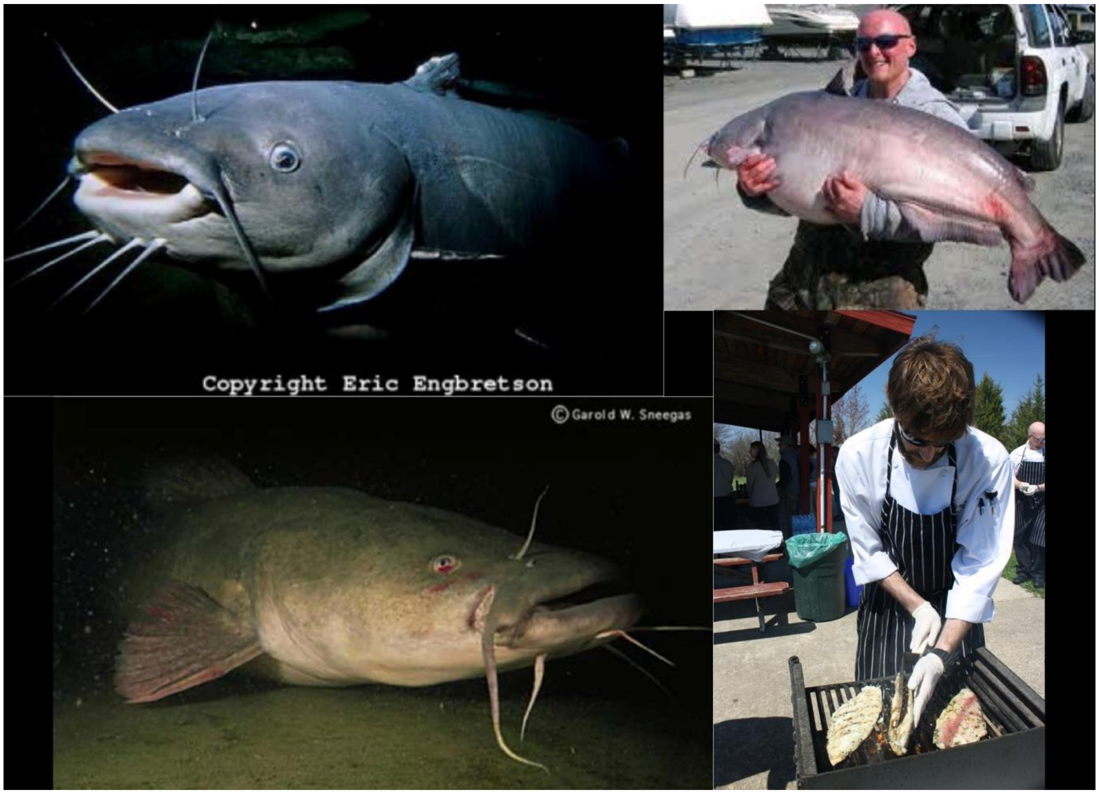
Review of the Final Report of the Sustainable Fisheries Goal Implementation Team Invasive Catfish Task Force



STAC Review Report
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About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

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The Review Team gratefully acknowledges the constant and critical contributions of Natalie Gardner (Chesapeake Research Consortium staff and the STAC Coordinator) throughout this review process.

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EXECUTIVE SUMMARY

Blue catfish (*Ictalurus furcatus)* and flathead catfish (*Pylodictis olivaris*) were both introduced to the Chesapeake Bay to establish recreational fisheries. Blue catfish were introduced into the James, Rappahannock, and York Rivers in Virginia during the 1970s and 1980s and flathead catfish were introduced into the James River in the late 1960s. Since that time, both non-native species have become established, spread, and are considered invasive because of their potential to negatively impact native species and the ecology of the Bay.

The Invasive Catfish Task Force (ICTF) was established in 2012 by the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (SF-GIT) and charged with identifying management options that could be applied Bay-wide to respond to the spread of invasive blue and flathead catfish and to concerns that these species may cause ecological and economic harm to Chesapeake Bay. In February 2014, the ICTF produced a draft report that included background information on the ICTF, the problem and scope, an overview of invasive catfishes, current management efforts, and seven recommendations. The stated intent of the draft report was that it was to be used "…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." The SF-GIT requested a review of the ICTF report and recommendations by the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC), and the request was approved by STAC in March 2014; focus questions for reviewers were presented to the Review Team by the ICTF in April 2014.

The STAC assembled a team of 7 professionals with backgrounds in the control and management of invasive fishes, fish biology, estuarine ecology, and resource economics to review the ICTF report. The charge from STAC to the review team was to provide comments on the technical feasibility, reasonableness, likelihood of success, and potential unintended effects that may result for each of 7 recommendations. In addition, reviewers were asked to identify other science or management approaches to consider and priority research challenges (and strategies to overcome these challenges) for effective management of invasive catfishes.

Reviewers commend the efforts of the ICTF to identify potential management recommendations, and the review team recognizes the substantial effort and inter-jurisdictional cooperation that has gone into the ICTF report. Unfortunately, as the ICTF report points out, the "…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." Because of the high level of uncertainty associated with many recommendations, reviewers advocate for the development of a comprehensive management plan prior to implementation of recommendations. A comprehensive plan would detail specific actions needed to fulfill the objectives, establish roles and responsibilities across jurisdictions, provide a framework to more fully evaluate control techniques, and prioritize actions and research needs. Reviewers and the ICTF identified scientific gaps that, if addressed, could help minimize uncertainty and increase the likelihood that management objectives could be met. Information needs include: population size and distribution; movement information and population modeling of the very large fish of interest to the trophy fishery; removal rates needed to elicit a response in the system; gear effectiveness; and fish contaminant levels. Consumption advisories for invasive catfish may be warranted for select tributaries which may conflict with the expansion of the commercial fishery or limit the willingness of jurisdictions to promote an expansion. Research efforts currently underway (e.g., pilot study of commercial electrofishing on blue catfish) will add to the knowledge base and should be considered during the development of a management plan.

A recommended resource for the development of a comprehensive management plan for invasive catfish is the Aquatic Nuisance Species Task Force (ANSTF), an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species. The ANSTF has supported and approved numerous species management plans (http://www.anstaskforce.gov/control.php) including one for Northern Snakehead, another introduced fish species to the Chesapeake Bay.

Though the overall tone of the review may be perceived as negative, the authors would like the ICTF to understand that that is not the intent, and we once again commend the ICTF for their imagination and their determination to "think outside the box" for developing new strategies to begin to control these invasive populations. Many of the strategies put forth in the recommendations may indeed 'bear fruit' eventually as part of an overarching, coordinated, and comprehensive plan for invasive catfish. However, *because* many of these strategies are so new and only minimally tested (if at all), the authors were compelled to point out throughout the review, as requested, all the areas of uncertainty that must first be addressed by further scientific studies before many of these strategies are invested in by the jurisdictions, and thus, before they can come to fruition in the Chesapeake Bay.

Recommendation 1: Design and implement targeted fishery-independent removals of invasive catfish in places of significant ecological value.

Reviewers agreed with the recommendation to conduct pilot studies to further evaluate the effectiveness of targeted fishery-independent removal of invasive catfish because, despite considerable efforts, there has been limited documented success for non-native fish removal/control programs in connected, larger systems (see Britton et al. 2011). Prior to system-wide implementation, (i) gear effectiveness and effects on invasive catfish and native fish must be understood; (ii) methodology for prioritization of targeted sites for removals needs to be clearly and transparently defined; (iii) adequate long-term resources should be secured; and (iv) strategies to evaluate program success (e.g., the influence on population dynamics of native fishes) should be clearly delineated. The ability of removals to reduce the population and lessen adverse impacts on important native species is dependent on the location of the removal activity in the watershed, connectivity among waterways, and continued influx of recruiting juveniles (Franssen et al. 2014). Short-term, local efforts are more likely to succeed, but effectiveness of this would be very low if there is a high replacement or recolonization rate of the invasive species. Responses by targeted populations by removal efforts should be carefully monitored as efforts could induce populations to increase recruitment and reach maturity at smaller sizes and younger ages and can result in increased sampling effort needed to obtain a maintenance control level (Bonvechio et al. 2011a).

Recommendation 2: Incentivize and accelerate efforts to develop a large-scale commercial fishery with coordination across jurisdictions.

Though the development of a large-scale commercial fishery may be a feasible approach to temporarily reduce populations of the invasive catfishes, (i) the threat posed to the public by contamination of the fillets with bioaccumulated toxins; (ii) the lack of desire to kill the largest, most fecund fish for the sake of the trophy fishery; (iii) the predicted population response to being fished; (iv) the perverse incentivization of the preservation of these populations to maintain the fishery; and (v) the potential negative consequences to native populations of catfish (through bycatch and misidentification), all suggest that this approach may be exceedingly limited in its potential to reduce or control invasive catfish populations over the long-term, or to realize the economic benefits desired for the watermen of the region. Moreover, the economic consequences of succeeding or failing to achieve this recommendation could both be very high.

Recommendation 3: Incentivize increased harvests of invasive catfishes by small boat operations and explore the use of electrofishing for commercial harvest purposes.

There is a high level of uncertainty that incentivizing commercial harvest of invasive catfish by small boat operations using electrofishing is technically feasible and would result in reductions of invasive catfishes and benefit native populations. Prior to implementation, extensive evaluation is needed of (i) both the effectiveness of the gear and of impacts of the gear on non-target species in different physical settings; (ii) potential fish contaminant issues; and (iii) whether a sustainable commercial fishery can result. Due to gear limitations (i.e., salinity and temperature restrictions), it is unlikely that this approach would be successful without the concurrent employment of other gears and approaches; therefore, this recommendation should be part of a broader comprehensive plan. For this to be a viable commercial fishery, strict controls will be required in the form of a limited entry fishery with permits and firm restrictions, mandatory safety and fish identification training, and observers. Subsidizing harvest through investments in gear and free licensing may lead to an economically unsustainable fishery, requiring continuous financial support from management. One potential solution to increase financial viability is adopting incentive schemes which promote long-term individual investment (e.g., Individual Transfer Quota's, TURFs).

Recommendation 4: Establish monitoring programs dedicated to identifying and tracking invasive catfish distributions and population status. Develop early detection and response programs to monitor ecologically significant areas.

Though establishing dedicated monitoring programs to identify and track invasive catfish may be technically possible, the reviewers were concerned that any new monitoring efforts would be compromised by a lack of dedicated funding (or, that such new monitoring could compromise other, existing monitoring programs), because state funding for monitoring is often limited. The reviewers point out that, to maximize success of this strategy it will be important to first perform an initial scoping of available resources and existing surveys. Subsequent to scoping, detection and monitoring of invasive catfishes should then be done primarily through reliance on existing surveys, in coordination with an Early Detection and Rapid Response (EDRR) plan designed for the control of invasive species, and enhanced by citizen science groups and by developing a reporting system for public sightings. Further, to minimize jurisdictional conflicts, the reviewers maintain that it will be most effective to coordinate the EDRR plan through a non-jurisdictional organization, ideally, one that has previous experience with invasive species. Though development of new technologies (like environmental DNA [eDNA]) to monitor invasive catfish populations could show long-term improvements in monitoring efficiency, in the short-term, leveraging existing monitoring efforts, in conjunction with reporting by the public seems likely to remain the most cost effective approach to detect the spread of invasive catfish.

Recommendation 5: Consideration of the effectiveness of existing barriers to invasive catfish spread and an assessment of the benefits of barrier removal weighed against the risk of invasive catfish expansion.

Consideration for invasive species during barrier removal prioritization is a reasonable recommendation to help prevent further spread. The success of this action is contingent on (i) whether consensus can be reached by the Chesapeake Bay Program Goal Implementation Teams and Workgroups that have conflicting goals (e.g., diadromous fish restoration), (ii) a comprehensive risk-benefit assessment, and (iii) if the maintenance of existing barriers actually prevents expansion of invasive catfish. An important concern is that diadromous fish restoration is a high priority in the Bay watershed and limiting barrier removals will reduce the restoration potential of those populations.

Recommendation 6: Cross-jurisdictional review of current fishing policies and regulations to evaluate their effectiveness in preventing persistence and further expansion of invasive catfish populations.

Overall, reviewers considered this recommendation an important and necessary strategy to employ to control the invasive catfish species *if* the intent of such a process would be to unify and simplify policies and regulations across the Bay jurisdictions as opposed to an effort limited to summarizing current regulations. Reviewers pointed out that the specific purpose(s) of the review must be clarified prior to such a review. The reviewers identified that this could also be an important opportunity to review, unify, and simplify consumption guidelines for blue and flathead catfish in regard to toxic contaminants, along with all regulations and policies concerning these species. Reviewers state that, to be successful, such a review would necessitate the representation of a variety of stakeholder groups (e.g., trophy anglers and guides, commercial fishers, independent recreational anglers, jurisdictional management representatives, catfish biologists, etc.), and this may, in turn, require facilitated discussion sessions between these groups prior to the implementation of new, unified policies. The review panel did express concerns here, and in reference to Recommendation 2, that actually stopping the illegal transport of these invasive species would be difficult at best, especially if commercial harvest is incentivized.

Recommendation 7: Make information on invasive catfishes more accessible, consistent, and clearer to anglers and the general public.

The recommendation to develop accurate and consistent messaging across all jurisdictions is an important element for effective management of invasive catfishes. The expected outcomes of the outreach should be clearly defined prior to implementation. In developing communication strategies, an adaptive approach to outreach communication will be needed and outreach should be linked to ongoing research efforts. The proposed web portal currently in development may be useful to accomplish effective and adaptable outreach, particularly if it is developed and promoted as an "official" portal with coordinated messaging across jurisdictions and organizations.

Other recommended management approaches to be considered as part of a comprehensive management plan for invasive catfish include (i) preventative measures (i.e., development of barriers, hazard analysis, and critical control points [HACCP] planning); (ii) a list of research needs and a clear plan to address such needs; and (iii) restoration actions that may follow control operations and rebuild native populations. The logic model presented in Appendix B of the ICTF report provides a starting point to a comprehensive plan. The ideas and actions within these tables should be built upon.

The main research priorities identified to inform invasive catfish management are 1) the assessment and monitoring of fish contaminant levels, 2) a better understanding of the basic biology, life history, movement, and habitat use of invasive catfish, and 3) the development of innovative preventative methods of control such as electrical, visual, acoustic, chemical, and hydrological deterrence techniques that may be used to prevent fish movements.

INTRODUCTION

Background and scope of review

The Invasive Catfish Task Force (ICTF) was established in 2012 by the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (SF-GIT) and charged with identifying management options that could be applied Bay-wide to respond to the spread of invasive blue and flathead catfish. In February 2014, the ICTF produced a Draft Report that included background information on the ICTF, the problem and scope, an overview of invasive catfishes, current management efforts, and seven recommendations. The stated intent of the draft report (p. 9) was that it was to be used "…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." The SF-GIT requested a review of the ICTF report and recommendations by the Scientific and Technical Advisory Committee (STAC), and the request was approved by STAC in March 2014; focus questions for reviewers were presented to the Review Team by the ICTF in April 2014.

The ICTF report outlined recommendations to address 4 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 catfish 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.

The request to the STAC (see Appendix I) from the SF-GIT was that the review be focused on the following questions:

1. Are the recommendations reasonable given what we currently know about invasive catfish biology and ecology?
2. Which recommendations are most likely to support the stated outcomes (reduce impacts on native species and slow spread)?
3. Which recommendations will have the most impact given the level of scientific uncertainty regarding invasive catfish biology and ecology?
4. Do the reviewers support/endorse the report as sound policy for beginning to manage invasive catfish in the Chesapeake Bay?
5. Do the reviewers suggest any additional management options?

The specific topics of review questions (Q1–3) generally fell into three broad categories, so the Review Team structured the review to address these categories for each recommendation: (i) technical feasibility and reasonableness, (ii) likelihood of success, and (iii) potential unintended effects. Reviewers were further asked to suggest additional management options not considered in the report (Q5) and identify important research challenges. Because the ICTF report was not written as a policy document or a comprehensive management plan for invasive catfishes, it was decided that evaluating the soundness of the report as policy (Q4) was beyond the purview of the Review.

The STAC assembled a team of 7 professionals with backgrounds in the control and management of invasive fishes, fish biology, estuarine ecology, and resource economics to review the ICTF report. The charge from STAC to the review team was "…that comments focus on the following [questions], but you are encouraged to provide additional comments that would improve the analyses, the report, or its recommendations. Whenever possible, please support your answers with reasoning and references to published or unpublished work." The body of the review is thus organized into sections under each recommendation in response to that series of questions.

1. Is this recommendation technically feasible? That is, is the proposed action reasonable based on previous use of the technique or current understanding of the science? *For the purposes of the review, determination of 'feasibility' encompassed considerations for whether a recommendation was capable of being accomplished, as well as suitable or reasonable.*
2. What is, in your opinion, the likelihood of success of this approach?
3. Do you see any potential unintended effects that might appear as a result of the proposed course of action?

In addition to recommendation-specific questions, reviewers were asked to address two additional overarching questions. Synthesized responses to these questions follow the sections with specific comments for individual recommendations.

1. If you think there are other science or management approaches to consider for this issue, please describe them below.
2. What, in your opinion, are the top 3 research challenges related to this problem? Would you offer any strategies to overcome these challenges?

General reaction of the review team to the ICTF report

Reviewers commend the efforts of the ICTF to identify potential management recommendations, and the review team recognizes the substantial effort and interjurisdictional cooperation that has gone into the ICTF report. Unfortunately, as the ICTF itself points out in its report, the "…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." Because of the high level of uncertainty associated with many recommendations, reviewers advocated for the development of a comprehensive management plan prior to implementation of recommendations. While many of the recommendations may be positive steps toward management of invasive catfish, further evaluation of control techniques, applied research efforts, and outreach strategies are needed. Specific actions, cost, or lead organizations necessary to implement recommendations are not outlined in the ICTF report. As the report states, the recommendations should be developed into a comprehensive strategy. A management plan will outline the specific actions needed to fulfill these requirements as well as help to prioritize the actions and establish roles and responsibilities.

One recommended approach towards development of a management strategy is to enlist the support of the Aquatic Nuisance Species Task Force (ANSTF), an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species. The ANSTF has supported and approved numerous species management plans (http://www.anstaskforce.gov/control.php). For example, the ANSTF recently supported and approved a 'National Control and Management Plan for Members of the Snakehead Family (*Channidae*)' which was initiated to address concerns about the introduction of northern snakehead and developed with multiple jurisdictional partners (http://anstaskforce.gov/Species%20plans/SnakeheadPlanFinal_5-22-14.pdf). The purpose of this Plan was to "…identify action items to guide agency activities and funding priorities and to focus the efforts of other stakeholders and non-governmental organizations (NGOs)". It also addressed several elements imperative to the invasive catfish management including early detection and rapid response, control, research, and education and outreach priorities. Further guidance may be also found in the ANSTF approved State Management Plan for Virginia (http://anstaskforce.gov/stateplans.php) detailing "…a framework for state agency action to minimize economic, environmental, and human harm from invasive species by acting on the seven goals of coordination, prevention, early detection, rapid response, control, research, and education". Lastly, the Mid-Atlantic panel on Aquatic Invasive Species has a template that allows agencies to develop their own Rapid Response Plans to address their specific needs. Rapid response plans are equally important, as preventing establishment of newly detected populations will require immediate attention. The use of the Incident Command System (ICS) is recommended as this will help establish roles and responsibilities of key players as well as identity available resources and tools prior to the event. EPA offers ISC training as well as online courses that will provide the information to develop the foundation for an EDRR plan.

A Maryland example can be found at:
http://www.mdsg.umd.edu/sites/default/files/files/MarylandPlanFinal-1.pdf.

SYNTHESIS OF INDIVIDUAL REVIEWERS' COMMENTS

ICTF 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.

Reviewers agreed with the recommendation to conduct pilot studies to further evaluate the effectiveness of targeted fishery-independent removal of invasive catfish because despite considerable efforts, there has been limited documented success for non-native fish removal/control programs in connected, larger systems (see Britton et al. 2011). Prior to system-wide implementation, (i) gear effectiveness and effects on invasive catfish and native fish must be understood; (ii) methodology for prioritization of targeted sites for removals needs to be clearly and transparently defined; (iii) adequate long-term resources should be secured; and (iv) strategies to evaluate program success (e.g., the influence on population dynamics of native fishes) should be clearly delineated. The ability of removals to reduce the population and lessen adverse impacts on important native species is dependent on the location of the removal activity in the watershed, connectivity among waterways, and continued influx of recruiting juveniles (Franssen et al. 2014). Short-term, local efforts are more likely to succeed, but effectiveness of this would be very low if there is a high replacement or recolonization rate of the invasive species. Responses by targeted populations by removal efforts should be carefully monitored as efforts could induce populations to increase recruitment and reach maturity at smaller sizes and younger ages and can result in increased sampling efforts needed to obtain a maintenance control level (Bonvechio et al. 2011a).

Feasibility

Reviewers noted that the level of uncertainty for both the technical approaches and predicted system responses was too high to consider this recommendation feasible and reasonable for immediate implementation. Technical and scientific hurdles to be overcome include: (i) developing a better understanding of the size and extent of invasive catfish populations, (ii) gear effectiveness in different physical (salinity, temperature) conditions, (iii) gear effects on invasive catfish and native fish populations, (iv) securing adequate resources (long-term funding), and (v) identifying the required removal rate to elicit a desired response in native populations and determining if it is attainable.

The recommendation to conduct pilot studies to further evaluate the effectiveness of proposed removal methods (ICTF report, p. 21) is important because despite considerable efforts, there has been limited documented success for non-native fish removal/control programs in connected, larger systems (see Britton et al. 2011). Examples of successful fish removal programs do exist for smaller systems, (e.g., Thompson and Rahel 1996; Vredenburg 2004; Knapp et al. 2007; Britton et al. 2011) and lessons learned from those programs should help inform this action and enhance its likelihood of success (although perhaps at a limited spatial scale). During program development, strategies to evaluate program success (i.e., the influence on population dynamics of native fishes) should be clearly delineated. Comparisons between areas with removal and control areas (no removal), if possible, may provide a mechanism to evaluate the effectiveness of the removal effort. In other systems, as much as 80–90% of an invasive fish population was required to be removed prior to observing a positive biological response (Mueller 2005). Such high removal targets may be technically difficult and costly, particularly if replacement rates are high.

Of further concern is whether the spatial scale at which invasive catfish can be effectively reduced or removed will correspond with the scale that the area of significant ecological value needs to be in order to see a beneficial response from native species and their habitats. The success of this action is therefore highly dependent on the criteria for selection of areas of significant ecological value. Methodology for prioritization of targeted sites for removals needs to be clearly and transparently defined. This is an essential piece that should be detailed and fully vetted with all affected stakeholders. When prioritizing sites, consideration of recreational value and potential commercial fishery interactions should also be made.

Likelihood of Success

The likelihood of success of targeted fishery-independent removals of invasive catfishes is uncertain, but the majority of the reviewers perceived this action as having a low likelihood of success Baywide, or, in the long-term. Success is dependent on the location of the removal activity in the watershed, connectivity among waterways, and continued influx of recruiting juveniles (Franssen et al. 2014). Short-term, local efforts are more likely to succeed, but effectiveness of this would be very low if there is a high replacement or recolonization rate. One reviewer noted that "…there seems to be little information available on movements of individual blue or flathead catfish, but it seems like some, at least, move quite a bit during certain times of the year". Use of barriers to keep blue and flathead catfish out of areas after removal was briefly mentioned, but may be infeasible given the types of habitats infested. For example, while the suggested use of constructed or non-physical barriers following removals to exclude predatory invasive catfishes from 'tidal spawning habitats for *Alosa* spp.' (ICTF report, p. 22) is attractive, in practice, however, this will likely be a large and costly technical hurdle that would only minimize predation of the very early life stages of some *Alosa* spp. (*A. aestivalis*, *A. pseudoharengus*) leaving late larval and juvenile stages susceptible once they have left those habitats. The practicality of applying this approach to numerous tidal creeks or tributaries will be dependent on jurisdictional support and the availability of resources within state agencies. All of this, and the fact that a modified version of the Chesapeake Bay Fisheries Ecosystem Model (CBFEM) showed that a tenfold decrease in blue catfish population abundance did not result in positive environmental outcomes (ICTF report, p. 41, Turner et al. *in prep*), suggest that removing invasive catfish from targeted areas would NOT result in positive environmental outcomes. Further, there may be variability in success due to unforeseen consequences, such as changes in survival or reproduction rates as the targeted population is reduced (Ricker 1975; Pasko and Goldberg 2014), or unattainable removal rates for a large, already established population.

Potential Unintended Effects
One significant potential unintended effect is that removal efforts may induce targeted populations to increase recruitment, reach maturity at smaller sizes and younger ages, and can result in increased sampling effort needed to obtain a maintenance control level (Bonvechio et al. 2011a). While intensive removal efforts of non-natives have been able to reduce densities in large systems, in some instances reduction in size and age structure of the target population has occurred. Such shifts in population dynamics could cause increase negative interactions including competition and predation of young fishes (e.g., Pitlo 1997; Bonvechio et al. 2011b; Franssen et al. 2014).

There may be conflicts with other sectors including the recreational trophy fishery. One way to minimize conflicts is to consider recreational value or commercial fishery interactions when selecting sites for targeted removals. This is particularly useful when prioritizing sites with equal ecological value (i.e., remove invasive catfish from sites with high ecological value, low recreational value, and high costs imposed on harvesters of non-catfish species). Other unintended effects may include bycatch of native fish, especially native catfishes, poor public perception if removed fish are not disposed of properly (donation to food banks may be complicated by health concerns from fish contaminants), and diversion of resources from other current jurisdictional commitments.

ICTF 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 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.

Though the development of a large-scale commercial fishery may be a feasible approach to temporarily reduce populations of the invasive catfishes, (i) the threat posed to the public by contamination of the fillets with bioaccumulated toxins; (ii) the lack of desire to kill the largest, most fecund fish for the sake of the trophy fishery; (iii) the predicted population response to being fished; (iv) the perverse incentivization of the preservation of these populations to maintain the fishery; and (v) the potential negative consequences to native populations of catfish (through bycatch and misidentification), all suggest that this approach may be exceedingly limited in its potential to reduce or control invasive catfish populations over the long-term, or to realize the economic benefits desired for the watermen of the region. Moreover, the economic consequences of succeeding or failing to achieve this recommendation could both be very high.

Feasibility

The paramount concern of most reviewers is the potential toxic contamination of the catfish sold to consumers. Hale et al. (2014) recently concluded that if "…increasing harvest of blue catfish is promoted as a management tool to control population size, than a more thorough understanding of contaminant loads is critical." A relatively small fillet would be produced from a fish 11.8 inches (300 mm) or smaller. Yet that is the approximate size that blue catfish become increasingly piscivorous (Schloesser et al. 2011) and the size at which accumulation of biotoxins may begin to be enhanced (Hale et al. 2014). When Hale et al. (2014) examined fish above this size threshold, they found that some of the fish tested would require consumption advisories that exceeded both VA and MD limits based on two or fewer meals per month, *and* that the bioaccumulated contaminants differed substantially by the tributary where the fish were caught. A precautionary approach to harvest regulations is therefore advisable, because the tributary the fish originate from might be uncertain in commercial catches, and past movements of the captured fish may cloud certainty of contaminant exposure history (Hale et al. 2014). Further, when considering a targeted size fish for a potential commercial fishery, jurisdictional managers should recognize that an individual fish could potentially exhibit contamination concentrations well in excess of the average fish for a given tributary (Hale et al. 2014). Until all subpopulations are rigorously tested and a size at which consumption of the fish is considered safe is determined for multiple bioaccumulating toxins that could pose a contamination risk (e.g., mercury, PCBs, see Hale et al. 2014) *by tributary*, the Review Panel strongly recommends that the most cautious approach be taken, and that any sale be accompanied with conservative consumption warnings. Reviewers expressed concerns that a less cautious approach could leave the jurisdictions liable to consumer claims of injury.

The reviewers were also concerned that any effort to reduce the population through harvest could be compromised because there are no proposed recommendations to simultaneously remove the largest, most fecund fish from some areas of the system. It seems possible that the largest fish could effectively negate any gains made in the reduction of only smaller fish. Overcompensation is another potential concern (Pasko and Goldberg 2014), even in areas where trophy fish are not a factor. This is clearly an area for further study prior to investment by the jurisdictions in this recommendation.

Likelihood of Success
Given the reviewers' concerns pointed out above, it appears that although a sustainable fishery could be established, it is unlikely that this strategy will produce the intended reduction in invasive catfish populations of the Chesapeake system over the long-term. Moreover, unless marketable-sized fish are found to be safe to harvest in some Chesapeake tributaries, without necessitating extremely limiting consumption advisories, the economic benefit to watermen, and the population reduction potential yielded by targeting only fish less than a foot long (300 mm, or 11.8"), seems likely to be minor.

Potential Unintended Effects
Reviewers identified several potential consequences that may be unexpected, but that should be considered carefully since their effects would counter efforts to control these populations. Developing a new commercial fishery will decrease abundance of the invasive populations as intended, but such an effort will also likely increase the recruitment, increase the growth rate, reduce the rate of natural mortality of these populations (Ricker 1975), and improve the survival of those invasive fish that remain (Invasive Species Advisory Committee 2013), dampening the intended effect. Such population-level responses, combined with the continued presence of the trophy-sized fish, seem likely to minimize the reduction in abundance that the ICTF is seeking. Moreover, the perverse incentive for fishers to maintain a large population of invasive catfish to meet ongoing market demand could result in an increase in the intentional seeding of previously uncontaminated (and sensitive) areas of the Bay, confounding efforts to keep the invaders out of such areas, and potentially interfering with the successful spawning and juvenile growth of native (especially diadromous) species. Finally, the economic consequences could be high, whether the jurisdictions fail or succeed in this recommendation. If an effort to undertake the development of such a fishery is pursued, and fails, the negative economic consequences could be large (costs would include building infrastructure to support the fishery, e.g. new fish houses, marketing costs, and mechanisms); moreover, increasing the demand for blue catfish may decrease the demand for other Chesapeake Bay products (since this product will take the place of other products), lowering revenues generated, and adversely impact harvesters in native fisheries.

ICTF 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.

There is a high level of uncertainty that incentivizing commercial harvest of invasive catfish by small boat operations using electrofishing is technically feasible and would result in reduction of invasive catfishes and benefit native populations. Prior to implementation, extensive evaluation is needed of (i) both the effectiveness of the gear and of impacts of the gear on non-target species in different physical settings; (ii) potential fish contaminant issues; and (iii) whether a sustainable commercial fishery can result. Due to gear limitations (i.e., salinity and temperature restrictions), it is unlikely that this approach would be successful without the concurrent employment of other gears and approaches; therefore, this recommendation should be part of a broader comprehensive plan. For this to be a viable commercial fishery, strict controls will be required in the form of a limited entry fishery with permits and firm restrictions, mandatory safety and fish identification training, and observers. Subsidizing harvest through investments in gear and free licensing may lead to an economically unsustainable fishery, requiring continuous financial support from management. One potential solution to increase financial viability is adopting incentive schemes which promote long-term individual investment (e.g., ITQs, TURFs).

Feasibility

The majority of the reviewers commented that there is a high level of uncertainty regarding the technical feasibility and reasonableness of this recommendation. Additional studies on the effectiveness of the gear in different physical settings, potential fish contaminant issues, and impacts on non-target species are all necessary prior to implementation. As stated in the ICTF report "…[low-frequency (≤15 pps), pulsed direct current (PDC) electrofishing (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." One reviewer reported that following an initial low frequency electrofishing sampling event, it may take as long as a week before the same stretch of river may be effectively electrofished again. Thus, legalization of electrofishing for multiple people may result in poor catch rates even if the fish were present, because they may not be vulnerable to the gear. Further, there is uncertainty that the proposed action would result in reduction of invasive catfishes and benefit native populations. For example, Moser and Roberts (1999) found recreational electrofishing did not impact non-native catfish stocks in North Carolina. Results from a Virginia pilot project (funded by the Fishery Resource Grant Program of Virginia Sea Grant, in progress) that is exploring the feasibility of using electrofishing gear for harvest of blue catfish, should inform some of the information gaps and provide guidance if this action becomes part of a comprehensive management plan.

Additional concerns to be addressed include uncertain life history response to fishing pressure, opposition by recreational fishers or the public, intentional or unintentional collection of non-target fish, safety of anglers and other recreational users, and whether a sustainable commercial fishery can result. Pasko and Goldberg (2014) outlined favorable and unfavorable characteristics to establish feasibility for an effective harvest incentive program for invasive species. There are several unfavorable characteristics applicable to invasive catfish in Chesapeake Bay that may limit the effectiveness of a harvest program including (i) necessity for considering a widespread geographical area, (ii) the fishes' ability to immigrate back into the management area, (iii) potential human health risks, (iv) our current inability to estimate changes in population density, and (v) high relative harvest costs. One reviewer commented that the "…high cost of low frequency electrofishing gear and narrow operating windows combined with the likely rapid drop in initially high catch rates will probably negate this as a viable alternative for commercial interests. Thus, this is not likely to result in long-term decreased abundances of targeted catfish". For this to be a viable commercial fishery, strict controls will be required in the form of a limited entry fishery with permits and firm restrictions, mandatory safety and fish identification training, and observers. Finally, subsidizing harvest through investments in gear and free licensing may lead to an economically unsustainable fishery, requiring continuous financial support from management. One potential solution to increase financial viability is adopting incentive schemes which promote long-term individual investment (e.g., ITQs, TURFs).

Likelihood of Success

Due to gear limitations, it is unlikely that this approach would be successful without the concurrent employment of other gears and approaches. Reviewers were concerned about the initial investment of the electrofishing gear, the potential misuse of the gear, and the difficulty of regulating the application of the gear, including the requirement of observers.

Potential Unintended Effects

A potentially significant unintended effect is bycatch of native species, especially catfishes, which has been previously reported to be captured with low-frequency electrofishing gear (ICTF report, p. 36, Hines unpublished data). If gear is misused, bycatch (poaching) levels could greatly increase. This activity could adversely affect anadromous fish because LFEF restriction to water temperatures between 18 and 25°C and locations with <2ppt salinity suggests that it would be used during key times and places for anadromous fish spawning and growth (and subsequent recruitment). There may also be conflicts with other commercial and recreational fishers (both reduced catch for other subsectors and gear conflicts). Without a limited entry into the fishery, too many harvesters will result in inadequate catches.

ICTF 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.

Though establishing dedicated monitoring programs to identify and track invasive catfish may be technically possible, the reviewers were concerned that any new monitoring efforts would be compromised by a lack of dedicated funding (or that such new monitoring could compromise other, existing monitoring programs), because state funding for monitoring is often limited. The reviewers point out that, to maximize success of this strategy, it will be important to first perform an initial scoping of available resources and existing surveys. Subsequent to scoping, detection and monitoring of invasive catfishes should then be done primarily through reliance on existing surveys, in coordination with an Early Detection and Rapid Response (EDRR) plan designed for the control of invasive species, and enhanced by citizen science groups and by developing a reporting system for public sightings. Further, to minimize jurisdictional conflicts, the reviewers maintain it will be most effective to coordinate the EDRR plan through a non-jurisdictional organization, ideally, one that has previous experience with invasive species. Though development of new technologies (like eDNA) to monitor invasive catfish populations could show long-term improvements in monitoring efficiency, in the short-term, leveraging existing monitoring efforts, in conjunction with reporting by the public, seems likely to remain the most cost effective approach to detect the spread of invasive catfish.

Feasibility

Careful planning and coordinated implementation will maximize the feasibility of this strategy. The strategy should begin with careful scoping of current resources and cautious planning through a highly structured EDRR plan (perhaps even an Incident Command System approach; EDRR plans are available for many agencies, e.g., an extensive national EDRR plan to detect invasive plants is seen at: http://www.fws.gov/ficmnew/FICMNEW_EDRR_FINAL.pdf; the Mid-Atlantic panel on Aquatic Invasive Species provides a template for agencies to develop such a plan; and an existing plan for Maryland aquatic invasive species can be found at: http://www.mdsg.umd.edu/sites/default/files/files/MarylandPlanFinal-1.pdf). The ICTF report suggests the ICTF already has such an approach in mind, but the report lacks specifics for the plan. Implementation should involve citizen science approaches (the ICTF report mentions some examples of these) and all efforts should be coordinated through a non-jurisdictional agency - preferably an existing agency with experience with control of invasive species. Existing Federal organizations like the Aquatic Nuisance Species Task Force and National Invasive Species Council may be helpful in establishing such coordination for invasive catfish in the Chesapeake. Identifying both new and existing technologies should be part of the initial scoping process, and as suggested by the ICTF, new technologies like eDNA may *eventually* prove to be an important element to the success of this strategy. However, the application of many new technologies (like eDNA use in an estuarine environment) are so new that they will also require further study and confirmation by additional visual surveys to determine if the technology has value for identifying invasive catfish at a useful scale in the Chesapeake system. Consequently, though new technologies may offer relatively inexpensive monitoring in the future, in the near term they may require substantial investment. Thus, further scientific study of new technologies like eDNA should be planned, and will increase the costs of detecting and monitoring the invasive catfish.

Likelihood of Success

If the above plan is followed, the reviewers feel this strategy will have a high likelihood of success in early detection and in accurate mapping of the most current status and extent of the invasion. However, careful consideration should be given to which technologies are applied to the detection of invasive catfish, since the leveraging of existing technologies and surveys will be much less costly than will be the testing of new technologies that is necessary before their application - potentially limiting monitoring efforts elsewhere in the Bay.

Potential Unintended Effects

The two areas of concern in regard to unintended consequences for the reviewers are: (1) the reduced efficacy of traditional programs and sampling if a jurisdiction's resources are spread too thin to accommodate new monitoring requirements for invasive catfish and (2) a missed opportunity for containment if a potential sighting is overlooked or a report is lost between jurisdictions. Both concerns can be minimized with careful planning in developing a well-designed EDRR plan, and coordination of the plan through a single (preferably non-jurisdictional) agency, where there are fewer opportunities to lose a report, compared to having to pass a report through multiple agencies.

ICTF 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.*

Consideration for invasive species during barrier removal prioritization is a reasonable recommendation to help prevent further spread. The success of this action is contingent on whether consensus can be reached by the Chesapeake Bay Program Goal Implementation Teams and Workgroups that have conflicting goals (e.g., diadromous fish restoration), a comprehensive risk-benefit assessment, and if the maintenance of existing barriers actually prevents expansion of invasive catfish. An important concern is that diadromous fish restoration is a high priority in the Bay watershed and limiting dam removals will reduce the restoration potential of those populations.

Feasibility

The majority of the reviewers commented that consideration of the risk of invasive catfish spread during prioritization of barrier removal discussions was reasonable but that important uncertainties exist. In many cases, the benefits of barrier removal have not been fully quantified, so comprehensive risk-benefit assessments may be difficult to complete. Removal of dams and/or providing fish passage structures to pass diadromous species remains a priority (Grote et al. 2014), and dams have been implicated as a significant factor in the depleted status of migratory fish such as American eel (Sweka et al. 2014), so this recommendation must be reconciled with conflicting restoration priorities. The need to maintain barriers to prevent spread of invasive catfishes has not been unequivocally demonstrated. Some previous observations suggest that past passage efforts have *not* resulted in expanding populations of blue catfish in Rappahannock, Staunton and James Rivers in Virginia (J. Odenkirk, J. Harris, and S. Smith, VDGIF *personal communication*). Additional investigation is warranted to verify dam removal effects on invasive catfish spread. Moreover, the reviewers were skeptical that illegal movement of invasive catfish could be curtailed, especially if a commercial fishery is incentivized (see discussion of Recommendation 6, below), undermining any efforts to retain barriers in an effort to restrict spreading of these populations.

Likelihood of Success
The majority of the reviewers agree that increased discussion of the risk of invasive species spread with those knowledgeable of invasive catfish biology would be beneficial for the planning and prioritization of barrier removals. However, several reviewers were pessimistic that invasive catfish expansion will be prevented by limiting barrier removals, or, by increasing obstacles for barrier removal. Strict control over unauthorized introductions will be imperative or the potential benefits of maintaining barriers will be unrealized. Variable and poorly defined diets for both blue and flathead catfish make it difficult to evaluate the risk to diadromous species from predation. For blue catfish, existing diet information in Chesapeake Bay indicates that major food items of blue catfish are not alosine species (Chandler 1998; Schlosser et al. 2011; ICTF report, p. 37, VCU unpublished data) which suggests that the benefits to diadromous species (and the cost saved) from barrier removal may override concerns about diadromous species predation by blue catfish. However, there remains significant uncertainty regarding potential localized pressures on diadromous species by flathead or blue catfish. For example, one study summarized in the report (ICTF report, p. 37, VCU unpublished data) reported a modeled consumption of between 7,680 and 10,002 spawning blueback herring at the James River Fall Zone by flathead catfish. It is evident that further diet studies are necessary for both blue and flathead catfish to ensure important diadromous species are not selectively preyed upon by these species and to conduct a comprehensive risk-benefit assessment for barrier removal. One reviewer suggested that "…advocating for invasive species risk assessments for all dam removal projects may be a start…" to ensuring that invasive species risks are given full consideration. Another identified potential approach is Hazard Analysis Critical Control Point (HACCP) which is a structured planning process to identify potential pathways for spread of invasive species, such as barrier removal, and apply preventative measures where appropriate.

Likelihood of success is contingent on whether consensus can be reached by the Chesapeake Bay Program Goal Implementation Teams and Workgroups that have conflicting goals, a comprehensive risk-benefit assessment, and if the maintenance of existing barriers actually prevents expansion of invasive catfish. Adjustments to Bay Agreement goals (i.e., miles opened) may have to be accommodated if the decision is reached that a significant number of reaches with planned barrier removal would be at high risk for catfish invasion and should remained closed.

Potential Unintended Effects
Reviewers again reiterated the unintended effect of this action may be to hinder attainment of diadromous and native fish conservation goals and limit the potential for improved connectivity of Bay waters.

ICTF 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.*

Overall, reviewers considered this recommendation an important and necessary strategy to employ to control the invasive catfish species *if* the intent of such a process would be to unify and simplify policies and regulations across the Bay jurisdictions as opposed to an effort limited to summarizing current regulations. Reviewers pointed out that the specific purpose(s) of the review must be clarified prior to such a review. The reviewers identified that this could also be an important opportunity to review, unify, and simplify consumption guidelines for blue and flathead catfish in regard to toxic contaminants, along with all regulations and policies concerning these species. Reviewers state that, to be successful, such a review would necessitate the representation of a variety of stakeholder groups (e.g., trophy anglers and guides, commercial fishers, independent recreational anglers, jurisdictional management representatives, catfish biologists, etc.), and this may, in turn, require facilitated discussion sessions between these groups prior to the implementation of new, unified policies. The review panel did express concerns here, and in reference to Recommendation 2, that actually stopping the illegal transport of these invasive species would be difficult at best, especially if commercial harvest is incentivized.

Feasibility
The reviewers agreed that, *if* the intent of the review outlined by the ICTF is to unify and simplify policies between jurisdictions, that this strategy is both feasible and a necessary step to control the invasive catfish populations effectively. The ICTF should revise this recommendation to state this intent clearly. However, reviewers also point out that the success

of this strategy is dependent on the inclusion of all necessary stakeholders, and this may necessitate the employment of a professional facilitator.

Likelihood of Success

Success will require a high level of inter-jurisdictional cooperation and willingness to compromise on established policy. Disagreement over the management of the trophy-sized catfish could be a difficult obstacle to overcome in regard to the review, but one reviewer pointed out that some strategy to reduce this segment of the blue catfish population may be needed if the high-level goals of the ICTF are to be achieved, namely, the reduction and control of the invasive catfish population in the system. Further scientific study of the life history, movement, and reproductive potential of this subset of the population will be required to determine the importance of this concern. Assuming that these issues can be overcome, and that such a review is successful in unifying regulations across jurisdictions, one reviewer stated that unified regulations still may not stop illegal transport and spreading of these populations. This will be especially true if a commercial harvest of these populations is incentivized, as outlined in Recommendation 2. Due to the high level of cooperation that would be necessary for this strategy to succeed, the difficulty posed by the continued presence of a growing subpopulation of trophy-sized fish, and given that incentivization of harvests of these animals is likely to undermine the success of this strategy, the reviewers maintain that this strategy has only a moderate likelihood of ultimate success.

Potential Unintended Effects

One concern identified by the reviewers is that the discussion of unifying regulations and policies would likely bring conflicts among stakeholder groups to the fore, especially when stakeholders advocate for policy change not desired by, or strongly opposed by, other stakeholders. Facilitated discussion and outreach may consequently be necessary prior to program implementation.

ICTF 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.*

The recommendation to develop accurate and consistent messaging across all jurisdictions is an important element for effective management of invasive catfishes. The expected outcomes of the outreach should be clearly defined prior to implementation. In developing communication strategies, an adaptive approach to outreach communication will be needed and outreach should be linked to ongoing research efforts. The proposed web portal currently in development may be useful to accomplish effective and adaptable outreach, particularly if it is developed and promoted as an "official" portal with coordinated messaging across jurisdictions and organizations.

Feasibility

The majority of the reviewers considered this recommendation to be both feasible and necessary. The message needs to be accurate and consistent across all jurisdictions (e.g., safe consumption levels). Conflicting messages may make the outreach campaign lose credibility. In developing communication strategies, an adaptive approach to outreach communication will be needed and outreach should be linked to ongoing research efforts. This is particularly important because ongoing and future research efforts will enhance the currently limited understanding of invasive catfish biology and ecology in Chesapeake Bay and improve upon a management plan to control the species. It should be recognized that messaging may change over time with new information and/or system changes. The expected outcomes of the outreach should also be clearly defined prior to implementation. For example, a goal may be to increase the number of people who realize catfish are a threat, or to increase the number of people consuming catfish. Specific messages can be developed for different target groups (e.g., anglers, divers, politicians, the general public, and/or businesses) and social media should be incorporated in an outreach campaign.

The proposed web portal currently in development may be useful to accomplish effective and adaptable outreach. One important point made by a reviewer was that "Informational portals are often managed by the interested members of the public or stakeholder groups. A large portion of the public receive their information from these various portals, yet these sources of information rarely undergo a formal vetting process and may represent various personal opinions on practices, regulations, and/or policies. Therefore, in developing a portal it is important to promote it as the "official" informational outlet for public information and consensus on policy and practice". One approach is to obtain assistance from the Chesapeake Bay Program to coordinate "official" messaging across jurisdictions and organizations. One potential roadblock to the creation of a comprehensive central database for synthesis of information may be some reluctance by research groups to share data.

Likelihood of Success

Reviewers affirm this recommendation is highly likely to be successful. To be successful the message needs to be clear, simple, and consistent among jurisdictions, as well as accurate. An important part of message should be clear guidance for the public on proper species identification (to prevent misidentification with native catfishes). Because the target audience is made up of diverse participants (Schloesser et al. 2011), the likelihood of success will be dependent on the use of multiple media platforms, such as social media, a web portal, in addition to signage on piers and at tackle shops.

Potential Unintended Effects

Increasing public awareness of invasive catfish species and their potentially negative ecological impacts may reduce the effectiveness of marketing efforts suggested in Recommendation 2 and/or confuse consumers and the public. Great care needs to be exercised when developing the communication to correctly distinguish the species of concern (from native species) to avoid the unintended consequence of reducing populations of native catfish.

SUMMARY OF REVIEWER IDENTIFIED ADDITIONAL SCIENCE OR MANAGEMENT APPROACHES:

- **Comprehensive management Plan**: The recommendations should be developed into a comprehensive management plan as suggested in the report. The recommendations offered are at the "10,000 foot" level and do not outline the specific actions, cost, or lead organizations necessary to implement these recommendations. It was clear in the report that further evaluation of control techniques, applied research efforts, and outreach strategies are needed. A comprehensive management plan will outline the specific actions needed to fulfill these requirements as well as help to prioritize the actions and establish roles and responsibilities.

- **Final Plan Review by The Aquatic Nuisance Species Task Force**: A management plan for invasive catfish in Chesapeake Bay would benefit from support and evaluation by the Aquatic Nuisance Species Task Force (ANSTF), which has supported and approved numerous species management plans (http://www.anstaskforce.gov/control.php)

- **Inclusion of Preventative Measures**: Most of these recommendations focus on control operations, with some emphasis on Early Detection and Rapid Response (EDRR) and outreach. The development of a management plan may assist with consideration of other aspects of invasive species management. Notable aspects that are missing from these recommendations are preventative measures (i.e., development of barriers, hazard analysis and critical control points [HACCP] planning), a list of research needs and a clear plan to address such needs, and restoration actions that may follow control operations and rebuild native populations. The logic model presented in Appendix B of the ICTF report provides a starting point to a comprehensive plan, and the ideas and actions within these tables should be built upon.

- **Investigation of other fishing gear**: There are other types of passive gear that may be used to catch catfish besides electrofishing, such as baited tandem hoop nets or mini-fyke nets, but caution is needed because there may be incidental catch of threatened and endangered fish as well as anadromous fish.

RESEARCH CHALLENGES AND STRATEGIES FOR INVASIVE CATFISH MANAGEMENT:

Many of these research activities will need to be accomplished in conjunction with one another, and could not be addressed in a priority list. However, since Recommendation 2 could introduce a public health concern, the number one research priority would be a better understanding of fish contaminant levels.

- **Assessing and monitoring contaminants levels in the Chesapeake Bay catfish:** Recently, blue catfish from three major Chesapeake Bay river systems (James, Rappahannock, and Potomac) were sampled for multiple contaminants (i.e., mercury, chlorinated and brominated organic micropollutants; Hale et al. 2014). Fish contaminant levels across the size range likely to support a fishery (>300 mm fork length) were sufficiently high to warrant consumption advisories in some tributaries which may present a challenge for the expansion of the commercial fishery. Assessments of additional tributaries and recurrent sampling will be needed to track fish contaminant levels.

- **Better understanding of basic biological information about blue and flathead catfishes**: This would include life history characteristics, reproductive potential, physical tolerances, ranges, important prey species, and bio-energetic demands. Efforts should continue to improve the understanding of the mechanisms that contribute to the spread and success of invasive catfishes in the Chesapeake Bay.

- **Understanding movements and habitat use of individuals**: This research is essential for targeted removals, as well as for commercial fishing, to result in positive biological outcomes. This information will also be essential as it pertains to the very large fish of interest to the trophy fishery.

- **Isolating measurable system and species responses to removal of invasive catfish to document program success**: Because Chesapeake Bay is a large, connected system an invasive catfish removal program is unlikely to result in detectable changes in the populations throughout the Bay. Removals would be subject to constant replacement of invasive catfish. Removals in smaller, targeted areas (e.g., an alosine spawning tidal creek) may produce a biological response. Carefully designed experiments with control systems (creeks) for comparison may enhance the understanding of species responses; however, outcomes may not be applicable at larger spatial scales (e.g., large tributary). Particular attention should be given to potential unintended consequences of removals, like life history rate changes, and the potential for overcompensation.

- **Evaluating effective capture methods**: The efficacy and limitations of electrofishing should be fully documented, including the susceptibility of both invasive catfish and native species to the gear and the effects of the gear under variable physical (temperature, salinity) conditions. There was a focus on electrofishing in the ICTF report; however, given the restrictions of the gear to use in specific seasons (water temperatures between 18° and 25° C) and locations (≤2 ppt salinity), other options should be explored.

- **Developing an affordable, integrated monitoring program**: While effective capture methods are evaluated, monitoring methods should also be evaluated. Although eDNA technology is promising, it may be many years before this method is consistent - the current state of the science for the application of eDNA is unlikely to be sufficient for the need to detect invasive catfish at the fine scales necessary for identification and targeting removals. In the meantime, alternative measures should be explored to monitor for catfish populations. The biggest challenge, particularly for funding, is to attempt to institute an ongoing, long-term survey which may be necessary to fully track invasive species status. One mechanism to reduce funding requirements is to add on catfish-related data acquisition to existing surveys and limit any new, dedicated surveys to the highest-risk areas (which still have to be identified and will necessarily change over time), viewing these dedicated surveys as short-term (several years only).

- **Investigating preventative methods of control**: Assessing and developing effective non-physical fish barriers for invasive catfish should be implemented. This may include the use and application of electrical, visual, acoustic, chemical, and hydrological deterrence techniques that may be used to prevent fish movements.

- **Genetic alteration of invasive catfish as a method of control**: Recent research efforts show promise for genetically altering invasive species to reduce genetic fitness of the population over time (e.g., daughterless carp, triploid flathead catfish, R. Dunham unpublished data 2007and 2008, Auburn University).

NEXT STEPS:

The most important next step is the development of a comprehensive management plan for invasive catfish in Chesapeake Bay. The logic model presented in Appendix B of the ICTF report provides a starting point to a comprehensive plan, the ideas and actions within these tables built upon, and existing organizations (e.g., Aquatic Nuisance Species Task Force) can support and inform species management plan development. The plan should establish the structure to ensure that evaluation of control techniques, applied research efforts, and outreach strategies are met in a timely manner. The Plan should further outline the specific actions needed to fulfill these requirements as well as help prioritize the actions and establish roles and responsibilities of collaborating agencies.

Since the intent to develop a commercial fishery based on the invasive catfish has already begun in some areas of the Chesapeake Bay, the most urgent need to be addressed by the ICTF is an evaluation of the risk posed to human health of potential consumption of toxins bioaccumulated in these fish. To that end, immediate scientific study should focus on delineating the risk of consuming toxins in a size range encompassing those fish targeted for market sale and determining appropriate consumption guidelines for each tributary in which the commercial fishery might operate.

LITERATURE CITED

Bonvechio, T.F., M.S. Allen, D. Gwinn, and J.S. Mitchell. 2011a. Impacts of electrofishing removals on the introduced flathead catfish population in the Satilla River, Georgia. Pages 395-407 *in* P.H. Michaletz and V.H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Bonvechio, T.F., C.A. Jennings, and D.R. Harrison. Submitted May 2011b. Diet and population metrics of the introduced blue catfish (*Ictalurus furcatus*) on the Altamaha River, Georgia. Proceedings of the Annual Conference of the Southeast. Association of Fish and Wildlife Agencies 65: 112-118.

Britton, J.R., R.E. Gozlan, and G.H. Copp. 2011. Managing non-native fish in the environment. Fish and Fisheries 12(3): 256-274.

Chandler, L.F. 1998. Trophic ecology of native an introduced catfishes in the tidal James River, Virginia. MS Thesis, Virginia Commonwealth University, Richmond, Virginia.

Franssen, N.R., J.E. Davis, D.W. Ryden, and K.B. Gido. 2014. Fish community responses to mechanical removal of non-native fishes in a large Southwestern River. Fisheries 39(8): 352-363.

Grote, A.B., M.M. Baily, and J.D. Zydlewski. 2014. Movements and demography of spawning American Shad in the Penobscot River Maine, prior to dam removal. Transactions of the American Fisheries Society 143: 552-563.

Hale, R.C., T.D. Tuckey, and M.C. Fabrizio. 2014. Risks of expanding the blue catfish fishery as a population control strategy: Influence of ecological factors on fish contaminant burdens. Final Report, NOAA Award NA11NMF4570220. 63pp.

Invasive Catfish Task Force (ICTF). *In prep*. Final report of the sustainable fisheries goal implementation team invasive catfish task force. NOAA Chesapeake Bay Program Office. Annapolis, Maryland. 53 pp.

Invasive Species Advisory Committee. 2013. Utilizing harvest incentives to control aquatic invasive species (White paper, draft), http://www.invasivespecies.gov/global/ISAC/ISAC_Minutes/2013/Tab6/ISAC%20Harvest%20White%20Paper%20final%20draft.pdf. 7p.

Knapp, R.A., D.M. Boiano, and V.T. Vredenburg. 2007. Removal of non-native fish results in population expansion of a declining amphibian (mountain yellow-legged frog, *Rana muscosa)*. Biological Conservation 135(1): 11-20.

Moser, M.L. and S.B. Roberts. 1999. Effects of nonindigenous ictalurids and recreational electrofishing on the ictalurid community of the Cape Fear River drainage, North Carolina. *In*: E.R. Irwin, W.A. Hubert, C.F. Rabeni, H.L. Schramm Jr, and T. Coon (Eds.), Catfish 2000: Proceedings of the international ictalurid symposium. American Fisheries Society, Symposium. Vol. 24, pp. 479-485.

Mueller, G.A., 2005. Predatory fish removal and native fish recovery in the Colorado River mainstem: What have we learned? Fisheries 30(9): 10-19.

Pasko, S. and J. Goldberg. 2014. Review of harvest incentives to control invasive species. Management of Biological Invasions 5(3): 263-277.

Pitlo J.R. 1997. Response of upper Mississippi River channel catfish populations to changes in commercial harvest regulations. North American Journal of Fisheries Management 17(4): 848-859.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries and Marine Service, Ottawa. Vol. 191, p. 382.

Schloesser, R.W., M.C. Fabrizio, R.J. Latour, G.C. Garman, B. Greenlee, M. Groves, and J. Gartland. 2011. Ecological role of blue catfish in Chesapeake Bay communities and implications for management. Pages 14-382 *in*: American Fisheries Society Symposium 77. American Fisheries Society, Bethesda.

Sweka, J.A., S. Eyler, and M.J. Millard. 2014. An egg-per-recruit model to evaluate the effects of upstream transport and downstream passage mortality of american eel in the Susquehanna River. North American Journal of Fisheries Management 34: 764-773.

Thompson, P.D., and F.J. Rahel. 1996. Evaluation of depletion-removal electrofishing of brook trout in small Rocky Mountain streams. *North American Journal of Fisheries Management*, 16(2), 332-339.

Vredenburg, V.T. 2004. Reversing introduced species effects: experimental removal of introduced fish leads to rapid recovery of a declining frog. Proceedings of the National Academy of Sciences of the United States of America, 101(20), 7646-7650.

APPENDIX I. REQUEST FOR THE SCIENTIFIC AND TECHNICAL ADVISORY COMMITTEE PEER REVIEW OF THE INVASIVE CATFISH TASK FORCE REPORT AND RECOMMENDATIONS.

March 2014

The Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team requests a review of the Invasive Catfish Task Force report and recommendations by the Scientific and Technical Advisory Committee (STAC).

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 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 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.

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. There are also significant gaps in our understanding of Blue and Flathead catfish biology, life history and ecological impacts. The ICTF report recommendations were drafted with this uncertainty in mind. The seven recommendations in the report are first steps to begin to address the challenges of invasive catfishes in the Chesapeake Bay.
Link 1-3 or 2-3 questions below.

Specifically we request STAC focus on the following questions:

1) Are the recommendations reasonable given what we currently know about invasive catfish biology and ecology?
2) Which recommendations are most likely to support the stated outcomes (reduce impacts on native species and slow spread)?
3) Which recommendations will have the most impact (IMPACT OF WHAT) given the level of scientific uncertainty regarding invasive catfish biology and ecology?

4) Do the reviewers support/endorse the report as sound policy for beginning to manage invasive catfish in the Chesapeake Bay?
5) Do the reviewers suggest any additional management options?
6) ID Gaps – or Level of independent effects. Technical feasibility, research gaps, approaches to fill the gaps – new to add.

IPCC report – doing literature and assigning likelihoods – this is what we have to lean on. Define likelihood based on current literature.

Background:
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. 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. 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.

APPENDIX II. ADDITIONAL REVIEWER COMMENTS ON THE ICTF REPORT

p. 4: The ICTF report authors indicate that flathead catfish were introduced into the James River in the late 1960s. However, flathead catfish are native to the Mississippi and Rio Grande Systems (Jackson 1999).

p. 5: Recommendation 1: The goal isn't to STOP, instead of slow and reduce?

p. 6: Recommendation 1: Expect a high chance of failure at this. Especially, considering the size of the system and you don't have a handle on how big the population really is based on current estimates. You tagged a pile of fish, with not much return. Chances are the blue cat population is gigantic. Especially when you consider Greenlee's CPE numbers that he has talked about for the past decade at various fisheries meetings. There are a lot of unknowns here. With that being said, a federally and state mandated targeted removal program could show promise. It demonstrates that you are taking action at the problem, with a high chance at failure, but at least you are giving it a shot. With most invasive introductions, once in and established, there is little a manager can do except throw their hands in the air and wave them like they just don't care. But, then came along the concept of maintenance control in aquatic plant management. Can we apply this same concept to invasive catfish that have invaded our Atlantic slope drainages? If the system is small enough, there is promise to reduce size and age structure and adult mouths that eat native fish and crustaceans (in your case) that we are trying to protect or restore. However, the Chesapeake Bay is entirely too big to actually see any kind of change in recruitment or size structure in the blue catfish population as a whole. But, in certain areas, where predation on several important species such as blue crabs, anadromous fish, etc., is a concern, Localized removals in those areas show a lot of promise in potentially reducing the predation pressure on the targeted natives you are trying to protect. Just realize that as (Britton et al 2011) mentions, source catfish populations will always be in the bay to repopulate the system.

p. 6: Recommendation 2: The levels of contaminants present in catfish species is alarming, along the whole coastal slope and fish in the Chesapeake don't look any better. 386 to 428 mm is not a very large window for a safe fish. Catfish, as stated in the report, are an apex predator. The bigger they get, the bigger the level of "hotness". Con: If you decide to promote this as a fishery, a commercial fishery, watch out for the ambulance chasers. Lawyers are looking to suit state and government agencies all the time. You need to make sure that the fish is highly regulated and individual consumers are tracked. This could be extremely hard to do.

p. 6: The commercial fishery must be presented as an eradication/control program, not a sustainable market.

p. 7: There are a lot of concerns with electrofishing. A carefully-planned, definitive study should examine: mortality of other species (including native catfishes, along with estimates of impacts for the already depressed populations of these other catfish species), effective size = range of affected subpopulations of the target species, salinity and temperature effects on effectiveness of the gear, as well as other issues before much credence is put into this recommendation.

p. 7: All catfish species should be part of this effort, not just invasive catfish. Native species need a benchmark so we can track whether their populations decline over time in response to the invaders.

p. 7: The information we are after cannot be taken from existing surveys. The "dedicated monitoring" should not be necessary in most areas, and may only be necessary in a limited number of areas in the Bay. Consequently, part of this recommendation should be to review datasets already available and ongoing, to determine where the real data gaps exist.

p. 7: Recommendation 4: This concept of identifying areas of concern where invasive fish may cause harm to native fish and crustaceans is not new. Saltwater biologists use MPAs to protect fish populations from humans. These areas have shown tremendous promise. What about setting up areas of targeted removal where native fish have a chance to make it? Trophy blue catfish movement needs to be looked at in these areas. Why do the numbers with the electrofishing gear change so much from year to year? Some of the largest fish are utilizing other prey resources. Undoubtedly, growth is slowing down and a density dependent effect is occurring on many of these blue cat populations that are beginning to get some age on them. In order to have targeted removals, it would be nice to know if there are more trophy blues in the river.

p. 7: Recommendation 5: Removing dams may cause more problems than they originally had in the first place with the dam in place. Dams serve as a barrier for flathead catfish to not go further upstream. Flathead catfish can move a lot. Tagging of unpublished data shows that a small portion (less than 20% of tagged fish) of flathead catfish in the Satilla River move substantially up and down (over 50 km) the river and act more like salmon than a sedentary catfish. Given the majority of fish are very sedentary, but it's that small portion that helps populate a new stretch of the river further upstream, especially where a dam might be taken down.

p. 10: Reduce the spread of invasive catfish in the Chesapeake could be very difficult to achieve given the large range in fluctuations of water regimes along the coastal drainages of the Atlantic slope. When the Satilla river stays up (the past 18 months years), the primary productivity is about 4 times as high as it normally is when the river stays within the banks (Junk et al. 1989). It is the floodplain pulse continuum concept. Although, the flathead removal project on the Satilla was a huge success for many reasons. First, there were zero Georgia DNR angler awards on the Satilla in 2013, but 12 in the spring and summer. Most of these angler awards were for 1lb or larger redbreast sunfish, the exact native we have been trying to restore and protect. The redbreast fishery was indescribably phenomenal this past spring. Unfortunately, many have seen a monster jump in flathead recruitment the past 2 years because of this high water. The fish are still small and the size structure is still fished way back down to mostly 1 and 2 years old, but the high water for the past 18 months gave the flatheads a decent shot at replacing themselves since we have been removing them, CPUE went from 19 to 40 to 77 fish per hour (2012, 2013, 2014, respectively. In the first 6 years of flathead removal, reduced maturation of flatheads at smaller sizes (Bonvechio et al. 2011a), but these past 2 years have altered perspectives on the removal.

Although we can reduce the size structure and age structure, we have had absolutely no impact on recruitment. Nonetheless, although there are 4 times as many flatheads in the Satilla as had been in the river in 2011 & 2012, the redbreast fishery responded in a tremendous way. There is only one explanation for this theory. Slaughter and Jacobson (2008) published a paper with regard to gape and body size relationship for flatheads. Average size flathead in the Satilla has been fished down from 512 mm TL in 2007 down to 240 mm TL in 2013. It went from 3 and 4 year old fish down to 0, 1 and some 2 year olds (age structure data via lapilla otoliths). A 240 mm TL flathead cannot eat a very big redbreast sunfish according to Slaughter and Jacobson's findings. This theory could be why there were so many trophy sized redbreast sunfish caught by anglers this spring and summer. While high water had a lot to do with it (Junk et al. 1989), but fishing down the large apex predator to a size that they cannot predate on trophy sunfish, had to play some large part in the tremendous success of the removal project.

p. 11: Is there an exact number of catfish that were introduced to the Virginia tributary? If so, cite. What tributaries were they stocked into? Which species was stocked where? It would be helpful to see a full list of the tributaries somewhere in the report.

p. 11: Is stocking becoming more widespread or are populations of invasive catfish spreading?

p. 11: It would be helpful to see a full list of the 10 major tributaries where catfishes are predominately established.

p. 11: If the results of the geospatial model are going to be presented, more information is needed about it. How was potential distribution determined? What criteria were used? How was the modeling done? The figure shows 'high risk watersheds'. What were there other risk categories? What is high risk? Additionally, the cross hatched areas are difficult to see. Perhaps that's why it isn't apparent that the distribution is predicted to double? Is that in area or number of watersheds?

p. 11: Is the expansion to 242 watersheds a recent expansion, given that first introduction occurred in 1960's, yet impacts have only been of concern in recent years? Is there a projected time frame for this expansion?

p. 12: VCU didn't develop the map, people did. Please provide names or at least provide the department name?

p. 12 (figure 1): What variables were used to create this map? Are the solids is the yellow areas and cross hatched are the paler yellow? If the red and blue (high value waters) are not important or explained on this figure, remove them because they're distracting. April 2013 was over a year ago. Is there any data more current?

p. 12 (figure 1): Is there a reason the Conowingo Dam is mentioned? If so, explain in text and show where the dam is located on the map. Does this mean the model is for only a part of the catfish distribution (below the dam) and not the entire Chesapeake Bay region?

p. 13 (figure 2): Does not depict anything about potential distribution. It's current distribution only. It therefore does not support the statement about expanding distribution.

p. 13 (figure 2): This figure should also indicate the areas of concern for the further invasion of flatheads - namely, wherever a dam is planned to be removed. Dams could be a huge problem in these circumstances, traveling far upstream of their current distribution. Also, the legend is far too small to be useful.

p. 13 (figure 2): Regarding current distributions, are they not predicted to expand their range, since no cross-hatched polygons are used, or has this study not been done? Also, the text states this figure shows the range expansion. This would be easier to interpret if the figure showed the original sites of introduction. Dating the map to show how quickly (or slowly) they were detected in additional sites would also be useful.

p. 14: It is not clear if the model included characteristics such as tolerance for wide range of environmental conditions.

p. 14: Are the factors containing channel cats well understood and projected to be constant into the future? If not, it seems dangerous to use a lack of spread as an indication of potential distribution. Many invasive species exhibit a lag phase followed by rapid expansion for reasons not easily identified.

p. 14: The ICTF report says that channel catfish, which are also nonnative in Atlantic Slope Rivers, also have a high salinity tolerance. This does not seem accurate. It was thought that channel catfish were native to the Satilla and the Atlantic Slope drainage. Maybe since they've been around for a century or more, it is kind of implied that they have resumed some sort of normalcy in the population? This brings up an interesting thought that should be entertained, especially as management considers whether to conduct selective removals on such a large amount of water. Dr. Adam Kaeser, and others, examined the population dynamics of introduced flathead catfish in several rivers in southern Georgia (Kaeser et al. 2011). One would argue that flathead and blue catfish are apex predators and eventually eat fish and are devastating to native fish. Following establishment, flathead catfish spread quickly through a system and attain high abundances and biomass (Guier et al. 1981; Quinn 1988; Dobbins et al. 1999; Moser and Roberts 1999, Weller and Geihsler 1999). The impacts on native fauna are well documented in Georgia (Thomas 1993; Bonvechio et al. 2009). In an attempt to mitigate these impacts, Electrofishing removals have been conducted on several Georgia Rivers and are ongoing on the Satilla (Bonvechio et al. 2011a). Little is known, however, of the trajectories and fates of introduced populations, whether they stabilize and what level and whether their dynamics change over time. Kaeser et al. (2011) demonstrated that flathead catfish have persisted for decades in rivers of Southern Georgia (since the 1950's in the Flint), (all populations examined in this study were over 30 years old or more), and eradications seems highly unlikely. Researchers observed several common trends in the dynamics of these older introduced populations and have provided evidence that growth, biomass and abundance can change dramatically over time following establishment in Georgia Rivers. Observations in this study suggest that a decline and persistence at low levels of abundance is not necessarily a characteristic outcome of flathead catfish invasions. Other populations need to be examined, it does appear, there seems to be some breaking point in the food resources and then populations start to decline with regard to abundance, growth and biomass; hence a popular ecological thought or concept called dampened oscillations over time. The population fluctuates some like a waveform but declines to some stable level over time, or what a native population would look like. Some might argue, that by removing a bunch of fish like the removal program targeting the younger introduced Satilla (introduced in the mid 1990's) population, may just be delaying the population from assuming a sense of normalcy like the Flint River now exhibits some 60+ years after introduction (Bonvechio et al. 2009, Bonvechio et al. 2011a, Dobbins et al. 1999, Guier et al. 1981, Kaeser et al. 2011, and Moster and Roberts 1999, Thomas 1993, and Quinn 1988, Weller and Geihsler 1999).

p. 14: Is it only presumed potential vectors of spread between flathead and catfish? If thought to be comprehensive, that should be stated. Baitfish, aquaculture, contaminated authorized stockings, etc., aren't potential contributors?

p. 15 (table 1): Flathead catfish's diet is very broad. Although, there is no formal published diet study on the Satilla, some have found anything from Gar to Bowfin in their bellies. None of these species should be consider very palatable. Flathead catfish will eat anything.

p. 15 (table 1): Flathead catfish's fecundity is highly variable but can be extremely high as well. About 46,000 eggs in a 540 mm fish in the Satilla were observed this spring. However, reduced maturation has been reported due to the high level of exploitation on the Satilla River in close to a decade (Bonvechio et al. 2011a) and 8 to 10 inch fish have been observed with eggs in them.

p. 15 (table 1): What does prior invader mean? What are the implications? What is environmental tolerance? It is recommended to either add a caption explaining those terms that are not self-explanatory, reword table and state "adapted from" source, or both. The report should verify and qualify the "high fecundity" for both species (i.e., relative to what?).

p. 16: 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 >18.8 cm FL; Chandler 1998) than for blue catfish (>30 cm FL). Piscivory has been observed in flathead catfish in their first year (fish less than 200 mm TL), while another blue catfish diet study on the Altamaha River (Bonvechio et al 2011b), revealed that that fish under 600 mm TL preferred Asiatic clams and but fish < 600 mm TL had a varied diet composed of organic material and American Eel (Bonvechio et al. 2011b).

p. 17: What are the impacts to native fish and the management implications behind this data? If this document is for decision makers, they may not have a scientific background to determine ecological consequences from size data.

p. 18: How will the draft management plan be incorporated into this report and recommendations?

p. 18: Specify if "catfishes" are native or invasive for line 1.

p. 19: The last sentence reads "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 inches from the James River; 1 meal per month of Blue Catfish caught from other tributaries)." This would be a recommendation for the James River. If people were allowed to commercially fish and keep everything under a certain size, this would really help the trophy fishery. This is not advocating keeping up to 32 inches because the fish look to be getting hot with contaminants when they are over 18 inches (457mm TL). The fish data presented a small window of say 386 to 428 was under the contaminant advisory consumption level. It's like an inverted slot where you direct all the harvest on the small fish, similar to the successful white sturgeon fishery out in the Pacific Northwest in the Columbia River and several other rivers out there. If you harvest juveniles, and the younger reproducing fish, the trophy population/size structure should stay intact, especially for longer lived fish. Additionally, if harvest is high enough on smaller fish (say less than 18 inches), growth rates should increase for the trophy fish. Maybe harvest all fish up to (457 mm TL) or 18 inches for human consumption. Then haul fish to a liner filled dump fish between 18 and 28 inches (457 to 711 mm TL). Does that mean that all fish over 711 mm TL get released for the trophy fishery? Let 28 inches and up go for the trophy fishery.

p. 19: What is the health reason for the consumption limitations? This should be specified in the report.

p. 20: Why have invasive catfish become more widespread in the last 30-40 years? Has the degree to damage just become known? This information should be provided in the species description.

p. 20: It is a huge waste of time for the state of Maryland and the Chesapeake Bay Program to post signs at key public access sites to raise awareness of the issue with invasive catfish. Other states did this for a while and the public still moved fish from waterbody to waterbody and damaged signs.

p. 20: Eradication is completely unlikely. Maintenance control is more appropriate (Bonvechio et al. 2011a).

p. 21: Suggest adding an interjurisdictional effort to at least evaluate a cooperative refinement to the existing recreational subsector trophy fishery to be catch and keep only. These are the animals that consume the most (of everything), and reproduce the most, by far.

p. 21: What factors qualify the areas to be “high-value?”

p. 22: Would non-physical barriers prevent migration of native species and what might the fall back be if barriers were deployed?

p. 22: What is low frequency electrofishing effectiveness in the range of salinity encountered in Bay sites? How about under a range of temperatures - it seems many intended efforts would be in the early spring, before alosines arrive, so temperature (esp. cold) would be an important variable to account for.

p. 23: Electrofishing needs to be done in a small system, preferably having a dam upstream to limit connectivity of source populations, not in a system like on the Eastern Shore of Maryland.

p. 23: Explain why Dragon Run, the Patuxent River, or an Eastern Shore tributary would be likely candidates for selected removal.

p. 23: The danger to other species (native catfishes as well as other fish groups) should not be so easily dismissed here, especially without specific references (if they exist) specifying bycatch effects of the gear at varying temperatures and salinities.

p. 23: The most lucrative recreational fishery is the monster fish charter fishery, in which the guides release the fish again. This fishery would have to be modified substantially, and this may not be an easy sell to the Guides/ Charters.

p. 23: Doesn't seem prudent to encourage or give incentives for building processing facilities when it is unknown if population reduction can be achieved? Seems like more baseline data is needed before going this route.

p. 24: A workshop could be good if (1) we can get past the consumption advisories, 2) will the market be flooded with smaller catfish driving the price down to fast and, 3) overseas markets need to be identified quickly.

p. 24: The report should not claim that catfish are healthy with all the contaminant issues. It's a slippery slope advocating a fisheries market with fish that need to be highly regulated per individual due to contaminants. Again, considering the invasive catfish fisheries to be "healthy" is a big stretch.

p. 24: How much should the population be reduced over the long-term? Initial modeling showed 10 fold decrease was not enough.

p. 25 (line 1): What about the collateral threat to the native catfish species, both by increased bycatch and by mis-identification?

p. 25: Developing a market and raising the value of an invasive species is a scary task at first, but, sometimes you have to take a risk and try something new.

p. 25: What specific restrictions does North Carolina include for electrofishing?

p. 25: One agency uses 18 ppt, instead of < 15 ppt as recommended in the report.

p. 26: Another challenge to implementation is the extremely high start-up costs, especially for such a low-value fishery.

p. 26: Larger fish captured by electrofishing would be re-released? Not sure this is wise. Restricting locations, perhaps?

p. 26: It is dangerous to encourage commercial, private electrofishing efforts unless proper training is provided. Also there may be concern with making a large capital investment in equipment when the goal is to deplete the fishery (thus making their expensive electrofishing equipment obsolete).

p. 26: Recommendation 3: 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. However, there were many problems with legalizing electrofishing for flathead catfish on the Satilla River. There will be incidental harvest of other species among other violations. The problems are endless.

p. 27: One way to leverage existing resources could be to incorporate catfish into existing agency surveys.

p. 27: The ecosystem is not static and there may be changes that will enhance the ability of catfish to invade other areas.

p. 28: There is debate that eDNA is useful and relatively inexpensive.

p. 28: In response to the 3,800 constructed impediments, unfortunately, the dams may be a hidden blessing and could be severely limiting upstream movement and establishment of flathead catfish.

p. 30: What has the actual proposal been for trophy fish? This appears to be an oversimplification of what a future "trophy fishery" is envisioned to be. The future envisioned would be either: to maintain the trophy fishery, but make it removal only (catch and kill) rather than catch and release, or simply to stop the fishery, period. The first would produce indigestion with the subsector, but they may still be willing to move forward, the second would be a non-starter.   Reviewers need to know the situation in order to comment on this.

p. 30: 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. This is certainly a big factor on whether a dam should be taken out or left in place.

p. 30: Stronger fines are necessary to enforce the current regulations regarding the illegal transport of live fish.

p. 30: Since MD and VA do not appear to favor removal of the trophy fisheries from the James or Potomac Rivers and eradication is not likely, nothing over 32 is a great idea in an effort to protect the trophy fishery. Because, if you fish down the population, you may see a positive reaction to the natives, as a result, the trophy's could benefit from reduced competition. This will likely not affect recruitment when catch rates are in the 1000 fish an hour range.

p. 30: Recommendation 6:   Blue catfish growth is slowing down in many of the systems over time. This was observed with introduced flathead catfish populations over time in South Georgia (Kaeser et al. 2011). The concept of dampened oscillations over time was already mentioned earlier in this review. Also, what about disagreement on the more effective measures or opposition to removing trophy fisheries?

p. 30: One con could be the time and effort required for this recommendation. What if there's no interest in harmonizing?

p. 32: There have not been events where invasive species are caught and removals have been successful. Please provide an example.

p. 35: Fish consumption rates are very hard to manage in a food bank situation.

p. 35: (mean TL = 65 cm): 32 inches is 812 mm TL.

p. 35: The 35 blue catfish analyzed in that study ranged between 386 and 428mm. That is only 15 to 17 inches long. That is not much of a window to harvest.

p. 35: Is it irresponsible to create/promote a commercial fishery for fishes contaminated with PCBs and Mercury. It seems that all larger predatory fishes exceed the unrestricted consumption threshold.

p. 36: It seems very important to understand movement (and recolonization rates) of these fishes when considering potential efficacy of targeted removal areas.

p. 37: Targeted removals may mitigate the consumption impacts on blue crabs.

p. 37: It was recommended to tag bigger fish with VEMCO's to look at the differential movement on size classes.

p. 38: 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. The gear does not always catch the big fish every year.

p. 38: It is highly unlikely that because blue catfish abundances are believed to be considerable higher now than they were 10+ years ago (Schloesser et al. 2011), these observed changes in growth may be related to fish density.

p. 39: Define what "sufficiently high" means.

p. 39: It's nearly always true that tag retention rates improved with increasing tagger experience.

p. 39: The results could also suggest that the population in the James River could be due to tag loss that might be occurring.

p. 40: The report must identify the type [and manufacturer] of the two dart tags (Hallprint? [Floy?, other?]).

p. 40: Predation impacts would also negatively impact sturgeons.

p. 41: Efforts to control the population through direct fishing mortality could have considerable challenges. The Satilla River is having extreme challenges going into the 8th year of removing flathead catfish. Although removal can severely suppress the invasive catfish population during a drought scenario and even on normal water regimes, but high water definitely is a determining factor of year-class strength for flathead catfish in these Atlantic Slope drainages. Environmental factors are probably the biggest effect on population size. There was high water in the Satilla River in all of 2013 and half of 2014 (18 months). Then catch rates of flatheads skyrocketed from 19 fish per hour in 2012 to 40 per hour in 2013 and are near 80 fish per hour in 2014. Granted they are all small fish, and 80% of the population is still age 0-2, but the population has been given a great chance to rebound and if we don't stay on them with the removal, they will rebound completely in a few years. Accessibility to the floodplain for the majority of the spawn produces a tremendous year-class of little guys (Junk et al. 1989).

p. 42: From experience, tag retention rates are much higher with hallprint dart tags then they are with tbar floy tags.

p. 43: Between 386 and 428 mm TL is a very small range. Is it assumed that you could harvest any size up to 428 mm TL?

p. 45: How is funding an input? Each of the other entries incorporates their own funding sources. Is there something specific that should be explained further here?

p. 51: Incomplete reference: Bonvechio, T.F., M.S. Allen, D. Gwinn and J. S. Mitchell. 2011. Impacts of electrofishing removals on the introduced flathead catfish in the Satilla River, Georgia. Pages 395-407 *in* P.H. Michaletz and V.H. Travnichek, editors. Conservation, ecology,

and management of catfish: the second international symposium. American Fisheries Society Symposium 77, Bethesda, Maryland.

Literature Cited

Bonvechio, T.F., D. Harrison, and B. Deener. 2009. Population changes of Sportfish following flathead catfish introduction in the Satilla River, Georgia. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 63:133-139.

Bonvechio, T.F., M.S. Allen, D. Gwinn, and J.S. Mitchell. 2011a. Impacts of electrofishing removals on the introduced flathead catfish population in the Satilla River, Georgia. Pages 395-407 *in* P.H. Michaletz and V.H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Bonvechio, T.F., C.A. Jennings, and D.R. Harrison. Submitted May 2011b. Diet and population metrics of the introduced blue catfish (*Ictalurus furcatus*) on the Altamaha River, Georgia. Proceedings of the Annual Conference of the Southeast. Association of Fish and Wildlife Agencies 65: 112-118.

Britton, J.R., R.E. Gozlan, and G.H. Copp. 2011. Managing non-native fish in the environment. Fish and Fisheries 12(3): 256-274.

Chandler, L.F. 1998. Trophic ecology of native an introduced catfishes in the tidal James River, Virginia. MS Thesis, Virginia Commonwealth University, Richmond, Virginia.

Dobbins, D.A., R.L. Cailteux, and J.J. Nordaus. 1999. Flathead catfish abundance and movement in the Appalachicola River, Florida. Pages 199-201 *in* E.R. Irwin, W.A. Hubert, C.F. Rabeni, H.L. Schramm, Jr., and T. Coon, editors. Catfish 2000: Proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Flowers, H.J., T.F. Bonvechio and D. Pederson. 2011. Observation of an Atlantic Sturgeon eaten by a flathead catfish. Transactions of the American Fisheries Society 140:250-252.

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

Jackson, D.C. 1999. Flathead catfish: biology, fisheries, and management. Pages 23-35 in E.R. Irwin, W.A. Huber, C.F. Rabeini, H.L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Proceedings of the International Large River Symposium (LARS). Canadian Special Publications in Fisheries and Aquatic Sciences 106:110-127.

Kaeser, A.J., T.F. Bonvechio, D. Harrison, and R.R. Weller. 2011. Population dynamics of introduced flathead catfish in rivers of southern Georgia. Pages 409-422 *in* P.H. Michaletz and V.H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Moser, M.L., and S.B. Roberts. 1999. Effects of nonindigenous ictalurids and recreational electrofishing on the ictalurid community of the Cape Fear River drainage, North Carolina. Pages 479-485 *in* E.R. Irwin, W.A. Hubert, C.F. Rabeni, H.L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Quinn, S.P. 1988. Flathead catfish abundance and growth in the Flint River, Georgia. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 42:141-148.

Schloesser, R.W., M.C. Fabrizio, R.J. Latour, G.C. Garman, B. Greenlee, M. Groves, and J. Gartland. 2011. Ecological role of blue catfish in Chesapeake Bay communities and implications for management. Pages 14-382 *in* American Fisheries Society Symposium 77. American Fisheries Society, Bethesda.

Slaughter, J.E. and B. Jacobson. 2008. Gape: body size relationship of flathead catfish. North American Journal of Fisheries Management 28:198-202.

Thomas, M.E. 1993. Monitoring the effects of introduced flathead catfish on the sportfish populations in the Altamaha River, Georgia. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 47:531-538.

Weller, R.R., and M.R. Geihsler. 1999. Angler attitudes concerning the management of the introduced flathead catfish in the Altmaha River system, Georgia. Pages 435-442 *in* E R. Irwin, W.A. Hubert, C.F. Rabeni, H L. Schramm, Jr., and T. Coon, editors. Catfish 2000: Proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Additional References Used To Inform This Review

Fury, J.R., and F.A. Morello. 1994. The contribution of an exotic fish, the Oscar, to the sport fishery of the Everglades water conservation areas. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 48:474-481.

Harris, S.A., and J.L. Jones. 2008. Fish consumption and PCB-associated health risks in recreational fishermen on the James River, Virginia. *Environmental research*, 107(2), 254-26.

Herndon, T.M., Jr., and C.T. Waters. 2000. Flathead catfish diet analysis, stock assessment, and effects of removal on Sutton Lake, North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 54:70-79.