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The Asian clam (*Corbicula fluminea*) and its relationship to the balanced indigenous population ("BIP") in Hooksett Pool, Merrimack River, New Hampshire

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I. EXECUTIVE SUMMARY

This report provides evidence that the cooling water release from PSNH's Merrimack Station facility and presence of the non-native invasive Asian clam are not causing appreciable harm to the balanced indigenous population (BIP) or displacing native bivalves in the Hooksett Pool of the Merrimack River, New Hampshire. The report presents a thorough review of published, peer-reviewed reports based on well-established scientific processes, a review and analysis of data and information made available from the U.S. Environmental Protection Agency (EPA) and New Hampshire Department of Environmental Services (NHDES), and results of an extensive three year study on the Asian clam in Hooksett Pool. Such assessments led to the following conclusions:

1. The Merrimack River's Hooksett Pool contains, in addition to other aquatic species, a balanced community of native bivalve fauna that includes several species in two families; Unionidae (particularly *Elliptio* spp.), and Sphaeriidae. There are no studies or evidence that suggest the thermal discharges from Merrimack Station have adversely affected or impacted either Hooksett Pool's native bivalves or other flora or fauna.

2. Hooksett Pool includes a population of non-native Asian clams that fluctuates from year to year. Such fluctuations are typical of this species; Hooksett Pool's Asian clam population fluctuations reflect a similar propensity for seasonal population declines and rebounds found in Asian clam populations elsewhere.

3. The discovery of Asian clams in Hooksett Pool significantly post-dates the construction of Merrimack Station. As was the case in numerous other locations around the world, it is most likely that Asian clams were introduced to Hooksett Pool from other locations in the region via boats or marine equipment operating in the Merrimack River, or by recreational fishermen using the clams as bait.

4. Published, peer-reviewed reports, based on well-established scientific processes, indicate the Asian clam is expanding its range northward in North America and Europe. A survey of reported findings on Asian clam northward dispersion into water bodies lacking thermal input in New Hampshire and elsewhere in the U.S. confirm that this range expansion is not solely attributable to thermal refugia provided by cooling water discharges. Of the 11 documented locations of Asian clam in New Hampshire, only one receives thermal effluent from a power station. Recent published findings suggest that successful northward spread may be due to the previously unrecognized genetic and physiological capacity of Asian clams to tolerate colder temperatures combined with the significant role played by recreational fishing and boating in the spread of this invasive species. The construction or operation of Merrimack Station did not cause the introduction of Asian clams to Hooksett Pool.

5. The term BIP is defined to mean "a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by a lack of domination by pollution tolerant species." Hooksett Pool's aquatic community demonstrates taxa diversity at all trophic levels, is a self-sustaining population with cyclical seasonal changes, contains the presence of necessary food chain species, and lacks domination by pollution tolerant species. It is a BIP.

6. There is no evidence of Asian clams displacing native bivalves in Hooksett Pool; on the contrary, evidence shows a lack of demonstrable differences when comparing native bivalve species in the Merrimack River from sites upstream of the cooling water release without Asian clams (*e.g.*, N10 an upstream reference site; see Appendix B for methods) to those sites downstream of the cooling water release with Asian clams.

7. There is no evidence of the Asian clam causing appreciable harm to Hooksett Pool's BIP. The Station has operated with a thermal variance for decades and with a thermal discharge

since beginning operation in the 1960s, yet there is no difference in the benthic communities between upstream of the cooling water release without Asian clams (see Appendix B for methods) to those sites downstream of the cooling water release with Asian clams when using any of a variety of EPA-approved BIP metrics. The same holds true when comparing the BIP at sites downstream of the cooling water release before and after Asian clam establishment using the same variety of metrics.

8. Published evidence and recent data suggest the presence of the Asian clam may, in fact, be beneficial to the pool's BIP by providing substrate for epibionts, refuge from predation, controlling transport of solutes and particles in the benthic environment, and through bioturbation of sediments.

9. While several often cited publications have suggested Asian clams may have a negative impact on their environment, upon close examination, these publications point out that the conclusions are speculative. Conclusions that Asian clams cause harm to the BIP are unsubstantiated, flawed, and disproven by extensive experience.

10. In 2015, EPA had intended to assess the presence and abundance of *Corbicula* in relation to the thermal discharge from Merrimack Station and "to evaluate *Corbicula's* capacity to displace native invertebrates, including mussels." [U.S. Environmental Protection Agency, Quality Assurance Project Plan – Quantifying the density of Asian clams (*Corbicula fluminea*) within and beyond the influence of the thermal discharge of a power plant (2015)]. Nevertheless, EPA did not undertake this study. Based on surveys conducted by Normandeau and AST and analysis of the data provided in this report, Asian clams are not only present in Hooksett Pool adjacent to and downstream of Merrimack Station but are also found upstream of the Station. Furthermore, Asian clam abundance is not causing a correlative decline in, or displacing, native macroinvertebrates, including mussels.

11. Although the Asian clam was identified by Normandeau as "numerically dominant" at certain locations in its 2012 report, high variability in population numbers is characteristic of Asian clam and other invertebrate populations and this is true of the Asian clam population in Hooksett Pool at Merrimack Station. These inherent annual abundance fluctuations cause numeric dominance of Asian clams to fluctuate year to year as well. At many locations, Asian clam numeric dominance in 2011 declines to well below numeric dominance of Asian clams in in 2014 and disappears altogether in 2016. These inherent fluctuations in invertebrate densities in Hooksett Pool are clear, especially in Asian clams, as clam densities dropped off drastically from 2011 to 2013, rebounded in 2014, only to decline again in 2016. Such year-to-year fluctuation is typical with Asian clam populations; annual abundances commonly fluctuate as much as 2-3 orders of magnitude.

12. The previously unrecognized genetic and physiological capacity of Asian clams to tolerate colder temperatures, their occurrence in New Hampshire waters lacking thermal input, and CFD modeling of the Merrimack Station thermal plume, strongly suggest the clam would continue to exist in Hooksett Pool even if the thermal discharges of Merrimack Station were to be terminated or mitigated altogether. Furthermore, efforts to extirpate the Asian clam in impacted water bodies throughout its range have failed. Accordingly, it would be highly speculative to conclude that measures aimed at Merrimack Station's cooling water discharges would eliminate Hooksett Pool's Asian clam population.

13. In conclusion, the available evidence, supported by a wide range of scientific literature and studies, indicates the Asian clam reached Hooksett Pool not because of the operation of Merrimack Station and its associated thermal discharges but rather through the same avenues and methods that have contributed to the spread of Asian clam throughout the world and into northern latitudes both in the United States and abroad. Furthermore, there is no credible evidence that the

Asian clam presence in Hooksett Pool is causing appreciable harm to the BIP; in fact, its presence may be benefitting the BIP.

14. Specific comments to EPA's "Statement of Substantial new Questions for Public Comment" concerning the presence of Asian clam in Hooksett Pool are included in Appendix D.

II. BACKGROUND OF REPORT

Public Service Company of New Hampshire (PSNH) owns and operates Merrimack Station, a coal-fired electricity generating facility in Bow, New Hampshire. Merrimack Station (Station) is located on the west bank of the Merrimack River, where it discharges its once-through cooling water into a reach of the river known as Hooksett Pool. This river stretch runs between Garvin's Hydro Station, located north and upriver from Merrimack Station, and PSNH's Hooksett Hydro Station, located to the south and downriver from Merrimack Station.

Merrimack Station's cooling water discharge is subject to National Pollutant Discharge Elimination System (NPDES) Permit No. NH0001465. The Station currently seeks renewal of its current NPDES permit, issued on September 30, 1985, and renewed on June 25, 1992, including its thermal variance under Section 316(a) of the federal Clean Water Act. This permit and its variance allow the Station to continue to discharge cooling water without further thermal treatment or amelioration other than that provided by the spray modular array currently in place in the Station's lengthy discharge canal. This array sprays the cooling water into the air, thereby reducing its temperature, before the water falls back into the canal. The canal ultimately flows into Hooksett Pool.

Normandeau Associates, Inc., (Normandeau) first discovered the Asian clam in Hooksett Pool in 2011. Based on its analysis of benthic macroinvertebrate data collected during 1972, 1973, and 2011, Normandeau determined the Station's past and current operations have resulted in no appreciable harm to the balanced, indigenous population (BIP) located in that segment of the Merrimack River receiving the station's discharge (Normandeau 2012).

Documents subsequently provided to PSNH by the EPA in response to public information requests suggested EPA was interested in assessing the non-native Asian clam's (*Corbicula fluminea*) presence in Hooksett Pool. To that end, EPA, in coordination with the NHDES, conducted a limited investigation of the Asian clam population in 2013 and 2014, and, further, considered conducting an additional investigation in 2015 "to improve [EPA's] understanding of the power plant's influence on [the Asian clam]" and, in turn, "evaluate the plant's ability to meet state and federal water quality standards, and its NPDES permit requirements, as they apply to protecting the resident biological communities." [U.S. Environmental Protection Agency, Quality Assurance Project Plan – Quantifying the density of Asian clams (*Corbicula fluminea*) within and beyond the influence of the thermal discharge of a power plant (2015)]. The limited investigation performed by EPA in 2013 and 2014 did not yield scientifically reliable or sufficient data for meaningful analysis or conclusions. Further, as noted, EPA did not undertake the additional investigation in 2015 intended to evaluate Asian clam presence and significance and assess its effect, if any, on other species in Hooksett Pool.

With EPA's studies producing inconclusive results, PSNH decided to undertake a concerted study of the Asian clam in Hooksett Pool. The focus of the effort was to scientifically obtain and analyze relevant data associated with Asian clam presence in Hooksett Pool to prevent erroneous conclusions and speculation from being used to determine the Asian clam impact on its BIP.

Accordingly, PSNH retained AST Environmental in 2014 to more thoroughly examine and evaluate the presence of the Asian clam in New Hampshire as well as its relationship to the balanced indigenous population of the Hooksett Pool segment of the Merrimack River. AST

Environmental, in coordination with Normandeau, undertook a comprehensive review of the available data and performed extensive quantitative sampling for the presence of the Asian clam and its relationship to the BIP of Hooksett Pool. This investigation included a two-year study of the Asian clam in Hooksett Pool and its relationship (or lack thereof) to Merrimack Station's thermal discharges and to the pool's BIP. Normandeau conducted extensive sampling aimed at clams and macroinvertebrates in November 2014 and again in summer 2016. These sampling efforts comprised Ponar samples, SCUBA diver excavated samples, and diver semi-quantitative assessments that were analyzed following the scientifically accepted methods set forth in Appendix B of this report. AST assisted in sampling design, and participated in the summer 2016 dives and sampling. Additionally, in 2017 AST conducted an extensive presence/absence survey diving 71 lake and river locations in New Hampshire assessing the presence of Asian clams.

AST assessed and evaluated the data collected to consider the origins, nature, presence, and impact of the Asian clams in Hooksett Pool; the relationship of the Asian claim to the BIP of Hooksett Pool (specifically, whether and to what extent the Asian clam or Merrimack Station's thermal influence is affecting the pool's BIP); and to address the need identified by EPA for further study and investigation in 2015. AST used data collected during the 2017 survey to address the ongoing spread of Asian clam into New Hampshire waters, especially those lacking thermal input.

III. THE ASIAN CLAM (*CORBICULA FLUMINEA*)

As a relatively recent addition to Hooksett Pool's ecology, and given its pertinence to this report's objectives, it is appropriate to begin this section with an examination of how the Asian clam has spread to such non-native locations as Hooksett Pool. Equally important is a discussion of the clam's general biology, its physiological tolerances, and its habitat requirements. An appreciation of these characteristics will contribute substantially to the best understanding of the Asian clam's likelihood to appreciably harm (or not) the BIP of Hooksett Pool.

A. THE GLOBAL SPREAD OF THE ASIAN CLAM

Originally native to Southeast Asia, the Asian clam has, in the last century, been introduced to North and South America, Europe, Africa, and the Pacific Islands (*e.g*., Ilarri and Sousa 2012; Clavero *et al.* 2012*;* Morgan *et al.* 2003; Müller and Baur 2011; Strayer 1999; McMahon 1999, 2002; McMahon and Bogan 2001). It has experienced considerable geographic dispersion in just the past few decades and currently occupies four continents (Ilarri and Sousa 2012; McMahon 1999; Morgan *et al.* 2003; Sousa *et al.* 2008). First reported in Western Europe in the 1980's, Asian clams are now fairly widespread throughout Europe. Current reports now show the Asian clam distribution as far north as 53.9426^{o}N in Ireland (Caffrey *et al.,* 2011), 52.6261^{o}N in the Netherlands, 52.3828^{o}N in Germany (Discover Life 2015), and at 53.3748^{o}N in Poland (Domagala *et al.* 2004) (Illustration 1).

In North America, live Asian clams were first documented in 1938. By 1953, the clams had spread through much of the U.S., especially the Southeast (McMahon 1983, Simard *et al.* 2008). The Asian clam can now be found in most of the lower 48 states of the U.S., including Hawaii, three of the Great Lakes (Erie, Michigan, and Superior), and the St. Clair River in Michigan (OFAH/OMNR 2012). Asian clams have spread north to areas of milder winters and water temperatures like Lake Whatcom, Washington, (48.7627^{o}N) and Vancouver Island, British Columbia (48.4510^{o}N), the Asian clam's northern-most North American locations. Asian clams continue to spread northward into cooler waters where it was thought they would not survive (A. Benson, USGS, *pers. comm.*) and, as a result, have recently been found in high altitude and northern latitudes in North America with low water temperatures and ice formation: several lakes and reservoirs in Colorado at ≥ 1,200 m elevation (Cordeiro *et al.* 2007); Lake Pend Oreille, Idaho (48.2296°N); St. Louis River, Duluth, Minnesota (46.7649°N); St. Lawrence River, Bécancour, Québec (46.4044°N); Lake George, New York (43.5649°N); Long Pond, New Hampshire (42.7006°N), and Cobbetts Pond, New Hampshire (42.4510°N) (USGS 2015); Little Island Pond, New Hampshire (42.7318°N); Merrimack River, Hooksett Pool upstream of Merrimack Station, New Hampshire (43.1426°N and 43.1549°N); Beaver Lake, New Hampshire (42.9049°N); Canobie Lake, New Hampshire (42.8057°N); Great Pond, New Hampshire (42.9140°N); and Merrimack River, upstream of Concord, New Hampshire (43.2838°N) (USGS 2017)(Illustration 2).

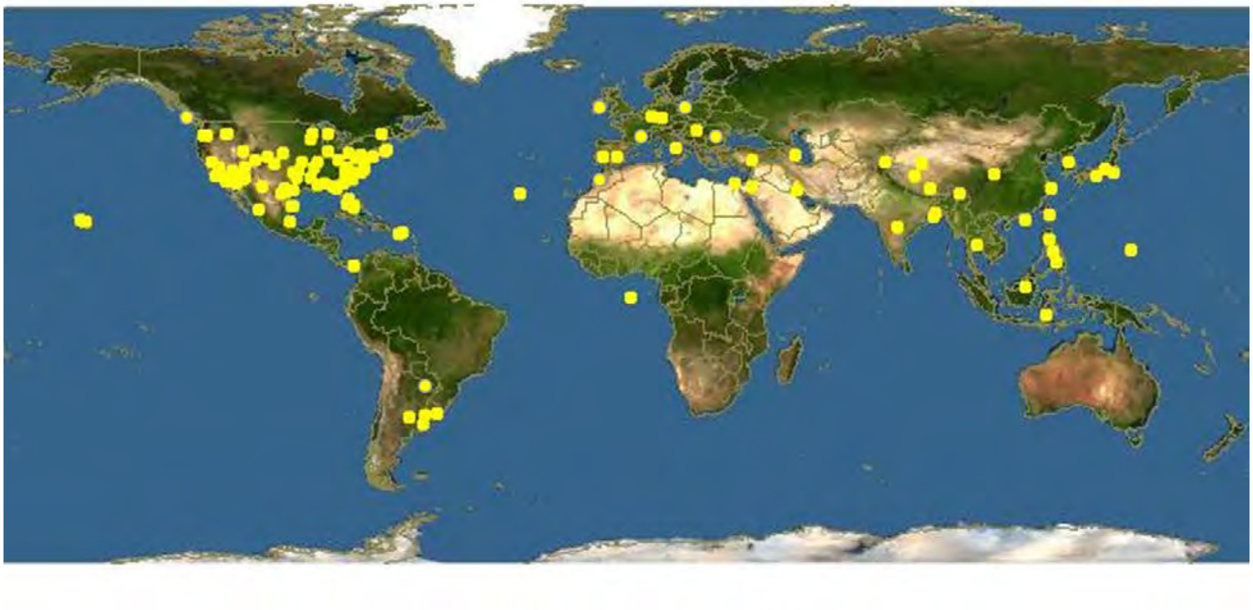

Illustration 1. Global geographic distribution of the Asian clam, *Corbicula fluminea*. From http://www.discoverlife.org/mp/20q?search=Corbicula+fluminea&guide=Mussel. Accessed [2015].

The reasons for the northern range extension for *C. fluminea* into areas with low water temperatures and winter ice formation is a matter of considerable scientific uncertainty. Often, such expansion is attributed to thermal plumes from cooling water discharge. For example, researchers have linked the populations established in the St. Lawrence River in Québec (Simard *et al.* 2008), the Connecticut River in Connecticut (Morgan *et al.* 2003, 2004), and the St. Louis River, Duluth, Minnesota (USGS 2015) to thermal discharges that elevated ambient water temperature. Because Asian clams do not survive extended exposure to water temperatures below 0-2°C, such thermal releases have been considered to provide a winter temperature refuge.

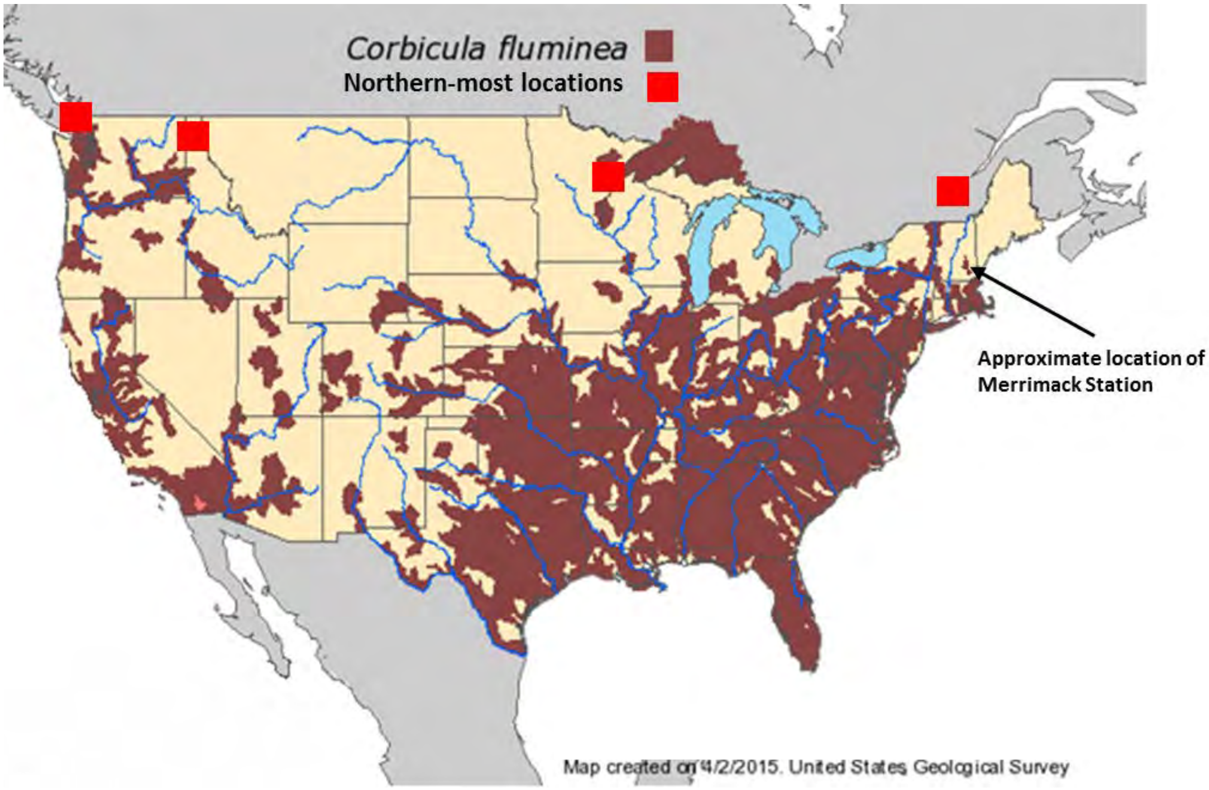

Illustration 2. Geographic distribution of the Asian clam, *Corbicula fluminea*, in the continental. United States and southern Canada. Adapted from United States Geological. Survey, http://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=92. Accessed [2015].

In Europe, however, northward and westward expansion has occurred independent of thermal discharges in the Vistula River, Kraków, Poland, and in the Crisuri Rivers and the Danube River and associated tributaries in Hungary (Mackiewicz 2013, Bódis *et al.* 2012). Similarly, in the U.S. and Canada, northward range extension has occurred into areas with low water temperature lacking thermal discharge influence in Lake Pend Oreille, Idaho; St. Croix River, Minnesota; Michigan River, Michigan (Janech and Hunter 1995); Lake George, Lake Champlain and Erie Canal system, New York; Gildersleeve Island, Connecticut River, Connecticut (Morgan *et al.* 2004); Long Pond, New Hampshire (USEPA and NHDES 2013, unpublished data; A. Smagula 2016), Cobbetts Ponds, New Hampshire (USEPA and NHDES 2013, unpublished data; A. Smagula 2016); Wash Pond, New Hampshire and upper Merrimack River above Concord, New Hampshire (A. Smagula, USGS 2017). Asian clams continue to spread into cooler waters where it was thought they would not survive (A. Benson, USGS Nonindigenous Aquatic Species, *pers. comm.*).

Specific to the point that thermal discharge is not necessary for northern range extension, a study conducted by EPA, in conjunction with NHDES (2013, unpublished data; A. Smagula 2016), examining range extension by Asian clams in New Hampshire, found no significant difference (ANOVA, $P = 0.687$) in Asian clam densities in July 2013 among all four New Hampshire sites: two sites with no thermal effluent, Cobbetts Pond and Long Pond; and two sites receiving Merrimack Station cooling water release, Hooksett Pool and Amoskeag Pool (Figure 1 – located in the Figures section of this report; see Appendix C3 for data). While there was no statistical difference among locations, the pattern suggests lower Asian clam densities at Hooksett Pool rather than at the sites without thermal input (Cobbetts and Long ponds). Furthermore, NHDES has not only documented Asian clams occurring at Wash Pond, which lacks thermal input, but also in the Merrimack River near Concord (USGS, A. Smagula 2016). For the purposes of this study, the latter site is of particular note given that, while in the Merrimack River, it is well upstream of Merrimack Station and thus not impacted by the station's thermal influence. Additionally, since the 2013 EPA and NHDES Asian clam survey, Asian clams have been reported from two sites in Hooksett Pool upstream of Merrimack Station, as well as in Beaver Lake, Great Pond, Canobie Lake, and Little Island Pond (AST, USGS 2017).

Accordingly, despite casual reference to the contrary and superficial appearances, scientific evidence does not support that the expansion of the Asian clam into Hooksett Pool at Merrimack Station is attributable to thermal discharges; rather, it suggests the clam's presence is a result of the naturally occurring northern range extension taking place in the absence of such discharges, as has occurred at Long Pond, Cobbetts Pond, Wash Pond, and upper Merrimack River, New Hampshire. In fact, Asian clams keep spreading into cooler waters where it was thought they would not survive (A. Benson, USGS Nonindigenous Aquatic Species, *pers. comm.*). The following discussion of the Asian clam's biology, physiological tolerances, and habitat requirements, will expound further on the Asian clam's ability to inhabit northern climes beyond its original range.

B. THE BIOLOGY OF THE ASIAN CLAM

Although some controversy still exists regarding reproductive mode (*sensu* Ilarri and Sousa 2012), Asian clams are generally considered to be a self-fertilizing, hermaphroditic species (Strayer 1999, McMahon 2002). The number of reproductive events per year for the Asian clam is variable (Ilarri and Sousa 2012, Sousa *et al.* 2008), although mature gametes may be present all year (Morgan *et al*. 2003). Two reproductive events per year are typical (McMahon 1999, Sousa *et al.* 2008, Ilarri and Sousa 2012). Eggs are fertilized internally, and developing larvae are held in the adult medial (inner) demibranch, or gill. Larvae develop through trocophore, veliger, and pediveliger stages within the adult and are released as D-shaped, straight-hinged juveniles. Illustration 3 depicts the Asian clam's life cycle, and Table 1 provides a summary of the species' life history characteristics. A highly fecund species, despite its allocation of a relatively small amount of non-respired energy toward reproduction (5-15%), the Asian clam's juvenile releases can range between 97 and 2,900 juveniles per adult per day (McMahon and Bogan 2001, Morgan *et al.*, 2004) and up to 75,000 per lifetime (Ilarri and Sousa 2012). Morgan *et al.* (2004) reported Asian clams at ambient St. Lawrence River temperatures spawned nearly 3,000 juveniles per clam per day. High juvenile output with relatively low adult survival is characteristic of species adapted to unstable and/or extreme habitats (*e.g.*, colder temperatures) and can lead to populations dominated by juveniles and immature individuals (McMahon 1999).

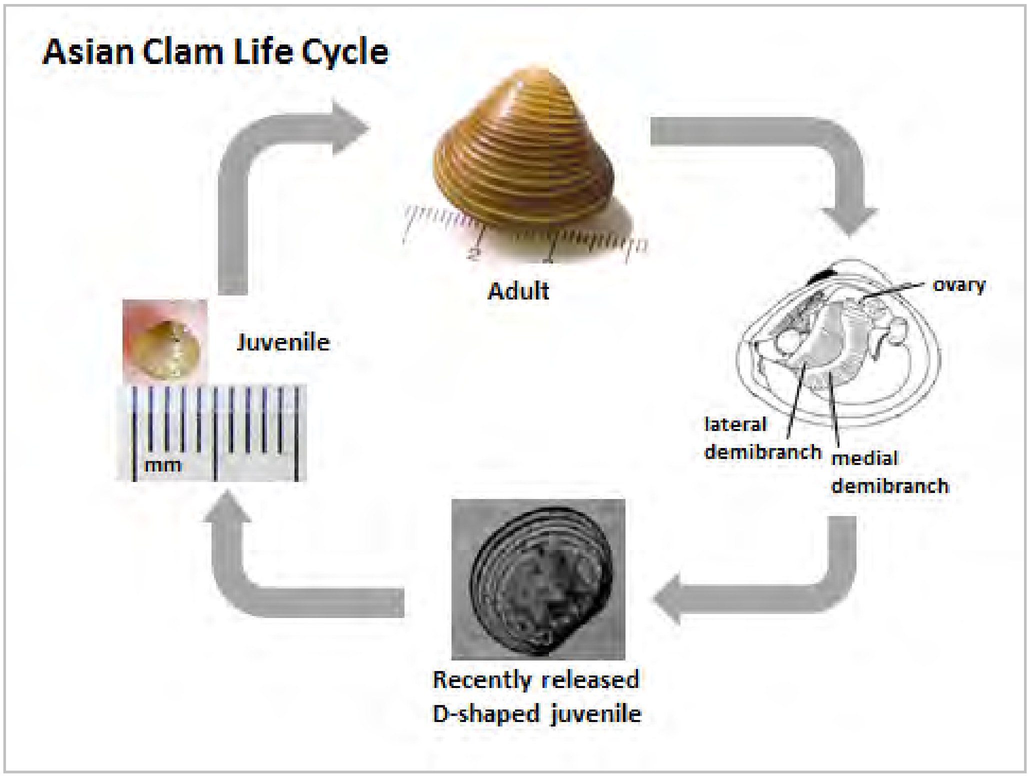

Illustration 3. Graphic representation of *Corbicula fluminea* life cycle. Larvae are incubated in the water tubes of the medial demibranchia.

After release, the tiny individual juveniles (≈ 230-250 μm) may spend a brief 4-day period in the plankton before anchoring with a mucilaginous byssal thread and starting life as fully-formed benthic juveniles (Rosa *et al*., 2012; Mackie and Claudi 2010) (Illustration 3; Table

1). These small juvenile clams may be re-suspended during turbulent flow and transported considerable distances by the current (Ilarri and Sousa 2012, McMahon 1999).

Asian clams typically mature in 3-6 months or at 6-10 mm shell length, with a variable life span that ranges from 1-5 years (Ilarri and Sousa 2012). Some correlation between water temperature and maturation rates has been documented. In areas with low water temperatures and winter ice formation, where juveniles may be released in late summer/early fall, maturation may be delayed until clams reach 12-17 mm or 8-9 months of age (McMahon 2002, Morgan *et al.*, 2004). Morgan *et al*. (2004) reported lowest growth rates in October and November (0.06 mm/week) and highest growth rates (1.08 mm/week) during June and July in the Connecticut River. Nevertheless, the relatively rapid growth of the Asian clam is primarily attributed not to water temperatures but to the clam's high feeding (filtration) rate and relatively high allocation (58-71%) of non-respired energy toward growth (McMahon 2002) (Table 1). According to McMahon (2002), Asian clams have the highest net production efficiencies of any freshwater bivalve, allocating most energy to growth and reproduction with only a small portion going toward respiration and maintenance. This is reflected in a rapid standing stock turnover rate of 73-91 days (McMahon 2002) (Table 1). Such high feeding rates with large allocations to growth led Foe and Knight (1985) to surmise that Asian clam growth is mostly determined by food availability and not water temperature.

The Connecticut River surveys cited above, even though they identify a connection between water temperature and maturation rates, support the secondary role of water temperature as a factor in Asian clam growth rates. Those studies reported that, in a cooling water discharge canal in the Connecticut River, where temperature was 10-12°C above ambient river temperatures, growth was still slow at 0.05 mm/week from November through February, similar to growth at the ambient Connecticut River sites in October and November. Additionally, fastest

Table 1. Summary of life history characteristics of *C. fluminea* (adapted from McMahon 2002, Ilarri and Sousa 2012, Morgan et al. 2003, Morgan *et al.* 2004, Sousa *et al.* 2008, Simard *et al.*, 2012, Rosa *et al.*, 2012, Doherty *et al.* 1987).

Life history trait	***Corbicula fluminea***
Life span (years)	1-5
Age at maturity (months)	3-6 typical, up to 8-9 depending on location and season
Size at maturity	6-17 mm shell length depending on location (larger in northern, cooler locales)
Reproductive mode	Self-fertilizing hermaphroditic
Fecundity (no. juveniles per adult per day)	97-2 862 per hermaphroditic individual
Fecundity (no. juveniles per average adult lifetime)	25 000-75 000 per hermaphroditic individual
Reproductive efforts per year	1-3; typically 2 (spring and summer-autumn); 1 in cooler areas (late summer); 3 in some locales (late spring, midsummer, and/or late summer-early fall)
Larval. Development	Trocophore, veliger and pediveliger develop within the medial demibranch of adult
Planktonic stage	No true plankton stage; juveniles may spend max 4-day period in water column; byssal. thread produced for anchoring
Mature gametes present	All year
Larval. Brooding	Early spring and/or into late summer-fall
Juvenile size at release	230-250 μm
Growth rate	Rapid throughout life
Relative juvenile survivorship	Extremely low
Relative adult survivorship	Low, 2–41% per year
Degree of iteroparity	Moderately iteroparous, 1–7 reproductive periods
Assimilated energy respired (%)	11–42%
Non-respired energy allocated to growth (%)	58–71% depending on cohort and season
Non-respired energy allocated to reproduction (%)	5–15% depending on cohort and season
Turnover time in days (= mean standing crop biomass : biomass produced per day)	73–91 depending on cohort
Habitat stability	Stable to unstable

growth in the cooling water discharge canal (0.36 mm/week) was still less than those at ambient river sites (0.44-0.68 mm/week) and occurred in May-July when temperatures in the canal were similar to ambient river temperatures (Morgan *et al*. 2004). These observations strongly support that Asian clam growth is largely determined by some primary factor other than temperature.

C. THE ASIAN CLAM'S PHYSIOLOGICAL TOLERANCES AND HABITAT REQUIREMENTS

The worldwide spread of the Asian clam suggests that its range expansion is limited only by intolerance to certain environmental and habitat conditions (*sensu e.g*., Cooper 2007; Ilarri and Sousa 2012; Mackie and Claudi 2010; Mattice and Dye 1975; McMahon 1983, 2002; Morgan *et al.* 2003; Müller and Baur 2011). The important abiotic variables fundamental to Asian clam growth, reproduction and survival are presented in Table 2 (adapted from Ilarri and Sousa 2012; Mackie and Claudi 2010).

Thermal tolerance has long been thought to be among the most important abiotic variables to define acceptable Asian clam habitat (Mattice and Dye 1975). Indeed, compared to other bivalve species, the Asian clam has a low temperature resistance and has been widely perceived as limited in its range due to intolerance of cold water < 2°C and warm water >36°C (Cairns and Cherry 1983; Mattice and Dye 1975; McMahon 2002, 1983 & 1979; Rosa *et al.* 2012; Verbrugge *et al.* 2012; Werner and Rothhaupt 2008a) (Table 2). In recent years, however, the Asian clam has spread in Europe and the northern U.S. into waters where water temperatures routinely fall below 2°C for extended periods during winter, yet are not influenced by external thermal input (Bódis *et al.* 2012; Janech and Hunter 1995; Mackiewicz 2013; Marsden and Hauser 2009; Schmidlin and Baur 2007; USGS 2015 & 2016; NHDES and EPA 2013, unpublished data; A. Smagula 2016).

Because of its spread into more northern locales, particularly those without external

Table 2. **Abiotic variables important to reproduction, survival. and establishment of Asian clams (adapted from Ilarri and Sousa 2012, and Mackie and Claudi 2010).**

Abiotic variable	Little potential for adult survival	Little potential. for larval development	Moderate potential for establishment	High potential for establishment
Temperature (°C)	<0 and >37	2-14 to 30-36	15-18 to 25-30	18 to 25
Dissolved oxygen (mg/L)	< 0.5	0.5 to 2	2 to 6	> 6
pH	< 5	5 – 6 to > 9.5	6 to 7	7 to 9
Calcium (mg Ca/L)	< 1	1 to 2	2 to 5	>5
Hardness (mg/L $CaCO_3$)	< 3	3 to 7	7 to 17	>17
Conductivity (µS/cm)*	>12,600	11,000 to 12,6000	8,100 to 11,000	<8,100
Salinity (‰ S)	>17	7 to 17	5 to 7	<5
Chlorophyll *a* (µg/L)	< 5 and > 25	5 to 10	10 to 20	20 to 25
Secchi depth (m)	< 0.1 and > 8	0.1-0.3 to 6-8	0.3-0.5 to 3-6	0.5-3
Total dissolved solids (mg/L)	>8,400	7,400 to 8,400	5,400 to 7,400	<5,400

*Not indicative of conductivities associated with highest salinities.

thermal influences, the precise lower water temperature tolerance of Asian clams is questionable. Müller and Baur (2011) found ≥75% survival when the Asian clam was exposed to 0°C water for up to 4 weeks and that 17.5% of clams survived 0°C exposure for 9 weeks. This experimental evidence combined with known distribution expansion into areas with low water temperature and ice formation, strongly suggest that the Asian clam has the genetic wherewithal and capacity adaptation to withstand cold winter temperatures and is able to establish in a much wider range of rivers and lakes than previously assumed, independent of thermal discharges.

Likewise, studies have specifically refuted the significance of manmade thermal refuges. For example, in a study conducted in the northeastern United States, researchers concluded "[t]he importance of [Connecticut Yankee] thermal discharge as a refuge for *Corbicula* survival in the Connecticut River during cold winters appears minimal" (Morgan *et al.* 2004) (emphasis added). Furthermore, Castañeda and Ricciardi (2012) cited human population density rather than temperature as being a more important factor than thermal discharge in Asian clam densities and establishment. As part of a study of Asian clams on the St. Lawrence River, Castañeda and Ricciardi (2012) found that, "[p]opulation densities [of Asian clam] did not differ between natural and artificially heated waterbodies in the Americas…" and, "[t]he probability of establishment in North American rivers was positively correlated with human population density in the basin…" The findings of EPA surveys of certain New Hampshire waters (Figure 1; unpublished data, 2013), which established that no significant difference was seen in July samples among sites receiving and not receiving cooling water releases, support the statement by Castañeda and Ricciardi (2012).

Dissolved oxygen is also important to Asian clam fitness (Table 2) (*e.g.,* Belanger 1991, Cooper 2007, Matthews and McMahon 1999). Low dissolved oxygen is an environmental stressor for the Asian clam (Cooper 2007; Simard *et al.* 2012), and the Asian clam is among one of the least hypoxia (*i.e.,* low dissolved oxygen) tolerant freshwater bivalve mollusks (Matthews and McMahon 1999). This could partially account for prevalence of the clam in well-oxygenated shallow water habitats. Under hypoxic conditions, Asian clams maintain blood oxygen by regulating the flow rate of water over the gills down to oxygen levels (P_{O2}'s) of 4 kPa or approximately 20-30% of full air O_2 saturation (Tran *et al.* 2000). However, the clams may not be able to compensate for reduced oxygen below this level and experience significantly reduced growth and an increase in certain stress-related biomarkers when exposed to hypoxic water (Belanger 1991; Vidal. *et al.* 2002).

Numerous other physical and biological factors may also contribute to Asian clam fitness (Table 2). For example, Cooper (2007) found that pH's between 6.1 and 6.6 were important in explaining variation in Asian clam density and biomass among different sites in the Roanoke River, NC. Similarly, Stites *et al.* (1995) considered the blackwater Ogeechee River, GA, to be a stressful environment for Asian clams owing, in part, to low pH. Vidal *et al.* (2002) demonstrated biomarker responses indicative of stress in Asian clams held briefly at pH's of 4.0-5.0 and 8.0-9.0.

As with mollusks in general, Asian clam biomass and densities also have been negatively linked to low calcium levels with < 10 mg/L considered stressful as are $CaCO_3$ levels less than 30 mg/L (Cooper 2007; Stites *et al.* 1995). Conductivity and salinity, two closely related parameters, are also important variables in determining *C. fluminea* abundance and biomass (Cooper 2007; Franco 2012; Verbrugge *et al.* 2012). Cooper (2007) found that conductivity was among four of the primary constituents that accounted for most of the variation in Asian clam biomass and abundance. While Asian clams tend to thrive best at salinities less than 5‰ S, they have been found to persist in areas with salinities up to 10.6 and 17‰ S (Franco 2012; Verbrugge 2012). Asian clams may be found in areas with extremely high conductivities when most of the conductivity is attributable to salinity, *i.e.*, 17 ‰ S ≈ 25,000 µS/cm (Verbrugge *et al.* 2012).

Food availability is another very important environmental variable for the Asian clam. As filter feeders, Asian clams feed on a variety of suspended particles including bacterioplankton, phytoplankton and seston (*i.e.*, fine and ultrafine particulate organic matter suspended in the water) in the broad size range of 5-30,000 µm (Lauritsen 1986, Silverman *et al.* 1995). Phytoplankton abundance is often measured as concentration of chlorophyll *a* (µg chl *a*/L), while both chl *a* and seston abundance combined are represented in Secchi depth measures. Both chl *a* and Secchi depth are reflections of food availability for Asian clams and exceedingly high or low levels of chlorophyll *a* and/or seston can limit clam survival and/or reproduction (Mackie and Claudi 2010)

(Table 2). Asian clam growth is often limited by low chl *a* and seston abundance (Cooper 2007; Foe and Knight 1986; Mouthon 2001; Stites *et al*. 1995; Vohmann *et al*. 2010). In some cases, decline in food availability has been thought to trigger incubation and spawning in Asian clams and be at least partially responsible for low seasonal recruitment (Mouthon 2001; Mouthon and Parghentanian 2004).

Another habitat parameter important to the Asian clam is composition of the lake or river bottom, *i.e.,* the substratum (Belanger *et al*. 1985; Cooper 2007; Halbrook 1995; Schmidlin and Baur 2007; Sickel and Burbank 1974). *Corbicula fluminea* flourishes well in nearly all substrata types where oxygen is sufficient and this is likely a contributing factor in its invasive success. However, clams do display a preference for certain substratum types and are found more abundantly in some substrata than in others. For example, in preference experiments, adult Asian clams have been shown to actively seek out fine sand (0.27-0.7 mm) over coarse sand (2.5-9.0 mm), sand without organic matter over sand containing organic matter, and any particulate substratum over a solid substratum (Belanger *et al.* 1985). Newly released juvenile clams preferred course sand over mud or bare concrete (Sickel and Burbank 1974). Furthermore, clams grew best in sand rather than gravel, clay or solid substrata (Halbrook 1995). Similarly, field studies have shown clam abundances to be higher in fine sand over coarser material in the New River, VA, Roanoke River, VA, and Rhine River, Switzerland (Belanger *et al.* 1985; Cooper 2007; Schmidlin and Baur 2007). Although Asian clams are known to use pedal feeding in substrata containing some organic matter (Majdi *et al.* 2014), substrata relatively high in organic matter (*e.g.,* mud and "muck"), clays and detritus-rich sediment tend to have a negative effect on clam abundance, likely due to pore water hypoxia (Belanger 1991; Belanger *et al*. 1985; Cooper 2007). The importance of substratum type to Asian clam population dynamics and success is further emphasized by the clams displaying an increased stress response in the form of biomarkers and elevated metabolic rates when unable to burrow (Belanger 1991; Vidal. *et al*, 2002).

As the foregoing discussion indicates, there are a number of variables capable of contributing to the presence (or absence) of Asian clams in a given water body. Asian clams have relatively low physiological resistance (McMahon 2002); therefore, to attribute the Asian clam's presence in a particular water body (such as Hooksett Pool) solely due to the introduction of thermal discharges would be scientifically unsound. In truth, a variety of abiotic requirements – not merely warm water – must be met to support the presence of Asian clams.

IV. PRIOR STUDIES AND ANALYSIS OF THE ASIAN CLAM IN HOOKSETT POOL

Hooksett Pool is an approximately 8 km (5 miles) long stretch of the Merrimack River that runs from Garvins Falls Dam to the Hooksett Dam (See Appendix B, Figure B1). Running adjacent to Merrimack Station, the pool begins some 28 miles from the river's headwaters and ends approximately 74 miles upriver of the point where the river flows into the Atlantic River at Newburyport, Massachusetts. Hooksett Pool is home to a balanced, indigenous community of various aquatic species. As revealed by the data generated by PSNH's 40-year biological monitoring program in the Merrimack River, freshwater fish species as the American eel, eastern silvery minnow, margined madtom, alewife, yellow bullhead, tessellated darter, spottail shiner, fallfish, common shiner, eastern blacknose dace, American shad, and golden shiner, are present in Hooksett Pool, as well as various macroinvertebrates discussed elsewhere in this report [Normandeau Associates, Inc., Merrimack Station Fisheries Survey Analysis of the 1972-2011 Catch Data (Normandeau 2011a)]. As discussed in more detail below, the non-native Asian clam is also present in Hooksett Pool.

A. THE 2012 NORMANDEAU REPORT'S FINDINGS

The Asian clam was first detected in the Merrimack River in 2007, 25 miles downstream of Hooksett Pool (A. Smagula 2017). Asian clams were documented in Hooksett Pool for the first time in 2011 (Normandeau, 2012), placing the species' arrival along an event horizon that corresponds with the detection of Asian clams in other New Hampshire waters. It is generally believed that the clam (or its juveniles) is introduced to new waterbodies by bait bucket introductions, accidental introductions associated with imported aquaculture species, or unintentional introductions when boat hulls, trailers, or ballast water provide vector mechanisms. Although there is no evidence of any one particular cause of the Asian clam arrival at Hooksett Pool, it is likely that recreational boating or fishing, at a time when the clam was spreading throughout New England, were responsible.

At the time of their identification and first sampling in 2011, Asian clam densities totaled around 1,100 clams/m^2 at Merrimack River Station S0, near 2,400/m^2 at S4, and just under 1,900/m^2 at S17 (Figure 2; see Appendix B for methods and Figure B1 therein for locations of these and other stations in the Merrimack River). Such impressive numbers are not necessarily surprising. Rapid population growth of the Asian clam is due in part to its high allocation of energy to growth and reproduction which is typical of opportunistic and invasive species (McMahon 2002). This high allocation of energy to growth and reproduction is responsible for the relatively high fecundity (25,000-75,000 per lifetime of a hermaphroditic individual; Table 1) and, due to relatively low physiological tolerances, these clams depend on this elevated fecundity for invasive success and rapid population recovery (McMahon 2002).[1]

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[1] Even in areas with relatively low water temperatures like the northeastern U.S. and southeastern Canada, where spread of the Asian clam was not expected due to low water temperatures, population growth is still rather rapid and can occur independent of thermal influence from cooling water discharges. During a study by Morgan *et al.* (2004), abundances at Gildersleeve Island, the second most abundant site with little influence by thermal discharge, increased from 168 to 3,300 clams/m^2 between November 1991 and November 1992. This led Morgan *et al.* (2004) to conclude

Comparing the Normandeau (2012) data to data on Asian clams subsequently obtained from Hooksett Pool, by 2013, *C. fluminea* densities had fallen dramatically to less than 250, 113, and 54 clams/m^2 at S0, S4, and S17, respectively (Figure 2; see Appendix C3 for 2013 data). Such large fluctuations in population density is typical with Asian clams. Asian clam populations may rapidly reach high abundances, but a low juvenile survivorship and a high mortality rate throughout adult life leads to considerable annual, seasonal, and site-to-site variability and fluctuations in abundances and frequent population mortality events (*e.g.*, Ilarri *et al.* 2011; Morgan *et al.* 2003 and 2004; Vohmann *et al.* 2010; Werner and Rothhaupt 2008a). Following the 2013 population crash at Hooksett Pool, Asian clam densities rebounded to over 5,000/m^2 at S4, 4,100/m^2 at S17, and back to around 1,000/m^2 at S0 in 2014 only to precipitously crash again in 2016 (Figure 2). Eventually, Asian clam population abundances at Merrimack Station are expected to reach a quasi-equilibrium, as is typical with other Asian clam populations, with annual abundances commonly fluctuating as much as 2-3 orders of magnitude (*e.g.*, 45 to 2,610 clams/m^2; Morgan *et al.* 2004).

Dramatic fluctuations in population numbers that are 2-3 orders of magnitude as is typical with Asian clams highlights the importance for multi-year surveys and assessments of clam populations in order to correctly ascertain numerical dominance and appreciable harm to the BIP. For example, of the nine sites sampled in 2011 that had Asian clams, Normandeau (2012) assessed seven of those sites as having Asian clam percent composition >50%, *i.e.*, clams were the numerically dominant benthic invertebrate (Table 3). Conversely, due to dramatic invertebrate population fluctuations and inherent variability in Asian clam population densities, by 2014 percent composition of Asian clam declined in seven of the nine sample locations and in six of the nine locations Asian clams were no longer numerically dominant (*i.e.*, <50%). By 2016, Asian

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that thermal discharge as a refuge for *Corbicula* survival in the Connecticut River during cold winters was of minimal importance.

Table 3. Percent composition of Asian clams as a portion of all BIP macroinvertebrates in ponar samples taken at all stations that were sampled in 2011, 2014 and 2016 where clams were present. Perecentages are based on the top three most abundant species per sample. Percentages marked with * are where Asian clam percent composition declined below 50% in at least some samples after 2011. Percentages marked with ** are those where Asian clams were not among the three most abundant species.

Percent Composition of Asian Clams

			Year	
Station	**Location**	**2011**	**2014**	**2016**
S0	East	13	**	**
S0	Middle	≥58	**	**
S0	West	≥63	≤ 54*	**
S4	East	≥89	≤ 44*	**
S4	Middle	78	≥ 87	< 8*
S4	West	≥67	≤ 25*	**
S17	East	19	**	**
S17	Middle	≥85	≥ 85	**
S17	West	≥87	≤ 34*	**

clams were no longer numerically dominant at any of the nine sites including the sites directly within the cooling water plume. Clearly, whether or not the Asian clam is the numerically dominant benthic invertebrate of the BIP in Hooksett Pool depends entirely upon which year's data are examined. These data clearly point out that numerical dominance of the BIP by a nonindigenous species with a life history like that of the Asian clam <u>cannot</u> be assessed based on 2011 data alone.

Although greater numbers of Asian clams existed at certain locations in Hooksett Pool compared to others, Normandeau significantly concluded that mean taxa richness, mean EPT richness, and mean EPT/Chironomidae abundance ratio (all EPA recommended indicators of overall BIP health) had all increased in Hooksett Pool from 1973 to 2011. Specifically, in kick samples, Normandeau stated the following conclusions from its 2012 study:

> Macroinvertebrate sampling was conducted during October 2011 using the same sampling techniques and sampling locations as was performed during

> 1972. When compared to samples collected during 1972, kick net data collected in 2011 at Monitoring Stations N-10, S-0, S-4 and S-17 showed an increase in EPT richness of 150-300%. Taxa richness increased from 7-10 in 1972 to 21-23 in 2011. The 2011 EPT/chironomid abundance ratio was higher than that recorded during the 1970s, as would be expected from samples collected in a river with improved water quality and habitat tolerable for more pollution sensitive species (Normandeau 2012a).

[Normandeau Associates, Inc. Comments on EPA's Draft Permit for Merrimack Station (Feb. 2012)]. Such increases indicated improvements to the pool's BIP even with the addition of the Asian clam. In addition to the substantial favorable increases in mean taxa richness, mean EPT richness, and mean EPT/Chironomidae abundance ratio seen in kick samples:

- The numerically dominant taxon collected during bankside kick sampling was the freshwater arthropod *Gammarus fasciatus*.[2]
- "Kick sample data collected from the aquatic insect community . . . showed dramatic improvements in the aquatic insect community composition between 1972 and 2011."

Furthermore, Normandeau's 2012 study also reported and analyzed benthic invertebrate data from ponar samples in 2011, comparing 2011 results to previous surveys conducted in 1972 and 1973. As the Normandeau study reported, Asian clams were detected at certain locations. However, "[d]ifferences in data collected in 1972 and 1973, when compared to 2011 data, showed increased values in 2011 for taxa richness, EPT richness, and EPT to Chironomidae abundance

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[2] Interestingly, *Gammarus fasciatus*, often incorrectly termed a "freshwater shrimp," "prefers unpolluted, clear, cold waters, including springs, pools, ponds, and lakes." Scientists categorize them as cold water stenotherms, meaning that they require a narrow range of cold temperatures in order to survive (10-15° C, with temperatures of 20-24 ° being tolerable, and temperatures above 34° causing death) (Bronmark and Hansson, 1998; Kipp, 2013; Lowry, 2012; Pennak, 1989; Van Overdijk, *et al.*, 2003). In short, the presence of this sensitive indigenous species in Hooksett Pool suggests members of the BIP are continuing to thrive in the presence of Merrimack Station and its thermal discharge.

ratio." These favorable increases in taxa richness, EPT richness, and EPT/Chironomidae abundance ratio were seen in 2011 with Asian clams present compared to 1972 and 1973 when no Asian clams were detected.

B. THE 2013 AND 2014 EPA LIMITED STUDY OF THE ASIAN CLAM POPULATION IN HOOKSETT POOL

A limited study and investigation of the Asian clam in certain New Hampshire waters was performed by EPA, in coordination with NHDES, in 2013 and 2014 (see Appendices C3-C5). This report has analyzed and considered EPA's work in order to acquire additional insight and data regarding the Asian clam population in Hooksett Pool. Reliance on such findings was limited because EPA's collection and analysis of the relevant Asian clam data did not follow established scientific processes.

1. Erroneous Reports and Inflationary Calculations of Asian Clam Abundances at Certain Sites

The 2013 EPA study of Asian clams in New Hampshire erroneously reported Asian clam abundances at three sites in New Hampshire (A. Smagula 2016; Appendix C3). Although the data report claims the Merrimack River had greater abundances of Asian clams than either Cobbetts Pond or Long Pond (Table 4), a review of EPA field data sheets reveals that the reported Asian clam densities were inaccurately and inappropriately calculated, thus inflating Asian clam density in the Merrimack River. Of particular note, over one third of the samples collected contained no clams whatsoever. However, these samples without clams were subsequently and inappropriately excluded from calculations. Eliminating zero-count clam samples from EPA's Asian clam estimates for Hooksett Pool artificially inflated densities to nearly twice what they should have been based on actual EPA field data sheets. As illustrated in Table 4, this mistake skews results and subsequent conclusions toward higher-than-actual clam abundances in the Merrimack River, and does not allow for an accurate assessment of Asian clam abundances or its significance

Table 4. Mean (+ SE) Asian clams per m^2 sampled by EPA using a ponar sampler in July 2013. Reported means are from A. Smagula (2016) and acquired through Freedom of Information Act (FOIA) and New Hampshire Right-to-Know requests, USEPA and NHDES. Field data sheet means are calculated directly from EPA/NHDES field data sheets acquired through Freedom of Information Act (FOIA) and New Hampshire Right-to-Know requests, EPA and NHDES. Percent difference reflects the error between reported density and actual observed density recorded on field data sheets.

	Asian Clam Density (clams/m^2)		
Site	**Reported**	**Field Data Sheets**	**% Difference**
Merrimack River	195 (+ 44.8)	110 (+ 26.40)	43.6
Cobbetts Pond	159 (+ 44.4)	153 (+ 45.00)	3.8
Long Pond	138 (+ 87.0)	147 (+ 56.34)	-6.5

in Hooksett Pool or as relative to other New Hampshire waters.

Furthermore, EPA's Asian clam data analysis from 2013 in the Merrimack River also included samples containing only native unionid bivalves that were counted as Asian clams. Including native bivalves erroneously further artificially inflated Asian clam estimates. This erroneous inclusion of unionid bivalves further skewed results and subsequent conclusions toward higher-than-actual clam abundances in the Merrimack River, and likewise prevented an accurate assessment of the Asian clam's impact on the balanced indigenous population of Hooksett Pool. Compounding the difficulty in relying on EPA's conclusions, the means reported were inappropriately calculated from replicate means, rather than means calculated directly using sample replicates, and thus did not follow accepted scientific protocol.

Conversely, correct and proper analysis of EPA data derived directly from field data sheets (Figure 1) supports the conclusion that the Asian clam's presence in the Merrimack River is not significantly different than found elsewhere (P = 0.687). Indeed, such a correct analysis suggests that the Asian clam presence in these waters is simply a part of the clam's naturally occurring, worldwide northern range extension often taking place in the absence of thermal discharges, such as has occurred elsewhere in New Hampshire at (1) Long Pond, (2) Cobbetts Pond, (3) Wash Pond, (4) the upper Merrimack River near Concord, NH, (5) Beaver Lake, (6) Canobie Lake, (7) Little Island Pond, (8) Great Pond, and (9) two sites in Hooksett Pool upstream of Merrimack Station (AST, USGS 2017).

A review of the sampling design that EPA utilized in 2014 indicates that it also was not based on acceptable scientific practices (Appendix C4 and C5). As a result, the inappropriate sample design led to inaccurate and inappropriate conclusions about the significance of the Asian clam and native bivalve species. Specifically, EPA's 2014 study employed an inappropriate sample design for the Asian clam in Hooksett Pool. EPA excavated Asian clam samples and conducted video observations along a single transect at station S0 (see p. 145, Appendix C4). The sample design located the survey transect parallel to the shore and within and along a known, high-density Asian clam area. This approach was contrary to well-established scientific protocol for river sampling of bivalves that dictates that (1) multiple transects be used, (2) transects be located perpendicular to the shoreline, and (3) transects span the width of the river when possible. Utilizing its flawed sampling design, all EPA excavated samples and video were taken from areas known to have high clam concentrations and were not indicative of conditions in Hooksett Pool. Where EPA did employ multiple transects for ponar samples in 2014, the samples were limited to the west and middle of the transects, all locations of known high clam abundance and were not indicative of conditions in Hooksett Pool. Such an approach adversely affected the accuracy of any impact or assessment of Asian clam on the balanced indigenous population in Hooksett Pool.

Finally, in none of EPA's 2013 and 2014 sampling efforts were data gathered on the resident benthic invertebrate community of Hooksett Pool. Such data are paramount to assessing appreciable harm (or lack thereof) to the BIP. All information provided through FOIA and New Hampshire Right-to-Know requests failed to provide any data or information on the Hooksett Pool benthic invertebrate community beyond clams. While some information was provided for native mussels, the sampling design was inappropriate for native unionid mussels, would only suffice for native fingernail clams (which was not apparent), and was clearly aimed at sampling Asian clams only. Using such an approach and not examining the entire resident benthic invertebrate community does not allow for assessment or discussion of appreciable harm (or lack thereof) to the BIP of Hooksett Pool. The importance of such information on the whole invertebrate community was recognized by EPA in the abandoned 2015 study (see discussion below at section IV. C.).

In summary, EPA's 2013 and 2014 sampling protocol and data handling methods artificially inflated the abundance and apparent relative importance of Asian clams in Hooksett Pool. This would not have happened if EPA had utilized proper statistical procedures and an appropriate sampling design, one that would have broadened the interpretation of the results to the entire reach of river system in question (Hooksett Pool) and the balanced indigenous population in general. As a result, data derived from EPA's 2013 and 2014 sampling efforts are not valid for determining the significance of the Asian clam's presence in Hooksett Pool, especially in assessing Asian clam impact (or lack thereof) to the BIP. In light of such concerns regarding the validity of the underlying data, EPA's information regarding the presence and abundance of Asian clams in Hooksett Pool is of limited reliability and use to an independent scientific analysis of such issues.

2. Omission of Relevant Range Data

EPA's analysis also omitted relevant range extension data which, in turn, could lead to unwarranted connections between the Asian clam and Merrimack Station. A more thorough analysis, however, reveals that, of the 11 documented locations of Asian clam in New Hampshire (USGS 2017), only one, Hooksett Pool, Merrimack River, receives cooling water discharge. Specifically, in July 2013, EPA developed data on clam presence at several sites in New Hampshire. EPA's data, however, show no significant differences (ANOVA, $P = 0.687$) among sites in Asian clam numbers with and without thermal discharge (Figure 1). Unlike other EPA data sets and analyses, these data were collected using multiple sample replicates and, in the case of the Merrimack River, using shore-to-shore transects as is standard protocol; there is no indication that EPA's information using this sampling protocol is incorrect. Asian clam densities among all four New Hampshire sites surveyed by NHDES for EPA were similar when comparing two sites with no thermal effluent, Cobbetts Pond and Long Pond; and two sites receiving Merrimack Station cooling water, Hooksett Pool and Amoskeag Pool (Figure 1). The pattern suggests Asian clam densities may even be lower at Hooksett Pool receiving cooling water discharge from Merrimack Station compared to the two sites lacking any thermal input, *i.e.*, Cobbetts and Long ponds. Such a discernable pattern warrants recognition; however, such analysis was not provided.

EPA also omitted information on Asian clams from Wash Pond, the upper Merrimack River north of Concord, and below Amoskeag Dam at the Pennichuck Water Works pipeline in the Merrimack River, all sites without the influence of cooling water discharge (Table 5).

The spread of the Asian clam into bodies of water lacking thermal input is well-documented throughout the northern U.S. and strongly supports the position that thermal discharge is not a requirement for spread and establishment of the Asian clam.

Table 5. Records of Asian clam northern range extensions in New Hampshire lacking thermal influence.

Location	Waterbody	Reference
New Hampshire	Merrimack River above Concord	A. Smagula, USGS (2016)
New Hampshire	Long Pond	A. Smagula (2016)
New Hampshire	Cobbetts Pond	A. Smagula (2016)
New Hampshire	Wash Pond	A. Smagula, USGS (2016)
New Hampshire	Merrimack River Pennichuck Water Works	Normandeau Assoc. (unpubl.)
New Hampshire	Beaver Lake	AST, USGS (2017)
New Hampshire	Canobie Lake	AST, USGS (2017)
New Hampshire	Little Island Pond	AST, USGS (2017)
New Hampshire	Great Pond	AST, USGS (2017)
New Hampshire	Hooksett Pool, Merrimack River 2,000 ft above Merrimack Station	AST, USGS (2017)
New Hampshire	Hooksett Pool, Merrimack River ≈1 mile above Merrimack Station	AST, USGS (2017)

- There are at least 25 documented locations of established Asian clam at locations as far north, or nearly so, as is Hooksett Pool of the Merrimack River (Table 6).
- Twelve of these documented locations are in the New England area of the U.S.
- Eleven of these documented locations are in New Hampshire and one in Maine.
- Four of these New England locations are as far or farther north than Hooksett Pool of the Merrimack River.

Table 6. **Examples of records of Asian clam northern range extensions in North America in areas lacking thermal input. Locations are provided west to east.**

Location	Waterbody	Reference
British Columbia	Fraser River	USGS 2016
Idaho	Lake Pend Oreille	USGS 2016
Washington	Lake Whatcom	USGS 2016
Montana	Lake McDonald	USGS 2016
Minnesota	Lake Superior	Trebitz, A.S. et al, 2010
Minnesota	St. Croix River	Cummings (2016)
Michigan	Michigan River	Janech and Hunter (1995)
Michigan	Buck Creek	USGS (2016)
Michigan	Eagle Creek	USGS (2016)
Ontario	Severn River	Bogan and Smith (2013)
New York	Champlain Canal System	Marsden and Hauser (2009)
New York	Erie Canal System	USGS (2016)
New York	Lake George, north	Nearing (2015)
Vermont*	Lake Bomoseen, southwest	USGS (2016)
Connecticut	Gilder Sleeve Island, Connecticut River	Morgan *et al.* (2004)
Massachusetts	Fort Meadow Reservoir	USGS (2016)
New Hampshire*	Merrimack River above Concord	A. Smagula, USGS (2016)
New Hampshire	Long Pond	A. Smagula (2016)
New Hampshire	Cobbetts Pond	A. Smagula (2016)
New Hampshire	Wash Pond	A. Smagula, USGS (2016)
New Hampshire	Merrimack River below Amoskeag Dam	Normandeau Assoc. (unpublished)
New Hampshire	Beaver Lake	AST, USGS (2017)
New Hampshire	Canobie Lake	AST, USGS (2017)
New Hampshire	Little Island Pond	AST, USGS (2017)
New Hampshire	Great Pond	AST, USGS (2017)

New Hampshire*	Hooksett Pool, Merrimack River 2,000 ft above Merrimack Station	AST, USGS (2017)
New Hampshire*	Hooksett Pool, Merrimack River ≈1 mile above Merrimack Station	AST, USGS (2017)
Maine*	Piscataqua River	AST, USGS (2017)

*Locations in New England as far or farther north than Hooksett Pool, NH.

As detailed above, the deficiencies with EPA's work rendered its data and conclusions of limited use in regard to assessing the occurrence and significance of Asian clam in Hooksett Pool.

C. EPA'S ABANDONED 2015 STUDY PLAN

In a follow-up to its limited investigation in 2013 and 2014, EPA developed a plan to study the presence and abundance of the Asian clam in the Merrimack River in order to improve the agency's understanding of the power plant's influence on the Asian clam and, in turn, "to further evaluate the plant's ability to meet state and federal water quality standards, and its NPDES requirements, as they apply to protecting the resident biological communities." [U.S. Environmental Protection Agency, Quality Assurance Project Plan – "Quantifying the density of Asian clams (*Corbicula fluminea*) within and beyond the influence of the thermal discharge of a power plant" (2015)]. Most pertinent, the EPA's study plan objectives included assessment of the effect of the Asian clam presence on the BIP: "The second objective is to assess the abundance of *Corbicula* relative to native epifaunal and infaunal macroinvertebrates. This will allow us to further evaluate *Corbicula's* capacity to displace native invertebrates, including mussels." Normandeau concluded Merrimack Station's thermal plume had not caused appreciable harm to the BIP of Hooksett Pool in their 2012 report. Specifically, with respect to its macroinvertebrate study, Normandeau noted that taxa richness, EPT richness, and EPT/Chironomidae abundance ratio (all EPA recommended indicators of overall BIP health) increased in Hooksett Pool from 1973 to 2011. EPA noted, however, that Normandeau had identified the Asian clam as the numerically dominant species at certain locations downstream of the discharge canal within Hooksett Pool in 2011. As a result, EPA planned in 2015 to study further the effect of the Asian clam on the BIP. However, as stated previously, by 2014 and 2016 Asian clams were no longer numerically dominant at sites sampled in 2011 (Table 3), clearly indicating additional benthic invertebrate data were needed to assess appreciable harm (or lack thereof) to the BIP of Hooksett Pool. Ultimately, EPA's planned 2015 study was not undertaken and no information was collected by the agency concerning its study objectives.

V. THE 2014, 2016, AND 2017 NORMANDEAU/AST SURVEYS AND ANALYSIS

PSNH retained AST Environmental in 2014 to more thoroughly examine and evaluate the presence of the Asian clam and its relationship to the BIP of Hooksett Pool. AST Environmental, in coordination with Normandeau, not only undertook a comprehensive review of the available data (as reflected in this report) but performed extensive investigation into the presence of the Asian clam in New Hampshire and its relationship to the Hooksett Pool BIP, specifically the native benthic macroinvertebrates. This investigation included a two-year study (2014 and 2016) of the Asian clam in Hooksett Pool and its relationship (or lack thereof) to Merrimack Station's thermal discharges and to the BIP of Hooksett Pool. Additionally, in 2017 AST conducted an extensive presence/absence survey diving 71 lake and river locations in New Hampshire assessing the presence of Asian clams. Normandeau conducted multiple dives excavating 0.25 m^2 samples and performing semi-quantitative assessments, and took numerous ponar grab samples along multiple transects in November/December 2014 and, subsequently, in July 2016 with AST's participation. These efforts collected numerous clam and macroinvertebrate samples that were analyzed following the scientifically accepted methods set forth in Appendix B of this report. From analyses of these data and the AST 2017 dives, it can be fairly said that Asian clams occur in numerous New Hampshire locations lacking thermal discharge and that the indigenous ecology of Hooksett Pool, supported by an apparently viable and self-sustaining food chain, is typical of what one would expect to find in a New Hampshire river system – and, it should be noted, represents a marked improvement over the river's pollution-impacted state in the first half of the 20th century. Whether or not the indigenous populations or communities found in this ecology are threatened by harmful imbalance caused by the Asian clam's introduction to Hooksett Pool is examined in the sections that follow.

A. STANDARDS FOR ASSESSING HARM TO A BIP

In order to fully understand and assess any discernable adverse effect of the Asian clam on Hooksett Pool's benthic macroinvertebrate community in a context such as the present one, AST Environmental performed its analysis after considering the applicable EPA regulations concerning BIP and the synonymous term, "balanced, indigenous community." found in 40 C.F.R. § 125.71(c) and applied this to interpretation of the benthic macroinvertebrate data.

AST Environmental also considered technical guidance concerning the assessment of harm to a BIP. Specifically, EPA requires the study of impacts to various plant and animal species, including: habitat formers, phytoplankton, zooplankton, macroinvertebrates and shellfish, fish, and other vertebrate wildlife. May 1, 1977 Draft Interagency 316(a) Technical Guidance Manual & Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements, at 18-34 ("Draft EPA 316(a) Guidance"). EPA directs that, "in attempting to judge whether the effects of a particular thermal discharge are causing the system to become imbalanced, it is necessary to focus on the magnitude of the changes in the <u>community as a whole and in individual species</u> i.e., whether the changes are 'appreciable,'" (EPA 1979) (emphasis added) and that nuisance species are those that exist "in large numbers <u>at the expense</u> of other members of the indigenous community" (EPA 1974) (emphasis added). AST applied this to interpretation of appreciable harm to the BIP to the benthic macroinvertebrate data.

As stated previously, numerical dominance of the Asian clam based on a single sampling event cannot alone be used to assess appreciable harm to the Hooksett Pool BIP. The numerically dominant Asian clam in 2011 was replaced as dominant by native species in 2014 at many sites and at all sites in 2016 (Table 3). As discussed below, there is no evidence of the Asian clam causing appreciable harm to Hooksett Pool's benthic macroinvertebrate community or replacing the native bivalves in Hooksett Pool. In fact, published evidence suggests the Asian clam may actually be benefitting the pool's benthic macroinvertebrate community.

B. THE NECESSITY FOR CAREFUL REVIEW OF EXISTING CONCLUSIONS REGARDING THE ASIAN CLAM'S PRESUMPTIVE IMPACTS ON NATIVE ECOLOGY AND NATIVE BIVALVE COMMUNITIES

The potential ecological consequences of invasive Asian clam populations have been discussed for years (Cooper *et al.* 2005; Ilarri and Sousa 2012; Sickel 1973; Sousa *et al.* 2005, 2008; Strayer 1999, Vaughn and Hakenkamp 2001). The frequently high population abundances achieved by Asian clams has often been conjectured to have impacted abundance and diversity of native bivalves in general, and unionids specifically, in North America (Strayer 1999; Sousa *et al.* 2008; Vaughn and Hakenkamp 2001; Williams *et al.* 1993). As a result, oft-cited works (*e.g.*, Ilarri and Sousa 2012, McMahon 1991, Sousa 2008, Strayer 1999, Vaughn and Hakenkamp 2001) regarding the <u>potential</u> ecological consequences of Asian clams have led to unfounded and misleading statements and concerns over appreciable harm to the BIP's of the relevant ecosystems. For example, when defining the Asian clam "problem" in Hooksett Pool and providing relevant background information, Nelson et al. (2015) point out that "[a]s described in Caffrey et al. 2011, *Corbicula* is known to competitively impact native macro-invertebrate communities, significantly reduce phytoplankton biomass, and alter benthic substrates." This statement is misleading, reading as though Caffery et al (2011) performed a study on macroinvertebrate competition, phytoplankton biomass, and alteration of benthic substrata. More accurately, Caffery et al. (2011) present only the results of a scuba survey for the presence of Asian clams in two Ireland rivers. Caffery et al. (2011), however, did cite other authors in their introduction stating, "Corbicula fluminea is known to competitively impact on [sic] native macro-invertebrate communities (e.g. McMahon 1991), significantly reduce phytoplankton biomass (Lucas et al. 2002; Lopez et al. 2006), alter benthic habitats and substrates (Hakenkamp et al. 2001)…". Actually, McMahon (1991) makes no such statement about "known" competitive impacts of Asian clams, but rather points out that other studies, "…may suggest an inability of [Asian clam] to out-compete native species in most North American habitats." (McMahon 1991, p. 364). Furthermore, while Lucas et al. (2002) and Lopez et al. (2006) do point out the reduction in phytoplankton biomass by Asian clam, Lopez et al. (2006) actually confirm that higher trophic levels like zooplankton that rely on phytoplankton are unaffected. Finally, the Hakenkamp et al. (2001) study does not address alteration of benthic substrata, but does clearly and experimentally point out that Asian clam had no effect on benthic protists and invertebrates. Clearly, a thorough review and accurate presentation of the pertinent peer-reviewed literature is necessary in presenting any concerns about Asian clams. Inaccurate representations of the peer-reviewed literature should not be used in any consideration of appreciable harm to the BIP

Despite the occurrence and recitations of such suppositions and misleading statements, the degree to which the Asian clam causes appreciable damage to the BIP, however, remains largely speculative, anecdotal, rarely quantitative, and largely scientifically unsubstantiated. Most touted negative impacts of Asian clams on the ecosystem they invade have simply not been scientifically confirmed or validated. When referring to effects on native bivalves, for example, Strayer (1999) subsequently states, "[u]nfortunately, the evidence for *Corbicula*'s impacts is weak, so its role…is unresolved," (emphasis added) and Vaughn and Hakenkamp (2001) point out, "[t]he invasion of *Corbicula* has been speculated to have negatively impacted native bivalve abundance and diversity in North America" (emphasis added). Still more recently, Ilarri and Sousa (2012) conclude for ecological impacts that, "[t]he majority of these effects remain speculative and further research is needed to clarify these interactions" (emphasis added). Unfortunately, these statements are overlooked or ignored.

Such concerns and caveats regarding speculation and the need for further research on Asian clam impacts are well founded. A thorough review of the published literature and unpublished reports (where available) revealed no studies that provided a substantive or scientifically valid causative link for a negative impact of Asian clam presence on native bivalve abundance and diversity. At best, studies were only suggestive of the causative links between Asian clams and any observed declines in native bivalves. As Strayer (1999) correctly recognizes, evidence for impacts of Asian clams on native bivalves is derived largely from examining non-overlapping, spatial distributions of bivalves or, less frequently, from changes in populations of native bivalves over time. Most of this evidence is anecdotal and not quantifiable with little or no experimental evidence, thus making it impossible to be precise about the impacts Asian clams may have on native bivalves (Strayer 1999).

More specifically to the point identified above, studies simply link or correlate declines in native bivalves; unionids and, more commonly, fingernail clams (Sphaeriidae); with the arrival of Asian clams in that area (Crumb 1977; Gardner *et al.* 1976). Further, numerous studies (*e.g.*, Belanger *et al*. 1990; Clarke 1986, 1988; Kraemer 1979; Sickel 1973) have reported that Asian clams and native bivalves, especially unionids, have non-overlapping spatial distributions, so that unionids are abundant only where Asian clams are rare, and *vice versa*. However, most of these studies were conducted during a time of unprecedented decline in native bivalves across North

America independent of Asian clams. It is likely that any such noted correlation would have been confounded with other more notable factors like habitat destruction, overutilization for commercial or other purposes, disease, predation, introduction of non-indigenous species other than Asian clams, pollution, hybridization, and restricted ranges (Williams *et al.* 1993). Any or all of these factors may have contributed to observed declines in native bivalves while allowing the spread of Asian clams (Strayer 1999).

Alternatively, negative correlations between Asian clams and native bivalves may be explained by the spatial scale at which the relationship is examined (Vaughn and Spooner 2006). Looking at different spatial scales, Vaughn and Spooner (2006) found that Asian clam densities varied widely in patches without native mussels or where native mussels were in low abundance, but Asian clam density was never high in patches where native mussels were dense. When Vaughn and Spooner (2006) pooled patch-scale density and biomass information to represent entire stream reaches, the negative relationship between native mussels and Asian clams disappeared and there was no significant relationship between native mussels and Asian clams. Vaughn and Spooner suggested that rather than Asian clam invasion impacting native bivalves, as is typically thought, native bivalves may actually impede Asian clam establishment (emphasis added); they hypothesize that the likelihood of successful Asian clam invasion decreases with increasing abundance of adult native mussels. Vaughn and Spooner (2006) suggested lack of space for Asian clams to colonize, physical displacement by actively burrowing native mussels, and locally reduced food resources in patches where native mussels feed as possible explanations for the likely impediment. Taken altogether, the results from Vaughn and Spooner (2006) suggest that the often observed negative correlations between native bivalves and Asian clams may exist simply because Asian clams do not successfully colonize where native bivalves are abundant. Similarly, Asian clams may only preferentially invade sites where native unionids have already been decimated (Kraemer 1979;

McMahon 2001; Strayer 1999) or these nonnative clams take advantage of underutilized benthic habitat not preferred or utilized by native bivalves (Diaz 1994; McMahon, *pers. com*., Professor Emeritus, University of Texas-Arlington). Nonetheless, competition between native bivalves and Asian clams is still often, and perhaps erroneously, cited as contributing to the observed negative relationship between Asian clams and native unionid bivalves.

As noted above, however, very few studies have actually examined competitive interactions between Asian clams and native mussels. In one such study that actually did look at the competitive interaction between native unionids and Asian clams, Belanger *et al.* (1990) found that Asian clam densities had no significant effect on growth or density of *Elliptio* sp, a native unionid, *i.e.,* no competition was observed. Likewise, Karatayev *et al.* (2003) reported that native unionids and Asian clams were both abundant and seen to occupy the same areas with distributions completely overlapping. Others have likewise seen overlapping distributions of Asian clams and native unionids co-occurring in relatively high abundances (T. Richardson, *pers. obs.*; J. Garner, *pers. comm.* State Malacologist, Alabama Department of Conservation and Natural Resources; R. McMahon, *pers. comm.*, Professor Emeritus, University of Texas-Arlington; Clarke 1988; Miller and Payne 1994). For northern, cold water populations, Morgan *et al.* (2004) state that, "*Corbicula* has established a permanent population in the Connecticut River with <u>little impact</u> on native bivalves…" (emphasis added) over a nine year period with Asian clam abundances reaching > 3,000 clams/m^2. Also in a colder, more northern location in the Czech Republic, Beran (2006) noted that there was no visible negative impact to original molluscan communities; however, Asian clams abundances were relatively low, *i.e.,* $\leq$ 100 clams/m^2. Indeed, if Asian clams are detrimental to native bivalves, examples of overlapping distributions, especially when accompanied by relatively high abundances of both clams and native bivalves, should be rare when, in fact, they are common.

In summary, the evidence for Asian clam impacts on BIPs in general, and native bivalves in particular, is, at best, weak and largely correlative with very few studies addressing the actual cause and effect of Asian clam establishment on the invaded ecosystem; furthermore, none support or report appreciable damage to the BIP.

C. ASIAN CLAMS ARE NOT REPLACING NATIVE BIVALVES IN HOOKSETT POOL OR OTHERWISE HARMING NATIVE BIVALVES

At Hooksett Pool near Merrimack Station, abundances and size-frequency distributions of native bivalves at designated river sampling sites with Asian clams and those without clams were compared to see if Asian clams were in any way causing appreciable harm to the native mussel community. Using SCUBA, in 2014 and 2016, divers excavated three-0.25 m^2 quadrate samples to a depth of 15 cm along each of several transects above, at, and below the cooling water discharge canal at Merrimack Station. Furthermore, divers performed semi-quantitative assessments of unionid and Asian clam abundances at 10 m intervals along these transects prior to excavating samples (see Appendix B for methods).

Analysis of the diver excavated 0.25 m^2 quadrates indicated a significant difference among native bivalve species (2-way ANOVA; P = 0.014), but did not reveal a significant difference among stations (P = 0.227), and there was no significant station by species interaction (P = 0.251) (Figure 3). No significant station by species interaction means that native bivalve abundance was unaffected by presence of Asian clams and certainly no appreciable harm was indicated. Notably, native bivalves, mostly *Elliptio complanata* and sphaeriids, had densities at Station N10, where no clams occurred, similar to those of Station S24, where clams were fairly abundant (Figure 3).

Examining the results of semi-quantitative diver transect surveys (Appendix C1 and C2) indicated that Asian clams were located at survey sites S0, S4, S17, and S24. Numerous native mussels were also located at those same survey sites (and elsewhere in Hooksett Pool). From these assessments, it is clear that native bivalves were as abundant and spatially distributed, *i.e.*, near the shore, along transects *without* Asian clams (USR through N5) as they were along transects *with* Asian clams (S0-S24). Also, the native bivalves appear to avoid the mid-channel area of the river. As suggested by Vaughn and Spooner (2006), it is highly likely that Asian clams in Hooksett Pool are mostly exploiting the highly disturbed mid-channel shifty and loose sand substrate generally uninhabited by native bivalves. These areas are largely unsuitable and inappropriate for most native bivalve species, especially members of the Unionidae, but provide typical habitat for Asian clams (McMahon 2002 and *pers. comm.*). No appreciable harm to the native bivalve community is indicated nor suggested by this semi-quantitative assessment. Furthermore, it is important to note that ignorance of the spatial distribution of native bivalves and Asian clams as seen in Appendix C would lead one to a spurious negative correlation between native bivalve abundance and Asian clam density. This subsequently would lead to an incorrect conclusion of a negative impact of Asian clams on native bivalves (*sensu* Vaughn and Spooner 2006), which is simply not the case.

In addition, if Asian clams were causing appreciable harm to the native bivalves through competitive interactions, one would expect to find differences in population size structure between stations with Asian clams versus those lacking Asian clams. But when pooling native bivalve (Eastern elliptio) data from stations with Asian clams and comparing the size-frequency distribution to data from stations without Asian clams, the size-frequency distributions are not significantly different (Kolmogorov-Smirnov $D_s = 0.1288 < D_\alpha = 0.1333$, $P > 0.65$) indicating no appreciable harm (Figure 4). The absence of such significant differences is relevant because if negative competitive interactions between native bivalves and Asian clams were occurring (with the subsequent appreciable harm), one would generally observe smaller native bivalves in those locations where Asian clams were present (as compared to those locations where they are absent).

But because the two size distributions were similar, there appears to be no negative competitive effect and certainly no appreciable harm to the native bivalves. Similarly, if Asian clams were causing appreciable harm to native bivalve recruitment by impacting glochidia and settling juveniles, there should be a corresponding lack of smaller individuals at stations with Asian clams compared to stations without Asian clams. Again, no difference was detected between the two distributions, thereby indicating Asian clams are not causing appreciable harm to the native bivalve component of the BIP through negative impacts on recruitment (Figure 4).

D. ASIAN CLAMS ARE NOT CAUSING APPRECIABLE HARM TO THE BENTHIC MACROINVERTEBRATE BIP OF HOOKSETT POOL

Application and careful analysis of various EPA-approved metrics for assessing appreciable harm, or lack thereof, to the BIP further demonstrates the Asian clam is not causing appreciable harm to the BIP of Hooksett Pool. Specifically:

- The Normandeau 2012 study points out that, although Asian clams were abundant in 2011, ". . . data collected in 1972 and 1973, when compared to 2011 data, showed increased values in 2011 for taxa richness, EPT richness, and EPT to Chironomidae abundance ratio" all of which are indicating an improvement in the BIP, not harm. If clam presence and abundance caused appreciable harm to the BIP, these metrics should have decreased from 1972 and 1973 compared to 2011 rather than increased; *i.e.*, Asian clams have had no effect on the integrity of the indigenous benthic invertebrate community and thus no appreciable harm to the BIP.
- Benthic invertebrate abundance (minus Asian clam) was the same or higher among many stations with versus those without Asian clams (Figure 5). There was no significant difference ($P > 0.05$) among many of the sites with Asian clams versus those sites without clams. Interestingly, there were even higher invertebrate abundances at

S17, one of the sites with the highest Asian clam densities. For Asian clam presence and abundance to have caused appreciable harm to the benthic macroinvertebrate BIP, the abundance of other benthic invertebrates should have been reduced at stations with clams; *i.e.,* Asian clams have no effect on the abundance of indigenous benthic invertebrates and thus no appreciable harm to the BIP.

- Benthic invertebrate abundances (minus Asian clam) were the same at the two stations with highest Asian clam abundance (S4 and S17) in 2011, 2014 or 2016 following Asian clam establishment compared to 1972 or 1973, prior to Asian clam establishment (Figure 6), although 1973 had higher abundances at S4 than in 1972, 2011, 2014 or 2016. For Asian clam presence and abundance to have caused appreciable harm, the abundance of other benthic invertebrates should have been significantly reduced in 2011, 2014 and 2016; *i.e.*, Asian clams have had no effect on the abundance of indigenous benthic invertebrates and thus no appreciable harm to the BIP.
- Benthic macroinvertebrate BIP taxa richness is an EPA "best candidate benthic [community] metric" (EPA 2012). Taxa richness reflects the number of different types (taxa) of benthic macroinvertebrates that are present in a sample, thereby providing a measure of diversity within the sample. Importantly, BIP taxa richness was the same (*e.g.*, 2014; ANOVA, $P = 0.116$) or higher (*e.g.*, 2016; LSD, $P < 0.05$) among *all* stations with *versus* those without Asian clams (Figure 7). For Asian clam presence and abundance to have caused appreciable harm, the taxa richness of other benthic invertebrates should have been significantly reduced at sites with clams; *i.e.,* Asian clams have had no effect on the taxa richness of indigenous benthic invertebrate community and thus no appreciable harm to the BIP.

- BIP taxa richness was the same (ANOVA, P = 0.278) at the two stations with highest Asian clam abundance (S4 and S17) in 2011, 2014 or 2016 following Asian clam establishment compared to 1972 or 1973, prior to Asian clam establishment (Figure 8). For Asian clam presence and abundance to have caused appreciable harm, the taxa richness of other benthic invertebrates should have been reduced in 2011, 2014 and 2016; *i.e.*, Asian clams have had no effect on the taxa richness of indigenous benthic invertebrate community and thus no appreciable harm to the BIP.
- The BIP Shannon Community Diversity Index focuses on quantifying the uncertainty in predicting the species identity of an individual that is taken at random from the dataset. These indices were the same among many stations with *versus* those without Asian clams (Figure 9). For Asian clam presence and abundance to have caused appreciable harm, the Shannon Community Diversity of other benthic invertebrates should have been significantly reduced at sites with clams; *i.e.*, Asian clams have no effect on the diversity of indigenous benthic invertebrate community and thus no appreciable harm to the BIP.
- BIP Shannon Community Diversity Indices were the same (ANOVA, P = 0.157) at the two stations with highest Asian clam abundance (S4 and S17) in 2011, 2014 and 2016 following Asian clam establishment compared to 1972 or 1973, prior to Asian clam establishment (Figure 10). For Asian clam presence and abundance to have caused appreciable harm, the Shannon Community Diversity of other benthic invertebrates should have been significantly reduced in 2011, 2014 and 2016; *i.e.*, Asian clams have had no effect on the diversity of indigenous benthic invertebrate community and thus no appreciable harm to the BIP.

- The Hilsenhoff Biotic Index (HBI) is another EPA-approved benthic macroinvertebrate BIP metric (EPA 2012). The HBI estimates the overall pollution tolerance of the community in a sampled area, weighted by the relative abundance of each taxonomic group. Lower HBI's indicate a less pollution tolerant benthic community and, therefore, a "healthier" benthic community. The HBI's <u>were the same or lower</u> among stations with *versus* those without Asian clams (Figure 11). For Asian clam presence and abundance to have caused appreciable harm, the HBI of benthic invertebrates would be expected to significantly increase at sites with clams; *i.e.*, Asian clams have no effect on the integrity of the indigenous benthic invertebrate community and thus no appreciable harm to the BIP.
- BIP Hilsenhoff Biotic Indices (HBI) <u>were the same or lower</u> at the two stations with highest Asian clam abundance (S4 and S17) in 2011, 2014 and 2016 following Asian clam establishment compared to 1972 or 1973, prior to Asian clam establishment (Figure 12). For Asian clam presence and abundance to have caused appreciable harm, the HBI of benthic invertebrates would be expected to increase in 2011, 2014 and 2016; *i.e.*, Asian clams have had no effect on the integrity of the indigenous benthic invertebrate community and thus no appreciable harm to the BIP.
- EPT taxa richness is considered by EPA to be one of the "best candidates for benthic invertebrate [community] metrics" for estimating response of the BIP to perturbation (EPA 2012). It derives its name from its reliance on counting the presence of three benthic insect groups: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EPT taxa richness <u>was the same or higher</u> among stations with *versus* those without Asian clams (Figure 13). For Asian clam presence and abundance to have caused appreciable harm, the EPT taxa richness should have been

significantly reduced at sites with clams; *i.e.*, Asian clams have no effect on the EPT taxa richness of the indigenous benthic invertebrates and thus no appreciable harm to the BIP.

- EPT taxa richness <u>was the same or higher</u> at the two stations with highest Asian clam abundance (S4 and S17) in 2011, 2014 and 2016 following Asian clam establishment compared to 1972 or 1973, prior to Asian clam establishment (Figure 14). For Asian clam presence and abundance to have caused appreciable harm, the EPT taxa richness of benthic invertebrates should have been significantly reduced in 2011, 2014 and 2016; *i.e.*, Asian clams have had no effect on the EPT taxa richness of the indigenous benthic invertebrates and thus no appreciable harm to the BIP.
- Similarly, HBI, Shannon Diversity Index, taxa richness, and total invertebrate abundance (minus Asian clams) estimates per sample were each analyzed for correlation with Asian clam abundances using samples taken in 2011 and 2014. There was no significant correlation between Asian clam abundance and HBI ($r = 0.018$, $P = 0.835$, $n = 130$), Shannon diversity ($r = -0.038$, $P = 0.669$, $n = 130$), taxa richness ($r = -0.069$, $P = 0.435$, $n = 130$), or total invertebrate abundance ($r = -0.136$, $P = 0.122$, $n = 130$). For Asian clam presence and abundance to have caused appreciable harm, the Shannon diversity index, taxa richness, and total invertebrate abundance (minus Asian clams) of benthic invertebrates would be expected to have significant negative correlations with Asian clam abundance; HBI would be expected to have a significant positive correlation; *i.e.*, Asian clams have had no correlation with any metric on the biotic integrity of the indigenous benthic invertebrate community and thus no appreciable harm to the BIP.

- Bray-Curtis Community Similarity Indices cluster analysis clustered stations into three groups, each containing stations with and those without Asian clams indicating similar macroinvertebrate BIPs among stations with and without Asian clams (Figure 15). For Asian clam presence and abundance to have caused appreciable harm, the Bray-Curtis Community Similarity clusters of benthic invertebrates should have separated sites with clams from sites without clam. Such separation was not encountered; *i.e.*, Asian clams have no effect on the community similarity of the indigenous benthic invertebrate community and thus no appreciable harm to the BIP.
- MDS Community Ordination based on Bray-Curtis Similarity lumped stations into three groups, each containing stations with and those without Asian clams indicating similar macroinvertebrate BIPs among stations with and without Asian clams (Figure 16). For Asian clam presence and abundance to have caused appreciable harm, the MDS Community Ordination based on Bray-Curtis Community Similarity of benthic invertebrates should have separated sites with clams from sites without clams. Such separation was not encountered; *i.e.*, Asian clams have no effect on the community similarity of the indigenous benthic invertebrate community and thus no appreciable harm to the BIP.

E. ASIAN CLAMS ARE FOUND AT NUMEROUS SITES IN NEW HAMPSHIRE LACKING THERMAL DISCHARGE

In 2017, AST conducted an extensive presence/absence survey looking for the presence of Asian clams. Specifically, these dives were to gather information to help elucidate the ongoing spread of the Asian clam into New Hampshire waters, especially those lacking thermal input. AST conducted dives on 71 lake and river locations in New Hampshire assessing the presence of Asian clams. These sites were chosen based specifically on one or more of the following criteria:

previous record of invasive species of any kind, accessibility to fishermen and recreational boaters, proximity to other locations known to harbor Asian clams, and lack of any known artificially heated water discharge.

AST found a total of six locations with Asian clams, bringing the total number of sites in New Hampshire with established Asian clam populations to 11 (Figure 17) (USGS 2017). Of these 11 known locations of Asian clam, Hooksett Pool downstream of Merrimack Station is the only site receiving thermal discharge. Most of the sites with clams contained several year classes (Figure 18) indicating clams have overwintered several years at these sites without thermal discharge to elevate water temperatures. The four sites in Figure 18; Great Pond, Beaver Lake, Canobie Lake, and Little Island Pond; all freeze over most winters (D. Kretchmer, DK Water Resources, NH, *pers. comm.*). Asian clams were found in shallow enough water at all locations to have been exposed to sub-2°C water temperatures during winter freezes. Asian clams are spreading throughout New Hampshire and parts of the Northeast without the need for water warmed by thermal discharge.

F. BENEFICIAL IMPACTS OF THE ASIAN CLAM ON THE BIP

Despite the popular conclusions and suppositions to the contrary identified in Subsection V.B. of this report, Asian clams may actually have *positive*, rather than negative, effects on their ecosystems. All bivalves, including the Asian clam, are considered ecosystem engineers (*i.e.*, organisms that can physically modify the environment) and their importance as such has been recognized (Gutiérrez *et al.*, 2003; Jones *et al.*, 1994; Sousa *et al.*, 2009). Asian clam shells can be abundant, persistent, and ubiquitous, thereby improving the physical structure of the substratum of the aquatic habitat for other species. It is commonly accepted that Asian clam shells have positive effects through providing substrate for epibionts, refuge from predation, reducing physical or physiological stress, control transport of solutes and particles in the benthic environment, stabilization of sediment, and through bioturbation of sediments. For example, clam shells form a more stable, complex, sheltered, and heterogeneous habitat that is attractive for several species including other mollusks, algae, freshwater sponges, crustaceans, and insects (Sousa *et al*, 2008a). Garner (J. Garner, *pers. comm.*, State Malacologist, Alabama Department Conservation and Natural Resources) has reported areas of the Tennessee River with silty sediments previously unsuitable for native bivalves transformed by Asian clams into suitable, more stable substrate increasing the presence of native unionid mussels. Likewise, Werner and Rothhaupt (2007) found that Asian clam shells had a positive effect on the abundance of *Caenis* spp. mayflies by providing valuable hard substrate. Their study did not show any difference in the overall benthic invertebrate community among treatments with Asian clams compared to those without Asian clams (Werner and Rothhaupt 2007).

Additionally, Asian clam movement within the top layer of sediments leads to bioturbation. Such bioturbation contributes to substantial changes in abiotic conditions like dissolved oxygen, redox potential, amount of organic matter, particle size, and the like, in a manner typically enhancing habitat conditions for other organisms (Ilarri and Sousa 2012; Werner and Rothhaupt 2007). Furthermore, high filtration rates by Asian clams remove a wide range of suspended particles having important repercussions for water clarity and subsequent light penetration that apparently benefit submerged plants (Phelps, 1994). In one of the few experimental studies examining Asian clam filter feeding effects on native bivalves, Leff *et al.* (1990) found "[t]here was no evidence of a negative impact on the distribution of the native bivalve in spite of high measured rates of water clearance by *C. fluminea.*" Also, Karatayev *et al.* (2003) ". . . found no correlation between the densities of *C. fluminea* and other benthic invertebrates" (emphasis added). In general, consideration of studies on the ecosystem engineering of bivalves, including Asian clams, overwhelmingly suggest that they either have no effect on native benthic invertebrates, *i.e.*, the BIP, or they ". . . mainly have positive effects on the density of benthic invertebrates" and conclude that invasive bivalve species, in general, ". . . have positive effects on invertebrate density, biomass and species richness" (Sousa *et al.* 2009) (emphasis added). The data presented in Section V. D. above using various community biotic integrity metrics concur with these findings of others; *i.e.*, Asian clams have no effect or a positive effect on the BIP of Hooksett Pool.

G. COMPUTATIONAL FLUID DYNAMIC MODELING OF MERRIMACK COOLING WATER DISCHARGE PLUME INTO HOOKSETT POOL

Computation Fluid Dynamic (CFD) modeling simulates complex scenarios involving fluid flow, heat transfer, and interaction with surfaces (see Enercon, 2017 for complete explanation of the CFD model and parameters and results). CFD simulation is able to incorporate turbulent flow conditions of the river and cooling water canal effluence along with heat transfer and the thermal and density properties of the ambient river and cooling water discharge to model the dynamics of the thermal plume as it interacts with the river bottom. The CFD model uses ambient river temperature upstream of Merrimack Station, temperature of the cooling water discharge canal, flow of the discharge canal, and flow of the river as input parameters. The discharge flow rate (443.4 cfs) and discharge temperature (12.0^{o}C) used were indicative of a "plant on" scenario where both Units 1 and 2 are operating at design conditions, *i.e.*, $\geq$ 90% capacity. Of particular interest in using CFD was modeling the extent to which the cooling water discharge plume into Hooksett Pool provides for >2^{o}C water at the river bottom during winter operations of Merrimack Station. As previously discussed, Asian clams are thought by many to have a 2^{o}C minimum thermal tolerance limit that excludes them from cold water habitats (see Sec. III. C. above). Modeling the thermal plume and simulating the extent to which it may elevate Hooksett Pool winter temperatures downstream of Merrimack Station above 2^{o}C would seem paramount in determining the influence of thermal discharge on the persistence of the Asian clam in Hooksett Pool.

The resulting CFD models of the thermal plume from Merrimack Station into Hooksett Pool (Figure 19) indicate that the thermal influence of cooling water discharge (1) minimally impacts the bottom where Asian clam and other invertebrates live and (2), perhaps more importantly, does not elevate ambient river temperatures above the 2°C minimum threshold for Asian clam survival at the east and middle Asian clam sampling stations at site S4, 2,000 ft. further downstream from the mouth of the cooling water canal; S4 is one of the two sites with the highest Asian clam abundances in Hooksett Pool. The model uses a discharge flow rate (443.4 cfs) and discharge temperature (12.0°C); indicative of both Units 1 and 2 operating at design conditions, *i.e.,* $\geq$ 90% capacity; with monthly averages (2010-2017) of river flow and an assumed ambient river temperature input of 33°F (0.6°C). Based on these parameters, it is clear that by 2,000 ft. downstream of the canal, the thermal influence of the cooling water discharge is minimal at the river bottom and river bottom temperatures do not exceed 4.9°C December through March. More importantly, bottom temperatures do not exceed the presumed minimum clam survival temperature of 2.0°C December through March for the middle S4 sampling station and do not rise above 0.6°C (ambient river temperature) at the east sampling station (Figure 19). The thermal influence of the cooling water discharge is expected to further dissipate by sampling stations S17 (8,500 ft below the discharge canal) and S24 (12,000 ft below the discharge canal). Thus, removal or mitigation of the minimal influence of the cooling water discharge from Merrimack Station is unlikely to ameliorate or eliminate the conditions for Asian clam persistence in Hooksett Pool.

Furthermore, the cooling water release has had no impact on Asian clams downstream in Hooksett Pool. When comparing the Asian clam abundances among the east, middle and west sampling stations at S4, clam abundances varied significantly among years; however, clam abundances were either the same or higher at the cooler east and middle locations when compared to the warmer west sampling station for 2011 and 2014 (Figure 20). Additionally, the sampling sites with the highest Asian clam abundances were S4, S17, and S24; sites that are 2,000 ft, 8,500 ft, and 12,000 ft, respectively, downstream of the cooling water canal entrance to Hooksett Pool. These results indicate that (1) the cooling water discharge has not had a positive impact on clam abundances and (2) that the clams have established and have been doing well at cold, ambient river temperatures below 2^{o}C. These data clearly signify that installation of a recirculating cooling water system and mitigation of the cooling water discharge will have little if any impact on the established Asian clam population of Hooksett Pool.

VI. CONCLUDING REMARKS

Normandeau first documented the Asian clam in Hooksett Pool in 2011, and, based on its analysis of benthic macroinvertebrate data collected during 1972, 1973, and 2011, determined the Station's past and current operations have resulted in no appreciable harm to the BIP located in the segment of the Merrimack River receiving the Station's discharge (Normandeau 2012). PSNH retained AST Environmental in 2014 to further examine and evaluate the presence of the Asian clam in, and its relationship to the BIP of, the Hooksett Pool segment of the Merrimack River. AST Environmental, in coordination with Normandeau, undertook a comprehensive review of the available data and two-year study of the Asian clam in Hooksett Pool and its relationship (or lack thereof) to Merrimack Station's thermal discharges and to the BIP of Hooksett Pool (specifically, whether and to what extent the Asian clam or Merrimack Station's thermal influence was affecting the pool's BIP). Normandeau also conducted multiple dives in November/December 2014 and, subsequently, in July 2016, collecting numerous clam and macroinvertebrate samples that were analyzed following the scientifically accepted methods set forth in Appendix B of this report and which were incorporated into this report.

This report concludes that neither Merrimack Station's thermal plume nor the Asian clam are causing appreciable harm to the BIP of Hooksett Pool. Specifically:

1. The Merrimack River's Hooksett Pool contains, in addition to other aquatic species, a balanced population of native bivalve fauna that includes several species in two families; Unionidae (particularly *Elliptio* spp.), and Sphaeriidae. There are no studies or evidence that suggest the thermal discharges from Merrimack Station have adversely affected or impacted either the pool's native bivalves or other flora or fauna in the pool.

2. Hooksett Pool includes a population of non-native Asian clams that fluctuates from year to year. Such fluctuations are typical of this species; Hooksett Pool's Asian clam population fluctuations reflect a similar propensity for seasonal population declines and rebounds found in Asian clam populations elsewhere.

3. The discovery of Asian clams in Hooksett Pool significantly post-dates the construction of Merrimack Station. As was the case in numerous other locations around the world, it is most likely that Asian clams were introduced to Hooksett Pool from other locations in the region via boats or marine equipment operating in the Merrimack River, or by recreational fishermen using the clam as bait.

4. Published, peer-reviewed reports based on well-established scientific processes indicate the Asian clam is expanding its range northward in North America and Europe. A survey of reported findings on the Asian clam's northward dispersion into water bodies lacking thermal input in New Hampshire and elsewhere in the U.S. confirm that this range expansion is not solely attributable to thermal refugia provided by cooling water discharges. Of the 11 documented locations of Asian clam in New Hampshire, only one receives thermal effluent from a power station. Furthermore, CFD modeling of the thermal plume from Merrimack Station into Hooksett Pool (Figure 19) indicates that the thermal influence of cooling water discharge (1) minimally

impacts the bottom where Asian clam and other invertebrates live and (2), perhaps more importantly, does not elevate ambient river temperatures above the 2^{o}C minimum threshold for Asian clam survival at S4 and further downstream; S4 and further downstream S17 and S24 are the sites with the highest Asian clam abundances in Hooksett Pool. This is not surprising as recent published findings suggest that successful northward spread is due to previously unrecognized genetic and physiological capacity of Asian clam to tolerate colder temperatures combined with the significant role played by recreational fishing and boating in the spread of this invasive species. The construction or operation of Merrimack Station did not cause the introduction of Asian clams to Hooksett Pool. Removal or mitigation of the minimal influence of the cooling water discharge from Merrimack Station is unlikely to ameliorate or eliminate the established Asian clam from Hooksett Pool.

5. The term BIP is defined to mean "a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by a lack of domination by pollution tolerant species." Hooksett Pool's aquatic community demonstrates taxa diversity at all trophic levels, is a self-sustaining population with cyclical seasonal changes, contains the presence of necessary food chain species, and lacks domination by pollution tolerant species. It is a BIP.

6. There is no evidence of Asian clams displacing native bivalves in Hooksett Pool; on the contrary, evidence shows a lack of demonstrable differences when comparing the BIP and native bivalve species in the Merrimack River from sites upstream of the cooling water release without Asian clams to those sites downstream of the cooling water release with Asian clams. The same holds true when comparing BIP and native bivalve species at sites downstream of the cooling water release before and after Asian clam establishment.

7. There is no evidence of the Asian clam causing appreciable harm to Hooksett Pool's benthic macroinvertebrate BIP. The Station has operated with a thermal variance for decades and with a thermal discharge since beginning operation in the 1960s, yet there is no difference in the benthic communities between sites upstream of the cooling water release without Asian clams to those sites downstream of the cooling water release with Asian clams when using any of a variety of EPA-approved BIP metrics. The same holds true when comparing the BIP at sites downstream of the cooling water release before and after Asian clam establishment using the same variety of metrics.

8. Published evidence and recent data suggest the presence of the Asian clam may, in fact, be beneficial to the pool's BIP by providing substrate for epibionts, refuge from predation, controlling transport of solutes and particles in the benthic environment, and through bioturbation of sediments.

9. While several often cited publications have suggested Asian clams may have a negative impact on their environment, upon close examination, these publications point out that the conclusions are speculative and more research is needed. Conclusions that Asian clams cause harm to the BIP are unsubstantiated, flawed, and disproven by extensive experience.

10. Based on surveys conducted by Normandeau and AST and analysis of the data provided in this report, Asian clams are not only present in Hooksett Pool adjacent to and downstream of Merrimack Station but <u>have also been identified upstream of the Station</u>. Furthermore, Asian clam abundance is not causing a correlative decline in, or displacement of, native macroinvertebrates, including native mussels.

11. Although the Asian clam was identified by Normandeau as "numerically dominant" at certain locations in its 2012 report, high variability in population numbers is characteristic of Asian clam and other invertebrate populations and this is true of the Asian clam population in

Hooksett Pool at Merrimack Station. These inherent annual abundance fluctuations cause numeric dominance of Asian clams to fluctuate year to year as well. At many locations, Asian clam numeric dominance in 2011 declines to well below numeric dominance of Asian clams in in 2014 and disappears altogether in 2016. These inherent fluctuations in invertebrate densities in Hooksett Pool are clear, especially in Asian clams, as clam densities dropped off drastically from 2011 to 2013, rebounded in 2014, only to decline again in 2016. Such year-to-year density fluctuation is typical with Asian clam populations; annual abundances commonly fluctuate as much as 2-3 orders of magnitude.

12. The previously unrecognized genetic and physiological capacity of Asian clams to tolerate colder temperatures, their occurrence in New Hampshire waters lacking thermal input, as well as CFD modeling of the Merrimack Station thermal plume, strongly suggest the clam would continue to exist in Hooksett Pool even if the thermal discharges of Merrimack Station were to be terminated or mitigated altogether. Furthermore, efforts to extirpate the Asian clam in impacted water bodies throughout its range have failed. Accordingly, it would be highly speculative to conclude that measures aimed at Merrimack Station’s cooling water discharges would eliminate Hooksett Pool’s Asian clam population.

13. In conclusion, the available evidence, supported by a wide range of scientific literature and studies, indicates the Asian clam reached Hooksett Pool not because of the operation of Merrimack Station and its associated thermal discharges but rather through the same avenues and methods that have contributed to the Asian clam spread throughout the world and into northern latitudes both in the United States and abroad. Furthermore, there is no credible evidence that the Asian clam presence in Hooksett Pool is causing appreciable harm to the BIP; in fact, its presence may be benefitting the BIP.

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FIGURES

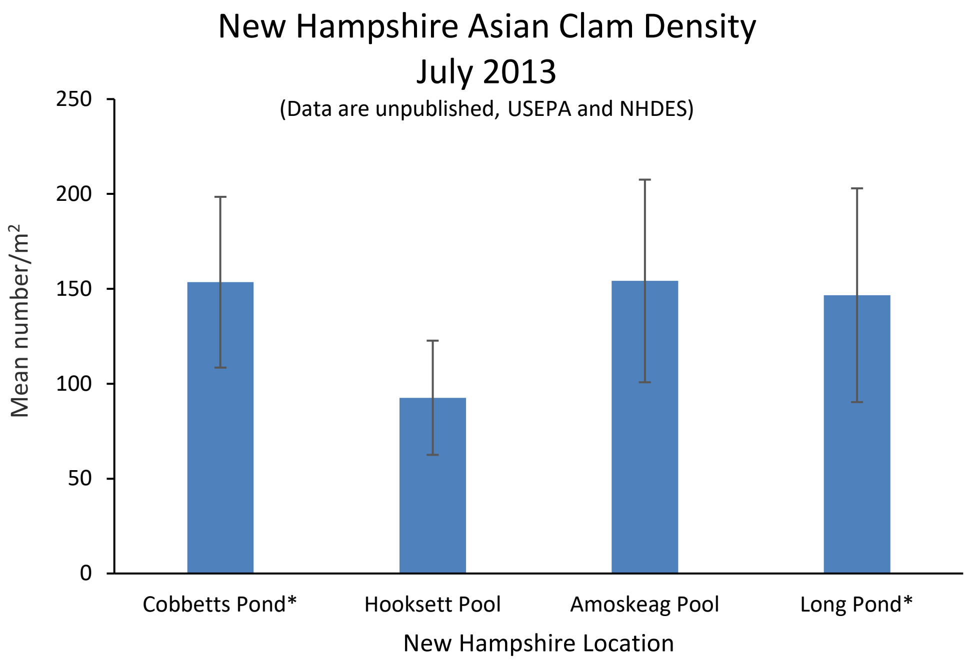

Figure 1. Mean (± standard error) of Asian clam abundances sampled using a ponar sampler in July 2013. There is no significant difference among locations in clam density (P = 0.687). Data were acquired through Freedom of Information Act (FOIA) and New Hampshire Right-to-Know requests, USEPA and NHDES. All data are taken directly from EPA/NHDES field data sheets. * denotes locations lacking thermal discharge.

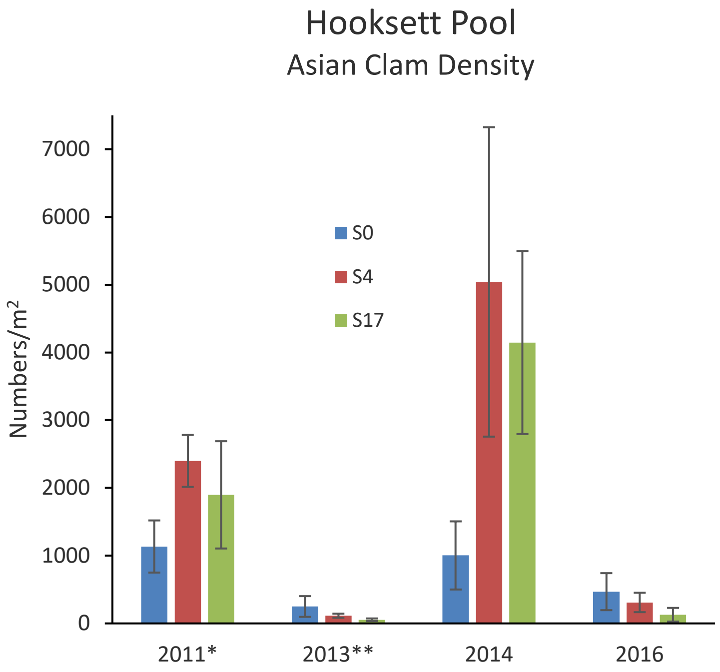

Figure 2. Mean (± standard error) Asian clam densities at three sampling stations for which multi-year data are available on Hooksett Pool at Merrimack Station. Station S0 is at the cooling water discharge into the river, S4 is 0.6 km downstream of the discharge, and S17 is 2.6 km downstream of the discharge. S0, S4 and S17 were the only sites for which all years were represented. Samples were taken using a ponar grab sampling device unless otherwise noted (see Appendix B for methods). 2011, 2013, 2014, and 2016 are significantly different ($P < 0.0001$). Sites and site*year interaction are all insignificant ($P \geq 0.177$). *First year Asian clams were observed in Hooksett Pool. **Data for 2013 are unpublished, Freedom of Information Act request USEPA and NHDES.

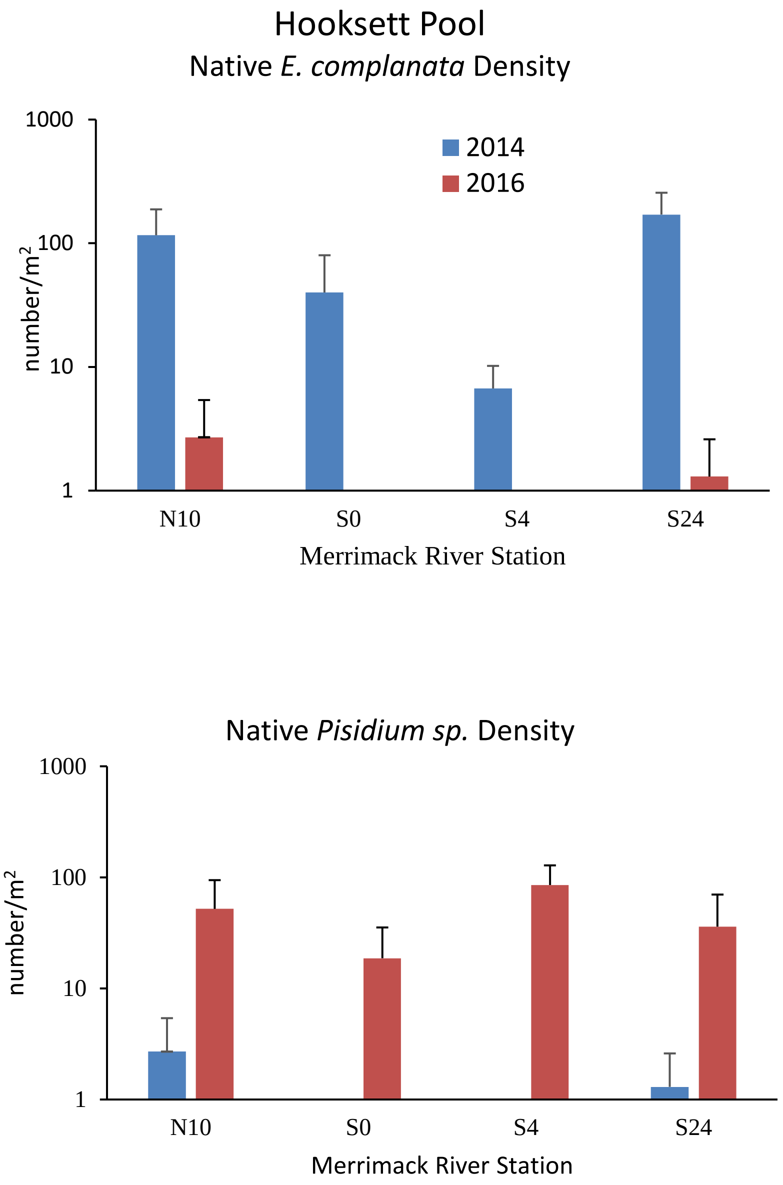

Figure 3. Mean (+ standard error) density of native bivalves at four Merrimack River Stations. Samples are 0.25 m^2 quadrates excavated to 15 cm substrate depth (see Appendix B for methods). *Elliptio complanata* densities differ between years (P = 0.014), but there is no difference among stations and there is no Station*Year interaction (P $\geq$ 0.230). *Pisidium sp*. densities differ between years (P = 0.003), but there is no difference among Stations and there is no Station*Year interaction (P $\geq$ 0.416). There is no significant effect of Asian clam density on native bivalve density.

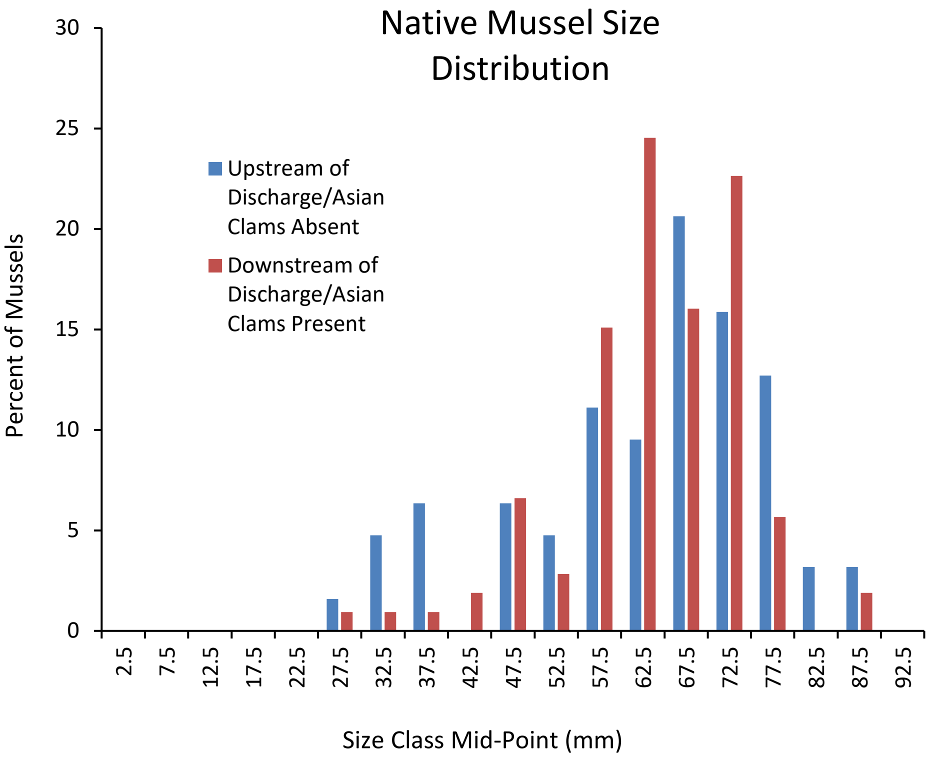

Figure 4. Size-frequency distribution of Eastern elliptio, *Elliptio complanata*, the predominant native bivalve in the Merrimack River. Samples are 0.25 m^2 quadrates excavated by divers to 15 cm substrate depth (see Appendix B for methods). Station N10 was used for “Clams absent” and S0, S4, and S24 were pooled for “Clams present.” The two distributions are not significantly different (Kolmogorov-Smirnov $D_s = 0.1288 < D_\alpha = 0.1333$, $P > 0.65$).

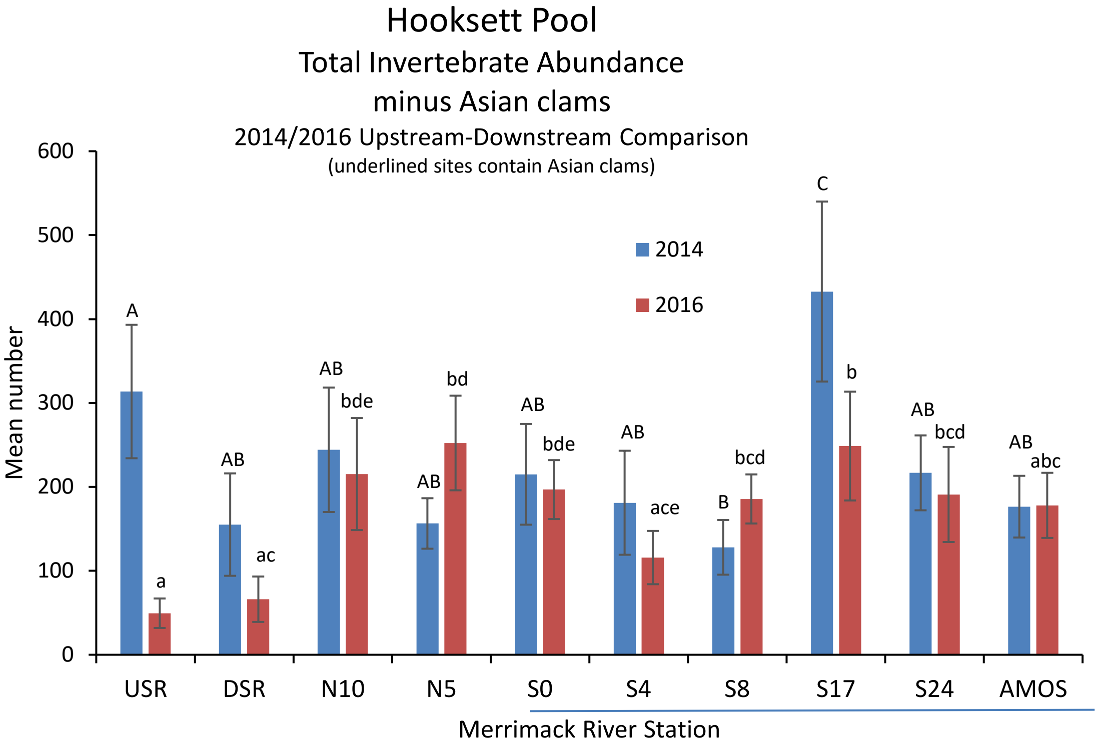

Figure 5. Mean (± standard error) of benthic invertebrate abundance near Merrimack Station. Abundances do not include Asian clam numbers. Underlined sites are sites known to have Asian clams present. Samples were taken using a ponar grab sampling device (see Appendix B for methods). Bars with different letters are significantly different (LSD; $P < 0.05$); uppercase letters are for 2014, lower case are for 2016. Invertebrate abundances at many stations with Asian clams are not significantly different or are higher in abundance compared to stations without clams.

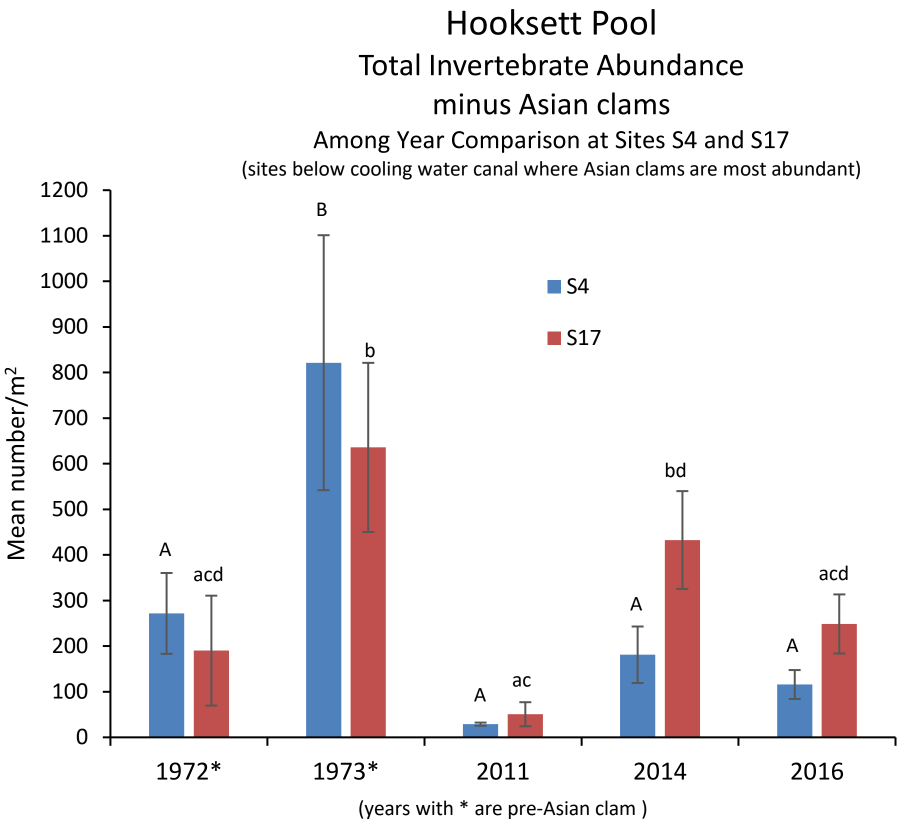

Figure 6. Mean (± standard error) of benthic invertebrate abundance near Merrimack Station. Abundances do not include Asian clam numbers. Samples were taken using a ponar grab sampling device (see Appendix B for methods). Bars with different letters are significantly different (LSD; $P < 0.05$); uppercase letters are for S4, lowercase are for S17. Invertebrate abundances for years with Asian clams are not significantly different compared to years without clams.

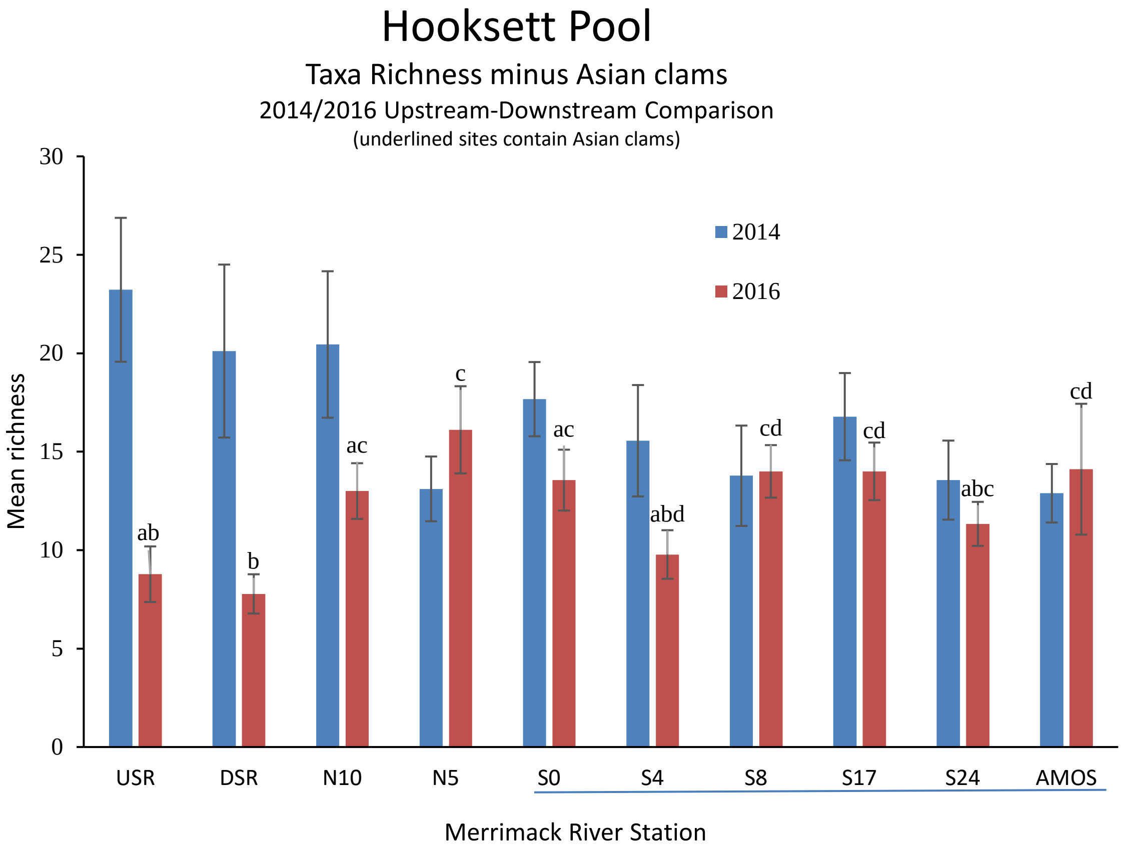

Figure 7. Mean (± standard error) taxa richness of benthic invertebrates near Merrimack Station. Taxa richness estimates do not include Asian clam. Underlined sites are sites known to have Asian clams present. Samples were taken using a ponar grab sampling device (see Appendix B for methods). There was a significant interaction between 2014 and 2016 among stations (2-way ANOVA interaction; P = 0.003). There is no significant difference among all Merrimack River Stations for 2014 (ANOVA; P = 0.116). For 2016, stations with different letters are significantly different (LSD; P < 0.05). Invertebrate taxa richness at stations with Asian clams is not significantly different or is significantly higher compared to richness at stations without clams including reference sites.

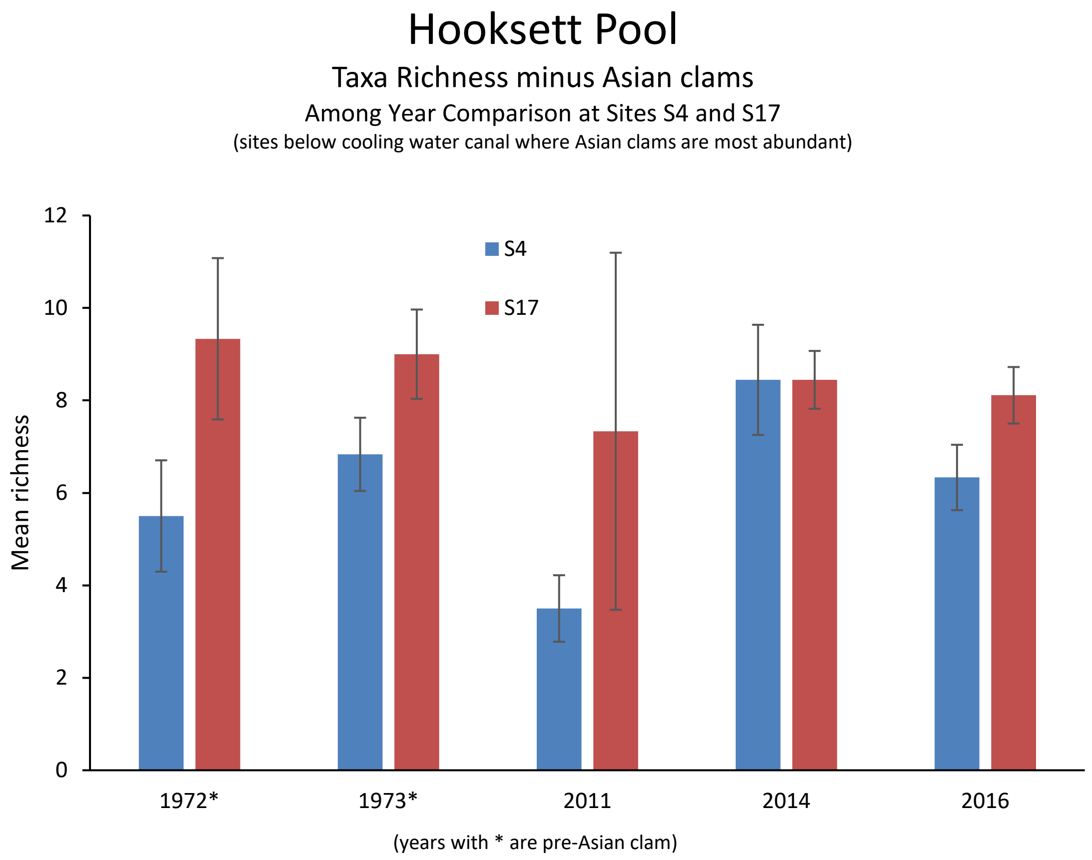

Figure 8. Mean (± standard error) taxa richness of benthic invertebrates near Merrimack Station. Taxa richness does not include the Asian clam. Samples were taken using a ponar grab sampling device (see Appendix B for methods). The taxa richness at S4 and S17 (the two sites with highest recorded Asian clam abundances) for years with Asian clams is not significantly different compared to years without Asian clams (P = 0.278). There was no significant year x site interaction (P = 0.709). Overall, S4 richness was significantly lower than S17 richness (P = 0.019); however, Asian clam abundances did not differ between the two sites (Figure 2).

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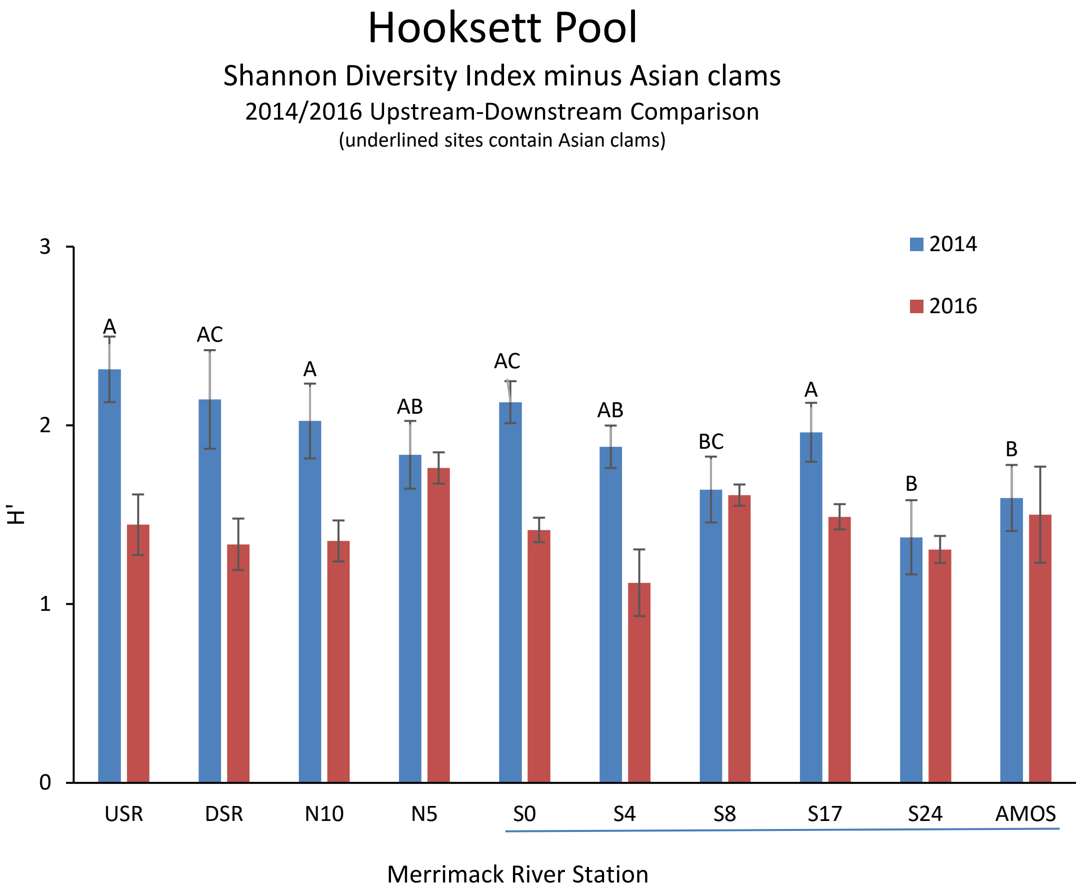

Figure 9. Mean (± standard error) Shannon Diversity Index of benthic invertebrates near Merrimack Station. Shannon diversity indices do not include Asian clam. Underlined sites are sites known to have Asian clams present. Samples were taken using a ponar grab sampling device (see Appendix B for methods). There was a significant interaction between 2014 and 2016 among stations (2-way ANOVA interaction; P = 0.022). There is no significant difference among all Merrimack River Stations for 2016 (ANOVA; P = 0.138). For 2014, stations with different letters are significantly different (LSD; P < 0.05). The Shannon Diversity Index at most stations with Asian clams is not significantly different compared to diversity at stations without clams including reference sites.

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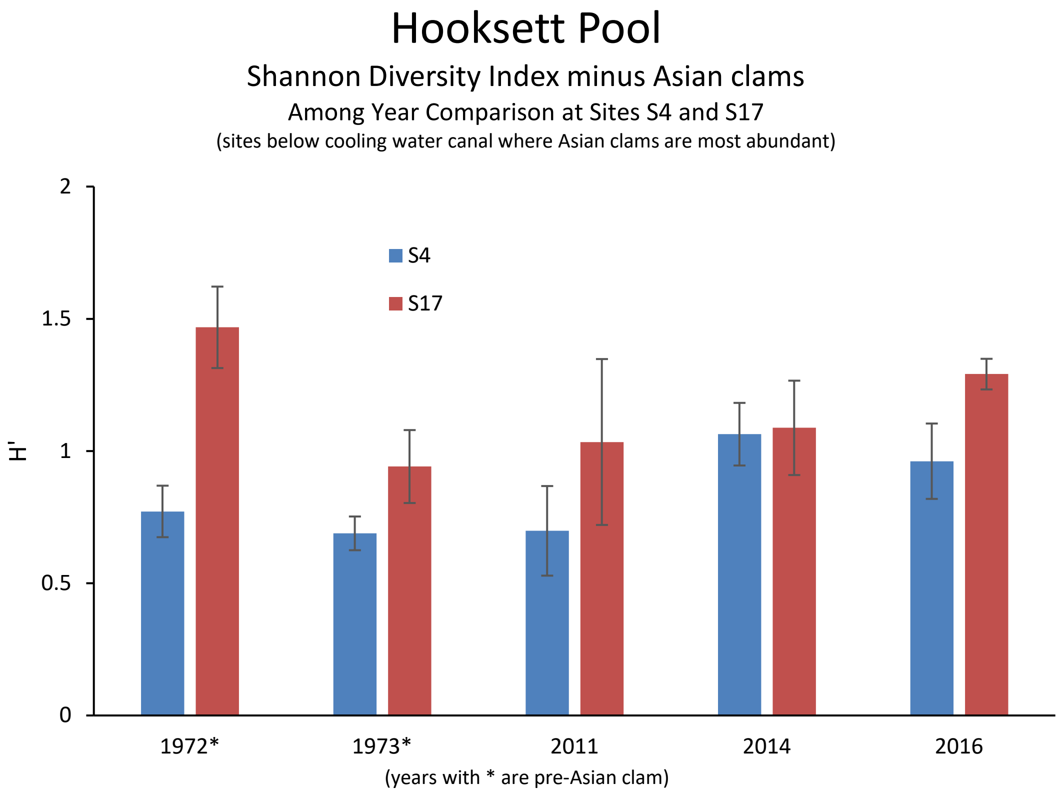

Figure 10. Mean (± standard error) Shannon Diversity Index of benthic invertebrates near Merrimack Station. Shannon diversity indices do not include the Asian clam. Samples were taken using a ponar grab sampling device (see Appendix B for methods). The Shannon Diversity Index at S4 and S17 (the two sites with highest recorded Asian clam abundances) for years with Asian clams is not significantly different compared to years without Asian clams ($P = 0.157$). There was no significant year x site interaction ($P = 0.311$). Overall, S4 diversity was significantly lower than S17 diversity ($P = 0.003$); however, Asian clam abundances did not differ between the two sites (Figure 2).

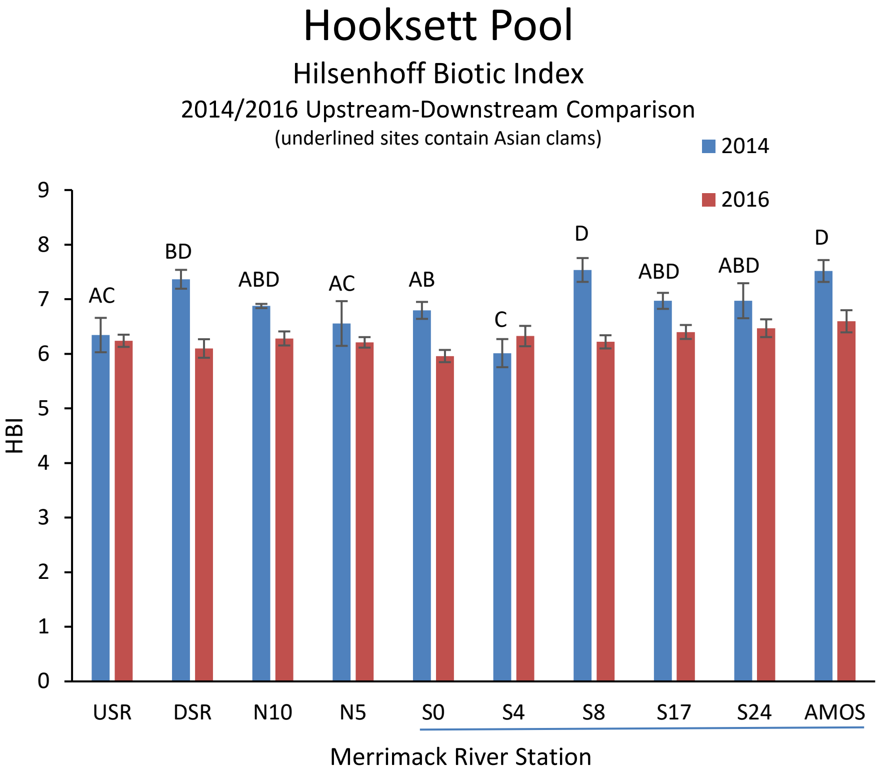

Figure 11. Mean (± standard error) Hilsenhoff Biotic Index of benthic invertebrates near Merrimack Station. The HBIs do not include Asian clam. Underlined sites are sites known to have Asian clams present. Samples were taken using a ponar grab sampling device (see Appendix B for methods). There was a significant interaction between 2014 and 2016 among stations (2-way ANOVA interaction; P = 0.002). There is no significant difference among all Merrimack River Stations for 2016 (ANOVA; P = 0.142). For 2014, stations with different letters are significantly different (LSD; P < 0.05). HBI at many stations with Asian clams is not significantly different or are significantly lower (*e.g.*, S4, reflects improved conditions) compared to HBI at stations without clams including upstream reference sites.

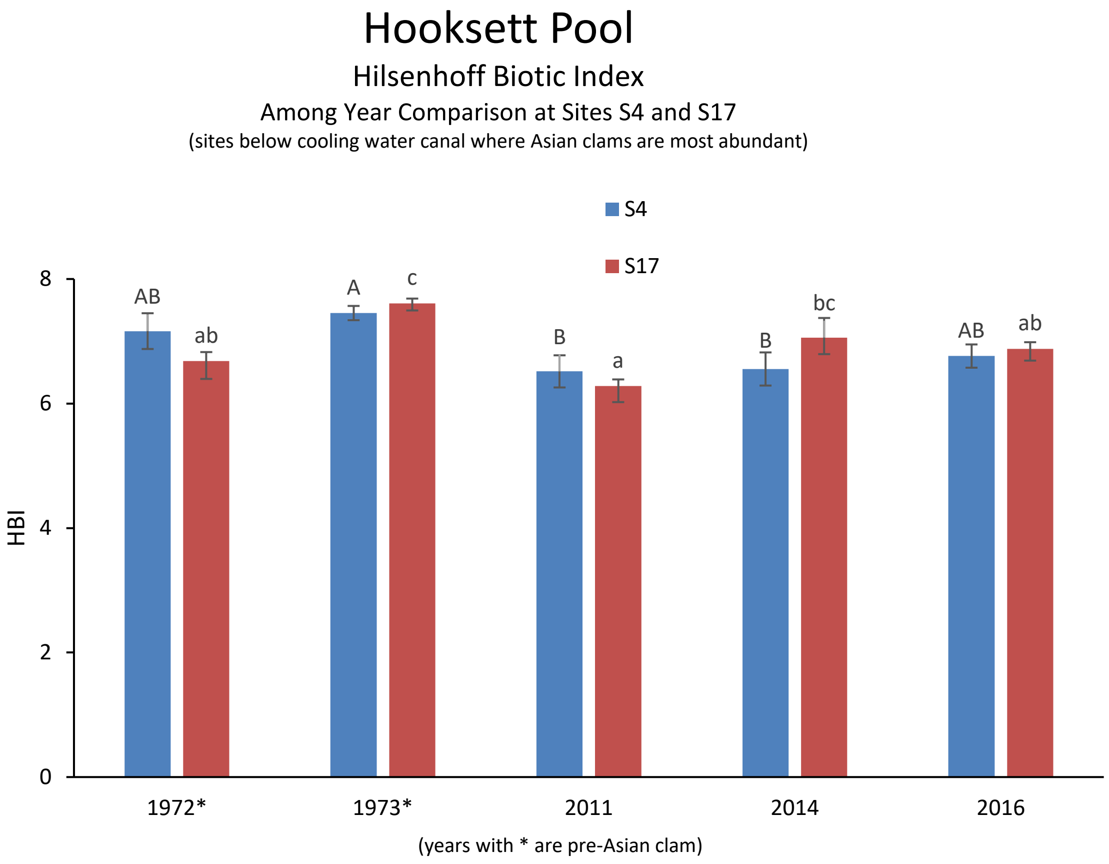

Figure 12. Mean (± standard error) Hilsenhoff Biotic Index near Merrimack Station. Samples were taken using a ponar grab sampling device (see Appendix B for methods). The HBI at S4 and S17 (the two sites with highest recorded Asian clam abundances) for years with Asian clams is significantly different compared to years without Asian clams (P = 0.001). In comparisons among years within sites, HBI's tended to be lower (improved biotic integrity) in 2011 and 2014 than in 1973 and 1972; 2011, 2014 and 2016 all tended to be similar. Bars with different letters are significantly different (LSD; $P < 0.05$); uppercase letters are for S4, lowercase are for S17. There was no significant year x site interaction (P = 0.217). Overall, HBI at S4 was not significantly different than HBI at S17 (P = 0.660).

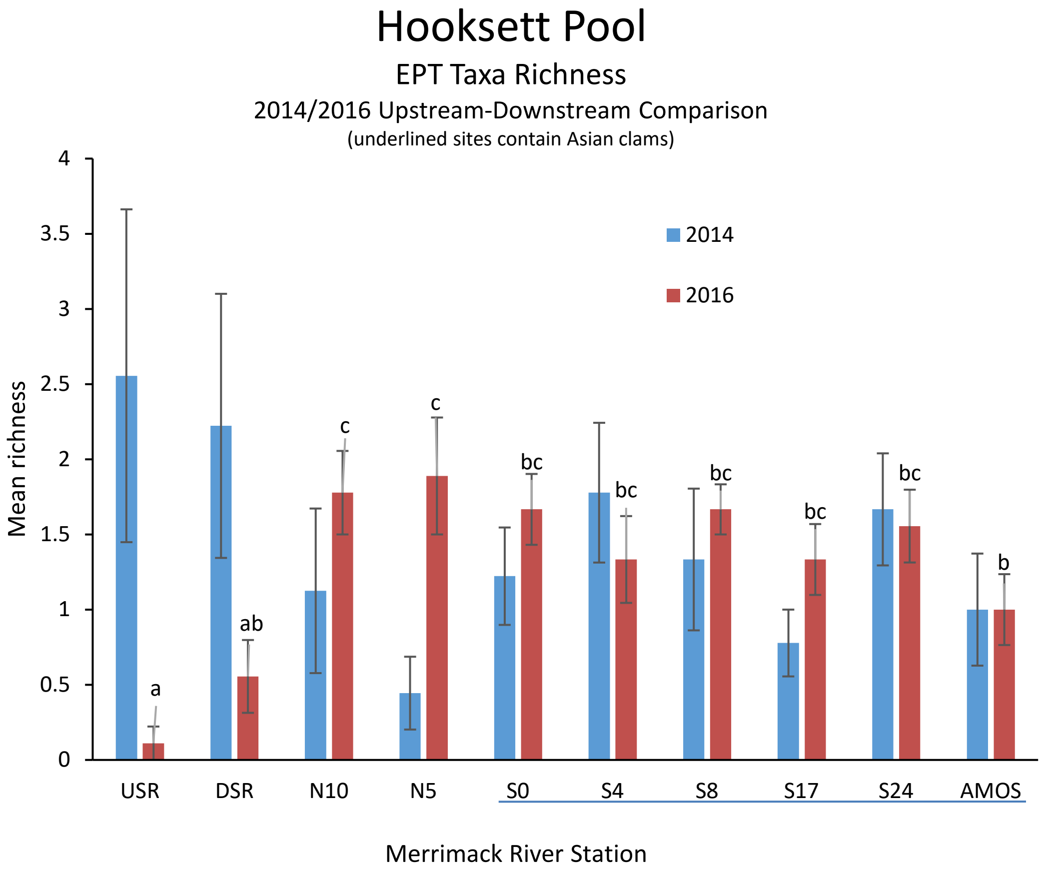

Figure 13. Mean (± standard error) EPT taxa richness near Merrimack Station. Samples were taken using a ponar grab sampling device (see Appendix B for methods). There was a significant interaction between 2014 and 2016 among stations (2-way ANOVA interaction; P = 0.001). There is no significant difference among all Merrimack River Stations for 2014 (ANOVA; P = 0.249). For 2016, stations with different letters are significantly different (LSD; P < 0.05). EPT taxa richness at stations with Asian clams is not significantly different or is significantly higher compared to EPT richness at stations without clams including reference

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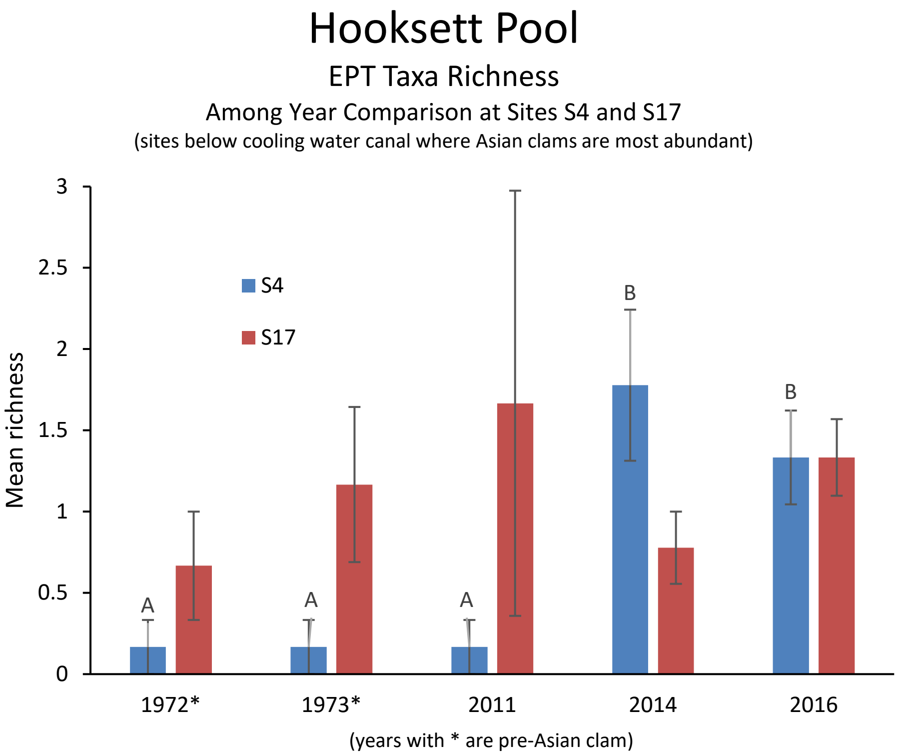

Figure 14. Mean (± standard error) EPT taxa richness near Merrimack Station. Samples were taken using a ponar grab sampling device (see Appendix B for methods). The EPT taxa richness at S4 and S17 (the two sites with highest recorded Asian clam abundances) for years with Asian clams is not significantly different compared to years without Asian clams (P = 0.390). Although there was no significant year x site interaction (P = 0.068), EPT richness at S4 was significantly higher in 2014 and 2016, than in 1972, 1973, and 2011 (ANOVA; P < 0.001). Bars with different letters are significantly different (LSD; P < 0.05). Overall, EPT richness at S4 was not significantly different than EPT richness at S17 (P = 0.220).

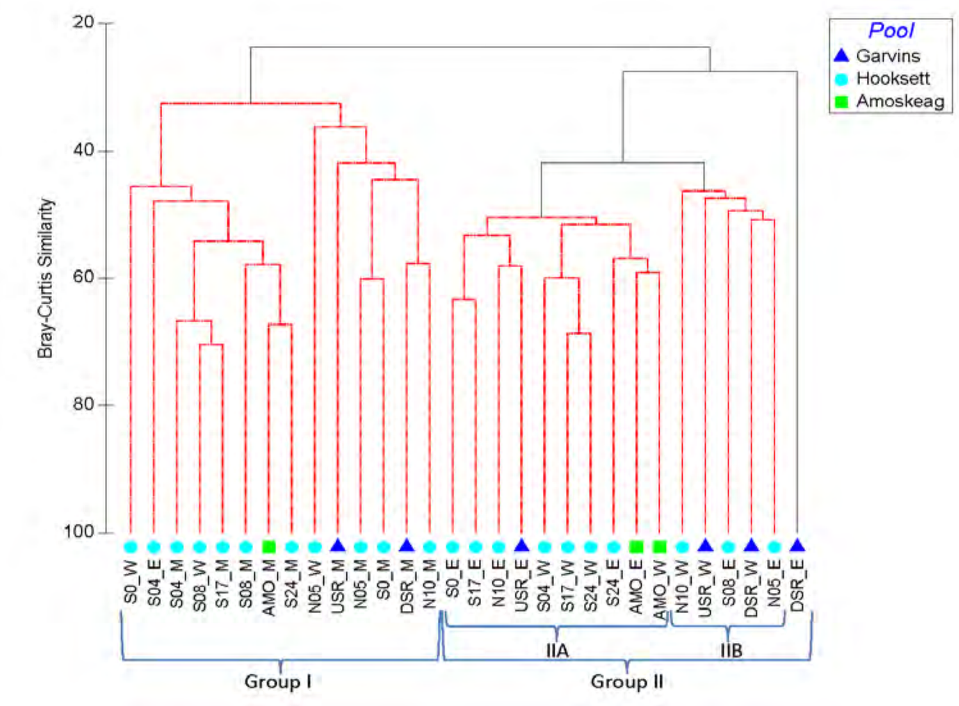

Figure 15**.** Cluster analysis results using Bray-Curtis similarities for the 2014 macroinvertebrate samples from the Merrimack River. The SIMPROF test results are indicated by the black and red lines on the dendrogram. Black lines on the dendrogram indicate statistically valid cluster groups, while red lines indicate branches of the dendrogram within which SIMPROF found no statistical evidence for sub-structure. AMO and S0-S24 sites are below the cooling water canal at Merrimack Station and contain Asian clams, while N5, N10, DSR and USR sites are above the cooling water canal and lack Asian clams.

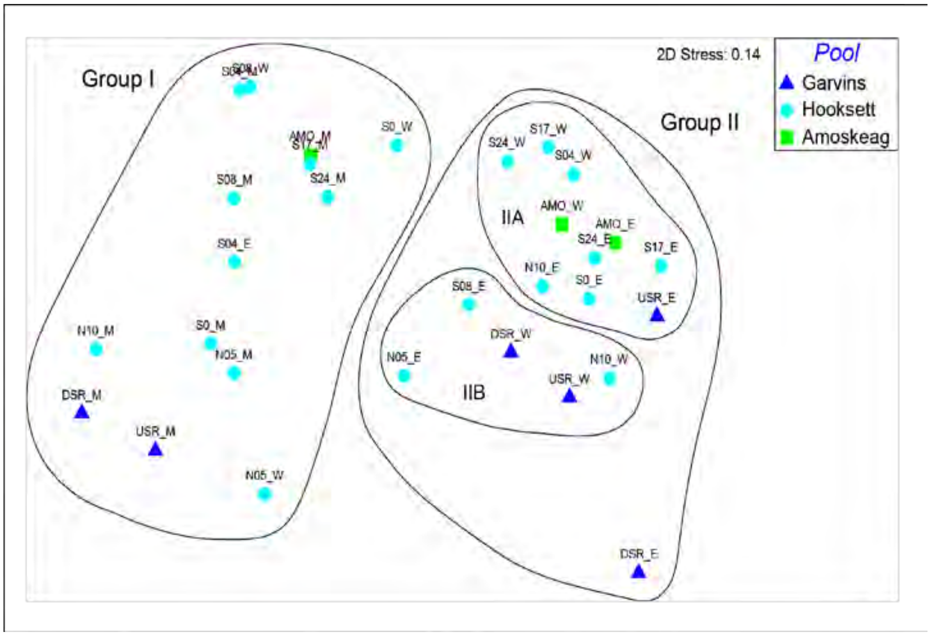

Figure 16. MDS ordination results for the 2014 macroinvertebrate samples from the Merrimack River. Each point on the plot represents one of 30 station locations; similarity of species composition is indicated by proximity of points on the plot. Faunal assemblages (Groups I-II, and sub-groups) identified by cluster analysis are circled on the plot. The ordination is based on Bray-Curtis Similarity. AMO and S0-S24 sites are below the cooling water canal at Merrimack Station and contain Asian clams, while N5, N10, DSR and USR sites are above the cooling water canal and lack Asian clams.

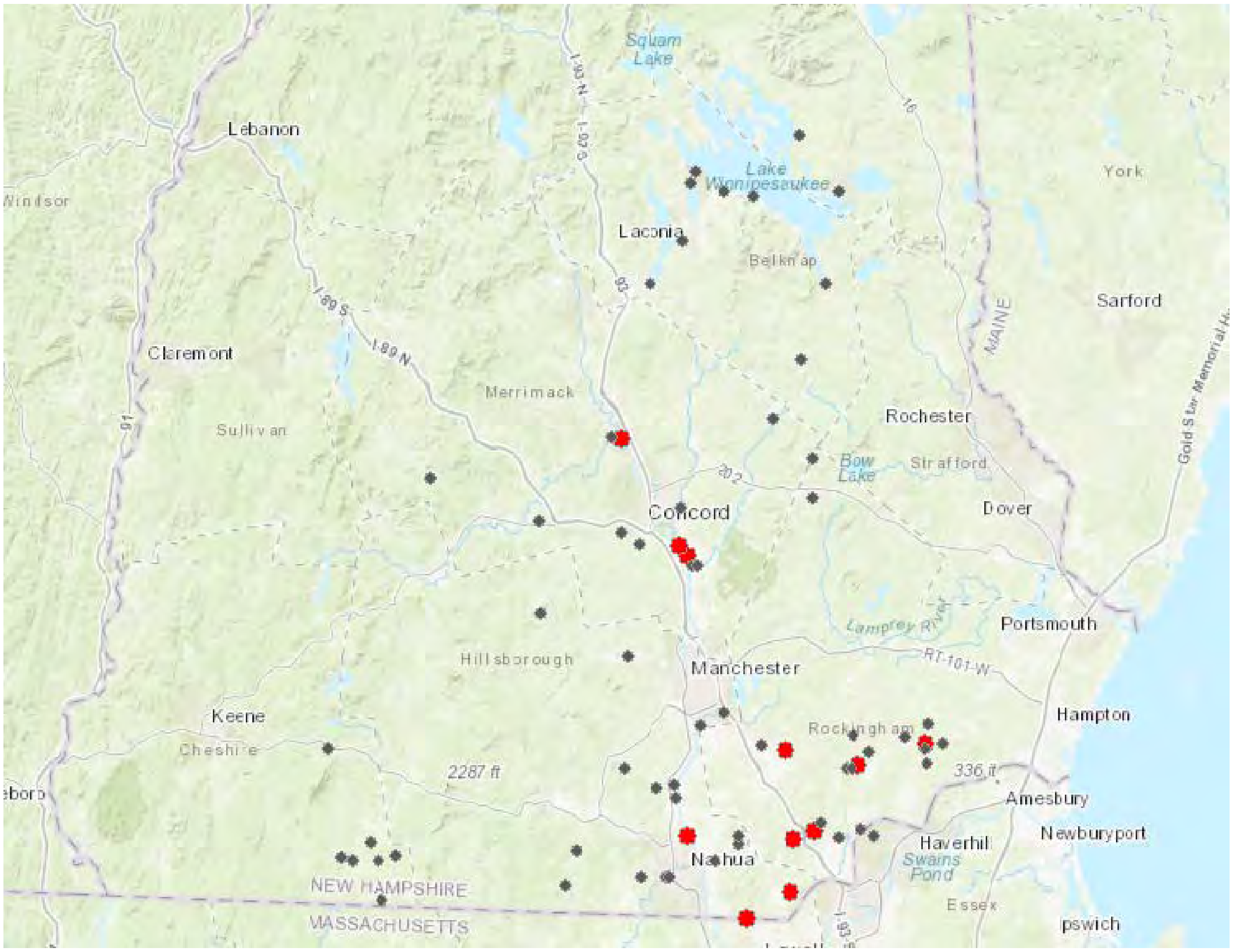

Figure 17. New Hampshire locations surveyed by AST in 2017 for the presence/absence of Asian clams as well as locations known to contain Asian clams. Areas with Asian clams are marked with red symbol (●).

Figure 18. Asian clams showing multiple year classes from Great Pond (A), Beaver Lake (B), Canobie Lake (C), and Little Island Pond (D). Clams were observed 8/16 and 8/17, 2017.

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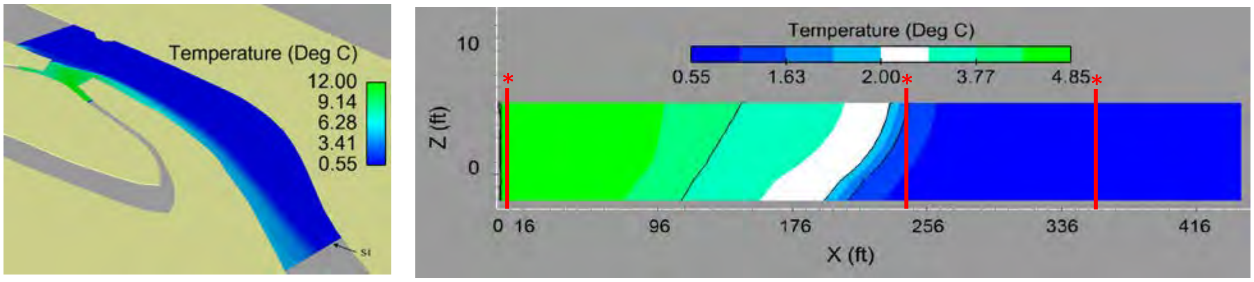

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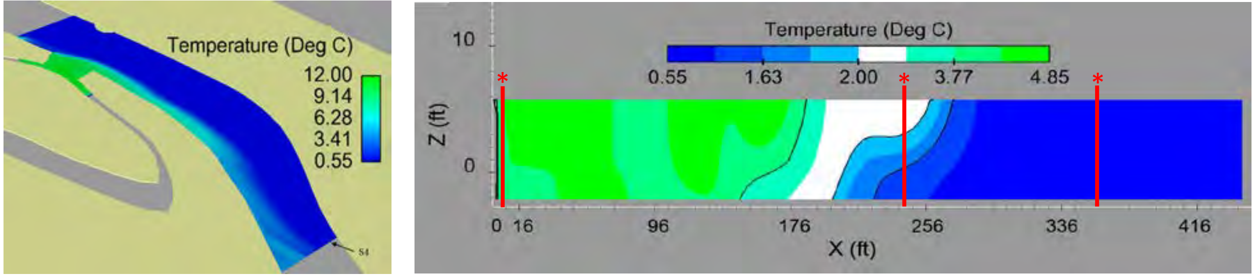

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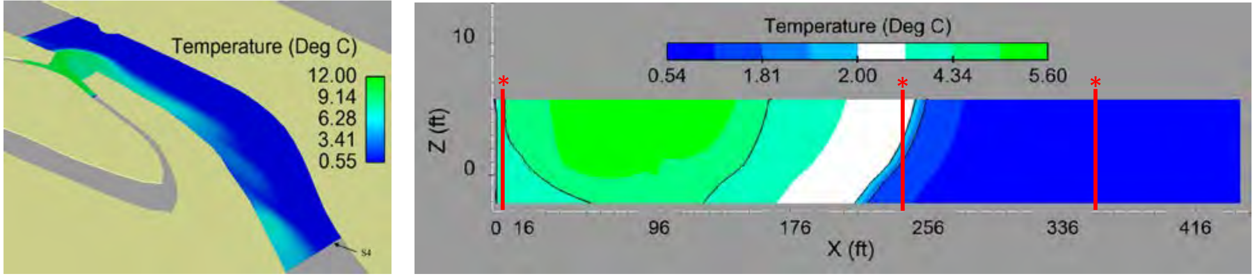


March

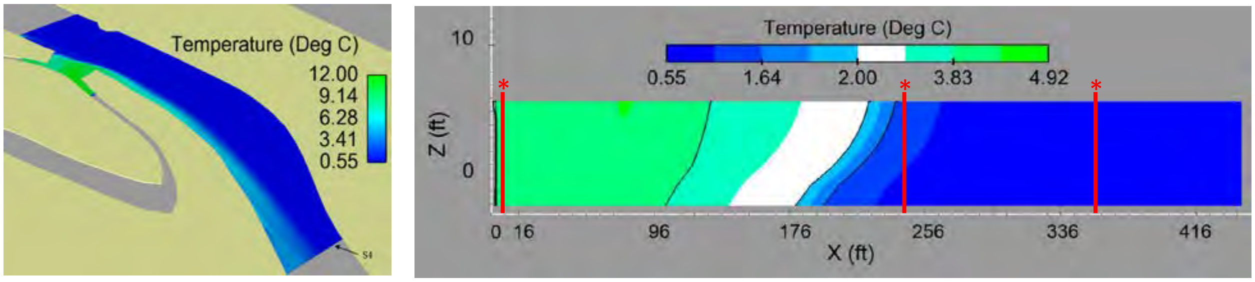


Figure 19. Computational fluid dynamics (CFD) model illustrating thermal plume mixing in the Merrimack River to 2,000 ft downstream of the cooling water canal (left panels) and in cross-section at site S4 (right panels) during winter months. Red lines with * indicate Asian clam sampling locations at S4 for West, Middle and East from left to right, respectively. See Enercon (2017) for complete explanation of the CFD model and parameters. Sampling site S4 is one of the sites with highest Asian clam abundances and is 2,000 ft downstream of S0.

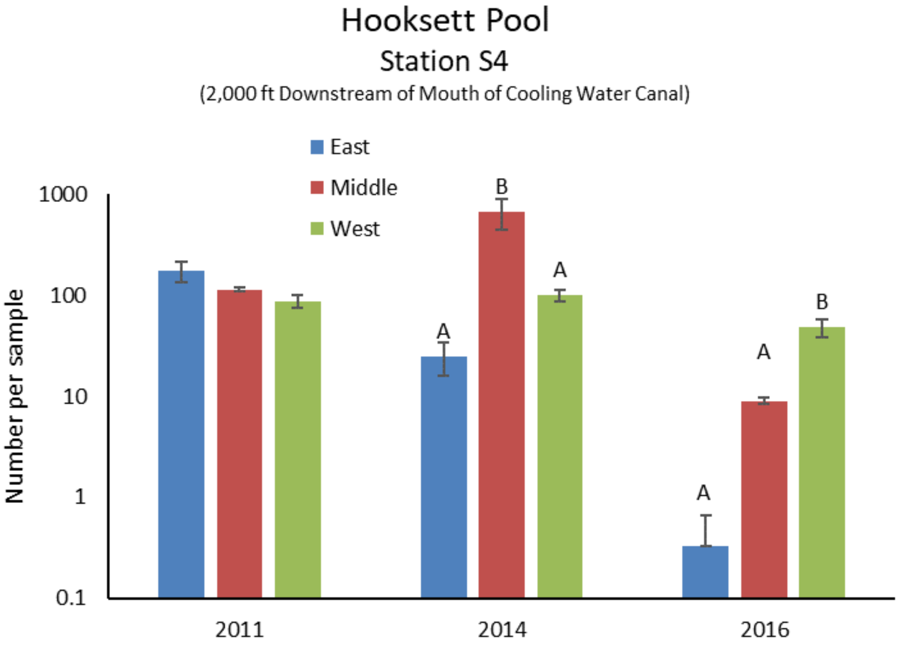


Figure 20. Mean (+ standard error) number of Asian clams per Ponar sample for 2011, 2014, and 2016 at the East, Middle and West sampling stations. Bars with different letters within a year are significantly different (LSD; $P < 0.05$). Asian clam abundances were the same or higher at the colder east and middle stations compared to the warmer west station, except for 2016. CFD modeling indicates bottom water does not exceed 1.8ºC in the winter at the Middle station or 1.0ºC at the East station when both Units 1 and 2 are operating at design conditions, *i.e.*, > 90% capacity.

APPENDIX A

APPENDIX A. PROFESSIONAL QUALIFICATIONS OF DR. TERRY RICHARDSON, PHD

Terry Richardson is a senior ecologist/malacologist for AST Environmental (AST) and Professor of Biology at the University of North Alabama (UNA). The work, opinions, and conclusions in this report are those of AST Environmental exclusively and are not the work, opinions, or conclusions of the University of North Alabama or of any state or governmental agency or affiliation of any kind and are not made in any public or official capacity of any kind. All matters contained in this report are exclusively those of AST Environmental and are independent of any employment with the University of North Alabama.

Dr. Richardson holds a B.S. degree in biology and earned a M.S. degree in stream ecology from the University of Alabama. He received his Ph.D. in zoology and physiology in 1990 from Louisiana State University specializing in freshwater and marine molluscan ecology. From 1990-1991, Dr. Richardson was a Fellow of the Oak Ridge Associated Universities in the U.S. Department of Energy's Oak Ridge National Laboratory in the Environmental Sciences Division. In 1991, Dr. Richardson joined the faculty at UNA as an Assistant Professor of Biology. While at UNA, Dr. Richardson became Director of Alabama's Rare and/or Endangered Species Research Center, focusing his efforts on rare and endangered freshwater mussel and snail conservation. He currently holds the rank of Professor at UNA and has over 30 years of extensive experience working with the identification, ecology, and conservation of benthic invertebrate communities including freshwater mussels and snails.

Dr. Richardson's specialties include presence/absence surveys, population ecology and the effects of environmental factors on molluscan ecology. During his 30-plus years of working with native mussels and snails, Dr. Richardson has gained extensive experience with various nonindigenous invasive species such as the Asian clam, *Corbicula fluminea;* zebra mussels, *Dreissena polymorpha*; and Japanese and Chinese mystery snails, *Bellamya japonica* and *B. chinensis*, respectively.

APPENDIX B

Appendix B. Methods for Hooksett Pool Study. From Normandeau Associates, Inc., standard protocol. Provided by Mark Mattson, Ph.D., Normandeau Associates.

Quantitative Macroinvertebrate Sampling

The objective of quantitative macroinvertebrate sampling was to determine the current extent of the distribution, abundance and age structure of *Corbicula* within Hooksett Pool and surrounding Merrimack River water body segment (i.e., Garvins Pool upstream and Amoskeag Pool downstream) and their interaction with other members of the benthic macroinvertebrate community sampled in the water body segment, particularly the BIP and the native Unionid mussels component of the BIP. All of the proposed work followed Standard Operating Procedures (SOP) that include Quality Assurance and Quality Control (QA/QC) measures.

Normandeau repeated the quantitative benthic macroinvertebrate sampling that was performed in Hooksett and Garvins Pools during October and November 2011 and reported in Normandeau (2012). A new Station was also established in Amoskeag Pool at a location of comparable habitat as found in Hooksett Pool. At each Station, three quarter-distance Locations along a transect line perpendicular to the Merrimack River flow were sampled: West, Middle, and East. A 9-inch by 9-inch standard Ponar grab sampler was used to collect five replicate samples at each Station and Location during November 2014. The following ten Stations were sampled (listed from upstream to downstream): Garvins Pool Stations USR and DSR (reference stations), Hooksett Pool Stations N-5, N-10, S-0, S-4, S-8, S-17, S-24 and one new Station in Amoskeag Pool (Figure B1). Each replicate sample was initially sieved in the field through a 0.6 mm mesh sieve, preserved in an individual sample container, labeled with a unique sample number, replicate number, the collection date, Station and Location, and taken to the Normandeau laboratory for analysis. The GPS coordinates of each Station and Location sampled

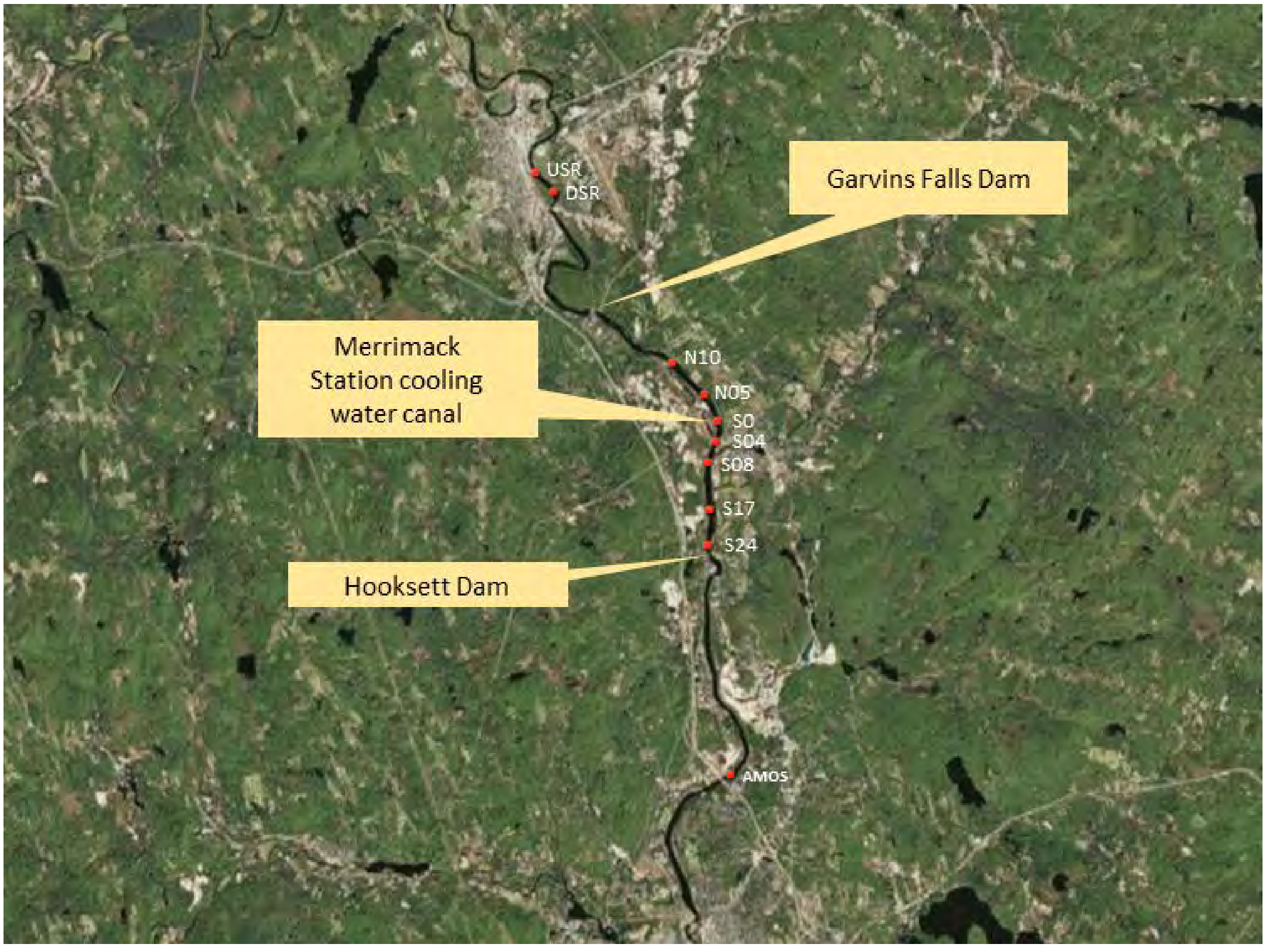


Figure B1. Satellite image showing location of sampling stations relative to Merrimack Station cooling water canal entry into the Merrimack River, Garvins Falls Dam and Hooksett Dam. Map was produced using www.arcgisonline.com.

were also be recorded on the field data sheet, along with the sample label information, water temperature, dissolved oxygen concentration, specific conductance, pH, and alkalinity from a grab sample collected at 1 foot above the bottom.

In the laboratory, Normandeau randomly selected three of the five replicate samples from each Station and Location for further processing and archived the remaining two samples for potential future use if variability is found to be high among the samples analyzed. The contents of each replicate sample was sorted (to separate the organisms from the substrate material), identified (to the lowest distinguishable taxon), and each taxon enumerated. The size and age structure of the *Corbicula* collected in each replicate sample processed was screened by washing through a series of screens of progressively smaller mesh size to enumerate the catch into shell length (age) classes (shell length measured as maximum total length in mm). An appropriate subsample of *Corbicula* within each size class of each replicate sample will assigned an alive or dead status as follows:

- Alive at the time of preservation,
- Fresh dead (both valves of shell with hinge attached, nacre shiny, tissue present),
- Recent dead (same as fresh dead but no tissue present), or
- Old dead (individual valves without hinge, nacre chalky).

All laboratory analysis (sorting, identification, measurements) were subjected to a QC inspection to insure an AOQL of 10% or better, meaning that these data originating from laboratory processing were certified by independent statistical re-inspection at a sampling frequency to document that less than one record (line of data) out of every ten records was outside of the established precision and accuracy for all contents of that record.

Diver Survey of Native Freshwater Bivalves

The native bivalve fauna of the Merrimack River is expected to include several species in two families; Unionidae (particularly *Elliptio* spp.), and Sphaeriidae. The native mussels in the family Unionidae are often referred to as “unionid mussels”. Unionid mussels may live ten or more years and achieve a size of between 30 mm and 80 mm total length (1.2 to 3.2 inches). The native clams in the family Sphaeriidae are often referred to as “fingernail clams”, and are typically much smaller than the unionids (2 mm to 20 mm total length; 0.08 to 0.8 inches), and typically live no longer than 12 to 18 months. The sphaeriid clams are typically found in higher abundance than the unionid mussels and are considered to be sampled adequately by the quantitative Ponar method described above. The unionid mussels are typically found in low abundance and may not be sampled adequately by the Ponar method, necessitating a SCUBA diver survey along transect lines to quantify their presence and abundance. Normandeau performed a diver survey coincident with the quantitative macroinvertebrate sampling described above to adequately quantify the abundance of native unionid mussels found in Garvins, Hooksett and Amoskeag Pools during November/December 2014. All of the proposed work will follow Standard Operating Procedures (SOP) that include Quality Assurance and Quality Control (QA/QC) measures.

Normandeau's biological dive team was deployed to identify and enumerate the abundance of native freshwater bivalves (unionid mussels) observed in bank to bank transects established at the same ten Stations used for quantitative benthic macroinvertebrate sampling in Garvins, Hooksett, and Amoskeag Pools during November 2014. The diver survey was performed coincident with benthic sampling, but after the quantitative grab samples have been collected at each Station and Location. Care was taken that the diver transects were established adjacent to, but not within the exact footprint of the substrate disturbed by Ponar sampling. At each Station, a weighted rope was secured to the east and west banks to establish a transect line perpendicular to the Merrimack River flow. The dive team then swam along the entire length of each Station transect line from bank to bank to visually and tactilely scan a one-meter wide path on either side of the line and collected (or estimated if mussels were abundant) all visible mussels and mussel shells. The one-meter wide transect scanned on the upstream side of the line at each Station was replicate 1 and the one-meter wide transect searched on the downstream side of the line was replicate 2 for that Station. The divers enumerated and recorded the unionid mussel species and abundance within each ten-meter long segment on a waterproof data sheet along each replicate one-meter wide transect. Only valid, use code = 1 transect samples will be tallied as completing the sampling design. A use code = 1 transect sample is one where river conditions are suitable for an accurate survey (e.g., visibility is no less than two feet and river flow does not prevent the divers from maintaining their positions along the transect line). Each of the two replicate samples of live mussels and relic shells were a composite of all specimens collected along the entire transect i.e., from all ten meter segments combined., and placed in a separate mesh bag. Each bag was labeled with Station and replicate number, and taken to shore where the contents were measured for total shell length in mm, and the alive or dead status determined as specified in Section 2.2 above. The native mussels and shells collected during the transect survey were returned to the river after processing, except for those used for a reference collection or those of questionable identification that were taken to the laboratory for positive identification. When possible, relic (dead, empty) shells were used for identification and reference specimens.

The same protocol described above was followed for the 2016 sampling efforts.

Data Analyses

Taxa richness, Shannon Diversity, Hilsenhoff, EPT Tax richness, size frequency distributions, and densities were calculated from sample data using standard methods and EPA protocol, where appropriate. Data analyses were conducted using QI-Macro (2015) single factor Analysis of Variance (ANOVA) or two factor ANOVA with replication with a significance level of P = 0.05. Post-hoc ANOVA comparisons of means were conducted with LSD comparisons at a significance level of P = 0.05. Size-frequency distributions were analyzed using Kolmogorov-Smirnoff with a significance level of P = 0.05. Non-normal data sets were also analyzed using conservative nonparametric statistics (Kruskal-Wallis or Firedman as appropriate) and produced similar results with respect to the null hypothesis tested.

Multivariate analyses were performed using data from the 90 ponar samples collected from the Merrimack River near Merrimack Station as discussed above. Prior to multivariate analyses, the taxon-mean counts per ponar grab sample were computed across the three replicate grab samples from each Station and Location. This reduced the input dataset for multivariate analyses to the mean count per taxon and grab sample for 30 station-locations. Data handling and preparation for multivariate analyses were completed using SAS system software (version 9.3). Multivariate analyses were then performed using PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software, following standard techniques for the evaluation of spatial patterns in the distribution of faunal assemblages (Clarke 1993, Warwick 1993, Clarke and Green 1988, Clarke and Warwick 2001). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group average linking and ordination by non-metric multidimensional scaling (MDS). Bray-Curtis similarity was used as the basis for both classification and ordination. Prior to analyses, faunal abundance data (i.e., mean count per taxon and grab sample) were square-root transformed to ensure that all taxa, not just the numerical dominants, would contribute to similarity measures.

Cluster analysis produces a dendrogram that represents discrete groupings of samples along a scale of similarity. This representation is most useful when delineating among sites with distinct community structure. MDS ordination produces a plot or "map" in which the distance between samples represents their rank ordered similarities, with closer proximity in the plot representing higher similarity. Ordination provides a more useful representation of patterns in community structure when assemblages vary along a steady gradation of differences among sites. Stress provides a measure of adequacy of the representation of similarities in the MDS ordination plot (Clarke 1993). Stress levels less than 0.05 indicate an excellent representation of relative similarities among samples with no prospect of misinterpretation. Stress less than 0.1 corresponds to a good ordination with no real prospect of a misleading interpretation. Stress less than 0.2 still provides a potentially useful two-dimensional picture, while stress greater than 0.3 indicates that points on the plot are close to being arbitrarily placed. Together, cluster analysis and MDS ordination provide a highly informative representation of patterns of community-level similarity among samples.

The “similarity profile test” (SIMPROF) was used to provide statistical support for the identification of faunal assemblages (i.e., selection of cluster groups). SIMPROF is a permutation test of the null hypothesis that the groups identified by cluster analysis (samples included under each node in the dendrogram) do not differ from each other in multivariate structure. The “similarity percentages” (SIMPER) analysis was used to identify contributions from individual taxa to the overall dissimilarity between cluster groups. This analysis was used to identify the contribution of macroinvertebrate taxa (including *Corbicula*) to the overall dissimilarity between cluster groups.

APPENDIX C

Appendix C1. Habitat semi-quantitative data summary and mollusk abundance estimates observed in the Merrimack River, December 2014, during SCUBA diver transect survey (see Appendix B for methods). Native mussel and Asian clam abundance estimates are color coded. Data provided by Normandeau Associates Environmental Consultants, Portsmouth, NH.

					Maximum Depth or Substrate Type																					
					West																					East
Station	Date	Time	Replicate	Habitat Parameter	0-10 m	11-20 m	21-30 m	31-40 m	41-50 m	51-60 m	61-70 m	71-80 m	81-90 m	91-100 m	101-110 m	111-120 m	121-130 m	131-140 m	141-150 m	151-160 m	161-170 m	171-180 m	181-190 m	191-200 m	201-210 m	211-220 m
USR	23-Dec-14	1229-1300	Upstream	Depth (m)	🟧 2.7	3.0	3.0	2.7	2.7	2.7	2.4	2.1	2.1	2.1	2.1	1.9	1.9	🟨 1.2	🟧 1.2							
			Upstream	Predominant Substrate	🟧 silt/sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	silt/sand	🟨 silt	🟧 silt							
			Downstrear	Depth (m)	🟧 2.4	🟧 2.4	2.7	3.0	2.7	2.7	2.4	2.4	2.1	2.1	1.9	2.1	1.9	1.9	1.2	🟧 1.2						
			Downstrear	Predominant Substrate	🟧 silt	🟧 silt/sand	sand/grave	sand/grave	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	silt/sand	🟧 silt						
DSR	23-Dec-14	1015-1040	Upstream	Depth (m)	🟧 1.9	1.9	1.9	1.9	2.4	2.1	2.7	2.7	2.4	2.4	1.9	1.5	1.9	1.9	1.2	1.5	1.5	1.5				
			Upstream	Predominant Substrate	🟧 silt/sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	silt				
			Downstrear	Depth (m)	🟧 2.1	1.9	1.9	1.9	1.9	2.4	2.7	2.7	2.4	2.1	1.9	1.9	1.9	1.5	🟨 1.2	🟨 1.5	🟨 1.2	🟧 1.2				
			Downstrear	Predominant Substrate	🟧 silt/sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 sand	🟨 silt/sand	🟨 silt/sand	🟧 silt/sand				
N10	2-Dec-14	0951-1033	Upstream	Depth (m)	🟥 0.9	🟧 1.2	🟨 1.5	1.5	1.9	2.1	2.1	2.1	2.1	🟨 2.4	2.4	2.4	2.4	2.7	2.7	2.7	3.0	3.4	🟧 3.0	🟥 3.0		
			Upstream	Predominant Substrate	🟥 silt	🟧 silt	🟨 silt/sand	sand	sand	sand	sand	sand	sand	🟨 sand	sand	sand	sand	sand	sand	sand	sand	sand	🟧 silt/debris	🟥 silt/debris		
			Downstrear	Depth (m)	🟥 0.6	🟧 1.2	🟨 1.9	1.9	1.9	🟨 1.9	2.1	2.1	2.1	2.1	2.4	2.4	2.4	2.4	2.4	🟨 2.4	2.7	3.0	🟧 3.4	🟥 1.9		
			Downstrear	Predominant Substrate	🟥 silt	🟧 silt	🟨 silt/sand	sand	sand	🟨 sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 sand	sand	silt/sand	🟧 silt/debris	🟥 silt/debris		
N5	2-Dec-14	1341-1412	Upstream	Depth (m)	🟩 3.0	🟨 2.7	2.4	2.4	2.4	2.1	1.9	1.9	1.9	1.5	1.2	1.2	1.2	1.2	0.9	0.9	0.9	0.9	0.9	🟨 1.2	🟥 1.2	
			Upstream	Predominant Substrate	🟩 cobble	🟨 sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 sand	🟥 silt	
			Downstrear	Depth (m)	🟩 2.4	2.4	2.4	2.1	2.1	1.9	1.9	1.5	1.5	1.5	1.2	1.2	1.2	0.9	0.9	0.6	0.9	0.9	0.9	🟥 0.9		
			Downstrear	Predominant Substrate	🟩 bble/bould	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟥 silt/sand		
																								🟥		
S0	3-Dec-14	1021-1047	Upstream	Depth (m)	🟨 2.1	2.7	2.7	2.4	2.4	2.4	2.4	2.4	2.7	2.7	3.0	3.0	3.4	3.4	3.4	3.4	🟨 1.9	🟥 1.9				
			Upstream	Predominant Substrate	🟨 sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 silt	🟥 silt				
			Downstrear	Depth (m)	🟨 1.0	🟨 1.9	2.7	2.4	2.4	2.4	2.4	2.4	2.7	2.7	3.0	3.4	3.4	3.4	3.6	3.4	🟨 3.0	🟥 2.1				
			Downstrear	Predominant Substrate	🟨 and/cobble	🟨 sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	silt/sand	🟨 silt/sand	🟥 silt/sand				
					🟦	🟦	🟦	🟦	🟦	🟦																
S4	3-Dec-14	1313-1335	Upstream	Depth (m)	🟥 2.1	2.4	2.7	3.0	3.0	3.4	3.4	3.4	3.4	3.4	4.0	4.0	4.0	3.4	🟨 2.1	🟨 2.1						
			Upstream	Predominant Substrate	🟥 silt	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 gravel	🟨 gravel						
			Downstrear	Depth (m)	🟥 0.9	🟧 2.4	2.7	3.0	3.4	3.4	3.4	3.6	3.4	3.4	3.6	3.6	🟨 4.0	🟨 3.0	🟧 2.7							
			Downstrear	Predominant Substrate	🟥 silt	🟧 silt/debris	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 sand	🟨 sand	🟧 silt							
					■	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	■						
S8	N/A	N/A																								
S17	22-Dec-14	1102-1123	Upstream	Depth (m)	🟥 2.1	2.7	2.7	2.7	2.4	2.4	2.4	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.4	2.4	2.7	🟧 2.4	🟥 2.1
			Upstream	Predominant Substrate	🟥 silt	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟧 silt/debris	🟥 silt/debris
			Downstrear	Depth (m)	🟨 2.7	2.4	2.4	2.4	2.1	2.1	1.9	1.9	2.1	2.1	2.1	2.1	🟨 2.1	1.9	2.1	2.1	2.4	2.4	🟨 2.4	2.7	🟧 2.4	🟥 2.1
			Downstrear	Predominant Substrate	🟨 sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 sand	sand	sand	sand	sand	sand	🟨 sand	sand	🟧 silt/debris	🟥 silt/debris
					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
S24	22-Dec-14	1310-1340	Upstream	Depth (m)	🟥 2.1	🟨 1.9	1.9	1.9	1.9	2.1	2.1	2.4	🟨 2.4	2.4	2.4	3.0	3.0	3.0	3.0	2.7	2.7	2.7	🟨 2.7	2.7	🟥 2.7	
			Upstream	Predominant Substrate	🟥 silt/sand	🟨 sand	sand	sand	sand	sand	sand	sand	🟨 sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟨 sand	sand	🟥 silt	
			Downstrear	Depth (m)	🟥 1.9	1.9	1.9	1.9	1.9	1.9	2.1	2.4	2.4	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	🟧 2.7	🟥 2.7	🟥 2.7
			Downstrear	Predominant Substrate	🟥 silt	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	🟧 silt	🟥 silt/debris	🟥 silt/debris
					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
				Native Mussel Abundances		🟨	= < 10		🟩	=10-100		🟧	= 100-500		🟥	= 500-1000										
				Asian Clam Abundances		🟦	=clams >100		■	=clams <100																

Appendix C2. Habitat semi-quantitative data summary and mollusk abundance estimates observed in the Merrimack River, July 2016, during SCUBA diver transect survey (see Appendix B for methods). Native mussel and Asian clam abundance estimates are color coded. Data provided by Normandeau Associates Environmental Consultants, Portsmouth, NH.

					Maximum depth or substrate type																			
					West																			
Station	Date	Time	Replicate	Habitat Parameter	1-10 m	11-20 m	21-30 m	31-40 m	41-50 m	51-60 m	61-70 m	71-80 m	81-90 m	91-100 m	101-110 m	111-120 m	121-130 m	131-140 m	141-150 m	151-160 m	161-170 m	171-180 m	181-190 m	191-200 m
USR	27-Jul-16	11:45 - 12:03	Upstream	Depth (m)	🟥 2.7	🟧 2.7	🟨 2.7	🟨 2.7	🟨 2.4	2.4	🟨 2.1	1.8	🟨 1.8	🟨 1.5	🟨 1.2	🟨 1.5	🟥 0.9							
				Predominant Substrate	🟥 silt/sand/gravel	🟧 sand/gravel	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 silt/sand	🟥 silt							
			Downstream	Depth (m)	🟧 2.7	🟩 3.1	🟨 2.7	2.7	🟨 2.7	🟨 2.4	🟨 2.1	🟨 1.8	🟨 1.5	1.5	🟨 1.5	🟨 1.5	🟧 0.6							
				Predominant Substrate	🟧 silt/sand/gravel	🟩 sand/gravel	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	🟨 sand	🟧 silt/sand							
DSR	27-Jul-16	9:05 - 9:35	Upstream	Depth (m)	🟧 1.8	🟨 1.8	🟨 1.8	🟨 1.8	🟨 2.1	🟨 2.1	🟨 2.1	🟨 1.8	🟨 2.1	🟨 1.8	🟨 1.5	🟨 1.2	🟨 1.2	🟩 1.2	🟩 1.5	🟧 1.2				
				Predominant Substrate	🟧 silt/sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 silt/sand	🟩 silt/sand	🟩 silt/sand	🟧 silt				
			Downstream	Depth (m)	🟧 1.5	🟨 1.8	1.8	🟨 2.1	🟨 2.4	🟨 2.1	🟨 2.1	🟨 1.8	🟨 2.1	🟨 1.8	🟨 1.5	🟨 1.2	🟩 1.5	🟩 1.5	🟩 1.5	🟧 1.2				
				Predominant Substrate	🟧 silt/sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟩 sand	🟩 sand	🟩 sand/gravel	🟧 silt/sand				
N10	25-Jul-16	9:42 - 10:25	Upstream	Depth (m)	🟥 0.9	🟨 1.2	🟨 1.2	🟨 1.5	🟨 1.5	🟨 1.8	🟨 1.8	1.8	🟨 1.8	1.8	🟨 1.8	1.8	🟨 1.8	🟩 1.5	🟥 1.2					
				Predominant Substrate	🟥 silt/sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	sand	🟨 sand	sand	🟨 sand	🟩 silt	🟥 silt					
			Downstream	Depth (m)	🟧 0.6	🟨 1.2	🟨 1.2	🟨 1.5	🟨 1.8	1.8	🟨 1.8	🟨 1.8	🟨 1.5	1.8	1.8	2.1	2.4	🟥 2.1	🟥 1.2					
				Predominant Substrate	🟧 silt/sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	sand	sand/shells	sand/shells	sand/shells	🟥 silt/sand	🟥 silt					
N05	N/A	N/A			N/A																			
S0	25-Jul-16	14:10 - 14:35	Upstream	Depth (m)	🟩 1.8	🟩 1.5	🟨 1.2	1.5	1.5	1.5	1.8	🟨 1.8	1.8	2.1	2.1	🟨 2.7	🟨 2.7	🟥 1.2	🟥 0.9					
				Predominant Substrate	🟩 sand/cobble	🟩 sand	🟨 sand	sand	sand	sand	sand	🟨 sand	sand	sand	sand	🟨 sand	🟨 sand/boulder	🟥 sand/cobble/boulder	🟥 silt					
			Downstream	Depth (m)	🟩 1.2	🟩 1.2	🟨 1.2	🟨 1.2	🟨 1.5	1.8	🟨 1.8	1.8	🟨 1.8	2.1	2.4	2.7	2.7	🟥 1.2	🟥 1.2					
				Predominant Substrate	🟩 sand/cobble	🟩 sand/cobble	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	sand	🟨 sand	sand	sand	sand	sand/cobble	🟥 silt/sand/cobble	🟥 sand/cobble					
					■	■	■		■															
S04	N/A	N/A			N/A																			
S08	N/A	N/A			N/A																			
S17	26-Jul-16	10:46 - 11:10	Upstream	Depth (m)	🟥 1.8	🟨 1.5	🟨 1.5	1.5	🟨 1.2	🟨 1.5	🟨 1.2	🟨 1.2	🟨 0.9	🟨 1.2	🟨 0.9	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.5	🟥 1.8
				Predominant Substrate	🟥 silt/sand	🟨 sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟥 silt/sand
			Downstream	Depth (m)	🟥 1.8	1.8	🟨 1.8	🟨 1.5	🟨 1.5	🟨 1.5	🟨 1.5	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.5	🟨 1.5	🟨 1.8	🟨 1.8	🟧 1.8
				Predominant Substrate	🟥 silt/sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟧 silt/sand
					🟦	■	🟦	🟦	🟦	🟦	🟦	■	■	■	■	■								
S24	26-Jul-16	8:41 - 9:20	Upstream	Depth (m)	🟧 0.9	🟨 0.9	🟨 0.9	0.9	🟨 1.2	🟨 1.2	🟨 1.2	🟨 1.5	🟨 1.8	1.8	🟨 1.8	🟨 2.1	🟨 2.1	🟨 2.1	🟨 1.8	🟨 1.8	🟨 1.8	🟨 1.5	🟥 0.9	
				Predominant Substrate	🟧 silt/sand	🟨 sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟥 silt	
			Downstream	Depth (m)	🟥 1.2	🟨 0.9	🟨 0.9	🟨 1.2	1.2	🟨 1.5	🟨 1.5	🟨 1.5	🟨 1.8	🟨 1.8	2.1	🟨 2.1	🟨 2.1	🟨 2.1	🟨 1.8	🟨 1.8	🟨 1.8	🟨 1.8	🟥 1.8	
				Predominant Substrate	🟥 silt/sand	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟨 sand	🟥 silt/sand	
					🟦	■	■	🟦	🟦	🟦	■	■	■	■	■	■	■							
				Native Mussel Abundance		🟨	= < 10		🟩	=10-100		🟧	= 100-500		🟥	= 500-1000								
				Asian Clam Abundance		🟦	=clams >100		■	=clams <100														

Appendix C3. EPA-NHDES 2013 Asian clam data.

Asian Clam Data NH DES & EPA
Merrimack - 2013

Sample Date	Site	Rep	Length (mm)	Height (mm)	Width (mm)	Wet weight (g)	Remaining		
	N-10-W		73.1	39.6	24.1				
			68.5	37.5	24.7				
			65.4	38.2	21.3				
			66.2	36.4	17.6				
		MEAN	**68.3**	**37.925**	**21.925**				
		ST DEV	**3.459287017**	**1.340087062**	**3.24178449**				
	S-0-W-1	CLAMS	29.3	24.2	14.9		38 LARGE HALF SHELLS		
			31.1	24.6	13.9				
			29.6	24	15.3				
			30.7	24.9	15.2				
			29.3	23.6	15.2				
			27.4	22.5	14.4				
			26.4	21.9	15.2				
			25.3	20.3	11.7				
			26.2	23	14.9				
			26.2	21.5	13.8				
			24.8	21.1	14.2				
			25.7	21.4	13.8				
			27	21.8	14				
			24.6	21.5	13.7				
			25.1	20.1	13.3				
		MEAN	**27.24666667**	**22.42666667**	**14.2333333**				
		ST DEV	**2.196057073**	**1.542477908**	**0.96263527**				
	S-0-W-2	CLAMS	33	24.8	17.1				
			28	22.1	15.3				
			29.9	23.6	15.4				
			29	24	16				
			28.8	23.3	15.6				
			28	22.5	15.3				
			25.2	20.9	13.9				
			26	20.9	14.7				

		25.4	20.6	14	
		25	20.9	14	
		25	20.7	13.8	
		25.9	21	14	
		14.5	12.5	8.7	
		11.7	9.9	7.3	
	MEAN	**25.38571429**	**20.55**	**13.9357143**	
	ST DEV	**5.707735256**	**4.223150483**	**2.70287799**	
S-0-W-3	1 CLAM HALF SHELL				
S-0-E-1	SNAILS				
S-0-E-3	SNAILS				
S-4-W-1	CLAMS	30	24.8	15.1	
		21.4	18.3	12.4	
	MEAN	**25.7**	**21.55**	**13.75**	
	ST DEV	**6.081118318**	**4.596194078**	**1.90918831**	
S-4-W-2	CLAMS	27.8	22.3	13.7	
		27.6	22.4	14.4	
		23.6	19.8	13	
		22.9	19.6	13.4	
		19.6	16	10.9	
	MEAN	**24.3**	**20.02**	**13.08**	
	ST DEV	**3.4525353**	**2.609980843**	**1.32174128**	
S-4-W-3	MUSSEL	63.7	36.6	20.4	
	CLAMS	24.6	20.8	13.6	
		20.9	17.7	12	
	MEAN	**22.75**	**19.25**	**12.8**	
	ST DEV	**2.61629509**	**2.192031022**	**1.13137085**	
S-4-M-1		19.6	17.3	11.9	2 HALF SHELLS
		14.9	12.3	9	
		14	12	9	
		8.2	6.8	4.9	

Appendix C3. EPA-NHDES 2013 Asian clam data.

	MEAN	14.175	12.1	8.7	
	ST DEV	4.67929838	4.28874496	2.87865709	
S-4-M-2		20.2	18.1	12.1	
		15.9	13.6	9.7	
		13.6	11.7	8.6	
		12.9	11	9	
		12.5	10.7	8	
	MEAN	15.02	13.02	9.48	
	ST DEV	3.180723188	3.055650504	1.58965405	
S-4-M-3		17.4	15.3	10.9	
		21.1	18.2	12.9	
		5.9	4.9	2.9	
	MEAN	14.8	12.8	8.9	
	ST DEV	7.926537706	6.993568474	5.29150262	
S-4-E-1	MUSSEL	77.3	43.2	25.8	SMALL CLAM HALF SHELL
S-4-E-3	SMALL SNAIL				
S-17-W-1	MUSSEL	68.6	38.8	24.1	
	CLAMS	17.3	15	10.6	
		15.1	13	9.8	
		9.2	7.5	5.4	
	MEAN	13.86666667	11.83333333	8.6	
	ST DEV	4.188476254	3.883726733	2.8	
S-17-W-2	CLAMS	16.9	14.5	10.2	1 HALF SHELL
		16.3	14.2	9.9	
		14.3	12.3	8.7	
	MEAN	15.83333333	13.66666667	9.6	
	ST DEV	1.361371857	1.193035345	0.79372539	
S-17-M-1	CLAMS	13.1	11.5	8.8	

Appendix C3. EPA-NHDES 2013 Asian clam data.

S-17-M-2	MUSSEL	86.3	51	29.7	1 HALF SHELL
	CLAMS	10.7	10	7.5	
		8.3	6.6	3.9	
	MEAN	**9.5**	**8.3**	**5.7**	
	ST DEV	**1.697056275**	**2.404163056**	**2.54558441**	
S-17-M-3		6.7	5.1	3.5	8 HALF SHELLS
S-17-E-1	MUSSELS	70.7	37.7	18.7	2 HALF CLAMS
		71	39.5	26.2	
		66.2	37.4	20.3	
		77.7	42.9	23	
		67	35.7	19	
	MEAN	**70.52**	**38.64**	**21.44**	
	ST DEV	**4.551593128**	**2.73642102**	**3.15642203**	
S-17-E-2	MUSSELS	72.9	40.9	22.9	
		82.5	44.3	25.3	
		72.3	39.5	21.6	
		56.5	29.5	14.9	
		68.1	39	24.6	
		70.6	38.8	20.2	
	MEAN	**70.48333333**	**38.66666667**	**21.5833333**	
	ST DEV	**8.423399947**	**4.930990435**	**3.77434321**	
S-17-E-3	SMASHED SHELL				
A-12-W-1					
A-12-W-2		14.7	13.8	10.3	
		14.4	13.5	9	
		14.3	13.7	9.9	
	MEAN	**14.46666667**	**13.66666667**	**9.73333333**	
	ST DEV	**0.2081666**	**0.152752523**	**0.66583281**	

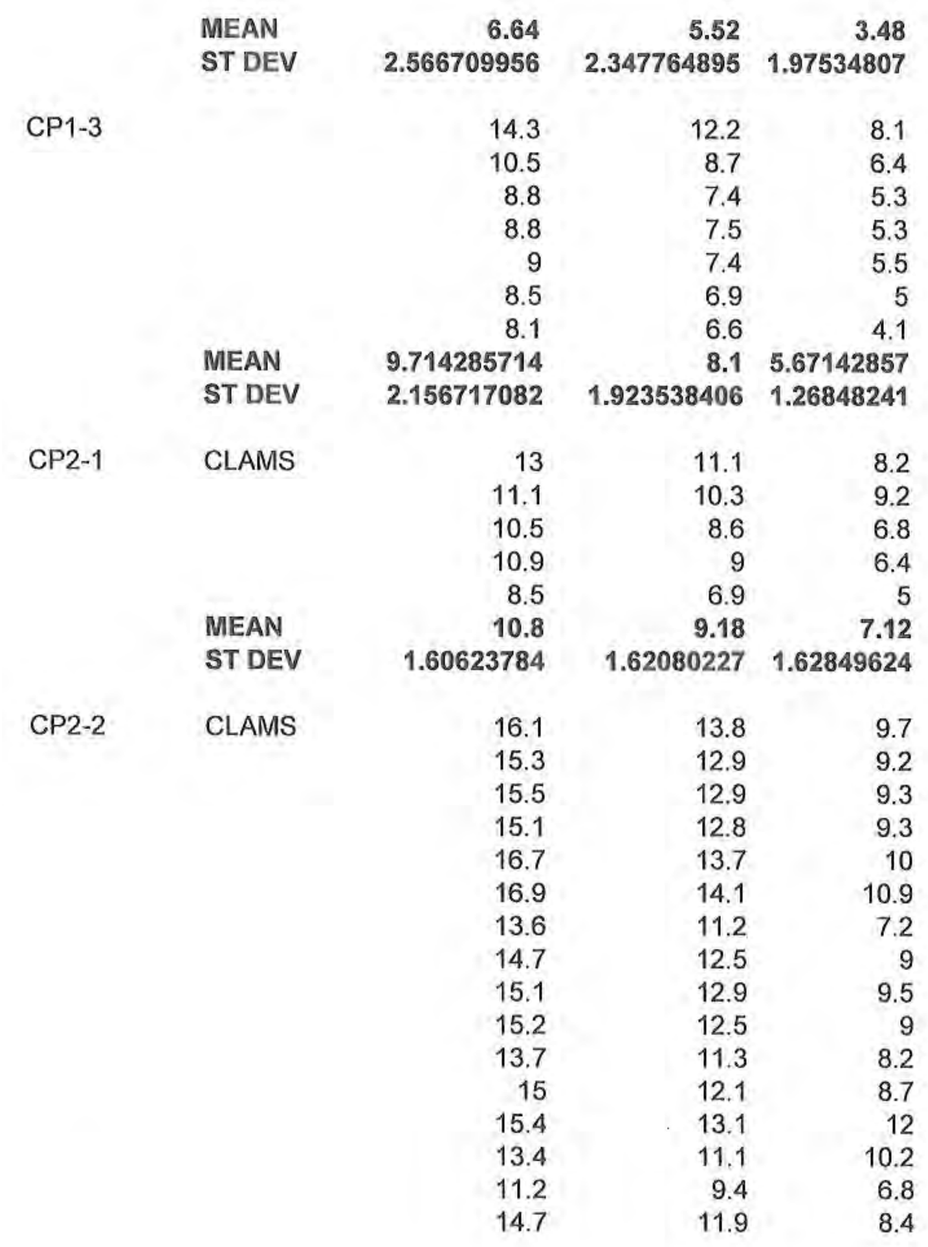
Appendix C3. EPA-NHDES 2013 Asian clam data.

					2 HALF CLAMS
A-12-W-3		13.8	13.7	10	
		14.6	13.8	10.5	
		14.4	13.5	10.5	
		14.5	13.8	10.5	
		14.9	14.1	10.5	
		13.3	12.7	10	
		14.1	13.7	10.4	
		14.8	13.2	10.9	
		13.3	12.5	10.9	
		13.2	12.5	9.6	
		13.3	12.9	10.3	
		10.8	10.4	7.9	
	MEAN	**13.75**	**13.06666667**	**10.1666667**	
	ST DEV	**1.122902084**	**1.003025726**	**0.80377895**	
					2 HALF CLAMS
A-12-M-1		14.3	13.2	9.5	
		4.4	3.1	2.4	
	MEAN	**9.35**	**8.15**	**5.95**	
	ST DEV	**7.000357134**	**7.14177849**	**5.02045815**	
A-12-M-2		14.2	13.9	9.9	1 HALF SHELL
					5 HALF SHELLS
A-12-M-3		11.1	9	7.5	
		7.2	5.6	3.7	
		7.5	6.7	4.3	
		7.4	5.7	4.4	
	MEAN	**8.3**	**6.75**	**4.975**	
	ST DEV	**1.870828693**	**1.580084386**	**1.71148084**	
A-12-E-1		15.4	14	10.6	1 HALF SHELL
		14.7	13.4	10.6	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		10.9	9.3	7.7	
		10.8	9.4	7.6	
		10.7	9.2	7.3	
		11.3	10.2	8	
		8.3	7.2	6.1	
	MEAN	**11.72857143**	**10.38571429**	**8.27142857**	
	ST DEV	**2.478382729**	**2.445695928**	**1.70070014**	
A-12-E-2	2 HALF SHELLS				
A-12-E-3		13.8	12.8	10	1 HALF SHELL
		13.9	13.3	10.4	
		10.8	9.5	7.8	
		10.3	9.4	7.4	
		10.4	9.1	7.7	
		10.2	9	7.3	
		10.5	8.8	7.6	
		11.7	10.1	8.1	
		10.3	9.1	7.4	
		9.6	8.2	6.6	
		9.1	8.5	6.1	
		9.5	8.2	6.6	
	MEAN	**10.84166667**	**9.666666667**	**7.75**	
	ST DEV	**1.552978565**	**1.673501139**	**1.28097974**	
CP1-1		14.6	12	8.8	
		15.8	13.7	10	
		8.1	6.7	4.7	
	MEAN	**12.83333333**	**10.8**	**7.83333333**	
	ST DEV	**4.142865353**	**3.651027253**	**2.77908858**	
CP1-2		11	9.5	6.9	1 HALF SHELL
		6.7	5.5	3.3	
		5.9	5	2.9	
		4.9	3.9	2.1	
		4.7	3.7	2.2	

Appendix C3. EPA-NHDES 2013 Asian clam data.



	MEAN	**6.64**	**5.52**	**3.48**
	ST DEV	**2.566709956**	**2.347764895**	**1.97534807**
CP1-3		14.3	12.2	8.1
		10.5	8.7	6.4
		8.8	7.4	5.3
		8.8	7.5	5.3
		9	7.4	5.5
		8.5	6.9	5
		8.1	6.6	4.1
	MEAN	**9.714285714**	**8.1**	**5.67142857**
	ST DEV	**2.156717082**	**1.923538406**	**1.26848241**
CP2-1	CLAMS	13	11.1	8.2
		11.1	10.3	9.2
		10.5	8.6	6.8
		10.9	9	6.4
		8.5	6.9	5
	MEAN	**10.8**	**9.18**	**7.12**
	ST DEV	**1.60623784**	**1.62080227**	**1.62849624**
CP2-2	CLAMS	16.1	13.8	9.7
		15.3	12.9	9.2
		15.5	12.9	9.3
		15.1	12.8	9.3
		16.7	13.7	10
		16.9	14.1	10.9
		13.6	11.2	7.2
		14.7	12.5	9
		15.1	12.9	9.5
		15.2	12.5	9
		13.7	11.3	8.2
		15	12.1	8.7
		15.4	13.1	12
		13.4	11.1	10.2
		11.2	9.4	6.8
		14.7	11.9	8.4

Appendix C3. EPA-NHDES 2013 Asian clam data.

		13.9	11.6	8.3
		12.6	10.5	7
		12.4	10.8	7.5
		12.8	10.8	7.3
		12.9	10.6	7.5
		12.5	10.2	6.9
		11.5	9.2	6.9
		12.7	10.4	7.1
		10.3	8.4	6.5
		10.3	8.4	6.4
		10.6	8.8	6.6
		10.5	8.9	6.4
		10.2	8.4	5.8
		9	7.7	5.9
		9.7	8.2	5.4
		11	8.9	6.1
		10.5	8.8	6.1
		11.3	9.2	6.7
		8.2	6.5	4.9
		7.2	6.8	4.1
		9	7.8	4.9
		5.8	4.7	2.6
	MEAN	**12.43421053**	**10.36315789**	**7.48157895**
	ST DEV	**2.722704966**	**2.270185259**	**1.9515559**
CP2-3	CLAMS	16.7	13.8	10.5
		16.1	13.5	9.5
		13	10.7	8.1
		11.5	9.5	6.8
	MEAN	**14.325**	**11.875**	**8.725**
	ST DEV	**2.485122398**	**2.110884491**	**1.61735381**
CP3-1		16.5	14.2	10
		16.7	14.3	10.5
		10.5	8.7	6.5
		9.6	7.8	5.6
	MEAN	**13.325**	**11.25**	**8.15**

Appendix C3. EPA-NHDES 2013 Asian clam data.

	ST DEV	**3.800328933**	**3.483771902**	**2.46102959**	
CP3-2		15.5	12.9	9.6	4 HALF CLAMS 1 HALF MUSSEL
		15	12.4	9.3	
		14	12.1	8.2	
		15.5	13.4	10.1	
		12.2	10.3	7.2	
		11.5	9.5	7.1	
		9.5	7.7	5.7	
		8.2	6.5	4.6	
	MEAN	**12.675**	**10.6**	**7.725**	
	ST DEV	**2.798851805**	**2.539403755**	**1.94183271**	
CP3-3		3.9	3	1.6	
		3.8	2.8	1.9	
	MEAN	**3.85**	**2.9**	**1.75**	
	ST DEV	**0.070710678**	**0.141421356**	**0.21213203**	
CP4-1		13	12.1	7.9	2 HALF CLAMS
		4	3.4	2.3	
	MEAN	**8.5**	**7.75**	**5.1**	
	ST DEV	**6.363961031**	**6.151828996**	**3.95979797**	
CP4-2		10.7	9.3	6.5	2 HALF CLAMS
		8	6.8	5.1	
	MEAN	**9.35**	**8.05**	**5.8**	
	ST DEV	**1.909188309**	**1.767766953**	**0.98994949**	
CP4-3		9.2	8.1	5.3	
		10.4	9.1	6.2	
	MEAN	**9.8**	**8.6**	**5.75**	
	ST DEV	**0.848528137**	**0.707106781**	**0.6363961**	

Appendix C3. EPA-NHDES 2013 Asian clam data.

CP5-1		6.1	5.1	2.9	
		7.7	6.5	4.5	
	MEAN	**6.9**	**5.8**	**3.7**	
	ST DEV	**1.13137085**	**0.989949494**	**1.13137085**	
CP5-2		8.5	7	5	
		5.6	4.6	2.7	
		6.4	5.3	3.1	
		7.5	6.5	4.5	
		6.3	4.8	2.8	
	MEAN	**6.86**	**5.64**	**3.62**	
	ST DEV	**1.141490254**	**1.059716943**	**1.05688221**	
CP5-3		7.5	6.2	3.5	2 HALF CLAMS
CP6-1		16.6	14.5	10.3	2 HALF CLAMS
		16	14.3	10.9	
	MEAN	**16.3**	**14.4**	**10.6**	
	ST DEV	**0.424264069**	**0.141421356**	**0.42426407**	
CP6 REP 2	MUSSEL	76.9	34.2	17.4	2 HALF CLAMS
	CLAMS	6.7	5.7	3.5	
		3.9	2.7	2.1	
	MEAN	**5.3**	**4.2**	**2.8**	
	ST DEV	**1.979898987**	**2.121320344**	**0.98994949**	
CP6-3		16.1	13.7	10.1	2 HALF CLAMS
		14	13.5	10.2	
		8.7	7.5	4.7	
		8.3	7.3	5.1	
	MEAN	**11.775**	**10.5**	**7.525**	
	ST DEV	**3.881043674**	**3.581433605**	**3.0357591**	

Appendix C3. EPA-NHDES 2013 Asian clam data.

CP7-1		6.5	5.7	3.1	1 HALF CLAM
		5.5	4.7	3.1	
	MEAN	**6**	**5.2**	**3.1**	
	ST DEV	**0.707106781**	**0.707106781**	**0**	
CP7-2		6.8	5.2	3.9	1 HALF CLAM
		6.6	5.5	3.9	
	MEAN	**6.7**	**5.35**	**3.9**	
	ST DEV	**0.141421356**	**0.212132034**	**0**	
CP7-3		7.8	6.4	4.6	1 HALF CLAM
CP8-1	MUSSEL	83.3	39.3	21.6	
CP8-2	1 SMALL SNAIL				
CP8-3		14	12.1	8.8	
		15.3	13.1	9.9	
		14.1	12.7	9.5	
		11.4	9.7	7.4	
	MEAN	**13.7**	**11.9**	**8.9**	
	ST DEV	**1.643167673**	**1.523154621**	**1.0984838**	
CP9-2		7.5	6.2	4.5	
CP10-1		19	16.5	12.2	1 HALF CLAM
		9.4	7.6	5.5	
		11	9.2	6.8	
	MEAN	**13.13333333**	**11.1**	**8.16666667**	
	ST DEV	**5.143280406**	**4.744470466**	**3.55293306**	
CP10-2		20.6	18.1	12.5	
		17.8	15.9	11.8	
		13.1	11.7	8.3	
		8.1	6.6	4.8	
		9	7.4	5.4	
		9.1	7.7	5.1	
		9.8	7.9	6	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		8.7	7.4	5.1	
		7.7	6.3	4.7	
		8.4	6.7	4.8	
		7.8	6.3	4.8	
		7.9	6.5	4.9	
	MEAN	**10.66666667**	**9.041666667**	**6.51666667**	
	ST DEV	**4.282381099**	**4.01801813**	**2.81516456**	
CP10-3		13.5	11.9	8.3	
		13.4	11.7	8.6	
		9.6	8	5.9	
		9.7	7.9	6	
	MEAN	**11.55**	**9.875**	**7.2**	
	ST DEV	**2.194690563**	**2.224672261**	**1.44913767**	
LP2-1		8.9	8	5.3	1 HALF CLAM
		8.7	8.3	5.5	
	MEAN	**8.8**	**8.15**	**5.4**	
	ST DEV	**0.141421356**	**0.212132034**	**0.14142136**	
LP2-2		12	10	7.5	
LP2-3		9.3	7.8	5.4	
LP3-2		17.4	15.7	11.2	1 HALF CLAM
		15.5	13.5	9.2	
	MEAN	**16.45**	**14.6**	**10.2**	
	ST DEV	**1.343502884**	**1.555634919**	**1.41421356**	
LP3-3		11.2	9.9	7.5	2 HALF CLAMS
		9.7	8.1	5.6	
		6.3	5.7	3.2	
	MEAN	**9.066666667**	**7.9**	**5.43333333**	
	ST DEV	**2.510644008**	**2.107130751**	**2.15483951**	
LP4-1		3.1	2.5	1.5	1 HALF CLAM

Appendix C3. EPA-NHDES 2013 Asian clam data.

LP4-2		6.4	4.9	3.3	2 HALF CLAMS
		6.4	4.9	3.7	
	MEAN	**6.4**	**4.9**	**3.5**	
	ST DEV	**0**	**0**	**0.28284271**	
LP4-3		18.4	15.6	10.8	
LP5-2		8.3	6.9	4.9	1 HALF CLAM
LP6-1		19.2	17.3	11.4	19 HALF CLAMS
		14.9	13.5	9.3	
		14.2	12.8	8.9	
		15.2	13.9	9.6	
		14.3	12.6	8.4	
		21.5	18.8	12.8	
		13.2	12.1	8.6	
		13.6	11.7	8.4	
		9.9	9.5	6.3	
		5.9	4.6	2.9	
		6.3	5.2	3.2	
		8.6	7.5	4.6	
		5.6	4.4	2.7	
		8.5	7.2	4.7	
		6.7	5.8	3.6	
		7.2	6	3.6	
		8.2	7.6	4.7	
		14.2	13.8	8.4	
		15.6	14.3	9.6	
	MEAN	**11.72631579**	**10.45263158**	**6.93157895**	
	ST DEV	**4.688620042**	**4.387022329**	**3.10430751**	
	MUSSEL	62.2	34.2	16.7	
LP6-2	MUSSEL	70.9	38.1	20	

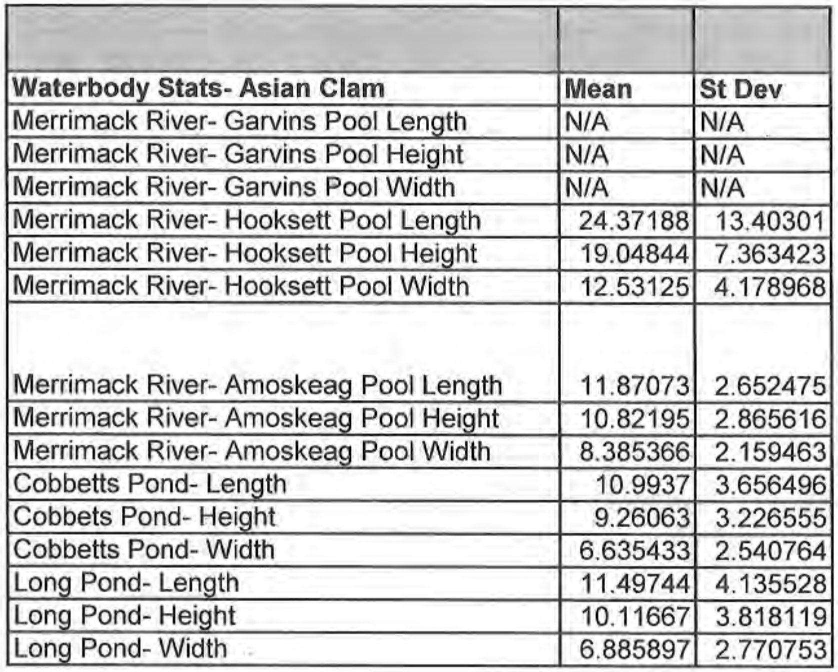
Appendix C3. EPA-NHDES 2013 Asian clam data.

	CLAMS	12.8	11.6	7.8	35 HALF CLAMS
		15.2	13.6	9.3	
		14.9	13.5	9.6	
		14.9	13.1	9	
		15	13.5	9.4	
		15.9	14.2	9.8	
		15.2	13.6	9.6	
		12.4	11.1	7.4	
		11.3	10.2	7.5	
		15.4	13.6	9.5	
		14	12.3	8.5	
		13.6	12	9.3	
		15.1	13.3	9.5	
		13.9	11.7	8	
		15.1	13.6	9.7	
		10.2	8.9	6.1	
		8.1	6.8	4.3	
		6	5.2	3	
		6.2	5.2	3	
		5.2	4.2	2.6	
		4	3.4	2	
		3.1	2.5	1.3	
	MEAN	**11.70454545**	**10.32272727**	**7.1**	
	ST DEV	**4.25031957**	**3.898465121**	**2.94812289**	
LP6-3	CLAMS	14.8	13.2	9	36 HALF CLAMS
		14.4	12.7	8.8	
		15.6	13.9	9.7	
		15.5	13.7	9.4	
		14.3	12.6	8.2	
		15.7	14	9.7	
		16	14.2	9.9	
		13.8	12.2	8.5	
		14.1	12.4	8.4	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		13.2	11.9	8	
		13.6	12	8	
		11.9	10.9	7.6	
		11.1	9.8	6.7	
		10.1	8.7	5.8	
		8.7	7.5	5	
		11.1	10	6.3	
		6.4	5.4	3.1	
	MEAN	**12.95882353**	**11.47647059**	**7.77058824**	
	ST DEV	**2.707641691**	**2.473997123**	**1.8563286**	
LP7-1	1 HALF CLAM				
LP7-2	MUSSEL	72.2	35.3	17.7	
	CLAMS	8	6.7	4.9	
LP7-3		16.4	14.4	10.5	1 HALF CLAM
		8.7	7.5	5.4	
		8.2	6.8	4.4	
		7.9	6.7	4.5	
		5.4	4.4	2.8	
	MEAN	**9.32**	**7.96**	**5.52**	
	ST DEV	**4.157763822**	**3.784573952**	**2.93717551**	

Appendix C3. EPA-NHDES 2013 Asian clam data.



Waterbody Stats- Asian Clam	**Mean**	**St Dev**
Merrimack River- Garvins Pool Length	N/A	N/A
Merrimack River- Garvins Pool Height	N/A	N/A
Merrimack River- Garvins Pool Width	N/A	N/A
Merrimack River- Hooksett Pool Length	24.37188	13.40301
Merrimack River- Hooksett Pool Height	19.04844	7.363423
Merrimack River- Hooksett Pool Width	12.53125	4.178968
Merrimack River- Amoskeag Pool Length	11.87073	2.652475
Merrimack River- Amoskeag Pool Height	10.82195	2.865616
Merrimack River- Amoskeag Pool Width	8.385366	2.159463
Cobbetts Pond- Length	10.9937	3.656496
Cobbets Pond- Height	9.26063	3.226555
Cobbetts Pond- Width	6.635433	2.540764
Long Pond- Length	11.49744	4.135528
Long Pond- Height	10.11667	3.818119
Long Pond- Width	6.885897	2.770753

Appendix C3. EPA-NHDES 2013 Asian clam data.

Sample Date	Site	Rep	Length (mm)	Height (mm)	Width (mm)	Remaining
11/6/2013	New Middle	2	none			
	New Middle	3	none			
	N-10-M	1	none			
	N-10-M	2	none			
	N-10-M	3	none			
	N-10-W	2	none			
	S-17-E	2	none			
	New East	1	1 snail			
	N-10-W	3	1 snail			
	New Middle	1	none			
	New East	3	none			
	N-10-W	1	none			
	New West	3	none			
	New West	1	none			
	N-10-E	2	none			
	New West	2	none			
	New East	2	none			
	S-0-E	3	none			
	S-0-M	1	none			
	S-0-E	2	none			
	S-17-E	3	none			
	S-17-M	2	9.5	8.3	6.1	
			9.6	8.4	6.2	
			9.9	8.3	6.3	
			7.2	6.1	4.6	
			7	5.7	4.1	
			9	7.7	5.9	
			7.8	6.2	4.8	
			6.9	5.4	4.2	
			6.4	5.2	3.5	
			5.4	4.6	2.8	
			5.9	4.7	3.1	
			6	4.8	3	
			5.2	4	2.7	

		5.5	4.5	2.9	
		5.1	4.2	2.6	
		5.2	4.2	2.7	
		4.9	3.8	2.8	
		4	3.1	2	
		5	3.9	2.4	
		4.2	3.3	1.9	
		4.3	3.5	2.5	
		3.7	3.1	1.8	
		3.6	2.9	1.7	
		3.9	3	1.8	
		3.4	2.7	1.8	
	MEAN	**5.944**	**4.864**	**3.368**	
	ST DEV	**1.971269**	**1.76821**	**1.496307**	
S-0-W	1	24.4	19.8	13.6	
		23.4	18.9	13.4	
		23.6	19.3	13.4	
		16.5	14	9.9	
	MEAN	**21.975**	**18**	**12.575**	
	ST DEV	**3.675482**	**2.691963**	**1.785824**	
S-4-W	1	20.7	17.4	12.3	
S-4-M	2	13.6	11.8	8.9	
		14.4	12.4	9.2	5 half clams
		14.3	12.3	9.2	
		5.8	4.5	3.1	
	MEAN	**12.025**	**10.25**	**7.6**	
	ST DEV	**4.165233**	**3.842308**	**3.003331**	
N-10-E	3				1 half clam & 2 snails
N-10-E	1				1 snail
S-17-M	3	9.2	8	6.3	
		8.6	6.9	5.1	8 half clams
		9.3	7.8	6	
		6.1	4.8	3.4	

Appendix C3. EPA-NHDES 2013 Asian clam data.

	6.1	4.8	3.2
	5.2	4.2	2.8
	5.6	4.5	3
	3.6	2.3	1.4
	6.4	5.1	3.4
	6.8	5.3	3.6
	4.9	3.7	2.4
	5.5	4.5	2.8
	5.8	4.7	3
	3.3	2.6	1.6
	6.3	5	3.2
	5.5	4.4	2.9
	3.4	2.6	1.6
	4.2	3.1	2.1
	6.5	5.2	3.5
	4.9	3.9	2.4
	4.9	3.8	2.3
	5.9	4.7	3.1
	3.9	3	1.8
	5.2	3.9	2.7
	4.4	3.4	2.1
	4.3	3.4	2.1
	3.9	3.2	1.9
	4.8	3.7	2.4
	3	2.2	1.2
	4.5	3.6	2.2
	4.3	3.5	2.2
	4.3	3.4	2
	3.5	2.8	1.6
	4.9	3.9	2.4
	5.4	3.9	2.5
	5.1	3.8	2.4
	3.4	2.7	1.6
	5.2	4.1	2.5
MEAN	**5.213158**	**4.115789**	**2.702632**
ST DEV	**1.497416**	**1.315916**	**1.114156**

S-17-W	3	3.9	3.2	2	
		3.2	2.5	1.6	1 snail
		3.1	2.4	1.4	
		3.4	2.4	1.6	
		3.5	2.8	1.7	
		9.8	8.2	5.9	
		14.9	12.9	9.2	
		14.8	12.8	9.4	
		18.3	15.9	11.2	
		23.6	21	14	
		16.1	13.9	9.8	
		18.4	16.3	11	
		16	14.5	10.6	
		18.3	15.7	11.1	
		13.9	12	8.7	
		17.6	15.5	11.1	
		13.7	11.9	8.7	
		15.4	13.5	9.6	
		12.8	10.8	8.2	
		17.3	15.7	10.8	
		15	12.9	9.4	
		16	14.2	9.8	
		3.5	2.7	1.6	
		12.9	11	8.2	
		15.9	13.7	9.6	
		15.1	12.8	9.3	
		14.4	12.7	8.9	
		15.9	13.7	9.7	
		15.6	13.6	9.7	
	MEAN	**13.18276**	**11.42069**	**8.062069**	
	ST DEV	**5.579495**	**5.047303**	**3.594581**	
S-17-M	1	10.2	8.6	6.5	4 half clams
		6.6	5.2	4	
		7.4	5.7	4.2	
		5.3	3.9	2.8	
		9.2	8	6.1	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		9.1	7.8	5.7	
		3	2.2	1.3	
		6.4	5.3	3.4	
		3.1	2.3	1.4	
		3.4	2.5	1.5	
		6.4	5	3.7	
		4	3.2	1.8	
		4.5	3.5	2.2	
		5.1	3.9	2.6	
		4.3	3.3	2.2	
		6.7	5.3	3.8	
		5.8	4.6	3	
		5	4.1	2.4	
		6.4	5.3	3.6	
		6.6	5.1	3.6	
		4.9	3.9	2.5	
		5.8	4.6	2.8	
		5.7	4.6	2.8	
		4.6	3.7	2.3	
		4.9	3.5	2.3	
		5.7	4.6	2.8	
		4.9	3.7	2.4	
		5.6	4.4	2.8	
	MEAN	**5.735714**	**4.564286**	**3.089286**	
	ST DEV	**1.729957**	**1.564943**	**1.306774**	
S-17-W	1	3.9	3	1.7	
		3.1	2.4	1.6	3 half clams
		7.6	6.4	4.4	
		8.2	7	5	
		8.9	7.7	5.2	
		17.5	15.6	11.2	
		18	16.1	11.3	
		17.3	15.1	11	
		19.5	17.1	11.9	
		22.6	19.7	13.8	
		17.3	15.6	10.9	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		18.2	15.8	11.1	
		16.2	13.8	9.9	
		18.4	16.2	11.3	
		17.5	14.9	10.4	
		17.6	15.6	10.7	
		18.1	15.6	10.7	
	MEAN	**14.7**	**12.8**	**8.947059**	
	ST DEV	**5.869412**	**5.270318**	**3.766981**	
S-0-M	2	6.7	5.1	3.6	
		4	3.1	1.8	
	MEAN	**5.35**	**4.1**	**2.7**	
	ST DEV	**1.909188**	**1.414214**	**1.272792**	
S-0-M	3	one open/empty clam			
S-0-W	2	25.3	22.7	14.7	
S-0-E	1	4.1	3.6	2.3	
S-17-E	1	5.4	4.2	3	
		5.6	4.4	2.8	
	MEAN	**5.5**	**4.3**	**2.9**	
	ST DEV	**0.141421**	**0.141421**	**0.141421**	
S-4-M	1	3.7	2.7	1.8	1 half clam
		5.1	4	2.6	
		5.4	4.1	2.7	
		6.6	5.2	3.7	
	MEAN	**5.2**	**4**	**2.7**	
	ST DEV	**1.191638**	**1.023067**	**0.778888**	
S-4-E	3	13.1	10.7	8.1	3 half clams
S-4-M	3	5.2	4	2.8	6 open clams & 1 half clam
		16.7	14.8	11.2	
		16.2	14.7	10.9	

Appendix C3. EPA-NHDES 2013 Asian clam data.

	MEAN	**12.7**	**11.16667**	**8.3**	
	ST DEV	**6.5**	**6.206717**	**4.765501**	
S-17-W	2	3	2.1	1.3	1 open clam
		7	5.8	3.7	
		7.8	6.6	4.2	
		7.6	6.3	4.5	
		9.3	7.6	5.8	
		9.9	8.2	6.3	
		17.5	15.5	11.1	
		17.8	15.7	10.8	
		18.6	16.2	10.8	
		17.5	15.4	11.2	
		15.8	14.1	10	
		15.3	13.1	9.2	
		16.3	14.6	10	
	MEAN	**12.56923**	**10.86154**	**7.607692**	
	ST DEV	**5.259972**	**4.852583**	**3.425021**	
S-4-W	2	1 open clam			
S-4-W	3	22.1	18.7	12.5	2 snails & 1 half clam
		23.3	20.5	13.4	
		23.6	20.3	13.5	
		23.2	19.9	13.5	
		20.2	17.2	12	
		19.5	16.9	11.5	
		19.7	16.6	11.4	
		19.4	16	11.4	
		17.4	14.5	10.5	
		19	15.6	11.1	
		17.6	14.9	10.6	
		18.5	15.4	11	
		17.3	15.1	10.4	
		16.4	14	9.7	
		16.6	14.6	10.1	
		17.4	14.5	10.5	

		17	14.5	10.2	
		17.8	14.8	10.4	
		17.4	14.8	10.5	
		15.3	13.8	9.5	
		15.8	13.6	9.7	
		16.1	13.5	9.3	
		16.6	14.4	9.8	
		13.4	12	8.7	
		17.2	14.7	10.3	
		16.8	14.4	10.3	
		13.6	12	8.7	
		12.4	11	7.8	
		12.7	11	8.1	
		12.3	10.6	7.6	
		12.6	10.9	7.7	
		12.4	10.5	8	
		11.6	10.2	7.4	
		11.1	9.6	7.1	
		11	9.5	7.1	
		10.9	9.5	7	
		9.2	8	5.9	
		10.1	8.4	6.2	
	MEAN	**16.17105**	**13.85263**	**9.747368**	
	ST DEV	**3.810576**	**3.199218**	**1.983682**	
S-4-E	2	14.4	12.8	9.7	6 open clams & 8 half clams
		9.7	8.5	6.3	
		6.6	5.2	3.5	
		6.4	5.1	3.5	
		5.2	4.2	3	
		5.2	4.1	3	
		4.4	3.4	2.5	
		4.1	3.4	2.2	
		5	4	2.8	
	MEAN	**6.777778**	**5.633333**	**4.055556**	
	ST DEV	**3.312393**	**3.104432**	**2.428534**	

Appendix C3. EPA-NHDES 2013 Asian clam data.

S-4-E	1	10.2	8.4	7	7 open clams & 4 half clams
		6.2	5	3.4	
	MEAN	**8.2**	**6.7**	**5.2**	
	ST DEV	**2.828427**	**2.404163**	**2.545584**	
S-0-W	3	4.8	3.8	2.3	
		25.1	22.2	14.9	
		27.3	21	14.8	
		24.2	19.6	13.7	
		24.1	19.4	13.5	
		23.8	19.3	13.6	
		23.9	19.4	13.8	
		24.2	19.3	13.5	
		24	19.5	13.8	
		24.1	19.5	13.5	
		21.2	17.4	12	
		21.3	16.9	12.2	
		20.9	17.2	12.1	
		20.8	17	11.9	
		21.1	17.2	12	
		18.5	15.1	10.7	
		17.8	14.7	10.4	
		15.4	13.3	9.7	
	MEAN	**21.25**	**17.32222**	**12.13333**	
	ST DEV	**5.034031**	**4.055578**	**2.852244**	

Appendix C3. EPA-NHDES 2013 Asian clam data.

Waterbody Stats- Asian Clam	**Mean**	**St Dev**
Merrimack River- Hooksett Pool Length	11.07125	6.640037
Merrimack River- Hooksett Pool Height	9.299167	5.76381
Merrimack River- Hooksett Pool Width	6.495417	4.106727

Appendix C3. EPA-NHDES 2013 Asian clam data.

JULY

CP1-1		14.6	12	8.8
		15.8	13.7	10
		8.1	6.7	4.7
CP1-2		11	9.5	6.9
		6.7	5.5	3.3
		5.9	5	2.9
		4.9	3.9	2.1
		4.7	3.7	2.2
CP1-3		14.3	12.2	8.1
		10.5	8.7	6.4
		8.8	7.4	5.3
		8.8	7.5	5.3
		9	7.4	5.5
		8.5	6.9	5
		8.1	6.6	4.1
CP2-1	CLAMS	13	11.1	8.2
		11.1	10.3	9.2
		10.5	8.6	6.8
		10.9	9	6.4
		8.5	6.9	5
CP2-2	CLAMS	16.1	13.8	9.7
		15.3	12.9	9.2
		15.5	12.9	9.3
		15.1	12.8	9.3
		16.7	13.7	10
		16.9	14.1	10.9
		13.6	11.2	7.2
		14.7	12.5	9
		15.1	12.9	9.5
		15.2	12.5	9
		13.7	11.3	8.2
		15	12.1	8.7
		15.4	13.1	12
		13.4	11.1	10.2

July

N-10-W		73.1	39.6	24.1
		68.5	37.5	24.7
		65.4	38.2	21.3
		66.2	36.4	17.6
S-0-W-1	CLAMS	29.3	24.2	14.9
		31.1	24.6	13.9
		29.6	24	15.3
		30.7	24.9	15.2
		29.3	23.6	15.2
		27.4	22.5	14.4
		26.4	21.9	15.2
		25.3	20.3	11.7
		26.2	23	14.9
		26.2	21.5	13.8
		24.8	21.1	14.2
		25.7	21.4	13.8
		27	21.8	14
		24.6	21.5	13.7
		25.1	20.1	13.3
S-0-W-2	CLAMS	33	24.8	17.1
		28	22.1	15.3
		29.9	23.6	15.4
		29	24	16
		28.8	23.3	15.6
		28	22.5	15.3
		25.2	20.9	13.9
		26	20.9	14.7
		25.4	20.6	14
		25	20.9	14
		25	20.7	13.8
		25.9	21	14
		14.5	12.5	8.7
		11.7	9.9	7.3
S-4-W-1	CLAMS	30	24.8	15.1

Appendix C3. EPA-NHDES 2013 Asian clam data.

		11.2	9.4	6.8
		14.7	11.9	8.4
		13.9	11.6	8.3
		12.6	10.5	7
		12.4	10.8	7.5
		12.8	10.8	7.3
		12.9	10.6	7.5
		12.5	10.2	6.9
		11.5	9.2	6.9
		12.7	10.4	7.1
		10.3	8.4	6.5
		10.3	8.4	6.4
		10.6	8.8	6.6
		10.5	8.9	6.4
		10.2	8.4	5.8
		9	7.7	5.9
		9.7	8.2	5.4
		11	8.9	6.1
		10.5	8.8	6.1
		11.3	9.2	6.7
		8.2	6.5	4.9
		7.2	6.8	4.1
		9	7.8	4.9
		5.8	4.7	2.6
CP2-3	CLAMS	16.7	13.8	10.5
		16.1	13.5	9.5
		13	10.7	8.1
		11.5	9.5	6.8
CP3-1		16.5	14.2	10
		16.7	14.3	10.5
		10.5	8.7	6.5
		9.6	7.8	5.6
CP3-2		15.5	12.9	9.6
		15	12.4	9.3
		14	12.1	8.2
		15.5	13.4	10.1
		12.2	10.3	7.2

		21.4	18.3	12.4
S-4-W-2	CLAMS	27.8	22.3	13.7
		27.6	22.4	14.4
		23.6	19.8	13
		22.9	19.6	13.4
		19.6	16	10.9
	CLAMS	24.6	20.8	13.6
		20.9	17.7	12
S-4-M-1		19.6	17.3	11.9
		14.9	12.3	9
		14	12	9
		8.2	6.8	4.9
S-4-M-2		20.2	18.1	12.1
		15.9	13.6	9.7
		13.6	11.7	8.6
		12.9	11	9
		12.5	10.7	8
S-4-M-3		17.4	15.3	10.9
		21.1	18.2	12.9
		5.9	4.9	2.9
	CLAMS	17.3	15	10.6
		15.1	13	9.8
		9.2	7.5	5.4
S-17-W-2	CLAMS	16.9	14.5	10.2
		16.3	14.2	9.9
		14.3	12.3	8.7
S-17-M-1	CLAMS	13.1	11.5	8.8
	CLAMS	10.7	10	7.5
		8.3	6.6	3.9
S-17-M-3		6.7	5.1	3.5
	MEAN	**24.37188**	**19.04844**	**12.53125**
	ST DEV	**13.40301**	**7.363423**	**4.178968**
A-12-W-1				
A-12-W-2		14.7	13.8	10.3
		14.4	13.5	9
		14.3	13.7	9.9
A-12-W-3		13.8	13.7	10

Appendix C3. EPA-NHDES 2013 Asian clam data.

		11.5	9.5	7.1
		9.5	7.7	5.7
		8.2	6.5	4.6
CP3-3		3.9	3	1.6
		3.8	2.8	1.9
CP4-1		13	12.1	7.9
		4	3.4	2.3
CP4-2		10.7	9.3	6.5
		8	6.8	5.1
CP4-3		9.2	8.1	5.3
		10.4	9.1	6.2
CP5-1		6.1	5.1	2.9
		7.7	6.5	4.5
CP5-2		8.5	7	5
		5.6	4.6	2.7
		6.4	5.3	3.1
		7.5	6.5	4.5
		6.3	4.8	2.8
CP5-3		7.5	6.2	3.5
CP6-1		16.6	14.5	10.3
		16	14.3	10.9
	CLAMS	6.7	5.7	3.5
		3.9	2.7	2.1
CP6-3		16.1	13.7	10.1
		14	13.5	10.2
		8.7	7.5	4.7
		8.3	7.3	5.1
CP7-1		6.5	5.7	3.1
		5.5	4.7	3.1
CP7-2		6.8	5.2	3.9
		6.6	5.5	3.9
CP7-3		7.8	6.4	4.6
CP8-3		14	12.1	8.8
		15.3	13.1	9.9
		14.1	12.7	9.5
		11.4	9.7	7.4
CP9-2		7.5	6.2	4.5

	14.6	13.8	10.5
	14.4	13.5	10.5
	14.5	13.8	10.5
	14.9	14.1	10.5
	13.3	12.7	10
	14.1	13.7	10.4
	14.8	13.2	10.9
	13.3	12.5	10.9
	13.2	12.5	9.6
	13.3	12.9	10.3
	10.8	10.4	7.9
A-12-M-1	14.3	13.2	9.5
	4.4	3.1	2.4
A-12-M-2	14.2	13.9	9.9
A-12-M-3	11.1	9	7.5
	7.2	5.6	3.7
	7.5	6.7	4.3
	7.4	5.7	4.4
A-12-E-1	15.4	14	10.6
	14.7	13.4	10.6
	10.9	9.3	7.7
	10.8	9.4	7.6
	10.7	9.2	7.3
	11.3	10.2	8
	8.3	7.2	6.1
A-12-E-3	13.8	12.8	10
	13.9	13.3	10.4
	10.8	9.5	7.8
	10.3	9.4	7.4
	10.4	9.1	7.7
	10.2	9	7.3
	10.5	8.8	7.6
	11.7	10.1	8.1
	10.3	9.1	7.4
	9.6	8.2	6.6
	9.1	8.5	6.1
	9.5	8.2	6.6

Appendix C3. EPA-NHDES 2013 Asian clam data.

CP10-1		19	16.5	12.2
		9.4	7.6	5.5
		11	9.2	6.8
CP10-2		20.6	18.1	12.5
		17.8	15.9	11.8
		13.1	11.7	8.3
		8.1	6.6	4.8
		9	7.4	5.4
		9.1	7.7	5.1
		9.8	7.9	6
		8.7	7.4	5.1
		7.7	6.3	4.7
		8.4	6.7	4.8
		7.8	6.3	4.8
		7.9	6.5	4.9
CP10-3		13.5	11.9	8.3
		13.4	11.7	8.6
		9.6	8	5.9
		9.7	7.9	6
	MEAN	**10.9937**	**9.26063**	**6.635433**
	ST DEV	**3.656496**	**3.226555**	**2.540764**
LP2-1		8.9	8	5.3
		8.7	8.3	5.5
LP2-2		12	10	7.5
LP2-3		9.3	7.8	5.4
LP3-2		17.4	15.7	11.2
		15.5	13.5	9.2
LP3-3		11.2	9.9	7.5
		9.7	8.1	5.6
		6.3	5.7	3.2
LP4-1		3.1	2.5	1.5
LP4-2		6.4	4.9	3.3
		6.4	4.9	3.7
LP4-3		18.4	15.6	10.8
LP5-2		8.3	6.9	4.9
LP6-1		19.2	17.3	11.4

MEAN	**11.87073**	**10.82195**	**8.385366**
ST DEV	**2.652475**	**2.865616**	**2.159463**

Appendix C3. EPA-NHDES 2013 Asian clam data.

LP6-2	CLAMS	14.9	13.5	9.3
		14.2	12.8	8.9
		15.2	13.9	9.6
		14.3	12.6	8.4
		21.5	18.8	12.8
		13.2	12.1	8.6
		13.6	11.7	8.4
		9.9	9.5	6.3
		5.9	4.6	2.9
		6.3	5.2	3.2
		8.6	7.5	4.6
		5.6	4.4	2.7
		8.5	7.2	4.7
		6.7	5.8	3.6
		7.2	6	3.6
		8.2	7.6	4.7
		14.2	13.8	8.4
		15.6	14.3	9.6
		12.8	11.6	7.8
		15.2	13.6	9.3
		14.9	13.5	9.6
		14.9	13.1	9
		15	13.5	9.4
		15.9	14.2	9.8
		15.2	13.6	9.6
		12.4	11.1	7.4
		11.3	10.2	7.5
		15.4	13.6	9.5
		14	12.3	8.5
		13.6	12	9.3
		15.1	13.3	9.5
		13.9	11.7	8
		15.1	13.6	9.7
		10.2	8.9	6.1
		8.1	6.8	4.3
		6	5.2	3
		6.2	5.2	3

Appendix C3. EPA-NHDES 2013 Asian clam data.

		5.2	4.2	2.6
		4	3.4	2
		3.1	2.5	1.3
LP6-3	CLAMS	14.8	13.2	9
		14.4	12.7	8.8
		15.6	13.9	9.7
		15.5	13.7	9.4
		14.3	12.6	8.2
		15.7	14	9.7
		16	14.2	9.9
		13.8	12.2	8.5
		14.1	12.4	8.4
		13.2	11.9	8
		13.6	12	8
		11.9	10.9	7.6
		11.1	9.8	6.7
		10.1	8.7	5.8
		8.7	7.5	5
		11.1	10	6.3
		6.4	5.4	3.1
LP7-2	CLAMS	8	6.7	4.9
LP7-3		16.4	14.4	10.5
		8.7	7.5	5.4
		8.2	6.8	4.4
		7.9	6.7	4.5
		5.4	4.4	2.8
	MEAN	**11.49744**	**10.11667**	**6.885897**
	ST DEV	**4.135528**	**3.818119**	**2.770753**
NOV				
S-17-M	2	9.5	8.3	6.1
		9.6	8.4	6.2
		9.9	8.3	6.3
		7.2	6.1	4.6
		7	5.7	4.1
		9	7.7	5.9

Appendix C3. EPA-NHDES 2013 Asian clam data.

		7.8	6.2	4.8	
		6.9	5.4	4.2	
		6.4	5.2	3.5	
		5.4	4.6	2.8	
		5.9	4.7	3.1	
		6	4.8	3	
		5.2	4	2.7	
		5.5	4.5	2.9	
		5.1	4.2	2.6	
		5.2	4.2	2.7	
		4.9	3.8	2.8	
		4	3.1	2	
		5	3.9	2.4	
		4.2	3.3	1.9	
		4.3	3.5	2.5	
		3.7	3.1	1.8	
		3.6	2.9	1.7	
		3.9	3	1.8	
		3.4	2.7	1.8	
S-0-W	1	24.4	19.8	13.6	
		23.4	18.9	13.4	
		23.6	19.3	13.4	
		16.5	14	9.9	
S-4-W	1	20.7	17.4	12.3	
S-4-M	2	13.6	11.8	8.9	
		14.4	12.4	9.2	
		14.3	12.3	9.2	
		5.8	4.5	3.1	
S-17-M	3	9.2	8	6.3	
		8.6	6.9	5.1	
		9.3	7.8	6	
		6.1	4.8	3.4	
		6.1	4.8	3.2	5 half clams
		5.2	4.2	2.8	
		5.6	4.5	3	
		3.6	2.3	1.4	1 half clam & 2 snails
		6.4	5.1	3.4	1 snail

Appendix C3. EPA-NHDES 2013 Asian clam data.

		6.8	5.3	3.6	
		4.9	3.7	2.4	8 half clams
		5.5	4.5	2.8	
		5.8	4.7	3	
		3.3	2.6	1.6	
		6.3	5	3.2	
		5.5	4.4	2.9	
		3.4	2.6	1.6	
		4.2	3.1	2.1	
		6.5	5.2	3.5	
		4.9	3.9	2.4	
		4.9	3.8	2.3	
		5.9	4.7	3.1	
		3.9	3	1.8	
		5.2	3.9	2.7	
		4.4	3.4	2.1	
		4.3	3.4	2.1	
		3.9	3.2	1.9	
		4.8	3.7	2.4	
		3	2.2	1.2	
		4.5	3.6	2.2	
		4.3	3.5	2.2	
		4.3	3.4	2	
		3.5	2.8	1.6	
		4.9	3.9	2.4	
		5.4	3.9	2.5	
		5.1	3.8	2.4	
		3.4	2.7	1.6	
		5.2	4.1	2.5	
S-17-W	3	3.9	3.2	2	
		3.2	2.5	1.6	
		3.1	2.4	1.4	
		3.4	2.4	1.6	
		3.5	2.8	1.7	
		9.8	8.2	5.9	
		14.9	12.9	9.2	
		14.8	12.8	9.4	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		18.3	15.9	11.2	
		23.6	21	14	
		16.1	13.9	9.8	1 snail
		18.4	16.3	11	
		16	14.5	10.6	
		18.3	15.7	11.1	
		13.9	12	8.7	
		17.6	15.5	11.1	
		13.7	11.9	8.7	
		15.4	13.5	9.6	
		12.8	10.8	8.2	
		17.3	15.7	10.8	
		15	12.9	9.4	
		16	14.2	9.8	
		3.5	2.7	1.6	
		12.9	11	8.2	
		15.9	13.7	9.6	
		15.1	12.8	9.3	
		14.4	12.7	8.9	
		15.9	13.7	9.7	
		15.6	13.6	9.7	
S-17-M	1	10.2	8.6	6.5	
		6.6	5.2	4	
		7.4	5.7	4.2	
		5.3	3.9	2.8	
		9.2	8	6.1	
		9.1	7.8	5.7	
		3	2.2	1.3	
		6.4	5.3	3.4	
		3.1	2.3	1.4	
		3.4	2.5	1.5	4 half clams
		6.4	5	3.7	
		4	3.2	1.8	
		4.5	3.5	2.2	
		5.1	3.9	2.6	
		4.3	3.3	2.2	
		6.7	5.3	3.8	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		5.8	4.6	3	
		5	4.1	2.4	
		6.4	5.3	3.6	
		6.6	5.1	3.6	
		4.9	3.9	2.5	
		5.8	4.6	2.8	
		5.7	4.6	2.8	
		4.6	3.7	2.3	
		4.9	3.5	2.3	
		5.7	4.6	2.8	
		4.9	3.7	2.4	
		5.6	4.4	2.8	
S-17-W	1	3.9	3	1.7	
		3.1	2.4	1.6	
		7.6	6.4	4.4	
		8.2	7	5	
		8.9	7.7	5.2	
		17.5	15.6	11.2	
		18	16.1	11.3	
		17.3	15.1	11	
		19.5	17.1	11.9	
		22.6	19.7	13.8	
		17.3	15.6	10.9	3 half clams
		18.2	15.8	11.1	
		16.2	13.8	9.9	
		18.4	16.2	11.3	
		17.5	14.9	10.4	
		17.6	15.6	10.7	
		18.1	15.6	10.7	
S-0-M	2	6.7	5.1	3.6	
		4	3.1	1.8	
S-0-W	2	25.3	22.7	14.7	
S-0-E	1	4.1	3.6	2.3	
S-17-E	1	5.4	4.2	3	
		5.6	4.4	2.8	
S-4-M	1	3.7	2.7	1.8	
		5.1	4	2.6	

Appendix C3. EPA-NHDES 2013 Asian clam data.

		5.4	4.1	2.7	
		6.6	5.2	3.7	
S-4-E	3	13.1	10.7	8.1	
S-4-M	3	5.2	4	2.8	
		16.7	14.8	11.2	
		16.2	14.7	10.9	
S-17-W	2	3	2.1	1.3	
		7	5.8	3.7	1 half clam
		7.8	6.6	4.2	
		7.6	6.3	4.5	
		9.3	7.6	5.8	
		9.9	8.2	6.3	3 half clams
		17.5	15.5	11.1	6 open clams & 1 half clam
		17.8	15.7	10.8	
		18.6	16.2	10.8	
		17.5	15.4	11.2	1 open clam
		15.8	14.1	10	
		15.3	13.1	9.2	
		16.3	14.6	10	
S-4-W	3	22.1	18.7	12.5	
		23.3	20.5	13.4	
		23.6	20.3	13.5	
		23.2	19.9	13.5	
		20.2	17.2	12	
		19.5	16.9	11.5	
		19.7	16.6	11.4	
		19.4	16	11.4	
		17.4	14.5	10.5	
		19	15.6	11.1	2 snails & 1 half clam
		17.6	14.9	10.6	
		18.5	15.4	11	
		17.3	15.1	10.4	
		16.4	14	9.7	
		16.6	14.6	10.1	
		17.4	14.5	10.5	
		17	14.5	10.2	
		17.8	14.8	10.4	

		17.4	14.8	10.5	
		15.3	13.8	9.5	
		15.8	13.6	9.7	
		16.1	13.5	9.3	
		16.6	14.4	9.8	
		13.4	12	8.7	
		17.2	14.7	10.3	
		16.8	14.4	10.3	
		13.6	12	8.7	
		12.4	11	7.8	
		12.7	11	8.1	
		12.3	10.6	7.6	
		12.6	10.9	7.7	
		12.4	10.5	8	
		11.6	10.2	7.4	
		11.1	9.6	7.1	
		11	9.5	7.1	
		10.9	9.5	7	
		9.2	8	5.9	
		10.1	8.4	6.2	
S-4-E	2	14.4	12.8	9.7	
		9.7	8.5	6.3	
		6.6	5.2	3.5	
		6.4	5.1	3.5	
		5.2	4.2	3	
		5.2	4.1	3	
		4.4	3.4	2.5	
		4.1	3.4	2.2	
		5	4	2.8	
S-4-E	1	10.2	8.4	7	6 open clams & 8 half clams
		6.2	5	3.4	
S-0-W	3	4.8	3.8	2.3	
		25.1	22.2	14.9	
		27.3	21	14.8	
		24.2	19.6	13.7	
		24.1	19.4	13.5	
		23.8	19.3	13.6	

Appendix C3. EPA-NHDES 2013 Asian clam data.

	23.9	19.4	13.8	
	24.2	19.3	13.5	7 open clams & 4 half clams
	24	19.5	13.8	
	24.1	19.5	13.5	
	21.2	17.4	12	
	21.3	16.9	12.2	
	20.9	17.2	12.1	
	20.8	17	11.9	
	21.1	17.2	12	
	18.5	15.1	10.7	
	17.8	14.7	10.4	
	15.4	13.3	9.7	
MEAN	**11.07125**	**9.299167**	**6.495417**	
ST DEV	**6.640037**	**5.76381**	**4.106727**	

Appendix C3. EPA-NHDES 2013 Asian clam data.

Appendix C3. EPA-NHDES 2013 Asian clam data.

S-4-W-3	MUSSEL	63.7	36.6	20.4
S-4-E-1	MUSSEL	77.3	43.2	25.8
S-17-W-1	MUSSEL	68.6	38.8	24.1
S-17-M-2	MUSSEL	86.3	51	29.7
S-17-E-1	MUSSELS	70.7	37.7	18.7
		71	39.5	26.2
		66.2	37.4	20.3
		77.7	42.9	23
		67	35.7	19
S-17-E-2	MUSSELS	72.9	40.9	22.9
		82.5	44.3	25.3
		72.3	39.5	21.6
		56.5	29.5	14.9

Appendix C3. EPA-NHDES 2013 Asian clam data.

68.1	39	24.6
70.6	38.8	20.2

Appendix C4. EPA field notes planning September 2014 dive.

Clam Survey 2014

would like to get lakes. (ponds)

Garvins?
Amoskeag?

- objectives -
- sampling locations
- WQ?
- QAPP SOP - basic methods @ DES. — lab samples —
- report? - working on chapters. - scientific paper.
- stills / videos -
- FOIA. -

Coastal survey.

N-10
N-5
S-0
S-4
S-17

Early detection & rapid response.

boat & multiprobe -/ WQ w/ Sonde.

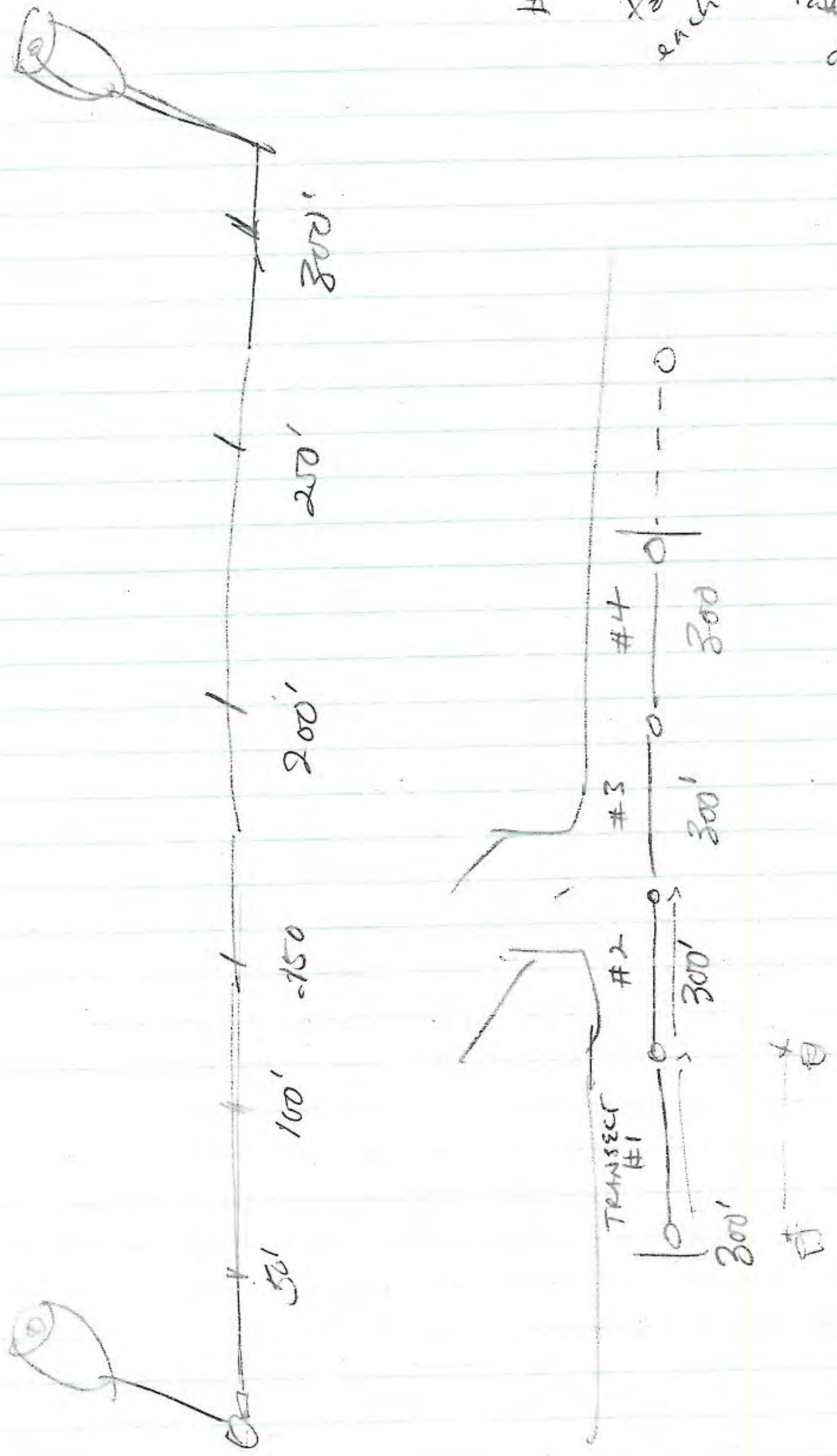
Send to

Will not be available.

will be ready anytime on Tuesday.

N-5 :	43- 08.7124'N	71- 28.3053'W
Dec. Degrees	43.1452066666°N	71.471755° W
DMS	43-00-52 N	71- 28-18 W

Appendix C4. EPA field notes planning September 2014 dive.



*If plant open take w.t. @ each end of T./

Locate position
~~Take position~~
drop buoy
take position
Save WP

[lay out line]
take posit (WP)
dive line
put slate down
@ start with
transect ID

At end of
transect -
diver unsnaps
line and
brings to
surface -
~~on boat~~ boat
retrieves d/s
buoy, and
brings up
to other
buoy.

D/S end
secured to
buoy left in
place, and
boat lays
out line.
Take WP @
u/s end -
& repeat.

Appendix C4. EPA field notes planning September 2014 dive.

TO DO

remark line. — add clips to transect line

make buoy lines w/ weights — clips or rings

go over cameras — operation - load batteries

put targets into GPS.

Appendix C4. EPA field notes planning September 2014 dive.

Equipment to bring

- GPS — extra batteries ☐
- video camera- lights, housing etc ☐ batteries
- 300' tape ☐
- dive slate or 2 ☐
- quadrat — count in place. ☐
- transect line w/pail ☐
- buoy, lines, weights w/pail ☐
- extra weight. ☐
- inflatable flag.

⊛ pictures of u/s sampling locations & 5-17.

⊛ towel for camera

Appendix C4. EPA field notes planning September 2014 dive.

5 Amy Smagula 603-271-2248

5 " She has a programmatic QA?

sampling in later part of July? (last 2 weeks)

- interested in distribution of age classes.
- find someone who knows how to age them.

- Collect clams from pond for size/age /growth comparison? She could collect.

Dan Mennelli?

Quadrat sampling vs. Eckman

Amy thinks diver sampling best for river
- go down 6" → typical range they're found.

- focus on biology vs. chemistry.
- possibly look at contaminates food webs → Hg?

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

Sample Date	Sample Site
9/24/2014	Sample 1 43-08-07.88N 71-27-47.17W

	Length (mm)	Height (mm)	Width (mm)	Total
Mean	21.3859	18.12179	12.34103	N=78

Comment

Sample taken by diver using
1/16 m2 quadrat and hand trowel

Rep	Length (mm)	Height (mm)	Width (mm
1	23.7	18.9	13.2
	20.7	17.3	12
	24.3	20.4	13.5
	24.8	20.5	13.9
	19.5	16.8	11.9
	20.5	17.4	11.9
	24.1	20.5	13.9
	26.5	21.6	14.7
	24.2	20	13.3
	26.1	21.3	14.3
	23.7	20.1	13.7
	24	20	13.2
	24.4	21.1	14.1
	24.1	20	13.7
	26.7	22.4	14.2
	23.8	20.4	14
	24.3	21	13.9
	26.1	21.2	14.3
	17.7	16	11.7
	11.8	9.8	7.5
	25.8	21.5	14.6
	24.1	19.8	13.3
	20.5	17.9	12.2
	23.8	20.2	13.9
	26.2	22.4	14.3
	23.9	20.3	13.8
	25.8	21.7	14.4
	23	19.5	12.8
	25.7	22.2	14.2
	23.8	20.8	13.5
	11.7	9.8	7.5
	23.9	20.5	13.8
	23.2	20.5	13.5

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

27.4	23.2	14.9
20.8	18.1	12.1
21	17.3	12.1
20.3	17.3	11.7
23.5	20.1	13.3
24	19.6	13.4
20.2	17.2	11.9
19.8	17.1	11.7
22.3	18.5	12.4
24.1	20.2	13.6
20.8	17.9	12.1
21.2	18	12.4
25	22.4	14.5
22.6	19.5	13.2
25.4	21.3	14.5
11.1	9.5	7.3
20.5	17.6	12.5
20	17.2	11.9
20.4	16.7	11.7
20	16.8	12.2
19.5	16.5	11.5
20.7	17.8	12.4
20.6	17.7	11.9
20	16.5	11.7
20.4	17	12.1
20.4	16	12.4
19.9	17	11.8
19.5	16.9	11.4
20.4	17.4	11.8
19.9	16.7	11.3
20	16.8	11.4
21.6	18.1	12.3
20.7	18	12.4
20.9	17.8	12

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

	20.3	17	11.8
	19.8	16.9	11.8
	20.5	17.9	12.4
	17.2	15.1	10.7
	20.8	18.1	11.9
	20.6	17.9	12.2
	19.7	17.2	11.8
	20.3	17.4	11.9
	19.2	16.7	11.6
	6.5	5.1	3
	5.9	4.7	3
Mean	**21.3859**	**18.12179**	**12.34103**

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

Sample Date	**Sample Site**
9/24/2014	Sample 2 43-08-11.28N 71-27-48.36W

	Length (mm)	**Height (mm)**	**Width (mm)**
Mean	23.53429	19.70571	13.47429
Total	N=35		

Comment

Sample taken by diver using 1/16 m2 quadrat and hand trowel

Rep	**Length (mm)**	**Height (mm)**	**Width (mm)**
1	24.3	20.4	13.6
	25.9	21.4	14.7
	24.4	19.9	13.5
	22.4	19.7	13.3
	24.7	20.5	14
	26.7	21.7	14.6
	25.8	21	14.2
	25.9	21.9	14.7
	24	20.2	13.4
	24.5	20.8	13.9
	11.9	9.8	8.2
	11.9	10.4	8.9
	24.4	20.8	14.3
	23.9	20.7	13.9
	23.8	20.1	13.4
	24.7	20.1	13.5
	20.7	17.5	12.3
	27.5	23.4	15.8
	26.7	21.7	14.6
	24.4	20.8	14.4
	25.4	20.1	14.2
	26.2	21.8	14.3
	26.6	23	15.4
	20.7	18.1	12.5
	23.5	19.4	13.3
	23	19.1	13.4
	24.3	21.2	13.5
	24.1	20.7	13.5
	20.2	17.5	12.1
	22.4	18.5	12.8
	20.2	16.9	11.9
	23	18.6	12.9
	24.2	20	14.1

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

	23.5	19.4	13.3	
	27.9	22.6	15.2	
Mean	**23.53429**	**19.70571**	**13.47429**	**N=35**

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

Sample Date	Sample Site
9/24/2014	Sample 3 43-08-11.5N 71-27-50.1W

	Length (mm)	Height (mm)	Width (mm)	Total
Mean	24.35093	18.89861	12.96157	N=216

Comment

Sample taken by diver using 1/16 m2 quadrat and hand trowel

Rep	Length (mm)	Height (mm)	Width (mm
1	26.2	21.2	14
	28	21	14.6
	22.7	18.4	12
	24.8	19.8	12.8
	24.1	17.5	13.3
	20.3	16.3	11.3
	25.6	19.9	14.1
	23.7	18.5	12.3
	25	19.8	13.2
	28.7	22.3	15.8
	20.3	16.8	11.6
	24.4	19	12.9
	27.1	20.7	13.9
	23.8	18	13.2
	28	22.8	14.9
	23.8	18.1	12.5
	21	16.8	12
	26.2	19.9	14.1
	24	18.4	12.7
	24.1	19.2	12.8
	24.2	18.4	12.7
	24.6	19	13.5
	24.5	18.9	12.2
	24.5	19	13
	28.6	22.2	13.8
	24.6	19.7	13.2
	24.8	19.6	13.3
	24.1	18.7	13.1
	23.9	18.7	12.8
	15	13	9
	18	14.8	10.1
	20.8	17.5	12
	27	20.2	13.8

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

29.5	22.9	15.3
26.1	19.6	13.6
24.3	18.7	12.7
26.2	20.1	13.7
28.6	22.4	13.8
26.6	20.8	13.7
24	18.4	12.4
24.7	18.9	13.8
23.4	17.7	12.4
24.3	18.5	13.1
26.3	19.8	13.6
26	19.9	14.4
23.5	17.6	11.8
24.3	19.4	13.1
24.2	19	13.1
26.6	20.7	14.5
29	22	15.6
26.5	20	14.6
23.7	18.6	12.7
23.6	18.5	12.6
24.3	18.8	12.9
26.2	20.2	13.5
24.7	19	13.4
23.5	18.5	12.8
23.5	18	12.7
24.2	19.1	12.4
22.7	18	12.3
23.8	19.7	13
23.9	18.2	12.8
23.9	19.5	12.4
22.5	17.7	10.8
22.2	18.8	12.4
27.2	20.5	14.5
23.1	18.5	12.1

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

23.7	18.5	12.9
25	19.9	13.7
23.4	18.2	12.1
23.9	18.5	13
20.8	16.7	11.5
24.7	19	12
24.9	19.6	12.9
24.6	18.7	12.4
24.5	18.8	12.8
24	17.6	12.9
23.5	17.9	12.5
24.4	18.3	13.5
24	18.6	12.7
20	15	11.2
23.2	17.6	11.7
26.6	21.1	13.8
27.2	22.2	14.1
24.7	18.5	12.1
26.5	20.2	13.1
24.3	18.9	13.1
26.2	20.5	13.6
24.6	19.8	13.3
24.3	18.8	12.4
25	19.5	13.6
24	19.2	12.9
24.9	18.7	13.1
24.3	18.7	12.8
24	18.9	13.3
24.5	19.4	12.7
24.8	19.5	12.8
23.8	19.2	12.5
23.5	19.1	12.2
23.9	18.4	12.8
24.1	18.6	12.9

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

25.1	19.9	13.5
21	17.1	11.8
21.8	16.7	11.4
24.5	19.1	12.2
24.5	18.8	13.2
25.5	20.3	13.5
23.6	18.7	12.8
24	19.1	12.7
23	18.9	12.6
24.1	18.3	12.6
23.2	18.3	12.9
25	18.7	12.7
24.3	17.9	12.3
26.1	19.7	13.8
24.5	13.5	18.5
23.4	18.3	12.4
22.5	18.6	12
24.7	19.1	13.5
26.3	20.4	14.5
23.6	18.1	12.5
28.4	22.5	15
28	21.1	14.5
24.5	19	13.3
24	18.6	12.3
24.8	18.9	13
25.3	19.9	13.7
24.7	18.8	12.5
23.5	18.1	12
24.6	18	13
23.6	17.8	12.2
24.4	17.8	11.4
24.3	18.9	12.9
24.4	19.1	13.7
20.9	16.6	10.4

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

26.5	20.5	13.7
24.4	18.9	12.9
24.7	19.7	13.2
23.7	18.2	12.9
24.1	18.5	12.6
24.5	19.5	13
26.4	20.1	13.4
23.6	18.3	13
23.9	18.5	13.2
20.9	16.7	11.7
24.5	18.8	12.8
24.2	18.8	12.5
21.6	17.7	12.1
24	17.8	12.8
22.5	17.7	11.9
24	18.3	12.1
24.2	18.8	12.7
26.8	19.7	12.5
26	19.3	13.3
23.4	18	12
23.8	18.2	13.3
20.1	16.3	10.4
21.5	17.9	12.5
21.1	17.6	12.5
23.9	19.5	13.3
23.8	17.8	12.5
25.1	19.8	13
29	21	15.6
24.9	19	13.8
24.2	18.8	13.5
19.8	16	10.6
21.5	17.9	12.7
26.7	19.9	13.7
30.6	22.8	16.6

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

13.1	18.6	24.6
12.7	18.6	24.2
11.3	16.7	21.1
13.3	19.8	25.2
13.4	18.3	24.2
12.7	18.1	23.2
14.5	20.6	26.6
12.6	18.2	24
13.1	19	24.9
13.4	19.9	25.3
14	20.8	27.3
10.8	15.1	18.5
11.5	16	20.2
13	19.1	23.8
11.8	17.3	21
13.5	19.5	25.6
15.7	21.8	28.6
12.8	18.4	24
13	19.1	24.2
12.2	17.6	23
12.9	19.1	23.6
14.1	20.5	27.7
13.1	19.1	23.8
12.5	18.2	23.1
12.8	17.8	23.5
13.1	18.8	24.4
12.6	19.4	24.2
11.8	17.5	23.3
13.1	18.7	24.6
12.2	17.9	22.6
12.8	19.1	24.4
14.6	21	27.7
12.7	20.9	27.5
14.8	22.4	28.8

Appendix C5. EPA September 2014 Asian clam data from excavated samples using divers.

	24.6	19.2	13.3
	23.9	19.4	13.4
	28.5	21.2	15
	24.6	18.8	12.6
	24.7	19.4	13.2
	26.1	19.9	13.4
	19.7	16.2	11.2
	23.6	18.9	12.7
	24.2	18.2	12.8
	25.3	19.3	13.1
	28.3	20.3	14.7
	24.3	18.5	12.7
	18	14.8	10.6
Mean	**24.35093**	**18.89861**	**12.96157**

APPENDIX D

AST Environmental

Natural Resource Consultants Specializing in

Protected Species, Streams and Wetlands

Comments to:

“Statement of Substantial New Questions for Public Comment (Discussion of Substantial New Questions and Possible New Conditions for the Merrimack Station Draft NPDES Permit that are Now Subject to Public Comment During the Comment Period Reopened by EPA under 40 C.F.R. § 124.14(b))”

Prepared for

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Project Number TR14-102

September 11, 2017

Comments to:

“Statement of Substantial New Questions for Public Comment (Discussion of Substantial New Questions and Possible New Conditions for the Merrimack Station Draft NPDES Permit that are Now Subject to Public Comment During the Comment Period Reopened by EPA under 40 C.F.R. § 124.14(b))”

Sec. IV.B.2, pp. 41-44. New Information Concerning the Presence of the Asian Clam (*Corbicula fluminea*) in Hooksett Pool and Substantial New Questions Regarding the Import of this Information for Application of CWA § 316(a) and New Hampshire Water Quality Standards to the Merrimack Station NPDES Permit. (hereafter, the “Statement”)

Comments (see accompanying excerpt from original “Statement” for line references):

Many of the following comments are more thoroughly considered in my report (hereafter, the “Report”)

1. p. 41, lns 16-17. “The presence of this highly invasive species, (*see* Sousa et al. 2008, AR-1406)…” (emphasis added).

   In fact, nowhere is it stated in Sousa *et al.* (2008) that the Asian clam is a “highly invasive species”. Sousa *et al.* (2008) do state in the abstract of their paper that “it is one of the most invasive species in freshwater aquatic ecosystems.” Sousa *et al.* (2008) correctly attribute the considerable geographic dispersion and invasive success of the Asian clam to “…their natural characteristics (*e.g.,* rapid growth, earlier sexual maturity, short life span, high fecundity, extensive dispersal capacities and its association with human activities) than in its physiological tolerance” (pp.85-86). In fact, Asian clams have relatively poor physiological tolerance compared to native unionid bivalves. Instead they depend on their ability for rapid growth, early maturity and high fecundity to re-establish populations after catastrophic density reductions (McMahon 2002 and *pers. comm.*). Nowhere do Sousa *et al.* (2008) mention the necessity for thermal effluents from power plants or other sources for dispersal and establishment. Indeed, Sousa *et al.* (2008) specifically refer to the Asian clam as being “…less tolerant to…elevated temperatures…” (p. 86), and state that the Asian clams “[t]olerate low water temperatures…” (Table 1, p. 89). Since a number of published reports now suggest that Asian clams are thriving in cold winter northern habitats (*e.g.,* high altitude reservoirs in Colorado (Cordeiro *et al.* 2007) and Lake George, NY and numerous sites in New Hampshire) without heated effluents, there is no reason to believe that they would completely disappear from Hooksett Pool in the Merrimack River if the power plant’s thermal discharge was eliminated. In fact, periodic discharge of warm water from a closed circuit wet cooling tower could provide a winter refuge for adults from which a river population could be re-established every spring (R.F. McMahon, *pers. comm*). These references and abilities of Asian clams appear to have been overlooked in EPA's preparation of the "Statement". Indeed, there appears to have been a number pertinent references that were overlooked in the EPA's "Statement" that indicate that Asian clams can survive overwinter in cold water (0-2°C) habits. References to established cold water populations of Asian clam, and other references, are provided in the "Report." The relevance of such references should be considered in any finding to regulate the Facility's thermal discharges under CWA § 316(a).

2. p. 41, lns 35-37. "…[the Asian clam's] limited presence in northern New England has been attributed to prolonged periods of cold water temperatures and ice cover that is believed to cause high mortality during winter months (Simard et al., 2003 [sic])."

   The actual year of the Simard *et al.* publication is 2012. Simard *et al.* (2012) do not make statements specific to New England, but rather to the Asian clam "…establishing itself in northern regions." (p. 86). Simard *et al.* 2012 do, however, state that "…[Asian clam] appears to be establishing itself in northern regions…" and this appears to be despite "…high mortality caused by cold temperatures [that] should nevertheless limit population densities…" (p. 86). Simard *et al.* (2012), citing Müller and Baur (2011) also correctly point out that it has been "…suggested that [Asian clam] is more tolerant to cold waters than previously assumed…" and this tolerance to cold water would likely results [sic] from high phenotypic plasticity of the species" citing McLeod 1986 for phenotypic plasticity (p. 86). Furthermore, Simard *et al.* (2012) go on to provide a cold water example actually from the northeastern U.S. stating "[i]n Lake George, despite water temperatures between -1°C and 2°C in winter, the preliminary data suggests an average density of 3,069 individuals/m^2 with a maximum of 6,359 individuals/m^2" citing personal communication with M. Modley and Darrin Freshwater Institute. Citing several studies from Michigan, New York and the Czech Republic, Simard *et al.* (2012) also point out from other studies that "…a significant proportion of [Asian clam] individuals seemed to tolerate low winter water temperatures. Those studies suggested that even if Asian clam populations suffer extensive winter mortality, the small number of survivors could possibly produce offsping [sic] that would be better tolerant to rigorous climates." Furthermore, the USGS Nonindigenous Aquatic Species website now lists Asian clams at 12 sites in New Hampshire, only one of which receives thermal effluent (USGS 2017). It is apparent from these statements that it is by no means a foregone conclusion that thermal discharge is necessary for Asian clam establishment and persistence, and supports the contention that installation of recirculating cooling systems may not, *de facto*, eliminate Asian clams in Hooksett Pool. In fact, the operation of wet evaporative cooling towers used in power stations, usually bring make-up water from a raw-water source to replace evaporated water lost to the evaporative cooling process and discharge (blow down) some water from their basins back to the raw water source to prevent excessive concentration of dissolved solids. Juvenile clams can be drawn into the basins of such cooling towers with make-up water where they grow to adults producing juveniles that can be discharged back into source waters to become adults. Thus, cooling towers become refuges for Asian clams from which juveniles are produced to be carried out on discharge water to re-infest the raw water source (R.F. McMahon, *pers. comm*). Post *et al*. (2000) describe Asian clam fouling of wet cooling towers. These references and clearly made points appear to have been overlooked in EPA's preparation of the "Statement". The relevance of such references and well-conveyed points should not be overlooked in any consideration to regulate the Facility's thermal discharges under CWA § 316(a).

3. p.41, lns. 38-41. "When PSNH submitted its report in 2012, the presence of Asian clams in New Hampshire had only been documented in the Merrimack River south of Bow, New Hampshire, and in Cobbetts Pond, in Windham, New Hampshire, according NHDES's environmental fact sheet on Asian clams (NHDES, 2012)." [emphasis added]

   In fact, A. Smagula of NHDES states "[t]he Asian clam was first documented in New Hampshire in 2007, when biologists from the Department of Environmental Services (DES) 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 later identified as [Asian clam]." [emphasis added] The region of the Merrimack River at Merrimack, NH is indeed "south of Bow," but it is well downstream of any potential thermal influence from Merrimack Station. Also, Cobbetts Pond lacks any thermal effluents. Furthermore, Asian clams have now been documented at two locations in the Merrimack River upstream of Merrimack Station in Hooksett Pool, at another Merrimack River site in north Concord, in Long Pond near Pelham, Wash Pond near Hampstead, in Beaver Lake near Derry, in Great Pond near Kingston, in Canobie Lake near Salem, and in Little Island Pond near Pelham; all of which are sites in New Hampshire lacking a thermal effluents. Much of this information was readily available at the time the "Statement" was produced, but was not included. Establishment of the Asian clam in these areas indicate thermal discharge is not necessary for Asian clam establishment and persistence, and that the installation of recirculating cooling systems may not, *de facto*, eliminate Asian clams in Hooksett Pool. Such relevant site-specific information cannot be overlooked in any consideration to regulate the Facility's thermal discharges under CWA § 316(a).

4. p. 42, lns. 4-8. "Both studies, one conducted in the Connecticut River (Connecticut) and the other in the St. Lawrence River (Canada), found that higher winter survival rates of Asian clams occurred within the influence of the power plants' thermal discharge than in ambient areas, and that the elevated temperatures appeared to affect the clam's reproductive success, growth, and abundance (Simard et al. 2012, and Morgan et al., 2003)"

   This statement made by EPA about the contents of these studies are generally true; however, EPA failed to examine a third, very important and relevant peer-reviewed journal article that studied the relationship between Asian clams and thermal discharges from a power plant. Morgan *et al.* (2004) produced a more extensive follow-up monograph to the Morgan *et al.* (2003) paper, cited here by EPA, where they expound more on some of their original conclusions. This Morgan *et al.* (2004) paper provides a more thorough examination of the relationship between the Connecticut Yankee (CY) power plant (Connecticut River) and the Asian clam's population dynamics as well as the Asian clam's interactions with other native bivalve species. In this paper, Morgan *et al.* (2004) state that "[t]he importance of CY thermal discharge as a refuge for [Asian clam] survival in the

Connecticut River during cold winters appears minimal." (p. 435; emphasis added). Morgan *et al.* (2004) add, "Additional evidence that the CY discharge was not necessary for survival of [Asian clam] populations in the Connecticut River is apparent when [Asian clam] abundance during CY operation (1991- 1996) was compared to abundance following the plant closure (1997-2000). Following closure of the CY power plant in 1996, the abundance of [Asian clam] at all sites was not significantly different than during the operational period." (p. 435; emphasis added). Finally, Morgan *et al.* (2004) conclude that "…annual densities during plant operation…were not significantly different from those following the plant closure…This suggests that the CY thermal discharge did not serve as an important refuge area for [Asian clam] overwintering in the vicinity of the plant." (p. 436; emphasis added). These statements clearly indicate that Morgan *et al.* (2004) did not think the discharge canal was necessary for Asian clam overwintering in the Connecticut River. The Lake George, NY, Asian clam population thriving in iced over waters during winter is a better example that thermal discharge is not necessary for an Asian clam winter refuge (Modley and Darrin, Freshwater Institute, *pers. comm.* in Simard *et al.* 2012) as are the high altitude ice-covered sites in Colorado (Cordeiro *et al.* 2007). The relevance of the findings of such a thorough follow-up, peer-reviewed study and other similar studies and information should be considered in any consideration to regulate the Facility's thermal discharges under CWA § 316(a).

Additionally, in their 2004 paper, Morgan *et al.* go on to state that "[w]hile [Asian clam] quickly established itself as the dominant bivalve in the Connecticut River, there was little change in native bivalve abundance found in the same sediments." (p. 436; emphasis added). They point out that "…these [Asian] clams took advantage of underutilized benthic resources." Finally, Morgan *et al.* (2004) conclude that, "[t]he lack of correlation between presence of [Asian clam] and abundance of native clams and mussels suggest no detrimental effect of [Asian clam] on native species in the Connecticut River." (p. 436; emphasis added). Clearly, Morgan *et al.* (2004) contend that Asian clams were not harming the native bivalve fauna and certainly were not causing appreciable harm to the native mussels. Furthermore, NHDES explicitly states that in, "2014: …While Asian clams can form dense clusters,…dominating the benthic community and altering the benthic substrate that has not yet been demonstrated [in Hooksett Pool] and have therefore been assessed as a potential problem." [emphasis added] (AR-1409). And again in, "2016: No control actions implemented, densities remain the same" [emphasis added] (AR-1409). Obviously, NHDES does not believe that Asian clams are currently causing appreciable harm to the BIP either through densities or through domination and only consider the Asian clam as a potential problem. The relevance of the findings of such a thorough follow-up, peer-reviewed study, as well as the water quality assessments by NHDES should be used in any consideration of appreciable harm to the BIP applicable to the Facility's thermal discharges under CWA § 316(a).

EPA has made similar misleading statements when citing other works elsewhere (see Nelson et al. 2015). For example, when defining the Asian clam "problem" and providing relevant background information, Nelson et al. (2015) point that "[a]s described in Caffrey et al. 2011, *Corbicula* is known to competitively impact native macro-invertebrate communities, significantly reduce phytoplankton biomass, and alter benthic substrates."

This statement reads as though Caffery et al (2011) performed a study on macroinvertebrate competition, phytoplankton biomass, and alteration of benthic substrata. In reality, Caffery et al. (2011) are merely presenting the results of a scuba survey for the presence of Asian clams in two Ireland rivers. Caffery et al. (2011), however, did state, "*Corbicula fluminea* is known to competitively impact on [sic] native macro-invertebrate communities (e.g. McMahon 1991), significantly reduce phytoplankton biomass (Lucas et al. 2002; Lopez et al. 2006), alter benthic habitats and substrates (Hakenkamp et al. 2001)…". Actually, McMahon (1991) makes no such statement about "known" competitive impacts of Asian clams, but rather points out that other studies, "…may suggest an inability of [Asian clam] to out-compete native species in most North American habitats." (McMahon 1991, p. 364). Furthermore, while Lucas et al. (2002) and Lopez et al. (2006) do point out the reduction in phytoplankton biomass by Asian clam, Lopez et al. (2006) actually confirm that higher trophic levels like zooplankton that rely on phytoplankton are unaffected. Finally, the Hakenkamp et al. (2001) study does not address alteration of benthic substrata, but does clearly and experimentally point out that Asian clam had no effect on benthic protists and invertebrates. Clearly, a thorough review and accurate presentation of the pertinent peer-reviewed literature is necessary in presenting any concerns about Asian clams in Hooksett Pool. Inaccurate representations of the peer-reviewed literature should not be used in any consideration of appreciable harm to the BIP applicable to the Facility's thermal discharges under CWA § 316(a).

5. <u>p. 42, lns. 18-23.</u> "During the sampling effort in September 2014, EPA divers collected samples and took video and photos of the river bottom in areas directly downstream of, at the mouth of, and directly upstream of the plant's discharge canal. This qualitative sampling revealed both higher densities of clams and larger individuals near the mouth of the discharge canal, as compared to clams collected farther downstream in Hooksett Pool, and in Amoskeag Pool below the Hooksett Dam."

   These 2014 EPA data appear in AR-1412. This comment is based solely on three samples, one upstream of the cooling water discharge canal, one at the mouth of the discharge canal, and the third just downstream of the discharge canal. Such a limited number of samples from which to draw conclusions is not scientifically or statistically valid or supportable. According to journal entries by Eric Nelson, these three samples were taken along a diver transect located parallel to shore and in an area of known clam abundance. This type of sample location and sample size severely limits the usefulness of these data, make it impossible to make inferences to Hooksett Pool in general, and otherwise call to question their veracity. More to this point, NHDES also conducted sampling in September 2014 (see document AR-1413) taking 17 samples from three stations; NHDES sampled station S0 at the mouth of the discharge canal, S04 approximately 2,000 ft downstream of the canal, and at S17 approximately 8,500 ft downstream of the canal. Statistical analysis of the data presented in AR-1413 showed no significant difference in Asian clam abundances among the three locations (ANOVA, $P = 0.3730$), *i.e.*, Asian clams <u>did not</u> have "…higher densities of clams...near the mouth of the discharge canal, as compared to clams collected farther downstream in Hooksett Pool" as EPA contends. Certainly the conflicting results of the two simultaneous studies should be taken into account or otherwise not used in any consideration to regulate the Facility's thermal discharges under CWA § 316(a).

6. p. 42, lns. 23-25. "Neither benthic sampling conducted by NHDES during 2013 (AR-1414), nor EPA dive investigations in 2014 (AR-1412), found evidence of Asian clams upstream from the plant in Hooksett Pool or Garvins Falls Pool."

   Normandeau Associates in 2016 diver quadrate samples and AST Environmental while conducting presence/absence Asian clam survey each found Asian clam upstream 2,500 ft upstream of the mouth of the discharge canal and upstream of the Unit 1 intake at location N5. Also, in April 2016, Normandeau divers found evidence of Asian clam over one mile upstream of the cooling water canal and on the eastern shore in Hooksett Pool. Furthermore, prior to the time the "Statement" was prepared, A. Smagula (2016) reported finding Asian clam in the Merrimack River upstream of Concord. At a minimum, this information suggests more information and data are needed on the Asian clam distribution in Hooksett Pool specifically and in the Merrimack River in general.

   This need for additional information is clearly reflected by NHDES in its Final 2014 Surface Water Quality Assessment (AR-1409) and in its Draft 2016 Surface Water Quality Assessment (AR-1407). In both 2014 and the 2016 draft, for "non-native fish, shellfish or zooplankton," NHDES gives a "3-PNS," or "insufficient data/potentially not attaining standard," rating for the section of Hooksett Pool downstream of the PSNH facility (AR-1409 and AR-1407). Furthermore, NHDES explicitly states that, "2014: …While Asian clams can form dense clusters,…dominating the benthic community and altering the benthic substrate <u>that has not yet been demonstrated [in Hooksett Pool]</u> and have therefore been assessed as a <u>potential</u> problem." And, "2016: No control actions implemented, <u>densities remain the same</u>" [emphasis added] (AR-1409). Any new findings related to the distribution and impacts of the Asian clam that augment the insufficient data should be taken into account in any consideration to regulate the Facility's thermal discharges under CWA § 316(a).

Cordeiro, J. R., Olivero, A. P., & Sovell, J. (2007). Corbicula fluminea (Bivalvia: Sphaeriacea: Corbiculidae) in Colorado. *The Southwestern Naturalist, 52*(3), 424-430.

McMahon, Robert F (2002). "Evolutionary and physiological adaptations of aquatic invasive animals: r selection versus resistance." Canadian Journal of Fisheries and Aquatic Sciences 59.7: 1235-1244.

Morgan, D. E., Keser, M., Swenarton, J. T., and Foertch, J. F. (2004). Effect of Connecticut Yankee Power Plant on population dynamics of Asiatic clams and their interactions with native bivalves. *American Fisheries Society Monograph,* (9), 419-439.

Nelson, E., A. Smagula, and H. Shook. 2015. Quantifying the density of Asian clams (Corbicula fluminea) within and beyond the influence of the thermal discharge of a power plant. Draft Quality Assurance Plan 9/30/2015. 15 pp.

Post, R. M., J. C. Petrille, and L. A. Lyons (2000). "A review of freshwater macrobiological control methods for the power industry." *Technical paper presented at the 20th Annual Electric Utility Chemistry Workshop of Illinois. University of Illinois, Champaign*. 2000.

USGS. (2017) Nonindigenous Aquatic Species Information Source. http://nas.er.usgs.gov [accessed 9/5/2017].

c) AR-1299 through AR-1307 (PSNH's response to EPA's request for information (excluding any CBI materials)).

Exert from the EPA "Statement" related to the Asian clam:

2. New Information Concerning the Presence of the Asian Clam (*Corbicula fluminea*) in Hooksett Pool and Substantial New Questions Regarding the Import of this Information for Application of CWA § 316(a) and New Hampshire Water Quality Standards to the Merrimack Station NPDES Permit

During the public comment period on the 2011 Draft Permit, PSNH submitted comments including a report by its consultant, Normandeau, entitled, "Comparison of Benthic Macroinvertebrate Data Collected from the Merrimack River near Merrimack Station During 1972, 1973, and 2011," dated January 2012. (Normandeau 2012). AR-870. In reviewing this report, EPA became aware of the presence of non-native organisms in Hooksett Pool; in particular, the Asian clam (*Corbicula fluminea*). The presence of this highly invasive species, (*see* Sousa et al. 2008, AR-1406), appeared notably concentrated in areas of Hooksett Pool with water temperatures directly affected by the plant's thermal discharge. *See* AR-870. The data provided in the report did not reveal if any individual Asian clams were collected in samples taken upstream from the plant's thermal discharge, but they were not listed as the dominant taxon. *See* AR-870, p. 12-14. Of the 18 samples taken at or downstream of the plant's discharge canal, however, Asian clams were the dominant taxon in 14 of them, ranging in relative abundance from 58 to 94 percent, with a mean of 78.6 percent at the sites where they were dominant. *Id.*, pp. 12-14.

EPA found this discovery worthy of further research because of the possibility that Merrimack Station's thermal discharge was contributing to the presence and/or prevalence of the Asian clam in the Hooksett Pool and the potential relevance of such a finding to regulating the Facility's thermal discharges under CWA § 316(a) and New Hampshire water quality standards. As explained in detail previously, CWA § 316(a) variance-based temperature limits must assure the protection and propagation of the balanced indigenous population of organisms, *see* AR-618, pp. 18-23, while New Hampshire water quality standards impose similar requirements for the protection of local aquatic life. *See id.*, pp. 174-178.

The Asian clam is widely distributed in the United States, but its limited presence in northern New England has been attributed to prolonged periods of cold water temperatures and ice cover that is believed to cause high mortality during winter months (Simard et al., 2003) (*See* AR-1404). When PSNH submitted its report in 2012, the presence of Asian clams in New Hampshire had only been documented in the Merrimack River south of Bow, New Hampshire, and in Cobbetts Pond, in Windham, New Hampshire, according NHDES's environmental fact sheet on Asian clams (NHDES, 2012) (*See* AR-1408). NHDES later documented them in Long Pond, as well. EPA notes that when Merrimack Station is operating, one of its most visible thermal effects can occur during periods in the winter when the river just upstream of the discharge canal is completely ice-covered, but the river is ice-free for miles downstream of the discharge canal, including in the waters of Amoskeag Pool below Hooksett Dam. *See, e.g.,* Satellite photo of Hooksett Pool taken on February 27, 2014 (AR-1894*)*.

EPA reviewed two peer-reviewed journal articles that studied the relationship between Asian clams and thermal discharges from power plants. Both studies, one conducted in the Connecticut River (Connecticut) and the other in the St. Lawrence River (Canada), found that higher winter survival rates of Asian clams occurred within the influence of the power plants' thermal discharge than in ambient areas, and that the elevated temperatures appeared to affect the clam's reproductive success, growth, and abundance (Simard et al. 2012, and Morgan et al., 2003) (*see* AR-1404 and AR-1405).

In response to interest and concern over the presence of Asian clams in Hooksett Pool, EPA not only evaluated the data provided by PSNH, *see* AR-870, and the literature cited above, but the Agency also collaborated with NHDES in 2013 (AR-1414) and 2014 (AR-1413) on a study to investigate the presence and abundance of Asian clams in the Hooksett Pool and other locations in New Hampshire. Sampling was conducted in July and November of 2013, and in September, 2014. Stations sampled by Normandeau in 2011 were revisited, while sites upstream of the Facility's discharge canal, including stations in Garvins Pool, and sites downstream of the discharge in Amoskeag Pool, were also investigated. During the sampling effort in September 2014, EPA divers collected samples and took video and photos of the river bottom in areas directly downstream of, at the mouth of, and directly upstream of the plant's discharge canal. This qualitative sampling revealed both higher densities of clams and larger individuals near the mouth of the discharge canal, as compared to clams collected farther downstream in Hooksett Pool, and in Amoskeag Pool below the Hooksett Dam. Neither benthic sampling conducted by NHDES during 2013 (AR-1414), nor EPA dive investigations in 2014 (AR-1412), found evidence of Asian clams upstream from the plant in Hooksett Pool or Garvins Falls Pool. The arrival of invasive Asian clams in NH represents a threat to the state's water quality. Their presence is regulated in New Hampshire, and it is illegal to import, possess or release Asian clams in the state, according to NHDES (NHDES 2012) (AR-1408).

Furthermore, in its Final 2014 Surface Water Quality Assessment (AR-1409), NHDES listed "non-native fish, shellfish or zooplankton" as a parameter that rated a "3-PNS," or "insufficient data/potentially not attaining standard," for the section of Hooksett Pool downstream from the Facility (NHIMP700060802-02). The same rating was applied to the Hooksett Pool bypass, just below the Hooksett Dam (NHRIV700060802-14-01) and in the Amoskeag Pool of the Merrimack River (NHRIV700060802-14-02) *See* AR-1409. Notably, there is no such listing for either the section of river immediately upstream of the plant's discharge canal within Hooksett Pool (NHRIV700060302-25-02), or for the section of river upstream of Merrimack Station in the southern end of Garvins Pool (NHRIV700060302-24). *See* AR-1409. These ratings have all remained unchanged in the latest,2016, draft Surface Water Quality Assessment by NHDES (AR-1407).

In response to a PSNH request for records under the Freedom of Information Act, EPA has already shared this Asian clam-related data with the Company. By this notice, EPA is also informing other potentially interested persons of this information. EPA also notes that in response to seeing the Asian clam data, PSNH hired a consultant scientist to evaluate the Asian clam issue and the Company has indicated that it will be submitting a report to EPA about the Asian clam in the near future. *See* AR-1364 (Email from Linda T. Landis, Senior Counsel, Eversource Energy, to Mark Stein, EPA Region 1 (March 10, 2017)). In this regard, PSNH stated as follows:

> … we have one the country's leading experts on the propagation of the [A]sian clam preparing a report documenting the results from his diving surveys in the Merrimack River over the last few years, his review of the NHDES [A]sian clam survey results, as well as a summary of his in-depth research on this topic. Based on my review of the FOIA response documents, I expect this report will be of particular interest to Eric Nelson. We hope to have this complete in early May.

Id. No report was submitted in early May, but EPA still expects PSNH to submit this report either by the time EPA has issued this notice or along with its comments in response to this notice.

EPA invites public comments addressing the information discussed above indicating the presence of the Asian clam in the Hooksett Pool, as well as comments addressing the import of this information for setting thermal discharge limits for the Merrimack Station permit under CWA § 316(a) and/or New Hampshire water quality standards. (As stated previously, EPA extensively discussed the requirements of CWA § 316(a) and New Hampshire water quality standards related to thermal conditions in Chapters 4 and 8 of the 2011 Draft Permit Determinations.) EPA also invites comments addressing the following specific items in the administrative record for the Merrimack Station permit that are related to the Asian clam issue and were added to the administrative record for the permit after closure of the public comment period for the 2011 Draft Permit:

AR-1405. Morgan, D.E., J.T. Swenarton, and J.F. Foertch. 2003. Population dynamics of the Asiatic clam, *Corbicula fluminea* (Müller) in the lower Connecticut River: establishing a foothold in New England. J. Shellfish Res., 22 (1) 193-203. New Hampshire Department of Environmental Services. 2012. Environmental Fact Sheet: Asian Clams in New Hampshire. 3 pp.

AR-1409. NHDES Surface Water Quality Assessments. New Hampshire Watershed Report Card FINAL 2014 305(b)/303(d). http://www4.des.state.nh.us/WaterShed_SWQA//WaterShed_SWQA.aspx. 89 pp.

AR-1407. NHDES Surface Water Quality Assessments. New Hampshire Watershed Report Card DRAFT 2016 305(b)/303(d). http://www4.des.state.nh.us/WaterShed_SWQA//WaterShed_SWQA.aspx. 62 pp.

AR-870. Normandeau (Normandeau Associates, Inc.). 2012. Comparison of Benthic Macroinvertebrate Data Collected from the Merrimack River near Merrimack Station During 1972, 1973, and 2011. 17 pp.

AR-1404. Simard, M. Anouk, Annie Paquet, Charles Jutras, Yves Robitaille, Pierre U. Blier, Réhaume Courtois and André L. Martel. 2012. North American range extension of the invasive Asian clam in a St. Lawrence River power station thermal plume. Aquatic Invasions, 7 (1) 81-89.

AR-1406. Sousa, R., C. Antunesand L. Guilhermino. 2008. Ecology of the invasive Asian clam *Corbicula fluminea* (Müller, 1774) in aquatic ecosystems: an overview. Ann. Limon. – Int. J. Lim., 44 (2), 85-94.