The Asian clam, *Corbicula fluminea:* A brief review of the scientific literature

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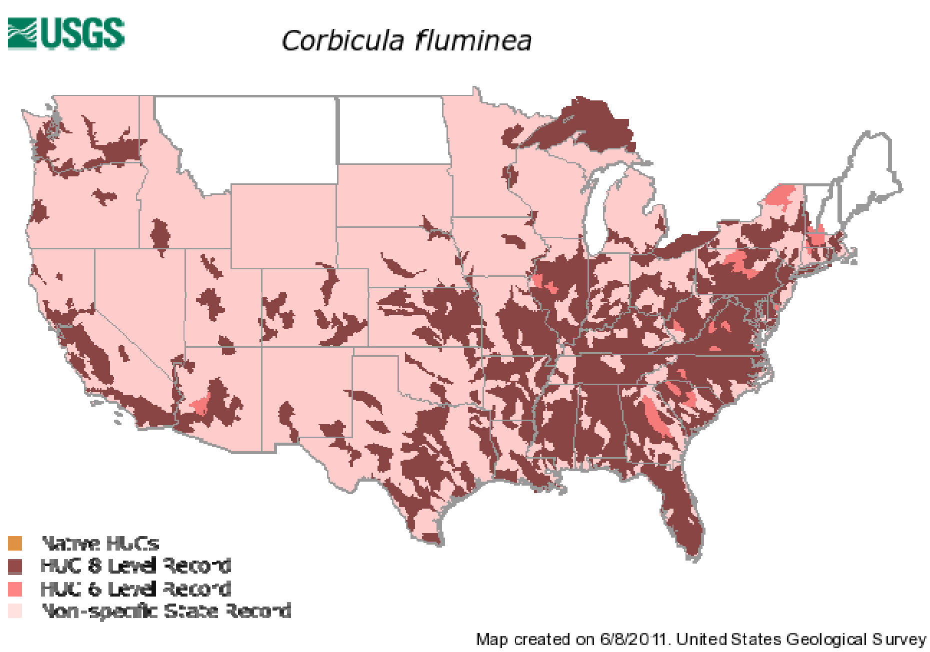
- *Corbicula fluminea* is widely distributed throughout the waters of North America, particularly the eastern US.
- We do not fully understand the pathways for secondary dispersal, although it likely involves human activities.
- *Corbicula* is less tolerant to fluctuating environmental conditions than native mussels, particularly oxygen levels and extreme temperatures, and is consequently prone to massive die-offs.
- *Corbicula* is adapted for rapid colonization of new habitats and population recovery after die-offs: Adults are hermaphrodites (it takes just 1 adult to start a population), mature quickly, and produce large numbers of offspring.
- Asian clams can quickly dominate the biomass of the river and lake bottoms, but its direct impacts on native mussels remains unclear. More studies are needed as current evidence is either anecdotal, based on the spatial distribution of clams after invasion, or confounds clam-effects with other ecological factors (e.g. human disturbance).
- Both a filter and sediment feeder, *Corbicula* couples nutrient and energy flows between the water column and sediment. Dense populations excrete nutrients that can stimulate algal growth.
- Asian clams can cause significant economic damage by fouling water intake pipes and impeding recreation and tourism at infested water bodies.
- To date, no scientific research has been published that evaluates the outcomes of Asian clam control practices.
- Eradication of Asian clams from infested waters is not likely; emphasis should be placed on containment and spread prevention.

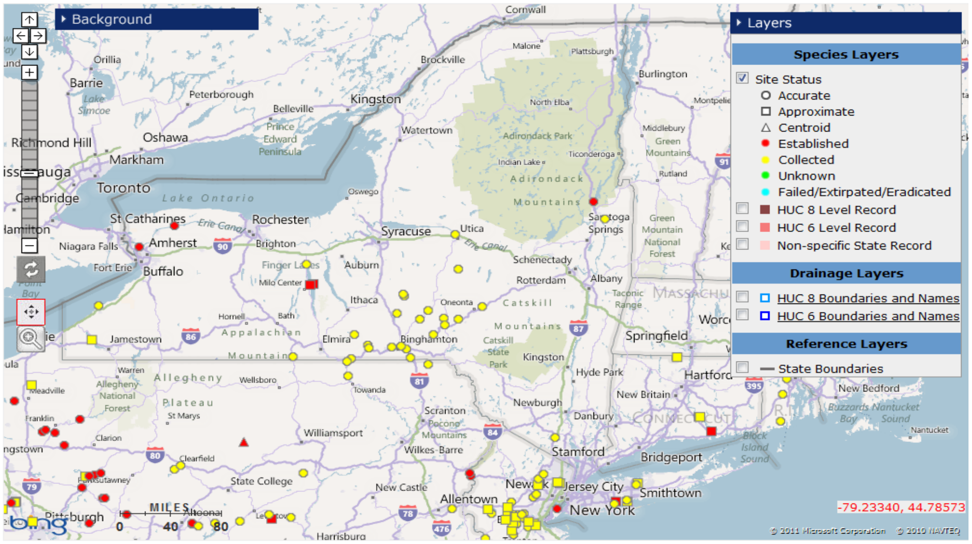
Origin and Spread

The Asian Clam *Corbicula fluminea* (Müller) is native to the fresh waters of eastern and southern Asia. It was likely introduced to the West Coast of North America around 1930 as a food source. Live Asian clams were first detected in US waters in 1938 in the Columbia River, Washington, and it quickly spread across the continent (44 states); the clam was detected in the Ohio River in 1957 and continues to spread through drainages in the Midwest and Northeast.



Distribution of *C. fluminea* in continental US. Source: USGS http://nas.er.usgs.gov/queries/speciesmap.aspx?SpeciesID=92

In New York State, the Asian clam has been collected in the running waters of central and western portions of the state, Seneca Lake and Owasco Lake in the Finger Lakes, and Lake George.



Distribution of *C. fluminea* in New York State. Source: USGS http://nas2.er.usgs.gov/viewer/omap.aspx?SpeciesID=92

The exact mechanism for secondary dispersal of *Corbicula* throughout North America is unknown, but likely involves human activity. Larval clams can attach to vegetation, floating debris, and boats for long distance dispersal. They may also be introduced via bait buckets or aquaculture releases.

Biology

The Asian clam burrows into the bottom sediments of streams and lakes and has the ability to feed from *both* the water column and the substrate. It uses its siphon to filter feed suspended particles (particularly phytoplankton) from the water and its fleshy foot appendage to pedal feed on detritus in the sediment. *Corbicula* can live in a variety of substrates, but prefers sand and gravel, over silt hard surfaces (McMahon 1999).

Corbicula is less tolerant than native mussels to environmental fluctuations. It is extremely sensitive to low oxygen conditions, and consequently its distribution is restricted to well-oxygenated streams and lake shallows. In its native semi-tropical/tropical habitat, the Asian clam is rarely exposed to temperature extremes. Its northern distribution in North America is thought to be limited by a 2°C lower lethal limit, and reproduction requires sustained water temperatures of 15-16°C. Asian clams have been known to find temperature refuges in cooler waters heated by power plant discharge.

Adult *Corbicula* are hermaphrodites (both male and female) that are capable of both cross and self-fertilization; thus, ***it takes only 1 individual to start a population***. Adults can live 3-4 years, and typically reproduce two times a year. A single adult can produce 1000 – 100,000 juveniles per year. Juveniles are tiny (0.25mm) and are capable of long distance dispersal via stream transport, water currents, or hitchhiking on animals, floating objects, or vegetation (to which they can attach via a byssal thread). Juvenile clams can reach maturity in 3-6 months.

Corbicula can rapidly grow into dense populations (> 2,000m^{-2}), but are prone to rapid die-offs with sudden changes in temperature (hot or cold) and low oxygen. However, their life history traits (i.e., quick maturity, high fecundity) enable rapid re-colonization and population recovery, even after near extirpation. Additionally, these traits allow the Asian clam to successfully colonize habitats disturbed by human activity (e.g., channels and impoundments) that are unsuitable for native mussels.

Impacts

Ecological

Like other invasive mussels (e.g. zebra and quagga mussels), *Corbicula* is highly successful coupling the nutrient and energy flows that occur in the water column and bottom sediments. With a high filtering capacity and population density, *Corbicula* filters out phytoplankton and other particles suspended in the water that are also important food sources for other filter-feeding organisms. Unlike zebra and quagga mussels, *Corbicula* also uses its pedal foot to feed on organic material and tiny organisms (microbes, protists, meiofauna) in the sediment (Hakenkamp et al. 2001). Whether *Corbicula* depletes these food resources to the extent that it negatively affects other organisms (particularly native unionid and sphaeriid mussels) remains an open question (Strayer 1999).

Corbicula can affect aquatic ecosystem processes in other ways. Bivalves, particularly when in dense populations, excrete significant amounts of inorganic nutrients, particularly nitrogen that, in turn, can stimulate the growth of algae and macrophytes (Lauritsen and Mozley 1989, Sousa et al. 2008). Additionally, Asian clam mass mortality events that occur in the summer followed by the release of nutrients via decomposition may also have negative effects on water quality. The shells of dead Asian clams can also provide a hard substrate on soft sediments, creating new habitat for other species that prefer hard substrates (e.g., zebra mussels).

It should be noted that to date, there are few studies on the ecological impacts of the Asian clam on native biota (McMahon 1999). In fact, most studies examine a water body after *Corbicula* invasion, with no comparable information on the biota or environmental conditions pre-invasion.

Moreover, recent justifications for expensive and intensive management actions (e.g., Lake Tahoe Asian Clam Response) overstate evidence in the scientific literature. For example, in "Asian clam (*Corbicula fluminea*) of Lake Tahoe: Preliminary scientific findings in support of a management plan," Wittman et al. (2008) state that:

> *Asian clam is known to aggressively outcompete native invertebrate communities.*

Here the report authors incorrectly interpret and cite the findings of Karatayev et al. (2003). Karatayev and colleagues studied *Corbicula* in a Texas reservoir. Although the Asian clam dominated the total animal biomass of the reservoir sediments (up to 95%), it was *not* associated with declines in native biodiversity. In fact, it was found to co-occur with an *abundant* population of native unionid mussels.

Studies claiming that the Asian clam has an impact on native bivalves (particularly unionids) are often anecdotal and only report the spatial distribution of bivalves after invasion (Strayer 1999). They assume that non-overlapping distributions of *Corbicula* and native mussels indicate that *Corbicula* have outcompeted the native species. As Strayer (1999) points out, this is just one possible explanation. *Corbicula* could also prefer different habitat than native mussels (e.g. sandy vs. silt/gravel). Native mussels have long experienced declines due to human-induced changes to habitat (pollution, land use change, channelization), and it is difficult to tease apart these changes versus direct impacts of invading *Corbicula* that also happen to do well in disturbed habitats. Thus, while it is quite possible that in some cases *Corbicula* has a direct, negative impact on native biota, more studies that monitor changes in mussel populations over time and that directly evaluate competitive interactions are warranted.

Economic

Asian clams can colonize the intake pipes of water treatment systems and power stations. Unlike zebra mussels, *Corbicula* do not attach to the hard substrate. Rather, juvenile clams pass through filter screens/strainers and settle on the floors of intake pipes where low flow allows silt and sand to settle. The clams reproduce in situ and continue to accumulate in pipes and are transported deeper into the system. *Corbicula* fouls the pipes, blocking structures with shells, altering flow, and increasing sedimentation rates (McMahon 1999).

Asian clam shells that accumulate in beach or swimming areas will also impede recreation and tourism.

Control

Little to no research regarding control practices have been published in the peer-reviewed scientific literature. The Lake Tahoe team has submitted a manuscript for publication to the journal *Biological Invasions* on the use of bottom barriers to control *Corbicula*, and it remains in the peer review process. Additionally, NYISRI had difficulty locating research-based Best Management Practices for *Corbicula.*

To date, given the life history traits of *Corbicula* that make it a successful invader and the widespread distribution of the species in North America, eradication is typically not a viable option. As with many aquatic invaders, emphasis ought to shift from eradication to containment and spread prevention.

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