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Analysis of Merrimack Station Fisheries Survey Data for 2010-2013

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Introduction

During the 4 years from 2010 through 2013, Normandeau Associates performed extensive electrofishing surveys in the Garvins, Hooksett, and Amoskeag pools of the Merrimack River (Normandeau 2011, 2017). During all 4 years samples were collected at the same 24 stations (6 in Garvins Pool, 12 in Hooksett Pool, and 6 in Amoskeag Pool), during the months of August and September. The same sampling procedures were used at every station during each of these 4 years. In addition, in 2012, spring sampling was conducted in all 3 pools to obtain information concerning the spawning condition of 2 species of interest, white sucker and yellow perch. These 2 species were identified by EPA as being thermally-sensitive species that have declined in abundance because of Merrimack Station's thermal discharge.

The 2 reports documenting these data are each organized into 3 major sections that address:

1) The compositions of the fish communities in the 3 pools during 2010-2013,
2) Trends in population abundance and community composition within Hooksett Pool, including comparison of recent data to data collected from 1972 through 2007, and
3) Biocharacteristics of Representative Important Species ("RIS") and other resident fish species, such as length-weight relationships, age-length relationships, mortality, parasitism, and (for white sucker and yellow perch) reproductive characteristics.

These surveys provide a high-quality data set for evaluating whether the operation of Merrimack Station is causing observable adverse changes in the fish community of the Hooksett Pool, as compared to communities in upstream and downstream pools. Examples of such changes would be comparatively low or high abundance of thermally sensitive fish species, anomalous values of community metrics, or impaired reproductive condition. Absence of these types of changes would indicate that the fish community in Hooksett Pool is not being affected by station operations.

The fact that the surveys included both upstream and downstream pools is especially important. If only the upstream Garvins Pool had been sampled, any differences between Hooksett and Garvins Pools could be due to natural upstream-downstream gradients in physical and biological conditions, not due to Merrimack Station's thermal discharge. The existence of such gradients was recognized more than 100 years ago (e.g., Shelford 1911), and is well-established in the ecological literature (Vannote et al. 1980). According to these ecological principles, the fish communities in Garvins, Hooksett, and Amoskeag pools should be different, but should differ in ways that are consistent with the expected upstream to downstream gradient in environmental conditions. Specifically, Garvins and Amoskeag Pools should be less similar to each other than either is to Hooksett Pool. Finding that these pools are *more* similar to each other than to Hooksett Pool would indicate that Hooksett Pool deviates from the expected gradient and could be adversely affected by Merrimack Station.

Fish community composition in Garvins, Hooksett, and Amoskeag pools

Relative abundance and catch-per-unit effort analyses

Tables 2-7 and 2-11 of Normandeau (2011) provide data on the total catch and relative abundance of fish species caught in Garvins, Hooksett, and Amoskeag pools in 2010 and 2011. Tables 2-4 and 2-5 of Normandeau (2017) provide the same data for the years 2012 and 2013. Comparison of these tables shows that, despite substantial year-to-year variability in the relative abundance of species within each pool, there are clear consistencies within each pool as well. Tables 1, 2, and 3 of this report list in descending order the 10 most abundant fish species within each pool during each year. Alewife was excluded from these lists because this species is maintained by stocking rather than by natural reproduction. These tables show that, except for a few occasionally abundant species such as tessellated darter (Garvins Pool, 2010) and margined madtom (Amoskeag Pool, 2012), the most abundant species during all 4 years were species discussed in

Table 1. The 10 most abundant species in Garvins Pool, by year.

2010	2011	2012	2013
Spottail shiner	Spottail shiner	Spottail shiner	Bluegill
Largemouth bass	Yellow perch	Largemouth bass	Pumpkinseed
Yellow perch	Bluegill	Bluegill	Yellow perch
Pumpkinseed	Largemouth bass	Fallfish	Largemouth bass
Chain pickerel	Pumpkinseed	Pumpkinseed	Chain pickerel
Bluegill*	Chain pickerel	Yellow perch	Spottail shiner
Tesselated darter*	Fallfish	Chain pickerel	Redbreast sunfish
Smallmouth bass	Smallmouth bass	Sunfish family	Smallmouth bass
Redbreast sunfish	White sucker	Redbreast sunfish	White sucker
Fallfish	Common shiner	Common shiner	Fallfish

*Tied values.

Table 2. the 10 most abundant species in Hooksett Pool, by year.

2010	2011	2012	2013
Spottail shiner	Fallfish	Largemouth bass	Bluegill
Largemouth bass	Largemouth bass	Redbreast sunfish	Fallfish
Smallmouth bass	Bluegill	Fallfish	Redbreast sunfish
Bluegill	Smallmouth bass	Bluegill	Pumpkinseed
Redbreast sunfish*	Spottail shiner	Smallmouth bass	Largemouth bass
Fallfish*	Yellow perch	Spottail shiner	Yellow perch
Sunfish family*	Redbreast sunfish	Sunfish family	White sucker
White sucker	White sucker	White sucker	Smallmouth bass
Common shiner	Pumpkinseed	Pumpkinseed	Chain pickerel*
Pumpkinseed	Common shiner	Yellow perch	Golden shiner*

*Tied values.

Table 3. The 10 most abundant species in Amoskeag Pool, by year.

2010	2011	2012	2013
Smallmouth bass	Smallmouth bass	Redbreast sunfish	Bluegill
Redbreast sunfish	Bluegill	Largemouth bass	Redbreast sunfish
Largemouth bass	Redbreast sunfish	Bluegill	Pumpkinseed
Bluegill	Pumpkinseed	Smallmouth bass	Smallmouth bass
White sucker	Fallfish	Pumpkinseed	Fallfish
Rock bass	American eel*	Rock bass	Largemouth bass
Pumpkinseed	Chain pickerel*	Fallfish	Yellow perch
Golden shiner	White sucker*	Chain pickerel*	Rock bass
Chain pickerel*	Yellow perch*	Margined madtom*	Chain pickerel*
Yellow perch*	Largemouth bass**	Sunfish family*	White sucker*
	Sunfish family**		

*Tied values. **Tied values.

EPA's §316 Determination and identified as RIS by Normandeau (2011, 2017). Within each pool, the same species tended to be numerically most abundant in most or all 4 years. Table 4 lists, for each pool, the species that were among the 10 most abundant in all 4 years. There were 7 such species in Garvins and Hooksett Pools, and 6 in Amoskeag Pool.

Thermal preference classifications for all of these species are provided in Table 4. Table 4 shows that the numerically most abundant species in all 3 pools included a mix of warmwater, coolwater, and warmwater/coolwater species. Three coolwater species were numerically most abundant in Garvins Pool, as compared to 2 in Hooksett Pool and 1 in Amoskeag Pool.

Although this pattern suggests a potential upstream-downstream gradient in thermal preference, examination of the percent contribution of coolwater species to the total catch does not support the existence of such a gradient. Table 5 presents the percent contribution of fish classified as coolwater species by Barnthouse (2017) to the total catch within each pool during the years 2010-2013. The percent contributions of coolwater fish to the total catch in Hooksett Pool is actually higher than in Garvins Pool for 3 of the 4 years.

Although no upstream-downstream trends in thermal preference are evident in the survey data, there is a clear trend in taxonomic composition, specifically in relative abundance of species belonging to the family Centrarchidae. The centrarchids are among the most diverse and abundant groups of freshwater fish in North America. Centrarchids collected in the Garvins, Hooksett, and Amoskeag pools during 2010-2013 include black crappie, bluegill, largemouth bass, pumpkinseed, redbreast sunfish, rock bass, and smallmouth bass. Four of the 5 most abundant species in Amoskeag Pool are centrarchids, as are 4 of the 6 most abundant species in Hooksett Pool. Table 6 shows the percentage of species in each pool that were centrarchids, for each of the years 2010 through 2013. The trend is clear. For all 4 years, centrarchids contributed the greatest

Table 4. Species that were among the 10 most abundant in all 4 years.

Garvins	Hooksett	Amoskeag
Spottail shiner (WW)	Largemouth bass (WW)	Largemouth bass (WW)
Largemouth bass (WW)	Smallmouth bass (WW)	Smallmouth bass (WW)
Yellow perch (CW)	Bluegill (WW)	Redbreast sunfish (WW)
Pumpkinseed (CW/WW)	Redbreast sunfish (WW)	Bluegill (WW)
Chain pickerel (CW)	Fallfish (CW)	Pumpkinseed (CW/WW)
Bluegill (WW)	White sucker (CW)	Chain pickerel (CW)
Fallfish (CW)	Pumpkinseed (CW/WW)	

Table 5. Percent of all fish collected that are classified as coolwater species

	Garvins	Hooksett	Amoskeag
2010	12.9	5.6	12.2
2011	33	37.1	6.8
2012	11.8	18	7.3
2013	20.5	28	10.9

Table 6. Percent of all fish collected belonging to the family Centrarchidae

	Garvins	Hooksett	Amoskeag
2010	34.1	58.5	88.5
2011	22.0	53.5	91.7
2012	24.3	76.1	91.1
2013	65.7	65.7	83.8

percentage of the total fish community in Amoskeag Pool and the least in Garvins Pool. Hooksett Pool was intermediate with respect to percent centrarchids in all 4 years. Upstream-downstream gradients in abundance of individual fish species are also apparent in the fish community survey data, although these are not related to thermal preferences. Tables 2-8 and 2-12 of Normandeau (2011) provide, respectively, catch-per-unit effort (CPUE) values for fish species collected during 2010 and 2011. Tables 2-6 and 2-9 of Normandeau (2017) provide the same estimates for 2012 and 2013. Table 7 of this report presents, for each of the 13 species abundant enough for any upstream-downstream trend in abundance to be identified, the average CPUE over all 4 years in each pool. If differences in the abundances of fish species between pools were due to chance alone, we would expect that for any given pool approximately 1/3 of these species would be more abundant than in any other pool, 1/3 would be less abundant than in any other pool, and 1/3 would be intermediate in abundance between the other pools. However, Table 7 shows that this is not the case. Instead, 7 of the 13 species were more abundant in Garvins Pool than in any other pool, 10 were less abundant in Amoskeag Pool than in any other pool, and 8 were intermediate in abundance in Hooksett Pool. The total CPUE for all species followed the same pattern (Table 7): Total CPUE was highest in Garvins Pool, lowest in Amoskeag Pool, and intermediate in Hooksett Pool.

This result implies that there is a clear upstream-downstream gradient in fish abundance within these three pools, consistent with established ecological principles (Shelford 1911, Vannote et al. 1980). Abundance is highest in the upstream Garvins Pool, lowest in downstream Amoskeag Pool, and intermediate in Hooksett Pool.

Table 7. Average CPUE of common fish species over the period 2010-2013. Species in boldface are species whose abundance in Hooksett Pool was intermediate between abundances in Garvins Pool and Amoskeag Pool.

	Garvins	Hooksett	Amoskeag
Bluegill	3.35	**2.66**	1.15
Chain pickerel	1.43	**0.20**	0.10
Common shiner	0.33	0.33	0.00
Fallfish	1.03	2.50	0.20
Largemouth bass	4.75	**4.74**	0.58
Pumpkinseed	2.33	**1.19**	0.85
Redbreast sunfish	0.58	1.91	1.78
Rock bass	0.10	**0.15**	0.20
Smallmouth bass	0.48	2.15	1.95
Spottail shiner	15.03	**2.64**	0.00
Sunfish family	0.35	**0.31**	0.05
White sucker	0.25	0.74	0.13
Yellow perch	3.35	**0.75**	0.13
Total	33.33	**20.26**	7.10

Community similarity indices

In addition to providing species-specific abundance data for each pool, Normandeau (2011, 2017) performed several analyses that condense the species-specific data into index values that quantify the similarities between the fish communities in Garvins, Hooksett, and Amoskeag pools.

The Bray-Curtis similarity index has a maximum value of 100% if the two communities being compared are identical, i.e., if they have exactly the same species and the number of individuals belonging to each species are equal. It has a minimum value of 0% if the 2 communities have no species in common. Table 2-18 of Normandeau (2011) presents Bray-Curtis similarities for the years 2010 and 2011. For each year, there are 3 pairwise comparisons: Garvins Pool vs Hooksett Pool, Hooksett Pool vs Amoskeag Pool, and Garvins Pool vs Amoskeag Pool. For both years, the Garvins Pool vs. Amoskeag Pool similarity values are the lowest of the 3. Tables 2-16 and 2-19 of Normandeau (2017) present the similarity values for 2012 and 2013. The results are the same as for 2010 and 2011: the Garvins Pool vs. Amoskeag Pool values are the lowest of the 3 pairs. These results imply that, for all of the years examined, the fish communities in Garvins and Amoskeag Pools were less similar to each other than either was to Hooksett Pool. In other words, moving from upstream to downstream, the fish communities become less similar, consistent with established ecological principles (Shelford 1911, Vannote et al. 1980).

The ANOSIM[1] analysis performed by Normandeau (2011, 2017) also evaluates similarities in species composition between communities. The "R" statistic calculated by the ANOSIM software has a minimum value of 0 if the communities being compared are identical, and a maximum value of 1 if they share no species in common. Normandeau

[1] ANOSIM (Analysis of Similarity) is a method of data analysis widely used by ecologists to compare variations in species abundance and composition among sampling units such as the Garvins, Hooksett, and Amoskeag pools of the Merrimack River.

(2011) used ANOSIM to quantify the influences of Pool (Garvins, Hooksett and Amoskeag), year (2010 and 2011) and month (August and September) on fish communities in the Merrimack River. Results are presented in Table 2-21 of Normandeau (2012). Year and month were found to have no significant[2] influence on fish community structure. Fish community structure did, however differ significantly among pools.[3] As measured using the R statistic, Garvins and Amoskeag Pools were more different from each other than either was from Hooksett Pool. Tables 2-15 and 2-18 of Normandeau (2017) present results of the ANOSIM analysis for 2012 and 2013. In both years, the R-statistic was higher for the Garvins vs. Amoskeag comparison than for the either the Garvins vs. Hooksett or the Amoskeag vs. Hooksett comparison. These results are consistent with the Bray-Curtis analysis in indicating that Garvins and Amoskeag Pools are less similar to each other than either is to Hooksett Pool.

One additional community analysis method was used for between-pool comparisons in Normandeau (2017). A method termed “multidimensional scaling” (MDS) was used to graphically plot patterns of community-level similarity among pools. The MDS methodology produces plots in which each point represents the species composition of the fish collected at a specific station during a specific month. The distances between 2 points on the MDS plot is a measure of the magnitude of the difference in composition of the fish collection between those 2 station by month combinations. Because there were 12 stations sampled in Hooksett Pool and 6 each in Garvins and Amoskeag Pools, the plots for each year contain 24 points for Hooksett Pool (12 for August and 12 for September) and 12 points each for Garvins and Amoskeag Pools. As shown in Figures 2-2 and 2-3 of Normandeau (2017), the MDS plots are consistent with the results of the Bray-Curtis and ANOSIM analyses. There is little or no overlap between the clusters of points representing Garvins and Hooksett Pools, and the cluster representing Hooksett Pool overlaps both of the other 2 clusters.

[2] Throughout this report, the term “significant” refers to statistical significance.
[3] Note that column headings for the Pool analysis in Table 2-21 are incorrect. The headings for the Hooksett and Amoskeag columns are reversed.

Hence, 3 different methods for community-level analysis of the 2010-2013 fish survey data all support the same conclusion: The fish communities in the upstream Garvins Pool and the downstream Amoskeag Pool are both more similar to the intermediately located Hooksett Pool than they are to each other, consistent with established ecological principles (Shelford 1911, Vannote et al. 1980).

Long-term abundance trends in Hooksett Pool

The two Normandeau reports contain similar analyses of population trends in Hooksett Pool, based on data collected in the 1970s, 1995, and the 2000s. Because the analyses performed in Normandeau (2017) are essentially the same as in Normandeau (2011) but included all of the years of available data, only Normandeau (2017) is discussed here.

Figure 3-1 of Normandeau (2017) presents trends plots for 15 fish species collected from 1972 through 2013; Table 3-4 of Normandeau (2017) presents results of statistical trends analyses. All fish were collected by electrofishing during the months of August and September. According to Table 3-4, statistically significant trends were found for only 3 species: pumpkinseed, which declined over the time series, and black crappie and rock bass, which increased. However, high inter-annual variability can make trends in abundance difficult to detect. In constructing Table 3-4, Normandeau applied a significance criterion of 0.05, meaning that an apparent trend was assumed to be significant, i.e., to indicate an actual trend in the abundance of a species, only if there was a 5% or smaller probability that the trend could have occurred through chance alone. Less restrictive criteria are sometimes used in interpreting field data to reduce the risk of falsely concluding that no trend exists, when an actual trend is present but being obscured by inter-annual variability. Using a significance criterion of 0.1 instead of 0.05, an apparent decline would be assumed significant if there were a 10% probability that the trend could have occurred through chance alone. Using this less restrictive criterion, apparent declines in abundance of brown bullhead and yellow perch would also be statistically significant.

None of the above trends can be interpreted as indicating adverse impacts of Merrimack Station's operations on the Merrimack River fish community. Of the increasing species, rock bass is a warmwater species and black crappie is a coolwater species. Of the declining species, yellow perch is a coolwater species, yellow bullhead is a warmwater species, and pumpkinseed and brown bullhead have been classified as both warmwater and coolwater by different authorities.

Considering the fish community as a whole, there have clearly been changes between the 1970s and the 2000s. Figure 3-2 of Normandeau (2017) provides an MDS plot similar to Figures 2-2 and 2-3. In this case, the points represent species compositions of samples collected during different groups of years rather than different pools. Figure 3-2 shows that samples collected during the 1970s and the 2000s form distinct clusters that do not overlap. Figure 3-2 also shows that 1995 is an outlier year that does not show any distinct clustering at all. As shown in Figure 3-1 of Normandeau (2017), 1995 was a year in which 2 species, bluegill and spottail shiner occurred at extremely high densities that were not repeated in later years. Clearly, the 1995 data are not comparable to either earlier or later years and for this reason are not useful for interpreting changes in the Hooksett Pool fish community through time.

The trends analyses discussed above show that there have been changes in the fish community of Hooksett Pool over the period 1972-2013. Some species have declined in abundance while others have increased, but many species have simply fluctuated in abundance without any apparent trend. As discussed by Normandeau (2011) and Barnthouse (2016), it is likely that some of the changes in the fish community are consequences of improved water quality. However, there is no indication that these changes reflect differences in thermal preferences between species that are currently numerically dominant in the Hooksett Pool and species that were numerically dominant in the 1970s.

Biocharacteristics of selected Merrimack River fish species

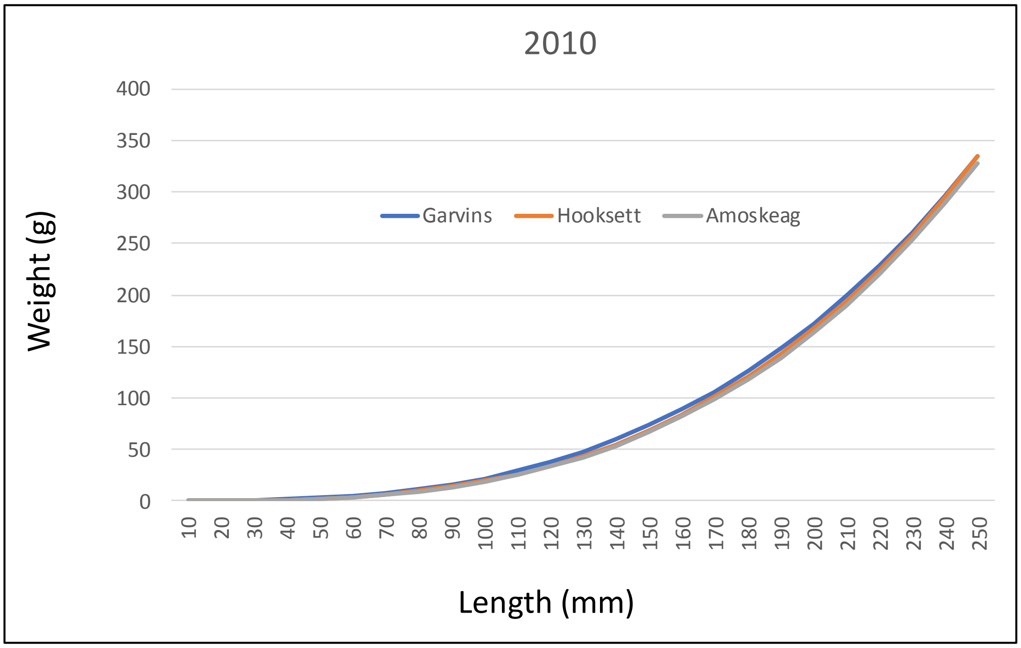
In addition to information on community composition and abundance trends, Normandeau (2011) and Normandeau (2017) present data on the length, weight, age, parasitism and mortality for various fish species present in the Garvins, Hooksett, and Amoskeag Pools of the Merrimack River. In addition, Normandeau (2017) contains data on the reproductive characteristics of white sucker and yellow perch collected during March and April of 2012. These data permit additional comparisons between the fish populations present in these 3 pools. Length-weight relationships, incidence of parasitism, and reproductive characteristics are especially important because all of these measures reflect the health of fish potentially exposed to elevated temperatures resulting from Merrimack Station's thermal discharge.

Length-weight relationships

Length-weight relationships can provide information concerning the condition of the fish present in a population. If the weight of fish at a given length is unusually small compared to the weight of an average fish of that length, this can indicate that the smaller fish is less healthy than the average fish. If, for a population of fish, the average weight at a given length is much smaller than in other populations of the same species, this can indicate that the population containing the smaller fish is on average less healthy than other populations. Figures 1 through 10 depict length-weight relationships for bluegill, largemouth bass, pumpkinseed, redbreast sunfish, and smallmouth bass collected from Garvins, Hooksett, and Amoskeag Pools between 2010 and 2013. These species were selected because they are the only species for which the data were sufficient to compute length-weight relationships in all 3 pools for 2 or more years.

No consistent pattern in length-weight relationships is evident for any of these species. For bluegill (Figures 1 and 2), fish in Hooksett Pool were heavier at a given length than in the other 2 pools during 2011 and 2012, but lighter in 2013. In 2010, the length-weight relationships for the 3 pools were essentially identical. For largemouth bass (Figures 3 and 4), fish in Amoskeag Pool were heavier at a given length than in the other

Figure 1. Length-weight relationships for bluegill in 2010 and 2011. Plotted using slope and intercept parameters from Tables 4-4-5 and 4-4-6 of Normandeau (2012).



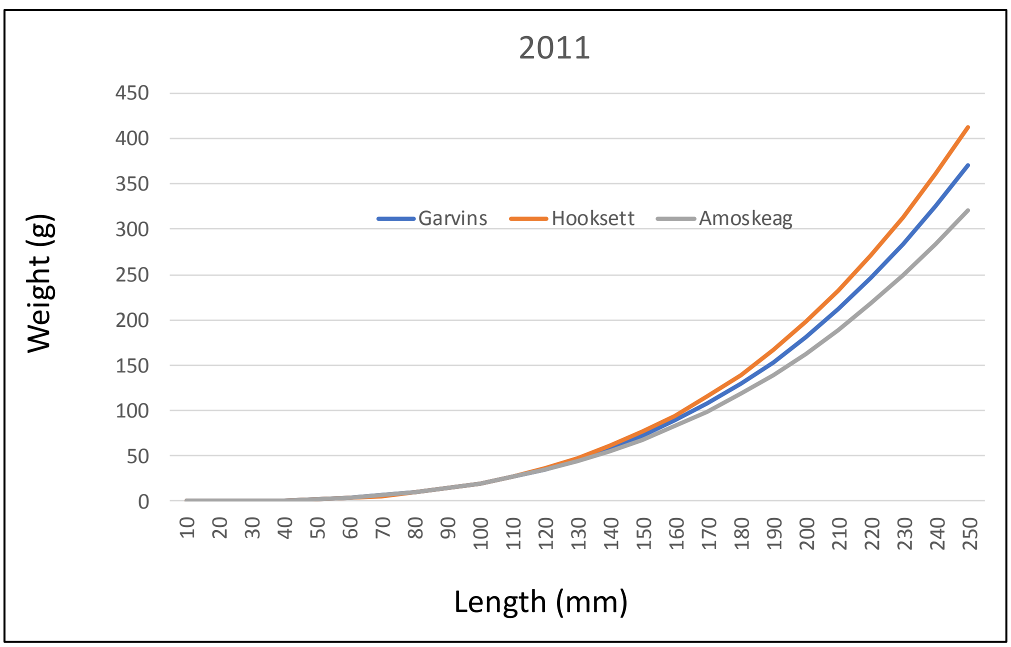
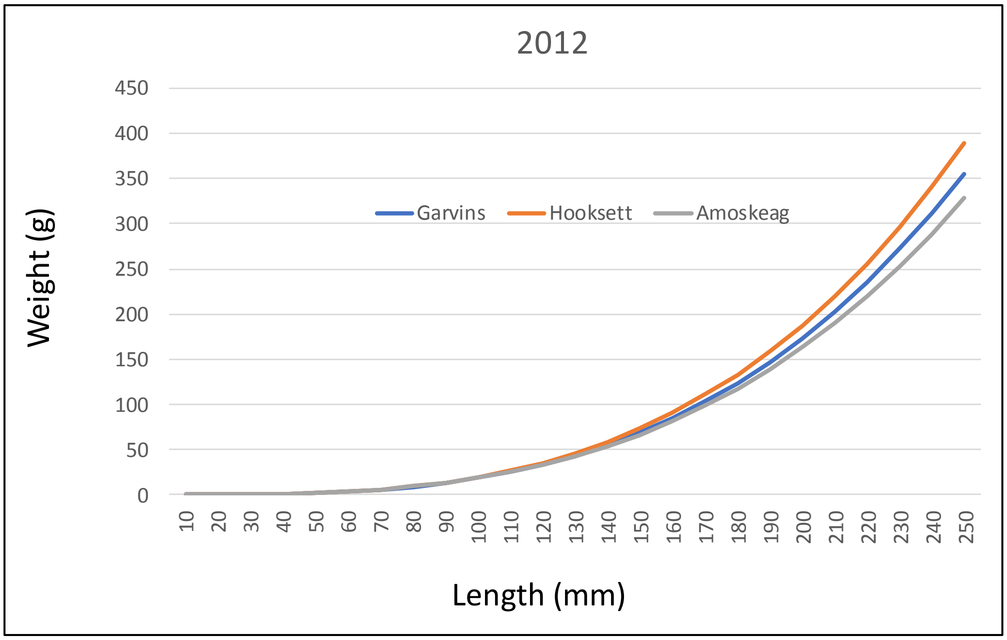


Figure 2. Length-weight relationships for bluegill in 2012 and 2013. Plotted using slope and intercept parameters from Tables 4.3.2-3 and 4.3.4-4 of Normandeau (2017).



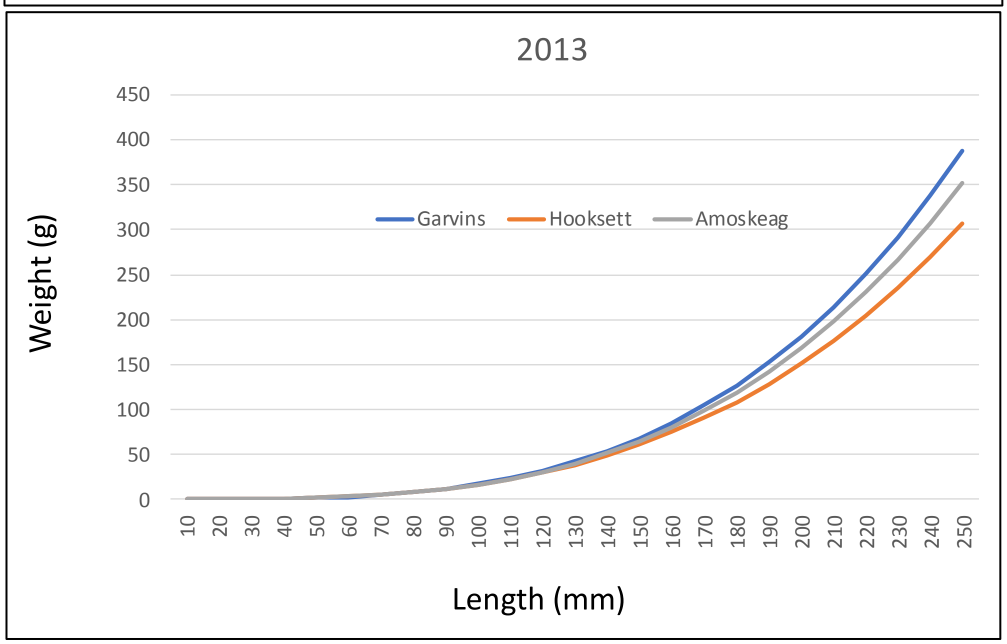
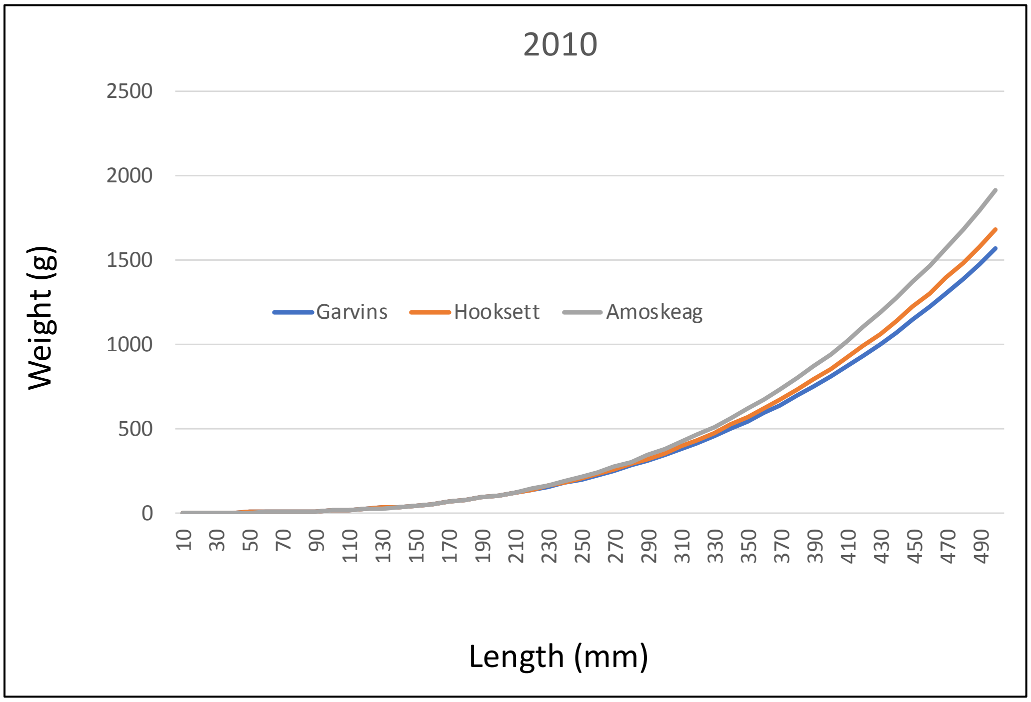


Figure 3. length-weight relationships for largemouth bass in 2010 and 2012 Plotted using slope and intercept parameters from Tables 4-8-5 of Normandeau (2012) and 4.3.5-3 of Normandeau (2017).



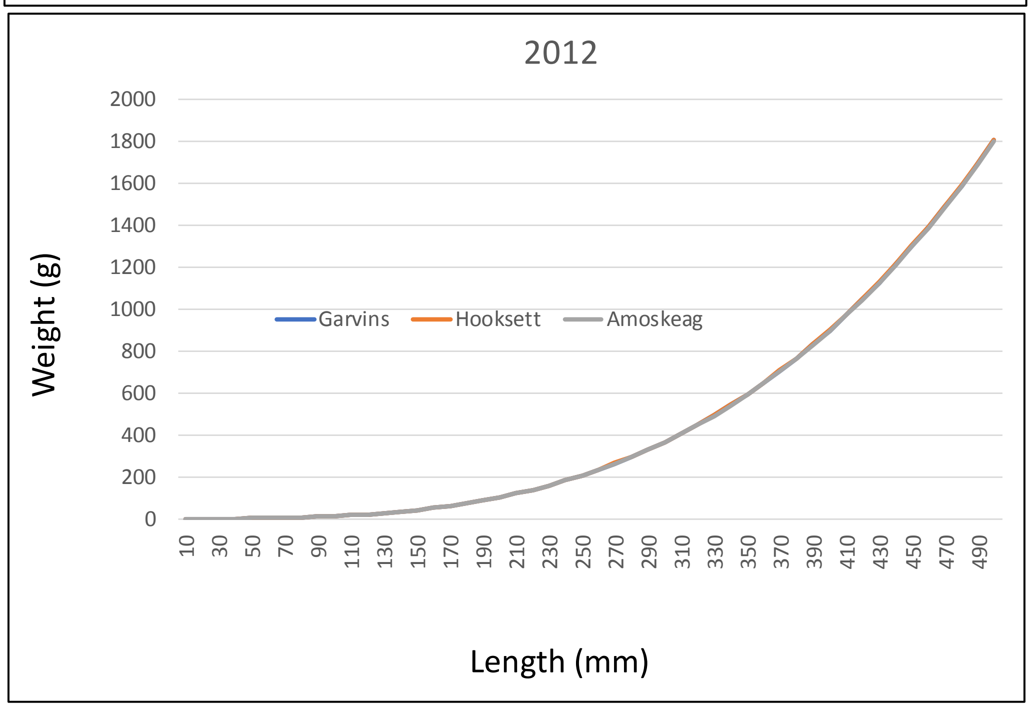


Figure 4. length-weight relationships for largemouth bass in 2013. Plotted using slope and intercept parameters from Table 4.3.5-4 of Normandeau (2017).

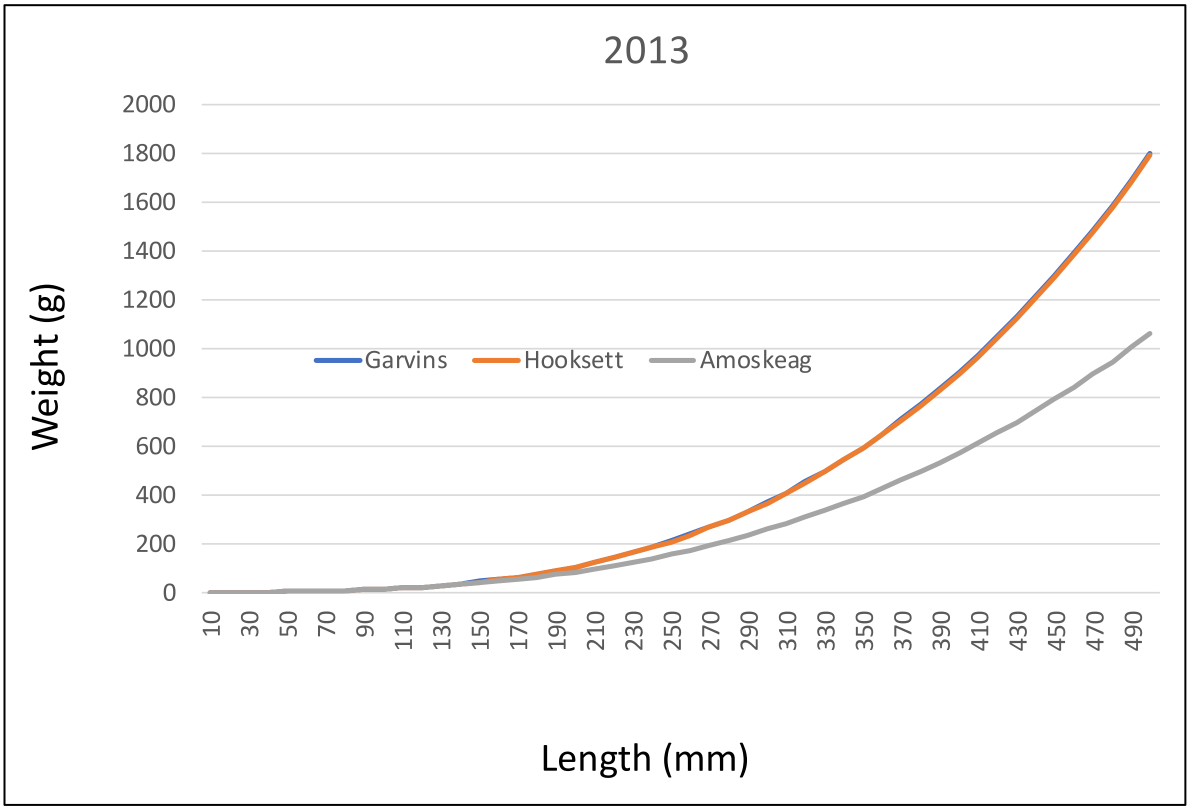
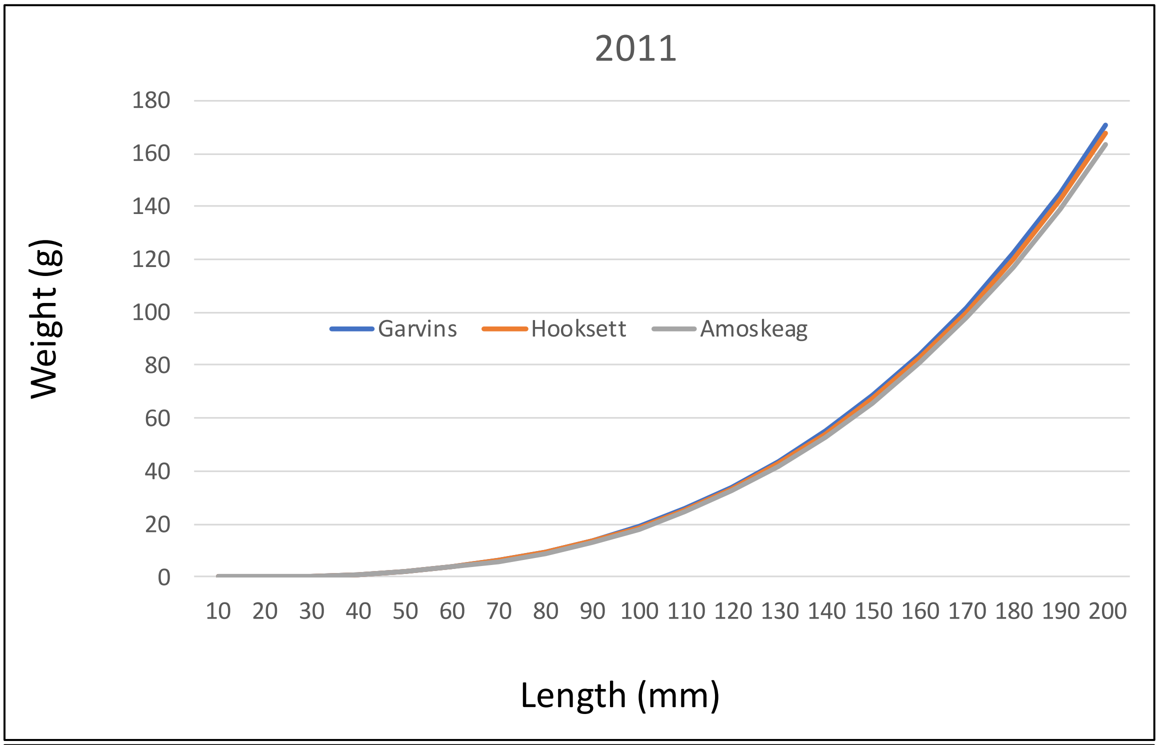


Figure 5. length-weight relationships for pumpkinseed in 2011 and 2012 Plotted using slope and intercept parameters from Tables 4-9-6 of Normandeau (2012) and 4.3.6-3 of Normandeau (2017).



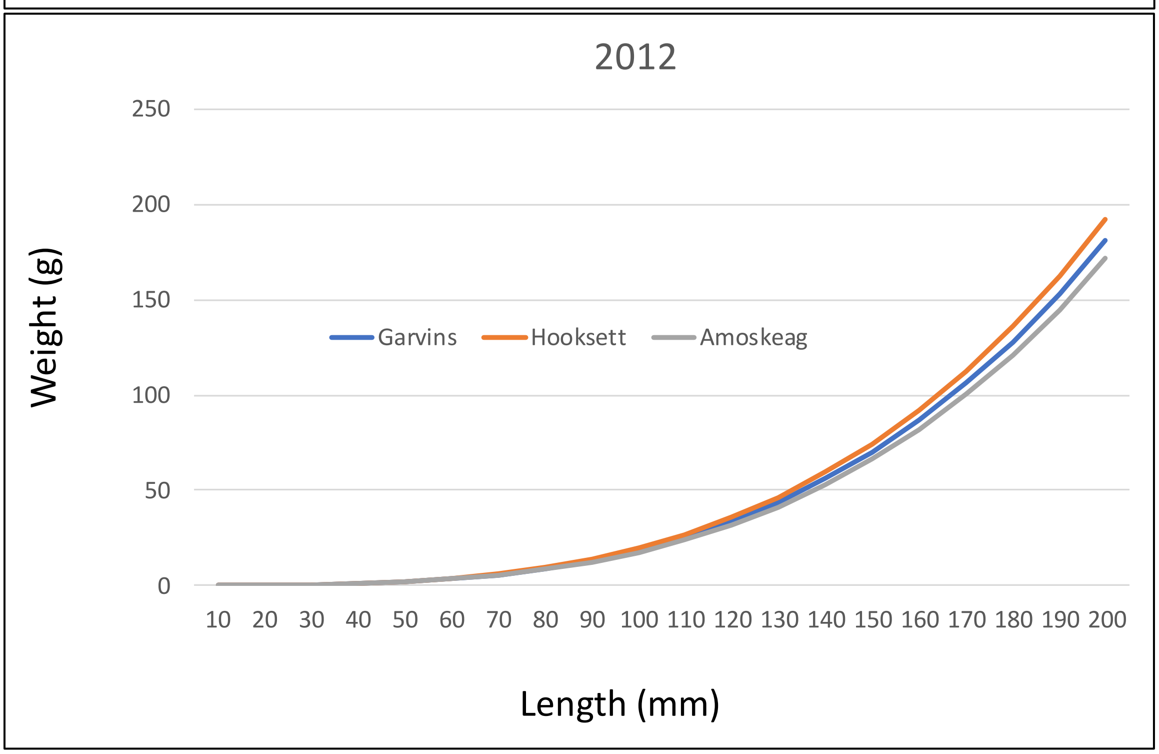


Figure 6. length-weight relationships for pumpkinseed in 2013. Plotted using slope and intercept parameters from Table 4.3.6-4 of Normandeau (2017).

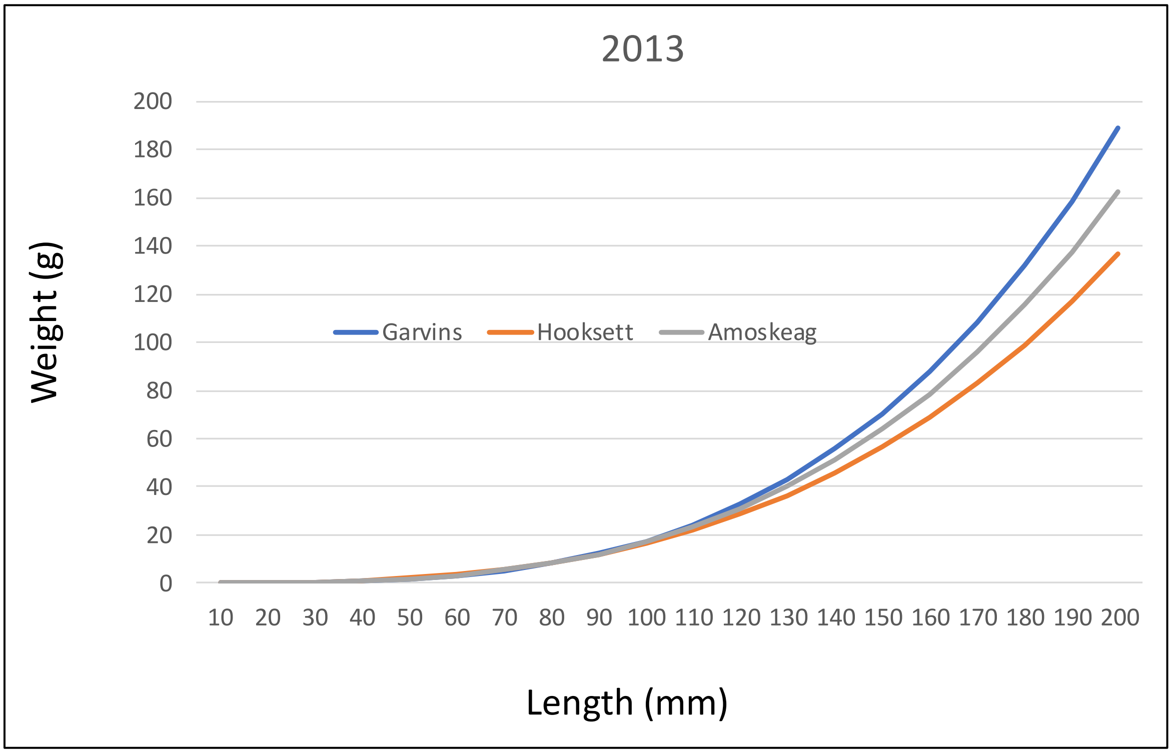
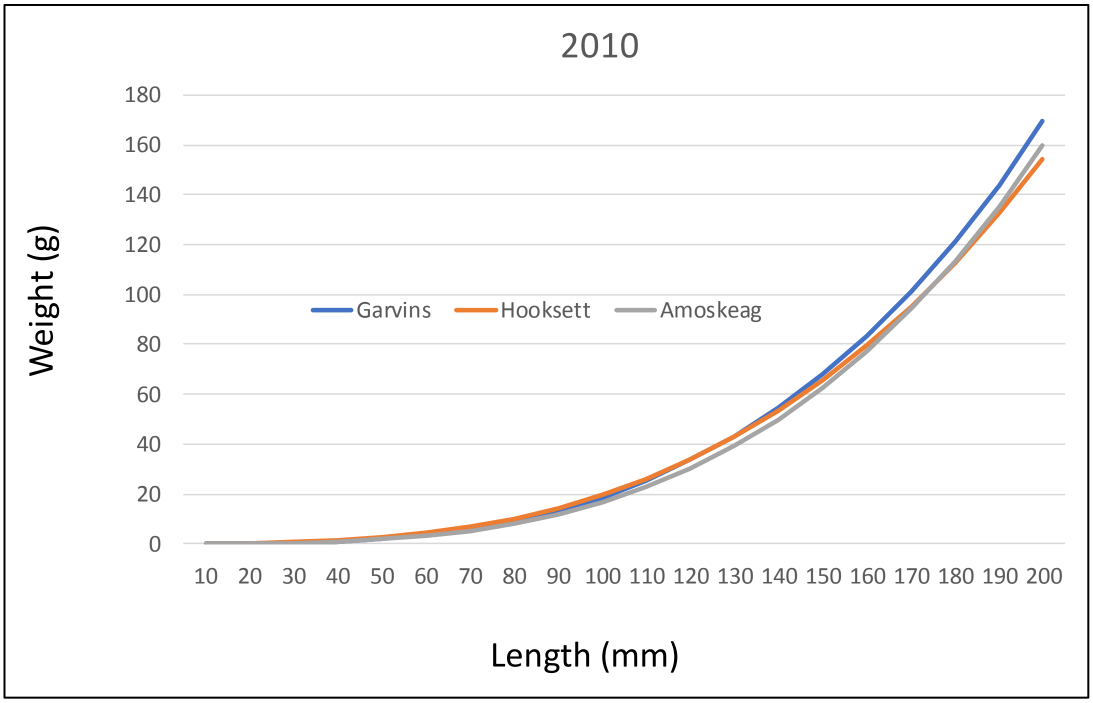


Figure 7. length-weight relationships for redbreast sunfish in 2010 and 2012 Plotted using slope and intercept parameters from Tables 4-10-5 of Normandeau (2012) and 4.3.7-3 of Normandeau (2017).



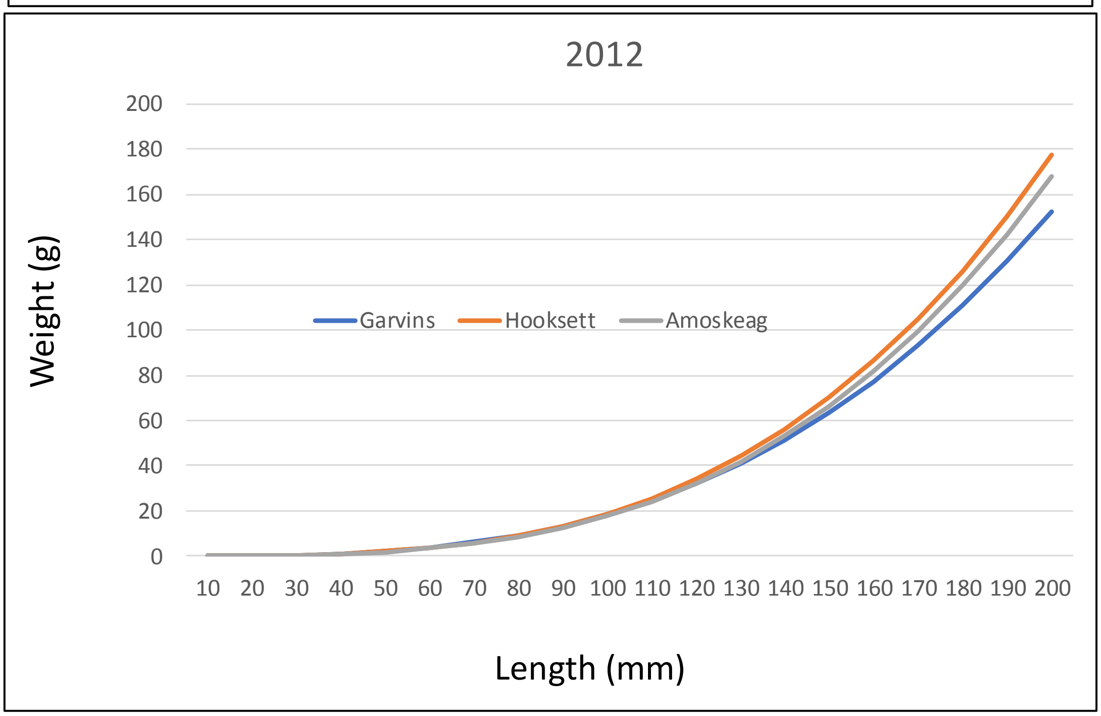


Figure 8. length-weight relationships for redbreast sunfish in 2013. Plotted using slope and intercept parameters from Table 4.3.7-4 of Normandeau (2017).

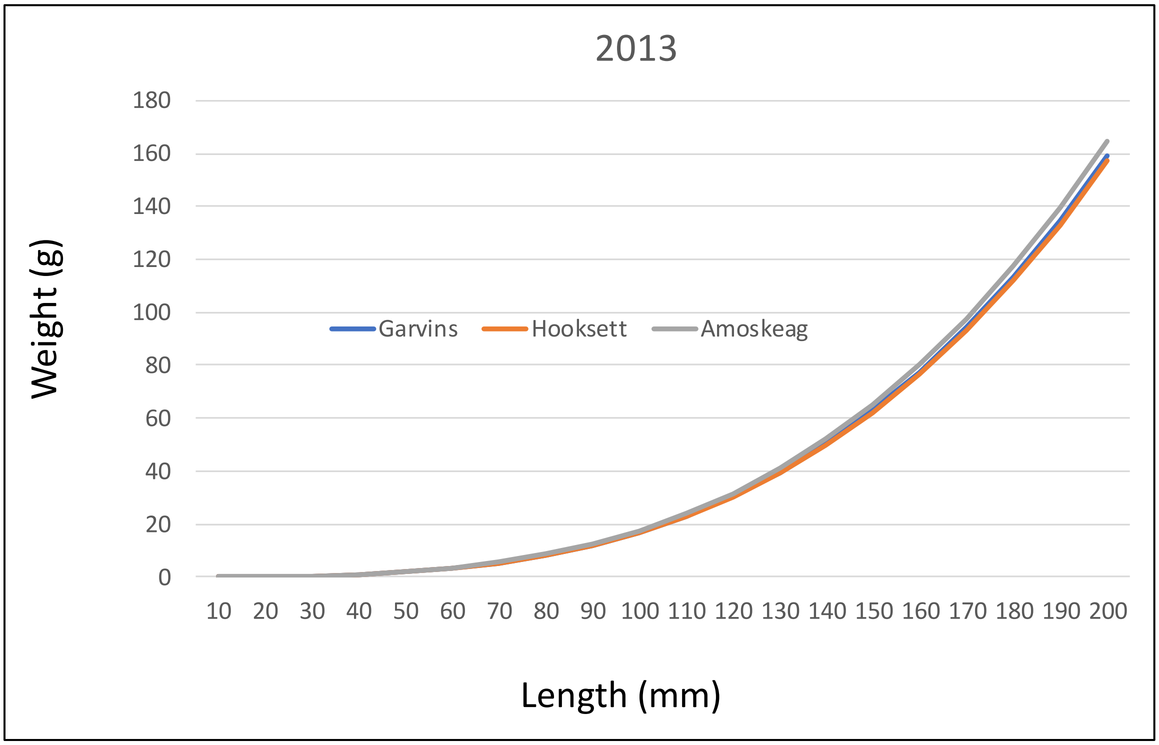
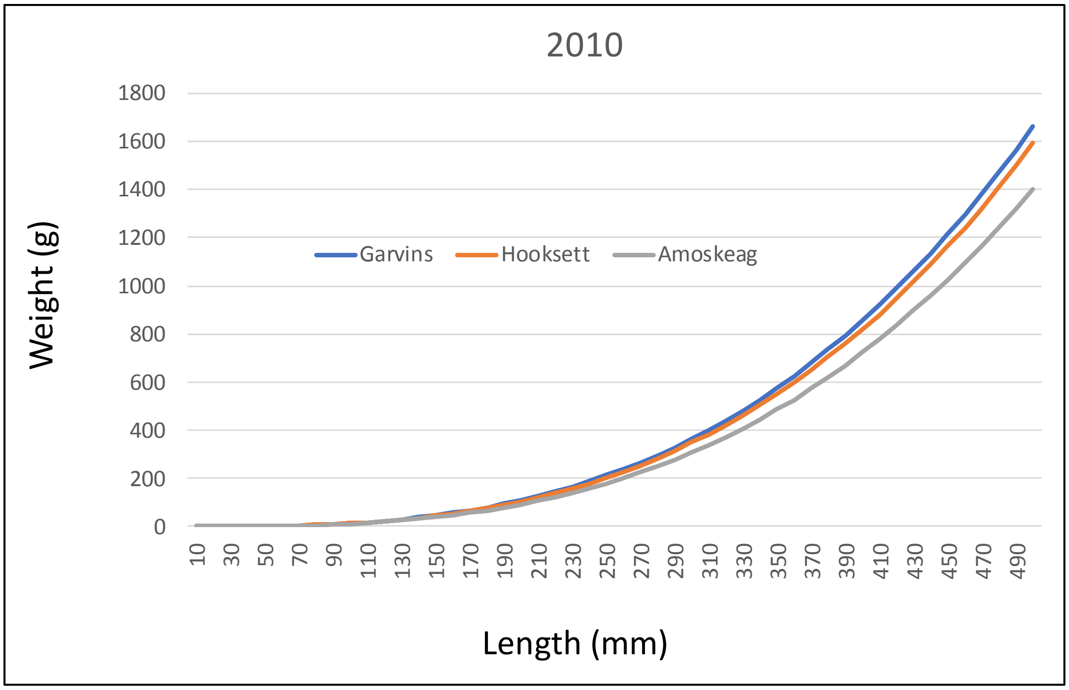


Figure 9. length-weight relationships for smallmouth bass in 2010 and 2011 Plotted using slope and intercept parameters from Tables 4-12-5 and 4-12-6 of Normandeau (2012).



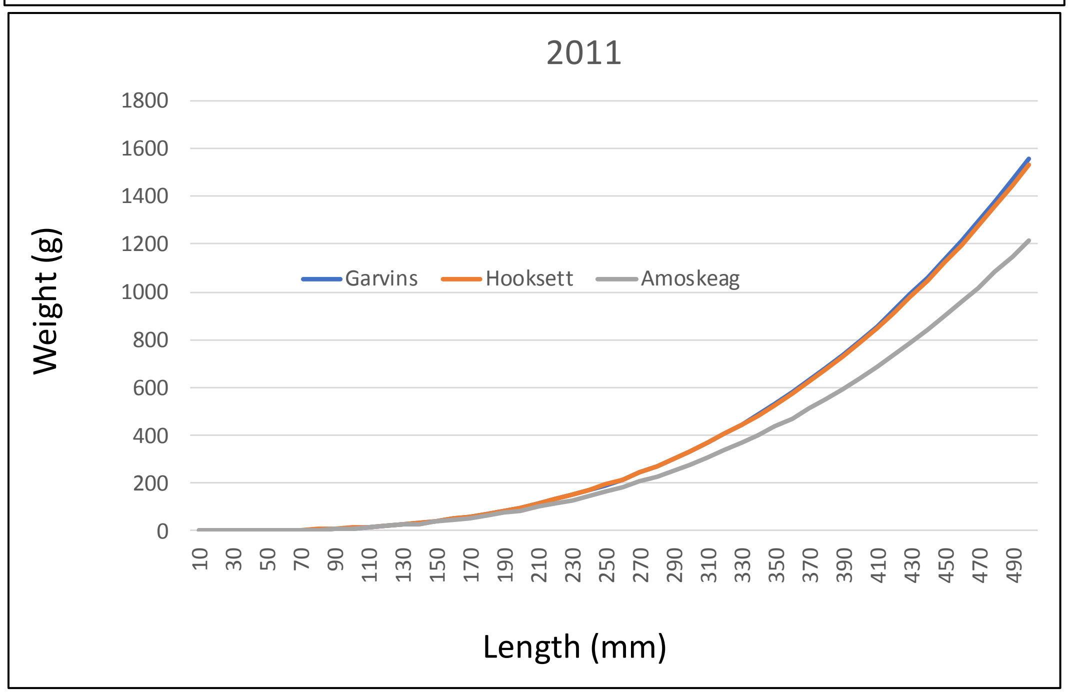
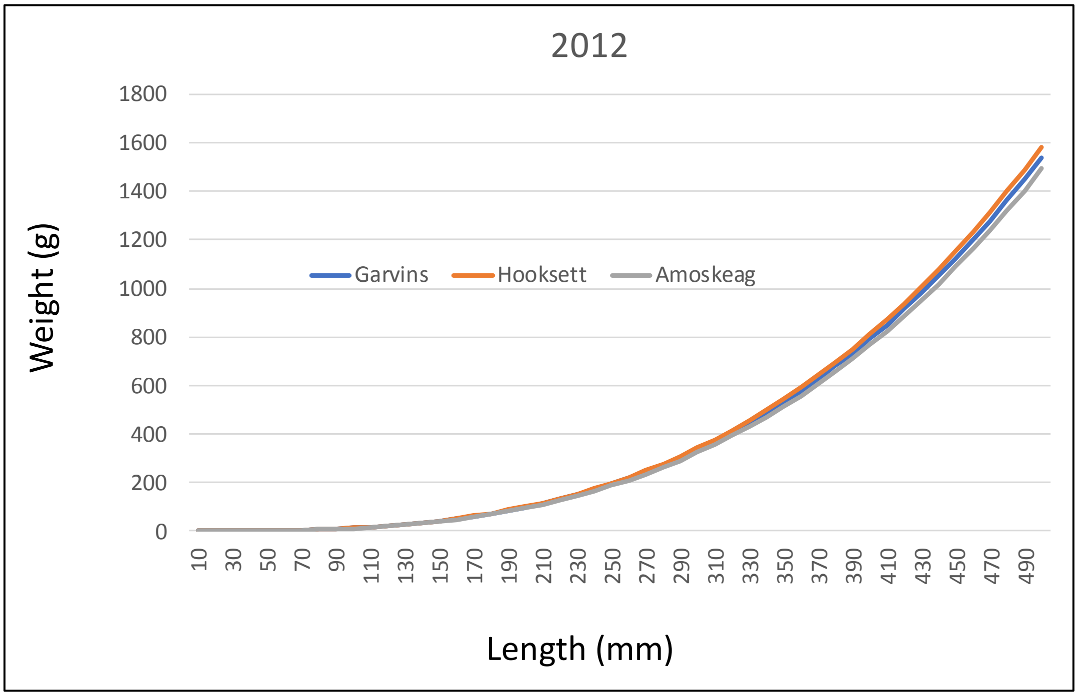


Figure 10. length-weight relationships for smallmouth bass in 2012. Plotted using slope and intercept parameters from Table 4.3.9-3 of Normandeau (2017).

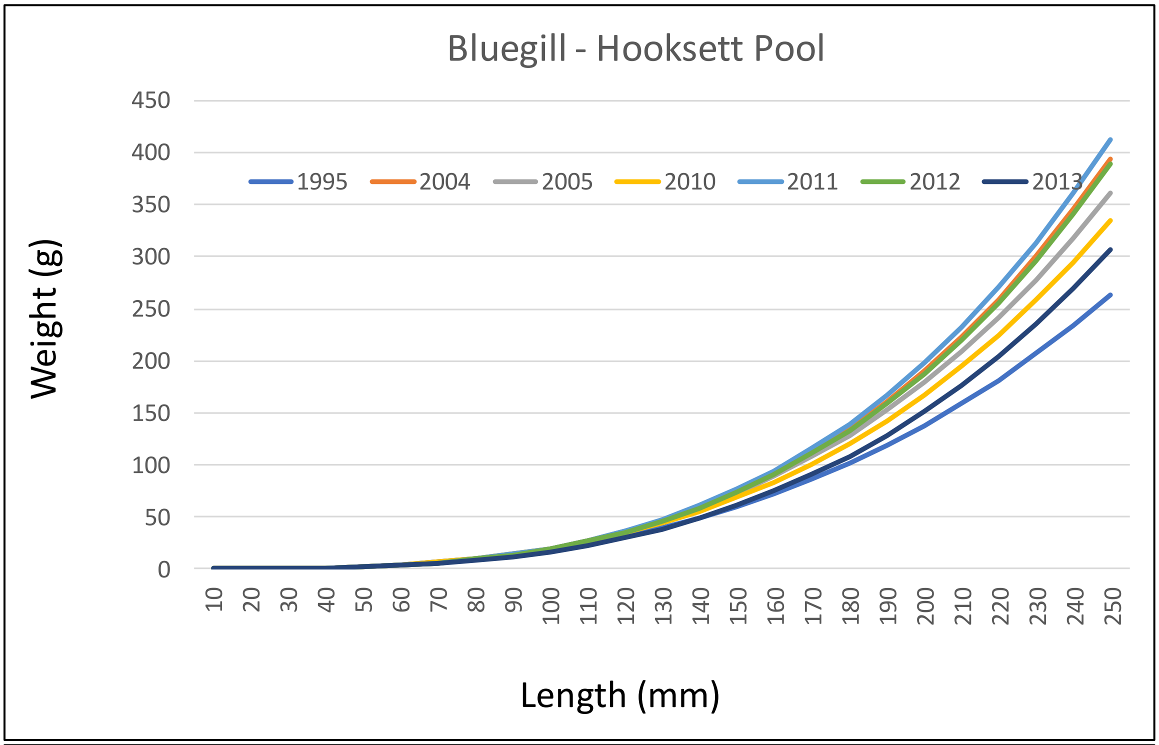


2 pools in 2010, but lighter in 2013. In 2012, the length-weight relationships for the 3 pools were essentially identical. For pumpkinseed (Figures 5 and 6), fish in Hooksett Pool were heavier at a given length than in the other pools in 2012 and lighter in 2013. In 2011, the length-weight relationships for the 3 pools were essentially identical. For redbreast sunfish (Figures 7 and 8), fish in Garvins Pool were heavier at a given length than in the other 2 pools in 2010, but lighter in 2012. In 2013, the length-weight relationships for the 3 pools were essentially identical. For smallmouth bass (Figures 9 and 10), fish in Amoskeag Pool were lighter at a given length in 2010 and 2011. In 2012, length-weight relationships for all 3 pools were essentially identical.

Figures 11 through 13 present length-weight relationships for the above 5 species in Hooksett Pool, for all available years between 1995 and 2013. These figures show that there is often substantial year-to-year variation in length-weight relationships within Hooksett Pool. For all 5 species, between-year variation within Hooksett Pool is similar to or greater than between-pool variation within years.

If fish in a particular population are consistently heavier at any given length than fish in another population, it might be inferred that the population with the heavier fish is healthier than the population with the lighter fish. No such pattern is evident in the Merrimack River. In many cases, the length-weight relationships for fish in the Garvins, Hooksett, and Amoskeag pools are nearly indistinguishable. Where differences are present, they are not consistent between years. Moreover, the differences in length-weight relationships between pools within any year are smaller than the between-year differences within Hooksett Pool. Taken together, these length-weight relationships support a conclusion that there is no systematic difference in condition between fish species present in Hooksett Pool and fish present in either Garvins Pool or Amoskeag Pool.

Figure 11. Length-weight relationships for bluegill and largemouth bass in Hooksett Pool for 1995 through 2013. Plotted using slope and intercept parameters from Tables 4.3.2-5 and 4.3.5-5 of Normandeau (2017).



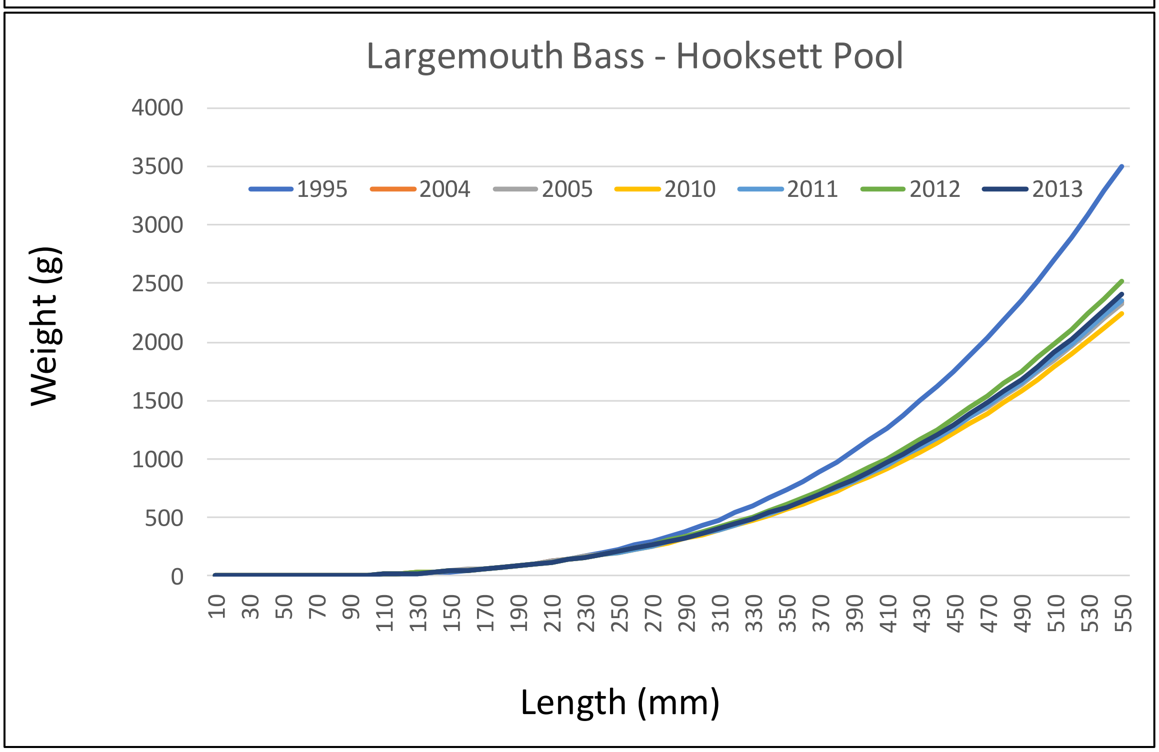
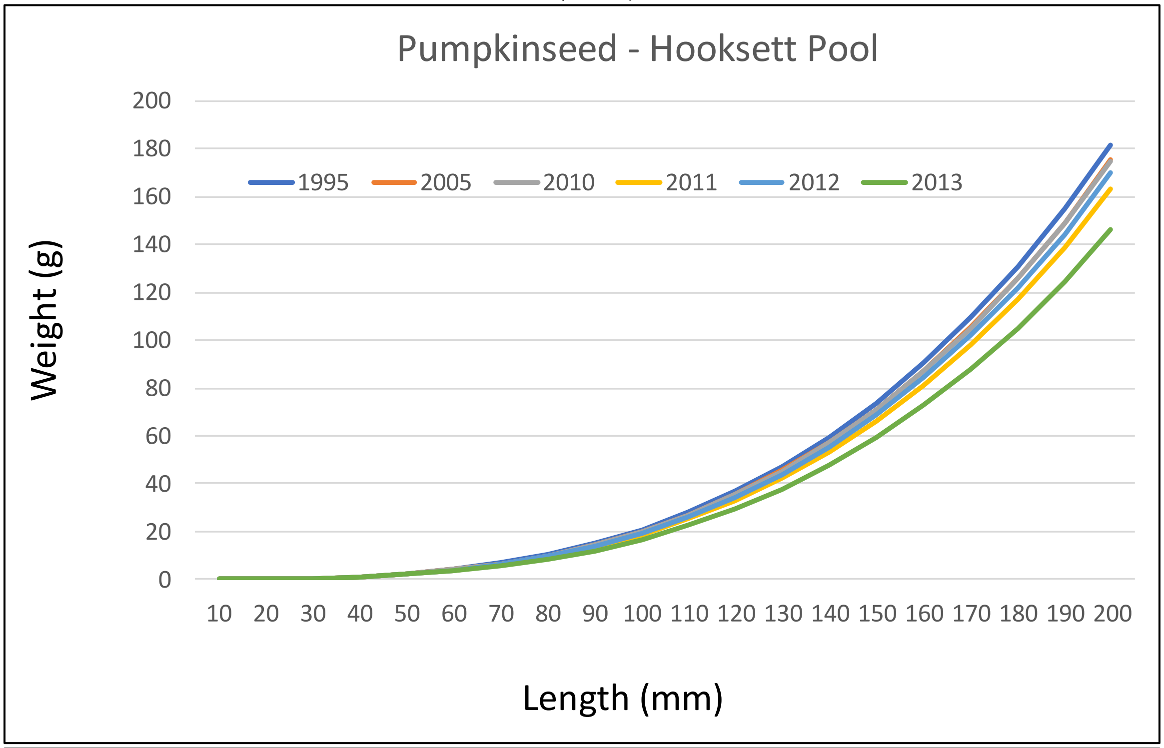


Figure 12. Length-weight relationships for pumpkinseed and redbreast sunfish in Hooksett Pool for 1995 through 2013. Plotted using slope and intercept parameters from Tables 4.3.6-5 and 4.3.7-5 of Normandeau (2017).



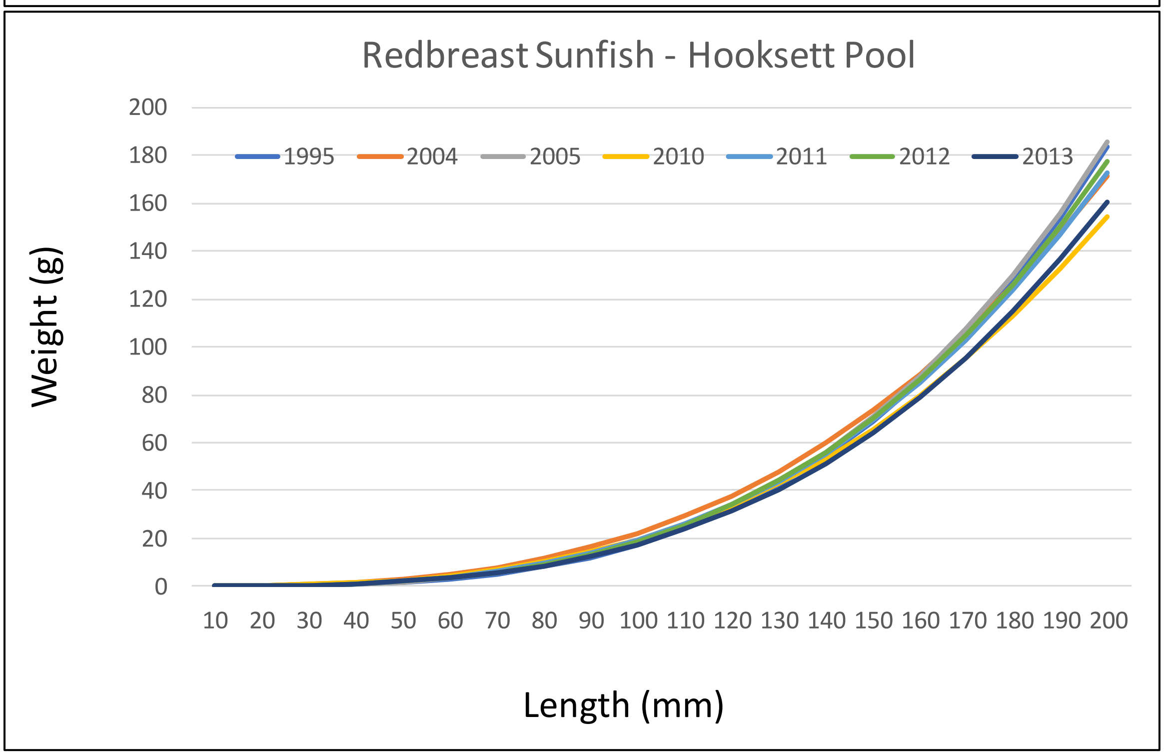
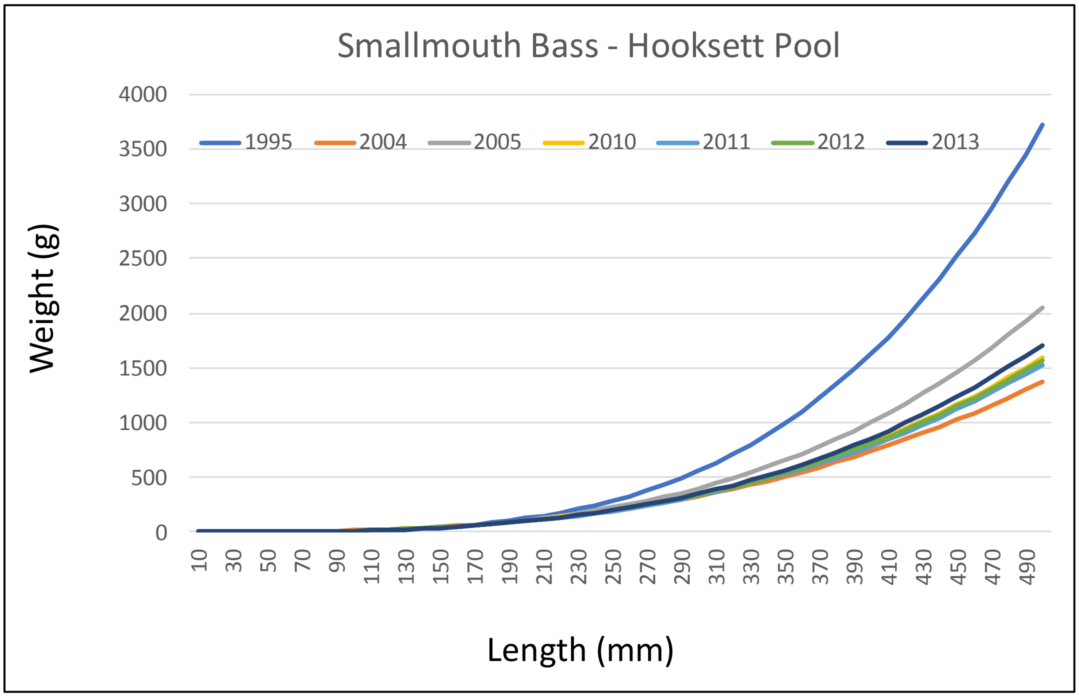


Figure 13. Length-weight relationships for smallmouth bass in Hooksett Pool for 1995 through 2013. Plotted using slope and intercept parameters from Table 4.3.9-5 of Normandeau (2017).



Parasitism

Parasitism can be an indicator of increased stress on fish. If the fish present in Hooksett Pool were undergoing stress because of thermal discharge from the Merrimack Station, then it might be expected that fish present in this pool would have higher parasite loading than fish from Garvins or Amoskeag Pools.

Information on external parasite loads for various Merrimack River fish species are available in Normandeau (2011) and Normandeau (2017). Normandeau (2011) provides, for each species, estimates based on the total number of fish caught between 2008 and 2011. Normandeau (2017) presents the same information tabulated separately for the years 2012 and 2013. Sufficient data to compare parasite loads between pools for all 3 time periods are available for nine species: bluegill, chain pickerel, fallfish, largemouth bass, pumpkinseed, redbreast sunfish, smallmouth bass, white sucker, and yellow perch. For the remaining species (black crappie, common shiner, rock bass, and spottail shiner) the numbers collected in one or more pools during 1 or more of the 3 time periods were insufficient for meaningful comparisons.

Table 8 summarizes data on parasite loads for the nine species identified above. In the 2 Normandeau reports, the fish were grouped into 3 categories: “absent,” “light,” and “moderate/heavy.” In Table 8, the “light” and “moderate/heavy” categories are combined, so that the table shows, for each species, the percent of fish that were parasitized to any degree. Bolded values indicate, for each species and time period, the pool that displayed the highest percentage of parasitized fish. For example, in Garvins Pool, the percentages of parasitized bluegill, pumpkinseed, and yellow perch were higher than in the other 2 pools during all 3 time periods. In Hooksett Pool, the percentage of parasitized fallfish was higher than in Garvins Pool or Amoskeag Pool for all 3 time periods. In Amoskeag Pool, the percentage of parasitized largemouth bass was higher than in Garvins Pool or Hooksett Pool for all 3 time periods. With 9 species and 3 time periods, there are a total of 27 species by time period combinations available for comparison. Altogether, the percentages of parasitized fish in Garvins Pool were the highest for 15 of the 27 combinations, compared to 7 for Hooksett Pool and 5 for Amoskeag Pool. Hence, the parasitism data show no evidence that fish in Hooksett Pool are parasitized to a greater extent than fish in Garvins Pool or Hooksett Pool; to the contrary, parasitism during the 3 time periods covered in Table 8 appears to have been highest in Garvins Pool.

If stress related to Merrimack Station's thermal discharge were adversely affecting the health of fish inhabiting Hooksett Pool, this stress might be expected to increase the vulnerability of fish to attack by parasites. No such vulnerability is evident in the parasitism data discussed above.

Reproduction

In 2008, 2009, and 2012, Normandeau conducted electrofishing surveys during the spring to characterize the reproductive condition of white sucker and yellow perch in Garvins, Hooksett, and Amoskeag Pools. Data collected included sex ratios, reproductive condition, percent maturity, gonadosomatic index (GSI[4]), age and length at maturity, and length-fecundity relationships.

For white sucker, few differences were found between pools. In 2008-2009, the percentage of white sucker that were female was higher in Hooksett Pool than in Garvins Pool or Amoskeag Pool (Normandeau 2012, Table 4-14-14), but in 2008 there were no

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[4] The ratio of gonad mass to total body mass; an index of reproductive condition.

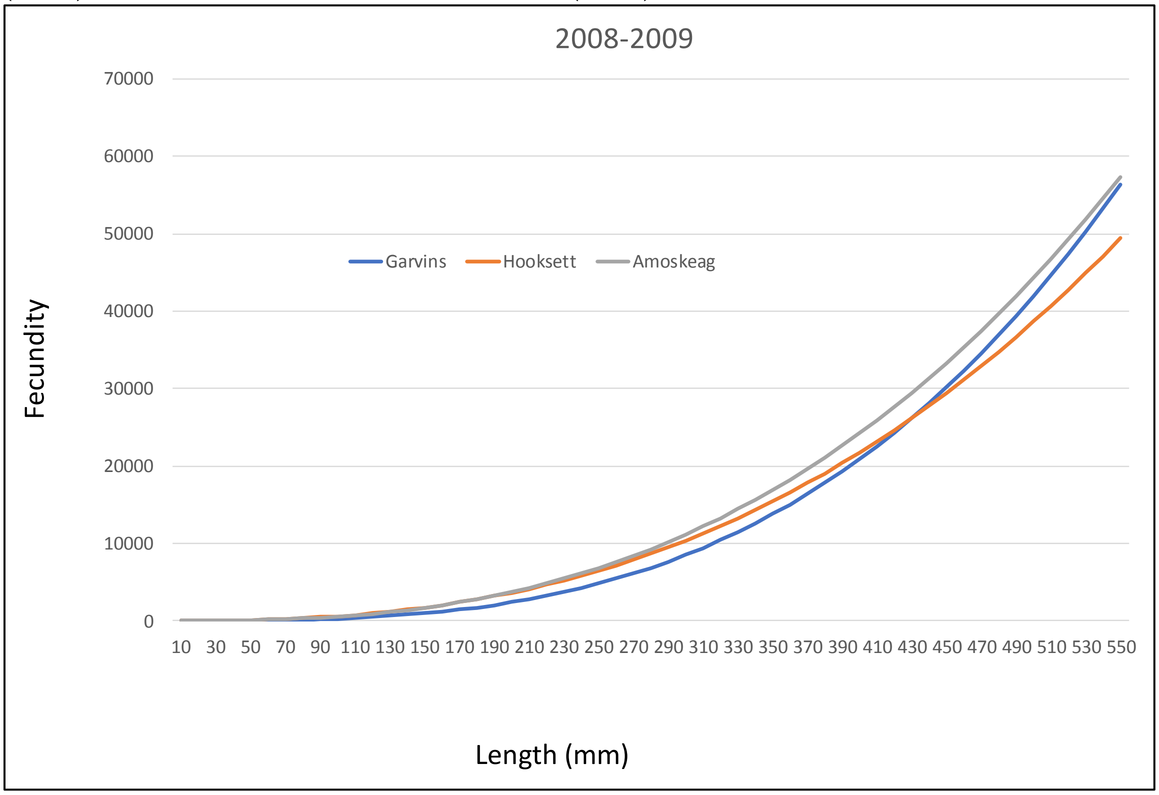
Table 8. Summary of external parasite loads in fish collected from Garvins, Hooksett, and Amoskeag Pools. Bolded values indicate, for each species and time period, the pool that displayed the highest percentage of parasitized fish

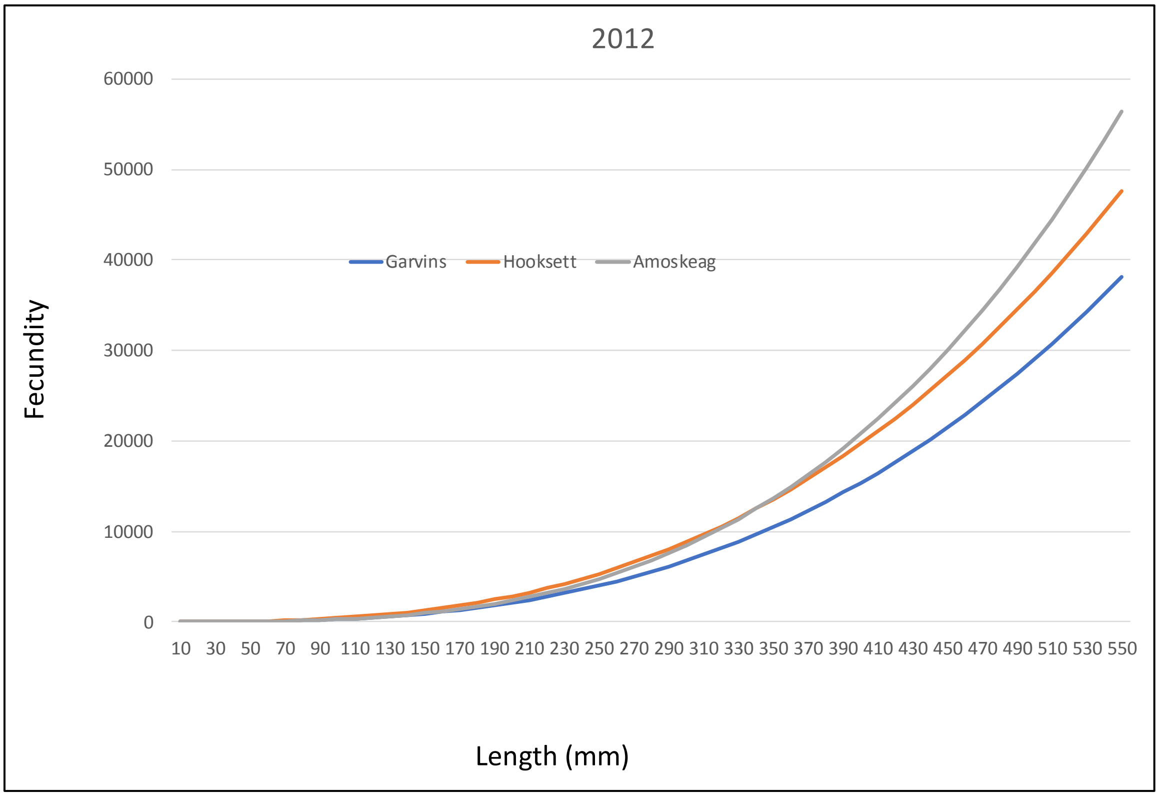
Pool	Year	Bluegill	Chain pickerel	Fallfish	Largemouth bass	Pumpkinseed	Redbreast sunfish	Smallmouth bass	White sucker	Yellow perch
Garvins	2008-2011	**26**	**48**	9	53	**35**	5	**45**	16	**77**
	2012	**42**	66	4	79	**58**	**40**	44	52	**38**
	2013	**43**	**43**	17	51	**56**	**58**	58	**91**	**82**
Hooksett	2008-2011	8	22	**25**	61	22	36	44	**31**	62
	2012	19	**72**	**37**	85	40	36	64	**61**	19
	2013	39	31	**20**	49	37	56	**76**	68	59
Amoskeag	2008-2011	14	30	14	**68**	31	**55**	34	17	40
	2012	6	33	17	**93**	13	28	**67**	44	27
	2013	22	40	0	**70**	28	43	75		17

between-pool differences in the percentage of female fish (Normandeau 2017, Table 4.3.11-12). In both 2008-2009 and 2012, there were no statistically significant between-pool differences in the percent of female white sucker that were sexually mature (Normandeau 2012, Table 4-14-16; Normandeau 2017, Table 4.3.11-14). In 2008-2009 there were no statistically significant between-pool differences in GSI values (Normandeau 2012, Table 4-14-17), although in 2012 GSI values for female white sucker in Garvins Pool were significantly lower than in Hooksett Pool or Amoskeag Pool (Normandeau 2017, Table 4.3.11-15). The age and length at maturity of female white sucker was similar in all 3 ponds (Normandeau 2012, Table 4-4-18; Normandeau 2017, Table 4.3.11-16). Length-fecundity relationships for white sucker are plotted in Figure 14 of this report based on regression parameters provided in Table 4-14-19 of Normandeau (2012) and Table 4.3.11-17 of Normandeau (2017). The relationships are very similar for 2008-2009, but for 2012 the fecundity of female white sucker in Garvins Pool was significantly lower than in Hooksett Pool or Amoskeag Pool.

Data relating to the reproductive health of female yellow perch are especially relevant to interpreting the effects of Merrimack Station's thermal discharge because EPA asserted in section 5.6.3.3f of its §316 Determination for Merrimack Station that the reproductive health of yellow perch in Hooksett Pool was being adversely affected by the station's thermal discharges during the winter months. EPA stated, based on a review of published literature, that female yellow perch must be exposed to water temperatures of 10°C or lower for a minimum of 188 days to ensure full gonadal development. Fish that overwinter within the Merrimack Station discharge canal would be exposed to substantially higher temperatures. Because of these high exposure temperatures, the gonads of female yellow perch overwintering within the canal would, according to EPA, not be fully developed and would produce reduced numbers of viable eggs. Any such impairment should be reflected in measurements of reproductive characteristics of female white perch in Hooksett Pool, especially in the numbers of eggs produced by mature fish.

Figure 14. Length-fecundity relationships for female white sucker in 2008-2009 and 2012. Plotted using slope and intercept parameters from Table 4-14-19 of Normandeau (2012) and Table 4.3.11-17 of Normandeau (2017).



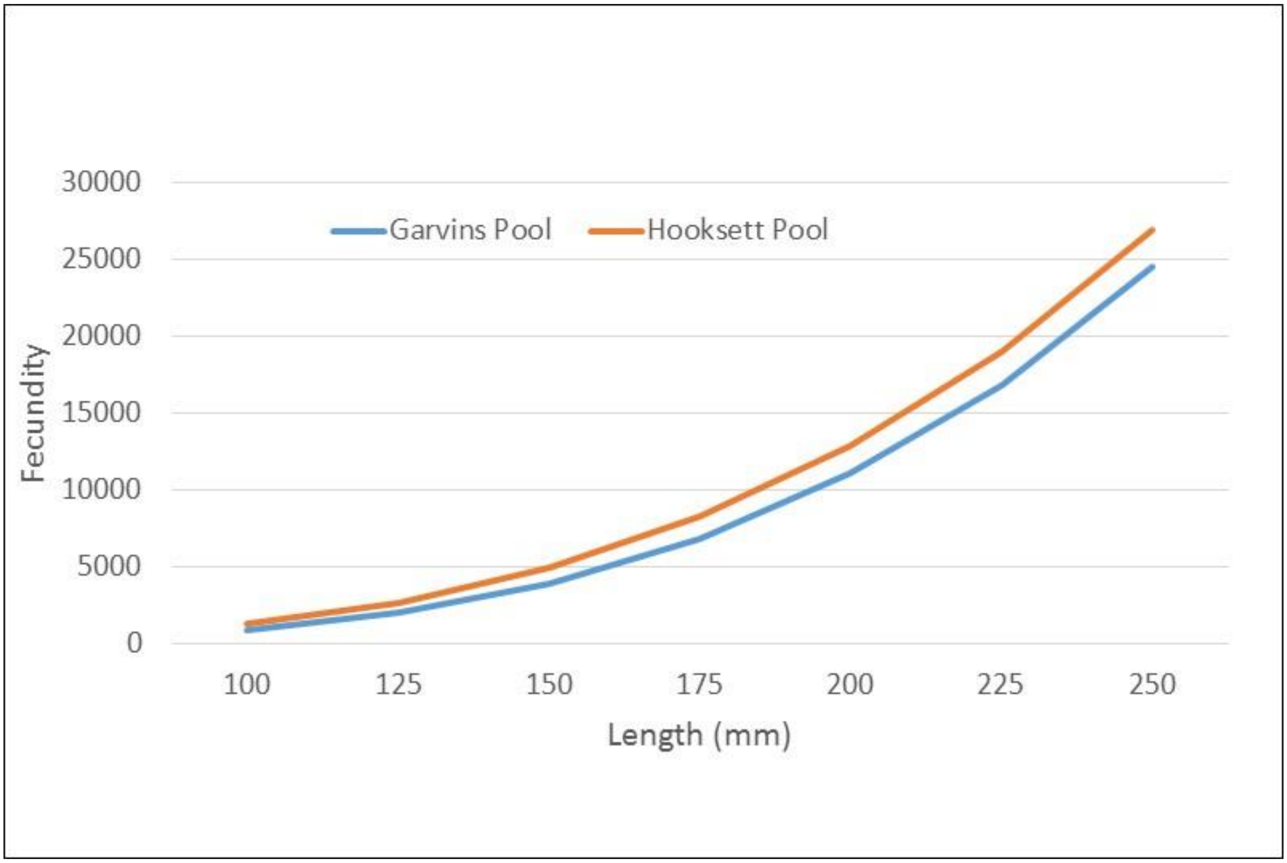


Section 4.15.6 of Normandeau (2012) compared the percent maturity, age and size at maturity, and fecundity of female yellow perch collected from Garvins Pool and Hooksett Pool during the spring spawning season in 2008 and 2009. The numbers of mature yellow perch collected in Amoskeag Pool were too small to support meaningful comparisons. Normandeau found that females from Hooksett Pool became sexually mature at a younger age and a smaller size than females from Garvins Pool. The percentage of females that were sexually mature was similar in both pools, and the GSI's of mature females were also similar. No numeric data were provided in Normandeau (2011) because the length-fecundity relationships in the 2 populations were not significantly different.

Normandeau (2017) provided similar data for 2012. As in 2008-2009, yellow perch were found to become sexually mature at a younger age and a smaller size in Hooksett Pool than in Garvins Pool. In 2012, the GSI for female yellow perch in Hooksett Pool was somewhat lower than in Garvins Pool, however, the length-fecundity relationships in both pools were similar. These relationships are plotted in Figure 15. If EPA's assertion were correct, mature female fish at any given length should have a lower fecundity in Hooksett Pool than in Garvins Pool. However, as shown in Figure 15, fecundity at any given length was actually higher in Hooksett Pool, although the difference is not statistically significant.

These results directly contradict EPA's assertion that female yellow perch are reproductively impaired in Hooksett Pool due to exposure to elevated winter temperatures. They are, however, fully consistent with results of winter thermal plume modeling performed by Enercon (2017). These results (depicted in Figures 4-11 of Enercon 2017) show that only fish residing within the discharge canal itself could be exposed to potentially harmful temperatures. During all of the months from December through March the plume remains close to the west bank of the river and cools rapidly. Only a small fraction of the river cross-section is exposed to the plume, and by the time it reaches Station S4, even the warmest parts of the plume are within the temperature range (4°C - 6°C) found by Hokanson (1977) to be optimal for yellow perch spawning success.

Figure 15. Length vs fecundity relationships for female yellow perch collected by electrofishing in Hooksett Pool and Garvins Pool during March and April 2012.



Given these plume temperatures, no impairment of yellow perch reproductive condition would be expected, and none has been found.

Discussion and Conclusions

In an earlier review of technical documents related to the NPDES permit for Merrimack Station, Barnthouse (2016) concluded that analysis of field data on the composition of the Merrimack River fish community is the most appropriate approach to evaluating the effects of Merrimack's thermal discharge. At that time, the most complete analysis available for those data was Normandeau's report analyzing the available data from the 1970s through 2011 (Normandeau 2011). The publication of 2 years of additional data in the most recent Normandeau report (Normandeau 2017) greatly expands the data set available for analysis. The trends analysis in section 3 of the new report confirms that, although some species have declined in Hooksett Pool while others have increased, most species have fluctuated in abundance without any obvious trends. Importantly, 4 years of comparative data are now available for both upstream (Garvins) and downstream (Amoskeag) pools.

The length-weight relationships documented in Normandeau (2012) and Normandeau (2017) show no consistent pattern of between-pool differences for any species, and also show that between-year variation in those relationships within Hooksett Pool is as large as between-pool variation within any one year. Comparison of parasite loads between pools shows that, contrary to what would be expected if fish in Hooksett Pool were being stressed due to the thermal discharge from Merrimack Station, high levels of parasitism have been more common in Garvins Pool than in Hooksett Pool.

Altogether, the data provided in the Normandeau reports discussed here demonstrate that key characteristics of the fish communities present in Garvins, Hooksett, and Amoskeag Pools are relatively consistent through time. These communities differ in ways that reflect an upstream-downstream gradient that is well-documented in published literature, with the fish community in Hooksett Pool being intermediate between the communities in Garvins Pool and Amoskeag Pool.

There is no indication of any anomalous fish population or community characteristics in Hooksett Pool that could be related to the operation of Merrimack Station, and therefore no evidence that those operations have caused or are now causing any appreciable harm to the fish community in the Merrimack River.

Implications for §316(b) Benefits Analysis

Section 122.21(r)(11) of the §316(b) Final Rule (FR 79, No. 158, August 15, 2014) requires operators of facilities subject to the rule to submit a detailed discussion of the benefits of candidate entrainment reduction technologies. This study must include:

> "…discussion of recent mitigation efforts already completed and how these have affected fish abundance and ecosystem viability in the intake structure's area of influence. Finally, the study must identify other benefits to the environment and the community, including improvements for mammals, birds, and other organisms and aquatic habitats." Section 122.21(r)(11), p. 48367.

These "other benefits" would be indirect and nonuse benefits of reducing the impacts of entrainment and impingement on the structure and function of the ecosystem from which cooling water is being withdrawn. These benefits also would include reducing potential impacts on threatened or endangered species.

The data discussed in this report, although not collected specifically to support compliance with the benefits analysis requirement of the §316(b) Final Rule, are relevant to the rule because the status of the fish community in the Hooksett Pool reflects impacts, if any, of both the thermal discharge and the cooling water intake structure of Merrimack Station.

None of the fish species collected in the surveys conducted by Normandeau (2011, 2017) are classified as threatened or endangered. Moreover, as demonstrated in this report, there is no evidence that operation of Merrimack Station – including entrainment of early life stages of fish, zooplankton, phytoplankton, and any other organisms present in the river – has caused any appreciable harm to the fish community of the Merrimack River. This fact implies that there would be no appreciable benefit to the fish community, either direct or indirect, from implementing new technologies to reduce entrainment. If there is no benefit to the fish community, then there would similarly be no benefit to any fish-eating birds or mammals that depend on the fish community.

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