Final Report of the Sustainable Fisheries Goal Implementation Team

Invasive Catfish Task Force

Winter 2014

Invasive Species Task Force Members

- Bruce Vogt, Chair, National Oceanic and Atmospheric Administration Chesapeake Bay Office (NCBO)
- Nancy Butowski, Maryland Department of Natural Resources (MD DNR)
- Ellen Cosby, Potomac River Fisheries Commission (PRFC)
- Mary Fabrizio, Virginia Institute of Marine Science (VIMS)
- Matt Fisher, Deleware Department of Natural Resources and Environmental Conservation (DNREC)
- Greg Garman, Virginia Commonwealth University (VCU)
- Bob Greenlee, Virginia Department of game and Inland Fisheries (VDGIF)
- Joe Grist, Virginia Marine Resources Commission (VMRC)
- Mary Groves, Maryland Department of Natural Resources (MD DNR)
- Robert Hale, Virginia Institute of Marine Science (VIMS)
- Mike Hutt, Virginia Marine Products Board
- Matt Ogburn, Smithsonian Environmental Research Center (SERC)
- Danny Ryan, District of Columbia Department of the Environment (DC DOE)
- Geoffrey Smith, Pennsylvania Fish and Boat Commission (PFBC)
- Howard Townsend, National Oceanic and Atmospheric Administration Chesapeake Bay Office (NCBO)
- Andrew Turner, National Oceanic and Atmospheric Administration Chesapeake Bay Office (NCBO)
- Steve Vilnit, Maryland Department of Natural Resources (MD DNR)

Special thanks to Mary Fabrizio and Greg Garman who authored significant portions of the report documenting the history, biology and invasiveness of Blue and Flathead Catfishes.

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Executive Summary

The Problem

There are several species of aquatic invasive plant and animal species in the Chesapeake Bay watershed that pose a risk to the ecology and economy of the region. According to federal Executive Order 13112 adopted in 1999, invasive species are defined as non-native species that can cause harm to the environment or to human health according to federal Executive Order 13112, signed in 1999. This report focuses on Blue Catfish (*Ictalurus furcatus)* and Flathead Catfish (*Pylodictis olivaris*) which are both considered invasive because they are not native to the Chesapeake Bay and have the potential to negatively impact native species and the ecology of the Bay. Blue Catfish are native to the Mississippi, Missouri, and Ohio River basins. They were introduced into the James, Rappahannock, and York Rivers in Virginia during the 1970s and 1980s to establish new recreational fisheries in Virginia. These catfish have quickly spread throughout the region into nearly every major tributary. Flathead Catfish were introduced into the James River in the late 1960s. Both Blue and Flathead Catfishes are long lived, and predators that as adults feed predominantly on native fishes and shellfish. The expanding range and increasing populations, particularly of Blue Catfish, have resource managers concerned that without management intervention, the damage to Chesapeake Bay resources may be irreversible.

The Need

There is no existing management strategy for invasive catfishes. Nor is there a coordinated effort across Chesapeake Bay management jurisdictions to comprehensively engage the public, slow and reduce the spread, and minimize the ecological and economic harm of Blue and Flathead catfishes. In addition, application of current research studies and monitoring efforts are needed to improve our knowledge and evolve management strategies into the future.

The Task Force

The Invasive Catfish Task Force (ICTF) was established in 2012 by the Sustainable Fisheries Goal Implementation Team (Fisheries GIT) of the Chesapeake Bay Program and tasked to recommend management options that could be applied Bay-wide to respond to the spread of invasive Blue and Flathead catfish populations in the Chesapeake Bay region. The ICTF is comprised of members from the state and local fishery management jurisdictions of Maryland, Virginia, Pennsylvania, District of Columbia, Potomac River Fisheries Commission, and Delaware, the National Oceanic and Atmospheric Administration, academic experts from the Virginia Institute of Marine Science (VIMS), Virginia Commonwealth University (VCU), and Smithsonian Environmental Research Center (SERC), and seafood marketing specialists from Maryland Department of Natural Resources and the Virginia Marine Products Board.

The ICTF met several times in-person and via teleconference to compile and evaluate existing information on Blue and Flathead catfishes and to discuss potential management options. The ICTF also briefed the Fisheries GIT and stakeholders on draft recommendations during the preparation of this report. The ICTF developed these recommendations to address the following four objectives:

1. To slow and reduce the spread of invasive catfishes populations into currently uninhabited waters;
2. To minimize the ecological impacts of invasive catfishes on native species;
3. To promote a large-scale fishery to significantly reduce abundance of invasive catfishes populations and provide economic benefits to the region; and
4. To increase outreach and education to improve public awareness that Blue and Flathead catfishes are not native and pose a risk to native species and to continue to lessen the probability of unauthorized introductions into other water bodies in the Bay watershed.

Recommendations

Recommendation 1

We recommend that jurisdictions work together to design and implement targeted fishery-independent removals of invasive catfish in places of significant ecological value (i.e. spawning and nursery habitat areas for anadromous species). There are some tributaries where well-planned, intensive, and repeated removals of invasive catfishes have the potential to reduce populations to a level that may lessen their impacts on important native species. We further recommend these fishery independent removals be conducted as pilot projects or studies to develop, test, quantify, and evaluate effective removal methods for invasive catfishes. As part of this effort, we recommend that jurisdictions identify areas of significant ecological value for native fish and shellfish species and their habitats and consider special protections to reduce the risk of invasive catfish introductions and expansion in these areas.

Recommendation 2

We recommended that efforts and incentives to develop a large-scale, commercial fishery be accelerated and coordinated across jurisdictions. Creation of a new fishery in the Chesapeake Bay exploiting the growing populations of invasive catfishes has the potential to help to reduce populations while also providing economic benefit to watermen and the region. This will require more immediate and coordinated action across jurisdictions to identify markets, increase the value of the fishery, and remove factors (e.g. lack of processing facilities) that are currently limiting expansion of the existing small- scale fishery. A key component of this recommendation is developing a sustainable fishery capable of maintaining reduced populations over the long term. This is critical to achieving ecological and economic outcomes. We recommend a workshop be held with current and prospective fishers, fishery managers and economists to identify the steps needed to expand the current fishery and make it sustainable and economically feasible. We note that Washington, D.C. restaurants have been successful in promoting ‘local, fresh catfish’ on their menus and suggest implementing similar measures throughout the Bay watershed.

Recommendation 3

We recommend jurisdictions consider options to incentivize increased harvests of invasive catfishes by small boat operations and explore the use of electrofishing for commercial harvest purposes. These options could be further discussed as a part of the workshop suggested in Recommendation 2. We note that at least one proposal was submitted to the Fishery Resource Grant Program of Virginia Sea Grant to explore the feasibility of using electrofishing gear for harvest of blue catfish. Similar evaluations of gear efficiency could be promoted elsewhere.

Recommendation 4

We recommend jurisdictions establish monitoring programs dedicated to identifying and tracking invasive catfish distributions and population status. We also recommend developing early detection and response programs to monitor ecologically significant areas. There are currently few dedicated monitoring and survey efforts for invasive catfishes. In addition, the applied research efforts underway should could be synthesized and used to improve effective implementation and refinement of the management options outlined in this report.

Recommendation 5

We recommend careful consideration of the effectiveness of existing barriers to invasive catfish spread (i.e. dams) and suggest that the benefits of barrier removal be weighed against the risk of damage to areas of significant ecological value by invasive catfish expansion. We suggest formal coordination between invasive catfish experts and the Fish Passage Workgroup of the Chesapeake Bay Program Habitat Goal Implementation Team to identify barriers and develop ecosystem-based recommendations of high risk for dam removals with the potential to allow invasion.

Recommendation 6

We recommend a cross-jurisdictional review of current fishing policies and regulations across jurisdictions to consider current regulations that may facilitate the persistence and expansion of invasive catfish populations. This review should also evaluate the efficacy of communications and enforcement of the current regulations regarding the illegal transport of live fish.

Recommendation 7

We recommend jurisdictions make information on invasive catfishes more accessible, and consistent, and clearer to anglers and the general public. Information on invasive catfishes is difficult to find and not well coordinated across jurisdictions. We suggest an immediate effort be made to convene communication experts from the Chesapeake Bay jurisdictions to identify inconsistences in messaging and develop an aggressive communication campaign to increase public awareness. This campaign should be paired with the development of a web portal that provides the public, researchers, and resource managers access to current information on invasive catfishes.

We believe that these recommendations implemented individually or collectively will begin to address the challenges of invasive catfishes in the Chesapeake Bay and that lessons learned during implementation will allow for adaptation and improvements. We suggest that the Fisheries GIT Executive Committee prioritize these recommendations and consider how jurisdictions will work together to implement.

Introduction

This report focuses on Blue Catfish (*Ictalurus furcatus)* and Flathead Catfish (*Pylodictis olivaris*) both considered invasive because they are not native to the Chesapeake Bay and have the potential to negatively impact native species and the ecology of the Bay. According to federal Executive Order 13112 adopted in 1999, invasive species are defined as non-native species that can cause harm to the environment or to human health according to federal Executive Order 13112, signed in 1999. Blue Catfish are native to the Mississippi, Missouri, and Ohio River basins. They were introduced into the James, Rappahannock, and York Rivers in Virginia during the 1970s and 1980s to establish new recreational fisheries in Virginia. These catfish have quickly spread throughout the region into nearly every major tributary. Flathead Catfish were introduced into the James River in the late 1960s. Both Blue and Flathead Catfishes are long lived, and predators that as adults feed predominantly on native fishes and shellfish. The expanding range and increasing populations, particularly of Blue Catfish, have resource managers concerned that without management intervention, the damage to Chesapeake Bay resources may be irreversible.

Purpose

The purpose of this report is to provide a range of options to address the expansion of invasive catfish populations and their impacts on living resources in the Chesapeake Bay. The report is intended as a resource for decision-makers with a suite of recommendations that can be taken for the Chesapeake Bay jurisdictions to develop coordinated management strategies for invasive catfishes.

Scope

Although this report specifically applies to the waters and resources in the Chesapeake Bay watershed (Maryland, Virginia, Pennsylvania, District of Columbia, and Delaware), the ICTF recognize that close coordination and cooperation is required with broader regional organizations such as the Atlantic States Marine Fisheries Commission and the Mid Atlantic Panel on Aquatic Invasive Species.

Invasive Catfish Task Force and Objectives

The Invasive Catfish Task Force (ICTF) was established in 2012 by the Sustainable Fisheries Goal Implementation Team (Fisheries GIT) of the Chesapeake Bay Program and tasked to recommend management strategies and actions that could be applied Bay-wide to respond to the spread of invasive Blue and Flathead catfish populations in the Chesapeake Bay. The ICTF is comprised of members from the fishery management jurisdictions of Maryland, Virginia, Pennsylvania, District of Columbia, Delaware and Potomac River Fisheries Commission, the National Oceanic and Atmospheric Administration (NOAA), academic experts from the Virginia Institute of Marine Science (VIMS), Virginia Commonwealth University (VCU) and Smithsonian Environmental Research Center (SERC), and seafood marketing specialists from Maryland Department of Natural Resources and the Virginia Marine Products Board.

The ICTF met several times in-person and via teleconference to compile and evaluate existing information on Blue and Flathead catfishes and to discuss potential management options. The ICTF also briefed the Fisheries GIT and stakeholders on draft recommendations during the preparation of this report. The ICTF developed these recommendations to address the following four objectives:

1. To slow and reduce the spread of and invasive catfishes populations into currently uninhabited waters;
2. To minimize the ecological impacts of invasive catfishes on native species;
3. To promote a large-scale fishery to significantly reduce abundance of invasive catfishes populations and provide economic benefits to the region; and
4. To increase outreach and education to improve public awareness that Blue and Flathead catfishes are not native and pose a risk to native species and to continue to lessen the probability of unauthorized introductions into other water bodies in the Bay watershed.

Overview of Invasive Catfishes (Blue and Flathead Catfishes) in the Chesapeake Bay

Introduction, Distribution, and Expansion

Blue Catfish (*Ictalurus furcatus)* and Flathead Catfish (*Pylodictis olivaris*) were introduced to a few Virginia tributaries of the Chesapeake Bay for recreational purposes and are now likely established in more than 10 major tributaries across Virginia, Maryland, and Pennsylvania. Initial stocking of Blue Catfish occurred in the 1970s and 1980s in the freshwater reaches of the rivers and has expanded rapidly into tidal riverine habitats. They are now commonly found in oligohaline and mesohaline waters of Chesapeake Bay tributaries, including all western shore rivers in Virginia as well as several Maryland and Eastern Shore tributaries.

Flathead Catfish were introduced to the James River, Virginia, *circa* 1965-1970's, and now occur in several Chesapeake Bay rivers, including the James, York, Potomac, and Susquehanna rivers. Unlike Blue Catfish, Flathead Catfish are habitat specialists and are generally confined to nontidal and tidal freshwater and oligohaline habitats.

A geospatial model developed by VCU suggests that Blue Catfish distribution has the potential to nearly double (Figure 1), from 136 watersheds (12-digit HUCs) to 242 watersheds, in the Chesapeake basin and that Flathead Catfish are also expanding their distribution in the region (Figure 2).

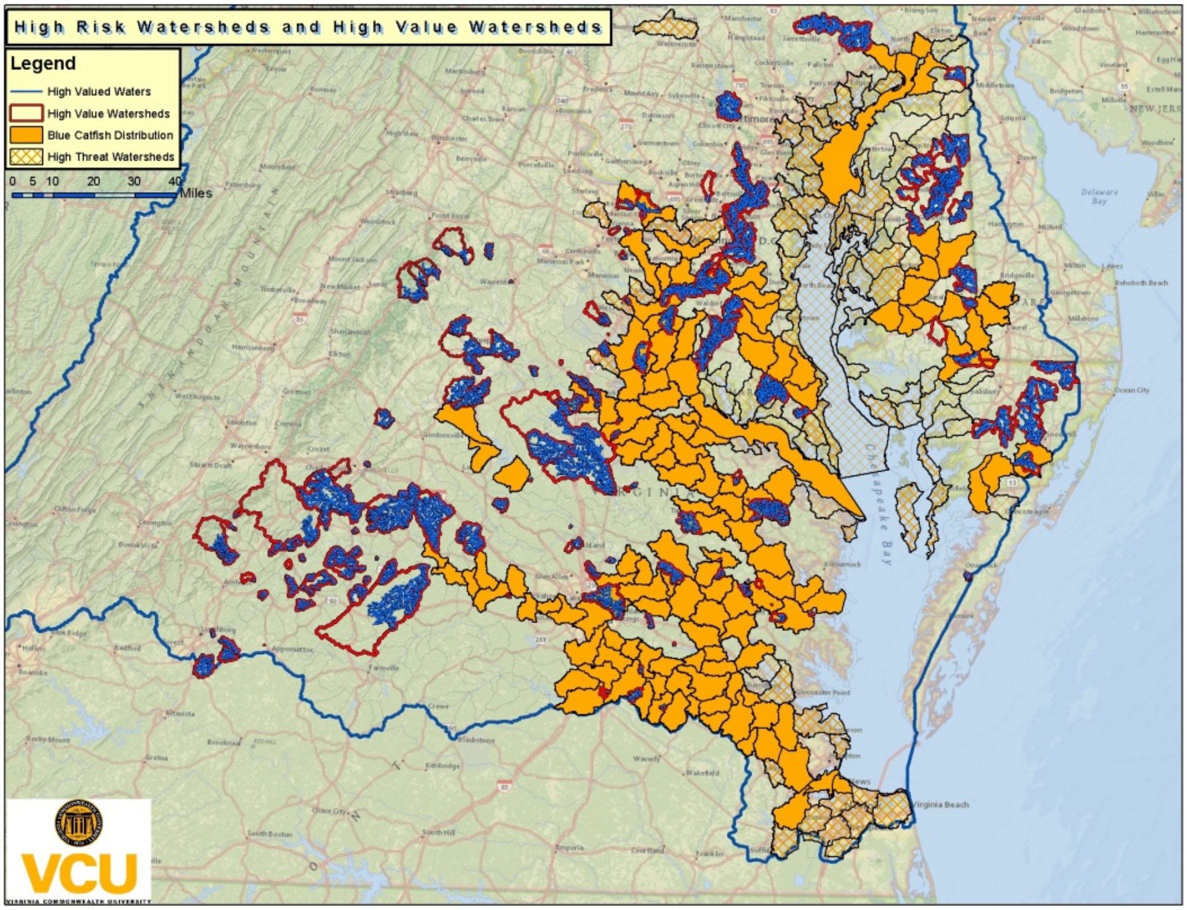

Figure 1. Current (solid polygons) and forecasted (cross-hatched polygons) distribution of Blue Catfish in Chesapeake Bay waters below Conowingo Dam. Geospatial units are 12-digit watersheds (HUCs). Data are compiled from several sources, including VCU, VIMS, VDGIF, and MD DNR; data were current as of 1 April, 2013.

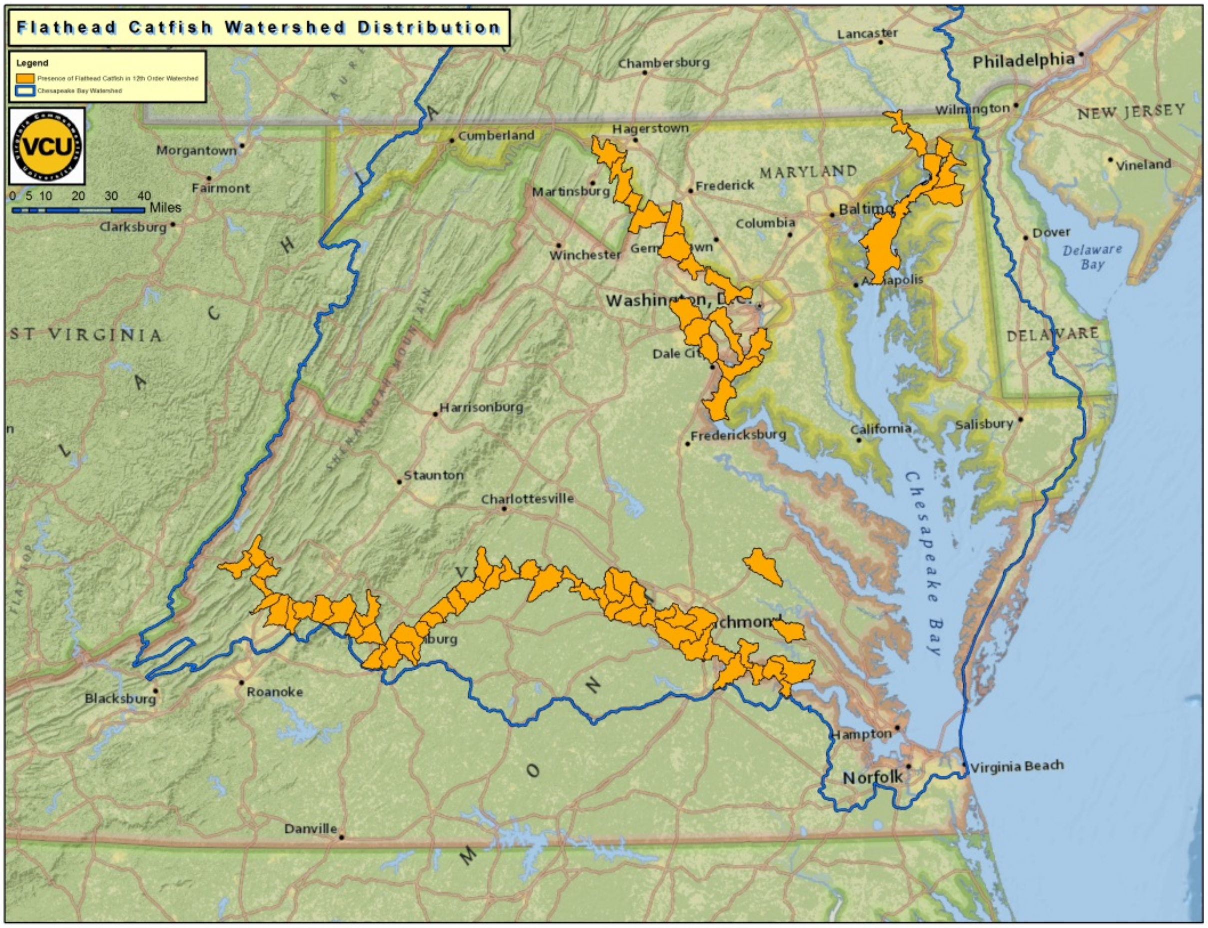

Figure 2. Current distribution of Flathead Catfish in Chesapeake Bay waters below Conowingo Dam. Geospatial units are 12-digit watersheds (HUCs). Data are compiled from several sources, including VCU, VIMS, VDGIF, and MD DNR; data were current as of 1 April, 2013.

Other biological characteristics such as tolerance for a wide range of environmental conditions may further enhance the spatial expansion of newly established nonnative populations. For instance, both Blue and Flathead catfishes can tolerate salinities of 14 parts per thousand (ppt) or higher and can therefore move into estuarine reaches of tidal tributaries (Schloesser et al. *2011*; Bringolf et al. 2005). The high salinity tolerance of these catfishes is not unique. Channel Catfish, which are also nonnative in Atlantic Slope rivers, also have a high salinity tolerance (Jenkins and Burkhead 1993). Unlike Blue Catfish and Flathead Catfish, this species has been established for over a century and is, therefore, unlikely to spread beyond its present range (Jenkins and Burkhead 1993). Blue Catfish expanded their range in Virginia tributaries when adult densities in tidal freshwater reaches were high and during years of high river flows or episodic flooding (Edmonds 2003 and Schloesser et al. 2011). Further range expansion of Blue Catfish may ensue when similar conditions co-occur (high adult abundance, high river flows). Increases in the range of newly established species accompanied by order-of-magnitude higher densities in new environments are a known characteristic of fish invaders (Morris and Whitfield 2009). In Maryland, the unauthorized stocking or transportation of live fish by anglers appears to have aided the spread of Blue Catfish among tidal tributaries of the upper Bay. Currently, Flathead Catfish are not as abundant as Blue Catfish (except in Pennsylvania where Flathead Catfish populations are the primary concern) and thus, populations may not yet exhibit dispersive movements in response to environmental cues. In the Chesapeake Bay watershed, redistribution of Flathead Catfish by anglers appears to play a major role in their dispersal.

Invasiveness and Ecological Impacts

The timing, sources, and possible implications of introduced Blue Catfish in Chesapeake Bay waters have been described recently by Schloesser et al. (2011). A similar synthesis concerning Flathead Catfish in this region is lacking. Both species of catfishes are considered invasive species of concern by the Mid Atlantic Panel on Aquatic Invasive Species because they are likely causing environmental and possibly economic harm to the Chesapeake Bay ecosystem. Blue and Flathead catfishes share several biological characteristics that are believed to enhance the likelihood of their establishment in new environments. These include a diverse diet (including other fish), adult trophic status as apex predators, long life span, large body size, high salinity tolerance, and parental care of young (Table 1; Morris and Whitfield 2009). Some of these characteristics may lead to environmental harm if native species or aquatic habitats are affected in a negative manner.

Table 1. Predictors of invasiveness for Blue and Flathead catfishes (adapted from Morris and Whitfield 2009). Propagule pressure refers to the density of individuals introduced, the number of introduction events, and the frequency of introductions. In addition to the predictors shown in the table, short distance to native source, young age at maturity, large egg diameter, and long reproductive season have been identified as additional predictors of invasiveness, however, none of these apply to Blue and Flathead Catfishes.

Predictor	Blue Catfish	Flathead Catfish
Prior invader	X	X
Large native range	X	X
Environmental tolerance	X	X
Long life span	X	X
Large body size	X	X
High adult trophic status	X	X
Broad diet	X	
Fast growth		X
High fecundity	X	
Parental care	X	X

Invasive catfishes in Chesapeake Bay tributaries may interact with native fish and shellfish in a negative manner as predators or competitors for resources. Ecological impacts from predation by or competition with invasive catfishes in Atlantic coastal and estuarine habitats, including Chesapeake Bay, may include declines in native resident (Bonvechio et al. 2011) and anadromous (McAvoy et al. 2009) fishes. Blue Catfish in these tributaries have a highly diverse diet and consume crustaceans, worms, bivalves (including native freshwater mussels), and fish, such as Atlantic Menhaden, American Shad, Blueback Herring, Bay Anchovy, and other Blue Catfish. The diet of Flathead Catfish tends to be dominated by fish with the onset of piscivory occurring at a smaller size (>20 cm TL or >16.8 cm FL; Chandler 1998) than for Blue Catfish (>30 cm FL). Because both species consume fish, and because several fish species that use Chesapeake Bay tributaries are the subject of restoration or stock rebuilding efforts (e.g., *Alosa* spp.), Blue and Flathead Catfishes have the potential to exert measurable 'ecological harm' to the ecosystem. Recent studies based on stable isotope analyses suggest that adult Blue Catfish and Flathead Catfish in these systems are novel apex predators that feed extensively on important fishery resources, including native, anadromous fishes (MacAvoy et al. 2009).

The extent of piscivory of these species and population-level effects are poorly understood, at least in Chesapeake Bay waters. In Atlantic Coastal rivers in North Carolina and Georgia, predation by introduced Flathead Catfish has been associated with declines of some native fishes, with concomitant effects on recreational fisheries (Pine et al. 2005; Bonvechio et al. *2011*). Comparable studies of predation effects of introduced Flathead Catfish in tributaries of Chesapeake Bay are lacking. Invasive catfish predation on native species such as American Shad, Blueback Herring, Alewife, and Blue crabs is likely to be spatially confined to habitats where these species co-occur with catfishes.

In addition, piscivory by Blue and Flathead catfishes is likely to vary seasonally and regionally (freshwater vs. oligohaline habitats). On finer spatial scales, we do not know how diets may be affected by depth; for example, catfish from shallow estuarine habitats may not exhibit the same pattern of piscivory as those from deeper estuarine areas (only a few samples from estuarine waters less than 1.5 meters deep have been collected for examination). Furthermore, ecosystem-level effects of piscivory must take into account the size dependency of this feeding behavior. In Blue Catfish, piscivory is strongly size-dependent such that the frequency with which fish are observed in the diet increases with increasing fish size. Based on electrofishing surveys in the freshwater reaches of the James River in 2010, about 46% of the population of Blue Catfish was <31 cm fork length (FL), 47% was between 31 and 61 cm FL, and about 7% of the population exceeded 61 cm FL (n = 6,725 fish). In freshwater reaches of the Patuxent and Nanticoke rivers in 2012-2013, about 20% of the population sampled by low-frequency electrofishing was >30 cm total length (TL) and <1% exceeded 60 cm TL (n = 320 fish) (Hines et al., unpublished data).

Nutrient enrichment has resulted in extremely high productivity in the freshwater tidal James and other bay tributaries, accommodating the presence of extremely high abundances of non-native high trophic level predators such as invasive catfish.

As bycatch, Blue Catfish interact with fisheries operating in Chesapeake Bay tidal tributaries and may negatively affect economic interests. For example, in the Potomac River, Blue Catfish are bycatch in gillnet fisheries, and due to their high abundance, may severely reduce gear efficiency for target species. Similar interactions may be occurring in gillnet fisheries in the James River. The amount and economic value of foregone harvest of the target species are currently unknown, but may represent significant local effects (Fabrizio et al. 2011).

Current Management Efforts

Regulations and Policies

There is no management strategy for Blue and Flathead catfish as invasive species and no coordinated strategy for their management across the Chesapeake Bay management jurisdictions. It is illegal in all jurisdictions to transport live Blue and Flathead catfish for the purpose of introduction into another body of water. Additionally, Maryland Department of Natural Resources, District of Columbia and the Potomac River Fisheries Commission officials discourage release of angler-caught fish and are asking anglers to remove and kill any Blue and Flathead catfish that they catch. Virginia resource managers in the Virginia Department of Game & Inland Fisheries do not support a kill- on- capture policy. The Pennsylvania Fish and Boat Commission encouraged anglers to kill all Flathead Catfish upon capture in Atlantic Slope water bodies upon discovery of these populations; however, this was never implemented as a formal regulation. Current regulations for Flathead Catfish in Pennsylvania include a liberal creel limit of 50 fish per day with no minimum length or seasonal limitations. A draft management plan that recommends measures to increase exploitation of Flathead Catfish within its non-native range is currently under review in Pennsylvania.

There are agreements by Chesapeake Bay jurisdictions and the Atlantic States Marine Fisheries Commission to develop management options, and these agreements led to the establishment of the ICTF and called for the drafting of this report. In January 2012, a policy statement (**http://www.chesapeakebay.net/documents/final_catfish_policy_git_1-24-12_(with_signatures).pdf**) signed by members of the Fisheries GIT Executive Committee concluded that Blue and Flathead catfishes are invasive and that the potential risk posed by Blue and Flathead Catfishes on native species warrants action to examine potential measures to reduce densities and limit range expansion, and to evaluate possible negative ecological impacts . Prior to that, the Atlantic States Marine Fisheries Commission approved a resolution expressing concern about the impacts of Blue and Flathead catfish on Atlantic Coast migratory fish species.

Commercial and Recreational Fisheries

Catfishes in the Chesapeake Bay watershed have supported recreational and commercial fisheries for several decades. Commercial fisheries are typically low valued because the price-per-pound has remained low, around $1/lb and hence, commercial extraction has been minimal (about 2 million pounds/year from tributaries of Chesapeake Bay in VA and MD). Both Maryland and Virginia are exploring the potential to develop new markets and hence increase commercial value of Blue Catfish. Important recreational fisheries have developed, particularly in the upper James and Potomac rivers, where populations currently support lucrative trophy fisheries. Catfishes are the third most sought-after species group by U.S. recreational anglers (USFWS Report), and there are more catfish anglers in the U.S. than there are marine recreational anglers. The popularity of catfishes stems from the ease with which these fish can be taken, the lack of economic barriers to participation in the fishery (i.e., fish can be accessed from shore, with minimal investment in gear), and the palatability of the flesh. These fisheries generate millions of dollars annually through angler expenditures and have been encouraged in recent years through state-wide competitions and tournaments. Maryland and Virginia also recognize anglers through angler citation programs for trophy fish and the District of Columbia recognizes anglers that harvest Blue Catfish through a newly established records program. A primary reason for these introductions was to develop a recreational trophy fishery for Blue Catfish in Virginia. The current (05-20-2009) state record Blue Catfish in Virginia weighed 102 pounds, 4 ounces, and measured 52-3/4 inches TL with a girth of 41-1/2 inches and was caught in the James River. The commercial fishery has a maximum size restriction of 32 inches in an attempt to minimize impacts on the trophy recreational fishery and to comply with the consumption advisory on this species (no consumption of Blue Catfish over 32 " from the James River; 1 meal per month of Blue Catfish caught from other tributaries).

Research and Monitoring

Fisheries programs at VIMS, VCU, VDGIF, SERC, District of Columbia Fisheries, University of Maryland, and MDDNR use a variety of gears to sample both the nontidal and tidal portions of the major coastal rivers. Other systems such as the Rhode, West, and other rivers in MD, have been sampled by SERC and University of Maryland, but these surveys have not yet encountered invasive catfishes. Where they have been encountered, such sampling can be used to infer changes in spatial distribution and relative abundance of Blue Catfish, composition of the diet of adult Blue Catfish, variations in age and growth rates, and concentrations of bioaccumulating contaminants (such as Polychlorinated biphenyls, Tributyltin, and Mercury (Hg)). There are few monitoring programs focused only on invasive catfishes. A full summary of current research efforts and findings is provided in Appendix A of this report.

Communication and Outreach

Very little has been done to increase awareness among anglers or the general public regarding the status of Blue and Flathead catfishes as invasive, the threat they pose to native species, or the "No Transport" regulations in effect. Maryland has partnered with the Chesapeake Bay

Program to post signs at key public access sites to raise awareness. Information on websites across the jurisdictions is difficult to find and not consistent, although Maryland, PRFC, and DC have taken action to improve messaging on invasive catfishes and communicate “no transport” regulations. The issue of Blue and Flathead Catfishes in the Chesapeake Bay and the draft recommendations in this report were presented to the Mid Atlantic Aquatic Invasive Species Panel and the ICTF has had some communication with catfish charter operators in Virginia. The National Park Service has offered to include information at their sites around the Bay but the details are still under negotiation.

Recommendations

The selection of appropriate management actions (e.g. prevention, eradication, control) in response to invasive fish species depends on an understanding of the steps in the invasion process and of the ecology of the host community (Kolar & Lodge 2001). For example, eradication is rarely feasible or cost-effective once a species has become widely dispersed in an open aquatic system like Chesapeake Bay (Sakai et al. 2001). In such situations, prevention of further expansion and control of established invasive populations are more likely to be effective strategies (Britton et al. 2010). These will be the focus of the actions and recommendations outlined below with emphasis on options to reduce impacts on vulnerable riverine and estuarine resources.

It is also important to note that although Blue and Flathead catfishes have been in the Chesapeake Bay for 30-40 years, to date, little has been done to manage these species. We are still working to understand their biology and ecology and will need to test and evaluate the proposed management strategies for efficacy.

Recommendations and the corresponding logic model (Appendix C) were developed within this context and the anticipated long term effort that will be required to measurably change the current condition and realize the desired ecological outcomes. Each of the recommendations will require extensive discussion prior to implementation, broad cooperation among agencies, and a willingness to adapt strategies to new information as it becomes available (adaptive management). The ordering of recommendations below does not necessarily imply priority. The following section includes ICTF context and findings used to formulate recommendations, the specific recommendations and an analysis of the pros and cons of each recommendation.

Recommendation 1

Invasive catfish populations have increased significantly since their introduction, aided in part by eutrophic conditions. Large abundances of invasive catfishes may be causing ecological harm by exerting predation pressure on native species such as Blue crab, Blueback Herring, and Atlantic Menhaden. Invasive catfishes can also cause economic harm through interference with commercial fishing operations. Catfishes may be captured by commercial gear that targets valuable species such as striped bass and may lead to a significant increase in the amount of time required to remove and handle this unintended bycatch.

We recommend that jurisdictions work together to design and implement targeted fishery-independent removals of invasive catfish in places of significant ecological value (i.e. spawning and nursery habitat areas for anadromous species). There are some tributaries where well planned, intensive, and repeated removals of invasive catfishes have the potential to reduce populations to a level that may lessen their impacts on important native species. We further recommend these fishery independent removals be conducted as pilot projects or studies to develop, test, quantify, and evaluate effective removal methods for invasive catfishes. Existing GIS tools such as the Catfish Portal, Coastal GEMS, the Fish Passage Prioritization Tool and Maryland GreenPrint can be used by experts to identify prospective removal areas.

A recent GIS-based analysis by VCU (Figure 3) identified 64 high-value Chesapeake Bay watersheds in Virginia and Maryland (i.e., below Conowingo Dam) that were at risk for establishment of Blue Catfish populations (n=9) or that already have established Blue Catfish populations (n=55). These watersheds could be candidates for removals and possibly special protections.

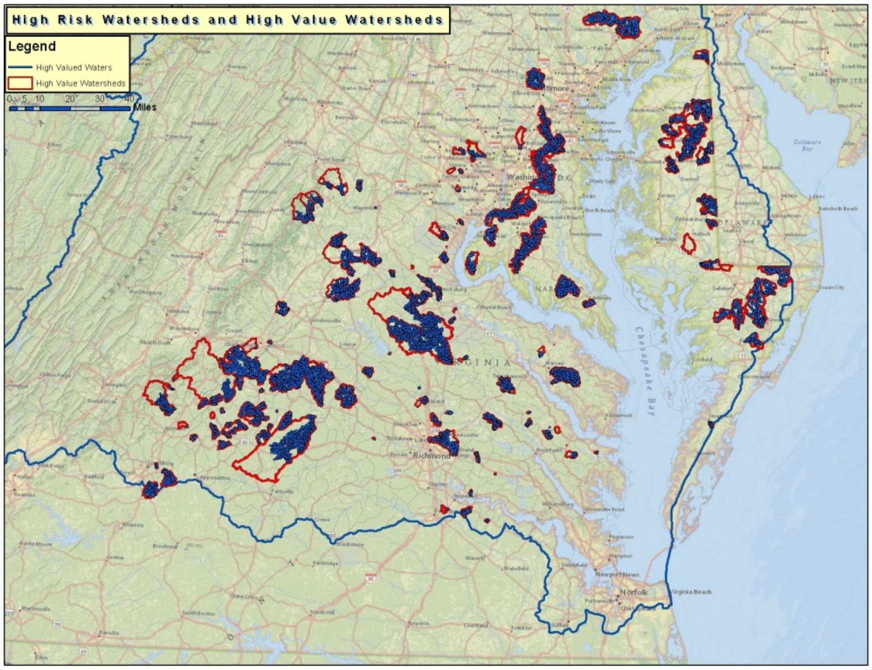

Figure 3. Ecologically significant watersheds (red polygons) and streams (blue lines) in the Chesapeake Bay that occur within high-risk watersheds for invasive catfishes. Geospatial units are 12-digit watersheds (HUCs). Data were compiled by VCU from various sources.

In these areas, the goal is not to eradicate the invasive catfishes, but rather to limit biomass and ecological impact. The use of electrofishing or piscicides as a control measure for invasive fishes may have the potential to reduce ecological impacts in some aquatic habitats, especially smaller systems with limited connectivity to source populations (Britton et al. 2010). For example, electrofishing removal (monthly for 33 months) reduced the abundance of invasive adult Tilapia by 87% in an impoundment with a concomitant reduction in ecological impacts (Thuesen et al. 2011). Low-frequency electrofishing as a catfish removal method has the advantage of limited effects on non-ictalurids. Control projects of this type require a long-term commitment of resources to maintain including effective surveillance. Following removals, carefully-designed, constructed or non-physical barriers (Noatch & Suski 2012) might be deployed temporarily in smaller creeks to exclude adult invasive species. For example, excluding predatory invasive catfishes from tidal spawning habitats for *Alosa* spp. during spring months may increase spawning success in those systems.

Over a decade ago, VDGIF regional biologists used electrofishing in an attempt to eradicate invading Blue Catfish from the Piankatank River, Virginia. That effort, which had limited departmental support, failed but the upper Piankatank system (Dragon Run) may still be a candidate for a renewed removal pilot study in Virginia. Similarly the Patuxent River in Maryland may serve as a test bed for removals and is under consideration by Maryland DNR now. Eastern Shore tributaries are other potential candidates.

Pro: Targeted removals may help mitigate impacts of invasive catfishes on native species in select tributaries.

Con: Removals could be costly and may not reduce numbers and may not achieve ecological outcomes for native species. There is also an issue of disposal of removed fish. Disposal of fish could be addressed by investigating donation to food banks modeled after Hunters for the Hungry that provides venison to food banks http://www.dgif.virginia.gov/hunting/hunters-for-the-hungry/ and industrial uses of the discarded biomass. The action may not appreciably reduce abundance in systems with high catfish biomass and may spur conflicts with the recreational anglers.

Recommendation 2

Typically, debates concerning the appropriate management of potentially invasive species focus on documenting economic and ecological impacts of the introduced taxa and (if warranted) identifying feasible eradication or control measures (Sakai et al. 2001). In the case of introduced Blue Catfish and Flathead Catfish in Chesapeake Bay, negative economic consequences may be mitigated—at least in part—by revenues generated from recreational and commercial fisheries for these species (Shogren & Tschirhart 2005).

We recommended that efforts and incentives to develop a large-scale, commercial fishery be accelerated and coordinated across jurisdictions. Creation of a new fishery in the Chesapeake Bay exploiting the growing populations of invasive catfishes has the potential to help to reduce populations while also providing economic benefit to watermen and the region. This will require more immediate and coordinated action across jurisdictions to identify markets, increase the value of the fishery, and remove factors (e.g. lack of processing facilities) that are currently limiting expansion of the existing small- scale fishery. A key component of this recommendation is developing a sustainable fishery capable of maintaining reduced populations over the long term. This is critical to achieving ecological and economic outcomes. We recommend a workshop be held with current and prospective fishers, fishery managers and economists to identify the steps needed to expand the current fishery and make it sustainable and economically feasible.

To increase exploitation, the ICTF recommends developing a market for Chesapeake Bay Blue Catfish through marketing campaigns that promote the fishery as sustainable, healthy and local. The Blue Ocean Institute has listed Blue Catfish from the Chesapeake Bay region as a sustainable seafood source (http://blueocean.org/seafoods/). Current data on mercury and methyl mercury concentrations in Blue Catfish indicate that these fish generally have levels below the EPA human health screening level, and current consumption advisories are no different than those applicable to Striped Bass. The ICTF recognizes that both Maryland and Virginia have efforts underway to develop markets and suggests these efforts continue with coordination across jurisdictions. We note that Washington, D.C. restaurants have been successful in promoting 'local, fresh catfish' on their menus and suggest implementing similar measures throughout the Bay watershed.

Pro: Developing a market may help raise the value of catfish on the market and spur fisheries targeting Blue catfish bay-wide. In turn this would increase effort, and subsequently harvest, which can help to reduce biomass. Additionally, reducing invasive catfish abundance would help decrease bycatch interference of Blue Catfish in other commercial fisheries. Actions that rebuild and sustain native species (and fisheries) provide long-term economic gain.

Con: Developing a market and raising the value of an invasive species may lead to pressure to manage the fishery for sustainable harvests contrary to the initial objective. Further, a successful effort to increase demand and market value may increase the threat of unauthorized introductions into new waters to create fisheries.

Recommendation 3

We recommend jurisdictions consider options to incentivize increased harvests of invasive catfishes by small boat operations and explore the use of electrofishing for commercial harvest purposes. These options could be further discussed as a part of the workshop suggested in Recommendation 2.

To jump-start the commercial industry, the ICTF recommends incentivizing fisheries that are pursued by small-boat operations (2-3 people), providing free licenses for the capture and sale of invasive catfish. This will increase harvest and promote profitable small-scale operations.

The idea of electrofishing as a commercial fishing technique has been around for a long time (Fitz 1970) but for many reasons, including cost, safety, and effects on non-target species, it is not widely applied. However, in both nontidal and tidal freshwater and oligohaline reaches of larger Chesapeake Bay tributaries, the use of low-frequency (≤ 15 pps), pulsed direct current (PDC) electrofishing (LFEF) by commercial catfishers could lead to the harvest of large numbers of non-trophy Blue Catfish. Whether or not commercial LFEF electrofishing could be an effective (i.e., ecologically relevant) control measure for Blue or Flathead catfish is unknown, but LFEF does have the advantage of limited by-catch (cp. gillnets) and low habitat impacts (cp. bottom trawls). On the other hand, LFEF would be restricted to specific seasons (water temperatures between 18° and 25° C) and locations (≤ 2 ppt salinity), and would be subject to variable market demand and contaminant issues like any other fishery. Experimental electrofishing for commercial applications would require a significant financial investment ($20K per vessel) and strict oversight by agencies but might be fundable through fishery resource grants (FRG) or similar programs. North Carolina currently allows recreational (but not commercial) catfish harvest with electrofishing, with specific restrictions (T. Kwak, NCSU, pers. comm.). We note that at least one proposal has been submitted to the Fishery Resource Grant

Program of Virginia Sea Grant to explore the feasibility of using electrofishing gear for harvest of blue catfish. Similar evaluations of gear efficiency could be promoted elsewhere.

Pro: Incentives and gear allowances would promote a fishery and may help increase landings of Blue Catfish, reduce biomass, and reduce impacts on native species. The fishery could also provide economic opportunities.

Con: Developing a market and raising the value of an invasive species may lead to pressure to manage the fishery for sustainable harvests contrary to the initial objective. Competing objectives could arise between small-scale operations and recreational fishing, however, if only smaller fish are targeted then these conflicts should be minimal. There is the possibility native White Catfish could be affected if species identification is not emphasized. Safety concerns and fishery enforcement requirements may create challenges to implementation. There are regulatory and legislative barriers to allowing catch of recreational fish to be sold.

Recommendation 4

Invasive catfish populations are rapidly expanding across tidal and nontidal reaches of the Chesapeake Bay watershed. This rapid expansion threatens the ecological integrity of the systems they are colonizing and may be negatively impacting native species and fisheries. A geospatial model developed by VCU (Figure 1) suggests that Blue Catfish distribution has the potential to nearly double, from 136 watersheds (12-digit HUCs) to 242 watersheds, in the Chesapeake basin and that distribution of Flathead Catfish is also expanding in the region.

We recommend jurisdictions establish monitoring programs dedicated to identifying and tracking invasive catfish distributions and population status. We also recommend developing early detection and response programs to monitor ecologically significant areas. There are currently few dedicated monitoring and survey efforts for invasive catfishes. In addition, the applied research efforts underway should could be synthesized and used to improve effective implementation and refinement of the management options outlined in this report.

Effective surveillance programs are essential for the management and potential control of invasive species but such programs are very expensive to maintain, especially across large areas. Opportunities to leverage existing resources (e.g. acoustic telemetry arrays) or new technologies (e.g. molecular genetics (eDNA), online data portals) should be identified and pursued as part of an overall strategy for monitoring the distribution and spread of Blue Catfish and Flathead Catfish in the region. For example, the recent development of environmental DNA (eDNA) analyses as a relatively inexpensive and accurate way to detect Asian carp and other biological invaders (Darling and Mahon 2011) in aquatic habitats could be applied to Chesapeake Bay surveillance programs for catfish and other invasive species.

Another example of surveillance is the use of a smartphone app that allows recreational and commercial fishers to upload photos and locations of captured Blue Catfish. SERC is studying the spread of Blue Catfish throughout upper Chesapeake Bay using the citizen science smartphone app Project Noah, backed by National Geographic, to collect catfish distribution information from commercial and recreational fishermen. The app is free to download and can be viewed at http://www.projectnoah.org/missions/38272048. This concept of using recreational and commercial users to help identify and document invasive catfish distributions using mobile devises could be applied more broadly in the Bay.

We also suggest continued support to improve our understanding of invasive catfish biology their ecological impacts and potential control mechanisms. Important gaps remain in our understanding of the role of invasive catfishes as predators in the Chesapeake Bay region in spite of recently-completed and ongoing studies supported by NCBO, ASMFC, VDGIF and others. Basic biological information about these species remains largely unknown including reproductive potential, salinity tolerance, and bio-energetic demands. Efforts should continue to improve our understanding of the mechanisms that contribute to the spread and success of invasive catfishes in the Bay area. The ecosystem is not static and there may be changes that we cannot anticipate that will enhance the ability of catfish to invade other areas. Applied research efforts will also assist in the development of new tools and more effective management approaches.

Pro: Improved monitoring would provide better distribution and population status of invasive species. Continued research and synthesis will allow for new tools and adaptive management strategies.

Con: Effective monitoring requires long-term commitment of resources, interagency coordination, technology development and public participation.

Recommendation 5

Over 3,800 constructed impediments to fish migration (mostly low head dams) are documented on Chesapeake Bay tributaries (E. Martin, TNC, unpubl. data). Many have been prioritized by wildlife resource agencies for removal or for construction of fish passage facilities to support regional diadromous fish restoration goals. Approximately 10 percent of these structures are identified as high priority (Tier 1 & 2) for removal in the near future. In most circumstances, removal of a dam will significantly increase the ecological health of a river by restoring its hydrologic connectivity to the watershed (Holmquist et al. 1998). However, some have argued that the benefits gained from successful fish passage projects may be offset by opening corridors to invasive species that had previously been blocked from upstream reaches (Freeman 2002). For example, the Bosher's Dam fishway on the James River passed at least 8,000 Blue Catfish between 2002 and 2005 (Fisher 2007) and the species is now well-established upstream as far as Columbia, Virginia. Similar information may be available for Flathead Catfish on the Susquehanna River at the Conowingo Dam in Maryland.

We recommend careful consideration of the effectiveness of existing barriers to invasive catfish spread (i.e. dams) and suggest that the benefits of barrier removal be weighed against the risk of damage to areas of significant ecological value by invasive catfish expansion. We suggest formal coordination between invasive catfish experts and the Fish Passage Workgroup of the Chesapeake Bay Program Habitat Goal Implementation Team to identify barriers and develop ecosystem-based recommendations of high risk for dam removals with the potential to allow invasion.

This could include requiring an assessment of the unintended consequences, including creation of expansion corridors for invasive species, of removing or modifying Tier 1 & 2 dams as part of the fish passage prioritization process. This is especially true for those Tier 1 or 2 dams within high-risk catfish watersheds identified by VCU's spatial model (Figure 4).

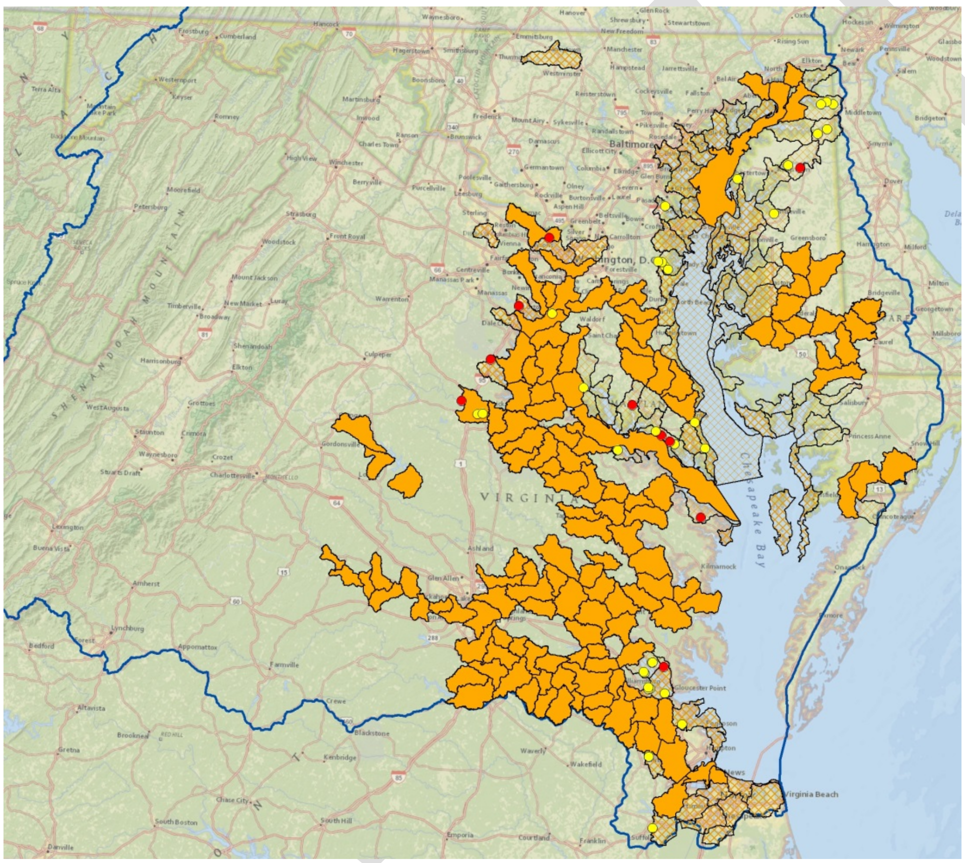

Figure 4. Tier 1 (red) and tier 2 (yellow) dams prioritized for fish passage in watersheds that currently support blue catfish (solid polygons) or at risk to support blue catfish (cross-hatched polygons); analysis limited to Chesapeake Bay waters below Conowingo Dam. Geospatial units are 12-digit watersheds (HUCs). Data are compiled from several sources, including VCU, TNC, VIMS, VDGIF, and MdDNR; data were current as of 1 April, 2013.

Pro: More formal consultation on and assessment of the risks of invasive catfish expansion as a result of dam removal could help limit the ability of invasive catfish to spread and fosters collaboration among fishery managers and habitat restoration specialists.

Con: The benefits of providing access to habitat for species like American Shad, river herring and American Eel may outweigh costs of invasive catfish range expansion. Studying invasive catfish expansion risk could increase cost, extend and timelines, and potentially prevent some dam removals. Dams that are left in place to prevent upstream expansion by invasive species are still subject to the possibility of illegal transport upstream by anglers.

Recommendation 6

We recommend a cross-jurisdictional review of current fishing policies and regulations across jurisdictions to consider current regulations that may facilitate the persistence and expansion of invasive catfish populations. This review should also evaluate the efficacy of communications and enforcement of the current regulations regarding the illegal transport of live fish.

Managers should discuss the risks associated with maintenance of trophy fisheries. The perpetuation of a trophy fishery permits these invasive species to persist in the environment for long periods of time, continue to reproduce, and potentially impact areas where control measures have been implemented. Neither MD nor VA appears to favor removal of the trophy fisheries from the James or Potomac rivers, so it is likely that other management actions will be ineffective in these two rivers. It would be difficult to support a trophy fishery in one or two systems while supporting control in the remaining systems. A consistent management approach is one that will likely be more credible and effective. Chesapeake Bay jurisdictions have regulations in place intended to limit human-assisted dispersal of nonindigenous species by anglers, the aquarium trade, or other pathways. Evaluation of existing rules and laws may be necessary to assess whether they are clear and comprehensive enough to effectively limit the unintentional and intentional spread of invasive species in the region.

Pro: Review of policies across the jurisdictions could promote dialogue on the trade-offs associated with existing policies and help jurisdictions develop shared management objectives.

Con: None.

Recommendation 7

We recommend jurisdictions make information on invasive catfishes more accessible, and consistent, and clearer to anglers and the general public. Information on invasive catfishes is difficult to find and not well coordinated across jurisdictions. We suggest an immediate effort be made to convene communication experts from the Chesapeake Bay jurisdictions to identify inconsistences in messaging and develop an aggressive communication campaign to increase public awareness. This campaign should be paired with the development of a web portal that provides the public, researchers, and resource managers access to current information on invasive catfishes.

Although information is available on invasive catfishes, it is not consistent across jurisdictions, regulations are not easily found, and there is no sense of urgency in the messaging to the public or anglers about the risk invasive catfishes pose. Jurisdictions working with the Chesapeake Bay Program should develop messaging that educates the public and anglers about the risk invasive catfish pose to native species. This messaging should be applied as comprehensively as possible to posters at boat ramps, websites, social media, anglers logs, bait and tackle shops, and press releases. A media campaign—similar to that for Northern Snakeheads could be effective. The media campaign can be sparked by taking journalists out to sites for demonstrations of electrofishing, learning about the latest research and risks.

In addition, there needs to be a single information source (website and database) that serves as a home to the most up-to-date scientific information on invasive catfishes perhaps maintained by the Chesapeake Bay Program with links to jurisdictional information. The site should also house the work that VCU has done to develop a comprehensive database. This database is only as good as the information that feeds it so it will be improved as jurisdictional monitoring programs share data to ensure the database is useful to managers and researchers.

Pro: Easily accessible information informs researchers and the interested public with consistent messaging, aids decision making by management entities, and promotes research and analysis by scientists. A consistent messaging campaign supported by all jurisdictions is important for success of any control or mitigation program.

Con: Cost of development and maintenance for message development, websites, and database.

Alternative approaches to engage the public and remove invasive catfishes

In addition to the above recommendations for which the ICTF reached consensus we also considered options that have been utilized in other regions and with other invasive species to raise public awareness and attempt to reduce populations. However, we were not able to reach consensus on including these other approaches as formal recommendations. These include alternative removal efforts that involve the public such as fishing derbies. Jurisdictions could work with local conservation and fishing organizations to hold fishing derbies for invasive catfish aimed at removing fish at selected locations (i.e. smaller tributaries, places of high ecological value, and where colonization is recent) and to raise public awareness. Events where invasive species are caught and removed have been successful in other instances (e.g. Silver Carp). In the James River and other systems where invasive catfish are well established, a measurable effect on populations may not result, but the primary purpose is to educate resource users, and to have a growing public awareness of the need to stop the spread of invasive species.

Conclusion

We believe that these recommendations implemented individually or collectively will begin to address the challenges of invasive catfishes in the Chesapeake Bay and that lessons learned during implementation will allow for adaptation and improvements. Refer to the Appendix B which lays out a draft logic model outlining how the recommendations in this report can meet the stated objectives over the near and long term. We suggest that the Fisheries GIT Executive Committee prioritize these recommendations and consider how jurisdictions will work together to implement. We also note that our understanding of invasive catfishes is still limited and we cannot say with certainty that the recommendations above will have the desired result of reducing impacts on native species, increasing public awareness, and slowing the spread of invasive catfishes. We can envision that as recommendations are implemented a more comprehensive management strategy will begin to emerge, a process that is playing out with other invasive fish species such as Lionfish in the South Atlantic, Gulf and Caribbean and Asian Carp in the Great Lakes.

Appendix A. Summary of Current Research and Findings

In late summer 2011, NOAA funded five research projects to address scientific knowledge gaps and management concerns about Blue Catfish in Chesapeake Bay tributaries (principal investigators and their home institution are provided in parentheses):

- Risks of expanding the Blue Catfish fishery as a population control strategy: influence of ecological factors on fish contaminant burdens (R. Hale, VIMS)
- Trophic dynamics of Blue Catfish in Maryland (A. Hines, SERC)
- Predation by introduced Blue Catfish as a potentially important and novel source of mortality for selected fishery resources in Chesapeake Bay waters (G. Garman, VCU)
- Characterizing the growth dynamics of Blue Catfish in the Chesapeake Bay watershed (R. Latour, VIMS)
- Estimating population size and survival rates of Blue Catfish in Chesapeake Bay tributaries (M. Fabrizio, VIMS)

Risks of expanding the Blue Catfish fishery as a population control strategy: influence of ecological factors on fish contaminant burdens -- As contaminants in edible fish tissues may present toxicological risks to human consumers, we determined concentrations of several known to pose human health concerns (i.e., mercury, chlorinated and brominated organic micropollutants) in fillets from blue catfish greater than 300 mm from three Chesapeake Bay tributaries: the James, Rappahannock and Potomac rivers. Fish from these locales were exposed to differing levels of point- and non-point sources of pollutants. Blue catfish from the upper Potomac and upper James exhibited greater fillet burdens of most contaminants than conspecifics from the lower James or Rappahannock rivers. However, despite high human population densities in the area, mercury levels were lower in Potomac blue catfish fillets. Fish sex and $\delta^{15}N$ values (as a surrogate for trophic position) had minimal influences on contaminant fillet burdens in blue catfish of the sizes examined in this study. Potomac catfish exhibited distinctly greater $\delta^{15}N$ values, suggestive of feeding at a higher trophic level or ingestion of prey items with higher $\delta^{15}N$ signatures. For most contaminants, pollutant burdens increased with fish size. Fillet % lipid was positively related to lipophilic organic pollutant concentrations, but not to total mercury. Our contaminant burden results support existing VA and MD advisories regarding regional fish consumption, i.e. concentrations of PCBs and Hg in blue catfish fillets from some locales pose risks to human health, and this risk varies with fish consumption rate. Based on the Hg and PCBs concentrations we observed, the majority of blue catfish sampled surpassed existing EPA recommended limits for unrestricted human consumption. Furthermore, river-segment specific consumption advisories are necessary as contaminant types and concentrations varied within rivers. Within river segments, fish length and weight were useful predictors of concentrations of most contaminants. Consideration of % lipid content improved predictions of fat-soluble organic pollutants, but not Hg. However, % lipid is not a measure that is readily usable by anglers or consumers to inform or limit their contaminant exposure.

A 1998 report by Garman & Hale evaluated contaminant concentrations in tissues from 48 blue catfish (mean TL = 65 cm) collected from the James River near Hopewell, Virginia. They found elevated levels for several contaminants, including TBT (up to 29 µg/kg, wet mass) and total PCBs (up to 5,309 µg/kg, dry mass; equivalent to approximately 1060 ug/kg on a wet weight basis). Concentrations were positively and significantly correlated with catfish size (mass, kg).

A study funded by Virginia Sea Grant in 2010 (Newman and Fabrizio, VIMS) included analysis of total mercury and methyl mercury concentrations in blue catfish (standard fillets) from Virginia tidal tributaries. The 35 blue catfish analyzed in that study ranged between 386 and 428mm total length (mean=407 mm TL) and had total mercury concentrations between 42.5 and 55.3 µg/kg wet weight (mean=48.4 µg/kg wet weight), which are below the EPA human health screening value of 300 µg/kg wet weight (Xu, X, M. C. Newman, M. C. Fabrizio, and L. Liang. 2013; US EPA 2009). On average, about 61.3% of the total mercury present in blue catfish muscle tissue was methyl mercury (Xu, X, M. C. Newman, M. C. Fabrizio, and L. Liang. 2013). For blue catfish, methyl mercury concentrations measured on a dry weight basis increased significantly with increasing $\delta^{15}N$, indicating that blue catfish that occupied higher trophic positions in the food web (i.e., those that consumed more fish) also accumulated more methyl mercury (MHg).

Trophic dynamics of Blue Catfish in Maryland -- Four river systems in Maryland were sampled in 2012 and 2013 via low-frequency electrofishing for catfish species: Patuxent, Nanticoke, Sassafras, and Northeast/Susquehanna Flats. In 2012, 172 Blue Catfish were collected along with 236 Channel Catfish and 118 white catfish. Stomach contents are currently being analyzed using traditional microscopic/visual approaches, in combination with DNA barcoding that enables species-specific identification of partially digested fish prey, to determine the diet of Blue Catfish and make comparisons with other catfish species, especially the native White Catfish. The composition of prey fish in the same areas in these four rivers was sampled via high-frequency electrofishing to determine whether Blue Catfish are generalist predators or whether they are targeting specific prey species. Muscle tissue samples from Blue Catfish were analyzed for stable isotopes (C^{13}, N^{15} and S^{34}) and total mercury concentration; tissues were also collected for genetic analysis and otoliths removed for age and growth rate determination.

In addition, SERC is studying the movement, migration, and spread of Blue Catfish in Chesapeake Bay using an acoustic telemetry study (funded by the Smithsonian Institution Competitive Grants for Science Program) and a smartphone app that allows recreational and commercial fishers to upload photos and locations of captured Blue Catfish. For the acoustic telemetry study, SERC has deployed an array of eight VEMCO VR2 acoustic receivers along the length of the Patuxent River (to be expanded to 12 receivers in 2014). To date, 13 Blue Catfish have been tagged with V-13 transmitters in the upper Patuxent River and we anticipate that at least 50 fish will be tagged by the end of 2014. The goal of this study is to document daily movements, seasonal migrations, and habitat use. The study of the spread of Blue Catfish throughout upper Chesapeake Bay uses the citizen science smartphone app Project Noah, backed by National Geographic, to collect catfish distribution information from commercial and recreational fishermen. The app is free to download and can be viewed at http://www.projectnoah.org/missions/38272048.

Predation by introduced Blue catfish as a potentially important and novel source of mortality for selected fishery resources in Chesapeake Bay waters -- This project seeks to determine the likely effects of predation from invasive catfishes on selected fishery resources; this project also investigated the use of an experimental barrier aimed at controlling [catfish] predator access to streams that are essential habitat for anadromous clupeids (*Alosa* spp.). More than 3,000 Blue Catfish and Flathead Catfish > 300 mm TL have been sampled for stomach content analysis at 17 locations in Virginia and Maryland. A diel consumption model that permits estimation of the overall catfish predation mortality on key resources (e.g. Blueback Herring) in the tidal James and Rappahannock rivers has been completed. GIS models to forecast future distributions and potential threats (predation and other interactions) from invasive catfishes in the Chesapeake Bay basin have been completed. Results indicate that although diets of Blue Catfish are highly variable over space and time, predation impacts on key fishery resources may be locally significant. For example, Blue Catfish consumption of juvenile Atlantic Menhaden in the lower James River (near Newport News) by averaged 41% (as frequency of occurrence) and ranged up to 71% during a five-week period in Spring 2012. Approximately 1 million juvenile Atlantic Menhaden and 0.6 million Blue crabs were estimated consumed by large Blue Catfish in Burwell Bay (lower James River, Virginia) during April and May 2012, using a spatially-explicit consumption model. A similar model was used to estimate that Flathead Catfish consumed between 7,680 and 10,002 spawning Blueback Herring (*A. aestivalis*) during April 2012 at the James River Fall Zone. At the James River Fall Zone, Flathead Catfish consumed between 7,680 and 10,002 spawning Blueback Herring (*A. aestivalis*) during April 2012. Tests in a tidal tributary of the James River (Kimages Creek, Virginia) with exclusion nets indicated that non-rigid nets were ineffective barriers for mitigating predation effects of invasive catfishes in tidal creeks.

In the Rappahannock basin and, to a lesser extent, in the James River, electrofishing survey results indicate a decline in the percent of large (>300 mm TL; i.e., piscivorous) Blue Catfish. For example, larger Blue Catfish (> 450 mm TL) in the upper tidal James River comprised 40.5 percent of the population in 2007, but only 11.5 percent of Blue Catfish in 2012 (using similar sampling gear and in the same location). Changes in the size frequency distribution of a population may reflect recruitment pulses or differential movement of size classes. For instance, large catfish may be moving out of tidal freshwater reaches and into mesohaline habitats further downstream. Overall densities remained high in these systems, but size distributions in long-established populations may have shifted. If these changes in size distribution reflect a permanent redistribution of size classes in the river, then it may be difficult to support upriver trophy fisheries. However, without additional data on year-class composition of the population, we cannot know which of these hypotheses may account for the observed shift in size frequency.

Characterizing the growth dynamics of Blue Catfish in the Chesapeake Bay watershed – This study aimed to develop a 'master' database of existing and newly collected data on the growth of Blue Catfish in the James, York, Rappahannock, and Potomac rivers, and to analyze existing and newly collected data to formally describe the growth patterns and dynamics of Blue Catfish in tributaries of Chesapeake Bay. The master database includes 'historic' data on age (yrs), size (FL, mm), and total weight (g) of Blue Catfish collected in the James, York, and Rappahannock Rivers from 1998-2000 (n=613 individuals; Connelly 2001). The database also includes 'current' data on FL and total weights for Blue Catfish collected in the same primary Virginia tributaries from 2010-present (n=560, otoliths not yet processed) and fish from the Potomac River from 2008-present (n=330, ages have been assigned to 97 specimens). Modeling results indicate that the mean weight of Blue Catfish at a given length is generally less for the current time period compared with the historic time period; this was true for the all rivers examined (James, York, and Rappahannock rivers). For the James and Rappahannock rivers, changes in the weight-at-length relationship were most likely due to time period rather than sexual dimorphism in growth. This result suggests that weight accumulation at length is currently slower than in the late 1990s. Because Blue Catfish abundances are believed to be considerably higher now than they were 10+ years ago (Schloesser et al. 2011), these observed changes in growth may be related to fish density. Interestingly, modeling results for the York River suggest that sexual dimorphic growth may be present in this population. It should be noted that the historic data from the Rappahannock River do not encompass a wide length range, so detecting density related impacts on growth is difficult for Blue Catfish in this river system. In terms of future sampling, there continues to be a need to collect specimens of larger lengths (> 600 mm

FL) in the James and Rappahannock rivers and a need to discern sex and determine the degree of sexual dimorphism in growth for Blue Catfish populations in Chesapeake Bay tributaries.

Estimating population size and survival rates of Blue catfish in Chesapeake Bay tributaries -- Experiments in early 2012 with 93 Blue Catfish held in captivity at VIMS indicated that coded-wire tags could be readily inserted in the dorsal musculature and that tag retention rates were sufficiently high to pursue a field-based tagging study in the James River. The lab-based tagging study also revealed that tag retention rates improved with increasing tagger experience. Blue Catfish (≥ 250 mm FL) were sampled from the James River and 15,721 fish > 250 mm FL were tagged with coded-wire tags between 9 July 2012 and 3 August 2012. All fish were trapped, tagged, and released in the 10-km area between the Chickahominy River confluence and Brandon Point (near the mouth of Upper Chippokes Creek); traps were set and tended by a cooperating waterman. During the tagging period, 930 fish were recaptured, representing a 5.9% recapture rate. Based on the pattern of catches and recaptures within our study site, tagged fish were more likely to move upriver after release. In 2013, coded wire tags were used to tag 18,531 blue catfish (≥ 250 mm FL) in the James River; about 1.2% of these fish were recaptured (n=216). Harvests from the commercial watermen operating in the James River were inspected for tags and this information will be used to adjust the population model to account for these removals.

To date, recaptured tagged fish have not been recovered in several electrofishing surveys conducted by Virginia Department of Game and Inland Fisheries and Virginia Commonwealth University. These sampling efforts have occurred within, downstream, and upstream of the tagging area in 2012 and 2013. These results suggest the population in the James River may be extremely large or that fish vulnerable to traps are not vulnerable to low-frequency electrofishing. Additionally, monthly sampling by the VIMS Trawl Survey has failed to encounter a single tagged fish (the survey area extends downstream from the mouth of the Chickahominy River, but overlaps somewhat with the tagging study site), suggesting that the population in the James River is extremely large or that fish movements are somewhat restricted within the river. An additional explanation is that only a small proportion of Blue Catfish are vulnerable to the trawl and most fish remain within relatively complex habitats that are not well sampled by bottom trawls.

A study of Blue Catfish movement was undertaken in the Potomac River in summer 2012 by the MD DNR (M. Groves); for this study, two dart tags were inserted in 739 large (>300 mm FL) catfish captured by low-frequency electrofishing in the tidal freshwater region of the Potomac River. By the end of 2012, 16 fish had been recaptured by anglers (2.2% recapture rate); of these, 15 retained both tags (93.8% tag retention rate). Fish recaptured by anglers tended to be larger (on average) than the average size tagged and released, indicating that anglers targeted the larger fish (> 480 mm). In addition, these fish moved between 0 and 64 km, but due to the type of tagging study, the time of year when the movement occurred could not be discerned. During the summer, however, most fish moved less than 10 km.

In addition to these five studies, NOAA Chesapeake Bay Office modeling team developed a modified version of the Chesapeake Bay Fisheries Ecosystem Model (CBFEM) to describe trophic interactions for fish communities of Chesapeake Bay tributaries with an emphasis on the role of Blue Catfish (Turner et al, *in prep*). The main purpose of this effort was to organize the sparse information available on Blue Catfish at the time and help highlight the research and monitoring that needed to be put into place so that we could understand the Blue Catfish population and its potential impacts on the food web.

This research highlighted a significant impact on key species of particular interest to recreational and commercial fisheries. Results from the model suggested that in a status quo scenario , i.e., no direct action taken to curb the Blue Catfish population, Blue Catfish populations would increase to a point where predation impacts would negatively impact Striped Bass, White Perch, alosines, native catfish as well as blue crab populations. Furthermore, simulations of nutrient reductions seemed to be the most effective control measure for Blue Catfish as they thrive in eutrophic systems. However, a recent review of the CBFEM's ability to model nutrient and eutrophication impacts on fisheries indicates that model produces variable results. In alternative model scenarios, where fishing mortality on Blue Catfish was increased tenfold to attempt to reduce the population; there was little evidence of any measurable impacts on populations of Blue Catfish biomass over the twenty year progression. However, the model runs were based on limited data on population biomass, landings, and diet composition. These initial model results demonstrate that Blue Catfish are likely going to have appreciable impacts on other important fisheries species and that efforts to control the population through direct fishing mortality are not as effective as controlling indirectly through environmental factors. Further study on the implications of environmental factors affecting the population is warranted.

The model has served its original purpose in highlighting needs for research and monitoring. The model and the ICTF have developed recommendations for Blue Catfish research and monitoring. Several agencies and academic are moving to fill these information gaps. NCBO and VDGIF have funded research that will help us understand the basic ecology of BCF in the Chesapeake (e.g., tagging studies, diet studies, geospatial databases). MD DNR, VMRC, and PRFC have improved BCF monitoring and landings data. The NCBO modeling team is working on a revised Fisheries Ecosystem Model. The Blue Catfish Taskforce is working to synthesize the new research and apply it to BCF management.

With the new information available from these monitoring and research programs and task force synthesis, the NCBO Modeling Team has planned and ongoing model improvements that include: 1) Incorporating new initial parameter inputs, 2) making a spatial model of the Chesapeake that incorporates spatial and temporal changes in environmental variables (e.g., salinity, temperature), 3) improving the way the model incorporates eutrophication.

With an improved model, the NCBO modeling team has plans to explore additional combinations of environmental (e.g., temperature and salinity) and fishing pressure as means to control the populations. Using this spatial model with environmental forcing functions, the team will be able to explore the extent to which the Blue Catfish population can be controlled in certain regions of the Chesapeake given environmental variability and focused fisheries efforts.

Summary of Research Findings to Date -- Together these studies indicate predation effects of Blue Catfish may be substantial depending on time of year (e.g., during Blueback herring spawning) and location. Findings also suggest that Blue Catfish may forage in mesohaline habitats (up to 14 ppt) and prey upon commercially important fishery resources. Additional studies in newly or recently colonized Maryland tributaries should prove useful in understanding the relationship between Blue Catfish diets and available prey. Geographically explicit information can be used to identify areas within the Chesapeake Bay basin that are vulnerable to colonization by Blue Catfish.

In recent years, the size-class composition of the population has shifted in favor of smaller individuals; although the cause of this shift remains unknown, such shifts could indicate that fewer trophy-size fish may be available to the sport fishery. Furthermore, biomass accumulation at length is slower now than it was in the late 1990s, indicating a potential density-dependent response.

Preliminary observations from fish tagged and recaptured in the James River indicate that population size in the James River may be extremely high; alternative explanations include relatively restricted movements of fish within the river (a hypothesis that is not supported by observations from the Potomac River), or differential vulnerability of fish to the gear. Fish tagged with dart tags in the Potomac River exhibit high tag-retention rates, higher than those typically reported for this species with similar tags (t-bar anchor tags); thus, dart tags are recommended for future studies where external tags are desired. Fish in the Potomac River can make long distance movements, up to 64 km, but their movements during summer appear to be more restricted (< 10 km).

The Blue Ocean Institute has listed Blue Catfish from the Chesapeake Bay region as a sustainable seafood source (http://Blueocean.org/seafoods/); analyses of the suite of contaminants found in Blue catfish from this region should be useful in providing consumption advice to consumers, but current data on mercury and methyl mercury concentration in fish ranging between 386 and 428 mm TL indicate these fish have levels below the EPA human health screening level. However, other contaminants in Blue Catfish may be present at levels that warrant consumption advisories.

Appendix B. Logic Model

The ICTF organized their thoughts on management recommendations and actions in the following logical model chart. This logic model clearly shows the management objectives for addressing invasive catfish in the Bay, the required inputs and activities to achieve these objectives, and the short- and long-term outcomes associated with those activities.

OBJECTIVE	Current Situation	Inputs	Activities/Outputs	Short-term Outcomes	Long-ter
TO MINIMIZE THE ECOLOGICAL IMPACTS OF INVASIVE CATFISHES ON NATIVE SPECIES	Blue Catfish make up a significant proportion of the biomass in several bay tributaries. Recent studies suggest Blue Catfish are having ecological impacts on native species via predation. There are also economic impacts as catfish co-occur with commercially important species. Further, predation of commercially important species can have economic impacts on fisheries. Eutrophication is likely supporting productive conditions advantageous to invasive catfish.	• ICTF • Science-VIMS, VCU, SERC, MD DNR, VDGIF (VT) • Jurisdiction Management-VMRC, VDGIF, MD DNR, PRFC, DENREC, DDOE, PA Fish and Boat, ASMFC • Federal-NOAA, FWS • CBP • Mid Atlantic Panel on Aquatic Invasive Species • Anglers • Funding	• Complete catfish population estimates for key tributaries • Apply the catfish portal mapping tool to identify candidate tributaries for targeted removals • Design removal methods and initiate pilot removal project /protection projects for the Dragon Run in Virginia and 1-2 to two Maryland tributaries • Use findings from removals projects to determine the extent to which populations can be reduced and develop population “control targets” • Complete a synthesis of current research quantifying ecological impacts	• Criteria are established to target tributaries for pilot removals and target tributaries are selected • Removal methods developed and tested • Pilot removals in targeted tributaries planned and initiated. • Population “control targets” are established for tributaries to achieve reasonable population reductions Extent to which populations can be reduced by targeted removals quantified • Synthesis of research projects complete and its applications communicated to managers • Anglers understand the impacts and help identify solutions	• Documented change abundance and decr impact in targeted tr comparative study o without removal eff • Targeted citizen grou and support manage populations and mit • Improved and tested removal methods of tributaries • Pilot removal study evaluated • Tributary- specific ca strategies developed • Develop scientifically specific control targe

OBJECTIVE	Current Situation	Inputs	Activities/Outputs	Short-term Outcomes	Long-ter
			on native species • Engage recreational and commercial fishing organizations in dialogue on known risks of invasive catfish • Engage community in education on pilot removals		
To slow and reduce the spread of and invasive catfishes populations into currently uninhabited waters	Blue catfish have been documented in all major tributaries of the Bay. Recent studies suggest impacts on native species are likely in these tributaries. Models suggest that Blue and Flathead catfish distribution will continue to expand throughout the Bay, which threatens the native fish species in tributaries that are not yet inhabited by invasive	• ICTF • Science-VIMS, VCU, SERC, MD DNR, VDGIF (VT) • Jurisdiction Management-VMRC, VDGIF, MD DNR, PRFC, DENREC, DDOE, PA Fish and Boat, ASMFC • Conservation areas and refuges (NEERS, etc.) • Watermen • Mid Atlantic Aquatic Nuisance Species Panel	• Develop targeting criteria to identify tributaries to protect from invasion (places where catfish not yet established, with high ecological value, already protected, etc.) • Update distribution data to determine current extent of tributary invasion • Review, communicate, and enforce catfish live transport policies • Design and early detection and monitoring	• Tributaries are identified that should be targeted for invasive catfish early detection and monitoring • Identify conservation partners to collaborate with and integrate invasive catfish monitoring into existing environmental programs • Watermen are informed of fines and regulations associated with invasive catfish • Necessary components of early detection and monitoring programs protocols are identified	• Develop tributary-sp plans in targeted are public and watermer catfish and their imp • Early detection and r methodology is teste • Early detection and r in targeted tributarie • Begin implementatio development of surv monitoring protocols

OBJECTIVE	Current Situation	Inputs	Activities/Outputs	Short-term Outcomes	Long-ter
	catfish. Eutrophication is likely supporting productive conditions advantageous to invasive catfish.		methodology • Complete development of Blue Catfish Portal with fishery independent data and new fishery dependent data to track spread • Create mobile device app to aid public in identifying and reporting invasive catfish	and accounted for • Conservation areas and groups are working with management agencies to monitor spread • Develop and implement test novel, rapid, and relatively inexpensive surveillance protocols (e.g. environmental DNA tools) to monitor expansions in near real time	

TO PROMOTE A LARGE-SCALE, FISHERY TO SIGNIFICANTLY REDUCE ABUNDANCE OF INVASIVE CATFISHES POPULATIONS AND PROVIDE ECONOMIC BENEFITS TO THE REGION	A recreational trophy fishery does exist for Blue catfish in the Bay. There is currently no significant commercial market or fishery for these catfish.	• Jurisdiction Management- VMRC, VDGIF, MD DNR, PRFC, DENREC, DDOE, PA Fish and Boat, ASMFC • Watermen	• Investigate the contaminant levels to inform any consumption advisories • Testing of different gear types • Use spatially explicit ecosystem models to determine what level of fishing is needed to have a significant impact on catfish populations in individual tributaries or Bay wide • Develop a marketing campaign to promote the commercial harvest and use of invasive catfish	• Watermen entry into the fishery • Tributaries are targeted for the fishery • Most efficient gear types and mechanism established	• A fishery built on a val catfish provides a new watermen • Catfish viewed as a va used by the consumer • Effective reduction in places where fishery t
TO INCREASE OUTREACH AND EDUCATION TO IMPROVE PUBLIC AWARENESS THAT BLUE AND	Although information is available on invasive catfish, it is not consistent across jurisdictions, regulations are not easily found, and	• Jurisdiction fishing guides and web resources • Watermen • ICTF • Social media • CBP • Jurisdiction	• Emphasize that it is illegal to transport Blue and Flathead catfish • Complete a synthesis of current research quantifying ecological impacts	• Increased information and messaging on jurisdiction websites on the impacts of Blue catfish and the associated no transport and other associated regulations • Conservation areas and	• The public and water that Blue and Flathea and are negatively im the Bay • Public support action Flathead catfish

FLATHEAD CATFISHES ARE NOT NATIVE AND POSE A RISK TO NATIVE SPECIES AND TO CONTINUE TO LESSEN THE PROBABILITY OF UNAUTHORIZED INTRODUCTIONS INTO OTHER WATER BODIES IN THE BAY WATERSHED	there is no sense of urgency in the messaging to public or anglers about the risk they pose.	Management- VMRC, VDGIF, MD DNR, PRFC, DENREC, DDOE, PA Fish and Boat, ASMFC	on native species • Create outreach materials that inform the public and watermen about the ecological impacts of catfish on native species in the Bay • Compile the catfish research into the catfish portal to have a “one-stop shop” for information on invasive catfish in the Bay • Continue research efforts to better understand invasive catfish and their impacts • Work with conservation organizations to integrate invasive catfish information into their programs • Create mobile device app to aid public in identifying and reporting invasive catfish	groups are working with management agencies to inform the public	

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