Invasive Clams in Seneca Lake (NY): An overview of the *Corbicula fluminea* invasion, Implications on Lake Ecology, and Potential Treatments

Bart Flynn
Hobart and William Smith Colleges
Department of Environmental Studies

April 16, 2012

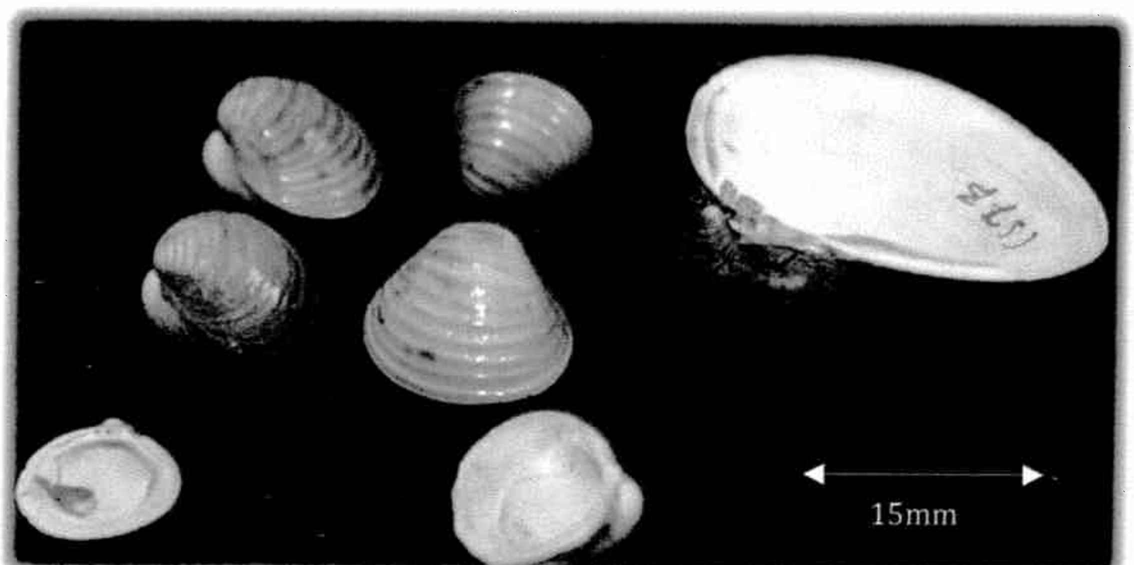

Figure 1. Shows live (gold) and dead shells of *Corbicula fluminea*.

Bart Flynn
Environmental Studies SIE 4-16-2012

Introduction:

Today's lakes are subject to a number of stress factors that work to change the overall ecology of the system. Seneca Lake (NY) is no exception. It is currently being exposed to nutrient loading and sedimentation from agricultural land, concentrated animal feed operations (CAFO's) and waste water treatment plants. In addition the lake is being exposed to invasive exotic species such as the well-known Zebra Mussels (*Dreissena polymorpha*), Quagga Mussels (*Dreissena bugensis*), and Eurasian watermilfoil (*Myriophyllum spicatum*), which can drastically change the lake's ecology. Among these highly invasive species is the lesser known *Corbicula fluminea*, or Asian Clam. *Corbicula* are highly invasive, small (<55mm) freshwater clams (fig. 1) that have become established to some extent in Seneca Lake. This paper will outline the history of *Corbicula's* invasion, its potential effects on Seneca Lake, both physical and biological, possible treatment methods underway in lakes elsewhere, and insights into how to deal with the current situation.

History of invasion:

Corbicula fluminea was introduced to North American on the Pacific coast of the United States as early as the 1920's. Native to southern Asia, they are thought to have been transported across the Pacific by Chinese immigrants for use as fishing bait and a potential food source (Counts 1986). Other possible vectors include use in aquariums, attachment to boat hulls, and ballast water tanks. Interestingly, species of the *Corbicula* genus have been found in the pre-glacial fossil records of North America, suggesting that populations similar to the current *C. fluminea* were once native to the continent (Araujo et al. 1993). Reasons for their downfall are unclear, however, current conditions in North America are suitable for re-invasion as is now apparent. Human surely interaction aided in re-dispersal across the Pacific, allowing *Corbicula* to establish in this already suitable environment. *Corbicula* was first discovered living naturally in the U.S. in the Columbia River Basin around 1938 (Burch 1944). Throughout the subsequent 40 years, they spread to the Atlantic coast and through most of the country's major waterways. Dispersal occurred partly through passive anthropogenic means and partly through natural dispersal (Burch 1944). Much of the natural dispersal is due to the veliger state of the juvenile clams, which can stay suspended in the water column for days and thus are highly susceptible to transportation by currents or passive transport by birds and other wildlife (McMahon 2002).

The first evidence that *Corbicula* inhabited Seneca Lake was in 1999 just offshore of the NYSEG generation station, located on the eastern shore just south of Sampson State Park (Finger Lakes Institute 2012). Evidence of colonization has also been found on the north end of the lake at the outlet of Castle Creek (2008) and in the Seneca River (2012). However, no thorough survey for *Corbicula* has been conducted in Seneca Lake to date.

Ecology of *Corbicula fluminea*:

Corbicula can live in highly diverse habitats. Though they prefer sandy sediment with a silt and clay mixture, they will colonize on a wide range of substrate with or without submerged vegetation (Sousa et al. 2008). Their temperature range is from 2-30°C and preferred depth is between 2m and 40m (though most common between 3m and 10m) (Sousa et al. 2008). Colonies require fairly high (>70% saturation) dissolved oxygen levels and thus are intolerant to hypoxia.

Cobicula's life history is key to its ability to both disperse into new environments and successfully invade and colonize. The incredible plasticity of their life cycle is a predominant reason for their ability to establish in a wide range of habitats. First, most *Corbicula* are hermaphroditic and can self fertilize allowing for consistent reproduction (Doherty et al. 1987). Some populations, however, have been shown to be primarily dioecious and release sperm into the water column where female clams accept it, thus allowing for increased genetic diversity and ability to adapt (Lee & Chung 1980). After fertilization juveniles mature within the parent clam until shells, foot, and other major morphology is formed (Sousa et al. 2008). The tiny veligers are then released into the water column where they can stay suspended for days, during which they are able to disperse large distances. Once settled, they anchor to the sediment with mucilaginous byssal threads (only present in juveniles). Maturation occurs in 3-9 months as the shell size grows from about 250μm to 6-10mm (Souse et al. 2008).

The timing of reproduction is plastic as well. Episodes of reproduction can occur between 1 and 3 times per year depending on environmental conditions (Doherty et al. 1987). Most populations reproduce twice a year: once in the early spring as water warms to the minimum reproductive temperature of 10-15° C and once in late summer (Wittmann et al. 2008). Judging by the temperature dynamics of the shallow parts of Seneca Lake, *Corbicula* are probably reproducing twice per year, once in late May and once in late August or early September. These fluctuations in reproductive timing are due to a combination of water temperature and food availability. Warm water and high food availability would provide resources for more reproductive episodes, whereas cold water and low resources would limit them to only 1 reproduction per year.

In addition to having highly adaptable life cycles, *Corbicula* have high fecundity (about 68,000/year) and high growth rates. According to McMahon 2002 their turnover rate can be as short as 73-91 days. Both of these factors allow *Corbicula* to invade and out-compete native benthic species for resources and space.

Coricula's feeding regime is also flexible. Depending on food availability, they can both filter feed from the water column or feed in the sediment using their food to pull food in. In oligotrophic environments with low water nutrients and limited suspended solids the clams attain more efficient feeding through pedal feeding on nutrients in the sediment (Wittmann et al. 2008). While pedal feeding the clams are removing nutrients form the sediment and releasing it into the water column. If water nutrients increase, the feeding preference shifts to filter feeding on waterborne phytoplankton and small zooplankton (Lauritsen 1986). These high filtration rates will reduce nutrient loading in the water column. In Seneca Lake, which is experiencing nutrient loading from agricultural and CAFO runoff, it is likely that *Corbicula* would be using the widespread waterborne nutrients by filter feeding. However, if the lake shifts to be more oligotrophic (through improvements in controlling nutrient loading), deposit pedal feeding may become more prominent. This distinction between filter and pedal feeding will become extremely important in the analysis of *Corbicula's* effect on its environment.

Ecological Implications:

Once established in an ecosystem, *Corbicula* can have a drastic effect on the physical structure and biotic function of an ecosystem. They pose a serious risk of altering water quality and nutrient levels, changing food web dynamics, and out competing native biota. Much of these changes can be attributed to *Corbicula* having a high filtration rate of water due to its filter feeding. Thought the rate is highly temperature dependent, they still possess one of the highest overall rates when compared to other freshwater mollusks (Lauritsen 1986). Rates range from 300 to over 800 ml/hr/clam (Buttner & Heidinger 1981). If one were to extrapolate this rate, *Corbicula* (at a density of 1250/m^2, filtering at 800ml/hr/clam) are able to filter the cubic meter of water above them every hour, and thus filter the volume of water 24 meters deep daily. Considering the average depth is between 3 and 10 meters, it is clear that a dense *Corbicula* colony has the ability to filter nearly all the water in and above its habitat multiple times per day. This high filtration rate will affect many aspects of the ecosystem. Firstly, populations of phytoplankton and zooplankton will decrease and may cause resource competition for native species such as fish and carnivorous zooplankton that feed on such suspended organisms. In addition to limiting food resources, *Corbicula* competes with native species heavily for benthic habitat space by accumulating high densities of dead shells. *Corbicula* also filter nitrogen and phosphorus directly out of the water, which can reduce the effects of nutrient loading and eutrophication. If nutrient loading is occurring, as it is in Seneca, *Corbicula* can actually negate the effects and make the water clearer much like zebra mussels (*Dreissena polymorpha*) did in the mid 1990's (Halfman 2003).

This high filtration rate is only applicable if resources are available in the water. As stated before, if nutrient levels in the water are low, *Corbicula* will change its feeding regime and begin pedal feeding from nutrients in the sediment. This pedal feeding can do the opposite of high rates of filter feeding. By feeding on deposits in the sediment, otherwise trapped nutrients are released back into the system through clams' excretion. This can increase the nutrient levels in the water and have major effects on the biota, most apparent of which is increased algal growth. In Lake Tahoe so much nutrients were released from the sediment over the clam beds that colonies of filamentous green algae began to grow exclusively over the clam colonies (Wittmann et al. 2008).

Eradication and Restoration Efforts:

In Lake George, *Corbicula* invaded over 15 acres at 4 sites at the southern end of the lake (Bauer et al. 2012). Since Lake George is a popular tourist destination, the maintenance of the clear, oligotrophic water is critical for the success of their economy. As such an intensive response was organized through the formation of the Lake George Asian Clam Rapid Response Task Force. Beginning in 2011 50' by 7.5' PVC benthic barrier mats were laid down over the clam colonies and weighed down with sandbags and rebar (Bauer et al. 2012). This treatment was targeted at 2 (Lake George Village and Norowal Marina) of the 4 sites and covered about 10 acres. The treated areas achieved nearly 100% mortality rates for the clams. Mortality was achieved through limiting DO and food uptake to the clams (Bauer et al. 2012). In addition to the benthic mats, suction harvesting by Aquacleaner Environmental was done in Middleworth Bay. Unfortunately the suction harvesting failed to eliminate clams efficiently and is though to have actually aided in further dispersal of *Corbicula* by resuspending juveniles (Bauer et al. 2012). The task force is planning to treat 15 acres in 2012 using the highly effective benthic barriers mats. The total cost of this extreme treatment for 2011 came to over $630,000.00 (Bauer et al. 2012).

Lake Tahoe is very similar to Lake George in that it is a popular destination for tourists seeking recreation on the lake, and that it is highly oligotrophic and thus susceptible to nutrient excretion from *Corbicula*. Scientists have recently discovered isolated colonies of *Corbicula* ranging from 70 – 3200 individuals/m^2 and have begun plans for eradication (Wittmann et al 2008). Their initial approach took the form of a thorough survey for *Corbicula* of any suitable habitat, and several experiments designed to evaluate the effect *Corbicula* could have on the lake. As part of their approach, they showed directly that *Corbicula* was altering the ecosystem. They concluded that *Corbicula* are actively excreting levels of nitrogen and phosphorus at the lake-sediment interface, that they filter high volumes of water, and were directly correlated with algal growth (Wittmann et. al 2008). Nutrient excretion differed greatly with temperature, ranging from 10.4 ppb/mm shell length NH_4 at 19°C and 0.6 ppb/mm shell length NH_4 at 4°C. Excretion of Soluble Reactive Phosphorus (SRP) ranged from 1.7ppb/mm shell length to 0.4 ppb/mm shell length over their respective temperatures (Wittmann et al 2008). Nutrient levels were measured in the proximity of clam bed and compared to clam-free areas to show that nutrient levels in the clam beds were higher than clam-free areas. In addition, Wittmann et al 2008 showed a direct correlation between the clam beds and algal growth.

Corbicula have also been found in Owasco Lake. In an effort to eradicate the clams, the lake level was lowered during the winter of 2011-2012 in hopes that freezing temperatures would reduce the population to below the minimum viable population (Marelli et al. 2011). Unfortunately, the water never froze due to uncharacteristically warm winter weather, and the eradication plan failed. It is unclear whether another approach like this will be attempted again.

It has also been shown that fish predation can be effective at keeping *Corbicula* populations at a manageable level. In a study done by Robinson & Wellborn 1988, the presence of predatory fish was show to have a 29-fold effect (density of 2605 individuals/m^2 without fish versus 93 individuals/m^2 with fish) on the colony size of *Corbicula*. Many of the fish present in the study that were consuming *Corbicula* are also found in Cayuga and Seneca Lake. These include Bluegill, Freshwater Drum, Lake Sturgeon, and Carp (Robinson & Wellborn 1988). The density of 93 clams/m^2 is on the same order of magnitude as densities found in the Seneca River of about 130 clams/m^2 (Flynn 2012). As such, we can assume that in areas with high densities of *Corbicula*, these fish species will take advantage of the prevalent food source and provide a natural control of the population as it did in the aforementioned study. Interestingly, Lake George has none of the *Corbicula*-eating species designated by Robinson & Wellborn 1988. There is therefore less of a natural control over the population sizes.

Conclusions:

Corbicula fluminea are a vigorous invasive species that can survive in a wide range of environments. They have been present at low levels in Seneca Lake since 1999, but have the capability of becoming a dominant benthic species. Depending on the environment, especially water temperature and nutrient levels in the water, the clams can have varied effects on the ecosystem. As shown by the analysis of Lake George and Lake Tahoe, lakes with clear, low-nutrient water are subject to nutrient excretion and algal blooms, and an overall decline in water quality and appeal. If, hypothetically, Seneca Lake were to reduce its nutrient loading and become more oligotrophic, it may face similar ecological effects. However, since Seneca is undergoing nutrient loading from the surrounding watershed, and is classified as borderline mesotrophic, *Corbicula* will most likely remain filter feeders and consume high amounts of suspended material, making the water clearer. The situation in Seneca now does not require drastic treatment as it does in Lake George and Lake Tahoe, however I would advise work to begin on a lake wide survey of Corbicula in order to accurately determine the degree to which they have established. In addition, analysis of the exact feeding behavior of *Corbicula* at the nutrient levels present in Seneca would be advised to more accurately determine the effect on the lake. Finally, with the restoration of Lake Sturgeon on Cayuga lake and the Seneca River, and there are hope that the Lake Sturgeon will re-establish in Seneca Lake using *Corbicula* as a major food source and thus provide a natural control of *Corbicula* population along with other native fish.

Work Cited:

ARAUJO, R., MORENO, D. & RAMOS, M. A. 1993. The Asiatic clam Corbicula fluminea (Müller, 1774) (Bivalvia: Corbiculidae) in Europe *American Malacological Bulletin*, 10, 39-49.

BAUER, P., DEBOLT, E., RATH, R., NIERZWICKI-BAUER, S., MARELLI, D. & FARRELL, J. 2012. Lake George Asian Clam Containment and Eradication Project: Report on 2011 Activities and 2012 Plan Lake George Asian Clam Rapid Response Task Force.

BURCH, J. Q. 1944. Checklist of west American mollusks. *Minutes, Concological Club of Southern California*, 38, 18.

BUTTNER, J. K. & HEIDINGER., R. C. 1981. Rate of filtration in the Asiatic clam, Corbicula fluminea. . *Transactions of the Illinois Academy of Science*, 74, 13-18.

COUNTS, C. L. 1986. The zoogeographyand history of the invasion of the United States by Corbicula fluminea (Bivalvia: Corbiculidae). *American Malacological Bulletin*, 2, 7-39.

DOHERTY, F. G., CHERRY, D. S. & JOHN CAIRNS, J. 1987. Spawning Periodicity of the Asiatic Clam Corbicula fluminea in the New River, Virginia. *American Midland Naturalist*, 117, 71-82.

FINGER LAKES INSTITUTE, Hobart. and. William. Smith. Colleges. 2012. *Asian Clams* [Online]. Geneva, NY. Available: http://fli.hws.edu/asian_clams.asp [4-10-12].

FLYNN, N. 2012. Population Survey of Corbicula fluminea in Finger Lakes Canal System: An Investigation of Suitable Lake Sturgeon Habitat. Geneva, NY(Unpublished)

HALFMAN, J. 2003. *Zebra Mussel Impact on Seneca Lake* [Online]. Geneva, NY. Available: http://people.hws.edu/Halfman/zebras/zebras.htm [Accessed 4-10-12].

LAURITSEN, D. D. 1986. Filter-feeding in *Corbicula fluminea* and its effect on seston removal. *American Benthological Society* 5, 165-172.

LEE, T. Y. & CHUNG., E. Y. 1980. Reproductive cycle of marsh clam Corbicula fluminea. . *Publications of Institute of Marine Sciences National Fisheries University of Busan*, 12, 47-54.

MARELLI, D. C., RESLER, S. & NIERZWICKI-BAUER, S. 2011. Preliminary Survey for Asian clams (Corbicula fluminea) in Owasco Lake, Cayuga County, NY *Cayuga County Soil and Water Conservation District*

MARION WITTMANN, JOHN REUTER, GEOFF SCHLADOW, SCOTT HACKLEY, BRANT ALLEN , CHANDRA, S. & CAIRES, A. 2008. *Asian clam (Corbicula fluminea) of Lake Tahoe: Preliminary scientific findings in support of a management plan*

MCMAHON, R. F. 2002. Evolutionary and physiological adaptations of aquatic invasive animals: r selection versus resistance. *Canadian Journal of Fisheries and Aquatic Sciences*, 59, 1235-1244.

ROBINSON, J. V. & WELLBORN, G. A. 1988. Ecological resistance to the invasion of a freshwater clam, *Corbicula fluminea*: fish predator effects. *Oecologia*, 77, 445-452.

SOUSA, R., ANTUNES, C. & GUILHERMINO, L. 2008. Ecology of the invasive Asian clam Corbicula fluminea (Müller, 1774) in aquatic ecosystems: an overview *International Journal of Limnology*, 44, 85-94.

STITES, D. L., BENKE, A. C. & GILLESPIE, D. M. 1995. Population dynamics, growth, and production of the Asiatic clam, Corbicula fluminea, in a blackwater river. *Canadian Journal of Fisheries and Aquatic Sciences*, 52, 425-437.