Plan to Contain and Eradicate the Infestation of the Invasive Species Asian Clam in Lake George

Lake George Asian Clam Rapid Response Task Force

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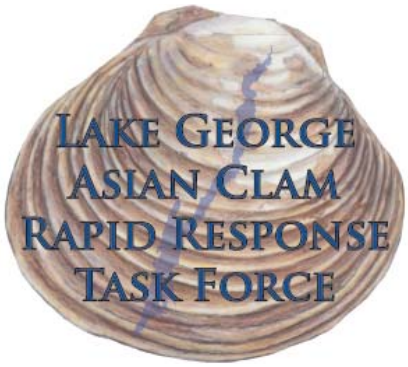

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Darrin Fresh Water Institute

FUND for Lake George

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April 2011

Plan to Contain and Eradicate the Infestation of the Invasive Species Asian Clam (*Corbicula fluminea*) in Lake George

The Asian Clam Infestation in Lake George

The long-term threat posed by the Asian clam (*Corbicula fluminea)* is the most serious to date from an aquatic invasive species for the environmental health and public recreational enjoyment of Lake George. For the Asian clam, Lake Tahoe serves as a cautionary tale for the Lake George community. Actions were delayed in Lake Tahoe for a number of years after the Asian clam infestation there was first discovered. The delay in action saw the area of infestation increase from a few acres to over 200 acres. Extensive Asian clam beds and accompanying algal blooms now dominate once beautiful and clear bays. Measurable water quality deterioration and impaired recreational uses have been found in these areas.

The Lake George community has the opportunity to eliminate the Asian clam while the infestation is believed to be relatively small and contained and every effort should be made to do so. A robust containment and eradication effort will begin in April 2011 before the clams begin to reproduce and continue into the fall. Though the eradication efforts will be somewhat disruptive for shoreline owners and the Lake George community, every effort is being made to minimize impacts. The long-term threats to the ecology of Lake George and the local economy are too great to either do nothing, delay, or minimize efforts.

Asian clams were discovered in the south end of Lake George, in the Lake George Village area, in August 2010 by RPI graduate student Jeremy Farrell and confirmed by the staff of the RPI Darrin Fresh Water Institute (DFWI), including Dr. Sandra Nierzwicki-Bauer, who has long studied native mollusk populations in Lake George. Identification was additionally confirmed by Dr. Dan Marelli and Dr. William Heard, two freshwater mollusk specialists contacted by DFWI.

Lake George has been spared many of the challenging aquatic invasive species that have wreaked havoc on many lakes and rivers across New York and the Northeast. Today, the Lake George community is actively managing three other aquatic invasive species, including Eurasian watermilfoil (*Myriophyllum spicatum*), curlyleaf pondweed (*Potamogeton crispus*), and zebra mussels

An Asian clam can reach the size of a dime or larger in 2-3 years and start reproducing in 3-8 months.

(*Dreissena polymorpha*), all of which have largely been brought under control. This pales in comparison with nearby waterbodies, such as Lake Champlain, which has dozens of aquatic invasive species.

The Asian clam infestation has been delineated through extensive field work to a primary area of 4.74 acres that runs largely along the Village shoreline from Pine Point to the English Brook delta. A secondary area of 3.31 acres was also identified where smaller populations of Asian clams may be found; this area requires more testing (see map on page 5). The Asian clam is believed to have been in the lake for 2-3 years and to have completed 4-6 reproduction cycles. A clam reaches sexual maturity capable of reproduction in 3-8 months and releases 2,000 - 4,000 offspring during each reproduction cycle. Asian clams have been known to complete two reproduction cycles in a single year depending on a variety of factors.

The Asian clam is an invasive exotic (non-indigenous) species of bivalve mollusk that has been reported to have been imported to the U.S. in 1924. The first report of its presence in the wild was from the Columbia River drainage of Washington in either 1937 or 1938, and the confirmation of this clam in Lake George represents the first confirmed infestation in New York's Adirondack Park and in the Lake Champlain watershed. A population currently exists in the Champlain Canal, near Fort Edward, and in the St. Lawrence River, near a nuclear power plant near Becancour, Quebec, Canada. Asian clam populations have also been identified in Seneca Lake, Owasco Lake, Niagara River, the Susquehana River, Cayuga Lake, Chenango River, and Schenevus Creek (near Albany), among other locations in New York.

The Asian clam easily populates new habitats because it is a functional hermaphrodite and capable of self fertilization. The method of dispersal (vector) between water bodies is unknown, but thought to involve bait transport, accidental transport with aquaculture (pet fish tank) species, and possibly intentional transport as a food item. Asian clams do not have a free-swimming larval stage, but instead release a small juvenile clam that can be moved by water currents and even transported in water drawn

from near the bottom or in sediment taken from a water body that has a current Asian clam population. There are several reasons why the Asian clam infestation is a major problem for Lake George:

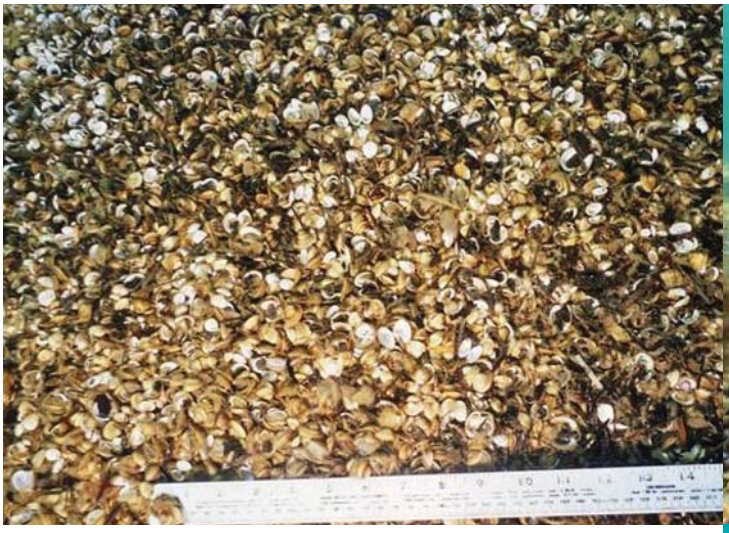
- Asian clams are detrimental to native clam or mussel species, as they outcompete and displace native populations. Asian clams feed from both the lake bottom sediment as well as algae content in the water column.
- Asian clams are prodigious breeders that can have two reproductive cycles each year. In Lake George, it is believed that the Asian clam population grew from a small number of individuals to an area of infestation between 5-8 acres.
- Individual Asian clams grow rapidly from a microscopic organism to the size of a dime or larger in just 2-3 years. Robust growth results in high levels of excrement that facilitate algal blooms over clam beds or areas of high populations.
- Documentation of long-term negative water quality impacts due to Asian clam populations exist for Lake Tahoe and the Potomac River, where native habitats and ecosystems have been severly impaired.

For all of these reasons the Asian clam is an unwanted inhabitant in Lake George. The Lake George Village area, which is where the Asian clam population is located, is the most stressed part of the lake ecologically and has experienced the most dramatic decline in water quality in the lake over the past several decades. A robust, long-term Asian clam population in the Village will exacerbate and accelerate declining water quality conditions, which will undermine both the health and public use and enjoyment of Lake George. If left untreated the Asian clam infestation will likely extend to Shepards Park and Million Dollar Beach and beyond to other parts of the lake.

Asian clams can reproduce twice each year. A single clam produces 2,000-4,000 juvenile offspring. Asian clams start reproducing within 3-8 months.

Lake George Asian Clam Rapid Response Task Force

The threat to Lake George and the Adirondack Park from the Asian clam (*Corbicula fluminea*) infestation was quickly grasped by Lake George and Adirondack Park civic and regulatory communities. A network



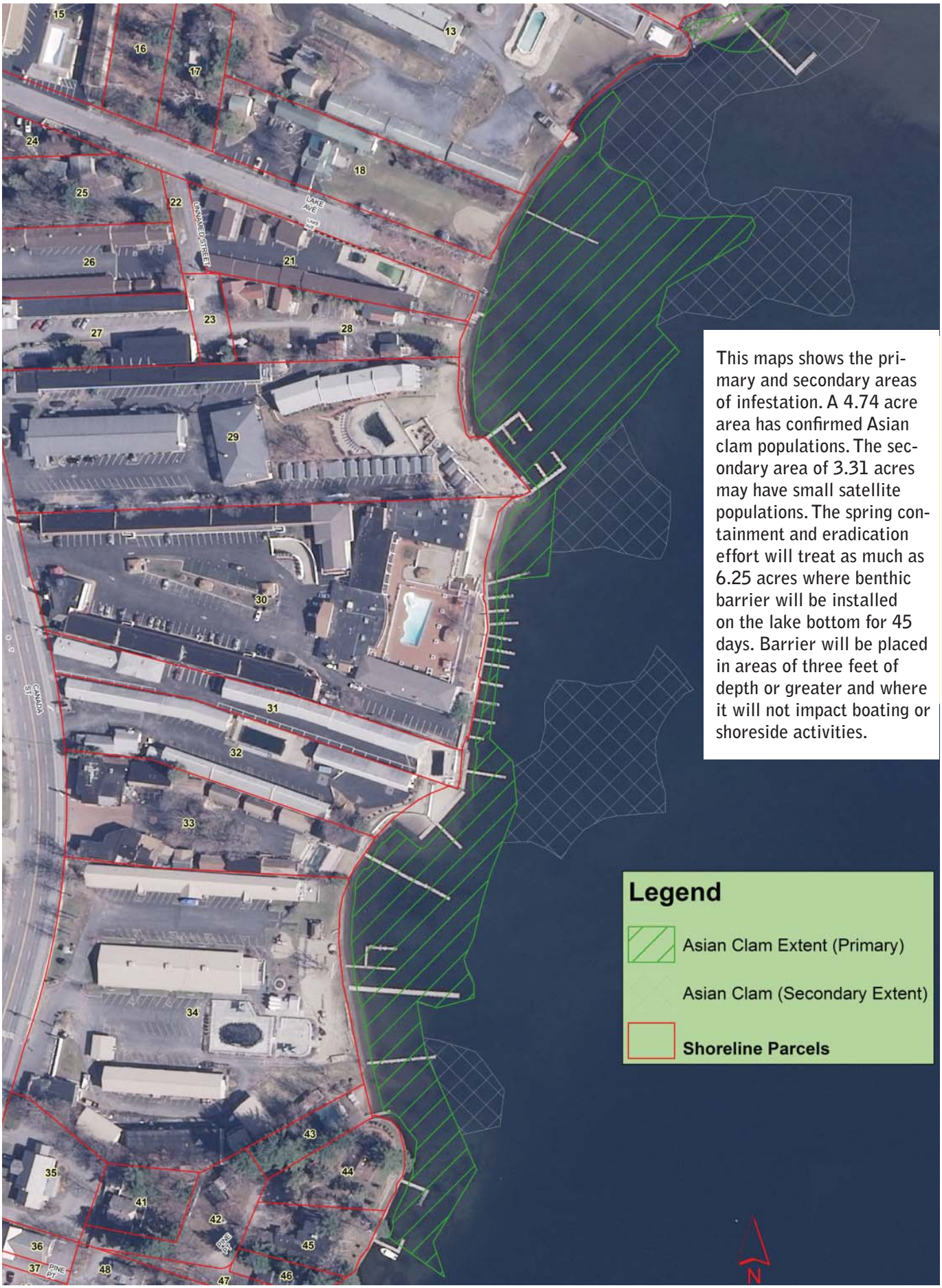
The Asian clam infestation in Lake Tahoe has grown from an area of less than one acre to over 200 acres in less than ten years. Dense clam beds now see regular algal blooms. Without successful treatment, this could happen in Lake George. All photos above are from Lake Tahoe.

of professionals and volunteers organized to gather and share information about the nature of the infestation and long-term threats. This group formalized into the ad hoc Lake George Asian Clam Rapid Response Task Force (LGACRRTF), which includes members from the Darrin Fresh Water Institute, Adirondack Park Agency, New York State Department of Environmental Conservation, Lake George Park Commission, Adirondack Park Invasive Plant Program, Lake George Watershed Coalition, Lake George Association, Lake Champlain Basin Program, Dome Island Committee, Lake George Waterkeeper, and FUND for Lake George. Additional technical services are provided by the divers associated with Bateaux Below, Inc., InnerSpace Scientific Diving, Scientific Diving International, the Lake Champlain Maritime Museum as well as by the Vermont Department of Environmental Conservation. The LGACRRTF has taken the lead in planning and implementing an eradication effort. This group has worked closely with the Village and Town of Lake George, which have been very supportive.

Containment and Eradication Plan

The LGACRRTF has organized a containment and eradication plan for the Asian clam. Scientific work on the extent and size of the population was completed in the fall 2010 and winter 2011. Various treatment methods were tested or researched. Permit applications were organized and funds were raised from many sources to support an eradication effort now planned in two stages, the first running from April – July of 2011, and second treatment may occur after Labor Day 2011.

Permits Required: A general permit and a wetlands permit are required from the Adirondack Park Agency. A nationwide permit is required from the US Army Corp of Engineers. An excavation in navigable waters permit is required from the Department of Environmental Conservation. The State



This maps shows the primary and secondary areas of infestation. A 4.74 acre area has confirmed Asian clam populations. The secondary area of 3.31 acres may have small satellite populations. The spring containment and eradication effort will treat as much as 6.25 acres where benthic barrier will be installed on the lake bottom for 45 days. Barrier will be placed in areas of three feet of depth or greater and where it will not impact boating or shoreside activities.

Historic Preservation Office has issued a Letter of No Impact. The Office of General Services has issued an authorization letter. The Natural Heritage Trust of the Department of Environmental Conservation has issued a determination about classified *Rare, Threatened or Endangered Species* that may be present in the treatment area. The Lake George Park Commission is the designated Lead Agency under the State Environmental Quality Review Act. The FUND for Lake George is the permit recipient.

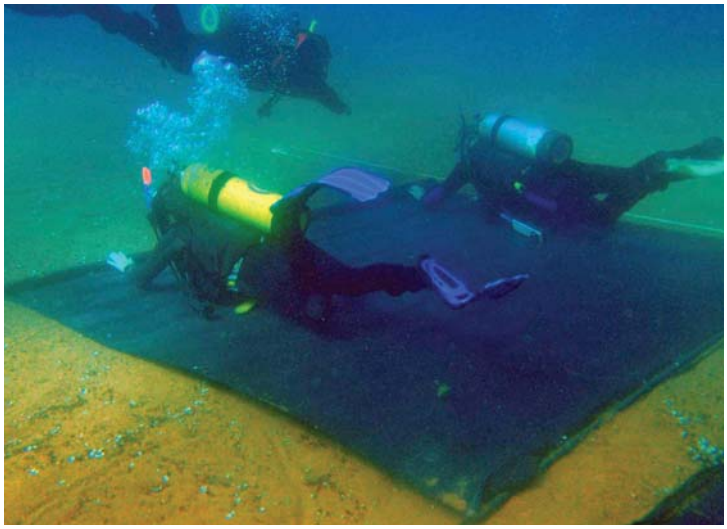
Project Timetable: The first stage of the containment and eradication treatment plan is designed to begin in April before the first reproduction cycle of the year begins, which will prevent expansion of the area of infestation. Clams will start reproduction when water temperatures reach 59 degrees (15 degrees C), which in Lake George Village Bay has occurred as early as May 11th. If treatment is delayed until the fall, it's likely that the treatment area would be significantly larger than it is now, as possibly two new reproduction cycles could be completed by then. A second stage will begin in the fall of 2011 after Labor Day and will be based on the success of the spring effort.

"If treatment is delayed until the fall, it's likely that the treatment area would be significantly larger than it is now, as possibly two new reproduction cycles could be completed by then."

Population Delineation: Extensive scientific work was completed to estimate the Asian clam population in Lake George and delineate the area of infestation. This work involved assessment with formal transects on the lake bottom, sample dredges, diver sieving, and extensive core samples with laboratory analysis throughout the Lake George Village Bay area, from Shepard Park to the English Brook delta. Additional work was undertaken outside this area to try and locate other Asian clam populations in the south end of Lake George. 60 surveys were conducted using transects at .25-mile intervals across 10 miles of lakeshore areas north and east of the Village. No other infestations were found. This work was overseen by the DFWI and managed by Scientific Diving International and Innerspace Scientific Diving International.

It is believed that the area of infestation is confined to an 8.1 acre area in the Village of Lake George, extending from south of the English Brook delta area to Pine Point. This area has 4.74 acres of confirmed high population densities and 3.31 acres with possible small satellite populations that need to be confirmed with further testing. In the area with the heaviest occurrences, the Asian clams seem to be restricted to sandy or sandy and gravel substrates in densities of up to 6,000 per square meter. In Lake George these sediment types are located very close to shore, particularly where beaches have been created and are regularly used. Size-frequency data suggest that the Asian clam has reproduced over one, and possibly two, summer seasons, meaning that the clams likely entered Lake George in 2009 or 2008, and have completed 4-6 reproduction cycles in the lake.

Testing Potential Treatment Methods: The LGACRRTF looked at various treatment methods to kill Asian clams. Treatment options considered included use of benthic barrier arrayed on the lake bottom and weighted down to prevent exchanges of water, which reduces dissolved oxygen (DO) to a point where the clams suffocate. This method has been used successfully in Lake Tahoe. This method was tested in Lake George in November-December where four different types of barrier were tested in the infested area to evaluate viability of this method and the most successful type of material. 20mm PVC barrier was the highest performing with stellar mortality levels. Another method was suction harvesting (dredging) where lakebottom sediment in a specified area is removed to a certain depth. Clam on the lake bottom and burrowed in the sediment are removed from the area by dredging. This treatment option has also been used in Lake Tahoe. The NYS Department of Environmental Conservation (DEC) Region 5 Fisheries Division tested the efficacy of the chemical *Bayluscide* to control Asian clams in Lake George in a laboratory assessment using lake conditions. Chemical treatment failed as a viable option.



Asian clams will be removed from Lake George through use of benthic barriers, which suffocate clams. Benthic barriers will be placed over 4+/- acre area in water of three feet of depth and greater. Another 2.25 acres of treatment is possible if satellite clam populations are found outside the treated areas. The images above are from treatments in Lake Tahoe.

Last, five heat tests were carried out on December 6, 2010 where hot water was used to kill clams on the surface and in the sediment. Heat treatment too failed as a viable option.

Spring Treatment Method Selected: It is the plan to initially install 565 benthic mats over a 4+/- acre area that includes as much of the 4.77 acre primary area of infestation as possible (see maps on pages 8-9). Once the 4+/- acres of benthic barrier has been installed (as shown on pages 8-9), researchers with DFWI will conduct surveys to identify satellite Asian clam populations outside the treated area. Every effort will be made to treat any clams found.

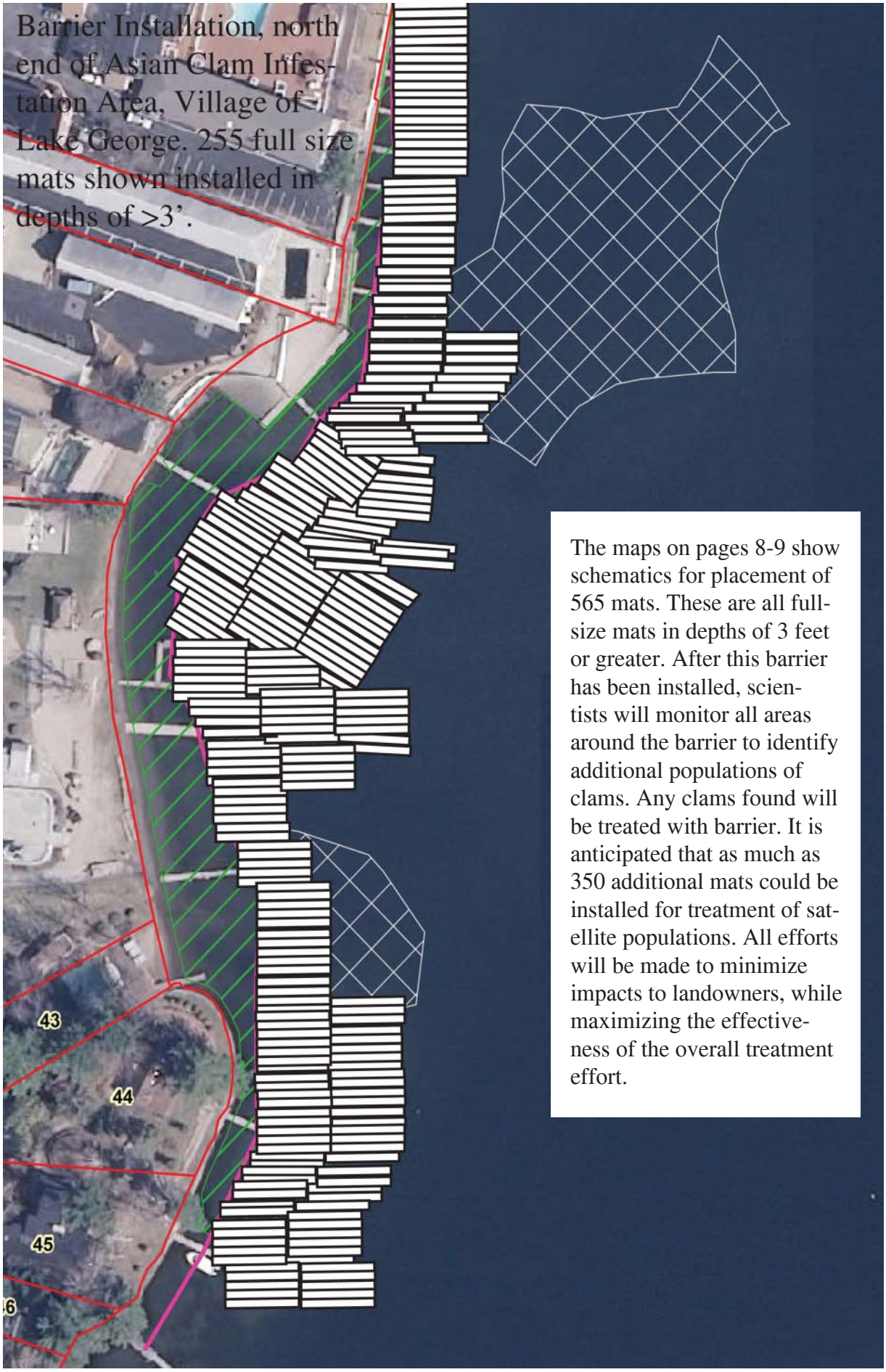
Benthic barrier is 7'x 50' PVC mats and 146 mats cover a square acre after accounting for a significant area of overlap to ensure an airtight seal. Supplies to cover a total of 6.25 acres will be available to this project. Barrier will be installed to avoid boater and swimmer contact at depths of three feet or greater. Barrier will be cut and fitted and secured under and around docks where necessary.

An additional 350 mats (covering 2.25+/- acres) will be available for secondary installations during the spring treatment for instances where clam populations are found by scientists in areas in deep or shallow waters outside the 4+/- acre initial treatment area. Barrier installed in shallow waters will be with agreement from adjacent landowners. It is possible that as much as 6.25 acres could be treated this spring with benthic barriers.

Originally, a suction harvesting operation was to be combined with use of benthic barriers. This operation was fully permitted by the regulatory agencies. Unfortunately, the high costs, late ice-out conditions on the lake, and logistical issues for staging this complex operation on shore, all forced the LGACRRTF to abandon these plans and pursue an expanded benthic-barrier-only treatment effort in the spring. Based on results from the spring treatment effort, a fall treatment effort that involves suction harvesting and benthic barriers in some combination or individually is likely.

The LGACRRTF is very aware of the impact of this treatment effort on adjacent landowners and businesses. The area of infestation is also one of the most important recreational areas in the Village of Lake George as shoreside resorts/marinas have over 600 rooms and 150 dock slips rented seasonally and


Barrier Installation, north end
of Asian Clam Infestation
Area, Village of Lake George.
310 full size mats shown in-
stalled in depths of >3'



Barrier Installation, north end of Asian Clam Infestation Area, Village of Lake George. 255 full size mats shown installed in depths of >3'.

The maps on pages 8-9 show schematics for placement of 565 mats. These are all full-size mats in depths of 3 feet or greater. After this barrier has been installed, scientists will monitor all areas around the barrier to identify additional populations of clams. Any clams found will be treated with barrier. It is anticipated that as much as 350 additional mats could be installed for treatment of satellite populations. All efforts will be made to minimize impacts to landowners, while maximizing the effectiveness of the overall treatment effort.

for guests. There is also one public beach and cartop boat launch area and one private boat launch in the treatment area. The LGACRRTF believes that installation of benthic barrier at depths of 3 feet or deeper will cause minimal disruptions, if any, to shoreside resorts and the general public during the spring and early summer months.

The selected benthic barrier is new PVC mats that are 7.01' x 50' in length and 20mm thick and are a type used successfully over the years by the Lake George Park Commission for control of Eurasian watermilfoil. The pilot study found that new PVC benthic barrier achieved the best results and, therefore, all barrier used as part of this project will be newly purchased specifically for Asian clam treatments. The pilot study was managed by DFWI and the LGPC under a permit from the Adirondack Park Agency.

Benthic barrier will be installed perpendicular to shore. Barrier will overlap one foot on all sides with other barrier to ensure seals against infiltration by dissolved oxygen. The weight on the barrier will consist of 21 5-foot pieces of No. 5 rebar (1.043 lb per foot) installed along the long seam. Rebar will be installed at the end of each mat and along each side where mats are overlap one foot, as well as spaced in intervals in the middle of the mats for the full length.

Benthic barrier will also be fitted under and around docks where water depths allow. It's likely that barrier will be cut into smaller pieces in lengths of 10, 15, 20 and 25 feet. In these locations No. 4 rebar in smaller pieces will be used, provided from stock managed by the LGPC.

Barrier will be installed over a 3-4 week period just after ice-out and when safe working conditions prevail, starting on April 25, 2011. Barrier installation will likely be completed by May 11, 2011. Installation will be start at the south end of the treatment area, in the area around Pine Point and proceed north. Deep water and dock areas will be managed at the same time. Schematics of the barrier plan are on pages 8-9.

Barrier and steel (rebar) will be loaded onto boats at the Lake Avenue Parking lot and beach area. This facility has a 12 car parking lot, which the Village has closed to facilitate staging for benthic barrier installation. The Town and Village of Lake George will coordinate transporting via backhoe/forklift pallets of barrier and steel to the lakeside where it will be loaded onto boats provided by the LGPC and the private contractor. Installation of the barrier will be performed under a contract by the FUND for Lake George.

Barriers will need to remain on the lake bottom for 45 days to ensure maximum success in killing Asian clams.

Secondary Treatments: It's important to note that the areas surrounding the initial 4+/- acre treatment area will be tested by DFWI for the presence of live Asian clams during the installation period, both shallow and deeper waters. Any satellite populations found will receive benthic barriers where feasible. Every effort will be made to treat areas with positively identified populations. Up to 6.25 acres could be treated.

Scientific Monitoring and Evaluation of Success: Once barrier installation has been completed and certified that all barrier has been properly installed, it will be left on the lake bottom for 45 days. DFWI will coordinate the scientific assessment during the treatment period to evaluate dissolved oxygen levels under the benthic barriers to ensure that the barrier maintains sufficiently low levels to kill the clams. There will be crews of divers and technicians managed by DFWI working on scientific monitoring

during the period when the barrier is in place and during the second half of July and August working in the treatment area after barrier is removed.

DFWI took the lead in delineation of the area of infestation and population estimates as well as organization of a pilot study to determine the best treatment options. DFWI will manage the effort to evaluate the success of the treatment by analysis of as many as 1800 core samples after the treatments have been completed.

Maintenance of Benthic Barrier Area for 45 Day Treatment Period: Routine monitoring inspections of benthic barrier will occur throughout the treatment period. Inspections will be made daily for the first ten days and then every third day thereafter. Inspections will survey all mats to ensure that barriers and steel remain in place. This work will be undertaken by two divers and a top water support person in a kayak.

Removal of Barrier/Steel: Materials will be removed from the lake bottom by divers loading it onto boats where it will be transported to the shore area along Beach Road, outside the Million Dollar Beach area, where it will be off loaded. Barrier will be placed in construction trailers and transported to another location for processing (cleaning, re-rolling and stacking/fastening onto pallets for future reuse). The steel will be stacked and tied to pallets and transported to a facility for storage. The removal will commence after the completion of 45-day treatment period at a point in late June. It is anticipated that removal will take 2-3 weeks. The NYSDEC has stated that Temporary Revocable Permit is necessary to use these state lands as a staging area for the removal of materials.

Anticipated Outcome: Based on results from the pilot study, the LGACRRTF anticipates a high rate of mortality for all areas treated with benthic barrier. In addition, because secondary treatment is an option for populations identified outside the initial area of barrier treatment we are confident of a rapid response for areas where satellite populations are determined. The margin for error is small with this eradication effort. It is likely that the infestation started with a small number of clams and has grown over the course of several years into a population of hundreds of thousands covering over five acres.

The LGACRRTF is confident that a very high percentage of the Asian clams will be killed throughout the infested area and acknowledges that complete eradication is possible, though not likely. More realistically, the LGACRRTF envisions subsequent smaller treatments will be necessary in the fall of 2011, and possibly beyond, to reach its goal of complete eradication.

A full detailed report on the results of this effort will be available in late August.

Impacts to Shoreline Property Owners and Resorts: Every effort is being made to minimize impacts to shoreline property owners and resorts. Outreach efforts are being made to fully inform this important group about the scope and schedule for the eradication treatment. Efforts to minimize impacts include:

- Installation of benthic barrier as early as feasible in difficult, cold water working conditions;
- Installation of barrier in areas of water depths of three feet or more;
- Careful installation under and around docks to ensure there is no interference with boating;
- Abundant shoreline signage/materials informing users of eradication effort underway;
- Educators will be patrol the treatment area to inform the swimming and boating public about the treatment effort and its importance for the lake;
- Removal of barrier using state lands at the south end of Lake George rather than the Lake Avenue Beach Area; and,

The area of infestation is one of the most popular resort areas on Lake George, with over 600 rental units and 150 boat slips. Extensive work is underway with shoreline resort owners to minimize disruptions to business operations.

- Creation of an informational number for the public 518.620.6240 and website www.stoptheasianclam.info.

Impact on Native Flora and Fauna: The benthic barrier treatment will eliminate some of the native plant life throughout the treatment area. Plants impacted by the benthic barrier will have a substantial amount of growing season to generate growth of stems and leaves from starchy reserves in the root mass after the barriers are removed. This may result in the survival of some of the individual plants, especially those that regenerate later in the growing season. A report was prepared on the current aquatic plant community and distribution in the infested site by DFWI. The site slopes gradually and in 2006 contained 22 different native aquatic plants as well as Eurasian watermilfoil (*Myriophyllum spicatum,* referred to as EWM). The plants and plant communities that exist in the lake are typical assemblages of the leading aquatic plant species.

Two plants of concern are *Myriophyllum alterniflorum*, or little milfoil, which is on the NYS Rare Plant List. Little milfoil is fairly common throughout Lake George, documented in aquatic plant survey work of DFWI. Also present is *Megalodonta beckii*, commonly known as water marigold. This plant is found on the NYS Watch List. This plant too is fairly common throughout Lake George, documented in aquatic plant survey work of DFWI. Both plants are also present in areas adjacent to the treatment area.

Native clams or mussels of the family *Unionidae* are present in the treatment area. The predominant species in the treatment area is *Elliptio complanata* (65.4%), followed by *Lampsilis radiata* (27.9%) and *Pyganodon cataracta* (6.7%). All unionids occurred in densities of 0 to 25 per m2 with a mean of 4.6 per m2. Distribution of the unionid mussels was nearly opposite of the Asian clams, with the majority of the population occurring in depths of 2 m or deeper. Four species of "pill" and "fingernail" clams

in the family Sphaeriidae (*Pisidium rotundatum*, *Pisidium ventricosum*, *Sphaerium partumeium*, and *Sphaerium stratinum)* are present.

Restoration of Native Flora and Fauna: Given the aquatic plant communities around the treatment site, it is anticipated that natural recolonization will occur over the next three years. There will be an active invasive species prevention and control program for the project site. The LGPC has managed a EWM control program in Lake George since 2002 under contract with Lycott Environmental, LLC. In addition, the FUND for Lake George has augmented this program with hand-harvesting operations under a separate contract since 2009. Both projects operate under APA permits.

Similar to the native plant recolonization, it is expected that the native fauna, as identified above, will recolonize this site. It should be noted that although native clams and mussels are found in this area, it is not part of the DFWI long-term study of native mollusks in the lake where dozens of other more dynamic habitat areas have been identified and studied.

During the summer of 2014, the FUND for Lake George will work with the DFWI to complete aquatic species plant and native fauna survey of the treatment area and produce a report to be submitted to the APA and other regulatory agencies.

Additionally, all equipment will be thoroughly cleaned and inspected for invasive species.

Impact on Historic Social and Cultural Resources: The eradication effort is highly unlikely to impact unknown historic social or cultural resources in the area. The project location is within an area identified as archeologically sensitive and adjacent to a site listed on the National and State Registers of Historic Places. The known resources, part of the 1758 sunken fleet of bateaus, are outside the treatment area and will not be impacted from this activity. The project design includes a plan to direct all project related activities away from submerged artifacts known to be present near the project site and include training on underwater cultural resources impacts for all volunteers and contractors. A formal Letter of No Impact was issued by the State Historic Preservation Office.

Potential Fall Treatment: Based on the results of the spring benthic barrier treatment effort, a fall effort at some point after Labor Day is a possibility. This effort could involve use of suction harvesting to remove the top six inches of sediment from the lake bottom at select locations. Sediment would be pumped into dewatering bags placed in the shore at permitted locations. After the dewatering process, sediment would be transported to a disposal location away from the lake. A fall treatment could also focus on a second benthic barrier treatment or a combination of suction harvesting and benthic barrier.

Costs

A total of $370,000 of has been committed as cash contributions to this effort. Another $37,000 of materials has been provided by the Lake George Park Commission. Many organizations have committed staff time and inkind services will be provided by area local governments, totaling over $100,000. Committed support includes three Lake Champlain Basin Program grants totaling $75,000; NYSDEC, $75,000; Lake George Park Commission, $75,000; Lake George Park Commission (equipment and supplies), $37,000; Adirondack Park Invasive Plant Program, $10,000; Village of Lake George/NYS Department of State, $30,000; Lake George area Local Governments, $25,000; FUND for Lake George, $25,000; Lake George Association, $25,000. Efforts continue to identify additional sources of support. Completion of the initial treatment for the spring and summer of 2011 will require additional resources as projections of total costs are upwards of $400,000. A fall treatment will also require considerable resources.

“Do-Nothing” Option

Peer reviewed scientific literature on ecological and economic effects of Asian Clam in a northern latitude water body like Lake George is limited. Most work on the clam occurred with its subsequent invasion in the 1980s and 1990s. This work had an emphasis on water treatment and cooling facilities in the Southern United States and on the St. Lawrence River where the clam was causing significant problems in water intake pipes. The most comparable research to Lake George comes from Wittmann, et al., in Lake Tahoe, NV. After monitoring the clam and its exceptional range expansion over the course of 8 years within Lake Tahoe, Wittmann suggests that while true eradication is difficult, the potential economic and ecological impacts are of such severity that management of the Asian clam, if detected early, is critical. Several key points of research are below:

- Two reports from Lake Tahoe find that the Asian clam is a aquatic invasive species that requires intensive management in order to protect the historic ecological health and recreational enjoyment of the lake:
  - 1) “The Asian clam has often been described as an ecosystem engineer, having the ability to alter a variety of habitats.” (Wittmann, et al., 2008) In Lake Tahoe “Its distribution is increasing and it has been linked to the large benthic algal blooms of summer 2008. Because of its ability to alter benthic habitats as well as to bioconcentrate calcium, it has a large role in the possible facilitation of invasion for other bivalves such as zebra or quagga mussel.” (Wittmann, et al., 2008)
  - 2) “The rapid expansion of Asian clams in one year combined with demonstrated potential to alter the ecology of the lake via unprecedented levels of algal biomass in the near shore represents a major new threat to Lake Tahoe.” (Chandra, 2009)

- The Asiatic clam (*Corbicula fluminea*) Invasion and System-Level Ecological Change in the Potomac River Estuary near Washington, DC. (Phelps 1994)
  - 1) Phytoplankton abundance was 40 – 60% less in a segment of river were the highest densities of Corbicula occur. In a laboratory setting, Corbicula removed 30% of the phytoplankton in a sample jar in 2 hours.
  - 2) Scientists tested this decrease against other factors that could have caused this, other than Corbicula (toxicity, sewage discharge, high flows), and did not find a similar correlation.
  - Additional findings from Phelps 1994:
    - First found in the estuary in 1977. In 1981, a tripling of water clarity was reported in the region of the clam beds, followed in 1983 by a reappearance of submerged aquatic vegetation absent for 50 years. The vegetation has been mapped by aerial photography every year between 1976-1993.
    - In addition, fisheries surveys in 1986 found fish populations had increased 7x in new beds of vegetation. Additionally, aquatic bird populations significantly increased as well.
    - In 1986 the clam population was 25% smaller than that of the 1984 population. Also, the 1992 population was also 25% of that of the 1986 population.
    - Since 1986, vegetation acreage has been decreasing and aquatic bird populations have declined. Yearly nuisance algae blooms (Microcystis) which had been absent since the early 1980s reappeared in 1993.
    - The authors believe the Asian clam invasion triggered system-level changes in biota, including increases and decreases in Potomac estuary populations (vegetation, bird, fish, algae) over 10 years from 1983-1993.

Asian clams on the lake bottom mixed in with aquatic plants, pictured on the top left. Above right divers take sediment core samples underwater.

- Ecological Resistance to the invasion of a freshwater clam, Corbicula fluminea: fish predation effects. (Robinson and Wellborn 1988)
  - Fish predation has had a significant impact on the abundance of Corbicula in a Texas reservoir.
  - The following fishes are known to eat Corbicula: Carp, Smallmouth buffalo, black buffalo, warmouth, bluegill, redear sunfish, freshwater drum, American shad, striped bass, river redhorse, channel catfish, blue catfish, sturgeon.

- Economic Effect of Aquatic Invvasive Species:
  - Research seems to show that macrophyte growth can substantially affect lake shore property values. In Vermont lakes, they found a 1-16% decrease in property values in lakes that had varying degrees of milfoil (Zhang and Boyle 2010). One could assume that dense algae growth caused by clams could cause a similar affect.
  - A study on New Hampshire lakes found aquatic recreationalists were 68% more likely to decrease their visits to a particular lake if the water purity (invasives, mercury, algae) increased (Nordstrom 2007).

While the scientific literature is not robust on the long-term impacts of the Asian clam to freshwater lake ecosystems, the 8-year infestation in Lake Tahoe, a lake at a similar high northern latitude, elevation and trophic status, serves as an example not to be replicated in Lake George. In fact, the leading Tahoe scientists studying the Asian clam infestation have strongly expressed the need to act quickly with an aggressive eradication effort.

Another factor to consider is that Lake George experiences boat traffic much higher than most other lakes in the Adirondack Park. (Lake George Park Commission, 2009) In the 1980 – 1990s, Lake George saw an infestation of the invasive Eurasian watermilfoil (*Myriophyllum spicatum*) (EWM). It is believed that this high boat traffic entering and exiting Lake George made the lake a key vector for the spread of EWM throughout the Adirondack Park.

The Tahoe example combined with the long-term experiences of Asian clam infestations in the Potomac River along with the EWM spread experience, makes the do-nothing option untenable for Lake George. The Lake George community, as it has organized with the LGACRRTF, is committed to an eradication effort of the Asian clam to be started in April 2011.

Conclusion

Because the Asian clam population is still believed to be confined to a reasonably small area, the LGACRRTF is hopeful that Asian clam can be eradicated from Lake George. Additional survey work will be coordinated in other parts of Lake George this summer to try and identify other populations of Asian clams that may exist. There remains grave concern about further spread around the lake.

Lake George was one of the first lakes in this area to experience an infestation of EWM. The popularity and high boat traffic on Lake George made the lake a key vector in the spread of EWM to much of the Adirondack Park since the 1980s and 1990s. There is great concern that the Asian clam could be similarly spread.

The margin for error is small with this eradication effort. It is likely that the infestation started with a small number of clams and has grown over the course of 2-3 years into a population of hundreds of thousands covering over five acres. The LGACRRTF is confident that a very high percentage of the Asian clams will be killed throughout the infested area and acknowledges that complete eradication is possible, though not likely. More realistically, the LGACRRTF envisions subsequent smaller treatments will be necessary in 2011, and possibly beyond, to reach its goal of complete eradication.

More Information about the Asian Clam *(Corbicula fluminea)*

The Asian clam (*Corbicula fluminea*) was first identified in the wild in 1938 in rivers of Washington (Counts, 1986). It has subsequently become naturalized in at least 40 states within the continental United States. There is some degree of uncertainty in use of the name *C. fluminea*, and it appears that there are two lineages in North America (Siripattrawan et al., 2000), but until such time as the systematic relationships are resolved the name *C. fluminea* will suffice.

Asian clams are easily transported within and between water bodies either as adults or as small juveniles along with water or sediment. Transport in water or sediment may be inadvertent, but public education should warn about transporting water, sediment, or anything living between water bodies. Transport of adults may be purposeful as live bait or as unwanted aquarium specimens. In Florida the Asian clam is promoted as bait by the Florida Fish and Wildlife Conservation Commission and also by angling websites. Disturbingly, *C. fluminea* is available at numerous aquaculture websites as a live item and is promoted, as the golden clam, as a beneficial aquarium species. Finally, golden clams and essence of golden or "good luck" clams is promoted by some Asian websites as a cure for various human disorders. The potential magnitude of these vectors is unknown, but they must be considered as potential sources of introduction to Lake George.

Asian clams reproduce rapidly and can form dense populations of thousands per square meter (see review by Strayer, 1999). They typically inhabit sand or gravel substrates (Aguirre and Poss, 1999) and have been associated with high levels of nitrogen and phosphorous at the sediment-water interface (Lauritsen and Mozley, 1980). The Asian clams have been implicated as competitors for food, space or habitat with native clams of the superfamily *Unionacea* (see review by Yeager et al., 1999). Lake George supports a healthy population of three species of unionacean clams (*Elliptio complanata*, *Lampsilis radiata*, and *Pyganodon cataracta*). Lake George also has a relatively unknown fauna of diminutive "pill" and "fingernail" clams in the family Sphaeriidae (*Pisidium rotundatum*, *Pisidium ventricosum*, *Sphaerium partumeium*, and *Sphaerium stratinum* (unpublished data, DFWI). Any and all of these may be at risk from an Asian clam invasion.

The Asian clam, like the native unionacean clams, feeds by removing algae, bacteria, and zooplankton from the water in a process known as suspension feeding. This process involves filtering lake water, removing food materials and other suspended particles, and returning the water to the lake. Unlike the unionacean bivalves but similar to the sphaeriid clams, the Asian clam also feeds using ciliary mucoid feeding tracks on its muscular foot (Hakenkamp and Palmer, 1999). In well oxygenated lakes and streams of about neutral pH, dissolved phosphate at the sediment-water interface is bound up into insoluble ferric phosphate by an oxidized iron compound. If oxygen is depleted the ferric compound is reduced to a ferrous compound and the phosphate is released into the water, where it can be utilized by phytoplankton, algae or rooted aquatic plants. Because the Asian clam is capable of "pedal feeding" it can move normally unavailable nutrients from below the sediment-water interface into the water, where they become available.

The usual effect of this is that phytoplankton and algae thrive above Asian clam beds, creating local algal blooms and moving low nutrient or oligotrophic lakes towards eutrophication. This has recently been demonstrated in Lake Tahoe. This makes the Asian clam an acute threat to the water quality of Lake George.

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Pictures and Maps

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