State of Michigan's

Status and Strategy for Fishhook Waterflea Management

Scope

Invasive fishhook waterfleas (*Cercopagis pengoi*), native to the Black, Caspian, Azov, and Aral Seas of Europe and Asia, threaten the waters of the State of Michigan (Makarewicz et al. 2001). The goals of this document are to:

- Summarize current level of understanding on the biology and ecology of fishhook waterfleas.
- Summarize current management options for fishhook waterfleas in Michigan.
- Identify possible future directions of fishhook waterfleas management in Michigan.

Biology and Ecology

I. Identification

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The fishhook waterflea is a predatory crustacean of the order Cladocera: Onchypoda within the family Cercopagididae. Anglers in Lake Ontario first identified the fishhook waterflea in 1998, but they have since spread to Lake Michigan, Lake Erie, and a number of inland lakes. It is the only species of the genus Cercopagis that has spread outside its native range in the Ponto-Caspian region (Gutkowska and Paturej 2010). A small trunk and long caudal process is highly characteristic of this species. Body length ranges from 1.2-2.3 mm in females and 1.1-2.1 mm in males. The fishhook waterflea has no abdominal segmentation or carapace and the head is comprised of a large eye and a second pair of large antennae. It has four pairs of thoracic legs, the first pair being 3-4 times longer than the rest. Another characteristic feature of *C. pengoi* is a toothed loop at the end of the caudal process that is 3-7 times longer than the body (Rivier 1998, Duriš et al. 2000). Adult females are slightly larger than adult males and have a brood pouch on their back (Gutkowska and Paturej 2010).

II. Life History

Spring neonates hatch from resting eggs and are characterized by a straight, short caudal process with four, forward-facing tentacles. Summer neonates have a long caudal process with an s-shaped loop and either straight or backward-facing tentacles (Ojaveer et al. 2003). Body length of neonates ranges from 0.80-0.88 mm (Antsulevich and Välipakka 2000). Their caudal appendage often acts as a defense mechanism against young of year or gape-limited fish, but has little effect on large planktivores.

C. pengoi commonly reproduces via parthenogenesis during the summer, allowing them to establish new populations quickly without a large number of males; however, they also reproduce sexually later in the season. Eggs produced early in the season are delicate and susceptible to damage, resulting in low recruitment. When temperatures decline later in the season, females produce over-wintering, or resting eggs, through sexual reproduction, which are resistant to desiccation, freeze-drying, and ingestion by predators. If environmental conditions become inhospitable, females have been known to produce resting eggs at any time of the year. Resting eggs survive over the winter, replenishing the population in the spring when they hatch (Benson et al. 2014). Distribution of eggs by fishes has been documented within infested water bodies.

Regardless of geographic location, *C. pengoi* populations are characterized by a similar sex structure. Generations of parthenogenetic females, gamogenetic females and males, as well as juvenile forms make up this species (Gutkowska & Paturej 2010). Parthenogenetic females are the predominant sexual form (Uitto et al. 1999, Grigorovich et al. 2000, Polunina 2005), accounting for 92% in Lake Ontario (MacIsaac et al. 1999). The alternation of sexual and parthenogenetic generations, called heterogony, within the species is a defining characteristic (Panov et al. 2007), (Fig. 2). Parthenogenesis supports rapid population growth within short periods of time and likely contributes to their success as an invasive species (Gutkowska & Paturej 2010). *C. pengoi* populations usually peak in the mid to late summer before disappearing in late autumn to early winter. *C. pengoi* can survive relatively high salinities and has been documented in waters with 14 ppt salinity in its home range (Lake Drevno & Caspian Lake). The ability to survive such salinities likely allowed *C. pengoi* to survive in ballast water while crossing the Atlantic.

III. Diet

C. pengoi is a generalist feeder consuming large amounts of prey, which reduces the abundance of small zooplankton, adversely affecting planktivorous fish species. It preys on various species of cladocerans, copepods, rotifers, and both micro- and mesozooplankton, although it prefers to feed on small-bodied zooplankton as its primary food source. It is able to capture and handle prey ranging from the size of its own body to those seventeen times smaller (IUCN 2010). It is currently unclear whether *C. pengoi* is an energy sink or source, which needs to be understood to fully grasp the effects this species could have in the Great Lakes (Benson et al. 2013).

IV. Habitat

The fishhook waterflea has a high tolerance of temperature and salinity (Gutkowska & Paturej 2010), but seems to favor large oligotrophic or mesotrophic lakes similar to its relative *B. longimanus*, another Great Lakes invader. It is a pelagic species that often occupies open water and is generally found in the epilimion at depths between 5 and 30 meters in North America (Laxson et al. 2003, Karasiova et al. 2004). During the day, *C. pengoi* will migrate to lower depths, usually near the metalimnion/epilimnion boundry, but has been found as deep as 50-200m in the Caspian Sea (Gorokhova et al. 2000). Because it is a euryhaline species, it is capable of colonizing both freshwater and brackish water bodies with salinity up to 14 ppt (Rivier 1998). This characteristic allows the species to have a widespread geographic range (Gutkowska & Paturej 2010). Populations usually peak when water temperatures warm to 20^{0}-25^{0} C and begin to crash once water temperatures drop below 16-13^{0} C. Sustained summer water temperatures of at least 15^{0}-16^{0} C seem to be required for successful establishment. Populations typically disappear when water temperatures drop below 10°C (Rivier 1998); however, *C. pengoi* has been observed at low densities at temperatures as low as 8°C in the Baltic Sea (Krylov et al. 1999). 30^{0} C appears to be the upper thermal limit for this species with severe population declines occurring above this temperature. Temperature is usually the main limiting factor of *C. pengoi's* invasion range.

V. Effects from Fishhook Waterfleas

Fishhook waterflea's ecological effect on colonized ecosystems has been evaluated based on changes in local zooplankton structures after invasion and through analysis of digestive samples from selected planktivorous species (Ojaveer et al. 2004). Because *C. pengoi* preys on native zooplankton, it competes with native zooplanktivores, affecting resident zooplankton communities with its selective predation in Lake Ontario (Benoit et al. 2002). *C. pengoi's* feeding preferences also contribute to eutrophication by freeing phytoplankton from the predation pressures of zooplankton (Uitto et al. 1999). These changes in ecology may result in enhanced algal blooms and major changes in higher trophic levels (IUCN 2010). The modification of local trophic levels this species causes could exert two effects on the food chain: competition with other planktivorous species that rely on the same nutritional sources or offering a dietary source for other organisms (Ojaveer et al. 2000, Vanderploeg et al. 2002). Due to *C. pengoi's* large size, it is preferred by large, planktivorous fish including the herring, sprat, and three-spined stickleback, all found in the Baltic Sea (Gutkowska and Paturej 2010). In the Great lakes, *C. pengoi* competes with alewife and rainbow smelt and is unpalatable to these fish because of its long spine. Alewife cannot consume *C. pengoi* until they reach their first year due to the long spine, resulting in direct competition between yearling alewives and the fishhook waterflea (Bushnoe et al. 2003). *C. pengoi's* establishment in 1998 in Lake Ontario corresponds with the lowest alewife populations in 20 years (Makerewicz et al. 2001).

The most severe effects of the fishhook waterflea invasion are felt by the fishing industry (Gutkowska and Paturej 2010). This large cladoceran attaches to fishing gear in dense clusters with the hook-shaped end of its caudal process, causing clogged nets and trawls, fouling the nets (Gutkowska and Paturej 2010, IUCN 2010). The removal of the waterfleas is costly, time-consuming, and has caused allergic reactions in fishermen cleaning fouled nets (Leppäkoski and Olenin 2000). Changes in the food web and energy transfer at lower trophic levels caused by *C. pengoi* are likely to be problematic to fish productions and stocks (Gutkowska and Paturej 2010, Gorokhova 2006, Ojaveer et al. 2001).

Current status and distribution in Michigan

C. pengoi became established in Lake Ontario in 1998 (MacIsaac et al. 1999; Makarewicz et al. 2001), Lake Michigan in 1999 (Charlebois 2001), Lake Erie and the Detroit River in 2001 (Vanderploeg et al. 2002, Kane et al. 2003, Laxson et al. 2003), and Lake Huron in 2002 (USEPA 2008). It was also found in Muskegon Lake east of Lake Michigan in the summer of 2001 (Therriault et al. 2002). A single specimen was found in Lake Superior in 2003; however, it is not believed to be an established population (Benson et al. 2014). According to MacIsaac et al. (1999) and Cristescu et al. (2001), the colonization of the Great Lakes by *C. pengoi* is almost certainly a result of transfer from the Baltic Sea via the water ballast of transatlantic vessels.

Twenty-eight sightings of *C. pengoi* were confirmed in 9 Michigan counties, including Alger (2), Benzie (2), Grand Traverse (4), Leelanau (2), Mason (4), Muskegon (2), Oceana (8), Presque Isle (2), and Wayne (2), according to the Midwest Invasive Species Information Network (MISIN) (Figure 2). According to the United States Geological Survey (USGS) database and as previously mentioned, *C. pengoi* has been found in Lake Erie, Lake Michigan, Lake Superior, Lake Huron, and Muskegon Lake (Figure 2).

Management of Fishhook Waterfleas

I. Prevention

In May 1993, the United States implemented a regulation method requiring inbound vessels to exchange freshwater/estuarine ballast with highly saline oceanic water after an increase in ship-borne exotic species in the Great Lakes. This should have greatly decreased vulnerability to invasion; however, the recent invasion of *C. pengoi* indicates that the regulations over water exchange were not effective and/or this procedure does not affect gametogenic eggs. (IUCN 2010). More rigorous regulations need to be developed to address this issue because ballast water is the main source of invasive species in the Great Lakes.

Bait and bait water should not be released into water bodies and should not be transported from water body to water body. Motors, bilges, transom wells, live wells, bait buckets, and fishing apparatus and gear should be rinsed and cleaned with hot water to help control the spread of adult *C. pengoi* and resting eggs (IUCN 2010).

Hot water (> 40°C), high pressure spraying, and drying of boats and recreational equipment for at least 5 days should be implemented before re-entering a water body. The cleaning and rinsing of boats and equipment will help control the spread of adult *C. pengoi* and should be the first line of defense (IUCN 2010).

Once *C. pengoi* has become established, it is very difficult to control their distribution and prevent spread. A major prevention measure that has been suggested is management of ballast water and cleaning of shipping equipment (Sea Grant 2004). Education and awareness of *C. pengoi* would also aid in preventing the spread of this species (Birnbaum 2006). Thorough inspection and cleaning of watercrafts and recreational gear can go a long way to prevent the spread of *C. pengoi*. Since sport fisherman are suspected to be one of the main invasion corridors, targeting this group with future outreach efforts is recommended. Bait and live wells need to be emptied on site and fishing equipment (rods, reels, nets, etc.) should be sanitized before being transferred to new sites. Currently there is no known method of eradication or control for *C. pengoi* (IUCN 2010). Because there is no way to eradicate a well-adapted population of *C. pengoi*, the best means of control is preventing the spread to adjacent bodies of water (Leppäkoski 2001).

II. Management/Control

No effective control methods exist to diminish established populations of planktonic invaders such as *C. pengoi.*

a. Biological

There are no true biological control methods for *C. pengoi*; predation has no measurable effect on populations and no species specific biological toxins have been developed. However, proper disposal and regulations of bait can prevent or slow the spread of this species. Since resting eggs can easily pass through the digestive system of most baitfish, bait should not be transferred between lakes.

b. Chemical

Chemical disinfection agents can be used to complement cleaning and drying of boat equipment and fishing gear to reduce the risk of spreading *C. pengoi* from one water body to another (Sea Grant 2004). Rotatone is the most common chemical used to kill *C. pengoi*, but is toxic to most aquatic organisms and open water applications are extremely limited.

Future Directions for Michigan and Fishhook Waterflea management

Prevention of spread into neighboring bodies of water seems to be the only way to manage *C. pengoi*, as eradication seems unlikely due to current population densities and distributions. Further investigation and analysis of what effects this species has on the fishing industry and North American ecosystems is needed to develop better prevention methods. Education and awareness of *C. pengoi* is essential in this area as citizens unwittingly transport *C. pengoi* to previously uninvaded waters. A reevaluation of ballast water regulations and efficacy needs to be done and new policies may need to be developed. Targeting ballast water will prevent additional species from entering the Great Lakes, while helping to control existing localized populations of invasive species.

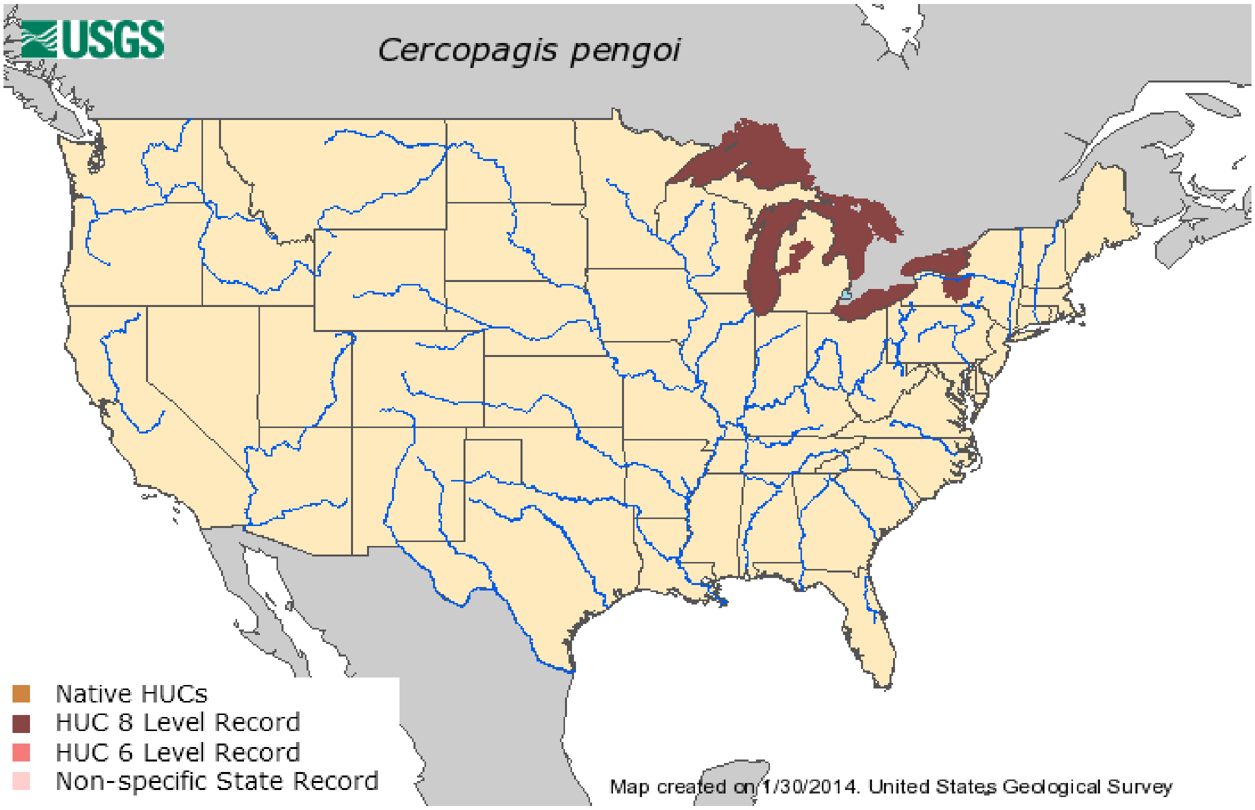

Figure 1. Distribution of fishhook waterfleas in the United States (Benson et al. 2014).

Michigan Counties with Fishhook Waterflea Detections

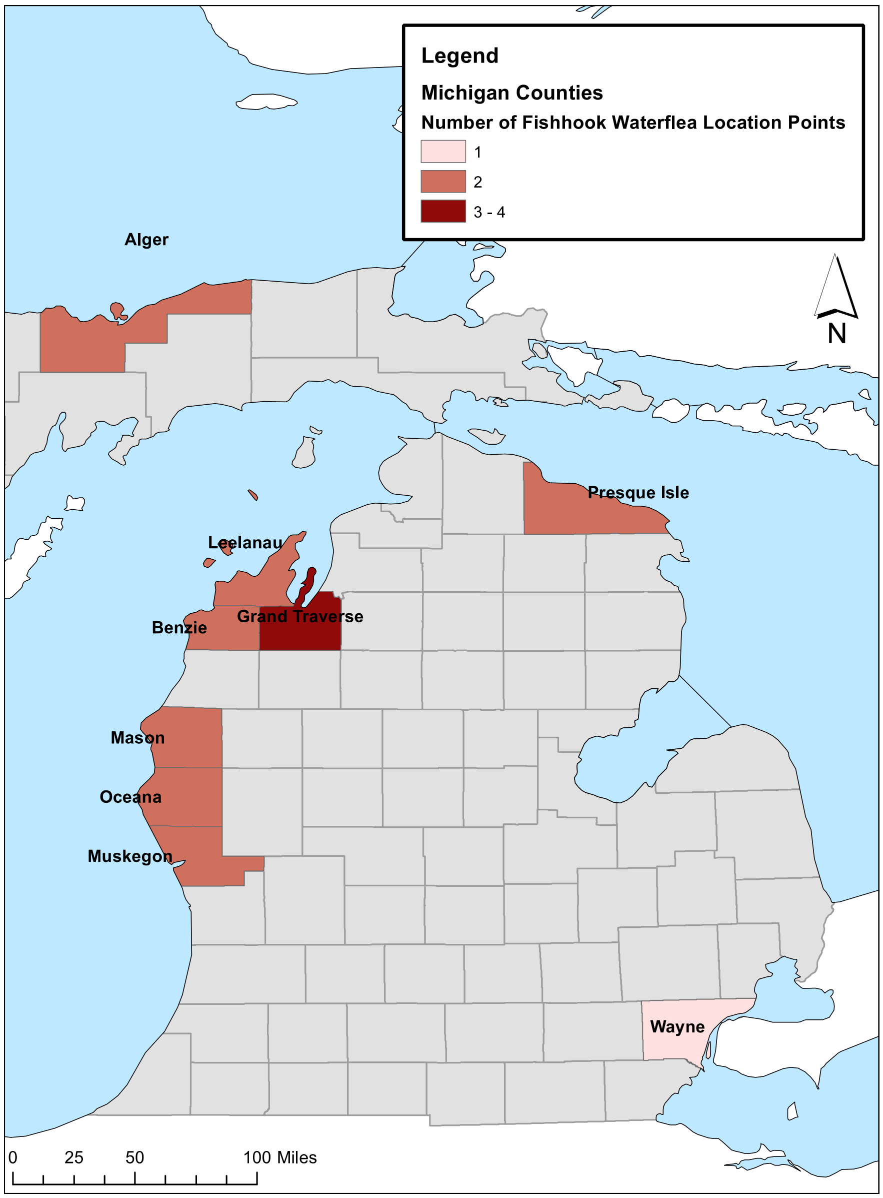

Figure 2. Number of unique coordinate location points within Michigan counties at which fishhook waterfleas were detected. This data is according to the United States Geological Survey (USGS), Midwest Invasive Species Information Network (MISIN), and Biodiversity Information Serving Our Nation (BISON) databases.

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