

## ***ASIAN CLAM, A NEW NEARSHORE INVASIVE SPECIES IN LAKE TAHOE***

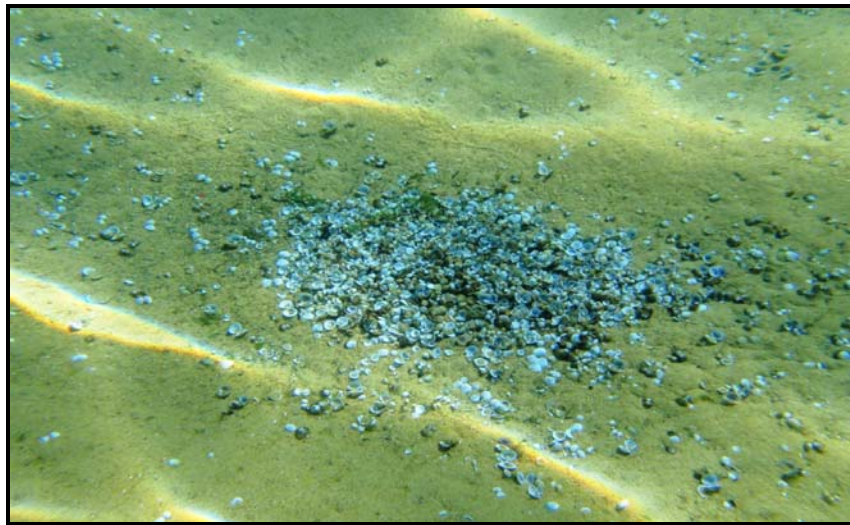
### ***Non-native introductions to Lake Tahoe***

During the last 130 years numerous nonnative fish, invertebrate, and plant species have been introduced intentionally and unintentionally to Lake Tahoe altering aspects of its ecology. The first series of fish introductions occurred at the end of the 19th century through the 1940's. Only rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), lake trout (*Salvelinus namaycush*), and brook trout (*Salvelinus fontinalis*), and kokanee salmon (*Oncorhynchus nerka*) still persist today. Predatory impacts from lake trout combined with over fishing, hybridization, and siltation of spawning streams contributed to the extirpation of Lahontan cutthroat trout from Lake Tahoe by 1939 (Cordone and Franz 1968, Moyle 2002). A second round of fish invasions occurred in the late 1970's and 80's but this time in the near shore environment (Reuter and Miller 2000). Other introductions of the popular sport fish largemouth bass and bluegill were illegal and not part of any management strategy. These invasions are thought to have contributed to reductions in nearshore, native fish through predation and competition (Kamerath et al. 2008). Aquatic plants have been a problem in the nearshore area of Lake Tahoe for a few decades. Aggressive non-native species such as Eurasian water milfoil (*Myriophyllum spicatum*) and Curly leaf pondweed (*Potamogeton crispus*) initially established in the Tahoe Keys lagoon where costly and annual control using mechanical harvesters has occurred since the mid-1980s. These species have since established along the south shore and various marinas and embayments including Emerald Bay, and are continuing to spread to other locations in the lake (Anderson 2006). Thus, over time managers are increasingly concerned of these near shore invasions because of negative ecological and aesthetic change and the direct interface between the nearshore and the public.

### ***Asian clam and Lake Tahoe***

In spring 2008 UC Davis researchers Scott Hackley and Brant Allen discovered extensive and often dense beds of an invasive bivalve, the Asian clam (*Corbicula fluminea*) in southeastern Lake Tahoe in nearshore areas from Zephyr Cove to El Dorado beach. Observations by Sudeep Chandra (UNR) of small numbers of clams (densities of 3-20 individuals per square meter) in 2002 suggest that Asian clam may have been in Lake Tahoe for at least 6 years; however, the densities and size of the recently observed beds are much larger than previously reported.

**Figure 1. A small (approximately 1 square meter) patch of Asian clam in southeast Lake Tahoe, 2008.**

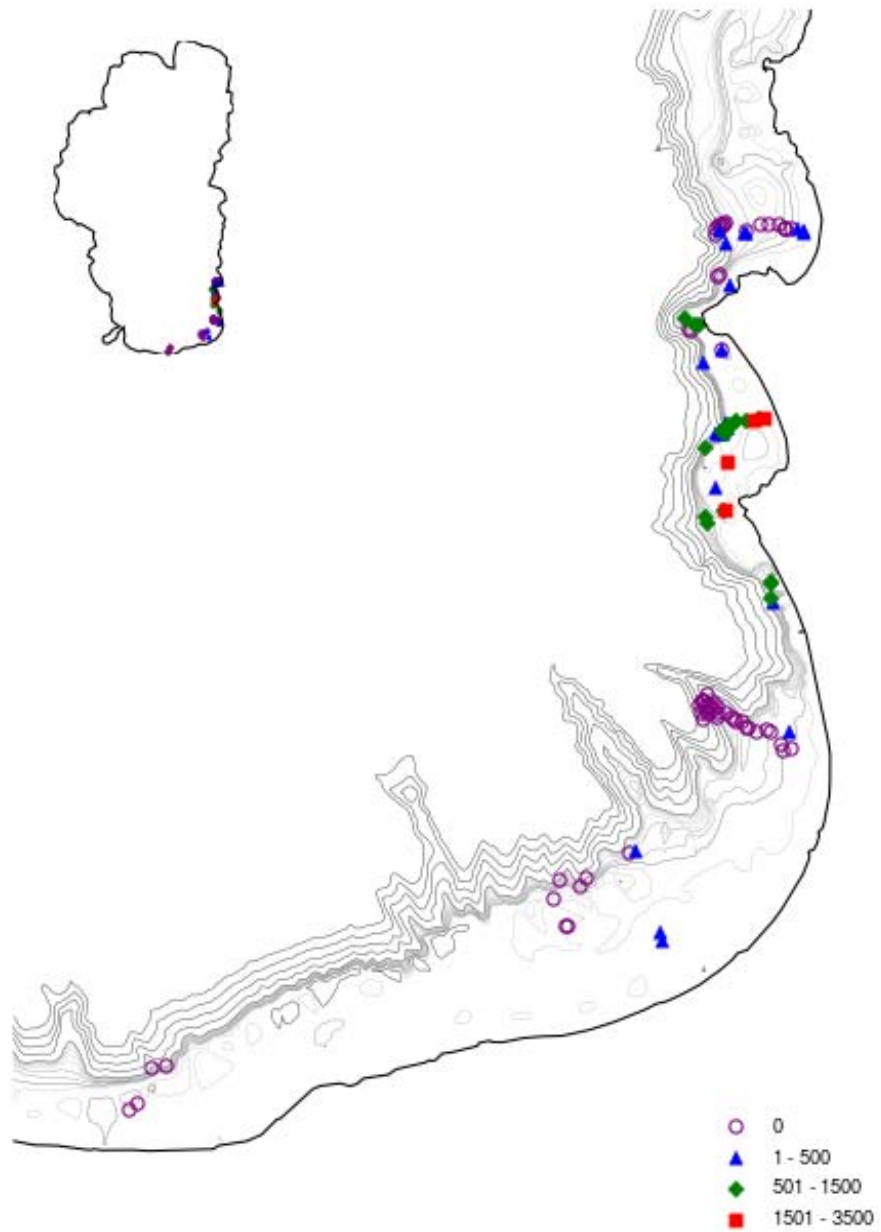


**Figure 2. UC Davis researcher Brant Allen swims over a large Asian clam bed off Elk Point, 2008**



Comprehensive surveys of the animals living in the lake sediments (benthic invertebrate surveys) by the California Department of Fish and Game (CDFG) and the Nevada Department of Wildlife (NDOW) in the 1960's did not find Asian clam in Lake Tahoe. Asian clam were first detected in the Tahoe region in 1981 when the Pyramid Lake Paiute Tribe noted its presence on the Lower Truckee River. Additional surveys by Chandra in 2005-2006 showed that clam densities were variable (4-212 individuals/m<sup>2</sup>) in the Lower Truckee River (Clark, Wadsworth, Nixon) and its tributaries (North Truckee Drain and Steam Boat Creek). In 2003, Dave Herbst (UC Santa Barbara) positively identified clams collected from Nevada Beach. Shells collected by a citizen had been sent to Herbst by the League to Save Lake Tahoe; a report of this sighting was first published in the League's summer 2003 Newsletter. Surveys conducted in summer 2008 by the UC Davis – Tahoe Environmental Research Center (TERC) and University of Nevada Reno (UNR) science team show that populations in Lake Tahoe are established and apparently expanding (Figure 3). Their distribution is patchy in space, with areas of very high clam density (>2000 clams per meter<sup>2</sup>) located next to areas with no or low densities (<100 clams per meter<sup>2</sup>). This patchiness is probably a result of differences in bottom substrate type, food availability, light penetration, temperature and other environmental variables. Understanding the survival strategies of Asian clam in different locations around the lake will be the objective of research efforts for UC Davis and UN Reno scientists in the next year.

**Figure 3. Asian clam distribution in South eastern Lake Tahoe, June-September 2008.**  
Units are in individual clams per square meter.



### ***Asian clam introduction and life history***

Asian clam (*Corbicula fluminea*) is an invasive bivalve species that has spread rapidly in lakes, canals, streams, rivers, and reservoirs throughout North America. Asian clam was first detected in the Western United States (Columbia River Basin) in 1938 and is known to aggressively out compete native invertebrate communities (Karatayev et al. 2003), limit phytoplankton biomass (Lucas et al. 2002, Lopez et al. 2006), biofoul water intakes (Eng 1979), alter benthic habitats (Hakenkamp et al. 2001), add biologically available nitrogen and phosphorus to systems (Lauritsen and Mozley 1989), and impact aesthetic and recreational values of public beaches, lake front properties, and swimming areas (Pimentel et al. 2005).

**Figure 4. Dense pile of Asian clam shells in southeastern Lake Tahoe, 2008.**

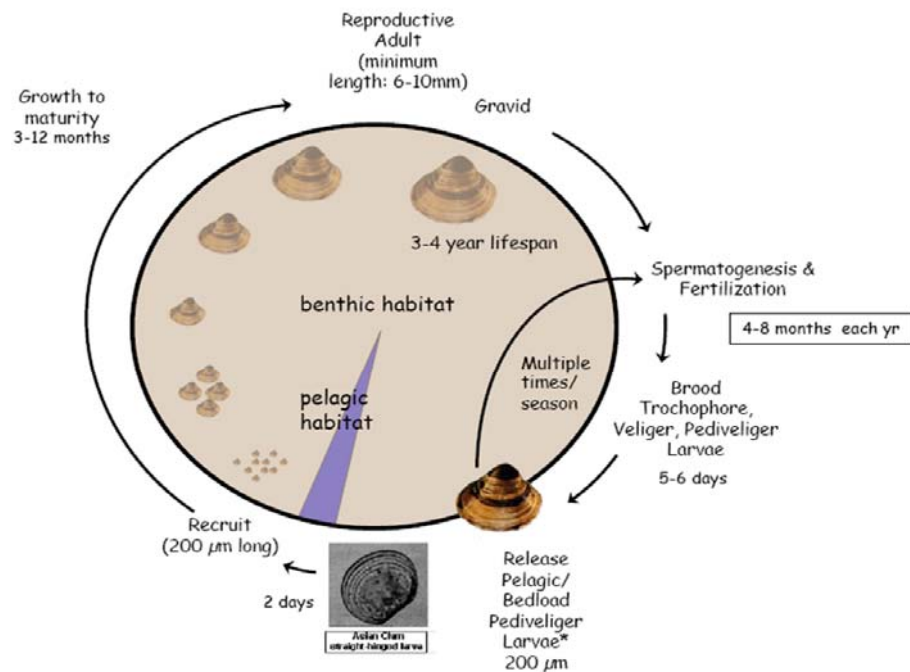


Their high rates of filtration, metabolism, reproduction, tolerance to wide ranges of physical habitats, and juvenile dispersal allows Asian clam to aggressively expand ranges and to rapidly re-invade areas; limiting management, reducing restoration efforts and impacting native benthic communities (Thompson et al. 2008). Asian clam are capable of both filter feeding (feeding from the water) and pedal feeding (feeding directly from the sediment). One reason for why Asian clam is successful in so many different environments is that it can effectively filter

phytoplankton and bacteria out of the water column and feed from the sediments when food from the water column becomes scarce. In Lake Tahoe they grow to be as large as 28 millimeters (Figure 6), but in other warmer systems can be as large as 55 mm. They are found in Lake Tahoe at water depths of 2 to 40 meters, and within the sediments buried in up to at least 4 inches below the surface. They are generally found in lakes and streams with silt, sand, and gravel substrate, can tolerate salinities of up to 13 parts per thousand for short periods (Aguirre and Poss 1999) and temperatures between 2 and 30° C. While there has been no definitive study on the impact of calcium on Asian clam, it appears that at 6 mg Ca/L populations can be relatively successful. The average calcium level in Lake Tahoe is 9.16 mg Ca/L with a range from 8 to 12 mg Ca/L.

Asian clam maximum lifespan is 7 years, averaging 2 to 4 years. It spends most of its life in sediments and adults have the ability to burrow and can move to new areas when food or water quality (high turbidity, low dissolved oxygen, etc.) is poor (Williams and McMahon 1989).

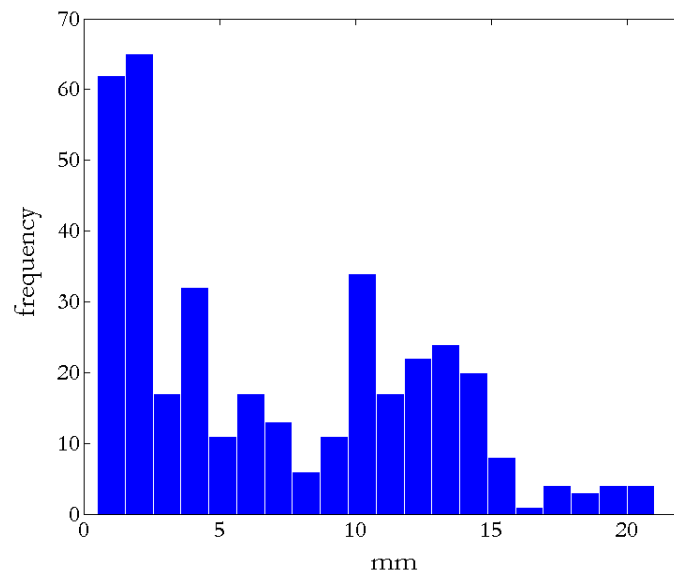
**Figure 5. Asian clam reproductive cycle. Image courtesy of Army Corps of Engineers, 2006.**



\*[http://el.erdc.usace.army.mil/zebra/zmis/zmishelp4/distinguishing\\_between\\_dreissenid\\_species.htm](http://el.erdc.usace.army.mil/zebra/zmis/zmishelp4/distinguishing_between_dreissenid_species.htm)

Asian clam are hermaphroditic meaning that they are both male and female in one body, and thus have the ability to start a new population from just a single clam. Sperm and egg production generally begin when temperatures rise in spring and exceed 10 and 15°C respectively. A majority of studies concluded that this species reproduces twice a year (Sousa 2008): one occurring in the spring and continuing during the summer and the other beginning in late summer and continuing through the fall (Figure 5). The timing of reproduction is controlled by temperature, but also by food availability (Rajagopal et al. 2000, Cataldo et al. 2001). Individuals continue to fertilize their eggs and brood larvae until the temperature falls outside the acceptable range or until sufficient food is lacking. Individuals become reproductive at shell lengths of 6 to 10 mm, and can produce over 68,000 individuals in a year (Williams and McMahan 1989). In cold, oligotrophic lakes (such as Lake Tahoe) Asian clam can reach densities greater than 3000 individuals/m<sup>2</sup> (Werner and Rothaupt 2007).

**Figure 6. 2008 Lake Tahoe Asian clam size class distribution in millimeters. Note the presence of several generational cohorts at ~2 mm, 4 mm, 10 mm, and greater than 12 mm**



Asian clam has been shown to change benthic structure in systems like this as a result of temperature and water quality driven die-offs that produce large piles of shell material. This shell material considerably increases availability of hard surfaces in primarily soft-bottomed habitats providing substrate for Mayfly (*Caenis sp.*) and other species that require harder strata like zebra or quagga mussels. In addition, these piles of shell material are areas of high calcium

concentrations because of the breakdown and dissolution of the calcium carbonate material that makes up the Asian clam shell matter. Zebra and quagga mussels are limited in part by the availability of calcium; but these Asian clam “hot spots” of high calcium concentrations may provide suitable chemical conditions for mussel growth and establishment.

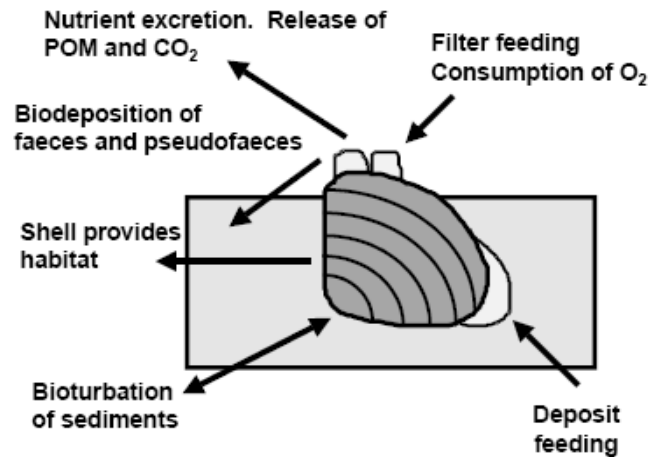
**Figure 7. Quagga mussel attaching to Asian clam with its byssal threads. Photos taken in Lake Mead, 2008.**



### ***Asian clam impact on Lake Tahoe***

Researchers from the UC Davis Tahoe Environmental Research Center and the University of Nevada Reno, in collaboration with the Tahoe Regional Planning Agency (TRPA) and the Tahoe Resource Conservation District (TRCD) have been conducting field surveys, literature reviews, laboratory experiments, and demographic studies on Asian clam populations in Lake Tahoe in response to the clam bed discovery in April 2008. Asian clam performs a variety of ecosystem functions within Lake Tahoe through its ability to feed from the water column as well as from the sediments, excrete nutrients, disturb sediments and provide substrate through its shell material (Figure 8).

**Figure 8. Potential ecosystem functions performed by the Asian clam in freshwater ecosystems (Vaughn and Hakenkamp 2001)**



Through research conducted since April 2008, UCD and UNR scientists have found that in Lake Tahoe Asian clam 1) excretes elevated levels of nitrogen and phosphorus into the water column and sediment substrate—promoting algal growth, 2) filters extremely high volumes of water, and 3) have a strong correlation to algal growth. Potential impacts of exponential increases of this species include degraded water quality, decline of phytoplankton and zooplankton communities, disruption to Lake Tahoe sports fisheries, increased levels of calcium through the concentration of dead shell matter with a promotion of other regional exotic species (quagga mussel), and out-competing Tahoe's native benthic species such as the Montane Pea clam (*Pisidium* spp.) and the Ramshorn snail (*Planorbidae*). Given these potential impacts, there is increasing recognition for the urgent need to develop an effective and minimally disruptive control strategy of Asian clam populations, predicting their spread, as well as the prevention of future invasive species introduction and establishment.

## References

- Aguirre, W. and S. Poss. 1999. Non-Indigenous Species In the Gulf of Mexico Ecosystem: *Corbicula fluminea* (Muller, 1774). Gulf States Marine Fisheries Commission (GSMFC).
- Anderson, L. 2006. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) and Curly leaf pondweed (*Potamogeton crispus*) in Lake Tahoe. USDA Agricultural Research Service.
- Cataldo, D., J. Colombo, D. Boltovsky, C. Bilos, and P. Landon. 2001. Environmental toxicity in the Paraná river delta (Argentina): simultaneous evaluation of selected pollutants and mortality rates of *Corbicula fluminea* (Bivalvia) early juveniles. *Environmental Pollution* **112**:379-389.
- Cordone, A. and T. Franz. 1968. An evaluation of trout planting in Lake Tahoe. California Department of Fish and Game.
- Eng, L. 1979. Population dynamics of the Asiatic clam, *Corbicula fluminea* (Muller) in the concret-lined Delta-Mendota Canal of central California. Pages 39-168 in First International *Corbicula* Symposium. Texas Christian University Research Foundation, Fort Worth, TX.
- Hakenkamp, C. C., S. G. Ribblett, M. A. Palmer, C. M. Swan, J. W. Reid, and M. R. Goodison. 2001. The impact of an introduced bivalve (*Corbicula fluminea*) on the benthos of a sandy stream. *Freshwater Biology* **46**:491-501.
- Kamerath, M., S. Chandra, and B. C. Allen. 2008. Distribution and impacts of warm water invasive fish in Lake Tahoe, USA. *Aquatic Invasions* **3**:35-41.
- Karatayev, A. Y., L. E. Burlakova, T. Kesterson, and D. K. Padilla. 2003. Dominance of the Asiatic clam, *Corbicula fluminea* (Muller), in the benthic community of a reservoir. *Journal of Shellfish Research* **22**:487-493.
- Lauritsen, D. D. and S. C. Mozley. 1989. NUTRIENT EXCRETION BY THE ASIATIC CLAM *CORBICULA-FLUMINEA*. *Journal of the North American Benthological Society* **8**:134-139.
- Lopez, C. B., J. E. Cloern, T. S. Schraga, A. J. Little, L. V. Lucas, J. K. Thompson, and J. R. Burau. 2006. Ecological values of shallow-water habitats: Implications for the restoration of disturbed ecosystems. *Ecosystems* **9**:422-440.
- Lucas, L. V., J. E. Cloern, J. K. Thompson, and N. E. Monsen. 2002. Functional variability of habitats within the Sacramento-San Joaquin Delta: Restoration implications. *Ecological Applications* **12**:1528-1547.
- Moyle, P. B. 2002. *Inland Fishes of California*. University of California Press, Berkeley.
- Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* **52**:273-288.
- Rajagopal, S., G. van der Velde, and A. Bij de Vaate. 2000. Reproductive biology of the Asiatic clams *Corbicula fluminalis* and *Corbicula fluminea* in the river Rhine. *Archiv für Hydrobiologie* **149**:403-420.
- Thompson, J., F. Parchaso, and H. Peterson. 2008. *Corbicula fluminea* Conceptual Model. U.S. Geological Survey.
- Vaughn, C. C. and C. C. Hakenkamp. 2001. The functional role of burrowing bivalves in freshwater ecosystems. *Freshwater Biology* **46**:1431-1446.
- Werner, S. and K. O. Rothhaupt. 2007. Effects of the invasive bivalve *Corbicula fluminea* on settling juveniles and other benthic taxa. *Journal of the North American Benthological Society* **26**:673-680.
- Williams, C. J. and R. F. McMahon. 1989. ANNUAL VARIATION OF TISSUE BIOMASS AND CARBON AND NITROGEN-CONTENT IN THE FRESH-WATER BIVALVE *CORBICULA-FLUMINEA* RELATIVE TO DOWNSTREAM DISPERSAL. *Canadian Journal of Zoology-Revue Canadienne De Zoologie* **67**:82-90.