



SCIENCE ADVICE FROM THE RISK ASSESSMENT OF THE INVASIVE BLOODY RED SHRIMP (*HEMIMYSIS ANOMALA*) IN CANADA



Photo credit: Kelly Bowen, DFO.

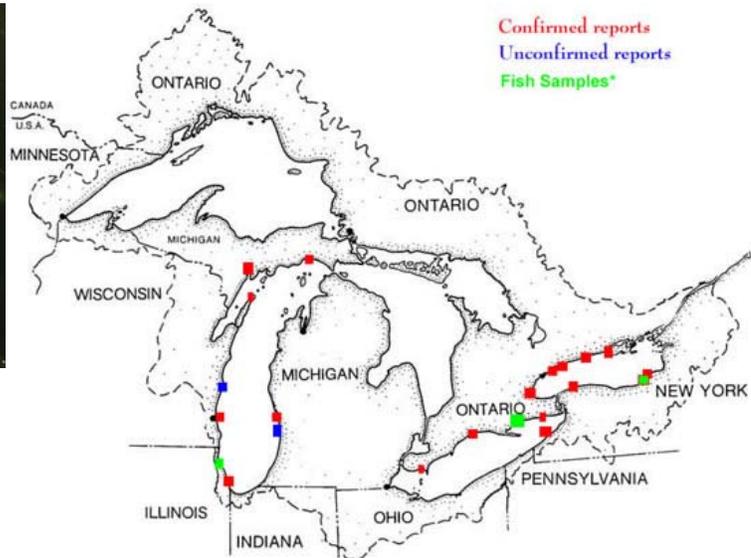


Figure 1. Map of *Hemimysis anomala* occurrence in the Great Lakes region. *Fish Samples are samples taken from the gut contents of fish which have been confirmed as *Hemimysis anomala*. Source: Marty 2008. Original source: NOAA, Great Lakes Environmental Research Laboratory web site (2007) (<http://www.glerl.noaa.gov/pubs/brochures/>).

Context

The bloody red shrimp (*Hemimysis anomala*) is a newly discovered potential aquatic invasive species (AIS) in the Great Lakes. It has the potential to negatively impact the ecosystems here, as has occurred in other regions where it is invasive, including Europe. Individuals of this species were first discovered in 2006 in lakes Michigan and Ontario. However, the species may have been present for several years before this. Within the last few years, the presence of *H. anomala* in Lake Erie has also been confirmed.

Fisheries and Oceans Canada's (DFO) Centre of Expertise for Aquatic Risk Assessment (CEARA) set out to determine the potential risk of *Hemimysis anomala* on the Great Lakes and inland lakes ecosystems. This followed the guidelines established by CEARA for assessing the biological risk of aquatic invasive species in Canada.

This risk assessment examined *H. anomala* presence using the Quantitative Biological Risk Assessment Tool (QBRAT), which organizes information and facilitates a quantitative or semi-quantitative method of conducting risk assessments. The purpose of the risk assessment and its review at the national advisory meeting was to identify the risks involved in the species' spread and establishment and to inform a plan of action.

SUMMARY

- The bloody red shrimp (*Hemimysis anomala*) is one of the recent non-native species to be discovered in the Great Lakes. It is believed to have been introduced through ballast water.
- *Hemimysis anomala* is a species of mysid native to the Ponto-Caspian region, first identified in the Great Lakes in 2006, though anecdotal evidence suggests it may have been present since 2002.
- An ecological risk assessment was conducted to evaluate the risk from *H. anomala* in Canada, focusing on two geographic areas: the Great Lakes and Ontario inland lakes.
- *H. anomala* presents a moderate to high risk to the Great Lakes. Persistence over multiple years at some sites suggests it can survive, is established and has already spread within the Great Lakes to lakes Michigan, Erie and Ontario.
- The impact of a locally established population could be low to moderate, but with some chance of high impacts, particularly if the location is an important nursery for fishes.
- Widespread establishment of *H. anomala* has the potential to cause food web disruptions, as well as alter nutrient and contaminant cycling.
- *H. anomala* seems to prefer structure and are found most consistently next to docks. Activities around docks that will pick up and move water likely represent a higher risk of secondary transport of *H. anomala*. Transportation of live bait is one such activity.
- There is a high probability that *H. anomala* will spread to inland lakes. While uncertainty is high, if *H. anomala* were to become established in inland lakes it would likely impact food webs. The probability that *H. anomala* will become widespread in inland lakes will depend on which inland lakes are initially invaded.
- Understanding the factors that will control the abundance of *H. anomala* will be important for predicting the probability of establishment. Understanding what may limit *H. anomala* abundances will also help to refine estimates of potential impacts.
- Additional efforts should focus on detecting *H. anomala* and developing standard sampling methods specific to this organism. Monitoring for *H. anomala*, which began in 2007, will be expanded in order to assess *H. anomala* presence in the remainder of the Great Lakes.

INTRODUCTION

Aquatic invasive species (AIS) are costly to the economy and pose a significant threat to biodiversity and species at risk. AIS risk assessments undertaken by the Centre of Expertise for Aquatic Risk Assessment (CEARA) characterize the likelihood of a potential introduction and the magnitude of the consequences of that introduction, in either qualitative or quantitative terms. This is an important process to identify AIS that require increased intervention and management (DFO 2009).

The bloody red shrimp (*Hemimysis anomala*) is a mysid species native to the Ponto-Caspian region that has been introduced to many other parts of the world, where it has become invasive. *H. anomala* was first discovered in the Great Lakes in 2006, although the species may have been present for several years before its discovery. Its tendency to swarm, concealment behaviour, fast swimming speed and the resulting challenge of collecting it using traditional methods may have allowed it to establish without being detected. This also presents the potential for it to spread further to Ontario's inland lakes. This type of spread has occurred with invasive invertebrates in the past including the spiny water flea, *Bythotrephes longimanus* (MacIsaac *et al.* 2004). In Europe, impacts involving all trophic levels have been observed and

therefore, its reported presence in several of the Great Lakes presents a significant threat to the food web dynamics here. However, no such effects have been observed thus far. Possible impacts to food web dynamics are illustrated in Figure 2.

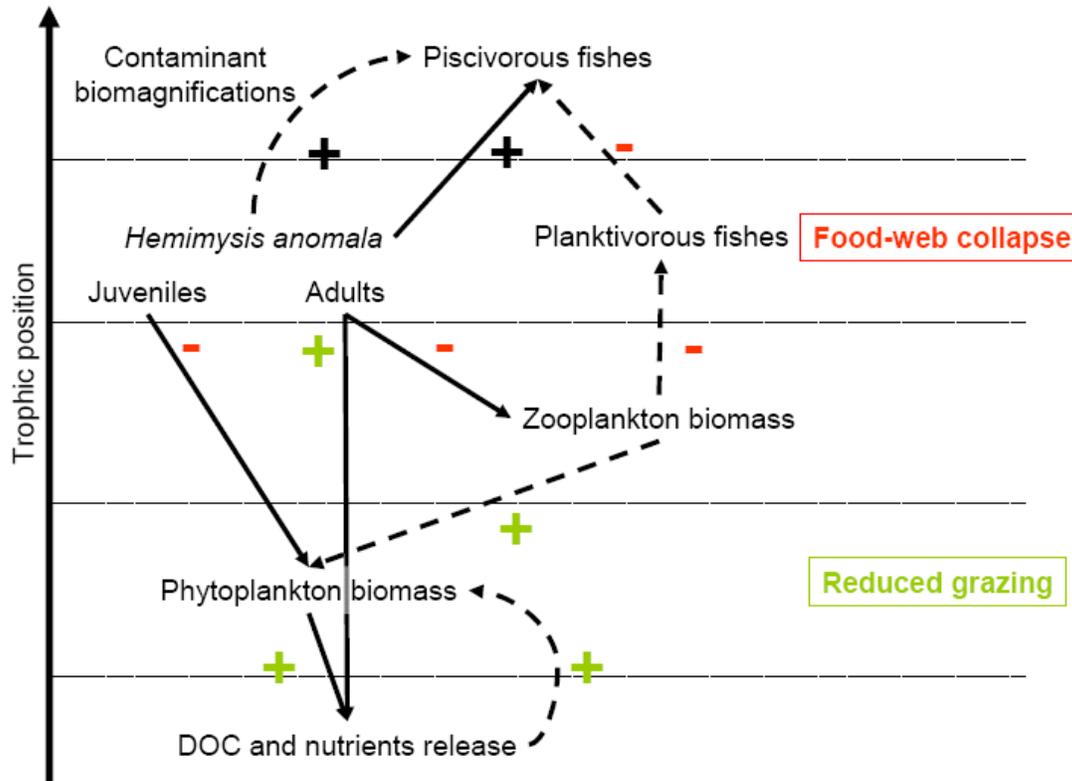


Figure 2. Trophic position of *Hemimysis anomala* in the food web and potential impacts (food web collapse, eutrophication and contaminant bioaccumulation) predicted for the Great Lakes (Marty 2008).

An increased understanding of *H. anomala* ecology in other regions, including its native range, where it is considered endangered, as well as in Europe, where it is invasive, could improve attempts to manage the invasion.

The risk assessment and its review at the national science advisory meeting took place to identify the risks involved in the species' spread and establishment in this area and to identify some of the mechanisms of spread. The outcome of the meeting and the advice from the risk assessment are intended to inform the development of an action plan.

ASSESSMENT

Potential Routes of Introduction

The most likely pathway of introduction is through the ballast water of transoceanic ships. This would explain the transport of this species from the Ponto-Caspian region to the Great Lakes, and because *H. anomala* can tolerate a wide range of salinities, it is likely able to tolerate the environment within ballast tanks for long periods of time. Introduction of the species could also have occurred by intentional introduction to improve fish production, or through boat bilge water.

However, there is no evidence of organizations illegally introducing this species to enhance fish production in the area nor is there evidence that the bilge water of small boats carried this species from its point of origin to the Great Lakes.

Distribution

Originating in the Ponto-Caspian region, *H. anomala* was intentionally introduced to various water bodies in Eastern Europe to increase fish populations. The species continued to spread throughout the latter half of the 20th century, both through invasions and intentional release, across Europe and eventually to the Great Lakes. In Canada, *H. anomala* has been observed in lakes Michigan, Erie and Ontario since 2006. This species is generally found at low population densities (less than 6 individuals/L) but have also been observed to swarm, reaching densities of more than 1500 individuals/L. *H. anomala* is generally found associated with hard surfaces, such as near docks, rather than on soft surfaces or in densely vegetated areas.

Biology

H. anomala is pale yellow or translucent in colour, with red in the carapace and telson regions, due to the presence of chromatophores; this colouration can vary with light and temperature changes. Lengths range between 11 and 16.6 mm for females and 8 to 10 mm for males depending on time of year. Individuals have a truncated telson with spines along its entire margin and a wide, straight posterior margin. *H. anomala* is omnivorous and will readily consume zooplankton or phytoplankton based on availability, time of day and stage of development.

Juvenile *H. anomala* consume a higher proportion of phytoplankton and adults consume a higher proportion of zooplankton. They reproduce sexually, reaching maturity at approximately 45 days, and reproducing between April and October. Females begin carrying eggs when the temperature reaches 8-9°C and newly hatched young appear at 11-12°C (Marty 2008). Among European populations, it is possible to determine the number of eggs in a brood based on female length; this relationship could be investigated for Great Lakes populations to predict population production.

Habitat

H. anomala is a euryhaline species. In its native range around the Ponto-Caspian seas, it can be found in salinities between freshwater and 18‰, perhaps allowing it to survive the long trips in ballast water, thus facilitating its invasion of the Great Lakes. *H. anomala* has also been observed in a wide range of water temperatures, between 0° and 28°C but the ideal range is thought to be between 9° and 20°C.

Risk Assessment

Risk assessments can provide information on research needs and where funds need to be allocated to manage an invasion. To perform a risk assessment, several pieces of information are needed-- biological information, which is used to determine the potential of the species encountering adequate resources and its subsequent ability to survive, reproduce and spread, and information on vectors, which is used to assess the potential and likelihood of spread beyond the natural capacity of the species to expand its range (DFO 2009). The Quantitative Biological Risk Assessment Tool (QBRAT) (Moore *et al.* 2007) was used to conduct the risk assessment (Koops *et al.* 2010). This tool considers invasion as occurring in four parts: arrival, survival, establishment and spread. For each of these steps, the probability of occurrence, the

impacts and the uncertainty on these values must be approximated by the user (DFO in prep.). Risk Levels are described in Table 1.

Table 1. Impact categories and descriptions.

Impact Category	Description
1. Negligible	Undetectable change in the structure or function of the ecosystem. No management action required.
2. 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.
3. Moderate	Detectable change in the structure or function of the ecosystem that would require consideration in the management of the ecosystem.
4. High	Significant changes to the structure or 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.
5. 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.

Great Lakes

Arrival, Survival, Establishment: *H. anomala* has been demonstrated to have arrived, survived and established itself in the Great Lakes with very high certainty.

Spread: Based on monitoring of *H. anomala* in the Great Lakes in 2007, the species has already spread to multiple sites in lakes Michigan, Erie and Ontario with very high certainty.

Impacts of a Local Population: The impact of a local population becoming established in the Great Lakes may be low to moderate, but there is a chance of high impacts, especially if the site of establishment is a nursery for fishes.

Impacts of a Widespread Invasion: A widespread Great Lakes invasion, which has a moderate to high likelihood of occurrence, may involve alteration of the food web. Overall, this species presents a moderate to high risk to the Great Lakes, with low to extreme uncertainty (Table 2).

Table 2. 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 (Koops et al. 2010).

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:

Arrival: The probability that *H. anomala* will disperse from the Great Lakes to inland lakes (likely through bilge water or bait buckets) is 1, with a moderate certainty.

Survival: The survival of *H. anomala* once it arrives in inland lakes is equivalent to its survival rate in the Great Lakes and the certainty of this is high.

Establishment: The likelihood of *H. anomala* establishment in inland lakes is low for a single event but because of the high number of introduction events, the probability of establishment is high. The certainty is low.

Spread: The spread of *H. anomala* in inland lakes will depend on the lake in which it becomes established, as some lakes allow greater dispersal.

Impacts of Non-Arrival, Non-Survival and Non-Establishment: Because of its short lifespan, if *H. anomala* were not to establish a population in a given area, its impacts would be negligible and by extension, so are the impacts of non-arrival, non-survival and non-establishment. There is high certainty on this estimate.

Impacts of a Local Population: The impacts of a locally established (inland lake) population are moderate, with moderate certainty.

Impacts of a Widespread Invasion: The impacts of a widespread invasion are high and include a high probability of alteration of the food web. Overall, this species presents a moderate to high risk to inland lakes with low to high certainty (Table 3).

Table 3. Parameter estimates for the risk assessment of *H. anomala* in inland lakes. Overall risk to inland lakes is low with negligible to moderate certainty (Koops et al. 2010).

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

Sources of Uncertainty

Most of the uncertainty in the Great Lakes arises from the fact that the effects of a widespread invasion are unclear. In inland lakes, the main source of uncertainty is the likelihood of *H. anomala* establishing itself here.

CONCLUSIONS AND ADVICE

Hemimysis anomala is a species of mysid native to the Ponto-Caspian region, first identified in the Great Lakes in 2006, though anecdotal evidence suggests it may have been present since 2002. Since 2006, the species has been found in lakes Erie, Michigan and Ontario. It is believed to have been introduced through ballast water. From here, it threatens to expand its range to the remaining Great Lakes and to the inland lakes of Canada.

An ecological risk assessment was conducted to evaluate the risk from *H. anomala* in Canada, focusing on two geographic areas: the Great Lakes and Ontario inland lakes. *H. anomala* presents a moderate to high risk to the Great Lakes. There is also a moderate to high risk to inland lakes with moderate to high uncertainty. The probability that *H. anomala* will arrive in inland lakes is very high. Introduction effort is low for current secondary movement vectors; however, the cumulative probability of establishment is high. If *H. anomala* were to become established in inland lakes it would likely impact food webs. The probability that *H. anomala* will become widespread in inland lakes will depend on which inland lakes are initially invaded.

Widespread establishment of *H. anomala* has the potential to cause food web disruptions, as well as alter nutrient and contaminant cycling. Food web studies should be conducted to estimate impact. The impact of a locally established population could be low to moderate, but with some chance of high impacts, particularly if the location is an important nursery area for fishes. If a large population of fishes is present in the waterbody, *H. anomala* may be limited as a result of predation.

Additional efforts should be invested to detect *H. anomala* and develop standard sampling methods specific to this organism. Bottle traps, when left for long periods, caught many *H. anomala* individuals, particularly when baited. More sampling should be carried out across lakes Michigan, Huron and Erie to determine the distribution of *H. anomala*.

It would also be beneficial to increase our understanding of what causes swarming in *H. anomala*, as this behaviour may increase the chance that this species will be transported among water bodies. It is important to determine the spatial distribution of *H. anomala*, both in the water column and in terms of its distance from the shoreline. Understanding the factors that control the abundance of *H. anomala* will be important for predicting the probability of establishment. Understanding what may limit *H. anomala* abundances will also help to refine estimates of potential impacts. *H. anomala* seems to prefer structure and are found most consistently next to docks. Activities around docks that will pick up and move water likely represent a higher risk of secondary transport of *H. anomala*. Transportation of live bait is one such activity.

It may be possible to predict population densities by determining the length of females and estimating the number of eggs in a brood, as there is a defined relationship between these variables within the populations in Europe. Improved methods of detection and standardization of sampling methods for *H. anomala* would be beneficial to address this species' invasion.

OTHER CONSIDERATIONS

This risk assessment focused on movement of *H. anomala* to the inland lakes of Ontario but not beyond this. If the species begins to spread further inland from here, another risk assessment may be required to assess risk beyond the inland lakes of Ontario, and in the remainder of Canada.

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