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Proceedings of the National Advisory meeting on the National Risk Assessment for bloody red shrimp (*Hemimysis anomala)*

January 30, 2008
Burlington, Ontario

Chairperson: Becky Cudmore

Fisheries and Oceans Canada
Canada Centre for Inland Waters,
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Canada

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

Many of the science issues facing Fisheries and Oceans Canada (DFO) are associated with significant knowledge gaps and uncertainties. This however, does not relieve the Department of the need to make decisions on these issues. Under these conditions, decisions must balance the risks and uncertainties while ensuring the sustainability of Canada's aquatic ecosystems. Risk assessment is the process of estimating the risk presented by a hazard, in either qualitative or quantitative terms, to aquatic ecosystems, fisheries resources, fish habitat, and aquaculture that DFO is mandated to manage and protect.

The *Canadian Action Plan to Address the Threat of Aquatic Invasive Species* identifies risk assessment as one of the implementation strategies to deal with the threat of AIS. By forming the Centre of Expertise for Aquatic Risk Assessment (CEARA), DFO has taken the first steps toward developing the necessary expertise in risk assessment across the country, building on expertise developed in Burlington at the Great Lakes Laboratory for Fisheries and Aquatic Sciences. To this end, one of the mandates and objectives of CEARA is to coordinate and to advise on biological risk assessments conducted on priority aquatic invasive species (AIS) of concern. One of these species is the bloody red shrimp, *Hemimysis anomala*, first identified in the Great Lakes in 2006. A national risk assessment was drafted for *Hemimysis* and was peer reviewed January 30, 2008 at Burlington, ON. The purpose of this external peer review was to gather experts on mysids, aquatic invasive species or risk assessment to discuss and provide comments on the draft risk assessment in a face to face forum.

These proceedings focus on the key points from the presentations and the resulting discussions and decisions about the draft risk assessment for *Hemimysis*.

SOMMAIRE

De nombreux enjeux scientifiques auxquels Pêches et Océans Canada (MPO) doit faire face sont liés à d'importantes incertitudes et lacunes dans les connaissances. Le Ministère doit néanmoins prendre des décisions concernant ces enjeux. Les décisions doivent alors tenir compte des risques et des incertitudes tout en assurant la durabilité des écosystèmes aquatiques canadiens. L'évaluation des risques consiste à estimer la menace que présente un danger, par sa nature ou sa gravité, pour les écosystèmes aquatiques, les ressources halieutiques, l'habitat du poisson et l'aquaculture, que le MPO est chargé de gérer et de protéger.

Le *Plan d'action canadien de lutte contre les espèces aquatiques envahissantes* établit par ailleurs que l'évaluation du risque est l'une des stratégies de mise en œuvre que l'on peut utiliser pour traiter la menace posée par les EAE. En formant le Centre d'expertise pour analyse des risques aquatiques (CEARA), le MPO a entrepris les premières étapes vers l'acquisition de l'expertise nécessaire en matière d'évaluation du risque dans l'ensemble du pays, en prenant appui sur l'expertise acquise à Burlington au Laboratoire des Grands Lacs pour les pêches et les sciences aquatiques (LGLPSA). À cette fin, l'un des mandats et objectifs du CEARA consiste à coordonner les évaluations du risque biologique menées sur les espèces aquatiques envahissantes (EAE) préoccupantes, et à donner des conseils à propos de ces évaluations. L'une de ces espèces est la crevette rouge sang, *Hemimysis anomala*, découverte pour la première fois dans les Grands Lacs en 2006. Une évaluation nationale du risque a été rédigée pour l'*Hemimysis* et examinée par les pairs le 30 janvier 2008 à Burlington, en Ontario. L'objectif du présent examen externe par les pairs était de réunir des experts sur les mysidacés, les espèces aquatiques envahissantes ou les évaluations du risque afin de discuter de l'ébauche d'évaluation des risques au cours d'un forum en face-à-face et de la commenter.

Le présent compte rendu se concentre sur les points saillants des présentations et sur les discussions et décisions qui en ont résulté concernant l'ébauche d'évaluation des risques pour l'*Hemimysis*.

INTRODUCTION

The terms of reference were reviewed (Appendix A) and an agenda was provided (Appendix B). Participants were welcomed and introduced themselves (see appendix C for a participant list). An overview and reminder of CSAS peer review guidelines was given.

CEARA OVERVIEW

Aquatic invasive species (AIS) are a growing problem estimated to cost the Canadian economy billions of dollars a year (Colautti et al. 2006). They have been identified as one of the leading threats to native biodiversity (Sala et al. 2000) and species at risk (Dextrase and Mandrak 2006), and have potentially wide ranging indirect impacts on ecosystems through effects such as trophic disruption (Shuter and Mason 2001). The Great Lakes are known to have been invaded by at least 182 non-native species (Ricciardi 2006). While not all these species have had impacts on the ecology or economy of the Great Lakes, some have had significant impacts such as the zebra mussel (*Dreissena polymorpha*). In addition, some AIS such as the spiny water flea (*Bythotrephes longimanus*) that initially invaded the Great Lakes have secondarily invaded inland lakes with subsequent impacts to these ecosystems (MacIsaac et al. 2004, Yan and Pawson 1997).

By creating the Centre of Expertise for Aquatic Risk Assessment (CEARA), DFO has taken the first steps toward developing the necessary expertise in risk assessment across the country.

Objectives of CEARA are:

- to develop a national standard for conducting biological Risk Assessment (RA) of AIS;
- to educate practitioners on the RA process;
- to develop a process for prioritizing RA needs;
- to provide advice to headquarters on national priorities for RA; and,
- to coordinate and track progress of national RA and ensure that deliverables are met.

One of the risk assessment projects undertaken in 2007/08 was to assess the biological risk associated with *Hemimysis*, an invertebrate from the Ponto-Caspian region discovered in the Great Lakes in 2006. This risk assessment focused on two geographic areas of Canada; the Great Lakes, where *Hemimysis* has been discovered, and inland lakes. Previous invertebrate invaders in the Great Lakes have been secondarily transported to inland lakes.

RISK ASSESSMENT APPROACH: A QUANTITATIVE BIOLOGICAL RISK ASSESSMENT TOOL

Overview

The Quantitative Biological Risk Assessment Tool (QBRAT), developed by Fisheries and Oceans Canada (Moore et al. 2007) was utilized to organize and frame the ecological risk assessment of *Hemimysis*. This framework models invasion as a four step process: arrival, survival, establishment and spread. Represented as an event tree, the invasion process has four event nodes and five end points. Each event node is associated with a probability of occurrence, and each end point is associated with a potential impact. The four probabilities are:

- p1 the probability of arrival,
- p2 the probability of survival,

- p3 the probability of establishing a self-reproducing population, and
- p4 the probability of spreading.

The five potential impacts are;

- I1 the impact if the AIS does not arrive,
- I2 the impact if the AIS arrives but cannot survive in the receiver ecosystem,
- I3 the impact if the AIS arrives, can survive, but cannot establish a reproductive population,
- I4 the impact from a locally established population, and
- I5 the impact from a widespread invasion.

QBRAT requires users to estimate each of the four probabilities and five impacts plus estimates of the uncertainty associated with each estimate. Probabilities are expressed on a zero to one scale. Impacts can be expressed as either continuous or categorical impacts. QBRAT can handle continuous impacts ranging from -10^{100} to $+10^{100}$, or up to five categorical impacts. All impacts must be of the same form (either continuous or categorical). Uncertainties can be expressed as either relative or absolute uncertainties. Relative uncertainties are defined as ± x%. Absolute uncertainties are expressed as standard deviations and can be described with a uniform, normal, lognormal, or beta (for probabilities only) distribution. When impacts are expressed categorically, uncertainties are not expressed with a distribution, but instead the user expresses the probability of each impact category for each potential impact (end point on the event tree).

For the *Hemimysis* ecological risk assessment, categorical impacts were defined on a scale of 1 to 5: negligible, low, moderate, high or extreme impacts (Table 1). A relative uncertainty (Table 2) is associated with each probability. QBRAT uses the distribution of values described by these uncertainties to run Monte Carlo simulations. Each simulation is run randomly and draws a parameter value from the uncertainty distributions and calculates the risk. This is repeated 5,000 times. The results provide an integrated estimate of risk and uncertainty. Sensitivity analyses on the Monte Carlo simulation results identify the parameters that have the strongest influence on the estimation of risk. Results of the sensitivity analyses in association with the parameter uncertainties are used to identify the key uncertainties and knowledge gaps.

The Quantitative Biological Risk Assessment Tool (QBRAT) has been used in the past for the Round Goby (*Neogobius melanostomus*) in Lake Simcoe, Ontario (Cudmore and Koops 2007), marine crabs (Locke and Klossen 2007), tunicates (*Ciona intestinalis*, *Styela clava*, colonial species *Botrylloides violaceus* and *Didemnum* spp., Herborg and Therriault 2007), and the marine algae known as dead man's fingers (*Codium fragile ssp. Tomentosoides,* Drouin and McKindsey 2007), and the spiny water flea (*Bythotrephes longimanus*) in Muskoka (Johannsson 2007). This tool was revised based on results from previous case studies.

Table 1. Impact categories and descriptions

Impact Category	Description
Negligible	Undetectable change in the structure or function of the ecosystem. No management action required.
Low	Minimally detectable change in the structure of the ecosystem, but small enough that it would not change the functional relationships or survival of species. Unlikely to affect management of the ecosystem.
Moderate	Detectable change in the structure or function of the ecosystem that would require consideration in the management of the ecosystem.
High	Significant changes to the structure and function of the ecosystem leading to changes in the abundance of native species and a need for management to adapt to the new food web. May have implications beyond the extraction or use of ecosystem resources.
Extreme	Impacts that restructure the ecosystem resulting in, for example, the extirpation or extinction of at least one species and the need for significant modification of the management of the ecosystem. Will probably have implications beyond the extraction or use of ecosystem resources.

Table 2. Relative uncertainty categories

Level	Uncertainty Category
± 10%	Very high certainty (e.g., extensive, peer-reviewed information)
± 30%	High certainty
± 50%	Moderate certainty
± 70%	Low certainty
± 90%	Very low certainty (e.g., little to no information; expert opinion)

Discussion

Q. Would it be possible to get existing probabilities and compare the results of the program with an established case study?

A. This has been done with an Asian carp assessment. The methodology used was qualitative and it gave comparable results between the two. This method is a way of structuring your uncertainty and it provides the information needed to develop a framework to work from. It is a good method for a range of users. You need to have a basic knowledge of risk assessment, but it does have flexibility for quantitative analysis. The method also takes into account how much information you have on a species; you can either use relative certainties or absolute uncertainties. It takes into account a lack of information on distribution; you can make choices.

For the analysis of *Hemimysis*, a uniform distribution was used however, other distributions were tested. This is something that can be experimented with to see if the uncertainty significantly influences the assessment of risk. If there is a lack of confidence about certain parameters that have been used, they can be altered to determine the impact on the risk assessment.

The risk assessment approach provides information for both science and management. You can determine the areas where further research is required to fill in the knowledge gaps, and for cumulative risks, where more resources need to be invested to reduce the risk.

Q. What is the timeframe for this risk assessment?

A. A timeframe needs to be established. It is specified as 5 years.

BIOLOGICAL SYNOPSIS OF THE BLOODY RED SHRIMP (*Hemimysis anomala*)

A version of this presentation has since been published in Marty (2008).

Comments on Biological Synopsis

Much of the Russian literature on *Hemimysis* has been translated by Igor Grigorovich and his wife. This provides us with very useful information.

It has been determined that the body size of *Hemimysis* is larger in North America, reaching 16 mm in size.

There is an unusual situation in the Ponto-Caspian where *Hemimysis* has an Endangered status, although we do not know why at this point. There are two possible explanations – predation and/or a parasite or virus in its native range that is reducing its density. This was speculative although some specimens appeared to have parasites.

There was some discussion about the swarming habit of Hemimysis. According to some literature, swarms may be juvenile, although it is more likely related to predator avoidance and there may be mature individuals in the swarms.

CURRENT STATUS OF *Hemimysis* IN CANADA

Overview

The bloody red shrimp (*Hemimysis anomala*) was identified as a species that would potentially be introduced to the Great Lakes with possible significant impacts (Ricciardi and Rasmussen 1998), and is the latest non-native species to be discovered in the Great Lakes (Pothoven et al. 2007). Hemimysis was first identified in the Great Lakes in 2006, though anecdotal evidence suggests it has been present since 2002. A concerted sampling effort in 2007 identified 15 additional sites around lakes Michigan, Erie and Ontario where Hemimysis were present.

Discussion

A question was raised as to whether there were two separate inoculations of *Hemimysis* into the Great Lakes. It is unknown how many introductions there have been and there is also a good chance that they have been spread once in the Great Lakes. None have been found in the Huron/Erie corridor but this may be because they prefer low flow habitats. It was agreed that this area should be sampled more strenuously to determine if there is a continuous distribution between lakes Michigan and Erie. Unfortunately, there are limited ports where you can gain access in Lake Huron. Ricciardi (2006) predicted an invasion for the St. Lawrence River, however, this area has not yet been sampled. Perhaps Environment Canada could be contacted for this work; bottle traps could be given to them for sampling. This will occur if there is funding available.

Q. Were *Hemimysis* found in fish gut samples?

A. Yes, they were found in Alewife (*Alosa pseudoharengus*), Channel Catfish (*Ictalurus punctatus*), Emerald Shiner (*Notropis atherinoides*), Rock Bass (*Ambloplites rupestris*), White Perch (*Morone americana*) and Yellow Perch (*Perca flavescens*) in lakes Erie, Michigan and Ontario.

Benthic samples were conducted using sleds that have a structure allowing the net to be set at different heights. It would be very useful to determine how far off the bottom *Hemimysis* can be found. These sleds can be dragged for a set distance; much more water is filtered through the nets once they are off the bottom. It needs to be set fairly high for rocky areas. A series of nets could be dragged at the same time at various heights to determine where *Hemimysis* may occur in the water column. It is critical to determine the best way to sample for *Hemimysis*; the perfect sampling solution has yet to be found. It is a complex situation and this has limited our ability to detect new occurrences. It would be useful to get biologists who sample larval fishes to also look for *Hemimysis* when they are conducting nearshore tows at night. This is how *Hemimysis* was discovered in Oswego, Lake Ontario.

There are many sampling gaps in lakes Huron, Superior and many inland lakes. This would be an ideal opportunity for outreach and awareness programs for aquatic invasive species. Marinas and school groups could become involved.

It was found there was greater success in catching *Hemimysis* when bottle traps were left for extended periods of time. It was thought that bottle traps would be a waste of time and that a net tow would be quicker and more efficient. However, some modifications have been made to the bottles so they fill more quickly. Fish flakes are added to the bottom and both larval fishes and *Hemimysis* are captured. Bottle traps are well worth the effort particularly if you are staying in a locality overnight. *Hemimysis* are best caught when it is dark, without moonlight. It is still necessary to determine how far from shore they are dispersed and if there is a spatial overlap with *Mysis* sp. It is unlikely that there is a spatial overlap between *Hemimysis* and *Relicta* sp. except perhaps in winter. They have been found as far out as 20 m depths. They have been found swarming during daylight in 2.4 m water depths, similar to Mysis that swarm during the day for predator avoidance and then spread out at night. Swarming has implications with regard to transferring *Hemimysis* between water bodies and this needs to be taken into consideration. Swarming also has implications for sampling as one can find them in great densities in one spot and absent a short distance away. Twenty five crews will be sampling inland lakes and invasive species monitoring will be incorporated into this. There will be night sets and night hauls included as well. Five hundred lakes will be sampled over the next five years and DFO staff will be able to examine any samples that may have invasive species.

It would be worthwhile to improve public awareness in Canada. The US National Oceanographic and Atmospheric Administration (NOAA) have an opportunity for people to report occurrences of invasive species. In Ontario, there is a program that includes kits to promote public involvement with anglers, cottage associations etc. There is also a toll free line and a hotline. A Watchcard could be added to the kits as *Hemimysis* are fairly distinctive. DFO is presently working on a national database; however, this will not be available to the public for some time. The database is being loaded into ‘Biotics’ and will have an aquatic invasive species aspect to it.

Data suggests that it has been present in the Great Lakes for longer than first thought. It was predicted by Ricciardi and Rasmussen (1998) to invade the Great Lakes. The highest densities are found in Lake Erie but swarming has not been observed. There have been no reports of the telson being found in the sediment although there is not a large dataset on this aspect.

RISK ASSESSMENT COMPONENTS

Discussion Regarding Arrival

A comment was made that since *Hemimysis* is rare in its home range that it is unlikely to have been imported as fish food. It has also been noted that invasive species are not necessarily found where they are released with ballast water.

A comment was made that too much emphasis is put on alternative mechanisms of introduction such as the aquarium trade. Unless *Hemimysis* has been reported in the aquarium trade in North America, it should be downplayed. Also, while stocking was very popular in the Soviet Union in the 1950s and perhaps 1960s, it was sharply curtailed thereafter, so even spread in Europe is hard to reconcile via 'aquaculture".

A comment was made in reference to the statement "Live mysids (a marine species, not *Hemimysis*) have been sampled from the ballast tanks of trans-oceanic ships." It would be useful to know the salinity of the water in the vessels with live mysids. The vessels must have been NOBOBs from Europe.

Discussion Regarding Survival

Q. Have there been any experiments indicating mortality at low temperatures?

A. Only field observations, although individuals could have been hiding and not observed. This is an important aspect for the risk assessment as is survival over winter as *Hemimysis* does not have any resting stages. It is also expected that they could survive in higher salinities than is listed, at least for a short period of time.

It is thought that the presence of zebra mussel (*Dreissena polymorpha*) may favour the establishment of *Hemimysis*, particularly in lakes with a sandy substrate such as Lake Michigan. *Hemimysis* prefers hard structure that the zebra mussel would provide. However, the zebra mussel will also compete for phytoplankton with the juvenile stage of *Hemimysis*.

Discussion Regarding Spread

Q. Has it been determined what constitutes widespread, is it moving within a lake, or moving from Great Lake to Great Lake?

A. Widespread would be moving from lake to lake for inland lakes, but moving within a lake for the Great Lakes; these definitions need to be made clear. There is no clear cut definition as it depends on the boundaries being set for each specific area of study.

A comment was made that without parthenogenesis, swarming behaviour may be a pre-requisite for sexual species to have any reasonable probability of establishment. Cues that determine swarming behaviour in *Hemimysis* need to be established. Invasion could potentially be hindered if induced swarming allowed for management intervention. Because it is not parthenogenetic, it might be possible to impair population growth either through massive collections or native planktivore stocking to knock out incipient invasions.

Q. Were there any calculations that took into account currents and how long it might take *Hemimysis* to spread?

A. No, this was not calculated although similar work done by Sarah Bailey on the Great Lakes might be useful. Joe Atkinson is trying to get information on movement via water currents. It should be possible to predict where something is going to end up if you know where it entered the system. NOAA is using something to trace movements in relation to beach closures. It has been suggested that most of the ballast water is being dumped in ports and not offshore, which would aid the invasive *Hemimysis*. Localities where *Hemimysis* has been found are not typical for vessel discharge.

There was an aquarium website that mentioned people going to collect *Hemimysis* for their home aquaria so this could possibly be a vector. In small streams in Europe, birds are considered to be vectors. In Ontario, Osprey have been observed dropping fishes into different localities from where they were picked up. Air transport would kill *Mysis relicta*, but perhaps not so for *Hemimysis*. An occasional flooding event that connects water bodies may allow for dispersal to smaller water bodies.

Discussion about Impact

It is not just how widespread an invasive species is that determines its impact, abundance must also be considered. The fact that we see them all around the lake makes them widespread. Will we see lots of swarms and high densities of *Hemimysis* as we see in reservoirs or will we continue to see low densities? And will that mean a lower impact? There is also the difficulty of not knowing what the widespread impacts will be. Maybe the next step is to catch females with eggs to measure the length and predict the number of eggs/brood. This would aid in determining the likelihood of densities.

The impact of *Hemimysis* is assessed based on changes in the function and structure of the ecosystem. Extirpation of a species could occur without affecting the function of an ecosystem, but it would affect the structure.

Q. If there was both extirpation and replacement in the functioning of the ecosystem, would this impact be considered as extreme or negligible?

A. It would likely be labelled as extreme because of the extirpation, even if the function remains the same. Both extirpation and replacement have weight and the native biodiversity and structure have changed. This would be a significant impact; similarly changes in function can cause extreme changes so they would both be labelled as extreme. Both structure and function can change independently, and effects can range from negligible to extreme.

A comment was made that the terms ‘structure’ and ‘function’ of the ecosystem need to be defined more clearly.

Q. Is the structure relating to species composition or species richness?

A. Both.

Q. Is the function referring to energy transfer, primary or secondary productivity?

A. All. There was no ecosystem risk modeling as there was insufficient data to do it.

Widespread to local occurrences of *Hemimysis* make sense if the impact changes from low to moderate. There will likely be detectable changes in the ecosystem, but will it be enough to affect the management of the ecosystem? Maybe wider probabilities need to be put between these. *Hemimysis* is a nearshore predator that will affect zooplankton and this will likely be detectable. In Europe, widespread occurrences were mainly because of intentional introductions and the food web collapsed, which would be considered an extreme situation. The collapse was difficult to confirm but reduced fish production was observed. These studies in Europe are important and they need to be examined further.

Although decreased phytoplankton has been observed in England, an increase in phytoplankton has also been suggested but not observed. *Hemimysis* also may disrupt the silica cycle, however, it is not known why. Massive accumulations of silicon on pipes have been observed in Dutch reservoirs invaded by *Hemimysis*. This would suggest altered dynamics of diatoms. So, another potential indirect mechanism by which fishes could be affected is altered availability of desirable phytoplankton that are consumed by either zooplankton (in turn becoming *Hemimysis* prey) or *Hemimysis*. Silicon monitoring should be added to programs of water quality assessment if it is not presently done.

Although there has been no evidence of any impact to the food web in the Great Lakes, it may be too early to detect. Studies in Europe indicate that it had moved from its native range to all of Western Europe between 1998 and 2004. Impacts on the food web have been documented in Europe. We are in a good position to detect the impact of *Hemimysis*. In Europe, *Hemimysis* had one of the highest impacts of any mysid.

The studies on *Hemimysis* from Europe were conducted in small lakes. Research from the Baltic Sea indicates that *Hemimysis* has not had much impact; it shows up occasionally, but never in really high abundance. There are however, quite a few mysid species in the Baltic and this could explain why there is a low impact *Hemimysis* is unlikely to affect phytoplankton density. However, there may be a decrease in macro-phytoplankton and an increase in micro-phytoplankton

The zooplankton decline and resulting increase in phytoplankton biomass resulting from *Hemimysis* invasion is likely a top down or predation release rather than a competition release. If benthic *Dreissena* consume a disproportionate amount of phytoplankton, then loss of zooplankton to *Hemimysis* is not likely to result in any significant increase in phytoplankton biomass (or production). Production is probably already high, and biomass is set by benthic grazers. What is expected is a switch from macrozooplankton to microzooplankton (e.g., rotifers and perhaps protozoa) if large *Cladocera* are suppressed by *Hemimysis*. Also, Round Goby would only benefit from the enhanced *Dreissena* production if they are currently food-limited. No evidence of this has been seen in the Great Lakes. Sufficient evidence exists from Europe to suggest at least strong local impacts.

As the Great Lakes have never before experienced a littoral mysid, we do not have anything to use as a comparison, but there is likely to be an extreme impact. There are no similar examples from large lakes, only reservoirs. There is also the question as to how it will interact with invasives that are already in the Great Lakes. We do know that they eat *Bythotrephes* as adults, but are also eaten by *Bythotrephes* when they are young. Most are between 1-2 mm in June in Lake Michigan, small enough to be consumed by *Bythotrephes*.

There have been *Bythotrephes* in Lake Ontario for 20 years, with population numbers vacillating, and their impact is still being determined. It is unknown if their population numbers have hit a maximum or if they are still increasing. It will take a few more years of monitoring to determine this.

Q. Is there any evidence from European studies of enhancement of fisheries after *Hemimysis* addition?

A. Russians commonly introduced *Hemimysis* to enhance fisheries. There are no known unexpected results owing to alternative trophic interactions in Scandinavia, western Canada, and Montana when *Mysis relicta* was introduced.

Q. Is there evidence from subsequent assessments if the stocking worked? Do we know if this exists for *Hemimysis* as well?

A. If the fish catches did go up then food enhancement for adult fishes appeared to be more important than any suppression of larval fishes that may have occurred.

If there are a lot of fishes in the system, *Hemimysis* will be picked off rapidly. There is still a lot of uncertainty, however, non-native fish species such as Chinook Salmon (*Oncorhynchus tschawitscha*), Alewife (*Alosa pseudoharengus*) and Rainbow Smelt (*Osmerus mordax*) will likely benefit from this food source.

There will likely be a high impact, but there is an uncertainty of what that impact will be. It may be a top down effect, which will impact phytoplankton; however, it could also be a widespread but low impact if densities remain low. It is not our knowledge base that is drawing conclusions at this point, but rather the rationale behind the probabilities. If we could get data from the Ponto-Caspian region our probabilities would be stronger. Another possibility would be to follow the introduction of *Neomysis* on the Pacific coast.

The final parameter estimates decided on for the Great Lakes are given in table 3.

Table 3. Parameter estimates for the risk assessment of H. anomala *in the Great Lakes. Overall risk to the Great Lakes is moderate to high and uncertainty is low to extreme.*

Parameter		Estimate	Certainty
p1	Probability of Arrival	1	Very High
p2	Probability of Survival	1	Very High
p3	Probability of Establishment	1	Very High
p4	Probability of Spread	1	Very High
I1	Impact of Non-arrival	Negligible	Very High
I2	Impact of Non-survival	Negligible	Very High
I3	Impact of Non-establishment	Negligible	Very High
I4	Impact of Local Invasion	Low - Moderate	High
I5	Impact of Widespread Invasion	Moderate - High	Moderate

INLAND LAKES RISK ASSESSMENT COMPONENTS

Discussion

Q. Is *Hemimysis* being spread by livewells?

A. Most fishermen indicate that they clean their livewell once they return home; however, it is usually not done immediately. Often livewell water is dumped from lake to lake. Bilgewater is less of a threat as it is usually mixed with oil and gas and it is unlikely *Hemimysis* would survive. It has been found with *Bythotrephes* that there is a high movement of propagules from Lake Ontario to inland lakes. The biggest concern now might be movement of boaters out of Lake

Ontario to inland lakes. There still are very high levels of movement from Georgian Bay to the biggest lakes in Muskoka, however, we would not expect this to be an inland source until such time that *Hemimysis* is established in nearshore Georgian Bay.

Are there any literature reports of density dependent mortality in this species? It would seem plausible that predation of young or cannibalism could occur, or anoxia would occur under very high densities.

We need to determine if *Hemimysis* can survive travelling through bilge pumps because the probability of them surviving this may be zero.

Q. Do we know if they are found in amongst plants?

A. They are generally found in macrophyte beds.

We need to add a question to the boaters survey regarding their movement between the Great Lakes and inland lakes. If they do move between the two, then how frequently? Commercial harvest needs to be considered as well. If a commercial fisherman catches bait and houses it in a holding tank at a facility, the fishes become calm enough to feed and they may eat any *Hemimysis* in the tank. If an angler catches bait and puts it in a bucket short term, these fishes may be unlikely to eat. There are new laws to restrict the dumping of bait buckets in a water body; we need to include dumping near the water body as well.

Is the probability of establishment the same in inland lakes as it is for the Great Lakes? In addition to low inoculum load, there is also the issue of biological integration. Is littoral planktivory typically lower or higher in inland lakes than coastal Great Lakes? If it is higher the establishment probability would be even lower.

The definition of geographic extent needs to be determined; if it is widespread only throughout one inland lake then this should be considered as local, if it is spread throughout multiple lakes it is widespread. We could consider the impact of *Hemimysis* to be the same in inland lakes as it is in the Great Lakes, however, the impact could be more significant in the littoral zones of small lakes and the effects could be greater. Also, shallow lakes could be completely colonized, depending on the substrate of the lake. Perhaps pond experiments would be appropriate as long as it is a closed containment. The Experimental Lakes Area (ELA) cannot be used, even for mesocosm experiments, with novel species.

Q. Would a widespread invasion in inland lakes be considered a high or extreme impact?

A. The impact would be considered as one step higher in terms of severity. Small lakes are also warmer. With fewer species in the food chain, impacts are usually greater. Probabilities used here are based on European data, so they should be kept as they are for now; the rationale behind the moderate impact probability is the localized aspect of the impact. Indications are that the impact would be greater in a small lake versus a large lake.

Q. Do you mean each inland lake or multiple lakes? Are you comparing one lake to the watershed?

A. Widespread in Ontario would be many lakes, whereas, localized would be one lake. This part of the risk assessment is linked to all of the inland lakes in Ontario; local would be one or a few lakes that are contained. It would only affect those lakes and the overall impact on all lakes would be minimal. Widespread means the overall impact on all lakes would be high.

The chance that they will become established in the lake needs to be multiplied up by a dramatic number because of the 250 occurrences per year. This would place it over a moderate risk. Changing it to 0.75 based on Muirhead and MacIsaac (2005) you get similar results.

Although this puts the range high, the average is still moderate risk. The spike means that many runs come out at that value but the distribution is not even.

The results between inland lakes and the Great Lakes corresponded well to our expectations. The next step is to finalize the biological synopsis and workshop proceedings including all discussions, decisions, and outcomes to make sure everything is captured and there are no misinterpretations. We will publish the results and put them on the CEARA website.

The final parameter estimates decided on for inland lakes are given in table 4.

Table 4. Parameter estimates for the risk assessment of H. anomala *in inland lakes. Overall risk to inland lakes is low with negligible to moderate certainty.*

Parameter		Estimate	Certainty
p1	Probability of Arrival	1	Moderate
p2	Probability of Survival	1	High
p3	Probability of Establishment	0.4	Low
p4	Probability of Spread	0.75	Very Low
I1	Impact of Non-arrival	Negligible	Very High
I2	Impact of Non-survival	Negligible	Very High
I3	Impact of Non-establishment	Negligible	Very High
I4	Impact of Local Invasion	Moderate	Moderate
I5	Impact of Widespread Invasion	High	Moderate

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APPENDIX 1. PARTICIPANTS LIST

Participant	Affiliation
Kelly Bowen	Fisheries and Oceans Canada
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Antonio Velez-Espino	Fisheries and Oceans Canada
Maureen Walsh	United States Geological Survey

APPENDIX 2: TERMS OF REFERENCE

Terms of Reference

National Advisory Meeting

Hemimysis Risk Assessment

January 30, 2008
Burlington, ON

Chair: Becky Cudmore

Background

Many of the science issues facing Fisheries and Oceans Canada (DFO) are associated with significant knowledge gaps and uncertainties. This, however, does not relieve the department of the need to make decisions on these issues. Under these conditions, decisions must balance the risks and uncertainties while ensuring the sustainability of Canada's aquatic ecosystems. Risk assessment is the process of estimating the risk presented by a hazard, in either qualitative or quantitative terms, to aquatic ecosystems, fisheries resources, fish habitat, and aquaculture that DFO is mandated to manage and protect. DFO currently faces hazards from aquatic invasive species (AIS), climate change, and fish habitat alteration, with the potential for any or all of these hazards to impact species at risk (SAR), biodiversity, aquaculture, or fisheries resources. AIS are now considered one of the lead threats to native biodiversity (Sala et al. 2000, Dextrase and Mandrak 2006).

The *National Code on Introductions and Transfers of Aquatic Organisms* identifies risk assessment as central to the process of assessing proposals to move aquatic organisms. The *Canadian Action Plan to Address the Threat of Aquatic Invasive Species* identifies risk assessment as one of the implementation strategies to deal with the threat of AIS. By forming the Centre of Expertise for Aquatic Risk Assessment (CEARA), DFO has taken the first steps toward developing the necessary expertise in risk assessment across the country, building on expertise developed in Burlington at the Great Lakes Laboratory for Fisheries and Aquatic Sciences. To this end, one of the mandates and objectives of CEARA is to coordinate and advise on biological risk assessments conducted on priority aquatic invasive species of concern. One of these species is the bloody red shrimp, *Hemimysis anomala*, an AIS first identified in the Great Lakes in 2006 (Pothoven et al. 2007). A national risk assessment has been drafted for *Hemimysis* for Canada. The purpose of this peer review is to gather experts on mysids, aquatic invasive species or risk assessment to discuss and provide comments on the draft risk assessment in a face to face forum.

Objectives

The objective for this workshop is:

1. to peer review the draft national risk assessment for *Hemimysis* following the Canadian Science Advisory Secretariat (CSAS) peer review process.

The workshop will generate a proceedings report summarizing the discussion and decisions of the participants. This will be published as part of the CSAS Proceedings Series. The finalized national risk assessment for *Hemimysis* will be documented as science advice via the CSAS Series.

Location and Date

Canada Centre for Inland Waters, Burlington, ON, 30 January 2008

Participants

Participants (approx. 25-30) will include the CEARA Directorate, *Hemimysis* risk assessment team and individuals (from within and outside DFO Science) with relevant expertise in mysids or invertebrate invasive species.

Timetable

• January 2008 – biological synopsis, draft risk assessment and final agenda provided to workshop participants

• 30 January 2008 – peer review

• March 2008 – risk assessment finalized and submitted to CEARA and CSAS

• Spring 2008 – proceedings circulated to workshop participants for review

• Summer 2008 – proceedings finalized and submitted to CSAS.

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