

State of Michigan's Status and Strategy for Asiatic Clam Management

Scope

Invasive Asiatic clams (*Corbicula fluminea*) threaten the State of Michigan's waters. The goals of this document are to:

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

Biology and Ecology

I. Identification

Corbicula fluminea is a freshwater bivalve mollusk that originates from Asia (Britton and Morton 1979, Mouthon 1981, Araujo et al. 1993). The species is known to be opportunistic, adapting to a wide range of lentic and lotic habitats and utilizing both filter- and deposit-feeding strategies (Way et al. 1990). *C. fluminea* is 2 to 3 cm in size and has the typical oval-triangular clam shape. It also has a centrally located umbo, a light-colored shell marked with concentric sulcations, a yellow-green to light brown periostracum, and finely serrated anterior and posterior lateral teeth (McMahon 1991). The range of dark shell morphs with periostraca ranging from dark olive green to black is limited to the southwestern United States (Foster et al. 2014).



II. Life History

Members of the *Corbicula* genus employ a variety of reproductive strategies (Motron 1986, Rajagopal et al. 2000, Kornuiushin and Glaubrecht 2003). *C. fluminea* is described as a simultaneous hermaphroditic species, with some documented cases of protandric sequential hermaphroditism in early stages of reproductive maturity (Rajagopal et al. 2000). Fertilization occurs inside the paleal cavity with larvae brooded in the inner dermibranchs (Qui et al. 2001, Foster et al. 2014). Larvae are released into the water column and subsequently anchor themselves to sediments, vegetation, or hard surfaces via a mucilaginous byssal thread structure (Cataldo and Boltovskoy 1999, McMahon 2000). Although they prefer sand or gravel, they will still attach to silty or hard substrates (McMahon 1999). Individuals may become suspended in the water column with sufficient turbulence, dispersing them downstream (McMahon 2002). At the time of release, juveniles are approximately 250 µm in length. Despite their small size, juveniles are equipped with a fully

developed shell, adductor muscles, foot, statocysts, gills, and digestive system (McMahon 2002). Maturation occurs within the first 3 to 6 months, allowing the shell to grow to a length of 6 to 10 mm. *C. fluminea*'s life span is variable, typically ranging from 1 to 5 years (McMahon 2000). The timing of commonly observed bivoltine reproductive periods varies regionally, but the first event generally occurs in late spring to early summer and the second in late summer to early autumn. Singular annual reproductive events have also been recorded and as many as three separate cohorts may be produced in a single season, with variation between years within the same site (Doherty et al. 1987, Darrigran 2002). Water temperature (Hornbach 1992, Rajagopal et al. 2000, Mouthon 2001b) and food resource availability (Cataldo and Boltovskoy 1999, Mouthon 2001a, Mouthon 2001b) have been identified as key determinants of the timing and number of reproductive events in a given year. Sustained water temperatures of 15 to 16 °C are necessary for their reproduction. Asiatic clams are very resistant to desiccation and can survive extended periods in moist sediments thus eliminating water drawdowns as a management method.

III. Diet

C. fluminea employ filter and deposit-feeding strategies, deriving nutrition from organic matter in bottom sediments through deposit feeding or from suspended organic matter including phytoplankton, microzooplankton, and even their own veligers through filter feeding (Way et al. 1990). Filter feeding also facilitates the bioaccumulation of organic pollutants and heavy metals suspended in the water column by *C. fluminea* (Doherty 1990, Basack et al. 1997, Inza et al. 1997, Narbonne et al. 1999). Once food sources in the water column become depleted, *C. fluminea* transitions from filter feeding to deposit feeding (Scherwass and Arndt 2005). This versatility and a rapid rate of reproduction contribute to the clam's ability to quickly establish colonizing populations in a broad range of aquatic habitats. The clam also effectively grazes ciliates and is capable of shifting zooplankton communities to favor copepods by selectively removing rotifers (Beaver et al. 1991). A Lake Tahoe study found that diatoms comprised a consistently larger proportion of the Asiatic clam diet than plankton; this pattern was attributed to enhanced preservation of algal siliceous frustules rather than feeding selectivity (Way and Hornback 1990), further indicating the flexible nature of nutritional resources for *C. fluminea*.

IV. Habitat

Asiatic clams can be found on the benthic surface or slightly buried in streams, canals, both freshwater and brackish lakes, and in reservoirs with silt, sand, and gravel substrates. Factors impacting population density and the distribution of *C. fluminea* include temperature extremes, high salinity, desiccation, low pH, environmental pollution, and bacterial, viral, and parasitic infections (Evans et al. 1979, Sickel 1986, Foster et al. 2014). *C. fluminea* is highly pH and temperature sensitive, with no tolerance for freezing temperatures (Wildlife Forever 2013). Oxygen availability may be one of the most critical factors affecting population growth and distribution, with mature individuals requiring >70% dissolved oxygen saturation for survival (McMahon 1979). Due to this high oxygen demand Asiatic clams typically inhabit well-oxygenated streams and lake shallows. The maximum tolerable salinity for *C. fluminea*

is ~13 parts per thousand, but this concentration may only be withstood for a short time (Aguirre and Poss 1999). Favorable habitat must maintain temperatures within a range of 2 to 30 °C, a calcium concentration of at least 6 mg/L, and pH greater than 5.6. Despite these requirements, several natural characteristics (i.e. rapid growth, precocious sexual maturity, short life span, high fecundity, and extensive dispersal capacities associated with human activities) allow *C. fluminea* to quickly establish new populations in aquatic environments (McMahon 2002). In Michigan, winter water temperature could limit the range of Asiatic clams, especially in northern counties. Although they have been documented to survive in water temperatures as low as 2 °C, they prefer warmer habitats and will be unable to reproduce in such conditions. While they may be able to find refuge in warm water discharges, these areas are limited and should pose little threat for future spread.

V. Effects of Asiatic Clams

The most prominent effect of *C. fluminea* in the United States has been the biofouling of complex power plants and industrial water systems (Isom et al. 1986, Williams and McMahon 1986), at a cost of approximately \$1 billion per year (Foster et al. 2014). Individuals accumulate and clog irrigation canals and pipes. Juveniles may be introduced to condensers in power generating plants by water currents where they anchor themselves, grow, and eventually obstruct water flow entirely (Prokopovich and Herbet 1965, Isom et al. 1986, Devick 1991). Ecological impacts include altering the physical, chemical, and biological characteristics of the invaded water way. Asiatic clams decrease turbidity by filter feeding and are suspected to be a significant source of bioaccumulation when taking in suspended pollutants during feeding (Graney et al. 1983). These changes can alter the biota that inhabits the area leading to the disruption of benthic and pelagic community structure (Sickel 1986). This causes a decrease in aquatic birds and increased frequency of nuisance species and algal blooms. Drastic reductions in native species populations are also observed due to direct competition with *C. fluminea* for limited resources (Devick 1991).

Current Status and Distribution in Michigan

Likely introduced by Asian immigrants as a food item, *C. fluminea* first occurred in the United States in 1938 in the state of Washington (Counts 1986). Ballast water is also a suspected invasion pathway and is thought to be responsible for *C. fluminea* introduction in San Francisco Bay (Cohen 1998). Since the Asiatic clam's introduction, its range has expanded to include 38 states and the District of Columbia, with human activity being the primary means of dispersal (Foster et al. 2014, Figure 1). Twenty-one sightings of *C. fluminea* have been confirmed in 6 Michigan counties including: Kalamazoo (3), Macomb (1), Marquette (2), Monroe (10), Ottawa (3), and St. Clair (2), according to the Midwest Invasive Species Information Network (MISIN, accessed May 22, 2014)(Figure 2). According to the United States Geological Survey (USGS) database, *C. fluminea* has been found in Lake Erie at Sterling State Park, Bolles Harbor, and Detroit Beach within Monroe county; the species has also been found in Lake Michigan (at the J.H. Power Plant) and Lake Superior (at the Upper Peninsula Power Company) within Ottawa and Marquette counties, respectively (Figure 2). The clam has additionally been reported in the St. Clair and Kalamazoo Rivers (Figure 2).

Management of Asiatic Clams

I. Prevention

Due to a lack of effective eradication methods, prevention is the most important part of controlling Asiatic clams. Individuals of all life stages may become attached to watercraft/recreational gear. Examining waders, hip boots, fishing/scuba gear, and boats exiting infested water bodies for the presence of *C. fluminea* is the first line of defense against the expansion of Asiatic clam ranges (Wildlife Forever 2013). Boats should be thoroughly cleaned with hot water (>60⁰ C) and dried between uses, at boating access inspection sites, and at state lines. Informative signage at access points could advise users how to prevent and identify Asiatic clams along with other invasive species (i.e. proper bait disposal, removal of plant fragments, mud, and debris from equipment). Lake associations should be conducting regular monitoring of their lakes especially when removing or installing docks, buoys, and other waterborne hardware.

Screens and traps may be utilized to prevent adult *C. fluminea* from entering industrial water intake pipes as a means of mechanical control, (INDNR 2009) but regular cleaning will be required to remove juveniles that make it through the screens. Due to the clams' temperature sensitivity, hot water can be injected into pipes that contain them and increased water flow will deter additional juveniles from settling in pipes. Laws prohibiting the possession of Asiatic clams are in place in many states, but in Michigan. Reliable methods for detecting the planktonic larval stages need to be developed and implemented. Rapid response when clams are detected increases the likelihood that an infestation can be prevented; this has been documented in Lake Tahoe where bottom barriers were effectively used to eradicate small clam populations before they were able to reach unmanageable levels (Way and Hornback 1990). Monitoring can be carried out any time of the year, but ice cover makes winter monitoring difficult. A sample bag and a tool to detach clams is generally all that is required for most monitoring efforts. Adult clams should be easily identifiable with the naked eye, even while underwater or using SCUBA equipment. Kits similar to those used for zebra mussel veligers can be used for collecting clam veligers and are usually in the range of \$150 per kit. Unfortunately, processing can be relatively lengthy and the presence of veligers in high enough densities to be detected often means the problem is beyond the scope of eradication efforts.

II. Management/Control

Few options exist for the management of established Asiatic clam populations, due to the persistence of larval stages in the water column.

A. Chemical

Chlorination and bromination are the most common chemical control methods used for both juveniles and adults. Because the systems treated are usually once-through systems, toxicant levels must be low enough that the receiving water body is not adversely affected. In open water systems, chlorine and bromine treatments can cause

severe environmental damage if administered incorrectly and are closely regulated by environmental agencies, making private permits difficult to obtain (INDNR 2009). However, chlorine in particular can be very toxic to the clams resulting in mortality at concentrations as low as 0.25 mg/L when applied in standard laboratory conditions (25^o C) and 5 mg/L under cold conditions (15^o C), outperforming standard molluscicides. Unfortunately, this also results in mortality of native species since selective chemicals have not been developed.

B. Physical

For industrial control, hot water (>37 °C) can be injected into affected water pipes to clear them of all *C. fluminea* and increased flow will prevent juveniles from settling. Physical or benthic barriers and SCUBA assisted suction could provide mechanisms of control. Suctioning removes the adult clams through a vacuum and benthic barriers lower oxygen levels causing the clams to suffocate. Benthic barriers are usually thin rubber, plastic, burlap, or Mylar mats placed by SCUBA divers. They come in a variety of sizes usually at least 10' long by 10' wide but can be much larger. For example, the mats used in Lake Tahoe were 10' wide by 100' long and were made of thin rubber (Way and Hornback 1990). Organic coatings can be added to help accelerate oxygen depletion and specialized ports allow for dissolved oxygen levels to be measured. A number of anchors can be used to hold mats down; some of the more common methods are sand bags or steel rebar laid across the mats at regular intervals. Regardless of what method is used to secure the barriers in, it is important the seal is tight and checked on a regular basis, weekly at least. In shallow areas signage should be posted to prevent recreational users from disturbing or damaging the mats. On average, Asiatic clams treated with benthic barriers in warm water (> 15^o C) experienced 100% mortality after 28 days. When used at lower temperatures, benthic barriers can take up to 90+ days to kill clams through reduced metabolic rates. However, these methods can fail to control veligers if implemented after the reproductive events and may not properly control large reproducing populations. It should also be noted that benthic barriers that effectively increase *C. fluminea* mortality also increase total macroinvertebrate mortality for treated areas (Wittman et al. 2011).

Dredging is also an option but will remove native organisms and can still leave behind veligers or juveniles; it should be considered only after other options have failed and infestations have reached levels high enough to cause serious harm to the environment or associated facilities. Overall, benthic barriers seem to be the most effective and environmentally friendly option. However, they have been tested at relatively shallow depths, and may be difficult to implement in the deeper Michigan waters.

Future Directions for Michigan Asiatic Clam Management

With highly limited options for managing existing populations, preventing range expansion within the state of Michigan by identifying habitats most at risk and by promoting volunteer-based watercraft inspections should be top priority. A predictive model for future spread should be made to identify which areas are at the greatest risk of invasion. Public outreach and education

efforts in combination with an easily accessible reporting system will increase the likelihood of early detection. It is imperative that these systems confirm and communicate results in a timely manner as delays could greatly hinder response efforts. To accomplish this, workshops can be held to better educate lake associations and interested citizens about how to identify and respond to Asiatic clams, as volunteer opportunities provide low-cost monitoring. If adequate monitoring and reporting at the state level is not possible, then regional monitoring networks must be bolstered. Further research into *C. fluminea* may reveal vulnerabilities at specific life stages that may be exploited for population control and shed light on secondary dispersal mechanisms.

The use of benthic barriers should be investigated further and, if funding is available, trial treatments should be attempted here in Michigan. Efficient, comprehensive response protocols must be developed so that if infestations are detected they can be eradicated before reaching unmanageable levels. As always, preparedness and planning are key to a rapid and successful containment effort and need to be high priority in any future aquatic invasive species planning.

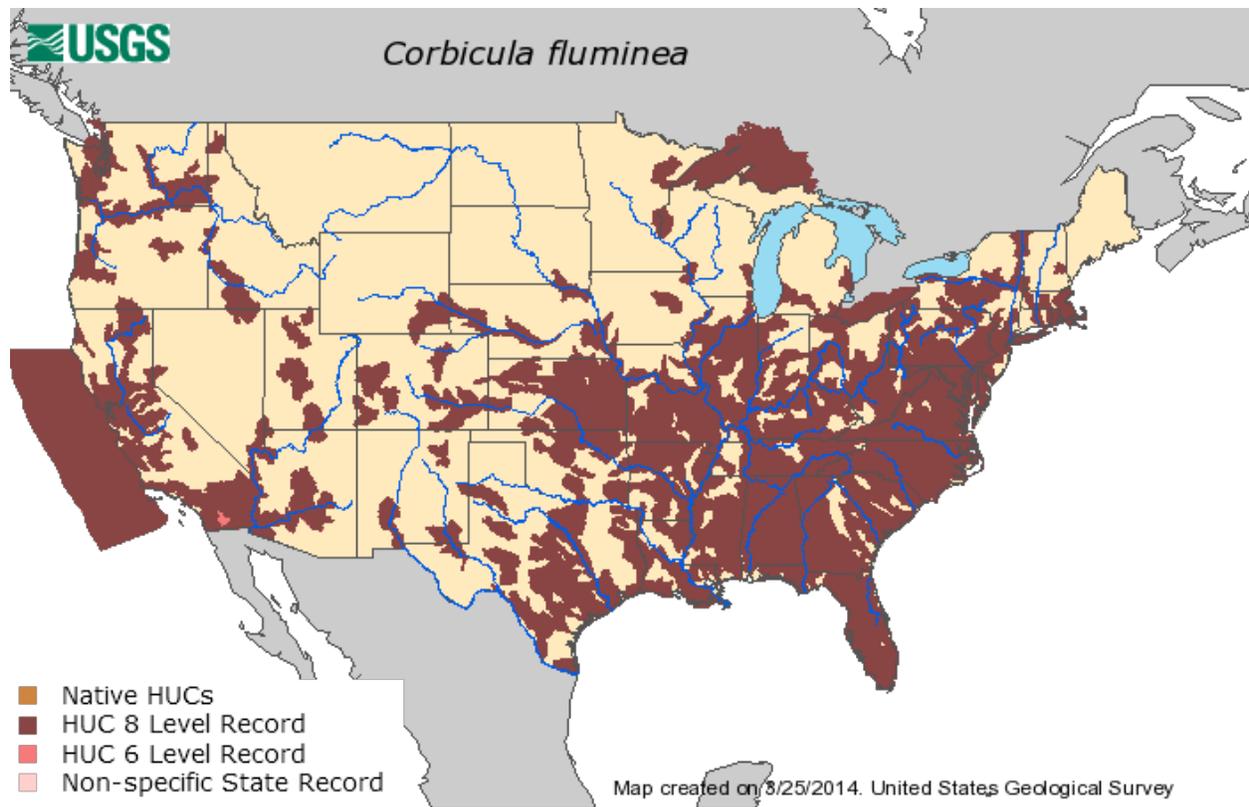


Figure 1. Distribution of *Corbicula fluminea* in the United States (Foster et al. 2014). Accessed April 4, 2014.

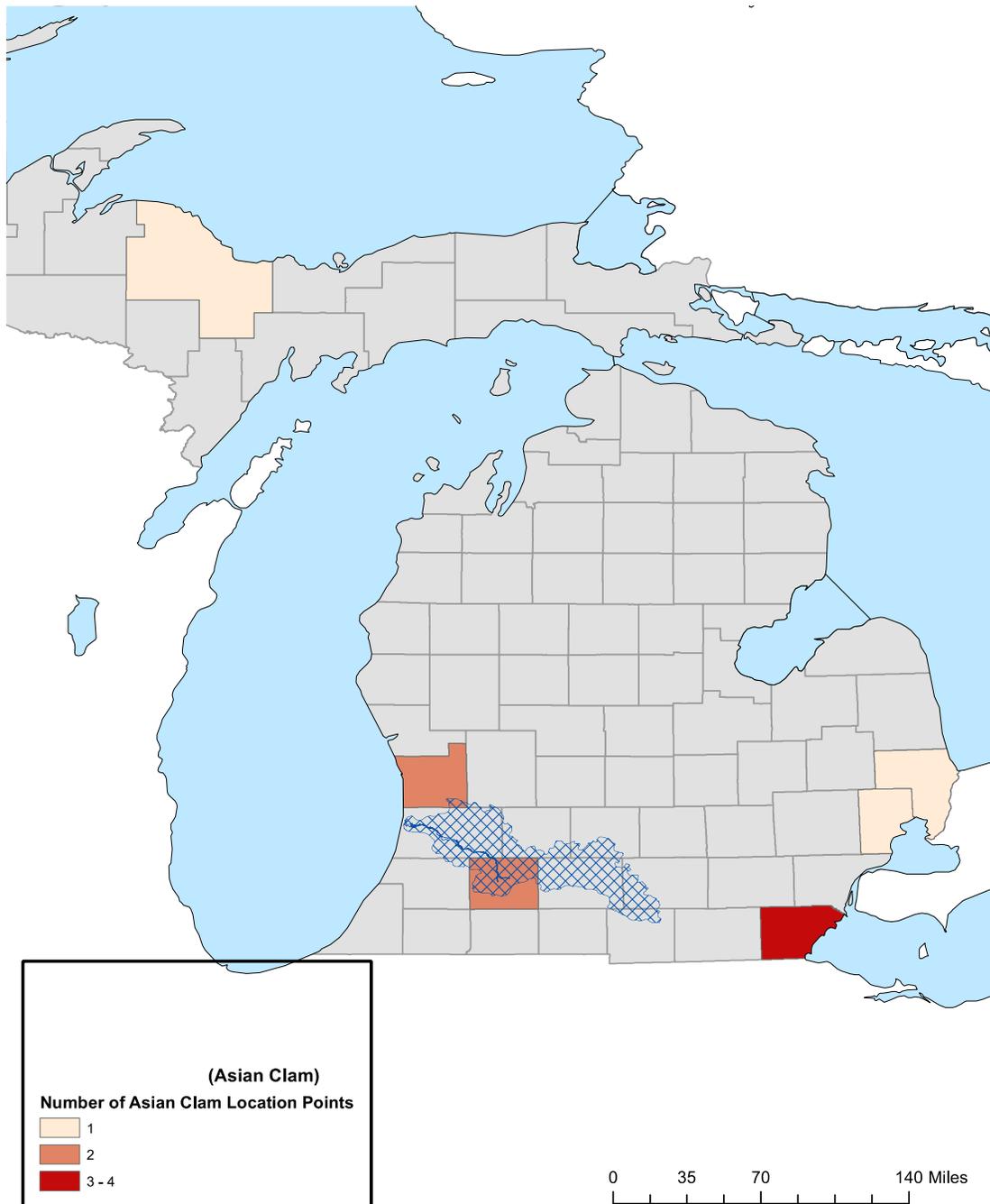


Figure 2. Number of unique coordinate location points within Michigan counties at which Asian clam were detected. This data is according to the United States Geological Survey (USGS) and Midwest Invasive Species Information Network (MISIN) databases. Asian clam have been detected in Lake Erie, Michigan, and Superior and in the Kalamazoo and St. Clair Rivers.

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