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Proceedings of the Regional Peer Review of the Binational Ecological Risk Assessment for Grass Carp in the Great Lakes Basin

June 1-3, 2015
Cleveland, Ohio

Chairperson: Gilles Olivier
Editor: Lia Kruger

Freshwater Institute
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

The binational ecological risk assessment peer-review was held to review the draft research document developed to assess the ecological risk of Grass Carp (*Ctenopharyngodon idella*) to the Great Lakes basin. The meeting was held on June 1-3, 2015 in Cleveland, Ohio, U.S. and included participants from Fisheries and Oceans Canada (DFO), Great Lakes Fishery Commission, U.S. Fish and Wildlife Service, U.S. Geological Survey and invited experts on risk assessment, freshwater invasive fishes, Great Lakes wetlands, and ecosystem modelling from both Canada and the United States. The purpose of this meeting was to review existing information to assess the ecological risk of Grass Carp to the Great Lakes basin. The results of this ecological risk assessment will provide advice for managers and decision makers to use when determining courses of action regarding prevention, monitoring, early detection, rapid response, management, and control of Grass Carp. Results from this ecological risk assessment will also be used to inform a separate socio-economic impact assessment.

This Proceedings report summarizes the presentations and relevant discussions from the peer-review and presents the changes and suggested revisions from the meeting to be made to the associated research documents. It is a compilation and summary of reviews from all participants. Advice resulting from the peer-review meeting will be published as a Science Advisory Report on the DFO Canadian Science Advisory Secretariat Website. The risk assessment, and the other research documents supporting it, will also be published on the same website.

Compte rendu de l'examen régional par les pairs de l'évaluation binationale du risque écologique de la carpe de roseau dans le bassin des Grands Lacs

SOMMAIRE

La réunion d'examen par les pairs sur l'évaluation binationale du risque écologique a été tenue pour passer en revue l'ébauche du document de recherche élaborée afin d'évaluer le risque écologique de la carpe de roseau (*Ctenopharyngodon idella*) dans le bassin des Grands Lacs. La réunion s'est déroulée du 1 au 3 juin 2015 à Cleveland, en Ohio (États-Unis), et incluait des participants provenant de Pêches et Océans Canada (MPO), de la Commission des pêcheries des Grands Lacs, de l'U.S. Fish and Wildlife Service, de l'U.S. Geological Survey et des experts du Canada et des États-Unis en évaluation du risque, en poissons d'eau douce envahissants, en zones humides côtières des Grands Lacs et en modélisation des écosystèmes. Le but de cette réunion était d'examiner les renseignements existants afin d'évaluer le risque écologique posé par la présence de la carpe de roseau dans le bassin des Grands Lacs. Les résultats de cette évaluation du risque écologique fourniront des renseignements que les gestionnaires et les décideurs pourront utiliser afin de déterminer les mesures à prendre en matière de prévention, de surveillance, de détection précoce, d'intervention rapide, de gestion, et de contrôle de la carpe de roseau. Les résultats de cette évaluation du risque écologique serviront aussi à orienter une analyse distincte des incidences socio-économiques.

Le présent compte rendu résume les présentations et les discussions pertinentes tenues lors de la réunion d'examen par les pairs et présente les propositions de modifications à apporter aux documents de recherche connexes. Il s'agit d'une compilation et d'un sommaire des examens de tous les participants. Les avis découlant de la réunion d'examen par les pairs seront publiés sous la forme d'un avis scientifique sur le site Web du Secrétariat canadien de consultation scientifique du MPO. L'évaluation des risques, et les autres documents de recherche à l'appui de celle-ci seront également publiés sur le même site Web.

INTRODUCTION

Grass Carp (*Ctenopharyngodon idella*) is currently threatening to invade the Great Lakes as evidenced by their reproduction in the U.S. waters of the Lake Erie basin and their increasing occurrence in, and proximity to the Great Lakes basin. Canadian and U.S. agencies share a similar goal of preventing the arrival, survival, establishment, spread, and consequences of Grass Carp in the Great Lakes. To achieve this goal, it is important to determine and understand the risk of Grass Carp to the Great Lakes basin, to provide useful, scientifically defensible advice for prevention, monitoring, early detection, and management actions that are underway or could be taken. As such, an ecological risk assessment was drafted to assess the probability and ecological consequences of an invasion by Grass Carp into the Great Lakes basin. The risk assessment considers the best available information known about Grass Carp to assess the likelihood of arrival, survival, establishment, and spread, and the magnitude of the ecological consequences to the Great Lakes basin at 5, 10, 20, and 50 years from the baseline year (2014). The results of the ecological risk assessment will subsequently be used to conduct a separate socio-economic impact analysis.

The intent of the peer-review, as described in the Terms of Reference (Appendix 1), was to review, assess, and discuss in a face-to-face forum, the draft ecological risk assessment document of Grass Carp to the Great Lakes basin. Meeting participants (Appendix 2) included DFO (Ecosystems and Oceans Science), Great Lakes Fishery Commission (GLFC), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), and invited experts on risk assessment, freshwater invasive fishes, Great Lakes wetlands, and ecosystem modelling from both Canada and the United States. The meeting generally followed the agenda (Appendix 3).

This Proceedings report summarizes the relevant meeting discussions and presents the key conclusions. Science advice resulting from this meeting is published on the DFO Canadian Science Advisory Secretariat (CSAS) website in the Science Advisory Report series. The risk assessment and the technical details supporting it and the advice included in the working paper presented at the meeting are published in the Research Document series.

WELCOME AND INTRODUCTIONS; DFO SCIENCE PEER-REVIEW AND ADVISORY PROCESS

The meeting Chair, Gilles Olivier (Contractor, Montreal, Quebec), welcomed the group and participants were introduced. The Chair provided an overview of the CSAS process, expected outputs and document timelines. Unlike other Canadian peer-review processes, this peer-review must consider the review processes undertaken by the USGS and USFWS, as this is a binational review. Following the meeting, the authors of the working paper will meet to discuss changes to the document proposed during the peer-review meeting. In cases when the authors are not in agreement with proposed changes, these recommendations will be documented in the proceedings with the rationale for not accepting the change(s) to the working paper included. The goal is for the authors and the peer reviewers to come to agreement at the meeting so that a final Research Document can be published based on all the outcomes of the peer review. In general, the rankings will be finalized during the meeting, while the rationale for the rankings may have some changes following the meeting.

RISK ASSESSMENT INTRODUCTION

Presenter: Becky Cudmore, Manager, Asian Carp Program, Aquatic Invasive Species Senior Advisor, DFO, Burlington, Ontario.

Summary

An overview of the risk assessment process was presented. The presenter defined risk assessment as a procedure to identify the likelihood of threats and vulnerabilities, and the likelihood of ecological consequences. The overview included: risk assessment objectives, principles of the peer-review process, standard steps, and expected meeting products. Individual author risk tables were developed following the authors' writing and review of the working paper (see Appendix 4 for individual risk tables). These risk tables were then used by the authors to come to consensus. The risk tables produced following consensus are what were included in the working paper presented at the peer-review meeting. A slight variation of the CSAS process was noted - where authors do not make suggested changes to the document, it will be documented in the proceedings, along with the reasons for not accepting those changes.

Discussion

A participant asked if the risk tables will be finalized outside of this meeting and the Chair responded that the goal is to finalize the risk tables during this meeting. Another participant asked if the peer-review team will hold control over the authors and it was clarified that the goal is for the authors and the peer-review team to come to an agreement, or at least understanding, of the final document wording and recommendation.

INTRODUCTION TO THE BINATIONAL RISK ASSESSMENT FOR GRASS CARP IN THE GREAT LAKES BASIN

Presenter: Becky Cudmore, Manager, Asian Carp Program, Aquatic Invasive Species Senior Advisor, DFO, Burlington, Ontario.

Summary

Grass Carp consumes large amounts of vegetation. This can alter plant, invertebrate and fish communities, as well as water quality. Current proximity to, and occurrences of, Grass Carp in the Great Lakes basin represents a potential threat to Great Lakes fisheries. There is evidence of reproduction in Lake Erie (U.S. waters). A previous risk assessment (Mandrak and Cudmore 2004) answered the broad question of what is the risk to Canadian waters but now there is a need for more targeted questions to address more specific management needs in the Great Lakes basin. Additional data are available and knowledge gaps have been identified, such as the need for more impact studies at the ecosystem level, more research in the Great Lakes region, more experimental studies with appropriate statistical power, and incorporating spatially explicit habitat layers to provide further refinement in assessing likelihood of establishment (Wittmann et al. 2014).

A risk assessment is needed because there is high uncertainty and conflicting information on Grass Carp, which makes difficult decisions even more difficult. Directions for effective prevention, monitoring, and control actions based on a foundation of science are needed. The presenter gave details about the scoping/progress meetings. The presenter reviewed the probability and relative certainty categories with participants, as well as the description of the ecological consequence ratings with an example of the graphical representation of overall risk (Tables 1-3 and Figure 3 in Cudmore et al. 2017).

Discussion

Participants expressed their concern with the terminology used for 'likelihood of introduction' since there seems to be an issue with the definition and how it is interpreted in other risk assessments. The term 'introduction' is not used the same way in the scientific literature for invasion ecology as it is in this risk assessment. The authors maintained that the terminology used will follow what has been used in past assessments and is considered a global definition and ensured that it is clearly defined in the risk assessment document.

There was some confusion with the acronyms used for the probability and certainty categories. VL=very low certainty, but VL= very likely with respect to probability. However, these are consistent with previous risk assessments. The authors assured that there will be a legend with every table in the document to avoid any confusion and to include a second letter for clarity (e.g., VLo and VLi).

One participant asked how the ellipse around the points in Figure 3 (Cudmore et al. 2017) was derived. It was explained that the ellipses reflect certainty of data and are useful for managers; however, they are not derived using quantitative methods, rather they are a graphical representation of certainty/uncertainty for the probability of introduction and the magnitude of ecological consequences. It was explained that the size of the ellipse was meant to represent the relative amount of uncertainty. An elongation of the ellipse along the x or y axis represents increased uncertainty.

DISCUSSION

Key findings, interpretation of likelihood/probability, uncertainties, and decisions on each of the risk assessment components (arrival, survival, establishment, spread, ecological consequences) follows**.**

ARRIVAL

Physical Connections

Presenter: Cynthia Kolar, USGS, Ecosystems Mission Area, Reston, Virginia

Summary

In this section of the risk assessment, authors looked at routes by which Grass Carp could enter each of the Great Lakes. To assess the likelihood of arrival through physical connections the following was considered: information about captures (including environmental DNA) from each of the Great Lakes and within physical connections to other waterbodies outside of the Great Lakes basin, regulations regarding Grass Carp in the Great Lakes and adjacent states and provinces, and potential hydrologic connections between the Great Lakes basin and adjacent watersheds was reviewed. The majority of physical connections are between the Great Lakes and Mississippi River basins and are outlined in the Great Lakes and Mississippi River Interbasin Study (GLMRIS) by the U.S. Army Corps of Engineers (USACE). The GLMRIS study involved two focus areas: Focus Area 1 (Chicago-Area Waterway System (CAWS)), and Focus Area 2 (18 other connections around the Great Lakes). The GLMRIS study focused on bigheaded carps. The authors assume Grass Carp could arrive via the same hydrologic connections as bigheaded carps.

For Lake Superior, no Grass Carp have been collected but there are three potential low-priority entry points (as identified in Focus Area 2). For Lake Michigan basin, 36 Grass Carp have been reported to the USGS Nonindigenous Aquatic Species database (NAS) (2015) between 1975 and 2014. There is no evidence of natural recruitment in the Lake Michigan basin. The CAWS was ranked as the connection with the highest likelihood of possible entry routes including passage through the electric barrier, barge leakage, or flooding of Des Plaines River or Illinois and Michigan Canal. There are nine other potential but low probability connections to Lake Michigan identified by the GLMRIS Focus Area 2 (USACE 2013). For Lake Huron, several Grass Carp were captured between 1989 and 2008. There are no physical connections to Lake Huron in the GLMRIS focus areas. For Lake Erie, 34 Grass Carp collections have been reported between 1985 and 2015 (USGS NAS 2015) and there is evidence of recruitment. Of the 18 connections identified in Focus Area 2 of the GLMRIS report, six potential hydrologic connections exist between Lake Erie basin and the Mississippi River basin. The New York Canal System may also be an entry route for Grass Carp to Lake Erie. For Lake Ontario, five Grass Carp were collected between 1985 and 2010. There are no connections to Lake Ontario basin in the GLMRIS study area but the New York Canal System may be a possible entry route for Grass Carp. The presenter gave an overview of the conclusions from the risk assessment for this component of arrival.

Discussion

There was some confusion about where the geographic boundary (i.e., the ‘red line’) was located for the risk assessment. The group thought it would be helpful to better define the boundaries. Chicago ponds have many Grass Carp and one participant thought this should be included in the working paper. A participant asked if Ohio, Pennsylvania and New York need to import triploids from out of state. The triploids are imported for grow out or stocking. Another participant asked if the risk assessment assessed different life stages individually to determine if there is a different probability of entering the lake by age. It was noted that the risk assessment included all Grass Carp together and that individual assessments of each life stage of fish could be recorded as a knowledge gap in the working paper. Another question was asked about the percentage of ‘fertile triploids’, and that any information available on this should be captured in the working paper. It was noted that in the assessment triploid Grass Carp that failed the triploid induction process were considered as diploids. The group also noted that the frequency of flooding should be included, as well as the relative magnitude of flooding events and the data on this should be available; perhaps in the GLMRIS study. A participant asked what the scope was to add new information to this document and was informed that new information can be added during this meeting with review but not after the meeting.

It was noted that the red line (boundary) was not accurate relative to the first barrier, especially the lower coast of Lake Michigan and the Upper Peninsula. One of the participants has a barrier layer available that could potentially be used to help clarify the red line. An author noted that the reason this red line was used relates to the impact side of the risk assessment as the risk assessment does not consider all the inland lakes. The author commented that in the section on the likelihood of arrival through physical connections, species above the red line but outside of the basin were considered and is delineated from across the watershed boundaries from the extended Great Lake basin. Although some parts of the basin are not included within the red line of the assessment, most Grass Carp are not being introduced from a physical connection in those areas. This conversation was put on hold until after discussing the Spread Section in the working paper.

A participant asked the authors to provide a baseline for which arrival will occur to be used to evaluate the probability of this happening. The authors noted that 2014 is the baseline year for the risk assessment and that this is provided in the working draft. Also noted, was that the lake-to-lake connection wasn’t mentioned in the working paper but it was clarified that this is addressed in the Spread Section.

Another participant said that it was also important to include triploid failure rate and how many are fertile (contamination). Available information will be stated in the document more clearly and authors will check to see if failure rate of induction is known. Information provided during the peer-review on eDNA detections in Chicago ponds and other areas will be included.

A participant thought that a paragraph should be added in the arrival section discussing that there are a lot of regulations and enforcement of these regulations are extremely important to reduce the likelihood of arrival. One of the authors thought that was fine as long as proper wording was used. Another author thought that they needed to be careful when saying ‘important to’ because that can be considered a suggestion and is not within the scope of the risk assessment.

Human-mediated Release

Presenter: John Dettmers, Fishery Management Program Director, GLFC, Ann Arbor, Michigan

Summary

The presenter gave an overview of human-mediated release. There are three types of potential human-mediated release; baitfish activities, use in aquatic macrophyte control in waterbodies (stocking; strong demand; legal and illegal), and illegal release for sport opportunities or spiritual/ethical reasons. There is a potential entry route for small Grass Carp into the Great Lakes by bait. Bait includes a variety of small fishes. Most states prohibit the use of carp as baitfish. Michigan and Ontario specifically prohibit the use of Asian Carp as bait. There are knowledge gaps in terms of the degree to which regulations are followed, which bait originates from areas with Grass Carp populations, and uncertainty regarding angler use and movement patterns. Various bait retailer surveys have found no eDNA or live Grass Carp within the Great Lakes basin. Live bait transport occurs within the Great Lakes basin in Canada (Drake 2011). Grass Carp are stocked in private waters for macrophyte control, recreational opportunities and may be involved in the live fish food market. Regulations among the Great Lake states and provinces are varied and further complicated by differing regulations for triploid and diploid Grass Carp.

Discussion

A participant suggested the need to ensure accuracy about the laws for each state/province and to clarify whether Grass Carp are prohibited in Quebec. It was confirmed that they are prohibited in Quebec. It was suggested that clarification of whether the laws apply to live and dead fish would be useful and if this is available to include it in Table 5 in Cudmore et al. (2017).

A participant asked how reliable eDNA reports are and this should be clarified in the working paper. Another meeting participant commented that the issue of stocking outside the Great Lakes basin should be sorted out. A statement on Canada is needed that clarifies that there is legislation but no regulation to enforce. Illegal trade has risks but these can’t be quantified.

Laker Ballast

Presenter: Nick Mandrak, University of Toronto Scarborough, Ontario (formerly Research Scientist, DFO, Burlington, Ontario)

Summary

Based on modelling efforts estimating the probability of spread and establishment of aquatic invasive species as a result of domestic ballast-water movement, the movement of Grass Carp from ports in the St. Lawrence River into the Great Lakes basin through laker ballast is likely negligible. The model output for the low invasiveness scenario in Drake et al. (2015) was used assuming that Grass Carp would most likely be associated with a low uptake probability due to habitat use by juveniles and low establishment probability at hypothetical transported population sizes. The likelihood of arrival through this vector was ranked very unlikely with moderate certainty for both triploid and diploid Grass Carp.

Discussion

The group agreed that the probability is low but one participant asked if there was any mathematical basis for these probability values provided in the Drake et al. (2015) report. It was acknowledged that species-specific values for Grass Carp are not known and this should be identified as a knowledge gap in the document. There was a discussion about the choice of using a low probability scenario for Grass Carp in ballast and that the rationale for choosing this invasiveness scenario reflected that commercial ports are not located in nursery habitat. This assumption suggested that uptake of juveniles would be unlikely. However, it was also noted that if Grass Carp reproduction is based on spawning river versus nursery habitat then the number of potential ports would increase. It is unknown if Grass Carp return to the same river to spawn. It needs to be clearly stated that it is assumed that Grass Carp are more likely to spawn in the rivers with nursery habitat than based on suitable spawning river alone. This will make a difference depending on where Montreal falls out on the curve. This will be added to the document clearly stating that adult Grass Carp are more likely to spawn in rivers with good nursery areas and that those nursery areas will house more juveniles than port areas.

A participant asked if there were any other aquatic invasive species introduced through this pathway. One example is Fourspine Stickleback (*Apeltes quadracus*), which is a small, pelagic species that is ideal for transport via ballast, unlike adult Grass Carp. Consensus was reached that the low invasiveness scenario is reasonable, but the assumptions need to be clearly outlined. One suggestion was to add arrows below St. Lawrence ports on Figures 17 and 18 of the risk assessment (Cudmore et al. 2017). Also, it was suggested to make a note about what the difference would be if the invasiveness scenario was increased to moderate (Figure 18 in Cudmore et al. 2017) and how the probability would change if done over longer periods of time. This was subsequently addressed during the meeting and it was noted that further analysis indicated that the same conclusions would still be reached.

There was a discussion around the potential for diploids contaminating triploid shipments especially with third-party haulers. This was identified as a major problem in the Mississippi Interstate Cooperative Resource Association (MICRA) report (2015). Operators with holding facilities are at greater risk of contamination. The availability of diploids in the supply chain can definitely lead to diploids in the triploid supply. Most Standard Operating Procedures are only oral. These details need to be clearly written in the working paper.

Review of Arrival Rankings

Presenter: Nick Mandrak, University of Toronto Scarborough, Ontario (formerly Research Scientist, DFO, Burlington, Ontario)

The group discussed the rankings table by ploidy and by lake (Table 7 in Cudmore et al. 2017).

Review of Arrival Rankings for Triploids

Lake Michigan

The group discussed Table 7a (Lake Michigan) in Cudmore et al. (2017). It should be clear that the ranks come from the authors' assessment of the information reviewed for arrival. A participant wondered what the values at the bottom of Table 7 (rank column) represent in the Overall Arrival row. It was clarified that these are the ranks representing the highest rank of the three elements (physical connections, laker ballast, and overall human-mediated release) in the table along with the associated level of certainty of data. If a tied rank occurs between these elements for a given year, then the lowest level of certainty associated with the tied ranks is retained. The idea of 'VL' (very likely) and 'H' (high) certainty for physical connections applies to above the barrier, because fish are present there. It is important to note the basin boundary is right at the lake and, therefore, the physical connection as a source is very likely because there are many Grass Carp above the barriers. 'Stocking' in private lakes and ponds, and not in the Great Lakes proper, needs to be clarified in the working document. Participants thought there needs to be some consistency when referring to 'L' (likely) and 'VL' (very likely).

Lake Superior

No Discussion.

Lake Huron

Need to clearly differentiate between arrival and spread in the document.

Lake Erie

There were some suggestions made for this section but no decision was made on any changes to the document. Suggestions included replacing letter abbreviations with numbers because the abbreviations represent likelihoods, that there should be two different spatial units (lakes and basins) or a clarification of spatial units. It was also suggested that the document should include levels of monitoring effort and relate it to ploidy testing.

Lake Ontario

Mention that the rank for arrival in Lake Ontario also considered land use area.

Review of Arrival Rankings for Diploids

The group discussed Table 7b (the likelihood of arrival rankings and certainties from Cudmore et al. 2017).

Lake Michigan

No discussion.

Lake Superior

A participant asked why for 10, 20, and 50 years the rank didn't stay very unlikely (VU). It was explained that the rationale was, that over time, if there are higher populations below, there is a higher likelihood for them to move up into the area of interest.

Lake Huron

No discussion.

Lake Erie

A participant thought the ratings for Lake Erie seemed inconsistent as there was no very likely (VL) anywhere in the rank column. It was noted that, while it is known that Grass Carp are reproducing in Lake Erie, it is uncertain where they came from (arrival or spread). But it was noted that there are two very likely rankings (Lake Michigan and Lake Erie), but they do not necessarily mean that the fish arrived the same way. Another participant suggested replacing VL with 'Arrived' in overall row. This conversation will continue after the formula for combining scores is discussed. The group agreed that the boundary for the risk assessment needs to be explicitly stated and that the red line needs to be clearly delineated in the text.

Lake Ontario

No discussion.

SURVIVAL

Presenter: Duane Chapman, USGS, Columbia Environmental Research Center, Columbia, Missouri.

Summary

The likelihood of survival is defined as individuals that do not die upon arrival and adults live through the winter months in the Great Lake basin. The differences between triploids and diploids are unknown and they are, therefore, treated together (associated rankings are the same). There is a strong match to environmental characteristics for the entire Great Lakes basin. Juvenile Grass Carp feed on both plants and animal food while adults feed primarily on macrophytes. Adults prefer submerged plants with soft leaves; often consuming the most preferred species first until they become scarce. Survival of adults in the Great Lakes is dependent, in part, on the presence of available plants for consumption. It is unlikely that there is insufficient food for Grass Carp to survive, including younger individuals that do not exclusively feed on macrophytes. Based on occurrence data and bioenergetics modelling, Grass Carp can overwinter in the basin. Predation pressure is not likely to be a significant factor except for smaller-sized Grass Carp. There are no known significant diseases or pathogens present in the Great Lake basin that would prevent the survival of Grass Carp.

Discussion

A participant asked if emergent vegetation was included in the evaluation. Emergent species would show up to some degree in satellite imagery, and wetland research would have shown that as well. Another participant asked if Grass Carp inhabit open-water habitats where *Cladophora* is likely to be found. Grass Carp inhabit primarily shallow water and wetlands. Wetlands are an important element of survival, except for *Cladophora* in areas outside of wetland areas, but that is not traditional food for Grass Carp. The authors will clarify the modelling technique and different criteria for data in the working paper. It was noted that the approach in Wittmann et al. (2016) was not an improved approach, just different methods.

Need to specify this is for juvenile and adult and not young-of-year (YOY); this is addressed in the Establishment section of the working paper.

Review of Survival Rankings

No discussion.

ESTABLISHMENT

Presenter: Nick Mandrak, University of Toronto Scarborough, Ontario (formerly Research Scientist, DFO, Burlington, Ontario)

Summary

The presenter defined the likelihood of establishment as the ability to reproduce, leading to a self-sustaining population. Given functional sterility of triploid Grass Carp, likelihood of their establishment is ranked very unlikely with very high certainty in all lake basins. Suitable spawning and nursery habitat are present in each Great Lake. Positive population growth will occur in the Great Lakes (based on two independent models: stage-structured life history model and a stock-recruitment model). According to the life-history model, establishment requires few individuals if older age classes are introduced. There are no known impediments to egg, larval, and YOY survival, but establishment is less probable in northern latitudes given overwinter survival of YOY is expected to be limited in Lake Superior and northern Lake Michigan.

Discussion

Spawning

A participant said that there are two knowledge gaps related to survival of eggs in lake currents. Spawning in lake currents has never been found in China, but that does not mean it cannot occur in the Great Lakes. A participant suggested, for increased clarity and understanding, including additional narrative surrounding the establishment model (Jones et al. 2017). A participant added that Grass Carp early life-history modelling (overwinter survival) provides useful information about the potential northern limit of reproduction. It could be useful to include this information in combination with niche models to project potential reproductive success in the northern Great Lakes. A participant noted that the working paper says that there are significant wetlands but the map appears to show few wetlands. This might need to be highlighted in the appropriate figures and text in Cudmore et al. (2017) that this is a scale issue with the map. Another participant asked if there were very few tributaries that are suitable for spawning in the U.S. but it was noted that this is not necessarily true; rather very few tributaries have been assessed. This needs to be clarified in the document. A participant thought that dam locations should be included in the working paper. There might be additional information to get a better understanding of dam locations or it may be a knowledge gap. A participant pointed out that there are two knowledge gaps; cue to spawn and lentic spawning. The presenter clarified that the success of spawning and recruitment depends on time, temperature, and place. A meeting participant commented that on the U.S. side, USGS Wisconsin Water Science Center, Great Lakes Science Center, Center for Integrated Data Analytics, and the Michigan Water Science Center office have a flow extrapolation model (Analysis of Flows in Networks of Channels; AFINCH) for all the ungauged tributaries so one could get monthly statistical flows. The ungauged flow estimates provide information to assess tributary stream flow within the basin. However, temperature may not be readily available so would have to make assumptions and assume/note that spring warming is not particularly variable as it is tied to air temperatures. Some northern streams or those with significant groundwater input may not be warm enough. So there may be additional information available but this may be a knowledge gap for now. They also commented that data are missing in the working paper for spawning tributary suitability and frequency. This should be added as a knowledge gap in the working paper.

Include the evidence for the potential of establishment to occur in the Great Lakes. Possibly spell out some of the conditions for establishment in brackets. The Sandusky River recruits might be addressed here.

Estimating spawning population needed for establishment

A participant asked how variability might play out from the model and suggested including a possibility of range of events in the text of the document (for example, taking the range of possible R_o values to qualify the R_o average value). Another participant wondered if this was the first time this model had been used for Grass Carp. It was noted that this is the first model of this nature for Grass Carp; while it is one of the most-studied species, it is most often in terms of aquaculture and most information is in foreign languages. There is a paucity of data for North America so such modelling has not been undertaken for Grass Carp before.

Stock recruitment

No discussion.

Overwinter survival

A participant asked if the model used was just for Grass Carp. It was clarified that this approach was developed for Smallmouth Bass (*Micropterus dolomieu*). There was a discussion around using thermal data and relating it to the northern part of the distribution in the native range. The challenge would then be to complete daily water temperature series or use niche models to compare outcomes. The conclusion that can be made right now is that there is uncertainty shown in the latitude, which is reflected in the matrix. The group agreed that this needs to be discussed further. A participant commented that overwinter survival always depends on who else is there (predators and alternate prey) and that in their own work they had found significant interaction in terms of predator and most abundant prey but that this did not add enough to explain any biological significance but, this also depends on abiotic and biotic conditions. However, these, on top of overwinter survival, are probably not strong enough to knock out a year class but would contribute to the variation in year class strength. This needs to be noted in the document.

Review of Establishment Rankings

A participant asked why they were not already established in Lake Erie. This is because there is evidence of reproduction but we do not know if they are established or a one-off spawning event. A participant commented that Lake Huron and maybe Lake Ontario rankings seem a little low at longer time scales. Another participant commented that the analysis shows differences within the lake, but what about at the lake as a whole. One of the authors replied that the survival over lake as a whole is reflected in the ranking system. There was a discussion about overwinter survival. There are two pieces of research provided for overwinter survival; overwinter survival of juveniles in the first generation of YOY and the potential for these individuals to produce successful cohorts in subsequent years. They vary and the probability tends to increase with time. The rankings need to be clarified. A participant asked what the authors meant by self-sustaining populations. Self-sustaining populations are self-spawning populations.

There was a discussion about the values in the formula for probability of introduction. A participant asked if they are independent values or linked. If linked, then the authors will need to provide another analysis. The group agreed that they need to be considered separately. The group also agreed that a new definition of establishment is needed and it will be clear that the likelihood of establishment has been derived independently.

A participant asked about time steps and why ranks were consistent after 5 years. It is important at the first time step of 5 years because of the definition of establishment but beyond 10 years, time steps do not matter as the likelihood of establishment will no longer change. In the modelling sense, these will all be the same thing, no time involved. Another participant suggested considering data only in this section and keeping a time stamp, and then it will be mostly consistent across time. A participant said that it was important at the first time step because of the definition of establishment, (with age at maturity at 5 years), but beyond that it won’t change unless there is a mechanism that drives change. The group agreed to avoid the time step after 5 years altogether as this does not agree with the analysis.

A participant said that the Table 11 (Cudmore et al. 2017) analysis is good but needs to be clarified. The rankings in Table 11 for Lake Huron and Lake Ontario jump around because the further you go, the more uncertain it is. A participant said it was important to be very clear in the table caption how the group defines establishment. Overall, it was decided that the authors will revisit these rankings considering the information and discussion and revise them accordingly.

SPREAD

Presenter: Nick Mandrak, University of Toronto Scarborough, Ontario (formerly Research Scientist, DFO, Burlington, Ontario)

Summary

The presenter defined the likelihood of spread as movement of individuals or expanding populations into new areas within the basin; specifically between lakes (does not include initial spread into the basin). Based on history of movement of fishes in the Great Lakes, there is evidence that fish can move from lake to lake (upstream and downstream). Studies of tagged Grass Carp and spread modelling (Currie et al. 2017) found significant movement between basins. Movement is influenced by habitat and food availability. Movement to a second lake basin can occur within 5–10 years. Telemetry studies indicate fish can pass freely across Erie, Huron and Michigan, and recent studies suggest movement between Huron and Superior is possible, while movement between Erie and Ontario is possible but less likely. Inter-lake ballast water transfer and bait are unlikely vectors of spread.

Discussion

A participant asked if the spread model includes reproduction, and if it does not, then with an increasing number of individuals spread could be even greater. It was noted that the model does not incorporate reproduction, so, yes; with more individuals more movement would be expected. Need to indicate that triploids and diploids are treated the same in rankings for individual movement and that spread is inter-lake.

Laker Ballast

A participant commented that salties are ships coming from salt water to the lakes, when they enter the lake they become functionally active lakers. Also, need to clarify why probability of uptake in ballast is considered to be low from ballast report.

Human-mediated Dispersal

A question was asked about whether Grass Carp would exist in nearshore waters where harvesting may occur. There was a conversation around the baitfish industry and its role in spread; it was downgraded in the risk assessment, although baitfish harvest numbers are significant. There are regulations on the U.S. side, but there isn't much information there so more of a knowledge gap. The probability of spread via baitfish activity would change based on population strength of Grass Carp in the basin. For example, substantial population sizes would increase the likelihood of bycatch and subsequent transfer throughout the supply chain.

Review of Spread Rankings

A participant asked if the inter-lake ballast transfer was conditional on the fish actually being there. It was noted, that Grass Carp would have to be present in the port for uptake into ballast. It was suggested that there is little information as to what is happening in the Erie Canal so in the ranking table the certainty rank should be much less, not the likelihood rank. Also, for bait, it is that the data are more uncertain for spread by this vector not that the likelihood is lower. YOY bycatch from harvest in the Great Lakes is frequently found and is higher than may be expected. Baitfish and laker ballast water were down-weighted in the ranking assessment of arrival. Nathan et al. (2014) has a list of all bait regulations in the Great Lakes and may be useful to include as a reference in arrival tables. Another participant asked about the frequency of harvesting in wetlands at the Great Lakes river mouths.

Add some clarification on movement. Some Grass Carp will move 200 miles in one week so spread could happen a lot faster than was modelled while others hardly move at all. Movement has been observed in some systems and is highly variable; more work is needed to understand Grass Carp movement but the spread model gives a good indication of what may be expected to occur. A participant noted that, in Lake Superior, native Lake Trout rarely moved out of the lake but moved far and fast from spawning grounds. Grass Carp seem to have individual movement patterns different from one another. More work is needed on this topic to draw a conclusion. A participant suggested that the definition of spread should be revisited and clarified for consistency.

There was a discussion about Table 12 (Cudmore et al. 2017). A participant asked if the group expected populations to increase and if that increases the spread. A meeting participant said yes and also that the spread would occur primarily from Lake Erie. Triploid Grass Carp are thought to not survive long enough to get to lakes Michigan, Superior, or Ontario. They have a 'self-destruct' mechanism so do not expect spread for triploids to be as great. One of the authors defined spread as movement from one basin to another within the Great Lakes. Another participant responded that the definition of spread is movement between lake basins not just between lakes. It was suggested that the authors may want to change the heading to better describe what the table was saying. Possibly starting the sentence with, 'assuming that…' instead of saying that it is there for clarification, would be useful. Another suggestion was to change it to 'inter-lake spread'. This needs to be clarified in the document and also needs to be consistent.

A meeting participant asked what the mechanism was for change over time. Population density changes over time, which is a cause and source of spread. Ranks over time very closely track the movement of the spread model because of the paucity of data. Make sure this is clear in the document. In the text, clarify that there are two starting points for the model: Maumee River and the CAWS. In near terms, those starting points are important. In long term, they may have other points and sources but the uncertainty changes over time.

ECOLOGICAL CONSEQUENCES

Presenter: John Dettmers, Fishery Management Program Director, GLFC, Ann Arbor, Michigan

Summary

The likelihood of ecological consequences considered for any part of a lake basin included consideration of the impact on vegetation, birds and fishes, as well as the potential to bring in any new diseases or pathogens and resulted in the following rankings:

- Triploid: negligible consequences, very high certainty across all years.
- Diploid: consequences increase over time; by 50 years, negligible (Lake Superior) to moderate (Lake Erie); moderate to low certainty.

However, after much discussion about the nature and extent of likely ecological consequences, it was decided that the authors would re-assess the rankings for this section, include information on the potential influence on abiotic and other biotic factors and propose a new structured process for determining the ranks of ecological consequences for each of the lakes. Following a discussion among the authors of the working paper, a process to generate a standardized ranking method was presented to the participants that involved creating consequence thresholds using recommended Grass Carp stocking rates for macrophyte control, modelled population growth (not including density-dependent effects), and submerged aquatic vegetation area for each lake.

Discussion

A question was asked about the consequence thresholds and whether they are based only on vegetation. The group of authors indicated that the vegetation was a surrogate for other ecosystem changes. A meeting participant thought that the authors should consider adding a comment about this being native vegetation and that it is possible that non-native vegetation would replace native vegetation. There was a good discussion about impacts to rare and imperiled species, which require wetland habitat. There are focal species in the policy arena, but the authors address impacts to imperiled fishes in the manner done so for common fishes so as not to up-weight impacts to imperiled species. The socio-economic analysis will go further in depth about particular species of societal interest (e.g., imperiled or game fishes). Some of this information may also be included in the supporting documents of the risk assessment. Another participant asked if water quality should be considered and that the issue of bank erosion is also not mentioned in the document. The authors will include information on bank erosion and its effects on water clarity/quality to the introductory paragraph of this section. A participant suggested being more specific about invertebrates and including information on phytoplankton and nutrients from Wittmann et al. (2014) meta-analysis. Authors agree it will be explained more clearly in document. Peer reviewers appreciate the rationale the authors have arrived at for rating ecological consequences.

Review of Ecological Consequence Ratings

Review of Ecological Consequence Rating for Triploids

Authors discussed impacts of triploids in Lake Erie. The difference was an expectation that diploid levels would increase, whereas, triploids would not change over time. The authors did not look at localized congregations of fish, but rather lake-wide abundance. It was suggested that the potential for other biotic interactions affected by Grass Carp should be captured in the document. The indirect effects could be quite significant, but are unknown at this time. A participant asked if the rate of stocking/escapement will continue as it has for the recent past.

For ratings, it is considered to remain the same and takes into consideration their finite lifespan and that they have been in the Great Lakes for 35 years already and have not seen detectable effects of their presence. The group agreed to reduce the certainty level from very high to moderate because there isn't extensive information on this.

Review of Ecological Consequence Rating for Diploids

A participant asked how many fish the authors think are currently in the Great Lakes. The authors are unsure and it was proposed to lower the certainty from very high to moderate or low. The group agreed. A participant suggested that the authors need to go into more detail about the scale of impacts and what that exactly means (lake versus local wetland scale). When first talking about the ranks, it was analysed at a smaller scale than what the authors were asked to do. Looking at a lake-wide scale magnifies the issues, because a 50% reduction in wetlands would have a great impact. One participant said she would like to see more text in the document about the scale, reminding readers about what scale the information they are getting is working on.

Climate change was not taken into account with these rankings. This will be noted in the document. Also, it will be noted that impacts in the wild are not well known and there is not enough information to assess potential for facilitated invasions of other species, such as those that could exploit a loss of wetlands or pathogens that may be associated with Grass Carp.

The group agreed that the ranking in Table 15 (Cudmore et al. 2017) is reasonable and seems to work. Results are, on average, across each lake basin, and local effects could be lesser or greater. Assumptions will be included in the text. A participant suggested that the term 'certainty' will be replaced with 'certainty of data' to make it clear to the public what is being referred to. The group decided to make that change. The authors will define each component in the document. Fifty-year diploid ranks went from low to extreme. Ecological consequence ratings were based on the modelling, which used population growth and recommended stocking rates for successful vegetation control in ponds. The consensus was that this was a good framework that was logical and defensible and based on the highest quality information available to project potential consequences.

OVERALL RISK

Presenter: Nick Mandrak, University of Toronto Scarborough, Ontario (formerly Research Scientist, DFO, Burlington, Ontario)

Summary

In determining the maximum rank of overall arrival and spread, the certainty associated with the highest rank was used or if tied ranks occurred, the lowest certainty associated with the tied rank was used (Table 13 in Cudmore et al. 2017). The formula for introduction was modified to accommodate the issue of triploid Grass Carp not being able to establish and this new formula is termed the probability of occurrence for triploid Grass Carp:

P (occurrence) = Min [(Max (Arrival, Spread)), Survival]

For probability of occurrence and introduction, the certainty associated with the lowest ranked element was retained, or if tied ranks occurred, the lowest certainty of that tied rank was used.

Discussion

A participant asked for clarification as to whether arrival and spread are talking about current state. The document needs to be clear that assumptions are based on current state. There was a conversation around the colours in the overall risk graphs (Figures 34 and 35 in Cudmore et al. 2017) about whether the gradients need to be more vertical to avoid the danger of people misreading the graph. The easiest solution would be to adjust the equation. Another participant noted that the graphs do not account for when the probability of introduction is unlikely but the magnitude of consequence is extreme. A knowledge gap exists in how the relationship/quantification does not allow for this to happen. There may be areas that would be greatly impacted that we would want to protect, even though the probability of introduction is low. This should be noted as a knowledge gap. After further discussion, authors proposed to change the y-axis title for triploid Grass Carp to “probability of occurrence” based on the removal of likelihood of establishment from the formula. This then allows for the relationship to have some overall risk attached to it even if they are unable to establish. The group agreed and these changes were made to the calculation and presentation of overall risk.

Review of Overall Risk

The measure of overall risk combines the probability of occurrence or introduction with the magnitude of ecological consequences.

Review of Overall Risk for Triploids

Within 5, 10, 20 and 50 years:

- P (occur.): increases over time for lakes Superior, Huron and Ontario; and is very likely for all years for lakes Michigan and Erie noting that arrival is considered to have occurred in these two lakes.
- Magnitude of ecological consequences: negligible consequences (moderate certainty): all lakes
  - No change over time:
    - Functionally sterile
    - No expectation of influx of triploid Grass Carp into Great Lakes basin

Review of Overall Risk for Diploids

- The probability of introduction increases over time for all lakes and is higher for lakes Michigan, Huron, and Erie compared to Superior and Ontario.
- Magnitude of ecological consequences is extreme by 50 years for all lakes except for Lake Superior which remains negligible.
- Overall risk is highest for lakes Michigan, Huron and Erie.
- Uncertainty in overall risk matrix is mainly associated with magnitude of consequences rankings (low certainty of data).

CONSIDERATIONS (SCIENCE ADVICE/RECOMMENDATIONS REVIEW)

Summary

- Specific management questions were compiled from two workshops held in June and December of 2014 for managers and decision makers around the Great Lakes from both sides of the border.
- These questions represent the key information managers and decision makers would like addressed, as much as possible, from this risk assessment.

- Information stemming from this risk assessment applicable to these questions will be highlighted in the “Targeted Management Questions” section of the Science Advisory Report; not as a prescription for management but general science advice.
- Revision of the risk assessment document will reflect the discussions and consensus reached during the peer-review meeting.
- Knowledge gaps will be identified in the Proceedings Report, in the “Considerations” section of the risk assessment document, and in the “Sources of Uncertainty” section of the Science Advisory Report.
- The confidential nature of all the documents was emphasized to participants of the peer-review meeting. The documents are not final until they are publicly available.

Knowledge Gaps

The group agreed to update the draft list to provide the following knowledge gaps and key areas of uncertainty based on the discussion at the peer-review meeting:

- Different life stages of Grass Carp were not assessed specifically for each step in the assessment. Information and knowledge on younger life stages remains a knowledge gap.
- Given lack of measurement of total monitoring effort, there is a knowledge gap as to what is actually the current status of Grass Carp.
- The extent to which biological and behavioural differences exist between triploid and diploid Grass Carp (e.g., mortality, growth, spawning behaviour, movement).
- Extent of trade of diploid and triploid Grass Carp.
- There is little knowledge on the extent of illegal trade.
- There is little knowledge on the possibility of intentional stocking for nefarious reasons.
- Information is lacking on the movement patterns of baitfish and the potential for bycatch of Grass Carp in baitfish harvest, especially on the U.S. side of the basin.
- Specific information on the potential invasiveness of Grass Carp was not available for use in the ballast-water movement model; values used represent generic scenarios that can be applied to reflect the establishment characteristics of a given species (results provide a sensitivity analysis of different input parameters involving uptake in ballast and probabilities of establishment).
- It is unknown whether Grass Carp would occur in areas of *Cladophora* abundance.
- There is a lack of data on the frequency of suitable spawning conditions in the Great Lakes basin.
- Cues to spawn are variable and represent a knowledge gap.
- Reproductive behavior is largely unknown as well as how individuals find each other for spawning.
- The potential for lentic spawning (i.e., where eggs fall to substrate) is a knowledge gap that needs to be further investigated as just because it has not been observed in native range, does not mean it can’t happen in the introduced range.

- The relationship between overwinter survival (L_{crit} and proportion survival) to thermal survival from environmental niche models is unknown.
- The effect of predation and competition and resource limitation on overwinter survival is not known.
- Whether reproductive movements would enhance or limit spread because of the need to remain close to spawning rivers or due to aggregation of fish because of reproductive behaviour or response to reproductive pheromones is a knowledge gap.
- There is a lack of knowledge regarding individual movements given there is some variability with individual fish.
- No published studies have been undertaken to directly determine the extent of fish movement through the New York Canal System.
- No published studies have been undertaken to directly determine the extent of fish movement through the Trent-Severn Waterway.
- Understanding movement of fishes from Lake Erie to Lake Ontario through the Niagara River, by surviving the descent over Niagara Falls.
- The depth limits of Grass Carp in lake systems.
- In general, there is a lack of information on ecological impacts in the wild.
- A comparison of macrophyte species preferences of Grass Carp to macrophyte species requirements of birds.
- Species composition of macrophytes within submerged aquatic vegetation locations within the Great Lakes basin is not known.
- The potential influence of Grass Carp on Zebra Mussel is unknown.
- Further targeted research of the ecological changes associated with Grass Carp is needed, particularly with natural populations in temperate climates and lake systems.
- There is no information available to predict facilitated invasions of other species by Grass Carp and biotic interactions.
- Lack understanding of lake-specific potential population biology (age to reproduction, spawning temperature patterns etc.) to inform population growth models for each lake.

Many of these knowledge gaps result in low certainty rankings due to the lack of data and the quality of data that are available. These key areas of uncertainty are:

- The extent of human-mediated release (i.e., bait, stocking and trade) into all lakes for both triploid and diploid Grass Carp represents a key area of uncertainty where more information and data would strengthen the advice surrounding arrival from this potential entry route.
- The likelihood of establishment of diploid Grass Carp over time for lakes Superior, Huron and Ontario.
- The likelihood of spread of diploid Grass Carp to lakes over time.
- Magnitude of ecological consequences ratings for diploid Grass Carp in all lakes were given low certainty; further targeted research of the ecological changes associated with Grass Carp is needed, particularly with natural populations in temperate climates and lake systems.

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APPENDIX 1: TERMS OF REFERENCE

Binational ecological risk assessment for Grass Carp in the Great Lakes basin

Regional Peer Review – Central and Arctic Region

June 1-3, 2015
Cleveland, Ohio

Chairperson: Gilles Olivier

Context

Grass Carp (*Ctenopharyngodon idella*) are currently threatening the Great Lakes as evidence of reproduction has been found in the American waters of the Lake Erie basin. Canadian and American agencies share a similar goal to prevent the establishment, spread and consequences of Grass Carp into the Great Lakes. Previously published information, compiled data and new research will be used to assess the risk of Grass Carp to the Great Lakes. The scientifically defensible results will provide useful management and decision-making advice for both sides of the border focusing on all aspects of the probability of introduction (likelihood of arrival, survival, establishment, and spread), and the magnitude of the ecological consequences of Grass Carp in the Great Lakes basin. Ecological risk assessment experts from Fisheries and Oceans Canada (DFO), Great Lakes Fishery Commission, the U.S. Geological Survey, and the U.S. Fish and Wildlife Service will use the best available research results to draft an ecological risk assessment following guidelines provided by DFO's Centre of Expertise for Aquatic Risk Assessment (CEARA). These results will be peer-reviewed by experts on risk assessment, freshwater invasive fishes, Great Lakes wetlands, and ecosystem modelling from both Canada and the United States in order to provide advice on questions asked by managers and decision makers at a previously held scoping meeting (December 2014). The results of the ecological risk assessment will subsequently be used to conduct a separate socio-economic impact analysis. The results of both the ecological risk assessment and the socio-economic impact analysis will form two separate pieces of advice for managers and decision makers to use when determining courses of action regarding prevention, monitoring, early detection, rapid response, management, and control of Grass Carp.

Objectives

The objective of the peer-review meeting is to collect expert advice on the following aspects of the draft risk assessment documents:

- Are components missing from the draft documents?
- Are the determined risk ratings scientifically sound and defensible?
- Are the limitations of the studies clearly outlined?

Expected Publications

- Science Advisory Report
- Proceedings Report
- Research Documents

Participation

- Fisheries and Oceans Canada (DFO) (Ecosystems and Oceans Science)
- Great Lakes Fishery Commission
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- Invited experts on risk assessment, freshwater invasive fishes, Great Lakes wetlands, and ecosystem modelling from both Canada and the United States

APPENDIX 2: PARTICIPANTS

NAME	AFFILIATION
Mike Bradford	DFO, Science
Duane Chapman	U.S. Geological Survey, Columbia Environmental Research Center
Earl Chilton	Texas Parks and Wildlife Department
Greg Conover	U.S. Fish and Wildlife Service
Becky Cudmore	DFO, Science
John Dettmers	Great Lakes Fishery Commission
Andrew Drake	University Toronto Scarborough
Christina Haska	Great Lakes Fishery Commission
Kristen Hebebrand	University of Toledo
Mike Hoff	U.S. Fish and Wildlife Service
Christopher Jerde	University Nevada Reno
Rachel Johnson	University of Toledo
Lisa Jones	DFO, Science
Cynthia Kolar	U.S. Geological Survey, Ecosystems Mission Area
Marten Koops	DFO, Science
Nicholas Mandrak	DFO, Science; University of Toronto Scarborough
Paul Seelbach	U.S. Geological Survey
Gilles Olivier (Chair)	Contractor
Marion Wittmann	University Nevada Reno
Yingming Zhao	Ontario Ministry of Natural Resources and Forestry

APPENDIX 3: AGENDA

Great Lakes Binational Grass Carp Ecological Risk Assessment

Peer-Review Meeting

June 1-3, 2015

June 1, 2015

9:00 a.m.	Welcome and Introduction, Review Terms of Reference, Agenda (Olivier)
9:15 a.m.	Review of Canadian Science Advisory Process (CSAS) (Olivier)
9:30 a.m.	Risk Assessment Introduction (Cudmore)
9:45 a.m.	Introduction to the Binational Risk Assessment for Grass Carp in the Great Lakes Basin (Cudmore)
10:00 a.m.	Arrival
10:30 a.m.	*Health Break*
11:00 a.m.	Arrival Continued
12:00 p.m.	*Lunch*
1:15 p.m.	Survival
3:00 p.m.	*Health Break*
3:15 p.m.	Survival Continued
4:30 p.m.	End Day 1

June 2, 2015

8:30 a.m.	Establishment
10:00 a.m.	*Health Break*
10:30 a.m.	Establishment continued
11:00 a.m.	Spread
12:00 p.m.	*Lunch*
1:15 p.m.	Spread continued
2:00 p.m.	Ecological Consequences
3:00 p.m.	*Health Break*
3:15 p.m.	Ecological Consequences continued
4:30 p.m.	End Day 2

June 3, 2015

8:30 a.m.	Ecological Consequences continued (if necessary)
9:30 a.m.	Overall Risk
10:00 a.m.	*Health Break*

10:15 a.m.	Overall Risk Continued
10:30 a.m.	Science Advice/recommendations review
12:00 p.m.	*Lunch*
1:15 p.m.	Science Advice/recommendations Review Continued
3:00 p.m.	*Health Break*
3:15 p.m.	Knowledge gaps and Next Steps
4:30 p.m.	Meeting Adjourned

APPENDIX 4: INDIVIDUAL AUTHOR RISK TABLES

ARRIVAL RISK TABLES

*Table 1. Rank of overall arrival for **Lake Superior** for (A) triploid, and (B) diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes. HM = human mediated dispersal.*

A) Lake Superior TRIPLOID

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Physical Connections	5,10,20=VU; 50=Lo	H	VU	5,20,50=VH; 10=H	VU	5,10,20=H; 50=M	VU	H	VU	H	VU	5=VH; 10,20,50=H	VU	M
Laker Ballast							VU	H	VU	H	VU	H	VU	M
Bait	VU	H	VU	VH	VU	5,10=H; 20,50=M	VU	H	VU	H	VU	5=VH; 10,20,50=H	VU	M
Stocking	VU	H	M	Lo	VU	5,10,20=H; 50=M	VU	M	VU	M	VU	5,10,20=H; 50=M	VU	M
Trade	5,10=VU; 20,50=Lo	M	VU	5,20,50=M; 10=H	VU	5=H; 10,20=M; 50=Lo	VU	M	VU	M	VU	5,20=H; 10,50=M	VU	M
Overall HM	5,10=VU; 20,50=Lo	M	M	5,20,50=M; 10=Lo	VU	5=H; 10,20,50=M	VU	M	VU	M	VU	5,20=H; 10,50=M	VU	M
Overall Arrival	5,10=VU; 20,50=Lo	M	M	5,20,50=M; 10=Lo	VU	5=H; 10,20,50=M	VU	M	VU	M	VU	5,20=H; 10,50=M	VU	M

B) Lake Superior DIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Physical Connections	5,10,20=Lo 50=M	M	VU	H	5,10,20=VU; 50=Lo	5,10,20=M; 50=Lo	5,10,20=VU; 50=Lo	5,10,20=H; 50=Lo	VU	H	VU	5=VH; 10,20,50=H	VU	M
Laker Ballast							VU	H	VU	H	VU	H	VU	M
Bait	VU	H	VU	5,20,50=M; 10=H	Lo	M	VU	M	VU	M	VU	M	VU	M
Stocking	VU	H	M	5,50=M; 10,20=Lo	VU	M	5,10,20=VU; 50=Lo	M	VU	M	VU	M	VU	M
Trade	VU	M	VU	5, 50=H; 10,20=Lo	Lo	5,10,20=M; 50=Lo	VU	M	VU	M	5,20,50=VU; 10=Lo	M	VU	M
Overall HM	VU	M	M	5,10,50=M; 20=Lo	5,10,50=Lo; 20=VU	M	5,10,20=VU; 50=M	5,10,20=M; 50=H	VU	M	VU	M	VU	M
Overall Arrival	5,10,20=Lo 50=M	M	M	5,20,50=M; 10=Lo	5,10,50=Lo; 20=VU	M	5,10,20=VU; 50=Lo	5,10,20=M; 50=VLi	VU	M	VU	M	VU	M

Table 2. Rank of overall arrival for ***Lake Michigan*** *for (A) triploid, and (B) diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

A) Lake Michigan TRIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Physical Connections	VLi	VH	VLi	H	5,10=H; 20,50=M	5,10=H; 20,50=M	VLi	VH	VLi	H	VLi	H	VLi	VH
Laker Ballast							VU	H	VU	H	VU	M	VU	M
Bait	VU	M	Lo	5,20,50=H; 10=M	VU	M	VU	H	Lo	M	5,10,50=VU; 20=Lo	M	5=L; 10=M; 20,50=H	M
Stocking	M	M	5,20=H; 10,50=VLi	M	Lo	M	H	M	M	M	Lo	M	H	M
Trade	Lo	M	VU	M	5,20,50=VU; 10=Lo	M	Lo	M	Lo	M	Lo	M	Lo	Lo
Overall HM	M	M	5,20=H; 10,50=VLi	M	Lo	M	H	H	M	M	Lo	M	H	M
Overall Arrival	VLi	VH	5,20,50=H; 10=VLi	5,20,50=M; 10=H	5,10=H; 20,50=M	5,20,50=M; 10=H	VLi	VH	VLi	H	VLi	H	VLi	VH

B) Lake Michigan DIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Physical Connections	VLi	VH	5=H; 10,20,50=VLi	H	H	H	VLi	VH	VLi	H	VLi	H	VLi	VH
Laker Ballast							VU	H	VU	H	VU	M	VU	M
Bait	Lo	M	Lo	5,10=M; 20,50=H	5,10,20=Lo; 50=M	M	5,10,20=Lo 50=M	5,10,20=M; 50=Lo	Lo	M	Lo	M	Lo	M
Stocking	M	M	5,10,20=H; 50=VLi	5=H; 10,20,50=M	Lo	M	H	H	M	M	M	M	H	M
Trade	Lo	M	5,10=Lo; 20,50=VU	M	Lo	M	Lo	M	Lo	M	Lo	M	Lo	Lo
Overall HM	M	M	5,10,20=H; 50=VLi	5=H; 10,20,50=M	5,10,20=Lo; 50=M	M	H	H	M	M	M	M	H	M
Overall Arrival	VLi	VH	5=H; 10,20,50 =VLi	5,10,20=H; 50=M	H	H	VLi	VH	VLi	H	VLi	H	VLi	VH

*Table 3. Rank of overall arrival for **Lake Huron** for (A) triploid, and (B) diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

A) Lake Huron TRIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Physical Connections	VU	5,10,20=VH; 50=M	VU	H	5=Lo; 10,20,50=VU	M	VU	VH	VU	M	VU	5,10=VH; 20=H; 50=M	VU	M
Laker Ballast							VU	H	VU	H	VU	H	VU	M
Bait	VU	M	VU	M	5=Lo; 10,20,50=VU	M	VU	H	VU	M	VU	5,10=H; 20,50=M	VU	Lo
Stocking	VU	H	Lo	M	5=Lo; 10,20,50=VU	M	Lo	M	Lo	M	5,10,20=VU; 50=Lo	M	Lo	Lo
Trade	Lo	M	Lo	M	Lo	Lo	Lo	M	Lo	M	Lo	M	VU	Lo
Overall HM	Lo	M	Lo	M	Lo	5=M; 10,20,50=Lo	Lo	M	Lo	M	Lo	M	Lo	Lo
Overall Arrival	Lo	M	Lo	M	Lo	5=M; 10,20,50=Lo	Lo	M	Lo	M	Lo	M	Lo	Lo

B) Lake Huron DIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Physical Connections	5=Lo; 10,20=VU; 50=M	M	VU	H	VU	M	VU	VH	VU	M	VU	5,10=VH; 20=H; 50=M	VU	M
Laker Ballast							VU	H	VU	H	VU	M	VU	M
Bait	5=VU; 10,20,50=Lo	M	VU	5=H; 10,20,50=M	Lo	M	Lo	M	VU	M	Lo	M	VU	Lo
Stocking	VU	H	5=VU; 10,20,50=Lo	M	VU	M	Lo	M	Lo	M	VU	M	Lo	Lo
Trade	VU	M	Lo	M	Lo	M	Lo	M	Lo	M	Lo	M	VU	Lo
Overall HM	5=VU; 10,20,50=Lo	M	Lo	M	Lo	M	Lo	M	Lo	M	Lo	M	Lo	Lo
Overall Arrival	5,10,20=Lo; 50=M	M	Lo	M	Lo	M	Lo	M	Lo	M	Lo	M	Lo	Lo

Table 4. Rank of overall arrival for ***Lake Erie*** *for (A) triploid, and (B) diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

A) Lake Erie TRIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Physical Connections	VLi	VH	Lo	M	VU	M	Lo	H	VLi	M	VLi	VH	VLi	VH
Laker Ballast							VU	H	VU	H	VU	M	VU	M
Bait	VU	M	Lo	M	VU	M	VU	H	Lo	M	5,10=VU; 20,50=Lo	M	5=Lo;10=M; 20,50=H	M
Stocking	5,10,20=M; 50=VU	M	VLi	VH	5,10,20=M; 50=H	5,10,20=M; 50=Lo	VLi	VH	M	M	M	M	H	M
Trade	Lo	M	Lo	H	Lo	Lo	Lo	Lo	Lo	Lo	Lo	M	Lo	Lo
Overall HM	5,10,20=M; 50=Lo	M	VLi	VH	5,10,20=M; 50=H	5,10,20=M; 50=Lo	VLi	VH	M	Lo	Lo	M	H	M
Overall Arrival	VLi	VH	VLi	VH	5,10,20=M; 50=H	5,10,20=M; 50=Lo	VLi	VH	VLi	M	VLi	VH	VLi	VH

B) Lake Erie DIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Physical Connections	VLi	VH	Lo	H	VU	M	5,10,20=Lo; 50=M	H	VLi	M	VLi	VH	VLi	VH
Laker Ballast							VU	H	VU	H	VU	H	VU	M
Bait	H	M	Lo	M	5,10=Lo; 20,50=M	M	5,10=Lo; 20,50=H	M	Lo	M	M	M	5=Lo; 10=M; 20,50=H	M
Stocking	M	M	5,10=Lo; 20,50=M	Lo	VU	M	M	M	M	M	M	M	H	M
Trade	Lo	M	Lo	M	Lo	M	5,10,20=Lo; 50=M	M	Lo	Lo	Lo	M	Lo	Lo
Overall HM	H	M	Lo	M	5,10=Lo; 20,50=M	M	5,10=M; 20,50=H	M	M	M	Lo	M	H	M
Overall Arrival	VLi	VH	Lo	M	5,10=Lo; 20,50=M	M	5,10=M; 20,50=H	M	VLi	M	VLi	VH	VLi	VH

*Table 5. Rank of overall arrival for **Lake Ontario** for (A) triploid, and (B) diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

A) Lake Ontario TRIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Physical Connections	5,10=Lo; 20,50=M	Lo	Lo	M	Lo	M	Lo	Lo	Lo	Lo	Lo	M	Lo	M
Laker Ballast							VU	H	VU	H	VU	H	VU	M
Bait	VU	M	VU	Lo	VU	M	VU	H	Lo	Lo	5,10,20=VU; 50=Lo	M	VU	Lo
Stocking	Lo	M	5,10,20=Lo; 50=M	M	Lo	M	Lo	Lo	Lo	M	Lo	M	5=Lo;10=M; 20,50=H	Lo
Trade	Lo	M	Lo	M	Lo	Lo	Lo	Lo	Lo	Lo	Lo	M	Lo	Lo
Overall HM	Lo	M	5,10,20=Lo; 50=M	M	Lo	Lo	Lo	Lo	Lo	Lo	Lo	M	5=Lo;10=M; 20,50=H	Lo
Overall Arrival	5,10=Lo; 20,50=M	Lo	5,10,20=Lo; 50=M	M	Lo	Lo	Lo	Lo	Lo	Lo	Lo	M	5=Lo;10=M; 20,50=H	Lo

B) Lake Ontario DIPLOID

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Physical Connections	VU	M	Lo	Lo	5,10,20=Lo; 50=M	5,10=H; 20,50=M	5,10,20=Lo; 50=M	5,10,20=M; 50=Lo	Lo	M	Lo	M	Lo	M
Laker Ballast							VU	5,10,20=H; 50=VH	VU	H	VU	H	VU	M
Bait	Lo	M	VU	M	Lo	M	Lo	M	Lo	Lo	Lo	M	VU	Lo
Stocking	VU	M	Lo	M	VU	M	5=VU; 10,20,50=Lo	5,10,20=M; 50=Lo	Lo	M	5,10,20=VU; 50=Lo	M	5=Lo;10=M; 20,50=H	Lo
Trade	Lo	Lo	VU	M	Lo	M	Lo	Lo	Lo	M	Lo	M	Lo	Lo
Overall HM	Lo	Lo	Lo	M	Lo	M	Lo	Lo	Lo	Lo	Lo	M	5=Lo;10=M; 20,50=H	Lo
Overall Arrival	Lo	Lo	Lo	Lo	5,10,20=Lo; 50=M	M	5,10,20=Lo; 50=M	Lo	Lo	Lo	Lo	M	5=Lo;10=M; 20,50=H	Lo

SURVIVAL RISK TABLES

*Table 6. Rank of overall survival for **Lake Superior** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	H	M	VLi	H	H	H	H	H	H	M	H	H	H	H
Diploid	H	M	VLi	VLi	H	H	H	H	H	M	H	H	H	H

*Table 7. Rank of overall survival for **Lake Michigan** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	VLi	VH	VLi	VLi	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H
Diploid	VLi	VH	VLi	VLi	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H

*Table 8. Rank of overall survival for **Lake Huron** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	VLi	VH	VLi	VLi	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H
Diploid	VLi	VH	VLi	VLi	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H

*Table 9. Rank of overall survival for **Lake Erie** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**
Triploid	VLi	VH	VLi	VLi	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H
Diploid	VLi	VH	VLi	VLi	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H

*Table 10. Rank of overall survival for **Lake Ontario** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**	**Rank**	**cert**
Triploid	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H
Diploid	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	VH	VLi	H

ESTABLISHMENT RISK TABLES

*Table 11. Rank of overall establishment for **Lake Superior** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Triploid	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH
Diploid	M	M	5=VU; 10,20,50=Lo	H	5,10=VU; 20=Lo; 50=M	5=H; 10,20=M; 50=Lo	Lo	M	5,10=VU; 20,50=Lo	M	5,10=VU; 20,50=Lo	5=H; 10,20,50=M	VU	M

*Table 12. Rank of overall establishment for **Lake Michigan** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Triploid	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH
Diploid	5=H; 10,20,50=VLi	5,10=VH; 20,50=H	5=Lo; 10,20,50=M	5,10=H; 20,50=Lo	VLi	VH	5=H; 10,20, 50=VLi	H	5=Lo; 10,20, 50=VLi	M	H	M	VLi	VH

*Table 13. Rank of overall establishment for **Lake Huron** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH
Diploid	M	M	5,10,20=Lo; 50=M	5=H; 10,20=M; 50=Lo	5=Lo; 10=M; 20,50=H	5=H; 10,20=M; 50=Lo	5,10=Lo; 20,50=M	H	5,10=Lo; 20,50=M	M	5=Lo; 10,20=M; 50=H	M	H	M

*Table 14. Rank of overall establishment for **Lake Erie** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH
Diploid	VLi	VH	5=H; 10,20,50=VLi	5=VH; 10,20,50=H	VLi	VH	5=H; 10,20,50=VLi	H	VLi	H	VLi	5,10,20=M; 50=H	VLi	VH

*Table 15. Rank of overall establishment for **Lake Ontario** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH	VU	VH
Diploid	5,10=VU; 20,50=Lo	H	5=VU; 10,20=Lo; 50=M	5,10,20=M; 50=Lo	5=Lo; 10,20=M; 50=H	5=H; 10,20=M; 50=Lo	5=VU; 10=Lo; 20=M; 50=H	H	5,10,20=Lo; 50=M	M	5,10=Lo; 20,50=M	M	5=VU; 10=Lo; 20,50=M	M

SPREAD RISK TABLES

*Table 16. Rank of overall spread for **Lake Superior** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	5,10,20=VU; 50=Lo	5,10,20=VH; 50=M	5,10=VU; 20,50=Lo	M	VU	5=VH; 10,20=H; 50=M	5=VH; 10,20,50=VU	H	VU	M	Lo	M	5,10=VU; 20,50=Lo	Lo
Diploid	5,10,20=VU; 50=Lo	5,10,20=VH; 50=M	5,10=VU; 20,50=Lo	M	5,10=VU; 20,50=Lo	5=VH; 10=H; 20=M; 50=Lo	5, 10=VU; 20, 50=Lo	M	5,10,20=VU; 50=Lo	M	5,10,20=Lo; 50=M	M	5,10=VU; 20,50=Lo	Lo

*Table 17. Rank of overall spread for **Lake Michigan** for triploid and diploid Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	5=VU; 10=Lo; 20,50=M	5=M; 10,20,50=Lo	VU	5=M; 10,20,50=Lo	VU	5=VH; 10,20=H; 50=M	VU	M	VU	M	5=VU; 10,20,50=Lo	M	VLi	H
Diploid	5=VU; 10=Lo; 20,50=M	5=M; 10,20,50=Lo	5,10,20=VU; 50=Lo	5=M; 10,20,50=Lo	5,10=VU; 20=Lo; 50=M	M	5=VU; 10=Lo; 20,50=M	M	5,10=VU; 20=Lo; 50=M	M	5=VU; 10=Lo; 20,50=M	M	VLi	H

Table 18. Rank of overall spread for ***Lake Huron*** *for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	5,10=M; 20,50=H	M	5,10=M; 20,50=H	5=Lo; 10,20,50=M	5=VU; 10,20=Lo; 50=M	5=H; 10,20=M; 50=Lo	5,10=M; 20,50=H	M	5,10=M; 20,50=H	M	H	M	VLi	H
Diploid	5,10=M; 20,50=H	M	5,10=M; 20,50=H	5=Lo; 10,20,50=M	5=VU; 10=Lo; 20=M; 50=H	5=H; 10,20,50=M	5=M; 10,20=H; 50=VLi	M	5,10=M; 20=H; 50=VLi	M	H	M	VLi	H

Table 19. Rank of overall spread for ***Lake Erie*** *for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	5,10=VU; 20=Lo; 50=M	5=VH; 10=M; 20,50=Lo	5,10,20=VU; 50=Lo	M	5,10,20=VU; 50=Lo	M	VU	M	VU	M	Lo	M	VLi	VH
Diploid	5,10=VU; 20=Lo, 50=M	5=VH; 10=M; 20,50=Lo	VU	M	5,10=Lo; 20,50=M	M	5=VU; 10=M; 20=H; 50=VLi	M	5,10=VU; 20=H; 50=VLi	M	5,10,20=Lo; 50=M	M	VLi	VH

*Table 20. Rank of overall spread for **Lake Ontario** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	5,10,20=VU; 50=Lo	5,10=VH; 20,50=M	5,10,20=VU; 50=Lo	Lo	VU	5,10=VH; 20=H; 50=M	VU	M	VU	M	Lo	M	5=VU; 10,20,50=Lo	M
Diploid	5,10,20=VU; 50=Lo	5=VH; 10,50=M; 20=Lo	5,10=Lo; 20,50=M	Lo	5,10=VU; 20=Lo; 50=M	5=H; 10=M; 20,50=Lo	5,10=VU; 20,50=Lo	M	5,10=VU; 20,50=Lo	M	Lo	M	5=VU; 10,20,50=Lo	M

MAGNITUDE OF ECOLOGICAL CONSEQUENCES

*Table 21. Rank of overall ecological consequences for **Lake Superior** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Negligible (N), Low (Lo), Moderate (M), High (H), Extreme (E); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	N	5,10=VH; 20,50=H	N	VH	N	5=VH; 10=H; 20,50=M	N	VH	N	5,10,20=VH; 50=H	N	VH	N	VH
Diploid	5,10,20=N; 50=Lo	5,20=M; 10=H; 50=Lo	N	5,10,20=VH; 50=M	5,10,20=N; 50=Lo	5=VH; 10=H; 20=M; 50=Lo	N	M	N	M	N	5,10=VH; 20=H; 50=M	N	M

*Table 22. Rank of overall ecological consequences for **Lake Michigan** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Negligible (N), Low (Lo), Moderate (M), High (H), Extreme (E); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Triploid	N	5=VH; 10=H; 20,50=M	N	VH	5,10=N; 20,50=Lo	5=VH; 10=H; 20,50=M	N	VH	N	5,10=H; 20,50=M	N	5,10=VH; 20=M; 50=H	N	VH
Diploid	5,10=N; 20,50=Lo	5=H; 10=M; 20,50=Lo	Lo	5,10,20=Lo; 50=M	5,10=N, 20=Lo; 50=M	5=H; 10,20,50=M	5,10=N; 20=Lo; 50=M	M	Lo	5=M; 10,20,50=Lo	5,10=N; 20,50=Lo	5,10=H; 20=M; 50=Lo	5,10=N; 20=Lo; 50=M	M

*Table 23. Rank of overall ecological consequences for **Lake Huron** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Negligible (N), Low (Lo), Moderate (M), High (H), Extreme (E); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		Author 2		Author 3		Author 4		Author 5		Author 6		Author 7	
	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert	Rank	Cert
Triploid	N	5=VH; 10=H; 20,50=M	N	VH	N	5=VH; 10=H; 20,50=M	N	VH	N	5,10,20=H; 50=M	N	5,10,20=VH; 50=H	N	VH
Diploid	5,10=N; 20,50=Lo	5,10=H; 20,50=Lo	5,10=N; 20,50=Lo	5,50=M; 10=H; 20=Lo	5,10=N; 20=Lo; 50=M	5=H; 10,20=M; 50=Lo	5,10=N; 20,50=Lo	M	5,10=N; 20,50=Lo	5,10=M; 20,50=Lo	N	5,10=H; 20=M; 50=Lo	5,10=N; 20,50=Lo	M

*Table 24. Rank of overall ecological consequences for **Lake Erie** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Negligible (N), Low (Lo), Moderate (M), High (H), Extreme (E); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	N	5=VH; 10,20=M; 50=Lo	5=N; 10,20,50=Lo	5=N; 10,20,50=VH	N	M	N	VH	N	5,10,20=H; 50=M	N	5,10, 20=H; 50=M	N	VH
Diploid	5=N; 10=Lo; 20=M; 50=H	5=H; 10=M; 20,50=Lo	5=N; 10=Lo; 20,50=M	M	5,10=N; 20,50=M	5,10=H; 20,50=M	5=N; 10=Lo; 20=M; 50=H	M	5=N; 10=Lo; 20=M; 50=H	5,10,20=M; 50=Lo	5=N; 10,20=L; o 50=M	5,10, 20=M; 50=Lo	N	M

*Table 25. Rank of overall ecological consequences for **Lake Ontario** for triploid and diploid, Grass Carp, 5, 10, 20, and 50 years from the risk assessment baseline (i.e., 2014). Likelihood (Rank): Negligible (N), Low (Lo), Moderate (M), High (H), Extreme (E); Certainty (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH). Note: If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes.*

	Author 1		**Author 2**		**Author 3**		**Author 4**		**Author 5**		**Author 6**		**Author 7**	
	Rank	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**	**Rank**	**Cert**
Triploid	N	5,10=VH; 20=H; 50=M	N	VH	5,10,50=N; 20=Lo	5=VH; 10=H; 20,50=M	N	VH	N	5,10,20=H; 50=M	N	5,10,20=VH; 50=M	N	VH
Diploid	N	5=VH; 10=H; 20,50=M	5=N; 10,20,50=Lo	5,10=M; 20,50=Lo	5,10,20=N; 50=Lo	5=VH; 10=H; 20,50=M	5,10=N; 20,50=Lo	M	N	M	N	5,10=VH; 20,50=M	N	M