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Proceedings of the Regional Advisory Meeting on the Sampling effort to detect Asian carps during response activities in the Great Lakes basin

Meeting dates: January 13–15, 2021
Location: Virtual meeting

Chairperson: Julia Colm
Editors: Tessa Brinklow and Adam Rego

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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

Asian carps (Bighead Carp [*Hypophthalmichthys nobilis*], Silver Carp [*H. molitrix*], Grass Carp [*Ctenopharyngodon idella*], Black Carp [*Mylopharyngodon piceus*]) are a group of invasive species that are nearing the Great Lakes basin and are anticipated to pose significant ecological and socio-economic threats, should they arrive. Grass Carp has already arrived in lakes Erie, Huron, Michigan, and Ontario. In response to these threats, Fisheries and Oceans Canada (DFO) developed the Asian Carp Program in 2012 that conducts early detection surveillance and implements a response plan following verified captures of Asian carps in Canadian waters. Science advice was requested by the Asian Carp Program to determine sampling effort required for the detection of Asian carps in the Great Lakes basin, as there is uncertainty regarding how much sampling is required to have confidence that additional fish would be detected if present.

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Science Advisory Meeting took place virtually via Microsoft Teams/Teleconference from January 13–15, 2021. The objectives of the meeting were to determine the sampling effort (time, intensity, search area) required to successfully detect Asian carps should they be present. A working paper that established a framework to assess the effort required to successfully detect and locally remove Asian carps during response activities was presented for peer review.

All participants were required to complete a review of the working paper prior to the meeting. The main topics discussed during the meeting addressed the major comments and feedback received from the participant's reviews. Major comments concerned the use of catchability values, the general modelling approach as well as specifics related to the schooling and informed sampling scenarios, incorporation of movement, and terminology related to eradication. There were no major changes to the methodology or framework of the models, as most concerns were addressed with terminology changes and additional clarifications in the text. This proceedings document summarizes the discussions during the meeting and the decisions made with regards to the Research Document and the Science Advisory Report. The conclusions and feedback from this meeting were used to develop a Science Advisory Report providing advice to Asian Carp Program strike teams, which can be applied to response efforts for targeting Asian carps and other aquatic invasive species.

The participants in this meeting included experts from various organizations including DFO Science and the Asian Carp Program, Ontario Ministry of Natural Resources and Forestry, Québec Ministère des Forêts, de la Faune et des Parcs, Michigan State University, McGill University, University of Toronto Scarborough, United States Geological Survey, and Michigan Department of Natural Resources. The Science Advisory Report, supporting Research Document, and Proceedings will be published on the DFO Canadian Science Advisory Secretariat (CSAS) website.

INTRODUCTION

Fisheries and Oceans Canada (DFO)'s Asian Carp Program was developed in 2012 in response to the threats of four species of Asian carps (Bighead Carp [*Hypophthalmichthys nobilis*], Silver Carp [*H. molitrix*], Grass Carp [*Ctenopharyngodon idella*], Black Carp [*Mylopharyngodon piceus*]) that are approaching the Great Lakes basin via connected waters in the Mississippi River basin. The Grass Carp has arrived to lakes Erie, Huron, Michigan, and Ontario and reproduction has been documented in two U.S. tributaries of Lake Erie. However, detections throughout the lakes, particularly in Canadian waters, remain relatively rare. The Asian Carp Program conducts early detection surveillance and implements a response plan based on the Incident Command System following verified captures of Asian carps in Canadian waters. There is limited scientific information regarding the amount of sampling effort needed to have confidence in detecting and/or locally removing Asian carps, should they be present.

To address this uncertainty following a request for science advice from the Asian Carp Program, a draft research document (working paper) was prepared that used simulation modelling to estimate the sampling effort required to detect Asian carps during sampling activities in the Great Lakes basin. A DFO Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting was held virtually over three days from January 13–15, 2021 to review the information presented by the authors in the working paper. The working paper was prepared and sent to meeting participants prior to the meeting. Participants were required to review the working paper and send critical comments back to the author team before the meeting. These comments were summarized and used for developing discussion points following the presentations during the meeting.

The meeting Chair opened the meeting by reviewing the Terms of Reference (ToR; found in Appendix 1), introducing the participants (list found in Appendix 2), and reviewing the meeting agenda (Appendix 3). An overview of the CSAS peer review process was given by the regional CSAS coordinator. Presentations were given to provide context to meeting participants related to existing approaches used by the Asian Carp Program, and to provide an overview of the modelling methods and results in the working paper. All participants were encouraged to contribute to the discussion and give feedback on the working paper and Science Advisory Report (SAR).

PRESENTATIONS

Overview of the Asian Carp Program's early detection and response efforts

Presenter: Dave Marson

The presentation gave an overview of the Asian Carp Program's early detection surveillance and response sampling operations, including the scope of coverage of Great Lakes tributaries and habitats, gear types used, and an example of how the Incident Command System is implemented during responses. It was determined that science advice was needed to understand the effort required to detect and locally remove Asian carps, and to have enough certainty in removal to end a response and allocate effort to other locations.

A participant wondered if the authors had considered the probability of non-detection, although this was answered at the end of the presentation. A member of the author team reiterated that early detection surveillance teams have been moving across the landscape, and that a detection has already occurred when a response is initiated. With that knowledge, the aim is to determine what efforts are required to remove Asian carp following that initial detection, and to think about effort requirements and subsequent sampling in that area. Another participant agreed, stating they are looking to increase confidence that no fish remain after searching, which is a basic need from a management perspective.

One participant sought clarification regarding the variety of sampling strategies (i.e., model scenarios) evaluated in the working paper, noting this was not mentioned in the ToR, and wondered if there is an already decided-upon sampling strategy. A member of the author team responded that, although the ToR did not specify evaluating alternative sampling strategies, the inclusion of different sampling schemes was an attempt to provide more value to the question to support future response efforts.

Sampling effort to detect Asian carps during response activities in the Great Lakes basin – working paper

Presenter: Eric Smyth

The presenter went through the working paper and the objectives in the ToR. The presentation was broken down into the different model scenarios that were used, with two different endpoints defined for each scenario, detection (effort required until the first fish is captured) and eradication (effort required until the last fish is captured). Clarification questions were taken throughout the presentation, but critical questions were addressed in the discussions at the end of the presentation.

One participant brought up the potential for using probability theory (as opposed to the simulation models that were used) for many of the analyses discussed in the paper. The presenter addressed this by stating that probability theory worked for most scenarios, but could not sufficiently incorporate all of the model scenarios (e.g., informed sampling and repeat sampling) in a clear and concise manner. Since the simulation approach was used for one scenario, the same approach was used for all to keep the methods consistent. The participant emphasized that there should be no hesitancy mixing methods to get more powerful models, and that catchability can be viewed in a probabilistic context, as a consideration. This was agreed to be discussed further in the discussion portion of the meeting.

Participants were looking for clarification of the term ‘catchability’ and the difference between ‘catchability’ and ‘probability of detection’. One participant noted that the definition of ‘catchability’ in a traditional fisheries context is the relationship between catch per unit effort (CPUE) and gear efficiency, which is different than what was used in this context. The presenter explained that catchability estimates used in the models reflect the individual probability that a fish will be captured during a simulated sampling event. Detection reflected the effort needed to capture a single fish, which is dependent on the catchability probabilities used in the models. The participant still wanted further clarification with Table 1 in the working paper in terms of how catchability is broken down by gears, and if the studies presented in the table used catchability in the same way that it was used in the working paper. Another participant clarified in the chat that catchability, as used in this study, is the probability of capture when encountered by the sampling gear, and detection probability is the probability of capturing at least one fish during a pass of the response area. The participant agreed that the catchabilities presented in Table 1 are not a probability of capturing individual fish, emphasizing that there needs to be a distinction. The discussion on the appropriateness of the term ‘catchability’ was continued later on in the meeting.

Further clarifications throughout the presentation were made. This included clarifying that a pass means sampling every site in the entire response area matrix, and that an empty pass means the entire matrix has been sampled and no fish were detected.

In regards to the randomized sampling scenario, a participant asked if a pass is only complete once all sites have been sampled. The presenter clarified that partial passes (determined from the number of sites sampled) are presented, where appropriate, as a complete pass is not necessarily achieved in the randomized sampling scenario; certain sites are revisited before all sites have been sampled once. Another participant asked how the randomized sampling scenario relates to reality, if the strike team can move to any site in the matrix during a simulation or if it must move to an adjacent site creating a track. The presenter clarified that the process was entirely randomized throughout the matrix.

Another participant asked how the decision was made to stop sampling (i.e., stop the simulation) in the randomized sampling scenario. The presenter responded that, for detection, the simulation stopped once a single fish was captured, and for eradication, the simulation was stopped when all fish were captured.

In relation to the informed sampling scenario, the presenter reiterated that simulations always began at the bottom left of the matrix. A participant asked how informed sampling differs from the scenarios with different response area sizes. The presenter responded that the informed scenario is functionally the same as the smaller response area scenario, but it was included to provide a logical comparison to the naïve scenario of equal response area size (where fish were found in an equivalent small area of suitable habitat in the matrix, but strike teams are unaware of this and sample the full matrix). It was clarified that the naïve scenario presents a worse-case scenario than the base model, as fish are aggregated in the right side of the matrix (50% scenario) or upper right quadrat (25% scenario) as opposed to randomly distributed throughout the entire matrix as per the base model.

DISCUSSION OF WORKING PAPER COMMENTS

The topics of discussion were based around six themes of comments from the reviews, and were addressed in that order:

1) Catchability values
2) General approach (analytical vs. simulation models)
3) Schooling approach
4) Informed sampling approach
5) Movement incorporated in models
6) Eradication

CATCHABILITY VALUES

The authors wanted to ensure all participants were clear on how catchability was referred to in the working paper and incorporated into the models. Further explanation of the term catchability was given using examples and slides, participants agreed that they understood and were satisfied with that explanation, but wanted this clarification in the final working paper (Research Document).

Table 1 was discussed in relation to catchability and the challenges associated with getting a realistic catchability range, as it is very context dependent. Some participants believed that Table 1 was a distraction and may not be necessary, as it isn’t directly related to what this work is examining. Other participants agreed with the points made about Table 1, but did not recommend removing it. Participants agreed that keeping Table 1 in the document is useful for strike teams to see the range of potential catchability values to provide context, but that the terminology needs to be clear. One participant justified a range of capture probabilities being important and valid since the results will be applied across gear type, habitat characteristics, and fish sizes. The authors agreed that the values presented in Table 1 could be better contextualized to reflect these uncertainties. Additionally, participants agreed to a suggested change in terminology in the model parameters from “catchability” to “probability of capture”.

The modelling approach was discussed, with one participant bringing up that modelling should inform the actual responses in an adaptive way, and use information in patterns of capture that can be exploited to make sampling procedures more powerful. The authors responded that this was explored with the repeated sampling scenario, but due to time constraints and the large number of other potential sampling schemes that could have been explored, these changes would not be made here, but may be appropriate for future research.

The potential for additional data or sources of information was discussed by the group, and an author asked the participants if various agencies had field data that could allow them to refine the probability of capture. One participant mentioned recent work by the University of Toledo looking at catchability of Grass Carp in Lake Erie, and by Michigan State University investigating catchability of surrogate species in the Great Lakes. The participant emphasized that there are uncertainties in relation to Table 1, and that a text-based description of estimated catchability values for Grass Carp could be useful. The value of a forthcoming Lake Erie depletion study was discussed, and other work in the Lake Erie group indicated the catchability of Grass Carp is at the low end of the 0 to 1 range. It was suggested that even a rough bounded range could be helpful. One of the authors brought up the idea of pulling in any new or existing estimates from additional sources to add into the text, rather than constraining the full range of catchability values in the models. The other participants agreed to this approach.

GENERAL APPROACH

One of the authors asked for the group’s opinion on the simulation model approach, or whether using a hybrid analytical and simulation approach may be more appropriate. One participant suggested additional approaches (e.g., using probability theory) might have clarified some of the relationships, but stated that the approach used was sufficient to address the objectives.

Another participant raised concerns that qualifying statements about effect sizes in the sensitivity analyses are not supported statistically. They brought up issues with presenting changes in effort outputs as percentages versus absolute values, and what the threshold for a meaningful change is; the benchmark for a significant or non-significant effect is not presented anywhere. One of the authors stated that the sensitivity analysis was intended to better understand what parameter changes resulted in the greatest differences in effort required, but that they didn’t evaluate effect sizes. The participant reiterated that the percentage difference may have different implications for strike teams compared to absolute values (e.g., a 2% decrease in effort on two thousand sites is different than a 2% decrease on two million sites). Another participant felt that the percentages were meaningful for judging the appropriate conclusion. The other participant reiterated that the percentages were sufficient, but that they could be presented more clearly with the threshold of what is considered a significant versus non-significant effect explained. The participant used an example statement from the paper of ‘schooling behaviour had little effect’ and emphasized that those statements qualifying the magnitude of effect needed contextualization, and that they would like to see either a clear statement defining the cut-offs or removal of the qualifying statements from the text. The authors and participants agreed to present results as a percent change only to allow results to speak for themselves, rather than inferring effect.

SCHOOLING APPROACH

The authors wanted feedback on whether the incorporation and calculation of schooling behaviour, along with the range of values used, were appropriate. They also wanted a discussion around the appropriateness of schooling at a high value, where it is possible to have multiple groups of schools, as well as one large school.

The potential data from the study by University of Toledo estimating catchability of Grass Carp was brought up again, and it was emphasized to connect and see what might be available for use. Another participant brought up using Lake Erie data, as they believed there could be an opportunity to leverage telemetry data to inform schooling (i.e., how frequently a single fish versus multiple fish are detected on a receiver at the same time). One of the authors addressed this by saying they considered the telemetry data, but there was concern about the temporal and spatial scales of the telemetry array, which make it challenging to transfer those results to the smaller response area used in the working paper. Additionally, a tag detection of a single fish does not necessarily mean it was alone, but simply was not occurring with other tagged fish. The participant agreed, and brought up the ‘Judas fish’ approach to leverage information about tagged fish to increase captures of untagged fish, in hopes of leading to more effective response efforts.

One participant had a question relating to the schooling rate and clustering of schools. At a relatively high schooling value, the example shown had all fish in one site clustered together. They wanted to know if this was the only possible outcome, or if rogue individuals were possible. One of the authors explained that rogue individuals could occur at high schooling rates where the last individuals to be assigned to sites were found not to be schooling. This is less likely as the schooling rate increases. Another participant wondered if a fish ‘decides’ not to school initially, can its decision be overwritten by schooling fish that are assigned after it. The author clarified that schooling rate is a misnomer, and that it is really the probability that a fish will join an existing school. Another participant brought up concerns with the definition of ‘schooling’ used in this model scenario, stating that many fish loosely packed together does not necessarily indicate schooling but simply an aggregation. They described schooling as the extreme level of aggregation, where fish are most densely aggregated and respond to predators and other stimuli as a unit. The authors suggested that schooling be described as an outcome rather than a process. The relevance is spatial aggregation of fish, and the term “schooling rate” should be replaced with “aggregation”.

One participant also noted that it was unclear if multiple individuals, when occupying a site together, could be removed in a single pass, or if only one was removed during the pass. The author team agreed that there needs to be a better working example in the introduction to illustrate that, if the probability of capture is high enough, more than one individual could be removed during a pass of the site. The participants confirmed that this added text would address this concern.

Another participant asked what information is available on schooling when trying to catch Grass Carp, notably while electrofishing. They wanted to know if there are available data on catchability and likelihood of detection and eradication when schooling, and wondered if there was consideration of how sampling can affect or disrupt schooling. The authors stated that it was challenging to pull data from the literature or the field based on the spatial scale of this study. Other studies at a broader spatial scale have found some evidence of schooling, but this is hard to translate to the models here. There is a poor understanding of how fish encounter the strike teams, as fish could flee and disaggregate, or aggregate and herd. One participant brought up that new fine-scale Lake Erie telemetry array data would allow for looking at fish movement and avoidance, particularly during removal events, but these data are not yet available. Another author noted that there are techniques being used that likely increase catchability of schools, for example trying to herd fish towards block nets, or sectioning off a response area with block nets. A participant offered some species-specific insights from the U.S., stating that Bighead and Silver carps aggregate and this is why the Unified Method of sampling works so well for those species. Grass and Black carps, however, do not seem to be as susceptible to the Unified Method. There is likely anecdotal evidence/observations, at minimum, available from U.S. Grass Carp strike teams related to catching multiple individuals together.

There was a discussion about whether fish size was considered in the schooling scenario or in the model approach as a whole. A participant pointed out that a smaller fish is harder to find than a larger fish. An author responded that incorporating fish size was difficult; they know that size affects probability of capture, but they did not feel it would be valuable to explore the influence of size without a baseline estimate of probability of capture. Another author stated that the propensity for juveniles to school more than adults is still unknown, so it may be more useful to think about the influence of those factors to better narrow down the range of probability of capture.

One participant wanted to expand the discussion on size to a broader context about variability between individuals and how this affects their probability of capture. They wondered if it is important to do a sensitivity analysis on size since eradication efforts are driven strongly by that variation with the most catchable ones being larger. They stated that this could affect the probability of eradication by orders of magnitude. They further stated that, in a given simulation, there is a distribution of probabilities of capture rather than a single value assumed for all individuals. One of the authors explained that they made this assumption about lack of variability in the probability of capture relating to size structure because, in most cases in Canadian waters, we are still dealing with a single size class (e.g., rogue adults). They recognized the probability of capture will change based on size, but within age and size classes, the variation is small. Another participant agreed that the inter-individual variation is a great question, but there are very limited data at this time; it may be something to consider for future work if/when progress is made on addressing the uncertainty around inter-individual variation and its impact on probability of capture with field data.

More concerns were raised relating to the size argument, stating that there is a small chance that all individuals would be part of the same age class when there are large numbers of fish. They also stated that it’s not necessary to fully model the size distribution, but the sensitivity of the models to different scenarios with individual-level variation in probability of capture would be useful to evaluate. Another author agreed with the participant, and suggested including this as an uncertainty that could be explored in the future. They liked the idea of running simulations using multiple individuals with different probabilities of capture, but was not sure how easy it would be to integrate that into the current simulations.

One author recommended using existing figures to coarsely inform detection and eradication of mixed populations. Using this approach, detection would be estimated by looking at the upper probability of capture as larger fish are more easily caught and more likely to be caught first, while local removal would be estimated by looking at the lower range of probability of capture as smaller fish would likely be the last individuals caught. A participant argued that this creates bounds, but wasn’t sure if that would yield the correct probability. They stated that using the plots would give the worst-case scenario for eradication, and an overestimation of ability for detection. They felt that a logical statement about this in the text would address their concerns. Another participant suggested that individual differences in probabilities are not essential for this modelling exercise since it is the probability spectrum that is of greatest interest. In interpreting and applying the probability surface, strike teams would consider the highest probability of capture for detection (i.e., the first fish caught had the greatest probability of being caught, but more elusive fish could still be out there) and the lowest probability of capture for eradication. The authors and other participants agreed to approach this by acknowledging the limitations of the models regarding inter-individual variation and how factors like fish size may affect probability of capture.

INFORMED SAMPLING APPROACH

One of the authors began this discussion by addressing the confusion between informed and naïve sampling. They stated that informed is similar to reducing the response area size, but the comparison between naïve and informed responses was designed to show the effect of wasting time sampling unoccupied habitat. Strike teams are trying to refine their sampling area as appropriately as possible, and the worst-case scenario is the naïve approach, where strike teams are unable to identify or narrow down areas of suitable habitat. Although this is not the most realistic scenario, it shows bounds on the effect of naivety.

One participant argued they do not see how the naïve scenario represents reality. They used the example of a large lake, where strike teams would not go to an offshore area for electrofishing, but that fishing activity would be constrained to nearshore areas most suited to Grass Carp. They argued that even a fairly naïve strike team will use some information about where they believe fish are to constrain the sampling area. An author agreed that when the area is heterogeneous, sampling will always be somewhat informed; however, responses have occurred in homogenous areas (e.g., shallow wetlands) where the habitat does not appear to be partitioning fish to certain areas. In these cases, there was no knowledge if fish were partitioning themselves, and what effect this has on eradication. The difference between the baseline (fish being randomly distributed throughout the matrix with some spatial aggregation occurring depending on schooling value), informed (fish partitioned into a quadrant of the response area, where strike teams only sample that quadrant but will still visit sites within the quadrant that do not contain Asian carps), and naïve (fish are partitioned into a quadrant of the response area, but strike teams are naïve to this partitioning and sample the entire matrix) scenarios is reiterated. Another participant liked the approach but suggested another sentence to help explain why the naïve is the worst-case scenario. The author agreed to add more clarification.

One participant suggested that there should be a terminology change to replace the term "naïve" as it is not entirely naïve; a strike team is still using some information to choose a sampling area, but they are creating a large buffer around it to capture their uncertainty. The term "buffered" was considered to replace "naïve" but an author explained that the informed scenario is also buffered – not every site in the narrowed-down quadrant will contain an Asian carp – the buffer is just smaller. The authors agreed to modify language to reflect that the naïve and informed scenarios reflect different sized buffers in the strike team's confidence of suitable habitat to be sampled.

MOVEMENT INCORPORATED IN MODELS

One of the authors began by clarifying that the movement scenario is more in line with the term 'avoidance' in terms of how that behaviour was incorporated into the models. There is limited information available regarding movement patterns of Asian carps. Telemetry data available from Lake Erie suggests Grass Carp movement is relatively limited at a coarse spatial scale, so without finer scale movement data, it was assumed Asian carps would remain in the site unless they encountered the strike team.

One participant suggested describing low movement rate as the likelihood to remain in the natal site of the model (stationarity). Another participant brought up that the distance a fish is capable of moving to avoid sampling is not clear. In a natural setting, a fish may flee several hundred metres away from the sampling location. They asked how fish movement away from sampling with electrofishing or trammel nets was incorporated into the model. The author responded that, in the model, it was assumed that fish could move to any site within the response area; distance, direction or whether the site had been previously sampled were not considered. The participant was concerned that a fish's redistribution after being startled should be more realistic, suggesting using body length as a reasonable measurement to move away from the site (e.g., 100 body lengths away). The authors clarified that this may be more realistic but there is a lack of information to say whether the startle behaviour would be more likely to be a long distance compared to a relatively short distance, and they would be making assumptions about the boundary; there just aren't enough data to justify rules for distance moved.

Participants discussed the difference between regular movement (or constant redistribution) in a system and avoidance or disturbance behaviour (i.e., do they move before they are even encountered?). Other participants added some anecdotal evidence about multiple Grass Carp being caught at the same sites over several back-to-back sampling events; the fish are tied to these particular habitats, and, even after repeated disturbances, do not flee long distances. They suggested that there may be data to mine from other Great Lakes responses on avoidance following repeated sampling events. It was concluded that the authors will revise the description and terminology from 'movement' to 'avoidance' to address concerns.

A participant wanted to discuss the validity of assuming the response area is a closed system and that fish cannot move or migrate out of it. They raised concerns that some fish can move greater distances than the size of the response area and may be likely to flee the area, and this is particularly problematic in large lake systems. The authors discussed how this was debated a lot during model development. Some systems may function as a closed system while others may not, but ultimately, it would be too difficult to capture the full range of scenarios from semi-closed to open. Additionally, it was acknowledged that the longer a response takes, the more likely fish may be to flee the area. The participant responded that this assumption of a closed system is fine when considering detection, but is problematic for eradication: in an open system, fish may flee, or if the habitat is good enough, more fish may come in. There was an agreement to add additional discussion on the assumptions made about the time it takes to sample these areas and about fish moving out of the system.

ERADICATION

One participant brought up concerns that eradication may be possible in a closed system, but in an open area or large lake, it is likely not feasible. From a management perspective, use of this term may be misleading. Other participants agreed, and pointed out that eradication distracts from the strength of the study, which they felt was the detection piece. Since eradication is not the central focus of the study, it was suggested to be treated in a sub-section of the paper. Another participant agreed, noting that the term 'eradication' was not mentioned in the title or the Terms of Reference objectives. Some participants were concerned that this could be misleading without proper context, and that the effort required for eradication would be viewed as unreasonable and would take eradication off the table as a response goal. One of the authors responded that the term eradication was used in the context of the response area, and the eradication end-point is defined as the point at which all fish have been removed from this area by sampling. The author asked the participants if they were more comfortable with the term 'removal' rather than 'eradication' in relation to the response area.

Another area of discussion surrounded whether developing advice based on one gear type (i.e., electrofishing) was sound, as it could be misleading for managers to say what effort is required to eradicate for one gear and not stating which method/gear is best for eradication. The author disagreed, as the model is not a single-gear model. The models show the effort required to detect and remove fish from a given area across different probability of capture values. Different gears have different probabilities of capture and strike teams can deploy different combinations of gears to try to increase the probability of capture – this is why presenting effort across the full probability of capture range is useful.

The participant stated that the issue may be with the terms 'removal' and 'eradication' with the latter being a management decision. Another participant reiterated the need to report how confident they are that there are no more individuals remaining. There were some suggestions of different terminology, and the group came to the consensus that 'local removal' worked best. Another participant offered 'complete removal from the modelling space', which was agreed to be used as phrasing to define 'local removal' in the text.

ADDITIONAL COMMENTS

One participant wanted to discuss random sampling without replacement and the assumption made in the paper that the results would be the same as systematic sampling. They felt that this assumption was likely true for detection, but not for eradication (now local removal). The point of local removal may be reached earlier with randomized sampling without replacement rather than systematic sampling just by chance. One author responded that randomized sampling without replacement would provide a similar outcome to the base model, as fish were randomly distributed throughout the response area. If other, more specific modelling scenarios were explored, the randomized sampling without replacement may result in different outcomes; however, none of these scenarios were explored using the randomized sampling with replacement scenario, and, therefore, randomized sampling without replacement was not explored that way either. The participant understood this for the initial detection, but for local removal, stated that there is a greater chance of a difference for random sampling without replacement. The authors offered to change the language around the decision to not explore the random sampling without replacement scenario, and the participant accepted that change.

After seeing a summarized list of changes discussed so far for the working paper, the participants were asked to bring up any final comments. One participant brought up the sensitivity analysis change related to effect size that was previously discussed, reiterating that important context is lost when changes in effort are reported only as percentages, and that the absolute differences have major consequences for strike teams on the ground. One participant brought up an example from the randomized sampling scenario, and showed changes in effort as both percentages and absolute values in a table, noting that putting those numbers into context is meaningful to managers. Participants agreed that the example table shown was very helpful in providing appropriate context for effect sizes, and the participant agreed to send the table to the authors to be captured in the Science Advisory Report.

No other issues were brought up to revisit with the working paper. It was agreed that the working paper would be accepted as a Research Document with minor revisions, as discussed, and would not be sent to participants again.

DRAFTING OF THE SCIENCE ADVISORY REPORT

Draft Science Advisory Report (SAR) summary bullets were provided by the author team, and were discussed and finalized on the third day of the meeting. Major discussions focused on clarifying terminology and precise wording to ensure changes agreed to during the meeting were reflected in the bullets. The MS Teams Chat feature was used extensively by participants to propose alternative phrasing. There was discussion surrounding how effort should be presented in the bullets and the body of the SAR, whether passes (as used in the working paper) was appropriate for the audience of the SAR or whether it should be converted to man-hours (or equivalent), and what context around spatial and temporal scales was needed when presenting effort results. It was agreed that a worked example converting passes to electrofishing hours would be presented as a sub-bullet. The group drafted a final bullet indicating how the results from this work could be applied to responses following detections of other aquatic invasive species.

Sources of uncertainty to be included in the body of the SAR were also developed and agreed to as a group. Major sources of uncertainty surrounded the influence of individual variation, and habitat and gear factors on probability of capture; the likelihood of fish leaving the response area; the lack of non-avoidance movement in the model; and characteristics of aggregations of Asian carps in the wild. The finalized SAR and Proceedings documents would be sent to all participants for a final review before publication on the CSAS website.

APPENDIX 1. TERMS OF REFERENCE

Sampling effort to detect Asian carps during response activities in the Great Lakes basin

Regional Advisory Meeting – Ontario and Prairie Region

January 13–15, 2021
Virtual Meeting

Chairperson: Julia Colm

Context

Asian carps (Bighead Carp [*Hypophthalmichthys nobilis*], Silver Carp [*H. molitrix*], Grass Carp [*Ctenopharyngodon idella*], Black Carp [*Mylopharyngodon piceus*]) were introduced in the southern U.S. in the late 1960's for pest control, but later escaped captivity and have spread throughout the Mississippi River basin causing significant losses to biodiversity and ecosystem services. These species are nearing the Great Lakes basin and are anticipated to pose significant ecological and socio-economic threats, should they arrive to the basin (Mandrak and Cudmore 2004, Cudmore et al. 2012, Hayder 2014, Cudmore et al. 2017, Hayder 2019). In response to these threats, DFO developed the Asian Carp Program in 2012, which is based on four pillars: prevention, early warning, response, and management. In addition, all four species of Asian carps were listed under Part 2 of the federal *Aquatic Invasive Species Regulations* in 2015.

To date, only one species, the Grass Carp, has arrived[1] to the Great Lakes (lakes Erie, Huron, Michigan and Ontario; Cudmore et al. 2017, DFO 2017). Grass Carp reproduction has been documented in two Ohio tributaries to Lake Erie; however, captures of Grass Carp in Canadian waters remain relatively rare. Given the early state of the invasion, efforts directed towards eradication (i.e., early detection and response) are warranted and have been a focus of the Asian Carp Program.

The Asian Carp Program conducts extensive early detection surveillance around the Great Lakes basin and implements a response plan based on the Incident Command System (ICS) following the verified capture of an Asian carp in Canadian waters. When on-water response operations are conducted, the response plan directs intensive, targeted sampling using traditional gears (e.g., boat electrofishing, hoop nets, mini fyke nets, trammel nets, trap nets) around the location of capture. Sampling efforts are scaled up or down depending on the fertility (ploidy), number, species, or life stage of captured individuals. The sampling effort (duration, intensity) and search area are determined at the discretion of the ICS team (made up of program staff and relevant experts), based largely on professional judgement. Professional judgement is employed as scientific information on optimal effort and detection probability of Asian carps during early detection and response efforts is limited for each species.

Previous responses conducted by the Asian Carp Program have occasionally resulted in the capture of multiple specimens; however, it remains unclear how much sampling is required to have confidence that additional fish would be detected if present. The current approach may result in insufficient sampling, leading to Asian carps being undetected, and ultimately, a failure to reduce population density in that location. Alternatively, over-sampling a location may not

[1] Arrived is defined here as "the repeated detection of at least one Grass Carp in at least one part of the lake basin within any continuous 5-year period" (Cudmore et al. 2017, DFO 2017).

increase confidence that no additional fish are present, but may reduce the program's capacity to conduct early detection surveillance elsewhere in the basin due to resource allocation. Science advice is needed to identify best practices for allocating optimal sampling effort during responses. The goal of this science advisory meeting is to identify the relationship between sampling effort (time, intensity, search area) and the probability of detecting Asian carps should they be present in the search area.

Objectives

To determine the sampling effort (time, intensity, search area) required to successfully detect Asian carps, including:

- The influence of density (or occupancy) and abundance on the relationship between sampling effort and catchability;
- The influence of sampling effort on confidence of Asian carp absence; and
- The identification of appropriate sampling effort targets for ending a response or changing response strategy.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (DFO)
- Ontario Ministry of Natural Resources and Forestry (MNRF)
- Quebec Ministère des Forêts, de la Faune et des Parcs (MFFP)
- U.S. federal and state agencies
- Academia

References

Cudmore, B., Mandrak, N.E., Dettmers, J., Chapman, D.C., and Kolar, C.S. 2012. Binational Ecological Risk Assessment of Bigheaded Carps (*Hypophthalmichthys* spp.) for the Great Lakes Basin. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/114. vi + 57 p.

Cudmore, B., Jones, L.A., Mandrak, N.E., Dettmers, J.M., Chapman, D.C., Kolar, C.S, and Conover, G. 2017. Ecological Risk Assessment of Grass Carp (*Ctenopharyngodon idella*) for the Great Lakes Basin. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/118. vi + 115 p.

DFO. 2017. Update to the Ecological Risk Assessment of Grass Carp (*Ctenopharyngodon idella*) for the Great Lakes Basin: Lake Ontario. DFO Can. Sci. Advis. Sci. Resp. 2016/049.

Hayder, S. 2014. Socio-economic Impact of the Presence of Asian Carp in the Great Lakes Basin. Fisheries and Oceans Canada, Policy and Economics, Winnipeg, MB. 2014–1919. iv + 76 p.

Hayder, S. 2019. Socio-economic Risk Assessment of the Presence of Grass Carp in the Great Lakes Basin. Fisheries and Oceans Canada, Policy and Economics, Winnipeg, MB. 2019-2032. 99 p.

Mandrak, N.E. and Cudmore, B. 2004. Risk Assessment for Asian Carps in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/103. iv + 48 p.

APPENDIX 2. LIST OF MEETING PARTICIPANTS

Name	Organization/Affiliation
Becky Cudmore	DFO – Asian Carp Program/Aquatic Invasive Species, Ontario and Prairie Region
Dave Marson	DFO – Asian Carp Program, Ontario and Prairie Region
Tessa Brinklow (Rapporteur)	DFO – Science, Ontario and Prairie Region
Julia Colm (Chair)	DFO – Science, Ontario and Prairie Region
Andrew Drake	DFO – Science, Ontario and Prairie Region
Eva Enders	DFO – Science, Ontario and Prairie Region
Kevin Hedges	DFO – Science, Ontario and Prairie Region
Marten Koops	DFO – Science, Ontario and Prairie Region
Adam Rego (Rapporteur)	DFO – Science, Ontario and Prairie Region
Jaclyn Hill	DFO – Science, Ontario and Prairie Region
Eric Smyth	DFO – Science, Ontario and Prairie Region
Justin Shead	DFO – CSAS, Ontario and Prairie Region
Collin Gyles	DFO – Policy and Economics, Ontario and Prairie Region
Tim Johnson	Ontario Ministry of Natural Resources and Forestry
Annick Drouin	Québec Ministère des Forêts, de la Faune et des Parcs
Frédéric Lecomte	Québec Ministère des Forêts, de la Faune et des Parcs
Patrick Kocovsky	United States Geological Survey
Brian Leung	McGill University
Lucas Nathan	Michigan Department of Natural Resources
Kelly Robinson	Michigan State University
Nicholas Mandrak	University of Toronto, Scarborough

APPENDIX 3. MEETING AGENDA

Sampling Effort to Detect Asian Carps During Response Activities in the Great Lakes Basin

CSAS Regional Science Peer Review Meeting
Ontario and Prairie Region
January 13–15, 2021
MS Teams Virtual Meeting

Chair: Julia Colm

Rapporteurs: Tessa Brinklow, Adam Rego

Day 1	**Wednesday January 13th – 4 hour block**	
9:00–9:15	Introductions and Roundtable	J. Colm + All
9:15–9:45	CSAS Peer Review Process	J. Paulic (CSAS)
9:45–10:10	Presentation: Overview of the Asian Carp Program's Early Detection and Response Efforts	D. Marson
10:10–10:25	Break	-
10:25–12:00	Presentation: Sampling effort to detect Asian carps during response activities in the Great Lakes basin – working paper	E. Smyth
12:00–13:00	Discussion of working paper comments: overview	All
Day 2	**Thursday January 14th– 4 hour block**	
9:00–9:15	Recap Day 1	J. Colm
9:15–11:00	Discussion of working paper comments: methods, results, discussion	All
11:00–11:15	Break	-
11:15–12:15	Discussion of working paper – continued	All
12:15–13:00	To finalize working paper	J. Colm
Day 3	**Friday January 15th – 4 hour block**	
9:00–9:15	Recap Day 2	J. Colm
9:15–11:00	Draft Science Advisory Bullets	All
11:00–11:15	Break	-
11:15–12:30	Draft Science Advisory Report	All
12:30–13:00	Final Remarks and Next Steps	J. Colm