Asian Clam Habitat, Population Density and Size Range in Select New Hampshire Waterbodies

New Hampshire Department of Environmental Services
November 2018

R-WD-18-18

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2018

Prepared by
Amy P. Smagula
Limnologist/Exotic Species Program Coordinator
Watershed Management Bureau

In conjunction with
Eric Nelson
USEPA Region 1
and
Hilary Snook
USEPA Region 1

Robert Scott, Commissioner
Clark Friese, Assistant Commissioner

New Hampshire Department of Environmental Services
29 Hazen Drive
Concord, NH 03301
des.nh.gov

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

NOVEMBER 2018

Executive Summary

Figure 1- Field sampling for Asian clam in Long Pond

The Asian clam (*Corbicula fluminea*) is established in New Hampshire, and has been sustaining populations in various waterbodies since at least 2011.

Various physical, chemical and biological characteristics of select New Hampshire waterbodies coincide with suitable ranges for Asian clam survival. As such, there was interest in determining the extent and degree of infestation in each of the waterbodies where populations had been documented.

The goal of the study was twofold: 1) Determine the densities and distributions of Asian clam in portions of the Merrimack River (Concord to Hooksett), Cobbetts Pond (Windham) and Long Pond (Pelham), and 2) Determine water quality and sediment characteristics in affected systems.

This study was done as a partnership between the US Environmental Protection Agency (EPA) Region 1 and the New Hampshire Department of Environmental Services (NHDES), and represents a snapshot in time of conditions in each study waterbody during the 2013 growing season. Long-term trend monitoring was not feasible due to limitations in staff time and funding; however, population studies during low temperature timeframes would be desirable to determine community vigor of Asian clam populations under stressful cold temperatures.

With its microscopic larvae, diversity of reproductive means, rapid maturity to sexual reproductive capabilities, broad range of environmental tolerances and other factors, the Asian clam is a good colonizer of new sites, and is apparently finding suitable habitat in New Hampshire.

Because eradication and management are a challenge, it becomes increasingly more important to document new infestations immediately so that appropriate steps can be taken to prevent further spread. It is imperative that Clean, Drain, Dry initiatives be implemented to reduce the likelihood of continued contamination of new waterbodies.

Contents

Introduction

Figure 2- Asian clams in sampling sieve

Corbicula fluminea (Müller, 1774), also known as the Asian clam, is a freshwater bivalve native to Asia, Australia and Africa (Saloom and Duncan 2005, Crespo et al. 2015, Pigneur et al. 2014) that is considered an aquatic invasive species (AIS) in the United States (Sousa et al. 2008, Lucy et al. 2012, Crespo et al. 2015).

Asian clam was likely intentionally introduced to the United States in the early 1900s as a food source for people, and more recently as accidental introductions through ballast water from trade ships (Sousa et al. 2008, Lucy et al. 2012) and transient recreational boating activities. The first report of Asian clam in the U.S. was in the Columbia River, Washington, in 1938, and the clam has since spread to over 40 states (Lucy et al. 2012) as a result of water currents (Morgan et al. 2004), recreational boating activities and movement, and improper disposal of bait and bait buckets (Wittmann et al. 2008, Crespo et al. 2015). One study of the distribution of Asian clam predicted the inevitability of the species spreading across the globe (Crespo 2015).

The Asian clam was first documented in New Hampshire in 2007, when biologists from the New Hampshire Department of Environmental Services (NHDES) responded to a complaint of a possible zebra mussel infestation in the Merrimack River in Merrimack, NH. No zebra mussels were found, but another small bivalve was commonly found on the river bottom, and was later identified as *Asian clam*. In 2011, during routine monitoring activities in the Merrimack River, approximately 25 miles north of Merrimack, private consultants documented the presence of the Asian clam in portions of the river in Bow and Hooksett, New Hampshire (Normandeau Associates, Inc. 2012).

Shortly afterward, a press release was issued by NHDES to alert the public of the presence of the clam in New Hampshire, and two more populations of Asian clam were documented, one in Cobbetts Pond in Windham and in Long Pond in Pelham. A year later an infestation was documented in Wash Pond in Sandown. More recently, Asian clam populations were documented by NHDES in 2017 in Beaver Lake in Derry and Great Pond in Kingston.Other infestations are suspected elsewhere, but are as yet unverified.

Asian clam was documented in abutting states of Massachusetts in 2001 (Colwell et al. 2017) and Vermont in 2016 (VT DEC personal communication). There are no documented infestations of Asian clam in Maine to date (ME DEP personal communication).

As an AIS, Asian clam is an opportunistic species which settles easily in lakes, ponds and rivers (Pigneur et al. 2014), where it can form dense colonies along bottom sediments. Varied reproductive capabilities allow Asian clam to colonize quite rapidly. Parthanogenesis, a form of hermaphroditic reproduction (Crespo et al. 2015, Pigneur et al. 2014), allows population propagation from a single clam. Small microscopic juveniles can stay up in the water column for as long as two days before settling due to secretion of byssal threads that aid in buoyancy in the water column, they are easily transported by water currents, which further extends colonization capability (Wittmann et al. 2008). High reproductive success is also possible through a rapid maturation (in as little as 3-7 months) and growth to reproductive maturity (Sousa et al. 2008, Pigneur et al. 2014). Studies show that Asian clam can reach a maximum diameter of 55 mm within a five- to six-year lifespan (Sousa et al. 2008, Wittmann et al. 2008).

Asian clam has been documented to be temperature tolerant from 2-30 ºC, which includes a lower threshold of temperature tolerance than originally thought for this species. Habitat range is thus somewhat expanded into colder northern latitudes due to the influence of unnatural thermal gradients or thermal pollution (Lucy et al. 2012, Crespo et al. 2015), as seen in the Connecticut River (Morgan et al. 2004) and the St. Lawrence River (Simard et al. 2012). Asian clam was identified near the Connecticut Yankee nuclear power station in the Connecticut River in the 1990s (Morgan et al. 2004), New York State and Vancouver Island in 2008, and the St. Lawrence River in Canada near the Gentilly-2 power plant of Hydro-Québec in 2011 (Simard et al. 2011).

The absence of thermal pollution is thought to limit Asian clam habitat north of Lake George (Werner and Rothhaupt 2008, Simard et al. 2011) due to low seasonal temperatures within those systems, and periods of ice cover (Crespo et al. 2015), much like the conditions we have in New Hampshire. The Asian clam population in Lake Constance, Germany, was subject to three months of 2 ºC water temperature, with only 1 percent survival (Werner and Rothhaupt 2008); however, populations have been seen to overwinter in lakes and ponds in New Hampshire that have absolutely no direct thermal influences. Low dissolved oxygen levels have been seen to further reduce survivability of the clams (Crespo et al. 2015).

As with most AIS, a key concern is a threat to native species richness, biodiversity and frequency in infested sites, where the clam can become dense enough to impact the ecological functions and designated uses of a system (Sousa et al. 2008, Crespo et al. 2015). Survival of native bivalves can be threatened because of the high filtering capacity of Asian clam, shifts in plankton communities can occur, biological oxygen demand can increase and aesthetic and recreational values of the waterbody can decrease (Crespo et al. 2015, Pigneur et al. 2014).

Figure 3- Asian clam shells littering fish beds on the bottom of Cobbetts Pond in Windham in 2016. Photo courtesy of Walter Henderson, NHDES.

Asian clam can degrade water quality due to increased rates of nutrient cycling and decomposition of increased clam tissue. Shells from dead clams foul recreational beaches with increased numbers of sharp shells, and alter the amount of calcium available in the waterbody (Wittmann et. al 2008). In 2008, a study on the Lake Tahoe ecosystem found that Asian clam increases biologically available nutrients, such as nitrogen and phosphorus, in the lake sediments and water column, and promotes algal growth and dead zones from high filtration capacity (Wittman et al.), including growth of harmful algal blooms.

Various physical, chemical and biological characteristics of select New Hampshire waterbodies coincide with suitable ranges for Asian clam survival. As such, there was interest in determining the extent and degree of infestation in each of the waterbodies where populations had been documented.

The goal of the study was twofold: 1) Determine the densities and distributions of Asian clam in portions of the Merrimack River (Concord to Hooksett), Cobbetts Pond (Windham) and Long Pond (Pelham), and 2) Determine water quality and sediment characteristics in affected systems.

This study was done as a partnership between the US Environmental Protection Agency (EPA) Region 1 and the New Hampshire Department of Environmental Services (NHDES), and represents a snapshot in time of conditions in each study waterbody. Long-term trend monitoring was not feasible due to limitations in staff time and funding, however population studies during low temperature timeframes would be desirable to determine community vigor of Asian clam populations under stressful cold temperatures. This write-up was completed by NHDES, using shared data from each partner.

Study Site and Methods

Long Pond, Cobbetts Pond and three pools in the Merrimack River (from north to south: Garvins, Hooksett and Amoskeag) were each sampled for physical, chemical and biological parameters to evaluate the conditions in which the Asian clam has established populations. Each water body was sampled by the NHDES Exotic Species Program and EPA Region 1 biologists between July 22-26, 2013. Methods used for site selection and field sampling are outlined below.

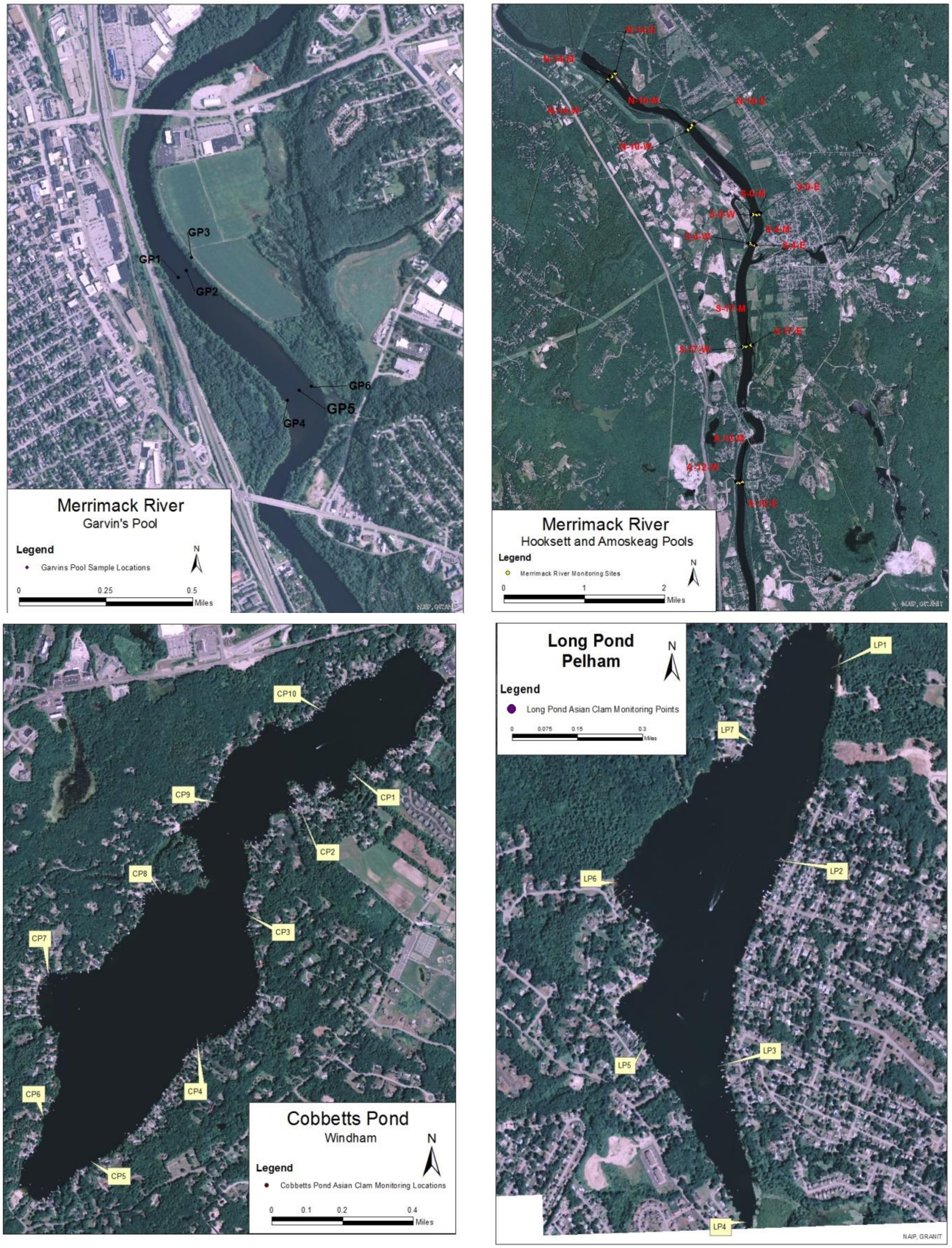
STUDY SITES

In the Merrimack River Hooksett and Amoskeag Pools, points along already established transects (Normandeau Associates 2012) were used as study sites for the purposes of this work. Sites in Garvins Pool (Concord) were selected randomly by NHDES and EPA biologists. In both Cobbetts Pond and Long Pond, equidistant points generated in ArcMap software were placed around the littoral zone of the ponds. Table 1 provides an overview of the number of sample sites and the date(s) of sampling for the purposes of this study. Figure 4 includes maps for each waterbody showing the sample points used for the purposes of this study.

Table 1. Waterbody, number of sites and actual sample dates

Waterbody	Total Number of Sites	Sample Date
Merrimack River Northern Study Reach (Garvins Pools)	6 (two transects, three points per transect)	July 22
Merrimack River Central Study Reach (Hooksett Pool)	15 (five transects, three points per transect)	July 22/23
Merrimack River Southern Study Reach (Amoskeag Pool)	3	July 23
Cobbetts Pond, Windham (344 acre lake)	10	July 25
Long Pond, Pelham (120 acre lake)	7	July 25/26

Figure 4- Sample Locations and Study Sites



METHODS

Each site was sampled for the full slate of parameters outlined in Table 2. Two teams performed the work, with one team focused on Asian clam sample collection (NHDES), and the other team focused on measuring various water quality parameters (USEPA) using a datalogger/multi-probe and other sampling equipment as outlined below.

Table 2. Measured Parameters

Parameter	Method	Location/Depth	Field/Laboratory
Water Depth	Sonar	At each sample point	Field
Secchi Depth	Std Method	At each sample point	Field
Temp/DO Profile	Multi-proble	At each sample point, 0.5 meter intervals in water column	Field
pH	Multi-probe	At each sample point, 0.5 meter intervals in water column	Field
pH (sediment)	Soil pH meter in field	In collected sediment	Field
Turbidity	Multi-probe in field	At each sample point, 0.5 meter intervals in water column	Field
Specific Conductance	Multi-probe in field	At each sample point, 0.5 meter intervals in water column	Field
Chloride	Field collection and bench top meter	At each sample point, 0.5 meter intervals in water column	NHDES JCLC
Calcium	Sample collection and laboratory analysis	At each sample point, 0.5 meter intervals in water column	EPA
Sediment Fractions	Field sample collection with dredge	At each sample point.	NHDES Laboratory drying and sieving
Asian clam count and shell length	Field sediment collection and sieving/counting	At each sample point.	Field and EPA

SAMPLE METHODS FOR ASIAN CLAM

The boat team assigned to Asian clam monitoring navigated to each sample station using GPS with pre-loaded sample locations. At the site, the boat was anchored and the bottom was either sounded using a weight on a calibrated chain, or using sonar. The depth was recorded on a field data sheet. Using an Eckman-type dredge sampler (305mm x 305mm), one member of the team collected a substrate grab and emptied it into a large clean bin. From there the sample was transferred in batches into a 2mm stainless steel sieve (see Figure 2) to remove fine-grained silt and sand. Organic detritus (leaves, etc) was hand removed. Remaining sieve contents were removed and placed in sample bags in the field (labeled with waterbody name, date, time, depth and sample location and put on ice in cooler). Any native mussels or macroinvertebrates collected as part of the sampling were immediately returned to the water at the site of collection: the team had previously obtained a field sampling permit for animals/invertebrates from New Hampshire Fish and Game. This team also used a soil pH meter to measure pH of substrate prior to removal of specimens. A fourth sediment grab was performed and the contents were placed in a one 1-Liter bottle for subsequent sediment fractioning in lab.

When data collection was complete at a site, all equipment was rinsed clean with surface water and then with deionized water. The team then navigated to the next sample location and repeated the sampling steps outlined above, until all sites were sampled.

Within 1-3 days of sample collection, Asian clam samples were processed in the lab, where they were measured using electronic calipers. Only live clams were measured. Empty shells and obviously long-dead clams were discarded. Shell length, width and height of individual live mussels were measured and recorded on laboratory data sheets and then entered into an Excel spreadsheet where basic statistics were performed on the data sets.

Sediment samples were analyzed in the NHDES Jody Connor Limnology Center (JCLC) following standard sieve analysis protocols.

SAMPLE METHODS FOR BIOLOGY/CHEMISTRY

The boat team assigned to water chemistry sampling navigated to each sample station using a GPS with pre-loaded sample locations. At the site, the boat was anchored and the bottom was either sounded using a weight on a calibrated chain, or using sonar. The depth was recorded on a field data sheet. One member of the team calibrated the data sonde/multi-probe using instrument specific methods.

Using the data sonde/multi-probe, the team recorded the following parameters at 0.1m, 0.5m and then at every 0.5m interval along the water column to just above the bottom, logging to a data storage device and also recording results on field data sheets: Temperature (^{o}C), Dissolved oxygen (mg/L), pH, Turbidity, Conductivity, Chloride (if available on multi-probe), Chlorophyll-a (if available on multi-probe).

Using a Kemmerer bottle, the team collected a water sample at mid water column (based on depth at station) as follows: Chloride (if no probe on multi-probe), fill one sample container for chloride analysis at NHDES laboratory (label bottle with waterbody name, date, time, depth and sample location), and fill one sample container for calcium analysis at EPA laboratory (label bottle with waterbody name, date, time, depth and sample location). Samples were stored on ice in a cooler for transport to the laboratory for analysis.

Using a Secchi disk attached to a calibrated chain, the team measured water clarity per standard methods, and recorded that information on a field data sheet.

When data collection was complete the team rinsed the probe with surface water, then deionized water, and moved on to the next sample location and repeated the sampling steps outlined immediately above.

STATISTICAL ANALYSIS

Basic statistical analyses were performed on water quality data (means, standard deviation). The residuals of the Asian clam count data were non-normally distributed. A natural log transformation was attempted on the count data; however, this did not resolve the normality issues. A nonparametric test was necessary. A Levene’s Test was run to determine if the data had equal variances. The Levene’s test was non-significant ($p > 0.17$). Since the variances were not significantly different, a non-parametric Kruskal-Wallis was run.

Results and Discussion

Based on summer 2013 sampling, the Asian clam was abundant and there appeared to be healthy populations in each of the subject waterbodies. Following is a review of the water and sediment quality results we gained from our field sampling activities, as well as an assessment of the population and overall sizes of Asian clam within and between waterbodies that were sampled.

WATER AND SEDIMENT CHEMISTRY

Water quality parameters identified in the literature as being important to Asian clam survival were monitored as a part of this study. It is important to note that data below represent a one-time sampling event, and that repetitive monitoring was not performed as part of this sampling due to time, cost and staff limitations. The goal was to assess conditions across sites during the summer 2013 growing season.

Water quality sampling results are summarized in Table 3 below.

Table 3. Means of water quality parameters for field sampling conducted July 22-25, 2013

Parameter	**Long Pond**	**Cobbetts Pond**	**Garvins Pool**	**Hooksett Pool**	**Amoskeag Pool**
Temperature (°C)	28.69	27.65	24.34	22.2	21.49
Dissolved Oxygen (mg/L)	8.05	7.73	7.63	8.49	9.04
Water Column pH	7.63	7.6	6.82	6.67	6.66
Sediment pH	6.6	6.14	6.71	5.97	5.5
Specific conductance (umhos/cm)	340	320	80	70	60
Calcium (mg/L)	13	16	3.95	3.33	3.1
Magnesium (mg/L)	2.2	2.4	0.73	0.65	0.63
Chlorophyll-α (ug/L)	9.89	2.59	5.72	4.73	4.41
Sodium (mg/L)	44	40	9.8	8.25	7.6
Turbidity (TDS)	0.22	0.21	0.05	0.05	0.04
Secchi Disk (m)	1.36	1.67	7.03	1.4	0.98
Bottom Depth (m)	2.3	2.68	7.72	8.45	11.13

Water temperature, dissolved oxygen (DO), sediment and water column pH, conductivity and turbidity results were all within the documented ranges suitable for Asian clam survival and represent typical summertime temperature conditions in NH surface waters. No data were collected during wintertime conditions to reflect the low water temperatures that Asian clam could be exposed to in these waterbodies.

Water temperature is not only important for Asian clam habitat (at both the low and high ends of the range), but it plays a role in dispersal behavior as well at the higher ranges of temperature exposure. When water temperatures increase over time to 25^{o}C and 30^{o}C, Asian clams increase their rate of production and release of mucus strands (drogue line) that the clams can use as floatation devices to move with water currents to other portions of waterbodies (such as slightly cooler areas that provide less metabolic stressors), potentially serving as an internal spread mechanism within individual systems (Rosa et al. 2012).

Conductivity values are less than 350 umhos/cm at each site, coinciding with a suitable freshwater habitat for Asian clam. Long Pond and Cobbetts Pond have much higher conductivity values than the Merrimack River pools, and the three river pools are very similar with conductivity values among each section.

All sites showed low turbidity with values for Cobbetts Pond and Long Pond less than 0.25 TDS while the Merrimack pools had values much less at approximately 0.05 TDS. Asian clam gills are disrupted by highly turbid waters, and survival rates are low in highly turbid conditions, despite the fact that bivalves can increase water clarity through their filter-feeding activities. (Simard et al. 2012).

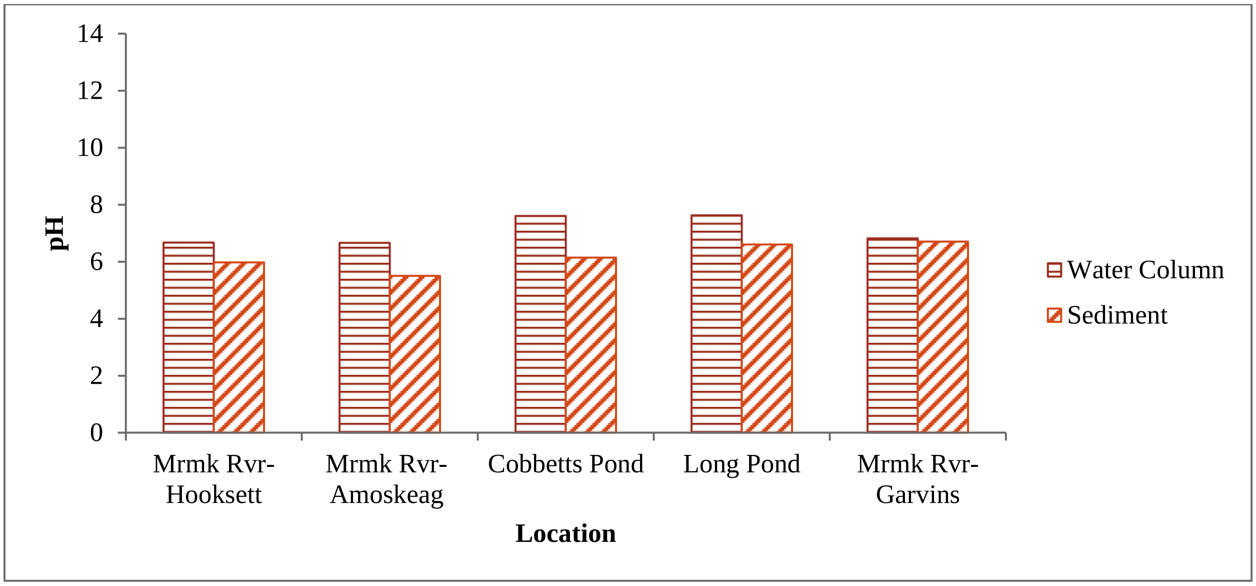
Water clarity was typically good to very good at most sites sampled. River sites can have more fluctuating turbidity levels, based on various factors; still, turbidity values for all sites in this study were less than 1 NTU on sample dates. This is likely a result of the time of year samples were collected. July is typically a drier month, and thus there is less runoff and erosion occurring in the watershed and along the banks.

Water clarity can be affected as a result of Asian clam feeding rates. Specifically, Chlorophyll-a densities have been shown to decline as a result of Asian clam filter feeding rates. One model suggests an estimated a 70% loss of phytoplankton biomass, a 61% decline in annual primary production, and a 75% loss in zooplankton biomass as a result of high populations of Asian clam (Pigneur et al. 2014). In terms of habitat preference, one study shows that Asian clam favors moderate levels of chlorophyll-a at approximately 5.5 ug/L in the water column (Cooper 2007). The study sites examined here had a range of chlorophyll-a concentrations between 2.59-9.89 mg/m^3.

All dissolved oxygen values across sample sites and waterbodies were >6mg/L. Like most aquatic organisms, Asian clams are not well adapted to low dissolved oxygen concentrations for sustained periods of time (Vidal et al. 2002)

Sediment pH was between 5.5-6.5 and was slightly lower across sites than water column pH, for which values were between 7.63-6.6 (Figure 5), and well within documented ranges suitable for Asian clam establishment. A sediment pH of 5.0 or less appears to limit Asian clam densities (Ferreira-Rodriguez and Pardo 2014).

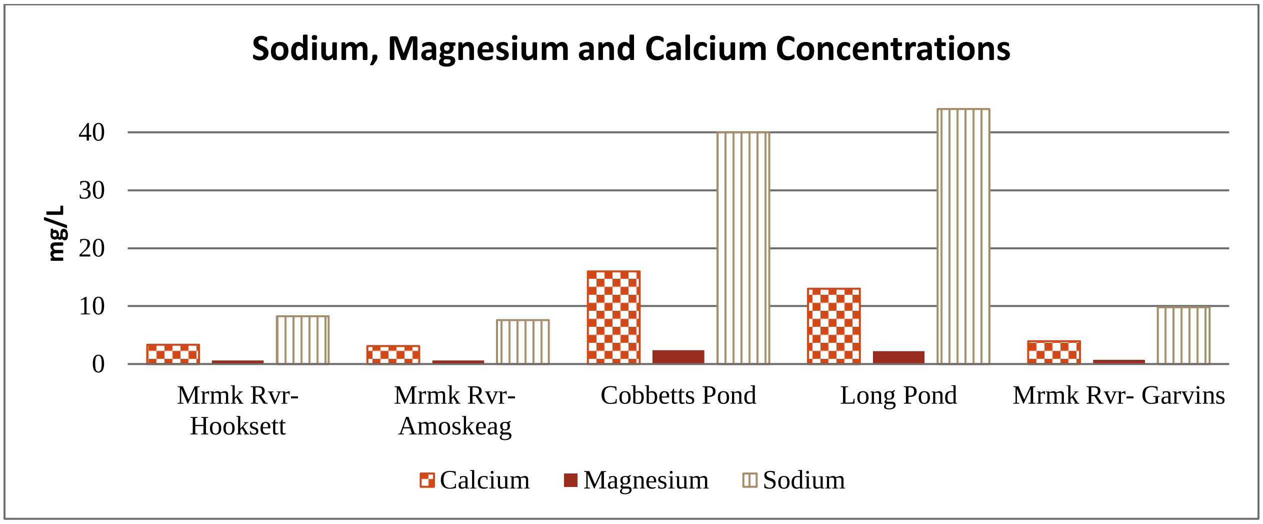
Figure 5- Water Column and Sediment pH



Sodium, magnesium and calcium concentrations are each important to Asian clam vigor and survival. Figure 6 illustrates the concentrations of each element across study sites. Sodium in high concentrations can be toxic to Asian clam, and both magnesium and calcium are important shell-building elements. In terms of sodium concentrations, the Merrimack River pools have less than 10mg/L, while Long Pond and Cobbetts Pond are higher with approximately 40 mg/L. For magnesium, the Merrimack River sites had a range from 0.73 to 0.63 mg/L and Long Pond and Cobbetts Pond had upwards of four times those concentrations at 2.2-2.4 mg/L, respectively (Table 3). Asian clams have the ability to remove magnesium from the water to reduce shell-growth inhibition in cold water conditions.

For calcium, Long Pond sites had a mean of 13 mg/L, Cobbetts Pond had a mean of 16 mg/L among sites, Garvins Pool mean is 3.95 mg/L, Hooksett Pool mean is 3.33 mg/L and Amoskeag Pool mean is 3.1 mg/L (Table 3 and Figure 6). Asian clam survival requires a minimum of 3 mg/L of calcium (Lucy et al. 2012), and based on our measurements and field observations of high Asian clam densities in each waterbody, there appears to be sufficient calcium present for shell-building.

Figure 6- Sodium, Magnesium and Calcium Concentrations across Study Sites



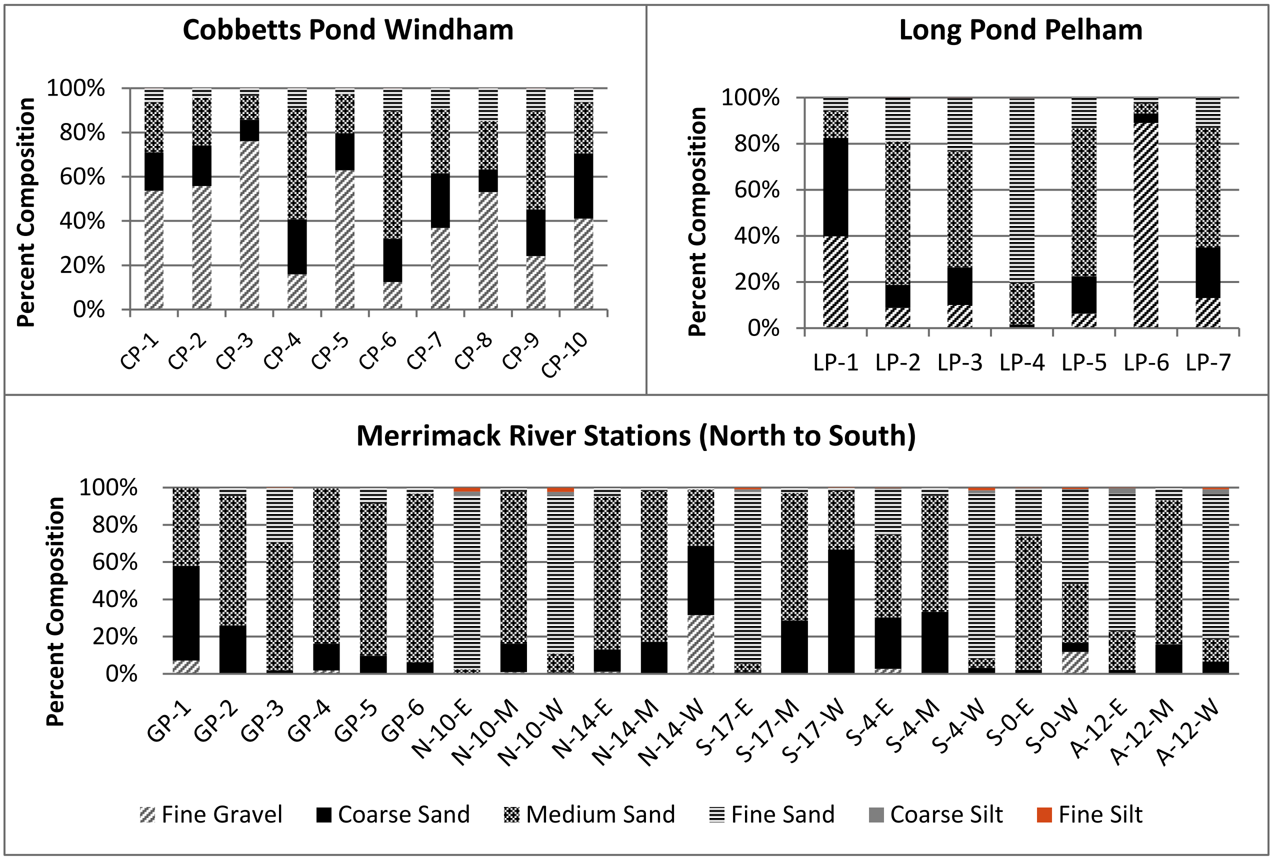
SEDIMENTS GRAIN SIZE ANALYSIS

Sediment composition among sites, based on the International Grain Size Scale, falls mostly within a range of sand-sized particles. Most sites (83%) had a mix of course, medium and fine sand as the primary components of the benthic matrix, and a few had a component of course silt mixed in (10%). Cobbetts Pond also had a mix of fine gravel at all sites. There was little to no fine silt present among the sample sites, which can be expected in river sites with higher flow rates, whereas finer silts can be more common in lakes with higher settling rates.

It is not surprising to find Asian clam among courser sediment types. The gills and feeding capabilities of Asian clam can become impaired by fine grained silt that is easily resuspended into the water column. Data from the Roanoke River showed higher densities of Asian clam in areas where sediments were comprised of coarser grain size (Cooper 2007).

Figure 7 shows the substrate composition of sediment at each of the sites sampled across the various waterbodies, as measured in 2013.

Figure 7- Sediment Composition at Sample Sites (CP= Cobbetts Pond, LP= Long Pond, GP=Garvins Pool of Merrimack River, N=Northern Hooksett Pool Points, S=South Hooksett Points, A=Amoskeag Pool Points)

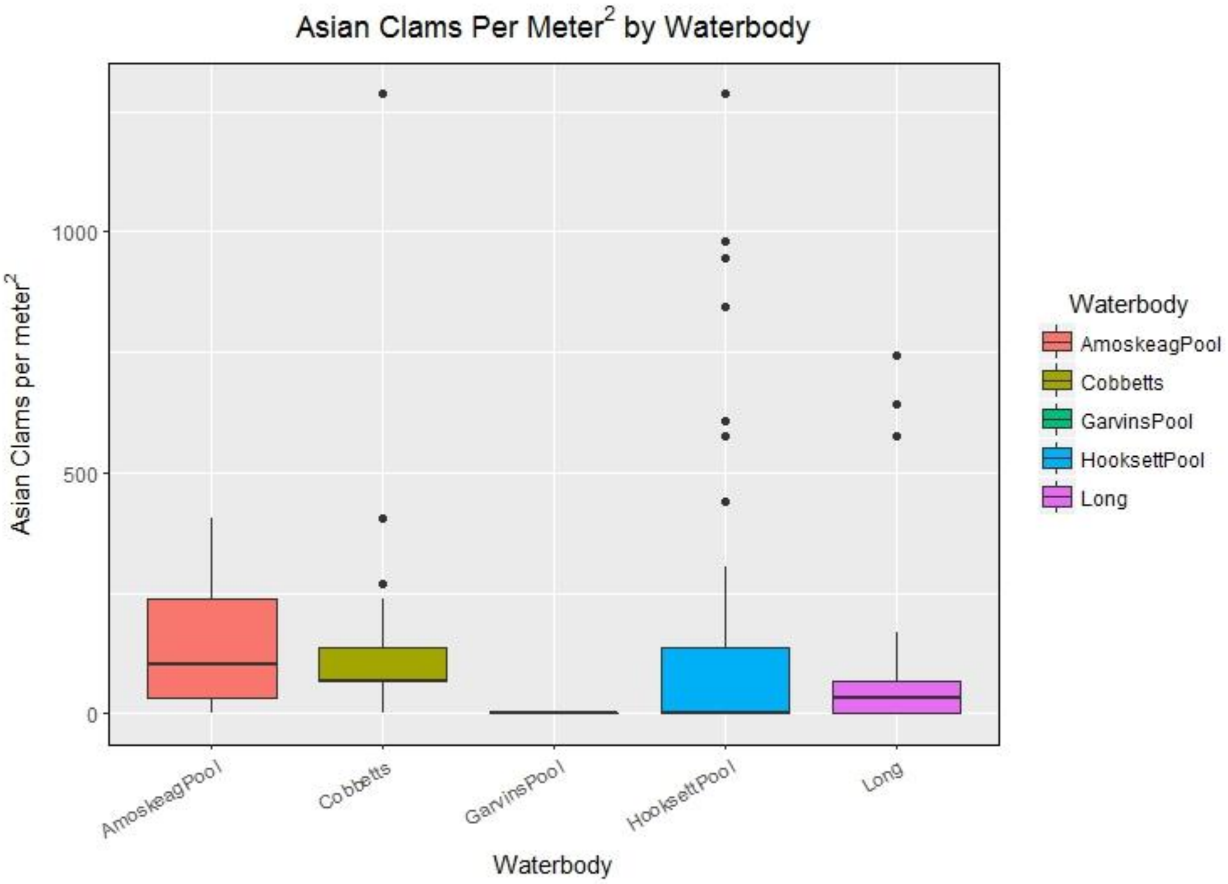


ASIAN CLAM POPULATION DATA

Based on our data, Asian clam densities in New Hampshire were observed to range between 34 clams/m^2 to 1286 clams/m^2. Densities observed by biologists in neighboring Massachusetts show Asian clams densities as high as 6,124 clams/m^2 in one of their 29 Asian clam infested waterbodies (Colwell et al. 2017). In the St. Lawrence River, populations ranged from 368 clams/m^2 in early stages of infestation to 3,380 clams/m^2 four kilometers downstream at a new population in the same river (Simard et al. 2012). Lake Tahoe, a significant and large lake system in the United States, reports Asian clam densities between 70-3,200 clams/m^2 (Wittmann et al. 2008).

Figure 8 and Figure 9 illustrate the minimum value, 25th percentile, median, 75th percentile of Asian clam per unit area (m^2) across study sites as a whole, and at individual sample sites within each waterbody, respectively. Amoskeag Pool of the Merrimack River had the highest mean density of Asian clams (156 clams/m^2). Hooksett Pool (mean of 121 clams/m^2) of the Merrimack River and Cobbetts Pond (122 clams/m^2) had similar mean densities. Long Pond had a mean density of 41 clams/m^2. Hooksett Pool had the greatest variability of Asian clam densities among all individual sample sites within that reach of the river. No Asian clams were observed in Garvins Pool.

Figure 8- Asian Clams/m2 by Waterbody



The K-W test found that there is a significant difference in Asian clam counts among waterbody groups (chi-squared = 29.63, df = 4, p-value =5.82e-06). Specifically, there were statistically significant differences between Asian clam densities at Garvins Pool site as compared with other waterbodies. Considering that Garvins Pool had zero Asian clam occurrences, this result is not a surprise; however, there were no statistically significant differences between Asian clam counts among the Merrimack Pool, Amoskeag Pool, Cobbetts Pond, and Long Pond. Looking at the different sites within each waterbody, Figure 9 illustrates Asian clam densities across study sites within each waterbody. Hooksett Pool, followed closely by Cobbetts Pond, had the greatest variability in Asian clam density between sample sites within the same waterbody.

Figure 9- Asian Clams/m2 by Site

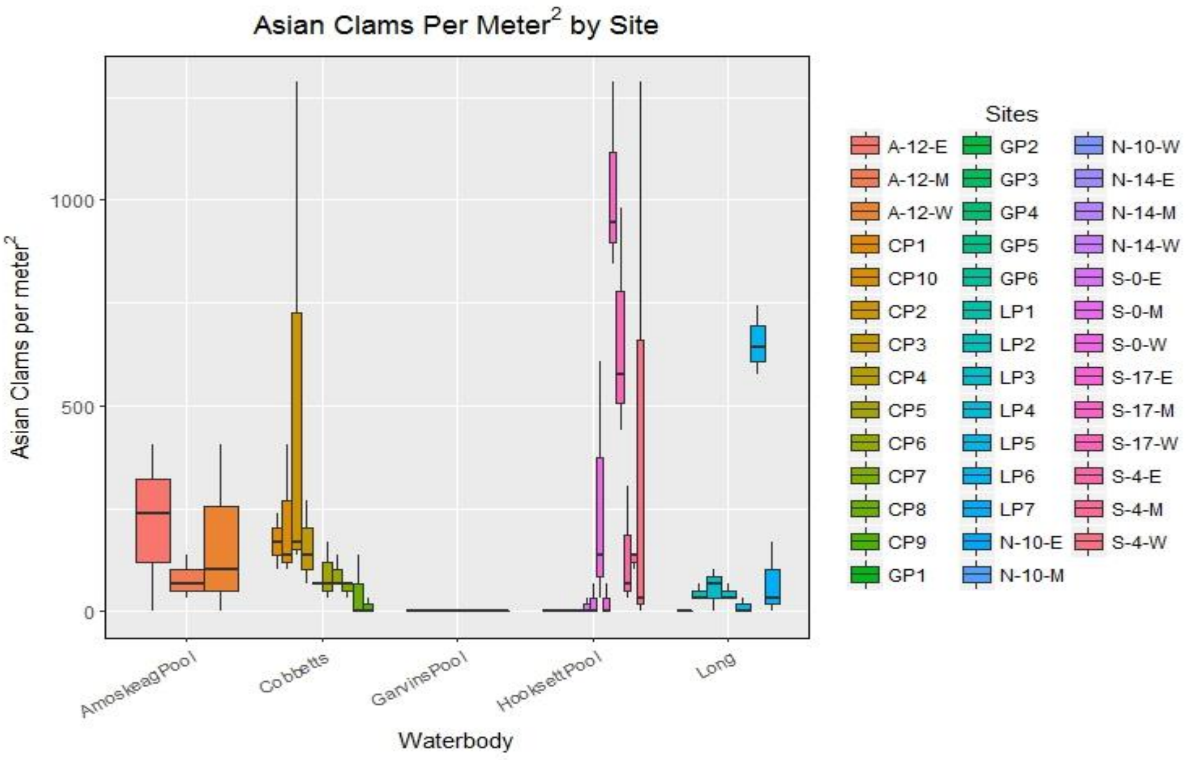
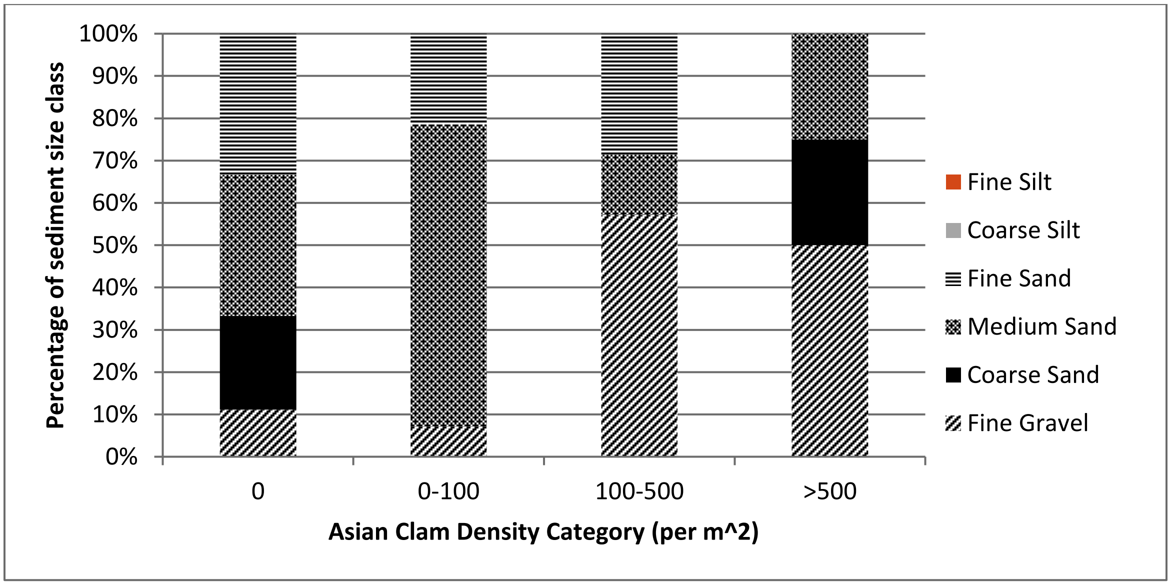


Figure 10 illustrates Asian clam densities across substrate types. Higher densities of Asian clam are more common among sites with higher percentages of course sand with gravel mixed in, and lesser amounts of fine sands.

Figure 10- Asian Clam Densities by Sediment Composition



From a visual perspective working on these sites, surficial Asian clams at some sample sites covered 100% of the bottom sediments. In other cases surface coverage was sparser, yet pools of old shells from dead clams were accumulating in the bottom of fish nests (see Figure 3 above), and littering the bottom substrates. In some cases though, Asian clams were not visible on the surface, but rather were buried in the sediments, so it is important to never assume they are absent from a site just because they are not be visible on the top of the sediments. Field sampling with sieves or dredges into the bottom sediments is required to determine presence below the sediment surface. The burrowing behavior may be in response to predation or other factors (Saloom and Duncan 2005). One study showed Asian clams burrowing as deep as 10-15 cm in bottom substrates (Wittmann et al. 2008).

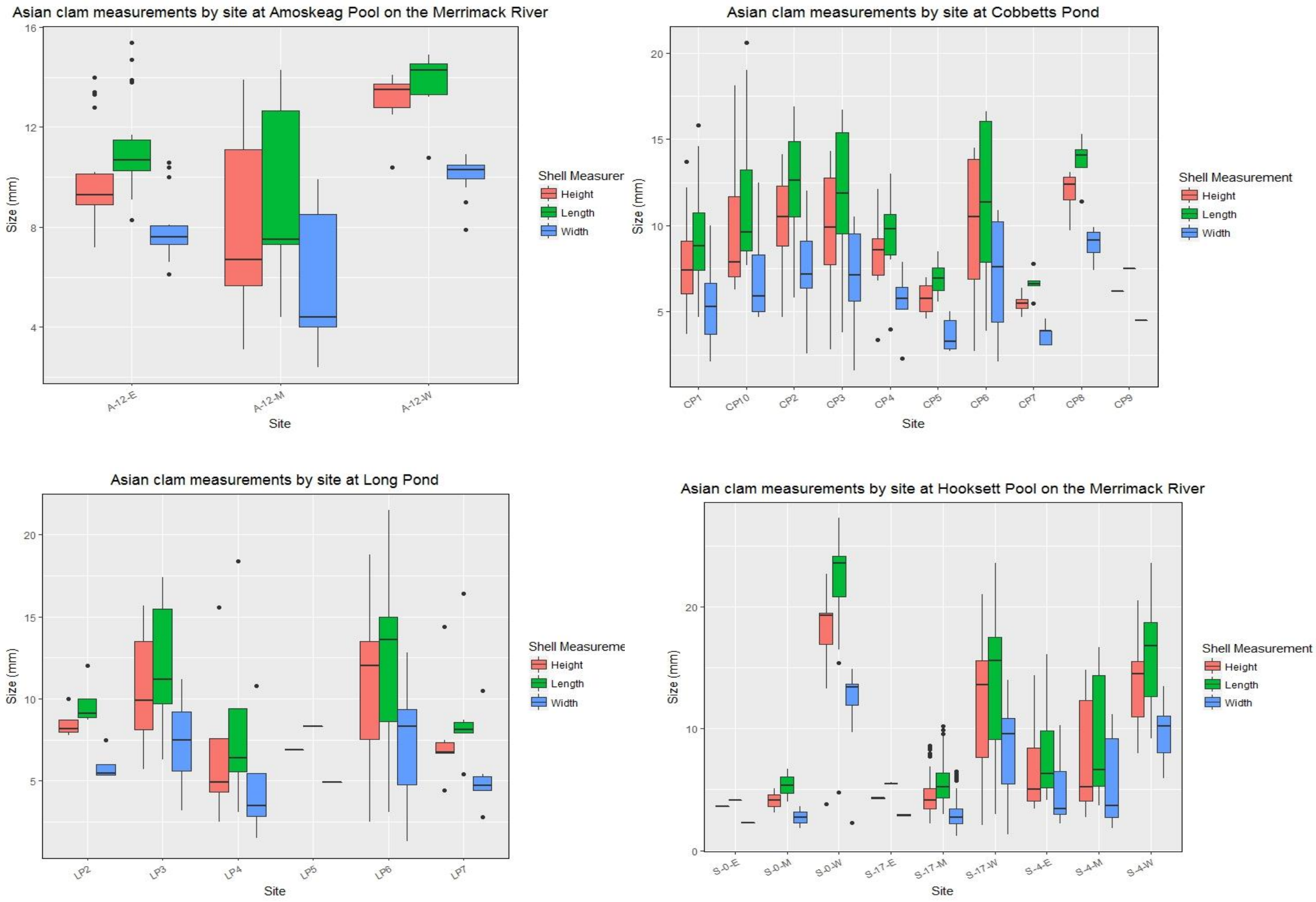
ASIAN CLAM SIZE ANALYSIS

For each of the Asian clams that were collected as part of this sampling, the shell length, width and height was measured. Overall, mean Asian clam total length measurements fell below 20mm at all sites. Massachusetts reported a maximum shell length of 22.64mm in an unnamed tributary in Forest Park, Springfield, MA (Colwell et al. 2017). More northern populations in the St. Lawrence River were documented to range between less than 1mm in length to 24 mm (Simard et al. 2012).

Cobbetts Pond clam lengths ranged from 3.8 to 20.6 mm, with a mean of 10.9mm. Asian clams in Long Pond ranged from 3.1 to 21.5 mm, and had a mean of 11.5 mm. Hooksett Pool clams ranged from 3mm to 27.3 mm, and averaged 11.1 mm +/-6.6. Amoskeag Pool clams ranged from 4.4 mm in length to 15.5 mm, and averaged 11.9mm +/- 2.7. Figure 11 illustrates the variability in Asian clam measurements (height, length and width) at the sample sites within each waterbody.

Based on the literature, sexually mature Asian clam shell lengths typically range from 25-30 mm (Vidal et al. 2002). A variety of shell lengths were documented, suggesting various stages of Asian clam maturity. If the Asian clams are too small to reach the size range for sexual maturity, perhaps they are presently reproducing only asexually at these sites.

Figure 11- Asian Clam Shell Measurements by Site



Summary and Management Implications

The preferred range for Asian clam survival and reproduction is typically between 20-25°C (Morgan et al. 2004), which are common surface water temperatures during the mid to late summer timeframe in New Hampshire. Based on literature documenting early Asian clam populations in the United States, it was originally thought that the probability of Asian clam establishment and survival in northern latitudes, where water temperatures drop to 2°C or less for an extended period of time during the winter, was low (Mattice and Dye 1976). A more recent study of the distribution of Asian clam predicted the species spreading across the globe, which it has done in less than 100 years since its initial introduction (Crespo 2015). Therefore, survival and establishment in New Hampshire waterbodies, with low water temperatures and often thick ice cover for 12 or more weeks out of the year, seemed unlikely.

Based on our observations, the Asian clam is established in New Hampshire, and has been sustaining populations in various waterbodies since at least 2011. New infestations are documented nearly annually at this point, with a total of six documented infestations, and at least as many reported and as yet unverified infestations.

With its microscopic larvae, diversity of reproductive means, rapid maturity to sexual reproductive capabilities, broad range of environmental tolerances and other factors, the Asian clam is a good colonizer of new sites, and is apparently finding suitable habitat in New Hampshire.

Despite concerted management efforts in large infested waterbodies like Lake Tahoe in California and Nevada (diver hand removal) and Lake George in New York (extensive impermeable benthic mat placement), Asian clam have continued to proliferate. While various microbes and chemistries have been developed to target invasive bivalves (Lund et al. 2018), preliminary evidence suggests that they are imperfect technologies, with both water quality and non-target impacts. As such, eradication and long-term reduction in Asian clam populations in already infested sites has been untenable. Advances in target-specific methods are still needed to effectively manage invasive bivalve species like the Asian clam.

Because eradication and management are a challenge, it becomes increasingly more important to document new infestations immediately so that appropriate steps can be taken to prevent further spread. It is imperative that Clean, Drain, Dry initiatives be implemented to reduce the likelihood of continued contamination of new waterbodies.

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Acknowledgements

Special thanks to Angela Piemonte and Kaleigh Wallace for their assistance in both the field and laboratory during their summer 2013 internships, and Brea Arvidson for her time spent performing literature searches and contributing to this report during her 2015 internship. NHDES staff biologist Walt Henderson is recognized for his hours spent in the laboratory processing the sediment samples for grain size analysis. NHDES staff biologist Kirsten Nelson is recognized for her time spent performing statistical analysis in R, and creating some of the figures for this report, particularly the Asian clam population and size distribution graphics.