Merrimack Station Fisheries Survey Analysis of 1972-2011 Catch Data

Prepared for
PUBLIC SERVICE OF NEW HAMPSHIRE
780 North Commercial Street
Manchester, NH

Prepared by
NORMANDEAU ASSOCIATES, INC.
25 Nashua Road
Bedford, NH 03110

R-22240.012

December 2011

Table of Contents

Page

List of Figures

List of Tables

Page

Executive Summary

Merrimack Station is entitled to a 316(a) variance from both technology-based and water-quality based thermal limits. Specifically, PSNH has shown that there has been no appreciable harm to the balanced indigenous population ("BIP"), even when taking into account other stresses upon the BIP. EPA's finding of appreciable harm is clearly incorrect for several reasons.

Specifically, there has not been appreciable: (1) decreases in all coolwater fish species in the Hooksett Pool; (2) increases in warmwater species in the Hooksett Pool; (3) decreases in diversity of species in the Hooksett Pool (in fact, the Shannon diversity index value shows that the current population is more diverse now than it was forty years ago); or increases in abundance of generalist feeders or pollution-tolerant species. In fact, when compared to the Garvins Pool (the thermally uninfluenced impoundment immediately upstream from Hooksett Pool and the proper reference to compare to the Hooksett Pool) the characteristics of the population and the individual species indicate no appreciable harm to the BIP.

- There has been no appreciable harm to the BIP in Hooksett Pool based on decreases in all coolwater species. Aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher abundance of fish species that are tolerant of warmer water, and a lower abundance of fish species that prefer cooler water. Merrimack Station's thermal discharge has not adversely impacted the abundance and distribution of fish in Hooksett Pool (the area of the Merrimack River from which Merrimack Station withdraws cooling water and into which it discharges heated effluent). Specifically, the abundance of all resident coolwater species in the pool (as estimated by standardized electrofish sampling efforts conducted between 1972 and 2011) has not significantly decreased for three out of the five coolwater fish species resident in Hooksett Pool. The abundance of chain pickerel and yellow perched has decreased, but there were no significant trends for fallfish and white sucker. The abundance of the remaining coolwater species, black crappie, increased in Hooksett Pool over the 1972-2011 period of time. These findings support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool.

- There has been no appreciable harm to the BIP in Hooksett Pool based on increases in warmwater species. As estimated by the same standardized electrofish sampling efforts, there have not been increases in abundance for any of the warmwater fish species resident in Hooksett Pool from 1972-2011. Specifically, there were no significant trends for seven out of ten warmwater species (bluegill, golden shiner, largemouth bass, rock bass, smallmouth bass, spottail shiner and yellow bullhead), and abundance of the remaining three warmwater species (brown bullhead, pumpkinseed and redbreast sunfish) decreased, suggesting causes unrelated to the Station's thermal discharge. These findings support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool.

- There has been no appreciable harm to the BIP in Hooksett Pool based on a decrease in diversity of the fish community. Based on the 1972-2011 electrofish sampling efforts, the highest Shannon diversity index value for the Hooksett Pool fish community observed was in 2011. Moreover, all of the per year diversity index values from the sampling years in the

2000s were higher than the values from the sampling years in the 1970s, indicating that the diversity of the fish community in Hooksett Pool – and therefore the biological health of that community – has generally increased, not decreased, over the past forty years. These findings support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool.

- There has been no appreciable harm to the BIP in Hooksett Pool based on an increase in generalist feeders or increase in pollution-tolerant species. Aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher percentage of both generalist feeders (which can capitalize on a variety of different food sources and often increase dramatically with habitat degradation) and pollution-tolerant individuals. However, neither of these findings was observed in Hooksett Pool for fish collected during the standardized electrofish sampling efforts that PSNH conducted between 1972 and 2011. These findings support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool.
- A review of warmwater and coolwater species compared between Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in the Hooksett Pool. As noted above, aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher abundance of fish species that are tolerant of warmer water, and a lower abundance of fish species that prefer cooler water. However, a comparison of the 2010 and 2011 fish communities in Hooksett Pool and Garvins Pool (the thermally uninfluenced impoundment immediately upstream from Hooksett Pool) shows no clear pattern consistent with the hypothesis that Merrimack Station's thermal discharge has caused an increase in the abundance of warmwater species or a decrease in the abundance of coolwater species in the pool. This comparison, therefore, supports the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool.
- A review of generalist feeders and pollution tolerant species compared between Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in the Hooksett Pool. As noted above, aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher percentage of both generalist feeders and pollution-tolerant individuals. Although the percentage of generalist and tolerant species were higher in Hooksett Pool than Garvins Pool during both 2010 and 2011, these differences were the result of increased relative abundance of both coolwater and warmwater species in Hooksett Pool. If Merrimack Station's thermal discharge has adversely impacted the BIP in Hooksett Pool by increasing the percentage of generalist feeders or pollution-tolerant individuals, it would not be expected that coolwater species would have significantly contributed to these increases, as documented.
- A review of length-weight-curve sampling data of fish compared between Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in Hooksett Pool. Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data tend to show a decreasing slope to the length-weight curve – signifying progressively lower weight for a given length – for a resident fish species over time or in comparison to the same species residing in thermally uninfluenced habitat. Such a decreasing slope indicates a reduction in quality of body condition due to the thermal impact. Here, the observations of

similar or increased growth among coolwater species residing in Hooksett Pool compared to the same species residing in thermally uninfluenced Garvins Pool during years of comparable sampling (2008-2011) indicated that there has been no appreciable harm to the BIP in Hooksett Pool.

- Changes in the mean length at age for resident species in the Hooksett Pool does not mean that the thermal discharges from Merrimack Station has caused appreciable harm to the BIP in the Hooksett Pool. Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data typically show lower mean length at age for a resident fish species compared to the same species in a thermally uninfluenced area, due to a reduction in growth rates associated with thermal stress. Here, the observation of reduced mean length at age for two coolwater fish species (white sucker and yellow perch) in Hooksett Pool suggests that growth (as estimated by mean length at age) may be reduced for some age classes in Hooksett Pool as compared to the same age classes of the same species in Garvins Pool. However, the inverse relationship between density and growth (i.e., the larger the fish population in a given water body, the slower the growth of individual fish in that population, due to competition for resources) has been well-studied and documented in other systems for both white sucker and yellow perch. Here, abundance of white sucker was greater in Hooksett Pool than Garvins Pool during the sampling period, suggesting that the causes for such lower mean length at age for one of the coolwater fish species in question are unrelated to the Station's thermal discharge.

- Decreases in mortality levels for resident species in Hooksett Pool as compared to Garvins Pool indicates that the thermal discharges from Merrimack Station have not caused appreciable harm to the BIP. Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data typically show a greater total mortality (Z) for a resident fish species compared to the same species in a thermally uninfluenced area, due to increased stress associated with thermal impacts. Here, the mortality levels observed in Hooksett Pool are lower than or equal to those observed in Garvins Pool for five of the seven species examined, including yellow perch and pumpkinseed, two fish species that have decreased in abundance in Hooksett Pool between 1972 and 2011. These findings support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool.

- Length-fecundity relations were significant for white suckers in both Hooksett and Garvins Pools, indicating that fecundity (i.e., the number of eggs per female) increases with length in both locations. The estimated range of number of eggs per female white sucker as well as the range of observed body lengths overlapped for individuals collected within Hooksett and Garvins Pools in 2008 and 2009, suggesting that the BIP in Hooksett Pool has not experienced appreciable harm from reduced reproductive success as a result of Merrimack Station's thermal discharge.

- A comparison of external and internal parasites on the same resident species in both Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in the Hooksett Pool. Resident fish species in aquatic habitat that has been adversely impacted by a thermal discharge characteristically manifest more frequent infestation of internal and external parasites compared to the same species resident in a thermally uninfluenced area, indicating a reduction in the overall health and conditions of the fish due to thermal impacts.

Parasitism levels in Hooksett Pool were less than or equal to those observed in Garvins Pool for seven of the thirteen species examined for external parasites (2008 to 2011) and both species examined for internal parasites (2008 to 2009). These observations support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool.

1.0 Introduction

Public Service of New Hampshire ("PSNH") owns and operates two separate generating units, Unit 1 and Unit 2, known together as Merrimack Station, in Bow, New Hampshire. Merrimack Station is located on the west bank of the Merrimack River adjacent to Hooksett Pool in freshwater, approximately 2.9 miles upstream from the Hooksett Dam and Hydroelectric Station and about 2.9 miles downstream from the Garvins Falls Dam and Hydroelectric Station. Merrimack Station withdraws and discharges once-through cooling water from the Merrimack River subject to and with the benefits of National Pollutant Discharge Elimination System ("NPDES") Permit No. NH001465 ("Permit"), which was last renewed by Region 1 of the United States Environmental Protection Agency ("USEPA") on 25 June 1992. Unit 1, which became operational in 1960, generates at a rated capacity of 120 MW, and withdraws once-through cooling water from the waters of the Merrimack River using a cooling water intake structure ("CWIS") located in a bulkhead at the shoreline of Hooksett Pool. Unit 2, which became operational in 1968, generates at a rated capacity of 350 MW, and withdraws once-through cooling water from the Merrimack River using a separate CWIS located in a bulkhead approximately 120 feet downstream from the Unit 1 CWIS.

The Station is seeking a renewal of its existing variance under §316(a) of the Clean Water Act ("CWA"), 33 U.S.C. §1326(a), as part of the renewal of its existing Permit. CWA §316(a) provides that a permit applicant may demonstrate that any effluent limitation proposed for the thermal component of any discharge is more stringent than necessary to assure the protection and propagation of a balanced, indigenous population ("BIP") of shellfish, fish, and wildlife in and on the body of water into which the discharge is made. Applicants with an existing thermal discharge may demonstrate that the existing discharge is protective of the BIP by evaluating the BIP over a series of years during which the discharge occurred, and showing an absence of appreciable harm (40 C.F.R. §125.73(c); USEPA 1977).

The data and analysis presented in this report and other reports prepared by Normandeau Associates, Inc. ("Normandeau") and submitted to the Merrimack Station Technical Advisory Committee ("TAC") demonstrate that the Station's thermal discharge has not resulted in appreciable harm to the BIP in Hooksett Pool (Normandeau 2006; Normandeau 2007a; Normandeau 2007b; Normandeau 2009a). (The TAC was established pursuant to the Permit to "make recommendations … to ensure protection of the aquatic community," and consists of senior biologists from USEPA, the NH Department of Environmental Services, the US Fish and Wildlife Service ("USFWS") and the NH Fish and Game Department ("NHFGD")). The majority of these reports have focused on the Merrimack River fish community, in accordance with the well-established biological assessment approach of using fish assemblages as indicators of overall ecological condition (Flotemersch et al. 2006). USEPA's technical framework document for the development and implementation of large river bioassessment programs, "Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers," describes the advantages of using fish assemblages as a direct measure of biological condition relative to biological integrity, noting that fish are relatively long-lived, mobile, feed at every trophic level (e.g., herbivores, omnivores, and predators), and can be relatively easy to identify to species (Flotemersch et al. 2006).

Specifically, Normandeau, on behalf of PSNH and under the direction of the TAC or one or more of its members, performed thermal and biological monitoring in Hooksett Pool from 1972 through 1978 to characterize the river biota in Hooksett Pool for the purpose of detecting potential long-term trends relating to the Station's operations (Normandeau 1972, 1973a, 1974, 1975a, 1976a, 1977a, 1979b). The same thermal and biological monitoring program was repeated during 1995 (Normandeau 1997) and again during 2004, 2005, 2010 and 2011 to obtain additional annual observations of the abundance of fish populations – including the Representative Important Species ("RIS") selected and approved by the TAC – in Hooksett Pool (Normandeau 2007a). The 2010 and 2011 fish abundance data (presented in this report) provide current observations for comparison with historic abundance data from the previous series of surveys.

According to USEPA's draft guidance for making §316(a) demonstrations, an applicant seeking a §316(a) variance may demonstrate that fish communities in the water body receiving its thermal discharge have not suffered appreciable harm from: (1) direct or indirect mortality from cold shocks, (2) direct or indirect mortality from excess heat, (3) reduced reproductive success or growth as a result of plant thermal discharges, (4) exclusion from unacceptably large areas, or (5) blockage of migration (USEPA 1977). Here:

- Merrimack Station has a 40-year record of thermal discharge without any documented fish kills due to winter shutdown and the associated cold water temperature shock. As a result, further investigation of direct or indirect mortality from cold shocks (No. 1 above) is not warranted.
- A fish population trend analysis was performed using the time series of abundance data (measured as catch per unit effort ("CPUE")) collected through standardized electrofish sampling efforts conducted between 1972 and 2011. This analysis demonstrated that the RIS, as well as other resident fish species in Hooksett Pool, have not suffered appreciable harm from direct or indirect mortality from excess heat (No. 2 above) or reduced reproductive success or reduced growth (No. 3 above) as a result of Merrimack Station's thermal discharge (Normandeau 2007a).
- Exclusion of fish (i.e., Merrimack Station RIS) from unacceptably large areas of habitat (No. 4 above) as a result of Merrimack Station's thermal discharge also was examined and found to be insignificant (Normandeau 2007a).
- Finally, an assessment of spring Atlantic salmon smolt passage downstream past the Station's thermal plume during 2003 and 2005 indicated that there is no blockage of migration (No. 5 above) as a result of the Station's thermal discharge (Normandeau 2006a).

In addition, USEPA's draft §316(a) guidance identifies five response metrics that may be used to assess whether a thermal discharge has caused a consequential adverse impact (i.e., "appreciable harm") to fish at the species level (No. 1 through No. 5 below) and four additional response metrics that may be used to assess appreciable harm at the community level (No. 6 through No. 9 below): (1) reproduction (spawning habitats and fecundity), (2) life stage habitat utilization, (3) condition factors (e.g., length and weight), (4) disease and parasitism,(5) age and growth, (6) general abundance of RIS, (7) relative abundance (% composition) of each species present (RIS and others), (8) association of principal groups of fish (i.e., guilds), and (9) habitat utilization maps for the indigenous fish communities (USEPA 1977). Here:

- The four community-level response metrics (Nos. 6 through 9) and the species-level response metrics of life stage habitat utilization (No. 2) and condition factors (No. 3) were examined and determined to support a finding of no prior appreciable harm to the fish community of

Hooksett Pool from the Station's thermal discharge over the 40-year period from 1972 through 2005 (Normandeau 2007a).

- Four species-level response metrics (Nos. 1, 3, 4 and 5) were examined and determined to support a finding of no prior appreciable harm to two Merrimack Station RIS (white sucker and yellow perch*)* as a result of the Station's thermal discharge during 2008 (Normandeau 2009a).

This report is organized into three major sections: (1) results and analysis of fish community data collected in Garvins, Hooksett and Amoskeag Pools during 2010 and 2011 (Report Section 2.0), (2) an updated RIS population trends analysis, for the 1972-2011 time period, that builds on the results first presented in Normandeau 2007a (Report Section 3.0), and (3) an assessment of biocharacteristics for RIS and other resident fish species during the 2008-2011 time period (Report Section 4.0). Specifically:

- Section 2.0 provides the most recent assessment of the fish communities in Garvins Pool (the thermally uninfluenced impoundment immediately upstream from Hooksett Pool and therefore the appropriate upstream reference), Hooksett Pool and Amoskeag Pool (the impoundment immediately downstream from Hooksett Pool) based on the 2010 and 2011 fisheries sampling efforts. Results in Section 2.0 encompass the entire fish community in these three pools, with emphasis on the RIS species: yellow perch, white sucker, smallmouth bass, largemouth bass, fallfish, alewife, pumpkinseed, Atlantic salmon and American shad.

- Section 3.0 presents an updated fish population trend analysis based on the entire time series of comparable abundance electrofish data collected between 1972 and 2011. This section supplements the trends analysis first presented in 2007 (Normandeau 2007a) by adding the most recent data collected from Hooksett Pool during the comparable time periods of August and September of 2010 and 2011. This section seeks to further demonstrate that the Hooksett Pool fish community has not suffered appreciable harm from direct or indirect mortality from excess heat (No. 2 above) as a result of Merrimack Station's thermal discharge. In addition, this section reexamines the community-level response metrics Nos. 6 (general abundance) and 7 (relative abundance of each fish species present) using the same time series of 1972-2011 fisheries data collected from the Merrimack River in the vicinity of the Station.

Section 4.0 examines and compares biological characteristics of certain resident RIS and other selected fish species among Garvins, Hooksett and Amoskeag Pools. Previous analyses of biocharacteristics for the yellow perch and white sucker populations from these three pools were reported for sampling conducted during two seasons (spring and fall) during 2008 (Normandeau 2009a). Those analyses focused on determining if there was evidence of prior appreciable harm to either RIS by interpreting biological characteristics information that addressed population-level response metrics Nos. 1, 3, 4 and 5 (USEPA 1977), including length, weight, age, gender, sexual condition, fecundity and incidence of disease or parasitism. Biocharacteristics data collected during 2008-2011 for RIS and other resident Merrimack River fish species were evaluated to determine if there was evidence of prior appreciable harm by interpreting biological characteristics information that addressed population-level response metrics Nos. 3, 4 and 5 (USEPA 1977), including length, weight, age, and incidence of disease or parasitism.

2.0 Fisheries Survey Results for 2010 and 2011

2.1 Overview

Electrofish sampling was conducted during August, September and October 2010, and August and September 2011 within Garvins, Hooksett and Amoskeag Pools (Figure 2-1).

2.2 Methods

2.2.1 Monitoring Station Placement

Electrofish sampling during 2010 and 2011 was conducted at a total of 24, 1,000 ft (300 m) stations within Garvins Pool, Hooksett Pool and Amoskeag Pool in the Merrimack River (Appendix A). These stations were established within Garvins Pool (Stations 1 to 6), Hooksett Pool north (Stations 7 to 12) and south (Stations 13 to 18) of Merrimack Station, and Amoskeag Pool (Stations 19 to 24). Within Hooksett Pool, the ten stations consistently electrofished during historical sampling (1972, 1973, 1974, 1976, 1995, 2004 and 2005; Normandeau 2007a) were maintained and sampled during 2010 and 2011. Table 2-1 provides the coordinates for all 24 stations as well as the current and historic station nomenclature for Hooksett Pool electrofish transects. Six of the historically sampled electrofish stations were located within Hooksett Pool south of Merrimack Station (Stations 13 to 18) and four were located within Hooksett Pool north of the Station (Stations 9 to 12). Two additional 1,000 ft transects were established within Hooksett Pool north of Merrimack Station prior to 2010 sampling (Stations 7 and 8).

Physical characteristics at each electrofish station were recorded prior to sampling on 3 August 2010 in Hooksett Pool, 5 August 2010 in Amoskeag Pool and 9 August, 2010 in Garvins Pool. The occurrence of woody debris and submerged aquatic vegetation at each station was recorded along with the dominant (i.e. greater than 50% of the total station length) shoreline type (e.g. tree, shrub, residential). Woody debris was ranked as low (0-3 major snags), moderate (4-6 major snags) or high (7+ major snags). Submerged aquatic vegetation was ranked as low (0-33% bottom coverage), moderate (34-66% bottom coverage) or high (67-100% bottom coverage). Water depth measurements (ft) were collected at the endpoints and mid-point of each station at a distance of 30 feet from waters edge. The average water depth was used to determine the bank slope at each station (rise/run; mean water depth/30ft). Current velocity (ft/sec) was recorded at the mid-depth at the mid-point of each 1,000 ft station. Physical characteristics recorded for each station in Garvins, Hooksett and Amoskeag Pools are presented in Table 2-2.

A comprehensive habitat survey of Garvins, Hooksett and Amoskeag Pools was conducted during September-November, 2010 using sidescan sonar imagery (Normandeau 2011d). The resulting habitat map was used to determine the substrate composition at each electrofish station. A 30 ft wide polygon, representing each 1,000 foot long electrofish station was created to represent each area of fish sampling (See Appendix A).

2.2.2 Electrofishing Sampling

For the 2010 and 2011 sampling effort, a total of 24 electrofish stations were sampled within Garvins, Hooksett (North and South) and Amoskeag Pools (Table 2-1). As defined in the Field Standard Operating Procedure (SOP; Normandeau 2010), two electrofish boats were to sample during 10 days in August and 10 days in September, providing a total of 20 sampling days during each month. Each sampling zone (Garvins, Hooksett (North and South) and Amoskeag) was to be visited an equal number of times (10) during the two month period and all six stations within a particular sampling zone were to be sampled during each visit. Within each month, the sampling order of locations (Garvins, Hooksett, and Amoskeag) and stations within each location were randomized to prevent any potential seasonal or temporal biases. The sampling design resulted in a total of 240 possible field samples. Each field sample was assigned a code by the field crew leader at the time of collection designating its use for subsequent data analysis. Samples collected without any sampling problems related to the gear or transect were considered valid for all analytical tasks and assigned a Use Code = 1. Samples in which fish were caught but sampling problems were encountered were assigned a Use Code = 2. Sampling problems were generally related to problems with gear performance or variance from standardized sampling effort. Use Code = 5 samples were the same as Use Code = 2 samples where no fish were caught. Use Code 5 samples were excluded from all analysis.

A total of 224 Use Code 1 and 2 samples were collected from Garvins, Hooksett and Amoskeag Pools in August and September 2010 (Table 2-3). During August 2010, electrofish sampling was not conducted on six occasions due to equipment failure and those samples were classified as Use Code 5. As a result, a total of 114 Use Code 1 or 2 samples were collected during that month and could be used for all or part of the analyses. Additionally, river conditions in September 2010 made it necessary to complete the final twelve samples in October 2010. As a result, a total of 108 Use Code 1 or 2 samples were collected during September 2010 that could be used for all or part of the analyses. While data collected during October was included in the 2010 sampling summary (Section 2 of this report), it was not used in the long term trends evaluation which includes only data from the standardized time period of August and September (Section 4.0 of this report).

A total of 239 Use Code 1 samples were collected from Garvins, Hooksett and Amoskeag Pools in August and September 2011 (Table 2-4). During August 2011, a total of 96 electrofish samples were collected of which 95 were Use Code 1 and one was Use Code 2. River conditions during the latter part of August 2011 prevented completion of the full sampling schedule. As a result, those samples were collected during September 2011 when river conditions permitted. During September 2011, 144 Use Code 1 samples were collected from Garvins, Hooksett and Amoskeag Pools.

Electrofishing in Garvins, Hooksett and Amoskeag Pools was conducted during daylight hours (½ hour after sunrise to ½ hour before sunset). Electrofishing followed shoreline transects at each station in an upstream direction in water depths from 0 to 8 ft for a distance of 1,000 ft.

Each fish caught by electrofishing was counted, identified to species, weighed to the nearest gram, and measured to the nearest millimeter total length, and released back into the river. If the literature-obtained minimum length requirements representative of individuals one year of age or older (Normandeau 2010) were met, scale samples were collected from RIS (largemouth bass, smallmouth bass, yellow perch, white sucker, pumpkinseed and fallfish) and other resident fish species including bluegill, black crappie, and rock bass prior to their release. Water temperature and dissolved oxygen concentration were measured at one foot below the surface and one foot above the bottom at the midpoint of each 1,000 ft electrofish station. Additional details of the field and data collection methods for electrofishing are described in the SOP that was prepared before sampling began and governed all sampling activities during 2010 and 2011 (Normandeau 2010).

2.2.3 Analytical Methods

2.2.3.2 Catch Per Unit Effort Indices of Fish Species Abundance

Catch per unit effort (“CPUE”) is commonly used by fisheries scientists as an index of population density or stock size (Flotemersch et al./USEPA 2006), and was used as a relative index of fish abundance in Garvins, Hooksett and Amoskeag Pools. Theoretically, CPUE should be directly proportional to the abundance of fish in the stock, but sampling design characteristics such as gear, season, location, water temperature, water level, turbidity and river currents can influence this proportionality (Hubert 1983; Guland 1988). Therefore, it is important to standardize these sampling design characteristics to insure that CPUE retains the same proportional relationship to fish stock abundance among years and is not influenced by changes in design.

The CPUE of each fish species was standardized to the number of fish per 1,000 ft (300 m) for each sample collected by electrofishing during August and September in 2010 and 2011, and For each species, CPUE was determined for all juvenile and adult individuals combined as well as three life stage categories (young of the year, immature and mature). Catch-at-age data were used to determine the CPUE of age-0 fish, and immature or mature fish based on age of sexual maturity (Table 2-5). After CPUE was $\log_{10}(x + 1)$ transformed, the parametric test assumptions of normality and homogeneity of variance was satisfied in many cases as determined by the Shapiro-Wilk test of normality and Levene’s homogeneity of variance test, but were assumed not grossly violated in other cases such that would change the inference (Hubert and Fabrizio 2007). A general linear model (PROC GLM; SAS Institute Inc. 2008) was used to fit an analysis of variance (ANOVA) for testing the null hypothesis that the mean transformed CPUE of a species and life stage was equal among Garvins, Hooksett and Amoskeag Pools for each of the 2010 and 2011 sampling seasons. If the null hypothesis was rejected at $\alpha = 0.05$, a Tukey-Kramer multiple pair-wise comparison test was used to identify significant differences of mean transformed CPUE among Garvins, Hooksett and Amoskeag Pools.

The use of the CPUE from this study as a relative index of the population size or abundance of each selected fish species was a reasonable assumption because the same electrofishing sampling gear was used to sample representative fixed stations during the period of August and September in 2010 and 2011 and similar diel periods. Constant catchability was assumed.

2.2.3.3 Comparison of Fish Community Structure

Five indices were used to compare the fish community structure among pools in 2010 and 2011: (1) taxa richness, (2) Shannon Diversity Index, (3) percent generalist feeders, (4) percent tolerant individuals, and (5) the Bray-Curtis Percent Similarity Index.

Taxa richness is one of several metrics commonly used by fisheries scientists to evaluate community structure (the number of different species). Taxa richness is simply a tabulation of the number of species present within a given area at a given time (Kwak and Peterson 2007). Taxa richness was calculated as the number of distinct species present in Garvins, Hooksett and Amoskeag Pools during 2010 and 2011. When combined with other indices of community structure, taxa richness is a useful tool for identifying potential shifts in Hooksett Pool species composition over time.

The Shannon Diversity Index (H’) combines information on the number of species in an assemblage (richness) and their relative abundance (evenness) to measure overall diversity in a given community (Kwak and Peterson 2007). The Shannon Diversity Index was calculated for the fish assemblies present within Garvins, Hooksett and Amoskeag Pools during 2010 and 2011 using the formula H' = -Σpi ln(pi), where pi is the relative abundance of each fish taxon.

Trophic guilds and tolerance to environmental perturbations were determined for all fish species collected in Garvins, Hooksett and Amoskeag Pools based on classifications presented for freshwater fish in the Northeastern United States in Halliwell et al. (1999). The percentage of generalist feeders was determined for the fish communities within Garvins, Hooksett and Amoskeag Pools sampled in August and September of 2010 and 2011. The percentage of generalist feeders in a community increases as the physical and chemical habitat deteriorates (Barbour et al. 1999). Similarly, the percentage of tolerant individuals was determined for the fish communities within Garvins, Hooksett and Amoskeag Pools sampled in August and September of 2010 and 2011. The percentage of tolerant individuals in a community increases as the physical and chemical habitat deteriorates (Barbour et al. 1999).

The Bray-Curtis Percent Similarity Index was used to quantitatively compare the fish communities within Garvins Pool, Hooksett Pool and Amoskeag Pool between the 2010 and 2011 sample years. Unlike taxa richness, the Bray-Curtis index (I_{BC}) computes percent similarity among the fish taxa common in two sets of survey data (Clarke 1993). The closer the Bray-Curtis value is to 100%, the more similar the two communities are. Among similarity indices used in multivariate descriptive techniques, the Bray-Curtis index has been found to most accurately reflect true similarity among communities (Bloom 1981). A value for the percent difference by which a particular pool's fish community differs from another sampled during 2010 and 2011 was calculated using this index.

Multivariate analyses were performed using PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software to examine spatial patterns in the overall similarity of fish assemblages in the survey area (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). Data preparation and univariate analyses were run in SAS system software (version 9.2). Bray-Curtis similarity was used as the basis for both classification and ordination. Prior to analyses, fish CPUE data 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 fish 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.

Spatial differences in fish assemblages were assessed in terms of a priori designated classification variables using the analysis of similarities (ANOSIM) procedure in PRIMER (Clarke 1993). The variables included in this analysis were Pool (Garvins, Hooksett, and Amoskeag), year (2010 and 2011), and month (August and September). Each variable was tested using a one-way ANOSIM. The null hypothesis that there are no differences in community composition among the classes for each variable (pool, year, and month) was tested. ANOSIM is a nonparametric permutation test applied to the rank Bray-Curtis similarity matrix. ANOSIM includes a global test, and also a pairwise test by the same procedure, which provides comparisons of classes within a variable. The ANOSIM test statistic (R) is approximately zero if the null hypothesis is true, and R=1 if all samples within a class level are more similar to each other than any samples from different classes. A significance level was also computed. In general, a probability of 5% or less is commonly used as a criterion for rejection of the null hypothesis (Flotemersch et al. 2006). A 5% significance level ($p = 0.05$) for the test statistic (R) was assumed ecologically meaningful in these analyses.

2.3 2010 Merrimack River Electrofishing Results

2.3.1 Electrofish Station Habitat

Table 2-2 presents a summary of the physical characteristics recorded for each of the electrofish stations within Garvins, Hooksett and Amoskeag Pools. The dominant riparian component at all 24 stations within Garvins, Hooksett and Amoskeag Pools was tree cover. Woody debris was present at stations within Garvins Pool (range from low to moderate density), and Hooksett and Amoskeag Pools (range from low to high density). Submerged aquatic vegetation ranked lowest at stations within Amoskeag Pool (all classified as low density) followed by Hooksett Pool (range from low to moderate density) then Garvins Pool (range from low to high density). Average sampling depth at stations in Garvins Pool ranged from 3.7-8.6 ft, in Hooksett Pool ranged from 4.4 to 9.7 ft, and in Amoskeag Pool ranged from 6.5-9.2 ft. Bank slope, as measured from waters edge to a distance 30 ft offshore, was consistent among pools ranging from 0.1-0.3 in Garvins, 0.2-0.3 in Hooksett and 0.2-0.3 in Amoskeag Pools. Similarly, the range of observed mid-column water velocities was similar among pools, ranging from 0.1-0.2 ft/s at all stations.

Table 2-6 presents the substrate composition of each station within Garvins, Hooksett and Amoskeag Pools as determined during the 2010 sidescan sonar survey. When habitat areas for all stations within each pool are combined, sand/silt/clay was the dominant substrate representing an estimated 89.1% of habitat sampled in Garvins Pool, an estimated 71.7% of habitat sampled in Hooksett Pool and an estimated 73.2% of habitat sampled in Amoskeag Pool. Woody debris represented an estimated 9.9% of habitat sampled in Garvins Pool, an estimated 15.5% of habitat sampled in Hooksett Pool and an estimated 14.4% of habitat sampled in Amoskeag Pool. Boulder habitat represented an estimated 1.0% of habitat sampled in Garvins Pool, 6.9% of habitat sampled in Hooksett Pool, and 12.4% of habitat sampled in Amoskeag Pool. Aquatic vegetation beds covered an estimated 27.3% of the habitat area sampled in Garvins Pool, an estimated 12.3% of the habitat area sampled in Hooksett Pool and an estimated 23.7% of the habitat area sampled in Amoskeag Pool.

2.3.2 Electrofishing General Catch Characteristics

Table 2-7 presents the 2010 Merrimack River electrofish survey results from Garvins Pool (Stations 1-6), Hooksett Pool (Stations 7-18) and Amoskeag Pool (Stations 19-24). A total of 6,320 fish representing 22 individual species were captured by electrofishing from 11 August 2010 to 11 October 2010 within the three pools combined. The additional two taxonomic categories (Carp and Minnow family and Sunfish family) in Table 2-7 represented individuals which were too small for species-specific identification in the field. Within Hooksett Pool, a total of 3,591 individuals represented by 20 taxa and two taxonomic categories were captured during 2010. Electrofish sampling within Garvins Pool resulted in a total of 2,407 individuals representing 18 taxa and one taxonomic category, and 322 individuals representing 13 taxa were captured within Amoskeag Pool.

When catch from Garvins, Hooksett and Amoskeag Pools are combined, spottail shiner was the most abundant species representing 37.6% (2,379 individuals) of the total catch (Table 2-7). Largemouth bass (1,496 individuals, 23.7% of total catch) and smallmouth bass (680 individuals, 10.8% of total catch) were the second and third most abundant species, respectively. Those three species accounted for 72.1% of the total catch during 2010. No other species exceeded 10.0% of the total catch. Spottail shiner and largemouth bass were the most abundant fish species collected within Garvins and Hooksett Pools. Spottail shiner represented 51.1% of the total catch in Garvins Pool (1,230 individuals) and 32.0% of the total catch within Hooksett Pool (1,149 individuals). Largemouth bass accounted for 23.3% of the total catch in Garvins Pool (560 individuals) and 25.3% of the total catch within Hooksett Pool (909 individuals). With the exception of spottail shiner and largemouth bass, there were no additional species in Garvins Pool which composed greater than 10% of all fish sampled during 2010. Of the additional species captured within Hooksett Pool, only smallmouth bass (477 individuals, 13.3% of the total catch) and bluegill (395 individuals; 11.0% of the total catch) accounted for greater than 10% of all fish sampled. Within Amoskeag Pool the most abundant species were smallmouth bass (161 individuals, 50.0% of the total catch), redbreast sunfish (46 individuals, 14.3% of the total catch) and largemouth bass (27 individuals, 8.4% of the total catch). Overall the three most abundant species accounted for the majority of the fish captured in each pool, ranging from 70.6% of the total in Hooksett Pool to 82.9% Garvins Pool.

2.3.3 Electrofishing Catch-Per-Unit-Effort

Table 2-8 presents the mean CPUE values calculated for each fish species collected during 2010 within Garvins, Hooksett and Amoskeag Pools, and all stations combined). Fish species with the highest CPUE for all stations were spottail shiner (9.7 fish per 1000 ft), largemouth bass (6.6 fish per 1,000 ft) and smallmouth bass (3.0 fish per 1,000 ft).

Results for an ANOVA and Tukey-Kramer multiple pairwise comparison tests on the log transformed mean CPUE values among Garvins, Hooksett, and Amoskeag Pools for each taxa collected by electrofish sampling during 2010 are presented in Table 2-9. There were no significant differences in the mean electrofish CPUE detected for 12 of the 22 taxa collected during 2010 when compared between Hooksett Pool and Garvins Pool. American eel, bluegill, redbreast sunfish, smallmouth bass and white sucker had a significantly higher mean CPUE within Hooksett Pool than was observed within Garvins Pool. Mean CPUE during 2010 was significantly higher within Garvins Pool than was observed within Hooksett Pool for chain pickerel, largemouth bass, pumpkinseed, tessellated darter and yellow perch. When Hooksett and Amoskeag Pools were compared, there were no significant differences in the mean electrofish CPUE detected for 15 of the 22 taxa collected during 2010. American eel, bluegill, fallfish, largemouth bass, redbreast sunfish, and spottail shiner had a significantly higher mean CPUE within Hooksett Pool than was observed within Amoskeag Pool. Mean CPUE during 2010 was significantly higher within Amoskeag Pool than was observed within Hooksett Pool for golden shiner. There were no significant differences in the mean electrofish CPUE detected for 14 of the 22 taxa collected during 2010 when compared between Amoskeag Pool and Garvins Pool. Golden shiner and smallmouth bass had a significantly higher mean CPUE within Amoskeag Pool than was observed within Garvins Pool. Mean CPUE during 2010 was significantly higher within Garvins Pool than was observed within Amoskeag Pool for chain pickerel, largemouth bass, pumpkinseed, spottail shiner, tessellated darter and yellow perch.

CPUE was significantly higher in Garvins Pool compared to the other pools for five taxa: chain pickerel, largemouth bass, pumpkinseed, tessellated darter, and yellow perch (Table 2-9). CPUE was significantly higher in Hooksett Pool compared to the other pools for three taxa: American eel, bluegill, and redbreast sunfish. CPUE was significantly higher in Amoskeag Pool only for golden shiner.

Potential differences for mean CPUE values among Pools (Garvins, Hooksett and Amoskeag) for young of year, immature and mature fish were examined for the nine taxa from which scale samples were collected during 2010 (Table 2-10). Abundance in Garvins and Hooksett Pools, as estimated by CPUE, of young of year largemouth bass, pumpkinseed, and yellow perch was significantly higher in Garvins Pool while abundance of young of year smallmouth bass was higher in Hooksett Pool. Immature pumpkinseed and yellow perch were significantly more abundant in Garvins Pool, whereas abundance of immature bluegill, largemouth bass, smallmouth bass, and white sucker was significantly higher in Hooksett Pool. Among mature fish, the abundance of yellow perch was significantly higher in Garvins Pool whereas the abundance of bluegill, fallfish, largemouth bass, and white sucker was significantly higher in Hooksett Pool.

Abundance in Garvins and Amoskeag Pools, as estimated by CPUE, of young of year largemouth bass, pumpkinseed, and yellow perch was significantly higher in Garvins Pool while abundance of young of year smallmouth bass was higher in Amoskeag Pool. Immature pumpkinseed, largemouth bass and yellow perch were significantly more abundant in Garvins Pool whereas immature white sucker were more abundant in Amoskeag Pool. Among mature fish, the abundance of largemouth bass and yellow perch were significantly higher in Garvins Pool than that observed in Amoskeag Pool.

Abundance in Amoskeag and Hooksett Pools, as estimated by CPUE, of young of year largemouth bass and bluegill was significantly higher in Hooksett Pool. Immature black crappie, bluegill, fallfish, largemouth bass and smallmouth bass were significantly more abundant in Hooksett Pool than that observed in Amoskeag Pool. Among mature fish, abundance of bluegill, fallfish, and largemouth bass was significantly higher in Hooksett Pool. Abundance of mature black crappie was significantly higher in Amoskeag Pool.

CPUE in Garvins Pool was significantly higher than the other two pools for six taxa and life stage combinations: young of the year largemouth bass, young of the year and immature pumpkinseed, and all three life stages of yellow perch. CPUE in Hooksett Pool was significantly higher than the other two pools for six taxa and life stage combinations: immature and mature bluegill, mature fallfish, immature and mature largemouth bass, and immature smallmouth bass.

2.4 2011 Merrimack River Electrofishing Results

Methodology and electrofish stations used during the 2011 electrofish survey of the Merrimack River were the same used during 2010 (see Section 2.3.1).

2.4.1 2011 Electrofishing General Catch Characteristics

Table 2-11 presents the 2011 Merrimack River electrofish survey results from Garvins Pool (Stations 1-6), Hooksett Pool (Stations 7-18) and Amoskeag Pool (Stations 19-24). A total of 4,614 fish representing 22 fish taxa were captured by electrofishing from 12 August 2011 to 29 September 2011 within the three combined Pools (Garvins, Hooksett and Amoskeag). The additional taxonomic category (Sunfish family) in Table 2-11 represented individuals which were too small for species-specific identification in the field. Within Hooksett Pool a total of 2,607 individuals represented by 20 taxa and one taxonomic category were captured during 2011. Electrofish sampling within Garvins Pool resulted in the capture of 1,642 individuals, representing 16 taxa and one taxonomic category whereas 365 individuals representing 15 taxa and one taxonomic category were captured within Amoskeag Pool.

When catch from Garvins, Hooksett and Amoskeag Pools are combined, spottail shiner was the most abundant species representing 20.5% (946 individuals) of the total catch (Table 2-11). Fallfish (591 individuals, 12.8% of total catch) and smallmouth bass (573 individuals, 12.4% of total catch) were the second and third most frequently captured species, respectively. Those three species accounted for 45.7% of the total catch during 2011. Other species comprising greater than 10% of the total catch included: yellow perch (528 individuals, 11.4% of total catch), bluegill (516 individuals, 11.2% of total catch) and largemouth bass (510 individuals, 11.1% of total catch). Total catch in Garvins Pool was dominated by spottail shiner (736 individuals; 44.8% of the total catch), yellow perch (333 individuals; 20.3% of the total catch) and bluegill (103 individuals; 6.3% of the total catch). Fallfish (522 individuals; 20.0% of the total catch), largemouth bass (409 individuals; 15.7% of the total catch), and bluegill (369 individuals; 14.2% of the total catch) were the most abundant species in Hooksett Pool. In Amoskeag Pool smallmouth bass composed 61.4% of the total catch (224 individuals) followed by bluegill (44 individuals; 12.1% of total catch).

2.4.2 Electrofishing Catch-Per-Unit-Effort

Table 2-12 presents the mean CPUE values calculated for each fish species collected during 2011 within Garvins, Hooksett and Amoskeag Pools (all stations combined). Fish species with the highest CPUE values for all stations were spottail shiner (4.0 fish per 1000 ft), fallfish (2.5 fish per 1,000 ft) and smallmouth bass (2.4 fish per 1,000 ft).

Results for an ANOVA and Tukey-Kramer multiple pairwise comparison tests on the log transformed mean CPUE values among Garvins, Hooksett, and Amoskeag Pools for each taxa collected by electrofish sampling during 2011 are presented in Table 2-13. There were no significant differences in the mean electrofish CPUE between Hooksett Pool and Garvins Pool for 13 of the 22 taxa collected during 2011. Fallfish, largemouth bass, redbreast sunfish, smallmouth bass, and white sucker had a significantly higher mean CPUE within Hooksett Pool than was observed within Garvins Pool. Mean CPUE during 2011 was significantly higher within Garvins Pool than was observed within Hooksett Pool for chain pickerel, pumpkinseed, spottail shiner and yellow perch. When Hooksett and Amoskeag Pools were compared, there were no significant differences in the mean electrofish CPUE detected for 12 of the 22 taxa collected during 2011. Bluegill, fallfish, golden shiner, largemouth bass, redbreast sunfish, spottail shiner, tessellated darter, white sucker and yellow perch had a significantly higher mean CPUE within Hooksett Pool than was observed within Amoskeag Pool. Mean CPUE during 2011 was significantly higher within Amoskeag Pool than was observed within Hooksett and Garvins Pools for smallmouth bass. There were no significant differences in the mean electrofish CPUE detected for 14 of the 22 taxa collected during 2011 when compared between Amoskeag Pool and Garvins Pool. Mean CPUE during 2011 was significantly higher within Garvins Pool than was observed within Amoskeag Pool for bluegill, chain pickerel, largemouth bass, pumpkinseed, spottail shiner, white sucker and yellow perch.

CPUE was significantly higher in 2011 in Garvins Pool than the other two pools for four taxa: chain pickerel, pumpkinseed, spottail shiner, and yellow perch. Similarly, CPUE was higher in Hooksett Pool compared to the other two pools for four taxa: fallfish, largemouth bass, redbreast sunfish, and white sucker.

2.5 2010 and 2011 Community Indices

In addition to evaluating trends in species-specific CPUE, differences in community trends were examined through the following indices: (1) taxa richness, (2) diversity, (3) percent generalist feeders, (4) percent tolerant individuals, and (5) the Bray-Curtis Percent Similarity Index.

2.5.1 Taxa Richness

When all samples collected by boat electrofishing during 2010 and 2011 are considered (Table 2-14), taxa richness was highest in Hooksett Pool (2010 and 2011: 20 species) and lowest in Amoskeag Pool (2010: 13 species; 2011: 15 species). During 2010 and 2011 Garvins Pool had a taxa richness of 18 and 16 species.

During 2010, three species (American eel, n=24; Eastern silvery minnow, n=3; and, margined madtom, n=7) present in Hooksett Pool were not detected in either Garvins or Amoskeag Pools (Table 2-7). Juvenile alewife were present within both Hooksett and Amoskeag Pools but were not detected in Garvins Pool during 2010. Species absent in Hooksett Pool electrofish samples but collected within Garvins or Amoskeag Pools during the 2010 electrofishing survey included brown bullhead and golden shiner. Golden shiner were present in both Amoskeag (n=10) and Garvins (n=1) Pools whereas brown bullhead (n=2) were only present in Garvins Pool. During 2010, five species (yellow bullhead, tessellated darter, spottail shiner, fallfish, and common shiner) present within both Garvins and Hooksett Pools were absent in Amoskeag Pool (Table 2-7).

During 2011 four species (yellow bullhead, n=1; margined madtom, n=2; eastern blacknose dace, n=1; and American shad, n=1) were present in Hooksett Pool but not detected within Amoskeag or Garvins Pools (Table 2-11). American eel were present within Hooksett Pool (n=8) and Amoskeag Pool (n=4) but not within Garvins Pool during 2011. During 2011, three species (golden shiner, common shiner and tessellated darter) present within both Garvins and Hooksett Pools were absent in Amoskeag Pool. Only brown trout (Garvins, n=1; Amoskeag, n=1) and brown bullhead (Amoskeag, n=1) were detected during 2011 electrofish sampling from locations other than Hooksett Pool.

The data demonstrate that the taxa richness of the Hooksett Pool fish community is comparable to the taxa richness of the thermally uninfluenced Garvins Pool fish community over two years of standardized electrofishing sampling (2010 and 2011). This similarity between the fish communities in the two pools supports a finding that Merrimack Station's thermal discharge has not reduced the species richness of the Hooksett Pool fish community, which in turn is indicative that the Station's discharge has not caused appreciable harm.

2.5.2 Shannon Diversity Index

The Shannon Diversity Index (H') was calculated for the fish communities present within Garvins, Hooksett and Amoskeag Pools during 2010 and 2011 and is presented in Table 2-15. Fish community diversity was greater in Hooksett Pool during both 2010 and 2011 than in either Garvins or Amoskeag Pools. This supports a finding that Merrimack Station's thermal discharge has not reduced the diversity of the fish community in Hooksett Pool, which in turn is indicative that the Station's discharge has not caused appreciable harm.

2.5.3 Percent Generalist Feeders

Trophic guilds for all fish species collected in Garvins, Hooksett and Amoskeag Pools during 2010 and 2011 are presented in Table 2-16. During 2010, there were 8 species of generalist feeder found in Garvins Pool, 7 in Hooksett Pool and 5 in Amoskeag Pool. During 2011, there were 7 species of generalist feeder found in Garvins Pool, 9 in Hooksett Pool and 6 in Amoskeag Pool. The percentage of generalist feeders was determined for the Garvins, Hooksett and Amoskeag Pool fish communities as sampled during 2010 and 2011 (Table 2-17). During 2010, the percentage of generalist feeders was highest in Amoskeag Pool and lowest in Garvins Pool. During 2011, the percentage of generalist feeders was highest in Hooksett Pool and lowest in Garvins Pool. However, the increased percentage of generalist feeders in Hooksett Pool during 2011 was driven by the catch of fallfish, which represented over 20% of the Hooksett Pool fish catch and only 3% of the Garvins and Amoskeag Pool fish catches during that year. The large contribution of fallfish (a coolwater species) to the observed difference supports a finding that Merrimack Station is not responsible for the increase in generalist feeders, which in turn is indicative that the Station's discharge has not caused appreciable harm.

2.5.4 Percent Tolerant Individuals

Tolerances to environmental perturbations for all fish species collected in Garvins, Hooksett and Amoskeag Pools during 2010 and 2011 are presented in Table 2-16. During 2010, there were 4 species tolerant of pollution found in Garvins and Hooksett Pools and 3 in Amoskeag Pool. During 2011, there were 3 species tolerant of pollution found in Garvins Pool, 6 in Hooksett Pool and 4 in Amoskeag Pool. The percentage of pollution-tolerant fish species was determined for the Garvins, Hooksett and Amoskeag Pool fish communities as sampled during 2010 and 2011 (Table 2-17). During 2010, the percentage of pollution-tolerant species was highest in Amoskeag Pool and lowest in Garvins Pool. During 2011, the percentage of pollution-tolerant species was highest in Hooksett Pool and lowest in Garvins Pool. However, differences in the percent of pollution-tolerant species between Garvins and Hooksett Pools can be attributed to the greater relative abundance of bluegill, American eel and white sucker in Hooksett Pool. Although bluegill (a warmwater species) partially contributed to the observed differences, the contribution of white sucker (the most thermally sensitive fish species in the pool) to the observed difference supports a finding that Merrimack Station is not responsible for the increase in tolerant individuals, which in turn is indicative that the Station's discharge has not caused appreciable harm.

2.5.5 Bray-Curtis Percent Similarity Index

Table 2-18 presents a comparison of the fish community sampled by electrofishing within Garvins, Hooksett and Amoskeag Pools in August and September of 2010 and 2011 as computed by the Bray-Curtis Percent Similarity Index. During both years, community similarity appeared to decrease as distance between sampling locations was increased. Comparing the 2010 fish communities, the Bray-Curtis similarity was greater between Garvins and Hooksett Pools (64.4%) than it was between Garvins and Amoskeag Pools (20.2%). Likewise, during 2011, the Bray-Curtis similarity was greater between Garvins and Hooksett Pool fish communities (43.2%) than it was between Garvins and Amoskeag Pool fish communities (23.4%). Year to year variations in the relative contributions of various fish species can impact the annual similarity calculated between Garvins and Hooksett Pools. However, that similarity between Garvins and Hooksett was not consistently low among sampled years (e.g. 64.4% similarity was recorded during 2010) suggests that Merrimack Station has not caused appreciable harm to the BIP. The Bray-Curtis similarity value comparing fish communities within Hooksett and Amoskeag Pools was intermediate during both years of sampling (Table 2-18).

Cluster analysis performed on the electrofishing data collected in August and September in 2010 and 2011 within Garvins, Hooksett and Amoskeag Pools discriminated among five species assemblages (Groups IA, IB, IIA, IIB1, IIB2), and the resulting dendrogram is presented in Figure 2-2. The cluster analysis utilized station, month and year to classify samples into appropriate groups. Figure 2-3 presents the MDS ordination results using station to identify sample location and a unique color to identify individual cluster groups (IA, IB, IIA, IIB1, IIB2). Cluster groups differed in terms of their species composition and relative abundance. These differences can be seen in Table 2-19, which presents the abundance of taxa composing each group.

Cluster groups were identified using a hierarchical naming convention to identify the similarities and differences among the groups. The two main groups (I and II) differ considerably from each other, separating at a Bray-Curtis similarity level of less than 40%. Three outlier groups, STN 19, STN 3,6 and STN 11, did not cluster with either Group I or II, likely due to small sample size or dissimilar catch data. These outliers were not considered in the remainder of analyses. Group I was further separated into Group IA and Group IB with Group IB containing the majority of the samples (n=22). As indicated by Figures 2-2 and 2-3, substantial differences in community similarity exist between Group IA and Group IB. Group II was separated into Group IIA and Group IIB, with the additional separation in Group IIB of Group IIB1 and Group IIB2. The number of samples within each subgroup of Group II were similar. Groups IIA, IIB1 and IIB2 consisted of 26, 22, and 19 samples respectively. Similarity between Group IIB1 and Group IIB2 was approximately 50%, and slightly higher than the similarity between either Group IIA and Group IIB1 or Group IIA and Group IIB2.

The SIMPROF (similarity profile test) analysis was used to define the characteristics of the species composition for each cluster group.

Group IA was a small cluster consisting of samples from Garvins (n=2) and Amoskeag (n=1) Pools and contained only 5 species. The primary species composing this grouping were, in order of abundance, largemouth bass, smallmouth bass and spottail shiner (Table 2-19).

Group IB contained the majority of samples which were clustered into Group I (n=22). Group IB consisted of 18 taxa (17 species, 1 family) and was made up of stations from Amoskeag Pool (n=21) as well as a single station from Garvins Pool. The primary species comprising this group were smallmouth bass, bluegill and redbreast sunfish (Table 2-19).

Group IIA contained 26 samples. The majority of the stations included in this group were from Garvins Pool (n=19) with the remainder coming from Hooksett Pool (n=7). Spottail shiner was the most abundant species followed by largemouth bass and yellow perch (Table 2-19).

Group IIB1 contained 22 samples, all of which were from Hooksett Pool. The most abundant species in this group were largemouth bass, bluegill and smallmouth bass (Table 2-19).

Group IIB2 contained 19 samples, all of which were from Hooksett Pool. Species composition in this pool was dominated by fallfish, spottail shiner and smallmouth bass (Table 2-19).

Electrofish stations tended to cluster spatially by location, with the majority of Garvins Pool stations creating Group IIA, Hooksett Pool stations creating Groups IIB1 and IIB2, and Amoskeag Pool stations creating Group IB (Figures 2-2, 2-3). As was previously noted for the Bray Curtis analysis (Table 2-18), similarities observed in the cluster analysis and based on taxa composition and relative abundance also indicate that the fish communities follow a spatial distribution, with Group IIA (composed mainly of Garvins Pool stations) being more similar to IIB1, and IIB2 (composed solely of Hooksett Pool stations) than to group IB (composed mainly of Amoskeag Pool stations). Group IA was the exception and was more similar to IB than IIA, the other group composed mainly from Garvins Pool stations.

2.5.5.1 Dissimilarity Comparisons

Table 2-20 presents the species contributing to approximately 50% of the overall dissimilarity between selected groups based on the SIMPER analysis. Defining characteristics in the species assemblage dissimilarity are discussed below in order of dissimilarity for four of the groups that represent the majority of the stations for each Pool (Group IB – primarily samples from Amoskeag Pool stations, Group IIA – primarily samples from Garvins Pool stations, Group IIB1 – primarily samples from Hooksett Pool stations south of Merrimack Station and Group IIB2 – primarily samples from Hooksett Pool stations north of Merrimack Station). Comparisons are detailed below in order of highest dissimilarity to lowest dissimilarity.

Groups IB and IIA. These two groups were the most dissimilar and characterize the majority of Amoskeag Pool stations (Group IB) and Garvins Pool stations (Group IIA). The overall dissimilarity between these two groups was 71.86% (Table 2-20). The top three fish species cumulatively contributing approximately 50% of the overall dissimilarity between Group IB and Group IIA were spottail shiner, largemouth bass and yellow perch. All three of those species exhibited greater abundance within stations clustered within Group IIA (primarily samples from Garvins Pool stations).

Groups IB and IIB2. These two groups characterize the majority of Amoskeag Pool stations (Group IB) and Hooksett Pool stations north of Merrimack Station (Group IIB2). The overall dissimilarity between these two groups was 60.32% (Table 2-20). The top five fish species cumulatively contributing approximately 50% of the overall dissimilarity between Group IB and Group IIB2 were fallfish, spottail shiner, white sucker, largemouth bass and redbreast sunfish. All five of those species exhibited greater abundance within stations clustered within Group IIB2 (primarily samples from Hooksett Pool stations north of Merrimack Station).

Groups IB and IIB1. These two groups characterize the majority of Hooksett Pool stations south of Merrimack Station (Group IIB1) and Amoskeag Pool stations (Group IB). The overall dissimilarity between these two groups was 58.70% (Table 2-20). The top three fish species cumulatively contributing approximately 50% of the overall dissimilarity between Group IB and Group IIB1 were largemouth bass, bluegill and smallmouth bass. All three of those species exhibited greater abundance at stations clustered within Group IIB1 (primarily samples from Hooksett Pool stations south of Merrimack Station).

Groups IIA and IIB1. These two groups characterize the majority of Hooksett Pool stations south of Merrimack Station (Group IIB1) and the majority of Garvins Pool stations (Group IIA). The overall dissimilarity between these two groups was 55.92% (Table 2-20). The top four fish species cumulatively contributing approximately 50% of the overall dissimilarity between Group IIA and Group IIB1 were spottail shiner, yellow perch, bluegill, and largemouth bass. Spottail shiner exhibited greater abundance at stations clustered within Group IIA (primarily samples from Garvins stations) and contributed 24% of average dissimilarity found between the two groups. Yellow perch, bluegill and largemouth bass each contributed less than 10% to the overall dissimilarity. Largemouth bass and bluegill were in greater abundance within Group IIB1 (primarily samples from Hooksett Pool stations south of Merrimack Station) while yellow perch abundance was higher in Group IIA (primarily samples from Garvins Pool stations).

Groups IIB2 and IIA. These two groups characterize the majority of Hooksett Pool stations north of Merrimack Station (Group IIB2) and Garvins Pool stations (Group IIA). The overall dissimilarity between these two groups was 53.33% (Table 2-20). The top five fish species cumulatively contributing approximately 50% of the overall dissimilarity between Group IIB2 and Group IIA were spottail shiner, fallfish, yellow perch, largemouth bass, and smallmouth bass. Spottail shiner, yellow perch and largemouth bass were in greater abundance within Group IIA (primarily samples from Garvins Pool stations) while fallfish and smallmouth bass abundance was higher in Group IIB2 (primarily samples from Hooksett Pool stations north of Merrimack Station).

Groups IIB2 and IIB1. These two groups were the least dissimilar and characterize the majority of Hooksett Pool stations south of Merrimack Station (Group IIB1) and Hooksett Pool stations north of Merrimack Station (Group IIB2). The overall dissimilarity between these two groups was 50.52% (Table 2-20). The top five fish species cumulatively contributing approximately 50% of the overall dissimilarity between Group IIB2 and Group IIB1 were largemouth bass, fallfish, bluegill, spottail shiner, and smallmouth bass. No fish species contributed greater than 14% of the dissimilarity and whereas largemouth bass and bluegill had higher average abundances at stations clustered in Group IIB1 (primarily samples from Hooksett Pool stations south of Merrimack Station), fallfish, spottail shiner, and smallmouth bass exhibited greater abundance at stations clustered within Group IIB2 (primarily samples from Hooksett Pool stations north of Merrimack Station).

Overall, the abundance of spottail shiner at stations clustered within Group IIA (primarily samples from Garvins Pool stations) appears to be the primary determinant separating that group from Groups IIB1 (all samples from Hooksett Pool stations south of Merrimack Station) and IIB2 (all samples from Hooksett Pool stations north of Merrimack Station) (as well as from Group IB (primarily samples from Amoskeag Pool stations)). This accounted for approximately 20% of the dissimilarity among those three comparisons (Table 2-20). The abundance of yellow perch at stations clustered within Group IIA (primarily samples from Garvins Pool stations) also contributed to the dissimilarity for that compared with Groups IB, IIB1 and IIB2, although the percent contribution was less than half that of spottail shiner in all cases (Table 2-20). The cluster analysis and associated dissimilarity analysis distinguishing Group IIA from Groups IIB1 and IIB2 does not entirely separate the Garvins Pool and Hooksett Pool fish communities, as Group IIA was composed of samples both from Hooksett Pool north of Merrimack Station (n=7) and samples from Garvins Pool stations (n=19). The clustering of stations from Hooksett Pool north of Merrimack Station and Garvins Pool emphasizes the similarity between these two locations. As the entire Hooksett Pool should be considered as a whole when assessing impacts to the BIP (USEPA 2011), the lack of complete separation of Garvins and Hooksett Pool samples within the cluster analysis as well as the significant contribution from a warmwater fish species (spottail shiner) in Garvins Pool to observed differences within the cluster analysis does not provide definitive evidence to support a finding that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

Within Groups IIB1 (primarily samples from Hooksett Pool stations south of Merrimack Station) and IIB2 (primarily samples from Hooksett Pool stations north of Merrimack Station), there was the least amount of dissimilarity (50.52%). Fish species contributing to approximately 50% of the average calculated dissimilarity were present in both groups, suggesting species abundance was an important variable. Group IB (primarily samples from Amoskeag Pool stations) had lower species richness (Table 2-16) and abundance (Table 2-20) in comparison with other groups. This trend is also evident in the SIMPER analyses comparing Group IB with Groups IIA, IIB1 and IIB2, where all species (excluding smallmouth bass) contributing to approximately 50% of the cumulative dissimilarity are in lower abundance within Group IB (primarily samples from Amoskeag Pool stations).

2.5.2.2 Comparison of Species Distributions to Pool, Year and Month

ANOSIM (Analysis of Similarities) was used to compare spatial differences in fish assemblages for the variables year (2010 and 2011), month (August and September) and pool (Garvins, Hooksett and Amoskeag) and results of those analyses are presented in Table 2-21.

The null hypotheses of no significant differences in community composition among the classes were rejected for year and month. Based on the significance level (16.3%), month (August and September) contribute little to the discrimination among groups in this analysis. Whereas the variable pool corroborates with the dendrogram (Figure 2-2) and MDS plot (Figure 2-3), year does not necessarily. The low R statistic for year (R=0.136) indicates similarities within and between pools will, on average, be the same. As a result, year (2010 and 2011) contributes little to the discrimination among groups in this analysis. The R-statistic is a useful comparative measure to determine degree of separation of pools, and its value is as, if not more, valuable as the statistical significance in this analysis (Clark and Warwick 2001). Based on the low R-statistic for year and the lack of apparent impacts to the groups in Figure 2-2 and 2-3, the statistical significance for year was not considered. Within the spatial component (Garvins, Hooksett, and Amoskeag Pools) of the ANOSIM analysis, all pools showed a significant (0.001) statistical difference when compared with each other as well as a substantial R-statistic. The R-statistic was greatest for the comparison between Garvins Pool and Amoskeag Pool and lowest for the comparisons with Hooksett Pool. These results are in agreement with the major Groups IB, IIA, IIB1, and IIB2 displayed in Figures 2-2 and 2-3. These findings suggest that temporal variables (year and month) did not contribute significantly to observed differences. Significant differences were attributed to where samples were collected (Pool). These findings are consistent with the dissimilarity comparisons presented above in Section 2.5.5.1. As determined in that analysis, the lack of complete separation of Garvins and Hooksett Pool samples within the cluster analysis as well as the significant contribution from a warmwater fish species (spottail shiner) in Garvins Pool to observed differences within the cluster analysis does not provide definitive evidence to support a finding that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

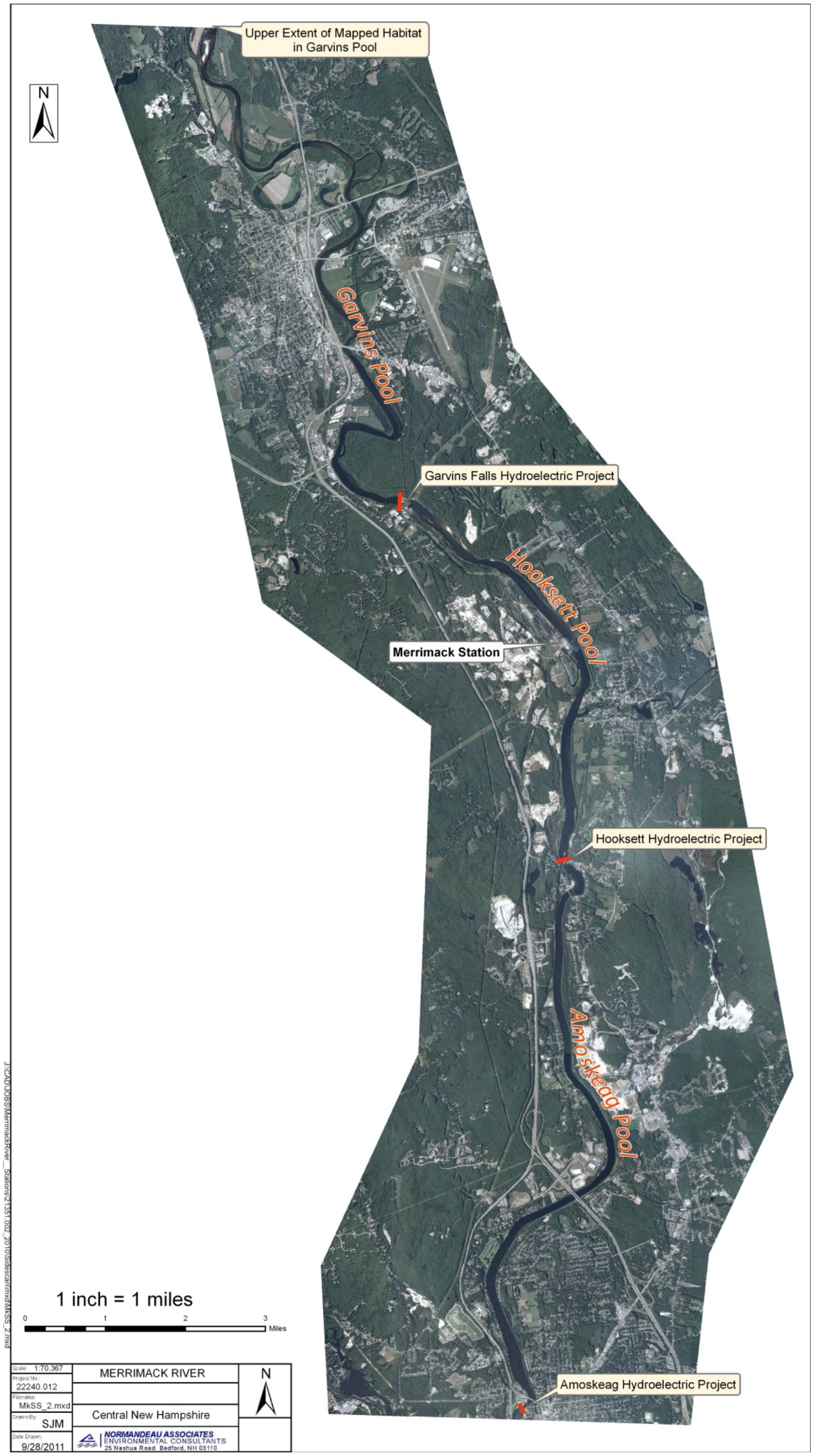


Figure 2-1. Study area on the Merrimack River showing the locations of Garvins Pool, Hooksett Pool, Amokseag Pool, and Merrimack Station.

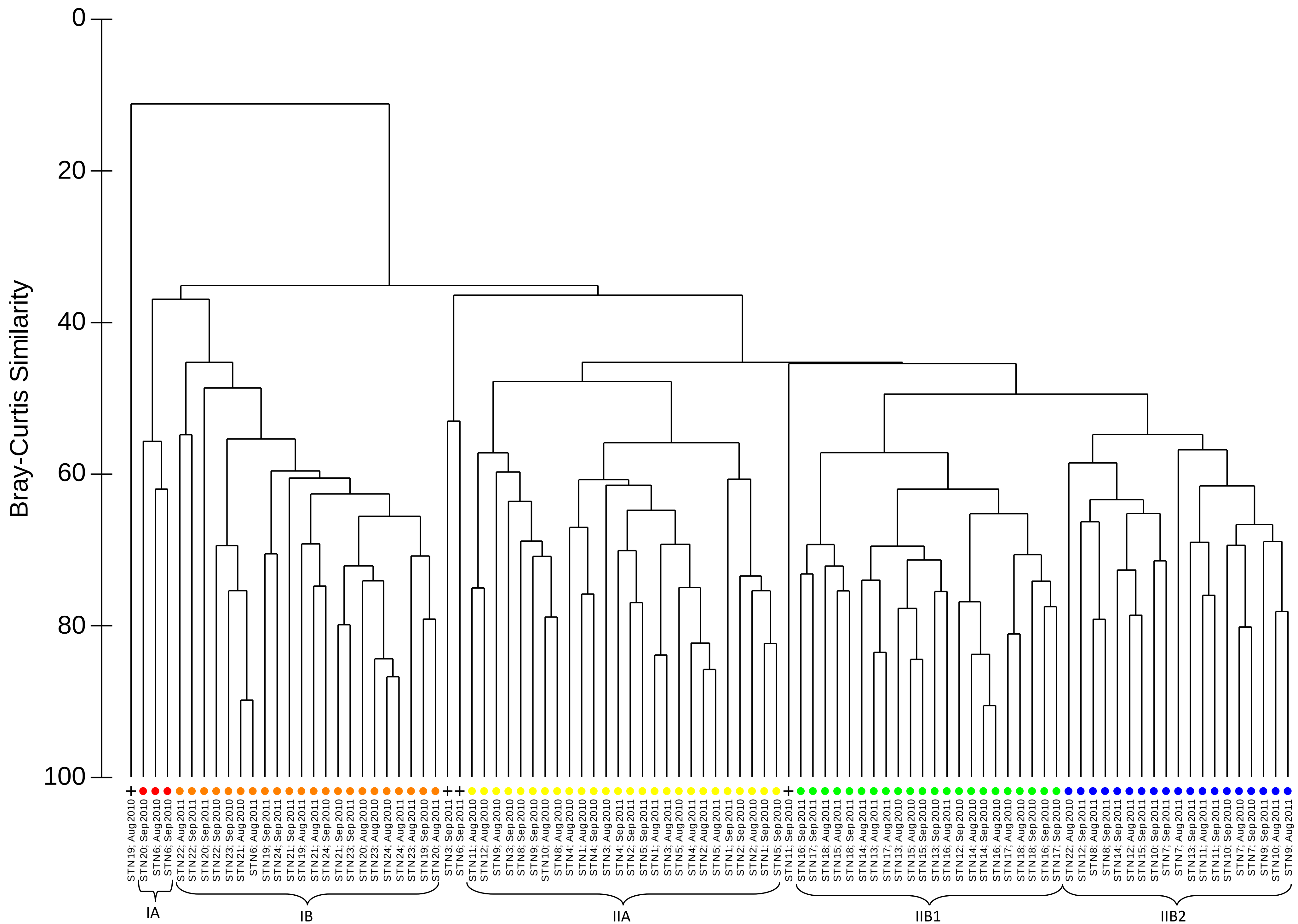


Figure 2-2. Results of cluster analysis based on Bray-Curtis similarities of square root transformed species abundances at 96 stations sampled in 2010 and 2011 within Garvins, Hooksett and Amoskeag Pools in the Merrimack River, NH.

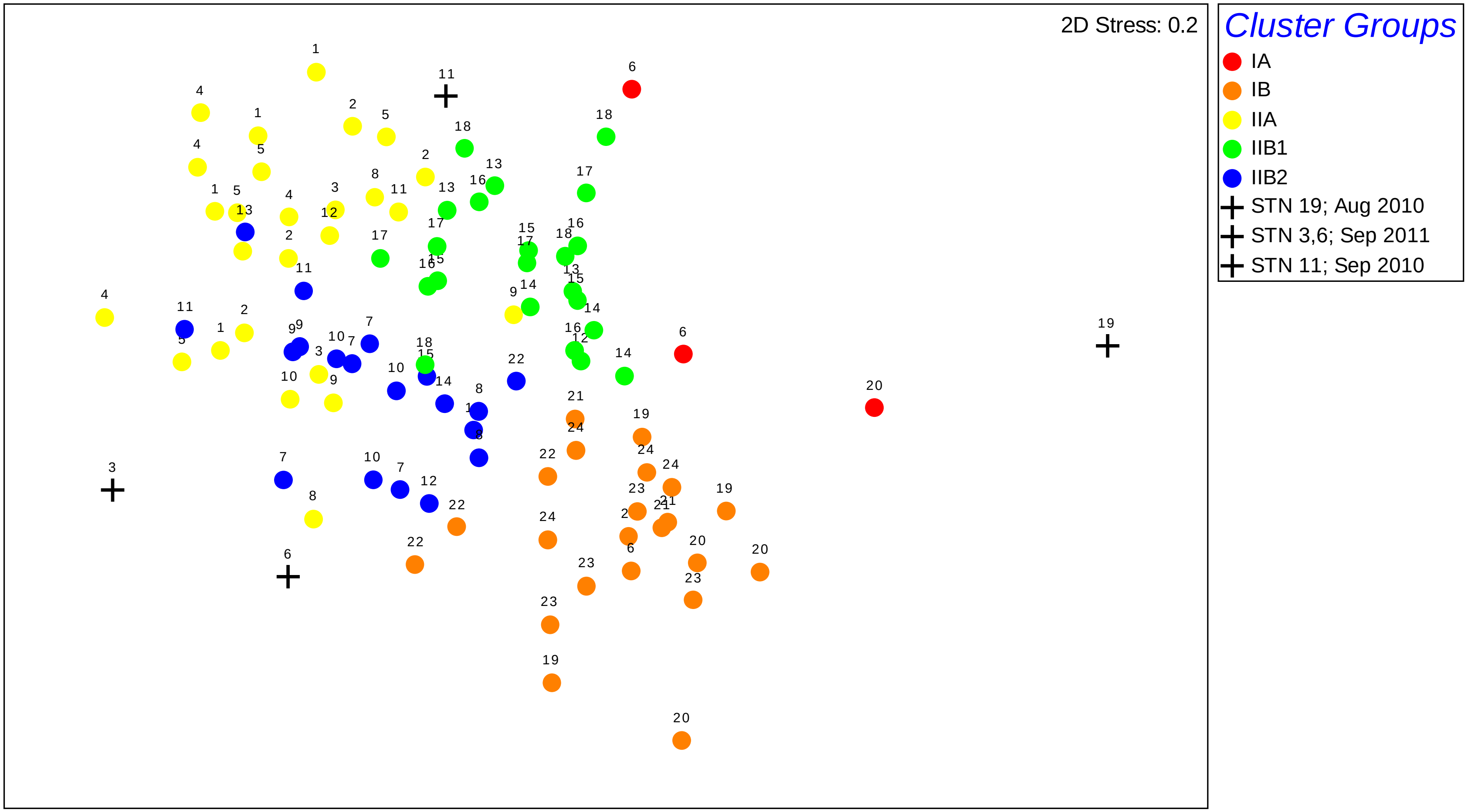


Figure 2-3. Results of MDS ordination based on Bray-Curtis similarities of square root transformed abundances at 96 stations sampled in 2010 and 2011 within Garvins, Hooksett and Amoskeag Pools in the Merrimack River, NH.

Table 2-1. Station locations and descriptions for the 2010 and 2011 Merrimack River Electrofishing Survey. Latitudes and Longitudes in NH State Plane NAD82 ft.

Sample Pool	2010-2011 Station Nomenclature		Historic Station Nomenclature*		Downstream Coordinates		Upstream Coordinates		Station Length (ft)
	Station ID	Bank	Station ID	Station ID	Latitude	Longitude	Latitude	Longitude	
Garvins Pool	1	E	-	-	43.216456	-71.520455	43.219001	-71.521944	1,000
Garvins Pool	2	W	-	-	43.2104	-71.529254	43.211714	-71.52598	1,000
Garvins Pool	3	E	-	-	43.20398	-71.529447	43.20664	-71.530518	1,000
Garvins Pool	4	W	-	-	43.201155	-71.525902	43.202906	-71.528348	1,000
Garvins Pool	5	E	-	-	43.198036	-71.521088	43.200003	-71.523843	1,000
Garvins Pool	6	W	-	-	43.195446	-71.522625	43.197824	-71.523492	1,000
Hooksett North	7	E	-	-	43.152841	-71.479231	43.154316	-71.481726	1,000
Hooksett North	8	W	-	-	43.151892	-71.480329	43.153275	-71.483162	1,000
Hooksett North	9	E	11	N9-N10 E	43.148551	-71.47396	43.150595	-71.476427	1,000
Hooksett North	10	W	11	N9-N10 W	43.147791	-71.47494	43.149807	-71.477485	1,000
Hooksett North	11	E	12	N6-N7 E	43.144461	-71.46775	43.146312	-71.470606	1,000
Hooksett North	12	W	12	N6-N7 W	43.143651	-71.46937	43.145546	-71.47207	1,000
Hooksett South	13	E	13	S0-S1 E	43.133661	-71.46101	43.136421	-71.46185	1,000
Hooksett South	14	W	13	S0-S1 W	43.133271	-71.46297	43.136091	-71.46328	1,000
Hooksett South	15	E	14	S4-S5 E	43.129631	-71.46338	43.132171	-71.46199	1,000
Hooksett South	16	W	14	S4-S5 W	43.129766	-71.464874	43.132321	-71.4634	1,000
Hooksett South	17	E	15	S17-S18 E	43.111831	-71.46351	43.114421	-71.46438	1,000
Hooksett South	18	W	15	S17-S18 W	43.111345	-71.465901	43.114111	-71.46649	1,000
Amoskeag Pool	19	E	-	-	43.09207	-71.465914	43.094391	-71.464809	1,000
Amoskeag Pool	20	W	-	-	43.093372	-71.466968	43.09571	-71.465364	1,000
Amoskeag Pool	21	E	-	-	43.086912	-71.465751	43.089718	-71.466247	1,000
Amoskeag Pool	22	W	-	-	43.085515	-71.4673	43.088319	-71.46754	1,000
Amoskeag Pool	23	E	-	-	43.081936	-71.465777	43.084736	-71.465512	1,000
Amoskeag Pool	24	W	-	-	43.081728	-71.467561	43.084495	-71.467324	1,000

*As referenced in the report titled “Merrimack Station Fisheries Survey Analysis of 1967 Through 2005 Catch and Habitat Data” (Normandeau 2007a)

Table 2-2. Physical characteristics recorded at electrofish stations within Garvins (Stations 1-6), Hooksett (Stations 7-18) and Amoskeag (Stations 19-24) Pools during August, 2010.

Pool	Location in relation to Merrimack Station	2010 Station	Historic Station	Bank	Dominant Riparian Habitat	Woody Debris[a]	SAV[b]	Depth 1 (ft)	Depth 2 (ft)	Depth 3 (ft)	Average Depth (ft)	Slope	Mid-column velocity (ft/s)
Garvins	North	1	-	E	Tree	low	High	4.5	9.5	9.2	7.7	0.26	0.1
Garvins	North	2	-	W	Tree	mod	Mod	4.5	9.2	12.2	8.6	0.29	0.2
Garvins	North	3	-	E	Tree	low	Low	5.4	5.2	7.6	6.1	0.20	0.2
Garvins	North	4	-	W	Tree	low	High	4.7	3.6	2.7	3.7	0.12	0.1
Garvins	North	5	-	E	Tree	low	High	5.4	3.2	2.8	3.8	0.13	0.2
Garvins	North	6	-	W	Tree	mod	Low	7.2	4	4.3	5.2	0.17	0.1
Hooksett	North	7	-	E	Tree	high	Mod	5.4	5.8	6	5.7	0.19	0.1
Hooksett	North	8	-	W	Tree	low	Mod	8.9	5.2	6	6.7	0.22	0.2
Hooksett	North	9	11	E	Tree	high	Low	7.4	9	7.1	7.8	0.26	0.1
Hooksett	North	10	11	W	Tree	high	Mod	7.8	5.4	3.5	5.6	0.19	0.1
Hooksett	North	11	12	E	Tree	low	Mod	5.8	4.4	3.2	4.5	0.15	0.1
Hooksett	North	12	12	W	Tree	low	Mod	8.2	7.2	8.4	7.9	0.26	0.2
Hooksett	South	13	13	W	Tree	low	Low	3.6	4.2	5.5	4.4	0.15	0.2
Hooksett	South	14	13	E	Tree	low	Low	5.4	9.4	6	6.9	0.23	0.1
Hooksett	South	15	14	E	Tree	low	Low	10.4	11.8	6.8	9.7	0.32	0.1
Hooksett	South	16	14	W	Tree	low	Mod	7.2	7.4	4.2	6.3	0.21	0.1
Hooksett	South	17	15	E	Tree	high	Low	7	5.2	6.5	6.2	0.21	0.1
Hooksett	South	18	15	W	Tree	mod	Mod	8.6	9	7.8	8.5	0.28	0.2
Amoskeag	South	19	-	E	Tree	mod	Low	6.9	7.5	5.2	6.5	0.22	0.1
Amoskeag	South	20	-	W	Tree	mod	Low	7.1	11.1	9.5	9.2	0.31	0.1
Amoskeag	South	21	-	E	Tree	high	Low	7.5	7.1	6.5	7.0	0.23	0.1
Amoskeag	South	22	-	W	Tree	high	low	11.5	8	5.4	8.3	0.28	0.1
Amoskeag	South	23	-	E	Tree	mod	low	4.9	7.2	8.1	6.7	0.22	0.2
Amoskeag	South	24	-	W	Tree	high	low	9	7.8	5.2	7.3	0.24	0.1

[a]Woody Debris
low 0-3 snags
mod 4-6 snags
high 7+ snags

[b]SAV = Submerged Aquatic Vegetation
low 0-33%
mod 34-66%
high 67-100%

Table 2-3. **Achieved electrofish sample design and designated Use Code for all samples collected within Garvins (Stations 1-6), Hooksett (Stations 7-18) and Amoskeag (Stations 19-24) Pools during August, September, and October, 2010.**

Sample Date	Station																							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
8/11/2010	1	1	1	1	1	1							1	1	1	1	1	1						
8/12/2010							1	1	1	1	1	1												
8/13/2010	1	1	1	1	1	1							1	1	1	1	1	1						
8/16/2010							1	1	1	1	1	1		1			1	1						
8/17/2010	1	1	1	1	1	1							1		1	1			2	1	1	1	1	1
8/18/2010							1	2	1	1	1	1							1	1	1	1	1	1
8/20/2010	1	1	1	1	1	1													1	1	1	1	1	1
8/24/2010	1	1	1	1	1	1							1	1	1	1	1	1						
8/27/2010							1	1	1	1	1	1							5	2	5	2	2	2
8/30/2010							1	1	1	1	1	1												
8/31/2010													2	5	5	5	1	5	2	1	1	1	1	2
9/1/2010							1	1	1	1	1	1												
9/2/2010																			1	1	1	1	1	1
9/3/2010													1	1	1	1	1	1						
9/8/2010	1	1	1	1	1	1																		
9/9/2010													1	1	1	1	1	1						
9/10/2010																			1	1	1	1	1	1
9/13/2010							1	1	1	1	1	1												
9/14/2010	1	1	1	1	1	1																		
9/15/2010							1	1	1	1	1	1												
9/16/2010													1	1	1	1	1	1	1	1	1	1	1	1
9/17/2010	1	1	1	1	2	1	1	1	1	1	1	1												
9/20/2010	1	1	1	1	1	1													1	1	1	1	1	1
9/23/2010							1	1	1	1	1	1												
9/24/2010													1	1	1	1	1	1						
9/27/2010	1	1	1	1	1	1																		
10/11/2010													1	1	1	1	1	1						
10/13/2010																			1	1	1	1	1	1

Table 2-4. **Achieved electrofish sample design and designated Use Code for all samples collected within Garvins (Stations 1-6), Hooksett (Stations 7-18) and Amoskeag (Stations 19-24) Pools during August and September, 2011.**

	Station																						
Sample Date	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
8/12/2011													1	1	1	1	1	1						
8/17/2011	1	1	1	1	1	1	1	1	1	1	1	1												
8/18/2011													1	1	1	1	1	1	1	1	1	1	1	1
8/19/2011							1	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.
8/22/2011																			1	1	1	1	1	1
8/23/2011	1	1	1	1	1	1	1	1	1	1	1	1												
8/24/2011	1	1	1	1	1	1	1	1	1	1	1	1												
8/25/2011													1	1	1	1	1	1	1	1	1	1	1	1
8/26/2011	1	1	1	1	1	2	1	1	1	1	1	1												
9/13/2011																			1	1	1	1	1	1
9/14/2011	1	1	1	1	1	1							1	1	1	1	1	1						
9/16/2011													1	1	1	1	1	1	1	1	1	1	1	1
9/19/2011							1	1	1	1	1	1	.	.	.	.	.	.	1	1	1	1	1	1
9/20/2011													1	1	1	1	1	1						
9/21/2011	1	1	1	1	1	1	1	1	1	1	1	1												
9/22/2011							1	1	1	1	1	1							1	1	1	1	1	1
9/23/2011	1	1	1	1	1	1	1	1	1	1	1	1												
9/24/2011																			1	1	1	1	1	1
9/25/2011													1	1	1	1	1	1	1	1	1	1	1	1
9/26/2011	1	1	1	1	1	1							1	1	1	1	1	1						
9/27/2011	1	1	1	1	1	1													1	1	1	1	1	1
9/28/2011							1	1	1	1	1	1	1	1	1	1	1	1						
9/29/2011	1	1	1	1	1	1																		

Table 2-5. **Total length (mm) at Age 0 and age at maturity for selected fish species assessed for significant differences in mean CPUE for young of year, immature and mature age groups.**

Common Name	Total Length at Age 0		Age at Maturity	
	TL (mm)	Reference	Years	Reference
Black Crappie	50	Carlander 1969	2	Scott and Crossman 1973
Bluegill	50	Carlander 1969	3	Scott and Crossman 1973
Fallfish	45	Carlander 1969	4	Scarola 1987
Largemouth bass	100	Carlander 1969	4	Scott and Crossman 1973
Pumpkinseed	50	Carlander 1969	2	Scott and Crossman 1973
Rock bass	40	Carlander 1969	3	Jenkins and Burkhead 1993
Smallmouth bass	100	Carlander 1969	4	Scarola 1987
White sucker	100	Carlander 1969	4	Scott and Crossman 1973
Yellow perch	75	Carlander 1969	4	Scott and Crossman 1973

Table 2-6. Substrate composition at electrofish Stations within Garvins (Stations 1-6), Hooksett (Stations 7-18) and Amoskeag (Stations 19-24) Pools as determined by interpretation of side-scan sonar imagery.

Habitat Type	Garvins Pool Stations						
	1	2	3	4	5	6	1-6
Sand/Silt/Clay	78.3%	60.0%	98.6%	100.0%	100.0%	99.9%	**89.1%**
Gravel/Cobble	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.0%**
Boulder	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**1.0%**
Rip-rap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.0%**
Ledge	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.0%**
Woody Debris	15.7%	40.0%	1.4%	0.0%	0.0%	0.1%	**9.9%**
Percentage of total area covered by submerged aquatic vegetation (SAV)							
SAV	*37.1%*	*9.9%*	*0.0%*	*77.7%*	*32.4%*	*9.6%*	***27.3%***

Habitat Type	Hooksett Pool Stations												
	7	8	9	10	11	12	13	14	15	16	17	18	7-18
Sand/Silt/Clay	30.7%	59.0%	71.8%	87.8%	100.0%	68.6%	94.6%	90.8%	67.7%	82.6%	67.0%	28.9%	**71.7%**
Gravel/Cobble	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.1%**
Boulder	68.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	24.0%	**6.9%**
Rip-rap	0.0%	0.0%	0.0%	0.0%	0.0%	26.8%	0.0%	2.5%	31.5%	5.8%	0.0%	0.0%	**5.6%**
Ledge	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	0.0%	0.0%	**0.1%**
Woody Debris	0.6%	41.0%	28.2%	12.2%	0.0%	4.6%	4.1%	6.7%	0.8%	10.3%	33.0%	47.1%	**15.5%**
Percentage of total area covered by submerged aquatic vegetation (SAV)													
SAV	*0.0%*	*9.0%*	*4.6%*	*30.0%*	*27.5%*	*0.0%*	*18.8%*	*1.1%*	*0.0%*	*4.9%*	*34.1%*	*15.3%*	***12.3%***

(Continued)

Table 2-6. (Continued)

Habitat Type	Amoskeag Pool Stations						
	19	**20**	**21**	**22**	**23**	**24**	**19-24**
Sand/Silt/Clay	95.6	22.8	86.4	67.7	98.4	66.9	**73.2**
Gravel/Cobble	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Boulder	3.8	75.0	0.0	0.0	0.0	0.0	**12.4**
Rip-rap	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Ledge	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Woody Debris	0.6	2.2	13.6	32.3	1.6	33.1	**14.4**
Percentage of total area covered by submerged aquatic vegetation (SAV)							
SAV	*41.0*	*2.6*	*33.5*	*0.0*	*59.9*	*5.6*	***23.7***

Table 2-7. Total catch (N) and relative abundance (%) of fishes caught by electrofish sampling within Garvins Pool (Stations 1-6), Hooksett Pool (Stations 7-18) and Amoskeag Pool (Stations 19-24) during 2010.

		Garvins Pool (Stations 1-6)		Hooksett Pool (Stations 7-18)		Amoskeag Pool (Stations 19-24)		All Pools (Stations 1-24)	
Common Name	**Scientific Name**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Alewife	*Alosa pseudoharengus*			21	0.6	1	0.3	22	0.3
American eel	*Anguilla rostrata*			24	0.7			24	0.4
American shad	*Alosa sapidissima*	3	0.1	69	1.9	1	0.3	73	1.2
Black crappie	*Pomoxis nigromaculatus*	5	0.2	26	0.7	2	0.6	33	0.5
Bluegill	*Lepomis macrochirus*	45	1.9	395	11	24	7.5	464	7.3
Brown bullhead	*Ameiurus nebulosus*	2	0.1					2	<0.1
Carp and minnow family	*Cyprinidae*			3	0.1			3	<0.1
Chain pickerel	*Esox niger*	75	3.1	12	0.3	5	1.6	92	1.5
Common shiner	*Luxilus cornutus*	4	0.2	36	1			40	0.6
Eastern silvery minnow	*Hybognathus regius*			3	0.1			3	<0.1
Fallfish	*Semotilus corporalis*	17	0.7	64	1.8			81	1.3
Golden shiner	*Notemigonus crysoleucas*	1	<0.1			10	3.1	11	0.2
Largemouth bass	*Micropterus salmoides*	560	23.3	909	25.3	27	8.4	1,496	23.7
Margined madtom	*Noturus insignis*			7	0.2			7	0.1
Pumpkinseed	*Lepomis gibbosus*	132	5.5	34	0.9	11	3.4	177	2.8
Redbreast sunfish	*Lepomis auritus*	21	0.9	186	5.2	46	14.3	253	4
Rock bass	*Ambloplites rupestris*	6	0.2	11	0.3	14	4.3	31	0.5
Smallmouth bass	*Micropterus dolomieu*	42	1.7	477	13.3	161	50	680	10.8
Spottail shiner	*Notropis hudsonius*	1,230	51.1	1,149	32			2,379	37.6
Sunfish family	*Lepomis spp.*	9	0.4	66	1.8			75	1.2
Tessellated darter	*Etheostoma olmstedi*	45	1.9	19	0.5			64	1
White sucker	*Catostomus commersonii*	4	0.2	65	1.8	15	4.7	84	1.3
Yellow bullhead	*Ameiurus natalis*	2	0.1	1	<0.1			3	<0.1
Yellow perch	*Perca flavescens*	204	8.5	14	0.4	5	1.6	223	3.5
Total		2,407	100	3,591	100	322	100	6,320	100

Table 2-8. **Mean CPUE (fish per 1,000 ft) and 95% upper (UCL) and lower (LCL) confidence limits of fishes caught by electrofish sampling within Garvins Pool (Stations 1-6), Hooksett Pool (Stations 7-18) and Amoskeag Pool (Stations 19-24) during 2010.**

	Garvins Pool (Stations 1-6)			Hooksett Pool (Stations 7-18)			Amoskeag Pool (Stations 19-24)			All Pools (Stations 1-24)		
Common Name	**95% LCL[a]**	**CPUE**	**95% UCL[b]**	**95% LCL[a]**	**CPUE**	**95% UCL[b]**	**95% LCL[a]**	**CPUE**	**95% UCL[b]**	**95% LCL[a]**	**CPUE**	**95% UCL[b]**
Alewife		0.0		0.0	0.2	0.4	0.0	0.0	0.1	0.0	0.1	0.2
American eel		0.0		0.1	0.2	0.3		0.0		0.1	0.1	0.2
American shad	0.0	0.1	0.1	0.0	0.6	1.2	0.0	0.0	0.1	0.0	0.3	0.6
Black crappie	0.0	0.1	0.2	0.1	0.2	0.4	0.0	0.0	0.1	0.1	0.1	0.2
Bluegill	0.4	0.8	1.1	2.5	3.4	4.3	0.2	0.5	0.7	1.6	2.0	2.5
Brown bullhead	0.0	0.0	0.1		0.0			0.0		0.0	0.0	0.0
Carp and minnow family		0.0		0.0	0.0	0.1		0.0		0.0	0.0	0.0
Chain pickerel	0.9	1.3	1.6	0.0	0.1	0.2	0.0	0.1	0.2	0.3	0.4	0.5
Common shiner	0.0	0.1	0.2	0.0	0.3	0.9		0.0		-0.1	0.2	0.5
Eastern silvery minnow		0.0		0.0	0.0	0.1		0.0		0.0	0.0	0.0
Fallfish	0.0	0.3	0.7	0.3	0.6	0.8		0.0		0.2	0.4	0.5
Golden shiner	0.0	0.0	0.1		0.0		0.0	0.2	0.4	0.0	0.0	0.1
Largemouth bass	7.7	9.4	11.1	6.3	7.9	9.5	0.3	0.5	0.8	5.6	6.6	7.6
Margined madtom		0.0		0.0	0.1	0.1		0.0		0.0	0.0	0.1
Pumpkinseed	1.3	2.2	3.2	0.2	0.3	0.4	0.0	0.2	0.4	0.5	0.8	1.1
Redbreast sunfish	0.1	0.4	0.6	1.2	1.6	2.0	0.4	0.9	1.4	0.9	1.1	1.4
Rock bass	0.0	0.1	0.2	0.0	0.1	0.2	-0.2	0.3	0.8	0.0	0.1	0.3
Smallmouth bass	0.4	0.7	1.1	3.0	4.2	5.4	1.9	2.9	3.8	2.3	3.0	3.6
Spottail shiner	4.8	20.8	36.9	5.2	8.3	11.4		0.0		5.2	9.7	14.2
Sunfish family	0.0	0.1	0.3	0.0	0.6	1.2		0.0		0.0	0.3	0.7
Tessellated darter	0.3	0.7	1.2	0.1	0.1	0.2		0.0		0.1	0.3	0.4
White sucker	0.0	0.1	0.1	0.2	0.5	0.8	0.0	0.3	0.6	0.2	0.4	0.5
Yellow bullhead	0.0	0.0	0.1		0.0			0.0		0.0	0.0	0.0
Yellow perch	2.3	3.5	4.6	0.0	0.1	0.2	0.0	0.1	0.2	0.6	1.0	1.4

[a] LCL = lower confidence limit. [b] UCL= upper confidence limit.

Table 2-9. Summary of the analysis of variance and Tukey-Kramer multiple pairwise comparisons of the mean $\log_{10}(x+1)$-transformed catch per unit effort (CPUE) of selected freshwater fish species among Garvins (G, Stations 1-6), Hooksett (H, Stations 7-18), and Amoskeag (A, Stations 19-24) Pools based on electrofishing in the Merrimack River during 2010.

Common Name	*F*	*P*	Tukey Pairwise Comparison
Alewife	1.47	0.2325	
American eel	9.40	0.0001	H G A
American shad	2.09	0.1258	
Black crappie	3.12	0.0463	H G A
Bluegill	26.31	<.0001	H G A
Brown bullhead	1.40	0.2480	
Chain pickerel	58.18	<.0001	G H A
Common shiner	0.33	0.7191	
Eastern silvery minnow	0.48	0.6193	
Fallfish	6.19	0.0024	H G A
Golden shiner	7.15	0.0010	A G H
Largemouth bass	69.67	<.0001	G H A
Margined madtom	2.33	0.1099	
Pumpkinseed	29.97	<.0001	G H A
Redbreast sunfish	17.34	<.0001	H A G
Rock bass	0.04	0.9648	
Smallmouth bass	22.72	<.0001	H A G
Spottail shiner	13.45	<.0001	G H A
Tessellated darter	10.13	<.0001	G H A
White sucker	4.59	0.0112	H A G
Yellow bullhead	2.86	0.0596	
Yellow perch	56.75	<.0001	G H A

Note: If the F-value for the overall model was not significant (i.e. P <0.05), pairwise comparisons were not provided. Pools indicated by their initials are ordered from highest to lowest mean transformed CPUE; means that are not significantly different are underlined.

Table 2-10. Summary of the analysis of variance and Tukey-Kramer multiple pair-wise comparisons of the mean $\log_{10}(x+1)$-transformed catch per unit effort (CPUE) of young of year (YOY), immature and mature individuals for nine species of resident freshwater fish among Garvins (G), Hooksett (H), and Amoskeag (A) Pools based on electrofishing in the Merrimack River during 2010.

Common Name	Life stage	Mean CPUE			*F*	*P*	Tukey Pariwise Comparison
		Garvins	Hooksett	Amoskeag			
Black Crappie	YOY	0	0	0	-	-	
	Immature	0.1	0.2	<0.1	3.25	0.0407	H G A
	Mature	0	0	<0.1	3.83	0.0233	A G H
Bluegill	YOY	0.3	0.6	0	5.8	0.0035	H G A
	Immature	0.4	2.7	0.5	22.42	<.0001	H A G
	Mature	0.1	0.2	<0.1	10.11	<.0001	H G A
Fallfish	YOY	<0.1	0	0	1.3	0.2746	
	Immature	0.3	0.3	0	3.49	0.0322	H G A
	Mature	0	<0.1	0	5.85	0.0034	H G A
Largemouth bass	YOY	6.6	2	0.1	72.5	<.0001	G H A
	Immature	2.7	6.1	0.4	33.86	<.0001	H G A
	Mature	0.1	0.2	0	22.52	<.0001	H G A
Pumpkinseed	YOY	0.2	0	0	7.25	0.0009	G H A
	Immature	2	0.2	<0.1	39.54	<.0001	G H A
	Mature	0.1	0.1	0.2	0.22	0.8042	
Rock bass	YOY	0	0	0	-	-	
	Immature	0.1	<0.1	0	1.53	0.2194	
	Mature	<0.1	<0.1	0	2.44	0.0897	
Smallmouth bass	YOY	0.4	1.7	1.9	12.94	<.0001	A H G
	Immature	0.3	2.4	0.8	24.7	<.0001	H A G
	Mature	0.1	0.1	<0.1	0.35	0.7077	
White sucker	YOY	0.1	0.1	0	1.48	0.2295	
	Immature	0	0.3	0.2	4.64	0.0106	H A G
	Mature	0	0.2	0.1	4.66	0.0105	H A G
Yellow perch	YOY	0.1	0	0	5.48	0.0048	G H A
	Immature	3.3	0.1	0.1	54.35	<.0001	G H A
	Mature	0.1	<0.1	<0.1	11.94	<.0001	G H A

Note: If the F-value for the overall model was not significant (i.e. P <0.05), pair-wise comparisons were not provided. Pools indicated by their initials are ordered from highest to lowest mean transformed CPUE; means that are not significantly different are underlined.

Table 2-11. Total catch (N) and relative abundance (%) of fishes caught by electrofish sampling within Garvins Pool (Stations 1-6), Hooksett Pool (Stations 7-18) and Amoskeag Pool (Stations 19-24) during 2011.

Common Name	Garvins Pool (Stations 1-6)		Hooksett Pool (Stations 7-18)		Amoskeag Pool (Stations 19-24)		All Pools (Stations 1-24)	
	N	%	N	%	N	%	N	%
American eel			8	0.3	4	1.1	12	0.3
American shad			1	<0.1			1	<0.1
Black crappie	6	0.4	13	0.5	2	0.5	21	0.5
Bluegill	103	6.3	369	14.2	44	12.1	516	11.2
Brown bullhead					1	0.3	1	<0.1
Brown trout	1	0.1			1	0.3	2	<0.1
Chain pickerel	88	5.4	26	1.0	4	1.1	118	2.6
Common shiner	28	1.7	63	2.4			91	2.0
Eastern blacknose dace			1	<0.1			1	<0.1
Fallfish	58	3.5	522	20.0	11	3.0	591	12.8
Golden shiner	2	0.1	13	0.5			15	0.3
Largemouth bass	98	6.0	409	15.7	3	0.8	510	11.1
Margined madtom			2	0.1			2	<0.1
Pumpkinseed	97	5.9	81	3.1	25	6.8	203	4.4
Redbreast sunfish	7	0.4	169	6.5	32	8.8	208	4.5
Rock bass	4	0.2	12	0.5	2	0.5	18	0.4
Smallmouth bass	44	2.7	305	11.7	224	61.4	573	12.4
Spottail shiner	736	44.8	209	8.0	1	0.3	946	20.5
Sunfish family	1	0.1	35	1.3	3	0.8	39	0.8
Tessellated darter	5	0.3	23	0.9			28	0.6
White sucker	31	1.9	154	5.9	4	1.1	189	4.1
Yellow bullhead			1	<0.1			1	<0.1
Yellow perch	333	20.3	191	7.3	4	1.1	528	11.4
Total	1,642	100.0	2,607	100.0	365	100.0	4,614	100.0

Table 2-12. Mean CPUE (fish per 1,000 ft) and 95% upper (UCL) and lower (LCL) confidence limits of fishes caught by electrofish sampling within Garvins (Stations 1-6), Hooksett (Stations 7-18) and Amoskeag (Stations 19-24) Pools during 2011.

	Garvins Pool (Stations 1-6)			Hooksett Pool (Stations 7-18)			Amoskeag Pool (Stations 19-24)			All Pools (Stations 1-24)		
Common Name	**95% LCL[a]**	**CPUE**	**95% UCL[b]**	**95% LCL[a]**	**CPUE**	**95% UCL[b]**	**95% LCL[a]**	**CPUE**	**95% UCL[b]**	**95% LCL[a]**	**CPUE**	**95% UCL[b]**
American eel		0.0		0.0	0.1	0.1		0.1	0.1	0.0	0.1	0.1
American shad		0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Black crappie	0.0	0.1	0.2	0.0	0.1	0.2	0.0	0.0	0.1	0.0	0.1	0.1
Bluegill	1.1	1.7	2.4	2.0	3.1	4.2	0.3	0.7	1.2	1.6	2.2	2.8
Brown bullhead		0.0			0.0		0.0	0.0	0.1	0.0	0.0	0.0
Brown trout	0.0	0.0	0.1		0.0		0.0	0.0	0.1	0.0	0.0	0.0
Chain pickerel	1.1	1.5	1.9	0.1	0.2	0.3	0.0	0.1	0.1	0.4	0.5	0.6
Common shiner	0.0	0.5	1.3	0.0	0.5	1.0		0.0		0.1	0.4	0.7
Eastern blacknose dace		0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Fallfish	0.5	1.0	1.5	3.0	4.4	5.7	0.0	0.2	0.4	1.7	2.5	3.2
Golden shiner	0.0	0.0	0.1	0.0	0.1	0.2		0.0		0.0	0.1	0.1
Largemouth bass	1.1	1.7	2.2	2.7	3.4	4.1	0.0	0.1	0.1	1.7	2.1	2.5
Margined madtom		0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Pumpkinseed	0.9	1.6	2.3	0.4	0.7	0.9	0.2	0.4	0.7	0.6	0.8	1.1
Redbreast sunfish	0.0	0.1	0.2	1.1	1.4	1.7	0.3	0.5	0.8	0.7	0.9	1.1
Rock bass	0.0	0.1	0.1	0.0	0.1	0.2	0.0	0.0	0.1	0.0	0.1	0.1
Smallmouth bass	0.5	0.7	0.9	2.0	2.5	3.1	2.5	3.7	4.9	1.9	2.4	2.8
Spottail shiner	6.5	12.5	18.4	0.7	1.7	2.8	0.0	0.0	0.1	2.3	4.0	5.6
Sunfish family	0.0	0.0	0.1	0.1	0.3	0.5	0.0	0.1	0.1	0.1	0.2	0.3
Tessellated darter	0.0	0.1	0.2	0.1	0.2	0.3		0.0		0.1	0.1	0.2
White sucker	0.3	0.5	0.8	0.9	1.3	1.7	0.0	0.1	0.1	0.6	0.8	1.0
Yellow bullhead		0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Yellow perch	4.4	5.6	6.9	0.9	1.6	2.3	0.0	0.1	0.1	1.7	2.2	2.7

[a] LCL = lower confidence limit. [b] UCL= upper confidence limit.

Table 2-13. Summary of the analysis of variance and Tukey-Kramer multiple pairwise comparisons of the mean $\log_{10}(x+1)$-transformed catch per unit effort (CPUE) of selected freshwater fish species among Garvins (G, Stations 1-6), Hooksett (H, Stations 7-18), and Amoskeag (A, Stations 19-24) Pools based on electrofishing in the Merrimack River during 2011.

Common Name	*F*	*P*	Adjusted Tukey Pairwise Comparison
American eel	1.64	0.1958	
American shad	0.49	0.6110	
Black crappie	1.08	0.3397	
Bluegill	8.81	0.0002	H G A
Brown bullhead	1.50	0.2257	
Brown trout	1.01	0.3647	
Chain pickerel	62.80	<.0001	G H A
Common shiner	1.42	0.2447	
Eastern blacknose dace	0.49	0.6110	
Fallfish	30.79	<.0001	H G A
Golden shiner	3.70	0.0261	H G A
Largemouth bass	52.72	<.0001	H G A
Margined madtom	1.00	0.3710	
Pumpkinseed	7.22	0.0009	G H A
Redbreast sunfish	23.67	<.0001	H A G
Rock bass	0.55	0.5756	
Smallmouth bass	22.19	<.0001	A H G
Spottail shiner	24.63	<.0001	G H A
Tessellated darter	4.69	0.0101	H G A
White sucker	20.62	<.0001	H G A
Yellow bullhead	0.49	0.6110	
Yellow perch	69.24	<.0001	G H A

Note: If the *F*-value for the overall model was not significant (i.e. *P* <0.05), pairwise comparisons were not provided. Pools indicated by their initials are ordered from highest to lowest mean transformed CPUE; means that are not significantly different are underlined.

Table 2-14. Taxa richness (number) of fish species captured by electrofishing in Garvins Pool, Hooksett Pool and Amoskeag Pool during 2010 and 2011.

Year	Hooksett Pool	Garvins Pool	Amoskeag Pool
2010	20	18	13
2011	20	16	15

Table 2-15. Shannon Diversity Index values for fish species captured by electrofishing in Garvins Pool, Hooksett Pool and Amoskeag Pool during 2010 and 2011.

Year	Hooksett Pool	Garvins Pool	Amoskeag Pool
2010	1.91	1.52	1.72
2011	2.29	1.80	1.40

Table 2-16. Pollution tolerance and trophic guilds for fish species collected in Garvins, Hooksett and Amoskeag Pools during 2010-2011 (taken from Halliwell et al. 1999).

Common Name	Pollution Tolerance	Trophic Guild
Alewife	Intermediate	Filter Feeder
American eel	Tolerant	Piscivore
American shad	Intermediate	Filter Feeder
Black crappie	Intermediate	Piscivore
Bluegill	Tolerant	Generalist Feeder
Brown bullhead	Tolerant	Generalist Feeder
Brown trout	Intolerant	Piscivore
Chain pickerel	Intermediate	Piscivore
Common carp	Tolerant	Generalist Feeder
Common shiner	Intermediate	Generalist Feeder
Eastern blacknose dace	Tolerant	Generalist Feeder
Eastern silvery minnow	Intolerant	Herbivore
Fallfish	Intermediate	Generalist Feeder
Golden shiner	Tolerant	Generalist Feeder
Largemouth bass	Intermediate	Piscivore
Margined madtom	Intermediate	Insectivore
Pumpkinseed	Intermediate	Generalist Feeder
Redbreast sunfish	Intermediate	Generalist Feeder
Rock bass	Intermediate	Piscivore
Smallmouth bass	Intermediate	Piscivore
Spottail shiner	Intermediate	Insectivore
Tessellated darter	Intermediate	Insectivore
White sucker	Tolerant	Generalist Feeder
Yellow bullhead	Tolerant	Generalist Feeder
Yellow perch	Intermediate	Piscivore

Table 2-17. Number (Percentage) of generalist feeders and pollution tolerant fish species collected in Garvins, Hooksett and Amoskeag Pools during 2010 and 2011.

Pool	% Generalist Feeders	% Pollution Tolerant	% Generalist Feeders	% Pollution Tolerant
	2010		2011	
Garvins	8 (9.5%)	4 (2.3%)	7 (19.9%)	3 (8.3%)
Hooksett	7 (22.3%)	4 (13.8%)	9 (53.4%)	6 (21.2%)
Amoskeag	5 (32.9%)	3 (15.2%)	6 (32.3%)	4 (14.6%)

Table 2-18. Bray-Curtis Percent Similarity Index for the fish communities sampled by electrofishing during 2010 and 2011 within Garvins Pool (Stations 1-6), Hooksett Pool (Stations 7-18) and Amoskeag Pool (Stations 19-24).

2010	Garvins Pool	Hooksett Pool	Amoskeag Pool
Garvins Pool			
Hooksett Pool	64.4		
Amoskeag Pool	20.2	39.8	

2011	Garvins Pool	Hooksett Pool	Amoskeag Pool
Garvins Pool			
Hooksett Pool	43.2		
Amoskeag Pool	23.4	42.4	

Table 2-19. Abundance (mean number of fish per 1,000 ft) of taxa composing species assemblages identified by cluster analysis from electrofishing surveys within Garvins Pool (Stations 1-6), Hooksett Pool (Stations 7-18) and Amoskeag Pool (Stations 19-24) during 2010 and 2011.

Taxa	Main Groups					Outlier Groups		
	IA (n=3)	IB (n=22)	IIA (n=26)	IIB1 (n=22)	IIB2 (n=19)	STN 19; Aug 2010 (n=1)	STN 3,6; Sep 2011 (n=2)	STN 11; Sep 2010 (n=1)
Alewife			0.02	0.03				2.80
American eel		0.04	0.05	0.16	0.10			
American shad		0.01	0.28		0.01			7.20
Black crappie		0.03	0.12	0.30	0.07			0.60
Bluegill		0.68	1.84	5.75	1.39			2.60
Brown bullhead		0.02	0.02					
Brown trout		0.01	0.01					
Carp and minnow family								0.60
Chain pickerel	0.07	0.07	1.18	0.19	0.16		1.33	
Common shiner			0.22	0.02	0.63			
Eastern blacknose dace				0.01				
Eastern silvery minnow			0.02					
Fallfish		0.07	0.52	0.84	4.68		1.75	0.40
Golden shiner		0.01	0.03	0.05	0.17			
Largemouth bass	2.70	0.26	6.24	8.84	1.97		0.50	19.80
Margined madtom			0.04		0.04			
Pumpkinseed		0.37	1.91	0.56	0.53		0.08	0.60
Redbreast sunfish	0.42	0.67	0.47	1.95	1.71	0.50		
Rock bass		0.02	0.11	0.06	0.12			
Smallmouth bass	0.55	3.19	1.49	3.26	3.33		0.67	1.60
Spottail shiner	0.53	0.01	21.48	0.09	4.10		0.17	1.00
Sunfish family		0.02	0.13	0.17	0.21			
Tessellated darter			0.43	0.05	0.21			0.20
White sucker		0.07	0.36	0.37	1.79		0.25	0.20
Yellow bullhead			0.02	0.01				
Yellow perch		0.06	3.85	0.64	1.35		2.67	0.20

Table 2-20. Results of SIMPER analyses displaying dissimilarity (%) between groups identified by cluster analyses (IB, IIA, IIB1 and IIB2) as well as the fish species accounting for approximately 50% of the cumulative dissimilarity.

Groups IB and IIA — **Avg. Dissimilarity = 71.86**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IB	IIA		
Spottail shiner	0.02	3.80	25.78	25.78
Largemouth bass	0.31	2.28	14.36	40.14
Yellow perch	0.10	1.61	11.13	51.27

Groups IB and IIB2 — **Avg. Dissimilarity = 60.32**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IB	IIB2		
Fallfish	0.10	1.87	16.54	16.54
Spottail Shiner	0.02	1.50	12.75	29.29
White Sucker	0.11	1.17	10.25	39.54
Largemouth bass	0.31	1.31	9.51	49.05
Redbreast sunfish	0.66	1.14	7.76	56.82

Groups IB and IIB1 — **Avg. Dissimilarity = 58.70**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IB	IIB1		
Largemouth bass	0.31	2.85	27.32	27.32
Bluegill	0.73	2.22	15.9	43.22
Smallmouth bass	1.72	1.57	9.4	52.62

(continued)

Table 2-20. (Continued)

Groups IIA and IIB1 **Avg. Dissimilarity = 55.92**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IIA	IIB1		
Spottail shiner	3.80	0.12	24.02	24.02
Yellow perch	1.61	0.50	9.56	33.58
Bluegill	1.17	2.22	8.74	42.32
Largemouth bass	2.28	2.85	8.31	50.63

Groups IIA and IIB2 **Avg. Dissimilarity = 53.33**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IIA	IIB2		
Spottail shiner	3.80	1.50	19.24	19.24
Fallfish	0.50	1.87	10.1	29.34
Yellow perch	1.61	0.86	8.97	38.31
Largemouth bass	2.28	1.31	8.37	46.68
Smallmouth bass	0.97	1.70	6.96	53.64

Groups IIB2 and IIB1 **Avg. Dissimilarity = 50.52**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IIB2	IIB1		
Largemouth bass	1.31	2.85	13.19	13.19
Fallfish	1.87	0.56	12.11	25.3
Bluegill	0.99	2.22	11.39	36.69
Spottail shiner	1.50	0.12	10.94	47.63
Smallmouth bass	1.70	1.57	7.64	55.27

Table 2-21. Results of one way ANOSIM (Analysis of Similarities) for Pool (Garvins, Hooksett and Amoskeag), Year (2010, 2011) and Month (August, September).

Factor: Pool

Model Results:
Sample Statistic (Global R): 0.551
Significance level of sample statistic: 0.1%

Pairwise Comparisons:

	Amoskeag	Garvins	Hooksett
Hooksett			
Garvins	0.422/0.1%		
Amoskeag	0.58/0.1%	0.733/0.1%	

(R-statistic/Significance level %)

Factor: Year

Model Results:
Sample Statistic (Global R): 0.136
Significance level of sample statistic: 0.1%[1]

Pairwise Comparisons:

	2010	2011
2010	n/a	
2011	n/a	n/a

(R-statistic/Significance level %)

Factor: Month

Model Results:
Sample Statistic (Global R): 0.011
Significance level of sample statistic: 16.3%

Pairwise Comparisons:

	August	September
August	n/a	
September	n/a	n/a

(R-statistic/Significance level %)

1 - statistical significance rejected in lieu of low R statistic (Clark and Warwick 2001)

3.0 Interannual Abundance Trends from the 1967-2011 Sampling Program

3.1 Overview

Population trend analysis of fish abundance in Hooksett Pool was used to examine the available fisheries data from electrofish sampling efforts conducted between 1972 and 2011, for evidence to support a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool. Station operations have not changed substantively, including with respect to cooling water withdrawal and discharge, since Unit 2 first became operational in 1968. As described in the report titled "Merrimack Station Fisheries Survey Analysis of 1967 through 2005 Catch and Habitat Data" (Normandeau 2007a), the field sampling design for the Merrimack River electrofish surveys for the years 1967 through 2005 was first examined, prior to the trend analysis, to identify all periods of comparable electrofish stations, months and monthly efforts that were of known and certain documentation (Normandeau 2007a). This standardized approach was utilized so that the statistical trend analysis would be unbiased by changes in sampling design or collection methods. Then, the occurrence and relative abundance (CPUE) of each RIS of fish found in Hooksett Pool during each year of known and consistent sampling in the 1967-2005 period (1972, 1973, 1974, 1976, 1995, 2004 and 2005) was evaluated (Normandeau 2007a). Theoretically, CPUE should be directly proportional to the abundance of fish in the stock, but sampling design characteristics such as gear, season, location, water temperature, water level, turbidity and river currents can influence this proportionality (Hubert 1983; Guland 1988). Therefore, it was important to standardize these sampling design characteristics to insure that CPUE retains the same proportional relationship to fish stock abundance among years and is not influenced by changes in design.

This report adds electrofish data collected within Hooksett Pool in August and September of 2010 and 2011 following the same sampling design and methodology that was used during all years included in the 2007 population trend analysis.

3.1.1 Data Selection

Selection of electrofish data for inclusion in the Hooksett Pool trends analysis for the period 1967-2005 is described in Section 3.0 of the report titled "Merrimack Station Fisheries Survey Analysis of 1967 through 2005 Catch and Habitat Data" (Normandeau 2007a). As described in that report, electrofishing data collected by Normandeau during 1972, 1973, 1974, 1976, 1995, 2004 and 2005 were collected using consistent and well-documented procedures, even though the sampling effort varied among months in some of these years due to environmental conditions that influenced effective sampling (typically storm events that caused high flows and high water conditions). Post hoc examination of the electrofishing data among those years identified August and September as the only months with consistent sampling design and effort applied to the same sampling stations, thus providing the maximum number of months and years of historic data for population trend analysis (Normandeau 2007a). The 2010 and 2011 electrofish sampling in Hooksett Pool was designed to collect fisheries data using the same consistent and documented procedures as in the years included in the original trends analysis. Table 3-1 presents the sampling design comparison of the electrofishing surveys conducted in Hooksett Pool during select years between 1967 and 2011.

The trends analysis presented in this report relies on fisheries data collected by boat electrofishing. The USEPA "Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers" identifies electrofishing as the most comprehensive and effective single method for the collection of fish from streams and rivers (Flotemersch et al. 2006). Passive gears, such as trap nets, can be more effective for specific species, guilds or size classes of fish and as a result, may only effectively sample a segment of the fish community in a specific survey area. The American Fisheries Society, in its "Standard Methods for Sampling North American Freshwater Fishes," advises that the use of trap nets is more appropriate for standing waters such as lakes and ponds (Bonar et al. 2009). Boat electrofishing is one of several active sampling methods that are recommended for sampling warmwater fish in rivers (Bonar et al. 2009). Deployment of trap nets in a riverine system such as Hooksett Pool can be problematic due to varying river flows and debris loading interfering with the ability of the gear to properly sample resident fish.

The USEPA "Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers" details a large river bioassessment protocol (LR-BP) for assessment of fish assemblage metrics (Flotemersch et al. 2006). The LR-BP states that "at sites with a mean thalweg depth <4 m, a daytime main-channel border design that includes electrofishing 1000 m along a single bank or 500 m on paired banks was sufficient to characterize sites for bioassessment purposes. At sites with a mean thalweg depth > 4 m, results were more variable. Therefore, at such sites, the LR-BP protocol suggests that a switch from daytime to nighttime electrofishing be considered". If night electrofishing is not conducted, the LR-BP protocol suggests sampling 1000 m along paired banks. The Hooksett Pool trends analysis presented in this report relies on daytime electrofish sampling from paired bank transects at locations with a mean thalweg depth of <4m. This LR-BP is designed to collect samples that are as unbiased and as representative as possible and are indicative of the ecological condition of a site when compared to sites of known condition (Flotemersch et al. 2006).

3.1.2 Data Analysis

The presence of long-term population trends of selected fish species in Hooksett Pool was investigated based on a time series of annual mean CPUE from electrofish sampling, as described above in Section 3.1.1. This same data set was analyzed to determine the structure of the Hooksett Pool fish community using five common community indices: (1) taxa richness, (2) Shannon Diversity Index, (3) percent generalist feeders, (4) percent tolerant individuals, and (5) the Bray-Curtis Percent Similarity Index. The derivation and use of these metrics is described below.

3.1.2.1 Catch Per Unit Effort (CPUE)

For this multi-year trend analysis, CPUE was calculated for selected species captured by electrofishing in August and September of the years with standardized sampling during the 1972-2011 time period (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010 and 2011). Electrofishing data available from the 1970s was presented as the total number of each individual species by station for each month of sampling (Normandeau 1972, 1972, 1974, 1976). Annual mean CPUE (number of fish per 1,000-ft transect) for the 1970s was calculated as the arithmetic average of the number of fish caught at each station and month, based on a 1,000 ft transect comprising a station. For later years (1995-2011), CPUE for each species was calculated for each sample and then averaged for each station and month sampled in August and September in Hooksett Pool. The annual mean CPUE for 1995-2011 was based on the arithmetic average of monthly station-averaged CPUE values.

The Kendall's tau-b correlation coefficient is a nonparametric measure of association that was used to test whether annual mean CPUE increased or decreased (monotonically) with time (Kawaguchi et al. 1997). The Kendall's tau-b test statistic is similar to the Mann-Kendall test statistic that has been used in temporal trend analysis of fisheries (Daufresne et al. 2004, Dobiesz et al. 2005, Ådjers et al. 2006) and water resources (Helsel and Hirsch 2002). The Kendall's tau-b correlation coefficient and the significance test at $\alpha = 0.05$ was computed using PROC CORR (SAS Institute 2010). The advantages of using a nonparametric Kendall tau-b rank correlation are that data do not need to conform to a normal distribution and missing data are allowed (Helsel and Hirsch 2002, Ådjers et al. 2006).

3.1.2.2 Comparison of Fish Community Structure

Five indices were used to compare the Hooksett Pool fish community structure during the standardized 1972-2011 time period: (1) taxa richness, (2) Shannon Diversity Index, (3) percent generalist feeders, (4) percent tolerant individuals, and (5) the Bray-Curtis Percent Similarity Index.

Taxa richness is one of several metrics commonly used by fisheries scientists to evaluate community structure (the number of different species). Taxa richness is simply a tabulation of the number of species present within a given area at a given time. For example, if 18 different fish species were caught by electrofishing in Hooksett Pool in 2004, then the taxa richness for this set of data was 18. The probability of detection of less common species will increase as effort is increased. As a result, taxa richness should only be compared across time periods where the sampling methodology has been standardized and maintained. When combined with other indices of community structure, taxa richness is used to evaluate for potential shifts in the species composition over time within a given fish community. Taxa richness was calculated as the number of distinct species present within Hooksett Pool (Stations 9-18) in a given standardized sample year during the 1972-2011 time period.

The Shannon Diversity Index (H') was calculated for the fish assemblies present within Hooksett Pool during August and September in each of the years with standardized sampling during the 1972-2011 time period and combines information on the number of species in an assemblage (richness) and their relative abundance (evenness) (Kwak and Peterson 2007). The Shannon Diversity Index was calculated using the formula $H' = -\Sigma p_i \ln(p_i)$; where p_i is the relative abundance of each fish taxon.

Trophic guilds and tolerance to environmental perturbations were determined for all fish species present within Hooksett Pool during August and September in each of the years with standardized sampling during the 1972-2011 time period based on classifications presented for freshwater fish in the Northeastern United States in Halliwell et al. (1999). The percentage of generalist feeders was determined for the Hooksett Pool fish communities present within Hooksett Pool during August and September for years with standardized sampling during the 1972-2011 time period. The percentage of generalist feeders in a community increases as the physical and chemical habitat deteriorates (Barbour et al. 1999). Similarly, the percentage of tolerant individuals was determined for the fish communities present within Hooksett Pool during August and September in each of the years with standardized sampling during the 1972-2011 time period. The percentage of tolerant individuals in a community increases as the physical and chemical habitat deteriorates (Barbour et al. 1999).

The Bray-Curtis Percent Similarity index was used to quantitatively compare the fish communities within Hooksett Pool among the years with standardized sampling during the 1972-2011 time period. Unlike taxa richness or rank abundance, the Bray-Curtis index (I_{BC}) computes percent similarity among the fish taxa common in two sets of survey data (Clarke 1993). This index will negate the influence of uncommon fish species that may be present within some years of the comparison. Its power of predicting similarity is based upon species present within both of the data sets being compared. The closer the Bray-Curtis value is to 100%, the more similar the two communities are. A value for the percent difference the current Hooksett Pool fish community differs from that sampled in previous years can be calculated using this index.

Multivariate analyses were performed using PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software to examine temporal patterns in the overall similarity of fish assemblages in the survey area (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). Data preparation and univariate analyses were run in SAS system software (version 9.2). Bray-Curtis similarity was used as the basis for both classification and ordination. Prior to analyses, fish CPUE data 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 samples 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 samples. 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 fish 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.

Temporal differences in fish assemblages were assessed in terms of a priori designated classification variables using the analysis of similarities (ANOSIM) procedure in PRIMER (Clarke 1993). The variables included in this analysis were year (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010 and 2011), period (1970s, 1995, 2000s), and month (August and September). Each variable was tested using a one-way ANOSIM. The null hypothesis that there are no differences in community composition among the classes for each variable (year, period, and month) was tested. ANOSIM is a nonparametric permutation test applied to the rank Bray-Curtis similarity matrix. ANOSIM includes a global test, and also a pairwise test by the same procedure, which provides comparisons of classes within a variable. The ANOSIM test statistic (R) is approximately zero if the null hypothesis is true, and R=1 if all samples within a class level are more similar to each other than any samples from different classes. A significance level was also computed. In general, a probability of 5% or less is commonly used as a criterion for rejection of the null hypothesis (Flotemersch et al. 2006). A 5% significance level (p) for the test statistic (R) was assumed ecologically meaningful in these analyses.

3.2 Results of Electrofishing Trend Analysis

3.2.1 General Catch Characteristics

Table 3-2 presents the raw catch and relative abundance of species captured by electrofishing in August and September of each of the years with standardized sampling during the 1972-2011 time period (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010 and 2011). A total of 24 species and two additional taxonomic categories (carp and minnow family, and sunfish family) were observed in Hooksett Pool electrofish catches during the months of August and September of the nine years included in this analysis. The total number of fish species observed among years varied, ranging from a high of 19 during the 2011 sampling season to a low of 12 during 1972 and 1976. The total electrofish catch of individuals in August and September of the selected years ranged from a low of 446 in 2005, to a high of 2,663 fish in 1995 (Table 3-2). Within the standardized sampling period of August and September, the species with the highest relative abundance during 1972, 1973, 1974 and 1976 was pumpkinseed, during 1995 and 2004 was spottail shiner, during 2005 and 2010 was largemouth bass and during 2011 was fallfish (Table 3-2).

Of the 24 fish species captured, chain pickerel, largemouth bass, pumpkinseed, redbreast sunfish, smallmouth bass, white sucker and yellow perch were present in Hooksett Pool during the August-September period of all nine years of electrofish sampling. Two species, brown bullhead and white perch, were present in the August-September electrofishing samples only during the 1970s. Although not observed within the standardized August and September samples during the 2000s, both brown bullhead and white perch are still present in Hooksett Pool and have been observed in years not selected for standardized trend analysis (specifically, 2005 and 2009). Bluegill and rock bass first appeared in the standardized August and September electrofishing catches in Hooksett Pool during 1995. However, bluegill were a part of the Hooksett Pool fish community during the 1970s, were first detected during the June 1972 electrofish sampling (Normandeau 1972), and were observed in Hooksett Pool during the June 1974 and 1975 electrofish sampling as well as the June 1976 and September 1978 seine survey sampling (Normandeau 1972, 1974, 1975, 1976, 1978). There are no records of rock bass from trap net, seine or electrofish sampling within Hooksett Pool during any year in the 1970s. Likewise, there were no sampling records for eastern silvery minnow, black crappie and alewife during the 1970s or 1990s, and these three species first appeared in electrofishing catches during 2004. Alewife present in Hooksett Pool in August and September of 2004 and 2010 are most likely the result of successful spawning of adults stocked by NHFGD in Northwood Lake. Although not present during the standardized August-September time period, American eel, present in the standardized August-September sampling during the 1970s, was absent from sampling during 1995 but has been a component of all sampling years during the 2000s. American eel were captured by the 1995 electrofish sampling during May and October and by trap net during August. Spottail shiner was first identified in the Hooksett Pool electrofishing catches during 1974. However, they did not show up in abundance within the standardized boat electrofish August-September sampling until 1995. Spottail shiners were present in high abundance within the seine surveys conducted in Hooksett Pool during 1974. Approximately 4,143 spottail shiners were captured in Hooksett Pool during 1974 seine sampling (Normandeau 1974). Although seine survey catch for *Notropis* shiner species during 1975 and 1976 were not identified to species, based on the percentage of *Notropis* catch (98.5%) identified as spottail shiner during 1974 it can be reasonably assumed that spottail shiner represented a large component of catch during those years as well (Normandeau 1974, 1975, 1976). American shad present in Hooksett Pool during 2010 are likely the result of successful spawning or larval stocking of shad by USFWS in Garvins Pool. Adult and larval (aged 8-14 days post-fertilization) American shad were stocked at the Boscawen boat ramp located approximately 23 river miles upstream of Garvins Falls Hydroelectric Project and the upper end of Hooksett Pool during 2010 and 2011 (USFWS, personal communication). There is a single record for American shad collected from Hooksett Pool during 1978, with a single individual collected at Station S-0 during a September seine survey. During 2011, an eastern blacknose dace was recorded during the standardized August-September electrofish sampling in Hooksett Pool. This species had not previously been observed in Hooksett Pool collections, although Wightman (1971) reported the species from electrofish catches in the Soucook River during 1967 and 1968.

3.2.2 Catch Per Unit Effort (CPUE)

Table 3-3 presents the CPUE for all individual taxa captured by electrofishing in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Table 3-4 presents results of the nonparametric Kendall’s tau b test used to test the null hypothesis that there is no statistically significant ($p<0.05$) interannual trend in abundance during the period analyzed. Trends analyses were conducted for the four resident RIS (smallmouth bass, largemouth bass, pumpkinseed and yellow perch), along with fallfish and white sucker. CPUE trends were not analyzed for anadromous RIS fish species. Alewife and American shad spend a relatively short time in Hooksett Pool as they pass through on their outmigration during the fall. Due to the current lack of fish passage on the Merrimack River to allow these species access to Hooksett Pool and inconsistent stocking of the species over the full time series (1967-2011), trends analyses for these two species were not conducted because doing so would not provide useful information regarding potential thermal impacts to abundance. The remaining RIS, Atlantic salmon, was not present during the August and September time period during any of the nine years sampled. In addition to the RIS, trends analyses were conducted for nine other fish species resident in Hooksett Pool. There were no significant trends for nine of the fifteen species examined, including both RIS and other resident species, supporting a finding that Merrimack Station’s thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. Black crappie had an increasing trend in CPUE while there were decreasing trends in CPUE for brown bullhead, chain pickerel, pumpkinseed, redbreast sunfish, and yellow perch (Table 3-4).

Temperature guilds for fish species assessed in the trends analysis for the years with standardized sampling during the 1972-2011 time period are presented in Table 3-5. There was no consistent pattern between the trends in CPUE and temperature guilds, supporting a finding that Merrimack Station’s thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over this time period. Among the members of the coolwater guild, CPUE increased for one species (black crappie) and decreased for two (chain pickerel and yellow perch), and there were no significant trends for two species (fallfish and white sucker). Among the members of the warmwater guild, there were no significant trends for seven species (bluegill, golden shiner, largemouth bass, rock bass, smallmouth bass, spottail shiner and yellow bullhead), and CPUE decreased for three species (brown bullhead, pumpkinseed and redbreast sunfish).

Figure 3-1 presents the annual mean electrofish CPUE for black crappie captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Black crappie are a relatively recent introduction to Hooksett Pool, having only been detected in August and September electrofish sampling during 2004, 2005, 2010 and 2011. The highest annual mean electrofishing CPUE value for the August and September period for black crappie captured in

Hooksett Pool occurred in 2010 (Table 3-3). The Kendall Tau results indicate that there was a statistically significant increasing trend in black crappie annual mean CPUE in Hooksett Pool during the time series (Table 3-4). This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period, especially given that black crappie is a coolwater fish species. A comparison of mean CPUE values for black crappie captured during 2010 (Table 2-9) and 2011 (Table 2-13) shows that the most recent estimates of black crappie abundance in Hooksett Pool did not differ significantly to those observed in Garvins Pool, which is not influenced by the Station's thermal discharge. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-2 presents the annual mean electrofish CPUE for bluegill captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Bluegill were collected within Hooksett Pool during the 1970s but first appeared within August and September electrofish sampling during 1995, when the highest annual mean electrofishing CPUE values for the August and September period occurred (Table 3-3). There was no significant trend in bluegill annual mean CPUE in Hooksett Pool during the time series (Table 3-4), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. A comparison of annual mean CPUE values for bluegill shows that the most recent estimates in Hooksett Pool were significantly greater during 2010 (Table 2-9), but did not differ significantly to those observed during 2011 (Table 2-13), in Garvins Pool, which is not influenced by the Station's thermal discharge. The lack of a consistent pattern of increased abundance of bluegill in Hooksett Pool also supports a finding that the discharge has not caused appreciable harm.

Figure 3-3 presents the annual mean electrofish CPUE for brown bullhead captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Brown bullhead were collected within Hooksett Pool during the 1970s but have not been present within the August and September electrofish sampling since 1976. The highest annual mean electrofishing CPUE values for the August and September period for brown bullhead captured in Hooksett Pool occurred in 1972 (Table 3-3). There was a statistically significant decreasing trend in brown bullhead annual mean CPUE in Hooksett Pool during the time series (Table 3-4). However, a comparison of annual mean CPUE values for brown bullhead captured during 2010 (Table 2-9) and 2011 (Table 2-13) shows that the most recent estimates of brown bullhead abundance in Hooksett Pool did not differ significantly to those observed in Garvins Pool, which is not influenced by Merrimack Station's thermal discharge. This supports a finding that the Station's thermal discharge has not caused appreciable harm.

Figure 3-4 presents the annual mean electrofish CPUE for chain pickerel captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Chain pickerel have been collected within Hooksett Pool during each sample year, with their highest annual mean electrofishing CPUE values for the August and September period occurring in 1972 (Table 3-3). The Kendall Tau results indicate that there was a statistically significant decreasing trend in chain pickerel annual mean CPUE in Hooksett Pool (Table 3-4). A comparison of annual mean CPUE values for chain pickerel captured during 2010 (Table 2-9) and 2011 (Table 2-13) shows that the most recent estimates of chain pickerel abundance in Hooksett Pool were significantly lower than those observed in Garvins Pool.

Figure 3-5 presents the annual mean electrofish CPUE for fallfish captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. (The TAC proposed including fallfish as a RIS for Merrimack Station in October 2006. Although this proposal was not formally recommended or approved, Normandeau has since included fallfish in its trends analyses and referred to the species as a RIS.) Fallfish have been collected within Hooksett Pool during each sample year except 1976. The highest annual mean electrofishing CPUE values for the August and September period for fallfish captured in Hooksett Pool occurred in 2011 (Table 3-3). There was no significant trend in fallfish annual mean CPUE in Hooksett Pool within the time series (Table 3-4). This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period, especially given that fallfish is a coolwater fish species. A comparison of annual mean CPUE values for fallfish shows that the most recent estimates in Hooksett Pool did not differ significantly during 2010 (Table 2-9), and were significantly greater than those observed during 2011 (Table 2-13), in Garvins Pool, which is not influenced by the Station's thermal discharge. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-6 presents the annual mean electrofish CPUE for golden shiner captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Golden shiner have been collected within Hooksett Pool during each of these nine years except 1976 and 2010. The highest annual mean electrofishing CPUE values for the August and September period for golden shiner captured in Hooksett Pool occurred in 2004 (Table 3-3). There was no significant trend for golden shiner annual mean CPUE in Hooksett Pool during the time series (Table 3-4), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. A comparison of annual mean CPUE values for golden shiner shows that the most recent estimates in Hooksett Pool did not differ significantly during 2010 (Table 2-9) or 2011 (Table 2-13) from those observed in Garvins Pool, which is not influenced by the Station's thermal discharge. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-7 presents the annual mean electrofish CPUE for largemouth bass captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Largemouth bass are one of four Hooksett Pool resident fish species that the TAC identified as a RIS in 1992. Largemouth bass have been collected within Hooksett Pool during each sample year, with their highest annual mean electrofishing CPUE values for the August and September period occurring in 2004 (Table 3-3). There was no significant trend in largemouth bass annual mean CPUE in Hooksett Pool within the time series (Table 3-4), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. A comparison of annual mean CPUE values for largemouth bass shows that the most recent estimates in Hooksett Pool did not differ significantly during 2010 (Table 2-9), and were significantly greater than those observed during 2011 (Table 2-13), in Garvins Pool, which is not influenced by the Station's thermal discharge. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-8 presents the annual mean electrofish CPUE for pumpkinseed captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Pumpkinseed are one of four Hooksett Pool resident fish species that the TAC identified as a RIS in 1992. Pumpkinseed have been collected within Hooksett Pool during each sample year, with their highest annual mean electrofishing CPUE values for the August and September period occurring in 1972 (Table 3-3). There was a statistically significant decreasing trend in pumpkinseed annual mean CPUE in Hooksett Pool during the time series (Table 3-4). A comparison of annual mean CPUE values for pumpkinseed captured during 2010 (Table 2-9) and 2011 (Table 2-13) shows that the most recent estimates of pumpkinseed abundance in Hooksett Pool were significantly lower than those observed in Garvins Pool.

Figure 3-9 presents the annual mean electrofish CPUE for redbreast sunfish captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Redbreast sunfish have been collected within Hooksett Pool during each sample year, and the highest annual mean electrofishing CPUE values for the August and September period occurred in 1976 (Table 3-3). There was a statistically significant decreasing trend in redbreast sunfish annual mean CPUE in Hooksett Pool during the time series (Table 3-4). A comparison of annual mean CPUE values for redbreast sunfish captured during 2010 (Table 2-9) and 2011 (Table 2-13) shows that the most recent estimates of redbreast sunfish abundance in Hooksett Pool were significantly greater than those observed in Garvins Pool, which is not influenced by Merrimack Station's thermal discharge.

Figure 3-10 presents the annual mean electrofish CPUE for rock bass captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Rock bass are a relatively recent introduction to Hooksett Pool, not having been found during the August and September sampling prior to 1995, when CPUE was highest (Table 3-3). There was no significant trend for rock bass annual mean CPUE in Hooksett Pool within the examined time series (Table 3-4), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. A comparison of annual mean CPUE values for rock bass shows that the most recent estimates in Hooksett Pool did not differ significantly during 2010 (Table 2-9) or 2011 (Table 2-13) from those observed in Garvins Pool, which is not influenced by Merrimack Station's thermal discharge. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-11 presents the annual mean electrofish CPUE for smallmouth bass captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Smallmouth bass are one of four Hooksett Pool resident fish species that the TAC identified as a RIS in 1992. Smallmouth bass have been collected within Hooksett Pool during each sample year, with their highest annual mean electrofishing CPUE values for the August and September period occurring in 2004 (Table 3-3). There was no significant trend for smallmouth bass annual mean CPUE in Hooksett Pool within the time series (Table 3-4), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. A comparison of annual mean CPUE values for smallmouth bass captured during 2010 (Table 2-9) and 2011 (Table 2-13) shows that the most recent estimates of smallmouth bass abundance in Hooksett Pool were significantly greater than those observed in Garvins Pool, which is not influenced by Merrimack Station's thermal discharge.

Figure 3-12 presents the annual mean electrofish CPUE for spottail shiner captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Spottail shiner have been collected within Hooksett Pool during six of the nine sample years, excluding 1972, 1973 and 1976. The highest annual mean electrofishing CPUE values for the August and September period for spottail shiner captured in Hooksett Pool occurred in 1995 (Table 3-3).

There was no significant trend for spottail shiner annual mean CPUE in Hooksett Pool within the time series (Table 3-4), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. A comparison of annual mean CPUE values for spottail shiner shows that the most recent estimates in Hooksett Pool did not differ significantly during 2010 (Table 2-9), and were significantly lower than those observed during 2011 (Table 2-13), in Garvins Pool. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-13 presents the annual mean electrofish CPUE for white sucker captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. (The TAC proposed including white sucker as a RIS for Merrimack Station in October 2006. Although this proposal was not formally recommended or approved, Normandeau has since included white sucker in its trends analyses and referred to the species as a RIS.) White sucker have been collected within Hooksett Pool during each sample year, with their highest annual mean electrofishing CPUE values for the August and September period occurring in 1974 (Table 3-3). There was no significant trend for white sucker annual mean CPUE in Hooksett Pool within the time series (Table 3-4). This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period, especially given that white sucker is a coolwater fish species. A comparison of annual mean CPUE values for white sucker shows that the most recent estimates in Hooksett Pool were significantly greater during 2010 (Table 2-9) and 2011 (Table 2-13) than in Garvins Pool, which is not influenced by Merrimack Station's thermal discharge. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-14 presents the annual mean electrofish CPUE for yellow bullhead captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Yellow bullhead are an uncommon resident in Hooksett Pool, having been detected in low relative abundance in August and September electrofish sampling during 1972, 1973, 1974, 1976 and 2011. The highest annual mean electrofishing CPUE values for the August and September period for yellow bullhead captured in Hooksett Pool occurred in 1976 (Table 3-3). There was no significant trend for yellow bullhead annual mean CPUE in Hooksett Pool within the time series (Table 3-4), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. A comparison of annual mean CPUE values for yellow bullhead shows that the most recent estimates in Hooksett Pool did not differ significantly during 2010 (Table 2-9) or 2011 (Table 2-13) from those observed in Garvins Pool, which is not influenced by Merrimack Station's thermal discharge. This also supports a finding that the discharge has not caused appreciable harm.

Figure 3-15 presents the annual mean electrofish CPUE for yellow perch captured in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period. Yellow perch is one of four Hooksett Pool resident fish species that the TAC identified as a RIS in 1992. Yellow perch have been collected within Hooksett Pool during each sample year, with their highest annual mean electrofishing CPUE values for the August and September period occurring in 1972 (Table 3-3). There was a significant decreasing trend in yellow perch annual mean CPUE in Hooksett Pool (Table 3-4). A comparison of annual mean CPUE values for yellow perch captured during 2010 (Table 2-9) and 2011 (Table 2-13) shows that the most recent estimates of yellow perch abundance in Hooksett Pool were significantly lower than those observed in Garvins Pool .

In sum, there were no significant trends – either decreasing or increasing – over the 1972-2011 time period for four of the six resident RIS (fallfish, largemouth bass, smallmouth bass and white sucker) or five of the nine additional resident species (bluegill, golden shiner, rock bass, spottail shiner and yellow bullhead) in Hooksett Pool. Moreover, of these nine species for which there were no significant trends, annual mean CPUE values were statistically similar to those observed in Garvins Pool for largemouth bass, fallfish and spottail shiner during 2010, bluegill during 2011, and golden shiner, rock bass and yellow bullhead during both years (2010 and 2011) (2010: Table 2-9; 2011: Table 2-13). During 2010, bluegill had a greater annual mean CPUE in Hooksett Pool than was observed in Garvins Pool. Similarly, during 2011, largemouth bass and fallfish had a greater annual mean CPUE in Hooksett Pool than was observed in Garvins Pool. While spottail shiner annual mean CPUE was greater in Garvins Pool than was observed in Hooksett Pool during 2011, annual mean CPUE was greater for both white sucker and smallmouth bass in Hooksett Pool than was observed in Garvins Pool for years 2010 and 2011. The lack of detection of a significant trend over time, and the similarity in CPUE between Hooksett and Garvins Pools, together support a finding that Merrimack Station's thermal discharge has not caused appreciable harm to these nine fish species (Table 3-4).

The Kendall tau b analysis detected a statistically significant decreasing trend over the 1972-2011 time period for two of the six resident RIS (pumpkinseed and yellow perch) and three of the nine additional resident species (brown bullhead, chain pickerel and redbreast sunfish) in Hooksett Pool. A decreasing trend in the mean annual CPUE was observed for two coolwater fish species (yellow perch and chain pickerel) and three warmwater fish species (pumpkinseed, redbreast sunfish, and brown bullhead). Annual mean CPUE values for brown bullhead and redbreast sunfish were the same or greater in Hooksett Pool as compared to Garvins Pool in 2010 and 2011. The similar catch rates for these two species during 2010 and 2011 in Hooksett Pool and thermally uninfluenced Garvins Pool suggest that the decline observed in abundance of brown bullhead and redbreast sunfish in Hooksett Pool is unrelated to Merrimack Station. Annual mean CPUE values for yellow perch, pumpkinseed and chain pickerel were lower in Hooksett Pool as compared to Garvins Pool in 2010 and 2011. The depressed catch rates in Hooksett Pool for these three species as compared to Garvins Pool in 2010 and 2011 suggest the presence of a limiting factor in Hooksett Pool that has decreased yellow perch, pumpkinseed and chain pickerel abundance. All three of these species show a strong affinity to water bodies with high amounts of submerged aquatic vegetation. Within Hooksett Pool, the amount of submerged aquatic vegetation has decreased with improvements in system water quality since the early 1970s (Normandeau 2011b). Abundance of pumpkinseed is likely reduced due to competition with bluegill. In areas of poor water quality (such as Hooksett Pool during the 1970s), it has been demonstrated that pumpkinseed have advantages over bluegill. In lakes where bluegill and pumpkinseed ranges overlap, it has been theorized that lakes containing only pumpkinseed are due to winterkill of bluegill unable to cope with the hypoxic (low DO) conditions (Osenburg et al. 1992, Fox 1994, Tomacek et al. 2007). Pumpkinseed are more capable of withstanding lower DO levels and fluctuating environmental conditions than bluegill (Fox 1994) allowing them to survive in conditions that effectively eliminate bluegill. It is likely that organic pollution in the Merrimack River prior to the enactment of the Clean Water Act in 1972 led to the low DO levels documented during the 1960s and early 1970s (Normandeau 2011b), conditions that would have been advantageous for a species such as pumpkinseed that are capable of tolerating these extremes. The Kendall tau b analysis detected a statistically significant increasing trend over the 1972-2011 time period for black crappie in Hooksett Pool. There were no detectable differences between annual mean CPUE values for black crappie in Hooksett Pool and Garvins Pool during either 2010 or 2011. Similar catch rates for black crappie during 2010 and 2011 in Hooksett Pool and thermally uninfluenced Garvins Pool suggests that the increase observed in abundance of this species is unrelated to Merrimack Station.

3.3 1972-2011 Community Indices

In addition to evaluating trends in species-specific CPUEs over the 1972-2011 time period, changes in community trends were examined through five indices: (1) taxa richness, (2) Shannon Diversity Index, (3) percent generalist feeders, (4) percent tolerant individuals, and (5) the Bray-Curtis Percent Similarity Index.

3.3.1 Taxa Richness

Taxa richness for electrofish sampling at monitoring stations 9-18 in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period is presented in Table 3-6. The number of taxa observed during 1972 and 1976 were the lowest overall of the nine sample years considered (12 species) while the greatest number of taxa were observed during 2011 (19 species). Within the Hooksett Pool time series, taxa richness increased from 12 species sampled during 1972 to 19 sampled in 2011 (with expected variability from sample year to sample year), supporting a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. Of the 12 species observed during the August-September electrofish sampling effort in 1972, only brown bullhead was not represented within the most recent (2011) August-September electrofish sampling effort (Table 3-2).

3.3.2 Shannon Diversity Index

The Shannon Diversity Index (H') was calculated for the fish communities present in Hooksett Pool during the years with standardized sampling during the 1972-2011 time period (Figure 3-16). Fish community diversity in Hooksett Pool was lowest during the 1995 sampling due to the domination of electrofish catch by bluegill during that single year and highest during the most recent sample year, 2011. This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool.

3.3.3 Percent Generalist Feeders

The percentage of generalist feeders in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period is presented in Figure 3-17. As noted above, the percentage of generalist feeders in a fish community increases as the physical and chemical habitat deteriorates (Barbour et al. 1999). Of the twelve fish species recorded in August and September of 1972 (the first year of available data with consistent and documented sampling effort), seven were listed as generalist feeders and the remainder were listed as piscivores. Of the nineteen fish species recorded in August and September of 2011 (the most recent year of available data with consistent and documented sampling effort), nine were listed as generalist feeders. The remaining fish species detected during 2011 represented the insectivore and piscivore trophic guilds. The percentage of generalist feeders in Hooksett Pool was highest during 1976 (75.7%) and lowest during 2010 (22.3%). The decrease in percent generalist feeders from the 1970s to present can be attributed to the decrease in abundance of pumpkinseed, a generalist feeder that represented more than 50% of the Hooksett Pool fish community during the early 1970s. As noted above in Section 3.2.2, decreases in pumpkinseed are likely linked to improved water quality leading to decreases in submerged aquatic vegetation and increase in competition for resources with bluegill. The reduced percentage of generalist feeders in Hooksett Pool from 1972 to 2011 supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool.

3.3.4 Percent Tolerant Individuals

The percentage of pollution-tolerant species in Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period is presented in Figure 3-17. As noted above, the percentage of pollution-tolerant individuals in a community increases as the physical and chemical habitat deteriorates (Barbour et al. 1999). Of the twelve fish species recorded in August and September of 1972 (the first year of available data with consistent and documented sampling effort), five were listed as pollution-tolerant with the remainder listed as intermediate in their tolerance to pollution. Of the nineteen fish species recorded in August and September of 2011 (the most recent year of available data with consistent and documented sampling effort), six were listed as pollution-tolerant with the remainder listed as intermediate in their tolerance to pollution. The percentage of pollution-tolerant species in Hooksett Pool was highest during 1995 (42.0%) and lowest during 1973 (5.2%). The increased abundance of bluegill in Hooksett Pool during 1995 is the princip al factor in the elevated percentage of pollution-tolerant species in Hooksett Pool observed during that year. The percentage of pollution-tolerant species observed during some of the more recent sampling years (such as 2004 and 2010) are comparable to the range of percentages (5.2-13.3%) observed during the 1970s.

3.3.5 Bray-Curtis Percent Similarity Index

Table 3-7 presents a comparison of the fish communities sampled by electrofishing within Hooksett Pool in August and September of the years with standardized sampling during the 1972-2011 time period, as computed by the Bray-Curtis Percent Similarity Index. The 1970s Hooksett Pool fish community shows a greater similarity to the 2000s Hooksett Pool fish community (49.7%) than to the Hooksett Pool fish community found in 1995 (40.8%).

Cluster analysis performed on the electrofish data collected within Hooksett Pool in August and September of the years with standardized sampling effort discriminated among 13 fish assemblages of which there were five main groups (Groups IA, IB, IIA, IIB1, and IIB2) as well as eight outlier groups and the resulting dendrogram is presented in Figure 3-18. The cluster analysis utilized station, month and year to classify samples into appropriate groups. Figure 3-19 presents the MDS ordination results using station to identify sample location and a unique color to identify individual cluster groups (IA, IB, IIA, IIB1, and IIB2). Cluster groups differed in terms of their species composition and relative abundance. These differences can be seen in Table 3-8, which presents the abundance of taxa comprising each group. The outlier groups (O1, O2, O3, IO1, IIO1, IIO2, IIO3, and IIO4) are each composed mainly of a small number of samples (n range = 1-3). These outlier groups are plotted on the MDS ordination and the dendrogram, but are not included in the discussion. Table 3-9 presents the distribution of samples into the five main groups by year and location relative to Merrimack Station (north or south).

Cluster groups were identified using a hierarchical naming convention to identify the similarities and differences among the groups. The two main groups (I and II) differ considerably from each other, separating at a Bray-Curtis similarity level of less than 35%. Group I was further separated into Groups IA and IB, with Group IA containing the majority (86%; 65 of 76) of the samples (Table 3-9). As indicated by Figures 3-18 and 3-19, differences in community similarity exist between Group IA and Group IB. Group II was separated into Groups IIA and IIB, with the additional separation of Group IIB into Group IIB1 and Group IIB2. Group IIA is composed of 29 samples, Group IIB1 is composed of 11 samples and Group IIB2 is composed of 44 samples (Table 3-9). Similarity between Groups IIB1 and IIB2 is approximately 45%, slightly higher than the similarity between either Groups IIB1 and IIA or Groups IIB2 and IIA.

Group IA contained the majority of samples clustered into Group I (86%; 65 of 76 samples). Group 1A was characterized by 16 taxa and represented samples primarily collected during the 1970s, as well as a single sample from the 2000s. Samples collected at electrofish stations located south of Merrimack Station accounted for slightly more than half of Group IA (62%; 40 of 65 samples), with the remainder having been collected at stations north of Merrimack Station. Pumpkinseed, redbreast sunfish and yellow perch were the three most abundant species within Group IA.

Group IB contained the remainder of samples initially clustered into Group I (14%; 11 of 76 samples). Group IB was characterized by 12 fish taxa and represented samples primarily collected during the 1970s, as well as a single sample from the 2000s. Group IB was dominated by samples collected at electrofish stations located south of Merrimack Station (82%; 9 of 11 samples), with the remainder having been collected at stations north of Merrimack Station. Pumpkinseed, redbreast sunfish and smallmouth bass were the three most abundant species within Group IB.

Group IIA contained 29 of the 84 (35%) samples clustered into Group II. Group IIA was characterized by 19 taxa. The majority of the samples included in this group were collected during the 2000s, with a single sample representing each of 1974 and 1995. Group IIA was dominated by samples collected at electrofish stations located north of Merrimack Station (76%; 22 of 29 samples), with the remainder having been collected at stations south of Merrimack Station. Spottail shiner, largemouth bass, and fallfish were the three most abundant species from Group IIA.

Group IIB1 consisted entirely of samples collected during 1995. Group IIB1 contained 11 of the 84 (13%) samples clustered into Group II, and was characterized by 12 taxa. Group IIB1 was dominated by samples collected at electrofish stations located south of Merrimack Station (91%; 10 of 11 samples). Within Group IIB1, bluegill was the most abundant species, followed by redbreast sunfish and largemouth bass.

Group IIB2 contained 44 of the 84 (52%) samples clustered into Group II. Group IIB2 was characterized by 18 taxa. The majority of the samples included in this group were collected during the 2000s, with an additional three samples representing 1995. Group IIB2 was dominated by samples collected at electrofish stations located south of Merrimack Station (86%; 38 of 44 samples). Largemouth bass, bluegill and smallmouth bass were the three most abundant species from Group IIB2.

Hooksett Pool electrofish samples tended to cluster both temporally (by year) and spatially (by location north or south of Merrimack Station). The majority of samples collected during the 1970s clustered to form Groups IA and IB, the majority of samples from 1995 clustered to form Group IIB1 and the majority of samples from the 2000s clustered to form Groups IIA and IIB2. When examined spatially, Group 1A (primarily samples from the 1970s) was representative of stations located both north and south of Merrimack Station whereas Group 1B (also primarily samples from the 1970s) was representative of stations located primarily south of Merrimack Station. Group IIB1 (composed of samples collected during 1995) was representative of stations located south of Merrimack Station. Groups IIA and IIB2, both composed by primarily samples from the 2000s, were representative of stations located north and south, respectively, of Merrimack Station.

3.3.6 Dissimilarity Comparisons

Table 3-10 presents the fish species contributing to approximately 50% of the overall dissimilarity between selected groups based on the SIMPER analysis. Defining characteristics in the species assemblage dissimilarity are discussed below for five of the groups that represent the species assemblages as they fell out by time period (1970s, 1995 and 2000s). Groups IA and IB accounted for the majority of the samples collected during the 1970s, with Group IA representing samples collected north and south of Merrimack Station and Group IB representing samples collected primarily south of Merrimack Station. Group IIB1 was composed entirely of samples collected during 1995, and Groups IIA and IIB2 accounted for the majority of samples collected the 2000s, with Group IIA representing samples collected primarily north of Merrimack Station and Group IIB2 representing samples collected primarily south of Merrimack Station. Comparisons are detailed below in order of highest dissimilarity to lowest dissimilarity.

Groups IB and IIB1. These two groups were the most dissimilar and are characterized primarily by samples collected at stations south of Merrimack Station during the 1970s (Group IB) and stations south of Merrimack Station during 1995 (Group IIB1). The overall dissimilarity between these two groups was calculated at 76.18% (Table 3-10). Bluegill accounted for approximately 50% of the overall dissimilarity between Groups IB and IIB1, with a greater abundance within samples clustered in Group IIB1.

Groups IA and IIB1. These two groups are characterized primarily by samples collected during the 1970s (Group IA) and during 1995 (Group IIB1), with the majority of the Group IIB1 samples collected south of Merrimack Station. The overall dissimilarity between these two groups was calculated at 73.78% (Table 3-10). Two fish species, bluegill and pumpkinseed, cumulatively contributed approximately 50% of the overall dissimilarity between these two groups. Bluegill (38.99% of total dissimilarity) was absent from samples in Group IA, and pumpkinseed was in greater abundance in Group IA than in Group IIB1.

Groups IB and IIA. These two groups are characterized primarily by samples collected at stations south of Merrimack Station during the 1970s (Group IB) and stations north of Merrimack Station during the 2000s (Group IIA). The overall dissimilarity between these two groups was calculated at 72.82% (Table 3-10). The fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IB and IIA were spottail shiner, pumpkinseed, fallfish, largemouth bass, and bluegill. Abundance of spottail shiner, fallfish, largemouth bass and bluegill were greater for samples in Group IIA, whereas abundance of pumpkinseed was greater for samples in Group IB.

Groups IA and IIA. These two groups are characterized primarily by samples collected during the 1970s (Group IA) and during the 2000s (Group IIA), with the majority of the Group IIA samples collected from stations located north of Merrimack Station. The overall dissimilarity between these two groups was calculated at 68.89% (Table 3-10). The five fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IA and IIA were pumpkinseed, spottail shiner, yellow perch, fallfish and redbreast sunfish. Spottail shiner and fallfish were in greater abundance within Group IIA (primarily samples from the 2000s, north of Merrimack Station), while pumpkinseed, yellow perch and redbreast sunfish abundance was higher in Group IA (primarily samples from the 1970s).

Groups IIA and IIB1. These two groups are characterized primarily by samples collected at stations north of Merrimack Station during the 2000s (Group IIA) and stations south of Merrimack Station during 1995 (Group IIB1). The overall dissimilarity between these two groups was calculated at 67.69% (Table 3-10). Fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IIA and IIB1 were bluegill, redbreast sunfish, and spottail shiner. Abundance of bluegill and redbreast sunfish was greater for samples in Group IIB1, whereas abundance of spottail shiner was greater for samples in Group IIA.

Groups IB and IIB2. These two groups are characterized primarily by samples collected at stations south of Merrimack Station during the 1970s (Group IB) and stations south of Merrimack Station during the 2000s (Group IIB2). The overall dissimilarity between these two groups was calculated at 66.60% (Table 3-10). Fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IB and IIB2 were largemouth bass, bluegill and pumpkinseed. Abundance of largemouth bass and bluegill were greater for samples in Group IIB2, whereas abundance of pumpkinseed was greater for samples in Group IB.

Groups IA and IIB2. These two groups are characterized primarily by samples collected during the 1970s (Group IA) and during the 2000s (Group IIB2), with the majority of the Group IIB2 samples collected from stations located south of Merrimack Station. The overall dissimilarity between these two groups was calculated at 65.66% (Table 3-10). The three fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IA and IIB2 were pumpkinseed, bluegill and yellow perch. Bluegill were in greater abundance within Group IIB2 (primarily samples from the 2000s, south of Merrimack Station), while pumpkinseed and yellow perch abundance was higher in Group IA (primarily samples from the 1970s).

Groups IA and IB. These two groups characterize the majority of samples from the 1970s. The overall dissimilarity between these two groups was calculated at 56.99% (Table 3-10). The four fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IA and IB were pumpkinseed, yellow perch, redbreast sunfish, and largemouth bass. All four of those species exhibited greater abundance in samples clustered within Group IA.

Groups IIA and IIB2. These two groups are characterized primarily by samples collected at stations north of Merrimack Station during the 2000s (Group IIA) and stations south of Merrimack Station during the 2000s (Group IIB2). The overall dissimilarity between these two groups was calculated at 53.98% (Table 3-10). Fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IIA and IIB2 were spottail shiner, fallfish, bluegill, largemouth bass, and smallmouth bass. Abundance of spottail shiner, fallfish, and smallmouth bass were greater for samples in Group IIA, whereas abundance of bluegill and largemouth bass was greater for samples in Group IIB2.

Groups IIB1 and IIB2. These two groups were the least dissimilar and are characterized primarily by samples collected at stations south of Merrimack Station during 1995 (Group IIB1) and stations south of Merrimack Station during the 2000s (Group IIB2). The overall dissimilarity between these two groups was calculated at 53.50% (Table 3-10). Fish species cumulatively contributing approximately 50% of the overall dissimilarity between Groups IIB1 and IIB2 were bluegill and redbreast sunfish. Abundance of both bluegill and redbreast sunfish was greater for samples in Group IIB1.

Group IA appears to be most representative of the fish community in Hooksett Pool (north and south of Merrimack Station) as sampled in August and September of the 1970s (1972, 1973, 1974 and

1976). Based on the results of the SIMPER analysis, Group IA (the 1970s) was most dissimilar to Group IIB1 (primarily samples collected during 1995 south of Merrimack Station). That dissimilarity was primarily driven by the abundance of pumpkinseed collected in Hooksett Pool during the 1970s and inversely, the abundance of bluegill collected at stations south of Merrimack Station during 1995. The level of dissimilarity between the fish community sampled during the 1970s (Group IA) and that sampled during the 2000s both north (Group IIA) and south (Group IIB2) of Merrimack Station was less than that observed for 1995. In both cases, approximately 30% of the total community dissimilarity was driven by the lowered abundance of pumpkinseed and yellow perch in the 2000s fish community relative to that observed during the 1970s. Increases during the 2000s in abundance of spottail shiner and fallfish at stations north of Merrimack Station and bluegill at stations south of Merrimack Station also contributed to the dissimilarity relative to the fish community present in Hooksett Pool during the 1970s, respectively accounting for approximately 17% and 13% of the dissimilarity. The largest factor contributing to the dissimilarity between the Hooksett Pool fish community sampled during the 1970s and that sampled during the 2000s appears to be the reduction in abundance of pumpkinseed and the increase in abundance of bluegill. Those two species accounted for approximately 29% of the community dissimilarity between the 1970s and stations north of Merrimack Station during the 2000s and approximately 39% of the community dissimilarity between the 1970s and stations south of Merrimack Station during the 2000s.

3.3.7 Comparison of Species Distributions Among Months, Years and Decades

Fish assemblage groups were observed to cluster both temporally and spatially (north and south of Merrimack Station). Analysis of Similarities (ANOSIM) was used to compare spatial differences in species assemblages for three temporal classifications: month (August, September), year (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, 2011), and decade (1970s, 1995, 2000s).

There were no significant differences in the fish assemblages when compared among months (Table 3-11). However, there were significant differences in the fish assemblages when compared among individual years. In general, years further apart in time were more likely to be significantly different from each other. Years in the 1970s were significantly different from 1995 and the 2000s, and the year 1995 was significantly different from all years except 2004. In contrast, when individual years in the 1970s (1972, 1973, 1974 and 1976) and the 2000s (2004, 2005, 2010 and 2011) were compared, the differences in the fish assemblages were not significant or had an R factor low enough to justify rejecting the statistical significance.

Similarly, the ANOSIM analysis detected significant differences in the fish assemblages when compared among decades (Table 3-11). The SIMPER analysis was used to identify contributions from individual taxa to the overall dissimilarity among decadal fish assemblage cluster groups. The fish species responsible for cumulatively contributing to the top 50% of dissimilarity among decades are presented in Table 3-12.

1970s vs. 1995

The overall dissimilarity between the 1970s and 1995 was calculated at 76.40% (Table 3-12). Fish species cumulatively contributing approximately 50% of the overall dissimilarity between the 1970s and 1995 were bluegill, pumpkinseed and redbreast sunfish (Table 3-12). Abundance of pumpkinseed and redbreast sunfish were greater for samples collected during the 1970s, whereas abundance of bluegill was greater for samples collected during 1995.

1970s vs. 2000s

The overall dissimilarity between the 1970s and the 2000s decade was calculated at 68.23% (Table 3-12). Fish species cumulatively contributing approximately 50% of the overall dissimilarity between the 1970s and 2000s were pumpkinseed, largemouth bass, bluegill and yellow perch (Table 3-12). Abundance of pumpkinseed and yellow perch were greater for samples collected during the 1970s, whereas abundance of bluegill and largemouth bass was greater for samples collected during the 2000s.

1995 vs. 2000s

The overall dissimilarity between 1995 and the 2000s was calculated at 62.66% (Table 3-12). Fish species cumulatively contributing approximately 50% of the overall dissimilarity between the 1995 and 2000s were bluegill, spottail shiner, and largemouth bass (Table 3-12). Abundance of bluegill and spottail shiner were greater for samples collected during 1995, whereas abundance of largemouth bass was greater for samples collected during the 2000s.

Findings from this analysis are consistent with observations for the other community analyses. Differences in the fish community present during the 1970s and 2000s are largely driven by the decrease of pumpkinseed and the rise in abundance of bluegill. Given the similar thermal tolerance of pumpkinseed and bluegill (RMC 1979), it is likely that improvements in system water quality following the enactment of the Clean Water Act are responsible for changes in the Hooksett Pool fish community. Reductions in nutrient loading likely contributed to the decrease in submerged aquatic macrophytes (Normandeau 2011b) and contributed to the decline in fish species with a strong affinity for that type of habitat (i.e. pumpkinseed). Additionally, bluegill, a species present in Hooksett Pool since at least 1972, were able to increase in abundance once pumpkinseed lost their competitive edge which was associated with the ability to withstand lower DO levels and fluctuating environmental conditions (Fox 1994) during the period of increase pollution (i.e. the 1970s).

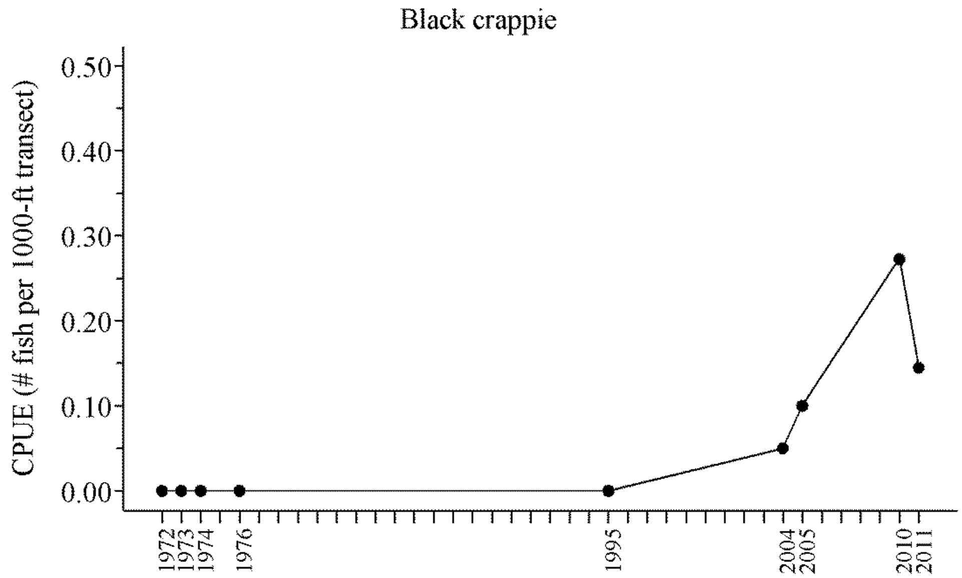


Figure 3-1. Electrofish CPUE for black crappie during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

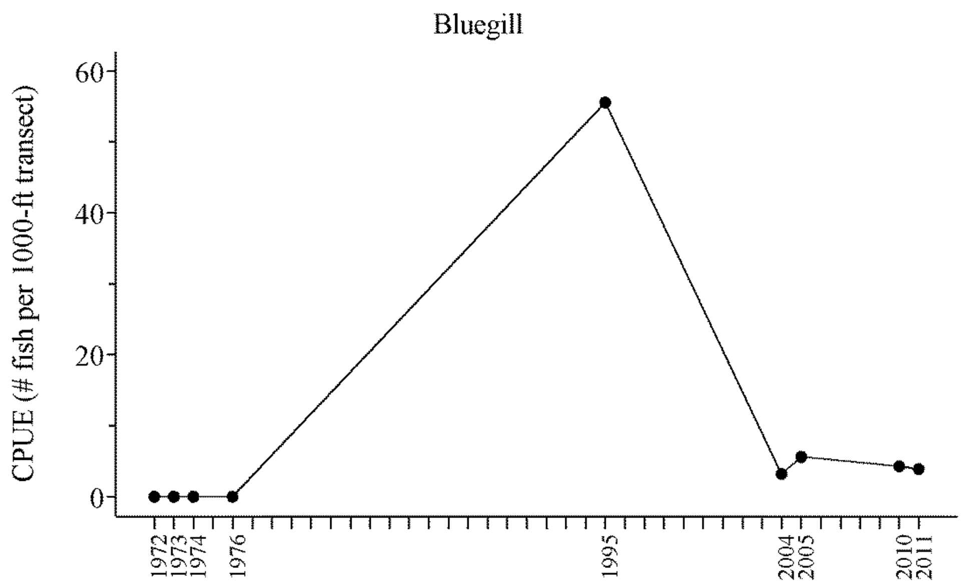


Figure 3-2. Electrofish CPUE for bluegill during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

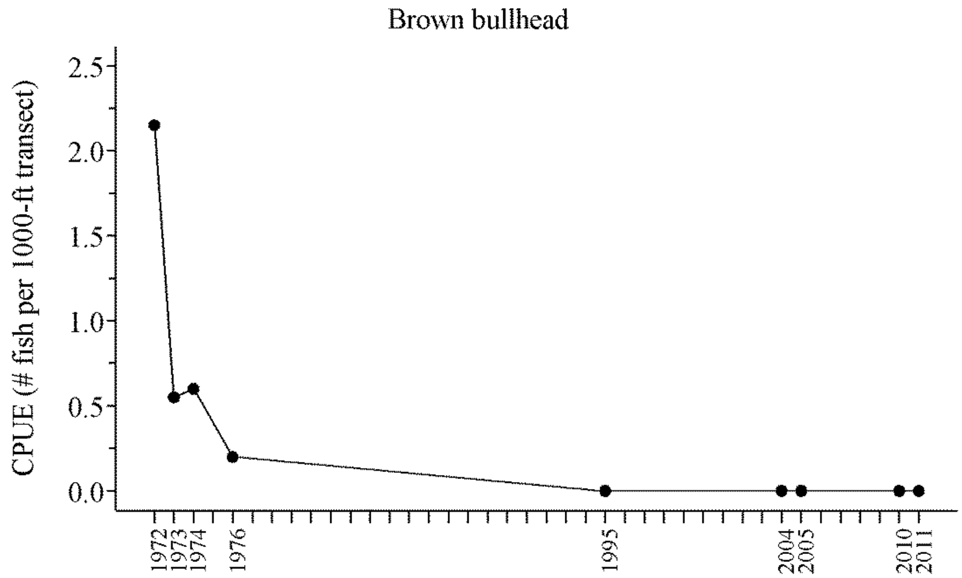


Figure 3-3. Electrofish CPUE for brown bullhead during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

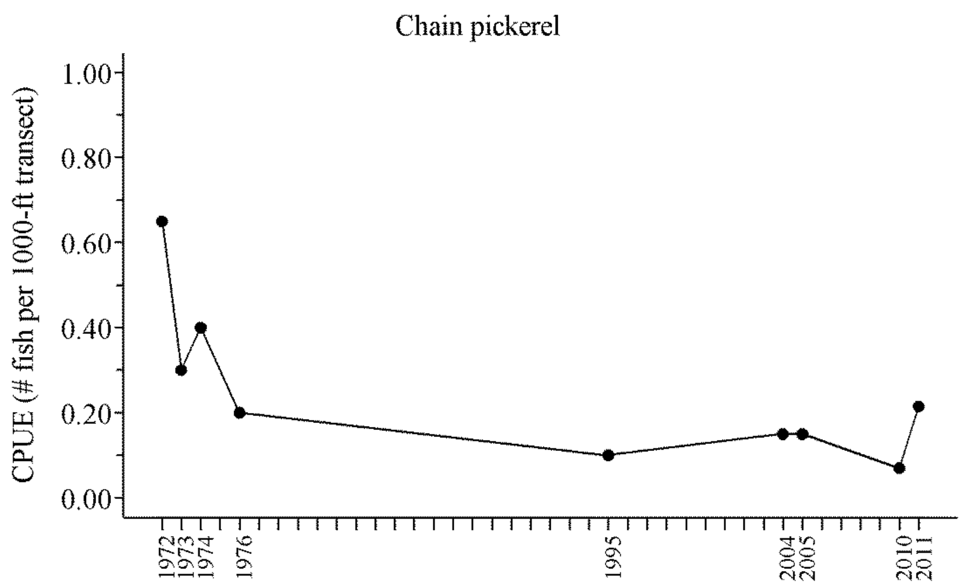


Figure 3-4. Electrofish CPUE for chain pickerel during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

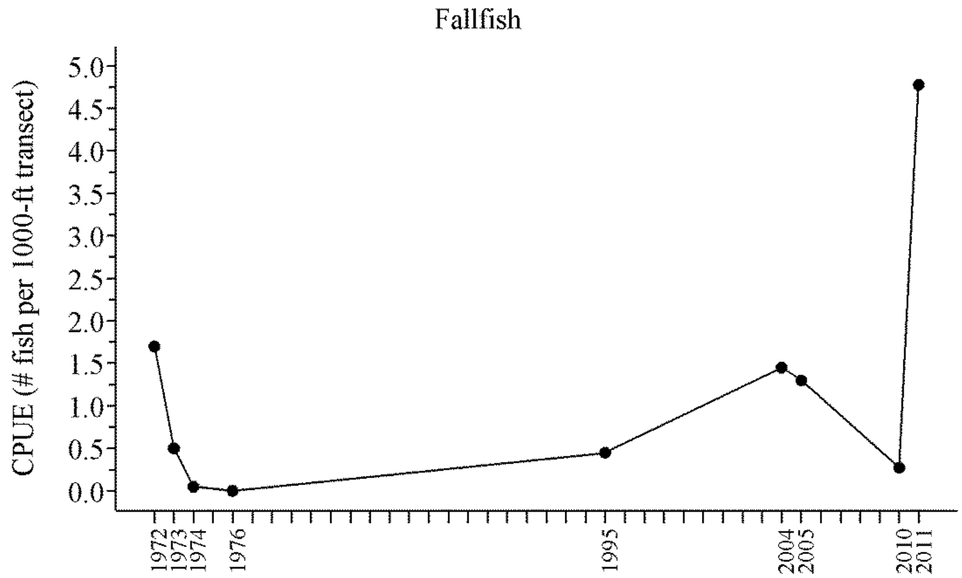


Figure 3-5. Electrofish CPUE for fallfish during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

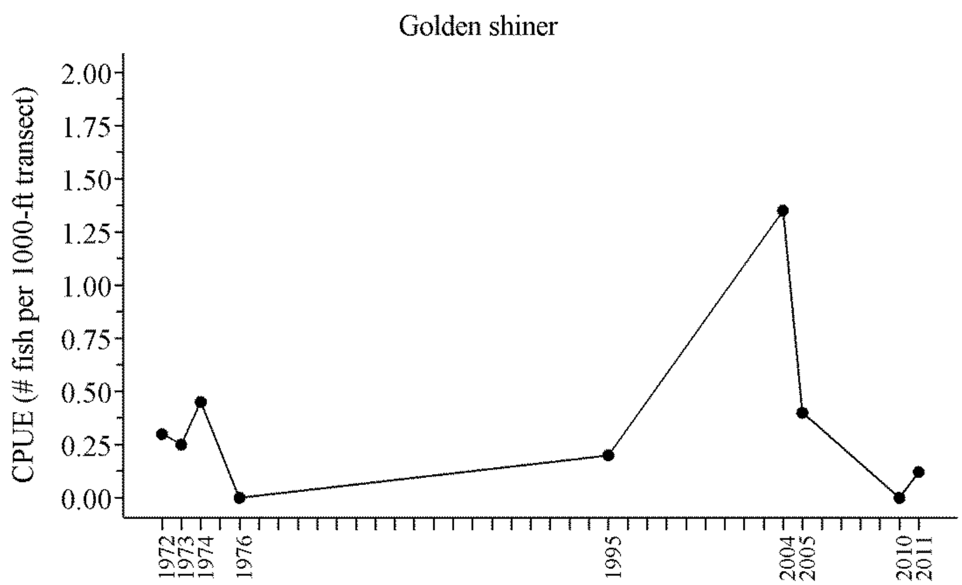


Figure 3-6. Electrofish CPUE for golden shiner during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

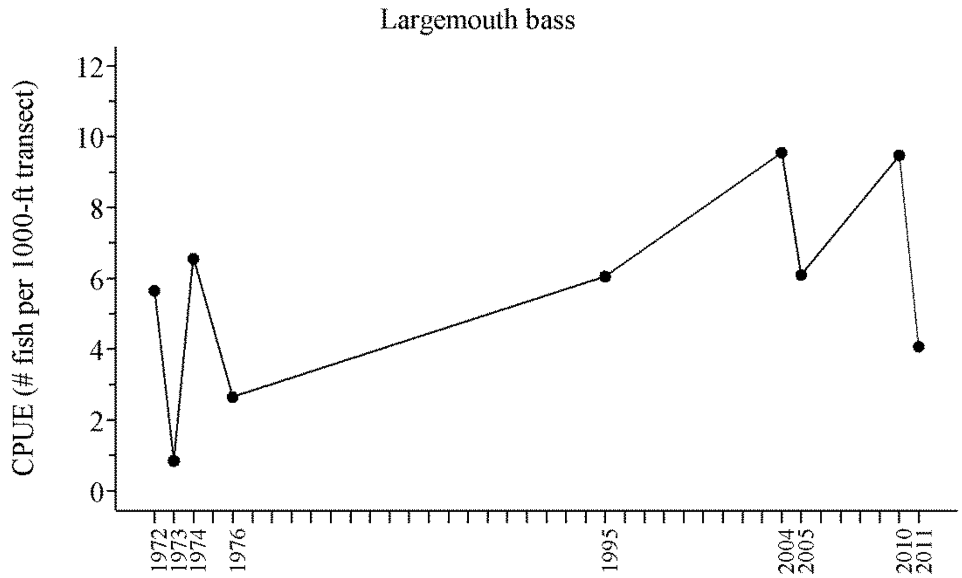


Figure 3-7. Electrofish CPUE for largemouth bass during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

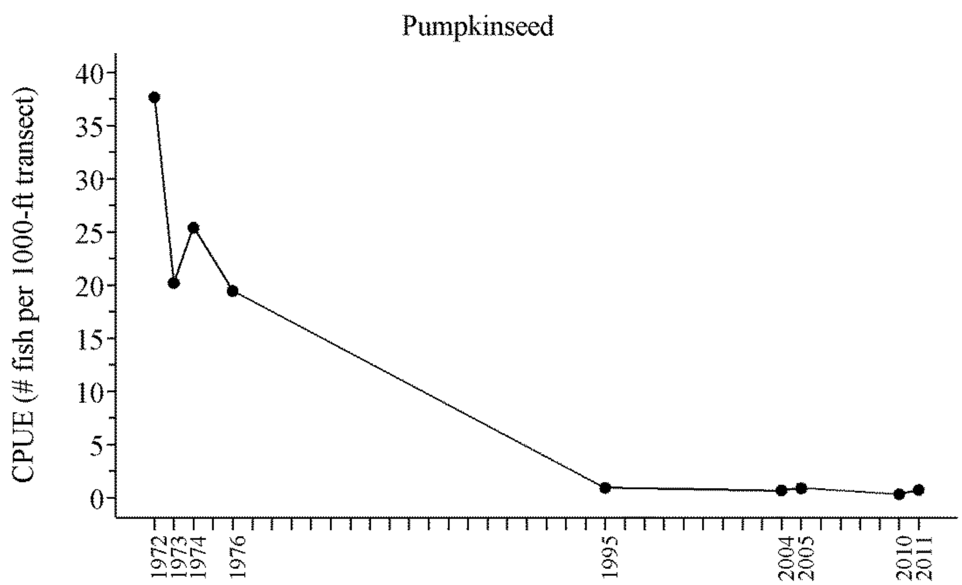


Figure 3-8. Electrofish CPUE for pumpkinseed during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

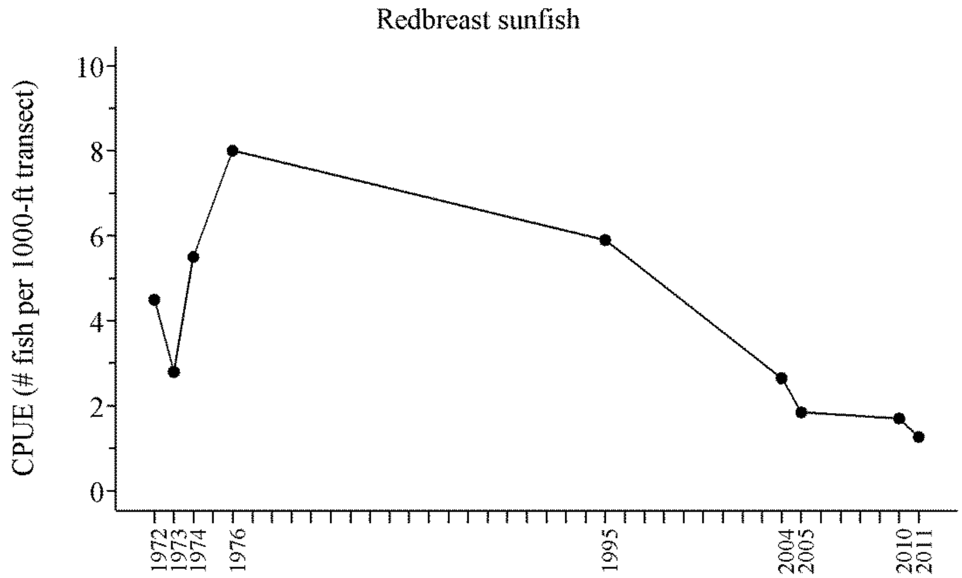


Figure 3-9. Electrofish CPUE for redbreast sunfish during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

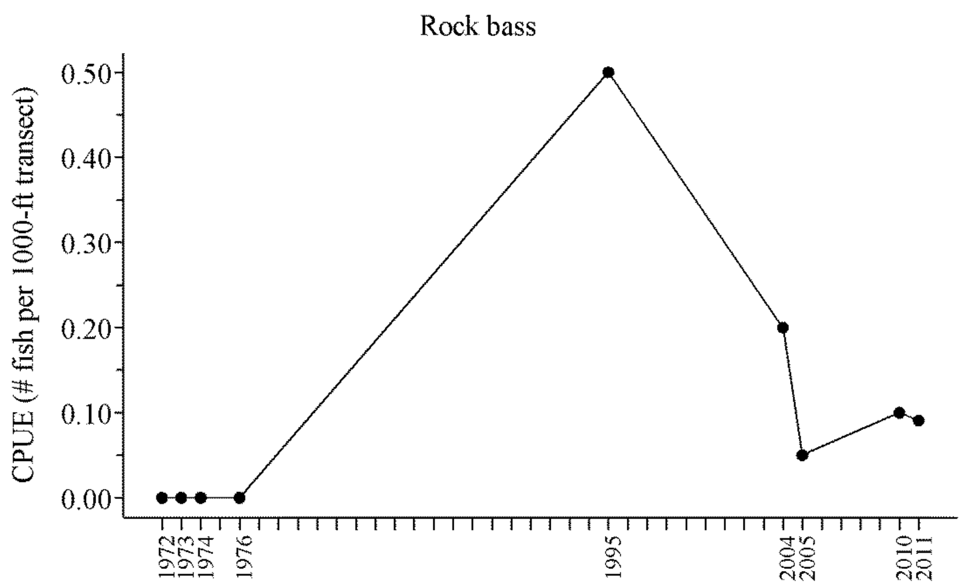


Figure 3-10. Electrofish CPUE for rock bass during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

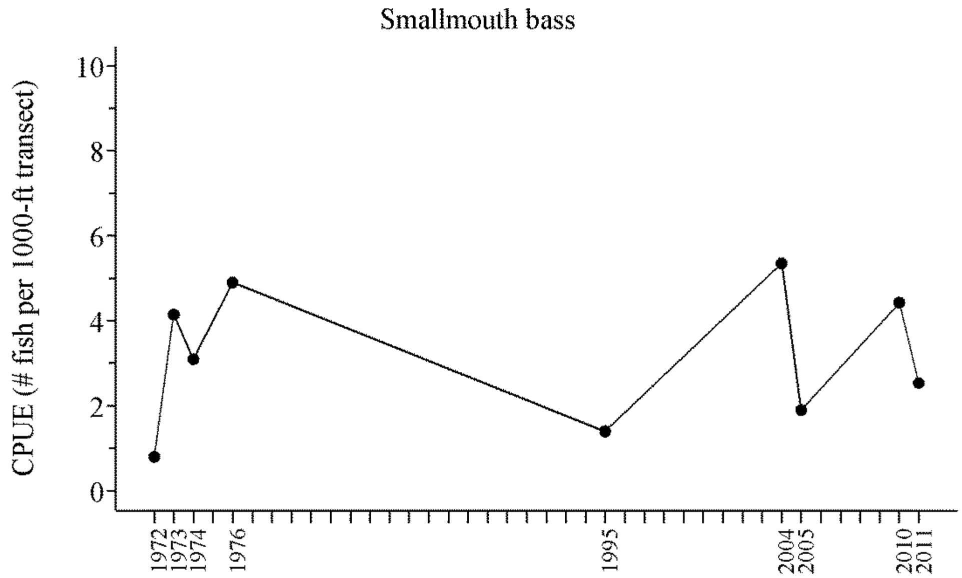


Figure 3-11. Electrofish CPUE for smallmouth bass during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

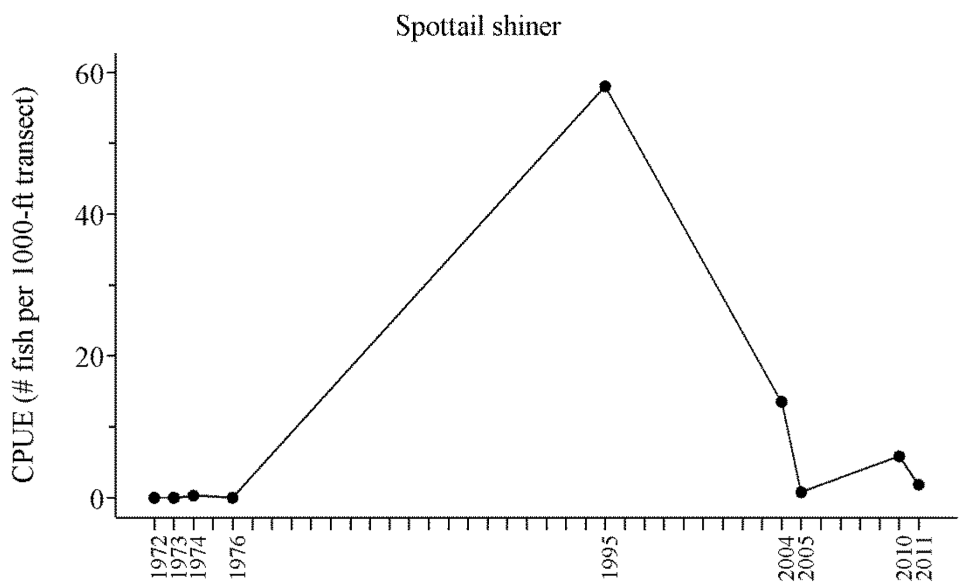


Figure 3-12. Electrofish CPUE for spottail shiner during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

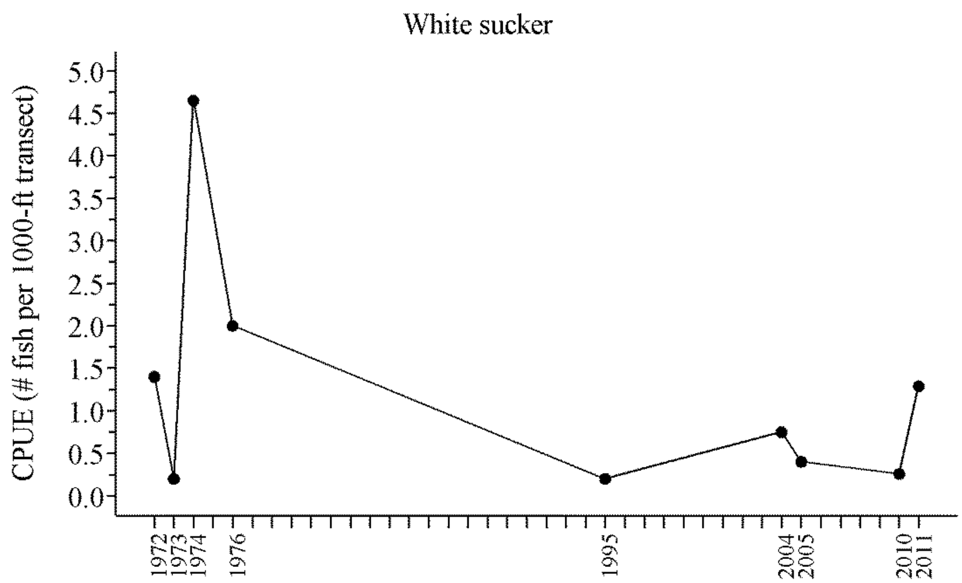


Figure 3-13. Electrofish CPUE for white sucker during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

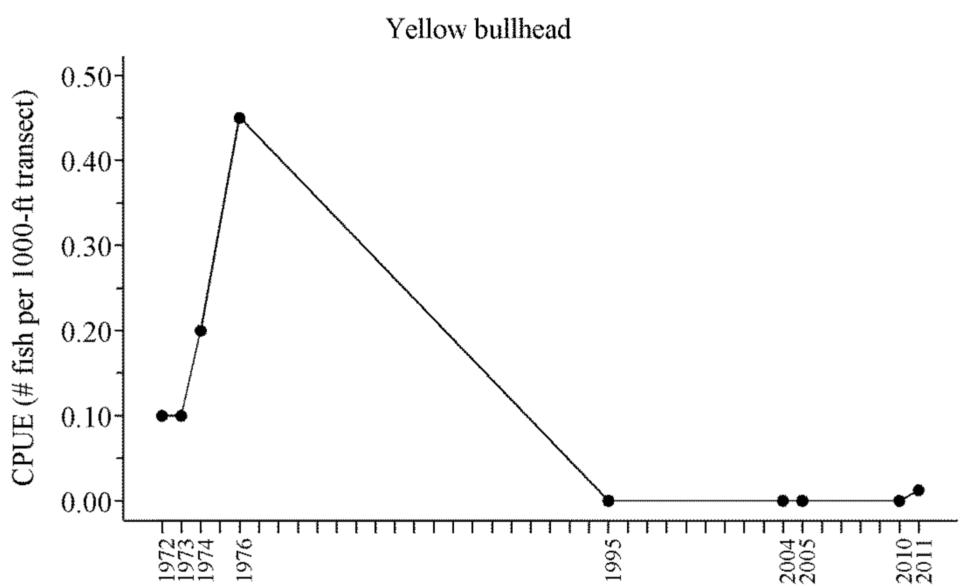


Figure 3-14. Electrofish CPUE for yellow bullhead during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

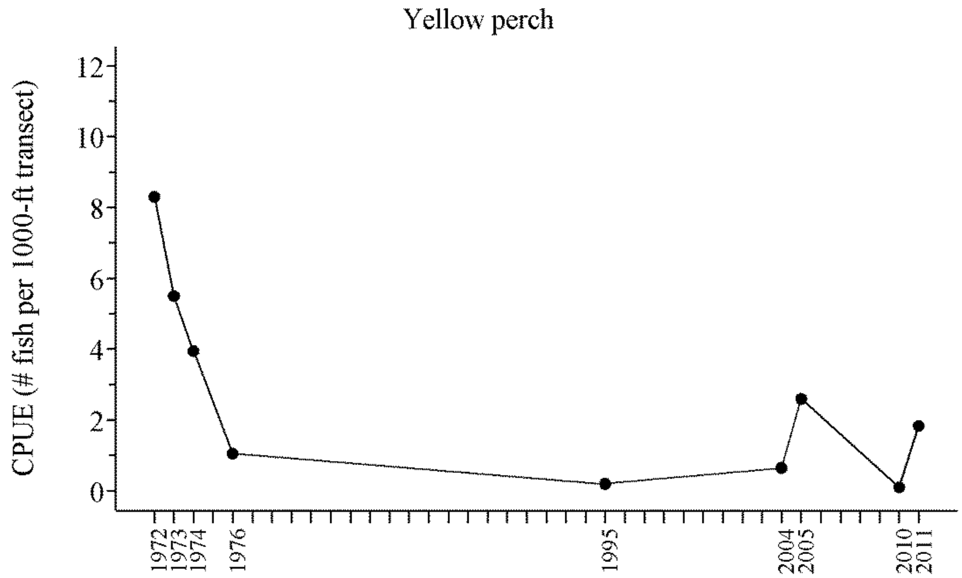


Figure 3-15. Electrofish CPUE for yellow perch during August and September of all years with consistent sampling effort in Hooksett Pool (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

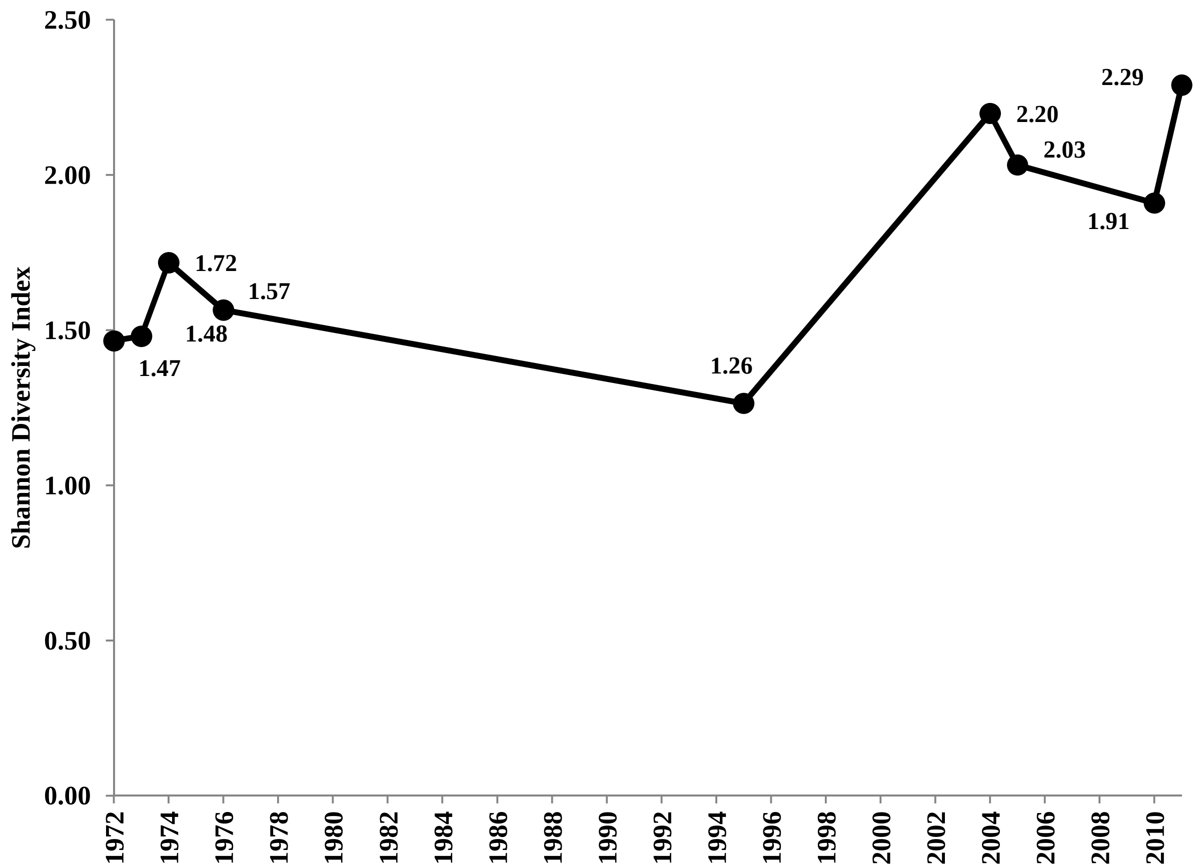


Figure 3-16. Shannon Diversity Index values for the Hooksett Pool fish community as sampled by boat electrofishing during August and September of all years with consistent sampling effort (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

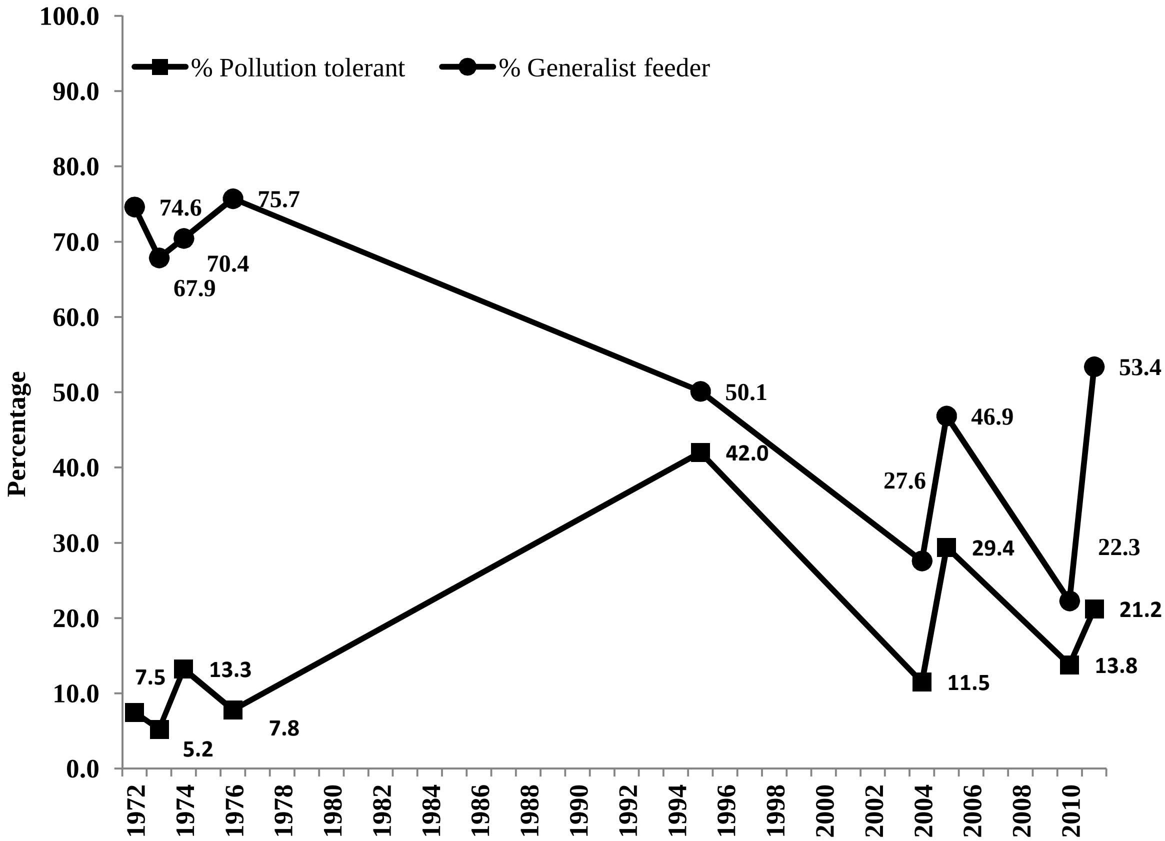


Figure 3-17. Percent generalist feeders and pollution tolerant species in the Hooksett Pool fish community as sampled by boat electrofishing during August and September of all years with consistent sampling effort (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

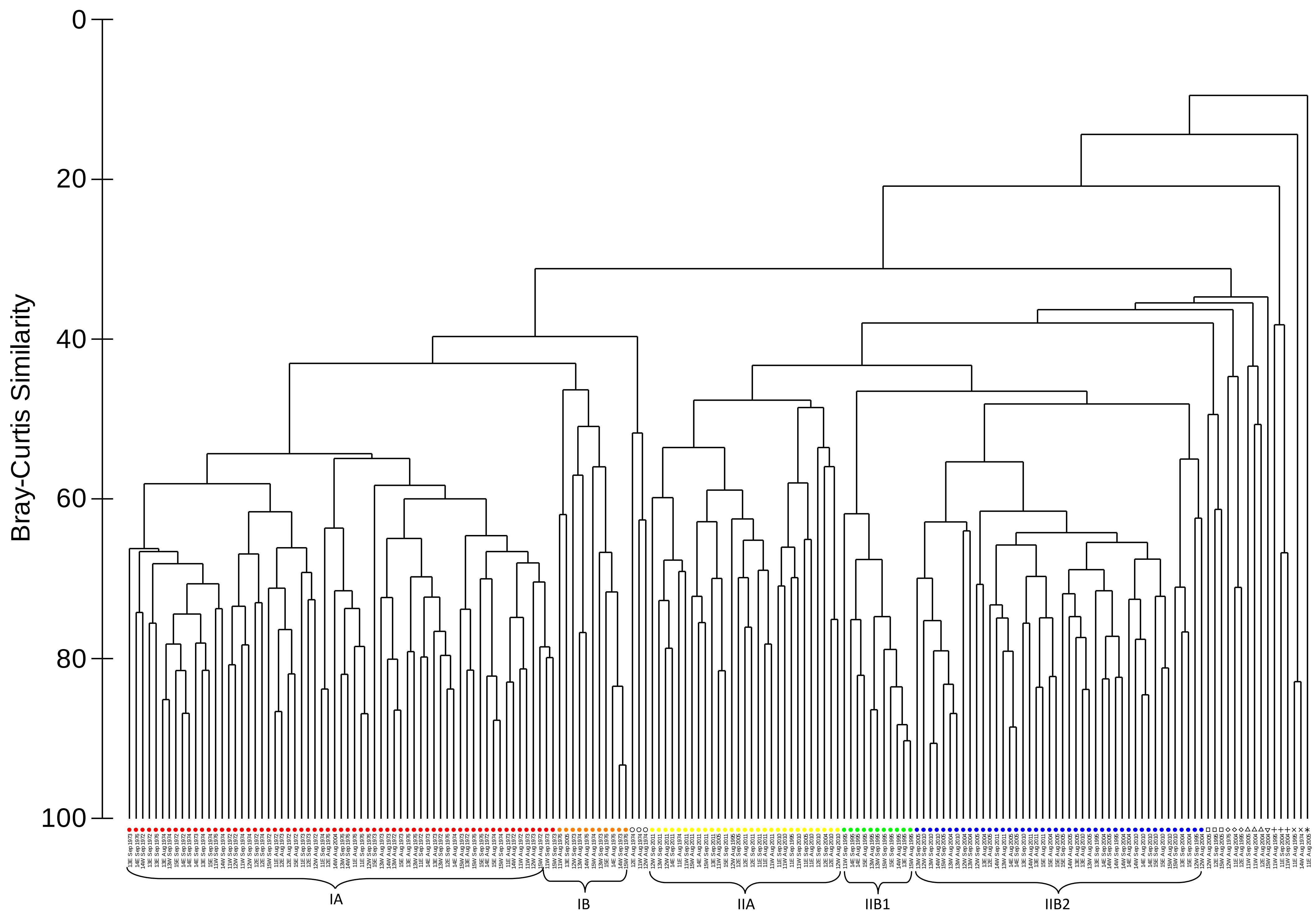


Figure 3-18. Results of cluster analysis based on Bray-Curtis similarities of square root transformed species abundances of 179 samples collected by electrofishing surveys within the Merrimack River during August and September of selected years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

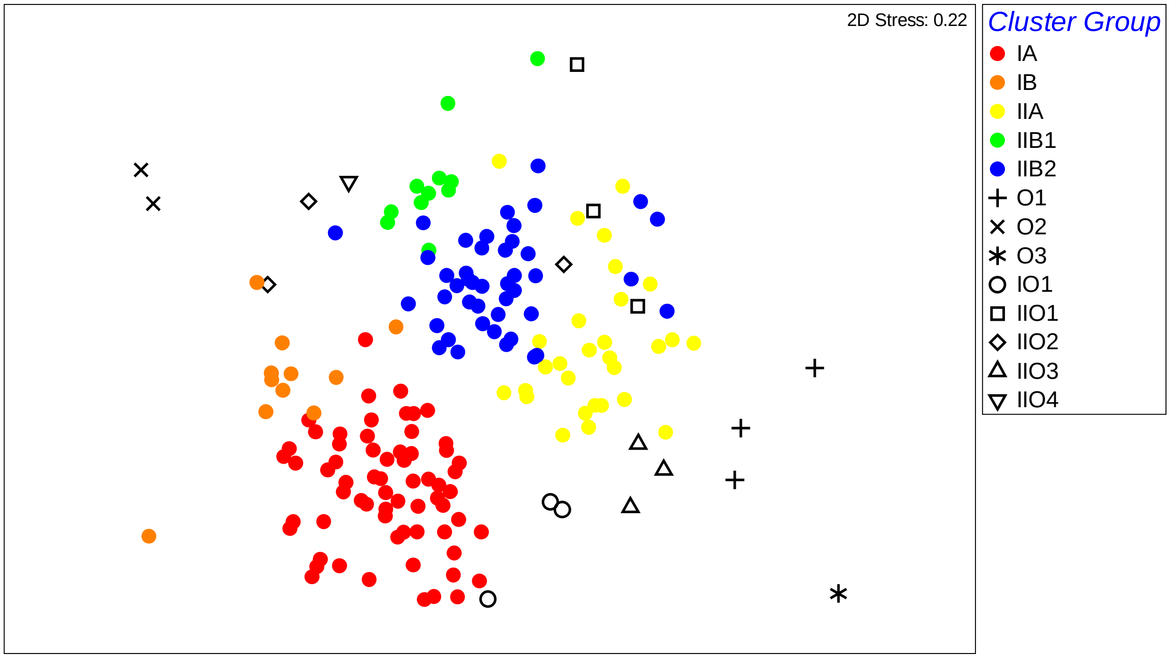


Figure 3-19. Results of MDS ordination based on Bray-Curtis similarities of square root transformed abundances at 179 samples collected by electrofishing surveys within the Merrimack River during August and September of selected years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

Table 3-1. Sampling design comparison of the Merrimack Station electrofishing surveys conducted in Hooksett Pool of the Merrimack River near Bow, NH during 1967 through 2011. Shading denotes data selected for analysis.

		Year												
		1967	1968	1969	1972	1973	1974	1975	1976	1995	2004	2005	2010	2011
Source		NH F&G	NH F&G	NH F&G	NAI[1]	NAI	NAI	NAI	NAI	NAI	NAI	NAI	NAI	NAI
Month	Unknown													
	March									x				
	April										x	x		
	May									x	x	x		
	June				x	x	x			x	x	x		
	July							x	x	x	x	x		
	August				x	x	x	x	x	x	x	x	x	x
	September	x	x	x	x	x	x		x	x	x	x	x	x
	October							x		x	x			
	November											x		
	December									x	x	x		
Station	North	x	x	x										
	South	x	x	x										
	N9-N10 E				x	x	x	x	x	x	x	x	x	x
	N9-N10 W				x	x	x	x	x	x	x	x	x	x
	N6-N7 E				x	x	x	x	x	x	x	x	x	x
	N6-N7 W				x	x	x	x	x	x	x	x	x	x
	Zero-S1 E				x	x	x	x	x	x	x	x	x	x
	Zero-S1 W				x	x	x	x	x	x	x	x	x	x
	S4-S5 E				x	x	x	x	x	x	x	x	x	x
	S4-S5 W				x	x	x	x	x	x	x	x	x	x
	S17-S18 E				x	x	x	x	x	x	x	x	x	x
	S17-S18 W				x	x	x	x	x	x	x	x	x	x
Transect Length	1,000				x	x	x	x	x	x	x	x	x	x
	Unknown	x	x	x										

Table 3-2. Total catch (N) and relative abundance (%) of fishes caught by electrofish sampling in Hooksett Pool (Stations 9-18) during August and September of select years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

Common Name	Year																	
	1972		1973		1974		1976		1995		2004		2005		2010		2011	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Alewife	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	80	8.4	0	0.0	20	0.8	0	0.0
American eel	17	1.3	16	2.2	21	2.0	9	1.1	0	0.0	4	0.4	3	0.7	16	0.6	6	0.3
American shad	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	69	2.7	0	0.0
Black crappie	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	2	0.4	23	0.9	13	0.5
Bluegill	0	0.0	0	0.0	0	0.0	0	0.0	1,111	41.7	64	6.7	112	25.1	366	14.1	356	15.0
Brown bullhead	43	3.4	11	1.5	12	1.1	4	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Carp and minnow family	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.1	0	0.0
Chain pickerel	13	1.0	6	0.8	8	0.8	4	0.5	2	0.1	3	0.3	3	0.7	6	0.2	20	0.8
Common shiner	0	0.0	0	0.0	2	0.2	0	0.0	70	2.6	62	6.5	0	0.0	0	0.0	39	1.6
Eastern blacknose dace	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1
Eastern silvery minnow	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	14	1.5	0	0.0	0	0.0	0	0.0
Fallfish	34	2.7	10	1.4	1	0.1	0	0.0	9	0.3	29	3.0	26	5.8	27	1.0	493	20.8
Golden shiner	6	0.5	5	0.7	9	0.9	0	0.0	4	0.2	27	2.8	8	1.8	0	0.0	13	0.5
Largemouth bass	113	8.8	17	2.3	131	12.5	53	6.7	121	4.5	191	20.0	122	27.4	829	32.0	393	16.6
Margined madtom	0	0.0	0	0.0	0	0.0	4	0.5	0	0.0	0	0.0	0	0.0	4	0.2	1	<0.1
Pumpkinseed	753	58.8	404	55.7	508	48.4	389	48.9	19	0.7	14	1.5	18	4.0	30	1.2	76	3.2
Redbreast sunfish	90	7.0	56	7.7	110	10.5	160	20.1	118	4.4	53	5.5	37	8.3	146	5.6	116	4.9
Rock bass	0	0.0	0	0.0	0	0.0	0	0.0	10	0.4	4	0.4	1	0.2	9	0.3	9	0.4
Smallmouth bass	16	1.2	83	11.4	62	5.9	98	12.3	28	1.1	107	11.2	38	8.5	400	15.4	261	11.0
Spottail shiner	0	0.0	0	0.0	6	0.6	0	0.0	1,161	43.6	271	28.3	16	3.6	585	22.6	197	8.3
Sunfish family	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	12	0.5	35	1.5
Tessellated darter	0	0.0	0	0.0	3	0.3	4	0.5	2	0.1	4	0.4	0	0.0	9	0.3	23	1.0
White perch	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
White sucker	28	2.2	4	0.6	93	8.9	40	5.0	4	0.2	15	1.6	8	1.8	25	1.0	131	5.5
Yellow bullhead	2	0.2	2	0.3	4	0.4	9	1.1	0	0.0	0	0.0	0	0.0	0	0.0	1	<0.1
Yellow perch	166	13.0	110	15.2	79	7.5	21	2.6	4	0.2	13	1.4	52	11.7	10	0.4	189	8.0
Total	1,281	100.0	725	100.0	1,049	100.0	795	100.0	2,663	100.0	956	100.0	446	100.0	2,589	100.0	2,373	100.0

Table 3-3. Mean CPUE (fish per 1,000 ft) of species captured by electrofish sampling in Hooksett Pool (Stations 9-18) during August and September of select years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

Common Name	Year								
	1972	1973	1974	1976	1995	2004	2005	2010	2011
Alewife	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.21	0.00
American eel	0.85	0.80	1.05	0.45	0.00	0.20	0.15	0.18	0.06
American shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00
Black crappie	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.27	0.15
Bluegill	0.00	0.00	0.00	0.00	55.55	3.20	5.60	4.28	3.89
Brown bullhead	2.15	0.55	0.60	0.20	0.00	0.00	0.00	0.00	0.00
Chain pickerel	0.65	0.30	0.40	0.20	0.10	0.15	0.15	0.07	0.22
Common shiner	0.00	0.00	0.10	0.00	3.50	3.10	0.00	0.00	0.38
Eastern blacknose dace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Eastern silvery minnow	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00
Fallfish	1.70	0.50	0.05	0.00	0.45	1.45	1.30	0.27	4.78
Golden shiner	0.30	0.25	0.45	0.00	0.20	1.35	0.40	0.00	0.12
Largemouth bass	5.65	0.85	6.55	2.65	6.05	9.55	6.10	9.47	4.07
Margined madtom	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.04	0.01
Pumpkinseed	37.65	20.20	25.40	19.45	0.95	0.70	0.90	0.35	0.74
Redbreast sunfish	4.50	2.80	5.50	8.00	5.90	2.65	1.85	1.70	1.27
Rock bass	0.00	0.00	0.00	0.00	0.50	0.20	0.05	0.10	0.09
Smallmouth bass	0.80	4.15	3.10	4.90	1.40	5.35	1.90	4.43	2.54
Spottail shiner	0.00	0.00	0.30	0.00	58.05	13.55	0.80	5.86	1.87
Tessellated darter	0.00	0.00	0.15	0.20	0.10	0.20	0.00	0.09	0.20
White perch	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White sucker	1.40	0.20	4.65	2.00	0.20	0.75	0.40	0.26	1.29
Yellow bullhead	0.10	0.10	0.20	0.45	0.00	0.00	0.00	0.00	0.01
Yellow perch	8.30	5.50	3.95	1.05	0.20	0.65	2.60	0.11	1.84

Table 3-4. Kendall tau b results for detection of increasing or decreasing species-specific trends within Hooksett Pool (Stations 9-18) for fish captured by electrofish sampling in August and September of select years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

Common Name	Type	Kendall-Tau	p-value	Trend
Black crappie	Resident	0.78446	0.0057	Increase
Bluegill	Resident	0.48686	0.0797	Unable to Detect Significant Trend
Brown bullhead	Resident	-0.78446	0.0057	Decrease
Chain pickerel	Resident	-0.53526	0.0464	Decrease
Fallfish	RIS	0.11111	0.6767	Unable to Detect Significant Trend
Golden shiner	Resident	-0.19720	0.4631	Unable to Detect Significant Trend
Largemouth bass	RIS	0.27778	0.2971	Unable to Detect Significant Trend
Pumpkinseed	RIS	-0.77778	0.0035	Decrease
Redbreast sunfish	Resident	-0.55556	0.0371	Decrease
Rock bass	Resident	0.42601	0.1251	Unable to Detect Significant Trend
Smallmouth bass	RIS	0.16667	0.5316	Unable to Detect Significant Trend
Spottail shiner	Resident	0.43519	0.1105	Unable to Detect Significant Trend
White sucker	RIS	-0.14086	0.6002	Unable to Detect Significant Trend
Yellow bullhead	Resident	-0.34044	0.2254	Unable to Detect Significant Trend
Yellow perch	RIS	-0.55556	0.0371	Decrease

Table 3-5. Temperature guilds for resident Hooksett Pool fish species assessed during trends analysis from standardized sampling conducted during August and September of select years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

Common Name	Guild	Reference
Black crappie	coolwater	Eaton et al. 1995
Bluegill	warmwater	Eaton et al. 1995
Brown bullhead	warmwater	Eaton et al. 1995
Chain pickerel	coolwater	Eaton et al. 1995
Fallfish	coolwater	Trial et al. 1982
Golden shiner	warmwater	Eaton et al. 1995
Largemouth bass	warmwater	Eaton et al. 1995
Pumpkinseed	warmwater	Wismer and Christie 1987
Redbreast sunfish	warmwater	Aho et al. 1986
Rock bass	warmwater	Eaton et al. 1995
Smallmouth bass	warmwater	Eaton et al. 1995
Spottail shiner	warmwater	Wismer and Christie 1987
White sucker	coolwater	Eaton et al. 1995
Yellow bullhead	warmwater	Wismer and Christie 1987
Yellow perch	coolwater	Eaton et al. 1995

Table 3-6. Taxa richness (number) of species captured within Hooksett Pool (Stations 9-18) by electrofish sampling during August and September of select years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010 and 2011).

Year	Number of Taxa
1972	12
1973	13
1974	15
1976	12
1995	14
2004	18
2005	14
2010	17
2011	19

Table 3-7. Decadal (1970s, 1995, 2000s) comparison of the Bray-Curtis Percent Similarity Index for the fish communities sampled by electrofishing during August and September of all years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011) with consistent sampling effort within Hooksett Pool (Stations 9-18).

Fish Communities Compared	Bray-Curtis % Similarity
1970s vs. 1995	40.8
1970s vs.2000s	49.7
1995 vs. 2000s	65.4

Table 3-8. Abundance (mean fish per 1,000 ft.) of taxa composing species assemblages identified by cluster analyses from electrofishing surveys within the Merrimack River during August and September of selected years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010 and 2011).

	Cluster Group					Outlier Group							
Common Name	**IA (n=65)**	**IB (n=11)**	**IIA (n=29)**	**IIB1 (n=11)**	**IIB2 (n=44)**	**IO1 (n=3)**	**IIO1 (n=3)**	**IIO2 (n=3)**	**IIO3 (n=3)**	**IIO4 (n=1)**	**O1 (n=3)**	**O2 (n=2)**	**O3 (n=1)**
Alewife			0.290		0.017				23.000	5.000	0.333		
American eel	0.908	0.182	0.126		0.183	0.333					0.333		
American shad			0.476										
Black crappie			0.098		0.148				0.667				
Bluegill		0.273	2.870	91.455	6.301		2.000		5.000		20.000		
Brown bullhead	1.015	0.091				1.000							
Carp and minnow family			0.021										
Chain pickerel	0.462	0.091	0.129	0.182	0.135				0.333		0.333		
Common shiner	0.031		0.262	0.182				1.333	20.000		22.000		
Eastern blacknose dace					0.006								
Eastern silvery minnow									4.667				
Fallfish	0.677		4.053		0.305		0.333	1.000	7.000		2.667		2.000
Golden shiner	0.308		0.515	0.364	0.102				2.667		3.333		
Largemouth bass	4.692	0.364	5.075	8.091	8.195	2.000	0.333	2.333	25.667	9.000	4.333		
Margined madtom	0.062		0.034										
Pumpkinseed	30.708	5.455	0.551	1.364	0.790	0.667			1.000				
Redbreast sunfish	6.015	2.273	0.875	9.636	2.523	1.000	0.667	1.000	1.333	5.000	1.667	1.500	
Rock bass			0.123	0.727	0.051				0.667		1.000		
Smallmouth bass	3.692	1.727	3.898	1.909	3.530	1.000	2.000	1.667	0.333		2.667		
Spottail shiner		0.545	6.992	0.091	0.043				1.000		464.67		
Sunfish family			0.199		0.078								
Tessellated darter	0.108		0.230	0.091	0.074						0.333		
White perch	0.015												
White sucker	2.277	0.091	1.298		0.211	4.667	1.667		0.333		2.000		1.000
Yellow bullhead	0.231	0.182			0.006								
Yellow perch	5.600	0.273	1.429	0.182	0.714	3.000		0.667	10.000		0.333		

Table 3-9. Distribution of samples by year and location (north or south of Merrimack Station) among groups identified by cluster analyses from electrofishing surveys within the Merrimack River during August and September of selected years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, and 2011).

	Cluster Group									
	IA		IB		IIA		IIB1		IIB2	
Year	North	South	North	South	North	South	North	South	North	South
1972	8	12								
1973	7	10	1	2						
1974	4	9		2	1					
1976	6	8	1	4						
1995					2		1	10	1	2
2004		1			1				2	9
2005				1	3				2	10
2010					7				1	12
2011					8	7				5
All	**25**	**40**	**2**	**9**	**22**	**7**	**1**	**10**	**6**	**38**

Table 3-10. Results of SIMPER analyses displaying dissimilarity (%) between groups identified by cluster analyses (IA, IB, IIA, IIB1 and IIB2) as well as the fish species accounting for approximately 50% of the cumulative dissimilarity.

Groups IB and IIB1 **Avg. Dissimilarity = 76.18**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IB	IIB1		
Bluegill	0.16	9.33	50.83	50.83

Groups IA and IIB1 **Avg. Dissimilarity = 73.78**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IA	IIB1		
Bluegill	0.00	9.33	38.99	38.99
Pumpkinseed	5.11	0.82	17.04	56.03

Groups IB and IIA **Avg. Dissimilarity = 72.82**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IB	IIA		
Spottail shiner	0.22	2.00	13.20	13.20
Pumpkinseed	2.25	0.57	12.65	25.85
Fallfish	0.00	1.65	11.30	37.15
Largemouth bass	0.36	2.02	11.12	48.28
Bluegill	0.16	1.44	9.21	57.49

Groups IA and IIA **Avg. Dissimilarity = 68.89**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IA	IIA		
Pumpkinseed	5.11	0.57	22.31	22.31
Spottail shiner	0.00	2.00	9.86	32.17
Yellow Perch	2.05	0.82	8.16	40.32
Fallfish	0.31	1.65	7.83	48.15
Redbreast sunfish	2.10	0.77	7.44	55.6

(continued)

Table 3-10. (Continued)

Groups IIA and IIB1 **Avg. Dissimilarity = 67.69**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IIA	IIB1		
Bluegill	1.44	9.33	37.75	37.75
Redbreast sunfish	0.77	2.61	9.87	47.62
Spottail shiner	2.00	0.09	8.84	56.46

Groups IB and IIB2 **Avg. Dissimilarity = 66.60**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IB	IIB2		
Largemouth bass	0.36	2.74	22.07	22.07
Bluegill	0.16	2.17	18.40	40.47
Pumkinseed	2.25	0.61	16.71	57.18

Groups IA and IIB2 **Avg. Dissimilarity = 65.66**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IA	IIB2		
Pumpkinseed	5.11	0.61	26.32	26.32
Bluegill	0.00	2.17	12.93	39.25
Yellow perch	2.05	0.47	10.84	50.09

Groups IA and IB **Avg. Dissimilarity = 56.99**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IA	IB		
Pumpkinseed	5.11	2.25	22.01	22.01
Yellow perch	2.05	0.22	16.01	38.02
Redbreast sunfish	2.10	1.25	11.22	49.23
Largemouth bass	1.67	0.36	10.89	60.12

(continued)

Table 3-10. (Continued)

Groups IIA and IIB2 **Avg. Dissimilarity = 53.98**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IIA	IIB2		
Spottail shiner	2.00	0.06	14.79	14.79
Fallfish	1.65	0.27	11.50	26.29
Bluegill	1.44	2.17	10.75	37.04
Largemouth bass	2.02	2.74	9.92	46.97
Smallmouth bass	1.63	1.58	8.60	55.56

Groups IIB1 and IIB2 **Avg. Dissimilarity = 53.50**

Common Name	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	IIB1	IIB2		
Bluegill	9.33	2.17	48.63	48.63
Redbreast sunfish	2.61	1.36	12.38	61.01

Table 3-11. Results of one way ANOSIM (Analysis of Similarities) for temporal variables (month, year, decade) from electrofishing surveys within the Merrimack River during August and September of selected years (1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010 and 2011).

Factor: Month

Model Results:
Sample statistic (Global R): 0.015
Significance level of sample statistic: 4.2%

Pairwise Comparisons:

	August	September
August		
September	n/a	

R-Statistic/Significance level %

Factor: Year

Model Results:
Sample statistic (Global R): 0.49
Significance level of sample statistic: 0.1%

Pairwise Comparisons:

	1972	1973	1974	1976	1995	2004	2005	2010
1972								
1973	0.112/0.4[1]							
1974	n/s	0.148/0.1[1]						
1976	0.36/0.1	0.196/0.1[1]	n/s					
1995	0.736/0.1	0.731/0.1	0.511/0.1	0.596/0.1				
2004	0.735/0.1	0.708/0.1	0395/0.1	0.523/0.1	0.177/0.1[1]			
2005	0.757/0.1	0.683/0.1	0.48/0.1	0.62/0.1	0.204/0.1	0.108/0.4[1]		
2010	0.967/0.1	0.944/0.1	0.681/0.1	0.818/0.1	0.325/0.1	0.119/0.1[1]	0.158/0.2[1]	
2011	0.925/0.1	0.868/0.1	0.651/0.1	0.848/0.1	0.458/0.1	0.356/0.1	.242/0.1	0.417/0.1

R-Statistic/Significance level %

1 – Clarke and Warwick (2001)

Factor: Decade

Model Results:
Sample statistic (Global R): 0.641
Significance level of sample statistic: 0.1%

Pairwise Comparisons:

	1970s	1995	2000s
1970s			
1995	0.829/0.1		
2000s	0.656/0.1	0.388/0.1	

R-Statistic/Significance level %

Table 3-12. Results of SIMPER analyses displaying dissimilarity (%) between time periods (1970s, 1995, 2000s) as well as the fish species accounting for approximately 50% of the cumulative dissimilarity.

Groups 1970s and 1995 Avg. Dissimilarity = 76.40

Fish species contributing to 50% of dissimilarity	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	1970s	1995		
Bluegill	0	6.17	27.01	27.01
Pumpkinseed	4.46	0.59	19.19	46.2
Redbreast sunfish	1.9	1.84	8.17	54.37

Groups 1970s and 2000s Avg. Dissimilarity = 68.23

Fish species contributing to 50% of dissimilarity	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	1970s	2000s		
Pumpkinseed	4.46	0.58	21.92	21.92
Largemouth bass	1.43	2.44	10.69	32.61
Bluegill	0	1.74	10.31	42.91
Yellow perch	1.76	0.68	8.99	51.9

Groups 1995 and 2000s Avg. Dissimilarity = 62.66

Fish species contributing to 50% of dissimilarity	Avg. Abundance (Square root transformed)		Contributing % to Dissimilarity	Cumulative % of Dissimilarity
	1995	2000s		
Bluegill	6.17	1.74	29.72	29.72
Spottail shiner	2.11	0.98	10.86	40.58
Largemouth bass	2.2	2.44	9.47	50.05

4.0 Biocharacteristics of Selected Merrimack River Fish Species

4.1 Methods

4.1.1 Field Sampling

2008 and 2009

Merrimack River fisheries sampling during 2008 and 2009 was primarily designed to examine and compare biological characteristics of two RIS of fish (yellow perch and white sucker) among Garvins, Hooksett and Amoskeag Pools. Yellow perch and white sucker populations were sampled weekly during two seasons (spring and fall; Table 4-1-1), and biological characteristics including length, weight, age, gender, sexual condition, fecundity and incidence of disease or parasitism were evaluated to determine whether they could support a finding that Merrimack Station's thermal discharge has caused appreciable harm to either species. During 2008, spring sampling occurred between 14 April and 2 May and fall sampling occurred between 1 September and 10 October (Table 4-1-1). During 2009, spring sampling occurred between 13 April and 1 May and fall sampling occurred between 7 September and 25 September (Table 4-1-1). Within each sampling week and pool, a target number of yellow perch (Table 4-1-2) and white sucker (Table 4-1-3) were collected and taken to the laboratory in fresh condition for biocharacteristics analysis.

Yellow perch and white sucker quotas during each sampling week and within each pool were filled by tallying all fish caught in each complete sampling effort (i.e., each electrofish transect), placing each sample of fish in a container labeled with the unique sample number, placing the sample container on ice, and delivering these samples to Normandeau's Bedford, NH Biological Laboratory at the end of each sampling day. Successive whole samples of yellow perch and white sucker were retained in their entirety until the week and sampling pool length group quota was reached. Yellow perch or white sucker caught in subsequent whole samples in length groups where the week and pool quota had been reached were processed in the field and released alive. There was no subsampling of fish within each sample to satisfy an individual length group quota.

Yellow perch and white sucker biocharacteristics sampling in 2008 and 2009 was conducted using boat electrofishing. Field crews specifically targeted white sucker and yellow perch and did not necessarily focus sampling efforts on the standardized electrofish stations located in Garvins, Hooksett or Amoskeag Pools (see Section 2.2 of this report). Electrofish sampling was conducted using a Smith-Root SR-16H electrofisher boat equipped with a 5.0 kH Generator Powered Pulsator (GPP) electrofish unit, and all electrofish sampling was conducted during daylight hours, defined as between one-half hour after sunrise and one-half hour before sunset. The electrofishing equipment was operated at 4-5 amps of pulsed DC (120 pps) current and followed the shoreline from downstream to upstream. Shocking runs were restricted to depths less than 6-8 ft since previous experience indicated that collection efficiency at greater depths may be substantially reduced. For each individual transect sampled, all stunned fish were captured by dip net and retained in a live well for processing.

Upon completion of each electrofish sample, yellow perch and white sucker were enumerated and, depending on the status of the weekly quota for the particular species and sampling pool, were either labeled and placed on ice for transport to the laboratory or processed in the field and released back into the river. All additional fish taxa caught were identified to species, counted, measured for total length (TL) to the nearest mm, weighed to the nearest g, and assessed for external parasite load. The degree of external parasite infection was categorized as none (0 parasites), light (1-5 parasites), moderate (6-20 parasites) or heavy (>20 parasites).

Scale samples were collected from all age-1 and older yellow perch, white sucker, smallmouth bass, largemouth bass, fallfish, pumpkinseed, bluegill, rock bass and black crappie caught during both the spring and late summer sampling seasons.   Yellow perch and white suckers scale samples were collected during examination at the Normandeau facility in Bedford, NH. Scale samples from age-1 and older individuals of all other species were taken in the field. To ensure that specimens were at least age-1, the literature-reported length at age-0 was obtained from available literature (Carlander 1969) and provided a species-specific length cut-off below which scale samples were not collected. Age-0 total length cut-off values were 40 mm for rock bass, 45 mm for fallfish, 50 mm for black crappie, bluegill and pumpkinseed, 75 mm for yellow perch and 100 mm for smallmouth and largemouth bass.

Scales samples were collected from the right side of the fish's body midway between the dorsal surface and the lateral line, and near the midpoint of the body length. Scales were placed in scale envelopes marked with a unique sample number, an individual fish ID number, date, time, river pool, and taxon ID. Following collection of scale samples from an individual fish, the collecting knife was wiped clean prior to proceeding with the next scale sample.

Additional sampling parameters recorded on the field data sheets included sampling time, date, location, latitude and longitude, physical-chemical data and investigators. Physical-chemical data included water depth as well as water temperature (^{o}C), dissolved oxygen (mg/L) and conductivity (µS/cm) recorded at the surface and bottom of the water column.

2010 and 2011

Merrimack River fisheries sampling during 2010 and 2011 was designed to provide a current assessment of the whole fish community in Garvins, Hooksett and Amoskeag Pools, as well as provide additional data for the Hooksett Pool fish population trends analysis based on the time series of comparable electrofish abundance data first presented in "Merrimack Station Fisheries Survey Analysis of 1967 through 2005 Catch and Habitat Data" (Normandeau 2007a).

Field methodology followed during 2010 and 2011 is presented in Sections 2.2.1 and 2.2.2 of this report. Processing of fish catch took place in the field following completion of each individual sample and followed methodology presented in Section 4.1.1.1 above.

4.1.2 Laboratory Methods

During 2008 and 2009, yellow perch and white sucker were returned to the laboratory where they were autopsied to gather biological information including length, weight, age, gender, sexual condition, fecundity and incidence of disease or parasitism. All individuals were processed in fresh condition, either immediately upon delivery from the field, or refrigerated and processed within 24 hours. Once in the laboratory, total length (mm) and total weight (nearest 0.1 g) were recorded. Gender was determined through an examination of the reproductive structures within each individual specimen and was recorded as male, female or undetermined. Those individuals classified as undetermined were generally juvenile fish that had not yet undergone significant development of the reproductive system. Gonad weights (nearest 0.1 g, wet weight) were determined for each individual of known gender. Reproductive condition categories used for classifying yellow perch and white sucker included ripe, ripe and running, partially spent, spent, immature, resting and developing (Table 4-1-4). The degree of external parasites was categorized as none, light (1-5 parasites), moderate (6-20 parasites) or heavy (>20 parasites) for each individual. Internal parasites were categorized as either present or absent. Scale samples were collected in the same manner as described in Section 4.1.1 for fish processed in the field.

Fecundity was assessed by enumerating the number of eggs in the gonads of ripe female yellow perch and white sucker using a subsample-weight extrapolation. Ovaries from yellow perch and white sucker in ripe or approaching ripe condition were preserved in 10% formalin for a minimum of one month. Following preservation, the total gonad weight was obtained to the nearest 0.1 g (wet weight). The right ovary of the fish was then cut transversely midway along the longitudinal axis and a triangular section 1-2 mm thick and consisting of 1/8 of the cross-section of the ovary was removed. This subsection was weighed to the nearest 0.01 g (wet weight) and each individual egg was separated from the ovarian tissue and enumerated.

Largemouth bass, smallmouth bass, pumpkinseed, white sucker, fallfish, yellow perch, rock bass, black crappie and bluegill scale samples collected during fisheries sampling in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 were processed for age determination. Prior to preparation, sample information from the sample envelope was transferred to a project-specific log sheet. The unique sample and/or fish ID number was etched into the corner of a prepared 1”x3” acetate slide. Scales were removed from the envelope, placed in a well dish and gently cleaned with 2% KOH (potassium hydroxide) and a soft brush. Scales were examined under a low-power scope, and 5-6 non-regenerated, symmetrical scales were selected. Selected scales were arranged on the acetate slide in a single row with all scales oriented in the same direction and the sculpted (convex) side of the scale facing the acetate slide. A top press plate was gently laid over the acetate slide (directly on the scales), sandwiching the scales, and scale impressions were made using a Carver Press.

The scale impressions made on the acetate slide were examined with a microfiche reader at approximately 46x magnification to determine the location of each annulus. General criteria used to determine the presence of annuli were (1) changes in the relative spacing of circuli in the anterior field of the scale, (2) crossing of circuli across previously deposited circuli in the lateral field of the scale, and (3) variations in the thickness and shape of the circuli. Generally, an annulus exhibited all three of the above characteristics. All scale samples were examined by two independent scale readers, resulting in a 100% QC. For scale impressions that could not be aged with reasonable confidence by the first reader, the sample was re-cleaned, pressed and examined. For all occasions where there was disagreement between readers one and two, an independent third party examined each disputed sample and produced a third age estimate. If the third age estimate was in agreement with readers one or two, then that age was accepted for analysis. In the case where there was disagreement among all three independent readers, the sample was discarded.

4.1.3 Analytical Methods

Data Management

Handwritten data sheets from the field and laboratory were double-keypunched and audited through systematic and random audit of the data to ensure an average outgoing quality limit of errors of 1% (Normandeau 2009c). All data manipulations and statistics were performed in SAS statistical programming software version 9.2 (SAS Institute Inc., Cary, North Carolina).

Each field sample was assigned a code by the field crew leader at the time of collection, designating its use for subsequent data analysis. Samples collected without any sampling problems related to the gear or deployment were considered valid for all analytical tasks and assigned a Use Code = 1. Samples in which fish were caught but sampling problems or changes in the sampling design occurred were assigned a Use Code = 2. Sampling problems were generally related to variance from standardized sampling effort. Use Code = 5 samples were the same as Use Code = 2 samples where no fish were caught. Use Code 5 samples were excluded from all analysis. Use Code = 1 and 2 samples were used for analysis of biocharacteristics.

An Age Code was assigned to each scale sample collected based on physical attributes and condition of each sample, to designate its use in age-related data analysis. Age Code = 1 scale samples were those in which the individual scales were clean, symmetrical and selected from the upper body of the fish, anterior to the lateral line. These scale samples were available for use in all data analysis. Age Code = 2 samples were those in which the individual scales were asymmetric. These samples were used only for determining age of an individual and would not have been useful for back calculation of growth due to the asymmetry. Age Code = 5 samples were ones where age could not be determined, because all scales were regenerated, there was evidence of scales from more than one fish in the sample (indicating sample contamination had occurred in the field) or agreement between multiple readers could not be attained. Age Code 5 samples were excluded from all analysis.

Length, Weight, and Condition

The condition or relative "fatness" of fish collected in Garvins, Hooksett and Amoskeag Pools of the Merrimack River was described by the relation between total length (L) and total weight (W). The minimum, mean, maximum and standard deviation for length and weight measurements used in this analysis was presented for each species, pool and year. The curvilinear L-W relation expressed as W = aLb was parameterized by estimating the growth parameters a and b based on coefficients obtained from similar linear regression of log10(W) = log10(a) + log10(L), where log10(a) is the y-intercept and b is the slope (Ricker 1975). An analysis of covariance (ANCOVA) was used to compare L-W relations of fish among pools or years within Hooksett Pool without assuming isometric growth or a L-W relation for a "standard" population, as when using a condition index such as Fulton's condition factor or relative weight (Ricker 1975, Cone 1989, Anderson and Neumann 1996, Pope and Krause 2007). The ANCOVA statistically compares regression lines for the L-W relation among pools or years of a selected species, and tests for significant differences based on the slope (form), y-intercept (elevation) or both. The ANCOVA model with an interaction term (slope) tested for equality of slopes and was later reduced without an interaction term (i.e., equal or common slopes) to test for differences in elevation.

Length-weight curves were based on inter-annual or inter-pool comparisons of particular months and years where sufficient standardized electrofishing catch data were available (≥ 15 fish). For comparing length-weight relations among Garvins, Hooksett and Amoskeag Pools, ANCOVAs were individually performed on each annual catch of selected species (2008-2011 for white sucker and yellow perch, and 2010-2011 for the other species). In addition, historic fisheries data from 1995 and 2004-2005 (Normandeau 2007a) were used in an ANCOVA to detect changes in the length-weight relation of each species among annual catches from Hooksett Pool during August-September 1995, 2004, 2005, 2008, 2009, 2010 and 2011. The time series of length and weight observations was limited to the common months (August and September) sampled among years to control for seasonal variation in condition (e.g., gonad development). Weight measurements were considered biologically unreasonable and excluded from analysis if the observation was either a statistically significant outlier based on derived L-W curves, or if the weight was recorded as 1 g. Statistical outliers were determined significant if the absolute value of the studentized deleted residual was greater than the t-critical value (Bowman and O'Connell 1990). Because of the uncertainty associated with the lowest measurable weight, particularly when a weight of 1 g was used as default for fish well under 1 g, these fish were excluded. Another species-specific length-weight curve was derived pooling the remaining data not included in the previous L-W regressions comparing pools or years. All ANCOVAs were computed using PROC GLM in SAS software (SAS Institute Inc. 2008).

Age Structure

Age and growth of selected fish in Garvins, Hooksett and Amoskeag Pools were described by the mean total length at age. The mean total length and 95% confidence limits were determined for each selected species, year and river pool based on length measurements of individual fish for each assigned age. Mean total length at age was compared among Garvins, Hooksett and Amoskeag Pools for each species and year where number at age was at least 15 individuals. Statistical differences in mean length at age among pools were detected at $\alpha = 0.05$ using a general linear model (PROC GLM) to fit an analysis of variance (ANOVA) of unbalanced data and a Tukey's studentized range test to make multiple pair-wise comparisons (PROC GLM; SAS Institute Inc. 2008).

Catch-at-age distribution was estimated for each RIS and river pool for use in catch curve analysis. For determining the catch at age, all available age information where Age Code = 1 or 2 from the combined 2008-2010 catch (Use Code = 1 or 2) was used to calculate the proportion of fish at a given age among all successfully aged fish (Page) for a species within a river pool. The Page was used to scale the number of fish at a given age to the entire catch to account for fish not assigned an age as result of missing scale sample or undetermined age. Because fish below a cutoff total length (see Section 4.1.1) were not aged and were assumed to be age 0, Page could only be applied to the catch equal to or above the cutoff total length. The catch of age-0 fish (CYOY) was therefore a sum of the catch below the cutoff total length ($C_{\mathrm{YOY<L}}$) and the catch of age-0 fish equal to or above the cutoff total length, as defined by Equation 1.

$$C_{\mathrm{YOY}} = (C)(1- P_{\mathrm{YOY<L}})(P_{\mathrm{age}}) + C_{\mathrm{YOY<L}} \qquad \text{(Equation 1)}$$

where C = the combined 2008-2010 electrofishing catch of a species within each pool and $P_{\mathrm{YOY<L}}$ = the proportion of the number of measured fish that were below the cutoff total length and assumed were age 0. Catch at age for age-1 and older fish ($C_{\mathrm{age>0}}$) was estimated as

$$C_{\mathrm{age>0}} = (C)(1- P_{\mathrm{YOY<L}})(P_{\mathrm{age}}) + C_{\mathrm{YOY<L}}. \qquad \text{(Equation 2)}$$

Both $P_{\mathrm{YOY<L}}$ and P_{age} were assumed to representative of each fish population within each pool.

Gender, Reproductive Condition and Fecundity

The proportion by gender, reproductive condition and length-fecundity relations were evaluated for yellow perch and white sucker caught by electrofishing during 2008-2009 in each river pool. The proportion of males and females for yellow perch and white sucker was statistically compared to equal proportions (i.e., = 0.5 or 1:1 male-to-female ratio) using the Z-statistic for a binomial test of proportions (Zar 1999). The proportion of males and females for yellow perch and white sucker was also compared among pools and tested for equality using the Chi-square (χ^2) statistic for a 2x3 contingency table followed by a Tukey-type multiple comparison tests of proportions that uses a q-statistic if the P-value of the χ^2-statistic was less than 0.05 (Zar 1999). The percent or proportion of mature white sucker and yellow perch were also tested individually for each gender for equality among the pools using the same χ^2 test and Tukey-type multiple comparisons. Length or age at 50% maturation (L_{50} and A_{50}, respectively) was estimated from a logistic regression curve in the form of

$$P_{\mathrm{mat50}} = 1/(1+e^{-(\alpha+\beta x)}) \qquad \text{(Equation 3)}$$

where P_{mat50} = the proportion mature at age or length x, x =either length or age, and α, β = model parameters estimated using PROC NLIN (SAS Institute 2008). Gonadosomatic index (GSI, %) of gravid or milting (ripe) white sucker and yellow perch was estimated for each gender and pool as

GSI = gonad weight / (total wet weight – gonad weight)*100 (Equation 4).

Fecundity was assessed by enumerating the number of eggs in weight-based subsamples taken from the gonads of ripe or ripe and running yellow perch and white sucker caught during 2008 and 2009, and then using a subsample-weight extrapolation. The following formula was used to estimate the number of eggs in the entire ovary of each selected fish:

Fecundity = Number of eggs x Gonad weight (g) / Subsample weight (g) (Equation 5).

Regression analysis was used to characterize the relationship between female length and fecundity for ripe female yellow perch and white sucker; a regression equation for each river pool with an appropriate sample size was developed. The length-fecundity data from the 2008 and 2009 sampling years were pooled separately for yellow perch and white sucker in an effort to maximize the sample sizes included in the pool comparison analysis. ANCOVA was used to compare the differences in the length-fecundity relations among Garvins, Hooksett and Amoskeag Pools.

Parasites

A frequency distribution describing the occurrence of external parasites was calculated on a rank scale (none, low, moderate, heavy load) for each fish species captured during 2008, 2009, 2010 and 2011. A frequency distribution describing the occurrence of internal parasites was calculated on a rank scale (present, absent) for yellow perch and white sucker captured during 2008 and 2009. Frequency distributions for each species (years pooled) were compared among pools with a Chi-square test of multi-contingency tables.

Mortality

Total instantaneous mortality (Z) rates for RIS with sufficient catch-at-age data were estimated from catch curve regressions and compared among pools by ANCOVA. Catch curve analysis is a well- established statistical catch-at-age method for estimating Z in the absence of sufficient cross-year mark-recapture data (Quinn and Deriso 1999, Hilborn and Walters 1992, Ricker 1975). Catch-at-age data were estimated by applying the proportion at age to the combined electrofishing catch from 2008-2010 (Use code = 1 and 2 samples only). Because catch-at-age data from 2008-2010 were insufficient for catch curves of individual cohorts (year classes), catch curves were based on a “synthetic” cohort based on pooled catch-at-age data from 2008-2010. Catch-at-age data were pooled among years to increase sample sizes, particularly of the oldest ages, and to dampen the influence of erratic inter-annual recruitment, but the absence of a trend in recruitment among years was assumed (Miranda and Bettoli 2007). The maximum catch at age that begins a linear decline when catch is plotted on a natural logarithmic scale determined the age that fish were fully recruited to the sampling gear. After the age at full recruitment to the gear, vulnerability for older fish was assumed to be constant and catch was assumed to be proportional to abundance of the age class. The oldest age classes are sometimes excluded from the regression if they are not well-represented (Hilborn and Walters 1992, Miranda and Bettoli 2007). For these catch curves, ages were generally excluded from the regression if catch at age was only represented by one fish or if the oldest ages were consecutively represented by a constant catch. The relation between abundance and age can be further expressed assuming that there is continuous natural and fishing mortality based on Hilborn and Walters (1992) as

$$N_{a+1} = N_a e^{-Z} \quad \text{(Equation 6)}$$

where N_a = the number of fish at age a, and N_{a+1} = the number of fish at age a + 1 year. The total instantaneous mortality rate was estimated by the following calculation:

$$Z = -[\ln(N_{a+1}) - \ln(N_a)] \quad \text{(Equation 7)}$$

The number of fish alive at age a can also be expressed as

$$N_a = R(e^{-Z})^a = R\,e^{-Za} \quad \text{(Equation 8)}$$

where R = recruitment to the cohort. If catch is proportional to abundance by the equation:

$$C = Nv \quad \text{(Equation 9)}$$

where C = catch, v= vulnerability to the gear, and N is the number of fish exposed to the gear, then Equation 8 can be written as the following equation for the catch curve regression.

$$\ln(C_a) = \ln(Rv) + (-Z)a \quad \text{(Equation 10)}$$

$$\ln(C_a) = b - Za$$

where C_a = catch at age a, and b = y-intercept or ln(Rv). The annual mortality rate (A) was estimated as $A = 1 - e^{-Z}$.

The assumptions of a catch curve on a synthetic cohort from within a single year or pooled across several years from similar effort were: (1) recruitment was constant from year to year, (2) fishing and natural mortality was constant, and (3) vulnerability to electrofishing was constant above a certain age. Constant mortality and vulnerability to gear are considered reasonable assumptions (Hilborn and Walters 1992), but the assumption of constant inter-annual recruitment may not always be satisfied and may manifest as curvilinear trends in the deviation or generally large variation in catch curve regression line. Average Z estimates (slopes) from catch curve regression were compared among pools by ANCOVA following Miranda and Bettoli (2007). Because the precision of the catch curve estimate of Z increases with the number of ages included and decreases with increasing scatter of points along the regression line, a decreasing slope that is not statistically significant (i.e., different than zero at $\alpha = 0.05$) may continue to serve as the best available estimate and may be considered biologically significant (Miranda and Bettoli 2007). For ANCOVAs, comparing catch curves represented by a low number of age classes (e.g., three) may not have sufficient power to detect statistical significance even when a large difference in Z may indicate biological significance.

Table 4-1-1. Sampling effort (number of Use Code = 1 or Use Code = 2 samples) within Garvins, Hooksett and Amoskeag Pools, sorted by calendar week for 2008 and 2009.

Pool	Sampling Week		Use Code	
	Beginning	Ending	1	2
Garvins	14-Apr-08	18-Apr-08	10	
	21-Apr-08	25-Apr-08		
	28-Apr-08	2-May-08	5	5
	1-Sep-08	5-Sep-08	7	2
	13-Apr-09	17-Apr-09	3	2
	20-Apr-09	24-Apr-09	3	12
	27-Apr-09	1-May-09	1	4
	7-Sep-09	11-Sep-09	3	
	14-Sep-09	18-Sep-09	1	2
	21-Sep-09	25-Sep-09		7
Hooksett	14-Apr-08	18-Apr-08	23	
	21-Apr-08	25-Apr-08	38	5
	28-Apr-08	2-May-08	12	10
	1-Sep-08	5-Sep-08	11	3
	29-Sep-08	3-Oct-08		8
	6-Oct-08	10-Oct-08	11	1
	13-Apr-09	17-Apr-09	7	8
	20-Apr-09	24-Apr-09	4	11
	27-Apr-09	1-May-09	7	4
	7-Sep-09	11-Sep-09	2	4
	14-Sep-09	18-Sep-09	1	10
	21-Sep-09	25-Sep-09		16
Amoskeag	14-Apr-08	18-Apr-08	7	
	21-Apr-08	25-Apr-08	21	6
	28-Apr-08	2-May-08	2	9
	8-Sep-08	12-Sep-08	8	3
	13-Apr-09	17-Apr-09	4	4
	20-Apr-09	24-Apr-09	7	7
	27-Apr-09	1-May-09	3	11
	31-Aug-09	4-Sep-09	7	
	14-Sep-09	18-Sep-09	20	2
	21-Sep-09	25-Sep-09	4	2

Table 4-1-2. Biocharacteristics quotas for yellow perch collections during each week and within Garvins, Hooksett and Amoskeag Pools during 2008 and 2009.

LG	Length Group (mmtl)	Quota Number
1	<101	30
2	101-150	30
3	151-200	30
4	201-250	30
5	251-300	30
6	>300	30
Total		**180**

Table 4-1-3. Biocharacteristics quotas for white sucker collections during each week and within Garvins, Hooksett and Amoskeag Pools during 2008 and 2009.

LG	Length Group (mmtl)	Quota Number
1	<101	20
2	101-150	20
3	151-200	20
4	201-250	20
5	251-300	20
6	301-350	20
7	351-400	20
8	401-450	20
9	451-500	20
10	>500	20
Total		**200**

Table 4-1-4. Criteria for determining sex and state of maturity of yellow perch and white sucker collected within Garvins, Hooksett and Amoskeag Pools during 2008 and 2009.

State of Maturity	Females	Males
Gravid or milting (ripe)	Ovaries full of granular eggs that are partially translucent. Eggs can be released when ovary is compressed.	Testes white, less firm in texture, and if compressed will readily milt.
Ripe and running	Adult prepared to spawn immediately; expulsion of eggs with little provocation.	Adult prepared to spawn immediately; expulsion of milt with little provocation.
Partially spent	Ovaries somewhat flaccid and convoluted, with a variable number of eggs left. Ovarian membrane somewhat vascular.	Testes whitish, somewhat flaccid and convoluted, with free flow of milt.
Spent	Ovaries flaccid, few translucent eggs left. Ovarian membrane very vascular or sac-like.	Testes brownish white, flaccid, convoluted, with no flow of milt upon compression.
Immature	Ovaries very small and stringlike, thicker than testes, somewhat opaque and gelatinous in appearance.	Testes very small and stringlike, thinner than ovaries, somewhat translucent, and extremely tender.
Not gravid or not milting (Resting)	Underdeveloped ovaries in an adult female. Ovaries larger, more firm, opaque, and relatively thick. No eggs discernible to naked eye.	Underdeveloped testes in an adult male. Testes larger, more firm, opaque, but still tender.
Semi-gravid semi-milting (developing)	Subripe females heading into spawning season. Ovaries considerably larger, yellow, granular in consistency. Eggs discernible to naked eye, but not readily released when ovary is compressed.	Subripe males heading or into spawning season. Testes considerably larger, white, firm in texture, but milt not running.

4.2 General Catch Characteristics

Thirty fish species were captured by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008 through 2011. Table 4-2-1 presents the common name and percent composition of the total catch for each species during the four year period.

Table 4-2-1. Common name and percent composition of fish species captured by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008, 2009, 2010, and 2011.

Common Name	Garvins	Hooksett	Amoskeag	All Pools
Alewife		0.5	0.1	0.3
American eel	<0.1	0.6	1.1	0.5
American shad	0.1	0.9	1.1	0.6
Atlantic salmon	<0.1	<0.1		<0.1
Black crappie	1.0	0.7	0.4	0.8
Bluegill	3.9	10.7	6.7	8.0
Brook trout	<0.1	<0.1	1.4	0.1
Brown bullhead	0.3	<0.1	0.2	0.1
Brown trout	<0.1		0.1	<0.1
Carp and minnow family		<0.1		<0.1
Chain pickerel	4.6	0.9	1.7	2.3
Common carp		<0.1	0.7	0.1
Common shiner	0.6	1.2	0.1	0.9
Eastern blacknose dace		<0.1		<0.1
Eastern silvery minnow		<0.1		<0.1
Emerald shiner		<0.1		<0.1
Fallfish	2.0	8.7	1.7	5.8
Golden shiner	0.3	0.4	2.7	0.5
Largemouth bass	14.0	19.6	3.3	16.2
Margined madtom	<0.1	0.1		0.1
Pumpkinseed	6.1	1.7	5.7	3.6
Rainbow trout			0.1	<0.1
Redbreast sunfish	0.9	4.7	9.7	3.7
Rock bass	0.4	0.4	1.8	0.5
Smallmouth bass	2.6	11.1	45.0	10.8
Spottail shiner	38.0	17.9	0.2	23.6
Sunfish family	0.2	1.2	0.2	0.8
Tessellated darter	1.0	0.6	0.1	0.7
White perch			0.2	<0.1
White sucker	4.1	10.9	10.7	8.5
Yellow bullhead	0.1	<0.1	0.1	<0.1
Yellow perch	19.6	7.2	4.9	11.4

4.3 Black Crappie

Biocharacteristics of the black crappie population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.3.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of black crappie collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-3-1 through 4-3-4. The total length of black crappie ranged from 50 to 305 mm in Garvins Pool and from 57 to 301 mm in Hooksett Pool during the years 2008-2011, and from 70 to 242 mm in Amoskeag Pool during the years 2009-2011. Total weight of black crappie ranged from 2 to 450 g in Garvins Pool, from 2 to 455 g in Hooksett Pool, and from 3 to 260 g in Amoskeag Pool.

4.3.2 Condition

Sample sizes were insufficient for comparing condition of black crappie among pools or years. The length-weight relation for black crappie in Hooksett Pool during 2010 is presented graphically in Figure 4-3-1.

4.3.3 Age-Length

The mean total length at age (±95% C.I.) of black crappie collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 is presented in Tables 4-3-5 through 4-3-7. For years with available age data (2008-2010), age of black crappie ranged from age-0 to age-8 in Garvins Pool, from age-0 to age-6 in Hooksett Pool, and from age-0 to age-4 in Amoskeag Pool. Insufficient sample size ($n<15$) prevented the comparison of mean length at age among pools for all cohorts of black crappie collected during 2008-2010.

4.3.4 Mortality

The total instantaneous mortality (Z) for ages 1-6 black crappie in Hooksett Pool was 0.49, but the regression of the catch curve was not statistically significant (Figure 4-3-2; $F = 8.60$, $P = 0.061$). The annual mortality rate of black crappie in Hooksett Pool based on this estimate was 39%. Annual mortality estimates for age-2 to age-4 black crappie in Indiana and Wisconsin lakes ranged from 64 to 91% (Carlander 1977).

4.3.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for black crappie collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 (pooled) is presented in Table 4-3-8. The prevalence of external parasites was significantly greater in Hooksett Pool than in Garvins Pool, and in Amoskeag Pool than in either Garvins or Hooksett Pools.

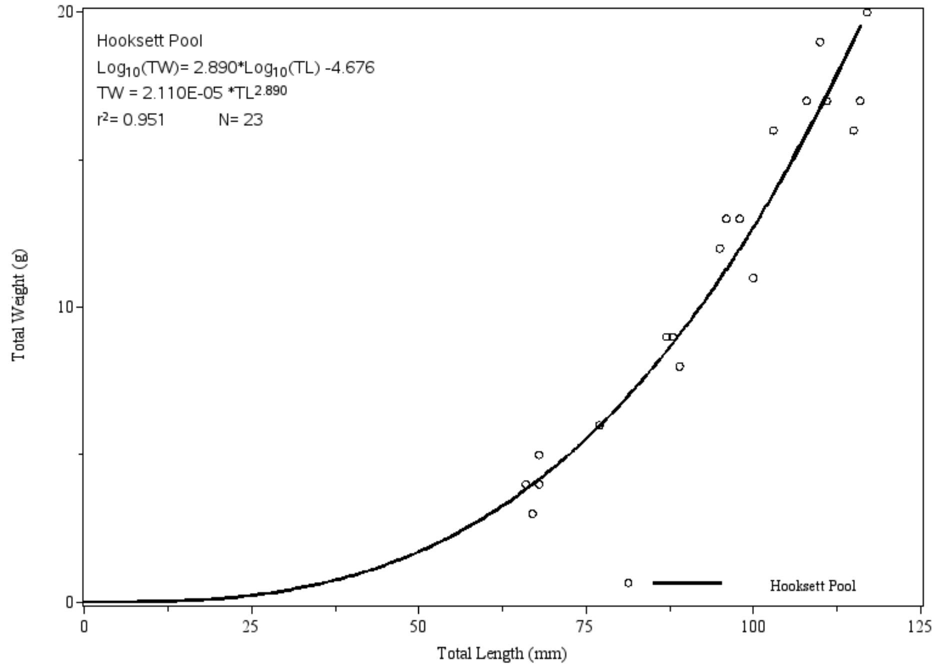


Figure 4-3-1. Empirical length-weight relation for black crappie captured via electrofishing within Hooksett Pool during 2010.

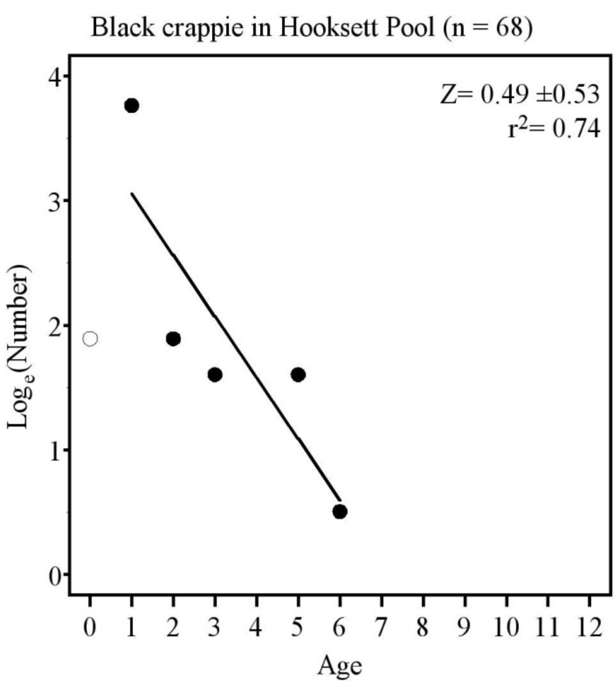


Figure 4-3-2. Catch curve estimate of total instantaneous mortality rate (Z ± 95% confidence interval) of back crappie from ages 1 to 6 (solid circles) based on the combined electrofishing catch in Hooksett Pool, Merrimack River during 2008-2010. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

Table 4-3-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for black crappie collected in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	2	76	160	118	59	2	6	70	38	45
Hooksett	4	181	301	242	52	4	82	455	242	155
Total	6	76	301	201	80	6	6	455	174	161

Table 4-3-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for black crappie collected in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	39	148	305	247	45	39	50	450	237	119
Hooksett	14	114	300	171	61	14	10	400	93	117
Amoskeag	1	220	220	220	.	1	165	165	165	.
Total	54	114	305	227	59	54	10	450	199	132

Table 4-3-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length mean total length (mm) and total weight (g) for black crappie collected in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	5	56	87	64	13	5	2	8	4	3
Hooksett	26	57	117	91	17	24	2	20	11	5
Amoskeag	2	70	242	156	122	2	3	260	132	182
Total	33	56	242	91	33	31	2	260	18	45

Table 4-3-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for black crappie collected in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

	Total Length (mm)					Weight (g)				
Pool	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	6	50	266	124	107	6	2	285	91	137
Hooksett	13	57	288	146	73	13	2	310	77	95
Amoskeag	2	106	149	128	30	2	24	50	37	18
Total	21	50	288	138	79	21	2	310	77	102

Table 4-3-5. Mean length at age (± 95% C.I.) for black crappie captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2008	Garvins		1	76	
2	2006	Hooksett		1	220	
4	2004	Garvins		1	160	
5	2003	Hooksett		1	180	
6	2002	Hooksett		1	300	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. Pairwise comparisons based on a minimum sample size of 15 individuals

Table 4-3-6. Mean length at age (± 95% C.I.) for black crappie captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
1	2008	Hooksett		4	124	18
2	2007	Garvins		2	152	28
		Hooksett		3	148	31
3	2006	Garvins		2	164	25
		Hooksett		3	208	55
4	2005	Garvins		8	208	23
5	2004	Garvins		7	260	9
		Hooksett		2	288	85
6	2003	Garvins		13	276	11
7	2002	Garvins		2	268	117
8	2001	Garvins		1	280	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-3-7. Mean length at age (± 95% C.I.) for black crappie captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins		4	60	2
		Hooksett		4	68	12
		Amoskeag		1	72	
1	2009	Garvins		1	88	
		Hooksett		22	96	5
4	2006	Amoskeag		1	244	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-3-8. Frequency distribution of external parasite loads for black crappie collected from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	49	94.2	3	5.8	0	0.0
Hooksett [B]	45	80.4	9	16.1	2	3.6
Amoskeag [C]	2	40.0	3	60.0	0	0.0

Notes: Different letters indicate significant within year differences between pools. No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.4 Bluegill

Biocharacteristics of the bluegill population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.4.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of bluegill collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-4-1 through 4-4-4. Over the four years of sampling, the total length of bluegill ranged from 31 to 260 mm in Garvins Pool, from 20 to 271 mm in Hooksett Pool, and from 44 to 239 mm in Amoskeag Pool. Total weight of bluegill ranged from 2 to 360 g in Garvins Pool, from 2 to 500 g in Hooksett Pool, and from 7 to 320 g in Amoskeag Pool.

4.4.2 Condition

The length-weight curves based on the 2010 and 2011 catches each showed that bluegill in Hooksett Pool grew significantly more rotund (or "fatter") with increasing length than in Garvins Pool (Figures 4-4-1 and 4-4-2, Tables 4-4-5 and 4-4-6). As reflected in the slopes of the length-weight curves based on the 2010 catch, bluegill grew significantly more rotund as length increased in Amoskeag Pool as compared to Garvins Pool, but did not differ significantly as compared to Hooksett Pool (Figure 4-4-1 and Table 4-4-5). During 2011 (Figure 4-4-2 and Table 4-4-6), bluegill in Garvins and Hooksett Pools grew significantly more rotund than those in Amoskeag Pool. During 2010, the *y*-intercept parameter in the length-weight relation was significantly higher for bluegill in Garvins Pool than in Hooksett and Amoskeag Pools, which indicates that bluegill in Garvins Pool weighed more at a given length early in life than in the other two pools, but gained weight at a faster rate in Hooksett and Amoskeag Pools. During 2011, the *y*-intercept parameter in the length-weight relation was significantly higher for bluegill in Amoskeag Pool than in Garvins and Hooksett Pools, which indicates that bluegill in Amoskeag Pool weighed more at a given length early in life than in the other two pools, but gained weight at a faster rate in Garvins and Hooksett Pools.

The length-weight relation of bluegill based on annual catches in Hooksett Pool varied among years (Figure 4-4-3, Table 4-4-7). The incremental weight gain of bluegill with increasing length based on the length-weight curve (slope) of the 2011 catch was significantly greater than that estimated from the 1995 catch. The slope estimates indicate that bluegill grew more slender with increasing length (slope <3) during 1995 and more rotund with increasing length (slope > 3) during 2011 (Figure 4-4-3, Table 4-4-7). The *y*-intercept parameter from the 1995 length-weight relation was significantly higher than the 2011 estimate, which supports that the 1995 young-of-year bluegill in Hooksett Pool were in better condition compared to those collected during the most recent sampling year.

4.4.3 Age-Length

The mean total length at age (±95% C.I.) of bluegill collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 are presented in Tables 4-4-8 through 4-4-10. For years with available age data (2008-2010), age of bluegill ranged from age-0 to age-9 in Garvins Pool, from age-0 to age-7 in Hooksett Pool, and from age-0 to age-5 in Amoskeag Pool. During 2010, the mean length at age of age-0 bluegill collected in Hooksett and Garvins Pools and the mean length of age-1 bluegill collected in Hooksett and Amoskeag Pools did not differ significantly, as indicated by a Tukey Pairwise comparison test. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools for all cohorts of bluegill collected in 2008 and 2009.

4.4.4 Mortality

The total instantaneous mortality rates (Z) for bluegill significantly differed among Merrimack River pools (Figure 4-4-4, ANCOVA, $F = 4.61$, $P = 0.035$). The total instantaneous mortality rate of bluegill for ages 1-3 in Amoskeag Pool (Z = 1.42) was significantly higher than the estimate for ages 0-6 from Garvins Pool (Z = 0.15; $F = 7.51$, $P = 0.019$), but was not significantly different than the estimate for ages 1-7 from Hooksett Pool (Z = 0.46; $F = 4.36$, $P = 0.061$). The Z estimate was not significantly different between Garvins and Hooksett Pools ($F = 3.19$, $P = 0.101$). The annual mortality rates of bluegill based on these estimates were 14% for Garvins Pool, 37% for Hooksett Pool, and 76% for Amoskeag Pool. Annual mortality estimates for bluegill over age-3 to age-4 in Midwestern lakes ranged from 57 to 99% (Carlander 1977).

4.4.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for bluegill collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 is presented in Table 4-4-11. The prevalence of external parasites was significantly greater in Garvins Pool than in either Hooksett or Amoskeag Pool.

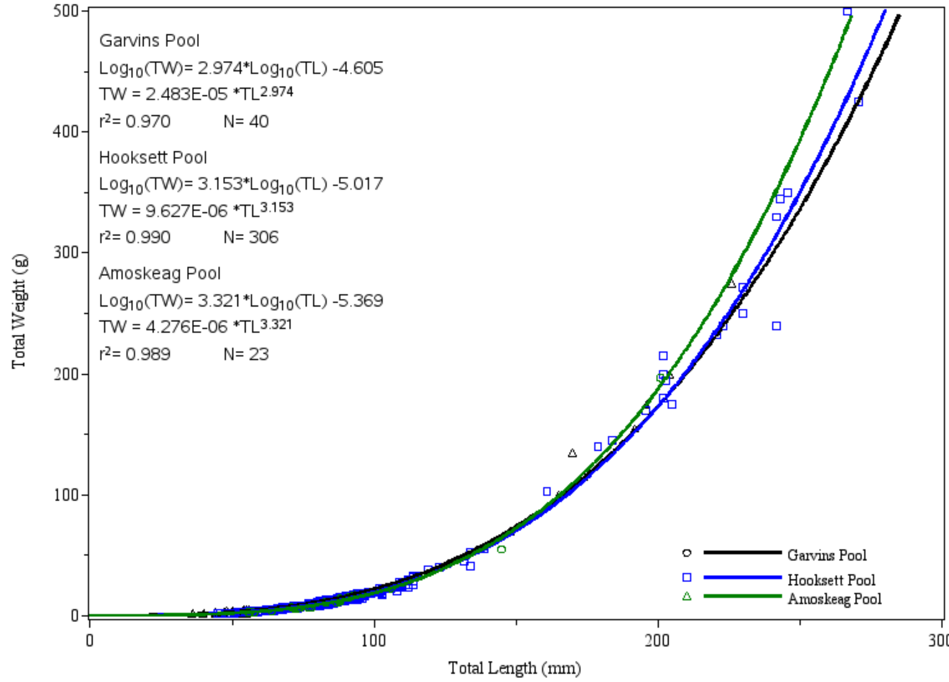


Figure 4-4-1. Empirical length -weight relations for bluegill captured via electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2010.

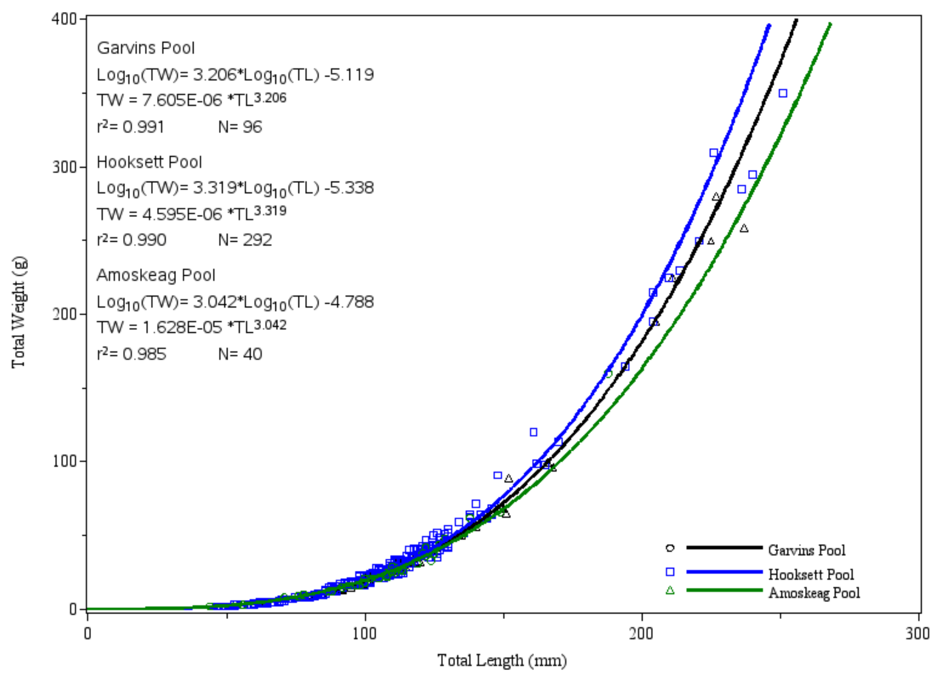


Figure 4-4-2. Empirical length -weight relations for bluegill captured via electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2011.

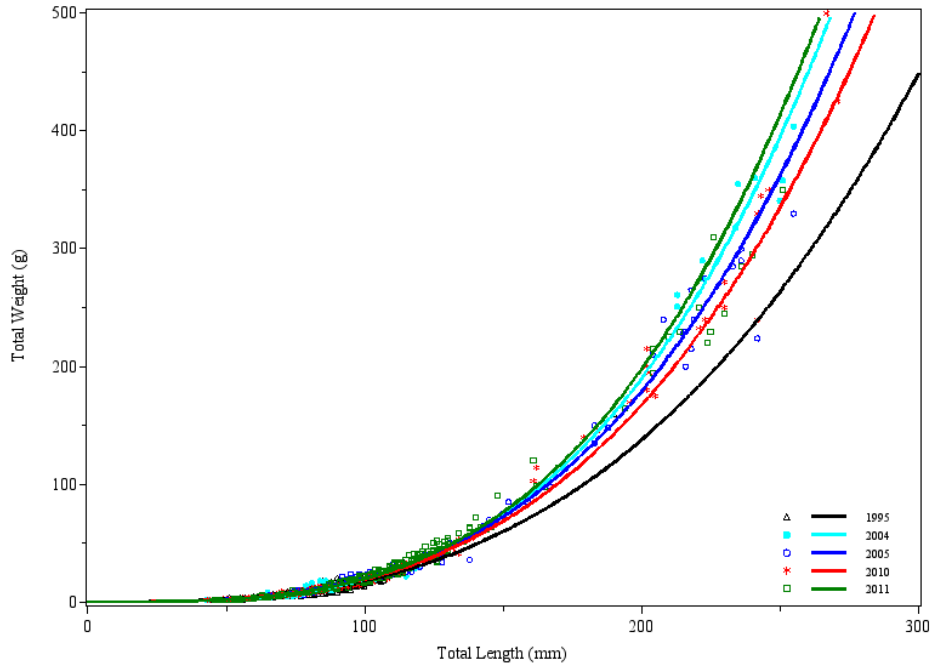


Figure 4-4-3. Empirical length -weight relations for bluegill captured via electrofishing during the months of August and September of 1995, 2004, 2005, 2010, and 2011 within Hooksett Pool.

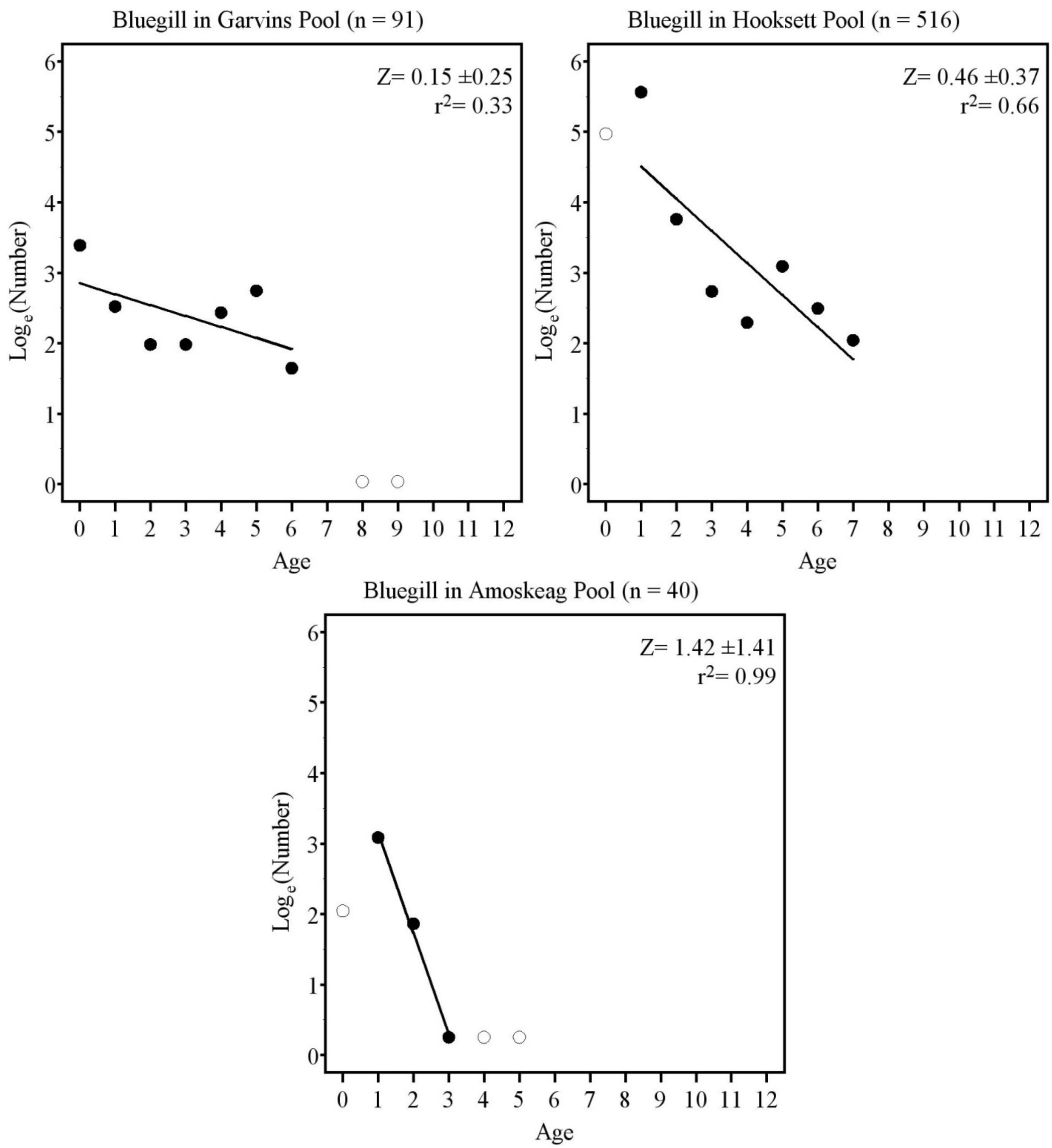


Figure 4-4-4. Catch curves comparing instantaneous total mortality rate (Z ± 95% confidence intervals) of bluegill for fully recruited ages (solid circles) in Garvins, Hooksett and Amoskeag Pools based on combined 2008-2010 electrofishing catch in the Merrimack River. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

Table 4-4-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) in grams for bluegill collected in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

	Total Length (mm)					Weight (g)				
Pool	**N**	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	7	100	234	162	47	7	10	280	117	94
Hooksett	48	39	262	130	73	47	3	490	107	147
Amoskeag	3	83	239	176	82	3	7	320	169	157
Total	58	39	262	136	71	57	3	490	111	141

Table 4-4-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) in grams for bluegill collected in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

	Total Length (mm)					Weight (g)				
Pool	**N**	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	49	42	260	168	45	47	15	360	132	84
Hooksett	67	55	247	160	61	67	2	360	121	118
Amoskeag	9	94	227	121	41	9	14	210	44	63
Total	125	42	260	160	55	123	2	360	120	104

Table 4-4-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) in grams for bluegill collected in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

	Total Length (mm)					Weight (g)				
Pool	**N**	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	45	31	226	76	53	40	2	275	34	66
Hooksett	395	26	271	81	39	336	2	500	25	61
Amoskeag	24	56	201	88	30	23	3	197	20	40
Total	464	26	271	80	41	399	2	500	26	61

Table 4-4-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) in grams for bluegill collected in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

	Total Length (mm)					Weight (g)				
Pool	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	103	34	237	112	33	96	3	280	39	51
Hooksett	369	20	251	94	39	306	2	350	34	50
Amoskeag	44	44	188	105	29	40	2	160	31	27
Total	516	20	251	98	38	442	2	350	35	48

Table 4-4-5. Regression statistics for total length (mm) vs. weight (g) for bluegill from Garvins, Hooksett, and Amoskeag Pools during 2010.

					ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
Pool	N	Slope (b)	Intercept ($\log_{10}a$)	R^2	Garvins	Hooksett	Garvins	Hooksett
Garvins	40	2.973	-4.605	0.97				
Hooksett	329	3.107	-4.926	0.98	*		*	
Amoskeag	23	3.321	-5.369	0.99	*	NS	*	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-4-6. Regression statistics for total length (mm) vs. weight (g) for bluegill from Garvins, Hooksett, and Amoskeag Pools during 2011.

					ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
Pool	N	Slope (b)	Intercept ($\log_{10}a$)	R^2	Garvins	Hooksett	Garvins	Hooksett
Garvins	96	3.206	-5.119	>0.99				
Hooksett	306	3.310	-5.321	0.99	*		NS	
Amoskeag	40	3.042	-4.788	0.99	*	*	*	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-4-7. Regression statistics for total length (mm) vs. total weight (g) for bluegill sampled during the months of August and September in 1995, 2004, 2005, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]							
					Slope				Intercept			
					1995	2004	2005	2010	1995	2004	2005	2010
1995	306	2.912	-4.562	0.95								
2004	42	3.282	-5.274	0.98	*				*			
2005	95	3.152	-5.000	0.98	*	*			*	*		
2010	392	3.107	-4.926	0.98	*	*	NS		*	*	NS	
2011	306	3.310	-5.321	0.99	*	NS	*	*	*	NS	*	*

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$

Table 4-4-8. Mean length at age (± 95% C.I.) for bluegill captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2008	Hooksett		2	80	6
		Amoskeag		1	84	
1	2007	Garvins		2	108	54
		Hooksett		21	80	4
2	2006	Garvins		1	148	
		Hooksett		4	144	61
3	2005	Garvins		1	152	
		Hooksett		2	160	189
4	2004	Garvins		1	188	
		Hooksett		1	244	
		Amoskeag		1	204	
5	2003	Hooksett		3	232	11
6	2002	Hooksett		2	236	63
7	2001	Hooksett		1	260	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-4-9. Mean length at age (± 95% C.I.) for bluegill captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2009	Hooksett		3	64	11
1	2008	Garvins		3	100	3
		Hooksett		7	92	5
		Amoskeag		1	100	
2	2007	Garvins		6	120	13
		Hooksett		17	116	7
		Amoskeag		3	108	16
3	2006	Garvins		5	160	19
		Hooksett		6	152	6
4	2005	Garvins		8	168	13
		Hooksett		4	164	19
5	2004	Garvins		13	196	7
		Hooksett		12	228	6
		Amoskeag		1	228	
6	2003	Garvins		4	220	13
		Hooksett		5	240	5
7	2002	Hooksett		3	224	37
9	2000	Garvins		1	260	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-4-10. Mean length at age (± 95% C.I.) for bluegill captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins	A	30	48	3
		Hooksett	A	130	52	2
		Amoskeag		5	76	10
1	2009	Garvins		7	72	14
		Hooksett	A	209	84	2
		Amoskeag	A	16	80	6
2	2008	Hooksett		18	108	6
		Amoskeag		2	124	123
3	2007	Garvins		1	164	
		Hooksett		6	156	30
		Amoskeag		1	200	
4	2006	Garvins		2	160	69
		Hooksett		4	200	5
5	2005	Garvins		2	184	69
		Hooksett		5	228	17
6	2004	Garvins		1	192	
		Hooksett		4	228	13
7	2003	Hooksett		3	260	26
8	2002	Garvins		1	204	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-4-11. Frequency distribution of external parasite loads for bluegill collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	152	74.5	44	21.6	8	3.9
Hooksett [B]	790	91.8	64	7.4	7	0.8
Amoskeag [AB]	69	86.3	10	12.5	1	1.3

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.5 Chain Pickerel

Biocharacteristics of the chain pickerel population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.5.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of chain pickerel collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-5-1 through 4-5-4. Over the four years of sampling (2008-2011), the total length of chain pickerel ranged from 81 to 510 mm in Garvins Pool, from 86 to 630 mm in Hooksett Pool, and from 117 to 443 mm in Amoskeag Pool. Total weight of chain pickerel ranged from 3 to 830 g in Garvins Pool, from 3 to 1,680 g in Hooksett Pool, and from 8 to 667 g in Amoskeag Pool.

4.5.2 Condition

Sample sizes of chain pickerel were insufficient for comparison of condition among pools during 2010. However, a length-weight relation for chain pickerel sampled during 2010 in Hooksett Pool is presented in Figure 4-5-1. The slopes of the length-weight curves based on the 2011 catch indicated chain pickerel from Garvins and Hooksett Pools maintained similar incremental weight gains with increasing length ($F = 0.79$, $P = 0.377$, Figure 4-5-2, Table 4-5-5). When a common slope was assumed for the length-weight relations of chain pickerel in Garvins and Hooksett Pools, a significant difference in the *y*-intercept parameter indicated chain pickerel from Hooksett Pool were significantly heavier at a given length (i.e., in better condition) than those from Garvins Pool (Table 4-5-5). This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool relative to the thermally uninfluenced Garvins Pool.

4.5.3 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for chain pickerel collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 is presented in Table 4-5-6. The prevalence of external parasites was significantly greater in Garvins Pool than was observed in either Hooksett or Amoskeag Pools.

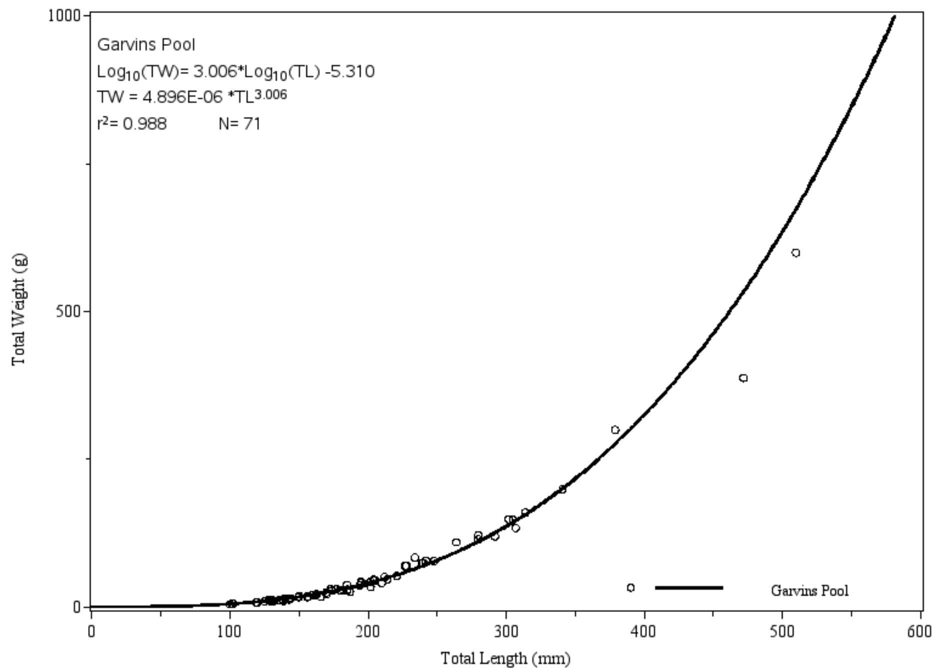


Figure 4-5-1. Empirical length-weight relation for chain pickerel captured via electrofishing within Garvins Pool during 2010.

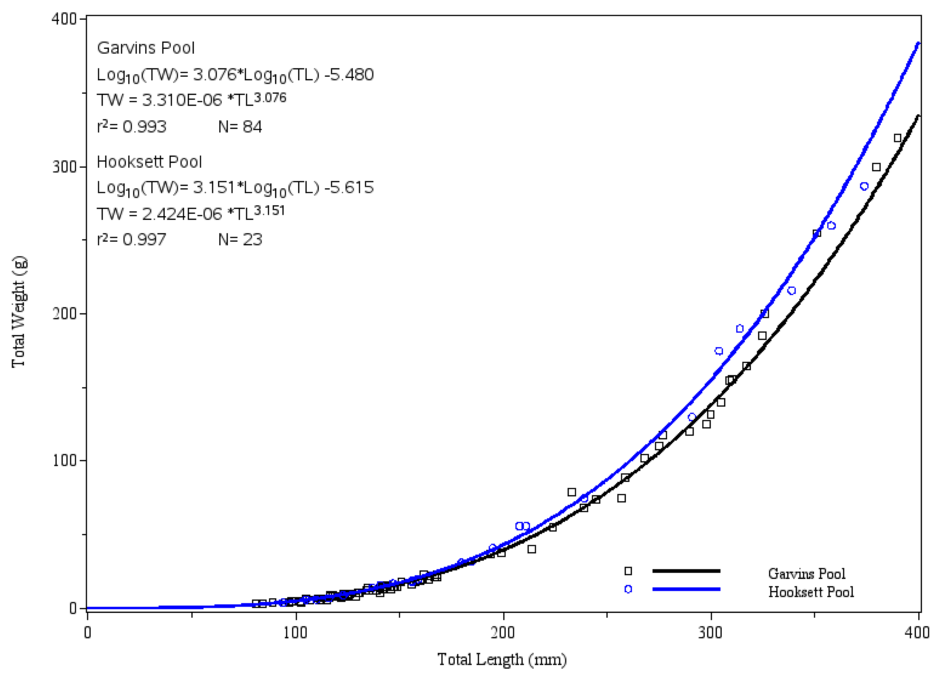


Figure 4-5-2. Empirical length-weight relations for chain pickerel captured via electrofishing within Garvins and Hooksett Pools during in 2011.

Table 4-5-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for chain pickerel collected in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	20	84	441	216	108	20	3	450	101	137
Hooksett	18	132	630	235	137	18	10	1680	186	411
Amoskeag	3	117	371	239	127	3	8	311	136	157
Total	41	84	630	226	120	41	3	1680	141	290

Table 4-5-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total l length (mm) and total weight (g) for chain pickerel collected in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	57	116	488	287	102	57	7	830	193	192
Hooksett	16	101	388	213	91	16	3	355	79	97
Amoskeag	9	151	278	232	46	9	16	105	68	36
Total	82	101	488	266	100	82	3	830	157	174

Table 4-5-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for chain pickerel collected in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	75	95	510	204	79	71	5	600	62	92
Hooksett	12	111	540	287	136	12	9	1000	244	351
Amoskeag	5	235	372	294	49	5	90	310	158	87
Total	92	95	540	220	92	88	5	1000	92	164

Table 4-5-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for chain pickerel collected in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	88	81	390	171	77	84	3	320	45	68
Hooksett	26	86	374	193	86	25	4	287	69	86
Amoskeag	4	228	443	341	90	4	60	667	300	264
Total	118	81	443	181	85	118	3	667	60	96

Table 4-5-5. Regression statistics for total length (mm) vs. weight (g) for chain pickerel from Garvins and Hooksett Pools during 2011.

Pool	N	Slope (b)[2]	Intercept ($\log_{10}$a)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	84	3.087	-5.506	>0.99				
Hooksett	25	3.087	-5.466	>0.99	NS		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$
[2] Assumed common slope due to non-significant finding

Table 4-5-6. Frequency distribution of external parasite loads for chain pickerel collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	125	52.1	72	30.0	43	17.9
Hooksett [B]	53	77.9	8	11.8	7	10.3
Amoskeag [C]	14	70.0	6	30.0	0	0.0

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.6 Common Shiner

Biocharacteristics of the common shiner population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.6.1 Length and Weight

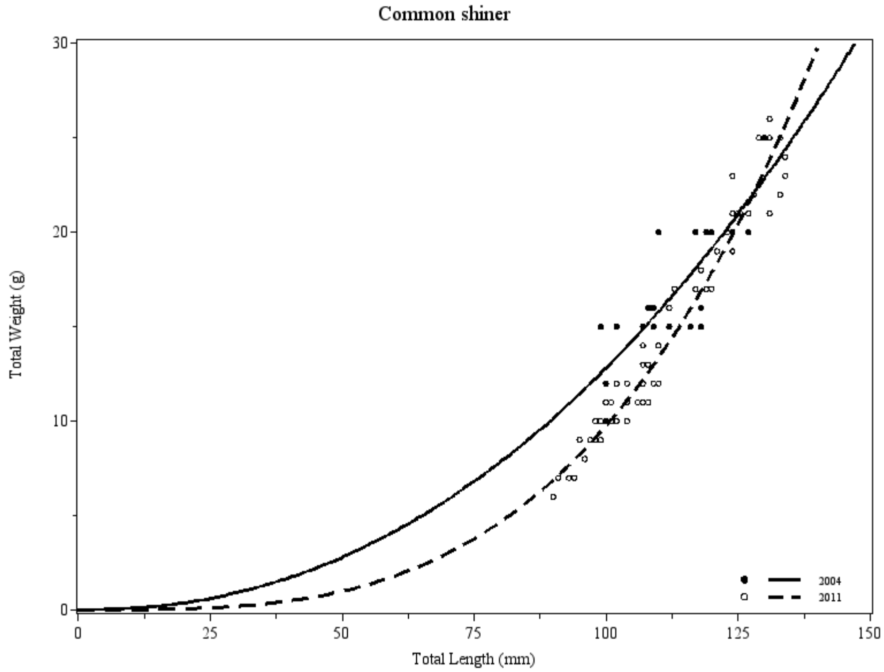
The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of common shiner collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2010 and 2011 are presented in Tables 4-6-1 through 4-6-3. Among the three years in which common shiner were identified in Merrimack River catch (2008, 2010 and 2011), total length ranged from 33 to 99 mm in Garvins Pool and from 62 to 134 mm in Hooksett Pool. Total weight of common shiner ranged from 3 to 20 g in Garvins Pool and from 2 to 26 g in Hooksett Pool. A single common shiner (TL = 66 g and W = 2 g) was collected from Amoskeag Pool during 2008.

4.6.2 Condition

Sample sizes of common shiner were insufficient for comparison of condition among pools during 2010 and 2011. The slope of the length-weight relation of common shiner from Hooksett Pool was significantly different between the 2004 and 2011 catch (Figure 4-6-1, Table 4-6-4). The length-weight relation of common shiner caught in Hooksett Pool during 2004 indicated common shiner grew more slender with increasing length (slope < 3), while the 2011 length-weight relation indicated common shiner grew more rotund with increasing length (slope > 3). The *y*-intercept parameter in the length-weight relation of common shiner was significantly higher based on the 2004 catch than on the 2011 catch, which indicates common shiner in 2004 weighed more at a given length early in life (e.g., young of the year) than in 2011. However, caution should be exercised interpreting the biological significance of the 2004 length-weight relation based on a sample size of 23 common shiner of a limited size range and higher variation ($r^2 = 0.70$) compared to 2011 ($r^2 = 0.96$).

4.6.3 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for common shiner collected by electrofishing in Garvins and Hooksett Pools during 2008-2011 is presented in Table 4-6-5. The prevalence of external parasites was significantly greater in Hooksett Pool than was observed in Garvins Pool.



3.5

Figure 4-6-1. Empirical length-weight relations for common shiners captured via electrofishing during the months of August and September of 2004 and 2010 within Hooksett Pool.

Table 4-6-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for common shiners collected in Garvins and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	1	63	63	63	.	1	3	3	3	.
Amoskeag	1	66	66	66	.	1	2	2	2	.
Total	2	63	66	65	2	2	2	3	3	1

Table 4-6-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for common shiners collected in Garvins and Hooksett Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	4	58	99	72	18	4	3	20	8	8
Hooksett	36	62	99	77	10	36	2	10	5	2
Total	40	58	99	77	11	40	2	20	5	3

Table 4-6-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for common shiners collected in Garvins and Hooksett Pools during August and September 2011.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	28	33	99	60	10	14	2	10	3	2
Hooksett	63	74	134	111	13	63	3	26	14	6
Total	91	33	134	95	27	77	2	26	12	7

Table 4-6-4. Regression statistics for total length (mm) vs. total weight (g) for common shiner sampled during the months of August and September in 1995, 2004, 2005, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					2004	2011	2004	2011
2004	23	2.205	-3.303	0.70				
2011	60	3.316	-5.643	0.96	*		*	

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$

Table 4-6-5 Frequency distribution of external parasite loads for common shiner collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2010-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	32	97.0	1	3.0	0	0.0
Hooksett [B]	57	57.6	40	40.4	2	2.0
Amoskeag	1	100.0	0	0.0	0	0.0

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.7 Fallfish

Biocharacteristics of the fallfish population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.7.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of fallfish collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 are presented in Tables 4-7-1 through 4-7-4. Over the four years of sampling (2008-2011), the total length of fallfish ranged from 35 to 415 mm in Garvins Pool, from 50 to 355 mm in Hooksett Pool, and from 64 to 225 mm in Amoskeag Pool. Total weight of fallfish ranged from 1 to 725 g in Garvins Pool, from 1 to 495 g in Hooksett Pool, and from 1 to 115 g in Amoskeag Pool.

4.7.2 Condition

Sample sizes of fallfish were insufficient for comparison of condition among pools during 2010. The length-weight curve based on the 2011 catch showed fallfish in Hooksett Pool grew significantly more rotund (or "fatter") with increasing length than in Garvins Pool (Figure 4-7-1, Table 4-7-5). The *y*-intercept parameter in the length-weight relation was significantly higher for fallfish in Garvins Pool than in Hooksett Pool, which indicates fallfish in Garvins Pool weighed more at a given length in early life than in Hooksett Pool.

The slopes of the Hooksett Pool length-weight curves derived from annual catches of fallfish were not significantly different (F = 2.10, P = 0.010, Figure 4-7-2, Table 4-7-6). When a common slope was assumed for the length-weight relations of fallfish among these annual catches in Hooksett Pool, the *y*-intercept parameter differed among some annual catches but there was insufficient evidence of a temporal trend in the weight at a given length of fallfish in Hooksett Pool (Table 4-7-6).

4.7.3 Age-Length

The mean total length at age (±95% C.I.) of fallfish collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 are presented in Tables 4-7-7 through 4-7-9. For years with available age data (2008-2010), age of fallfish ranged from age-0 to age-8 in Garvins Pool, from age-0 to age-6 in Hooksett Pool, and from age-1 to age-3 in Amoskeag Pool. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools within individual cohorts of fallfish collected in 2008, 2009 and 2010.

4.7.4 Mortality

The total instantaneous mortality rate (Z) of fallfish for ages 2-4 in Hooksett Pool (Z = 1.02) was significantly higher than the estimate for ages 0-6 from Garvins Pool (Z = 0.10; Figure 4-7-3, ANCOVA, F = 8.35, P = 0.034). The annual mortality rates of fallfish based on these estimates were 10% for Garvins Pool and 64% for Hooksett Pool.

4.7.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for fallfish collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 is presented in Table 4-7-10. The prevalence of external parasites was significantly greater in Hooksett Pool than was observed in Garvins Pool but did not differ from that observed in Amoskeag Pool.

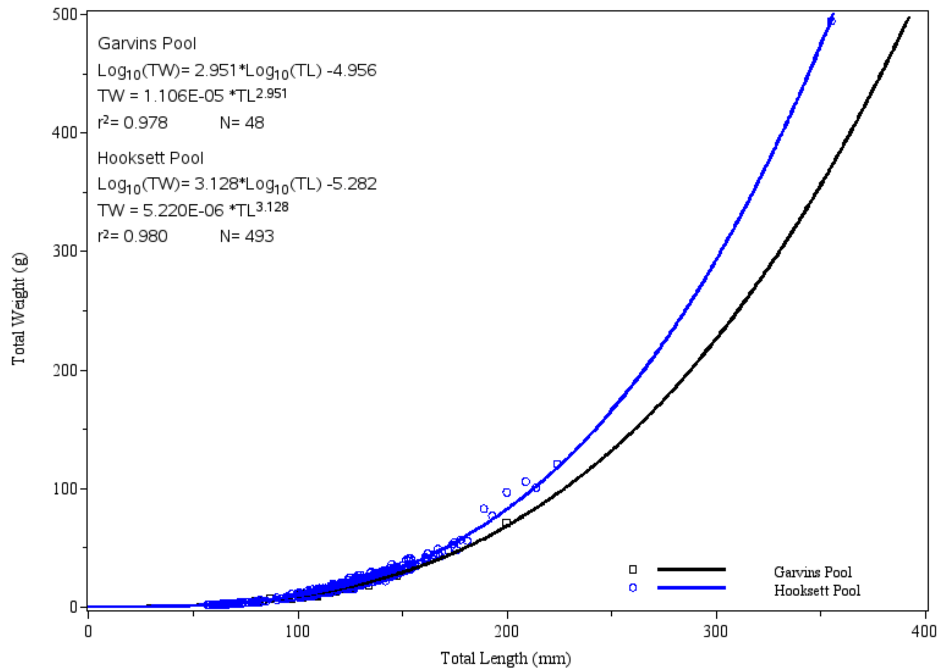


Figure 4-7-1. Empirical length-weight relations for fallfish captured via electrofishing within Garvins and Hooksett Pools during 2011.

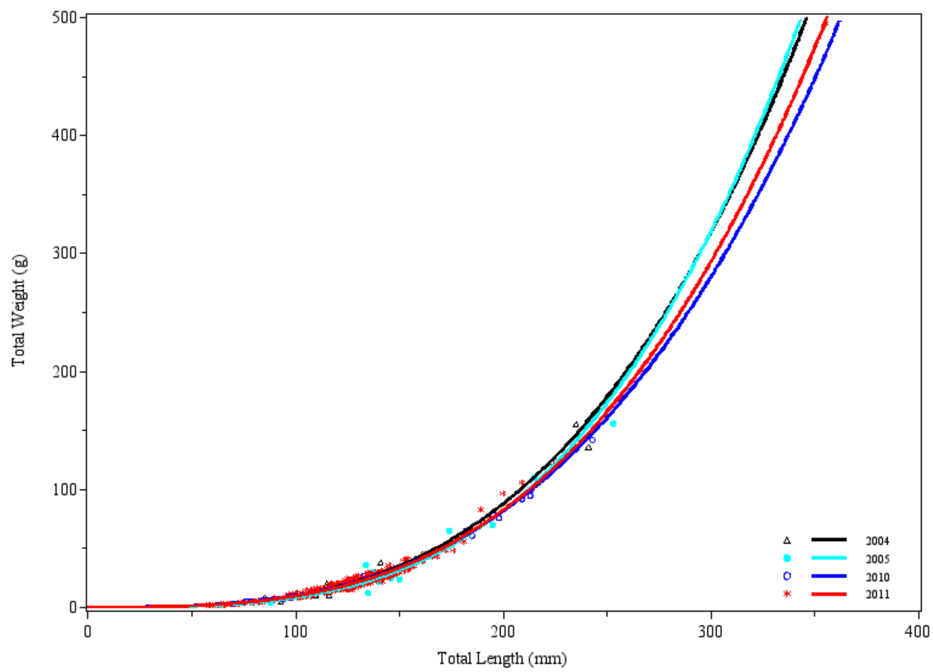


Figure 4-7-2. Empirical length-weight relations for fallfish captured via electrofishing during the months of August and September 2004, 2005, 2010, and 2011 within Hooksett Pool.

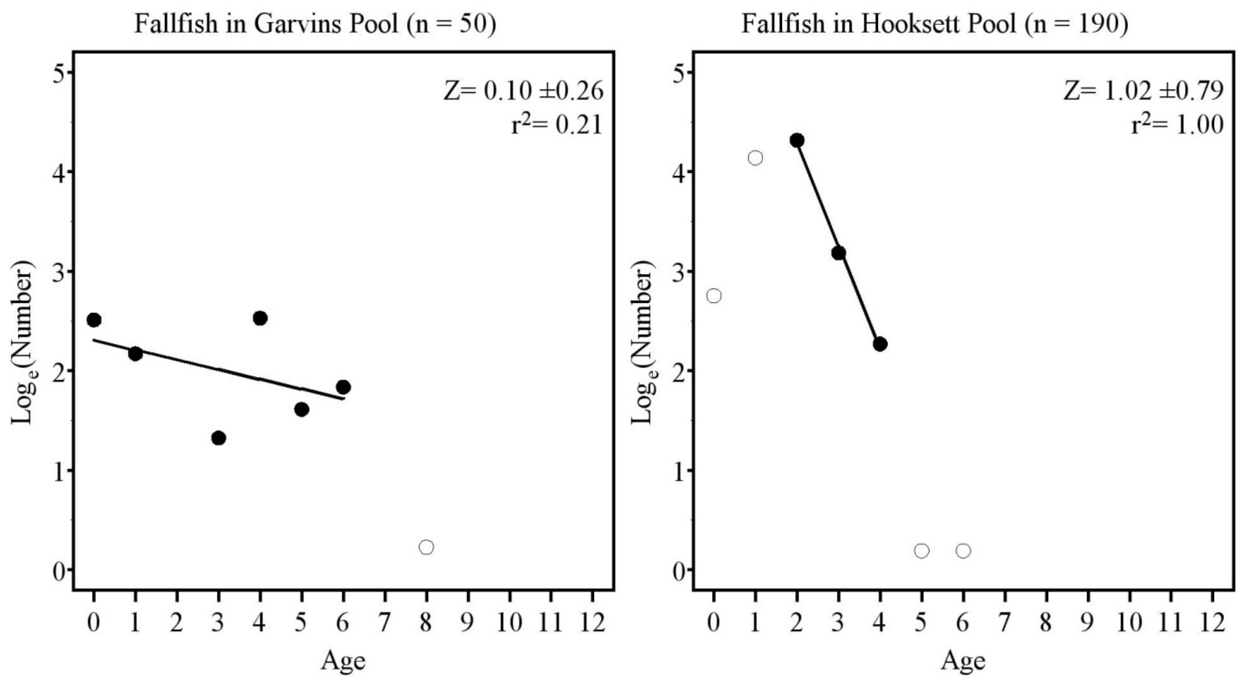


Figure 4-7-3. Catch curves comparing instantaneous total mortality rate (Z ± 95% confidence intervals) of fallfish for fully recruited ages (solid circles) in Garvins and Hooksett Pools based on combined 2008-2010 electrofishing catch in the Merrimack River. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

Table 4-7-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for fallfish collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	1	226	226	226	-	1	100	100	100	-
Hooksett	92	54	312	134	42	92	2	345	31	45
Amoskeag	5	64	129	85	29	5	1	22	8	9
Total	98	54	312	132	44	98	1	345	30	44

Table 4-7-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for fallfish collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	30	98	415	266	81	30	9	725	251	212
Hooksett	38	56	231	137	40	38	1	158	29	28
Amoskeag	5	113	225	177	58	5	10	115	72	55
Total	73	56	415	193	87	73	1	725	123	174

Table 4-7-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for fallfish collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	17	39	130	59	20	17	1	21	2	5
Hooksett	64	65	243	107	46	64	2	157	20	34
Total	81	39	243	97	46	81	1	157	17	31

Table 4-7-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for fallfish collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

	Total Length (mm)					Weight (g)				
Pool	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	58	35	200	104	33	58	1	71	13	11
Hooksett	519	50	355	121	28	518	1	495	21	25
Amoskeag	11	64	153	127	25	11	1	36	21	11
Total	588	35	355	120	29	587	1	495	20	24

Table 4-7-5. Regression statistics for total length (mm) vs. weight (g) for fallfish from Garvins and Hooksett Pool during 2011.

					ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
Pool	N	Slope (b)	Intercept ($log_{10}a$)	R^2	Garvins	Hooksett	Garvins	Hooksett
Garvins	48	2.951	-4.956	0.098				
Hooksett	493	3.127	-5.282	0.98	*		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$

Table 4-7-6. Regression statistics for total length (mm) vs. total weight (g) for fallfish sampled during the months of August and September in 2004, 2005, 2010, and 2011 from Hooksett Pool.

					ANCOVA test for differences in length vs. weight equations[1]					
					Slope			Intercept		
Year	N	Slope (b)[2]	Intercept ($log_{10}a$)	R^2	2004	2005	2010	2004	2005	2010
2004	26	3.125	-5.259	0.94						
2005	24	3.125	-5.306	0.92	NS			*		
2010	37	3.125	-5.264	0.99	NS	NS		NS	*	
2011	493	3.125	-5.277	0.98	NS	NS	NS	NS	*	NS

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$
[2] Assumed common slope due to non-significant finding

Table 4-7-7. Mean length at age (± 95% C.I.) for fallfish captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2008	Hooksett		3	60	20
1	2007	Hooksett		16	100	10
2	2006	Hooksett		44	140	3
		Amoskeag		1	128	
3	2005	Garvins		1	228	
		Hooksett		7	176	30
4	2004	Hooksett		3	232	47
5	2003	Hooksett		1	240	
6	2002	Hooksett		1	312	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-7-8. Mean length at age (± 95% C.I.) for fallfish captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
1	2008	Garvins		2	100	3
		Hooksett		3	116	31
		Amoskeag		2	116	6
2	2007	Hooksett		10	144	12
3	2006	Garvins		2	204	0
		Hooksett		10	168	8
		Amoskeag		2	224	19
4	2005	Garvins		10	264	26
		Hooksett		1	232	
5	2004	Garvins		4	324	17
6	2003	Garvins		5	364	32
8	2001	Garvins		1	400	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-7-9. Mean length at age (± 95% C.I.) for fallfish captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins		10	52	4
		Hooksett		10	76	4
1	2009	Garvins		5	76	30
		Hooksett		33	88	4
2	2008	Hooksett		8	124	8
3	2007	Hooksett		3	192	29
4	2006	Hooksett		4	228	21

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-7-10. Frequency distribution of external parasite loads for fallfish collected via electrofishing from Garvins Pool, Hooksett Pool, and Amoskeag Pool during the spring and fall, 2008-2011.

	Absent		Light		Moderate/ Heavy	
Pool	**N**	**%**	**N**	**%**	**N**	**%**
Garvins [A]	96	90.6	10	9.4	0	0.0
Hooksett [B]	530	75.4	147	20.9	26	3.7
Amoskeag [AB]	18	85.7	2	9.5	1	4.8

Notes: Different letters indicate significant within year differences between pools. No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.8 Largemouth Bass

Biocharacteristics of the largemouth bass population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.8.1 Length and Weight

The mean, minimum, maximum, and standard deviation of total length (mm) and total wet weight (g) of largemouth bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-8-1 through 4-8-4. Over the four years of sampling (2008-2011), the total length of largemouth bass ranged from 53 to 525 mm in Garvins Pool, from 38 to 554 mm in Hooksett Pool, and from 76 to 405 mm in Amoskeag Pool. Total weight of largemouth bass ranged from 1 to 2,450 g in Garvins Pool, from 2 to 3,200 g in Hooksett Pool, and from 5 to 1,110 g in Amoskeag Pool.

4.8.2 Condition

The length-weight curves based on the 2010 and 2011 catches both showed largemouth bass in Hooksett Pool grew significantly more rotund (or "fatter") with increasing length than in Garvins Pool (Figures 4-8-1 and 4-8-2, Tables 4-8-5 and 4-8-6). Based on slopes of the length-weight curves of the 2010 catch, largemouth bass grew significantly more rotund as length increased in Amoskeag Pool than in either Garvins or Hooksett Pools (Figure 4-8-1 and Table 4-8-5). The *y*-intercept parameter in the length-weight relation was significantly higher for largemouth bass in Garvins Pool than in Hooksett and Amoskeag Pools, which indicates largemouth bass in Garvins Pool weighed more at a given length early in life than in the other two pools, but gained more weight at a faster rate in Hooksett and Amoskeag Pool.

The length-weight relation based on the 1995 catch showed allometric growth (slope > 3) that produced significantly more rotund fish with increasing length compared to the growth observed during the most recent sampling year, 2011(Figure 4-8-3, Table 4-8-7). The *y*-intercept parameter from the 1995 length-weight relation was significantly lower than the 2011 estimate, which supports that the 1995 young-of-year largemouth bass in Hooksett Pool were in worse condition compared to those collected during the most recent sampling year.

4.8.3 Age-Length

The mean total length at age (±95% C.I.) of largemouth bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 are presented in Tables 4-8-8 through 4-8-10. For years with available age data (2008-2010), age of largemouth bass ranged from age-0 to age-12 in Garvins Pool, from age-0 to age-10 in Hooksett Pool, and from age-0 to age-6 in Amoskeag Pool. During 2010, the mean length at age of age-0 largemouth bass collected in Hooksett Pool was significantly larger than that observed in Garvins Pool (88 mm vs. 84 mm). Age-1 and age-2 largemouth bass collected in Hooksett and Garvins Pools did not differ significantly, as indicated by a Tukey Pairwise comparison test. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools for all cohorts of largemouth bass collected in 2008 and 2009.

4.8.4 Mortality

Total instantaneous mortality rates (Z) for largemouth bass did not significantly differ among Garvins, Hooksett and Amoskeag Pools (Figure 4-8-4, ANCOVA, $F = 0.04$, $P = 0.962$). The annual mortality rates of largemouth bass based on these estimates were 39% for Garvins Pool, 37% for Hooksett Pool, and 38% for Amoskeag Pool. Annual mortality estimates for largemouth bass in Midwestern and New York lakes ranged from 19.5 to 40% (Carlander 1977).

4.8.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for largemouth bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 is presented in Table 4-8-11. There were no significant differences in the prevalence of external parasites found on largemouth bass within Garvins, Hooksett or Amoskeag Pools.

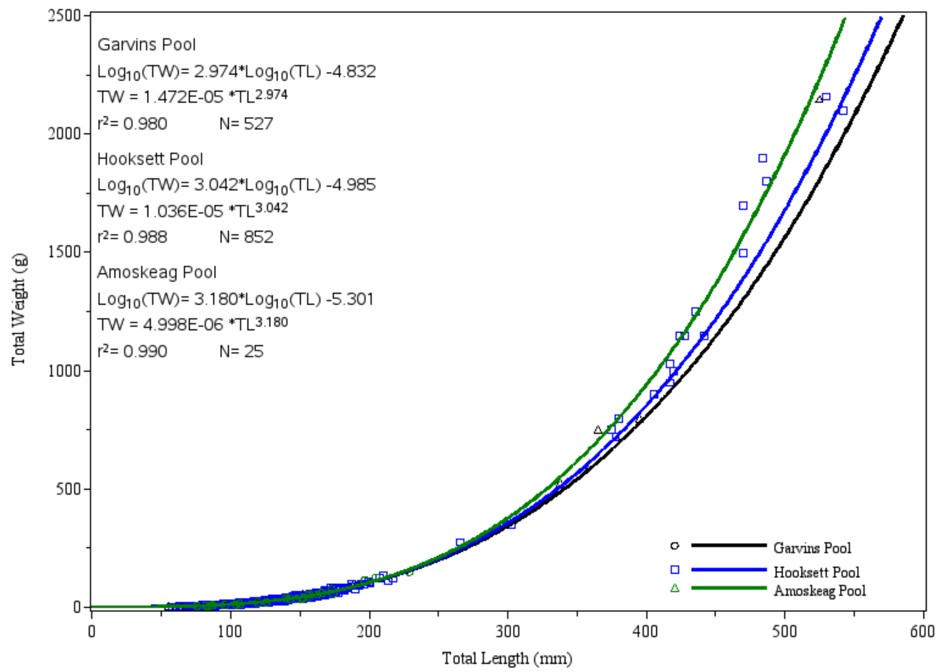


Figure 4-8-1. Empirical length-weight relations for largemouth bass captured via electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2010.

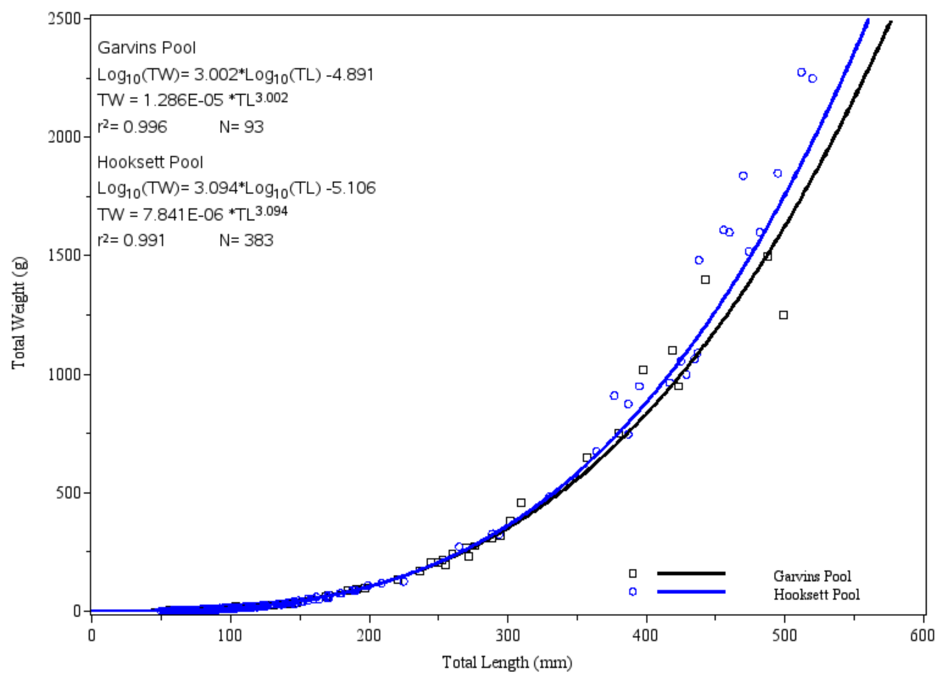


Figure 4-8-2. Empirical length-weight relations for largemouth bass captured via electrofishing within Garvins and Hooksett Pools during 2011.

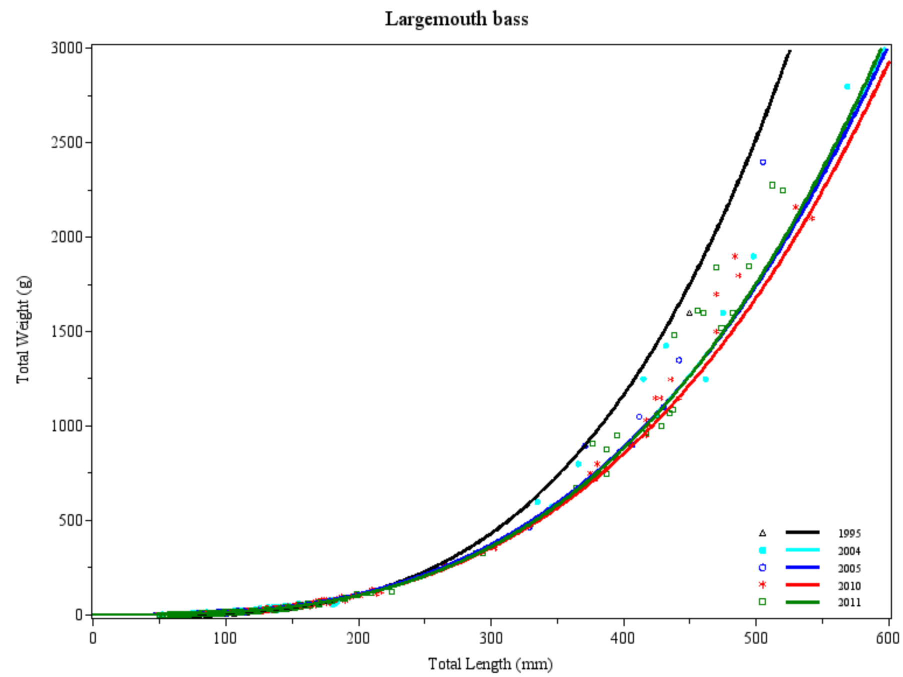


Figure 4-8-3. Empirical length-weight relations for largemouth bass captured via electrofishing during the months of August and September of 1995, 2004, 2005, 2010, and 2011 within Hooksett Pool.

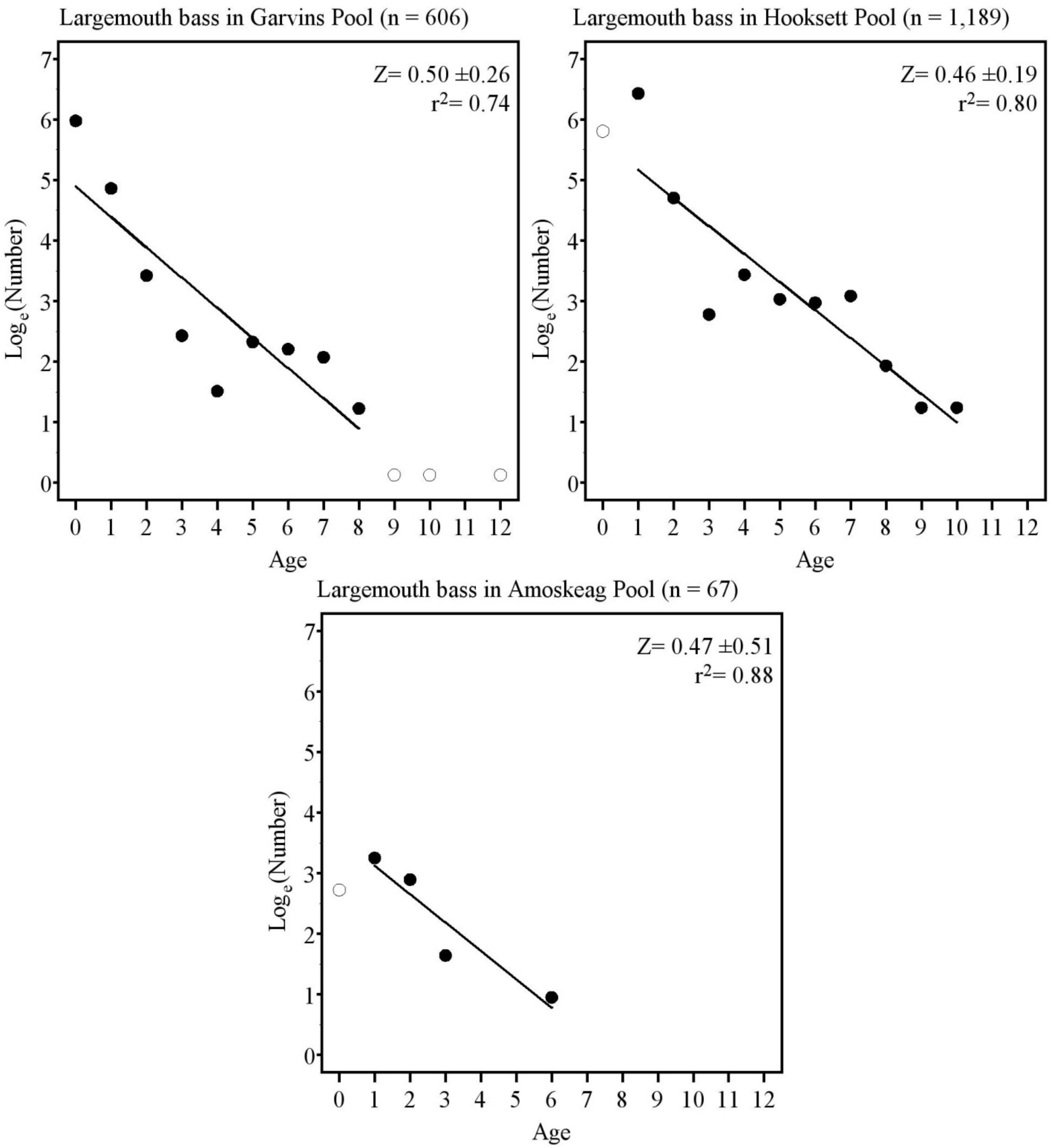


Figure 4-8-4. Catch curve estimate of total instantaneous mortality rate (Z ± 95% confidence interval) of largemouth bass for fully recruited ages (solid circles) in Garvins, Hooksett, and Amoskeag Pools based on the combined electrofishing catch in the Merrimack River during 2008-2010. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

Table 4-8-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for largemouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	18	55	446	214	130	18	2	1480	306	448
Hooksett	212	53	554	222	142	209	2	3200	361	501
Amoskeag	5	137	405	241	129	5	29	1110	380	494
Total	235	53	554	222	140	232	2	3200	357	495

Table 4-8-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for largemouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	50	72	520	348	98	50	6	2450	793	623
Hooksett	76	58	522	261	162	75	2	2500	581	723
Amoskeag	5	97	145	124	21	5	10	43	26	14
Total	131	58	522	289	147	130	2	2500	641	687

Table 4-8-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length in millimeters and total weight in grams for largemouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	560	55	525	100	40	560	1	2150	24	108
Hooksett	908	58	542	125	56	908	2	3100	55	221
Amoskeag	27	76	229	138	41	27	5	150	41	38
Total	1495	55	542	115	52	1495	1	3100	43	185

Table 4-8-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length in millimeters and total weight in grams for largemouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	98	53	499	147	112	97	2	1500	138	309
Hooksett	409	38	520	112	81	409	1	2277	78	298
Amoskeag	3	81	92	88	6	3	5	9	8	2
Total	510	38	520	119	88	509	1	2277	89	300

Table 4-8-5. Regression statistics for total length (mm) vs. weight (g) for largemouth bass from Garvins, Hooksett, and Amoskeag Pools during 2010.

Pool	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	527	2.974	-4.832	0.98				
Hooksett	852	3.042	-4.985	0.99	*		*	
Amoskeag	25	3.180	-5.301	0.99	*	*	*	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p $\leq$0.05
NS = not significant, p > 0.05

Table 4-8-6. Regression statistics for total length (mm) vs. weight (g) for largemouth bass from Garvins and Hooksett Pools during 2011.

Pool	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	93	3.002	-4.891	>0.99				
Hooksett	383	3.094	-5.106	>0.99	*		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p $\leq$0.05
NS = not significant, p > 0.05

Table 4-8-7. Regression statistics for total length (mm) vs. total weight (g) for largemouth bass sampled during the months of August and September of 1995, 2004, 2005, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]							
					Slope				Intercept			
					1995	2004	2005	2010	1995	2004	2005	2010
1995	111	3.456	-5.926	0.94								
2004	164	3.040	-4.962	0.97	*				*			
2005	115	3.019	-4.907	0.97	*	NS			*	NS		
2010	852	3.042	-4.985	0.99	*	NS	NS		*	NS	NS	
2011	383	3.094	-5.106	>0.99	*	NS	*	*	*	*	*	*

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p $\leq$0.05
NS = not significant, p > 0.05

Table 4-8-8. Mean length at age (± 95% C.I.) for largemouth bass captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2008	Garvins		1	116	
		Hooksett		8	108	7
1	2007	Garvins		1	152	
		Hooksett		34	148	8
		Amoskeag		3	148	16
2	2006	Garvins		2	236	66
		Hooksett		10	212	31
3	2005	Garvins		2	252	253
		Hooksett		7	272	54
4	2004	Hooksett		20	364	12
5	2003	Hooksett		14	392	17
6	2002	Hooksett		12	416	13
		Amoskeag		1	404	
7	2001	Garvins		2	432	79
		Hooksett		8	448	14
8	2000	Hooksett		1	404	
9	1999	Hooksett		1	536	
10	1998	Hooksett		1	556	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-8-9. Mean length at age (± 95% C.I.) for largemouth bass captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2009	Amoskeag		1	112	
1	2008	Hooksett		7	124	15
		Amoskeag		1	124	
2	2007	Garvins		2	248	120
		Hooksett		5	188	42
3	2006	Garvins		7	260	23
		Hooksett		4	268	24
4	2005	Garvins		3	280	47
		Hooksett		5	312	50
5	2004	Garvins		8	340	27
		Hooksett		3	408	19
6	2003	Garvins		6	420	17
		Hooksett		4	416	27
7	2002	Garvins		5	408	29
		Hooksett		3	476	35
8	2001	Garvins		2	468	246
		Hooksett		3	496	6
9	2000	Garvins		1	508	
		Hooksett		1	516	
10	1999	Garvins		1	520	
		Hooksett		1	472	
12	1997	Garvins		1	500	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-8-10. Mean length at age (± 95% C.I.) for largemouth bass captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins	B	398	84	1
		Hooksett	A	243	88	1
		Amoskeag		6	84	5
1	2009	Garvins	A	113	124	3
		Hooksett	A	499	120	1
		Amoskeag		6	116	13
2	2008	Garvins	A	23	160	8
		Hooksett	A	81	160	4
		Amoskeag		7	164	19
3	2007	Garvins		1	192	
		Hooksett		3	184	48
		Amoskeag		2	168	22
4	2006	Garvins		1	296	
		Hooksett		2	320	104
5	2005	Garvins		1	364	
		Hooksett		1	376	
6	2004	Garvins		2	368	180
		Hooksett		1	416	
7	2003	Hooksett		8	424	17
8	2002	Garvins		1	432	
		Hooksett		2	380	0
9	2001	Hooksett		1	488	
10	2000	Hooksett		1	460	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-8-11. Frequency distribution of external parasite loads for largemouth bass collected from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	340	46.8	297	40.9	89	12.3
Hooksett [A]	623	39.0	705	44.1	271	17.0
Amoskeag [A]	13	32.5	21	52.5	6	15.0

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.9 Pumpkinseed

Biocharacteristics of the pumpkinseed population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.9.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of pumpkinseed collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-9-1 through 4-9-4. Over the four years of sampling (2008-2011), the total length of pumpkinseed ranged from 46 to 225 mm in Garvins Pool, from 50 to 173 mm in Hooksett Pool, and from 73 to 177 mm in Amoskeag Pool. Total weight of pumpkinseed ranged from 1 to 285 g in Garvins Pool, from 1 to 110g in Hooksett Pool, and from 7 to 90 g in Amoskeag Pool.

4.9.2 Condition

There were no significant differences among slope parameters for the length-weight curves based on 2010 (F = 1.52, P = 0.219) and 2011(F = 1.49, P = 0.229) catches, indicating that pumpkinseed increased in weight with length at similar rates within Garvins and Hooksett Pools (Figures 4-9-1 and 4-9-2, Tables 4-9-5 and 4-9-6). As a result, a common slope was assumed for the length-weight relation of pumpkinseed caught in both pools during each year. The *y*-intercept parameter in the length-weight relation did not differ significantly for pumpkinseed in Garvins and Hooksett Pools during either the 2010 or 2011 catches. Based on 2010 and 2011 catches, the weight at a given length and the incremental weight gain with increasing length of pumpkinseed in Garvins and Hooksett Pools was similar. This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool relative to the thermally uninfluenced Garvins Pool.

The slopes of the Hooksett Pool length-weight curves derived from catches of pumpkinseed were not significantly different (F = 1.55, P = 0.204). This finding indicates that pumpkinseed increased in weight with length at similar rates during 1995 as well as the most recent sampling year, 2011 (Figure 4-9-3, Table 4-9-7). After assuming a common slope among all annual length-weight curves, the *y*-intercept parameter from the 2011 length-weight relation was significantly lower than the 1995 estimate, which supports that pumpkinseed from Hooksett Pool were in worse condition compared to those collected during 1995.

4.9.3 Age-Length

The mean total length at age (±95% C.I.) of pumpkinseed collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 are presented in Tables 4-9-8 through 4-9-10. For years with available age data (2008-2010), age of pumpkinseed ranged from age-0 to age-8 in Garvins Pool, from age-0 to age-6 in Hooksett Pool, and from age-1 to age-4 in Amoskeag Pool. During 2010, the mean length at age of age-1 pumpkinseed collected in Hooksett and Garvins Pools differed significantly from one another with a mean length at age of age-1 pumpkinseed in Garvins Pool of 64 mm and in Hooksett Pool of 80 mm. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools for all cohorts of pumpkinseed collected in 2008 and 2009.

4.9.4 Mortality

The total instantaneous mortality rates for pumpkinseed (Z = 0.28 to 0.84) did not significantly differ among Garvins, Hooksett and Amoskeag Pools (Figure 4-9-4, ANCOVA, F = 1.84, P = 0.263). The regression for the catch curve of ages 1-4 pumpkinseed in Amoskeag Pool was not statistically significant (F = 9.83, P = 0.197). This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool relative to the thermally uninfluenced Garvins Pool. The annual mortality rates of pumpkinseed based on these estimates were 24% for Garvins Pool, 36% for Hooksett Pool, and 57% for Amoskeag Pool. Annual mortality estimates for age-2 to age-4 pumpkinseed Indiana and Wisconsin lakes ranged from 80-95% (Carlander 1977).

4.9.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for pumpkinseed collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 is presented in Table 4-9-11. The prevalence of external parasites did not differ significantly for pumpkinseed captured within Garvins and Hooksett Pools. External parasite prevalence for pumpkinseed was significantly greater in Amoskeag Pool than in Hooksett Pool.

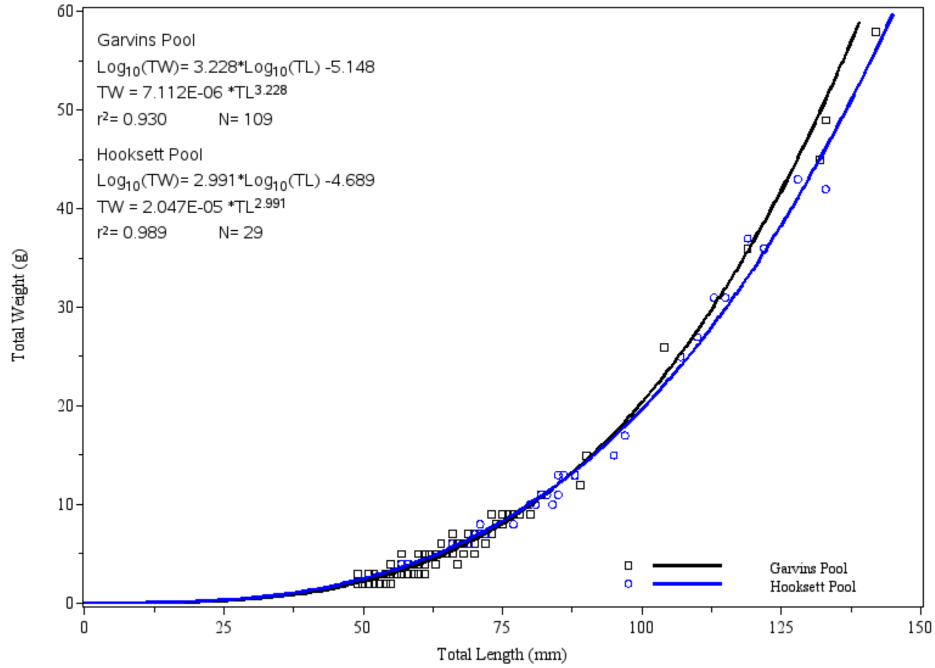


Figure 4-9-1. Empirical length-weight relations for pumpkinseed captured via electrofishing within Garvins and Hooksett Pools during 2010.

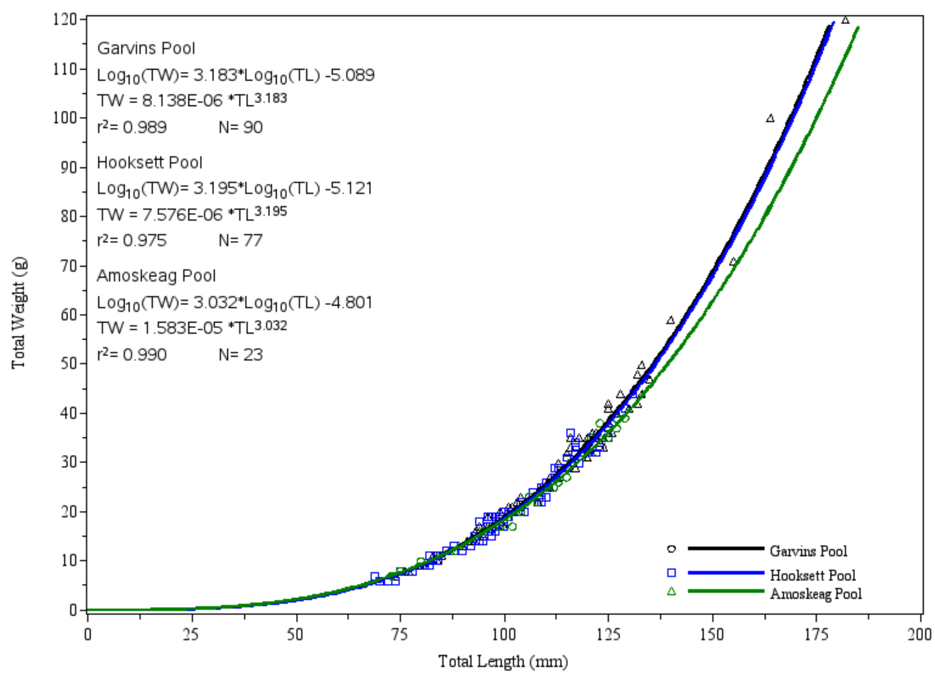


Figure 4-9-2. Empirical length-weight relations for pumpkinseed captured via electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2011.

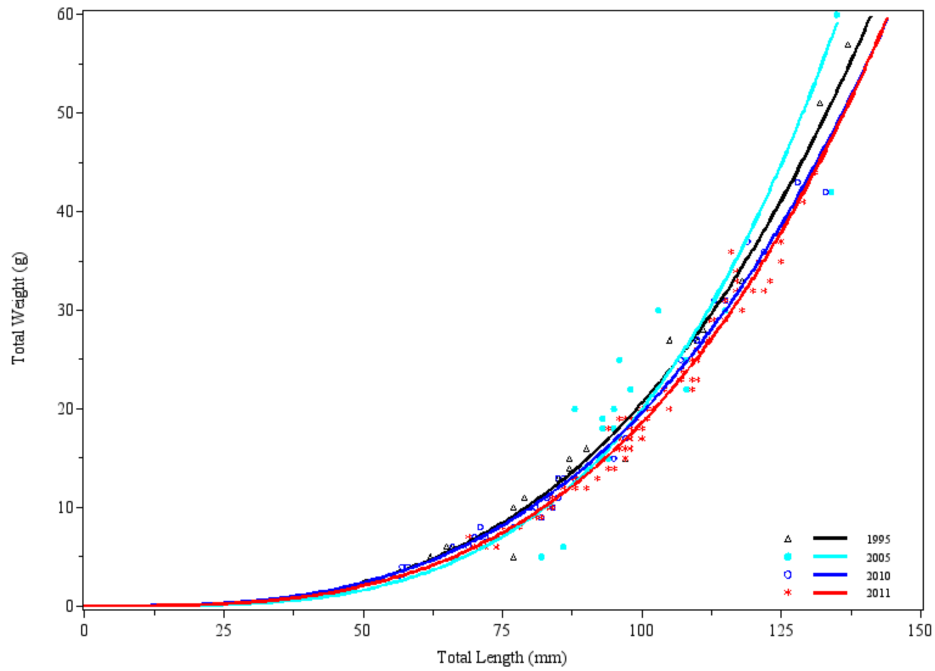


Figure 4-9-3. Empirical length-weight relations for pumpkinseed captured via electrofishing during the months of August and September 1995, 2005, 2010, and 2011 from Hooksett Pool.

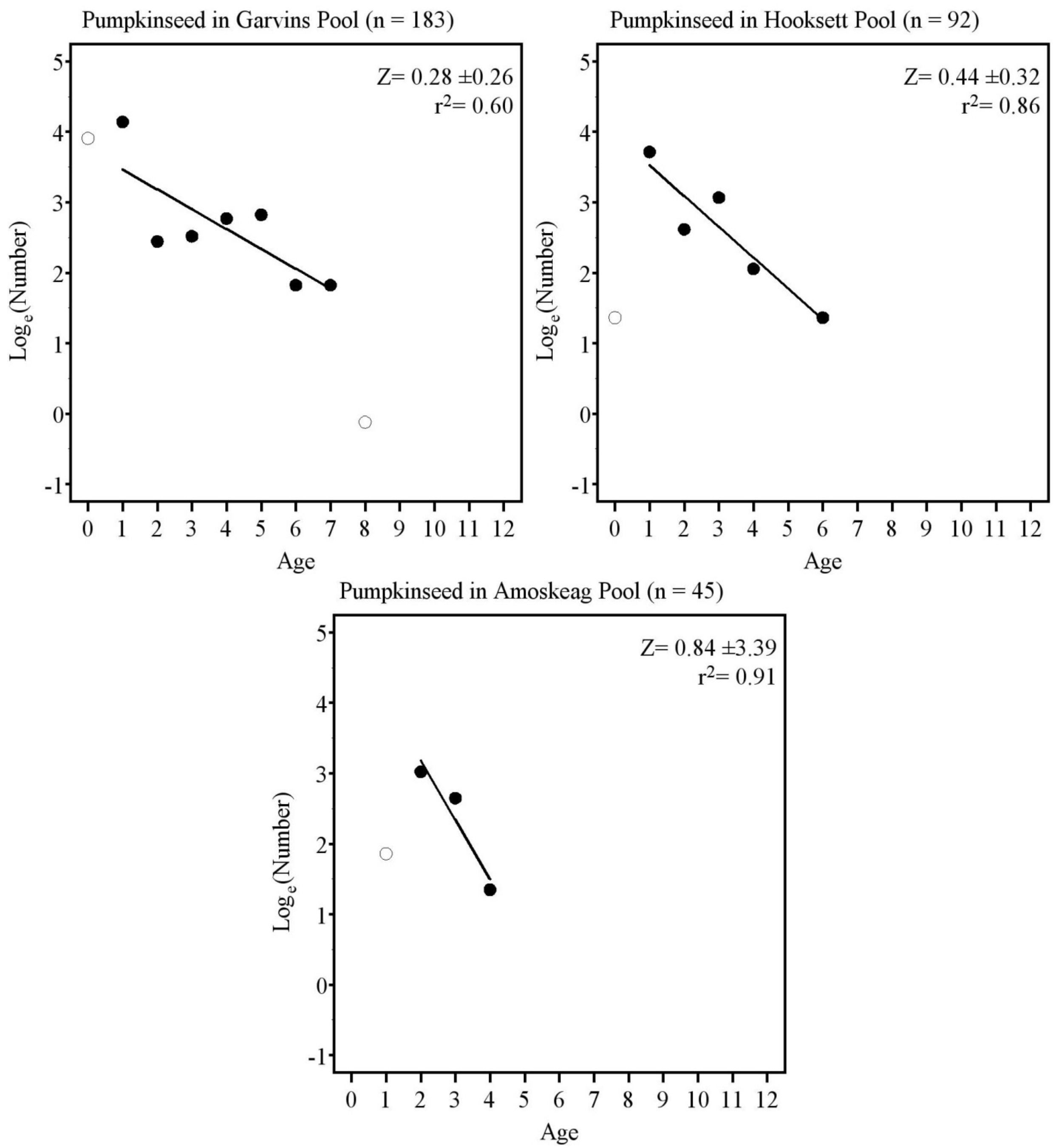


Figure 4-9-4. Catch curve estimate of total instantaneous mortality rate (Z ± 95% confidence interval) of pumpkinseed for fully recruited ages (solid circles) in Garvins, Hooksett, and Amoskeag Pools based on the combined 2008-2010 electrofishing catch in the Merrimack River. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

Table 4-9-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for pumpkinseed collected in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

	Total Length (mm)					Weight (g)				
Pool	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	17	79	212	137	44	17	4	190	81	66
Hooksett	8	79	173	130	33	8	9	110	50	34
Amoskeag	3	104	177	130	41	3	17	90	44	40
Total	28	79	212	134	40	28	4	190	68	57

Table 4-9-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for pumpkinseed collected in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

	Total Length (mm)					Weight (g)				
Pool	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	73	56	225	156	44	73	2	285	103	69
Hooksett	13	83	165	118	31	13	8	105	41	36
Amoskeag	29	75	127	98	13	29	10	40	17	9
Total	115	56	225	137	45	115	2	285	74	68

Table 4-9-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for pumpkinseed collected in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

	Total Length (mm)					Weight (g)				
Pool	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	132	46	142	64	16	131	1	58	6	8
Hooksett	34	57	133	88	20	34	3	43	15	11
Amoskeag	11	82	166	131	20	11	12	84	46	17
Total	177	46	166	73	25	176	1	84	10	14

Table 4-9-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for pumpkinseed collected in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	97	74	182	111	19	97	7	120	29	18
Hooksett	81	50	131	99	16	81	1	44	20	9
Amoskeag	25	73	142	110	18	25	7	60	26	12
Total	203	50	182	106	19	203	1	120	25	15

Table 4-9-5. Regression statistics for total length (mm) vs. weight (g) for pumpkinseed from Garvins and Hooksett Pools during 2010.

Pool	N	Slope (b)[2]	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	109	3.177	-5.056	0.93				
Hooksett	31	3.177	-5.055	0.99	NS		NS	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-9-6. Regression statistics for total length (mm) vs. weight (g) for pumpkinseed from Garvins Pool, Hooksett Pool, and Amoskeag Pool during 2011.

Pool	N	Slope (b)[2]	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	90	3.169	-5.060	0.99				
Hooksett	77	3.169	-5.068	0.98	NS		NS	
Amoskeag	23	3.169	-5.078	0.99	NS	NS	*	NS

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-9-7. Regression statistics for total length (mm) vs. total weight (g) for pumpkinseed sampled during the months of August and September in 1995, 2005, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)[2]	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]					
					Slope			Intercept		
					1995	2005	2010	1995	2005	2010
1995	17	3.152	-4.989	0.95						
2005	17	3.152	-5.006	0.72	NS			NS		
2010	31	3.152	-5.006	0.98	NS	NS		NS	NS	
2011	77	3.152	-5.036	0.98	NS	NS	NS	*	NS	*

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-9-8. Mean length at age (± 95% C.I.) for pumpkinseed captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
1	2007	Garvins		3	92	13
		Hooksett		1	88	
2	2006	Garvins		5	108	21
		Hooksett		2	100	120
		Amoskeag		3	132	68
3	2005	Garvins		2	156	51
		Hooksett		1	160	
4	2004	Garvins		4	176	15
		Hooksett		2	156	117
6	2002	Garvins		1	212	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-9-9. Mean length at age (± 95% C.I.) for pumpkinseed captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
1	2008	Garvins		9	72	7
		Hooksett		2	92	38
		Amoskeag		4	96	8
2	2007	Garvins		6	112	4
		Hooksett		1	84	
		Amoskeag		12	96	6
3	2006	Garvins		10	132	7
		Hooksett		6	116	20
		Amoskeag		4	112	15
4	2005	Garvins		14	168	9
		Amoskeag		1	112	
5	2004	Garvins		18	180	6
6	2003	Garvins		6	196	8
		Hooksett		2	164	3
7	2002	Garvins		7	204	10
8	2001	Garvins		1	220	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-9-10. Mean length at age (± 95% C.I.) for pumpkinseed captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins		57	56	2
		Hooksett		2	56	3
1	2009	Garvins	B	59	64	2
		Hooksett	A	18	80	3
		Amoskeag		1	84	
2	2008	Garvins		2	112	139
		Hooksett		4	104	22
		Amoskeag		1	132	
3	2007	Garvins		2	132	73
		Hooksett		4	116	11
		Amoskeag		7	136	11
4	2006	Hooksett		2	124	57
		Amoskeag		2	140	19
5	2005	Garvins		1	132	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-9-11. Frequency distribution of external parasite loads for pumpkinseed collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [AB]	207	65.1	84	26.4	27	8.5
Hooksett [A]	106	77.9	21	15.4	9	6.6
Amoskeag [B]	47	69.1	20	29.4	1	1.5

Notes: Different letters indicate significant within year differences between pools. No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.10 Redbreast Sunfish

Biocharacteristics of the redbreast sunfish population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.10.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of redbreast sunfish collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 are presented in Tables 4-10-1 through 4-10-4. Over the four years of sampling (2008-2011), the total length of redbreast sunfish ranged from 37 to 204 mm in Garvins Pool, from 37 to 195 mm in Hooksett Pool, and from 61 to 203 mm in Amoskeag Pool. Total weight of redbreast sunfish ranged from 2 to 188 g in Garvins Pool, from 2 to 170 g in Hooksett Pool, and from 4 to 160 g in Amoskeag Pool.

4.10.2 Condition

The length-weight curve based on the 2010 catch showed redbreast sunfish in Garvins and Amoskeag Pools grew significantly more rotund (or "fatter") with increasing length than in Hooksett Pool (Figure 4-10-1, Table 4-10-5). The *y*-intercept parameter in the length-weight relation was significantly higher for redbreast sunfish in Hooksett Pool than in Garvins and Amoskeag Pools, which indicates that redbreast sunfish in Hooksett Pool weighed more at a given length early in life than in the other two pools, but gained more weight at a faster rate in Amoskeag and Garvins Pools. The ANCOVA based on the 2011 catch showed no significant differences in the length-weight relation of redbreast sunfish between Hooksett and Amoskeag Pools (Figure 4-10-2, Table 4-10-6).

The length-weight relation based on 1995 catch showed allometric growth (slope > 3) that produced significantly more rotund redbreast sunfish with increasing length compared to the growth observed during the most recent sampling year, 2011 (Figure 4-10-3, Table 4-10-7). The *y*-intercept parameter from the 1995 length-weight relation was significantly lower than the 2011 estimate, which supports that the 1995 young-of-year redbreast sunfish in Hooksett Pool were in worse condition compared to those collected during the most recent sampling year.

4.10.3 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for redbreast sunfish collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 is presented in Table 4-10-8. There were no significant differences in the prevalence of external parasites on redbreast sunfish within Garvins, Hooksett and Amoskeag Pools.

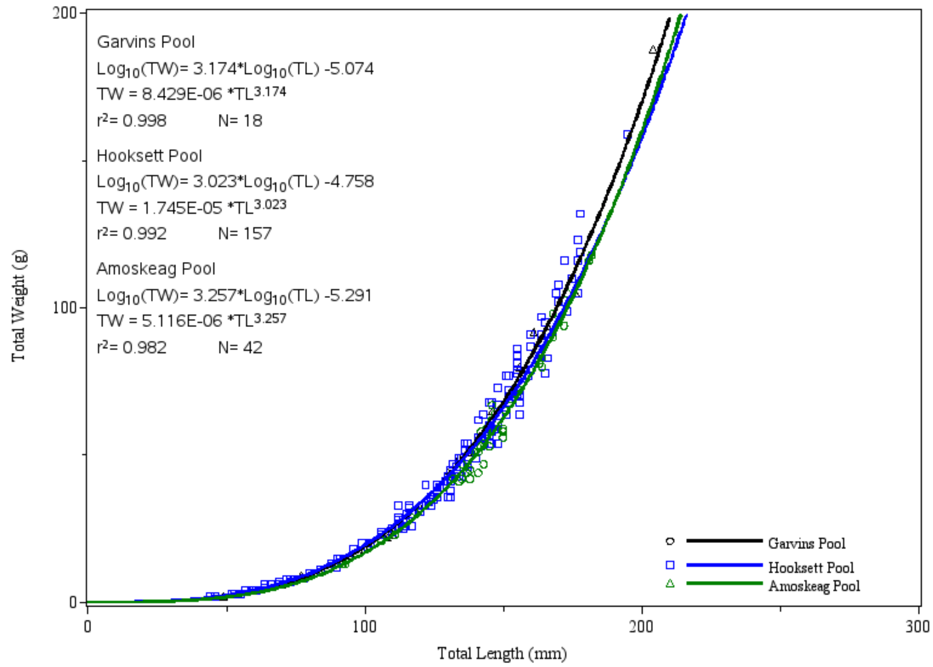


Figure 4-10-1. Empirical length-weight relations for redbreast sunfish captured via electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2010.

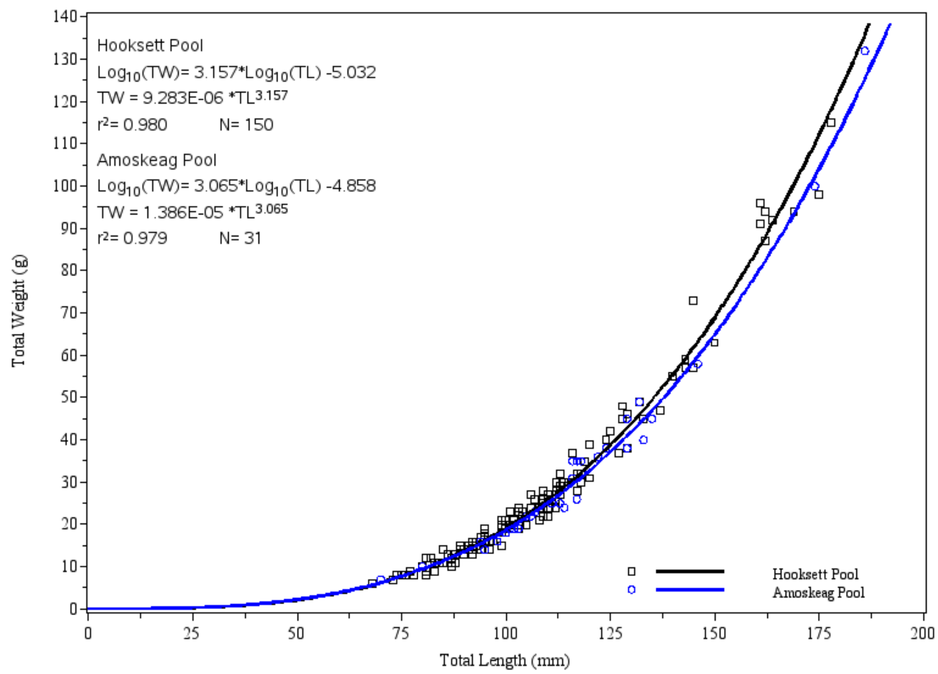


Figure 4-10-2. Empirical length-weight relations for redbreast sunfish captured via electrofishing within Hooksett and Amoskeag Pools during 2011.

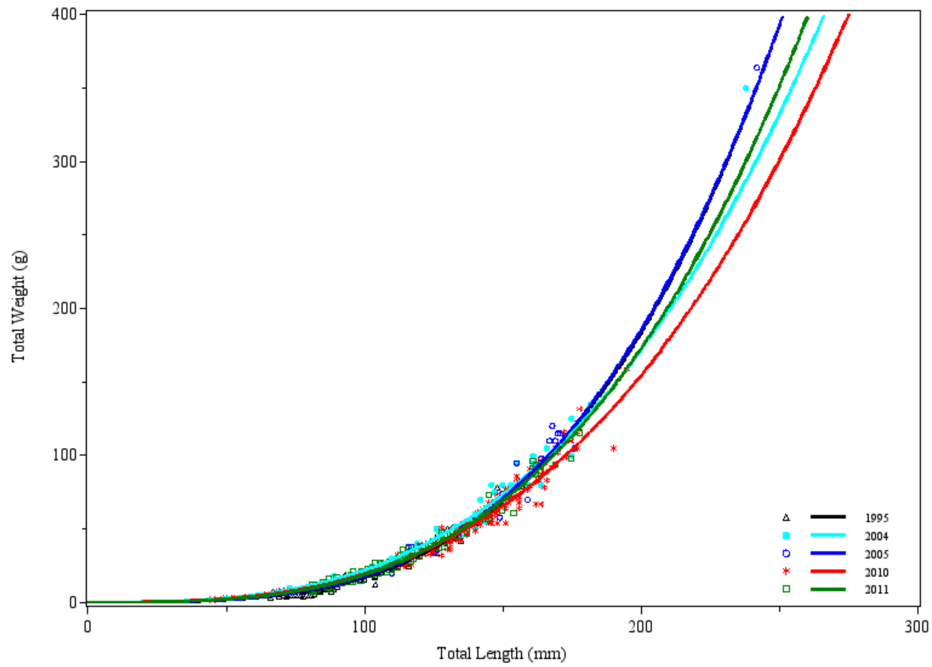


Figure 4-10-3. Empirical length-weight relations for redbreast sunfish captured via electrofishing during the months of August and September 1995, 2004, 2005, 2008, 2009, and 2010 from Hooksett Pool.

Table 4-10-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for redbreast sunfish collected in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	15	77	171	133	26	15	10	118	59	30
Hooksett	20	77	177	111	27	20	7	91	25	19
Amoskeag	7	70	147	104	31	7	4	58	24	22
Total	42	70	177	118	29	42	4	118	37	29

Table 4-10-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for redbreast sunfish collected in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	2	96	116	106	14	2	16	31	24	11
Hooksett	8	75	195	132	37	8	11	170	55	54
Amoskeag	31	75	203	129	36	31	6	160	50	43
Total	41	75	203	128	35	41	6	170	50	44

Table 4-10-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for redbreast sunfish collected in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	21	37	204	122	44	18	2	188	50	48
Hooksett	186	37	195	122	40	171	2	159	49	33
Amoskeag	46	61	182	142	25	42	13	118	60	25
Total	253	37	204	126	39	231	2	188	51	33

Table 4-10-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for redbreast sunfish collected in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	7	73	191	139	45	7	7	130	68	48
Hooksett	169	68	178	104	22	160	6	115	26	20
Amoskeag	32	70	186	116	23	32	7	132	34	25
Total	208	68	191	107	24	208	6	132	29	24

Table 4-10-5. Regression statistics for total length (mm) vs. weight (g) for redbreast sunfish from Garvins, Hooksett, and Amoskeag Pools during 2010.

Pool	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	18	3.174	-5.074	>0.99				
Hooksett	167	2.983	-4.675	>0.99	*		*	
Amoskeag	42	3.257	-5.291	0.98	NS	*	NS	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-10-6. Regression statistics for total length (mm) vs. weight (g) for redbreast sunfish from Hooksett and Amoskeag Pools during 2011.

Pool	N	Slope (b)[2]	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Hooksett	Amoskeag	Hooksett	Amoskeag
Hooksett	160	3.162	-5.042	0.97				
Amoskeag	31	3.162	-5.058	0.98	NS		NS	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-10-7. Regression statistics for total length (mm) vs. total weight (g) for redbreast sunfish sampled during the months of August and September in 1995, 2004, 2005, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]							
					Slope				Intercept			
					1995	2004	2005	2010	1995	2004	2005	2010
1995	105	3.410	-5.583	0.95								
2004	43	2.958	-4.572	0.97	*				*			
2005	34	3.359	-5.461	0.98	NS	*			NS	*		
2010	167	2.983	-4.675	>0.99	*	NS	*		*	NS	*	
2011	160	3.180	-5.080	0.97	*	NS	NS	*	*	*	NS	*

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$

Table 4-10-8. Frequency of external parasite loads for redbreast sunfish collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	35	77.8	9	20.0	1	2.2
Hooksett [A]	284	74.7	84	22.1	12	3.2
Amoskeag [A]	80	69.0	34	29.3	2	1.7

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.11 Rock Bass

Biocharacteristics of the rock bass population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.11.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of rock bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 are presented in Tables 4-11-1 through 4-11-4. Over the four years of sampling (2008-2011), the total length of rock bass ranged from 51 to 270 mm in Garvins Pool, from 40 to 242 mm in Hooksett Pool, and from 72 to 248 mm in Amoskeag Pool. Total weight of rock bass ranged from 2 to 410 g in Garvins Pool, from 2 to 305 g in Hooksett Pool, and from 7 to 310 g in Amoskeag Pool.

4.11.2 Age-Length

The mean total length at age (±95% C.I.) of rock bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2009 and 2010 are presented in Tables 4-11-5 and 4-11-6. For years with available age data (2009-2010), age of rock bass ranged from age-0 to age-6 in Garvins Pool, from age-0 to age-4 in Hooksett Pool, and from age-0 to age-6 in Amoskeag Pool. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools for all cohorts of rock bass collected during 2009 and 2010.

4.11.3 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for rock bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 is presented in Table 4-11-7. The prevalence of external parasites was significantly greater in Amoskeag Pool than in either Garvins or Hooksett Pools, and in Hooksett Pool than in Garvins Pool.

Table 4-11-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for rock bass collected in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

	Total Length (mm)					Weight (g)				
Pool	**N**	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	5	205	230	215	12	5	190	270	215	33
Hooksett	1	69	69	69	.	1	5	5	5	.
Amoskeag	4	122	228	176	46	4	34	235	120	89
Total	10	69	230	185	53	10	5	270	156	90

Table 4-11-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for rock bass collected in Garvins, Hooksett, and Amoskeag Pools during spring April, May and September 2009.

	Total Length (mm)					Weight (g)				
Pool	**N**	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	6	158	270	206	41	6	80	410	203	119
Hooksett	7	89	242	148	61	7	14	305	96	110
Amoskeag	2	171	182	177	8	2	110	110	110	0
Total	15	89	270	175	55	15	14	410	141	114

Table 4-11-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g)for rock bass collected in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

	Total Length (mm)					Weight (g)				
Pool	**N**	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	6	51	142	75	37	6	2	64	16	25
Hooksett	11	46	195	115	57	11	2	166	53	58
Amoskeag	14	72	248	174	39	14	7	310	122	70
Total	31	46	248	134	59	31	2	310	77	72

Table 4-11-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g)for rock bass collected in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

	Total Length (mm)					Weight (g)				
Pool	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	4	103	195	131	44	4	22	141	55	58
Hooksett	12	40	225	159	61	12	2	247	120	100
Amoskeag	2	127	176	152	35	2	37	115	76	55
Total	18	40	225	152	54	18	2	247	101	90

Table 4-11-5. Mean length at age for rock bass captured by electrofishing from Garvins Pool during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
4	2005	Garvins		1	160	
6	2003	Garvins		1	172	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-11-6. Mean length at age for rock bass captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins		3	56	6
		Hooksett		2	56	63
		Amoskeag		1	72	
1	2009	Garvins		2	76	145
		Hooksett		4	72	10
3	2007	Garvins		1	144	
		Hooksett		4	168	8
		Amoskeag		10	172	9
4	2006	Hooksett		1	196	
		Amoskeag		2	196	95
6	2004	Amoskeag		1	248	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-11-7 Frequency distribution of external parasite loads for rock bass collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	20	95.2	0	0.0	1	4.8
Hooksett [B]	20	64.5	8	25.8	3	9.7
Amoskeag [C]	10	45.5	10	45.5	2	9.1

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.12 Smallmouth Bass

Biocharacteristics of the smallmouth bass population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008- 2011.

4.12.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of smallmouth bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 are presented in Tables 4-12-1 through 4-12-4. Over the four years of sampling (2008-2011), the total length of smallmouth bass ranged from 58 to 465 mm in Garvins Pool, from 55 to 475 mm in Hooksett Pool, and from 62 to 526 mm in Amoskeag Pool. Total weight of smallmouth bass ranged from 2 to 1,500 g in Garvins Pool, from 2 to 1,400 g in Hooksett Pool, and from 2 to 2,200 g in Amoskeag Pool.

4.12.2 Condition

The slopes of the length-weight curves based on the 2010 catch did not differ significantly for smallmouth bass among Garvins, Hooksett and Amoskeag Pools ($F = 0.58$, $P = 0.562$), indicating that smallmouth bass from these three populations maintain a similar incremental weight gain with increasing length (Figure 4-12-1, Tables 4-12-5). When a common slope was assumed for the length-weight relations of smallmouth bass caught in 2010, significant differences in the *y*-intercept parameter indicated smallmouth bass from Garvins Pool were heavier at a given length (better condition) than those from Hooksett and Amoskeag Pools, and those from Hooksett Pool were heavier at a given length than those from Amoskeag Pool. However, the slope estimates of the length-weight relation for smallmouth bass caught in 2011 indicated smallmouth bass in Amoskeag Pool grew significantly more slender (slope < 3) with increasing length than in Garvins and Hooksett Pool (Figure 4-12-2, Table 4-12-6). The *y*-intercept parameter in the length-weight relation based on the 2011 catch was significantly higher for smallmouth bass in Amoskeag Pool than in Hooksett and Garvins Pools, which indicates largemouth bass in Amoskeag Pool weighed more at a given length early in life than in the other two pools, but gained less weight with increasing length than in Garvins and Hooksett Pool.

The length-weight relation based on the 1995 catch in Hooksett Pool showed allometric growth (slope > 3) that produced significantly more rotund smallmouth bass with increasing length compared to the near isometric growth (slope ≈ 3) based on the length-weight relation of the most recent annual catch of 2011 (Figure 4-10-3, Table 4-10-7). The *y*-intercept parameter from the 1995 length-weight relation was significantly lower than the estimate from 2011, which potentially indicates the 1995 young-of-year smallmouth bass in Hooksett Pool were in worse condition (weighed less at a given length) compared to the YOY caught in 2011.

4.12.3 Age-Length

The mean total length at age (±95% C.I.) of smallmouth bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 are presented in Tables 4-12-8 through 4-12-10. For years with available age data (2008-2010), age of smallmouth bass ranged from age-0 to age-9 in Garvins and Amoskeag Pools, and from age-0 to age-11 in Hooksett Pool. During 2009, the mean length at age of age-1 smallmouth bass collected in Hooksett and Amoskeag Pools did not differ significantly, as indicated by a Tukey Pairwise comparison test. During 2010, the mean length at age of age-0 smallmouth bass collected in Hooksett and Amoskeag Pools differed significantly from one another but were similar to the mean length at age of age-0 smallmouth bass in Garvins Pool. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools for all cohorts of smallmouth bass collected during 2008.

4.12.4 Mortality

The total instantaneous mortality rates (Z) for smallmouth bass significantly differed among Merrimack River pools (Figure 4-11-4, ANCOVA, $F = 3.81$, $P = 0.042$). The total instantaneous mortality rate of smallmouth bass for ages 1-7 in Hooksett Pool (Z = 0.70) was significantly higher than the estimate for ages 0-7 from Garvins Pool (Z = 0.39; $F = 6.67$, $P = 0.019$) and Amoskeag Pool (Z = 0.45; $F = 5.79$, $P = 0.027$), but there was no significant difference in Z detected between Garvins and Amoskeag Pools ($F = 0.41$, $P = 0.530$). The annual mortality rates of smallmouth bass based on these estimates were 32% for Garvins Pool, 50% for Hooksett Pool, and 36% for Amoskeag Pool. The smallmouth bass annual mortality rate (natural and fishing mortality combined) for Lake Oneida (NY) was reported at 43% over a fourteen year period (Carlander 1977).

4.12.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for smallmouth bass collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 are presented in Table 4-12-11. The prevalence of external parasites differed significantly among Garvins and Hooksett Pools. Smallmouth bass in Garvins were more prone to moderate/heavy external parasite loads as compared to smallmouth bass in Hooksett Pool. There were no significant differences in the prevalence of external parasites for smallmouth bass between Hooksett and Amoskeag Pools.

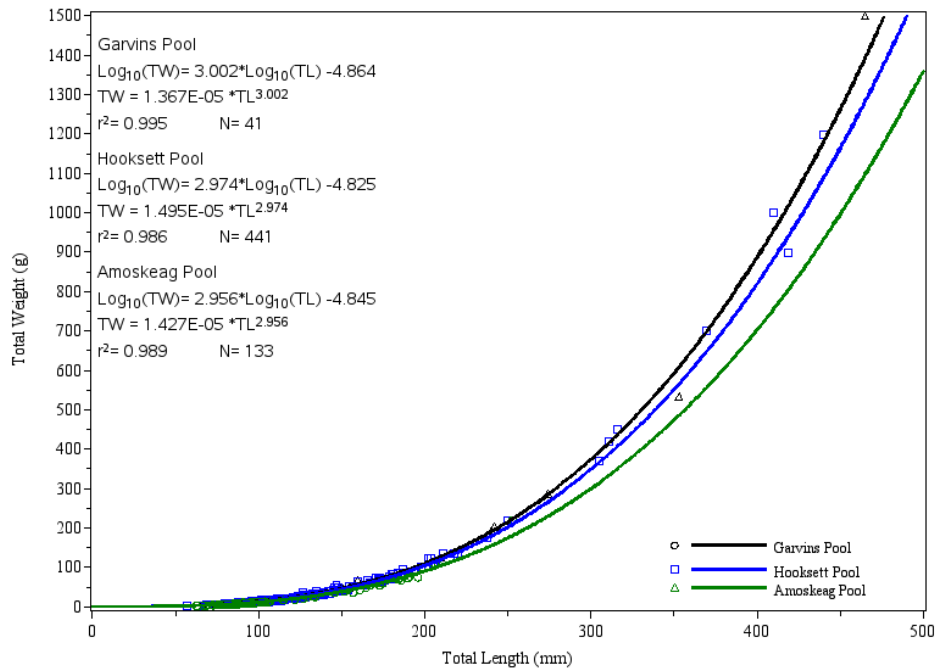


Figure 4-12-1. Empirical length-weight relations for smallmouth bass captured via electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2010.

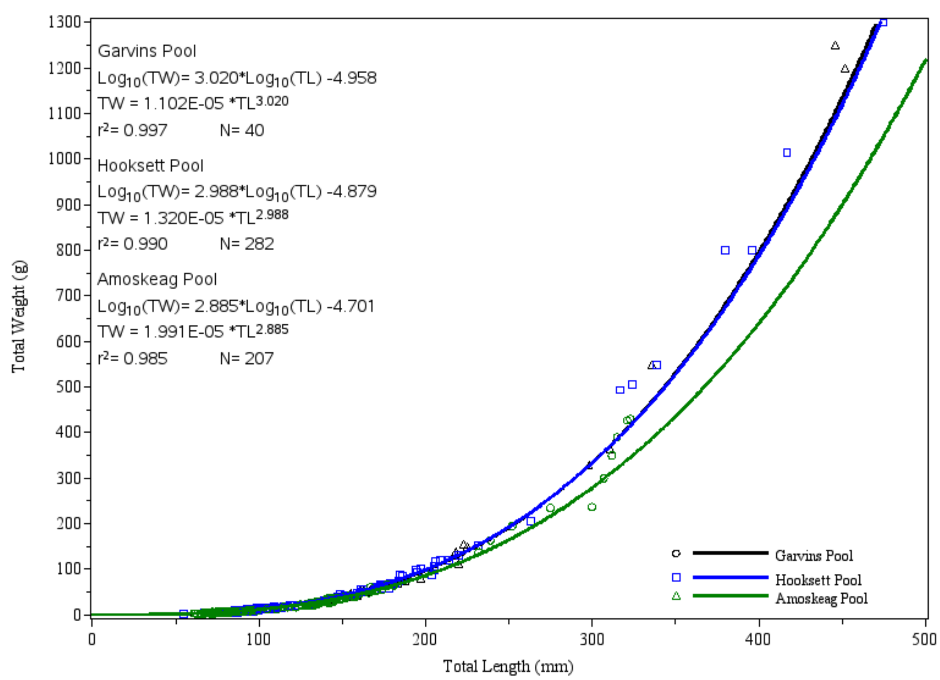


Figure 4-12-2. Empirical length-weight relations for smallmouth bass captured via electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2011.

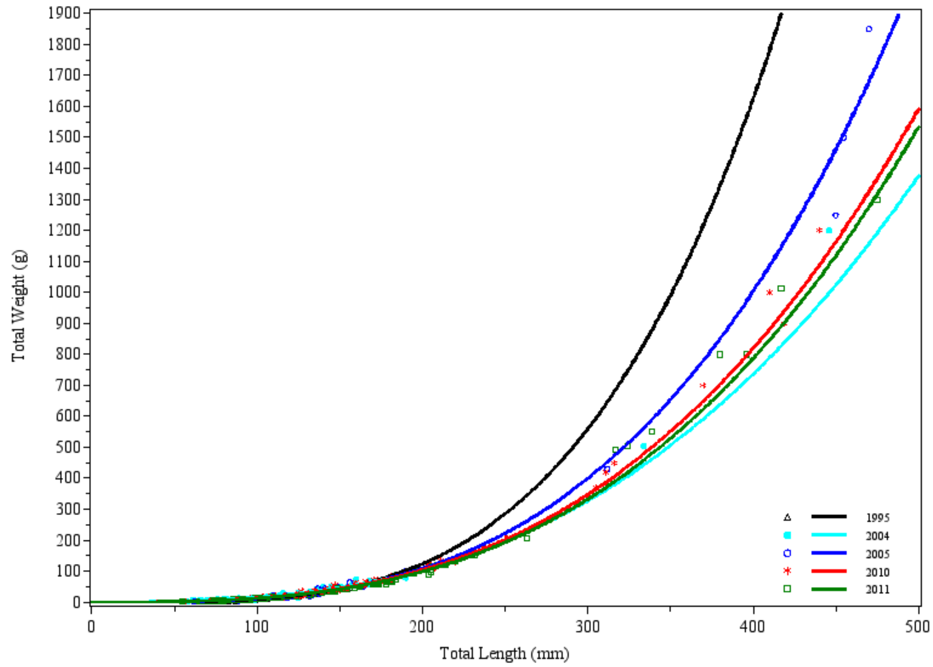


Figure 4-12-3. Empirical length-weight relations for smallmouth bass captured via electrofishing during the months of August and September of 1995, 2004, 2005, 2010, and 2011 within Hooksett Pool.

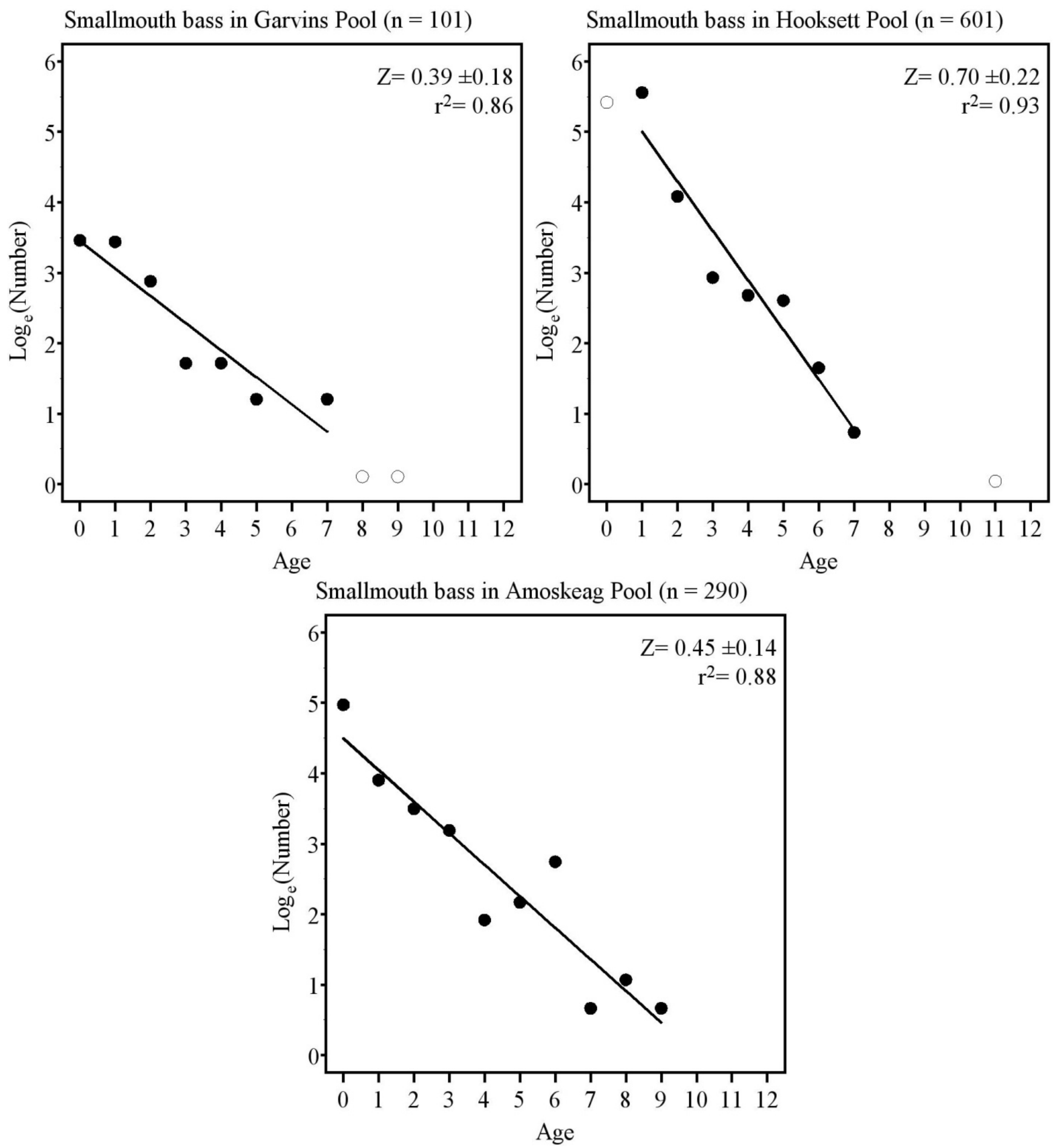


Figure 4-12-4. Catch curves comparing instantaneous total mortality rate (Z ± 95% confidence intervals) of smallmouth bass for fully recruited ages (solid circles) in Garvins, Hooksett and Amoskeag Pools based on combined 2008-2010 electrofishing catch in the Merrimack River. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

Table 4-12-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for smallmouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	14	58	344	161	78.42	14	2	600	105	166
Hooksett	72	60	468	208	131.1	72	2	1320	254	353
Amoskeag	48	64	522	243	148.34	48	2	1950	400	494
Total	134	58	522	215	134.79	134	2	1950	291	405

Table 4-12-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for smallmouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	36	70	440	202	97	36	5	1400	196	308
Hooksett	53	75	454	202	108	53	5	1400	220	352
Amoskeag	108	62	526	203	133	108	3	2200	306	528
Total	197	62	526	202	120	197	3	2200	263	452

Table 4-12-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for smallmouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	42	70	465	131	80	42	3	1500	82	244
Hooksett	477	57	440	116	44	477	3	1200	34	99
Amoskeag	161	63	259	107	42	161	3	220	22	34
Total	680	57	465	115	47	680	3	1500	34	105

Table 4-12-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for smallmouth bass collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	44	72	452	166	101	44	5	1250	147	316
Hooksett	304	55	475	107	55	303	1	1300	36	125
Amoskeag	224	61	323	108	52	224	2	430	28	62
Total	572	55	475	112	61	571	1	1300	41	135

Table 4-12-5. Regression statistics for total length (mm) vs. weight (g) for smallmouth bass from Garvins, Hooksett, and Amoskeag Pools during 2010.

Pool	N	Slope (b)[2]	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	41	2.974	-4.806	>0.99				
Hooksett	441	2.974	-4.825	0.99	NS		*	
Amoskeag	133	2.974	-4.880	0.99	NS	NS	*	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-12-6. Regression statistics for total length (mm) vs. weight (g) for smallmouth bass from Garvins, Hooksett, and Amoskeag Pools during 2011.

Pool	N	Slope (b)	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	40	3.020	-4.958	>0.99				
Hooksett	282	2.988	-4.879	>0.99	NS		NS	
Amoskeag	207	2.885	-4.701	0.99	*	*	*	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-12-7. Regression statistics for total length (mm) vs. total weight (g) for smallmouth bass sampled during the months of August and September in 1995, 2004, 2005, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]							
					Slope				Intercept			
					1995	2004	2005	2010	1995	2004	2005	2010
1995	25	3.706	-6.435	0.98								
2004	96	2.807	-4.437	0.96	*				*			
2005	37	3.201	-5.328	0.98	*	*			*	*		
2010	441	2.974	-4.825	0.99	*	*	*		*	*	*	
2011	282	2.988	-4.879	>0.99	*	*	*	NS	*	*	*	NS

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-12-8. Mean total length at age for smallmouth bass captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2008	Hooksett		2	88	117
		Amoskeag		1	104	
1	2007	Garvins		9	144	9
		Hooksett		10	144	8
		Amoskeag		8	152	9
2	2006	Garvins		1	188	
		Hooksett		8	164	15
		Amoskeag		4	204	47
3	2005	Garvins		1	308	
		Hooksett		6	272	58
		Amoskeag		4	292	57
4	2004	Garvins		1	344	
		Hooksett		7	352	20
		Amoskeag		3	360	19
5	2003	Hooksett		6	372	32
		Amoskeag		5	412	33
6	2002	Hooksett		3	424	28
		Amoskeag		5	412	29
7	2001	Hooksett		1	416	
8	2000	Amoskeag		1	492	
9	1999	Amoskeag		1	524	
11	1997	Hooksett		1	468	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-12-9. Mean total length at age for smallmouth bass captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2009	Amoskeag		2	88	161
1	2008	Garvins		10	120	5
		Hooksett	A	25	120	6
		Amoskeag	A	30	124	5
2	2007	Garvins		13	176	7
		Hooksett		9	216	20
		Amoskeag		17	192	10
3	2006	Garvins		2	248	170
		Hooksett		5	248	56
		Amoskeag		9	220	18
4	2005	Garvins		3	304	10
		Hooksett		3	340	71
		Amoskeag		2	360	300
5	2004	Garvins		2	320	221
		Hooksett		5	392	25
		Amoskeag		4	424	61
6	2003	Hooksett		1	448	
		Amoskeag		11	432	11
7	2002	Garvins		3	376	54
		Hooksett		1	456	
		Amoskeag		2	460	19
8	2001	Garvins		1	440	
		Amoskeag		2	452	114
9	2000	Amoskeag		1	528	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-12-10. Mean total length at age for smallmouth bass captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins	BA	25	88	4
		Hooksett	A	196	92	1
		Amoskeag	B	119	84	1
1	2009	Garvins		9	132	14
		Hooksett		214	116	2
		Amoskeag		13	128	12
2	2008	Garvins		2	144	79
		Hooksett		40	172	8
		Amoskeag		13	168	10
3	2007	Garvins		2	260	101
		Hooksett		7	216	35
		Amoskeag		12	200	13
4	2006	Garvins		1	240	
		Hooksett		4	340	36
		Amoskeag		2	232	142
5	2005	Garvins		1	352	
		Hooksett		2	416	28
6	2004	Hooksett		1	440	
9	2001	Garvins		1	464	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-12-11. Frequency distribution of external parasite loads for smallmouth bass collected from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	75	55.2	29	21.3	32	23.5
Hooksett [B]	496	55.6	331	37.1	65	7.3
Amoskeag [B]	351	66.4	141	26.7	37	7.0

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.13 Spottail Shiner

Biocharacteristics of the spottail shiner population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.13.1 Length

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of spottail shiner collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-13-1 through 4-13-4. Over the four years of sampling (2008-2011), the total length of spottail shiner ranged from 33 to 103 mm in Garvins Pool, from 39 to 122 mm in Hooksett Pool, and from 54 to 80 mm in Amoskeag Pool.

4.13.2 Condition

The length-weight curve based on the 2010 catch showed spottail shiner in Hooksett Pool grew significantly more rotund (or "fatter") with increasing length than in Garvins Pool, but the length-weight regression was for limited size range and had high variation, as indicated by a low r2 (Figure 4-13-1, Table 4-13-5). The y-intercept parameter in the length-weight relation was significantly higher for spottail shiner in Garvins Pool than in Hooksett Pool, which indicates spottail shiner in Garvins Pool weighed more at a given length early in life than in Hooksett Pool. The slopes of the length-weight curves based on the 2011 catch showed no significant differences in the amount of growth with increasing length for spottail shiner in Hooksett and Garvins Pools ($F = 2.72$, $P = 0.1003$, Figure 4-13-2, Table 4-13-6). The 2011 length-weight relations of spottail shiner were less variable than the 2010 data. When a common slope was assumed for the length-weight relations of spottail shiner caught during 2011 in Garvins and Hooksett Pools, the y-intercept parameter indicated spottail shiner were in better condition (weighed more at a given length) in Garvins Pool than in Hooksett Pool (Table 4-13-6).

The slope of the length-weight relation of spottail shiner from Hooksett Pool was significantly different between the 1995 and 2011 catch (Figure 4-13-3, Table 4-3-7). The length-weight relation of spottail shiner caught in Hooksett Pool during 1995 indicated common shiner grew more rotund with increasing length (slope > 3), while the 2011 length-weight relation indicated spottail shiner grew more slender with increasing length (slope < 3). The y-intercept parameter in the length-weight relation of spottail shiner was significantly higher based on the 2011 catch than on the 19995 catch, which indicates spottail shiner in 2011 weighed more at a given length early in life (e.g., young of the year) than in 1995.

4.13.3 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for spottail shiner collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Table 4-13-8. The prevalence of external parasites was significantly greater in Hooksett Pool than was observed in Garvins Pool.

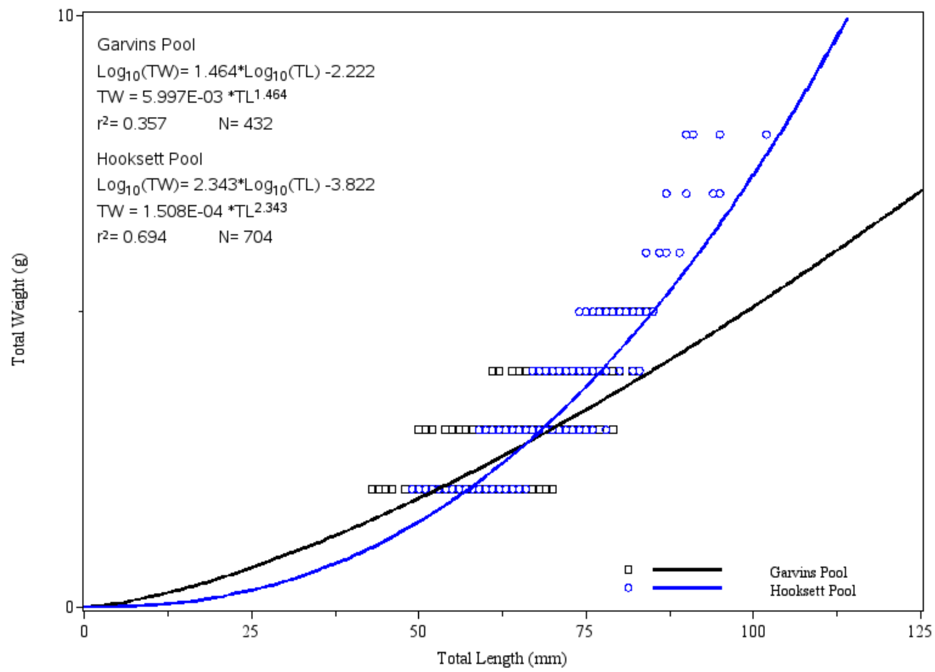


Figure 4-13-1. Empirical length-weight relations for spottail shiner captured via electrofishing within Garvins and Hooksett Pools during 2010.

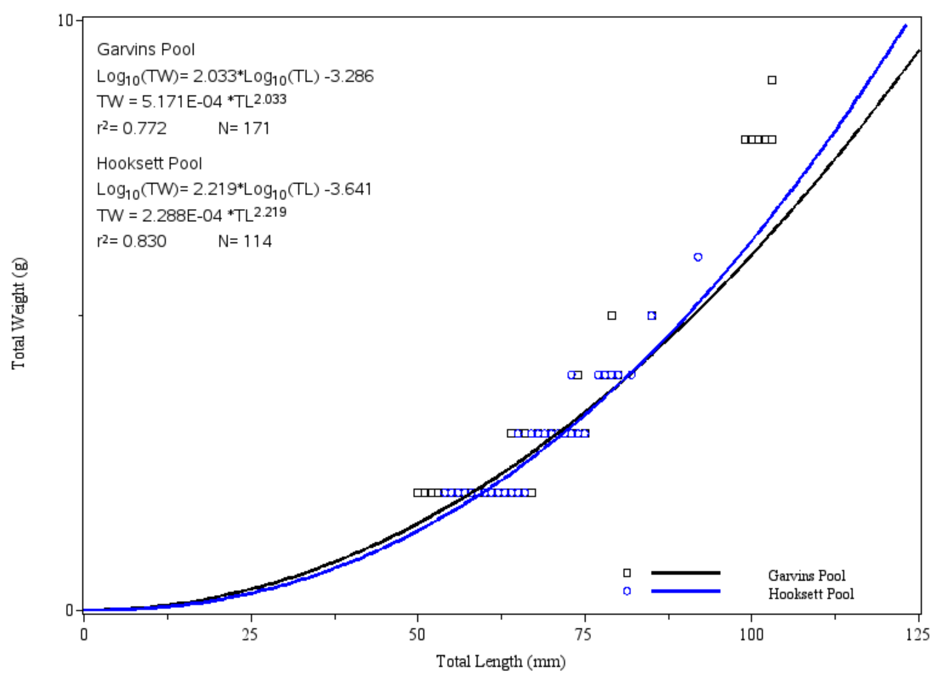


Figure 4-13-2. Empirical length-weight relations for spottail shiner captured via electrofishing within Garvins and Hooksett Pools during 2011.

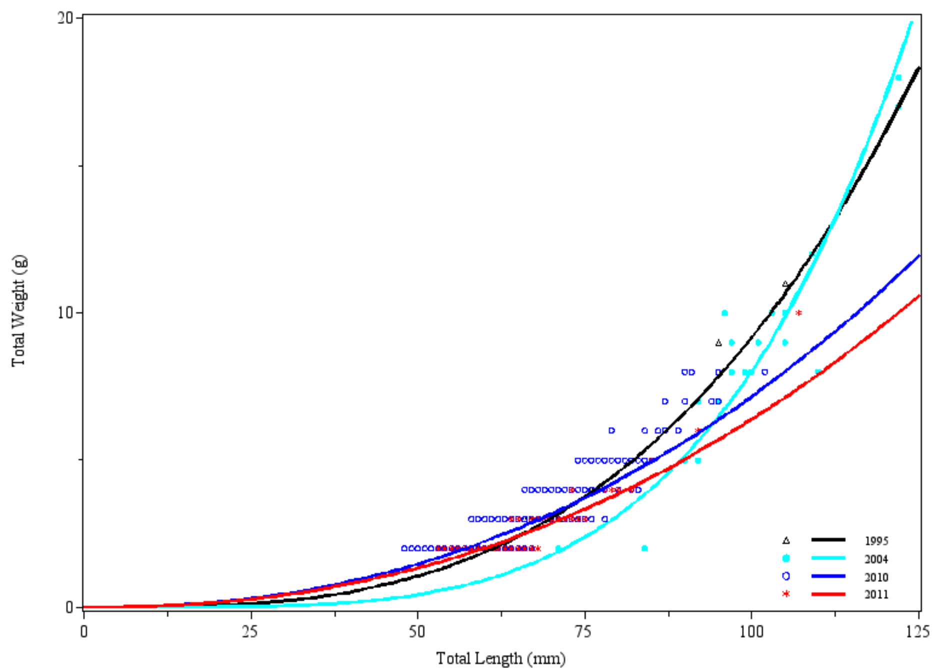


Figure 4-13-3. Empirical length-weight relations for spottail shiner captured via electrofishing during the months of August and September of 1995, 2004, 2010, and 2011 within Hooksett Pool.

Table 4-13-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) for spottail shiner collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)				
	N	Min.	Max.	Mean	STD
Garvins	6	39	51	44	4
Hooksett	82	39	114	48	13
Amoskeag	2	54	80	67	18
Total	90	39	114	48	13

Table 4-13-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) for spottail shiner collected via electrofishing in Garvins and Hooksett Pools during April, May and September 2009.

Pool	Total Length (mm)				
	N	Min.	Max.	Mean	STD
Garvins	1	99	99	99	
Hooksett	31	50	122	88	23
Total	32	50	122	89	22

Table 4-13-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) for spottail shiner collected via electrofishing in Garvins and Hooksett Pools during August, September and October 2010.

Pool	Total Length (mm)				
	N	Min.	Max.	Mean	STD
Garvins	551	36	84	62	9
Hooksett	913	43	102	64	8
Total	1464	36	102	63	8

Table 4-13-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) for spottail shiner collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

Pool	Total Length (mm)				
	N	Min.	Max.	Mean	STD
Garvins	615	33	103	52	10
Hooksett	209	44	109	62	9
Amoskeag	1	54	54	54	.
Total	825	33	109	55	11

Table 4-13-5. Regression statistics for total length (mm) vs. weight (g) for spottail shiner from Garvins and Hooksett Pools during 2010.

Pool	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	432	1.463	-2.222	0.36				
Hooksett	727	2.282	-3.709	0.66	*		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$

Table 4-13-6. Regression statistics for total length (mm) vs. weight (g) for spottail shiner from Garvins and Hooksett Pools during 2011.

Pool	N	Slope (b)[2]	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	171	2.108	-3.422	0.77				
Hooksett	121	2.108	-3.438	0.82	NS		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, $p \leq 0.05$
NS = not significant, $p > 0.05$
[2] Assumed common slope due to non-significant finding

Table 4-13-7. Regression statistics for total length (mm) vs. total weight (g) for spottail shiner sampled during the months of August and September in 1995, 2004, 2005, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)	Intercept ($log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]					
					Slope			Intercept		
					1995	2004	2010	1995	2004	2010
1995	29	3.103	-5.244	0.94						
2004	21	4.219	-7.534	0.84	*			*		
2010	727	2.282	-3.709	0.66	*	*		*	*	
2011	121	2.257	-3.709	0.82	*	*	NS	*	*	NS

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-13-8. Frequency distribution of external parasite loads for spottail shiners collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	1127	97.1	30	2.6	4	0.3
Hooksett [B]	1066	87.5	142	11.7	10	0.8
Amoskeag	2	100.0	0	0.0	0	0.0

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

4.14 White Sucker

Biocharacteristics of the white sucker population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.14.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of white sucker collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-14-1 through 4-14-4. Over the four years of sampling (2008-2011), the total length of white sucker ranged from 75 to 549 mm in Garvins Pool, from 68 to 561 mm in Hooksett Pool, and from 91 to 554 mm in Amoskeag Pool. Total weight of white sucker ranged from 4 to 1,710 g in Garvins Pool, from 3 to 1,800 g in Hooksett Pool, and from 4 to 2,110 g in Amoskeag Pool.

4.14.2 Condition

The slopes of the length-weight curves were not significantly different among the three pools for white sucker caught during 2008 ($F = 0.87$, $P = 0.3519$) and 2009 ($F = 0.11$, $P = 0.8966$). This finding indicates that white sucker maintained similar incremental weight gain with increasing length between Hooksett and Amoskeag Pools during 2008 and among Garvins, Hooksett and Amoskeag Pools during 2009 (Figures 4-14-1 and 4-14-2, Tables 4-14-5 and 4-14-6). As a result, a common slope was assumed for the length-weight relations for each catch from 2008 and 2009. Although no differences in the *y*-intercept parameter in the length-weight relation were detected by the ANCOVA based on the 2008 catch, the *y*-intercept parameter from 2009 length-weight relation was significantly higher for white sucker in Amoskeag Pool than in Garvins and Hooksett Pool, which supports that white sucker from Amoskeag Pool were in better condition than in Garvins and Hooksett Pool, and in similar condition between Garvins and Hooksett Pool

Sample sizes of white sucker were insufficient for comparison of condition among pools during 2010. However, a length-weight relation for white sucker sampled during 2010 in Hooksett Pool is presented in Figure 4-14-3. The length-weight curve based on the 2011 catch showed white sucker in Hooksett Pool grew significantly more rotund (or “fatter”) with increasing length than in Garvins Pool (Figure 4-14-4, Table 4-14-7). The *y*-intercept parameter in the length-weight relation was significantly higher for white sucker in Garvins Pool than in Hooksett Pool, which indicates white sucker in Garvins Pool weighed more at a given length early in life than in Hooksett Pool, but gained less weight with increasing length than in Hooksett Pool.

The length-weight relation based on 2004 catch from Hooksett Pool showed allometric growth (slope < 3) that produced significantly more slender white sucker with increasing length compared to the near isometric growth (slope ≈ 3) based on the length-weight relation of the most recent annual catch of 2011 (Figure 4-14-5, Table 4-14-8). However, the *y*-intercept parameter from the 2011 length-weight relation was significantly lower than the 2004 estimate, which suggests the 2011 young-of-year white sucker from Hooksett Pool were in worse condition (lower weight for a given length) than those collected during the 2004 sampling year.

4.14.3 Age-Length

The mean total length at age (±95% C.I.) of white sucker collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 are presented in Tables 4-14-9 through 4-14-11. For years with available age data (2008-2010), age of white sucker ranged from age-0 to age-8 in Garvins Pool, from age-0 to age-12 in Hooksett Pool, and from age-0 to age-12 in Amoskeag Pool. During 2009, the mean length at age of age-2 and age-3 white sucker collected in Hooksett and Garvins Pools differed significantly from one another, with larger mean length at age for white sucker in Garvins Pool for both cohorts. The mean length at age of age-2 white sucker in Hooksett and Amoskeag Pools and age-4 white sucker in Garvins and Hooksett Pools did not differ significantly for individuals collected during 2009. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools for all cohorts of white sucker collected during 2008 and 2010.

4.14.4 Mortality

The total instantaneous mortality rates (Z) for white sucker did not significantly differ between Hooksett (Z = 0.18) and Amoskeag Pools (Z = 1.04; Figure 4-14-6, ANCOVA, $F = 5.21$, $P = 0.063$). The catch curve regressions for white sucker were not statistically significant for Hooksett ($F = 2.88$, $P = 0.150$) and Amoskeag Pool ($F = 27.00$, $P = 0.121$). The annual mortality rates of white sucker based on these estimates were 17% for Hooksett Pool and 65% for Amoskeag Pool.

4.14.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for white sucker collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 are presented in Table 4-14-12. The prevalence of external parasites was significantly greater in Hooksett Pool than was observed in Garvins Pool. The frequency distributions of external parasites on white sucker in Amoskeag Pool did not differ from those observed within either Garvins or Hooksett Pools.

The frequency distribution of internal parasite loads, as assessed by presence/absence, for white sucker collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008 and 2009 are presented in Table 4-14-13. There was no significant difference in the prevalence of internal parasites between Garvins and Hooksett Pools for white sucker collected during 2008-2009. However, internal parasites were more prevalent from white sucker collected in Garvins and Hooksett Pools than in Amoskeag Pool.

4.14.6 Gender, Reproduction, and Fecundity

The percentages of male and female white sucker caught in Garvins, Hooksett and Amoskeag Pools by electrofishing during 2008-2009 are shown in Table 4-14-14. The percentage of male and female white sucker in the combined 2008-2009 catch was not significantly different in Garvins Pool (Z-statistic = 0.53, $P = 0.652$) and Amoskeag Pool (Z-statistic = 0.98, $P = 0.378$), but the percentage of female white sucker in Hooksett Pool (61%) was significantly greater than the percentage of males (39%; Z-statistic = -5.20, $P < 0.001$). The percentage of female white sucker in Hooksett Pool was significantly greater than in either Garvins (q-statistic = 4.18, $P < 0.05$) or Amoskeag Pool (q-statistic = 4.24, $P < 0.05$), but was the same between Garvins and Amoskeag Pool (q-statistic = 0.64, $P > 0.05$). Conversely, the percentage of male white sucker in Hooksett Pool was significantly lower than in either Garvins or Amoskeag Pools, but was the same between Garvins and Amoskeag Pool.

The frequency and percent composition of each stage of maturity for white sucker is presented in Table 4-14-15. The percentage of mature (gravid or milting, ripe and running, partially spent, spent and semi-gravid) male white sucker was significantly greater in Garvins Pool than in either Hooksett (q-statistic = 4.13, P <0.05) or Amoskeag Pool (q-statistic = 4.03, P <0.05), but were similar between Hooksett and Amoskeag Pools (q-statistic = 1.13, P >0.05) (Table 4-14-16). The proportion of mature female white sucker did not differ significantly among Garvins, Hooksett and Amoskeag Pools (X^2-statistic = 4.61, $P = 0.099$).

Table 4-14-17 presents the gonadosomatic index (GSI) values for gravid female and milting male white sucker for Garvins, Hooksett and Amoskeag Pools during 2008 and 2009. As suggested by overlapping 95% confidence intervals, there were no differences among the GSI values for male or female white sucker in Garvins, Hooksett and Amoskeag Pools. This finding supports the similarity of the white sucker reproductive state among Garvins, Hooksett and Amoskeag Pools during the spring sampling period and suggests no appreciable harm from Merrimack Station's thermal discharge.

The ages at 50% maturity for male and female white sucker captured by electrofishing from Garvins, Hooksett and Amoskeag Pools during combined 2008-2009 are shown in Figure 4-14-7 and Table 4-14-18. The age at 50% maturity for male white sucker was 3.4 years in Garvins, 3.7 years in Hooksett Pool and 4.1 years in Amoskeag Pool. The age at 50% maturity for female white suckers was 4.6 years in Garvins Pool, 6.2 years in Hooksett Pool and 5.3 years in Amoskeag Pool. The mean length at 50% maturity for male white sucker was 298 mm in Garvins Pool, 221 mm in Hooksett Pool and 224 mm in Amoskeag Pool. For female white sucker, the mean length at 50% maturity was 391 mm in Garvins Pool, 401 mm in Hooksett Pool and 309 mm in Amoskeag Pool.

A significant relation existed between length and fecundity for ripe female white sucker within Garvins (F = 81.90, P < 0.001), Hooksett (F = 4.89, P = 0.035) and Amoskeag (F = 43.85, P = 0.001) Pools. Although sample sizes were insufficient for comparing length-fecundity of white sucker among pools, the regression statistics for those relations are presented in Table 4-14-19. Estimates for white sucker fecundity from individuals collected during 2008 and 2009 ranged from 17,254 to 59,494 eggs per ripe female in Garvins Pool, 16,400 to 67,333 eggs per ripe female in Hooksett Pool and 18,124 to 61,863 eggs per ripe female in Amoskeag Pool.

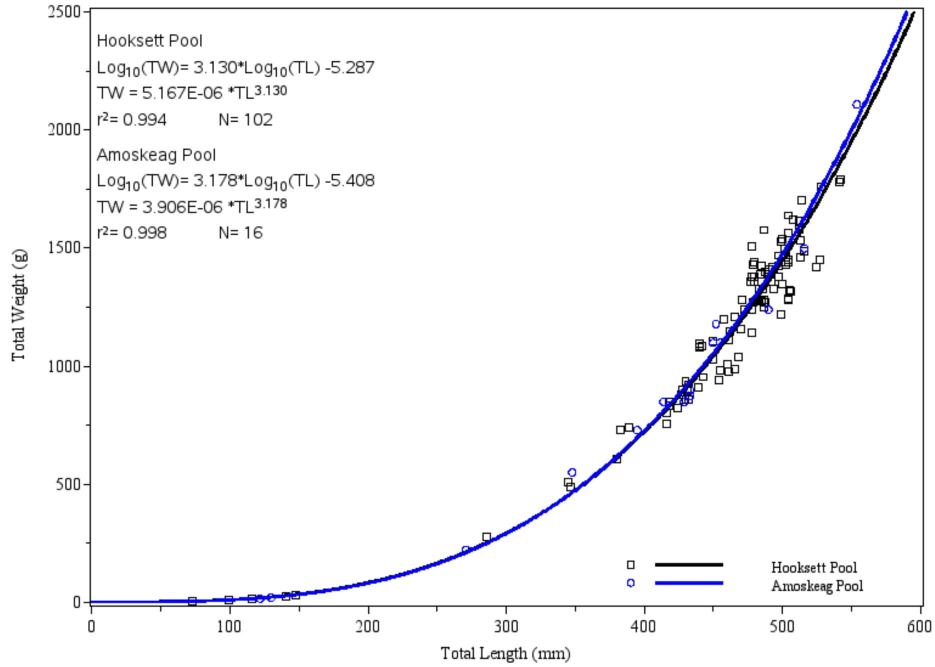


Figure 4-14-1. Empirical length-weight relations for white sucker captured via electrofishing within Hooksett and Amoskeag Pools during 2008.

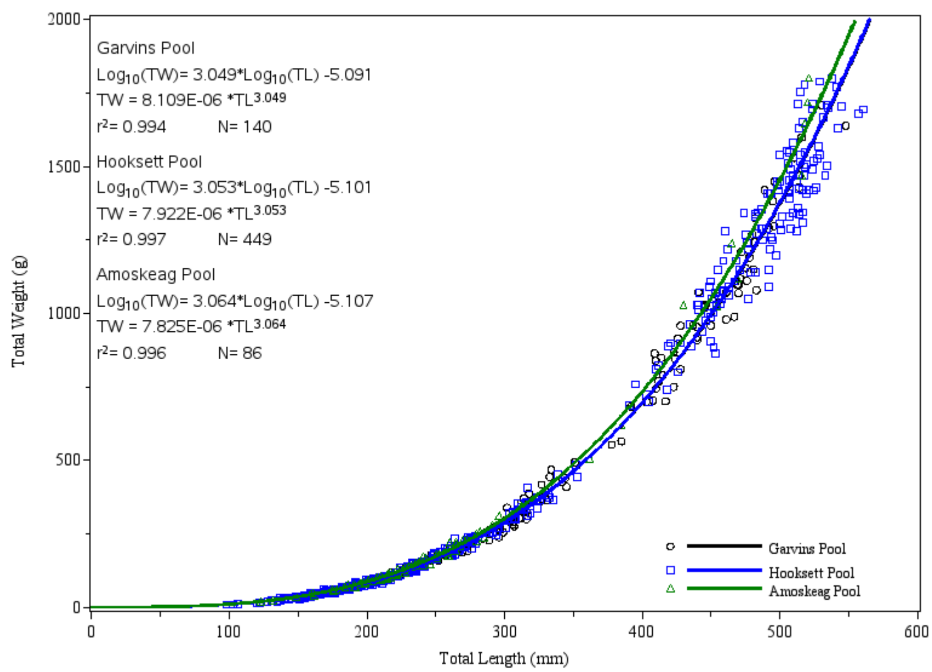


Figure 4-14-2. Empirical length-weight relations for white sucker captured via electrofishing within Garvins Pool, Hooksett Pool, and Amoskeag Pool in 2009.

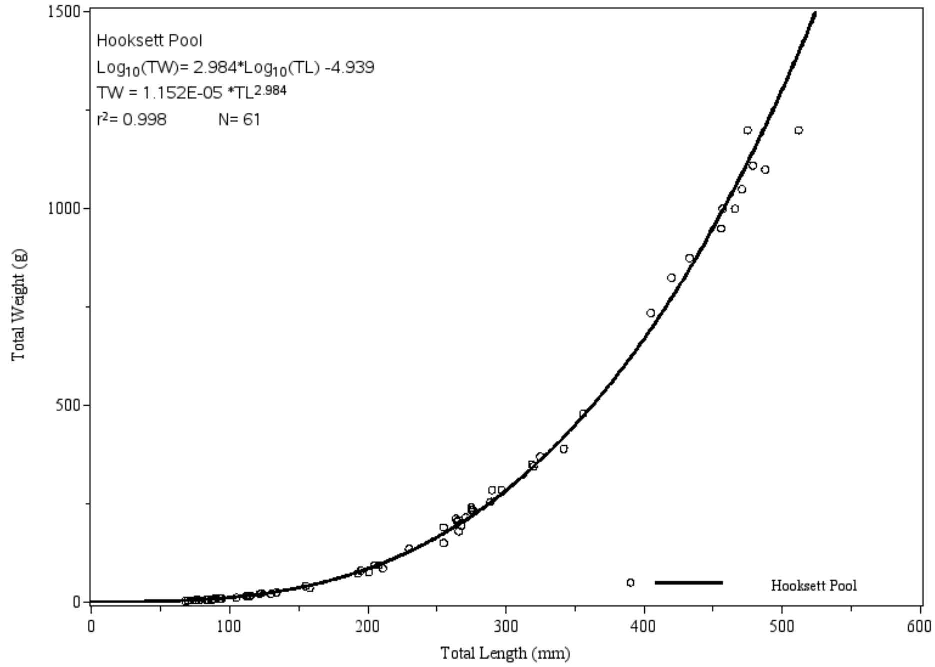


Figure 4-14-3. Empirical length-weight relation for white sucker captured via electrofishing within Hooksett Pool in 2010.

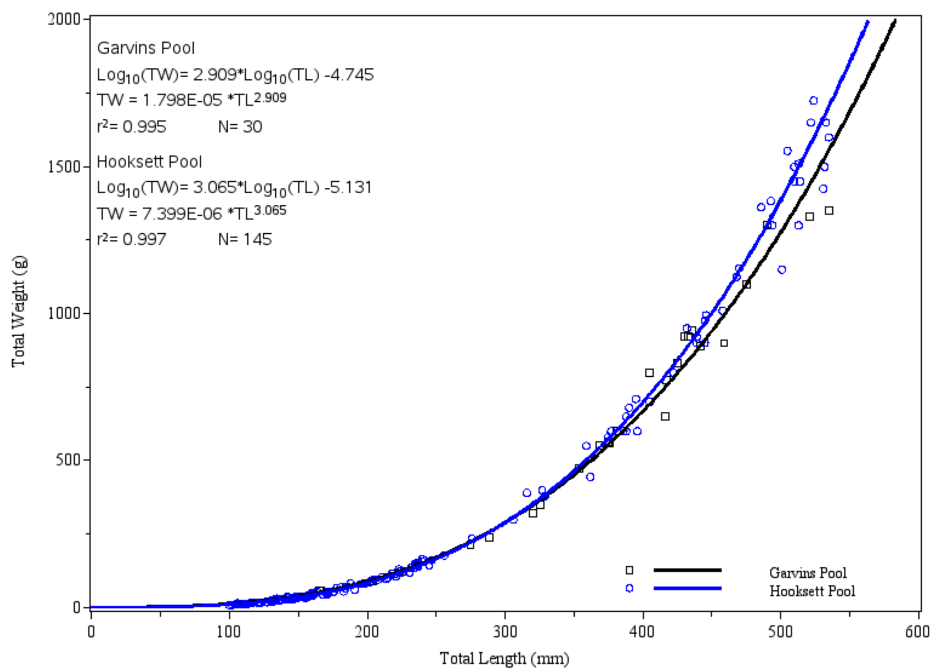


Figure 4-14-4. Empirical length-weight relations for white sucker captured via electrofishing within Garvins and Hooksett Pools in 2011.

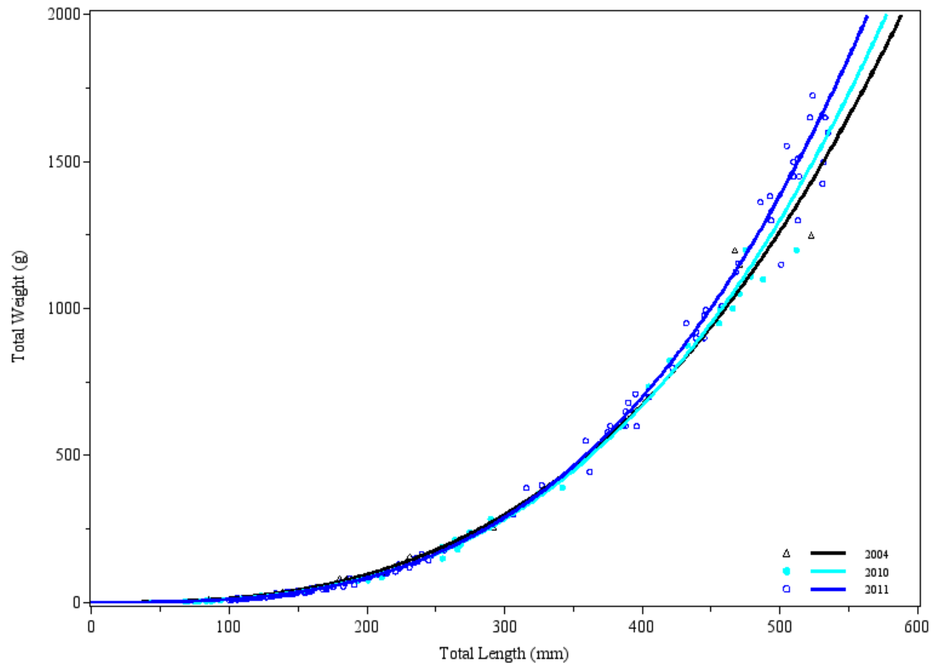


Figure 4-14-5. Empirical length-weight relations for white sucker captured via electrofishing during the months of August and September of 2004, 2010, and 2011 within Hooksett Pool.

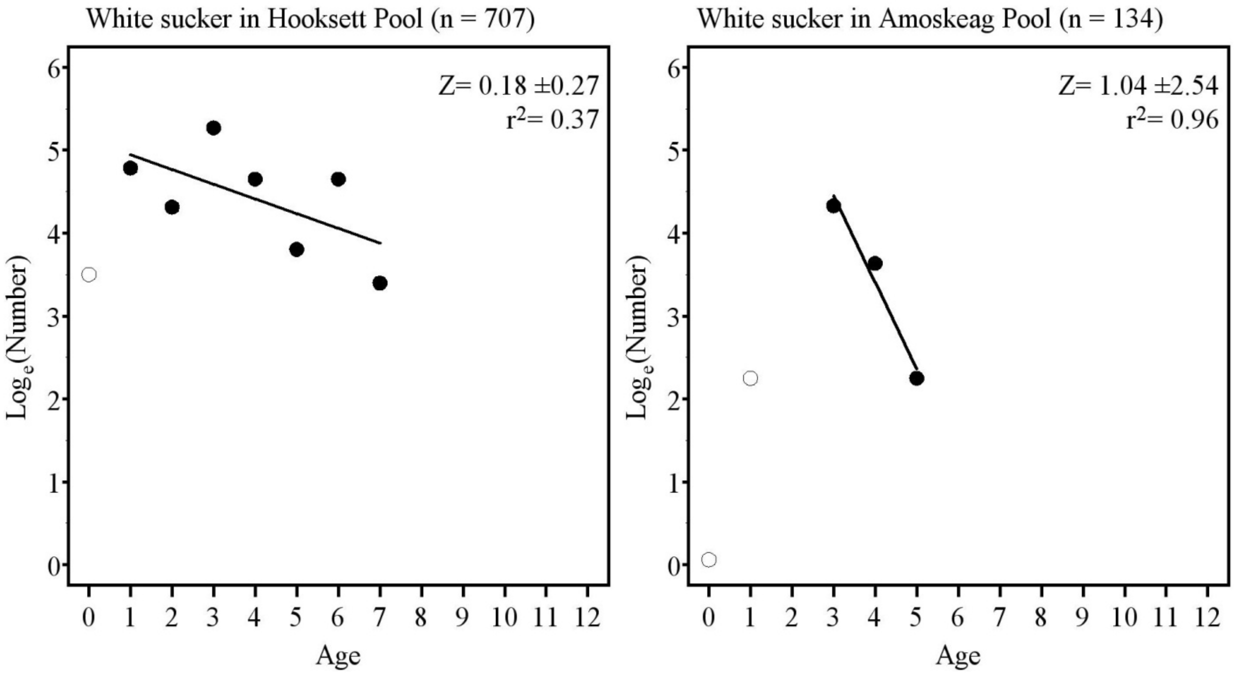


Figure 4-14-6. Catch curves comparing instantaneous total mortality rate (Z ± 95% confidence intervals) of white sucker for fully recruited ages (solid circles) in Hooksett and Amoskeag Pools based on combined 2008-2010 electrofishing catch in the Merrimack River. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

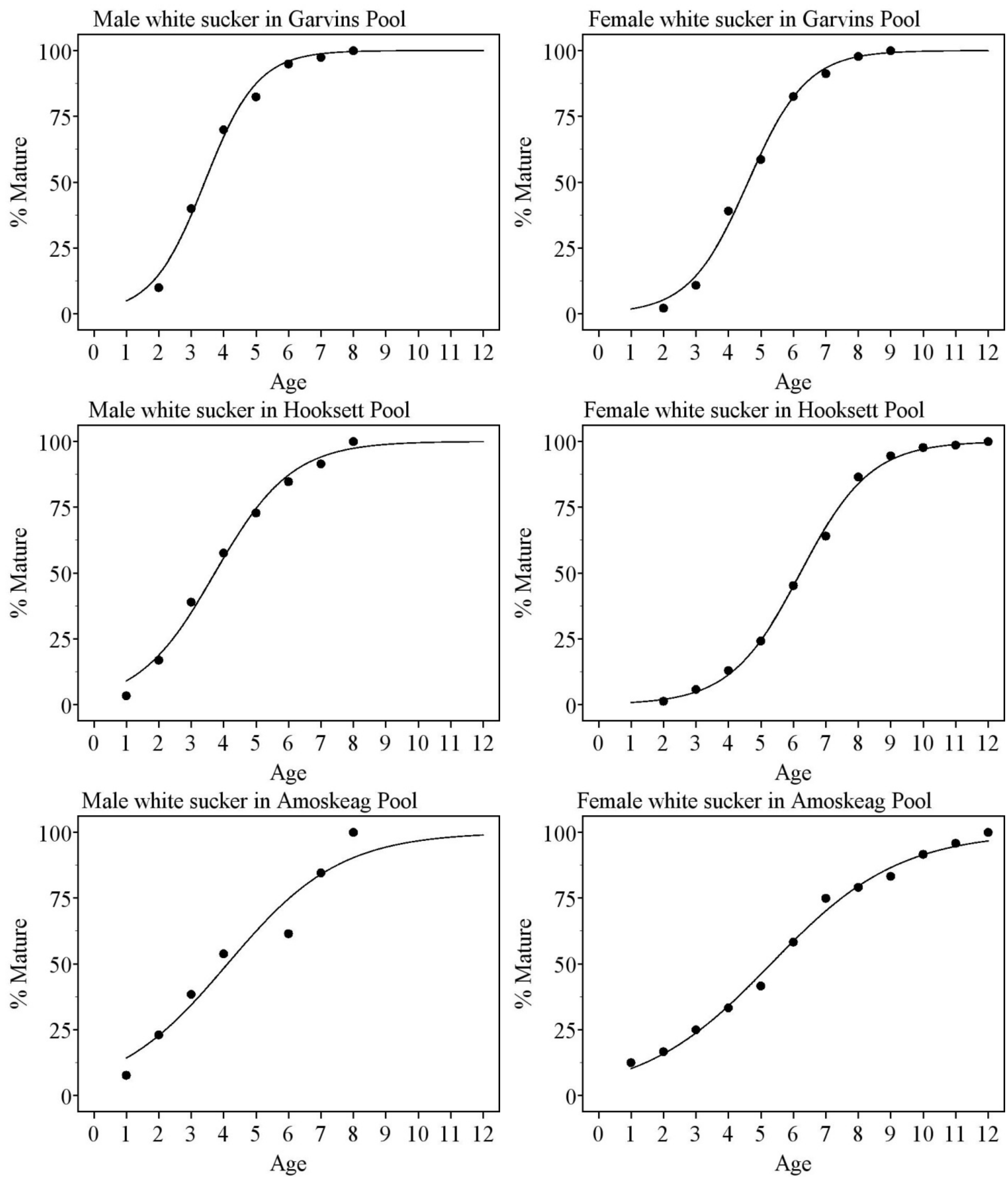


Figure 4-14-7. Calculated (solid line) and observed (dot) proportion mature at age of female and male white sucker in Garvins, Hooksett, and Amoskeag Pools of the Merrimack River based on the combined 2008-2009 electrofishing catch.

Table 4-14-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for white sucker collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Total Length (mm)					Weight (g)				
	N	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	26	177	507	315	112	26	65	1695	523	518
Hooksett	220	73	542	336	158	220	4	1790	718	626
Amoskeag	20	122	554	417	118	20	16	2110	1050	574
Total	266	73	554	340	153	266	4	2110	724	621

Table 4-14-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for white sucker collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Total Length (mm)					Weight (g)				
	N	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	151	176	549	355	96	151	57	1710	601	452
Hooksett	453	73	561	292	134	453	3	1800	461	559
Amoskeag	91	91	521	245	91	91	10	1802	249	376
Total	695	73	561	300	126	695	3	1802	464	525

Table 4-14-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for white sucker collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Total Length (mm)					Weight (g)				
	N	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	4	75	98	84	11	4	4	10	6	3
Hooksett	65	68	512	239	136	65	3	1200	281	362
Amoskeag	15	130	392	287	59	15	26	600	274	133
Total	84	68	512	240	128	84	3	1200	267	328

Table 4-14-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for white sucker collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

Pool	Total Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	31	143	535	346	115	31	31	1350	561	417
Hooksett	154	100	535	245	136	154	9	1725	324	479
Amoskeag	4	273	438	327	75	4	216	750	390	244
Total	189	100	535	263	137	189	9	1725	364	472

Table 4-14-5. Regression statistics for total length (mm) vs. weight (g) of white sucker from Hooksett and Amoskeag Pools during 2008.

Pool	N	Slope (b)[2]	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Hooksett	Amoskeag	Hooksett	Amoskeag
Hooksett	102	3.140	-5.315	>0.99				
Amoskeag	16	3.140	-5.320	>0.99	NS		NS	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-14-6. Regression statistics for total length (mm) vs. weight (g) of white sucker from Garvins, Hooksett, and Amoskeag Pools during 2009.

Pool	N	Slope (b)[2]	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	140	3.054	-5.102	>0.99				
Hooksett	449	3.054	-5.102	>0.99	NS		NS	
Amoskeag	86	3.054	-5.083	>0.99	NS	NS	*	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-14-7. Regression statistics for total length (mm) vs. weight (g) of white sucker from Garvins and Hooksett Pools during 2011.

Pool	N	Slope (b)	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	30	2.909	-4.745	>0.99				
Hooksett	145	3.066	-5.131	>0.99	*		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-14-8. Regression statistics for total length (mm) vs. total weight (g) of white sucker sampled during the months of August and September in 2004, 2010, and 2011 from Hooksett Pool.

Year	N	Slope (b)	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					2004	2010	2004	2010
2004	15	2.819	-4.507	>0.99				
2010	61	2.984	-4.939	>0.99	*		*	
2011	145	3.065	-5.131	>0.99	*	*	*	*

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-14-9. Mean length at age (± 95% C.I.) for white sucker captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
1	2007	Hooksett		28	132	7
		Amoskeag		1	124	
2	2006	Garvins		2	212	66
		Hooksett		53	164	6
		Amoskeag		1	132	
3	2005	Garvins		9	236	27
		Hooksett		10	240	30
4	2004	Garvins		3	272	118
		Hooksett		4	244	57
		Amoskeag		2	308	243
5	2003	Garvins		2	388	98
		Hooksett		5	388	60
		Amoskeag		2	412	107
6	2002	Garvins		4	424	71
		Hooksett		21	432	11
		Amoskeag		2	432	114
7	2001	Garvins		2	460	66
		Hooksett		24	468	8
		Amoskeag		5	448	16
8	2000	Garvins		2	508	6
		Hooksett		40	484	5
		Amoskeag		2	464	167
9	1999	Hooksett		19	500	7
		Amoskeag		1	508	
10	1998	Hooksett		6	516	11
		Amoskeag		2	536	117
11	1997	Hooksett		2	520	88
		Amoskeag		1	516	
12	1996	Hooksett		3	528	24
		Amoskeag		1	512	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-14-10. Mean length at age (± 95% C.I.) for white sucker captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2009	Hooksett		1	92	
		Amoskeag		1	128	
1	2008	Garvins		3	212	52
		Hooksett		112	172	4
		Amoskeag		13	180	28
2	2007	Garvins	A	30	248	11
		Hooksett	B	128	216	5
		Amoskeag	B	46	224	8
3	2006	Garvins	A	42	308	7
		Hooksett	B	50	276	9
		Amoskeag		10	276	12
4	2005	Garvins	A	23	416	19
		Hooksett	A	25	400	19
		Amoskeag		3	420	91
5	2004	Garvins		8	456	19
		Hooksett		26	472	7
6	2003	Garvins		10	476	16
		Hooksett		25	496	8
		Amoskeag		3	500	52
7	2002	Garvins		3	516	46
		Hooksett		19	516	6
		Amoskeag		2	488	202
8	2001	Garvins		1	516	
		Hooksett		11	516	12
		Amoskeag		1	520	
10	1999	Hooksett		1	556	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-14-11. Mean length at age (± 95% C.I.) for white sucker captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins		4	84	13
		Hooksett		15	84	6
1	2009	Hooksett		8	120	7
		Amoskeag		1	132	
2	2008	Hooksett		5	212	40
3	2007	Hooksett		13	268	15
		Amoskeag		8	276	22
4	2006	Hooksett		7	296	20
		Amoskeag		4	312	12
5	2005	Hooksett		3	440	68
		Amoskeag		1	328	
6	2004	Hooksett		7	460	16
7	2003	Hooksett		2	496	104

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort.
No letters indicates that inadequate sample sizes (n = 15) prevented between pool comparisons for a cohort

Table 4-14-12. Frequency distribution of external parasite loads for white sucker collected via electrofishing from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	178	84.0	28	13.2	6	2.8
Hooksett [B]	616	69.1	190	21.3	86	9.6
Amoskeag [AB]	108	83.1	13	10.0	9	6.9

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

Table 4-14-13. Frequency of internal parasites for white sucker collected from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008 and 2009.

Pool	Absent		Present	
	N	%	N	%
Garvins [A]	336	94.9	18	5.1
Hooksett [A]	511	96.2	20	3.8
Amoskeag [B]	60	100.0	0	0.0

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

Table 4-14-14. Frequency of male and female white sucker collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

Pool	Gender[1]	2008		2009		Total	
		N	%	N	%	N	%
Garvins	Male [A]	17	65.4	75	49.7	92	52.0
	Female [A]	9	34.6	76	50.3	85	48.0
Hooksett	Male [B]	50	29.1	176	43.5	226	39.2
	Female [B]	122	70.9	229	56.5	351	60.8
Amoskeag	Male [A]	8	40.0	49	58.3	57	54.8
	Female [A]	12	60.0	35	41.7	47	45.2

Notes: 1 – Different letters indicate significant within pool between gender differences (2008-2009 combined).

Table 4-14-15. Frequency distribution of the reproductive condition of white sucker (sexes combined) collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

Reproductive condition	Garvins		Hooksett		Amoskeag		Total	
	N	%	N	%	N	%	N	%
Gravid or milting (ripe)	17	9.6	39	6.5	12	11.0	68	7.7
Ripe and running	5	2.8	8	1.3	2	1.8	15	1.7
Partially spent	6	3.4	32	5.3	3	2.8	41	4.6
Spent	35	19.8	163	27.1	7	6.4	205	23.1
Immature	84	47.5	305	50.7	71	65.1	460	51.9
Not gravid or not milting (resting)	12	6.8	45	7.5	11	10.1	68	7.7
Semi-gravid or semi-milting (developing)	18	10.2	9	1.5	3	2.8	30	3.4
Total	177	100.0	601	100.0	109	100.0	887	100.0

Table 4-14-16. Percent maturity of female and male white sucker collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

Pool	Male	Female
Garvins	45.7 [A]	60.0 [A]
Hooksett	28.3 [B]	66.1 [A]
Amoskeag	22.8 [B]	51.1 [A]

Notes: Different letters indicate significant within gender between pool differences (2008-2009 combined).

Table 4-14-17. Gonadosomatic index (GSI, %) of gravid female and milting male white sucker collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

	Male				Female			
Pool	N	95% LCL	Mean GSI	95% UCL	N	95% LCL	Mean GSI	95% UCL
Garvins	4	0.8	3.2	5.7	13	14.5	16.6	18.7
Hooksett	8	1.6	7.2	12.7	31	11.5	13.4	15.4
Amoskeag	3	-0.3	4.5	9.3	9	13.7	17.2	20.7
Total	15	2.8	5.6	8.4	53	13.5	14.8	16.2

Table 4-14-18. Age and length at 50% maturity of male and female white sucker collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

	Age at 50% Maturity		Length (mm) at 50% Maturity	
Pool	Male	Female	Male	Female
Garvins	3.4	4.6	298	391
Hooksett	3.7	6.2	221	401
Amoskeag	4.1	5.3	224	309

Table 4-14-19. Regression statistics for total length (mm) vs. fecundity of female white sucker collected from Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009 (combined).

Pool	N	Slope (b)	Intercept ($\log_{10} a$)	R^2	p-value
Garvins	13	3.119	-3.796	0.88	<0.0001
Hooksett	30	2.575	-2.363	0.45	0.035
Amoskeag	8	2.700	-2.641	0.88	0.0006

4.15 Yellow Perch

Biocharacteristics of the yellow perch population are described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools of the Merrimack River during 2008-2011.

4.15.1 Length and Weight

The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) of yellow perch collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008-2011 are presented in Tables 4-15-1 through 4-15-4. Over the four years of sampling (2008-2011), the total length of yellow perch ranged from 60 to 338 mm in Garvins Pool, from 61 to 304 mm in Hooksett Pool, and from 46 to 217 mm in Amoskeag Pool. Total weight of yellow perch ranged from 1 to 436 g in Garvins Pool, from 1 to 360 g in Hooksett Pool, and from 1 to 120 g in Amoskeag Pool.

4.15.2 Condition

The length-weight curve based on the 2008 catch showed that yellow perch in Hooksett Pool grew significantly more rotund (or "fatter") with increasing length than in Garvins Pool (Figure 4-15-1, Table 4-15-5). The length-weight curve based on the 2011 catch showed that yellow perch in Garvins Pool grew significantly more rotund (or "fatter") with increasing length than in Hooksett Pool (Figure 4-15-4, Table 4-15-7), and the length-weight curve based on the 2009 catch showed no significant difference between Garvins and Hooksett Pools in incremental weight gain with increasing length (Figure 4-15-2, Table 4-15-6). The *y*-intercept parameter in the length-weight relation was significantly higher for yellow perch in Garvins Pool than in Hooksett Pool based on the 2008 and 2009 catch, which indicates yellow perch in Garvins Pool weighed more at a given length early in life than in Hooksett Pool. The opposite was observed for the 2011 catch, where the *y*-intercept parameter in the length-weight relation was significantly higher for yellow perch in Hooksett Pool than in Garvins Pool, indicating that yellow perch in Hooksett Pool weighed more at a given length early in life than in Garvins Pool. Sample sizes of yellow perch were insufficient for comparison of condition among pools during 2010. The length-weight relation for yellow perch in Hooksett Pool during that year is presented in Figure 4-15-3.

The slopes of the length-weight curves derived from catches of yellow perch from Hooksett Pool during 2005 and 2011 were not significantly different ($F = 1.08$, $P = 0.300$). This finding indicates that yellow perch from Hooksett Pool maintained a similar incremental weight gain with increasing length between the 2005 and 2011 catch (Figure 4-15-4, Table 4-15-8). When a common slope was assumed for the length-weight relation of yellow perch from Hooksett Pool, the *y*-intercept parameter from the 2011 length-weight relation was significantly lower than the 2005 estimate, which supports that the yellow perch in Hooksett Pool collected during 2011 were in worse condition compared to those collected during 2005.

4.15.3 Age-Length

The mean total length at age (±95% C.I.) of yellow perch collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009 and 2010 are presented in Tables 4-15-9 through 4-15-11. For years with available age data (2008-2010), age of yellow perch ranged from age-0 to age-11 in Garvins Pool, from age-0 to age-9 in Hooksett Pool, and from age-0 to age-5 in Amoskeag Pool. During 2008, the mean length at age of age-1 yellow perch collected in Hooksett and Garvins Pools did not differ significantly from one another. Although the mean length at age of age-0 yellow perch in Hooksett and Garvins Pools did not differ significantly for individuals collected during 2009, the mean length at age of age-1, age-2 and age-3 yellow perch was significantly larger in Garvins Pool than was observed in

Hooksett Pool. Insufficient sample size (n <15) prevented the comparison of mean length at age among pools for all cohorts of yellow perch collected during 2010.

4.15.4 Mortality

The total instantaneous mortality rates (Z) for yellow perch did not significantly differ among Garvins, Hooksett and Amoskeag Pools (Figure 4-15-6, ANCOVA, $F = 2.10$, $P = 0.218$). The catch curve regressions for yellow perch were not statistically significant for Hooksett ($F = 8.33$, $P = 0.212$) and Amoskeag Pool ($F = 16.33$, $P = 0.154$). This supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool relative to the thermally uninfluenced Garvins Pool. The annual mortality rates of yellow perch based on these estimates were 51% for Garvins Pool, 50% for Hooksett Pool, and 17% for Amoskeag Pool.

4.15.5 Parasitism

The frequency distribution of external parasite loads, as assessed on a rank scale from absent to moderate/heavy, for yellow perch collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 are presented in Table 4-15-12. There was no significant difference in the prevalence of external parasites on yellow perch within Garvins and Hooksett Pools. However, the prevalence of external parasites was significantly lower in Amoskeag Pool than in either Garvins or Hooksett Pools.

The frequency distribution of internal parasite loads, as assessed by presence/absence, for yellow perch collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008 and 2009 are presented in Table 4-15-13. The prevalence of internal parasites was significantly greater in Garvins Pool than in either Hooksett or Amoskeag Pools.

4.15.6 Gender, Reproduction, and Fecundity

The percentages of male and female yellow perch caught in Garvins, Hooksett and Amoskeag Pools by electrofishing during 2008-2009 are shown in Table 4-15-14. The percentage of male and female yellow perch in the combined 2008-2009 catch was not significantly different in Hooksett Pool (Z-statistic = -0.65, $P = 0.559$) and Amoskeag Pool (Z-statistic = -0.60, $P = 0.652$), but the percentage of male yellow perch in Garvins Pool (61%) was significantly greater than the percentage of females (39%; Z-statistic = 4.86, $P < 0.001$). The percentage of male yellow perch in Garvins Pool was significantly greater than in Hooksett (q-statistic = 5.22, $P < 0.05$), but was the same between Garvins and Amoskeag Pool (q-statistic = 2.88, $P > 0.05$) and Hooksett and Amoskeag (q-statistic = 0.48, $P > 0.05$). Conversely, the percentage of female yellow perch in Garvins Pool was significantly lower than in Hooksett but was the same between Garvins and Amoskeag Pools and between Hooksett and Amoskeag Pools.

The frequency and percent composition of each stage of maturity for yellow is presented in Table 4-15-15. The percentage of mature male yellow perch was significantly higher in Garvins Pool than in either Hooksett (q-statistic = 1.50, $P < 0.05$) or Amoskeag Pool (q-statistic = 1.39, $P < 0.05$) (Table 4-15-16). The percentage of mature male yellow perch was significantly higher in Hooksett Pool than in Amoskeag Pool (q-statistic = 2.80, $P < 0.05$). The percentage of mature female yellow perch was significantly lower in Amoskeag Pool than in either Hooksett (q-statistic = 4.01, $P < 0.05$) or Garvins Pool (q-statistic = 4.41, $P < 0.05$), but were similar between Hooksett and Garvins Pools (q-statistic = 0.08, $P > 0.05$) (Table 4-15-16).

Table 4-15-17 presents the GSI for gravid female and milting male yellow perch for Garvins and Hooksett Pools during 2008 and 2009. As suggested by overlapping 95% confidence intervals, there were no differences among the GSI values for male or female yellow perch. This finding supports the similarity of the yellow perch reproductive state within Garvins and Hooksett Pools during the spring sampling period. This supports a finding that Merrimack Station’s thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool relative to the thermally uninfluenced Garvins Pool.

The ages at 50% maturity for male and female yellow perch in Garvins and Hooksett Pools captured by electrofishing during combined 2008-2009 are shown in Figure 4-15-7 and Table 4-15-18. The age at 50% maturity for male yellow perch was 4.2 years in Garvins Pool and 1.6 years in Hooksett Pool. The age at 50% maturity for female yellow perch was 4.1 years in Garvins Pool and 2.3 years in Hooksett Pool. The mean length at 50% maturity for male yellow perch was 201 mm in Garvins Pool and 135 mm in Hooksett Pool. For female yellow perch, the mean length at 50% maturity was 176 mm in Garvins Pool and 141 mm in Hooksett Pool.

The relation between length and fecundity for ripe female yellow perch was non-significant within both Garvins (F = 0.54, P = 0.503) and Hooksett (F = 9.91, P = 0.196) Pools. Estimates for yellow perch fecundity from individuals collected during 2008 and 2009 ranged from 4,192 to 22,056 eggs per ripe female in Garvins Pool and 13,049 to 29,619 eggs per ripe female in Hooksett Pool.

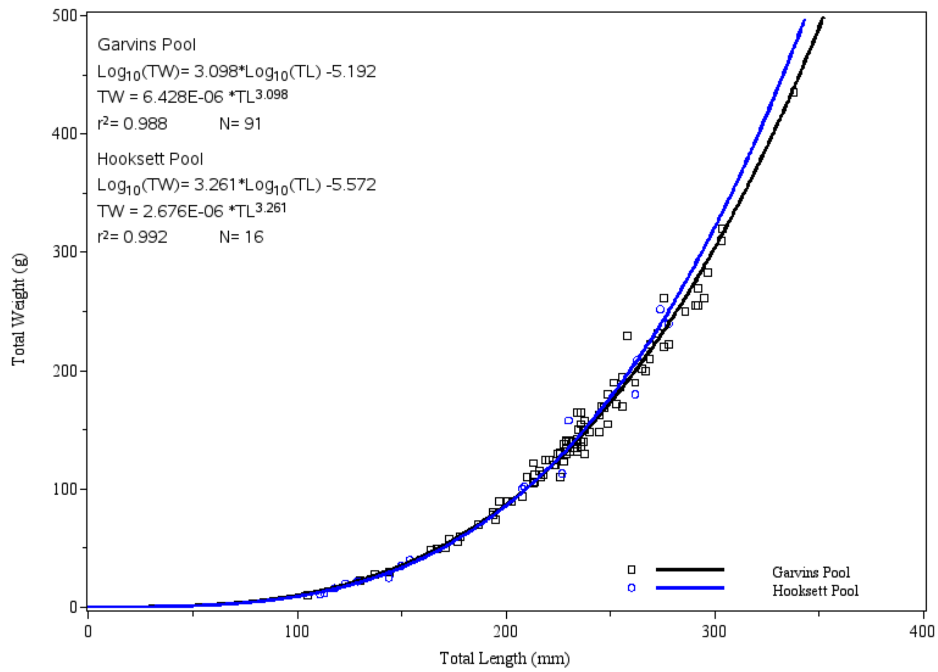


Figure 4-15-1. Empirical length-weight relations for yellow perch captured via electrofishing within Garvins and Hooksett Pools during 2008.

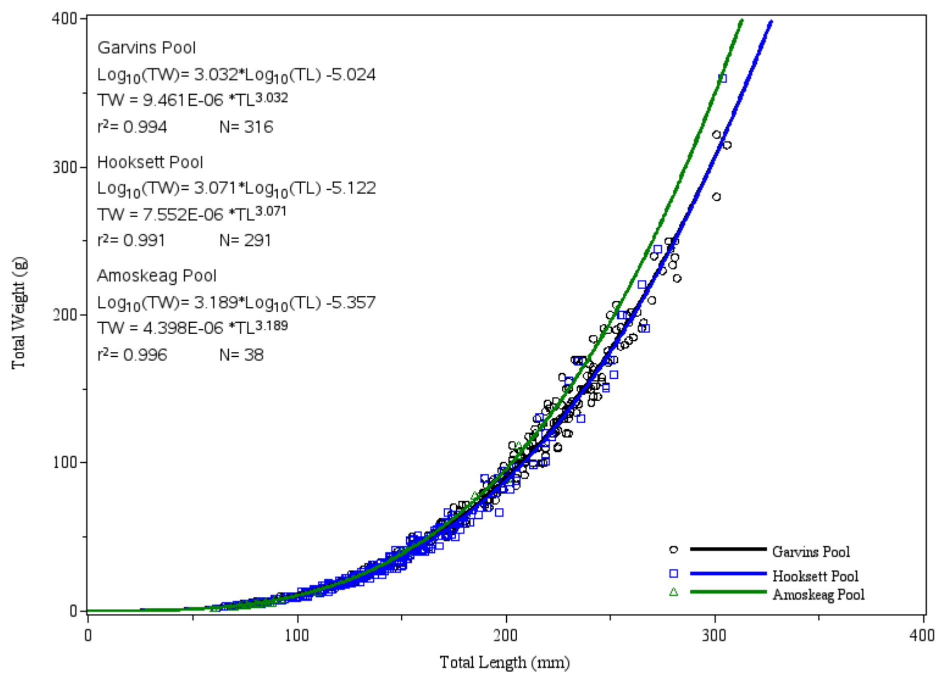


Figure 4-15-2. Empirical length-weight relations for yellow perch captured via electrofishing within Garvins, Hooksett and Amoskeag Pools during 2009.

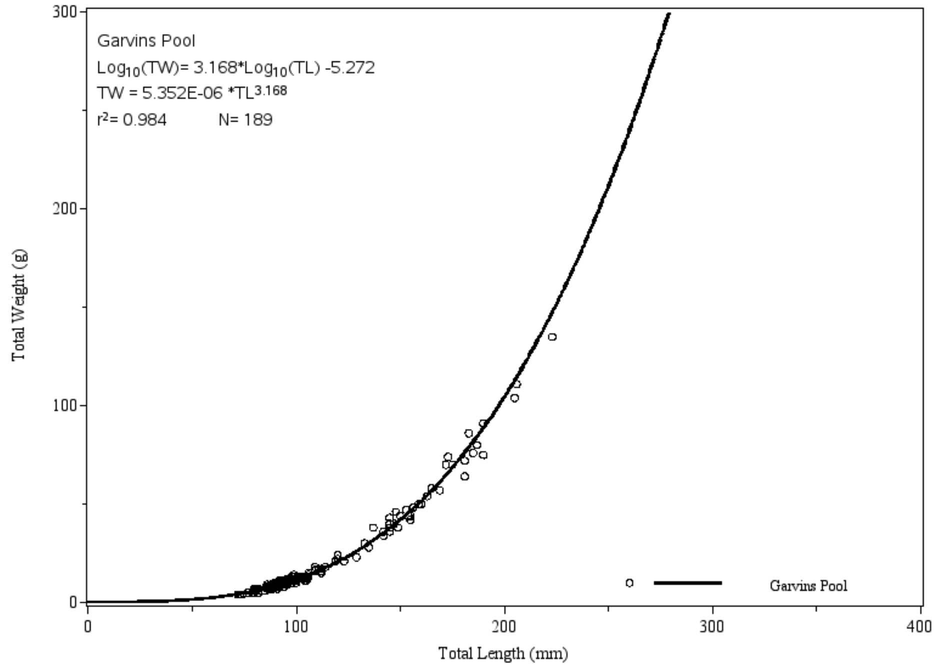


Figure 4-15-3. Empirical length-weight relation for yellow perch captured via electrofishing within Garvins Pool during 2010.

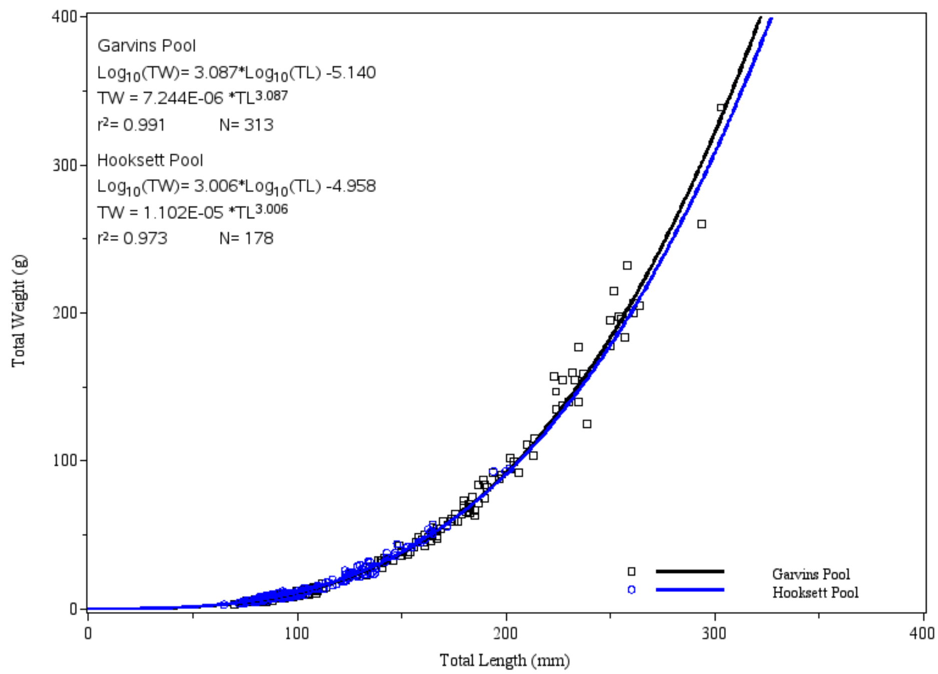


Figure 4-15-4. Empirical length-weight relations for yellow perch captured via electrofishing within Garvins and Hooksett Pools during 2011.

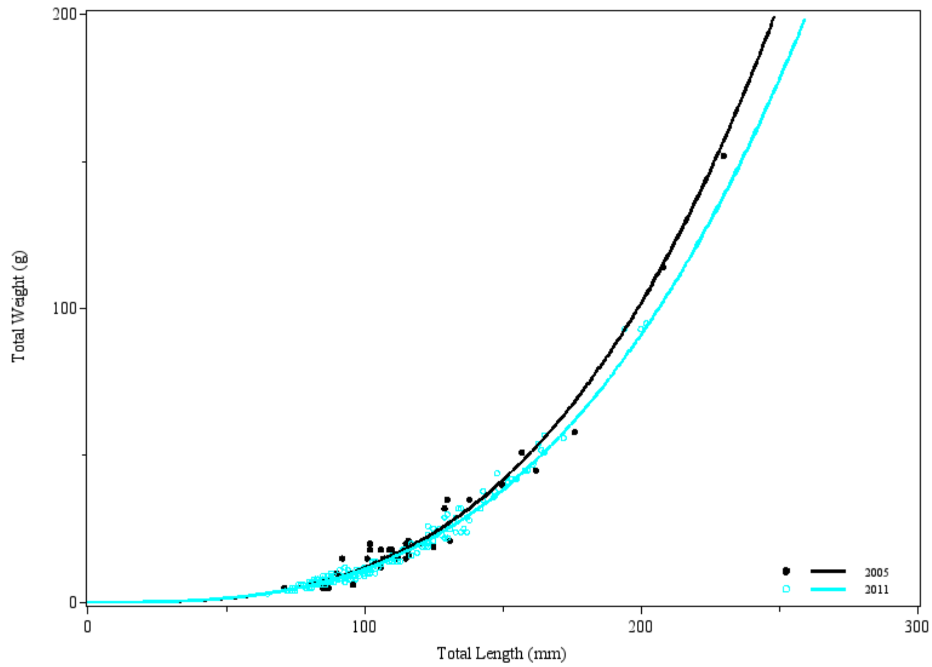


Figure 4-15-5. Empirical length-weight relations for yellow perch captured via electrofishing during the months of August and September 2005 and 2011 within Hooksett Pool.

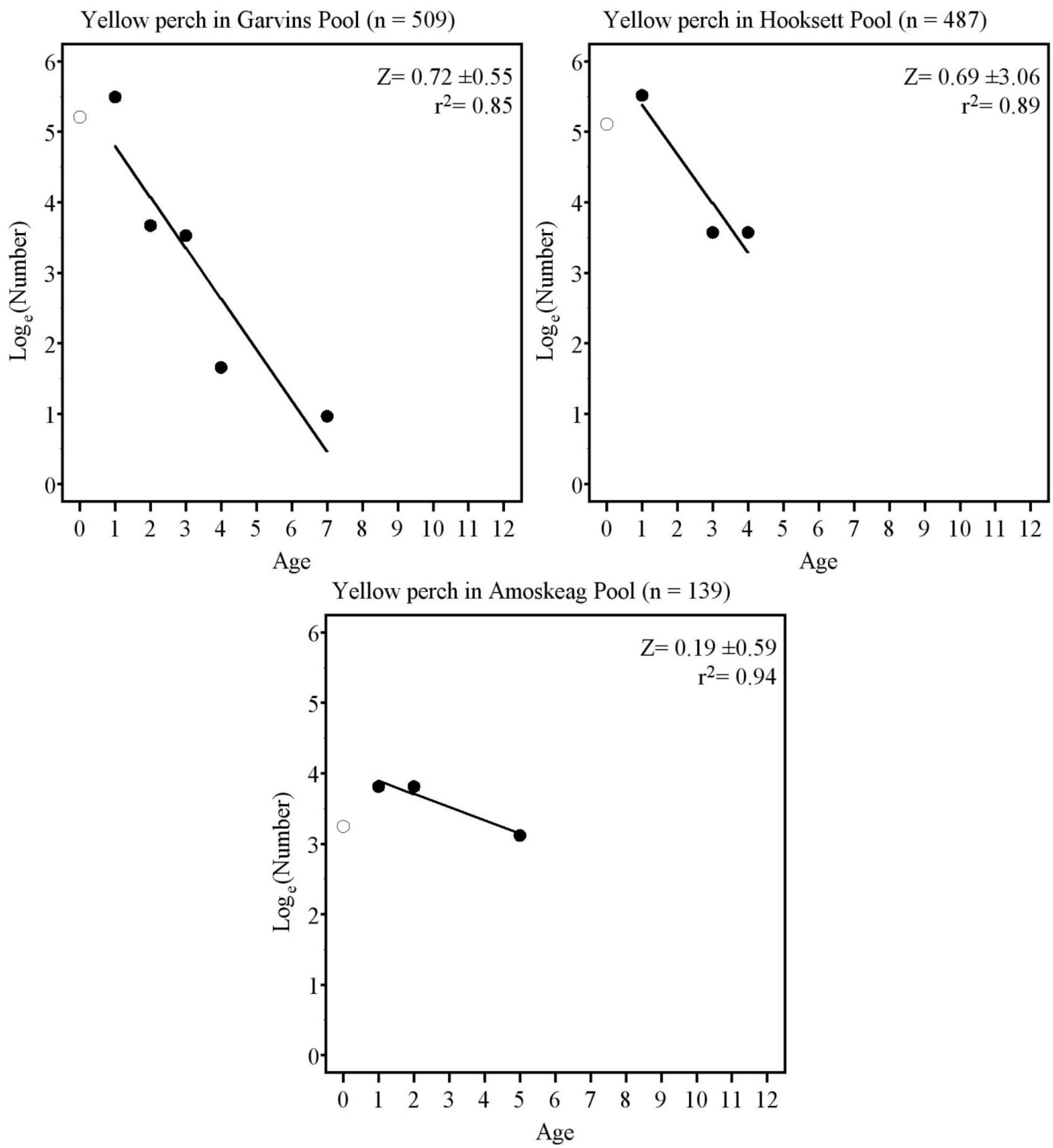


Figure 4-15-6. Catch curves comparing instantaneous total mortality rate (Z ± 95% confidence intervals) of yellow perch for fully recruited ages (solid circles) in Garvins, Hooksett and Amoskeag Pools based on combined 2008-2010 electrofishing catch in the Merrimack River. Ages either not fully recruited to the gear or older ages not well represented were excluded (open circles).

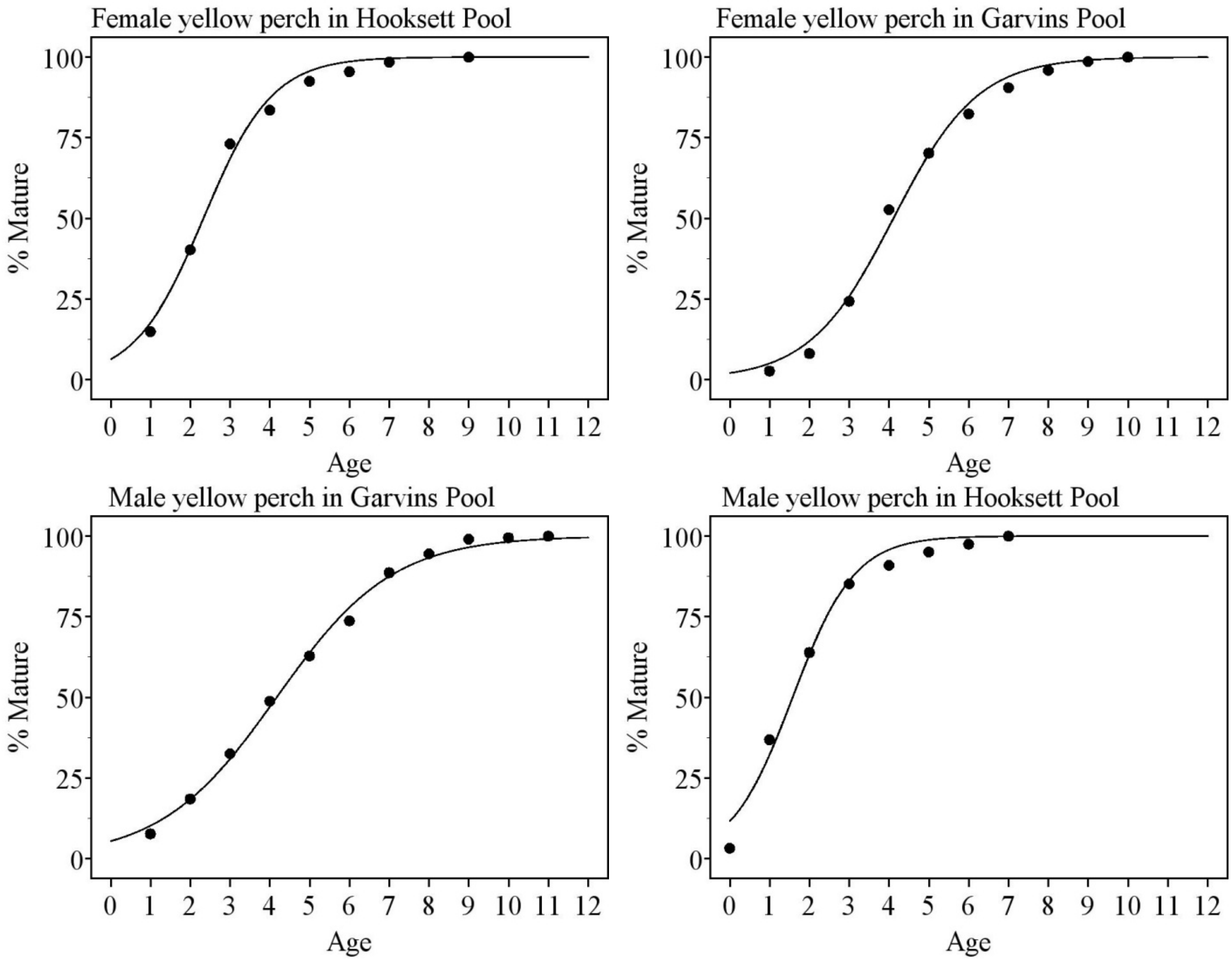


Figure 4-15-7. Calculated (solid line) and observed (dot) proportion mature at age of female and male yellow perch in Garvins and Hooksett Pools of the Merrimack River based on the combined 2008-2009 electrofishing catch.

Table 4-15-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for yellow perch collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May, September and October 2008.

Pool	Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	152	64	338	197	61	152	1	436	109	83
Hooksett	72	66	278	146	59	72	1	265	57	68
Amoskeag	9	46	118	72	25	9	1	16	5	5
Total	233	46	338	177	67	233	1	436	89	82

Table 4-15-2. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for yellow perch collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during April, May and September 2009.

Pool	Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	328	65	306	180	55	328	3	322	83	65
Hooksett	311	61	304	135	42	311	1	360	35	41
Amoskeag	40	60	206	107	44	40	2	112	22	30
Total	679	60	306	155	55	679	1	360	58	59

Table 4-15-3. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for yellow perch collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August, September and October 2010.

Pool	Length (mm)					Weight (g)				
	N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Garvins	204	60	304	109	34	203	3	296	21	31
Hooksett	14	71	210	116	41	14	4	125	29	40
Amoskeag	5	133	217	167	33	5	23	120	57	38
Total	223	60	304	111	36	222	3	296	22	32

Table 4-15-4. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for yellow perch collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during August and September 2011.

	Length (mm)					Weight (g)				
Pool	**N**	**Min.**	**Max.**	**Mean**	**STD**	**N**	**Min.**	**Max.**	**Mean**	**STD**
Garvins	333	70	303	124	49	332	3	339	34	51
Hooksett	191	65	202	106	27	191	3	95	17	16
Amoskeag	4	109	194	158	38	4	12	80	49	31
Total	528	65	303	118	43	527	3	339	28	43

Table 4-15-5. Regression statistics for total length (mm) vs. weight (g) of yellow perch from Garvins and Hooksett Pools during 2008.

					ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
Pool	**N**	**Slope (b)**	**Intercept ($log_{10}a$)**	**R^2**	**Garvins**	**Hooksett**	**Garvins**	**Hooksett**
Garvins	91	3.098	-5.192	0.99				
Hooksett	16	3.261	-5.572	>0.99	*		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-15-6. Regression statistics for total length (mm) vs. weight (g) of yellow perch from Garvins, Hooksett, and Amoskeag Pools during 2009.

					ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
Pool	**N**	**Slope (b)**	**Intercept ($log_{10}a$)**	**R^2**	**Garvins**	**Hooksett**	**Garvins**	**Hooksett**
Garvins	316	3.032	-5.024	>0.99				
Hooksett	291	3.071	-5.122	>0.99	NS		*	
Amoskeag	38	3.189	-5.357	>0.99	*	*	*	*

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-15-7. Regression statistics for total length (mm) vs. weight (g) of yellow perch from Garvins and Hooksett Pools during 2011.

Pool	N	Slope (b)	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					Garvins	Hooksett	Garvins	Hooksett
Garvins	313	3.087	-5.140	>0.99				
Hooksett	178	3.006	-4.958	0.97	*		*	

Notes: If slope differed significantly between pools, ANCOVA tested for difference in intercept; if slope did not differ significantly between pools, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05

Table 4-15-8. Regression statistics for total length (mm) vs. total weight (g) of yellow perch sampled during the months of August and September of 2005 and 2011 from Hooksett Pool.

Year	N	Slope (b)[2]	Intercept ($\log_{10}a$)	R^2	ANCOVA test for differences in length vs. weight equations[1]			
					Slope		Intercept	
					2005	2011	2005	2011
2005	49	3.028	-4.980	0.92				
2011	178	3.028	-5.002	0.97	NS		*	

Notes: If slope differed significantly between years, ANCOVA tested for difference in intercept; if slope did not differ significantly between years, ANCOVA tested for difference in elevation.
[1]Test results symbols for probability (p) levels of significance:
* = significant, p ≤0.05
NS = not significant, p > 0.05
[2] Assumed common slope due to non-significant finding

Table 4-15-9. Mean length at age (± 95% C.I.) for yellow perch captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2008.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2008	Garvins		1	64	
		Hooksett		9	72	4
		Amoskeag		1	52	
1	2007	Garvins	A	18	108	9
		Hooksett	A	24	104	5
		Amoskeag		7	68	14
2	2006	Garvins		15	128	4
		Hooksett		12	144	10
		Amoskeag		1	120	
3	2005	Garvins		23	148	8
		Hooksett		10	172	14
4	2004	Garvins		9	192	11
		Hooksett		6	196	14
5	2003	Garvins		11	220	14
		Hooksett		2	220	76
6	2002	Garvins		14	224	9
		Hooksett		2	264	88
7	2001	Garvins		24	244	9
		Hooksett		5	252	24
8	2000	Garvins		15	248	10
9	1999	Garvins		12	252	10
		Hooksett		1	276	
10	1998	Garvins		2	276	177
11	1997	Garvins		1	292	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. Pairwise comparisons based on a minimum sample size of 15 individuals

Table 4-15-10. Mean length at age (± 95% C.I.) for yellow perch captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2009.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2009	Garvins	A	26	80	3
		Hooksett	A	45	84	3
		Amoskeag	A	23	80	3
1	2008	Garvins	A	46	128	3
		Hooksett	B	110	116	3
		Amoskeag		4	88	16
2	2007	Garvins	A	48	156	5
		Hooksett	B	66	144	4
		Amoskeag		7	152	4
3	2006	Garvins	A	57	188	5
		Hooksett	B	54	168	4
		Amoskeag		3	184	35
4	2005	Garvins		46	216	5
		Hooksett		10	200	14
		Amoskeag		2	204	16
5	2004	Garvins		30	232	5
		Hooksett		10	232	16
6	2003	Garvins		20	248	8
		Hooksett		3	260	20
7	2002	Garvins		14	264	12
8	2001	Garvins		2	280	145

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. Pairwise comparisons based on a minimum sample size of 15 individuals

Table 4-15-11. Mean length at age (± 95% C.I.) for yellow perch captured by electrofishing from Garvins, Hooksett, and Amoskeag Pools during 2010.

Age	Cohort	Pool	Test [1]	N	Mean	± 95% C.I.
0	2010	Garvins		69	88	2
		Hooksett		5	92	13
1	2009	Garvins		93	100	2
		Hooksett		7	108	6
		Amoskeag		2	140	32
2	2008	Garvins		15	156	7
		Amoskeag		2	172	38
3	2007	Garvins		13	184	9
		Hooksett		1	212	
4	2006	Garvins		2	216	54
		Hooksett		1	208	
5	2005	Amoskeag		1	216	
7	2003	Garvins		1	304	

Notes: 1 – Letters indicate results of Tukey Pairwise comparison test for differences in mean length at age between pools for a cohort. Pairwise comparisons based on a minimum sample size of 15 individuals

Table 4-15-12 Frequency distribution of external parasite loads for yellow perch collected from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008-2011.

Pool	Absent		Light		Moderate/ Heavy	
	N	%	N	%	N	%
Garvins [A]	237	23.3	414	40.7	366	36.0
Hooksett [A]	223	37.9	197	33.5	168	28.6
Amoskeag [B]	35	60.3	18	31.0	5	8.6

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

Table 4-15-13 Frequency of internal parasites for yellow perch collected from Garvins, Hooksett, and Amoskeag Pools during the spring and fall, 2008 and 2009.

Pool	Absent		Present	
	N	%	N	%
Garvins [A]	461	85.1	81	14.9
Hooksett [B]	363	94.0	23	6.0
Amoskeag [B]	48	98.0	1	2.0

Notes: Different letters indicate significant within year differences between pools.
No letter indicates insufficient sample size (i.e <5) for pairwise comparison.

Table 4-15-14. Frequency of male and female yellow perch collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

Pool	Gender [1]	2008		2009		Total	
		N	%	N	%	N	%
Garvins	Male [B]	108	73.5	168	55.6	276	61.5
	Female [B]	39	26.5	134	44.4	173	38.5
Hooksett	Male [A]	20	47.6	144	48.3	164	48.2
	Female [A]	22	52.4	154	51.7	176	51.8
Amoskeag	Male [A]	2	50.0	18	45.0	20	45.5
	Female [A]	2	50.0	22	55.0	24	54.5

Notes: 1 – Different letters indicate significant within pool between gender differences (2008-2009 combined).

Table 4-15-15. Frequency distribution of the reproductive condition of yellow perch (sexes combined) collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

Reproductive condition	Garvins		Hooksett		Amoskeag		Total	
	N	%	N	%	N	%	N	%
Gravid or milting (ripe)	42	8.9	19	5.2			61	6.9
Ripe and running	33	7.0	15	4.1			48	5.5
Partially spent	56	11.9	3	0.8			59	6.7
Spent	76	16.1	6	1.6			82	9.3
Immature	161	34.2	168	46.2	37	82.2	366	41.6
Not gravid or not milting (resting)	33	7.0	82	22.5	1	2.2	116	13.2
Semi-gravid or semi-milting (developing)	70	14.9	71	19.5	7	15.6	148	16.8
Total	471	100.0	364	100.0	45	100.0	880	100.0

Table 4-15-16. Percent maturity of female and male yellow perch collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

Pool	Male	Female
Garvins	85.8 [A]	43.4 [A]
Hooksett	76.2 [B]	40.3 [A]
Amoskeag	25.0 [B]	12.5 [A]

Notes: Different letters indicate significant within gender between pool differences (2008-2009 combined).

Table 4-15-17. Gonadosomatic index (GSI, %) of gravid female and milting male yellow perch collected by electrofishing within Garvins, Hooksett, and Amoskeag Pools during 2008 and 2009.

	Male				Female			
Pool	N	95% LCL	Mean GSI	95% UCL	N	95% LCL	Mean GSI	95% UCL
Garvins	35	2.8	3.6	4.3	7	13.2	20.0	26.9
Hooksett	15	3.1	4.0	4.9	4	16.8	24.7	32.6
Total	50	3.1	3.7	4.3	11	17.2	21.7	26.3

Table 4-15-18. Age and length of male and female yellow perch collected by electrofishing within Garvins and Hooksett Pools during 2008 and 2009.

	Age at 50% Maturity		Length (mm) at 50% Maturity	
Pool	Male	Female	Male	Female
Garvins	4.2	4.1	201	176
Hooksett	1.6	2.3	135	141

4.16 Additional Fish Species

Due to low catch numbers, detailed biocharacteristics for populations of a number of fish species described from samples collected by boat electrofishing from Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010 and 2011 were not conducted. Those species are alewife, American eel, American shad, Atlantic salmon, brook trout, brown bullhead, brown trout, common carp, eastern blacknose dace, eastern silvery minnow, emerald shiner, golden shiner, margined madtom, rainbow trout, tessellated darter, white perch and yellow bullhead. The mean, minimum, maximum and standard deviation of total length (mm) and total wet weight (g) for each additional fish species collected by electrofishing in Garvins, Hooksett and Amoskeag Pools during 2008, 2009, 2010, and 2011 are presented in Tables 4-16-1.

Table 4-16-1. Total number of fish (N), minimum (Min.), maximum (Max.), mean (Mean), and standard deviation (STD) of the mean total length (mm) and total weight (g) for additional fish species collected via electrofishing in Garvins, Hooksett, and Amoskeag Pools during spring and fall, 2008-2011.

Common Name	Year	Pool	Length (mm)					Weight (g)				
			N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Alewife	2008	Hooksett	16	111	126	119	4	16	9	15	12	1
	2010	Amoskeag	1	75	75	75	.	1	4	4	4	.
		Hooksett	21	75	136	112	17	21	4	24	13	5
American eel	2008	Hooksett	8	445	620	523	70	8	200	800	497	212
	2009	Amoskeag	8	350	602	500	100	9	75	500	278	134
		Garvins	1	610	610	610	.	1	610	610	610	.
		Hooksett	10	450	660	574	67	9	150	505	337	118
	2010	Hooksett	23	270	840	537	154	22	70	1300	397	
	2011	Amoskeag	4	460	570	528	49	4	150	335	256	77
		Hooksett	8	380	800	493	134	8	105	1200	308	367
American shad	2008	Amoskeag	12	96	112	104	4	12	5	11	8	2
		Hooksett	4	107	116	112	4	4	10	12	11	1
	2010	Amoskeag	1	134	134	134	.	1	19	19	19	.
		Garvins	3	65	105	91	23	3	4	10	7	3
		Hooksett	69	83	130	108	13	69	6	20	11	4
	2011	Hooksett	1	95	95	95	.	1	7	7	7	.
Atlantic salmon	2008	Hooksett	1	284	284	284	.	1	271	271	271	.
	2009	Garvins	1	645	645	645	.	1	2300	2300	2300	.
Brook trout	2008	Hooksett	2	255	274	265	13	2	190	280	235	64
	2009	Amoskeag	17	196	270	230	19	17	90	210	139	32
		Garvins	2	225	230	228	4	2	150	150	150	0
Brown bullhead	2008	Garvins	2	270	272	271	1	2	280	300	290	14
	2009	Amoskeag	1	155	155	155	.	1	45	45	45	.
		Garvins	11	99	309	257	56	11	25	400	250	100
		Hooksett	1	328	328	328	.	1	485	485	485	.
	2010	Garvins	2	60	61	60.5	0.71	2	3	3	3	0
	2011	Amoskeag	1	232	232	232	.	1	180	180	180	.
Brown trout	2011	Amoskeag	1	492	492	492	.	1	700	700	700	.
		Garvins	1	658	658	658	.	1	2625	2625	2625	.
Common carp	2008	Amoskeag	4	710	875	778	69	2	4700	4750	4725	35
		Hooksett	1	565	565	565	.	1	230	230	230	.
	2009	Amoskeag	2	820	830	825	7	2	8000	8100	8050	71
Eastern blacknose dace	2009	Hooksett	1	38	38	38	.	1	1	1	1	.
	2011	Hooksett	1	35	35	35	.	1	1	1	1	.
Eastern silvery minnow	2010	Hooksett	3	52	61	57	5	3	1	2	2	1
Emerald shiner	2008	Hooksett	1	52	52	52	.	1	4	4	4	.

(continued)

Table 4-16-1. (Continued)

Common Name	Year	Pool	Length (mm)					Weight (g)				
			N	Min.	Max.	Mean	STD	N	Min.	Max.	Mean	STD
Golden shiner	2008	Amoskeag	16	52	144	90	29	13	2	30	10	9
		Hooksett	12	94	144	112	16	12	8	42	20	10
	2009	Amoskeag	6	89	164	117	28	6	3	39	15	13
		Garvins	14	75	273	172	57	14	3	270	81	81
		Hooksett	5	93	174	117	32	5	7	55	20	20
	2010	Amoskeag	10	92	178	134	26	10	9	62	29	16
		Garvins	1	64	64	64	.	1	2	2	2	.
	2011	Garvins	2	118	136	127	13	2	16	22	19	4
		Hooksett	13	89	149	119	19	13	6	39	17	9
Margined madtom	2008	Garvins	1	134	134	134	.	1	28	28	28	.
	2009	Garvins	1	109	109	109	.	1	13	13	13	.
	2010	Hooksett	7	97	132	117	13	7	8	26	16	6
	2011	Hooksett	2	116	129	123	9	2	14	19	17	4
Rainbow trout	2008	Amoskeag	1	362	362	362	.	1	445	445	445	.
Tessellated darter	2008	Hooksett	2	59	95	77	25	2	2	22	12	14
	2009	Amoskeag	1	91	91	91	.	1	10	10	10	.
		Garvins	4	86	94	90	3	4	6	8	7	1
		Hooksett	4	74	89	79	7	4	3	8	5	2
	2010	Garvins	45	43	82	60	9	45	1	4	2	1
		Hooksett	19	49	84	65	10	19	1	6	3	1
	2011	Garvins	5	49	70	64	8	5	1	3	2	1
		Hooksett	23	43	88	61	11	23	1	6	2	1
White perch	2009	Amoskeag	2	160	192	176	23	2	51	93	72	30
Yellow bullhead	2009	Amoskeag	1	137	137	137	.	1	33	33	33	.
		Garvins	1	231	231	231	.	1	160	160	160	.
	2010	Garvins	2	52	118	85	47	2	1	12	7	8
	2010	Hooksett	1	160	160	160	.	1	61	61	61	.
	2011	Hooksett	1	192	192	192	.	1	110	110	110	.

5.0 Discussion

5.1 Hooksett and Garvins Pool Comparison (2010-2011)

There have been substantial improvements in water quality in the Merrimack River since the enactment of the Clean Water Act in 1972, which resulted in a major reduction in the historic discharge of nutrients to the river (Normandeau 2011b). These changes in water quality have appreciably influenced the fish community in the river, including in Hooksett and Garvins Pools, during the operation of Merrimack Station. When the "natural variability inherent in aquatic communities" (USEPA 1990) is considered along with such significant changes in water quality, it becomes clear that there was not an unaffected, unchanging fish community in Hooksett Pool during the 1960s and 1970s that can now be used as a baseline for comparison to the pool's current fish community.

Given this, it is more constructive to use Garvins Pool as an "upstream-downstream reference condition" (USEPA 1990) by which to assess the current fish community in Hooksett Pool. Immediately upstream of Hooksett Pool, Garvins Pool is uninfluenced by Merrimack Station's thermal discharge but has similarly benefited from the significant water quality improvements that have occurred in the Merrimack River since 1972. This makes it an appropriate point of comparison that may allow the identification of trends in Hooksett Pool that are potentially due to the Station's thermal discharge. As in most ecological studies involving comparisons, Garvins Pool is not the ideal reference area, because of certain differences from Hooksett Pool in habitat and physical area. Sand/silt/clay is the dominant substrate type within both pools, followed by boulder and woody debris (Normandeau 2011d). Abundance of submerged aquatic macrophytes is greater in Garvins Pool than in Hooksett Pool. Moreover, the Garvins Pool impoundment has a surface area of approximately 640 acres at full pond versus 350 acres at full pond for Hooksett Pool (PSNH 2003). Additionally, fish in Garvins Pool have access to productive oxbow and backwater habitats that are not available in Hooksett Pool. Backwater habitat in riverine systems serve as important nursery and spawning areas for resident fish species.

Aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher abundance of fish species that are tolerant of warmer water, and a lower abundance of fish species that prefer cooler water. However, a comparison of the 2010 and 2011 fish communities in Hooksett Pool and Garvins Pool (the thermally uninfluenced impoundment immediately upstream from Hooksett Pool) shows no clear pattern consistent with the hypothesis that Merrimack Station's thermal discharge has caused an increase in the abundance of warmwater species or a decrease in the abundance of coolwater species in the pool. This finding is not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

Specifically, in 2010, there were no significant differences in electrofish CPUE between Garvins and Hooksett Pools for 12 out of 22 fish species (Table 2-9). Among the RIS and other resident species belonging to the warmwater guild (Table 3-5), Hooksett Pool had higher CPUE for bluegill, redbreast sunfish and smallmouth bass. There were no significant differences in CPUE, or CPUE was higher in Garvins Pool, for the following seven warmwater fish: brown bullhead, golden shiner, largemouth bass, pumpkinseed, rock bass, spottail shiner, and yellow bullhead. For coolwater fish, lower CPUE in Hooksett Pool relative to Garvins Pool could be a reflection of higher water temperatures in Hooksett Pool. However, among the coolwater fish, there were no significant differences in CPUE in 2010 between Garvins and Hooksett Pool for black crappie and fallfish. Furthermore, CPUE of white sucker, a coolwater fish, was significantly higher in Hooksett Pool. While two species among the coolwater fish, yellow perch and chain pickerel, had a significantly lower CPUE in Hooksett Pool during 2010, both of these species make use of habitats with submerged aquatic vegetation (Armbruster 1959; Scarola 1987), which is more common in Garvins Pool than Hooksett Pool.

In 2011, there were no significant differences in CPUE between Garvins and Hooksett Pools for 13 out of 22 species (Table 2-13). Warmwater fish would be expected to be more abundant in Hooksett Pool if Merrimack Station's thermal discharge were adversely affecting the abundance and distribution of fish. Among the RIS and other resident species belonging to the warmwater guild, in 2011 three species were more abundant in Hooksett Pool: largemouth bass, redbreast sunfish and smallmouth bass. There were no significant differences in CPUE, or CPUE was higher in Garvins Pool, for seven warmwater fish: bluegill, brown bullhead, golden shiner, pumpkinseed, rock bass, spottail shiner and yellow bullhead. If the Station's thermal discharge were adversely affecting fish distribution and abundance, CPUE might be expected to be lower in Hooksett Pool for coolwater species, and this did occur for chain pickerel and yellow perch. However, equally important, CPUE was higher in Hooksett Pool for fallfish and white sucker, both native coolwater species.

Aquatic habitat that has been adversely impacted by a thermal discharge also characteristically contains a higher percentage of both generalist feeders (which can capitalize on a variety of different food sources and often increase dramatically with habitat degradation) and pollution-tolerant individuals. Although the percentage of generalist and tolerant species were higher in Hooksett Pool than Garvins Pool during both 2010 and 2011, these differences were the result of increased relative abundance of both coolwater and warmwater species in Hooksett Pool. More particularly, while a higher percentage of generalist feeders was observed in Hooksett Pool than in Garvins Pool during both 2010 and 2011, that difference can be attributed to greater relative abundance in Hooksett Pool of a warmwater species (bluegill) during 2010 and a coolwater species (fallfish) during 2011. Similarly, while a higher percentage of tolerant species was observed in Hooksett Pool than in Garvins Pool during both 2010 and 2011, that difference can primarily be attributed to greater relative abundance in Hooksett Pool of a warmwater species (bluegill) and coolwater species (white sucker) during both years. (Eastern silvery minnow, a species intolerant to pollution, was only recorded in Hooksett Pool during 2010.) If Merrimack Station's thermal discharge has adversely impacted the BIP in Hooksett Pool by increasing the percentage of generalist feeders or pollution-tolerant individuals, it would not be expected that coolwater species would have significantly contributed to these increases, as documented. Neither of these findings is consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

In short, while some warmwater species were more abundant in Hooksett Pool in 2010 and 2011, there were no significant differences in abundance between Garvins and Hooksett Pools for others, and some warmwater species were more abundant in Garvins Pool. Among coolwater species, only the abundance of yellow perch and chain pickerel was higher in Garvins Pool in 2010 and 2011, and, as noted above, this pool contains more of the aquatic vegetated habitat that is preferred by both species. Similarly, although the percentage of generalist and tolerant fish species was higher in Hooksett Pool than in Garvins Pool during 2010 and 2011, this difference stems from the increased relative abundance of both warmwater and coolwater species in Hooksett Pool. If Merrimack Station's thermal discharge had caused appreciable harm to the BIP in Hooksett Pool, it would be expected that the differences observed between Garvins and Hooksett Pools would be directly attributable to only warmwater, generalist and tolerant species. However, it was two coolwater fish species, fallfish and white sucker that contributed to these differences.

A community analysis was conducted by comparing the results of electrofish sampling in Garvins, Hooksett and Amoskeag Pools in August and September of 2010 and 2011. This analysis showed that significant differences existed among the fish communities of each of the three pools, and that there was a clear trend of decreasing similarity among pools moving downriver from Garvins Pool to Hooksett Pool to Amoskeag Pool. Differences in community similarity of fish residing in a regulated river have been observed elsewhere for spatially separated segments (Pegg and McClelland 2004; Pegg and Taylor 2007). Five major groups were identified by Bray-Curtis numerical classification. Of these five groups, three – IIA, IIB1 and IIB2 – were the most similar, with dissimilarities ranging from 50.52% to 55.92%. These groups consisted of a combination of samples from Garvins and Hooksett Pools. Group IIA contained 19 samples from Garvins Pool and seven from Hooksett Pool. Group IIB1 contained 22 samples from Hooksett Pool, and Group IIB2 contained 19 samples from Hooksett Pool. Importantly, the samples from Garvins Pool did not form a unique group, but were instead clustered with samples from Hooksett Pool to form Group IIA, indicating that the fish community in Garvins Pool, which is not subject to Merrimack Station's thermal discharge, is not wholly distinct from the fish community in Hooksett Pool. If the Station's thermal discharge has adversely affected the fish community in Hooksett Pool, the differences between these groups could be explained by an increase in the abundance of warmwater species in Hooksett Pool or a decrease in the abundance of coolwater species. However, the two Hooksett Pool groups (IIB1 and IIB2) were distinguished from the majority Garvins Pool group (IIA) by generally lower abundances of fish including both warmwater and coolwater species (Table 2-19). This finding is not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

5.2 Hooksett Pool Historical Trends Analysis (1972-2011)

The trend analysis of CPUE of fish in Hooksett Pool since the 1970s provides additional insight into whether Merrimack Station's thermal discharge caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. As noted above, aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher abundance of fish species that are tolerant of warmer water, and a lower abundance of fish species that prefer cooler water. If the Station's thermal discharge had adversely impacted the abundance and distribution of fish in Hooksett Pool over the 1972-2011 time period, the abundance of resident coolwater species in the pool (as estimated by the standardized electrofish sampling efforts conducted between 1972 and 2011) should have significantly decreased during this time period. However, no such significant decrease in abundance was observed for three out of the five coolwater fish species resident in Hooksett Pool. Specifically, abundance of chain pickerel and yellow perched decreased, but there were no significant trends for fallfish and white sucker, and abundance of the remaining coolwater species, black crappie, increased in Hooksett Pool over the 1972-2011 time period (Table 3-4). None of these findings is consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

Similarly, if Merrimack Station's thermal discharge had adversely impacted the abundance and distribution of fish in Hooksett Pool over the 1972-2011 time period, the abundance of resident warmwater species in the pool (as estimated by the same standardized electrofish sampling efforts) should have significantly increased during this time period. However, no such increase in abundance was observed for any of the warmwater fish species resident in Hooksett Pool during this time period. Specifically, there were no significant trends for seven out of ten warmwater species (bluegill, golden shiner, largemouth bass, rock bass, smallmouth bass, spottail shiner and yellow bullhead), and abundance of the remaining three warmwater species (brown bullhead, pumpkinseed and redbreast sunfish) decreased, suggesting causes unrelated to the Station's thermal discharge. None of these findings is consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

In addition to investigating trends in abundance of individual species, community attributes were investigated to determine whether Merrimack Station's thermal discharge caused appreciable harm to the BIP in Hooksett Pool over the 1972-2011 time period. Aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher percentage of both generalist feeders and pollution-tolerant individuals. However, abundance of generalist feeders peaked during the 1976 sampling year and was lowest during 2010. Moreover, the percentage of pollution-tolerant species peaked during the 1995 sampling year, and the percentage of pollution-tolerant species in Hooksett Pool during two of the four most recent sampling years (2004 and 2010) were similar to levels observed during the 1970s. Neither of these findings is consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

A community analysis was conducted by comparing the results of standardized electrofish sampling in Garvins, Hooksett and Amoskeag Pools in August and September of 1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010 and 2011. Five major groups were identified consisting of sample collections primarily from the 1970s (Groups IA and IB), the 2000s (Group IIA), 1995 (Group IIB1) and the 2000s (Group IIB2). As would be expected from these groupings, there were significant differences among each of the decades (1970s, 1995, 2000s), indicating a high degree of temporal variability (Table 3-11). Many individual years were also significantly different from each other.

If Merrimack Station's thermal discharge had adversely impacted the abundance and distribution of fish in Hooksett Pool over the 1972-2011 time period, there should have been a consistent increase in the abundance of warmwater fish and an accompanying decrease in abundance of coolwater fish in the Hooksett Pool fish community over the 1970-2011 time period. However, the data indicate no such consistent increases and decreases. The groups from the 1970s (Groups IA and IB) were most similar to each other and least similar to the group from 1995 (Group IIB1) and the 2000s (Groups IIA and IIB2) (Table 3-10). An increase in the abundance of bluegill, a warmwater fish, contributed most to the differences among the 1970s groups and the 1995 group. However, abundance of bluegill decreased between 1995 and the 2000s (Figure 3-1), and this decrease made the major contribution to the differences between Group IIB1 (1995) and Groups IIA and IIB2 (2000s). The increase in the abundance of bluegill between the 1970s and 1995 was accompanied by a decrease in the abundance of pumpkinseed. The 1970s were distinguished from the 2000s by a general increase in the abundance of spottail shiner, largemouth bass and bluegill, all warmwater fish. However, a decrease in the abundance of pumpkinseed, another warmwater fish, also distinguished the 1970s from the 2000s. Among coolwater fish, an increase in the abundance of fallfish and a decrease in the abundance of yellow perch contributed to the differences between these decades. In sum, a combination of increases and decreases in the abundances of both warmwater and coolwater contributed to the differences in the Hooksett Pool fish community between the 1970s and 1995, and the 1970s and the 2000s. None of these findings is consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

There was also evidence that the fish community was separated into communities north and south of Merrimack Station. Groups IB (1970s), IIB1 (1995) and IIB2 (2000s) were composed of collections primarily from south of Merrimack Station, while Group IIA (2000s) was composed of collections primarily from north of Merrimack Station. However, the entire length of Hooksett Pool should be considered as a single unit. Most fish species in Hooksett Pool are highly mobile and can move freely through the pool. As a result, patterns in abundance observed throughout the entire pool are indicative of population-level effects.

5.3 Biocharacteristics Sampling (2008-2011)

Fisheries biocharacteristics data for resident species were collected over a four-year period (2008-2011) from Garvins, Hooksett and Amoskeag Pools of the Merrimack River. USEPA's draft §316(a) guidance identifies five response metrics that may be used to assess whether a thermal discharge has caused appreciable harm to the resident fish community of Hooksett Pool (USEPA 1977). Comparison of biocharacteristics data collected during 2008-2011within Hooksett Pool and Garvins Pool (the thermally uninfluenced impoundment immediately upstream from Hooksett Pool), allows for assessment of four of those metrics: condition factors (e.g., length and weight), age and growth, reproduction, and disease and parasitism.

5.3.1 Condition Factors

With regard to the length-weight relationship in fish, it is well-established that the magnitude of the slope in the regression equation reflects the condition (or robustness) of the fish, with a higher slope indicating a greater weight relative to a constant increase in length (Anderson and Neumann 1996). At the same time, since juvenile fish usually have a lower length-weight slope than older individuals, variation in the length-weight slope can also be the result of changes in the age composition of the samples. Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data typically show a decreasing length-weight curve – signifying progressively lower weight for a given length – for a resident fish species over time or in comparison to the same species residing in thermally uninfluenced habitat. Such a decreasing curve indicates a reduction in quality of body condition due to the thermal impact. Here, the observations of similar or increased growth among coolwater species residing in Hooksett Pool compared to the same species residing in thermally uninfluenced Garvins Pool are not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

Adequate length-weight data was available to compare within-year condition for four coolwater species in Garvins and Hooksett Pools (Table 5-2). Of the seven possible comparisons, there were no significant differences observed in weight growth relative to a constant increase in length in three cases (2011 chain pickerel, 2009 white sucker, 2009 yellow perch). In three instances (2011 fallfish, 2011 white sucker, 2008 yellow perch), the length-weight curves showed coolwater species in Hooksett Pool grew significantly more rotund (or "fatter") with increasing length than in Garvins Pool. Only yellow perch during 2011 grew significantly more rotund with increasing length in Garvins Pool than was observed in Hooksett Pool.

In addition, adequate length-weight data was available to compare within-year condition for six warmwater species in Garvins and Hooksett Pools. In ten of the eleven comparisons, the length-weight curves showed warmwater species in Hooksett Pool grew either equal to or significantly more rotund with increasing length than in Garvins Pool. The observations of similar or increased growth of coolwater species residing in Hooksett Pool relative to thermally uninfluenced Garvins Pool are not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

5.3.2 Age and Growth

Similarly, where aquatic habitat has been adversely impacted by a thermal discharge, sampling data tend to show lower mean length at age for a resident fish species compared to the same species in a thermally uninfluenced area, due to a reduction in growth rates associated with thermal stress. Adequate age data for the comparison of mean length at age for individual cohorts between Garvins and Hooksett Pools was collected for two coolwater species during 2009 and four warmwater species during 2010 (Table 5-2). Mean length at age was significantly greater in Garvins Pool for two of the three cohorts of the coolwater white sucker (age-2 and age-3) and three of the four cohorts of the coolwater yellow perch (age-1, age-2, and age-3) collected during 2009. The remaining two cohorts (white sucker, age-4; yellow perch, age-0) did not show a significant difference in mean length at age between Garvins and Hooksett Pools. Mean length at age for four of the six cohorts of warmwater species examined during 2010 did not differ between Garvins and Hooksett Pool. The remaining two cohorts (largemouth bass, age-0; pumpkinseed, age-1) exhibited a significantly higher mean length at age for individuals collected in Hooksett Pool.

The observation of reduced mean length at age for these two coolwater fish species in Hooksett Pool suggests that growth (as estimated by mean length at age) may be reduced in Hooksett Pool for some age classes relative to that in Garvins Pool. The inverse relationship between density and growth of fish has been well-studied and has been documented in other systems for both white sucker and yellow perch (Chen and Harvey 1995, Irwin et al. 2009). Here, abundance of white sucker was greater in Hooksett Pool than Garvins Pool, suggesting that the causes for such lower mean length at age are unrelated to the Station's thermal discharge. Observations for white sucker are not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in the Merrimack River.

In addition to mean length at age, total instantaneous mortality rates (Z) were compared for fish species common to Garvins and Hooksett Pools (Table 5-2). Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data typically show a greater total mortality (Z) for a resident fish species compared to the same species in a thermally uninfluenced area, due to increased stress associated with thermal impacts. Mortality rates were calculated for seven fish species (four warmwater and three coolwater) with adequate sample sizes and common to both Garvins and Hooksett Pools. No significant differences in Z were detected for two of the three coolwater fish species (white sucker and yellow perch) as well as three of the four warmwater fish species (bluegill, largemouth bass and pumpkinseed).

Mortality estimates for both fallfish (a coolwater species) and smallmouth bass (a warmwater species) were significantly higher in Hooksett Pool than in Garvins Pool. However, elevated mortality estimates observed for smallmouth bass in Hooksett Pool may be impacted by heavy recreational fishing pressure (total instantaneous mortality (Z) represents the sum of natural mortality (M) and fishing mortality (F)). Unfortunately, creel data from the Hooksett Pool bass fishery is not available to estimate the fishing mortality component of Z for smallmouth bass. Overall, the mortality levels observed in Hooksett Pool are less than or equal to those observed in Garvins Pool for five of the seven species examined, including yellow perch and pumpkinseed, two fish species that have decreased in abundance in Hooksett Pool between 1972 and 2011. These observations are not consistent with the hypothesis that the operation of Merrimack Station has caused appreciable harm to the balanced indigenous population in the Merrimack River.

5.3.3 Reproduction

Assessment of the impacts to reproduction were limited to two coolwater fish species (yellow perch and white sucker) collected during spring of 2008 and 2009. Due to the sampling design, which targeted the collection of spawning perch and sucker for assessment of fecundity, it is likely that the significant differences observed in the sex ratios within species and among pools were biased. Yellow perch in particular often form large spawning aggregations of one to several females with larger numbers of male individuals. As a result, collections made during that time of the year may not be ideal for assessing sex ratios.

Significant length-fecundity relations were detected for white suckers within both Hooksett and Garvins Pool, indicating that fecundity (i.e., the number of eggs per female) increases with length in both locations. Due to limited sample size, a statistical comparison of the length-fecundity relation was not possible. However, the estimated range of number of eggs per female white sucker as well as the range of observed body lengths overlapped for individuals collected with Hooksett and Garvins Pools. Due to difficulty in collecting yellow perch prior to their spawning in Garvins and Hooksett Pools, an adequate number of ovaries could not be collected to provide any useful comparisons of fecundity. Yellow perch in the Merrimack River spawn just following ice out. River flows during that time of the year are often high, which leads to decreased efficiency of electrofish sampling and creates a safety hazard to field crews attempting to collect samples.

5.3.4 Disease and Parasitism

Resident fish species in aquatic habitat that has been adversely impacted by a thermal discharge characteristically manifest more frequent infestation of internal and external compared to the same species resident in a thermally uninfluenced area, indicating a reduction in the overall health and conditions of the fish (USEPA 1977). The prevalence of external parasites was assessed for thirteen fish species (five coolwater species and eight warmwater species) common to both Hooksett and Garvins Pools over the four year period (2008-2011, Table 5-2). Of the five coolwater fish species, the prevalence of external parasites was greater for three species in Hooksett Pool (black crappie, fallfish and white sucker) and a single species in Garvins Pool (chain pickerel). There was no significant difference in the prevalence of external parasites on yellow perch collected within Hooksett and Garvins Pools. Prevalence of external parasites among warmwater fish species was greater for common shiner, rock bass and spottail shiner in Hooksett Pool, and for bluegill, pumpkinseed and smallmouth bass in Garvins Pool. There were no significant difference in the prevalence of external parasites on largemouth bass or redbreast sunfish collected within Hooksett and Garvins Pools. The prevalence of internal parasites was assessed for two coolwater species collected during 2008-2009 (Table 5-2). Presence of internal parasites in white sucker did not differ between Hooksett and thermally uninfluenced Garvins Pool whereas internal parasites were present in a greater percentage of yellow perch collected in Garvins Pool.

In general, the prevalence of internal and external parasites associated with resident fish species common to both Garvins and Hooksett Pools has been variable. There is no consistent evidence of warm or coolwater fish species residing in Hooksett Pool being subjected to increased parasitism. Parasitism levels are less than or equal to those observed in Garvins Pool for seven of the thirteen species examined for external parasites and both species examined for internal parasites. These observations are not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool.

In summary, fisheries surveys in the Merrimack River in the vicinity of Merrimack Station over the course of 39 years have highlighted the variability in the fish community. When compared to an appropriate balanced indigenous population such as that found in Garvins Pool, abundance of some coolwater species is greater in Hooksett Pool and for some warmwater species is greater in Garvins Pool.

These findings do not support the hypothesis that Merrimack Station's discharge has caused appreciable harm to Hooksett Pool. Similarly, the time series of available and comparable boat electrofish data for the 1972-2011 time period shows an increase in some coolwater fish species and a decrease in some warmwater species. Similar to the comparison with Garvins Pool, the inconsistent nature of the changes in abundance of warm and coolwater fish species do not support the hypothesis that the Station's thermal discharge has caused appreciable harm to Hooksett Pool. The overall health and condition of fish in Hooksett Pool is comparable to that found in Garvins Pool. Although differences do exist, the inconsistent pattern of findings does not support the hypothesis that Merrimack Station has caused appreciable harm to Hooksett Pool. When both community richness and evenness are considered, diversity of the fish assemblage is greater at the present time than was found historically in Hooksett Pool.

Table 5-1. Summary of multiple comparison and trends in abundance for selected species collected in August and September 2010 and 2011.

Common Name	Guild	Type	2010 Multiple Comparisons	2011 Multiple Comparisons	Multi Year Trends in Hooksett Pool
Black crappie	Coolwater	Resident	H G A	H G A	Increase
Bluegill	Warmwater	Resident	H G A	H G A	Unable to Detect Significant Trend
Brown bullhead	Warmwater	Resident	H G A	H G A	Decrease
Chain pickerel	Coolwater	Resident	G H A	G H A	Decrease
Fallfish	Coolwater	RIS	H G A	H G A	Unable to Detect Significant Trend
Golden shiner	Warmwater	Resident	A G H	H G A	Unable to Detect Significant Trend
Largemouth bass	Warmwater	RIS	G H A	H G A	Unable to Detect Significant Trend
Pumpkinseed	Warmwater	RIS	G H A	G H A	Decrease
Redbreast sunfish	Warmwater	Resident	H A G	H A G	Decrease
Rock bass	Warmwater	Resident	H G A	H G A	Unable to Detect Significant Trend
Smallmouth bass	Warmwater	RIS	H A G	A H G	Unable to Detect Significant Trend
Spottail shiner	Warmwater	Resident	G H A	G H A	Unable to Detect Significant Trend
White sucker	Coolwater	RIS	H A G	H G A	Unable to Detect Significant Trend
Yellow bullhead	Warmwater	Resident	H G A	H G A	Unable to Detect Significant Trend
Yellow perch	Coolwater	RIS	G H A	G H A	Decrease

Table 5-2. Summary of biocharacteristics findings for selected species collected in Garvins, Hooksett and Amoskeag Pools, 2008-2011.

Common Name	Guild	Type	L-W Relations										Mean Length at Age						Mortality	Parasites		Reproduction			
			2008		2009		2010[a]		2011[b]		1995-2011[c]		2008		2009		2010								
			Slope	y-int	Slope	y-int	Slope	y-int	Slope	y-int	Slope	y-int	Age	Comparison	Age	Comparison	Age	Comparison	Mortality	Internal [i]	External[i]	% Mature Male	% Mature Female	Male GSI	Female GSI
Black crappie	Coolwater	Resident																			A H G				
Bluegill	Warmwater	Resident					A H G	G H A	H G A	A G H	2011 1995	1995 2011					0 1	G H H A	A H G		G A H				
Chain pickerel	Coolwater	Resident							H G	H G											G A H				
Common shiner	Warmwater	Resident									2011 2004	2004 2011									H G				
Fallfish	Coolwater	RIS							H G	G H	2004 2011	2004 2011							H G		H A G				
Largemouth bass	Warmwater	RIS					A H G	G H A	H G	G H	1995 2011	2011 1995					0 1 2	H G G H G H	G H A		G H A				
Pumpkinseed	Warmwater	RIS					G H	H G	H G A	G H A	1995 2011	1995 2011					1	H G	G H A		A G H				
Redbreast sunfish	Warmwater						A G H	H G A	H A	H A	1995 2011	2011 1995									G H A				
Rock bass	Warmwater	Resident																			A H G				
Smallmouth bass	Warmwater	RIS					G H A	G H A	G H A	A H G	1995 2011	2011 1995			1	H A	0	H G A	H G A		G H A				
Spottail shiner	Warmwater	Resident					H G	G H	H G	G H	1995 2011	2011 1995									H G				
White sucker	Coolwater	RIS	H A	H A	G H A	A G H			H G	G H	2011 2004	2004 2011			2 3 4	G H A G H G H			G H A	A G H	H A G	G H A	G H A		
Yellow perch	Coolwater	RIS	H G	G H	A H G	G H A			G H	H G	2005 2011	2005 2011	1	G H	0 1 2 3	G H A G H G H G H			G H A	G H A	A G H	G H A	H G A		

6.0 REFERENCES

Ådjers, K., M. Appelberg, R. Eschbaum, A. Lappalainen, A. Minde, R. Repečka, and G. Thoresson. 2006. Trends in coastal fish stocks of the Baltic Sea. Boreal Environment Research 11: 13-25.

Aho, J.M., C.S. Anderson and J.W. Terrell. 1986. Habitat suitability index models and instream flow suitability curves: redbreast sunfish. U.S. Fish Wildl. Serv. Biol.Rep. 82 (10.119). 23 pp.

Anderson, R. O. and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Armbruster, D.C. 1959. Observations on the natural history of the chain pickerel (*Esox niger*). The Ohio Journal of Science. 59: 55-58.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841–B–99–002. U.S. Environmental Protection Agency; Division of Water; Washington, D.C.

Bloom, S.A. 1981. Simlarity indices in community studies: Potential pitfalls. Marine Ecology Progress Series. 5: 125-128.

Bonar, S.A., W.A. Hubert, and D.W. Willis. 2009. Standard Methods for Sampling North American Freshwater Fishes. American Fisheries Society, Bethesda, Maryland.

Bowerman, B.L. and R.T. O'Connell. 1990. Linear Statistical Models: An Applied Approach, 2nd edition. Duxbury Press, Belmont, California. 1024 p.

Carlander, K.D. 1969. Handbook of freshwater fishery biology, Volume 1. The Iowa State University Press, Ames, Iowa.

Carlander, K.D. 1977. Handbook of freshwater fishery biology, Volume 2. Iowa State University Press, Ames Iowa

Chen, Y. and H.H. Harvey. 1995. Growth, abundance, and food supply of white sucker. Transactions of the American Fisheries Society. 124: 262-271.

Clarke, K.R. and R.H. Green. 1988. Statistical design and analysis for a 'biological effects' study. Mar. Ecol. Prog. Ser., 46: 213-226.

Clarke, K. R. and R. M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth: Plymouth Marine Laboratory; 144 pp.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology. 18: 117-143.

Cone, R.S. 1989. The need to reconsider the use of condition indices in fishery science. Trans. Am. Fish. Soc. 118:510-514.

Daufresne, M., M.C. Roger, H. Capra, N. Lamouroux. 2004. Long-term changes within invertebrate and fish communities of the Upper Rhone River: effects of climatic factors. Global Change Biology 10: 124-140.

Dobiesz, N.E., D.A. McLeish, R.L. Eshenroder, J.R. Bence, L.C. Mohr, M.P. Ebener, T.F. Nalepa, A.P. Woldt, J.E. Johnson, R.L. Argyle, and J.C. Makarewicz. 2005. Ecology of the Lake Huron fish community, 1970-1999. Canadian Journal of Fisheries and Aquatic Sciences 62: 1432-1451.

Eaton, J.G., J. H. McCormick, B. E. Goodno, D. G. O'Brien, H. G. Stefany, M. Hondzo & R. M. Scheller. 1995. A Field Information-based System for Estimating Fish Temperature Tolerances, Fisheries 20: 10-18.

Flotemersch, J.E., J.B. Stribling, and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. 2nd edition. EPA 600-R-06-127. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Fox, M.G. 1994. Growth, Density, and Interspecific Influences on Pumpkinseed Sunfish Life Histories. Ecology. 75(4), pp. 1157-1171.

Guland, J.A.1988. Fish Population Dynamics: Second Edition. John Wiley & Sons, New York. New York.

Halliwell, D.B., R.W. Langdon, R.A. Daniels, J.P. Kurtenback, and R.A. Jacobson. 1999. Classification of Freshwater Fish Species of the Northeastern United States for Use in the Development of Indices of Biological Integrity, with Regional Applicaions. Pages 301-338 in T. P. Simon (editor). Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Florida.

Helsel, D.R. and R.M. Hirsch. 2002. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4, Chapter A3. U.S. 510 p. http://water.usgs.gov/pubs/twri/twri4a3/

Hilborn, R. and C.J. Walters. 1992. Quantitative Fisheries Stock Assessment. Kluwer Academic Publishers, Boston. 570 p.

Hubert, W.A. 1983. Passive capture techniques. Chapter 6 *in* Nielsen, L.A. and D.L. Johnson, eds. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Hubert, W.A. and M.C. Fabrizio. 2007. Pages 279-326 *in* C.S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Irwin, B.J., L.G. Rudstam,J.R. Jackson, A.J. VanDeValk, J.L Forney, and D.G. Fitzgerald. 2009. Depensatory mortality, density-dependent growth, and delayed compensation: Disentangling the interplay of mortality, growth and density during early life stageso f yellow perch. Transactions of the American Fisheries Society. 138: 99-110.

Jenkins, R.E. and N.M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Kawaguchi, S., T. Ichii, and M. Naganobu. 1997. Catch per unit effort and proportional recruitment indices from Japanese krill fishery data in Subarea 48.1. CCAMLR Science 4: 47-63.

Kwak, T.J. and J.T. Peterson. 2007. Pages 677-764 *in* C.S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Miranda, L.E. and P. W. Bettoli. 2007. Pages 229-269 *in* C.S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Normandeau (Normandeau Associates, Inc.). 1979b. Merrimack Station Monitoring Program: Summary Report. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2006. Merrimack Station Thermal Discharge Effects on Downstream Salmon Smolt Migration. Report December 2006.

Normandeau (Normandeau Associates, Inc.). 2007a. Merrimack Station Fisheries Survey Analysis of 1967 Through 2005 Catch and Habitat Data. Report April 2007.

Normandeau (Normandeau Associates, Inc.) 2007b. A Probabalistic Thermal Model of the Merrimack River Downstream of Merrimack Station. Report November 2006.

Normandeau (Normandeau Associates, Inc.) 2009a. Biocharacteristics of yellow perch and white sucker in Hooksett Pool of the Merrimack River. Report June 2009.

Normandeau (Normandeau Associates, Inc.) 2009c. Merrimack Station yellow perch and white sucker stock assessment: field standard operating procedures.

Normandeau (Normadeau Associates, Inc.). 2010. 2010 Merrimack Station fisheries survey: field standard operating procedures.

Normandeau (Normandeau Associates, Inc.). 2011b. Historic Water Quality and Selected Biological Conditions of the Upper Merrimack River, New Hampshire. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.). 2011d. Quantification of the Physical Habitat within Garvins, Hooksett, and Amoskeag Pool of the Merrimack River. Report March 2011.

Osenburg, C.W., G.G. Mittelbach, and P.C. Wainwright. 1992. Two-Stage Life Histories in Fish: The Interaction Between Juvenile Competition and Adult Performance. Ecology. 73(1), pp. 255-267Pope, K.L. and C. G. Krause. 2007. Pages 423-471 *in* C.S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Pegg, M.A. and M.A. McClelland. 2004. Spatial and temporal patterns in fish communities along the Illinois River. Ecology of Freshwater Fish. 13: 125-135.

Pegg, M.A., and R. M. Taylor. 2007. Fish species diversity among spatial scales on altered temperate rivers. Journal of Biogeography. 34: 549-558.

Public Service of New Hampshire (PSNH). 2003. Merrimack River Project (Amoskeag, Hooksett and Garvins Falls) FERC No 1893-NH. Application for new license for major project existing dams. Volume 1.

Quinn, T. J., II and R.B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York. 542 p.

Ricker, W.W. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191. 382 p.

RMC (RMC Ecological Division). 1979. Relationships of preferred, avoided, upper and lower lethal temperatures of fishes of Conowingo Pond, Pennsylvania. Report Prepared for Philadelphia Electric Company.

SAS Institute Inc. 2010. Base SAS® 9.2 Procedures Guide: Statistical Procedures, Third Edition. Cary, NC: SAS Institute Inc.

Scarola, J. F. 1987. Freshwater Fishes of New Hampshire. New Hampshire Fish and Game Department.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. of Can., Bull. 184.

Tomecek, J., V. Kovac, and S. Katina. 2007. Pages 307-336 *in* F. Gherardi, editor. Biological Invaders in Inland Waters: Profiles, Distribution, and Threats.

Trial, J.G., C.S. Wade, J.G. Stanley, and P.C. Nelson. 1983. Habitat suitability information: fallfish. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.48. 15 pp.

U.S. Environmental Protection Agency (USEPA). 1977. Draft interagency 316(a) technical guidance manual for thermal effects sections of nuclear facilities environmental impact statement.

U.S. Environmental Protection Agency (USEPA). 1990. Biological Criteria: National Program Guidance for Surface Waters (EPA-440-5-90-004) - April 1990.

U.S. Environmental Protection Agency (USEPA). 2011. Draft Clean Water Act NPDES permitting determinations for the thermal discharge and cooling water intake structures at Merrimack Station in Bow, New Hampshire.

Warwick, R.M. (1993). Environmental impact studies on marine communities: pragmatical considerations. Aust. J. Ecol., 18: 63-80.

Wismer, D.A., and A.E. Christie. 1987. Temperature relationships of Great Lakes fishes: a data compilation. Great Lakes Fish. Comm. Spec. Pub. 87-3. 165 p.

Zar, J.H. 1999. Biostatistial Analysis, Fourth Edition. Prentice Hall, Englewoods Cliffs, New Jersey. 663 p.

APPENDIX A

Electrofish Maps

Appendix Figure 2-1. Location and habitat composition of electrofish stations 7 and 8 in Hooksett Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-2. Location and habitat composition of electrofish stations 9 (previously N9-N10E) and 10 (previously N9-N10W) in Hooksett Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-3. Location and habitat composition of electrofish stations 11 (previously N6-N7E) and 12 (previously N6-N7W) in Hooksett Pool, Merrimack River Monitoring Program, 2010 and 2011.

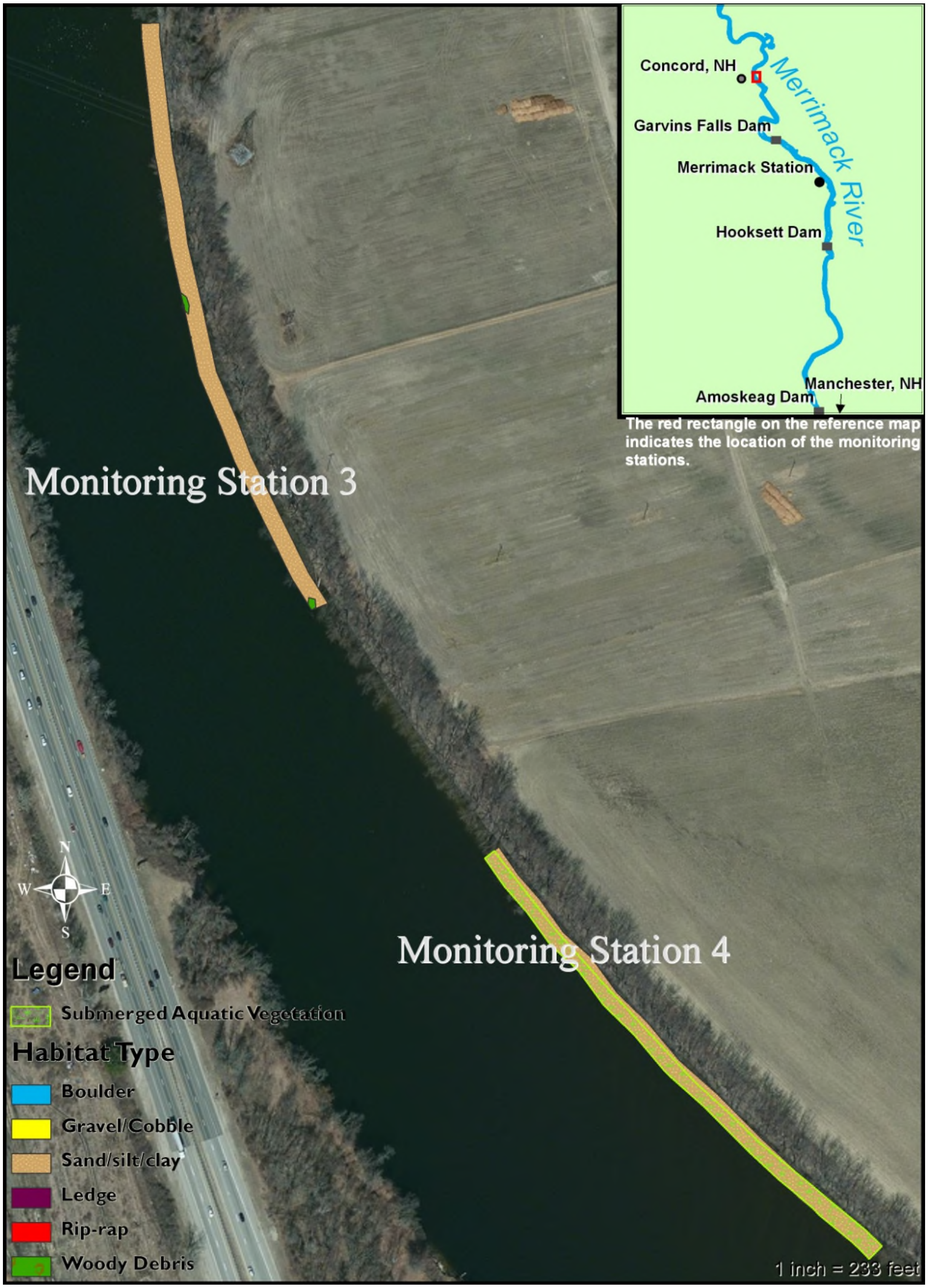
Appendix Figure 2-4. Location and habitat composition of electrofish stations 13 (previously S0-S1E) and 14 (previously S0-S1W) in Hooksett Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-5. Location and habitat composition of electrofish stations 15 (previously S4-S5E) and 16 (previously S4-S5W) in Hooksett Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-6. Location and habitat composition of electrofish stations 17 (previously S-17-S18E) and 18 (previously S17-S18W) in Hooksett Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-7. Location and habitat composition of electrofish station 1 in Garvins Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-8. Location and habitat composition of electrofish station 2 in Garvins Pool, Merrimack River Monitoring Program, 2010 and 2011.

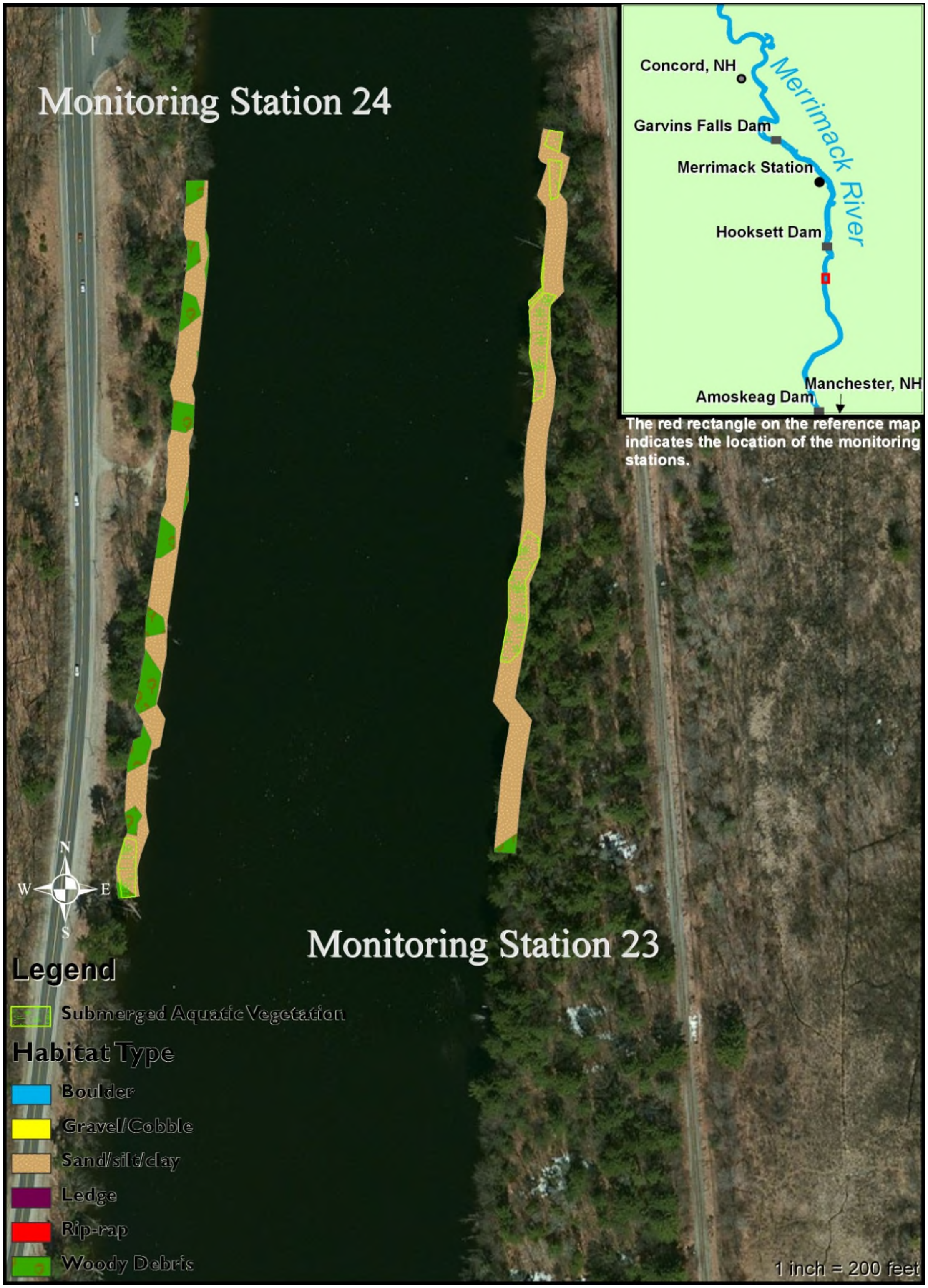


Appendix Figure 2-9. Location and habitat composition of electrofish stations 3 and 4 in Garvins Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-10. Location and habitat composition of electrofish stations 5 and 6 in Garvins Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-11. Location and habitat composition of electrofish stations 19 and 20 in Amoskeag Pool, Merrimack River Monitoring Program, 2010 and 2011.

Appendix Figure 2-12. Location and habitat composition of electrofish stations 21 and 22 in Amoskeag Pool, Merrimack River Monitoring Program, 2010 and 2011.



Appendix Figure 2-13. Location and habitat composition of electrofish stations 23 and 24 in Amoskeag Pool, Merrimack River Monitoring Program, 2010 and 2011.