review and complete the assessment. Based on the expert review, species vetted through the protocol were ranked by the level of invasiveness in Delaware. The ranks were categorized as high, medium, low, and insignificant. If a species was not ranked as insignificant, it was deemed invasive to some degree and included in the current iteration of the DISC list of Invasive Aquatic Species or Watch List (Appendix 1). DISC also has a list of Invasive Plant Species, which includes several submerged and emergent aquatic plants. For the purposes of this AIS State Management Plan, the aquatic plants were added to the DISC Invasive Aquatic Species and Watch Lists. These lists will be reevaluated by DISC every two years.

At the request of the AIS Biologist, biologists within the DFW developed a list of aquatic species to consider for this AIS management plan based on their expertise. Many of the species considered were already on the DISC list, however, additional species were included. These species considered for listing in Delaware's AIS management plan will be vetted using the protocol established by DISC.

Also included in this plan are species listed as invasive in current DFW regulations. These regulations prohibit the transport or possession of various AIS without a permit from the DFW Director. Delaware's List of AIS can be found in Appendix 2. The following species are some of the highest priority species because of their potential impacts to native species, or their ability to spread quickly, or both.

Northern Snakehead (*Channa argus*) is considered a priority species in Delaware because of the potential impact on native species and its ability to spread during flooding. Although a self-sustaining population of NSH was discovered in the tidal freshwater Potomac River in 2004, it was initially thought that higher salinity in the Chesapeake Bay would prevent spread into other areas within the Bay. Concurrently, a population was discovered in Meadow Lake in Philadelphia County, PA. Reports of fish escaping the lake and entering the Schuylkill River and Delaware River were also confirmed (NSWG 2011). In 2010, NSH were discovered in Broad Creek, a tributary to the Nanticoke River and in 2011, DFW received a report of a kayaker that was "attacked" by a NSH guarding young in Becks Pond, New Castle County Delaware, which resulted in the collection of one adult and several juveniles from this Delaware River watershed impoundment. Two additional adult fish were also observed in Becks Pond. An Enforcement Officer's request for information on NSH led to confirmation of an angler catch about eight miles downstream of Becks Pond in Shellpot Creek, a tributary to the Christina River. These events led to the development of a Delaware Action Plan (Martin 2012; Appendix 3).

Blue Catfish (*Ictalurus furcatus*) are considered a priority species since their 2013 discovery in Delaware waters because of their potential impact on native fish species; primarily in the Nanticoke and Delaware River systems. A study of the stomach contents of BC from the Chesapeake Bay showed the presence of DNA from at-risk species such as American Shad (*Alosa sapidissima*), Alewife (*Alosa pseudoharengus*), Blueback Herring (*Alosa aestivalis*), and the Endangered Species Act listed Atlantic Sturgeon (*Acipenser oxyrinchus*) (Evans et al. 2021). Additional research conducted in Chesapeake Bay tributaries has shown that an increase in the invasive BC population results in a decline in the abundance of native White Catfish (*Ameiurus catus*) (Schloesser et.al. 2011). Another factor is their ability to grow to large sizes. Blue Catfish have been documented at lengths greater than 5 feet and weighing over 100 pounds (Graham, 1999). Research to estimate relative abundance using a juvenile abundance index in the Nanticoke River was funded for 2023. This river system is important because the endangered Atlantic Sturgeon occupy these waters (Park 2023), and American Shad populations have been declining in this system since BC were first discovered (Moore 2022). Continued research is needed to determine the short and long-term impacts this catfish species is having on native species in Delaware.

Flathead Catfish (*Pylodictis olivaris*) are a priority species because of a recent invasion into one of Delaware's most fished ponds, Lums Pond. Concurrently, survey data has shown a decline in the Lums Pond centrarchid population in recent years (Stetzar 2022). Electrofishing surveys conducted in 2022 resulted in the capture of multiple FC, one as large as 956 mm. Preliminary stomach content analysis of the catfish revealed Bluegill (*Lepomis macrochirus*), White Perch (*Morone americana*), and Yellow Perch (*Perca flavescens*) were their main food source. This piscivorous catfish has also been spreading in the Delaware portion of the Delaware River. The first collection of FC in the Delaware River Watershed was from the mainstem Schuylkill River in 1999 at Fairmount Dam in Philadelphia, PA, and the species has become well established in the lower non-tidal portion of the river (Smith et al. 2021). A telemetry study conducted on FC in the Delaware River documented a 17-km downriver expansion of the species' range and provided the first record of FC in the Christina River (Brundage 2022). The occurrence of Flathead Catfish in the Christina River is a concern because of potential impacts on efforts to restore anadromous alosine populations to the Christina River watershed (Park 2020). Biologists captured 150 Flathead Catfish in the lower Schuylkill River from 1999–2003, with most of the fish collected using dip nets at the Fairmount Fishway (N=123) when the fishway was being drained for maintenance (Brown 2005). This is a concern for the 10 fish ladders currently operated by DFW for alosine passage (Boucher 2021) because a large presence of FC at these fish passages would hinder efforts to restore alosine populations. Additional research is needed to determine the distribution effects of this invasive catfish species on native fish populations overall.

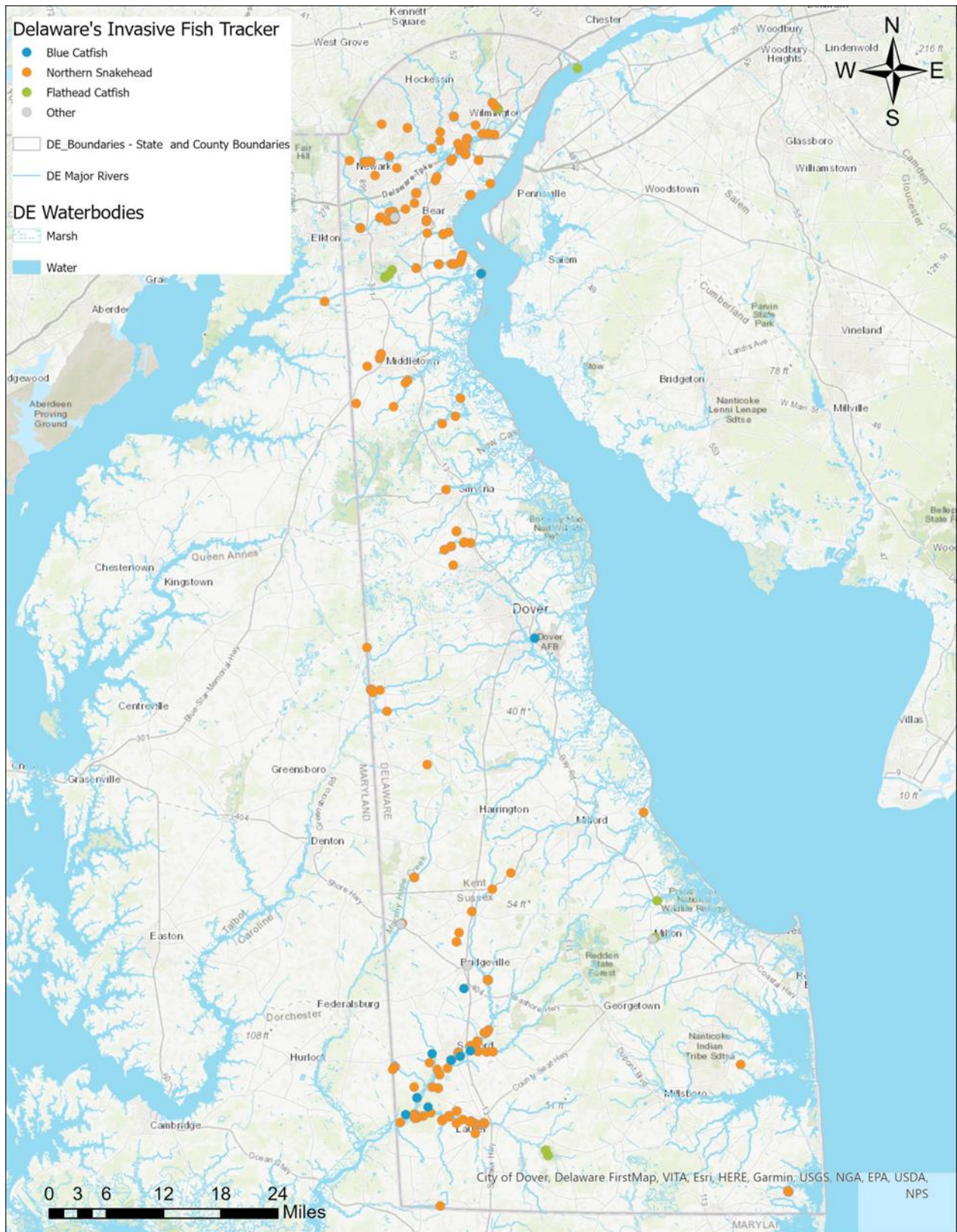


Figure 2. AIS catch data from Delaware's Invasive Fish Tracker App. 2014-2023

Hydrilla (*Hydrilla verticillate*) is a high-priority species because of its impact on fishing and recreational access to public waters. In the late 1960s, a large-scale aquatic vegetation survey was completed on 55 state- and privately-owned water bodies. Hydrilla was not found in any of these waterbodies (Lesser 1966). From 2003-2007, a survey was conducted to determine the colonization of invasive, non-native plant species in Delaware's public ponds and to document temporal changes in the plant communities. The aquatic vegetation in 35 public ponds was mapped, and Hydrilla was found in fifteen of them (Martin 2008). Hydrilla was introduced and has since grown to nuisance levels in at least two more ponds. The Delaware Division of Fish and Wildlife (DFW) Fisheries Section allocates an average of \$200,000 annually for Hydrilla management in state-managed fishing ponds. An integrated vegetation management approach, consisting of partial herbicide treatments and mechanical harvesting, is used to control this invasive species. Multiple DNREC staff run and maintain mechanical weed harvesters for Hydrilla and algae removal. Without these management strategies in place, many state managed fishing ponds would become unusable to the public due to thick beds of Hydrilla and large mats of algae that impede boat, canoe, and kayak navigation, and interfere with shoreline angling as well as waterfowl use. Control efforts have remained the same in recent years, and those efforts will continue.

Creeping Water Primrose (*Ludwigia peploides*) is a high priority species because of its hindrance to recreation and its presence in DFW ponds. This highly invasive, non-native plant will quickly crowd out other forms of aquatic vegetation and cover the water's surface with growth to three feet tall. The resultant vegetative mat extending from shoreline out into the pond prohibits fishing and other recreation to occur. The Division conducts up to 20 treatments a year to control this invasive. One particular problem area is Wagamons Pond located in Milton, Delaware. The multiple treatments, made annually from 2006 to 2018 (except 2010, 2014 and 2016), have achieved reasonable control, however, it is likely to be a recurring problem since the source (a dense stand immediately upstream and under private ownership) cannot be controlled (Zimmermann 2018). Another source of primrose are stormwater ponds managed by Delaware Department of Transportation (DelDOT). These ponds are not open for public use but can be a source of spread for this invasive plant. Staff from DFW will coordinate efforts to control this species with DelDOT as well as other partners such as Delaware Forest Service who maintain Delaware's State Forests.

Grass Carp (*Ctenopharyngodon idella* var. *triploid*) are a regulated invasive species that can only be legally stocked in Delaware waters by permit to control aquatic vegetation. The purchase and stocking of triploid (i.e., sterile) grass carp is controlled by the permitting process (see authorized stocking pathway, page 11). Applicants must go through a permit process that includes a site visit to ensure either there is no connection to public waters, or that barriers are in place to prevent the spread downstream into public waters. Since 2002, 59 permits were issued for stocking grass carp in Delaware, totaling 2,450 individual fish. Water bodies stocked since 2019 are reinspected every three years by DFW staff to ensure compliance with barrier requirements and to evaluate vegetation control.

The intent of the permit process is to ensure that any grass carp legally stocked in Delaware waters are the triploid variety and are unable to escape from the stocked water body. However, over 50 feral grass carp have been documented by DFW surveys in the Nanticoke River system

since 1998 (DFW unpublished data). Preventing the escape and spread of this species is a priority due to the potential impact it can have on endemic aquatic vegetation that positively supports native fish species and water quality.

Phragmites (*Phragmites australis subsp. Australis*) is a species that is controlled on an annual basis in Delaware using aerial spraying via helicopter. The Wildlife section of DFW controls approximately 3,400 acres of Phragmites on public and private land each year at a cost of approximately \$225,000. Federal Wildlife Restoration Program funds with state matching funds are utilized for cost sharing when treatments are done on public lands. This cost share program with private landowners has been in existence in Delaware since 1986. Control efforts will continue on public properties that have a history of maintaining the invasive plant at a manageable level.

Existing Delaware Authorities

DNREC Division of Fish and Wildlife (DFW) – laws and regulations governing fish and wildlife within the State include possession of certain non-native species and permission requirement for stocking any fish species into non-tidal public waters (7 DE Admin. Code 3308). Many regulations give the Director of DFW control over the possession or importation of invasives, and the handling of permits:

- 7 DE Admin. Code 3545: It is unlawful to transport, purchase, possess, or sell a live invasive finfish without the written permission of the Director.
- 7 Delaware Code § 604: The DFW Director has legal authority to permit importation of any species of fish or wildlife for various purposes unless prohibited by any Federal law or regulation.
- 7 Delaware Code § 911: The DFW Director has authority through scientific collecting permits over finfish within tidal waters of the state.

Under 7 DE Admin. Code 2110, it is unlawful for any person to bring oysters from outside the State to be placed in the waters of the State without permission from the Department of Natural Resources & Environmental Control. Delaware allows limited shellfish aquaculture to be conducted in the Inland Bays. The regulations can be found under 7 DE Admin. Code 3801 Shellfish Aquaculture. The sections related to controlling this as an AIS pathway are:

12.0 Importation of Shellfish for Shellfish Aquaculture

- 12.1 It is unlawful to collect wild stock shellfish for the purposes of shellfish aquaculture from Delaware waters, except as authorized in writing by the Department.
- 12.2 It is unlawful to possess, place, or cause to be placed, undersized wild stock shellfish except as authorized in writing by the Department.
- 12.3 It is unlawful for a person to import or possess shellfish from outside of the State, for the purpose of shellfish aquaculture, without first obtaining a permit from the Department.

13.0 Shellfish Aquaculture Species

- 13.1 It is unlawful to produce or culture bivalve shellfish species other than *Crassostrea virginica*, the eastern oyster, in Rehoboth Bay, Indian River and Indian River Bay and their respective tidal tributaries.
- 13.2 It is unlawful to produce or culture bivalve shellfish species other than *Crassostrea virginica*, the eastern oyster, and *Mercenaria mercenaria*, the hard clam, in Little Assawoman Bay and its tidal tributaries.

DNREC Division of Parks and Recreation (DPR) – Under 7 DE Admin. Code 9201 it is prohibited for any person to bring into or introduce any species of domestic or wild animal onto lands administered by the DPR, DNREC.

DNREC Division of Watershed Stewardship – Regulations (Surface Water Quality Standards 7 DE Admin. Code 7401) governs nuisance species (any species of fish, other animals, or plant) living in or near the water, which causes unreasonable interference with the designated uses of the waters or of adjoining land areas.

Delaware Department of Agriculture (DDA) – A permit from the DDA is required to import, possess, sell, or exhibit any live wild mammal or live reptile not native to or generally found in Delaware (3 DE Admin. Code 7201). DDA also has authority to seek out all injurious plant pests destructive to agricultural, forest, or horticultural interest of Delaware (including insects, snails, nematodes, fungi, viruses, bacterium, etc.) (3 DE Admin. Code 1103). DDA has authority to enter any public or private premises to inspect, examine, destroy, treat, insects and diseases (3 DE Admin. Code 101).

DDA also has the authority over closed-system aquaculture practices within the State. Aquaculture activities must not promote the introduction of any non-indigenous species that harbor disease or parasites or are capable of surviving and adversely competing with indigenous plant or animal species (3 DE Admin. Code 406).

3 DE Code Chapter 29 prohibits the import, export, sale, transport, distribution, or propagation of any plant identified by the Secretary of the Delaware Department of Agriculture, with the advice of the Delaware Native Species Commission, as an invasive plant. This regulation also requires that plants identified as potentially invasive be sold with a tag that identifies the plant as potentially invasive. A violation of this regulation may result in a civil penalty of \$50 to \$500, but only after the person has had the opportunity for an administrative hearing and the opportunity to come into compliance.

Current Impacts of AIS

It is difficult to predict the impacts a given AIS may have on the aquatic environment that they invade. The following predicted impacts that priority AIS may have on native species and the environment, as well as current programs to alleviate those impacts, are based on current literature as well as research and programs that are underway in Delaware.

Predation

Predation in Delaware waters may impact threatened or endangered species covered by the Endangered Species Act, such as Shortnose Sturgeon (*Acipenser brevirostrum*) and Atlantic Sturgeon. Adult Blue Catfish and Flathead Catfish are two piscivorous AIS that can impact sturgeon. Flathead Catfish have been observed directly predating on juvenile Atlantic Sturgeon in Georgia (Flowers 2011). This is particularly concerning in Delaware because FC have shown, via telemetry tracking, to inhabit the same sections of the Delaware River as juvenile Atlantic Sturgeon (Brundage 2022). This same area of the Delaware River is also inhabited by BC (DFW unpublished data). A study performed by Evans et al. (2021) in the Chesapeake Bay confirmed the presence of Atlantic Sturgeon DNA within the stomach contents of Blue Catfish. While predation of Atlantic Sturgeon by FC and BC has not yet been confirmed in Delaware, the presence of these two species increases the level of concern. The negative impacts of BC on sturgeon are not limited to the Delaware River system. Atlantic Sturgeon migrate each fall to the Nanticoke River system in southern Delaware (Park 2023). Blue Catfish have an established population in the river and their abundance has grown (Moore 2022). The 48.2 lb. state-record Blue Catfish was caught from the Nanticoke River in 2022. Given that Atlantic Sturgeon and BC populations occur in this river system, impacts from predation are highly probable.

Concerns about predation by FC and BC are not just limited to federally listed endangered species in Delaware, but also to state endangered species and species identified in Delaware's Wildlife Action Plan (DEWAP) as Species of Greatest Conservation Need (SGCN) (DNREC 2014). The abundance of many of these species is very low or their populations are known from just one or two watersheds, making them especially vulnerable to extirpation by predation from AIS. Currently there are seven fish species listed as endangered in Delaware (7 Del. Reg §3900 Wildlife, 16.0 Endangered Species) and at least another 18 that are considered rare and susceptible to extirpation within the state. Out of 177 fish species in Delaware, 105 are listed as SGCN in the most recent version of DEWAP due to a variety of threats. Detrimental impacts by invasive catfish on recreationally important American and Hickory Shad, and ecologically important Blueback Herring, and Alewife (i.e., collectively referred to as River Herring) is a concern. Restoration efforts for American Shad in the Nanticoke River have been hampered by BC. A decline in juvenile shad abundance was noted after BC were first documented in 2015 (Moore 2022). The occurrence of FC in the northern part of the state is a concern because of potential impacts on efforts to restore shad and river herring populations to the Christina River watershed (Park 2020). There is also concern statewide at the 10 fish ladders operated by DFW for passage of adult river herring (Boucher 2021) because FC can block the ladder entrance and consume large numbers of prey that include river herring.

The potential impacts to native species by FC is not limited to lotic systems in Delaware. Research into the loss of biodiversity in Delaware's lakes and ponds has become more of a priority since the discovery of FC in Delaware's largest public pond, Lums Pond, in 2021. Electrofishing survey data has shown a decline in the Lums Pond centrarchid population in recent years (Stetzar 2022). Brown Bullhead *Ameiurus nebulosus* and White Catfish *Ameiurus catus* were historically caught by anglers in Lums Pond (Samantha Sobel, DNREC Division of Parks and Recreation, personal communication.). In 2022 a low-frequency electrofishing survey was conducted to assess the catfish population in the pond, and to remove FC. During the survey, 5.53 hours of electrofishing resulted in the capture of 32 FC and one Brown Bullhead (DFW

unpublished data). A fish community electrofishing survey conducted at Lums Pond in 2021 resulted in few observations of Brown Bullhead and no observations of White Catfish, which were previously documented (Stetzar 2022). A reduced population of these two small-bodied native catfish species is not uncommon following the introduction of FC. A FC diet study conducted on the impounded section of Deep River in the Cape Fear River drainage showed selectivity for members of the Ictaluridae family. Cannibalism was evident by the occurrence of juvenile FC in the diet, but the ictalurid component also included madtoms *Noturus* spp. and Channel Catfish *Ictalurus punctatus* (Baumann 2011). The fish community at Lums Pond will continue to be monitored, and the FC removal program will continue in the near future.

Hindrance or Loss of Recreational Opportunities

Invasive flora and fauna can hinder or eliminate water based recreational opportunities. For example, dense or complex invasive aquatic vegetation can physically limit recreational fishing and boating. AIS species out compete native species for habitat and resources, thus reducing diversity and impacting fishing opportunities for popular gamefish.

Northern Snakehead have the potential to hinder recreational fishing opportunities. While some predation of gamefish such as Largemouth Bass and Bluegill may occur, competition with native species for spawning habitat and forage is also a concern. A predictive model showed that a range expansion of NSH, in the absence of control measures, would cause a 35.5% reduction in the abundance of Largemouth Bass where the two species co-occur (Love 2012). NSH were first documented by DFW in the Nanticoke River system in 2010. Angler removal has been the only control measure implemented. A 2008 DFW mark-recapture study of the Nanticoke River Largemouth Bass population estimated a population size of 8,684 individuals (Martin 2008). A similar assessment of the population in 2021 showed a decline to 5,310 individuals (Stetzar 2021). This equates to a reduction of 39% in abundance since NSH were documented in the river system. While the invasion of NSH cannot be blamed entirely for the decline in abundance of Largemouth Bass, it is probably a factor as they occupy similar cover, feeding, and nursery habitat. DFW staff have stocked Largemouth Bass fingerlings in the Nanticoke River system since 1995 to mitigate for the limited availability of spawning habitat, and for the loss of production when bass are removed from nests by anglers in the spring and transported to central weigh-in stations during tournaments (Stetzar 2021). Although the intent of stocking fingerlings is to supplement natural reproduction, the stockings help offset bass losses from AIS predation. In 2021 the Nanticoke River system was stocked with 8,000 fingerlings (Stetzar 2021). Despite annual fingerling stockings, adult abundance estimates remain low for the Nanticoke River bass population. DFW typically purchases bass fingerlings from out of state hatcheries but recently entered into an agreement with the Delaware Department of Corrections (DOC) to grow fish for DFW at their Sussex County aquaculture facility. In 2023, DOC grew bass to larger sizes (i.e., >200mm) for stocking non-tidal waters at an affordable cost to DFW. Stocking larger fish in water bodies invaded by AIS may benefit recruitment and help mitigate the associated loss of recreational angling opportunities from low gamefish abundance.

Hindrance or loss of recreational opportunities are not limited to invasive fish species in Delaware but can also result from the presence of aquatic invasive plant species. Hydrilla and Creeping Water Primrose are two plant species that, when left unchecked, hinders aquatic recreation in Delaware. Hydrilla is a widespread AIS and is found in 17 of the 35 impoundments

managed by DFW (Martin 2008). An integrated vegetation management approach, consisting of partial herbicide treatments and mechanical harvesting, is used to control this invasive species. DFW staff treat an average of 150 acres annually with Sonar PR® to control Hydrilla, at various application rates depending on plant density and water depth. These treatments are made because unchecked weed growth can become extensive enough to exclude boating access or normal fishing activity (Zimmerman 2022). Multiple DNREC staff members also operate and maintain mechanical weed harvesters for Hydrilla and filamentous algae removal. Approximately 228 loads of aquatic vegetation with an estimated total volume of 912 cubic yards were removed from five ponds in 2022 (Zimmerman 2022).

Submerged aquatic plants and algae are not the only species that plague Delaware ponds. An emergent plant, Creeping Water Primrose, is an invasive aquatic plant that impedes navigation and fishing access on public ponds. This highly invasive, non-native plant will quickly crowd out other forms of aquatic vegetation and cover the water's surface with growth up to three feet tall. Creeping Water Primrose has plagued Wagamons Pond, located in the Broadkill River watershed, since 2006. Rooted near the shoreline, intertwined bands of this vine-like plant has grown 20-30 feet outward into Wagamons Pond. The source of this plant is Lavinia Pond, which flows into the upper portion of Wagamons Pond. It was thought for many years that Lavinia Pond was private property, but further examination by DFW and the adjacent property owner revealed that the pond itself might be owned by DFW. Pond bottom ownership in Delaware is ambiguous at times and can differ according to property deeds, surveys, etc. Additional record searches and surveys will be conducted to confirm ownership. If the pond is DFW property, the feasibility of control within this pond will be explored.

Without these management strategies in place, invasive plants would hinder native plant growth. State managed ponds would become unusable to the public due to thick beds of Hydrilla, large mats of filamentous algae, and Creeping Water Primrose. Excessive vegetation impedes boat, canoe, and kayak access and navigation, interferes with shoreline angling and waterfowl use.

Current Programs and Activities

Delaware has many different programs across multiple government agencies, councils, academia, and non-government organizations to prevent introductions, detect, and manage AIS. This management plan will direct these efforts. This list highlights efforts that are being made across the State.

Prevention

3 DE Code Chapter 29 prohibits the import, export, sale, transport, distribution, or propagation of any plant identified by the Secretary of the Delaware Department of Agriculture (DDA), with the advice of the Delaware Native Species Commission, as an invasive plant. This regulation also requires that plants identified as potentially invasive be sold with a tag that identifies the plant as potentially invasive. A violation of this regulation may result in a civil penalty of \$50 to \$500, but only after the person had an administrative hearing and the opportunity to come into compliance. The bill passed unanimously in January 2021, was signed into law by the governor in March 2021, and took effect on July 1st, 2022. The law lists 37 species as invasive, but only seven are considered aquatic. DFW staff will continue to coordinate with the Native Species Commission and DDA to add more aquatic invasive plant species to the list as necessary.

Public outreach and education are important tools to prevent the introduction and spread of AIS. Many organizations have websites tailored to provide information about invasive species. DFW, DISC, and DESG have websites dedicated to disseminating information to the public regarding AIS. The DFW invasive species page provides fact sheets and informational videos on commonly encountered AIS, contact information for the Fisheries Section, and a link to Delaware's Invasive Fish Tracker <https://dnrec.alpha.delaware.gov/fish-wildlife/fishing/invasive-species/>. The DISC website provides factsheets on invasive species as well as links and information about other organizations working with invasives. The website also has a list of plant, aquatic, and terrestrial species that DISC considers invasive https://delawareinvasives.net/?page_id=1235. DESG's website provides information similar to the DFW and DISC websites. The website also has short YouTube videos called "15 Second Science" that distribute information to the public quickly. A story map with information and the distribution of invasive crab species in Delaware can also be found on this page <https://www.deseagrant.org/invasive-species>. Employees from DESG and DFW created a story map presenting basic location and catch information of invasive fish that were reported via the Invasive Fish Tracker. This map helps anglers who may want to target invasive fish species, as well as members of the public who are interested in learning more about these species. The story map can be found at: <https://storymaps.arcgis.com/stories/833554f0e35e4633b95a382959633230>.

Detection

An online reporting tool that enables public reporting of invasive fish catches was developed by DNREC Environmental Scientist Lori Brown in 2019. The Delaware Invasive Fish Tracker application can be accessed from a mobile device, and it allows DFW to utilize the public (e.g., anglers) as a passive early detection system for new invasive species. The population of BC in the Delaware River and its tributaries, and the FC population in Lums Pond were first detected by anglers. DFW staff will continue to update species occurrences and modify Delaware's online AIS reporting system as necessary to stay technologically current and encourage angler reporting of AIS.

DFW staff have also documented new invasions of AIS during fisheries research. Electrofishing and haul seine surveys are used frequently by DFW staff to research a variety of native and invasive fish species in tidal and non-tidal waters. These fish community surveys can act as an early detection tool for new introductions or range expansions of invasive fish species. In 2010, a NSH was captured during a routine electrofishing survey for Largemouth Bass in Broad Creek, a tributary of the Nanticoke River. This was the first detection of this invasive species in Delaware waters. Juvenile BC were captured for the first time during haul seine surveys on the Nanticoke River in 2015, and on the Brandywine and Christina rivers in 2019. On average, six different electrofishing surveys are conducted on up to 15 unique water bodies annually and two haul seine surveys cover four river systems. These surveys require approximately 1,140 staff hours to complete (DFW internal data) and provide an opportunity to monitor the invasion or expansion of invasive fish species. A juvenile abundance index for BC will be generated, in part, from the haul seine survey data on the Nanticoke River and Broad Creek starting in 2023. While these surveys cover a lot of area, detect AIS, and provide valuable information on native species, they are very labor intensive. Less labor intensive methods to detect AIS are also being used. One

relatively new, but effective tool utilized by Delaware to detect native and invasive species is eDNA.

DNREC Division of Water built an eDNA lab in 2022 to analyze water samples for the presence of Delaware native and invasive species using real-time qPCR methods. Currently, the AIS eDNA monitoring is confined to northern Delaware, but future activities will include statewide sampling. The lab will stay abreast of advances in digital PCR technology that may be used to determine the presence of individual DNA copies to determine absolute numbers and work with fisheries staff to confirm detections and add appropriate species-specific markers to the eDNA database for screening.

The Delaware Environmental Monitoring Coordination Council (DEMCC), formed in 2018 and comprised of members of Delaware's environmental monitoring community from government, academic, and non-profit sectors, is a group that can help detect new introductions or expanded ranges of AIS. While council activities are not dedicated to monitoring invasive species, all monitoring efforts are in Delaware, and it expands DFW's capability to detect AIS. This type of attention by a community of experts is needed when trying to detect AIS across an entire State. While prevention and early detection of AIS is important to minimize the invasion of new species, the management of established AIS populations is also a priority.

Management

Delaware's aquatic plant management program controls multiple invasive species as well as natives that have grown to a nuisance level. The aquatic invasive plants primarily controlled by this program are: Creeping Water Primrose and Hydrilla. An integrated vegetation management approach, consisting of partial herbicide treatments and mechanical harvesting is used for control. During 2022 approximately 228 loads of aquatic vegetation with an estimated total volume of 912 cubic yards was removed from five ponds and spread on State wildlife areas in close proximity to the ponds. Herbicide treatments for control of Hydrilla and were conducted on two ponds. Approximately 84.3 acres were treated with Sonar PR™® at various application rates depending on plant density and water depth (Zimmermann 2022). By using both mechanical and chemical methods of control Delaware DFW is able to keep aquatic vegetation from being a nuisance to outdoor recreation such as fishing and boating.

Aerial Phragmites control on public as well as adjoining private property is performed by DFW's Wildlife Section staff. The planning and implementation of the program requires approximately 25% of a Biologist's time. The annual budget of \$225,000 covers the aerial spraying of approximately 3,400 acres. This program is aerial only and DFW does not assist with ground-based control efforts on private lands. The Natural Resources Conservation Service (NRCS) manages private landowner requests to participate in the United State Department of Agriculture-Environmental Quality Incentives Program which provides federal funds to reimburse private landowners. This significantly reduces the cost to private landowners as they typically are only responsible for 12% of the total application cost if enrolled in the program. The Natural Resources Conservation Service reviews applications and if the landowner is approved, the information is shared with DFW, which then manages the mapping and herbicide application. DFW makes all decisions regarding fieldwork and herbicide spraying, whereas the NRCS oversees the applications to establish contracts for federal assistance, and issues payments to

landowners based on the acreage of Phragmites sprayed. This effective cost-share program has been utilized by DFW and private landowners in Delaware to control Phragmites since 1986. A similar cost-share structure is being investigated by DFW for the control of other aquatic plants on private property. The overall cost to the Division and the lack of staff are current hurdles that need to be addressed.

Control of invasive species from public ponds is not limited to plants in Delaware. Flathead Catfish, weighing up to 40 pounds, were reported by anglers from the Brandywine River in northeastern Delaware during 2018. A single catch of this species in Lums Pond during a Largemouth Bass fishing tournament in 2020 prompted further investigation by DFW to determine the extent of the invasion. Lums Pond, located in New Castle County Delaware, is the largest freshwater pond in the state at 81 hectares. It is heavily fished by the public and is the location of an annual children's fishing tournament hosted by DFW's Natural Resources Police and Fisheries Section staff. Lums Pond is also one of the most utilized ponds by fishing clubs for Largemouth Bass tournaments with 3,632 angling hours reported from 30 tournaments since 2008 (Stetzar 2023). Data from seining and electrofishing surveys have shown a decline in the centrarchid population in recent years (Stetzar 2022). Electrofishing surveys were conducted by DFW Fisheries staff July - October 2022 resulting in the removal of 31 (7" to 37") FC from Lums Pond. The most common size class of FC removed was 19" to 24", representing 16 of the 31 fish captured (51%). This is concerning because FC in that size class are an estimated four to six years old. Flathead Catfish generally become sexually mature at four to five years old or 18 inches in length. Most of the catfish captured in the survey were potentially mature enough to reproduce and expand this predatory catfish population. A preliminary stomach contents analysis was dominated by Yellow Perch and White Perch but Bluegill, Black Crappie, and an unknown catfish species were also consumed. Removal efforts will continue in the future to curb the FC population and reduce their impact on the fish community, especially to native catfish that co-occur.

DNREC will continue efforts to prevent, detect, and manage the AIS within state boundaries. Because of Delaware's high connectivity to neighboring states, this effort will take inter-state and inter-agency cooperation. Delaware will continue to alert other states, agencies, task forces, and panels as necessary to address AIS issues in the Mid-Atlantic region. Delaware will continue to share AIS data with USGS for inclusion in the NAS database.

Gaps in AIS Prevention, Response, and Management

There are many gaps in the prevention, response, and management of AIS in Delaware. There is a lack of authority to regulate certain activities and a lack of enforceable laws or regulations related to AIS. An overall lack of staff dedicated to AIS issues in Delaware has also slowed efforts to prevent, respond to, and manage AIS.

Regulations

Current regulations provide DFW minimal control over the introduction or spread of AIS within the State. 7 DE Admin. Code 3308 prohibits stocking any fish species in non-tidal public waters without written authorization from the Division of Fish and Wildlife. However, this regulation does not prohibit stocking in tidal waters of the State. Fishing tournaments in tidal waters are the primary reason for this loophole. Fishing tournaments are common in tidal waters, especially in

the Chesapeake Bay watershed. The Nanticoke River originates in Delaware and flows through the southwestern portion of the state into Maryland before emptying into the Chesapeake Bay. Anglers that start a tournament in Delaware waters will often fish in Maryland waters, and transport fish back to Delaware for a central weigh-in. Anglers fishing in Maryland based tournaments may also fish in Delaware waters, but weigh-in and stock the fish in Maryland. The fish are “stocked” at the weigh-in site regardless of where they were caught. This releasing of fish does not violate any Delaware regulations. This regulation provides a loophole that could allow for the stocking of potentially invasive fish species in public tidal waters if they are not prohibited by other regulations. A Common Carp for example, could be captured, transported, and released into public tidal waters without violating any current regulations.

This regulation also does not address the discard (i.e., release of live bait) other than fish. An angler could use an invasive crayfish species as bait and discard the unused crayfish into public tidal and non-tidal waters of the State and not violate any regulations.

Under 7 DE Admin. Code 3545: Invasive Finfish, it is unlawful to transport, purchase, possess, or sell a live invasive finfish without the written permission of the DFW Director. It is also unlawful to stock any invasive finfish, including the eggs thereof or other biological material, capable of spread, reproduction, or propagation, into the tidal waters of Delaware without the written permission of the DFW Director. Under this regulation invasive finfish are defined as any species of the family Channidae, including but not limited to the Northern Snakehead (*Channa argus*) and Blotched Snakehead (*C. maculata*); Blue Catfish (*Ictalurus furcatus*); Flathead Catfish (*Pylodictis olivaris*); Walking Catfish (*Clarias batrachus*); and Grass Carp (*Ctenopharyngodon idella*). Besides the species listed, there are few regulations that address the legality of stocking non-native or invasive species in private water bodies. This regulation also does not address the transport, purchase, possession, or sale of a live AIS that is not a finfish or is not listed as a prohibited species.

Current laws and regulations will be assessed to determine the effectiveness at stopping the introduction and spread of AIS. If new laws and regulations are necessary, pertinent parties will be consulted to ensure the regulatory process runs smoothly and the laws and regulations are easily understood by the public as well as enforceable. A dedicated law enforcement effort will be needed to impose current and new regulations.

Management

The lack of authority to address AIS on private property is a gap in Delaware’s ability to manage and control the spread of AIS. DFW has no inspection authority to monitor or survey for invasive species on private lands, nor the emergency authority to force the treatment or eradication of an invasive species on private property. State Senate Bill No. 229, enacted in 2018, requires DNREC staff to obtain written consent prior to physically entering onto private property for the purpose of collecting Natural Resource Data. DFW offers advice to homeowners but cannot require treatment or removal of the AIS.

A cost-share program has been effective and utilized by DFW Wildlife Section and private landowners in Delaware to control Phragmites since 1986. A similar structure is being

investigated by DFW to cost share for the control of other aquatic plants on private property (see Current Programs and Activities, Management, page 28).

Marine Data

Fisheries independent surveys conducted by DFW are primarily focused on freshwater and estuarine environments, with few surveys that could potentially detect AIS in marine environments. Most of Delaware is bordered by the Delaware River and Delaware Bay to the East and tributaries of the Chesapeake Bay to the West. There are also three inland bays in the southeastern part of the state, including one with a direct connection (i.e., Indian River Inlet) to the Atlantic Ocean. Only a small portion (28 miles) of Delaware borders the Atlantic Ocean. DFW conducts annual trawl surveys at site-specific locations in the Delaware Bay and inland bays. The lack of coverage within the marine environment creates a situation where Delaware is vulnerable to AIS invasions from associated marine vectors.

One potential tool for passively surveying the marine environment is the Access Point Angler Intercept Survey (APAIS). The intercept surveys are conducted by DFW Fisheries Section personnel at fishing access points along the coast of Delaware. Questions that are asked during the survey relate to the species and number of fish kept or released. By adding a question pertaining to catches of invasive species that include species such as Lionfish (Appendix 1), Delaware could strengthen its early detection of marine AIS. This action will be discussed with DFW Fisheries Section and APAIS staff to determine its plausibility given time and staffing constraints.

Objectives, Strategies, and Actions

The actions identified in this section are essential components of Delaware's statewide AIS management plan. The timing and implementation of the actions listed below will require additional funding sources, cross-jurisdictional cooperation, and be determined by state and Federal processes.

1. Prevent New AIS Introductions into Delaware Waters and Detect Introductions Early

1.A Strategy Anticipate future invaders and their potential impacts

1.A.1 Action: Foster Relationships

Foster stronger relationships with MAPAIS, ANSTF, surrounding states, and interested parties within Delaware. The focus will be on neighboring states including Maryland, New Jersey, and Pennsylvania as Delaware's waterways are most interconnected with these states. Interested parties within the state are DISC, Delaware Sea Grant, Delaware's Master Naturalist Program, Native Species Commission, and multiple divisions and sections within DNREC. This is not an exhaustive list at this time; an approved management plan will help generate future relationships with other interested parties.

1.A.2 Action: Update AIS List

DNREC staff will continue to recommend species suitable for vetting through DISC's invasive species matrix to assess their potential for listing by DISC. The aquatic invasive species list in Delaware's AIS management plan should match DISC's Invasive Species List, but also include species listed in Delaware or Federal regulations. New potential species for listing should be assessed every two years at a minimum and be discussed at periodic meetings of the DISC and the Native Species Commission.

1.A.3 Action: eDNA

Use real-time qPCR methods for eDNA monitoring to detect the presence of AIS and stay abreast of advances in digital PCR technology that may be used to determine absolute numbers. Add appropriate anticipated species-specific markers to the eDNA database for screening. Species that are currently unknown in Delaware waters should be included in eDNA analysis protocols to aid detection.

1.B Strategy Take action to prevent or minimize the chance of AIS introduction via identified pathways.

1.B.1 Action: Assess current laws and regulations

Assess current laws and regulations to determine effectiveness at stopping the introduction and spread of AIS. Presentations will be made to gather input from the Advisory Council on Tidal Finfisheries, the Advisory Council on Wildlife and Freshwater Fish, and DNREC's Natural Resources Police will be consulted to ensure the regulatory process runs smoothly and the laws and regulations are easily understood by the public as well as enforceable. Concurrence from Advisory Council members will be obtained to warrant regulatory action imperative for AIS management.

1.B.2 Action: New Laws and Regulations

Generate new regulations to address gaps and loopholes that may inadvertently or intentionally introduce AIS. Introduce legislation aimed at curtailing the introduction and spread of AIS into Delaware waters. Policymakers as well as the public and DNREC's Natural Resources Police will be involved in the regulatory process.

1.C Strategy Identify new and use existing outlets to conduct outreach and education to raise public awareness and inform various industries on the consequences of AIS introduction.

1.C.1 Action: Outreach and Education Beyond DNREC

Continue to build relationships with organizations and agencies beyond DNREC that provide AIS outreach and education for the public. Delaware Sea Grant and DISC have already produced educational materials and videos. University of Delaware's Master Naturalists Program is an opportunity to train and educate members of the public on the importance of stopping the introduction and spread of AIS. Utilize materials from

established programs such as Stop Aquatic Hitchhikers!, Habitattitude, and Clean Drain Dry.

1.C.2 Action: Develop Educational Materials

Develop educational materials as necessary to educate the general public as well for specific audiences such as angling groups and NGO's. The materials could include signage, pamphlets etc., and digital media developed for public distribution, and for private entities such as marinas, and pet trade/aquarium vendors.

1.C.3 Action: Guidance

Provide guidance to private landowners and businesses that have an invasive on their property. This may include outreach materials and or requested site visits.

1.C.4 Action: Update Species Occurrences

Update species occurrences and modify Delaware's online AIS reporting system as necessary to stay technologically current. Utilize the public (e.g., anglers) as an early detection system for new invasive species using outreach tools. DFW's 'Angler's Pocket Guide' is an example of outreach materials produced to educate the public on the identification of invasive species. A copy of this guide can be found in Appendix 4.

1.C.5 Action: Staff Education

Educate DNREC staff on the identification of current AIS and species of concern. This will allow early detection of these species by field staff while conducting research throughout Delaware.

1.C.6 Action: Strategies to Control AIS

Develop a list of strategies for public entities, such as DNREC, to control high priority AIS. Cost effectiveness, and practicality will be taken into consideration when developing these strategies. Examples of strategies might include messaging on packaging at the point of sale, incentives for both commercial and recreational fisheries, and outreach at marinas, and pet/aquarium stores. The use of these strategies will depend on funding availability and cooperation from stakeholders.

2. Rapid Response to New Introductions

2.A Strategy Develop a rapid response system to contain or eradicate an AIS introduction

2.A.1 Action: Rapid Response Plan

Develop a detailed rapid response plan for Delaware. The plan will identify key personnel and include the names and phone numbers of response staff throughout the state as well as include an organizational structure. Supplies needed to launch a response will be kept in specified locations to ease retrieval and avoid delays. Create and maintain a database of updated contact information and gear locations to ensure a timely response.

This database should be updated as personnel and gear locations change. This database should include the locations of essential equipment such as trucks, boats, motors, sampling gear, pesticides and sprayers needed to control a sudden introduction.

2.A.2 Action: Rapid Response Implementation

Develop and conduct personnel training, inventory equipment needs, and identify storage locations to support implementing the rapid response plan.

3. Control and Management of Aquatic Invasive Species

3.A Strategy When possible, control aquatic invasive species that have significant impacts in Delaware through various removal and control methods including integrated pest management strategies. Reduce harmful effects of AIS through management when eradication is not possible.

3.A.1 Action: Best Management Practices

Conduct studies and review literature on high priority AIS in the Mid-Atlantic to determine best management practices for removing or reducing the biomass of these species. Cost effectiveness, and practicality should be taken into consideration when developing these strategies.

3.A.2 Action: Explore Cost-assistance for Private Landowners

Explore the development of incentive programs or cost-assistance for private landowners to control invasive species, especially if there is a potential for the AIS to escape into public waterbodies.

3.A.3 Action: Licensing

Obtain and maintain licenses, permits and certifications needed for controlling potential invaders. This includes a pesticide applicators license, as well as a piscicide license to apply chemicals such as Rotenone. The current DNREC general permit for discharges from the application of pesticides will be addressed to include this effort, so that any work performed meets NPDES compliance standards. This will allow DFW staff to control current invasions as well as aid eradication efforts.

3.A.4 Action: Fisheries Plant Management

Continue to monitor and control invasive aquatic plants such as Hydrilla, Creeping Water Primrose, and Parrot's Feather that occur in Delaware's public ponds using an integrated pest management approach.

3.A.5 Action: Wildlife Phragmites Program

Continue to use various methods to control Phragmites in Delaware's public waterways and wetlands.

4. Research and Restoration

4.A Strategy Research the effects that aquatic invasive species are having on native plant and animal communities and possible control measures to minimize impacts.

4.A.1 Action: Establish Long-term Monitoring

Establish long-term monitoring studies or utilize other DNREC studies that determine AIS biomass or estimate population abundance. The results of these studies can be used to determine a plan for control and assess if control methods are impacting AIS populations.

4.A.2 Action: Research Impacts

Conduct research to assess the impacts of AIS on native aquatic plant and animal communities and base restoration efforts on the results. Native plant and animal species should be used when possible to combat AIS introductions. Through field research and literature review, restoration expectations and goals should be prioritized and set at a manageable level.

4.A.3 Action: Coordination

Coordinate efforts to research AIS between State and Federal agencies as well as academic institutions and nonprofit groups to eliminate duplication of effort.

4.A.4 Action: Research Funding

Support research necessary to control, manage, and assess the status of AIS in Delaware by providing funding and dedicated staff.

Implementation Table. This implementation table was designed to define possible funding sources and agencies involved in the continued prevention, detection, management, and research of AIS in Delaware. A Status column was added to describe how the action will be implemented when necessary. The Lead Organization (LO) is the organization that will coordinate the effort to implement the associated action. The Cooperating Organizations (CO) are organizations or other entities within the state government that will take part in implementing the action. In instances where no budget is given, the action has not been initiated, or the action will be part of a salary that is already listed under another action. Many of these actions will fall under the salary of DFW's newly established AIS Biologist position.

Objective	Strategy/Action	Status	Funding	LO	CO	FY 23	FY 24-27
1. Prevent new AIS introductions into Delaware waters and detect introductions early	1.A Anticipate future invaders and their potential impacts						
	1.A.1 Foster Relationships	This action is ongoing and travel to various conferences through the Mid-Atlantic will be helpful to support this action. Current projects funded by USFWS grant	DNREC, USFWS, AIS Program	DNREC	MAPAIS, ANSTF,	\$1,100	\$4,400
	1.A.2 Update AIS List	Associated cost is DISC membership dues. Current projects funded by USFWS grant	DNREC	DNREC	DISC	\$20	\$80
	1.A.3 eDNA	Current project funded by USFWS grant	DNREC, USFWS	DNREC		\$25,000	\$100,000
	1.B Take action to prevent or minimize the chance of AIS introduction via identified pathways						
	1.B.1 Assess current laws and regulations.		DNREC, USFWS, AIS Program	DNREC			
	1.B.2 New Laws and Regulations		DNREC, USFWS, AIS Program, DDA	DNREC	DEGA, DDA		
	1.C Identify new and use existing outlets to conduct outreach and education to raise public awareness and inform various industries on the consequences of AIS introduction.						

Objective	Strategy/Action	Status	Funding	LO	CO	FY 23	FY 24-27
1. Prevent new AIS introductions into Delaware waters and detect introductions early	1.C.1 Outreach and Education Beyond DNREC	Delaware Sea Grant and DISC have already produced educational materials and videos.	DNREC, USFWS, AIS Program, UD	DNREC	UD, DISC, DESG	\$3,000	\$1,200
	1.C.2 Develop Educational Materials	Cost is generated by materials to print and post signs. Current projects funded by USFWS grant	DNREC, USFWS	DNREC		\$100	\$400
	1.C.3 Guidance	Current projects funded by USFWS grant	DNREC, USFWS	DNREC		\$1,000	\$4,000
	1.C.4 Update Species Occurrences	Currently funded by USFWS grant	DNREC, USFWS, AIS Program	DNREC	DISC	\$1,000	\$4,000
	1.C.5 Staff Education	This action will be a yearly training held at various DNREC staff meetings	DNREC, AIS Program	DNREC		\$600	\$2,400
	1.C.6 Strategies to Control AIS		DNREC, USFWS, AIS Program	DNREC		\$600	\$2,400
2. Rapid Response to an introduction	2.A Develop a rapid response system to contain or eradicate an AIS introduction						
	2.A.1 Rapid Response Plan		DNREC, USFWS, AIS Program	DNREC		\$2,000	\$8,000
	2.A.2 Rapid Response Implementation	Travel expenses for continuing education	DNREC, USFWS, AIS Program	DNREC		\$1,000	\$4,000
3. Control and Management of Aquatic Invasive Species	3.A When possible, control aquatic invasive species that have significant impacts in Delaware through various removal and control methods including integrated pest management strategies. Reduce harmful effects of AIS through management when eradication is not possible						
	3.A.1 Best Management Practices		DNREC, USFWS, AIS Program	DNREC		\$1,000	\$4,000

Objective	Strategy/Action	Status	Funding	LO	CO	FY 23	FY 24-27
3. Control and Management of Aquatic Invasive Species	3.A.2 Explore Cost-assistance for Private Landowners	Possibly expand DISC small grants program	DNREC, USFWS, AIS Program, DISC	DISC	DNREC	\$2,000	\$8,000
	3.A.3 Licensing	These licenses will allow DFW staff to control current invasions as well as aid eradication efforts. Current projects funded by USFWS grant	DNREC, USFWS	DNREC		\$300	\$1,200
	3.A.4 Fisheries Plant Management	This includes part salary and pesticides and contracts needed for applications. Current projects funded by USFWS and NOAA grants	DNREC, USFWS,	DNREC	DNERR	\$200,000	\$800,000
	3.A.5 Wildlife Phragmites Program	This includes part salary and pesticides and contracts needed for applications. Current projects funded under NOAA and USFWS	DNREC, USFWS,	DNREC	DNERR	\$225,000	\$900,000
4. Research and Restoration	4.A Research the affects aquatic invasives are having on native communities and possible control measure the alleviate these affects.						
	4.A.1 Establish Long-term Monitoring	The cost would cover multiple salaries across multiple projects	DNREC, USFWS, AIS Program	DNREC		\$43,763	\$175,052
	4.A.2 Research Impacts	No projects have been established yet, cost is an estimate	DNREC, USFWS, AIS Program	DNREC		\$30,000	\$120,000
	4.A.3 Coordination		DNREC, USFWS, AIS Program	DNREC			
	4.A.4 Research Funding	This cost covers the full salary of the AIS Scientist who will perform or coordinate many of the actions listed above. Position currently funded by USFWS grant.	DNREC, USFWS, AIS Program	DNREC		\$50,500	\$202,000
Total						\$578,783	\$2,315,132

Priorities for Action

There are 22 actions outlined to fully implement this plan. There are neither the funds nor time to implement all actions that are outlined in this plan in the next five years. Therefore 10 actions were prioritized based on available funds, time, and impact on invasive species. These are not in order by priority; all actions listed below are important to the control of aquatic invasive species in Delaware.

1. Foster stronger relationships with MAPAIS, ANSTF, surrounding states, and interested parties within Delaware. (Action 1.A.1).
2. Continue to suggest species suitable for vetting through DISC's invasive species matrix to assess their potential for listing by DISC. The aquatic invasive species list in Delaware's AIS management plan should match DISC's Invasive Species List, but also include species listed in State or Federal regulations (1.A.2).
3. Assess current laws and regulations to determine effectiveness at stopping the introduction and spread of AIS. Presentations will be made to gather input from the Advisory Council on Tidal Finfisheries, the Advisory Council on Wildlife and Freshwater Fish, and DNREC's Natural Resources Police will be consulted to ensure the regulatory process runs smoothly and the laws and regulations are easily understood by the public as well as enforceable (1.B.1).
4. Develop a detailed rapid response plan for Delaware. The plan will identify key personnel and include the names and phone numbers of response staff throughout the state as well as include an organizational structure. Supplies needed to launch a response will be kept in specified locations to ease retrieval and avoid delays. Create and maintain a database of updated contact information and gear locations to ensure a timely response (2.A.1).
5. Develop and conduct personnel training, inventory equipment needs, and identify storage locations to support implementing the rapid response plan (2.A.2).
6. Conduct studies and review literature on high priority AIS in the Mid-Atlantic to determine best management practices for removing or reducing the biomass of these species. Cost effectiveness, and practicality should be taken into consideration when developing these strategies (3.A.1).
7. Continue to monitor and control invasive aquatic plants such as Hydrilla, Creeping Water Primrose, and Parrot's Feather that occur in Delaware's public ponds using an integrated pest management approach (3.A.4).
8. Continue to use various methods to control Phragmites in Delaware's public waterways and wetlands (3.A.5).

9. Establish long-term monitoring studies or utilize other DNREC studies that determine AIS biomass or estimate population abundance. The results of these studies can be used to determine a plan for control and assess if control methods are impacting AIS populations (4.A.1).
10. Support research necessary to control, manage, and assess the status of AIS in Delaware by providing funding and dedicated staff (4.A.4).

The priorities of Delaware for AIS management align with the priorities of ANSTF. Not all ANSTF priorities can be fully addressed at this time, but many will be at least partially implemented by this plan in the first 5 years.

Develop cost-efficient genetic tools (e.g., metabarcoding, eDNA) and evaluate their potential and limitations for use in early detection of new species introductions.

Delaware Action/Strategy (1.A.3 eDNA) will address this ANSTF priority. Delaware will use real-time qPCR methods for eDNA monitoring to detect the presence of AIS and stay abreast of advances in digital PCR technology that may be used to determine absolute numbers of AIS present. Currently, eDNA AIS monitoring is confined to northern Delaware, but future activities will include statewide sampling. Adding appropriate anticipated species-specific markers to the eDNA database for screening will be important. Species that are currently unknown in Delaware waters should be included in eDNA analysis protocols to aid detection.

Develop and evaluate tools and methods to more effectively track movement of organisms from established AIS populations and spread into uninfested locations.

Funding was secured for an acoustic telemetry study of BC in the Delaware portion of the Delaware River and its tributaries. Adult BC have been captured in these waters since 2013, but establishment of a population has not been confirmed. This study has the potential to fill data gaps related to the movement and establishment of this species by tracking individuals within the Delaware River and potentially upriver into New Jersey and Pennsylvania.

Delaware's acoustic telemetry array coverage will be evaluated using data from tagged AIS to determine efficient coverage of areas inhabited by AIS. This will also help Delaware to detect acoustically tagged AIS that could invade Delaware waters via connected water ways such as the Delaware River, and the C&D Canal.

Delaware's Invasive Fish Tracker app will be evaluated and upgraded as necessary to effectively track AIS movements. Additions to the app may include new species, or new interactive material to inform managers and the public of AIS spread.

Conduct a comparative analysis of existing AIS control options, evaluating these tools for aspects such as effectiveness, cost, feasibility, environment impact, and human health impacts to inform development of control strategies and plans.

Delaware Action/Strategy (3.A.1) of this plan is to conduct studies and review literature on high priority AIS in the Mid-Atlantic to determine best management practices for removing or reducing the biomass of these species. Cost effectiveness, and practicality should be taken into consideration when developing these strategies.

Evaluate/review control options and strategies at the federal level (e.g., USFWS) to determine how these strategies can best align with Delaware's control strategies and plan.

Pursue environmentally sound technologies (e.g., biocontrol, chemical, mechanical) to aid in the eradication or control of AIS.

The targeted removals of FC at Lums Pond as described above achieves this ANSTF goal and meets Delaware Action/Strategy (4.A.2). Low frequency electrofishing techniques are being used to remove this invasive species. By using low frequency electrofishing, removals are more efficient, and other species are minimally affected.

Delaware will continue to eradicate and control AIS and will utilize sound technological advances to eradicate and manage newly detected invasions as needed.

Program Monitoring and Evaluation

The management actions and strategies within this plan will be evaluated on an annual basis to ensure they achieve the desired outcomes. The number of actions listed in the implementation table that were initiated, ongoing, or completed will be used as a benchmark to quantify annual progress. Some actions are difficult to quantify, such as building relationships with interested groups. This type of action will be evaluated based on the number of participating partners or associates actively engaged with the AIS coordinator or that are implementing actions in this plan. Education and outreach actions will be evaluated by metrics such as the:

- Number of people that attend AIS presentations.
- Number of 'clicks' or opens of AIS social media campaigns (including average time of engagement).
- Percentage increase in public reporting of AIS after a press release, and
- Number of requests for outreach materials.

Evaluation of control measures used to address widespread species such as *Phragmites* and *Hydrilla*, will be based on the level of localized control achieved. Density estimates or coverage area will be compared pre and post-treatment to determine the most effective control method. Monitoring long-term biomass, abundance, or population trends is important for evaluating the effectiveness of many control or management actions. Comparing these data sets will help to determine the increase in AIS populations, and therefore the effectiveness of other control measures. Uncontrollable factors such as a change in physical, chemical, and biological factors may impact the effectiveness of management actions. Negative impacts to management strategies would be discovered through the data comparison section of the program evaluation process. Management strategies will be adjusted as necessary to attain the objectives set forth in this plan. Data resulting from the actions in this plan will be shared among interested parties and used as content or to support information in public outreach and education materials.

The data and information resulting from completion of the actions outlined in this plan will be included in Federal aid grant reports, presented to the councils and committees previously described, and shared with other jurisdictions. This plan will also be posted on the DFW invasive species webpage, which is available to the public at any time. This feedback will aid in streamlining the plan and guiding implementation so that Delaware can more effectively combat issues caused by AIS. The data and feedback will be used to adjust strategies and actions as necessary. The priority actions will be amended by DFW as new information, priorities, or threats arise. Updates to this plan and its goals and associated actions will mirror the research priorities set forth by ANSTF. Key contributors to the current Plan can be found in Appendix 5. Any major revisions made to this plan in the future will be noted in Appendix 6. Public comments received for future actions or revisions of this plan will be appended to Appendix 7.

Public Comment Period

The Plan was posted on the DNREC public notice website on October 17th, 2023, and was open for comment until November 15th, 2023. The public comment period was also announced on DFW's Facebook page and was sent to DNREC Fisheries Listserv subscribers. The Fisheries Listserv email group receives notices of regulatory changes, public hearings and workshops, and fisheries council meetings and agendas. Only one comment was received during the public comment period (Appendix 7).

After the public comment period ended, members of the Shellfish Advisory Council, the Advisory Council on Wildlife and Freshwater Fish, the Tidal Finfish Advisory Council, and Delaware Invasive Species Council were invited to comment on the Plan. No comments were received from council members. A complete timeline can be found in Appendix 6.

Literature Cited

- ANSTF (Aquatic Nuisance Species Task Force) 1994. Aquatic Nuisance Species Program. Aquatic Nuisance Species Task Force, Washington D.C., 150 pages.
- Baumann, J.R. and Kwak, T.J., 2011. Trophic relations of introduced Flathead Catfish in an Atlantic river. *Transactions of the American Fisheries Society*, 140(4), pp.1120-1134.
- Boucher, J.M. 2021. Anadromous Species Investigations. F-47-R-30 Interim Performance Report. Federal Aid in Fisheries Restoration Anadromous Species Investigations, Study 2: Shad and Herring Research, Activity 5: Delaware Fish Ladder Operation, Maintenance and Biological Monitoring. Delaware Division of Fish and Wildlife, DNREC, Dover, DE.
- Brown, J.J., Perillo, J., Kwak, T.J. and Horwitz, R.J., 2005. Implications of *Pylodictis olivaris* (flathead catfish) introduction into the Delaware and Susquehanna drainages. *Northeastern Naturalist*, 12(4), pp.473-484.
- Brundage, H.M, III., and Park, I. A. 2022. First Observations of Movements of Invasive Flathead Catfish (*Pylodictis olivaris*) in the Tidal Delaware River Based on Acoustic Telemetry. *Northeastern Naturalist*, 29(4), N61-N71.
- Delaware Department of Natural Resources and Environmental Control. 2014. Delaware Wildlife Action Plan 2015-2025, DNREC, Dover, DE.
- Evans, H. K., Bunch, A. J., Schmitt, J. D., Hoogakker, F. J., and Carlson, K. B. 2021. High-throughput sequencing outperforms traditional morphological methods in Blue Catfish diet analysis and reveals novel insights into diet ecology. *Ecology and Evolution*, 11(10), 5584-5597.
- Flowers, H.J., Bonvechio, T.F. and Peterson, D.L. 2011. Observation of Atlantic sturgeon predation by a flathead catfish. *Transactions of the American Fisheries Society*, 140(2), pp.250-252.
- Graham, K. 1999. A review of the biology and management of blue catfish. In *Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium* (Vol. 24, pp. 37-49).
- Hewitt, C. L., and Campbell, M. L. 2007. Mechanisms for the prevention of marine bioinvasions for better biosecurity. *Marine pollution bulletin*, 55(7-9), 395-401.
- Lesser, C.A. 1966. Aquatic vegetation survey. Final Report Federal Aid in Fish Restoration Project No. F-21-R. DE Game & Fish Commission, Dover.
- Love, J.W. and Newhard, J.J., 2012. Will the expansion of Northern Snakehead negatively affect the fishery for Largemouth Bass in the Potomac River (Chesapeake Bay)?. *North American Journal of Fisheries Management*, 32(5), pp.859-868.
- Martin, C.C. 2008. Aquatic Vegetation Program – Inventory and Control of Aquatic Weeds in Public Fishing Ponds in Delaware. Annual Report of Federal Aid in Fisheries Restoration

Project F-70-D-6. Department of Natural Resources and Environmental Control, Division of Fish and Wildlife, Dover, DE.

Moore, J.E. 2022. Anadromous Species Investigations. F-47-R-30 Interim Performance Report. Federal Aid in Fisheries Restoration Study 2: Nanticoke River Shad and Herring Restoration, Activity 2: Nanticoke River shad and river herring restoration, Activity 3: Determination of a juvenile and adult abundance index for American and Hickory Shad in the Nanticoke River and tributaries. Delaware Division of Fish and Wildlife, DNREC, Dover, DE.

National Invasive Species Council. 2001. Meeting the Invasive Species Challenge: National Invasive Species Management Plan. Washington, DC 80pp.

National Invasive Species Council. Management Plan: 2016–2018. Washington, DC, 2016.

Northern Snakehead Working Group (NSWG). 2011. National Control and Management Plan for the Northern Snakehead (*Channa argus*). Submitted to the Department of Interior (Draft).

Park, I.A. 2020. Anadromous species investigations. F-47-R-25 annual report. Federal Aid in Fisheries Restoration Study 2: Shad and herring research, activity 4: Adult alosine abundance, juvenile alosine abundance, and American Shad nursery habitat evaluation in the Christina system. Delaware Division of Fish and Wildlife, DNREC, Dover, DE. 16 pp.

Park, I. A. 2023. Molecular assessment of a stressed Atlantic sturgeon nursery habitat: The Nanticoke River- Marshyhope Creek, Chesapeake Bay. Delaware Division of Fish and Wildlife. Interim Report to National Marine Fisheries Service. Award NA22NMF4720108

Reilly Jr, F.A. 2005. Delaware Invasive Species Management Plan. Delaware Invasive Species Council.

Schloesser, R. W., Fabrizio, M. C., Latour, R. J., Garman, G. C., Greenlee, B., Groves, M., and J. Gartland. 2011. Ecological role of blue catfish in Chesapeake Bay communities and implications for management.

Smith, G.D., D.L. Massie, J. Perillo, T. Wagner, and D. Pierce. 2021. Range expansion and factors affecting abundance of invasive Flathead Catfish in the Delaware and Susquehanna rivers, Pennsylvania, USA. *North American Journal of Fisheries Management* 41 (Special Issue 1): S11–S26.

State of Delaware. 2020. Combined watershed assessment report (305b) and determination for the Clean Water Act Section 303 (d) list of waters needing TMDLs. DNREC, Division of Watershed Stewardship, Watershed Assessment and Management Section.

Stetzar, E. 2021. Tidal Freshwater Fisheries Management Program-Enhancement and Monitoring of Tidal River Bass Populations. Annual Report of Federal Aid in Fisheries Restoration Project F-75-R-16. Department of Natural Resources and Environmental Control, Division of Fish and Wildlife, Dover, DE.

Stetzar, E. 2022. Delaware's Freshwater Fisheries Management Program-Pond Fish Management. Annual Report of Federal Aid in Fisheries Restoration Project F-41-R-30, Year 4. Department of Natural Resources and Environmental Control, Division of Fish and Wildlife, Dover, DE.

Stetzar, E. 2023. Delaware's Freshwater Fisheries Management Program. Freshwater Fishing Statistical Survey– Tournament Reporting Program. Annual Report- Federal Aid in Fisheries Restoration Project F-41-R-30 (Year 5). Delaware Division of Fish and Wildlife, Dover, DE

Zimmermann, M. 2018. Aquatic Vegetation Program. Federal Aid in Fisheries Restoration F-70-D-16 Interim Performance Report. Department of Natural Resources and Environmental Control, Division of Fish and Wildlife, Dover, DE.

Zimmermann, M. 2022. Aquatic Vegetation Program. Federal Aid in Fisheries Restoration F-70-D-16 Interim Performance Report. Department of Natural Resources and Environmental Control, Division of Fish and Wildlife, Dover, DE.

Appendices

Appendix 1. DISC list of Invasive Aquatic Species and DISC Watch list

Scientific Name	Common Name
<i>Acorus calamus</i>	European Sweetflag
<i>Alliaria petiolata</i>	Garlic Mustard*
<i>Anguillicola crassus</i>	Eel Swimbladder Nematode
<i>Carcinus maenas</i>	Green Crab
<i>Channa argus</i>	Northern Snakehead
<i>Corbicula fluminea</i>	Asian Clam
<i>Ctenopharyngodon idella</i> var. <i>triploid</i>	Grass Carp (triploid)
<i>Cyprinus carpio</i>	Common Carp
<i>Eriocheir sinensis</i>	Chinese Mitten Crab
<i>Fallopia japonica</i>	Japanese Knotweed*
<i>Ficaria verna</i>	Lesser Celandine*
<i>Hemigrapsus sanguineus</i>	Asian Shore Crab
<i>Hydrilla verticillata</i>	Hydrilla
<i>Ictalurus furcatus</i>	Blue Catfish
<i>Iris pseudacorus</i>	Yellow Flag Iris, Water Flag
<i>Lythrum salicaria</i>	Purple Loosestrife
<i>Microstegium vimineum</i>	Japanese Stilt Grass*
<i>Murdannia keisak</i>	Marsh Dewflower
<i>Persicaria perfoliata</i>	Mile-a-Minute*
<i>Phalaris arundinacea</i>	Reed Canary Grass
<i>Phragmites australis</i> subsp. <i>australis</i>	European Reed
<i>Procambarus clarkii</i>	Red Swamp Crayfish
<i>Pylodictis olivaris</i>	Flathead Catfish

DISC Watch List

Scientific Name	Common Name
<i>Channa maculata</i>	Blotched Snakehead
<i>Channa marulius</i>	Bullseye Snakehead
<i>Cipangopaludina chinensis</i>	Chinese Mystery Snail
<i>Crassostrea ariakensis</i>	Suminoe Oyster
<i>Crassostrea gigas</i>	Pacific Oyster
<i>Ctenopharyngodon idella</i>	Grass Carp
<i>Didymosphenia geminata</i>	Didymo
<i>Dreissena bugensis</i>	Quagga Mussel
<i>Dreissena polymorpha</i>	Zebra Mussel
<i>Gambusia affinis</i>	Western Mosquitofish
<i>Hypophthalmichthys harmandi</i>	Largescale Silver Carp
<i>Hypophthalmichthys molitrix</i>	Silver Carp
<i>Hypophthalmichthys nobilis</i>	Bigheaded Carp

<i>Leuciscus idus</i>	Ide
<i>Misgurnus anguillicaudatus</i>	Oriental Weatherfish
<i>Monopterus albus</i>	Asian Swamp Eel
<i>Myriophyllum aquaticum</i>	Parrot Feather
<i>Neogobius melanostomus</i>	Round Goby
<i>Notropis volucellus</i>	Mimic Shiner
<i>Orconectes rusticus</i>	Rusty Crayfish
<i>Oreochromis aureus</i>	Blue Tilapia
<i>Potamopyrgus antipodarum</i>	New Zealand Mud Snail
<i>Pterois miles</i>	Common Lionfish
<i>Pterois volitans</i>	Red Lionfish
<i>Pterois volitans</i>	Lionfish
<i>Rapana venosa</i>	Veined Rapa Whelk
<i>Scardinius erythrophthalmus</i>	European Rudd

**Note that while these species are considered invasive aquatic species in Delaware, it does not meet the definition of an aquatic nuisance species according to the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA as amended by NISA, 1996) and USFWS State Plan funding via NANPCA will not be used to fund activities related to this species.*

Appendix 2. State of Delaware’s Aquatic Invasive Species List. This list is comprised of all species on the DISC list of AIS as well as any species listed in regulations. This list will be updated as species are added to DISC’s list or are added to new or current regulations.

Scientific Name	Common Name
<i>Corbicula fluminea</i>	Asian Clam
<i>Hemigrapsus sanguineus</i>	Asian Shore Crab
<i>Ictalurus furcatus</i>	Blue Catfish
<i>Eriocheir sinensis</i>	Chinese Mitten Crab
<i>Cyprinus carpio</i>	Common Carp
<i>Ludwigia peploides</i>	Creeping Water Primrose
<i>Anguillicola crassus</i>	Eel Swimbladder Nematode
<i>Phragmites australis subsp. australis</i>	European Reed
<i>Acorus calamus</i>	European Sweetflag
<i>Pylodictis olivaris</i>	Flathead Catfish
<i>Ctenopharyngodon idella var. triploid</i>	Grass Carp (triploid)
<i>Carcinus maenas</i>	Green Crab
<i>Hydrilla verticillata</i>	Hydrilla
<i>Fallopia japonica</i>	Japanese Knotweed*
<i>Microstegium vimineum</i>	Japanese Stilt-grass*
<i>Murdannia keisak</i>	Marsh Dewflower
<i>Persicaria perfoliata</i>	Mile-a-minute-vine*
<i>Channa argus</i>	Northern Snakehead
<i>Myriophyllum aquaticum</i>	Parrot's Feather
<i>Lythrum salicaria</i>	Purple Loosestrife
<i>Procambarus clarkii</i>	Red Swamp Crayfish
<i>Phalaris arundinacea</i>	Reed Canary-grass
<i>Clarias batrachus</i>	Walking Catfish
<i>Eichhornia crassipes</i>	Water Hyacinth
<i>Iris pseudacorus</i>	Yellow Flag Iris

**Note that while these species are considered invasive aquatic species in Delaware, it does not meet the definition of an aquatic nuisance species according to the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA as amended by NISA, 1996) and USFWS State Plan funding via NANPCA will not be used to fund activities related to these species.*

Appendix 3. Action Plan for Northern Snakehead (*Channa argus*) in Delaware



S. Trammell-USGS

Drafted by Catherine C. Martin
Delaware Division of Fish and Wildlife
Department of Natural Resources and Environmental Control
2012



Action Plan for Northern Snakehead (*Channa argus*) in Delaware

In 2006, the U.S. Fish and Wildlife Service (USFWS) assembled the Northern Snakehead Working Group (NSWG) in response to a congressional mandate to address concerns about the introduction of northern snakeheads. The NSWG began development of a national Northern Snakehead Control and Management Plan (NSCMP) and agreed on some objectives and management actions to achieve those objectives.

The goal of this NSCMP is: Use sound science and management to prevent future introduction of northern snakeheads into new areas, minimize impacts in areas where they are already established, and recommend effective eradication methods where appropriate.

Objectives:

- 1. Prevent new introductions of northern snakehead (NSH) within the US and limit the spread of established populations into new areas.*
- 2. Detect and rapidly respond to NSH introductions in US waters.*
- 3. Wherever possible, contain and eradicate newly discovered populations of NSH.*
- 4. Provide long-term adaptive management and mitigate impacts of NSH in US waters where eradication is not possible.*
- 5. Conduct research to better understand impacts of NSH on native aquatic organisms.*
- 6. Develop outreach tools to prevent new introductions of NSH within the US and control the spread of established populations into new areas.*
- 7. Review and assess progress of the National Management Plan.*

The probability of northern snakehead population spread, and risk of invasion are high and suggests a major impact on native biota and, thus, a need for immediate control (Jiao et al. 2009). Higher survival rates of non-indigenous species occur during establishment due to low intraspecific density and a paucity of predators and parasites (Jiao et al. 2009). The purpose of this action plan is to prevent the further introduction and spread of the invasive northern snakehead (*Channa argus*-NSH) in Delaware's waters and, to the extent practical, waters of adjoining states.

History

Although a self-sustaining population of NSH was discovered in the tidal freshwater Potomac River in 2004, it was initially thought that higher salinity in the Chesapeake Bay would prevent escapement into other areas within the Bay. Concurrently, a population was discovered in Meadow Lake in Philadelphia County, PA. Reports of fish escaping the lake and entering the Schuylkill River and Delaware River have also been confirmed (NSCMP 2011). However, the collection of a NSH in Broad Creek in October 2010 by a Delaware Division of Fish and Wildlife electrofishing crew was the first confirmed incidence of this fish in Delaware waters. By 2011, several angler-caught NSH were reported from the mainstem Nanticoke near Middleford and the Marshyhope Creek at Rt. 404. A report of a kayaker "attacked" by a fish guarding young in Becks Pond resulted in the collection of an adult and juveniles from this Delaware River watershed impoundment. Two other adult fish were also observed. An Enforcement request for

information on NSH in New Castle County led to confirmation of an angler catch about eight miles downstream of Becks Pond in Shellpot Creek, a tributary to the Christina.

These discoveries in 2011 led to a meeting hosted by the Delaware Department of Natural Resources and Environmental Control (DNREC)-Division of Fish and Wildlife's (DDFW) Fisheries Section with staff from the USFWS, The Maryland Department of Natural Resources (MDNR), as well as DDFW's Enforcement Section, Natural Heritage Program (now the Wildlife Species Conservation and Research Program or WSCR), and the Director of DDFW. Staff from the USFWS presented up to date information about NSH natural history and behavior in US waters. One point was that high river flows result in disbursement of NSH. Another important point was high flows in the Chesapeake Bay in spring 2011 led to salinities less than 10 ppt (parts per thousand) in the Bay between the Potomac and MD's Eastern Shore (personal communication, S Minkinen USFWS). The USFWS and MDNR conducted several experiments on NSH tolerance to salinity and found that individuals held in 10 ppt exhibited indefinite survival at water temperatures of 15-20°C. These findings indicated that it would be possible for NSH to travel from the Potomac across the Chesapeake Bay, and upstream to the Nanticoke River.

As a result of the aforementioned meeting, the Director of DDFW authorized development of a Delaware NSH Action Plan to prevent the further introduction and spread of the invasive northern snakehead in Delaware's waters. This action plan is based on the natural history, environmental tolerances, eradication efforts, and research provided in the NSCMP (Northern Snakehead Working Group 2011). That information is not repeated herein, but is available to support these recommendations.

Priorities for Implementation

1. *Prevention*

The first step in controlling NSH is to prevent further introductions. The best tactic to accomplish this is through outreach and education. DDFW initiated a modest outreach program via the Fishing Guide beginning in 2007. Invasive species information, focusing on the NSH, has been posted on the DDFW website to inform the general public of the problem. An easily printed poster has been developed with identification characteristics, life history information, and potential impacts to the native fish community. DDFW and MDNR have cooperated in this endeavor by maintaining updated communication on all NSH finds and promoting the angler log snakehead lottery hosted by MDNR.

Of particular concern in Delaware is a significant largemouth bass (*Micropterus salmoides*) fishery. A periodic newsletter distributed to bass anglers and posted on the DDFW website includes an invasive column in each issue. NSH has been the focus of several issues and anglers are kept updated about new sightings via this newsletter.

Enactment of clear, effective, and enforceable regulations and statutes should be a priority in preventing future introductions of NSH. Currently, although it is illegal to possess a live NSH without a permit from the Director of DDFW, the fine for possession or stocking into public waters is minimal. The NSCMP Priority 1.2 recommends that states authorize substantial penalties for violating statutes pertaining to NSH.

2. *Early Detection and Rapid Response*

An information system should be in place to notify other jurisdictions of sightings of NSH including the USFWS and U.S. Geological Survey (USGS). Online outreach materials directed toward anglers should assist in the early detection of this species. All DNREC personnel, especially field monitoring crews and enforcement staff, should be trained in identification of NSH. Monitoring for NSH should be incorporated into other, existing aquatic surveys.

Legislation should be enacted to allow appropriate agency access on public/private property to assess a potential introduction, implement control measures, or eradicate NSH.

In response to a credible report, DDFW staff should further investigate to confirm identification of the fish using photographic evidence, a physical specimen, a credible description of species or of behavior consistent with species, etc. If the presence of NSH is confirmed or judged likely, the evaluation of possible management options (Appendix) should be followed depending on the habitat type.

3. *Eradication*

The feasibility of eradication of a NSH introduction depends on several factors of which the most important is the location of the introduction. Eradication of any introduction in tidal waters would not be feasible due to the size of the system, the tidal flows, and, in the case of the Nanticoke, the possible continued introduction via immigration from other systems. A population within a small closed system may be possible to eradicate via a piscicide, however, even this situation can be costly and require a lot of effort (i.e. Crofton Pond in MD). A larger system such as Becks Pond (25 acres) would be difficult and costly due to multiple headwater streams and the large volume of water that would be treated. Additionally, in the case of Becks, two other factors were important: a 5-inch rainfall event occurred four days prior to discovery of the NSH and an angler caught a NSH downstream in a tributary within the same watershed (Christina River). The likelihood of dispersal as a result of high flows, and presence of the fish downstream indicated that the success of a piscicide application would be doubtful. Each introduction site must be evaluated separately to determine the feasibility of eradication versus management.

4. *Long-term Management*

In most cases, long-term management may be the most practical way to keep NSH populations at a low level and prevent adverse impacts to the current aquatic communities present. Several actions should be pursued in this regard:

- Pursue a regulation making it legal to bow fish for NSH in any waters where bow fishing is not prohibited.
- Develop regulations liberalizing other gears used to catch snakeheads.

- Post signage at all NSH locations informing anglers of their invasiveness and the need to remove them when caught. Request that the DDFW be contacted when a NSH is caught so routine biological data (length, weight, age, sex, genetic samples, and stomach contents) can be obtained.
- Monitor current populations of NSH via electrofishing or other gear if found to be more effective.
- Consider a “reward” program for capture and kill if population levels warrant this action.

5. *Research*

Although DDFW does not have the resources to conduct large research projects on NSH, it will cooperate with USFWS and any states sharing public waters as requested to include:

- Providing biological data collected to the USFWS for inclusion into their NSH database.
- Evaluating the effectiveness of different field collection techniques for NSH.
- Maintaining contacts via NSH introduction sites and options for control.

6. *Outreach*

As noted above, outreach, using both online and traditional formats, is the most cost-effective and broad-based mechanism to prevent future introductions or spread of NSH and most other invasive species. Efforts should be coordinated with adjacent states and federal agencies such as USGS and US FWS in order to have the greatest impact.

Online information should include:

- Identification
- Life history
- Potential Impacts
- Current laws and regulations
- Contact information
- Web-based reporting system for angler-submitted digital photos for positive identification

Traditional outreach should be directed at a variety of audiences

- Signage at access areas in watersheds where NSH have been confirmed to include: identification, instructions for kill at capture, and contact information.
- Presentations to stakeholders (fishing clubs, environmental organizations, councils, etc.)
- Information in the Delaware Fishing Guide, on fishing rulers, and in DNREC publications such as *Outdoor Delaware* and *Tournament Newsletter*.
- Training of Enforcement staff and field personnel within DNREC and possibly, Delaware Department of Agriculture (DDA).

- Periodic press releases over the long-term to keep the invasive species issue current for the general public.

7. Review and Assess Program

This Action plan should be reviewed biennially to determine progress on implementation of activities in the plan. Updated information on NSH natural history, impacts, and control options must be incorporated into the Action plan as it becomes available.

Relative cost of responses to NSH invasion:

Control	Isolated Pond	Pond - outlet/inlet	Tidal Waters	Remarks
Outreach/ education	\$	\$	\$	Most cost-effective and broad benefits
Drawdown	\$\$	\$\$\$	N/A	Potentially costly; should be used in conjunction with salvage operation
Physical Removal	\$\$	\$\$	\$\$	Unlikely to be effective for large introduction or if complex habitats present
Piscicide	\$\$\$\$	\$\$\$\$\$	N/A	Potentially costly; should be used in conjunction with salvage operation; should consider use in conjunction with drawdown and/or herbicides

Literature Cited

Jiao, Y., N.W.R. Lapoint, P.L. Angermeier, and B.R. Murphy. 2009. Hierarchical demographic approaches for assessing invasion dynamics of non-indigenous species: An example using northern snakehead (*Channa argus*). *Ecological Modelling*, v. 220, p. 1681-1689.

Northern Snakehead Working Group. 2011. (Draft) National Control and Management Plan for the Northern Snakehead (*Channa argus*). Submitted to the Department of Interior.

Appendix: Evaluation and Management Options for NSH introductions

Once determined to be present, Jiao et al. (2009) concluded that limiting the number of spawners is the best control for northern snakehead. They proposed targeting spawners and juveniles from May through September; however, DDFW staff have captured or recovered females with eggs in late October indicating that the target time period should be extended to at least November.

1. Impoundments – without inlets or outlets

- Contact all landowners
- Eliminate any pathways for spread to nearby waters
 - Limit access
 - Ensure containment (e.g., consider if pathways for expansion to nearby waters possible in flood event)
- Establish extent of infestation and remove
 - Electrofishing boat
 - Backpack electrofisher
 - Seines
 - Traps
 - Hook & line
- Consider rotenone use
 - Consider drawdown
 - Consider herbicides
- Consider dewatering
- Post with appropriate signage

2. Impoundments – with inlets or outlets

- Contact all landowners
- Where possible, eliminate pathways to nearby waters
 - Consider screening or eliminating/reducing outflow
 - Consider barriers such as silt curtains or block nets
- Establish extent of infestation and to remove
- Consider rotenone use
 - Consider drawdown
 - Consider impact to non-target biota
 - Consider impact to agriculture
 - Consider impact to recreation
 - Consider herbicides
 - Consider impact to non-target biota
 - Consider impact to agriculture
 - Consider impact to recreation
- Consider dewatering
 - Impacts on non-target biota
 - Impact on agriculture
 - Impact on recreation
- Post with appropriate signage
- Prepare advisory press releases and updates online

3. Tidal waters

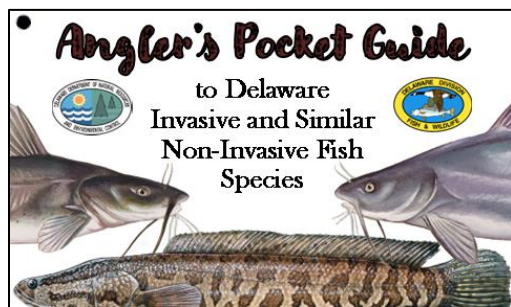
- Where possible, eliminate pathways to nearby waters (e.g. a
- Establish extent of infestation and appropriate gear to remove
 - Electrofishing boat
 - Backpack electrofisher
 - Seines

- Traps
 - Hook & line
- Post with appropriate signage
- Prepare advisory press releases and updates online

Post-intervention Monitoring or Removal

- Initiate follow-up sampling/removal in spring when temperatures are at or near 18 – 20 °C and continue as warranted until late fall.
- Maintain follow-up sampling or removal in summer targeting spawning/guarding fish and larvae prior to dispersal. Also consider sampling in the late summer/fall as NSH are repeat spawners (likely twice per season).

Appendix 4. Angler's Pocket Guide to Delaware Invasive and Similar Non-Invasive Fish Species
Produced by Bruce Cole Environmental Scientist IV DFW.



PLEASE Report Invasive Fish Species to:
Division of Fish & Wildlife
Email: DNREC Fisheries@Delaware.gov
302-739-9914

Did you know it is **ILLEGAL** to transport an Invasive Species Alive?

Please do not return to the water, but kill it and contact us.
Document the catch by freezing it or taking a good photo.

Invasive Fish Species can hurt aquatic ecosystems, negatively impact desirable fish and wildlife populations, and even cause economic harm.

bit.ly/reportinvasivefish

Catfish and Bowfin illustrations by Duane Raver, Jr.
Snakehead Illustration by Susan Trammel (Courtesy of USGS)

Blue Catfish **Invasive**

Often misidentified as Channel Catfish

Blueish-gray sides with a darker back and a white belly (body without dark spots)

Can grow to over 100 pounds

Straight edged anal fin

Deeply forked tail

Invasive Flathead Catfish

Large flattened head

Body pale yellow to light brown on the back and sides, and highly mottled with black and/or brown

Can grow to over 100 pounds

Lower jaw extends beyond upper jaw

The belly is usually pale yellow or cream colored

Slightly notched tail

Channel Catfish **Non-Invasive**

Often misidentified as Blue Catfish

Blueish-gray sides with dark spots and a white belly (spots may be absent in large adults)

Can grow to over 50 pounds but typically much smaller

Outer edge of anal fin slightly rounded

Deeply forked tail

Non-Invasive White Catfish

Rarely exceed 6 pounds and 24 inches long

Usually distinctly two toned body, darker on top and white, or nearly white, on the lower sides and belly

Short, very large head

White chin whiskers under jaw

Moderately forked tail with rounded tips

Brown Bullhead **Non-Invasive**

Typically less than 1 pound and less than 12 inches long

Various shades of brown body with darker mottling or speckles and a yellowish to white belly

Black chin whiskers under jaw

Slightly notched tail

Non-Invasive Yellow Bullhead

Typically less than 1 pound and less than 12 inches long

Solid dark brown to an almost golden yellow body with yellowish to white belly

White chin whiskers under jaw

Evenly rounded tail

Northern Snakehead **Invasive**

Golden tan to pale brown, with dark blotches on the sides often in a snake-like pattern

Protruding lower jaw

Pectoral fin above Pelvic fin

Long anal fin

Truncated tail (not fully rounded)

Non-Invasive Bowfin

Sides and back are olive to brown, often with vertical bars and dark net or camouflaged pattern.

Eye spot present in males and juveniles

Pectoral fin forward of Pelvic fin

Short anal fin

Rounded tail

Rare, Please Release

Appendix 5. Key Contributors/Reviewers of Delaware AIS Management Plan

Support

Delaware Sea Grant provided a letter of support for the MAPAIAS grant application to write this plan.

Delaware's Master Naturalist program provided a letter of support for the MAPAIS grant application to write this plan.

Delaware Invasive Species Council provided input on the plan and allowed use of their invasive species list.

Drafting

Michael Steiger, Invasive Species Biologist III, drafted Delaware's AIS Management Plan.

Edna Stetzar, Fisheries Biologist IV, provided insight into development of the plan. Edna was integral into the development of this management plan.

Editing

Edna Stetzar, Fisheries Biologist IV, provided multiple rounds of extensive edits and insight into development of the plan.

Michael Stangl, Program Manager, Fisheries Section, provided multiple rounds of edits and approved the management plan.

John Clark, Administrator, Fisheries Section, provided edits and approved the management plan.

Don Maclean USFWS, provided extensive suggestions and edits via Word document.

Dr. Kimberly Holzer, USFWS provided edits and suggestions via Word document.

ANSTF provided suggestions that were compiled by Don Maclean into a Word document.

Members of the public were given the opportunity to provide suggestions during the 20 day public comment period.

Appendix 6. Timeline of Delaware AIS Management Plan Development

March 26, 2021: DFW applied for a MAPAIS Grant to develop an AIS Management Plan for Delaware.

May 14, 2021: DFW received a grant award notice from MAPAIS with a start date of September 1, 2021.

May 14, 2021 – February 27, 2022: DFW staff gathered preliminary information on aquatic invasive species distribution, control, and management within Delaware and surrounding states. Identified stakeholders, partner agencies, and gathered information on laws and regulations associated with AIS. Presented intent to draft an AIS plan at Advisory Council on Wildlife and Freshwater Fish and Native Species Commission meetings.

February 27, 2022: Invasive Species Biologist was hired to develop Delaware's invasive species management program and begin drafting the plan.

February 27, 2022, to March 31, 2023:

AIS management plan was drafted by Michael Steiger, Invasive Species Biologist III, with input from DISC board members, MAPAIS members, DFW staff, and Delaware Sea Grant.

Edna Stetzar, Fisheries Biologist IV, provided multiple rounds of extensive edits and insight into development of the plan. Edna was integral into the development of this management plan.

Michael Stangl, Program Manager, Fisheries Section, provided edits and approved the management plan.

John Clark, Administrator, Fisheries Section, provided edits and approved the management plan.

March 31, 2023: Draft of management plan was sent to Don MacLean and Sandra Keppner, U.S. Fish and Wildlife Service for initial plan review by ANSTF members.

May 15, 2023: Comments were received from ANSTF members, Don Maclean USFWS, and Dr. Kimberly Holzer USFWS.

October 17th, 2023: The Plan was posted for public comment on the DNREC website and was open until November 15th, 2023.

October 20th, 2023: Public comment period was announced on Division of Fish and Wildlife's Facebook page.

October 25th, 2023: Public comment period announcement was sent to DNREC Fisheries Listserv subscribers.

December 5th-7th, 2023: Members of the Shellfish Advisory Council, the Advisory Council on Wildlife and Freshwater Fish, the Tidal Finfish Advisory Council, and Delaware Invasive Species Council were invited to comment on the Plan. Comments were accepted through January 1st, 2024.

Appendix 7. Summary of Public Comments Received

A public comments page was open to submissions on the DNREC public notice website from October 17th through November 15, 2023. Options to send comments via email or U.S. postal mail was also available. The public comment period was announced on the DFW Facebook page and sent to subscribers of the DNREC Fisheries Listserv.

Comments from the public comments page:

October 26th, 2023

Eric Vitelli

Comments:

I know the snakehead is a huge problem in other states waterways. Our State must be proactive.

No mail or emails responses were received.

No comments were received from Delaware Advisory Council members.

Suggested citation: DNREC (Delaware Department of Natural Resources and Environmental Control), Division of Fish and Wildlife. 2024. Delaware's Aquatic Invasive Species Management Plan. Dover, DE. 45 pp + Appendices.