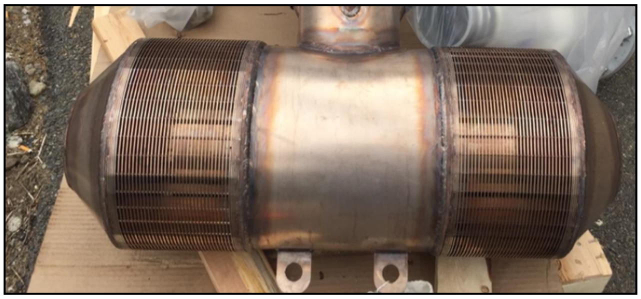
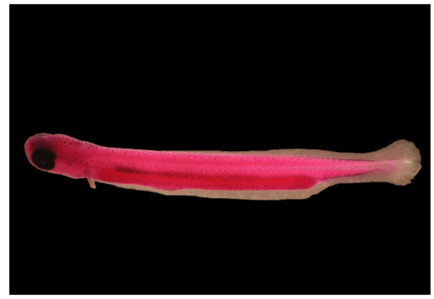
# Biological Benefit Evaluation of Entrainment Reducing Technologies at Merrimack Station





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# Acronyms and Abbreviations

| | |
|---|---|
| AE1 | Age-1 Equivalent |
| AIF | Actual intake flow |
| BTA | Best Technology Available |
| CWA | Clean Water Act |
| CWIS | Cooling Water Intake Structure |
| DIF | Design intake flow |
| *F* | Instantaneous fishing mortality rate |
| gpm | Gallons per minute |
| GSI | Gonadosomatic index |
| h | hour |
| kg | kilograms |
| M | Instantaneous natural mortality rate |
| $m^3$ | cubic meters |
| MGD | Million gallons per day |
| ml | milliliters |
| mm | Millimeters |
| $Mm^3$ | Million cubic meters |
| MW | Megawatts |
| NERA | NERA Economic Consulting, Inc. |
| Normandeau | Normandeau Associates, Inc. |
| NPDES | National Pollutant Discharge Elimination System |
| psig | pounds per square inch |
| PSNH | Public Service of New Hampshire |
| PYSL | Post Yolk-Sac Larvae |
| TL | Total length |
| UNID | Unidentified larval stage |
| USEPA | U.S. Environmental Protection Agency |
| WWS | Wedgewire Screen |
| YOY | Young of the Year |
| YROL | Yearling or older |
| YSL | Yolk-Sac Larvae |
| Z | Total instantaneous mortality rate |

# 1 INTRODUCTION

## 1.1 Background

Public Service Company of New Hampshire ("PSNH") owns and operates two separate steam electric power 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, 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. The Station withdraws and discharges non-contact cooling water from the Merrimack River subject to and with the benefits of National Pollutant Discharge Elimination System ("NPDES") Permit NH0001465 (the "Permit"). 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 United States Environmental Protection Agency ("USEPA") last renewed the Permit in 1992. PSNH submitted a timely NPDES permit renewal application to USEPA in 1997. On September 30, 2011, USEPA issued a new draft NPDES permit (the "Draft NPDES Permit") and Fact Sheet (USEPA 2011) for the continued operation of the Station.

In the Fact Sheet, USEPA determined seasonal use of closed-cycle (wet) cooling towers was the best technology available ("BTA") for reducing entrainment and impingement mortality at Unit 1 and Unit 2 at Merrimack Station, while screening technologies and variable speed pumps were either deemed not feasible or offered inadequate reductions (USEPA 2011). In response to USEPA's BTA determination and economic assessment, NERA Economic Consulting, Inc. ("NERA", NERA 2012), on behalf of PSNH, provided a preliminary benefit-cost analysis of five BTA alternatives (Ristroph traveling screens, Multi-Disc traveling screens, cylindrical wedgewire screens, Gunderboom Marine Life Exclusion System, and seasonally operated mechanical draft close-cycle cooling towers). NERA (2012) determined the cooling tower alternative was not BTA based on costs (~$99 million, 2010 US dollars) that were wholly disproportionate and significantly greater than its benefits ($102,000, 2010 US dollars). NERA's estimates of benefits for each BTA alternative were based on classifying increases in harvest (pounds) of 11 target species estimated by ASA (2012) using 2005-2007 impingement and entrainment data (Normandeau 2007). In that study, panfish and bass biomass from those 11 target species was converted to individuals by dividing an average panfish or bass weight, and multiplying the number of fish by price per fish.

Subsequent to the preliminary economic assessment by NERA (2012), USEPA issued a revised draft NPDES Permit and Fact Sheet on 18 April 2014. Shortly thereafter, the Federal Clean Water Act ("CWA") Section 316(b) Final Regulations to Establish Requirements for CWISs at Existing Facilities were published on 15 August 2014 in the Federal Register (79 Fed. Reg. 48300-439)("final §316(b) regulations"). Most recently, the comment period on the draft NPDES Permit for Merrimack Station was reopened on 4 August 2017 and on 17 August 2017 was extended to 4 December 2017, and then further extended to 18 December 2017. The comment period provided an opportunity for the public and PSNH to provide comment or information on selected issues such as compliance with the final §316(b) regulations and evaluations of efficacy of wedgewire half-screens at reducing entrainment at Merrimack Station.

For 15 consecutive weeks from 22 May 2017 through 3 September 2017, Normandeau Associates, Inc. ("Normandeau") tested the performance of a 3-mm wedgewire test screen at reducing entrainment relative to coincidental control samples collected at Unit 1 at Merrimack Station (Normandeau 2017a). Given the observed high (89%) overall effectiveness of reducing entrainment by operating 3-mm wedgewire half-screens at Unit 1 during the study period, the seasonal use of 3-mm half-screen wedgewire screens at Merrimack Station will be considered as a potential BTA for reducing entrainment at Merrimack Station. Consistent with the Comprehensive Technical Feasibility and Cost Evaluation Study and Benefits Valuation Study required by 40 C.F.R. §122.21 (r) (10) and §122.21 (r)(11) of the final §316(b) regulations, the wedgewire screen performance study (Normandeau 2017a) and a full benefit-cost analysis will evaluate 3-mm wedgewire half-screens as a potential BTA alternative to closed-cycle cooling towers for reducing entrainment at Merrimack Station (Units 1 and 2). In this report, the biological benefits of potentially implementing either seasonal use of 3-mm wedgewire half screens or year-round use of closed-cycle cooling towers as BTA (ENERCON and Normandeau 2007) were estimated in terms of additional equivalent number of fish recruited to the recreational fishery in Hooksett Pool as input data for monetizing the benefits in a comprehensive economic assessment to be done by NERA.

## 1.2 Objectives

The purpose of this evaluation was to provide estimates of additional equivalent number of fish recruited to the recreational fishery in Hooksett Pool, Merrimack River as input data for NERA to monetize the benefits of implementing two potential entrainment-reducing technologies as potential BTA alternatives. Specifically, the equivalent number of fish potentially recruited to the recreational fishery in Hooksett Pool lost due to annual entrainment and impingement mortality was estimated for three cooling water withdrawal scenarios:

1) recent 10-year actual intake flow ("AIF"),
2) design intake flow ("DIF") at 100% capacity factor, and
3) 50% DIF (50% capacity factor);

and under three CWIS configurations:

1) existing CWIS for Units 1 and 2 combined,
2) seasonal (April through July) operation of 3-mm wedgewire half-screens at Units 1 and 2 combined, and
3) year-round operation of closed-cycle cooling towers for Units 1 and 2 combined.

# 2 METHODS

## 2.1 Technical Approach

The technical approach used in this assessment to evaluate the non-monetized biological benefits from entrainment-reducing technologies at Merrimack Station is described by the flow chart in Figure 2–1. In most benefit evaluations where commercial fisheries are present, an equivalent fishery yield model (also known as harvest foregone model) is used to estimate the loss in commercial catch in pounds (EPRI 2012; USEPA 2006, 2014) and often relies on regional fishing mortality rates derived from stock assessments. This approach was considered inappropriate and not relevant because most fish caught are released (i.e.

few fish kept or "harvested"). Furthermore, data on catch-and-release rates, catch rates, individual recapture rates, fishing effort, and population size in the recreational fisheries within Hooksett Pool are unavailable to adequately model recreational catch as number of fish harvested and number of fish caught and released (potentially multiple times).

Instead of estimating equivalent fishery yield for a predominantly catch-and-release recreational fishery, this assessment uses a method similar in concept to the one used by USEPA (2014) for the Inland Region. This method estimated the number of equivalent "harvestable" fish due to entrainment-reducing technologies at Merrimack Station, where the "harvestable" age of equivalence is defined as the age first susceptible to angling gear (i.e., initially recruited to the fishery) since the goal is to provide input estimates of fish for valuing each time an angler catches a fish putatively for sport in Hooksett Pool. The estimate of the number of equivalent recruits to the fishery involves two assumptions with offsetting biases: (1) all of the incremental equivalent number recruited to the fishery (i.e., harvestable or catchable fish) are caught and valued when in reality perhaps only a portion of a particular cohort of fish would ever be caught (overestimates benefit); and (2) there are no multiple captures of individual fish, when it is possible that fish are caught multiple times in a year (underestimates benefit).

The benefit to the recreational fishery from reductions in entrainment and impingement abundance (and mortality) if entrainment-reducing technologies (3-mm wedgewire half screens or closed-cycle cooling towers) were implemented at Merrimack Station considers direct and indirect estimates of equivalent recruits. Direct estimates were defined as the number of each recreationally important fish species at an age susceptible to anglers that would have resulted if individuals at a particular early life stage were not entrained or impinged. The biomass from natural mortalities (assuming 100% due to predation) that would have resulted from the entrained or impinged life stage to the age first recruited to the fishery provided an indirect forage benefit to predatory species (assumed to be Age-2 Largemouth Bass) at 10:1 forage-to-predator biomass conversion. The number of equivalent Age-2 Largemouth Bass was also estimated from the lifetime total production foregone from entrainment and impingement of forage species.

## 2.2 Input Data Description

### *2.2.1 Entrainment Monitoring Data*

Representative monthly mean entrainment densities at Merrimack Station Units 1 and 2 combined used in this assessment were based on entrainment abundance data collected from two sampling programs completed about a decade apart between 2006-2007 (Normandeau 2007) and 2017 (Normandeau 2017a).

**2006-2007 Study**

The scheduled sampling occurred weekly from late May through August (15 sampling weeks) and bi-weekly during the first half of September (1 sampling week). Sampling restarted during early April of 2007 and continued through June 2007. The scheduled sampling occurred biweekly from early April to mid-May (4 sampling weeks) and weekly during the remainder of the 2007 period (9 sampling weeks). Entrainment sampling was completed from 31 May 2006 through 30 August 2006 and 4 April 2007 through 27 June 2007 at Unit 1, and 24 May 2006 through 13 September 2006 and 4 April 2007 through 27 June 2007 at Unit 2. A total of 48 valid entrainment samples were collected at Unit 1 and 47 were collected at Unit 2.

Entrainment sampling was not conducted at an individual unit on days when one or both of the two circulating pumps were not operating. On each sampling day, one daytime sample and one nighttime sample were collected. For sampling purposes, daytime was defined as occurring between one hour after local sunrise and one hour before local sunset as observed at the plant site. Nighttime was defined as occurring between one hour after local sunset and one hour before local sunrise as observed at the plant site. Entrainment samples were collected through a 0.300-mm mesh plankton net suspended over a barrel sampler located outside of the pumphouses at Units 1 and 2. Water was supplied to each tank from a 3-inch raw-water tap drawing un-chlorinated ambient cooling water from the condenser supply line at a point after the supply (discharge) lines from each intake pump have joined into a common line within the CWIS. Water in the 3-inch tap at ambient condenser pressure (15-22 psig) flowed from the condenser supply line located in the basement of each pumphouse, up and out through the upper floor of the pumphouse in a rigid 3-inch PVC pipe to the sampling tank located at ground level. Flow was calculated for each sample using a timed volumetric method to ensure that a sample volume of at least 100 $m^3$ was filtered and collected.

Entrainment samples were preserved in 10% buffered-formalin and processed in Normandeau's biological laboratory in Bedford, New Hampshire. Entrainment samples were manually sorted and eggs and larvae were enumerated and identified to the lowest distinguishable taxon. Samples with high abundances were subsampled in the laboratory using a plankton splitter such that a minimum of 200 eggs and larvae were analyzed. If numbers of eggs and larvae were low but the amount of detritus in the sample was high (more than 400 ml settled volume), then a maximum of one-half of the sample was sorted. Ichthyoplankton was enumerated into the following life stages: eggs, yolk-sac larvae, post-yolk-sac larvae, young of the year and yearling (and older). Yolk-sac larvae ("YSL") were defined as the transition stage from hatching through the development of a complete, functional digestive system. Post yolk-sac larvae ("PYSL") were defined as the transitional life stage of larval development occurring from the time when a complete functional digestive system has been fully developed to the time when the organism transforms into a fully formed juvenile fish. Young of year ("YOY") were defined as the stage from completed transformation into a juvenile fish to Age 1 (12 months). Larvae that could not be staged due to the damaged condition of the individuals in the sample were enumerated as unidentified larvae. The total length to the nearest 0.1 mm was measured for up to 30 individuals of each ichthyoplankton life stage (except eggs) per sample. If more than 30 ichthyoplankton larvae were present in a sample, measurements from a random subsample of 30 specimens provided statistically sufficient precision and were considered representative of the entire sample (Garner 1997; Normandeau 2006).

## 2017 Wedgewire Test Screen Performance Study

Normandeau evaluated the entrainment reduction performance of a single 3-mm slot width wedgewire ("test") screen (z-alloy Johnson Screens model T-12), measuring 12.5 inches in diameter and 35 inches long, by contrasting ichthyoplankton densities from paired test and in-plant control samples ("control") collected at Merrimack Station Unit 1 from 15 consecutive weeks of testing (weeks 3 through 17) beginning 22 May 2017 and continuing through 3 September 2017 (Normandeau 2017a). Control samples were paired in two-hour time intervals throughout each sampling day with the test 3-mm wedgewire screen samples and collected from the Unit 1 CWIS using the same sampling equipment and procedures from the May 2006 through June 2007 entrainment study (Normandeau 2007) and as used for the test wedgewire screen samples.

Control samples were taken from a 3-inch raw-water tap drawing un-chlorinated ambient cooling water from the condenser supply/circulating water pump discharge within the Unit 1 CWIS. Water in the 3-inch diameter tap, at ambient circulating water pressure, flowed from the tap into a sample collection tank located on the floor of the Unit 1 pump house. The control sampling flow discharged from the collection tank into a sump where it was pumped to drain into the Unit 1 CWIS traveling screen wash water sluice located on the south side of the Unit 1 CWIS. Volume sampled by the control system was measured by a second factory-calibrated Signet flowmeter mounted in a straight run of pipe between the tap valve and the collection tank. As with the 3-mm wedgewire screen test samples, a target control sample volume of about 100 $m^3$ was filtered for the control samples and the contents were collected in each two-hour interval at a flow rate of about 220 gpm to 240 gpm. Also, as with the 3-mm wedgewire screen test samples, control samples were filtered through a 0.300-mm mesh cylindrical collection net with a short conical section at the lower end tapering to the cod end collection cup in a tank sampler filled with ambient water to buffer the flow and help ensure that ichthyoplankton were in good condition for identification and enumeration. Each net was changed out frequently (about every 20 minutes) with a clean net and washed into a collection jar during each two-hour sample to help minimize damage to the collected ichthyoplankton due to turbulence in the net. At the end of each two-hour sampling interval, the remaining material in the collection net was washed into the sample jar to terminate the two-hour sample, and replaced with a clean net to begin the next two-hour sample collection. Each net removed from the collection tank was washed down from the outside with filtered water to concentrate the sample material in the cod end collection cup, the sample was then rinsed into one or more labeled jars and preserved with a final concentration of 6% buffered formalin. Sampling was nearly continuous during each sampling day, with only about one minute needed to switch nets between the end of each two-hour interval and the beginning of the next.

Laboratory analyses were similar to the 2006-2007 entrainment study with a few exceptions. Instead of a 200-specimen subsampling quota used in 2006 and 2007, the 2017 screen test and control samples with high abundances (at least 400 eggs and 400 larvae) were subsampled in the laboratory for eggs or larvae (or both). In addition to measuring total length for up to 30 eggs and 30 larvae per taxon, limiting dimension, referred to as “Body Depth”, was also measured. Body Depth for larvae was defined as the largest limiting dimension besides total length from each larva among the following: body depth, head depth, head width, and body width. Body depth for eggs was the diameter for a round egg, and if the egg was oval, both maximum and minimum lengths were measured.

### *2.2.2 Impingement Monitoring Data*

Impingement sampling was conducted at the Merrimack Station Unit 1 and Unit 2 CWISs beginning on 29 June 2005 and continuing for two years through 28 June 2007 (Normandeau 2007). Impingement sampling was conducted one day per week from late-June 2005 through mid-December of 2005 (25 sampling weeks), from mid-March of 2006 through November of 2006 (34 sampling weeks) and from mid-March of 2007 through the end of June 2007 (15 sampling weeks). During the intervening time periods, 24-hour impingement samples were collected one day every other week (14 sampling weeks). Weekly impingement sampling consisted of one 24-hour sample followed by one six-day sample, and biweekly sampling consisted of one 24-hour sample followed by one 13-day sample. The 24-hour impingement samples were considered the primary sampling units, and “long interval” samples of six or 13 days were considered secondary sampling units.

Impingement sampling at each Merrimack Station CWIS was conducted by placing a basket with standard 3/8-inch (0.375-inch) square stainless-steel wire mesh in the fish and debris return sluice of Unit 1 and Unit 2 to catch all fish and debris washed off of the operating traveling screens during the sampling interval. Impingement collection efficiency was determined during one 24-hour sampling period in each month to adjust each 24-hour sample for fish that are lost between the time they are impinged on the operating intake screens and their collection in the sampling device. These impingement collection efficiency factors were applied to other 24-hour impingement collections from each period centered on the date of the collection efficiency test. Collection efficiency adjustments were not applied to the “long interval” samples. The primary estimates of adjusted 24-hour impingement density were used to estimate the monthly mean impingement density and the secondary long-interval samples were not used in this assessment because Normandeau (2007) found the 24-hour impingement samples led to significantly higher (and therefore more conservative, i.e., overestimate) impingement rates than those based on the long-interval impingement samples.

### *2.2.3 Intake Flow Data*

The three case scenarios of monthly water withdrawal volumes used for extrapolating entrainment and impingement density to entrainment and impingement abundance estimates were based on 10 years of monthly actual intake flows at Merrimack Station Units 1 and 2 combined from 2007 through 2016; design intake flow of 287.3 million gallons per day ("MGD") assuming 100% capacity factor; and 50% of DIF (143.65 MGD) assuming 50% capacity factor as specified by the memorandum, dated 15 December 2017, from ENERCON to NERA. For the year-round closed-cycle cooling tower BTA alternative, the water withdrawal case scenarios were reduced by 95%. Table 2–1 presents the monthly mean intake flow rate and total monthly water withdrawal volumes used in this assessment.

### *2.2.4 Wedgewire Screen Performance*

The overall reduction (efficacy) in entrainment of ichthyoplankton at the Merrimack Station Unit 1 CWIS due to the operation of the 3-mm wedgewire test screen was estimated for weeks 3 through 17 (Monday, 22 May through Sunday, 3 September 2017) for each life stage and taxon group (Normandeau 2017a). Based on paired t-tests using concurrently collected (i.e., pairs) of valid Unit 1 control and 3-mm wedgewire screen test samples during each of the survey weeks 3 through 17, entrainment density for the 3-mm wedgewire test screen was significantly lower ($p < 0.01$) than the control entrainment density for each week 3 through 14. The proportion entrained from the results of this study (Normandeau 2017a) and shown in Table 2–2 was used to estimate entrainment abundance from water withdrawal through a 3-mm wedgewire screen at Merrimack Station Units 1 and 2 combined during April through July, assuming this proportion was representative for future April through July periods. In some cases, the data were lacking or unavailable for some species and life stages in which case other species or life stage data were used as surrogates (e.g., Margined Madtom PYSL for Brown Bullhead PYSL, Common Shiner PYSL for Spottail Shiner PYSL, and Golden Shiner YROL for Spottail Shiner YOY). Outside of the April-July entrainment season, the proportion entrained was assumed to be 1 (i.e., 0% exclusion) if the wedgewire half-screens are bypassed during water withdrawal.

## 2.3 Species Classification

### *2.3.1 Taxonomy*

While there were differences in presence and absence of some taxa identified between the 2006-2007 and 2017 entrainment sample collections, there were also differences in taxonomic resolution (Table 2–3). The presence of damaged specimens could cause a taxon to be assigned to a higher category than species if one or more distinguishing features were absent and more than one similar species were identified in the samples. Furthermore, the ichthyoplankton identification using traditional morphological features and meristics for some species did not allow identification to the species level of taxonomy, e.g., Carp and Minnow family (Cyprinidae), Blueback Herring/Alewife (*Alosa aestivalisAlosa pseudoharengus*), or Sunfish family (Centrarchidae, including *Lepomis* sp.). Damaged herring or sunfish larvae without identifying characteristics were identified to the family level in 2006, 2007, and 2017 (e.g., Clupeidae, Centrarchidae). Laboratory identification criteria, supplementary information and level of acceptable uncertainty changed from the 2006-2007 study to provide finer taxonomic resolution in 2017 that led to differences in taxonomic resolution rather than changes in biodiversity. For example, instead of a clupeid larvae without identifying characteristics for speciation being classified as Herring family (Clupeidae) as would have been done in 2006 or 2007, the knowledge of Atlantic Herring or Gizzard Shad being absent in Hooksett Pool would lead to a more specific identification as *Alosa* sp. in 2017. The *Lepomis* sp. and *Lepomis* sp./*Pomoxis* sp. taxa identified in 2017 would have been classified as Sunfish family in 2006 and

2007, along with other Sunfish species not identifiable to species (presumably due to damage of key characteristics). In addition, some entrained specimens were identified as simply "Unidentified" taxon in 2006 and 2007 but were re-classified to the taxon of "Unidentified Osteichthyes" (bony fish) used in 2017 since such specimens in Hooksett Pool would not likely belong to Chondrichthyes (sharks and rays) or Agnatha (jawless fishes).

Taxonomy of juvenile and adult fish collected in the 24-hour impingement samples was straightforward, unless severely damaged or decomposed. Only two species (Banded Sunfish and Rainbow Smelt) identified in impingement samples were not identified in the electrofishing samples collected during the 1972 through 2013 period, lending credence to laboratory identification results (Table 2–4).

### *2.3.2 Species Apportionment*

The monetization of the benefits of implementing entrainment-reducing technologies at Merrimack Station requires the comparison in equivalent loss of recreationally important species (i.e., equivalent catch), directly or indirectly via trophic transfers, between a candidate technology and the existing CWIS. In contrast to the preliminary assessment of a selected target species (ASA 2012), this assessment estimates the losses and benefits from annual entrainment and impingement of all identified taxa, but to do so, required several abundant taxa identified to genus or family or species complexes to be apportioned to species level for modelling and ultimately to provide benefit data as input for monetization. These taxa identified to higher-than-species level were apportioned to species proportionally by month based on the monthly mean densities among member species identified in the respective month and by the most similar life stage. As a hypothetical example, if entrainment density of Sunfish family PYSL for a particular month was 10 larvae per 100 $m^3$ and the only entrained sunfish PYSL identified to species in that month were Bluegill (4 larvae per 100 $m^3$) and Largemouth Bass (1 larvae per 100 $m^3$) then the Sunfish family PYSL density would be apportioned 80% to Bluegill (8 larvae per 100 $m^3$) and 20% to Largemouth Bass (2 larvae per 100 $m^3$).

There were some exceptions where other information was used to make an assignment to a species or taxon. The entrainment densities identified as Blueback Herring/Alewife taxon were assigned to Alewife since there is no record of Blueback Herring in Hooksett Pool from entrainment, impingement and electrofishing (Normandeau 2007, 2017a; Table 2–4). The taxon identified as *Lepomis* sp. were classified 100% to Bluegill because no other *Lepomis* species were identified in entrainment and there was no objective basis to apportion to other potentially entrained *Lepomis* species (e.g., Pumpkinseed identified in impingement). Because entrained eggs were identified as Carp and Minnow family or as Unidentified Osteichthyes, all entrained eggs were classified as Carp and Minnow family. Densities of damaged or unidentified eggs and larvae were allocated proportionally to identifiable taxa.

### *2.3.3 Economic and Ecological Importance of Species Entrained and Impinged*

All taxa identified or apportioned to species in entrainment and impingement samples from Merrimack Station were classified as either "recreationally important" fishery species (i.e., game or sport fish) or as "forage" species largely based on the classifications made by USEPA for freshwater source waterbodies in inland regions (Appendix G1 in USEPA 2016). The recreationally important fishery species included in this assessment were further classified by economic value categories ("Bass", "Panfish", "Small Game", and "Walleye/Pike") consistent with USEPA (Appendix I-25 in USEPA 2014) and are listed in Table 2–5. Commercial harvest was excluded from this assessment due to the lack of commercial fisheries in Hooksett Pool and other regions of the Merrimack River. Exclusion of commercial fisheries in this assessment is consistent with the USEPA's exclusion of commercial fishing benefits evaluation for the inland regions (USEPA 2014).

Based on the species identified from entrainment and impingement sampling from 2005 through 2007 (Normandeau 2007) and electrofishing during selected years in the period from 1972 through 2013 (Normandeau 2011, 2017b), there is no evidence of federally listed threatened or endangered fish species in Hooksett Pool that are protected under the Endangered Species Act. However, three state-listed threatened Bridle Shiner (*Notropis bifrenatus*) specimens were collected in the six-day impingement samples collected at Merrimack Station (NHFG 2017a; Normandeau 2007). In addition, three species (American Eel, American Shad, and Banded Sunfish) were collected in entrainment and/or impingement samples at Merrimack Station that are currently considered by NHFG (2017b) as state-listed category-1 (near-threatened) species of concern. Alewife and Rainbow Smelt have been observed in Hooksett Pool, but the absence of a fish ladder implies these populations are not considered sea-run and as such, should not be considered NH-listed species of concern.

## 2.4 Entrainment and Impingement Abundance Estimation

### *2.4.1 Differentiation between Entrainment and Impingement Abundance*

Entrainment is defined as those life stages of fish and shellfish in the intake water flow entering and passing through a CWIS, but excluding those organisms retained on a sieve with a maximum opening of 0.56 inches (14.2 mm), equivalent to the diagonal opening of a ½ x ¼ inch mesh screen or 3/8-inch square mesh screen as specified by §125.92(h) of the final §316(b) regulations. Organisms that are larger than this 0.56-inch sieve opening and would be retained on a 3/8-inch square mesh travelling screen at Merrimack Station were defined as impinged. Entrainment samples from 2006, 2007 and 2017 (control samples) were collected downstream of the 3/8-inch square mesh travelling screens at Merrimack Station so sample densities should reflect entrainable organisms. A 55-mm TL Bluegill with limiting body dimensions of 9.0 mm width and 1.0 mm depth, and an 85-mm TL Margined Madtom with limiting body dimensions of 16.5 mm width and 14.3 mm depth were excluded from the 2017 control samples based on this 0.56-inch (14.2 mm) limit for entrainable-sized organisms. Based on the size distribution of ichthyoplankton collected in the 2006 and 2007 entrainment samples and the morphometrics (total length, maximum body depth, and maximum body width) measured in the control entrainment samples during the 2017 wedgewire screen performance study (Normandeau 2017a), no further exclusions were needed to meet the definition of entrainment.

When fine mesh screen technologies are used, the portion of organisms that would normally be entrained with a 3/8-inch mesh, but instead become impinged, are called impingeable entrainables or “converts”. For this assessment, the impingeable entrainables excluded from entering and passing through the CWIS by the 3-mm wedgewire half screens were assumed to have 100% survival.

### *2.4.2 Baseline Calculations for Existing Cooling Water Intake Structure*

The weekly entrainment and adjusted 24-hour impingement densities by life stage for each apportioned species from Normandeau (2007 and 2017a) were first used to estimate monthly mean densities by year and unit and then used to calculate monthly mean densities for a “typical” 12-month impingement season and 6-month (April through September) entrainment sampling season. Based on the assumptions in the final §316(b) regulations and by USEPA (2014), entrainment and impingement density (and abundance) was considered to be directly proportional to CWIS flow. Entrainment and impingement densities from samples were assumed representative of the density within a given week and month, and were assumed to be equal between Units 1 and 2. For this assessment, 100% mortality was assumed for impingement and entrainment (i.e., entrainable organisms that pass through the cooling water system). Entrainment and impingement densities from sampled years (2005 through 2007, and 2017) were assumed to be representative of the 2007 through 2016 period and during future periods of operation if entrainment-reducing technologies were implemented.

The monthly entrainment abundance ($E_{t,i,m}$) for taxon $t$ and life stage $i$ at Merrimack Station was calculated as:

$$E_{t,s,m} = D_{ENT,t,i,m} V_m \quad \text{(Equation 1)}$$

where $D_{ENT,t,i,m}$ = entrainment density (n per m$^3$) of taxon $t$ and life stage $i$ at month $m$, and
$V_m$ = water withdrawal volume (m$^3$) for Units 1 and 2 combined at month $m$.

The monthly impingement abundance and mortality ($I_{t,i,m}$) for taxon $t$ and life stage $i$ at Merrimack Station was calculated as:

$$I_{t,i,m} = D_{IMP,m} V_m \quad \text{(Equation 2)}$$

where $D_{IMP,t,i\,m}$ = impingement density (n per m$^3$) of taxon $t$ and life stage $i$ at month $m$, and
$V_m$ = water withdrawal volume (m$^3$) for Units 1 and 2 combined at month $m$.

For baseline impact calculations under existing CWIS configuration, monthly entrainment and impingement abundance was estimated using Equation 1 for three withdrawal case scenarios of $V_m$ (10-year AIF, DIF, and 50% DIF) based on Table 2–1. Annual entrainment and impingement abundance of taxon $t$ and life stage $i$ ($E_{t,i}$ and $I_{t,i}$, respectively) at Merrimack Station Units 1 and 2 combined under existing CWIS configurations was estimated for each of the three water withdrawal case scenarios by summation of $E_{t,i,m}$ and $I_{t,i,m}$, respectively as:

$$E_{t,i} = \sum_{m=1}^{N_m} E_{t,i,m} \text{ and} \quad \text{(Equation 3)}$$

$$I_{t,i} = \sum_{m=1}^{N_m} I_{t,i,m} \quad \text{(Equation 4)}$$

### *2.4.3 Wedgewire Screen Calculations of Entrainment and Impingement Abundance*

Annual and monthly entrainment and impingement abundance by taxon and life stage with 3-mm slot-width wedgewire half screens at Merrimack Station Units 1 and 2 were estimated using Equations 1 through 4 except a taxon-species proportion entrained ($P_{WWS}$) was first applied to densities identified at the lowest identifiable taxon prior to species apportionment. For August through March, $P_{WWS}$ =1 was used and values shown in Table 2–2 were used for the April through July period.

### *2.4.4 Closed-Cycle Cooling Tower Calculations of Entrainment and Impingement Abundance*

Annual and monthly entrainment and impingement abundance by taxon and life stage with closed-cycle cooling towers at Merrimack Station Units 1 and 2 were estimated using Equations 1 through 4 except the water withdrawal volumes were 95% less as shown in Table 2–1.

## 2.5 Equivalent Recruit Model for Estimating Direct Use Benefits

The number of equivalent recruits to the recreational fishery from entrained ichthyoplankton or impinged juveniles at Merrimack Station was estimated following methods of the equivalent adult model established by Saila *et al.* (1997), USEPA (2004), EPRI (2004, 2012), and Barnthouse (2005). Instead of estimating equivalent adults, this analysis estimates the number of equivalent recruits (i.e., “catchable fish”), defined as the equivalent number that would reach the age at first recruitment to the recreational fishery (i.e., age first susceptible to hook-and-line gear), that would have resulted if the early life stages had not been entrained or impinged (Horst 1975; Goodyear 1978). It was conservatively assumed that entrainment mortality was 100%, and all entrained species were lost from the environment. The number of equivalent recruits ($N_R$) for each taxon $t$ and life stage $i$ entrained or impinged fish younger than the age of recruitment in month $m$ was estimated as follows:

$$N_{R,t,i,m} = E_{t,s,m} S_{t,i \rightarrow R} \quad \text{for entrainment and} \qquad \text{(Equation 5)}$$

$$N_{R,t,i,m} = I_{t,i,m} S_{t,i \rightarrow R} \quad \text{for impingement} \qquad \text{(Equation 6)}$$

where $S_{t,i \rightarrow R}$ = fraction of fish expected to survive from life stage $i$ to recruitment to the recreational fishery (age of equivalence) as determined by age at initial recruitment (i.e., age first susceptible to hook-and-line gear) as shown in Table 2–5,

$E_{t,i,m}$ is defined as in Equation 1 and $I_{t,i,m}$ is defined as in Equation 2. For impinged fish at age of recruitment or older, $S_{t,i \rightarrow R}$ was equal to 1.

The $S_{t,i \rightarrow R}$ parameter was estimated as follows:

$$S_{t,i \rightarrow R} = S_{\text{adj},i} \prod_{j=i+1}^{j_{\max}} S_j \qquad \text{(Equation 7)}$$

where:

$S_{\text{adj},i}$= survival fraction adjusted for mixed ages within the entrained or impinged life stage *i* and calculated as $2S_i\exp(-\text{Log}_e(1+S_i))$ (EPRI 2004, 2012),

$S_j$ = survival fraction from life stage *j* to *j*+1, and

$j_{\max}$ = the life stage immediately prior to age of recruitment (=*R*-1).

The survival fractions were calculated from the instantaneous total mortality rate (*Z*) for each life stage by *S* = exp(-*Z*) or exp(-(*M*+*F*)) where *M* is the instantaneous natural mortality rate and *F* is the instantaneous fishing mortality rate. Since *F* = 0 for ages or life stages younger than age of recruitment, *S* = exp(-*M*). Age of recruitment, unless otherwise noted, was determined as the age where *v*, the fraction vulnerable to the fishery, was greater than zero from life history tables in USEPA (2006) and EPRI (2012) and is shown in Table 2–5.

Balanced life history tables for fish were constructed and lifetime average fecundities were estimated to provide reasonable species-specific survival fractions (*S*) for each life stage using the methods of Saila *et al.* (1997) and EPRI (2012). The age with the highest uncertainty in mortality, often YOY, was derived by subtracting the *Z* for each pre-adult life stage from the total *Z* from egg to adulthood, assuming the population was at equilibrium such that two eggs from a female survive to reproductive age (i.e., each female produces two offspring to replace herself and a male). The life-history parameters based on an equilibrium population are presented by life stage or age in Appendix A. Life History Tables.

In addition to equivalent recruits, age-1 equivalents were estimated following Equations 5 through 7 except the terminal age was Age 1 instead of age of recruitment (*R*).

## 2.6 Estimation of Indirect Use of Forage Benefits

### *2.6.1 Production Foregone of Forage Species*

The production foregone of nine entrained and impinged forage species listed in Table 2–5 was estimated following standard methods established by USEPA (2004) and EPRI (2004, 2012). Production forgone is the reduction in prey biomass available to predators due to, in this case, entrainment or impingement at

Merrimack Station, and includes the expected future growth prior to consumption by predators if the fish was not entrained or impinged. In this assessment, 100% of foregone production was conservatively assumed to be consumed by recreationally valuable predator species. Specifically, the Rago (1984) model was used to estimate production foregone of a particular species due to fish entrained at any given life stage by integrating the instantaneous growth and mortality rates over the life stage *i* as follows:

$$P_i = \frac{G_i N_i W_i [\exp(G_i - Z_i) - 1]}{(G_i - Z_i)} \qquad \text{(Equation 8)}$$

where $P_i$ = production forgone (number of individuals) for age or life stage *i*,

$G_i$ = instantaneous growth rate for individuals of age or life stage *i*,

$Z_i$ = instantaneous total mortality rate for individuals of age or life stage *i*,

$W_i$ = average weight of individuals at start of age or life stage *i*, and

$N_i$ = number of individuals lost due to entrainment or impingement (assuming 100% mortality) of age or life stage *i*.

While Equation 8 estimates the production foregone for the entrained or impinged life stage *i*, the equation may also be used to estimate production foregone at a later life stage *j* instead of *i* by accounting $N_i$ for mortality from stage *i* to *j*. Therefore, production foregone at any future life stage *j*, for a fish entrained or impinged at life stage *i* ($P_{i,j}$) is equal to:

$$P_{i,j} = \frac{G_j N_i S_{i,j} W_j \left[\exp\left(G_j - Z_j\right) - 1\right]}{\left(G_j - Z_j\right)}, \qquad \text{(Equation 9)}$$

where $S_{ij}$ = proportion of individuals that survive from entrained or impinged stage *i* to later stage *j*, and by analogy to Equation 8 is calculated as:

$$S_{i,j} = S_{\text{adj},i} \prod_{k=i+1}^{j-1} S_j, \qquad \text{(Equation 10)}$$

Analogous to the adjustment to survival fraction for the entrained or impinged life stage to account for individuals entrained or impinged at any age within the life stage (i.e., median age-at-entrainment) rather than assuming individuals were entrained at the beginning of the stage, Equation 8 is similarly adjusted to account for a median life-stage length over which production can occur:

$$P_i = \frac{G_i N_i W_i \left[\exp\left\{(g_i - z_i)\left(d_i - \widehat{d_i}\right)\right\} - 1\right]}{(G_i - Z_i)} \qquad \text{(Equation 11)}$$

where $P_i$ = production forgone for age or life stage *i*,

$G_i$ = instantaneous growth rate for individuals of age or life stage *i*,

$Z_i$ = instantaneous total mortality rate for individuals of age or life stage *i*,

$d_i$ = duration (in days) of age or life stage *i* with $d_i/2$ equal to time interval between assumed median age-at-entrainment and end of the life stage,

$\hat{d}_i$ = median age-at-death as $\hat{d}_i = \left(\log_e 2 - \log_e(1 + e^{-z_i d_i})\right)/z_i$,

$g_i$ = daily instantaneous growth rate for individuals of age or life stage $i$ ($=G_i/d_i$),

$z_i$ = daily instantaneous total mortality rate for individuals of age or life stage $i$ ($=Z_i/d_i$),

$W_i$ = average weight of individuals at start of age or life stage $i$, and

$N_i$ = number of individuals lost due to entrainment (assuming 100% mortality) of age or life stage $i$.

The total production foregone ($P_T$) of all life stages entrained for a given species is then estimated by the adjusted Rago (1984) model as:

$$P_T = \sum_{i=t_{\min}}^{t_{\max}} \sum_{j=i}^{A_{\max}} P_{i,j} \qquad \text{(Equation 12)}$$

where $P_{i,j}$ = $P_i$ for entrained stage (i.e., $j=i$) as calculated by Equation 11 otherwise by Equation 9 for later stages,

$A_{\max}$ = theoretical maximum age,

$t_{\min}$ = the earliest entrained life stage, and

$t_{\max}$ = the oldest entrained life stages (i.e., number of life stages entrained).

The Rago (1984) model for production forgone estimates the biomass production lost but does not include biomass lost at time of entrainment or impingement that is not consumed by predators. To correct for this bias, the entrained or impinged biomass lost ($B_L$), as calculated by Equation 13 below, was added to the total production foregone estimate from Equation 12.

$$B_L = N_i \hat{W}_i \qquad \text{(Equation 13)}$$

where $B_L$ = direct biomass lost (in pounds) of individuals at entrained stage $i$,

$\hat{W}_i$ = median weight at stage $i$ calculated as $W_i e^{g_i \hat{d}_i}$ .

Herein, the adjusted total production forgone model estimate ($P_F$) is defined as

$$P_F = P_T + B_L \qquad \text{(Equation 14)}$$

To evaluate the reduction of economically valuable predators as a result of the foregone production that would be consumed, the $P_F$ estimate for entrained or impinged forage species was then converted to predator biomass lost due to entrainment or impingement of forage species ($B_P$) by

$$B_P = (k)(P_F) \qquad \text{(Equation 15)}$$

where $k$ = trophic transfer efficiency of 0.1 (USEPA 2004, 2006; EPRI 2012).

### *2.6.2 Natural Mortality Biomass of Recreational Fishery Species*

A fraction of recreationally important fishery species can also provide indirect benefit as prey biomass before they mature and enter the fishery. This indirect benefit was estimated as the biomass of the natural mortalities of recreationally important fishery species before reaching recruitment age that would have resulted if the early life stage had not been entrained or impinged. The biomass associated with natural mortality from the entrained or impinged stage $i$ ($B_{M,i}$) and later stage $j$ ($B_{M,j}$) for a particular recreational fishery species was assumed to serve as forage biomass by predation and was calculated as

$$B_{M,i} = N_i\left(1 - S_{adj,i}\right)\hat{W}_i \qquad \text{(Equation 16)}$$

$$B_{M,j} = N_i S_{i,j}\left(1 - S_j\right)\widehat{W}_j \qquad \text{(Equation 17)}$$

$$B_M = \sum_{j=i}^{R-1} B_{M,j} \qquad \text{(Equation 18)}$$

where $B_{M,j}$ = $B_{M,i}$ for entrained or impinged stage (i.e., $j=i$) as calculated by Equation 16 otherwise by Equation 17 for later stages to and including the age prior to recruitment ($R$-$1$),

$N_i$ = number of individuals lost due to entrainment (assuming 100% mortality) of age or life stage $i$,

$S_{\mathrm{adj},i}$= survival fraction adjusted for mixed ages within the entrained or impinged life stage $i$ as defined in Equation 7,

$S_{ij}$ = proportion of individuals that survive from entrained or impinged stage $i$ to later stage $j$ as defined by Equation 10,

$S_j$ = proportion of individuals that survive from stage $j$ to next stage $j+1$, and

$\widehat{W}_i$ and $\widehat{W}_j$ is the median weight at life stage $i$ and $j$ as defined in Equation 13.

The indirect (secondary) benefit of a fraction of recreational fishery species serving as forage to a predator is quantified by converting the total biomass associated with natural mortalities of fishery species (from summation of the $B_M$ estimates from each species) to predator biomass ($B_P$) by applying a 10% trophic transfer efficiency similar to Equation 15.

### *2.6.3 Equivalent Predator*

Largemouth Bass (Age 2) was selected as the equivalent predator for modeling indirect recreational fisheries benefit from the production foregone from forage species and the natural mortality biomass of recreational fishery species prior to recruitment. Largemouth Bass was selected because it was one of the most abundant fish species in Hooksett Pool (Normandeau 2012, 2017b) and was the single most preferred fish species targeted by recreational anglers (Responsive Management 2016). Based on the smallest size of 279-305 mm TL (11-12 inches) valued by anglers (Responsive Management 2016), mean length at age of Largemouth Bass (Normandeau 2017b), and age with some vulnerability to fishing (age at first recruitment) used by USEPA (2006), Age 2 was selected as the age of Largemouth Bass to serve as the equivalent predator for converting forage benefits to the equivalent number of fish with economic value. The equivalent number of Age-2 Largemouth Bass from the predator biomass ($B_P$), which was derived from adjusted total production foregone of forage species and forage biomass associated with natural mortalities of all recreational fishery species prior to age of recruitment, was estimated as:

$$N_{B\rightarrow R,LMB} = B_P/\widehat{W}_{Age\ 2} \qquad \text{(Equation 19)}$$

where $\widehat{W}_{Age\ 2}$ = median weight at age 2 (140 grams) based on start weight and growth rate shown in the life history tables in Appendix A.

## 2.7 Equivalent Recreational Catch

The additional fish (equivalent recreational catch) that would result from implementing each entrainment-reducing technology at Merrimack Station was quantified by the change in number of equivalent recruits (Section 2.5) of each recreational fishery species and Largemouth Bass recruits from production foregone of forage species (Section 2.6.1) and biomass lost due to predation (natural mortality) of early life stages of recreational fishery species (Section 2.6.2) due to entrainment and impingement losses with and without the entrainment-reducing technology.

## 2.8 Summary of Assumptions

In no particular order of importance, the principal assumptions of the methods used to estimate the benefit, in number of fish of recreational importance, from entrainment-reducing technologies at Merrimack Station were the following:

1. This assessment is based on entrainment and impingement abundance directly linked to three flow regimes: (1) 10-year AIF, (2) 100% DIF, and (3) 50% DIF.
2. This assessment estimates the recreational benefit (number of fish) that would result from reductions in entrainment and impingement from implementing one of two entrainment-reducing technologies compared to the existing CWIS at Merrimack Station. Specifically, this assessment evaluates a 3-mm wedgewire half screen operational from April through July (the period representing about 99% of annual entrainment) and year-round operation of closed-cycle cooling towers that reduces intake flow by 95%.
3. Entrainment and impingement of fish at Merrimack Station has zero to negligible direct impact to commercial fisheries because there are no known commercial fisheries in Hookset Pool and zero to little downstream contribution to marine fisheries.
4. Recreational harvest was assumed to be negligible in Hooksett Pool because of the common practice of catch-and-release angling; therefore, an equivalent fishery yield model was not used to estimate harvest foregone due to entrainment and impingement since it would be inappropriate to use instantaneous fishing mortality rates available for all inland regions (USEPA 2006; EPRI 2012) and lead to an overestimate of recreational harvest for a catch-and-release fishery.
5. The number of equivalent fish at the age first susceptible to recreational fishing, as defined by the age initially or partially vulnerable to fishing (USEPA 2006; EPRI 2012; life history tables in Appendix A), is considered representative of the equivalent catch by anglers from reductions in annual entrainment and impingement at Merrimack Station.
6. The number of equivalent recruits to the fishery involves two assumptions with offsetting biases: (1) all of the incremental equivalent number recruited to the fishery (i.e., harvestable or catchable fish) are caught and valued when in reality perhaps only a portion of a particular cohort of fish would ever be caught (overestimates benefit); and (2) there are no multiple captures of individual fish, when it is possible that fish are caught multiple times in a year (underestimates benefit).
7. All of the production foregone of forage species and biomass lost due to predation on early life stages of fishery species (assuming 100% of natural mortality is due to predation) would be transferrable to predatory species of economic value at a 10% trophic transfer efficiency (USEPA 2004, 2006; EPRI 2012).
8. The selection of Age-2 Largemouth Bass as the single predator species converted from lost forage biomass has the bias to overestimate the recreational benefit because Age 2 has the lowest individual weight among ages vulnerable to fishing, overestimates predation by this species alone when in reality there are many predatory species, and Largemouth Bass has the highest economic value in Hooksett Pool.
9. Production foregone models assume no trophic dead ends from species reaching a size too large for consumption by predators.

10. The life-history parameters were based on an equilibrium population such that two eggs from a female survive to reproductive age (i.e., each female produces two offspring to replace her and a male). The life-history parameters based on an equilibrium population are presented by life stage or age in Appendix A. Life History Tables.
11. Equivalent recruit model and production foregone model assumes constant year-to-year mortality for each life stage/age.
12. Taxa identified to higher-than-species level could be appropriately apportioned to species proportionally by month based on the monthly mean densities among member species identified in the respective month and by the most similar life stage.
13. Densities of damaged or unidentified eggs and larvae could be allocated proportionally to identifiable taxa.
14. The classification of species as recreationally important fishery species and forage species based on USEPA (2006) was considered representative of the fishery in Hooksett Pool.
15. For this assessment, the impingeable entrainables excluded from entering and passing through the CWIS by 3-mm wedgewire half screens were assumed to have 100% survival.
16. Entrainment and impingement density (and abundance) was assumed to be directly proportional to CWIS flow.
17. Entrainment and impingement densities from samples were assumed representative of the density within a given week and month, and were assumed to be equal between the Units 1 and 2.
18. One-hundred percent (100%) mortality was assumed for impingement and entrainment.
19. Entrainment and impingement densities from sampled years (2005 through 2007, and 2017) were assumed to be representative of the 2007 through 2016 period and during future periods of operation if entrainment-reducing technologies were implemented.
20. The proportion entrained from the results of 2017 wedgewire screen performance study (Normandeau 2017a) and presented in Table 2–2 was used to estimate entrainment abundance from water withdrawal through a 3-mm wedgewire screen at Merrimack Station Units 1 and 2 combined during April through July, assuming this proportion was representative for future April through July periods. No exclusion was assumed from August through March when wedgewire screen (“WWS”) would not be in use.

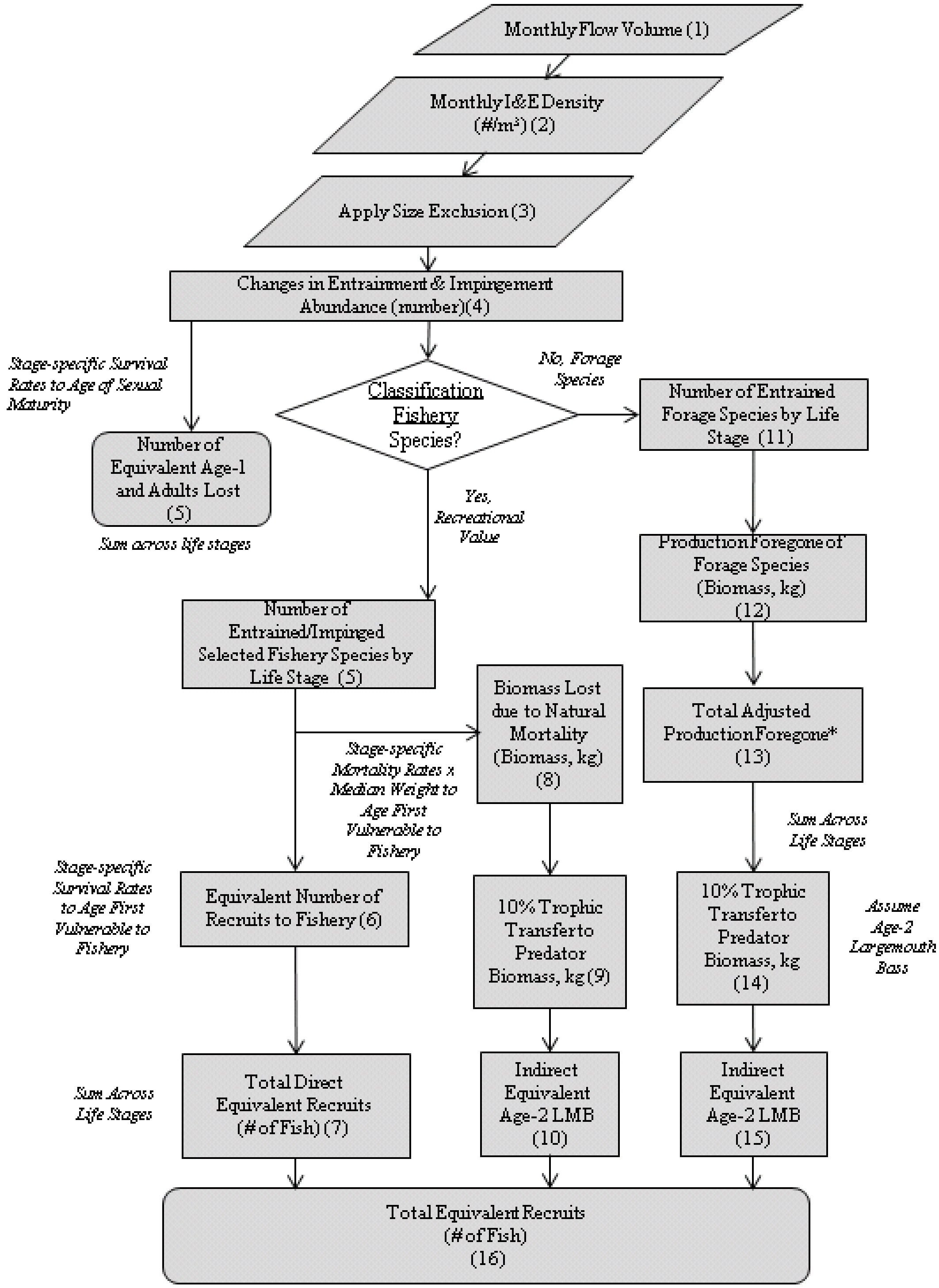


**Figure 2–1. General approach used to evaluate annual entrainment and impingement abundance expressed as equivalent recruit loss to the recreational fishery at three water withdrawal scenarios under three cooling water intake structure configurations at Merrimack Station.**

**Table 2–1. Estimated flow rate (million gallons per day, MGD) and volume (million cubic meters, $Mm^3$) of water withdrawn by cooling water intake structure units 1 and 2 at Merrimack Station based on a 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF), and 50% capacity factor at DIF for baseline conditions, installed 3-mm wedgewire screen (WWS), and closed-cycle cooling towers.**

| | 10-year AIF | | | | 100% DIF | | | | 50% DIF | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline & 3-mm WWS | | Closed-cycle Cooling Towers | | Baseline & 3-mm WWS | | Closed-cycle Cooling Towers | | Baseline & 3-mm WWS | | Closed-cycle Cooling Towers | |
| Month | MGD | $Mm^3$ | MGD | $Mm^3$ | MGD | $Mm^3$ | MGD | $Mm^3$ | MGD | $Mm^3$ | MGD | $Mm^3$ |
| Jan | 199.6 | 23.4 | 10.0 | 1.2 | 287.3 | 33.7 | 14.4 | 1.7 | 143.7 | 16.9 | 7.2 | 0.8 |
| Feb | 206.3 | 21.9 | 10.3 | 1.1 | 287.3 | 30.5 | 14.4 | 1.5 | 143.7 | 15.2 | 7.2 | 0.8 |
| Mar | 191.4 | 22.5 | 9.6 | 1.1 | 287.3 | 33.7 | 14.4 | 1.7 | 143.7 | 16.9 | 7.2 | 0.8 |
| Apr | 89.4 | 10.2 | 4.5 | 0.5 | 287.3 | 32.6 | 14.4 | 1.6 | 143.7 | 16.3 | 7.2 | 0.8 |
| May | 82.7 | 9.7 | 4.1 | 0.5 | 287.3 | 33.7 | 14.4 | 1.7 | 143.7 | 16.9 | 7.2 | 0.8 |
| Jun | 127.8 | 14.5 | 6.4 | 0.7 | 287.3 | 32.6 | 14.4 | 1.6 | 143.7 | 16.3 | 7.2 | 0.8 |
| Jul | 173.6 | 20.4 | 8.7 | 1.0 | 287.3 | 33.7 | 14.4 | 1.7 | 143.7 | 16.9 | 7.2 | 0.8 |
| Aug | 119.2 | 14.0 | 6.0 | 0.7 | 287.3 | 33.7 | 14.4 | 1.7 | 143.7 | 16.9 | 7.2 | 0.8 |
| Sep | 78.1 | 8.9 | 3.9 | 0.4 | 287.3 | 32.6 | 14.4 | 1.6 | 143.7 | 16.3 | 7.2 | 0.8 |
| Oct | 59.4 | 7.0 | 3.0 | 0.3 | 287.3 | 33.7 | 14.4 | 1.7 | 143.7 | 16.9 | 7.2 | 0.8 |
| Nov | 111.8 | 12.7 | 5.6 | 0.6 | 287.3 | 32.6 | 14.4 | 1.6 | 143.7 | 16.3 | 7.2 | 0.8 |
| Dec | 179.8 | 21.1 | 9.0 | 1.1 | 287.3 | 33.7 | 14.4 | 1.7 | 143.7 | 16.9 | 7.2 | 0.8 |
| Total | 134.9 | 15.5 | 6.7 | 0.8 | 287.3 | 33.1 | 14.4 | 1.7 | 143.7 | 16.5 | 7.2 | 0.8 |

**Table 2–2. Efficacy of a 3-mm wedgewire half-screen for reducing entrainment by taxon and life stage at Merrimack Station, Unit 1, based on the 3-mm wedgewire test screen performance study from 22 May 2017 through 3 September 2017 at Unit 1 (Normandeau 2017a).**

| Lowest Taxon Identified | Life Stage | % Exclusion | Proportion Entrained |
|---|---|---|---|
| Alosa Species | PYSL | 100.0 | 0.000 |
| | Unid Larvae | 90.8 | 0.092 |
| American Eel | YROL | 100.0 | 0.000 |
| American Shad | YSL | 65.6 | 0.344 |
| | PYSL | 100.0 | 0.000 |
| Black Crappie | YSL | 100.0 | 0.000 |
| | PYSL | 99.2 | 0.008 |
| | YOY | 100.0 | 0.000 |
| | Unid Larvae | 100.0 | 0.000 |
| Blacknose Dace | PYSL | 100.0 | 0.000 |
| | Unid Larvae | 100.0 | 0.000 |
| Blueback Herring/Alewife | PYSL | 100.0 | 0.000 |
| | Unid Larvae | 85.3 | 0.147 |
| Bluegill | PYSL | 100.0 | 0.000 |
| | YROL | 100.0 | 0.000 |
| Brown Bullhead | PYSL | 0.0 | 1.000 |
| Carp and Minnow Family | Eggs | -2164 | 1.000 |
| | YSL | -3.5 | 1.000 |
| | PYSL | 87.5 | 0.125 |
| | Unid Larvae | 81.2 | 0.188 |
| Common Shiner | PYSL | 100.0 | 0.000 |
| Fallfish | PYSL | 99.4 | 0.006 |
| | Unid Larvae | 100.0 | 0.000 |
| Golden Shiner | PYSL | 100.0 | 0.000 |
| | YROL | 100.0 | 0.000 |
| Herring Family | PYSL | 0.0 | 1.000 |
| | Unid Larvae | 100.0 | 0.000 |

(Continued)

**Table 2-2. Continued.**

| Lowest Taxon Identified | Life Stage | % Exclusion | Proportion Entrained |
|---|---|---|---|
| Largemouth Bass | YSL | 100.0 | 0.000 |
| | PYSL | 66.7 | 0.333 |
| | YOY | 100.0 | 0.000 |
| | Unid Larvae | 100.0 | 0.000 |
| Lepomis Species | YSL | 77.5 | 0.225 |
| | PYSL | 96.0 | 0.040 |
| | Unid Larvae | 91.6 | 0.084 |
| Lepomis Species/Crappie Species | YSL | 100.0 | 0.000 |
| | PYSL | 96.1 | 0.039 |
| | Unid Larvae | 97.8 | 0.022 |
| Margined Madtom | PYSL | 0.0 | 1.000 |
| | YOY | 51.3 | 0.487 |
| Rock Bass | PYSL | 100.0 | 0.000 |
| | Unid Larvae | 100.0 | 0.000 |
| Smallmouth Bass | PYSL | 100.0 | 0.000 |
| Spottail Shiner | PYSL | 100.0 | 0.000 |
| | YOY | 100.0 | 0.000 |
| Sucker Family | PYSL | 100.0 | 0.000 |
| | Unid Larvae | 100.0 | 0.000 |
| Sunfish Family | YSL | 0.0 | 1.000 |
| | PYSL | 100.0 | 0.000 |
| Tessellated Darter | YSL | 89.6 | 0.104 |
| | PYSL | 63.1 | 0.369 |
| | Unid Larvae | 92.5 | 0.075 |
| Unidentified Osteichthyes | Eggs | 6.6 | 0.934 |
| | PYSL | 92.3 | 0.077 |
| | Unid Larvae | 86.3 | 0.137 |
| Walleye | PYSL | 100.0 | 0.000 |

(Continued)

**Table 2-2. Continued.**

| Lowest Taxon Identified | Life Stage | % Exclusion | Proportion Entrained |
|---|---|---|---|
| White Sucker | YSL | 97.5 | 0.025 |
| | PYSL | 98.8 | 0.012 |
| | YOY | 0.0 | 1.000 |
| | Unid Larvae | 94.2 | 0.058 |
| Yellow Bullhead | YOY | 51.0 | 0.490 |
| Yellow Perch | YSL | 100.0 | 0.000 |
| | PYSL | 87.5 | 0.125 |
| Total | Eggs | -3471 | 1.000 |
| | YSL | 64.1 | 0.359 |
| | PYSL | 96.4 | 0.036 |
| | YOY | 56.2 | 0.438 |
| | YROL | 100.0 | 0.000 |
| | Unid Larvae | 86.8 | 0.132 |
| | Total | 89.0 | 0.110 |

**Table 2–3. Common and scientific names of all fish taxa identified from entrainment samples collected at Units 1 and 2 at Merrimack Station from May 2006 through September 2006 and April 2007 through June 2007 at Units 1 and 2 combined, and May through September 2017 at Unit 1 (Normandeau 2007, Normandeau 2017a).**

| Common Taxon Name | Scientific Name | 2006 | 2007 | 2017 |
|---|---|---|---|---|
| **Anguillidae (Freshwater Eels)** | | | | |
| American Eel | *Anguilla rostrata* | | | X |
| **Clupeidae (Herrings)** | | | | |
| Alosa Species | *Alosa sp.* | | | X |
| American Shad | *Alosa sapidissima* | | | X |
| Blueback Herring/Alewife | *Alosa aestivalis/A. pseudoharengus* | | | X |
| Herring Family | Clupeidae | | X | X |
| **Cyprinidae (Carps and Minnows)** | | | | |
| Blacknose Dace | *Rhinichthys atratulus* | | | X |
| Carp and Minnow Family | Cyprinidae | X | X | X |
| Common Shiner | *Luxilus cornutus* | | | X |
| Fallfish | *Semotilus corporalis* | | | X |
| Golden Shiner | *Notemigonus crysoleucas* | | | X |
| Spottail Shiner | *Notropis hudsonius* | X | X | |
| **Catostomidae (Suckers)** | | | | |
| Sucker Family | Catostomidae | | | X |
| White Sucker | *Catostomus commersonii* | X | X | X |
| **Ictaluridae (North American catfishes)** | | | | |
| Brown Bullhead | *Ameiurus nebulosus* | X | | |
| Margined Madtom | *Noturus insignis* | X | | X |
| Yellow Bullhead | *Ameiurus natalis* | | | X |
| **Moronidae (Temperate Basses)** | | | | |
| White Perch | *Morone americana* | | | X |
| **Centrarchidae (Sunfish Family)** | | | | |
| Black Crappie | *Pomoxis nigromaculatus* | | | X |
| Bluegill | *Lepomis macrochirus* | | | X |
| Largemouth Bass | *Micropterus salmoides* | | | X |
| Lepomis Species | *Lepomis* sp. | | | X |
| Lepomis Species/Crappie Species | *Lepomis* sp./*Pomoxis* sp. | | | X |
| Rock Bass | *Ambloplites rupestris* | X | | X |
| Smallmouth Bass | *Micropterus dolomieu* | | | X |
| Sunfish Family | Centrarchidae | X | X | X |
| **Percidae (Perches and Darters)** | | | | |
| Tessellated Darter | *Etheostoma olmstedi* | X | X | X |
| Walleye | *Sander vitreus* | | | X |
| Yellow Perch | *Perca flavescens* | X | X | X |
| | | | | |
| Unidentified Osteichthyes | | X | X | X |

**Table 2–4. Common and scientific names of all fish taxa identified in 24-hour impingement samples collected at Merrimack Station Units 1 and 2 combined from 29 June 2005 through 28 June 2007 (Normandeau 2007) and electrofishing catch in Hooksett Pool during August and September from 1972 through 2013[a] (Normandeau 2017b).**

| Common Name | Scientific Name | 2005-2007 Impingement Study | 1972-2013 Electrofishing Program |
|---|---|---|---|
| Alewife | *Alosa pseudoharengus* | | X |
| American Eel | *Anguilla rostrata* | X | X |
| American Shad | *Alosa sapidissima* | | X |
| Banded Sunfish | *Enneacanthus obesus* | X | |
| Black Crappie | *Pomoxis nigromaculatus* | X | X |
| Bluegill | *Lepomis macrochirus* | X | X |
| Brown Bullhead | *Ameiurus nebulosus* | X | X |
| Carp and minnow family | Cyprinidae | | X |
| Chain Pickerel | *Esox niger* | X | X |
| Common Shiner | *Luxilus cornutus* | | X |
| Blacknose Dace | *Rhinichthys atratulus* | | X |
| Eastern Silvery Minnow | *Hybognathus regius* | | X |
| Fallfish | *Semotilus corporalis* | X | X |
| Golden Shiner | *Notemigonus crysoleucas* | X | X |
| Largemouth Bass | *Micropterus salmoides* | X | X |
| Margined Madtom | *Noturus insignis* | X | X |
| Pumpkinseed | *Lepomis gibbosus* | X | X |
| Rainbow Smelt | *Osmerus mordax* | X | |
| Redbreast Sunfish | *Lepomis auritus* | X | X |
| Rock Bass | *Ambloplites rupestris* | X | X |
| Smallmouth Bass | *Micropterus dolomieu* | X | X |
| Spottail Shiner | *Notropis hudsonius* | X | X |
| Sunfish family | Centrarchidae | X | X |
| Tessellated Darter | *Etheostoma olmstedi* | X | X |
| White Perch | *Morone americana* | X | X |
| White Sucker | *Catostomus commersonii* | X | X |
| Yellow Bullhead | *Ameiurus natalis* | X | X |
| Yellow Perch | *Perca flavescens* | X | X |

[a] Electrofishing catch from Hooksett Pool (Stations 9-18) during 1972, 1973, 1974, 1976, 1995, 2004, 2005, 2010, 2011, 2012, and 2013 (Normandeau 2017b).

**Table 2–5. Species importance, economic value categories, and age of equivalence for species identified from entrainment and impingement samples at Merrimack Station (Normandeau 2007, Normandeau 2017a).**

| Species | Species Importance[a] | Economic Value Category[b] | Age at Initial Recruitment to Angling[c] | Age at Adulthood[d] | Maximum Age[e] |
|---|---|---|---|---|---|
| Alewife | Forage | | | 4 | 8 |
| American Eel | Recreational Fishery | Panfish | 3 | 6 | 25 |
| American Shad | Recreational Fishery | Small Game | 4 | 4 | 10 |
| Banded Sunfish | Recreational Fishery | Panfish | 2 | 2 | 4 |
| Black Crappie | Recreational Fishery | Panfish | 2 | 2 | 9 |
| Blacknose Dace | Forage | | | 1 | 3 |
| Bluegill | Recreational Fishery | Panfish | 2 | 2 | 7 |
| Brown Bullhead | Recreational Fishery | Panfish | 2 | 2 | 7 |
| Chain Pickerel | Recreational Fishery | Walleye/Pike | 2 | 1 | 9 |
| Common Shiner | Forage | | | 1 | 6 |
| Fallfish | Forage | | | 2 | 6 |
| Golden Shiner | Forage | | | 1 | 9 |
| Largemouth Bass | Recreational Fishery | Bass | 2 | 2 | 17 |
| Margined Madtom | Forage | | | 1 | 4 |
| Pumpkinseed | Recreational Fishery | Panfish | 2 | 2 | 7 |
| Rainbow Smelt | Recreational Fishery | Panfish | 2 | 2 | 7 |
| Redbreast Sunfish | Recreational Fishery | Panfish | 2 | 2 | 7 |
| Rock Bass | Recreational Fishery | Panfish | 2 | 2 | 7 |
| Smallmouth Bass | Recreational Fishery | Bass | 3 | 3 | 12 |
| Spottail Shiner | Forage | | | 1 | 4 |
| Tessellated Darter | Forage | | | 1 | 4 |
| Walleye | Recreational Fishery | Walleye/Pike | 3 | 2 | 11 |
| White Perch | Recreational Fishery | Panfish | 2 | 2 | 10 |
| White Sucker | Forage | | | 3 | 8 |
| Yellow Bullhead | Recreational Fishery | Panfish | 2 | 2 | 7 |
| Yellow Perch | Recreational Fishery | Panfish | 2 | 2 | 7 |

[a] USEPA 2006.

[b] USEPA 2014.

[c] See life history tables for citations on age at first recruitment to the recreational fishery (i.e., age first susceptible to angling gear) for individual species in Appendix A.

[d] See life history tables for citations on age at first sexual maturity (i.e., earliest age of adulthood) for individual species in Appendix A.

[e] See life history tables for citations on maximum age in Appendix A.

# 3 RESULTS

## 3.1 Entrainment Abundance

Fish entrained at Merrimack Station consisted primarily of larvae from forage fish species and, to a lesser extent, fishery species, and not many eggs and YOY or older. The most abundant taxa identified in entrainment samples were White Sucker PYSL (33.0%), Carp and Minnow family PYSL (13.6%), Sunfish Family PYSL (10.9%), and Yellow Perch PYSL (9.3%) at Unit 1 during 2006, 2007 and 2017 (Table 3–1). At Unit 2, the most abundant taxa in 2006 and 2007 entrainment samples were White Sucker PYSL (53.9%), Carp and Minnow family PYSL (20.7%) and YSL (5.7%), Sunfish Family PYSL (5.0%) and YSL (4.5%), and Yellow Perch PYSL (2.5%)(Table 3–1). The monthly entrainment densities at the taxon and life stage identified by the laboratory are presented in Table 3–2.

Annual entrainment at Merrimack Station is essentially limited to late spring through summer seasons. About 99% of entrainment occurs from April through July when the wedgewire screen operation was proposed (Table 3–3). The timing of spawning may shift from year to year largely dependent on flows and water temperature, but April (0.5% of annual entrainment) was included in the WWS operational season to capture the potential onset of early spawning in response to changes in environmental conditions associated with climate change. June (52.5%) followed by May (38.1%) were the peak months of entrainment.

Entrainment density was estimated to species level after apportioning taxa identified at higher taxonomic levels to species level based on monthly mean densities of identified member species. Sunfish family YSL densities were apportioned to Black Crappie, Bluegill and Largemouth Bass and *Lepomis/Pomoxis* sp. densities were apportioned to Black Crappie and Bluegill (Table 3–4). Larvae identified to *Alosa* sp., Carp and Minnow family, Herring family, Sucker family, Sunfish family, *Lepomis/Pomoxis* sp, and unidentified osteichthyes were apportioned to species on a monthly basis (Table 3–5). Higher-level taxa of larvae not identifiable to YSL or PYSL stages, presumably from damage, were also apportioned to species (Table 3–6). Due to data limitations, some higher-level taxa were apportioned based on the next stage or from densities in adjacent months. Based on the monthly proportional density, monthly mean entrainment density was apportioned to species level as shown in Table 3–7.

Based on the species-apportioned entrainment density averaged by month, annual entrainment abundance at the 10-year AIF was estimated to be 416,279 individuals for 3-mm WWS and 158,589 for closed-cycled cooling which was substantially lower than the expected 3,171,776 to be entrained at the existing CWIS (Table 3–8). The highest annual entrainment abundance estimated was 7,789,245 organisms for existing CWIS under DIF. Table 3–9 through Table 3–17 show the monthly breakdown by species for each cooling water withdrawal and technology scenario.

## 3.2 Impingement Abundance

Monthly mean impingement densities at the lowest taxon possible were estimated for each calendar month based on 24-hour samples adjusted for collection efficiency and collected from June 2005 through June 2007 (Table 3–18). The dominant species collected in impingement samples at Merrimack Station Units 1 and 2 combined were Bluegill (54.0%), Spottail Shiner (9.7%), Black Crappie (6.5%) and Yellow Perch (5.9%) (Table 3–19). Presumably damaged impinged juveniles were identified to Sunfish Family so when present (July and September), densities were apportioned to identified sunfish species in July and September proportional to monthly densities (Table 3–20; Table 3–21).

To estimate equivalent recruits from individuals impinged at earlier life stages (e.g., YOY or Age 1), the species-apportioned monthly densities were further apportioned into age classes determined by applying proportion at age (determined from length measurements) to density on a monthly basis (Table 3–22; Table 3–23). Annual impingement abundance ranged from 2,285 to 4,902 individuals for the existing CWIS, 949 to 1,898 individuals for the 3-mm wedgewire half screens and 114 to 245 individuals with a 95% water withdrawal reduction from closed-cycle cooling towers (Table 3–24).

## 3.3 Equivalent Loss of Recruits the Recreational Fishery

### *3.3.1 Equivalent Recruits due to Entrainment Losses*

At the 10-year AIF, annual entrainment losses at Merrimack Station Units 1 and 2 combined with the existing CWIS were equivalent to 449 Bluegill, 383 American Eel and 236 Yellow Perch among the most abundant three species (Table 3–25). These same species would amount to an equivalent recruitment loss of 23 Bluegill, no American Eel, and 29 Yellow Perch due to annual entrainment with an April through July operation of 3-mm wedgewire half screens and 22 Bluegill, 19 American Eel, and 12 Yellow Perch due to entrainment with closed-cycle cooling towers. These estimates were higher at 100% DIF. Age-1 equivalent loss under the 10-year AIF for the existing CWIS was 1,383 Bluegill, 711 Yellow Perch, and 530 American Eel (Table 3–26).

### *3.3.2 Equivalent Recruits due to Impingement Losses*

At the 10-year AIF, annual impingement losses at Merrimack Station Units 1 and 2 combined with the existing CWIS were equivalent to 92 Yellow Perch, 76 Bluegill, and 31 Pumpkinseed among the most abundant three species (Table 3–27). These same species would amount to an equivalent recruitment loss of 84 Yellow Perch, 46 Bluegill, and 25 Pumpkinseed due to annual impingement with an April through July operation of 3-mm wedgewire half screens and 5 Yellow Perch, 4 Bluegill, and 2 Pumpkinseed due to impingement with closed-cycle cooling towers. These estimates were higher at 100% DIF. Age-1 equivalent loss under the 10-year AIF for the existing CWIS was 163 Yellow Perch, 125 Bluegill, and 35 Pumpkinseed (Table 3–28).

## 3.4 Indirect Forage Benefits

### *3.4.1 Production Foregone from Entrainment Losses*

Total production foregone of forage species due to annual entrainment at the existing Merrimack Station Units 1 and 2 CWISs under the 10-year AIF was about 726 kg of forage biomass, equivalent to 519 Age-2 Largemouth Bass (Table 3–29; Table 3–30). The implementation of 3-mm wedgewire half screens or closed-cycle cooling towers would result in a lower total production foregone of 208 kg or 36 kg and 149 or 26 equivalent Largemouth Bass, respectively.

### *3.4.2 Production Foregone from Impingement Losses*

Total production foregone of forage species due to annual impingement at the existing Merrimack Station Units 1 and 2 CWISs under the 10-year AIF was about 13 kg of forage biomass, equivalent to 9 Age-2 Largemouth Bass (Table 3–31; Table 3–32). The implementation of 3-mm wedgewire half screens or closed-cycle cooling towers would result in a lower total production foregone of 6 kg or <1 kg and 5 or <1 equivalent Age-2 Largemouth Bass, respectively.

### *3.4.3 Entrainment Loss of Forage Biomass of Recreational Fishery Species*

The biomass that would have resulted from predation (natural mortality) of recreationally important fishery species from an entrained early life to age of recruitment if entrainment did not occur at

Merrimack Station Units 1 and 2 combined was presented in Table 3–33. The total biomass associated with natural mortality under the 10-year AIF was 56 kg for the existing CWIS, 9.0 kg for the WWS, and 2.8 kg for the closed-cycle cooling towers corresponding to 40, 6, and 2 equivalent Age-2 Largemouth Bass, respectively (Table 3–34).

### *3.4.4 Impingement Loss of Forage Biomass of Recreational Fishery Species*

The biomass that would have resulted from predation (natural mortality) of recreationally important fishery species from an impinged early life to age of recruitment if impingement did not occur at Merrimack Station Units 1 and 2 combined was presented in Table 3–35. The total biomass associated with natural mortality under the 10-year AIF was 3.4 kg for the existing CWIS, 2.6 kg for the WWS, and 0.2 kg for the closed-cycle cooling towers corresponding to 2, 2, and <1 equivalent Age-2 Largemouth Bass, respectively (Table 3–34).

## 3.5 Equivalent Catch

The number of equivalent recruits that would have entered the recreational fishery in Hooksett Pool either directly or indirectly through foraging if entrainment and impingement did not occur under the two entrainment-reducing technologies and three flow case scenarios are presented in Table 3–37 and Table 3–38. The benefit of additional gains to the recreational fishery from reductions of entrainment and impingement as a result of implementing either 3-mm wedgewire half screens or closed-cycle cooling towers were quantified by the change in number of equivalent recruits relative to the baseline scenarios of the existing CWISs (Table 3–39). Based on the 10-year AIF scenario, the 3-mm wedgewire half screens would reduce annual entrainment and impingement that would result in a gain of 456 Bluegill, 418 Largemouth Bass, 383 American Eel and 216 Yellow Perch to the recreational fishery in Hooksett Pool. These benefits were not substantially greater with closed-cycle cooling towers: 498 Bluegill, 554 Largemouth Bass, 368 American Eel, and 312 Yellow Perch.

This assessment quantified the recreational fishery benefits of entrainment-reducing technologies at Merrimack Station Units 1 and 2 by estimating the equivalent number of fish that would reach the first age susceptible to anglers (recruitment to the fishery) as a result of any entrainment and/or impingement reductions. This approach was taken in absence of adequate catch-and-release and harvest information for modeling recreational harvest and catch in the predominantly catch-and-release recreational fishery in Hooksett Pool. Recapture rates ranging from 4 to 15% and catch rates ranging from about 5% to 60% depending on species and waterbody observed in other studies (Table 3–40) for some common sport fish in Merrimack River indicate the estimates of equivalent catch or additional gains were likely to be overestimates.

**Table 3–1. Relative composition (%) of ichthyoplankton density by life stage and lowest taxon identified in entrainment samples collected at Units 1 and 2 at Merrimack Station from 31 May 2006 through 30 August 2006 and 4 April 2007 through 27 June 2007 at Unit 1 (Normandeau 2007), 24 May 2006 through 13 September 2006 and 4 April 2007 through 27 June 2007 at Unit 2 (Normandeau 2007), and 22 May through 3 September 2017 at Unit 1 (Normandeau 2017a).**

| Lowest Taxon Identified | Life Stage | Unit 1 | | | | Unit 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2017 | Mean | 2006 | 2007 | Mean |
| Alosa species | PYSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| American Eel | YROL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| American Shad | YSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | PYSL | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| Black Crappie | YSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | PYSL | 0 | 0 | 1.6 | 0.5 | 0 | 0 | 0 |
| | YOY | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| Blacknose Dace | PYSL | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| Blueback Herring/Alewife | PYSL | 0 | 0 | 0.2 | 0.1 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| Bluegill | PYSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | YROL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| Brown Bullhead | PYSL | 1.8 | 0 | 0 | 0.6 | 1.4 | 0 | 0.7 |
| Carp and Minnow Family | Eggs | 0 | 0.6 | <0.1 | 0.2 | 0 | 0 | 0 |
| | YSL | 0 | 4.4 | 2.2 | 2.2 | 1.7 | 9.8 | 5.7 |
| | PYSL | 20.5 | 17.7 | 2.8 | 13.6 | 26.9 | 14.6 | 20.7 |
| | Unid Larvae | 0 | 0 | 11.4 | 3.8 | 0 | 0 | 0 |
| Common Shiner | PYSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| Fallfish | PYSL | 0 | 0 | 3.6 | 1.2 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| Golden Shiner | PYSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | YROL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| Herring Family | PYSL | 0 | 0 | 0 | 0 | 0 | 2.5 | 1.2 |
| | Unid Larvae | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |

(continued)

**Table 3-1. Continued.**

| Lowest Taxon Identified | Life Stage | Unit 1 | | | | Unit 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2017 | Mean | 2006 | 2007 | Mean |
| Largemouth Bass | YSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | PYSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | YOY | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| Lepomis Species | YSL | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| | PYSL | 0 | 0 | 9.9 | 3.3 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | 1.7 | 0.6 | 0 | 0 | 0 |
| Lepomis Species/Crappie Species | YSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | PYSL | 0 | 0 | 2.6 | 0.9 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | 4.1 | 1.4 | 0 | 0 | 0 |
| Margined Madtom | PYSL | 0.9 | 0 | 0 | 0.3 | 0.7 | 0 | 0.3 |
| | YOY | 1.7 | 0 | <0.1 | 0.6 | 0 | 0 | 0 |
| Rock Bass | PYSL | 7.4 | 0 | 0.3 | 2.6 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| Smallmouth Bass | PYSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| Spottail Shiner | PYSL | 0 | 0.3 | 0 | 0.1 | 0 | 0 | 0 |
| | YOY | 3.5 | 0 | 0 | 1.2 | 0 | 0 | 0 |
| Sucker Family | PYSL | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| | Unid Larvae | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| Sunfish Family | YSL | 1.8 | 0 | 0 | 0.6 | 0.9 | 8.2 | 4.5 |
| | PYSL | 26.4 | 6.4 | 0.1 | 10.9 | 5.1 | 4.9 | 5.0 |
| Tessellated Darter | YSL | 1.2 | 1.7 | 6.0 | 3.0 | 0 | 0 | 0 |
| | PYSL | 1.4 | 0.3 | 0.7 | 0.8 | 0 | 4.9 | 2.4 |
| | Unid Larvae | 0 | 0 | 1.6 | 0.5 | 0 | 0 | 0 |
| Unidentified Osteichthyes | Eggs | 1.1 | 0.6 | <0.1 | 0.6 | 1.7 | 0 | 0.9 |
| | PYSL | 0 | 0 | 0.3 | 0.1 | 0 | 0 | 0 |
| | Unid Larvae | 6.3 | 2.2 | 12.6 | 7.0 | 1.7 | 0 | 0.8 |
| Walleye | PYSL | 0 | 0 | 0.3 | 0.1 | 0 | 0 | 0 |
| White Perch | YSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |
| | PYSL | 0 | 0 | <0.1 | <0.1 | 0 | 0 | 0 |

(continued)

**Table 3–1. Continued.**

| Lowest Taxon Identified | Life Stage | Unit 1 | | | | Unit 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2017 | Mean | 2006 | 2007 | Mean |
| White Sucker | YSL | 0 | 0 | 0.7 | 0.2 | 0 | 0 | 0 |
| | PYSL | 26.0 | 40.2 | 32.9 | 33.0 | 57.5 | 50.3 | 53.9 |
| | YOY | 0 | 0.6 | 0 | 0.2 | 0 | 2.4 | 1.2 |
| | Unid Larvae | 0 | 0 | 0.3 | 0.1 | 0 | 0 | 0 |
| Yellow Bullhead | YOY | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| Yellow Perch | YSL | 0 | 0 | 0.1 | <0.1 | 0 | 0 | 0 |
| | PYSL | 0 | 25.2 | 2.8 | 9.3 | 2.6 | 2.5 | 2.5 |
| Total | Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

YSL = Yolk-Sac Larvae; PYSL = Post Yolk-Sac Larvae; YOY = Young of the Year; YROL = Yearling or older

**Table 3–2. Monthly mean density (number per 100 m$^3$) of ichthyoplankton identified to the lowest taxon possible and life stage from entrainment samples collected at Merrimack Station, Unit 1 and 2 combined, from May through September 2006, April through June 2007 and May through early September 2017.**

| Taxon | Life Stage | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Alosa Species | PYSL | | | <0.01 | | | | <0.01 |
| | Unid Larvae | | | <0.01 | 0.02 | | | <0.01 |
| | Total | | | <0.01 | 0.02 | | | <0.01 |
| American Eel | YROL | | | <0.01 | <0.01 | | | <0.01 |
| | Total | | | <0.01 | <0.01 | | | <0.01 |
| American Shad | YSL | | | <0.01 | <0.01 | | | <0.01 |
| | PYSL | | | <0.01 | 0.01 | | | <0.01 |
| | Total | | | <0.01 | 0.01 | | | <0.01 |
| Black Crappie | YSL | | | <0.01 | | | | <0.01 |
| | PYSL | | 0.04 | 0.13 | 0.01 | | | 0.03 |
| | YOY | | | | <0.01 | | | <0.01 |
| | Unid Larvae | | 0.01 | <0.01 | | | | <0.01 |
| | Total | | 0.05 | 0.14 | 0.01 | | | 0.03 |
| Blacknose Dace | PYSL | | | 0.01 | | | | <0.01 |
| | Unid Larvae | | | <0.01 | | | | <0.01 |
| | Total | | | 0.01 | | | | <0.01 |
| Blueback Herring/Alewife | PYSL | | | 0.02 | 0.02 | | | 0.01 |
| | Unid Larvae | | <0.01 | <0.01 | <0.01 | <0.01 | | <0.01 |
| | Total | | <0.01 | 0.02 | 0.02 | <0.01 | | 0.01 |
| Bluegill | PYSL | | | | <0.01 | | | <0.01 |
| | YROL | | | <0.01 | | | | <0.01 |
| | Total | | | <0.01 | <0.01 | | | <0.01 |
| Brown Bullhead | PYSL | | | | 0.13 | | | 0.02 |
| | Total | | | | 0.13 | | | 0.02 |
| Carp and Minnow Family | Eggs | | <0.01 | 0.02 | | | | <0.01 |
| | YSL | | 0.12 | 0.48 | <0.01 | | | 0.10 |
| | PYSL | | 0.09 | 2.18 | 0.34 | 0.04 | | 0.44 |
| | Unid Larvae | | 0.19 | 1.07 | 0.06 | <0.01 | | 0.22 |
| | Total | | 0.40 | 3.75 | 0.40 | 0.05 | | 0.77 |
| Common Shiner | PYSL | | | <0.01 | | | | <0.01 |
| | Total | | | <0.01 | | | | <0.01 |
| Fallfish | PYSL | | | 0.41 | 0.01 | | | 0.07 |
| | Unid Larvae | | | 0.01 | | | | <0.01 |
| | Total | | | 0.42 | 0.01 | | | 0.07 |
| Golden Shiner | PYSL | | | <0.01 | | | | <0.01 |
| | YROL | | | | <0.01 | | | <0.01 |
| | Total | | | <0.01 | <0.01 | | | <0.01 |

(continued)

**Table 3-2 Continued.**

| Taxon | Life Stage | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Herring Family | PYSL | | | 0.03 | | | | <0.01 |
| | Unid Larvae | | | <0.01 | | | | <0.01 |
| | Total | | | 0.03 | | | | <0.01 |
| Largemouth Bass | YSL | | | <0.01 | <0.01 | | | <0.01 |
| | PYSL | | | <0.01 | <0.01 | | | <0.01 |
| | YOY | | | <0.01 | <0.01 | | | <0.01 |
| | Unid Larvae | | | <0.01 | | | | <0.01 |
| | Total | | | 0.01 | 0.01 | | | <0.01 |
| Lepomis Species | YSL | | | 0.01 | <0.01 | <0.01 | | <0.01 |
| | PYSL | | | 0.73 | 0.65 | <0.01 | | 0.23 |
| | Unid Larvae | | | 0.04 | 0.22 | 0.02 | | 0.05 |
| | Total | | | 0.78 | 0.87 | 0.03 | | 0.28 |
| Lepomis Species/Crappie Species | YSL | | | <0.01 | | | | <0.01 |
| | PYSL | | 0.01 | 0.23 | 0.09 | | | 0.05 |
| | Unid Larvae | | 0.02 | 0.41 | 0.06 | | | 0.08 |
| | Total | | 0.03 | 0.64 | 0.15 | | | 0.14 |
| Margined Madtom | PYSL | | | | 0.07 | | | 0.01 |
| | YOY | | | 0.04 | 0.01 | | | 0.01 |
| | Total | | | 0.04 | 0.07 | | | 0.02 |
| Rock Bass | PYSL | | | 0.10 | 0.11 | 0.04 | | 0.04 |
| | Unid Larvae | | | | <0.01 | | | <0.01 |
| | Total | | | 0.10 | 0.11 | 0.04 | | 0.04 |
| Smallmouth Bass | PYSL | | | | <0.01 | | | <0.01 |
| | Total | | | | <0.01 | | | <0.01 |
| Spottail Shiner | PYSL | | | 0.02 | | | | <0.01 |
| | YOY | | | 0.07 | | | | 0.01 |
| | Total | | | 0.09 | | | | 0.02 |
| Sucker Family | PYSL | | | 0.01 | | | | <0.01 |
| | Unid Larvae | | | 0.01 | | | | <0.01 |
| | Total | | | 0.02 | | | | <0.01 |
| Sunfish Family | YSL | 0.15 | 0.02 | 0.03 | 0.07 | | | 0.04 |
| | PYSL | | 0.05 | 0.68 | 0.52 | 0.04 | | 0.22 |
| | Total | 0.15 | 0.07 | 0.71 | 0.58 | 0.04 | | 0.26 |
| Tessellated Darter | YSL | | 0.52 | 0.26 | | | | 0.13 |
| | PYSL | | 0.04 | 0.10 | 0.05 | | | 0.03 |
| | Unid Larvae | | 0.12 | 0.06 | | | | 0.03 |
| | Total | | 0.68 | 0.42 | 0.05 | | | 0.19 |
| Unidentified Osteichthyes | Eggs | | 0.05 | 0.02 | <0.01 | 0.04 | | 0.02 |
| | PYSL | | 0.01 | 0.02 | 0.01 | | | 0.01 |
| | Unid Larvae | | 0.29 | 1.09 | 0.52 | 0.03 | | 0.32 |
| | Total | | 0.35 | 1.14 | 0.53 | 0.07 | | 0.35 |

(continued)

**Table 3-2 Continued.**

| Taxon | Life Stage | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Walleye | PYSL | | 0.03 | | | | | 0.01 |
| | Total | | 0.03 | | | | | 0.01 |
| White Perch | YSL | | | <0.01 | | | | <0.01 |
| | PYSL | | | <0.01 | | | | <0.01 |
| | Total | | | <0.01 | | | | <0.01 |
| White Sucker | YSL | | 0.07 | 0.02 | | | | 0.01 |
| | PYSL | 0.10 | 5.21 | 3.06 | 0.03 | | | 1.40 |
| | YOY | | | 0.05 | | | | 0.01 |
| | Unid Larvae | | 0.04 | <0.01 | | | | 0.01 |
| | Total | 0.10 | 5.31 | 3.13 | 0.03 | | | 1.43 |
| Yellow Bullhead | YOY | | | | 0.02 | | | <0.01 |
| | Total | | | | 0.02 | | | <0.01 |
| Yellow Perch | YSL | | 0.01 | <0.01 | | | | <0.01 |
| | PYSL | | 1.47 | 0.09 | | | | 0.26 |
| | Total | | 1.47 | 0.10 | | | | 0.26 |
| Total | Eggs | | 0.05 | 0.05 | <0.01 | 0.04 | | 0.02 |
| | YSL | 0.15 | 0.74 | 0.80 | 0.08 | <0.01 | | 0.30 |
| | PYSL | 0.10 | 6.95 | 7.83 | 2.06 | 0.13 | | 2.84 |
| | YOY | | | 0.16 | 0.03 | | | 0.03 |
| | YROL | | | <0.01 | <0.01 | | | <0.01 |
| | Unid Larvae | | 0.66 | 2.70 | 0.88 | 0.06 | | 0.72 |
| | Total | 0.25 | 8.40 | 11.55 | 3.05 | 0.24 | | 3.91 |

YSL = Yolk-Sac Larvae; PYSL = Post Yolk-Sac Larvae; YOY = Young of the Year; YROL = Yearling or older

**Table 3–3. Monthly mean density (number per 100 m$^3$) and relative abundance (%) of ichthyoplankton collected in entrainment samples collect at Units 1 and 2 at Merrimack Station from 31 May 2006 through 30 August 2006 and 4 April 2007 through 27 June 2007 at Unit 1 (Normandeau 2007), 24 May 2006 through 13 September 2006 and 4 April 2007 through 27 June 2007 at Unit 2 (Normandeau 2007), and 22 May through 3 September 2017 at Unit 1 (Normandeau 2017a).**

| | Unit 1 | | | | | | | | Unit 2 | | | | | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | | 2007 | | 2017 | | Mean | | 2006 | | 2007 | | Mean | | | |
| Month | N/100 m$^3$ | % | N/100 m$^3$ | % | N/100 m$^3$ | % | N/100 m$^3$ | % | N/100 m$^3$ | % | N/100 m$^3$ | % | N/100 m$^3$ | % | N/100 m$^3$ | % |
| Apr | – | – | 0 | 0 | – | – | 0 | 0 | – | – | 0.50 | 9.7 | 0.50 | 2.5 | 0.25 | 0.5 |
| May | 0 | 0 | 8.09 | 35.7 | 25.53 | 45.0 | 11.21 | 37.3 | 7.74 | 52.6 | 0.62 | 12.1 | 4.18 | 42.2 | 8.40 | 38.1 |
| Jun | 6.70 | 61.8 | 14.61 | 64.3 | 25.96 | 45.8 | 15.76 | 52.4 | 6.48 | 44.0 | 4.00 | 78.2 | 5.24 | 52.8 | 11.55 | 52.5 |
| Jul | 3.65 | 33.6 | – | – | 5.00 | 8.8 | 4.33 | 9.6 | 0.50 | 3.4 | – | – | 0.50 | 2.5 | 3.05 | 8.3 |
| Aug | 0.50 | 4.6 | – | – | 0.22 | 0.4 | 0.36 | 0.8 | 0 | 0 | – | – | 0 | 0 | 0.24 | 0.6 |
| Sep | – | – | – | – | – | – | – | – | 0 | 0 | – | – | 0 | 0 | 0 | 0 |
| Total | 2.71 | 100.0 | 7.57 | 100.0 | 14.18 | 100.0 | 8.21 | 100.0 | 2.94 | 100.0 | 1.70 | 100.0 | 2.48 | 100.0 | 5.79 | 100.0 |

Not Sampled represented by "–"

**Table 3–4. Density of yolk-sac larvae (YSL) identified to taxon complexes (e.g., family or genus) were apportioned to species by monthly YSL density (D) and percent (%) composition of identified species within each taxon complex identified in ichthyoplankton collected in entrainment samples collect at Units 1 and 2 combined at Merrimack Station during May 2006 through September 2006, April 2007 through June 2007 at May through early September 2017.**

| | | Apr | | May | | Jun | | Jul | | Aug | | Sep | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxon Complex** | **Species** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** |
| Sunfish Family | Black Crappie | 0 | 0 | 0 | 0 | 0.001 | 13.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0.005 | 57.5 | 0.005 | 72.3 | 0.005 | 100.0 | 0 | 0 |
| | Largemouth Bass | 0 | 0 | 0 | 0 | 0.003 | 28.7 | 0.002 | 27.7 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0 | 100.0 | 0.009 | 100.0 | 0.007 | 100.0 | 0.005 | 100.0 | 0 | 100.0 |
| Lepomis/Pomoxis sp. | Black Crappie | 0 | 0 | 0 | 0 | 0.001 | 19.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0.005 | 80.6 | 0.005 | 100.0 | 0.005 | 100.0 | 0 | 0 |
| | Total | 0 | 100.0 | 0 | 100.0 | 0.006 | 100.0 | 0.005 | 100.0 | 0.005 | 100.0 | 0 | 100.0 |

**Table 3–5. Density of post yolk-sac larvae (PYSL) identified to taxon complexes (e.g., family or genus) were apportioned to species by monthly PYSL density and percent (%) composition of identified species within each taxon complex identified in ichthyoplankton collected in entrainment samples collect at Units 1 and 2 combined at Merrimack Station during May 2006 through September 2006, April 2007 through June 2007 at May through early September 2017.**

| Taxon Complex | Species | Apr | | May | | Jun | | Jul | | Aug | | Sep | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D | % | D | % | D | % | D | % | D | % | D | % |
| Alosa sp. | Alewife | 0 | 0 | 0 | 0 | 0.017 | 87.0 | 0.019 | 64.0 | 0 | 0 | 0 | 0 |
| | American Shad | 0 | 0 | 0 | 0 | 0.002 | 13.0 | 0.011 | 36.0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0 | 100.0 | 0.019 | 100.0 | 0.029 | 100.0 | 0 | 100.0 | 0 | 100.0 |
| Carp and Minnow Family | Blacknose Dace | 0 | 0 | 0 | 0 | 0.013 | 2.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Common Shiner | 0 | 0 | 0 | 0 | 0.001 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fallfish | 0 | 0 | 0 | 0 | 0.410 | 93.0 | 0.005 | 100.0 | 0 | 0 | 0 | 0 |
| | Golden Shiner | 0 | 0 | 0 | 0 | 0.001 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Spottail Shiner | 0 | 0 | 0 | 0 | 0.015 | 3.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0 | 100.0 | 0.441 | 100.0 | 0.005 | 100.0 | 0 | 100.0 | 0 | 100.0 |
| Herring Family | Alewife | 0 | 0 | 0 | 0 | 0.017 | 87.0 | 0.019 | 64.0 | 0 | 0 | 0 | 0 |
| | American Shad | 0 | 0 | 0 | 0 | 0.002 | 13.0 | 0.011 | 36.0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0 | 100.0 | 0.019 | 100.0 | 0.029 | 100.0 | 0 | 100.0 | 0 | 100.0 |
| Sucker Family | White Sucker | 0.100 | 100.0 | 5.205 | 100.0 | 3.061 | 100.0 | 0.033 | 100.0 | 0 | 0 | 0 | 0 |
| | Total | 0.100 | 100.0 | 5.205 | 100.0 | 3.061 | 100.0 | 0.033 | 100.0 | 0 | 100.0 | 0 | 100.0 |
| Sunfish Family | Black Crappie | 0 | 0 | 0.042 | 100.0 | 0.132 | 13.6 | 0.007 | 0.9 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0.732 | 75.7 | 0.654 | 83.9 | 0.002 | 5.2 | 0 | 0 |
| | Largemouth Bass | 0 | 0 | 0 | 0 | 0.003 | 0.3 | 0.002 | 0.2 | 0 | 0 | 0 | 0 |
| | Rock Bass | 0 | 0 | 0 | 0 | 0.101 | 10.4 | 0.112 | 14.4 | 0.042 | 94.8 | 0 | 0 |
| | Smallmouth Bass | 0 | 0 | 0 | 0 | 0 | 0 | 0.005 | 0.6 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0.042 | 100.0 | 0.967 | 100.0 | 0.780 | 100.0 | 0.044 | 100.0 | 0 | 100.0 |

(Continued)

**Table 3-5. Continued.**

| | | Apr | | May | | Jun | | Jul | | Aug | | Sep | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxon Complex** | **Species** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** |
| Lepomis/Pomoxis sp. | Black Crappie | 0 | 0 | 0.042 | 100.0 | 0.132 | 15.2 | 0.007 | 1.0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0.732 | 84.8 | 0.654 | 99.0 | 0.002 | 100.0 | 0 | 0 |
| | Total | 0 | 100.0 | 0.042 | 100.0 | 0.864 | 100.0 | 0.661 | 100.0 | 0.002 | 100.0 | 0 | 100.0 |
| Unidentified Osteichthyes | Alewife | 0 | 0 | 0 | 0 | 0.017 | 0.4 | 0.019 | 1.7 | 0 | 0 | 0 | 0 |
| | American Shad | 0 | 0 | 0 | 0 | 0.002 | 0.1 | 0.011 | 1.0 | 0 | 0 | 0 | 0 |
| | Black Crappie | 0 | 0 | 0.042 | 0.6 | 0.132 | 2.8 | 0.007 | 0.6 | 0 | 0 | 0 | 0 |
| | Blacknose Dace | 0 | 0 | 0 | 0 | 0.013 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0.732 | 15.6 | 0.654 | 59.5 | 0.002 | 5.2 | 0 | 0 |
| | Brown Bullhead | 0 | 0 | 0 | 0 | 0 | 0 | 0.133 | 12.1 | 0 | 0 | 0 | 0 |
| | Common Shiner | 0 | 0 | 0 | 0 | 0.001 | <0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fallfish | 0 | 0 | 0 | 0 | 0.410 | 8.8 | 0.005 | 0.5 | 0 | 0 | 0 | 0 |
| | Golden Shiner | 0 | 0 | 0 | 0 | 0.001 | <0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Largemouth Bass | 0 | 0 | 0 | 0 | 0.003 | 0.1 | 0.002 | 0.2 | 0 | 0 | 0 | 0 |
| | Margined Madtom | 0 | 0 | 0 | 0 | 0 | 0 | 0.067 | 6.1 | 0 | 0 | 0 | 0 |
| | Rock Bass | 0 | 0 | 0 | 0 | 0.101 | 2.2 | 0.112 | 10.2 | 0.042 | 94.8 | 0 | 0 |
| | Smallmouth Bass | 0 | 0 | 0 | 0 | 0 | 0 | 0.005 | 0.5 | 0 | 0 | 0 | 0 |
| | Spottail Shiner | 0 | 0 | 0 | 0 | 0.015 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tessellated Darter | 0 | 0 | 0.040 | 0.6 | 0.099 | 2.1 | 0.052 | 4.7 | 0 | 0 | 0 | 0 |
| | Walleye | 0 | 0 | 0.034 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | White Perch | 0 | 0 | 0 | 0 | 0.001 | <0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | White Sucker | 0.100 | 100.0 | 5.205 | 76.7 | 3.061 | 65.4 | 0.033 | 3.0 | 0 | 0 | 0 | 0 |
| | Yellow Perch | 0 | 0 | 1.466 | 21.6 | 0.094 | 2.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0.100 | 100.0 | 6.787 | 100.0 | 4.683 | 100.0 | 1.099 | 100.0 | 0.044 | 100.0 | 0 | 100.0 |

**Table 3–6. Density of fish larvae (unidentifiable to YSL or PYSL stage) identified to taxon complexes (e.g., family or genus) were apportioned to species by monthly unidentified larval density (D) and percent (%) composition of identified species within each taxon complex identified in ichthyoplankton collected in entrainment samples collect at Units 1 and 2 combined at Merrimack Station during May 2006 through September 2006, April 2007 through June 2007 at May through early September 2017.**

| Taxon Complex | Species | Apr | | May | | Jun | | Jul | | Aug | | Sep | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D | % | D | % | D | % | D | % | D | % | D | % |
| Alosa sp. | Alewife | 0 | 0 | 0.003 | 100.0 | 0.004 | 100.0 | 0.003 | 100.0 | 0.002 | 100.0 | 0 | 0 |
| | Total | 0 | 100.0 | 0.003 | 100.0 | 0.004 | 100.0 | 0.003 | 100.0 | 0.002 | 100.0 | 0 | 100.0 |
| Carp and Minnow Family | Blacknose Dace | 0 | 0 | 0 | 0 | 0.001 | 12.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fallfish | 0 | 0 | 0 | 0 | 0.009 | 87.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0 | 100.0 | 0.011 | 100.0 | 0 | 100.0 | 0 | 100.0 | 0 | 100.0 |
| Herring Family | Alewife | 0 | 0 | 0.003 | 100.0 | 0.004 | 100.0 | 0.003 | 100.0 | 0.002 | 100.0 | 0 | 0 |
| | Total | 0 | 100.0 | 0.003 | 100.0 | 0.004 | 100.0 | 0.003 | 100.0 | 0.002 | 100.0 | 0 | 100.0 |
| Sucker Family | White Sucker | 0 | 0 | 0.035 | 100.0 | 0.003 | 100.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0.035 | 100.0 | 0.003 | 100.0 | 0 | 100.0 | 0 | 100.0 | 0 | 100.0 |
| Lepomis/Pomoxis sp. | Black Crappie | 0 | 0 | 0.008 | 100.0 | 0.003 | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0.044 | 94.5 | 0.215 | 100.0 | 0.025 | 100.0 | 0 | 0 |
| | Total | 0 | 100.0 | 0.008 | 100.0 | 0.047 | 100.0 | 0.215 | 100.0 | 0.025 | 100.0 | 0 | 100.0 |
| Unidentified Osteichthyes | Alewife | 0 | 0 | 0.003 | 1.6 | 0.004 | 3.1 | 0.003 | 1.5 | 0.002 | 9.0 | 0 | 0 |
| | Black Crappie | 0 | 0 | 0.008 | 4.7 | 0.003 | 2.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Blacknose Dace | 0 | 0 | 0 | 0 | 0.001 | 1.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0.044 | 35.8 | 0.215 | 97.7 | 0.025 | 91.0 | 0 | 0 |
| | Fallfish | 0 | 0 | 0 | 0 | 0.009 | 7.6 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Largemouth Bass | 0 | 0 | 0 | 0 | 0.001 | 1.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Rock Bass | 0 | 0 | 0 | 0 | 0 | 0 | 0.002 | 0.7 | 0 | 0 | 0 | 0 |
| | Tessellated Darter | 0 | 0 | 0.120 | 72.6 | 0.059 | 47.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | White Sucker | 0 | 0 | 0.035 | 21.1 | 0.003 | 2.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 100.0 | 0.166 | 100.0 | 0.124 | 100.0 | 0.220 | 100.0 | 0.027 | 100.0 | 0 | 100.0 |

**Table 3–7. Monthly mean density (number per 100 $m^3$) by life stage of ichthyoplankton identified or apportioned to species from entrainment samples collected at Merrimack Station, Unit 1 and 2 combined, from May through September 2006, April through June 2007 and May through early September 2017.**

| | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Season | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Life Stage** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** | **D** | **%** |
| Alewife | PYSL | | | | | 0.04 | 0.3 | 0.02 | 0.6 | | | | | 0.01 | 0.3 |
| | Unid Larvae | | | 0.01 | 0.1 | 0.04 | 0.4 | 0.03 | 0.9 | 0.01 | 2.3 | | | 0.01 | 0.3 |
| | Total | | | 0.01 | 0.1 | 0.08 | 0.7 | 0.05 | 1.6 | 0.01 | 2.3 | | | 0.02 | 0.6 |
| American Eel | YROL | | | | | <0.01 | <0.1 | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| | Total | | | | | <0.01 | <0.1 | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| American Shad | YSL | | | | | <0.01 | <0.1 | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| | PYSL | | | | | 0.01 | 0.1 | 0.01 | 0.3 | | | | | <0.01 | 0.1 |
| | Total | | | | | 0.01 | 0.1 | 0.01 | 0.5 | | | | | <0.01 | 0.1 |
| Black Crappie | YSL | 0.15 | 59.8 | 0.02 | 0.3 | <0.01 | <0.1 | | | | | | | 0.03 | 0.8 |
| | PYSL | | | 0.10 | 1.2 | 0.26 | 2.2 | 0.01 | 0.4 | | | | | 0.06 | 1.6 |
| | YOY | | | | | | | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| | Unid Larvae | | | 0.04 | 0.4 | 0.05 | 0.4 | | | | | | | 0.01 | 0.4 |
| | Total | 0.15 | 59.8 | 0.16 | 1.9 | 0.31 | 2.7 | 0.01 | 0.5 | | | | | 0.11 | 2.7 |
| Blacknose Dace | Eggs | | | <0.01 | <0.1 | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | YSL | | | <0.01 | <0.1 | 0.01 | 0.1 | | | | | | | <0.01 | 0.1 |
| | PYSL | | | <0.01 | <0.1 | 0.08 | 0.7 | | | | | | | 0.01 | 0.3 |
| | Unid Larvae | | | 0.02 | 0.3 | 0.14 | 1.2 | 0.01 | 0.2 | <0.01 | 0.1 | | | 0.03 | 0.7 |
| | Total | | | 0.03 | 0.4 | 0.24 | 2.0 | 0.01 | 0.2 | <0.01 | 0.1 | | | 0.05 | 1.2 |
| Bluegill | YSL | | | | | 0.02 | 0.2 | 0.05 | 1.7 | <0.01 | 1.9 | | | 0.01 | 0.3 |
| | PYSL | | | | | 1.44 | 12.5 | 1.18 | 38.8 | <0.01 | 1.9 | | | 0.44 | 11.2 |
| | YROL | | | | | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | Unid Larvae | | | | | 0.83 | 7.2 | 0.79 | 25.8 | 0.06 | 23.2 | | | 0.28 | 7.1 |
| | Total | | | | | 2.29 | 19.8 | 2.02 | 66.3 | 0.06 | 27.0 | | | 0.73 | 18.6 |
| Brown Bullhead | PYSL | | | | | | | 0.13 | 4.4 | | | | | 0.02 | 0.6 |
| | Total | | | | | | | 0.13 | 4.4 | | | | | 0.02 | 0.6 |

(Continued)

**Table 3-7. Continued.**

| Species | Life Stage | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Season | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D | % | D | % | D | % | D | % | D | % | D | % | D | % |
| Brown Bullhead | PYSL | | | | | | | 0.13 | 4.4 | | | | | 0.02 | 0.6 |
| | Total | | | | | | | 0.13 | 4.4 | | | | | 0.02 | 0.6 |
| Common Shiner | Eggs | | | <0.01 | <0.1 | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | YSL | | | <0.01 | <0.1 | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | PYSL | | | <0.01 | <0.1 | 0.01 | 0.1 | | | | | | | <0.01 | <0.1 |
| | Total | | | <0.01 | <0.1 | 0.01 | 0.1 | | | | | | | <0.01 | <0.1 |
| Fallfish | Eggs | | | 0.05 | 0.6 | 0.05 | 0.4 | <0.01 | 0.1 | 0.04 | 17.5 | | | 0.02 | 0.6 |
| | YSL | | | 0.11 | 1.3 | 0.45 | 3.9 | <0.01 | 0.1 | | | | | 0.09 | 2.4 |
| | PYSL | | | 0.08 | 1.0 | 2.44 | 21.1 | 0.35 | 11.3 | 0.04 | 18.5 | | | 0.49 | 12.4 |
| | Unid Larvae | | | 0.16 | 2.0 | 1.03 | 8.9 | 0.05 | 1.7 | <0.01 | 0.8 | | | 0.21 | 5.3 |
| | Total | | | 0.41 | 4.9 | 3.96 | 34.3 | 0.40 | 13.1 | 0.09 | 36.8 | | | 0.81 | 20.7 |
| Golden Shiner | Eggs | | | <0.01 | <0.1 | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | YSL | | | <0.01 | <0.1 | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | PYSL | | | <0.01 | <0.1 | 0.01 | 0.1 | | | | | | | <0.01 | <0.1 |
| | YROL | | | | | | | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| | Total | | | <0.01 | <0.1 | 0.01 | 0.1 | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| Largemouth Bass | YSL | | | | | 0.01 | 0.1 | 0.02 | 0.7 | | | | | 0.01 | 0.1 |
| | PYSL | | | | | <0.01 | <0.1 | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| | YOY | | | | | <0.01 | <0.1 | <0.01 | 0.1 | | | | | <0.01 | <0.1 |
| | Unid Larvae | | | | | 0.01 | 0.1 | | | | | | | <0.01 | 0.1 |
| | Total | | | | | 0.03 | 0.2 | 0.03 | 0.9 | | | | | 0.01 | 0.2 |
| Margined Madtom | PYSL | | | | | | | 0.07 | 2.2 | | | | | 0.01 | 0.3 |
| | YOY | | | | | 0.04 | 0.3 | 0.01 | 0.2 | | | | | 0.01 | 0.2 |
| | Total | | | | | 0.04 | 0.3 | 0.07 | 2.4 | | | | | 0.02 | 0.5 |

(Continued)

**Table 3-7. Continued.**

| Species | Life Stage | Apr D | Apr % | May D | May % | Jun D | Jun % | Jul D | Jul % | Aug D | Aug % | Sep D | Sep % | Season D | Season % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rock Bass | YSL | | | | | | | | | | | | | | |
| | PYSL | | | | | 0.17 | 1.5 | 0.19 | 6.2 | 0.08 | 33.8 | | | 0.07 | 1.9 |
| | Unid Larvae | | | | | | | 0.01 | 0.2 | | | | | <0.01 | <0.1 |
| | Total | | | | | 0.17 | 1.5 | 0.19 | 6.3 | 0.08 | 33.8 | | | 0.07 | 1.9 |
| Smallmouth Bass | YSL | | | | | | | | | | | | | | |
| | PYSL | | | | | | | 0.01 | 0.3 | | | | | <0.01 | <0.1 |
| | Total | | | | | | | 0.01 | 0.3 | | | | | <0.01 | <0.1 |
| Spottail Shiner | Eggs | | | <0.01 | <0.1 | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | YSL | | | <0.01 | <0.1 | 0.02 | 0.1 | | | | | | | <0.01 | 0.1 |
| | PYSL | | | <0.01 | <0.1 | 0.09 | 0.8 | | | | | | | 0.02 | 0.4 |
| | YOY | | | | | 0.07 | 0.6 | | | | | | | 0.01 | 0.3 |
| | Total | | | 0.01 | 0.1 | 0.18 | 1.6 | | | | | | | 0.03 | 0.8 |
| Tessellated Darter | YSL | | | 0.52 | 6.2 | 0.26 | 2.3 | | | | | | | 0.13 | 3.3 |
| | PYSL | | | 0.04 | 0.5 | 0.10 | 0.9 | 0.05 | 1.7 | | | | | 0.03 | 0.8 |
| | Unid Larvae | | | 0.33 | 3.9 | 0.57 | 5.0 | | | | | | | 0.15 | 3.8 |
| | Total | | | 0.89 | 10.6 | 0.94 | 8.1 | 0.05 | 1.7 | | | | | 0.31 | 8.0 |
| Walleye | PYSL | | | 0.03 | 0.4 | | | | | | | | | 0.01 | 0.1 |
| | Total | | | 0.03 | 0.4 | | | | | | | | | 0.01 | 0.1 |
| White Perch | YSL | | | | | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | PYSL | | | | | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | Total | | | | | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| White Sucker | YSL | | | 0.07 | 0.8 | 0.02 | 0.1 | | | | | | | 0.01 | 0.4 |
| | PYSL | 0.10 | 40.2 | 5.21 | 62.1 | 3.08 | 26.7 | 0.03 | 1.1 | | | | | 1.41 | 35.9 |
| | YOY | | | | | 0.05 | 0.4 | | | | | | | 0.01 | 0.2 |
| | Unid Larvae | | | 0.10 | 1.1 | 0.03 | 0.3 | | | | | | | 0.02 | 0.5 |
| | Total | 0.10 | 40.2 | 5.38 | 64.0 | 3.18 | 27.6 | 0.03 | 1.1 | | | | | 1.45 | 37.0 |

(Continued).

**Table 3-7. Continued.**

| Species | Life Stage | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Season | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D | % | D | % | D | % | D | % | D | % | D | % | D | % |
| Yellow Bullhead | YOY | | | | | | | 0.02 | 0.6 | | | | | <0.01 | 0.1 |
| | Total | | | | | | | 0.02 | 0.6 | | | | | <0.01 | 0.1 |
| Yellow Perch | YSL | | | 0.01 | 0.1 | <0.01 | <0.1 | | | | | | | <0.01 | <0.1 |
| | PYSL | | | 1.47 | 17.5 | 0.09 | 0.8 | | | | | | | 0.26 | 6.7 |
| | Total | | | 1.47 | 17.6 | 0.10 | 0.8 | | | | | | | 0.26 | 6.7 |
| Total | Total | 0.25 | 100.0 | 8.40 | 100.0 | 11.55 | 100.0 | 3.05 | 100.0 | 0.24 | 100.0 | | | 3.91 | 100.0 |

YSL = Yolk-Sac Larvae; PYSL = Post Yolk-Sac Larvae; YOY = Young of the Year; YROL = Yearling or older; Unid. Larvae =damaged YSL or PYSL

**Table 3–8. Estimated monthly entrainment abundance (number and %) at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS , 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| | | Existing CWIS | | 3-mm WWS | | Closed-cycle Cooling Towers | |
|---|---|---|---|---|---|---|---|
| **Intake Flow** | **Month** | **N** | **%** | **N** | **%** | **N** | **%** |
| 10-year AIF | Apr | 25,260 | 0.2 | 15,227 | 0.8 | 1,263 | 0.2 |
| | May | 815,215 | 5.5 | 59,281 | 3.2 | 40,761 | 5.5 |
| | Jun | 1,676,497 | 11.3 | 210,352 | 11.2 | 83,825 | 11.3 |
| | Jul | 621,545 | 4.2 | 98,160 | 5.2 | 31,077 | 4.2 |
| | Aug | 33,260 | 0.2 | 33,260 | 1.8 | 1,663 | 0.2 |
| | Sep | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 3,171,776 | 100.0 | 416,279 | 100.0 | 158,589 | 100.0 |
| 100% DIF | Apr | 81,140 | 0.5 | 48,912 | 2.6 | 4,057 | 0.5 |
| | May | 2,831,031 | 19.1 | 205,867 | 11.0 | 141,552 | 19.1 |
| | Jun | 3,768,249 | 25.4 | 472,807 | 25.3 | 188,412 | 25.4 |
| | Jul | 1,028,628 | 6.9 | 162,450 | 8.7 | 51,431 | 6.9 |
| | Aug | 80,197 | 0.5 | 80,197 | 4.3 | 4,010 | 0.5 |
| | Sep | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 7,789,245 | 100.0 | 970,233 | 100.0 | 389,462 | 100.0 |
| 50% DIF | Apr | 40,570 | 0.3 | 24,456 | 1.3 | 2,029 | 0.3 |
| | May | 1,415,516 | 9.5 | 102,934 | 5.5 | 70,776 | 9.5 |
| | Jun | 1,884,124 | 12.7 | 236,403 | 12.6 | 94,206 | 12.7 |
| | Jul | 514,314 | 3.5 | 81,225 | 4.3 | 25,716 | 3.5 |
| | Aug | 40,099 | 0.3 | 40,099 | 2.1 | 2,005 | 0.3 |
| | Sep | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 3,894,622 | 100.0 | 485,116 | 100.0 | 194,731 | 100.0 |

**Table 3–9. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS) based on 10-year (2007-2016) actual intake flow (AIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 149 | 212 | 0 | 0 | 0 | 361 |
| | Common Shiner | 0 | 15 | 21 | 0 | 0 | 0 | 36 |
| | Fallfish | 0 | 4,764 | 6,746 | 373 | 5,816 | 0 | 17,698 |
| | Golden Shiner | 0 | 15 | 21 | 0 | 0 | 0 | 36 |
| | Spottail Shiner | 0 | 177 | 251 | 0 | 0 | 0 | 428 |
| | Total | 0 | 5,120 | 7,251 | 373 | 5,816 | 0 | 18,559 |
| Larvae | Alewife | 0 | 697 | 11,686 | 9,747 | 759 | 0 | 22,890 |
| | American Shad | 0 | 0 | 1,051 | 2,859 | 0 | 0 | 3,910 |
| | Black Crappie | 15,105 | 15,875 | 45,316 | 2,483 | 0 | 0 | 78,780 |
| | Blacknose Dace | 0 | 2,834 | 33,956 | 1,448 | 38 | 0 | 38,277 |
| | Bluegill | 0 | 0 | 332,381 | 411,977 | 8,966 | 0 | 753,324 |
| | Brown Bullhead | 0 | 0 | 0 | 27,366 | 0 | 0 | 27,366 |
| | Common Shiner | 0 | 60 | 1,317 | 0 | 0 | 0 | 1,377 |
| | Fallfish | 0 | 35,164 | 568,406 | 81,242 | 6,425 | 0 | 691,236 |
| | Golden Shiner | 0 | 60 | 1,313 | 0 | 0 | 0 | 1,373 |
| | Largemouth Bass | 0 | 0 | 3,817 | 4,702 | 0 | 0 | 8,519 |
| | Margined Madtom | 0 | 0 | 0 | 13,689 | 0 | 0 | 13,689 |
| | Rock Bass | 0 | 0 | 25,050 | 39,414 | 11,256 | 0 | 75,720 |
| | Smallmouth Bass | 0 | 0 | 0 | 1,694 | 0 | 0 | 1,694 |
| | Spottail Shiner | 0 | 713 | 15,596 | 0 | 0 | 0 | 16,308 |
| | Tessellated Darter | 0 | 86,312 | 136,038 | 10,660 | 0 | 0 | 233,009 |
| | Walleye | 0 | 3,298 | 0 | 0 | 0 | 0 | 3,298 |
| | White Perch | 0 | 0 | 391 | 0 | 0 | 0 | 391 |
| | White Sucker | 10,155 | 521,977 | 454,738 | 6,833 | 0 | 0 | 993,702 |
| | Yellow Perch | 0 | 143,105 | 13,881 | 0 | 0 | 0 | 156,986 |
| | Total | 25,260 | 810,095 | 1,644,936 | 614,115 | 27,444 | 0 | 3,121,850 |
| YOY | Black Crappie | 0 | 0 | 0 | 340 | 0 | 0 | 340 |
| | Largemouth Bass | 0 | 0 | 190 | 699 | 0 | 0 | 889 |
| | Margined Madtom | 0 | 0 | 5,439 | 1,505 | 0 | 0 | 6,944 |
| | Spottail Shiner | 0 | 0 | 10,878 | 0 | 0 | 0 | 10,878 |
| | White Sucker | 0 | 0 | 7,252 | 0 | 0 | 0 | 7,252 |
| | Yellow Bullhead | 0 | 0 | 0 | 3,822 | 0 | 0 | 3,822 |
| | Total | 0 | 0 | 23,759 | 6,366 | 0 | 0 | 30,125 |
| YROL | American Eel | 0 | 0 | 181 | 349 | 0 | 0 | 530 |
| | Bluegill | 0 | 0 | 370 | 0 | 0 | 0 | 370 |
| | Golden Shiner | 0 | 0 | 0 | 342 | 0 | 0 | 342 |
| | Total | 0 | 0 | 550 | 691 | 0 | 0 | 1,241 |

(Continued)

**Table 3-9 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 697 | 11,686 | 9,747 | 759 | 0 | 22,890 |
| | American Eel | 0 | 0 | 181 | 349 | 0 | 0 | 530 |
| | American Shad | 0 | 0 | 1,051 | 2,859 | 0 | 0 | 3,910 |
| | Black Crappie | 15,105 | 15,875 | 45,316 | 2,823 | 0 | 0 | 79,120 |
| | Blacknose Dace | 0 | 2,983 | 34,168 | 1,448 | 38 | 0 | 38,638 |
| | Bluegill | 0 | 0 | 332,751 | 411,977 | 8,966 | 0 | 753,694 |
| | Brown Bullhead | 0 | 0 | 0 | 27,366 | 0 | 0 | 27,366 |
| | Common Shiner | 0 | 75 | 1,338 | 0 | 0 | 0 | 1,413 |
| | Fallfish | 0 | 39,927 | 575,152 | 81,615 | 12,240 | 0 | 708,934 |
| | Golden Shiner | 0 | 75 | 1,334 | 342 | 0 | 0 | 1,751 |
| | Largemouth Bass | 0 | 0 | 4,006 | 5,401 | 0 | 0 | 9,408 |
| | Margined Madtom | 0 | 0 | 5,439 | 15,194 | 0 | 0 | 20,633 |
| | Rock Bass | 0 | 0 | 25,050 | 39,414 | 11,256 | 0 | 75,720 |
| | Smallmouth Bass | 0 | 0 | 0 | 1,694 | 0 | 0 | 1,694 |
| | Spottail Shiner | 0 | 890 | 26,725 | 0 | 0 | 0 | 27,615 |
| | Tessellated Darter | 0 | 86,312 | 136,038 | 10,660 | 0 | 0 | 233,009 |
| | Walleye | 0 | 3,298 | 0 | 0 | 0 | 0 | 3,298 |
| | White Perch | 0 | 0 | 391 | 0 | 0 | 0 | 391 |
| | White Sucker | 10,155 | 521,977 | 461,989 | 6,833 | 0 | 0 | 1,000,954 |
| | Yellow Bullhead | 0 | 0 | 0 | 3,822 | 0 | 0 | 3,822 |
| | Yellow Perch | 0 | 143,105 | 13,881 | 0 | 0 | 0 | 156,986 |
| | Total | 25,260 | 815,215 | 1,676,497 | 621,545 | 33,260 | 0 | 3,171,776 |

**Table 3–10. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, with April through July operation of a 3-mm wedgewire half screen at the existing cooling water intake structure (CWIS) based on 10-year (2007-2016) actual intake flow (AIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 140 | 205 | 0 | 0 | 0 | 345 |
| | Common Shiner | 0 | 14 | 20 | 0 | 0 | 0 | 35 |
| | Fallfish | 0 | 4,465 | 6,524 | 348 | 5,816 | 0 | 17,152 |
| | Golden Shiner | 0 | 14 | 20 | 0 | 0 | 0 | 34 |
| | Spottail Shiner | 0 | 166 | 243 | 0 | 0 | 0 | 409 |
| | Total | 0 | 4,799 | 7,012 | 348 | 5,816 | 0 | 17,975 |
| Larvae | Alewife | 0 | 98 | 3,965 | 656 | 759 | 0 | 5,478 |
| | American Shad | 0 | 0 | 540 | 239 | 0 | 0 | 779 |
| | Black Crappie | 15,105 | 2,689 | 1,381 | 19 | 0 | 0 | 19,194 |
| | Blacknose Dace | 0 | 794 | 6,988 | 272 | 38 | 0 | 8,093 |
| | Bluegill | 0 | 0 | 17,182 | 34,301 | 8,966 | 0 | 60,448 |
| | Brown Bullhead | 0 | 0 | 0 | 27,139 | 0 | 0 | 27,139 |
| | Common Shiner | 0 | 37 | 320 | 0 | 0 | 0 | 358 |
| | Fallfish | 0 | 14,947 | 129,466 | 11,019 | 6,425 | 0 | 161,857 |
| | Golden Shiner | 0 | 37 | 319 | 0 | 0 | 0 | 357 |
| | Largemouth Bass | 0 | 0 | 1,385 | 3,869 | 0 | 0 | 5,254 |
| | Margined Madtom | 0 | 0 | 0 | 13,576 | 0 | 0 | 13,576 |
| | Rock Bass | 0 | 0 | 5 | 124 | 11,256 | 0 | 11,385 |
| | Smallmouth Bass | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Spottail Shiner | 0 | 444 | 3,792 | 0 | 0 | 0 | 4,236 |
| | Tessellated Darter | 0 | 10,321 | 20,178 | 3,905 | 0 | 0 | 34,405 |
| | Walleye | 0 | <1 | 0 | 0 | 0 | 0 | <1 |
| | White Perch | 0 | 0 | 193 | 0 | 0 | 0 | 193 |
| | White Sucker | 122 | 7,298 | 6,015 | 86 | 0 | 0 | 13,521 |
| | Yellow Perch | 0 | 17,814 | 1,710 | 0 | 0 | 0 | 19,524 |
| | Total | 15,227 | 54,482 | 193,440 | 95,206 | 27,444 | 0 | 385,798 |
| YOY | Black Crappie | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Largemouth Bass | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Margined Madtom | 0 | 0 | 2,649 | 733 | 0 | 0 | 3,382 |
| | Spottail Shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | White Sucker | 0 | 0 | 7,252 | 0 | 0 | 0 | 7,252 |
| | Yellow Bullhead | 0 | 0 | 0 | 1,873 | 0 | 0 | 1,873 |
| | Total | 0 | 0 | 9,901 | 2,606 | 0 | 0 | 12,506 |
| YROL | American Eel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Golden Shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(Continued)

**Table 3-10 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 98 | 3,965 | 656 | 759 | 0 | 5,478 |
| | American Eel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | American Shad | 0 | 0 | 540 | 239 | 0 | 0 | 779 |
| | Black Crappie | 15,105 | 2,689 | 1,381 | 19 | 0 | 0 | 19,194 |
| | Blacknose Dace | 0 | 934 | 7,193 | 272 | 38 | 0 | 8,438 |
| | Bluegill | 0 | 0 | 17,182 | 34,301 | 8,966 | 0 | 60,448 |
| | Brown Bullhead | 0 | 0 | 0 | 27,139 | 0 | 0 | 27,139 |
| | Common Shiner | 0 | 52 | 341 | 0 | 0 | 0 | 392 |
| | Fallfish | 0 | 19,412 | 135,990 | 11,367 | 12,240 | 0 | 179,009 |
| | Golden Shiner | 0 | 51 | 340 | 0 | 0 | 0 | 391 |
| | Largemouth Bass | 0 | 0 | 1,385 | 3,869 | 0 | 0 | 5,254 |
| | Margined Madtom | 0 | 0 | 2,649 | 14,309 | 0 | 0 | 16,957 |
| | Rock Bass | 0 | 0 | 5 | 124 | 11,256 | 0 | 11,385 |
| | Smallmouth Bass | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Spottail Shiner | 0 | 610 | 4,035 | 0 | 0 | 0 | 4,645 |
| | Tessellated Darter | 0 | 10,321 | 20,178 | 3,905 | 0 | 0 | 34,405 |
| | Walleye | 0 | <1 | 0 | 0 | 0 | 0 | <1 |
| | White Perch | 0 | 0 | 193 | 0 | 0 | 0 | 193 |
| | White Sucker | 122 | 7,298 | 13,267 | 86 | 0 | 0 | 20,773 |
| | Yellow Bullhead | 0 | 0 | 0 | 1,873 | 0 | 0 | 1,873 |
| | Yellow Perch | 0 | 17,814 | 1,710 | 0 | 0 | 0 | 19,524 |
| | Total | 15,227 | 59,281 | 210,352 | 98,160 | 33,260 | 0 | 416,279 |

**Table 3–11. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, with closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 7 | 11 | 0 | 0 | 0 | 18 |
| | Common Shiner | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| | Fallfish | 0 | 238 | 337 | 19 | 291 | 0 | 885 |
| | Golden Shiner | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| | Spottail Shiner | 0 | 9 | 13 | 0 | 0 | 0 | 21 |
| | Total | 0 | 256 | 363 | 19 | 291 | 0 | 928 |
| Larvae | Alewife | 0 | 35 | 584 | 487 | 38 | 0 | 1,144 |
| | American Shad | 0 | 0 | 53 | 143 | 0 | 0 | 196 |
| | Black Crappie | 755 | 794 | 2,266 | 124 | 0 | 0 | 3,939 |
| | Blacknose Dace | 0 | 142 | 1,698 | 72 | 2 | 0 | 1,914 |
| | Bluegill | 0 | 0 | 16,619 | 20,599 | 448 | 0 | 37,666 |
| | Brown Bullhead | 0 | 0 | 0 | 1,368 | 0 | 0 | 1,368 |
| | Common Shiner | 0 | 3 | 66 | 0 | 0 | 0 | 69 |
| | Fallfish | 0 | 1,758 | 28,420 | 4,062 | 321 | 0 | 34,562 |
| | Golden Shiner | 0 | 3 | 66 | 0 | 0 | 0 | 69 |
| | Largemouth Bass | 0 | 0 | 191 | 235 | 0 | 0 | 426 |
| | Margined Madtom | 0 | 0 | 0 | 684 | 0 | 0 | 684 |
| | Rock Bass | 0 | 0 | 1,252 | 1,971 | 563 | 0 | 3,786 |
| | Smallmouth Bass | 0 | 0 | 0 | 85 | 0 | 0 | 85 |
| | Spottail Shiner | 0 | 36 | 780 | 0 | 0 | 0 | 815 |
| | Tessellated Darter | 0 | 4,316 | 6,802 | 533 | 0 | 0 | 11,650 |
| | Walleye | 0 | 165 | 0 | 0 | 0 | 0 | 165 |
| | White Perch | 0 | 0 | 20 | 0 | 0 | 0 | 20 |
| | White Sucker | 508 | 26,099 | 22,737 | 342 | 0 | 0 | 49,685 |
| | Yellow Perch | 0 | 7,155 | 694 | 0 | 0 | 0 | 7,849 |
| | Total | 1,263 | 40,505 | 82,247 | 30,706 | 1,372 | 0 | 156,093 |
| YOY | Black Crappie | 0 | 0 | 0 | 17 | 0 | 0 | 17 |
| | Largemouth Bass | 0 | 0 | 9 | 35 | 0 | 0 | 44 |
| | Margined Madtom | 0 | 0 | 272 | 75 | 0 | 0 | 347 |
| | Spottail Shiner | 0 | 0 | 544 | 0 | 0 | 0 | 544 |
| | White Sucker | 0 | 0 | 363 | 0 | 0 | 0 | 363 |
| | Yellow Bullhead | 0 | 0 | 0 | 191 | 0 | 0 | 191 |
| | Total | 0 | 0 | 1,188 | 318 | 0 | 0 | 1,506 |
| YROL | American Eel | 0 | 0 | 9 | 17 | 0 | 0 | 26 |
| | Bluegill | 0 | 0 | 18 | 0 | 0 | 0 | 18 |
| | Golden Shiner | 0 | 0 | 0 | 17 | 0 | 0 | 17 |
| | Total | 0 | 0 | 28 | 35 | 0 | 0 | 62 |

(Continued)

**Table 3-11 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 35 | 584 | 487 | 38 | 0 | 1,144 |
| | American Eel | 0 | 0 | 9 | 17 | 0 | 0 | 26 |
| | American Shad | 0 | 0 | 53 | 143 | 0 | 0 | 196 |
| | Black Crappie | 755 | 794 | 2,266 | 141 | 0 | 0 | 3,956 |
| | Blacknose Dace | 0 | 149 | 1,708 | 72 | 2 | 0 | 1,932 |
| | Bluegill | 0 | 0 | 16,638 | 20,599 | 448 | 0 | 37,685 |
| | Brown Bullhead | 0 | 0 | 0 | 1,368 | 0 | 0 | 1,368 |
| | Common Shiner | 0 | 4 | 67 | 0 | 0 | 0 | 71 |
| | Fallfish | 0 | 1,996 | 28,758 | 4,081 | 612 | 0 | 35,447 |
| | Golden Shiner | 0 | 4 | 67 | 17 | 0 | 0 | 88 |
| | Largemouth Bass | 0 | 0 | 200 | 270 | 0 | 0 | 470 |
| | Margined Madtom | 0 | 0 | 272 | 760 | 0 | 0 | 1,032 |
| | Rock Bass | 0 | 0 | 1,252 | 1,971 | 563 | 0 | 3,786 |
| | Smallmouth Bass | 0 | 0 | 0 | 85 | 0 | 0 | 85 |
| | Spottail Shiner | 0 | 44 | 1,336 | 0 | 0 | 0 | 1,381 |
| | Tessellated Darter | 0 | 4,316 | 6,802 | 533 | 0 | 0 | 11,650 |
| | Walleye | 0 | 165 | 0 | 0 | 0 | 0 | 165 |
| | White Perch | 0 | 0 | 20 | 0 | 0 | 0 | 20 |
| | White Sucker | 508 | 26,099 | 23,099 | 342 | 0 | 0 | 50,048 |
| | Yellow Bullhead | 0 | 0 | 0 | 191 | 0 | 0 | 191 |
| | Yellow Perch | 0 | 7,155 | 694 | 0 | 0 | 0 | 7,849 |
| | Total | 1,263 | 40,761 | 83,825 | 31,077 | 1,663 | 0 | 158,589 |

**Table 3–12. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS) based on design intake flow (DIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 519 | 476 | 0 | 0 | 0 | 994 |
| | Common Shiner | 0 | 52 | 48 | 0 | 0 | 0 | 100 |
| | Fallfish | 0 | 16,543 | 15,164 | 616 | 14,023 | 0 | 46,346 |
| | Golden Shiner | 0 | 52 | 48 | 0 | 0 | 0 | 99 |
| | Spottail Shiner | 0 | 615 | 564 | 0 | 0 | 0 | 1,180 |
| | Total | 0 | 17,781 | 16,299 | 616 | 14,023 | 0 | 48,719 |
| Larvae | Alewife | 0 | 2,422 | 26,266 | 16,131 | 1,830 | 0 | 46,650 |
| | American Shad | 0 | 0 | 2,363 | 4,731 | 0 | 0 | 7,094 |
| | Black Crappie | 48,521 | 55,130 | 101,857 | 4,110 | 0 | 0 | 209,618 |
| | Blacknose Dace | 0 | 9,841 | 76,324 | 2,397 | 93 | 0 | 88,654 |
| | Bluegill | 0 | 0 | 747,091 | 681,803 | 21,618 | 0 | 1,450,512 |
| | Brown Bullhead | 0 | 0 | 0 | 45,290 | 0 | 0 | 45,290 |
| | Common Shiner | 0 | 209 | 2,960 | 0 | 0 | 0 | 3,169 |
| | Fallfish | 0 | 122,114 | 1,277,601 | 134,452 | 15,492 | 0 | 1,549,659 |
| | Golden Shiner | 0 | 208 | 2,952 | 0 | 0 | 0 | 3,160 |
| | Largemouth Bass | 0 | 0 | 8,578 | 7,782 | 0 | 0 | 16,361 |
| | Margined Madtom | 0 | 0 | 0 | 22,655 | 0 | 0 | 22,655 |
| | Rock Bass | 0 | 0 | 56,304 | 65,229 | 27,142 | 0 | 148,674 |
| | Smallmouth Bass | 0 | 0 | 0 | 2,803 | 0 | 0 | 2,803 |
| | Spottail Shiner | 0 | 2,474 | 35,054 | 0 | 0 | 0 | 37,529 |
| | Tessellated Darter | 0 | 299,738 | 305,771 | 17,641 | 0 | 0 | 623,151 |
| | Walleye | 0 | 11,453 | 0 | 0 | 0 | 0 | 11,453 |
| | White Perch | 0 | 0 | 878 | 0 | 0 | 0 | 878 |
| | White Sucker | 32,620 | 1,812,692 | 1,022,110 | 11,308 | 0 | 0 | 2,878,730 |
| | Yellow Perch | 0 | 496,967 | 31,201 | 0 | 0 | 0 | 528,168 |
| | Total | 81,140 | 2,813,250 | 3,697,310 | 1,016,332 | 66,174 | 0 | 7,674,208 |
| YOY | Black Crappie | 0 | 0 | 0 | 562 | 0 | 0 | 562 |
| | Largemouth Bass | 0 | 0 | 427 | 1,157 | 0 | 0 | 1,584 |
| | Margined Madtom | 0 | 0 | 12,226 | 2,491 | 0 | 0 | 14,716 |
| | Spottail Shiner | 0 | 0 | 24,451 | 0 | 0 | 0 | 24,451 |
| | White Sucker | 0 | 0 | 16,300 | 0 | 0 | 0 | 16,300 |
| | Yellow Bullhead | 0 | 0 | 0 | 6,326 | 0 | 0 | 6,326 |
| | Total | 0 | 0 | 53,403 | 10,536 | 0 | 0 | 63,939 |
| YROL | American Eel | 0 | 0 | 406 | 578 | 0 | 0 | 984 |
| | Bluegill | 0 | 0 | 831 | 0 | 0 | 0 | 831 |
| | Golden Shiner | 0 | 0 | 0 | 566 | 0 | 0 | 566 |
| | Total | 0 | 0 | 1,237 | 1,143 | 0 | 0 | 2,380 |

(Continued)

**Table 3-12 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 2,422 | 26,266 | 16,131 | 1,830 | 0 | 46,650 |
| | American Eel | 0 | 0 | 406 | 578 | 0 | 0 | 984 |
| | American Shad | 0 | 0 | 2,363 | 4,731 | 0 | 0 | 7,094 |
| | Black Crappie | 48,521 | 55,130 | 101,857 | 4,672 | 0 | 0 | 210,180 |
| | Blacknose Dace | 0 | 10,360 | 76,799 | 2,397 | 93 | 0 | 89,649 |
| | Bluegill | 0 | 0 | 747,922 | 681,803 | 21,618 | 0 | 1,451,343 |
| | Brown Bullhead | 0 | 0 | 0 | 45,290 | 0 | 0 | 45,290 |
| | Common Shiner | 0 | 261 | 3,008 | 0 | 0 | 0 | 3,269 |
| | Fallfish | 0 | 138,657 | 1,292,765 | 135,068 | 29,514 | 0 | 1,596,004 |
| | Golden Shiner | 0 | 260 | 2,999 | 566 | 0 | 0 | 3,825 |
| | Largemouth Bass | 0 | 0 | 9,005 | 8,939 | 0 | 0 | 17,944 |
| | Margined Madtom | 0 | 0 | 12,226 | 25,146 | 0 | 0 | 37,371 |
| | Rock Bass | 0 | 0 | 56,304 | 65,229 | 27,142 | 0 | 148,674 |
| | Smallmouth Bass | 0 | 0 | 0 | 2,803 | 0 | 0 | 2,803 |
| | Spottail Shiner | 0 | 3,090 | 60,070 | 0 | 0 | 0 | 63,159 |
| | Tessellated Darter | 0 | 299,738 | 305,771 | 17,641 | 0 | 0 | 623,151 |
| | Walleye | 0 | 11,453 | 0 | 0 | 0 | 0 | 11,453 |
| | White Perch | 0 | 0 | 878 | 0 | 0 | 0 | 878 |
| | White Sucker | 32,620 | 1,812,692 | 1,038,410 | 11,308 | 0 | 0 | 2,895,030 |
| | Yellow Bullhead | 0 | 0 | 0 | 6,326 | 0 | 0 | 6,326 |
| | Yellow Perch | 0 | 496,967 | 31,201 | 0 | 0 | 0 | 528,168 |
| | Total | 81,140 | 2,831,031 | 3,768,249 | 1,028,628 | 80,197 | 0 | 7,789,245 |

**Table 3–13. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, with April through July operation of a 3-mm wedgewire half screen at the existing cooling water intake structure (CWIS) based on design intake flow (DIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 486 | 460 | 0 | 0 | 0 | 946 |
| | Common Shiner | 0 | 49 | 46 | 0 | 0 | 0 | 95 |
| | Fallfish | 0 | 15,506 | 14,663 | 576 | 14,023 | 0 | 44,768 |
| | Golden Shiner | 0 | 49 | 46 | 0 | 0 | 0 | 95 |
| | Spottail Shiner | 0 | 577 | 545 | 0 | 0 | 0 | 1,122 |
| | Total | 0 | 16,666 | 15,761 | 576 | 14,023 | 0 | 47,025 |
| Larvae | Alewife | 0 | 341 | 8,912 | 1,086 | 1,830 | 0 | 12,169 |
| | American Shad | 0 | 0 | 1,213 | 396 | 0 | 0 | 1,609 |
| | Black Crappie | 48,521 | 9,339 | 3,104 | 32 | 0 | 0 | 60,995 |
| | Blacknose Dace | 0 | 2,758 | 15,707 | 451 | 93 | 0 | 19,008 |
| | Bluegill | 0 | 0 | 38,620 | 56,766 | 21,618 | 0 | 117,004 |
| | Brown Bullhead | 0 | 0 | 0 | 44,914 | 0 | 0 | 44,914 |
| | Common Shiner | 0 | 130 | 720 | 0 | 0 | 0 | 850 |
| | Fallfish | 0 | 51,906 | 291,001 | 18,236 | 15,492 | 0 | 376,634 |
| | Golden Shiner | 0 | 130 | 718 | 0 | 0 | 0 | 848 |
| | Largemouth Bass | 0 | 0 | 3,113 | 6,403 | 0 | 0 | 9,515 |
| | Margined Madtom | 0 | 0 | 0 | 22,467 | 0 | 0 | 22,467 |
| | Rock Bass | 0 | 0 | 11 | 205 | 27,142 | 0 | 27,357 |
| | Smallmouth Bass | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Spottail Shiner | 0 | 1,542 | 8,523 | 0 | 0 | 0 | 10,065 |
| | Tessellated Darter | 0 | 35,843 | 45,355 | 6,463 | 0 | 0 | 87,661 |
| | Walleye | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| | White Perch | 0 | 0 | 433 | 0 | 0 | 0 | 433 |
| | White Sucker | 391 | 25,345 | 13,520 | 142 | 0 | 0 | 39,400 |
| | Yellow Perch | 0 | 61,865 | 3,843 | 0 | 0 | 0 | 65,708 |
| | Total | 48,912 | 189,201 | 434,792 | 157,562 | 66,174 | 0 | 896,641 |
| YOY | Black Crappie | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Largemouth Bass | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Margined Madtom | 0 | 0 | 5,954 | 1,213 | 0 | 0 | 7,167 |
| | Spottail Shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | White Sucker | 0 | 0 | 16,300 | 0 | 0 | 0 | 16,300 |
| | Yellow Bullhead | 0 | 0 | 0 | 3,100 | 0 | 0 | 3,100 |
| | Total | 0 | 0 | 22,254 | 4,313 | 0 | 0 | 26,566 |
| YROL | American Eel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Golden Shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(Continued)

**Table 3-13 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 341 | 8,912 | 1,086 | 1,830 | 0 | 12,169 |
| | American Eel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | American Shad | 0 | 0 | 1,213 | 396 | 0 | 0 | 1,609 |
| | Black Crappie | 48,521 | 9,339 | 3,104 | 32 | 0 | 0 | 60,995 |
| | Blacknose Dace | 0 | 3,244 | 16,167 | 451 | 93 | 0 | 19,955 |
| | Bluegill | 0 | 0 | 38,620 | 56,766 | 21,618 | 0 | 117,004 |
| | Brown Bullhead | 0 | 0 | 0 | 44,914 | 0 | 0 | 44,914 |
| | Common Shiner | 0 | 179 | 766 | 0 | 0 | 0 | 945 |
| | Fallfish | 0 | 67,412 | 305,664 | 18,812 | 29,514 | 0 | 421,401 |
| | Golden Shiner | 0 | 178 | 764 | 0 | 0 | 0 | 942 |
| | Largemouth Bass | 0 | 0 | 3,113 | 6,403 | 0 | 0 | 9,515 |
| | Margined Madtom | 0 | 0 | 5,954 | 23,680 | 0 | 0 | 29,634 |
| | Rock Bass | 0 | 0 | 11 | 205 | 27,142 | 0 | 27,357 |
| | Smallmouth Bass | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Spottail Shiner | 0 | 2,119 | 9,068 | 0 | 0 | 0 | 11,187 |
| | Tessellated Darter | 0 | 35,843 | 45,355 | 6,463 | 0 | 0 | 87,661 |
| | Walleye | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| | White Perch | 0 | 0 | 433 | 0 | 0 | 0 | 433 |
| | White Sucker | 391 | 25,345 | 29,820 | 142 | 0 | 0 | 55,699 |
| | Yellow Bullhead | 0 | 0 | 0 | 3,100 | 0 | 0 | 3,100 |
| | Yellow Perch | 0 | 61,865 | 3,843 | 0 | 0 | 0 | 65,708 |
| | Total | 48,912 | 205,867 | 472,807 | 162,450 | 80,197 | 0 | 970,233 |

**Table 3–14. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, with closed-cycle cooling towers based on design intake flow (DIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 26 | 24 | 0 | 0 | 0 | 50 |
| | Common Shiner | 0 | 3 | 2 | 0 | 0 | 0 | 5 |
| | Fallfish | 0 | 827 | 758 | 31 | 701 | 0 | 2,317 |
| | Golden Shiner | 0 | 3 | 2 | 0 | 0 | 0 | 5 |
| | Spottail Shiner | 0 | 31 | 28 | 0 | 0 | 0 | 59 |
| | Total | 0 | 889 | 815 | 31 | 701 | 0 | 2,436 |
| Larvae | Alewife | 0 | 121 | 1,313 | 807 | 92 | 0 | 2,332 |
| | American Shad | 0 | 0 | 118 | 237 | 0 | 0 | 355 |
| | Black Crappie | 2,426 | 2,757 | 5,093 | 205 | 0 | 0 | 10,481 |
| | Blacknose Dace | 0 | 492 | 3,816 | 120 | 5 | 0 | 4,433 |
| | Bluegill | 0 | 0 | 37,355 | 34,090 | 1,081 | 0 | 72,526 |
| | Brown Bullhead | 0 | 0 | 0 | 2,265 | 0 | 0 | 2,265 |
| | Common Shiner | 0 | 10 | 148 | 0 | 0 | 0 | 158 |
| | Fallfish | 0 | 6,106 | 63,880 | 6,723 | 775 | 0 | 77,483 |
| | Golden Shiner | 0 | 10 | 148 | 0 | 0 | 0 | 158 |
| | Largemouth Bass | 0 | 0 | 429 | 389 | 0 | 0 | 818 |
| | Margined Madtom | 0 | 0 | 0 | 1,133 | 0 | 0 | 1,133 |
| | Rock Bass | 0 | 0 | 2,815 | 3,261 | 1,357 | 0 | 7,434 |
| | Smallmouth Bass | 0 | 0 | 0 | 140 | 0 | 0 | 140 |
| | Spottail Shiner | 0 | 124 | 1,753 | 0 | 0 | 0 | 1,876 |
| | Tessellated Darter | 0 | 14,987 | 15,289 | 882 | 0 | 0 | 31,158 |
| | Walleye | 0 | 573 | 0 | 0 | 0 | 0 | 573 |
| | White Perch | 0 | 0 | 44 | 0 | 0 | 0 | 44 |
| | White Sucker | 1,631 | 90,635 | 51,105 | 565 | 0 | 0 | 143,937 |
| | Yellow Perch | 0 | 24,848 | 1,560 | 0 | 0 | 0 | 26,408 |
| | Total | 4,057 | 140,663 | 184,866 | 50,817 | 3,309 | 0 | 383,710 |
| YOY | Black Crappie | 0 | 0 | 0 | 28 | 0 | 0 | 28 |
| | Largemouth Bass | 0 | 0 | 21 | 58 | 0 | 0 | 79 |
| | Margined Madtom | 0 | 0 | 611 | 125 | 0 | 0 | 736 |
| | Spottail Shiner | 0 | 0 | 1,223 | 0 | 0 | 0 | 1,223 |
| | White Sucker | 0 | 0 | 815 | 0 | 0 | 0 | 815 |
| | Yellow Bullhead | 0 | 0 | 0 | 316 | 0 | 0 | 316 |
| | Total | 0 | 0 | 2,670 | 527 | 0 | 0 | 3,197 |
| YROL | American Eel | 0 | 0 | 20 | 29 | 0 | 0 | 49 |
| | Bluegill | 0 | 0 | 42 | 0 | 0 | 0 | 42 |
| | Golden Shiner | 0 | 0 | 0 | 28 | 0 | 0 | 28 |
| | Total | 0 | 0 | 62 | 57 | 0 | 0 | 119 |

(Continued)

**Table 3-14 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 121 | 1,313 | 807 | 92 | 0 | 2,332 |
| | American Eel | 0 | 0 | 20 | 29 | 0 | 0 | 49 |
| | American Shad | 0 | 0 | 118 | 237 | 0 | 0 | 355 |
| | Black Crappie | 2,426 | 2,757 | 5,093 | 234 | 0 | 0 | 10,509 |
| | Blacknose Dace | 0 | 518 | 3,840 | 120 | 5 | 0 | 4,482 |
| | Bluegill | 0 | 0 | 37,396 | 34,090 | 1,081 | 0 | 72,567 |
| | Brown Bullhead | 0 | 0 | 0 | 2,265 | 0 | 0 | 2,265 |
| | Common Shiner | 0 | 13 | 150 | 0 | 0 | 0 | 163 |
| | Fallfish | 0 | 6,933 | 64,638 | 6,753 | 1,476 | 0 | 79,800 |
| | Golden Shiner | 0 | 13 | 150 | 28 | 0 | 0 | 191 |
| | Largemouth Bass | 0 | 0 | 450 | 447 | 0 | 0 | 897 |
| | Margined Madtom | 0 | 0 | 611 | 1,257 | 0 | 0 | 1,869 |
| | Rock Bass | 0 | 0 | 2,815 | 3,261 | 1,357 | 0 | 7,434 |
| | Smallmouth Bass | 0 | 0 | 0 | 140 | 0 | 0 | 140 |
| | Spottail Shiner | 0 | 154 | 3,003 | 0 | 0 | 0 | 3,158 |
| | Tessellated Darter | 0 | 14,987 | 15,289 | 882 | 0 | 0 | 31,158 |
| | Walleye | 0 | 573 | 0 | 0 | 0 | 0 | 573 |
| | White Perch | 0 | 0 | 44 | 0 | 0 | 0 | 44 |
| | White Sucker | 1,631 | 90,635 | 51,920 | 565 | 0 | 0 | 144,751 |
| | Yellow Bullhead | 0 | 0 | 0 | 316 | 0 | 0 | 316 |
| | Yellow Perch | 0 | 24,848 | 1,560 | 0 | 0 | 0 | 26,408 |
| | Total | 4,057 | 141,552 | 188,412 | 51,431 | 4,010 | 0 | 389,462 |

**Table 3–15. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS) based on 50% design intake flow (DIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 259 | 238 | 0 | 0 | 0 | 497 |
| | Common Shiner | 0 | 26 | 24 | 0 | 0 | 0 | 50 |
| | Fallfish | 0 | 8,271 | 7,582 | 308 | 7,011 | 0 | 23,173 |
| | Golden Shiner | 0 | 26 | 24 | 0 | 0 | 0 | 50 |
| | Spottail Shiner | 0 | 308 | 282 | 0 | 0 | 0 | 590 |
| | Total | 0 | 8,890 | 8,149 | 308 | 7,011 | 0 | 24,359 |
| Larvae | Alewife | 0 | 1,211 | 13,133 | 8,066 | 915 | 0 | 23,325 |
| | American Shad | 0 | 0 | 1,182 | 2,366 | 0 | 0 | 3,547 |
| | Black Crappie | 24,260 | 27,565 | 50,928 | 2,055 | 0 | 0 | 104,809 |
| | Blacknose Dace | 0 | 4,921 | 38,162 | 1,198 | 46 | 0 | 44,327 |
| | Bluegill | 0 | 0 | 373,545 | 340,902 | 10,809 | 0 | 725,256 |
| | Brown Bullhead | 0 | 0 | 0 | 22,645 | 0 | 0 | 22,645 |
| | Common Shiner | 0 | 104 | 1,480 | 0 | 0 | 0 | 1,585 |
| | Fallfish | 0 | 61,057 | 638,801 | 67,226 | 7,746 | 0 | 774,829 |
| | Golden Shiner | 0 | 104 | 1,476 | 0 | 0 | 0 | 1,580 |
| | Largemouth Bass | 0 | 0 | 4,289 | 3,891 | 0 | 0 | 8,180 |
| | Margined Madtom | 0 | 0 | 0 | 11,328 | 0 | 0 | 11,328 |
| | Rock Bass | 0 | 0 | 28,152 | 32,614 | 13,571 | 0 | 74,337 |
| | Smallmouth Bass | 0 | 0 | 0 | 1,401 | 0 | 0 | 1,401 |
| | Spottail Shiner | 0 | 1,237 | 17,527 | 0 | 0 | 0 | 18,764 |
| | Tessellated Darter | 0 | 149,869 | 152,886 | 8,821 | 0 | 0 | 311,576 |
| | Walleye | 0 | 5,727 | 0 | 0 | 0 | 0 | 5,727 |
| | White Perch | 0 | 0 | 439 | 0 | 0 | 0 | 439 |
| | White Sucker | 16,310 | 906,346 | 511,055 | 5,654 | 0 | 0 | 1,439,365 |
| | Yellow Perch | 0 | 248,483 | 15,600 | 0 | 0 | 0 | 264,084 |
| | Total | 40,570 | 1,406,625 | 1,848,655 | 508,166 | 33,087 | 0 | 3,837,104 |
| YOY | Black Crappie | 0 | 0 | 0 | 281 | 0 | 0 | 281 |
| | Largemouth Bass | 0 | 0 | 213 | 578 | 0 | 0 | 792 |
| | Margined Madtom | 0 | 0 | 6,113 | 1,245 | 0 | 0 | 7,358 |
| | Spottail Shiner | 0 | 0 | 12,226 | 0 | 0 | 0 | 12,226 |
| | White Sucker | 0 | 0 | 8,150 | 0 | 0 | 0 | 8,150 |
| | Yellow Bullhead | 0 | 0 | 0 | 3,163 | 0 | 0 | 3,163 |
| | Total | 0 | 0 | 26,702 | 5,268 | 0 | 0 | 31,969 |
| YROL | American Eel | 0 | 0 | 203 | 289 | 0 | 0 | 492 |
| | Bluegill | 0 | 0 | 415 | 0 | 0 | 0 | 415 |
| | Golden Shiner | 0 | 0 | 0 | 283 | 0 | 0 | 283 |
| | Total | 0 | 0 | 618 | 572 | 0 | 0 | 1,190 |

(Continued)

**Table 3-15 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 1,211 | 13,133 | 8,066 | 915 | 0 | 23,325 |
| | American Eel | 0 | 0 | 203 | 289 | 0 | 0 | 492 |
| | American Shad | 0 | 0 | 1,182 | 2,366 | 0 | 0 | 3,547 |
| | Black Crappie | 24,260 | 27,565 | 50,928 | 2,336 | 0 | 0 | 105,090 |
| | Blacknose Dace | 0 | 5,180 | 38,400 | 1,198 | 46 | 0 | 44,824 |
| | Bluegill | 0 | 0 | 373,961 | 340,902 | 10,809 | 0 | 725,671 |
| | Brown Bullhead | 0 | 0 | 0 | 22,645 | 0 | 0 | 22,645 |
| | Common Shiner | 0 | 130 | 1,504 | 0 | 0 | 0 | 1,634 |
| | Fallfish | 0 | 69,329 | 646,382 | 67,534 | 14,757 | 0 | 798,002 |
| | Golden Shiner | 0 | 130 | 1,500 | 283 | 0 | 0 | 1,913 |
| | Largemouth Bass | 0 | 0 | 4,503 | 4,470 | 0 | 0 | 8,972 |
| | Margined Madtom | 0 | 0 | 6,113 | 12,573 | 0 | 0 | 18,686 |
| | Rock Bass | 0 | 0 | 28,152 | 32,614 | 13,571 | 0 | 74,337 |
| | Smallmouth Bass | 0 | 0 | 0 | 1,401 | 0 | 0 | 1,401 |
| | Spottail Shiner | 0 | 1,545 | 30,035 | 0 | 0 | 0 | 31,580 |
| | Tessellated Darter | 0 | 149,869 | 152,886 | 8,821 | 0 | 0 | 311,576 |
| | Walleye | 0 | 5,727 | 0 | 0 | 0 | 0 | 5,727 |
| | White Perch | 0 | 0 | 439 | 0 | 0 | 0 | 439 |
| | White Sucker | 16,310 | 906,346 | 519,205 | 5,654 | 0 | 0 | 1,447,515 |
| | Yellow Bullhead | 0 | 0 | 0 | 3,163 | 0 | 0 | 3,163 |
| | Yellow Perch | 0 | 248,483 | 15,600 | 0 | 0 | 0 | 264,084 |
| | Total | 40,570 | 1,415,516 | 1,884,124 | 514,314 | 40,099 | 0 | 3,894,622 |

**Table 3–16. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, with April through July operation of a 3-mm wedgewire half screen at the existing cooling water intake structure (CWIS) based on 50% design intake flow (DIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 243 | 230 | 0 | 0 | 0 | 473 |
| | Common Shiner | 0 | 24 | 23 | 0 | 0 | 0 | 47 |
| | Fallfish | 0 | 7,753 | 7,332 | 288 | 7,011 | 0 | 22,384 |
| | Golden Shiner | 0 | 24 | 23 | 0 | 0 | 0 | 47 |
| | Spottail Shiner | 0 | 288 | 273 | 0 | 0 | 0 | 561 |
| | Total | 0 | 8,333 | 7,880 | 288 | 7,011 | 0 | 23,513 |
| Larvae | Alewife | 0 | 170 | 4,456 | 543 | 915 | 0 | 6,084 |
| | American Shad | 0 | 0 | 607 | 198 | 0 | 0 | 805 |
| | Black Crappie | 24,260 | 4,669 | 1,552 | 16 | 0 | 0 | 30,498 |
| | Blacknose Dace | 0 | 1,379 | 7,854 | 225 | 46 | 0 | 9,504 |
| | Bluegill | 0 | 0 | 19,310 | 28,383 | 10,809 | 0 | 58,502 |
| | Brown Bullhead | 0 | 0 | 0 | 22,457 | 0 | 0 | 22,457 |
| | Common Shiner | 0 | 65 | 360 | 0 | 0 | 0 | 425 |
| | Fallfish | 0 | 25,953 | 145,500 | 9,118 | 7,746 | 0 | 188,317 |
| | Golden Shiner | 0 | 65 | 359 | 0 | 0 | 0 | 424 |
| | Largemouth Bass | 0 | 0 | 1,556 | 3,201 | 0 | 0 | 4,758 |
| | Margined Madtom | 0 | 0 | 0 | 11,234 | 0 | 0 | 11,234 |
| | Rock Bass | 0 | 0 | 5 | 102 | 13,571 | 0 | 13,679 |
| | Smallmouth Bass | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Spottail Shiner | 0 | 771 | 4,261 | 0 | 0 | 0 | 5,033 |
| | Tessellated Darter | 0 | 17,922 | 22,677 | 3,232 | 0 | 0 | 43,831 |
| | Walleye | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | White Perch | 0 | 0 | 216 | 0 | 0 | 0 | 216 |
| | White Sucker | 196 | 12,673 | 6,760 | 71 | 0 | 0 | 19,700 |
| | Yellow Perch | 0 | 30,933 | 1,922 | 0 | 0 | 0 | 32,854 |
| | Total | 24,456 | 94,600 | 217,396 | 78,781 | 33,087 | 0 | 448,321 |
| YOY | Black Crappie | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Largemouth Bass | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Margined Madtom | 0 | 0 | 2,977 | 606 | 0 | 0 | 3,583 |
| | Spottail Shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | White Sucker | 0 | 0 | 8,150 | 0 | 0 | 0 | 8,150 |
| | Yellow Bullhead | 0 | 0 | 0 | 1,550 | 0 | 0 | 1,550 |
| | Total | 0 | 0 | 11,127 | 2,156 | 0 | 0 | 13,283 |
| YROL | American Eel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Bluegill | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Golden Shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(Continued)

**Table 3-16 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 170 | 4,456 | 543 | 915 | 0 | 6,084 |
| | American Eel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | American Shad | 0 | 0 | 607 | 198 | 0 | 0 | 805 |
| | Black Crappie | 24,260 | 4,669 | 1,552 | 16 | 0 | 0 | 30,498 |
| | Blacknose Dace | 0 | 1,622 | 8,084 | 225 | 46 | 0 | 9,977 |
| | Bluegill | 0 | 0 | 19,310 | 28,383 | 10,809 | 0 | 58,502 |
| | Brown Bullhead | 0 | 0 | 0 | 22,457 | 0 | 0 | 22,457 |
| | Common Shiner | 0 | 89 | 383 | 0 | 0 | 0 | 472 |
| | Fallfish | 0 | 33,706 | 152,832 | 9,406 | 14,757 | 0 | 210,701 |
| | Golden Shiner | 0 | 89 | 382 | 0 | 0 | 0 | 471 |
| | Largemouth Bass | 0 | 0 | 1,556 | 3,201 | 0 | 0 | 4,758 |
| | Margined Madtom | 0 | 0 | 2,977 | 11,840 | 0 | 0 | 14,817 |
| | Rock Bass | 0 | 0 | 5 | 102 | 13,571 | 0 | 13,679 |
| | Smallmouth Bass | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Spottail Shiner | 0 | 1,059 | 4,534 | 0 | 0 | 0 | 5,594 |
| | Tessellated Darter | 0 | 17,922 | 22,677 | 3,232 | 0 | 0 | 43,831 |
| | Walleye | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | White Perch | 0 | 0 | 216 | 0 | 0 | 0 | 216 |
| | White Sucker | 196 | 12,673 | 14,910 | 71 | 0 | 0 | 27,850 |
| | Yellow Bullhead | 0 | 0 | 0 | 1,550 | 0 | 0 | 1,550 |
| | Yellow Perch | 0 | 30,933 | 1,922 | 0 | 0 | 0 | 32,854 |
| | Total | 24,456 | 102,934 | 236,403 | 81,225 | 40,099 | 0 | 485,116 |

**Table 3–17. Estimated monthly entrainment abundance by life stage and species at Merrimack Station, Units 1 and 2 combined, with closed-cycle cooling towers based on 50% design intake flow (DIF).**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Eggs | Blacknose Dace | 0 | 13 | 12 | 0 | 0 | 0 | 25 |
| | Common Shiner | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| | Fallfish | 0 | 414 | 379 | 15 | 351 | 0 | 1,159 |
| | Golden Shiner | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| | Spottail Shiner | 0 | 15 | 14 | 0 | 0 | 0 | 29 |
| | Total | 0 | 445 | 407 | 15 | 351 | 0 | 1,218 |
| Larvae | Alewife | 0 | 61 | 657 | 403 | 46 | 0 | 1,166 |
| | American Shad | 0 | 0 | 59 | 118 | 0 | 0 | 177 |
| | Black Crappie | 1,213 | 1,378 | 2,546 | 103 | 0 | 0 | 5,240 |
| | Blacknose Dace | 0 | 246 | 1,908 | 60 | 2 | 0 | 2,216 |
| | Bluegill | 0 | 0 | 18,677 | 17,045 | 540 | 0 | 36,263 |
| | Brown Bullhead | 0 | 0 | 0 | 1,132 | 0 | 0 | 1,132 |
| | Common Shiner | 0 | 5 | 74 | 0 | 0 | 0 | 79 |
| | Fallfish | 0 | 3,053 | 31,940 | 3,361 | 387 | 0 | 38,741 |
| | Golden Shiner | 0 | 5 | 74 | 0 | 0 | 0 | 79 |
| | Largemouth Bass | 0 | 0 | 214 | 195 | 0 | 0 | 409 |
| | Margined Madtom | 0 | 0 | 0 | 566 | 0 | 0 | 566 |
| | Rock Bass | 0 | 0 | 1,408 | 1,631 | 679 | 0 | 3,717 |
| | Smallmouth Bass | 0 | 0 | 0 | 70 | 0 | 0 | 70 |
| | Spottail Shiner | 0 | 62 | 876 | 0 | 0 | 0 | 938 |
| | Tessellated Darter | 0 | 7,493 | 7,644 | 441 | 0 | 0 | 15,579 |
| | Walleye | 0 | 286 | 0 | 0 | 0 | 0 | 286 |
| | White Perch | 0 | 0 | 22 | 0 | 0 | 0 | 22 |
| | White Sucker | 815 | 45,317 | 25,553 | 283 | 0 | 0 | 71,968 |
| | Yellow Perch | 0 | 12,424 | 780 | 0 | 0 | 0 | 13,204 |
| | Total | 2,029 | 70,331 | 92,433 | 25,408 | 1,654 | 0 | 191,855 |
| YOY | Black Crappie | 0 | 0 | 0 | 14 | 0 | 0 | 14 |
| | Largemouth Bass | 0 | 0 | 11 | 29 | 0 | 0 | 40 |
| | Margined Madtom | 0 | 0 | 306 | 62 | 0 | 0 | 368 |
| | Spottail Shiner | 0 | 0 | 611 | 0 | 0 | 0 | 611 |
| | White Sucker | 0 | 0 | 407 | 0 | 0 | 0 | 407 |
| | Yellow Bullhead | 0 | 0 | 0 | 158 | 0 | 0 | 158 |
| | Total | 0 | 0 | 1,335 | 263 | 0 | 0 | 1,598 |
| YROL | American Eel | 0 | 0 | 10 | 14 | 0 | 0 | 25 |
| | Bluegill | 0 | 0 | 21 | 0 | 0 | 0 | 21 |
| | Golden Shiner | 0 | 0 | 0 | 14 | 0 | 0 | 14 |
| | Total | 0 | 0 | 31 | 29 | 0 | 0 | 60 |

(Continued)

**Table 3-17 Continued.**

| Life Stage | Species | Apr | May | Jun | Jul | Aug | Sep | Season |
|---|---|---|---|---|---|---|---|---|
| Total | Alewife | 0 | 61 | 657 | 403 | 46 | 0 | 1,166 |
| | American Eel | 0 | 0 | 10 | 14 | 0 | 0 | 25 |
| | American Shad | 0 | 0 | 59 | 118 | 0 | 0 | 177 |
| | Black Crappie | 1,213 | 1,378 | 2,546 | 117 | 0 | 0 | 5,254 |
| | Blacknose Dace | 0 | 259 | 1,920 | 60 | 2 | 0 | 2,241 |
| | Bluegill | 0 | 0 | 18,698 | 17,045 | 540 | 0 | 36,284 |
| | Brown Bullhead | 0 | 0 | 0 | 1,132 | 0 | 0 | 1,132 |
| | Common Shiner | 0 | 7 | 75 | 0 | 0 | 0 | 82 |
| | Fallfish | 0 | 3,466 | 32,319 | 3,377 | 738 | 0 | 39,900 |
| | Golden Shiner | 0 | 7 | 75 | 14 | 0 | 0 | 96 |
| | Largemouth Bass | 0 | 0 | 225 | 223 | 0 | 0 | 449 |
| | Margined Madtom | 0 | 0 | 306 | 629 | 0 | 0 | 934 |
| | Rock Bass | 0 | 0 | 1,408 | 1,631 | 679 | 0 | 3,717 |
| | Smallmouth Bass | 0 | 0 | 0 | 70 | 0 | 0 | 70 |
| | Spottail Shiner | 0 | 77 | 1,502 | 0 | 0 | 0 | 1,579 |
| | Tessellated Darter | 0 | 7,493 | 7,644 | 441 | 0 | 0 | 15,579 |
| | Walleye | 0 | 286 | 0 | 0 | 0 | 0 | 286 |
| | White Perch | 0 | 0 | 22 | 0 | 0 | 0 | 22 |
| | White Sucker | 815 | 45,317 | 25,960 | 283 | 0 | 0 | 72,376 |
| | Yellow Bullhead | 0 | 0 | 0 | 158 | 0 | 0 | 158 |
| | Yellow Perch | 0 | 12,424 | 780 | 0 | 0 | 0 | 13,204 |
| | Total | 2,029 | 70,776 | 94,206 | 25,716 | 2,005 | 0 | 194,731 |

**Table 3–18. Monthly mean adjusted 24-hour impingement density (number per million m$^3$) of fish identified to lowest taxon possible in samples collected from June 2005 through June 2007 at Merrimack Station Units 1 and 2 combined.**

| Taxon | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 0.22 | | | | | | | | | | | 0.02 |
| Banded Sunfish | | | | 0.83 | 0.31 | | | | | | | | 0.10 |
| Black Crappie | | | | 0.71 | 2.36 | 0.13 | | | 0.99 | 2.51 | 1.99 | 0.92 | 0.80 |
| Bluegill | 0.21 | | 1.37 | | 7.19 | 62.29 | 2.52 | 0.43 | 0.72 | 1.04 | 1.65 | 2.59 | 6.67 |
| Brown Bullhead | | | | | | 0.51 | 0.32 | | | | | | 0.07 |
| Chain Pickerel | 0.58 | | | | | | | | | | | | 0.05 |
| Fallfish | 1.12 | | | | | | | | | | | | 0.09 |
| Golden Shiner | 0.27 | | 0.43 | 0.71 | 0.26 | 0.37 | 0.15 | | | | 0.08 | | 0.19 |
| Largemouth Bass | | 0.77 | | | | 0.37 | 0.27 | | | 2.36 | 1.71 | 0.49 | 0.50 |
| Margined Madtom | 0.58 | | 0.80 | 1.76 | 0.85 | 1.45 | 0.12 | | | 0.33 | | | 0.49 |
| Pumpkinseed | | | 0.28 | | 1.82 | 0.99 | | | | 2.41 | 0.71 | 0.72 | 0.58 |
| Rainbow Smelt | 0.82 | 1.00 | | | | | | | | | | 1.69 | 0.29 |
| Redbreast Sunfish | | | 0.28 | | 0.29 | 0.38 | | | 0.58 | | | | 0.13 |
| Rock Bass | | | | | | 0.43 | | | | | | 0.36 | 0.07 |
| Smallmouth Bass | | | 0.28 | | | 0.12 | 0.31 | 0.19 | | | 0.27 | 0.14 | 0.11 |
| Spottail Shiner | 2.03 | 1.00 | 0.23 | | 0.29 | 0.60 | 0.56 | | | 0.30 | 0.08 | 9.25 | 1.20 |
| Sunfish Family | | | | | | | 0.24 | | 0.23 | | | | 0.04 |
| Tessellated Darter | | | 1.43 | | | | 0.12 | | | | | | 0.13 |
| White Perch | 0.22 | | | | | | | | | | 0.08 | | 0.03 |
| White Sucker | | | | | | 0.17 | 0.39 | | | | | | 0.05 |
| Yellow Bullhead | | | 0.50 | | | | 0.15 | | | | | | 0.05 |
| Yellow Perch | 1.16 | | 2.01 | | 0.51 | 0.58 | | | | | | 4.46 | 0.73 |
| Total | 6.98 | 3.00 | 7.61 | 4.00 | 13.88 | 68.38 | 5.15 | 0.62 | 2.52 | 8.95 | 6.57 | 20.63 | 12.36 |

**Table 3–19. Percent composition of taxa impinged at Merrimack Station Units 1 and 2 combined from June 2005 through June 2007 based on monthly mean adjusted 24-hour impingement densities.**

| Taxon | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 7.3 | | | | | | | | | | | 0.1 |
| Banded Sunfish | | | | 20.8 | 2.3 | | | | | | | | 0.8 |
| Black Crappie | | | | 17.7 | 17.0 | 0.2 | | | 39.3 | 28.0 | 30.3 | 4.5 | 6.5 |
| Bluegill | 3.0 | | 18.0 | | 51.8 | 91.1 | 49.0 | 69.7 | 28.7 | 11.7 | 25.2 | 12.5 | 54.0 |
| Brown Bullhead | | | | | | 0.7 | 6.3 | | | | | | 0.6 |
| Chain Pickerel | 8.3 | | | | | | | | | | | | 0.4 |
| Fallfish | 16.0 | | | | | | | | | | | | 0.8 |
| Golden Shiner | 3.9 | | 5.7 | 17.7 | 1.9 | 0.5 | 2.9 | | | | 1.3 | | 1.5 |
| Largemouth Bass | | 25.8 | | | | 0.5 | 5.2 | | | 26.4 | 26.0 | 2.4 | 4.0 |
| Margined Madtom | 8.3 | | 10.5 | 43.8 | 6.1 | 2.1 | 2.3 | | | 3.7 | | | 4.0 |
| Pumpkinseed | | | 3.7 | | 13.1 | 1.4 | | | | 26.9 | 10.7 | 3.5 | 4.7 |
| Rainbow Smelt | 11.7 | 33.4 | | | | | | | | | | 8.2 | 2.4 |
| Redbreast Sunfish | | | 3.7 | | 2.1 | 0.6 | | | 22.8 | | | | 1.0 |
| Rock Bass | | | | | | 0.6 | | | | | | 1.8 | 0.5 |
| Smallmouth Bass | | | 3.6 | | | 0.2 | 6.1 | 30.3 | | | 4.0 | 0.7 | 0.9 |
| Spottail Shiner | 29.0 | 33.4 | 3.1 | | 2.1 | 0.9 | 10.8 | | | 3.4 | 1.3 | 44.9 | 9.7 |
| Sunfish Family | | | | | | | 4.6 | | 9.2 | | | | 0.3 |
| Tessellated Darter | | | 18.8 | | | | 2.3 | | | | | | 1.0 |
| White Perch | 3.1 | | | | | | | | | | 1.3 | | 0.2 |
| White Sucker | | | | | | 0.2 | 7.5 | | | | | | 0.4 |
| Yellow Bullhead | | | 6.6 | | | | 3.0 | | | | | | 0.4 |
| Yellow Perch | 16.6 | | 26.4 | | 3.7 | 0.8 | | | | | | 21.6 | 5.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

**Table 3–20. Monthly mean adjusted 24-hour impingement density (number per million $m^3$) of Sunfish family identified to species for apportioning impingement of unidentified Sunfish family.**

| | July | | September | |
|---|---|---|---|---|
| **Species** | **D** | **%** | **D** | **%** |
| Banded Sunfish | 0 | 0.0% | 0 | 0.0% |
| Black Crappie | 0 | 0.0% | 0.992 | 43.3% |
| Bluegill | 2.523 | 81.3% | 0.724 | 31.6% |
| Largemouth Bass | 0.267 | 8.6% | 0 | 0.0% |
| Pumpkinseed | 0 | 0.0% | 0 | 0.0% |
| Redbreast Sunfish | 0 | 0.0% | 0.575 | 25.1% |
| Rock Bass | 0 | 0.0% | 0 | 0.0% |
| Smallmouth Bass | 0.314 | 10.1% | 0 | 0.0% |
| Identified Sunfish Species Total | 3.104 | 100.0% | 2.291 | 100.0% |

**Table 3–21. Monthly mean adjusted 24-hour impingement density (number per million m$^3$) apportioned to species based on samples collected from June 2005 through June 2007 at Merrimack Station Units 1 and 2 combined.**

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 0.22 | | | | | | | | | | | 0.02 |
| Banded Sunfish | | | | 0.83 | 0.31 | | | | | | | | 0.10 |
| Black Crappie | | | | 0.71 | 2.36 | 0.13 | | | 1.09 | 2.51 | 1.99 | 0.92 | 0.81 |
| Bluegill | 0.21 | | 1.37 | | 7.19 | 62.29 | 2.72 | 0.43 | 0.80 | 1.04 | 1.65 | 2.59 | 6.69 |
| Brown Bullhead | | | | | | 0.51 | 0.32 | | | | | | 0.07 |
| Chain Pickerel | 0.58 | | | | | | | | | | | | 0.05 |
| Fallfish | 1.12 | | | | | | | | | | | | 0.09 |
| Golden Shiner | 0.27 | | 0.43 | 0.71 | 0.26 | 0.37 | 0.15 | | | | 0.08 | | 0.19 |
| Largemouth Bass | | 0.77 | | | | 0.37 | 0.29 | | | 2.36 | 1.71 | 0.49 | 0.50 |
| Margined Madtom | 0.58 | | 0.80 | 1.76 | 0.85 | 1.45 | 0.12 | | | 0.33 | | | 0.49 |
| Pumpkinseed | | | 0.28 | | 1.82 | 0.99 | | | | 2.41 | 0.71 | 0.72 | 0.58 |
| Rainbow Smelt | 0.82 | 1.00 | | | | | | | | | | 1.69 | 0.29 |
| Redbreast Sunfish | | | 0.28 | | 0.29 | 0.38 | | | 0.63 | | | | 0.13 |
| Rock Bass | | | | | | 0.43 | | | | | | 0.36 | 0.07 |
| Smallmouth Bass | | | 0.28 | | | 0.12 | 0.34 | 0.19 | | | 0.27 | 0.14 | 0.11 |
| Spottail Shiner | 2.03 | 1.00 | 0.23 | | 0.29 | 0.60 | 0.56 | | | 0.30 | 0.08 | 9.25 | 1.20 |
| Tessellated Darter | | | 1.43 | | | | 0.12 | | | | | | 0.13 |
| White Perch | 0.22 | | | | | | | | | | 0.08 | | 0.03 |
| White Sucker | | | | | | 0.17 | 0.39 | | | | | | 0.05 |
| Yellow Bullhead | | | 0.50 | | | | 0.15 | | | | | | 0.05 |
| Yellow Perch | 1.16 | | 2.01 | | 0.51 | 0.58 | | | | | | 4.46 | 0.73 |
| Total | 6.98 | 3.00 | 7.61 | 4.00 | 13.88 | 68.38 | 5.15 | 0.62 | 2.52 | 8.95 | 6.57 | 20.63 | 12.36 |

**Table 3–22. Monthly age distribution (%) of species impingement estimates at Merrimack Station Units 1 and 2 combined from June 2005 through June 2007.**

| Species | Month | Age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| American Eel | Feb | | | | | | | | | 100.0 |
| Banded Sunfish | Apr | 75.0 | 12.5 | 12.5 | | | | | | |
| | May | 100.0 | | | | | | | | |
| Black Crappie | Apr | 82.4 | 11.8 | | 5.9 | | | | | |
| | May | 95.1 | 4.9 | | | | | | | |
| | Jun | 73.3 | 26.7 | | | | | | | |
| | Sep | 51.5 | 36.3 | | | | 12.1 | | | |
| | Oct | 90.0 | 10.0 | | | | | | | |
| | Nov | 74.1 | 25.9 | | | | | | | |
| | Dec | 66.7 | 33.3 | | | | | | | |
| Bluegill | Jan | 52.9 | 23.5 | 11.8 | | 5.9 | 5.9 | | | |
| | Mar | 80.0 | 5.0 | 10.0 | 5.0 | | | | | |
| | May | 96.8 | 2.6 | | | | 0.6 | | | |
| | Jun | 96.3 | 2.2 | 0.4 | | | 1.1 | | | |
| | Jul | 93.8 | 4.1 | 2.1 | | | | | | |
| | Aug | | 28.6 | 14.3 | 14.3 | 14.3 | 28.6 | | | |
| | Sep | 60.6 | 27.2 | | | 9.1 | 3.1 | | | |
| | Oct | 80.5 | 18.0 | 0.8 | | | 0.8 | | | |
| | Nov | 32.9 | 48.2 | 12.9 | 2.4 | | 3.5 | | | |
| | Dec | 30.9 | 49.1 | 16.4 | 1.8 | 1.8 | | | | |
| Brown Bullhead | Jun | 33.3 | | 33.3 | 33.3 | | | | | |
| | Jul | 50.0 | 25.0 | 25.0 | | | | | | |
| Chain Pickerel | Jan | | 100.0 | | | | | | | |
| Fallfish | Jan | | | 66.7 | 33.3 | | | | | |
| Golden Shiner | Jan | | | 40.0 | 60.0 | | | | | |
| | Mar | | | 25.0 | 75.0 | | | | | |
| | Apr | | | | 100.0 | | | | | |
| | May | | | 50.0 | 50.0 | | | | | |
| | Jun | | 15.4 | 46.2 | 38.5 | | | | | |
| | Jul | | | 100.0 | | | | | | |
| | Nov | | | | 100.0 | | | | | |

(Continued)

**Table 3–22 Continued.**

| Species | Month | Age 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| Largemouth Bass | Feb | 100.0 | | | | | | | | |
| | Jun | 100.0 | | | | | | | | |
| | Jul | 100.0 | | | | | | | | |
| | Oct | 100.0 | | | | | | | | |
| | Nov | 100.0 | | | | | | | | |
| | Dec | 100.0 | | | | | | | | |
| Margined Madtom | Jan | | 100.0 | | | | | | | |
| | Mar | | 33.3 | 12.5 | 25.0 | 29.2 | | | | |
| | Apr | | 20.5 | 13.6 | 29.5 | 36.4 | | | | |
| | May | | 47.6 | 23.8 | 9.5 | 19.0 | | | | |
| | Jun | | 39.1 | 21.7 | 13.0 | 26.1 | | | | |
| | Jul | | 25.0 | 50.0 | 25.0 | | | | | |
| | Oct | | 100.0 | | | | | | | |
| Pumpkinseed | Mar | 100.0 | | | | | | | | |
| | May | 60.0 | 10.0 | 25.0 | | 5.0 | | | | |
| | Jun | 100.0 | | | | | | | | |
| | Oct | 59.6 | 12.8 | 25.5 | 2.1 | | | | | |
| | Nov | 20.0 | 10.0 | 45.0 | 22.5 | 2.5 | | | | |
| | Dec | 10.5 | 15.8 | 52.6 | 10.5 | 5.3 | 5.3 | | | |
| Rainbow Smelt | Jan | 100.0 | | | | | | | | |
| | Feb | 100.0 | | | | | | | | |
| | Dec | 100.0 | | | | | | | | |
| Redbreast Sunfish | Mar | | | | | | 50.0 | | | 50.0 |
| | May | | | | 50.0 | | | | | 50.0 |
| | Jun | 16.7 | | 16.7 | 16.7 | 16.7 | 16.7 | | | 16.7 |
| | Sep | 6.1 | | | 30.3 | 30.3 | 3.1 | | | 30.3 |
| Rock Bass | Jun | 100.0 | | | | | | | | |
| | Dec | | 40.0 | 60.0 | | | | | | |

(Continued)

**Table 3–22 Continued.**

| Species | Month | Age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Smallmouth Bass | Mar | 66.7 | 16.7 | | | | 16.7 | | | |
| | Jun | 50.0 | 25.0 | | | | 25.0 | | | |
| | Jul | 44.2 | 37.2 | | | | 18.6 | | | |
| | Aug | | 25.0 | 25.0 | 25.0 | | 25.0 | | | |
| | Nov | 50.0 | | | | | 50.0 | | | |
| | Dec | 87.5 | | | | | 12.5 | | | |
| Spottail Shiner | Jan | 24.1 | 3.4 | 51.7 | 20.7 | | | | | |
| | Feb | 33.3 | 8.3 | 41.7 | 16.7 | | | | | |
| | Mar | 100.0 | | | | | | | | |
| | May | 25.0 | 75.0 | | | | | | | |
| | Jun | 75.0 | 25.0 | | | | | | | |
| | Jul | 80.0 | 20.0 | | | | | | | |
| | Oct | 100.0 | | | | | | | | |
| | Nov | 100.0 | | | | | | | | |
| | Dec | 22.0 | 4.0 | 44.0 | 20.0 | 10.0 | | | | |
| Tessellated Darter | Mar | | | | 100.0 | | | | | |
| | Jul | | | 100.0 | | | | | | |
| White Perch | Jan | | | | 100.0 | | | | | |
| | Nov | | 100.0 | | | | | | | |
| White Sucker | Jun | | | | | | | 33.3 | 66.7 | |
| | Jul | | | | | | | | 100.0 | |
| Yellow Bullhead | Mar | 20.0 | 40.0 | 20.0 | 20.0 | | | | | |
| | Jul | | 100.0 | | | | | | | |
| Yellow Perch | Jan | 27.1 | 62.7 | 3.4 | 1.7 | 3.4 | 1.7 | | | |
| | Mar | 33.3 | 61.9 | 4.8 | | | | | | |
| | May | | 42.9 | 42.9 | 14.3 | | | | | |
| | Jun | 50.0 | | 16.7 | | 16.7 | 16.7 | | | |
| | Dec | 6.7 | 76.7 | 10.0 | 6.7 | | | | | |

**Table 3–23. Monthly mean adjusted 24-hour impingement density (number per million m$^3$) apportioned to species and length-based age class for samples collected from June 2005 through June 2007 at Merrimack Station Units 1 and 2 combined.**

| Species | Month | Age | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| American Eel | Feb | | | | | | | | | 0.22 | 0.22 |
| Banded Sunfish | Apr | 0.62 | 0.10 | 0.10 | | | | | | | 0.83 |
| | May | 0.31 | | | | | | | | | 0.31 |
| Black Crappie | Apr | 0.58 | 0.08 | | 0.04 | | | | | | 0.71 |
| | May | 2.24 | 0.11 | | | | | | | | 2.36 |
| | Jun | 0.10 | 0.04 | | | | | | | | 0.13 |
| | Sep | 0.56 | 0.40 | | | | 0.13 | | | | 1.09 |
| | Oct | 2.26 | 0.25 | | | | | | | | 2.51 |
| | Nov | 1.47 | 0.52 | | | | | | | | 1.99 |
| | Dec | 0.62 | 0.31 | | | | | | | | 0.92 |
| Bluegill | Jan | 0.11 | 0.05 | 0.02 | | 0.01 | 0.01 | | | | 0.21 |
| | Mar | 1.09 | 0.07 | 0.14 | 0.07 | | | | | | 1.37 |
| | May | 6.96 | 0.18 | | | | 0.05 | | | | 7.19 |
| | Jun | 60.00 | 1.37 | 0.23 | | | 0.69 | | | | 62.29 |
| | Jul | 2.55 | 0.11 | 0.06 | | | | | | | 2.72 |
| | Aug | | 0.12 | 0.06 | 0.06 | 0.06 | 0.12 | | | | 0.43 |
| | Sep | 0.48 | 0.22 | | | 0.07 | 0.02 | | | | 0.80 |
| | Oct | 0.84 | 0.19 | 0.01 | | | 0.01 | | | | 1.04 |
| | Nov | 0.54 | 0.80 | 0.21 | 0.04 | | 0.06 | | | | 1.65 |
| | Dec | 0.80 | 1.27 | 0.42 | 0.05 | 0.05 | | | | | 2.59 |
| Brown Bullhead | Jun | 0.17 | | 0.17 | 0.17 | | | | | | 0.51 |
| | Jul | 0.16 | 0.08 | 0.08 | | | | | | | 0.32 |
| Chain Pickerel | Jan | | 0.58 | | | | | | | | 0.58 |
| Fallfish | Jan | | | 0.74 | 0.37 | | | | | | 1.12 |

(Continued)

**Table 3-23 Continued.**

| Species | Month | Age | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| Golden Shiner | Jan | | | 0.11 | 0.16 | | | | | | 0.27 |
| | Mar | | | 0.11 | 0.32 | | | | | | 0.43 |
| | Apr | | | | 0.71 | | | | | | 0.71 |
| | May | | | 0.13 | 0.13 | | | | | | 0.26 |
| | Jun | | 0.06 | 0.17 | 0.14 | | | | | | 0.37 |
| | Jul | | | 0.15 | | | | | | | 0.15 |
| | Nov | | | | 0.08 | | | | | | 0.08 |
| Largemouth Bass | Feb | 0.77 | | | | | | | | | 0.77 |
| | Jun | 0.37 | | | | | | | | | 0.37 |
| | Jul | 0.29 | | | | | | | | | 0.29 |
| | Oct | 2.36 | | | | | | | | | 2.36 |
| | Nov | 1.71 | | | | | | | | | 1.71 |
| | Dec | 0.49 | | | | | | | | | 0.49 |
| Margined Madtom | Jan | | 0.58 | | | | | | | | 0.58 |
| | Mar | | 0.27 | 0.10 | 0.20 | 0.23 | | | | | 0.80 |
| | Apr | | 0.36 | 0.24 | 0.52 | 0.64 | | | | | 1.76 |
| | May | | 0.40 | 0.20 | 0.08 | 0.16 | | | | | 0.85 |
| | Jun | | 0.57 | 0.31 | 0.19 | 0.38 | | | | | 1.45 |
| | Jul | | 0.03 | 0.06 | 0.03 | | | | | | 0.12 |
| | Oct | | 0.33 | | | | | | | | 0.33 |
| Pumpkinseed | Mar | 0.28 | | | | | | | | | 0.28 |
| | May | 1.09 | 0.18 | 0.46 | | 0.09 | | | | | 1.82 |
| | Jun | 0.99 | | | | | | | | | 0.99 |
| | Oct | 1.43 | 0.31 | 0.61 | 0.05 | | | | | | 2.41 |
| | Nov | 0.14 | 0.07 | 0.32 | 0.16 | 0.02 | | | | | 0.71 |
| | Dec | 0.08 | 0.11 | 0.38 | 0.08 | 0.04 | 0.04 | | | | 0.72 |
| Rainbow Smelt | Jan | 0.82 | | | | | | | | | 0.82 |
| | Feb | 1.00 | | | | | | | | | 1.00 |
| | Dec | 1.69 | | | | | | | | | 1.69 |

(Continued)

**Table 3-23 Continued.**

| Species | Month | Age | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| Redbreast Sunfish | Mar | | | | | | 0.14 | | | 0.14 | 0.28 |
| | May | | | | 0.14 | | | | | 0.14 | 0.29 |
| | Jun | 0.06 | | 0.06 | 0.06 | 0.06 | 0.06 | | | 0.06 | 0.38 |
| | Sep | 0.04 | | | 0.19 | 0.19 | 0.02 | | | 0.19 | 0.63 |
| Rock Bass | Jun | 0.43 | | | | | | | | | 0.43 |
| | Dec | | 0.14 | 0.22 | | | | | | | 0.36 |
| Smallmouth Bass | Mar | 0.18 | 0.05 | | | | 0.05 | | | | 0.28 |
| | Jun | 0.06 | 0.03 | | | | 0.03 | | | | 0.12 |
| | Jul | 0.15 | 0.13 | | | | 0.06 | | | | 0.34 |
| | Aug | | 0.05 | 0.05 | 0.05 | | 0.05 | | | | 0.19 |
| | Nov | 0.13 | | | | | 0.13 | | | | 0.27 |
| | Dec | 0.12 | | | | | 0.02 | | | | 0.14 |
| Spottail Shiner | Jan | 0.49 | 0.07 | 1.05 | 0.42 | | | | | | 2.03 |
| | Feb | 0.33 | 0.08 | 0.42 | 0.17 | | | | | | 1.00 |
| | Mar | 0.23 | | | | | | | | | 0.23 |
| | May | 0.07 | 0.21 | | | | | | | | 0.29 |
| | Jun | 0.45 | 0.15 | | | | | | | | 0.60 |
| | Jul | 0.45 | 0.11 | | | | | | | | 0.56 |
| | Oct | 0.30 | | | | | | | | | 0.30 |
| | Nov | 0.08 | | | | | | | | | 0.08 |
| | Dec | 2.04 | 0.37 | 4.07 | 1.85 | 0.93 | | | | | 9.25 |
| Tessellated Darter | Mar | | | | 1.43 | | | | | | 1.43 |
| | Jul | | | 0.12 | | | | | | | 0.12 |
| White Perch | Jan | | | | 0.22 | | | | | | 0.22 |
| | Nov | | 0.08 | | | | | | | | 0.08 |
| White Sucker | Jun | | | | | | | 0.06 | 0.11 | | 0.17 |
| | Jul | | | | | | | | 0.39 | | 0.39 |
| Yellow Bullhead | Mar | 0.10 | 0.20 | 0.10 | 0.10 | | | | | | 0.50 |
| | Jul | | 0.15 | | | | | | | | 0.15 |
| Yellow Perch | Jan | 0.31 | 0.73 | 0.04 | 0.02 | 0.04 | 0.02 | | | | 1.16 |
| | Mar | 0.67 | 1.24 | 0.10 | | | | | | | 2.01 |
| | May | | 0.22 | 0.22 | 0.07 | | | | | | 0.51 |
| | Jun | 0.29 | | 0.10 | | 0.10 | 0.10 | | | | 0.58 |
| | Dec | 0.30 | 3.42 | 0.45 | 0.30 | | | | | | 4.46 |

**Table 3–24. Estimated annual impingement abundance (number of individuals) at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS) , 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| American Eel | 5 | 5 | <1 | 7 | 7 | <1 | 3 | 3 | <1 |
| Banded Sunfish | 12 | | 1 | 38 | | 2 | 19 | | 1 |
| Black Crappie | 104 | 72 | 5 | 323 | 216 | 16 | 162 | 108 | 8 |
| Bluegill | 1,161 | 132 | 58 | 2,637 | 270 | 132 | 1,318 | 135 | 66 |
| Brown Bullhead | 14 | | 1 | 28 | | 1 | 14 | | 1 |
| Chain Pickerel | 14 | 14 | 1 | 20 | 20 | 1 | 10 | 10 | <1 |
| Fallfish | 26 | 26 | 1 | 38 | 38 | 2 | 19 | 19 | 1 |
| Golden Shiner | 35 | 17 | 2 | 75 | 26 | 4 | 38 | 13 | 2 |
| Largemouth Bass | 77 | 66 | 4 | 197 | 176 | 10 | 99 | 88 | 5 |
| Margined Madtom | 83 | 34 | 4 | 195 | 58 | 10 | 97 | 29 | 5 |
| Pumpkinseed | 79 | 47 | 4 | 232 | 138 | 12 | 116 | 69 | 6 |
| Rainbow Smelt | 77 | 77 | 4 | 115 | 115 | 6 | 58 | 58 | 3 |
| Redbreast Sunfish | 20 | 12 | 1 | 52 | 30 | 3 | 26 | 15 | 1 |
| Rock Bass | 14 | 8 | 1 | 26 | 12 | 1 | 13 | 6 | 1 |
| Smallmouth Bass | 24 | 15 | 1 | 44 | 29 | 2 | 22 | 14 | 1 |
| Spottail Shiner | 296 | 273 | 15 | 480 | 432 | 24 | 240 | 216 | 12 |
| Tessellated Darter | 35 | 32 | 2 | 52 | 48 | 3 | 26 | 24 | 1 |
| White Perch | 6 | 6 | <1 | 10 | 10 | 1 | 5 | 5 | <1 |
| White Sucker | 10 | | 1 | 19 | | 1 | 9 | | <1 |
| Yellow Bullhead | 14 | 11 | 1 | 22 | 17 | 1 | 11 | 8 | 1 |
| Yellow Perch | 180 | 166 | 9 | 293 | 257 | 15 | 147 | 129 | 7 |
| Total | 2,285 | 1,012 | 114 | 4,902 | 1,898 | 245 | 2,451 | 949 | 123 |

**Table 3–25. Estimated equivalent loss of recruitment (number of fish) to the recreational fishery due to annual entrainment at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|
| | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers |
| American Eel | 383 | 0 | 19 | 711 | 0 | 36 | 356 | 0 | 18 |
| American Shad | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Black Crappie | 101 | 21 | 5 | 256 | 68 | 13 | 128 | 34 | 6 |
| Bluegill | 449 | 23 | 22 | 917 | 44 | 46 | 458 | 22 | 23 |
| Brown Bullhead | 15 | 15 | 1 | 24 | 24 | 1 | 12 | 12 | 1 |
| Largemouth Bass | 13 | 3 | 1 | 23 | 5 | 1 | 12 | 3 | 1 |
| Rock Bass | 29 | 4 | 1 | 56 | 10 | 3 | 28 | 5 | 1 |
| Smallmouth Bass | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Walleye | 1 | <1 | <1 | 2 | <1 | <1 | 1 | <1 | <1 |
| White Perch | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| Yellow Bullhead | 44 | 22 | 2 | 73 | 36 | 4 | 37 | 18 | 2 |
| Yellow Perch | 236 | 29 | 12 | 794 | 99 | 40 | 397 | 49 | 20 |

**Table 3–26. Estimated age-1 equivalent loss (number of fish) of recreational fishery species due to annual entrainment at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers |
| American Eel | 530 | 0 | 26 | 984 | 0 | 49 | 492 | 0 | 25 |
| American Shad | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Black Crappie | 232 | 49 | 12 | 587 | 156 | 29 | 293 | 78 | 15 |
| Bluegill | 1,383 | 81 | 69 | 2,781 | 157 | 139 | 1,391 | 79 | 70 |
| Brown Bullhead | 33 | 33 | 2 | 55 | 55 | 3 | 28 | 27 | 1 |
| Largemouth Bass | 30 | 7 | 1 | 54 | 13 | 3 | 27 | 6 | 1 |
| Rock Bass | 102 | 15 | 5 | 200 | 37 | 10 | 100 | 18 | 5 |
| Smallmouth Bass | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| Walleye | 2 | <1 | <1 | 5 | <1 | <1 | 3 | <1 | <1 |
| White Perch | 1 | <1 | <1 | 2 | 1 | <1 | 1 | <1 | <1 |
| Yellow Bullhead | 100 | 49 | 5 | 166 | 81 | 8 | 83 | 41 | 4 |
| Yellow Perch | 711 | 88 | 36 | 2,392 | 298 | 120 | 1,196 | 149 | 60 |

**Table 3–27. Estimated equivalent loss of recruitment (number of fish) to the recreational fishery due to annual impingement at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|
| | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers |
| American Eel | 4 | 4 | <1 | 6 | 6 | <1 | 3 | 3 | <1 |
| Banded Sunfish | 2 | 0 | <1 | 5 | 0 | <1 | 3 | 0 | <1 |
| Black Crappie | 17 | 14 | 1 | 50 | 40 | 3 | 25 | 20 | 1 |
| Bluegill | 76 | 46 | 4 | 158 | 91 | 8 | 79 | 45 | 4 |
| Brown Bullhead | 8 | 0 | <1 | 16 | 0 | 1 | 8 | 0 | <1 |
| Chain Pickerel | 8 | 8 | <1 | 11 | 11 | 1 | 6 | 6 | <1 |
| Largemouth Bass | 1 | 1 | <1 | 2 | 2 | <1 | 1 | 1 | <1 |
| Pumpkinseed | 31 | 25 | 2 | 86 | 64 | 4 | 43 | 32 | 2 |
| Rainbow Smelt | 3 | 3 | <1 | 4 | 4 | <1 | 2 | 2 | <1 |
| Redbreast Sunfish | 19 | 12 | 1 | 49 | 29 | 2 | 24 | 14 | 1 |
| Rock Bass | 6 | 6 | <1 | 10 | 9 | <1 | 5 | 5 | <1 |
| Smallmouth Bass | 7 | 4 | <1 | 13 | 9 | 1 | 7 | 5 | <1 |
| White Perch | 6 | 6 | <1 | 9 | 9 | <1 | 5 | 5 | <1 |
| Yellow Bullhead | 9 | 7 | <1 | 14 | 11 | 1 | 7 | 5 | <1 |
| Yellow Perch | 92 | 84 | 5 | 154 | 130 | 8 | 77 | 65 | 4 |

**Table 3–28. Estimated age-1 equivalent loss (number of fish) of recreational fishery species due to annual impingement at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|
| | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers | Existing CWIS | 3-mm WWS | Closed-cycle Cooling Towers |
| American Eel | 5 | 5 | <1 | 7 | 7 | <1 | 3 | 3 | <1 |
| Banded Sunfish | 2 | 0 | <1 | 7 | 0 | <1 | 4 | 0 | <1 |
| Black Crappie | 30 | 24 | 1 | 86 | 68 | 4 | 43 | 34 | 2 |
| Bluegill | 125 | 71 | 6 | 265 | 143 | 13 | 133 | 71 | 7 |
| Brown Bullhead | 8 | 0 | <1 | 17 | 0 | 1 | 8 | 0 | <1 |
| Chain Pickerel | 14 | 14 | 1 | 20 | 20 | 1 | 10 | 10 | <1 |
| Largemouth Bass | 2 | 1 | <1 | 4 | 4 | <1 | 2 | 2 | <1 |
| Pumpkinseed | 35 | 28 | 2 | 100 | 74 | 5 | 50 | 37 | 2 |
| Rainbow Smelt | 13 | 13 | 1 | 19 | 19 | 1 | 9 | 9 | <1 |
| Redbreast Sunfish | 19 | 12 | 1 | 49 | 29 | 2 | 24 | 14 | 1 |
| Rock Bass | 8 | 8 | <1 | 12 | 12 | 1 | 6 | 6 | <1 |
| Smallmouth Bass | 11 | 7 | 1 | 23 | 14 | 1 | 11 | 7 | 1 |
| White Perch | 6 | 6 | <1 | 10 | 10 | 1 | 5 | 5 | <1 |
| Yellow Bullhead | 12 | 9 | 1 | 19 | 14 | 1 | 9 | 7 | <1 |
| Yellow Perch | 163 | 151 | 8 | 266 | 235 | 13 | 133 | 117 | 7 |

**Table 3–29. Total production foregone (kg) of forage species entrained annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| | | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life Stage | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| Alewife | Larvae | 1.5 | 0.4 | 0.1 | 3.1 | 0.8 | 0.2 | 1.5 | 0.4 | 0.1 |
| Blacknose Dace | Eggs | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | Larvae | 0.8 | 0.2 | <0.1 | 1.9 | 0.4 | 0.1 | 1.0 | 0.2 | <0.1 |
| Common Shiner | Eggs | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | Larvae | <0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Fallfish | Eggs | 2.2 | 2.1 | 0.1 | 5.8 | 5.6 | 0.3 | 2.9 | 2.8 | 0.1 |
| | Larvae | 641.9 | 150.3 | 32.1 | 1,438.9 | 349.7 | 71.9 | 719.5 | 174.9 | 36.0 |
| Golden Shiner | Eggs | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | Larvae | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | YROL | 0.6 | 0 | <0.1 | 1.0 | 0 | <0.1 | 0.5 | 0 | <0.1 |
| Margined Madtom | Larvae | 2.9 | 2.8 | 0.1 | 4.7 | 4.7 | 0.2 | 2.4 | 2.4 | 0.1 |
| | YOY | 1.6 | 0.8 | 0.1 | 3.5 | 1.7 | 0.2 | 1.7 | 0.8 | 0.1 |
| Spottail Shiner | Eggs | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | Larvae | 0.4 | 0.1 | <0.1 | 0.8 | 0.2 | <0.1 | 0.4 | 0.1 | <0.1 |
| | YOY | 1.8 | 0 | 0.1 | 4.0 | 0 | 0.2 | 2.0 | 0 | 0.1 |
| Tessellated Darter | Larvae | 6.6 | 1.0 | 0.3 | 17.8 | 2.5 | 0.9 | 8.9 | 1.2 | 0.4 |
| White Sucker | Larvae | 15.5 | 0.2 | 0.8 | 44.8 | 0.6 | 2.2 | 22.4 | 0.3 | 1.1 |
| | YOY | 50.4 | 50.4 | 2.5 | 113.3 | 113.3 | 5.7 | 56.7 | 56.7 | 2.8 |
| Total | | 726.2 | 208.3 | 36.3 | 1,639.7 | 479.6 | 82.0 | 819.9 | 239.8 | 41.0 |

**Table 3–30. Number of equivalent Age-2 Largemouth Bass supported by total production foregone of forage species entrained annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | Life Stage | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| Alewife | Larvae | 1 | <1 | <1 | 2 | 1 | <1 | 1 | <1 | <1 |
| Blacknose Dace | Eggs | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | Larvae | 1 | <1 | <1 | 1 | <1 | <1 | 1 | <1 | <1 |
| Common Shiner | Eggs | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | Larvae | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Fallfish | Eggs | 2 | 2 | <1 | 4 | 4 | <1 | 2 | 2 | <1 |
| | Larvae | 458 | 107 | 23 | 1,028 | 250 | 51 | 514 | 125 | 26 |
| Golden Shiner | Eggs | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | Larvae | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | YROL | <1 | 0 | <1 | 1 | 0 | <1 | <1 | 0 | <1 |
| Margined Madtom | Larvae | 2 | 2 | <1 | 3 | 3 | <1 | 2 | 2 | <1 |
| | YOY | 1 | 1 | <1 | 2 | 1 | <1 | 1 | 1 | <1 |
| Spottail Shiner | Eggs | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | Larvae | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| | YOY | 1 | 0 | <1 | 3 | 0 | <1 | 1 | 0 | <1 |
| Tessellated Darter | Larvae | 5 | 1 | <1 | 13 | 2 | 1 | 6 | 1 | <1 |
| White Sucker | Larvae | 11 | <1 | 1 | 32 | <1 | 2 | 16 | <1 | 1 |
| | YOY | 36 | 36 | 2 | 81 | 81 | 4 | 40 | 40 | 2 |
| | Total | 519 | 149 | 26 | 1,171 | 343 | 59 | 586 | 171 | 29 |

**Table 3–31. Total production foregone (kg) of forage species impinged annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | Age | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| Fallfish | 2 | 2.4 | 2.4 | 0.1 | 3.5 | 3.5 | 0.2 | 1.8 | 1.8 | 0.1 |
| | 3 | 2.1 | 2.1 | 0.1 | 3.0 | 3.0 | 0.1 | 1.5 | 1.5 | 0.1 |
| Golden Shiner | 1 | <0.1 | | <0.1 | <0.1 | | <0.1 | <0.1 | | <0.1 |
| | 2 | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 |
| | 3 | 0.2 | 0.1 | <0.1 | 0.5 | 0.2 | <0.1 | 0.2 | 0.1 | <0.1 |
| Margined Madtom | 1 | 0.4 | 0.2 | <0.1 | 0.8 | 0.4 | <0.1 | 0.4 | 0.2 | <0.1 |
| | 2 | 0.2 | <0.1 | <0.1 | 0.5 | 0.1 | <0.1 | 0.3 | <0.1 | <0.1 |
| | 3 | 0.3 | 0.1 | <0.1 | 0.8 | 0.2 | <0.1 | 0.4 | 0.1 | <0.1 |
| | 4 | 0.5 | 0.1 | <0.1 | 1.2 | 0.2 | 0.1 | 0.6 | 0.1 | <0.1 |
| Spottail Shiner | 0 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | 1 | <0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | 2 | 0.6 | 0.6 | <0.1 | 0.9 | 0.9 | <0.1 | 0.4 | 0.4 | <0.1 |
| | 3 | 0.4 | 0.4 | <0.1 | 0.6 | 0.6 | <0.1 | 0.3 | 0.3 | <0.1 |
| | 4 | 0.2 | 0.2 | <0.1 | 0.2 | 0.2 | <0.1 | 0.1 | 0.1 | <0.1 |
| Tessellated Darter | 2 | <0.1 | | <0.1 | <0.1 | | <0.1 | <0.1 | | <0.1 |
| | 3 | 0.1 | 0.1 | <0.1 | 0.2 | 0.2 | <0.1 | 0.1 | 0.1 | <0.1 |
| White Sucker | 6 | 0.4 | | <0.1 | 0.8 | | <0.1 | 0.4 | | <0.1 |
| | 7 | 4.9 | | 0.2 | 8.6 | | 0.4 | 4.3 | | 0.2 |
| Total | | 12.7 | 6.4 | 0.6 | 21.8 | 9.4 | 1.1 | 10.9 | 4.7 | 0.5 |

**Table 3–32. Number of equivalent Age-2 Largemouth Bass supported by total production foregone of forage species impinged annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | Age | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| Fallfish | 2 | 2 | 2 | <1 | 3 | 3 | <1 | 1 | 1 | <1 |
| | 3 | 1 | 1 | <1 | 2 | 2 | <1 | 1 | 1 | <1 |
| Golden Shiner | 1 | <1 | | <1 | <1 | | <1 | <1 | | <1 |
| | 2 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 3 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Margined Madtom | 1 | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| | 2 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 3 | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| | 4 | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| Spottail Shiner | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 2 | <1 | <1 | <1 | 1 | 1 | <1 | <1 | <1 | <1 |
| | 3 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 4 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Tessellated Darter | 2 | <1 | | <1 | <1 | | <1 | <1 | | <1 |
| | 3 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| White Sucker | 6 | <1 | | <1 | 1 | | <1 | <1 | | <1 |
| | 7 | 3 | | <1 | 6 | | <1 | 3 | | <1 |
| Total | | 9 | 5 | <1 | 16 | 7 | 1 | 8 | 3 | <1 |

**Table 3–33. Biomass (kg) lost as forage from natural mortality (predation) of early life stages of recreationally important fishery species entrained annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | Life Stage | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| American Eel | YROL | 2.8 | 0 | 0.1 | 5.3 | 0 | 0.3 | 2.6 | 0 | 0.1 |
| American Shad | Larvae | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 |
| Black Crappie | Larvae | 7.7 | 1.9 | 0.4 | 20.4 | 5.9 | 1.0 | 10.2 | 3.0 | 0.5 |
| | YOY | 1.1 | 0 | 0.1 | 1.8 | 0 | 0.1 | 0.9 | 0 | <0.1 |
| Bluegill | Larvae | 24.1 | 1.9 | 1.2 | 46.5 | 3.7 | 2.3 | 23.2 | 1.9 | 1.2 |
| | YROL | 2.1 | 0 | 0.1 | 4.7 | 0 | 0.2 | 2.4 | 0 | 0.1 |
| Brown Bullhead | Larvae | 1.6 | 1.5 | 0.1 | 2.6 | 2.5 | 0.1 | 1.3 | 1.3 | 0.1 |
| Largemouth Bass | Larvae | 0.3 | 0.2 | <0.1 | 0.5 | 0.3 | <0.1 | 0.3 | 0.2 | <0.1 |
| | YOY | 0.4 | 0 | <0.1 | 0.7 | 0 | <0.1 | 0.3 | 0 | <0.1 |
| Rock Bass | Larvae | 2.4 | 0.4 | 0.1 | 4.8 | 0.9 | 0.2 | 2.4 | 0.4 | 0.1 |
| Smallmouth Bass | Larvae | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 |
| Walleye | Larvae | 0.3 | <0.1 | <0.1 | 1.1 | <0.1 | 0.1 | 0.5 | <0.1 | <0.1 |
| White Perch | Larvae | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Yellow Bullhead | YOY | 4.0 | 2.0 | 0.2 | 6.7 | 3.3 | 0.3 | 3.3 | 1.6 | 0.2 |
| Yellow Perch | Larvae | 9.2 | 1.1 | 0.5 | 30.8 | 3.8 | 1.5 | 15.4 | 1.9 | 0.8 |
| Total | | 56.1 | 9.0 | 2.8 | 126.0 | 20.6 | 6.3 | 63.0 | 10.3 | 3.1 |

**Table 3–34. Equivalent Age-2 Largemouth Bass from predation of the biomass lost accrued from natural mortality from the entrained life stage to age of first recruitment annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | Life Stage | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| American Eel | YROL | 2 | 0 | <1 | 4 | 0 | <1 | 2 | 0 | <1 |
| American Shad | Larvae | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Black Crappie | Larvae | 5 | 1 | <1 | 15 | 4 | 1 | 7 | 2 | <1 |
| | YOY | 1 | 0 | <1 | 1 | 0 | <1 | 1 | 0 | <1 |
| Bluegill | Larvae | 17 | 1 | 1 | 33 | 3 | 2 | 17 | 1 | 1 |
| | YROL | 2 | 0 | <1 | 3 | 0 | <1 | 2 | 0 | <1 |
| Brown Bullhead | Larvae | 1 | 1 | <1 | 2 | 2 | <1 | 1 | 1 | <1 |
| Largemouth Bass | Larvae | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | YOY | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 | <1 |
| Rock Bass | Larvae | 2 | <1 | <1 | 3 | 1 | <1 | 2 | <1 | <1 |
| Smallmouth Bass | Larvae | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Walleye | Larvae | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| White Perch | Larvae | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Yellow Bullhead | YOY | 3 | 1 | <1 | 5 | 2 | <1 | 2 | 1 | <1 |
| Yellow Perch | Larvae | 7 | 1 | <1 | 22 | 3 | 1 | 11 | 1 | 1 |
| Total | | 40 | 6 | 2 | 90 | 15 | 4 | 45 | 7 | 2 |

**Table 3–35. Biomass (kg) lost as forage from natural mortality (predation) of early life stages of recreationally important fishery species impinged annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | Age | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers | Existing CWIS | 3-mm WWS | Cooling Towers |
| Banded Sunfish | 0 | <0.1 | | <0.1 | <0.1 | | <0.1 | <0.1 | | <0.1 |
| | 1 | <0.1 | | <0.1 | <0.1 | | <0.1 | <0.1 | | <0.1 |
| Black Crappie | 0 | 0.3 | 0.2 | <0.1 | 0.8 | 0.5 | <0.1 | 0.4 | 0.3 | <0.1 |
| | 1 | 0.5 | 0.4 | <0.1 | 1.3 | 1.1 | 0.1 | 0.6 | 0.6 | <0.1 |
| Bluegill | 0 | 0.2 | <0.1 | <0.1 | 0.5 | <0.1 | <0.1 | 0.3 | <0.1 | <0.1 |
| | 1 | 0.4 | 0.3 | <0.1 | 0.8 | 0.5 | <0.1 | 0.4 | 0.3 | <0.1 |
| Brown Bullhead | 0 | <0.1 | | <0.1 | <0.1 | | <0.1 | <0.1 | | <0.1 |
| | 1 | <0.1 | | <0.1 | 0.1 | | <0.1 | <0.1 | | <0.1 |
| Chain Pickerel | 1 | 0.3 | 0.3 | <0.1 | 0.4 | 0.4 | <0.1 | 0.2 | 0.2 | <0.1 |
| Largemouth Bass | 0 | <0.1 | <0.1 | <0.1 | 0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Pumpkinseed | 0 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | 1 | <0.1 | <0.1 | <0.1 | 0.1 | 0.1 | <0.1 | 0.1 | <0.1 | <0.1 |
| Rainbow Smelt | 0 | <0.1 | <0.1 | <0.1 | 0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Redbreast Sunfish | 0 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Rock Bass | 0 | <0.1 | | <0.1 | <0.1 | | <0.1 | <0.1 | | <0.1 |
| | 1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Smallmouth Bass | 0 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | 1 | 0.1 | <0.1 | <0.1 | 0.2 | 0.1 | <0.1 | 0.1 | <0.1 | <0.1 |
| | 2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| White Perch | 1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Yellow Bullhead | 0 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| | 1 | 0.2 | 0.1 | <0.1 | 0.3 | 0.2 | <0.1 | 0.1 | 0.1 | <0.1 |
| Yellow Perch | 0 | 0.2 | 0.2 | <0.1 | 0.3 | 0.3 | <0.1 | 0.2 | 0.1 | <0.1 |
| | 1 | 1.1 | 1.0 | 0.1 | 1.7 | 1.6 | 0.1 | 0.8 | 0.8 | <0.1 |
| Total | | 3.4 | 2.6 | 0.2 | 6.9 | 5.0 | 0.3 | 3.4 | 2.5 | 0.2 |

**Table 3–36. Equivalent Age-2 Largemouth Bass from predation of the biomass lost accrued from natural mortality from the impinged life stage to age of first recruitment annually at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS), 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| Species | Age | 10-year AIF | | | 100% DIF | | | 50% DIF | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing | 3-mm | Cooling | Existing | 3-mm | Cooling | Existing | 3-mm | Cooling |
| Banded Sunfish | 0 | <1 | | <1 | <1 | | <1 | <1 | | <1 |
| | 1 | <1 | | <1 | <1 | | <1 | <1 | | <1 |
| Black Crappie | 0 | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| | 1 | <1 | <1 | <1 | 1 | 1 | <1 | <1 | <1 | <1 |
| Bluegill | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1 | <1 | <1 | <1 | 1 | <1 | <1 | <1 | <1 | <1 |
| Brown Bullhead | 0 | <1 | | <1 | <1 | | <1 | <1 | | <1 |
| | 1 | <1 | | <1 | <1 | | <1 | <1 | | <1 |
| Chain | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Largemouth | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Pumpkinseed | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Rainbow | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Redbreast | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Rock Bass | 0 | <1 | | <1 | <1 | | <1 | <1 | | <1 |
| | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Smallmouth Bass | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 2 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| White Perch | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Yellow Bullhead | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Yellow Perch | 0 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1 | 1 | 1 | <1 | 1 | 1 | <1 | 1 | 1 | <1 |
| Total | | 2 | 2 | <1 | 5 | 4 | <1 | 2 | 2 | <1 |

**Table 3–37. Number of equivalent recruits[1] from annual entrainment reductions from the existing cooling water intake structure at Merrimack Station, Units 1 and 2 combined, with April through July operation of 3-mm wedgewire half screens (WWS) and year-round operation of closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| | | Entrainment | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10-year AIF | | 100% DIF | | 50% DIF | |
| Species | Model | 3-mm CWW | Cooling Towers | 3-mm CWW | Cooling Towers | 3-mm CWW | Cooling Towers |
| American Eel | Equivalent Recruit | 383 | 364 | 711 | 676 | 356 | 338 |
| American Shad | Equivalent Recruit | <1 | <1 | <1 | <1 | <1 | <1 |
| Banded Sunfish | Equivalent Recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| Black Crappie | Equivalent Recruit | 80 | 96 | 188 | 243 | 94 | 122 |
| Bluegill | Equivalent Recruit | 426 | 427 | 873 | 871 | 436 | 436 |
| Brown Bullhead | Equivalent Recruit | <1 | 14 | <1 | 23 | <1 | 12 |
| Chain Pickerel | Equivalent Recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| Largemouth Bass | Equivalent Recruit | 10 | 12 | 18 | 22 | 9 | 11 |
| Largemouth Bass | Production Foregone | 370 | 493 | 829 | 1113 | 414 | 556 |
| Largemouth Bass | Natural Mortality Biomass | 34 | 38 | 75 | 85 | 38 | 43 |
| Largemouth Bass | Total | 413 | 543 | 922 | 1220 | 461 | 610 |
| Pumpkinseed | Equivalent Recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| Rainbow Smelt | Equivalent Recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| Redbreast Sunfish | Equivalent Recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| Rock Bass | Equivalent Recruit | 24 | 27 | 46 | 54 | 23 | 27 |
| Smallmouth Bass | Equivalent Recruit | 0 | 0 | 0 | <1 | <1 | 0 |
| Walleye | Equivalent Recruit | 1 | 1 | 2 | 2 | 1 | 1 |
| White Perch | Equivalent Recruit | <1 | 0 | <1 | 1 | 0 | <1 |
| Yellow Bullhead | Equivalent Recruit | 23 | 42 | 37 | 70 | 19 | 35 |
| Yellow Perch | Equivalent Recruit | 207 | 224 | 696 | 755 | 49 | 50 |

[1]Number of equivalent fish at age first susceptible to angling as a proxy for equivalent catch (harvest and catch-and-release).

**Table 3–38. Number of equivalent recruits[1] from annual impingement reductions from the existing cooling water intake structure at Merrimack Station, Units 1 and 2 combined, with April through July operation of 3-mm wedgewire half screens (WWS) and year-round operation of closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| | | Impingement | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10-year AIF | | 100% DIF | | 50% DIF | |
| Species | Model | 3-mm CWW | Cooling Towers | 3-mm CWW | Cooling Towers | 3-mm CWW | Cooling Towers |
| American Eel | Equivalent Recruit | 0 | 4 | 0 | 6 | 0 | 3 |
| American Shad | Equivalent Recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| Banded Sunfish | Equivalent Recruit | 2 | 1 | 5 | 5 | 3 | 2 |
| Black Crappie | Equivalent Recruit | 3 | 17 | 10 | 48 | 5 | 24 |
| Bluegill | Equivalent Recruit | 30 | 72 | 67 | 150 | 34 | 75 |
| Brown Bullhead | Equivalent Recruit | 8 | 7 | 16 | 15 | 8 | 7 |
| Chain Pickerel | Equivalent Recruit | 0 | 7 | 0 | 11 | 0 | 5 |
| Largemouth Bass | Equivalent Recruit | <1 | 1 | 0 | 2 | <1 | 1 |
| Largemouth Bass | Production Foregone | 4 | 9 | 9 | 15 | 4 | 7 |
| Largemouth Bass | Natural Mortality Biomass | 1 | 2 | 1 | 5 | 1 | 2 |
| Largemouth Bass | Total | 5 | 12 | 10 | 21 | 5 | 11 |
| Pumpkinseed | Equivalent Recruit | 6 | 29 | 21 | 81 | 11 | 41 |
| Rainbow Smelt | Equivalent Recruit | 0 | 2 | 0 | 4 | 0 | 2 |
| Redbreast Sunfish | Equivalent Recruit | 7 | 18 | 20 | 47 | 10 | 23 |
| Rock Bass | Equivalent Recruit | <1 | 6 | <1 | 9 | 0 | 5 |
| Smallmouth Bass | Equivalent Recruit | 2 | 6 | 4 | 13 | 2 | 6 |
| Walleye | Equivalent Recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| White Perch | Equivalent Recruit | 0 | 6 | 0 | 9 | 0 | 4 |
| Yellow Bullhead | Equivalent Recruit | 2 | 9 | 3 | 13 | 2 | 7 |
| Yellow Perch | Equivalent Recruit | 9 | 88 | 25 | 147 | 12 | 73 |

[1]Number of equivalent fish at age first susceptible to angling as a proxy for equivalent catch (harvest and catch-and-release).

**Table 3–39. Number of equivalent recruits[1] from annual entrainment and impingement reductions from the existing cooling water intake structure at Merrimack Station, Units 1 and 2 combined, with April through July operation of 3-mm wedgewire half screens (WWS) and year-round operation of closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

| | | Benefit of Entrainment & Impingement Reductions | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10-year AIF | | 100% DIF | | 50% DIF | |
| Species | Model | 3-mm CWW | Cooling Towers | 3-mm CWW | Cooling Towers | 3-mm CWW | Cooling Towers |
| American Eel | Equivalent Recruit | 383 | 368 | 711 | 681 | 356 | 341 |
| American Shad | Equivalent Recruit | <1 | <1 | <1 | 0 | 0 | <1 |
| Banded Sunfish | Equivalent Recruit | 2 | 1 | 5 | 5 | 3 | 2 |
| Black Crappie | Equivalent Recruit | 83 | 113 | 198 | 291 | 99 | 145 |
| Bluegill | Equivalent Recruit | 456 | 498 | 940 | 1021 | 470 | 511 |
| Brown Bullhead | Equivalent Recruit | 8 | 21 | 16 | 38 | 8 | 19 |
| Chain Pickerel | Equivalent Recruit | 0 | 7 | 0 | 11 | 0 | 5 |
| Largemouth Bass | Equivalent Recruit | 10 | 13 | 18 | 23 | 9 | 12 |
| Largemouth Bass | Production Foregone | 374 | 501 | 837 | 1127 | 419 | 564 |
| Largemouth Bass | Natural Mortality Biomass | 34 | 40 | 77 | 90 | 38 | 45 |
| Largemouth Bass | Total | 418 | 554 | 932 | 1241 | 466 | 621 |
| Pumpkinseed | Equivalent Recruit | 6 | 29 | 21 | 81 | 11 | 41 |
| Rainbow Smelt | Equivalent Recruit | 0 | 2 | 0 | 4 | 0 | 2 |
| Redbreast Sunfish | Equivalent Recruit | 7 | 18 | 20 | 47 | 10 | 23 |
| Rock Bass | Equivalent Recruit | 24 | 33 | 46 | 63 | 23 | 31 |
| Smallmouth Bass | Equivalent Recruit | 2 | 6 | 4 | 13 | 2 | 6 |
| Walleye | Equivalent Recruit | 1 | 1 | 2 | 2 | 1 | 1 |
| White Perch | Equivalent Recruit | <1 | 6 | 0 | 10 | <1 | 5 |
| Yellow Bullhead | Equivalent Recruit | 24 | 51 | 41 | 83 | 20 | 41 |
| Yellow Perch | Equivalent Recruit | 216 | 312 | 720 | 901 | 62 | 124 |

[1]Number of equivalent fish at age first susceptible to angling as a proxy for equivalent catch (harvest and catch-and-release).

**Table 3–40. Comments on catch-and-release and exploitation of selected fishery species based on literature review.**

| Species | Catch and Release/Exploitation Summary | Citation |
|---|---|---|
| **Largemouth Bass**<br>(B. Everett Jordan Lake, North Carolina) | In 1989, 529 age-0 largemouth bass were tagged, of which 40 were recaptured (7.6%); In 1990, 1,090 age-0 largemouth bass were tagged, of which 47 were recaptured (4%); | Copeland and Noble 1994 |
| (unknown waterbody) | From 1979 to 1983, author angled, tagged, and released 339 largemouth bass and recaptured 74 of them (22% or 4.4% per year). There was no statistically significant relationship between fish size and probability of recapture. | Quinn 1989 |
| (nationwide) | Total mortality declined with the decline in u (annual exploitation), suggesting that changes in u caused lower overall total mortality rates. The evidence further suggests that the decline in u was caused by the voluntary release of fish by anglers rather than by changes in overall fishing effort. The simulation model showed that the decline in exploitation increased adult largemouth bass abundance but reduced the ability of size and bag regulations to improve population metrics owing to low rates of directed harvest. Discard mortality (i.e., the mortality of fish caught and released) would not negate the benefits of lower exploitation unless the mortality of fish caught and released was 0.3 or higher. Changes in angler behavior have substantially reduced fishing mortality for largemouth bass fisheries, which should be considered when developing management plans for this species and others with high rates of voluntary release. | Allen *et al* 2008 |
| **Smallmouth Bass**<br>(Snake River) | Only 8% of the tagged fish recaptured were taken by anglers; | Munther 1970 |
| (Zumbro River) | For all areas combined, an average of 16% of the fish that were caught at least one time and released were recaught by anglers during the 2 years the fishery was studied. | Hayes *et al*. 1997 |
| **Black Crappie**<br>(three Georgia Reservoirs) | Annual survival estimates ranged from 8 to 18% at all reservoirs; exploitation estimates ranged from 40 to 68%. | Larson *et al*. 1991 |
| (four Minnesota Lakes) | Rates of exploitation of black crappie were consistent across years in Lake Le Homme Dieu (26%) and Maple Lake (28%), increased from 9% in 1994 to 34% in 1996 on Lake Andrew, and declined from 33% in 1994 to 7% in 1996 on Lake Victoria. | Parsons and Reed 1998 |
| (Weiss Reservoir, Alabama) | Fishing mortality (F = 34%) accounted for only 20% of total annual mortality. Because of the high natural mortality and low exploitation, harvest restrictions on the Weiss Reservoir crappie fishery do not appear warranted at this time. | Reed and Davies 1991 |
| Walleye<br>(Seven sites in VA) | Anglers were offered a US$20 reward for the return of each tag, and 530 tags (17%) were returned. Adjusted annual catch rates ranged from 15%–61%, with a mean of 29%. Annual exploitation ranged from 2%–29% with a mean of 12%. | Owens *et al*. 2014 |
| (Lake Erie and Grand River, OH) | Exploitation rates adjusted for tag loss ranged from 14% to 39% | Isermann and Knight 2005 |
| Escanaba Lake and Northern WI | We conclude that population size structure was most strongly driven by recruitment and growth, rather than exploitation, in northern Wisconsin walleye populations. Studies of other species over wide spatial and temporal ranges of recruitment, growth, and mortality are needed to determine which dynamic rate most strongly influences population size structure of other species. Our findings indicate a need to be cautious about assuming exploitation is a strong driver of walleye population size structure. | Hansen and Nate 2014 |

(Continued)

**Table 3-40. Continued**

| Species | Catch and Release/Exploitation Summary | Citation |
|---|---|---|
| **Bluegill** (four Minnesota Lakes) | Rates of exploitation of bluegill varied among lakes and years and ranged from 8% on Lake Le Homme Dieu in 1994to 32% on Maple Lake in 1996. | Parsons and Reed 1998 |
| Literature review | Data from the literature indicate that angling commonly affects populations of bluegills Lepomis macrochirus. Substantial exploitation rates (mean, 27%) are not unusual; exploitation is directly related to fishing effort, and angling reduces average size and increases total mortality. | Coble 1988 |
| Lake Panasoffkee, Florida | The average u of 15.0-cm total length (TL) or larger fish was 0.14 for bluegills and redear sunfish during the 2-year period. For both species, exploitation increased up to threefold as fish size increased (e.g., u = 0.37 for bluegills ≥23.0 cm TL in 1999). Separation of fishing mortality and natural mortality allowed us to conclude that natural mortality had a greater influence on Lake Panasoffkee sunfish population abundance and fishing quality than did fishing mortality, so a minimum size limit was not recommended. | Crawford and Allen 2006 |

# 4 LITERATURE CITED

List of literature cited includes references from Appendix A.

Ahn, H. Y. Yamada, A. Okamura, N. Horie, N. Mikawa, S. Tanaka, and K. Tsukamoto. 2012. Effect of water temperature on embryonic development and hatching time of the Japanese eel Anguilla japonica. Aquaculture 330–333:100-105.

Allen, M.S., C.J. Walters, and R. Myers. 2008. Temporal Trends in Largemouth Bass Mortality, with Fishery Implications. North American Journal of Fisheries Management 28(2):418-427.

Altman, P.L. and D.S. Dittmer. 1962. Growth, including reproduction and morphological development. Federation of American Societies for Experimental Biology Washington, D.C., 1962. xiv + 608 pp. Illus.

ASA (ASA Analysis and Communications, Inc.). 2012. Estimates of the equivalent loss of entrainment and impingement at the Merrimack Generating Station. Prepared for NERA Economic Consulting. February 2012.

Atkinson, T., S. Desrosiers, T. Townsend, and T.P. Simon. 2015. Length-weight relationships of the Emerald Shiner (Notropis atherinoides - Rafinesque, 1818) in the Western Basin of Lake Erie. Ohio J Sci 114(2): 27-35.

ASMFC (Atlantic States Marine Fisheries Commission). 2007. American Shad Stock Assessment Report for Peer Review Volume II. Stock Assessment Report No. 07-01 (Supplement), 422pp.

ASMFC. 2012. American Eel Benchmark Stock Assessment. Atlantic States Marine Fisheries Commission, Stock Assessment Report No. 12-01.

ASMFC. 2017. River Herring Stock Assessment Update Volume II: State Specific Reports. August 2017.

Barnthouse, L.W. 2005. Parameter development for equivalent adult and production foregone models. EPRI report 1008832 (draft).

Barbin, G.P. and J.D. McCleave. 1997. Fecundity of the American eel *Anguilla rostrata* at 45° N in Maine, USA. J. Fish Biol. 51(4):840-847.

Beamesderfer, R.C.P. and J.A. North. 1995. Growth, natural mortality, and predicted response to fishing for largemouth bass and smallmouth bass populations in North America. N. Am. J. Fish. Manage. 15:688-704.

Begley, M., S.M. Coghlan,Jr., and J. Zydlewski.2017. A comparison of age, size, and fecundity of harvested and reference White Sucker populations. North American Journal of Fisheries Management. 37(3):510-523, DOI:10.1080/02755947.2017.1290719.

Brokaw, R.K. and J. Lucas. 2008. Chain Pickerel assessment. Report from the Mane Department of Inland Fisheries and Wildlife, Divisions of Fisheries and Planning. Brokaw (2001) report apparently updated by Lucas in 2008. 17pp.

Brown, S. J. and M. J. Maceina. 2002. The influence of disparate levels of submersed aquatic vegetation on largemouth bass population characteristics in a Georgia reservoir. J. Aquat. Plant Manage. 40:28-35.

Carlander, K.D. 1969. Handbook of freshwater fishery biology, volume 1. The Iowa State University Press, Ames. Iowa. 752 p.

Carlander, K. D. 1997. Handbook of Freshwater Fishery Biology, Vol. 3. The Iowa State University Press, Ames, IA. X.

Caron, F. and G. Verreault. 1997. Le reseau sentinelle de l'anguille. Pages 144–160 In: R.H. Petersen (editor), The American eel in Eastern Canada: Stock Status and Management Strategies. Proceedings of Eel Workshop, January 13–14, 1997, Quebec City, QC. Biological Station, St. Andrews, NB. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2196. 191p.

Carrier, J. and G. Gries. 2014. Assessment of Black Crappie and White Perch in Highland Lake, Stoddard-Washington, NH. Anadromous and Inland Fisheries Operational Management Investigations. Job 9. Warmwater and Coolwater Fisheries Population Assessments, F-50-R-31.

Coble, D.W. 1988. Effects of Angling on Bluegill Populations: Management Implications. North American Journal of Fisheries Management 8(3):277-283.

Conard, W.M. 2015. A Population Study of Northern Madtom in the St. Clair—Detroit River System, Michigan. Master of Science thesis, Natural Resources and Environment, University of Michigan. April 2015.

Copeland, J.R., and R.L. Noble. 1994. Movements by Young-of-Year and Yearling Largemouth Bass and Their Implications for Supplemental Stocking. North American Journal of Fisheries Management 14(1):119-124.

Crawford, S., and M.S. Allen. 2006. Fishing and Natural Mortality of Bluegills and Redear Sunfish at Lake Panasoffkee, Florida: Implications for Size Limits. North American Journal of Fisheries Management 26(1):42-51. DOI: 10.1577/M04-109.1

Dahlburg, M.D. 1979. A review of survival rates of fish eggs and larvae in relation to impact assessments. Marine Fisheries Review (March):1-12.

Dicenzo, V. and D.A Garren. 2001. Trophy largemouth bass abundance and harvest in a central Virginia impoundment: implications for restrictive slot limits. Conference: Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 55:194-207.

ENERCON and Normandeau (Enercon Services, Inc. and Normandeau Associates, Inc.) 2007. Response to United States Environmental Protection Agency CWA § 308 Letter. November 2007.

EPRI (Electric Power Research Institute). 2012. Fish Life History Parameter Values for Equivalent Adult and Production Foregone Models: Comprehensive Update. EPRI, Palo Alto, CA: 2012. 1023103.

Finger, B. L. 2001. Life history and range of Pennsylvania's endangered bridle shiner, Notropis bifrenatus (Cope). M.S. thesis, Pennsylvania State University. xii + 54 pp.

Fuchs, E.H. 1966. Life History of the Emerald Shiner in Lewis and Clark Lake, South Dakota.Theses and Dissertations. South Dakota State University. Paper 91.

Garner, P. 1997. Sample sizes for length and density estimation of 0+ fish when using point sampling by electrofishing. Journal of Fish Biology. 50: 95–106

Ganias, K., J.N. Divino, K.E. Gherard, J.P. Davis, F, Mouchlianitis, and E.T. Schultz. 2015. A reappraisal of reproduction in anadromous alewives: determinate versus indeterminate fecundity, batch size, and batch number. Transactions of the American Fisheries Society, 144(6):1143-1158, DOI:10.1080/00028487.2015.1073620.

Gilbert, C.R. 1992. Southern tessellated darter, *Etheostoma olmstedi maculaticeps*. Pp. 88-92. In: C.R. Gilbert, ed., Rare and Endangered Biota of Florida. Vol. II. Fishes. University Press of Florida, Gainesville.

Goodyear, C.P. 1978. Entrainment Impact Estimates using the Equivalent Adult Approach. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-78/65.

Hansen, M.J., and N.A. Nate. 2014. Effects of recruitment, growth, and exploitation on walleye population size structure in northern Wisconsin lakes. Journal of Fish and Wildlife Management 5(1):99-108.

Hayes, M.C., L.F. Gates, and S.A. Hirsh. 1997. Multiple Catches of Smallmouth Bass in a Special Regulation Fishery. North American Journal of Fisheries Management 17(1):182-187.

Herke, W.H. 1959. Comparison of the length-weight relationship of several species of fish from two different, but connected, habitats. Proc. S.E. Assoc. Game Fish Comm. 13:299-313.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82:898–903.

Höök, T.O., E.S. Rutherford, D.M. Mason, and G.S. Carter. 2007. Hatch dates, growth, survival, and overwinter mortality of age-0 alewives in Lake Michigan: implications for habitat-specific recruitment success. Transactions of the American Fisheries Society, 136(5):1298-1312, DOI: 10.1577/T06-194.1

Horst, T.J. 1975. The assessment of impact due to entrainment of ichthyoplankton. Pages 107-118 in S.B. Saila, ed. Fisheries and energy production: a symposium. D.C. Heath, Lexington MA.

Hugg, D.O. 1996. MAPFISH georeferenced mapping database. Freshwater and estuarine fishes of North America. Life Science Software. Dennis O. and Steven Hugg, 1278 Turkey Point Road, Edgewater, Maryland, USA.

Isermann, D.A., and C.T. Knight. 2005. Potential Effects of Jaw Tag Loss on Exploitation Estimates for Lake Erie Walleyes. North American Journal of Fisheries Management 25(2):557-562.

Jackson, Z. J., M. C. Quist, and J. G. Larscheid. 2008. Growth standards for nine North American fish species. Fisheries Management and Ecology 15:107-118.

Jessop, B.M., J. C. Shiao, and Y. Iizuka. 2009. Life History of American Eels from Western Newfoundland, Transactions of the American Fisheries Society, 138:4, 861-871, DOI:10.1577/T08-190.1.

Jones, P.W., F.D. Martin and J.D. Hardy Jr. 1978. Development of fishes of the Mid-Atlantic Bight. An atlas of eggs, larval and juvenile stages. Vol. 1. Acipenseridae through Ictaluridae. U.S. Fish Wildl. Ser. Biol. Serv. Program FWS/OBS-78/12. 336 p.

Kottelat, M. and J. Freyhof, 2007. Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, Berlin. 646 pp.

Larson, M.C., B. Saul, and S. Schleiger. 1991. Exploitation and Survival of Black Crappies in Three Georgia Reservoirs. North American Journal of Fisheries Management 11(4):604-613.

Layzer, J.B. and R.J. Reed. 1978. Age and Growth of the Tessellated Darter, Etheostoma olmstedi, in Massachusetts. The American Midland Naturalist 100,(2):459-462.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49:627-647.

Mattson, M.T., P. Lindsay, J. Young, and J. Black. 2011. Larval avoidance enhances the entrainment reduction performance of cylindrical wedgewire screens. August 2011. Presentation to the American Fisheries Society annual meeting in Seattle, WA on behalf of Entergy's Indian Point Energy Center, Buchanan, NY.

Mattson, M.T., P. Lindsay, J. Young, D. Heimbuch, and L. Barnthouse. 2014. In-river Performance of a 2-mm slot wedgewire screen for reducing entrainment at Indian Point Station. August 2014. Presentation to the American Fisheries Society annual meeting in Quebec City, Quebec, Canada on behalf of Entergy's Indian Point Energy Center, Buchanan, NY.

Mosel, K.J., D.A. Isermann, and J.F. Hansen. 2015. Evaluation of daily creel and minimum length limits for Black Crappie and Yellow Perch in Wisconsin. North American Journal of Fisheries Management, 35(1):1-13. DOI: 10.1080/02755947.2014.963752

Mukhaysin, A.A and L.A. Jawad. 2012. Larval Development of the Cyprinid Fish Barbus sharpeyi (Gunther, 1874). Journal of Fisheries and Aquatic Science 7: 307-319.

Munther, G.L. 1970. Movement and Distribution of Smallmouth Bass in the Middle Snake River. Transactions of the American Fisheries Society 99(1):44-53.

Murawski, S.A. and C.F. Cole. 1978 Population dynamics of anadromous rainbow smelt *Osmerus mordax*, in a Massachusetts River system. Transactions of the American Fisheries Society Vol. 107(4):535-542.

Murdy, E.O. and J.A. Musick, 2013. Field guide to fishes of the Chesapeake Bay. JHU Press, 360 p.

NERA (NERA Economic Consulting). 2012. Preliminary Economic Analysis of Cooling Water Intake Alternatives at Merrimack Station. Prepared for Public Service of New Hampshire. February 2012.

NHFG (New Hampshire Fish and Game). Undated. Eastern Silvery Minnow. http://www.wildlife.state.nh.us/fishing/profiles/eastern-silvery-minnow.html.

NHFG. 2017a. Endangered and Threatened Wildlife of NH http://www.wildlife.state.nh.us/nongame/endangered-list.html. Accessed on 11 November 2017.

NHFG. 2017b. Wildlife Species of Concern. http://www.wildlife.state.nh.us/nongame/documents/species-special-concern.pdf. Accessed on 11 November 2017.

Normandeau (Normandeau Associates, Inc.). 2006. Merrimack Station Quality Assurance Plan and Standard Operating Procedures for Entrainment Monitoring. March 2006.

Normandeau. 2007. Entrainment and Impingement Studies Performed at Merrimack Generating Station from June 2005 through June 2007. Report October 2007.

Normandeau. 2011. Merrimack Station fisheries survey analysis of 1972 through 2011 catch data. Report December 2011.

Normandeau. 2017a. Evaluation of the Entrainment Reduction Performance of a 3-mm Wedgewire Screen at Merrimack Station October 2017.

Normandeau. 2017b. 2012-2013 Data Supplement to the Merrimack Station Fisheries Survey Analysis of 1972-2011 Catch Data. August 2017

Novomeska, A. and V. Kovac. 2009. Life-history traits of non-native black bullhead *Ameiurus melas* with comments on its invasive potential. J. Appl. Ichthyol. 25:79–84.

Odenkirk, J. 2016. Lake Anna Fisheries Management Report. Federal Aid Project-F111R. March 2016. https://www.dgif.virginia.gov/wp-content/uploads/Lake-Anna-Popular-Report-2016.pdf

Owens, S.J., G. Palmer, T. Hampton, D. Wilson, and J. Harris. 2014. Differences in Angler Catch and Exploitation of Walleye from Virginia Waters. Journal of the Southeastern Association of Fish and Wildlife Agencies 1:14–19

Palomares, M.L.D., 1991. La consommation de nourriture chez les poissons: étude comparative, mise au point d'un modèle prédictif et application à l'étude des réseaux trophiques. Thèse de Doctorat, Institut National Polytechnique de Toulouse, 211 p.

Panek, F.M. and C.R. Cofield. 1978. Fecundity of Bluegill and Warmouth from a South Carolina Blackwater Lake. The Progressive Fish-Culturist 40(2):67-68.

Parsons, B.G., and J.R. Reed. 1998. Angler Exploitation of Bluegill and Black Crappie in Four West-Central Minnesota Lakes. Minnesota Department of Natural Resources, Investigation Report 468. 35 pp.

Partridge, D.G. and D.R. DeVries. 1999. Regulation of growth and mortality in larval Bluegills: implications for juvenile recruitment. Transactions of the American Fisheries Society, 128(4):625-638. DOI: 10.1577/1548-8659(1999)128<0625:ROGAMI>2.0.CO;2

Paukert, C.P, D.W. Willis, and A.L Glidden. 2001. Growth, condition, and mortality of Black Crappie, Bluegill, and Yellow Perch in Nebraska Sand Hills lakes. Great Plains Research 11:264-271.

Priegel, Gordon R. 1966. Age-length and length-weight relationship of bullheads from Little Lake Butte Des Morts, 1959.

Quinn, S.P. 1989. Recapture Rates of Voluntarily Released Largemouth Bass. North American Journal of Fisheries Management 9(1):86-91.

Rago, P.J., 1984. Production forgone: an alternative method for assessing the consequences of fish entrainment and impingement losses at power plants and other water intakes. Ecological Modelling, 24(1), pp.79-111.

Reed, J.R., and W.D. Davies. 1991. Population Dynamics of Black Crappies and White Crappies in Weiss Reservoir, Alabama: Implications for the Implementation of Harvest Restrictions. North American Journal of Fisheries Management 11(4):598-603.

Reid, S. M. 2009. Age, growth, and mortality of black redhorse (*Moxostoma duquesnei*) and shorthead redhorse (*Moxostoma macrolepidotum*) in the Grand River, Ontario. Journal of Applied Ichthyology 25:178-183.

Responsive Management. 2016. New Hampshire Freshwater Anglers' Fishing Participation and Preferences. Conducted for the New Hampshire Fish and Game Department.

Saila, S.B. and D. Horton. 1957. Fisheries investigations and management in Rhode Island lakes and ponds. R.I. Div. Fish., Game Fish Publ. 3:1-134.

Saila, S.B., E. Lorda, J.D. Miller, R.A. Sher, and W.H. Howell. 1997. Equivalent adult estimates for losses of fish eggs, larvae, and juveniles at Seabrook Station with use of fuzzy logic to represent parametric uncertainty. North American Journal of Fisheries Management 17:811-825.

Scheibly, J.F., D.J. Eisenhour, and L.V. Eisenhour. 2008. Reproductive Biology of the Northern Madtom, *Noturus stigmosus* (Siluriformes: Ictaluridae) from the Licking River, Kentucky. Journal of the Kentucky Academy of Science 69(2):178-186.

Scott, W.B. and E.J. Crossman, 1998. Freshwater fishes of Canada. Oakville (Ontario, Canada): Galt House Publications. xx+966 p.

Simon, T. and B. Burr. 2004. Description of developmental stages of the stonecat, Noturus flavus and the slender madtom, *Noturus exilis* (Siluriformes: Ictaluridae). Proceedings of the Indiana Academy of Science. 113. 123-132.

Snyder, D.J. and M.S. Peterson. 1999. Life history of a peripheral population of bluespotted sunfish Enneacanthus gloriosus (Holbrook) with comments on geographic variation. Am. Midland Naturalist 141:345-357.

Stuber, R.J., Gebhart, G. and Maughan, O.E., 1982. Habitat suitability index models: largemouth bass (No. 82/10.16). US Fish and Wildlife Service.

Swingle, W.E., 1965. Length-weight relationships of Alabama fishes. Auburn Univ. Agric. Exp. Sta. Zool.-Ent. Ser. Fish. 3:87 p.

Thomas, M.V., and R.C. Haas. 2000. Status of Yellow Perch and Walleye Populations in Michigan Waters of Lake Erie, 1994-98. Michigan Department of Natural Resources Fisheries Research Report No. 2054. 39 pp.

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.

Tsai, C. 1972. Life history of the eastern johnny darter, *Etheostoma olmstedi* Storer, in cold tailwater and sewage-polluted water. Transactions of the American Fisheries Society 101(1): 80-88.

USEPA (U.S. Environmental Protection Agency). 2004. Regional Benefits Analysis for the Final Section 316(b) Phase III Existing Facilities Rule. Office of Water (4303T), Washington, DC 20460. EPA-821-R-02-003

USEPA. 2006. Regional Benefits Analysis for the Final Section 316(b) Phase III Existing Facilities Rule. Office of Water (4303T), Washington, DC 20460. EPA-821-R-04-007.

USEPA. 2011. Fact Sheet. Draft National Pollutant Discharge Elimination System (NPDES) Permit To Discharge To Waters Of The United States Pursuant To The Clean Water Act (CWA). https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/ MerrimackStationFactSheet.pdf

USEPA. 2014. Revised Draft Permit. Authorization To Discharge Under The National Pollutant Discharge Elimination System (NPDES). https://www3.epa.gov/region1/npdes/permits/draft/2014/draftnh0001465permit.pdf

USEPA. 2014. Technical Development Document for the Final Section 316(b) Existing Facilities Rule. Office of Water (4303T), Washington, DC 20460. EPA-821-R-14-002

Victor, B.C. and G.B. Brothers. 1982. Age and growth of the fallfish *Semotilus corporalis* with daily otolith increments as a method of annulus verification. Can. J. Zool. 60: 2543-2550.

Young, J, M.T. Mattson, L. Barnthouse, D. Heimbuch, and D. Gessler. 2014. Evaluating 2 mm Slot Wedgewire Screens for Reducing Entrainment at a High-Volume Cooling Water Intake. August 2014. Presentation to the American Fisheries Society annual meeting in Quebec City, Quebec, Canada on behalf of Entergy's Indian Point Energy Center, Buchanan, NY.

Wilk, S.J., W.W. Morse and D.E. Ralph. 1978. Length-weight relationships of fishes collected in the New York Bight. Bull. New Jersey Acad. Sci. 23(2):58-64.

Wilk, S.J., W.M. Morse, and L.L Stehllk. 1990. Annual cycles of gonad-somatic indices as indicators of spawning activity for selected species of finfish collected from the New York Bight. Fishery Bulletin, U.S. 88:775-786.

Wilson, K.L., B.G. Matthias, A.B. Barbour, R.N. M. Ahrens, T. Tuten, and M.S. Allen. 2015. Combining samples from multiple gears helps to avoid fishy growth curves. North American Journal of Fisheries Management, 35(6):1121-1131, DOI:10.1080/02755947.2015.1079573

Zipkin, E.F., P.J. Sullivan, E.G. Cooch, C.E. Kraft, B.J. Shuter, and B.C. Weidel. 2008. Overcompensatory Response of a Smallmouth Bass (*Micropterus dolomieu*) Population to Harvest: Release from Competition? Canadian Journal of Fisheries and Aquatic Sciences 65(10):2279-2292.

# 5 APPENDICES

# Appendix A. Life History Tables

**Table A–1. Life history parameters for an Alewife population at equilibrium**

| Stage | $M_i$[a] | Post-spawn$M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.900 | 0.000 | 0.000 | 0.00 | 0.90 | 0.40657 | 0.57810 | 0.00094 | 6 | 0.000 |
| Larvae | 4.265 | 0.000 | 0.000 | 0.00 | 4.27 | 0.01405 | 0.02771 | 0.00094 | 53 | 4.173 |
| YOY | 3.007 | 0.000 | 0.000 | 0.00 | 3.01 | 0.04943 | 0.09421 | 0.06120 | 306 | 4.873 |
| Age 1 | 1.285 | 0.000 | 0.000 | 0.00 | 1.28 | 0.27670 | 0.43346 | 8 | 365 | 1.322 |
| Age 2 | 0.941 | 0.000 | 0.000 | 0.00 | 0.94 | 0.39019 | 0.56135 | 30 | 365 | 1.006 |
| Age 3 | 0.772 | 0.000 | 0.000 | 0.00 | 0.77 | 0.46218 | 0.63218 | 82 | 365 | 0.542 |
| Age 4 | 0.686 | 1.500 | 0.000 | 0.00 | 1.01 | 0.36325 | 0.53291 | 141 | 365 | 0.319 |
| Age 5 | 0.638 | 1.500 | 0.000 | 0.00 | 1.50 | 0.22313 | 0.36485 | 194 | 365 | 0.200 |
| Age 6 | 0.610 | 1.500 | 0.000 | 0.00 | 1.50 | 0.22313 | 0.36485 | 237 | 365 | 0.127 |
| Age 7 | 0.582 | 1.500 | 0.000 | 0.00 | 1.50 | 0.22313 | 0.36485 | 269 | 365 | 0.186 |
| Age 8 | 0.582 | 1.500 | 0.000 | 0.00 | 1.50 | 0.22313 | 0.36485 | 324 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates for eggs and post-spawning were based on an equilibrium population (EPRI 2012, Table 5-4,5-5). Larval mortality based on weighted average of mean estimates for yolk-sac larvae (Höök *et al.* 2007) and post yolk-sac larvae (EPRI 2012, Table 5-5). Natural mortality of immature fish was derived from Lorenzen (1996) relation using mid-age weights and were roughly in agreement with the constant M=0.7 used in ASMFC (2017).

[b] Age-specific fishing mortality assumed zero for New Hampshire stocks.

[c] No vulnerability to fishing inferred for New Hampshire river stocks assumed.

[d] Total instantaneous mortality, Z, as -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012, Eq 3-4).

[g] Start weights for based on EPRI (2012, Table 5-6), fecundity based on 898 eggs/g gonad-free body weight (Ganias *et al.* 2015) and 5% GSI (Wilk *et al.* 1990) to estimate total-body weight equivalent. Linear extrapolation made for start weight to age-8.

[h] Egg and yolk-sac larvae stage duration (days) and maturity was based on EPRI (2012, Table 5-6). Höök *et al.* (2007) provided post yolk-sac larvae stage duration.

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Fecundity bases on estimated weights multiplied by mean relative fecundity (Ganais *et al.* 2015).

[k] Maturity is based on EPRI (2012, Table 5-6).

**Table A–2. Life history parameters for an American Eel population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ (=$2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 1.040 | 0.000 | 0.00 | 1.04 | 0.35345 | 0.52230 | 0.00001 | 2 | 4.442 |
| Larvae | 7.700 | 0.000 | 0.00 | 7.70 | 0.00045 | 0.00091 | 0.00072 | 365 | 5.718 |
| YOY | 1.689 | 0.000 | 0.00 | 1.69 | 0.18467 | 0.31176 | 0.21818 | 365 | 3.590 |
| Age 1 | 0.237 | 0.000 | 0.00 | 0.24 | 0.78883 | 0.88195 | 8 | 365 | 0.854 |
| Age 2 | 0.199 | 0.000 | 0.00 | 0.20 | 0.81983 | 0.90100 | 19 | 365 | 0.616 |
| Age 3 | 0.173 | 0.260 | 0.50 | 0.29 | 0.74458 | 0.85359 | 34 | 365 | 0.473 |
| Age 4 | 0.156 | 0.260 | 1.00 | 0.42 | 0.66001 | 0.79519 | 55 | 365 | 0.378 |
| Age 5 | 0.142 | 0.260 | 1.00 | 0.40 | 0.66883 | 0.80156 | 80 | 365 | 0.310 |
| Age 6 | 0.132 | 0.260 | 1.00 | 0.39 | 0.67571 | 0.80648 | 110 | 365 | 0.259 |
| Age 7 | 0.124 | 0.260 | 1.00 | 0.38 | 0.68122 | 0.81038 | 142 | 365 | 0.220 |
| Age 8 | 0.117 | 0.260 | 1.00 | 0.38 | 0.68571 | 0.81356 | 177 | 365 | 0.189 |
| Age 9 | 0.112 | 0.260 | 1.00 | 0.37 | 0.68944 | 0.81617 | 214 | 365 | 0.164 |
| Age 10 | 0.107 | 0.260 | 1.00 | 0.37 | 0.69257 | 0.81836 | 252 | 365 | 0.144 |
| Age 11 | 0.104 | 0.260 | 1.00 | 0.36 | 0.69523 | 0.82022 | 291 | 365 | 0.126 |
| Age 12 | 0.100 | 0.260 | 1.00 | 0.36 | 0.69751 | 0.82180 | 331 | 365 | 0.112 |
| Age 13 | 0.097 | 0.260 | 1.00 | 0.36 | 0.69948 | 0.82317 | 370 | 365 | 0.099 |
| Age 14 | 0.095 | 0.260 | 1.00 | 0.35 | 0.70120 | 0.82436 | 408 | 365 | 0.089 |
| Age 15 | 0.093 | 0.260 | 1.00 | 0.35 | 0.70271 | 0.82540 | 446 | 365 | 0.079 |
| Age 16 | 0.091 | 0.260 | 1.00 | 0.35 | 0.70403 | 0.82631 | 483 | 365 | 0.071 |
| Age 17 | 0.089 | 0.260 | 1.00 | 0.35 | 0.70520 | 0.82712 | 519 | 365 | 0.064 |
| Age 18 | 0.088 | 0.260 | 1.00 | 0.35 | 0.70624 | 0.82783 | 553 | 365 | 0.058 |
| Age 19 | 0.086 | 0.260 | 1.00 | 0.35 | 0.70716 | 0.82847 | 586 | 365 | 0.052 |
| Age 20 | 0.085 | 0.260 | 1.00 | 0.35 | 0.70799 | 0.82903 | 617 | 365 | 0.047 |

**Table A-2. Continued.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Age 21 | 0.084 | 0.260 | 1.00 | 0.34 | 0.70873 | 0.82954 | 647 | 365 | 0.043 |
| Age 22 | 0.083 | 0.260 | 1.00 | 0.34 | 0.70939 | 0.82999 | 675 | 365 | 0.039 |
| Age 23 | 0.083 | 0.260 | 1.00 | 0.34 | 0.70999 | 0.83040 | 702 | 365 | 0.035 |
| Age 24 | 0.082 | 0.260 | 1.00 | 0.34 | 0.71053 | 0.83077 | 727 | 365 | 0.032 |
| Age 25 | 0.082 | 0.260 | 1.00 | 0.34 | 0.71053 | 0.83077 | 751 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values: USEPA (2006; Table G1-36), for egg and larval stages; and based on Lorenzen (1996) relation with mid-age weight for ages 1-25.

[b] Age-specific fishing from estimate made in St. Lawrence River (Caron and Verrealt 1997).

[c] Vulnerability to fishing inferred from ASMFC (2012).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on USEPA (2006) for egg, larvae, and YOY; for ages 1-25 weights were calculated as lengths (Jessop *et al.* 2009) converted to weights (Wilk *et al.* 1978).

[h] Stage duration (days) was based on Ahn *et al.* (2012) for eggs and general life history information on leptocephalus stage for anguilid larvae.

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Mean fecundity calculated from applying Barbin and McCleave (1997) fecundity relation to predicted lengths at age (Jessop *et al.* 2009).

[k] Maturity taken from ages associated with Murdy and Musick (2013) report on size at maturity.

**Table A–3. Life history parameters for an American Shad population at equilibrium.**

| Stage | $M_i$[a] | Post-spawn$M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.944 | 0.000 | 0.000 | 0.00 | 0.94 | 0.38907 | 0.56019 | 0.00188 | 2 | 0.000 |
| Larvae | 2.565 | 0.000 | 0.000 | 0.00 | 2.57 | 0.07692 | 0.14285 | 0.00188 | 27 | 1.609 |
| YOY | 7.619 | 0.000 | 0.000 | 0.00 | 7.62 | 0.00049 | 0.00098 | 0.00940 | 336 | 8.174 |
| Age 1 | 0.603 | 0.000 | 0.000 | 0.00 | 0.60 | 0.54708 | 0.70724 | 33 | 365 | 1.883 |
| Age 2 | 0.474 | 0.000 | 0.000 | 0.00 | 0.47 | 0.62277 | 0.76754 | 219 | 365 | 0.970 |
| Age 3 | 0.403 | 0.000 | 0.000 | 0.00 | 0.40 | 0.66860 | 0.80139 | 578 | 365 | 0.602 |
| Age 4 | 0.359 | 1.500 | 0.087 | 0.45 | 0.54 | 0.58051 | 0.73458 | 1056 | 365 | 0.406 |
| Age 5 | 0.331 | 1.500 | 0.115 | 0.90 | 0.97 | 0.37991 | 0.55063 | 1584 | 365 | 0.287 |
| Age 6 | 0.312 | 1.500 | 0.134 | 1.00 | 1.63 | 0.19510 | 0.32650 | 2111 | 365 | 0.209 |
| Age 7 | 0.298 | 1.500 | 0.148 | 1.00 | 1.65 | 0.19245 | 0.32279 | 2601 | 365 | 0.155 |
| Age 8 | 0.288 | 1.500 | 0.158 | 1.00 | 1.66 | 0.19056 | 0.32011 | 3037 | 365 | 0.117 |
| Age 9 | 0.279 | 1.500 | 0.167 | 1.00 | 1.67 | 0.18884 | 0.31768 | 3413 | 365 | 0.089 |
| Age 10 | 0.275 | 1.500 | 0.171 | 1.00 | 1.67 | 0.18797 | 0.31646 | 3730 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates for eggs and larvae were based on an equilibrium population (EPRI 2012,Table 5-2). For ages 1-10, estimates of M were made using Lorenzen (1996) relation with mid-age weight.

[b] Age-specific fishing mortality uses geometric mean Z from ASMFC (2007) for New Hampshire rivers with F = Z-immatureM.

[c] Vulnerability to fishing from EPRI (2012, Table 5-1).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on EPRI (2012, Table 5-3).

[h] Stage duration (days) was based on EPRI (2012 Table 5-3).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Fecundity was based on EPRI (2012 Table 5-1).

[k] Maturity was based on EPRI (2012 Table 5-1).

## Table A–4. Life history parameters for a Banded Sunfish population at equilibrium.

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.044 | 0.000 | 0.000 | 0.04 | 0.95676 | 0.97790 | 0.00094 | 2 | 0.000 |
| Larvae | 2.338 | 0.000 | 0.000 | 2.34 | 0.09652 | 0.17605 | 0.00094 | 28 | 4.173 |
| YOY | 4.683 | 0.000 | 0.000 | 4.68 | 0.00925 | 0.01833 | 0.06120 | 335 | 4.442 |
| Age 1 | 1.264 | 0.000 | 0.000 | 1.26 | 0.28248 | 0.44052 | 5 | 365 | 1.907 |
| Age 2 | 0.918 | 0.223 | 1.000 | 1.14 | 0.31948 | 0.48425 | 35 | 365 | 0.914 |
| Age 3 | 0.758 | 0.223 | 1.000 | 0.98 | 0.37471 | 0.54515 | 87 | 365 | 0.541 |
| Age 4 | 0.683 | 0.223 | 1.000 | 0.91 | 0.40398 | 0.57547 | 150 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based Bluegill life history (this workbook) but shortened to maximum age of 4 years for closely related blue-spotted sunfish (Snyder and Peterson 1999).

[b] Age-specific fishing derived from Crawford and Allen (2006) catch-curve and tag-recapture studies in Florida lake for Bluegill.

[c] Vulnerability to fishing inferred from Bluegill population dynamics.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based multiple studies reviewed in EPRI (2012, Table 5-122).

[h] Stage duration (days) was based on EPRI (2012, Table 5-123).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Mean fecundity calculated from length-at-age using Paneck and Cofield (1978) length-fecundity relation.

[k] Maturity taken from EPRI (2012, Table 5-123).

**Table A–5. Life history parameters for a Black Crappie population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.750 | 0.000 | 0.00 | 0.75 | 0.47237 | 0.64164 | 0.00094 | 5 | 0.000 |
| Larvae | 3.600 | 0.000 | 0.00 | 3.60 | 0.02732 | 0.05319 | 0.00094 | 40 | 4.173 |
| YOY | 3.037 | 0.000 | 0.00 | 3.04 | 0.04800 | 0.09160 | 0.06120 | 320 | 6.264 |
| Age 1 | 0.830 | 0.000 | 0.00 | 0.83 | 0.43606 | 0.60730 | 32 | 365 | 1.479 |
| Age 2 | 0.650 | 0.429 | 1.00 | 1.08 | 0.34000 | 0.50746 | 141 | 365 | 0.625 |
| Age 3 | 0.574 | 0.505 | 1.00 | 1.08 | 0.34000 | 0.50746 | 264 | 365 | 0.314 |
| Age 4 | 0.536 | 0.542 | 1.00 | 1.08 | 0.34000 | 0.50746 | 361 | 365 | 0.170 |
| Age 5 | 0.517 | 0.562 | 1.00 | 1.08 | 0.34000 | 0.50746 | 428 | 365 | 0.095 |
| Age 6 | 0.506 | 0.573 | 1.00 | 1.08 | 0.34000 | 0.50746 | 470 | 365 | 0.054 |
| Age 7 | 0.500 | 0.579 | 1.00 | 1.08 | 0.34000 | 0.50746 | 496 | 365 | 0.031 |
| Age 8 | 0.496 | 0.582 | 1.00 | 1.08 | 0.34000 | 0.50746 | 512 | 365 | 0.018 |
| Age 9 | 0.495 | 0.584 | 1.00 | 1.08 | 0.34000 | 0.50746 | 521 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates were based on an equilibrium population (EPRI 2012, p.5-124). Egg stage includes a very short yolk-sac larvae development stage. Mortality for ages 1-9 are derived from the Lorenzen (1996) equation predicting mortality from mid-age weight.

[b] Age-specific fishing mortality based on Paukert *et al.* (2001) Z's for midwest lakes and given age-specific M, F=Z-M.

[c] Vulnerability to fishing inferred from Carrier and Greis (2014) size frequencies for New Hampshire landings and predicted size at age.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights are based on Wilson *et al.* (2014) predicted lengths and Mosel *et al.* (2014) length-weight relation.

[h] Stage duration (days) was based on EPRI (2012, 5-125).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Mean fecundity taken from EPRI (2012, Table 5-124).

**Table A–6. Life history parameters for a Blacknose Dace population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.183 | 0.000 | 0.00 | 0.18 | 0.83277 | 0.90875 | 0.00182 | 3 | 0.000 |
| Larvae | 2.562 | 0.000 | 0.00 | 2.56 | 0.07715 | 0.14325 | 0.00182 | 42 | 3.241 |
| YOY | 3.964 | 0.000 | 0.00 | 3.96 | 0.01899 | 0.03728 | 0.04650 | 320 | 2.666 |
| Age 1 | 2.511 | 0.000 | 0.00 | 2.51 | 0.08122 | 0.15024 | 0.66883 | 365 | 1.515 |
| Age 2 | 1.960 | 0.000 | 0.00 | 1.96 | 0.14081 | 0.24686 | 3.04298 | 365 | 0.631 |
| Age 3 | 1.729 | 0.000 | 0.00 | 1.73 | 0.17754 | 0.30155 | 5.72021 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on Emerald Shiner population dynamics reported elsewhere in this workbook, except a maximum age was assumed 3 years (Hugg 1996).

[b] No age-specific fishing mortality, assumed F=0.

[c] No vulnerability to fishing assumed.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based growth curve developed for Fuchs (1966) observed lengths and length-weight relationship from Atkinson *et al.* (2015) for Emerald Shiner.

[h] Stage duration (days) was based on EPRI (2012).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Fecundity bases on EPRI (2012, Table 5-91).

[k] Maturity is based on EPRI (2012, Table 5-91).

**Table A–7. Life history parameters for a Bluegill population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.044 | 0.000 | 0.00 | 0.04 | 0.95676 | 0.97790 | 0.00094 | 2 | 0.000 |
| Larvae | 2.338 | 0.000 | 0.00 | 2.34 | 0.09652 | 0.17605 | 0.00094 | 28 | 4.173 |
| YOY | 4.875 | 0.000 | 0.00 | 4.87 | 0.00764 | 0.01516 | 0.06120 | 335 | 4.442 |
| Age 1 | 1.264 | 0.000 | 0.00 | 1.26 | 0.28248 | 0.44052 | 5 | 365 | 1.907 |
| Age 2 | 0.918 | 0.223 | 1.00 | 1.14 | 0.31948 | 0.48425 | 35 | 365 | 0.914 |
| Age 3 | 0.758 | 0.223 | 1.00 | 0.98 | 0.37471 | 0.54515 | 87 | 365 | 0.541 |
| Age 4 | 0.671 | 0.223 | 1.00 | 0.89 | 0.40890 | 0.58045 | 150 | 365 | 0.350 |
| Age 5 | 0.618 | 0.223 | 1.00 | 0.84 | 0.43116 | 0.60253 | 213 | 365 | 0.238 |
| Age 6 | 0.583 | 0.223 | 1.00 | 0.81 | 0.44624 | 0.61710 | 270 | 365 | 0.167 |
| Age 7 | 0.557 | 0.223 | 1.00 | 0.78 | 0.45829 | 0.62853 | 319 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values: EPRI (2012, Table 5-121) for egg stage, Partridge and DeVries (1999) for larvae, and based on Lorenzen (1996) relation with mid-age weight for ages 1-7.

[b] Age-specific fishing derived from Crawford and Allen (2006) catch-curve and tag-recapture studies in Florida lake.

[c] Vulnerability to fishing inferred from Crawford and Allen (2006) observation of near-constant exploitation larger than 13cm and this size representative of age 2 (Jackson *et al.* 2008).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based multiple studies reviewed in EPRI (2012, Table 5-123).

[h] Stage duration (days) was based on EPRI (2012, Table 5-123).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Mean fecundity calculated from length-at-age using Paneck and Cofield (1978) length-fecundity relation.

[k] Maturity taken from EPRI (2012, Table 5-123).

**Table A–8. Life history parameters for a Brown Bullhead population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 1.104 | 0.000 | 0.00 | 1.10 | 0.33154 | 0.49798 | 0.00170 | 8 | 0.000 |
| Larvae | 3.174 | 0.000 | 0.00 | 3.17 | 0.04184 | 0.08031 | 0.00170 | 23 | 3.298 |
| YOY | 4.191 | 0.000 | 0.00 | 4.19 | 0.01513 | 0.02981 | 0.04600 | 334 | 6.663 |
| Age 1 | 0.817 | 0.000 | 0.00 | 0.82 | 0.44196 | 0.61300 | 36 | 365 | 1.408 |
| Age 2 | 0.642 | 0.200 | 0.50 | 0.74 | 0.47863 | 0.64740 | 147 | 365 | 0.627 |
| Age 3 | 0.565 | 0.200 | 1.00 | 0.76 | 0.46554 | 0.63532 | 276 | 365 | 0.333 |
| Age 4 | 0.525 | 0.200 | 1.00 | 0.72 | 0.48434 | 0.65260 | 385 | 365 | 0.190 |
| Age 5 | 0.503 | 0.200 | 1.00 | 0.70 | 0.49513 | 0.66232 | 465 | 365 | 0.113 |
| Age 6 | 0.490 | 0.200 | 1.00 | 0.69 | 0.50153 | 0.66802 | 521 | 365 | 0.069 |
| Age 7 | 0.481 | 0.200 | 1.00 | 0.68 | 0.50597 | 0.67195 | 558 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values (EPRI 2012, Table 5-78,egg/larvae for channel catfish) and from Lorenzen (1996) estimated M at mid-age weight for ages 1-7.

[b] Age-specific fishing from (EPRI 2012, Table 5-74).

[c] Assumed vulnerability to fishing from (EPRI 2012, Table 5-74).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for egg/larvae and YOY based on EPRI (2012, Table 5-75). Start weights for ages 1-7 included growth curve estimated lengths (Palomares 1991) converted to weight (Swingle 1965, Priegel 1966).

[h] Stage duration (days) on EPRI (2012).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Fecundity bases on estimated weights multiplied by mean relative fecundity of Black Bullhead (Novomesca and Kovac 2009).

k Maturity is based on ages reported by Kottelat and Freyhof (2007).

**Table A–9. Life history parameters for a Chain Pickerel population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 2.301 | 0.000 | 0.00 | 2.30 | 0.10016 | 0.18208 | 0.00094 | 18 | 0.000 |
| Larvae | 1.921 | 0.000 | 0.00 | 1.92 | 0.14646 | 0.25550 | 0.00094 | 30 | 4.173 |
| YOY | 3.554 | 0.000 | 0.00 | 3.55 | 0.02862 | 0.05565 | 0.06120 | 317 | 5.956 |
| Age 1 | 0.898 | 0.000 | 0.00 | 0.90 | 0.40758 | 0.57913 | 24 | 365 | 1.798 |
| Age 2 | 0.623 | 0.351 | 0.50 | 0.78 | 0.45669 | 0.62702 | 143 | 365 | 0.921 |
| Age 3 | 0.506 | 0.351 | 1.00 | 0.86 | 0.42433 | 0.59583 | 358 | 365 | 0.571 |
| Age 4 | 0.442 | 0.351 | 1.00 | 0.79 | 0.45245 | 0.62302 | 634 | 365 | 0.385 |
| Age 5 | 0.402 | 0.351 | 1.00 | 0.75 | 0.47072 | 0.64012 | 932 | 365 | 0.273 |
| Age 6 | 0.376 | 0.351 | 1.00 | 0.73 | 0.48323 | 0.65159 | 1,225 | 365 | 0.199 |
| Age 7 | 0.358 | 0.351 | 1.00 | 0.71 | 0.49212 | 0.65963 | 1,494 | 365 | 0.148 |
| Age 8 | 0.345 | 0.351 | 1.00 | 0.70 | 0.49860 | 0.66542 | 1,732 | 365 | 0.112 |
| Age 9 | 0.338 | 0.351 | 1.00 | 0.69 | 0.50187 | 0.66833 | 1,936 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates were based on daily survival rate estimates for eggs and larvae, compiled by Dahlburg (1979). Lorenzen (1996) relation was used to predict M from mid-age weight for ages 1-9.

[b] Age-specific fishing mortality inferred from Brokaw and Lucas (2008) observation that a 10-15% increase in harvest would lead to overfishing in Maine and the assumption that the overfishing threshold is when F=M. Therefore, fishing mortality was calculated as average M for fully recruited ages divided by 1.125.

[c] Vulnerability to fishing inferred from average size harvested in Maine (17" or 432mm) and growth curve predicting size at age, FishBase cited from Carlander (1969).

[d] Total instantaneous mortality $Z = -\ln(S)$.

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on FishBase reported growth in length from Carlander (1969) and weight-length relation (Herke 1959).

[h] Stage duration (days) for eggs and larvae from Dahlburg (1979).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity as linear relation with weight using endpoints of 936 eggs at age-1 predicted weight and 30,000 eggs at age-9 predicted weight; fecundity range from Jones *et al.* (1978).

[k] Maturity reported by age and size (Jones *et al.* 1978) .

**Table A–10. Life history parameters for a Common Shiner population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.183 | 0.000 | 0.00 | 0.18 | 0.83277 | 0.90875 | 0.00182 | 3 | 0.000 |
| Larvae | 2.562 | 0.000 | 0.00 | 2.56 | 0.07715 | 0.14325 | 0.00182 | 42 | 3.241 |
| YOY | 4.932 | 0.000 | 0.00 | 4.93 | 0.00721 | 0.01433 | 0.04650 | 320 | 2.666 |
| Age 1 | 2.511 | 0.000 | 0.00 | 2.51 | 0.08122 | 0.15024 | 1 | 365 | 1.515 |
| Age 2 | 1.960 | 0.000 | 0.00 | 1.96 | 0.14081 | 0.24686 | 3 | 365 | 0.631 |
| Age 3 | 1.729 | 0.000 | 0.00 | 1.73 | 0.17754 | 0.30155 | 6 | 365 | 0.316 |
| Age 4 | 1.623 | 0.000 | 0.00 | 1.62 | 0.19735 | 0.32964 | 8 | 365 | 0.279 |
| Age 5 | 1.482 | 0.000 | 0.00 | 1.48 | 0.22725 | 0.37034 | 10 | 365 | 0.210 |
| Age 6 | 1.403 | 0.000 | 0.00 | 1.40 | 0.24589 | 0.39472 | 13 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values from Emerald Shiner (EPRI 2012, Table 5-92,egg and larvae) and Lorenzen (1996) M relation at mid-age Emerald shiner weights for ages 1-6. Weights were linearly extrapolated to age 6 from Emerald shiner weight at age.

[b] No age-specific fishing mortality, assumed F=0.

[c] No vulnerability to fishing assumed.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based growth curve developed for Fuchs (1966) observed lengths and length-weight relationship from Atkinson *et al.* (2015) for Emerald Shiner.

[h] Stage duration (days) was based on EPRI (2012).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity bases on EPRI (2012, Table 5-91).

[k] Maturity is based on EPRI (2012, Table 5-91).

## Table A–11. Life history parameters for an Emerald Shiner population at equilibrium.

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ (=$2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.183 | 0.000 | 0.00 | 0.18 | 0.83277 | 0.90875 | 0.00182 | 3 | 0.000 |
| Larvae | 2.562 | 0.000 | 0.00 | 2.56 | 0.07715 | 0.14325 | 0.00182 | 42 | 3.241 |
| YOY | 3.953 | 0.000 | 0.00 | 3.95 | 0.01919 | 0.03766 | 0.04650 | 320 | 2.666 |
| Age 1 | 2.511 | 0.000 | 0.00 | 2.51 | 0.08122 | 0.15024 | 0.66883 | 365 | 1.515 |
| Age 2 | 1.960 | 0.000 | 0.00 | 1.96 | 0.14081 | 0.24686 | 3.04298 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on population dynamics of Emerald Shiner but limited to maximum age of about 2 years (Finger 2001).

[b] No age-specific fishing mortality, assumed F=0.

[c] No vulnerability to fishing assumed.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based growth curve developed for Fuchs (1966) observed lengths and length-weight relationship from Atkinson *et al.* (2015).

[h] Stage duration (days) was based on EPRI (2012, Table 5-92).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage *i*.

[j] Fecundity bases on EPRI (2012, Table 5-91).

[k] Maturity is based on EPRI (2012, Table 5-91).

**Table A–12. Life history parameters for a Fallfish population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ (=$2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 2.016 | 0.000 | 0.00 | 2.02 | 0.13319 | 0.23507 | 0.00182 | 6 | 0.000 |
| Larvae | 2.150 | 0.000 | 0.00 | 2.15 | 0.11648 | 0.20866 | 0.00182 | 50 | 3.241 |
| YOY | 2.710 | 0.000 | 0.00 | 2.71 | 0.06653 | 0.12475 | 0.04650 | 309 | 6.114 |
| Age 1 | 1.5 | 0.000 | 0.00 | 1.46 | 0.23227 | 0.37698 | 21 | 365 | 0.876 |
| Age 2 | 1.1 | 0.000 | 0.00 | 1.07 | 0.34265 | 0.51041 | 50 | 365 | 0.749 |
| Age 3 | 0.9 | 0.000 | 0.00 | 0.85 | 0.42585 | 0.59733 | 107 | 365 | 0.549 |
| Age 4 | 0.7 | 0.000 | 0.00 | 0.71 | 0.48938 | 0.65716 | 185 | 365 | 0.476 |
| Age 5 | 0.6 | 0.000 | 0.00 | 0.62 | 0.53889 | 0.70036 | 297 | 365 | 0.329 |
| Age 6 | 0.6 | 0.000 | 0.00 | 0.55 | 0.57527 | 0.73038 | 413 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values (EPRI 2012, Table 5-115 for eggs survival in Yellow Perch; Carlander (1997) for survival of Yellow Perch larvae. Lorenzen M at mid-age weight was used to determine M for ages 1-6.

[b] Age-specific fishing mortality was assumed to be zero (forage species).

[c] Vulnerability to fishing assumed zero.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on Victor and Brothers (1982) growth in length and length-weight conversion.

[h] Stage duration (days) was based on EPRI (2012, Table 5-115) for eggs (Yellow Perch), Muykaysen and Jawad (2012) for *Barbus Sharpeyi* larval duration.

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity from Hugg (1996) estimate of Fallfish fecundity.

[k] Maturity from Trial *et al.* (1983) - some fallfish reach maturity at age 2 or three and all by age 4.

**Table A–13. Life history parameters for a Golden Shiner population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.183 | 0.000 | 0.00 | 0.18 | 0.83277 | 0.90875 | 0.00182 | 3 | 0.000 |
| Larvae | 2.562 | 0.000 | 0.00 | 2.56 | 0.07715 | 0.14325 | 0.00182 | 42 | 3.241 |
| YOY | 8.859 | 0.000 | 0.00 | 8.86 | 0.00014 | 0.00028 | 0.04650 | 320 | 2.666 |
| Age 1 | 2.511 | 0.000 | 0.00 | 2.51 | 0.08122 | 0.15024 | 1 | 365 | 1.515 |
| Age 2 | 1.960 | 0.000 | 0.00 | 1.96 | 0.14081 | 0.24686 | 3 | 365 | 0.631 |
| Age 3 | 1.729 | 0.000 | 0.00 | 1.73 | 0.17754 | 0.30155 | 6 | 365 | 0.316 |
| Age 4 | 1.457 | 0.000 | 0.00 | 1.46 | 0.23290 | 0.37780 | 8 | 365 | 0.756 |
| Age 5 | 1.250 | 0.000 | 0.00 | 1.25 | 0.28637 | 0.44524 | 17 | 365 | 0.405 |
| Age 6 | 1.135 | 0.000 | 0.00 | 1.13 | 0.32143 | 0.48649 | 25 | 365 | 0.288 |
| Age 7 | 1.056 | 0.000 | 0.00 | 1.06 | 0.34794 | 0.51625 | 33 | 365 | 0.223 |
| Age 8 | 0.996 | 0.000 | 0.00 | 1.00 | 0.36919 | 0.53928 | 42 | 365 | 0.182 |
| Age 9 | 0.951 | 0.000 | 0.00 | 0.95 | 0.38639 | 0.55740 | 50 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates were based on daily survival rate estimates for eggs and larvae, compiled by Dahlburg (1979) and Lorenzen (1996) relation predicting M from mid-age weight for ages 1-9. Maximum age reported to nine years (Altman and Dittmer 1962).

[b] Age-specific fishing mortality assumed zero.

[c] No vulnerability to fishing assumed.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on Emerald Shiner and extrapolated for age 4-9.

[h] Stage duration (days) for eggs and larvae from EPRI (2012, Table 5-92).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity taken as the maximum reported by Huggs (1996).

[k] Maturity as reported for Emerald Shiner.

**Table A–14. Life history parameters for a Largemouth Bass population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 1.900 | 0.000 | 0.00 | 1.90 | 0.14957 | 0.26022 | 0.00077 | 5 | 0.000 |
| Larvae | 2.700 | 0.000 | 0.00 | 2.70 | 0.06721 | 0.12595 | 0.00077 | 10 | 3.594 |
| YOY | 4.560 | 0.000 | 0.00 | 4.56 | 0.01046 | 0.02071 | 0.02800 | 350 | 6.229 |
| Age 1 | 0.860 | 0.000 | 0.00 | 0.86 | 0.42316 | 0.59468 | 14 | 365 | 1.845 |
| Age 2 | 0.290 | 0.049 | 0.50 | 0.31 | 0.73037 | 0.84418 | 90 | 365 | 0.957 |
| Age 3 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 234 | 365 | 0.600 |
| Age 4 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 426 | 365 | 0.410 |
| Age 5 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 642 | 365 | 0.294 |
| Age 6 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 862 | 365 | 0.218 |
| Age 7 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1072 | 365 | 0.164 |
| Age 8 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1263 | 365 | 0.126 |
| Age 9 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1432 | 365 | 0.098 |
| Age 10 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1579 | 365 | 0.076 |
| Age 11 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1704 | 365 | 0.060 |
| Age 12 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1809 | 365 | 0.047 |
| Age 13 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1896 | 365 | 0.037 |
| Age 14 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 1968 | 365 | 0.030 |
| Age 15 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 2028 | 365 | 0.024 |
| Age 16 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 2076 | 365 | 0.019 |
| Age 17 | 0.261 | 0.049 | 1.00 | 0.31 | 0.73345 | 0.84623 | 2115 | 365 | 0.000 |

YOY= young of the year

[a] Egg and larval instantaneous mortality rate was based on bass species (*Micropterus* sp.) (USEPA 2004). YOY mortality was adjusted to balance the life history table assuming population is at equilibrium by subtracting mortalities for eggs, larvae, and Age 1 from the total mortality from egg to Age 12 = 2/ *f*a where *f*a =lifetime average fecundity (Saila *et al.* 1997; EPRI 2012). Age-1 natural mortality was based on USEPA (2004). Instantaneous fishing mortality (F=0.049) was based on apportioning Z (=0.315) from a catch-curve estimate equivalent to a constant 73% survival for Ages 2-12 (Odenkirk 2016) by subtraction of instantaneous natural mortality (M), which was equally estimated as a constant natural mortality (=0.261) over Ages 2-12 using Hoenig's equation (1983), $Log_e(M)=1.44-0.982(Log_e(t_{max}))$ where the theoretical maximum age ($t_{max}$) for Virginia reservoirs is accepted as 17 years of age (DiCenzo and Garren 2001). Mortality rates for Ages 13-17 were assumed equal to Ages 2-12.

[b] Age-specific fishing mortality was based on based on total survival of 73% (Odenkirk 2016) and the average contribution of M and F to Z from USEPA (2004).

[c] Vulnerability to fishing based on USEPA (2004).

[d] Total instantaneous mortality Z = M+F

[e] $S_i$ = Probability of survival of stage *i* to the next stage = $e^{-Z}$

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on smallmouth bass for eggs, larvae, and YOY (EPRI (2012) and converted lengths-at-age (Beamesderfer and North 1995) using length-weight relation (Saila and Horton 1957).

[h] Stage duration (days) was based on Stuber *et al.* (1982) and EPRI (2012) information on smallmouth bass.

[i] Growth rate (G) was estimated as Loge(Wi+1/Wi) where $W_i$ is the weight at start of stage i.

[j] Mean fecundity for Ages 3-10 based on Figure 7 in Brown and Maceina (2002); Age 2 was estimated as half of Age 3 fecundity, and Ages 11-12 were based on the fitted trend of the Age 3-10 data given by Fecundity=29731Log(age)-31746.

[k] Proportion at age that are sexually mature was based size and age expected to be first mature (assumed 50%) from Odenkirk (2016).

**Table A–15. Life history parameters for a Margined Madtom population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.109 | 0.000 | 0.00 | 0.11 | 0.89702 | 0.94571 | 0.00180 | 13 | 0.000 |
| Larvae | 0.142 | 0.000 | 0.00 | 0.14 | 0.86752 | 0.92906 | 0.00180 | 17 | 0.000 |
| YOY | 4.020 | 0.000 | 0.00 | 4.02 | 0.01795 | 0.03527 | 0.00180 | 335 | 7.704 |
| Age 1 | 1.504 | 0.000 | 0.00 | 1.50 | 0.22224 | 0.36366 | 4 | 365 | 1.007 |
| Age 2 | 1.297 | 0.000 | 0.00 | 1.30 | 0.27336 | 0.42936 | 11 | 365 | 0.527 |
| Age 3 | 1.187 | 0.000 | 0.00 | 1.19 | 0.30516 | 0.46762 | 19 | 365 | 0.308 |
| Age 4 | 1.119 | 0.000 | 0.00 | 1.12 | 0.32668 | 0.49248 | 25 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values (EPRI 2012, Table 5-92, Slimy Sculpin egg and larvae); and Lorenzen (1996) M for mid-age weights, ages 1-4.

[b] No fishing assumed for this group.

[c] No vulnerability to fishing assumed for this group.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on EPRI (2012, Table 5-92 for Slimy Sculpin eggs, larvae; for ages 1-4 from Conard (2015) study of Northern Madtom in Michigan).

[h] Stage duration (days) from Simon and Burr (2004) for Stoncats egg stage. Larval stage duration from Northern Madtom study (Scheibly *et al.* 2008).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity from maximum eggs seen in Northern Madton study (Scheibly *et al.* 2008).

[k] Maturity reported for Northern Madtom at 60mm study (Scheibly *et al.* 2008)., implying full maturity at age 1.

**Table A–16. Life history parameters for a Pumpkinseed population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.044 | 0.000 | 0.00 | 0.04 | 0.95676 | 0.97790 | 0.00094 | 2 | 0.000 |
| Larvae | 2.338 | 0.000 | 0.00 | 2.34 | 0.09652 | 0.17605 | 0.00094 | 28 | 4.173 |
| YOY | 4.875 | 0.000 | 0.00 | 4.87 | 0.00764 | 0.01516 | 0.06120 | 335 | 4.442 |
| Age 1 | 1.264 | 0.000 | 0.00 | 1.26 | 0.28248 | 0.44052 | 5 | 365 | 1.907 |
| Age 2 | 0.918 | 0.223 | 1.00 | 1.14 | 0.31948 | 0.48425 | 35 | 365 | 0.914 |
| Age 3 | 0.758 | 0.223 | 1.00 | 0.98 | 0.37471 | 0.54515 | 87 | 365 | 0.541 |
| Age 4 | 0.671 | 0.223 | 1.00 | 0.89 | 0.40890 | 0.58045 | 150 | 365 | 0.350 |
| Age 5 | 0.618 | 0.223 | 1.00 | 0.84 | 0.43116 | 0.60253 | 213 | 365 | 0.238 |
| Age 6 | 0.583 | 0.223 | 1.00 | 0.81 | 0.44624 | 0.61710 | 270 | 365 | 0.167 |
| Age 7 | 0.557 | 0.223 | 1.00 | 0.78 | 0.45829 | 0.62853 | 319 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on Bluegill found elsewhere in this workbook.

[b] Age-specific fishing derived from Crawford and Allen (2006) catch-curve and tag-recapture studies in Florida lake.

[c] Vulnerability to fishing inferred from Crawford and Allen (2006) observation of near-constant exploitation larger than 13cm and this size representative of age 2 (Jackson *et al.* 2008).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based multiple studies reviewed in EPRI (2012, Table 5-122).

[h] Stage duration (days) was based on EPRI (2012, Table 5-121).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Mean fecundity calculated from length-at-age using Paneck and Cofield (1978) length-fecundity relation.

[k] Maturity taken from EPRI (2012, Table 5-123).

**Table A–17. Life history parameters for a Rainbow Smelt population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 3.480 | 0.000 | 0.00 | 3.48 | 0.03081 | 0.05977 | 0.00086 | 20 | 0.000 |
| Larvae | 2.340 | 0.000 | 0.00 | 2.34 | 0.09633 | 0.17573 | 0.00086 | 90 | 4.238 |
| YOY | 2.420 | 0.000 | 0.00 | 2.42 | 0.08892 | 0.16331 | 0.05980 | 255 | 3.153 |
| Age 1 | 1.583 | 0.000 | 0.00 | 1.58 | 0.20531 | 0.34067 | 1 | 365 | 2.497 |
| Age 2 | 1.257 | 0.016 | 1.00 | 1.27 | 0.28000 | 0.43750 | 17 | 365 | 0.345 |
| Age 3 | 1.041 | 0.232 | 1.00 | 1.27 | 0.28000 | 0.43750 | 24 | 365 | 0.829 |
| Age 4 | 0.914 | 0.359 | 1.00 | 1.27 | 0.28000 | 0.43750 | 55 | 365 | 0.227 |
| Age 5 | 0.857 | 0.416 | 1.00 | 1.27 | 0.28000 | 0.43750 | 69 | 365 | 0.220 |
| Age 6 | 0.757 | 0.516 | 1.00 | 1.27 | 0.28000 | 0.43750 | 86 | 365 | 0.576 |
| Age 7 | 0.683 | 0.590 | 1.00 | 1.27 | 0.28000 | 0.43750 | 153 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values (EPRI 2012, Table 5-101) for eggs and larvae and using mid-age weights and the Lorenzen (1996) M function for ages 1-7.

[b] Age-specific fishing mortality was calculated as Z-M.

[c] Vulnerability to fishing assumed complete at age 2 (Murawski and Cole 1978).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on EPRI (2012, Table 5-101).

[h] Stage duration (days) and maturity was based on EPRI (2012, Table 5-101).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity from USEPA (2012, Table 5-101).

[k] Maturity from USEPA (2012, Table 5-101).

**Table A–18. Life history parameters for a Redbreast Sunfish population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.044 | 0.000 | 0.00 | 0.04 | 0.95676 | 0.97790 | 0.00094 | 2 | 0.000 |
| Larvae | 2.338 | 0.000 | 0.00 | 2.34 | 0.09652 | 0.17605 | 0.00094 | 28 | 4.173 |
| YOY | 4.875 | 0.000 | 0.00 | 4.87 | 0.00764 | 0.01516 | 0.06120 | 335 | 4.442 |
| Age 1 | 1.264 | 0.000 | 0.00 | 1.26 | 0.28248 | 0.44052 | 5 | 365 | 1.907 |
| Age 2 | 0.918 | 0.223 | 1.00 | 1.14 | 0.31948 | 0.48425 | 35 | 365 | 0.914 |
| Age 3 | 0.758 | 0.223 | 1.00 | 0.98 | 0.37471 | 0.54515 | 87 | 365 | 0.541 |
| Age 4 | 0.671 | 0.223 | 1.00 | 0.89 | 0.40890 | 0.58045 | 150 | 365 | 0.350 |
| Age 5 | 0.618 | 0.223 | 1.00 | 0.84 | 0.43116 | 0.60253 | 213 | 365 | 0.238 |
| Age 6 | 0.583 | 0.223 | 1.00 | 0.81 | 0.44624 | 0.61710 | 270 | 365 | 0.167 |
| Age 7 | 0.557 | 0.223 | 1.00 | 0.78 | 0.45829 | 0.62853 | 319 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on Bluegill found elsewhere in this workbook.

[b] Age-specific fishing derived from Crawford and Allen (2006) catch-curve and tag-recapture studies in Florida lake.

[c] Vulnerability to fishing inferred from Crawford and Allen (2006) observation of near-constant exploitation larger than 13cm and this size representative of age 2 (Jackson *et al.* 2008).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based multiple studies reviewed in EPRI (2012, Table 5-122).

[h] Stage duration (days) was based on EPRI (2012, Table 5-121).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Mean fecundity calculated from length-at-age using Paneck and Cofield (1978) length-fecundity relation.

[k] Maturity taken fr om EPRI (2012, Table 5-123).

## Table A–19. Life history parameters for a Rock Bass population at equilibrium.

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.044 | 0.000 | 0.00 | 0.04 | 0.95676 | 0.97790 | 0.00094 | 2 | 0.000 |
| Larvae | 2.338 | 0.000 | 0.00 | 2.34 | 0.09652 | 0.17605 | 0.00094 | 28 | 4.173 |
| YOY | 4.875 | 0.000 | 0.00 | 4.87 | 0.00764 | 0.01516 | 0.06120 | 335 | 4.442 |
| Age 1 | 1.264 | 0.000 | 0.00 | 1.26 | 0.28248 | 0.44052 | 5 | 365 | 1.907 |
| Age 2 | 0.918 | 0.223 | 1.00 | 1.14 | 0.31948 | 0.48425 | 35 | 365 | 0.914 |
| Age 3 | 0.758 | 0.223 | 1.00 | 0.98 | 0.37471 | 0.54515 | 87 | 365 | 0.541 |
| Age 4 | 0.671 | 0.223 | 1.00 | 0.89 | 0.40890 | 0.58045 | 150 | 365 | 0.350 |
| Age 5 | 0.618 | 0.223 | 1.00 | 0.84 | 0.43116 | 0.60253 | 213 | 365 | 0.238 |
| Age 6 | 0.583 | 0.223 | 1.00 | 0.81 | 0.44624 | 0.61710 | 270 | 365 | 0.167 |
| Age 7 | 0.557 | 0.223 | 1.00 | 0.78 | 0.45829 | 0.62853 | 319 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on Bluegill found elsewhere in this workbook.

[b] Age-specific fishing derived from Crawford and Allen (2006) catch-curve and tag-recapture studies in Florida lake.

[c] Vulnerability to fishing inferred from Crawford and Allen (2006) observation of near-constant exploitation larger than 13cm and this size representative of age 2 (Jackson *et al.* 2008).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based multiple studies reviewed in EPRI (2012, Table 5-122).

[h] Stage duration (days) was based on EPRI (2012, Table 5-121).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Mean fecundity calculated from length-at-age using Paneck and Cofield (1978) length-fecundity relation.

[k] Maturity taken from EPRI (2012, Table 5-123).

**Table A–20. Life history parameters for a Smallmouth Bass population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ (=$2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.060 | 0.000 | 0.00 | 0.06 | 0.94176 | 0.97001 | 0.00077 | 5 | 0.000 |
| Larvae | 0.695 | 0.000 | 0.00 | 0.70 | 0.49885 | 0.66564 | 0.00077 | 10 | 3.594 |
| YOY | 7.858 | 0.000 | 0.00 | 7.86 | 0.00039 | 0.00077 | 0.02800 | 350 | 5.521 |
| Age 1 | 0.702 | 0.000 | 0.00 | 0.70 | 0.49562 | 0.66276 | 7 | 365 | 1.966 |
| Age 2 | 0.584 | 0.000 | 0.00 | 0.58 | 0.55764 | 0.71600 | 50 | 365 | 1.051 |
| Age 3 | 0.510 | 0.390 | 0.50 | 0.69 | 0.50342 | 0.66970 | 143 | 365 | 0.686 |
| Age 4 | 0.460 | 0.390 | 1.00 | 0.85 | 0.42721 | 0.59866 | 284 | 365 | 0.489 |
| Age 5 | 0.425 | 0.390 | 1.00 | 0.82 | 0.44254 | 0.61356 | 463 | 365 | 0.365 |
| Age 6 | 0.399 | 0.390 | 1.00 | 0.79 | 0.45420 | 0.62468 | 667 | 365 | 0.281 |
| Age 7 | 0.379 | 0.390 | 1.00 | 0.77 | 0.46328 | 0.63320 | 883 | 365 | 0.221 |
| Age 8 | 0.364 | 0.390 | 1.00 | 0.75 | 0.47044 | 0.63986 | 1101 | 365 | 0.178 |
| Age 9 | 0.352 | 0.390 | 1.00 | 0.74 | 0.47616 | 0.64514 | 1315 | 365 | 0.144 |
| Age 10 | 0.344 | 0.390 | 1.00 | 0.73 | 0.47979 | 0.64846 | 1518 | 365 | 0.117 |
| Age 11 | 0.340 | 0.390 | 1.00 | 0.73 | 0.48172 | 0.65022 | 1707 | 365 | 0.097 |
| Age 12 | 0.333 | 0.390 | 1.00 | 0.72 | 0.48546 | 0.65361 | 1880 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates for eggs and larvae were based on an equilibrium population (EPRI 2012,Table 5-119). For ages 1-12, estimates of M were made using Lorenzen (1996) relation with mid-age weight.

[b] Age-specific fishing mortality from EPRI (2012, Table 5-118).

[c] Vulnerability to fishing from EPRI (2012, Table 5-118).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on EPRI (2012, Table 5-119).

[h] Stage duration (days) was based on EPRI (2012 Table 5-119).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity was based on Scott and Crossman (1998) fecundity range and assumption of linear relation between fecundity and weight.

[k] Maturity was based on EPRI (2012 Table 5-119).

**Table A–21. Life history parameters for a Spottail Shiner population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.183 | 0.000 | 0.00 | 0.18 | 0.83277 | 0.90875 | 0.00182 | 3 | 0.000 |
| Larvae | 2.562 | 0.000 | 0.00 | 2.56 | 0.07715 | 0.14325 | 0.00182 | 42 | 3.241 |
| YOY | 3.966 | 0.000 | 0.00 | 3.97 | 0.01896 | 0.03721 | 0.04650 | 320 | 2.666 |
| Age 1 | 2.511 | 0.000 | 0.00 | 2.51 | 0.08122 | 0.15024 | 0.7 | 365 | 1.515 |
| Age 2 | 1.960 | 0.000 | 0.00 | 1.96 | 0.14081 | 0.24686 | 3.0 | 365 | 0.631 |
| Age 3 | 1.729 | 0.000 | 0.00 | 1.73 | 0.17754 | 0.30155 | 5.7 | 365 | 0.316 |
| Age 4 | 1.623 | 0.000 | 0.00 | 1.62 | 0.19735 | 0.32964 | 7.8 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on Emerald Shiner.

[b] No age-specific fishing mortality, assumed F=0.

[c] No vulnerability to fishing assumed.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based growth curve developed for Fuchs (1966) observed lengths and length-weight relationship from Atkinson *et al.* (2015).

[h] Stage duration (days) was based on EPRI (2012).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity bases on EPRI (2012, Table 5-91).

[k] Maturity is based on EPRI (2012, Table 5-91).

**Table A–22. Life history parameters for a Tessellated Darter population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.183 | 0.000 | 0.00 | 0.18 | 0.83277 | 0.90875 | 0.00182 | 3 | 0.000 |
| Larvae | 2.562 | 0.000 | 0.00 | 2.56 | 0.07715 | 0.14325 | 0.00182 | 42 | 3.241 |
| YOY | 3.178 | 0.000 | 0.00 | 3.18 | 0.04166 | 0.07998 | 0.04650 | 320 | 2.893 |
| Age 1 | 2.572 | 0.000 | 0.00 | 2.57 | 0.07635 | 0.14186 | 1 | 365 | 0.753 |
| Age 2 | 2.180 | 0.000 | 0.00 | 2.18 | 0.11300 | 0.20306 | 2 | 365 | 0.478 |
| Age 3 | 1.957 | 0.000 | 0.00 | 1.96 | 0.14131 | 0.24762 | 3 | 365 | 0.307 |
| Age 4 | 1.832 | 0.000 | 0.00 | 1.83 | 0.16005 | 0.27593 | 4 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values (EPRI 2012, Table 5-92, for Emerald shiner egg and larvae) and Lorenzen (1996) M relation at mid-age weight (derived from Layzer and Reed (1972)) Tessellated darter back-calculated sizes) for ages 1-4.

[b] No fishing assumed for this group.

[c] No vulnerability to fishing assumed for this group.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights from weights calculated for Layzer and Reed (1972) average back-calculated size at age for tessellated darter, using Emerald shiner length weight relation reported in Carlander (1969).

[h] Stage duration (days) based on Emerald shiner from EPRI (2012).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity from maximum eggs in Tsai (1972) for Eastern Johnny Darter.

[k] Maturity is derived from Gilbert (1992) reported maturity at 40 mm TL for Tessellated Darter.

## Table A–23. Life history parameters for a Walleye population at equilibrium.

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 2.622 | 0.000 | 0.00 | 2.62 | 0.07266 | 0.13547 | 0.00055 | 6 | 0.000 |
| Larvae | 6.400 | 0.000 | 0.00 | 6.40 | 0.00166 | 0.00332 | 0.00055 | 25 | 3.776 |
| YOY | 1.968 | 0.000 | 0.00 | 1.97 | 0.13980 | 0.24531 | 0.02400 | 334 | 7.927 |
| Age 1 | 0.607 | 0.000 | 0.00 | 0.61 | 0.54480 | 0.70534 | 67 | 365 | 1.903 |
| Age 2 | 0.448 | 0.000 | 0.00 | 0.45 | 0.63867 | 0.77950 | 446 | 365 | 0.831 |
| Age 3 | 0.380 | 0.250 | 0.50 | 0.50 | 0.60820 | 0.75638 | 1024 | 365 | 0.437 |
| Age 4 | 0.341 | 0.250 | 1.00 | 0.59 | 0.55354 | 0.71261 | 1586 | 365 | 0.327 |
| Age 5 | 0.315 | 0.250 | 1.00 | 0.56 | 0.56855 | 0.72494 | 2200 | 365 | 0.251 |
| Age 6 | 0.295 | 0.250 | 1.00 | 0.54 | 0.57997 | 0.73415 | 2827 | 365 | 0.207 |
| Age 7 | 0.280 | 0.250 | 1.00 | 0.53 | 0.58833 | 0.74082 | 3478 | 365 | 0.144 |
| Age 8 | 0.269 | 0.250 | 1.00 | 0.52 | 0.59507 | 0.74613 | 4017 | 365 | 0.144 |
| Age 9 | 0.260 | 0.250 | 1.00 | 0.51 | 0.60040 | 0.75032 | 4638 | 365 | 0.094 |
| Age 10 | 0.258 | 0.250 | 1.00 | 0.51 | 0.60193 | 0.75151 | 5093 | 365 | -0.023 |
| Age 11 | 0.258 | 0.250 | 1.00 | 0.51 | 0.60167 | 0.75130 | 4975 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates for eggs and larvae were based on an equilibrium population (EPRI 2012,Table 5-117). For ages 1-11, estimates of M were made using Lorenzen (1996) relation with mid-age weight.

[b] Age-specific fishing mortality from EPRI (2012, Table 5-116).

[c] Vulnerability to fishing from EPRI (2012, Table 5-116).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on EPRI (2012, Table 5-117).

[h] Stage duration (days) was based on EPRI (2012 Table 5-117).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity was based on EPRI (2012 Table 5-117).

[k] Maturity was based on EPRI (2012 Table 5-117).

**Table A–24. Life history parameters for a White Perch population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 3.120 | 0.000 | 0.00 | 3.12 | 0.04416 | 0.08458 | 0.00037 | 4 | 0.000 |
| Larvae | 5.120 | 0.000 | 0.00 | 5.12 | 0.00598 | 0.01188 | 0.00037 | 30 | 5.946 |
| YOY | 1.779 | 0.000 | 0.00 | 1.78 | 0.16873 | 0.28874 | 0.14300 | 331 | 3.990 |
| Age 1 | 0.630 | 0.000 | 0.00 | 0.63 | 0.53259 | 0.69502 | 8 | 365 | 0.945 |
| Age 2 | 0.640 | 0.150 | 0.10 | 0.65 | 0.51995 | 0.68417 | 20 | 365 | 0.681 |
| Age 3 | 0.630 | 0.150 | 0.20 | 0.66 | 0.51775 | 0.68226 | 39 | 365 | 0.523 |
| Age 4 | 0.630 | 0.150 | 0.40 | 0.69 | 0.50292 | 0.66925 | 66 | 365 | 0.419 |
| Age 5 | 0.640 | 0.150 | 0.50 | 0.71 | 0.49057 | 0.65823 | 101 | 365 | 0.345 |
| Age 6 | 0.630 | 0.150 | 0.60 | 0.72 | 0.48808 | 0.65599 | 142 | 365 | 0.290 |
| Age 7 | 0.630 | 0.150 | 0.84 | 0.75 | 0.47028 | 0.63971 | 190 | 365 | 0.248 |
| Age 8 | 0.630 | 0.150 | 1.00 | 0.78 | 0.45841 | 0.62864 | 244 | 365 | 0.214 |
| Age 9 | 0.630 | 0.150 | 1.00 | 0.78 | 0.45841 | 0.62864 | 302 | 365 | 0.187 |
| Age 10 | 0.630 | 0.150 | 1.00 | 0.78 | 0.45841 | 0.62864 | 365 | 365 | 0.000 |

YOY= young of the year

[a] Natural instantaneous mortality rates for eggs, larvae, and age 1-11 were based on an equilibrium population (EPRI 2012,Table 5-26 and Table 5-27).

[b] Age-specific fishing mortality from EPRI (2012, Table 5-26).

[c] Vulnerability to fishing from EPRI (2012, Table 5-26).

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on EPRI (2012, Table 5-28).

[h] Stage duration (days) was based on EPRI (2012 Table 5-28).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity was based on EPRI (2012 Table 5-28).

[k] Maturity was based on EPRI (2012 Table 5-28).

**Table A–25. Life history parameters for a White Sucker population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 0.552 | 0.000 | 0.00 | 0.55 | 0.57580 | 0.73080 | 1.80E-03 | 4 | 0.00000 |
| Larvae | 6.348 | 0.000 | 0.00 | 6.35 | 0.00175 | 0.00349 | 1.80E-03 | 46 | 1.41218 |
| YOY | 2.610 | 0.000 | 0.00 | 2.61 | 0.07356 | 0.13704 | 4.65E-02 | 315 | 1.43053 |
| Age 1 | 0.505 | 0.000 | 0.00 | 0.51 | 0.60345 | 0.75269 | 1 | 365 | 1.89015 |
| Age 2 | 0.382 | 0.000 | 0.00 | 0.38 | 0.68226 | 0.81112 | 97 | 365 | 0.22090 |
| Age 3 | 0.337 | 0.000 | 0.00 | 0.34 | 0.71377 | 0.83298 | 162 | 365 | 0.16943 |
| Age 4 | 0.306 | 0.000 | 0.00 | 0.31 | 0.73632 | 0.84814 | 239 | 365 | 0.12935 |
| Age 5 | 0.284 | 0.000 | 0.00 | 0.28 | 0.75267 | 0.85888 | 322 | 365 | 0.09907 |
| Age 6 | 0.268 | 0.000 | 0.00 | 0.27 | 0.76470 | 0.86666 | 404 | 365 | 0.07642 |
| Age 7 | 0.257 | 0.000 | 0.00 | 0.26 | 0.77370 | 0.87241 | 482 | 365 | 0.05940 |
| Age 8 | 0.248 | 0.000 | 0.00 | 0.25 | 0.78053 | 0.87674 | 553 | 365 | 0.00000 |

YOY= young of the year

[a] Egg and larval instantaneous mortality rate was Sucker family life history found elsewhere in the workbook.

[b] No fishing assumed for this group though some catastomids are harvested for bait.

[c] No vulnerability to fishing assumed for this group.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage = $e^{-Z}$

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on growth and length-weight relations reported for black and shorthead redhorse (Reid 2009).

[h] Stage duration (days) from USEPA (2012, Table 5-106) for shorthead redhorse.

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Mean fecundity for was taken as a linear relation with predicted weight, starting at 5,000 eggs for age 3 and 59,000 for age 17 (Begley *et al.* 2017).

[k] Proportion at age that are sexually mature was based Begley *et al.* (2017) White Sucker age at maturity.

**Table A–26. Life history parameters for a Yellow Bullhead population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 1.104 | 0.000 | 0.00 | 1.10 | 0.33154 | 0.49798 | 0.00170 | 8 | 0.000 |
| Larvae | 3.174 | 0.000 | 0.00 | 3.17 | 0.04184 | 0.08031 | 0.00170 | 23 | 3.298 |
| YOY | 4.322 | 0.000 | 0.00 | 4.32 | 0.01327 | 0.02620 | 0.04600 | 334 | 6.663 |
| Age 1 | 0.817 | 0.000 | 0.00 | 0.82 | 0.44196 | 0.61300 | 36 | 365 | 1.408 |
| Age 2 | 0.642 | 0.100 | 0.50 | 0.69 | 0.50129 | 0.66782 | 147 | 365 | 0.627 |
| Age 3 | 0.565 | 0.100 | 1.00 | 0.66 | 0.51450 | 0.67943 | 276 | 365 | 0.333 |
| Age 4 | 0.525 | 0.100 | 1.00 | 0.62 | 0.53528 | 0.69731 | 385 | 365 | 0.190 |
| Age 5 | 0.503 | 0.100 | 1.00 | 0.60 | 0.54720 | 0.70735 | 465 | 365 | 0.113 |
| Age 6 | 0.490 | 0.100 | 1.00 | 0.59 | 0.55427 | 0.71323 | 521 | 365 | 0.069 |
| Age 7 | 0.481 | 0.100 | 1.00 | 0.58 | 0.55918 | 0.71728 | 558 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on Brown Bullhead found elsewhere in workbook.

[b] Age-specific fishing assumed zero.

[c] Assumed no vulnerability to fishing.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability and maturity associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for egg/larvae and YOY based on EPRI (2012, Table 5-78). Start weights for ages 1-7 included growth curve estimated lengths (Palomares 1991) converted to weight (Swingle 1965, Priegel 1966).

[h] Stage duration (days) on EPRI (2012).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity bases on estimated weights multiplied by mean relative fecundity (Novomesca and Kovac 2009).

k Maturity is based on ages reported by Kottelat and Freyhof (2007).

**Table A–27. Life history parameters for a Yellow Perch population at equilibrium.**

| Stage | $M_i$[a] | $F_i$[b] | Fraction Vulnerable to Fishing[c] (v) | $Z_i$[d] | $S_i$[e] | Adjusted[f] $S_i$ ($=2Se^{-Ln(1+S)}$) | Start Weight[g] (g) | Duration[h] (days) | Instant. Growth Rate[i] |
|---|---|---|---|---|---|---|---|---|---|
| Egg | 2.016 | 0.000 | 0.00 | 2.02 | 0.13319 | 0.23507 | 0.00057 | 6 | 0.000 |
| Larvae | 4.925 | 0.000 | 0.00 | 4.93 | 0.00726 | 0.01442 | 0.00057 | 25 | 4.623 |
| YOY | 1.158 | 0.000 | 0.00 | 1.16 | 0.31407 | 0.47801 | 0.05800 | 334 | 5.056 |
| Age 1 | 1.102 | 0.000 | 0.000 | 1.10 | 0.33213 | 0.49864 | 9 | 365 | 1.810 |
| Age 2 | 0.826 | 0.016 | 1.000 | 0.84 | 0.43070 | 0.60208 | 56 | 365 | 0.772 |
| Age 3 | 0.707 | 0.232 | 1.000 | 0.94 | 0.39071 | 0.56189 | 120 | 365 | 0.411 |
| Age 4 | 0.647 | 0.359 | 1.000 | 1.01 | 0.36570 | 0.53554 | 181 | 365 | 0.238 |
| Age 5 | 0.613 | 0.416 | 1.000 | 1.03 | 0.35739 | 0.52658 | 230 | 365 | 0.145 |
| Age 6 | 0.593 | 0.516 | 1.000 | 1.11 | 0.32976 | 0.49597 | 266 | 365 | 0.089 |
| Age 7 | 0.577 | 0.590 | 1.000 | 1.17 | 0.31132 | 0.47482 | 291 | 365 | 0.000 |

YOY= young of the year

[a] Instantaneous mortality rates were based on an literature-derived values (EPRI 2012, Table 5-115,egg and larvae; Lorenzen M at mid-age weight for ages 1-7). Carlander (1997) mean larval Z used.

[b] Age-specific fishing mortality was assumed equal to that of Rainbow Smelt.

[c] Vulnerability to fishing assumed equal to that of Rainbow Smelt.

[d] Total instantaneous mortality Z = -ln(S).

[e] $S_i$ = Probability of survival of stage *i* to the next stage accounting for vulnerability associated mortality.

[f] Adjustment to the survival for the stage at which entrainment occurs to account for multiple ages within a stage, with the assumption of equal vulnerability throughout a stage (EPRI 2012).

[g] Start weights for based on EPRI (2012, Table 5-115).

[h] Stage duration (days) and maturity was based on EPRI (2012, Table 5-115).

[i] Growth rate (G) was estimated as $Log_e(W_{i+1}/W_i)$ where $W_i$ is the weight at start of stage i.

[j] Fecundity from USEPA (2012) cited relation, $\log_{10}F = 1.88057 + 1.10369\log_{10}W$

[k] Maturity from USEPA (2012, Table 5-115).

# Appendix B. Monthly Impingement Estimates

**Table B–1. Estimated monthly impingement abundance (number) at Merrimack Station, Units 1 and 2 combined, under the existing cooling water intake structure (CWIS , 3-mm wedgewire half screen (WWS) and closed-cycle cooling towers based on 10-year (2007-2016) actual intake flow (AIF), 100% capacity factor at design intake flow (DIF) and 50% capacity factor at 50% DIF.**

**10-year AIF, Existing CWIS**

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 5 | | | | | | | | | | | 5 |
| Banded Sunfish | | | | 8 | 3 | | | | | | | | 12 |
| Black Crappie | | | | 7 | 23 | 2 | | | 10 | 17 | 25 | 19 | 104 |
| Bluegill | 5 | | 31 | | 70 | 904 | 55 | 6 | 7 | 7 | 21 | 55 | 1,161 |
| Brown Bullhead | | | | | | 7 | 7 | | | | | | 14 |
| Chain Pickerel | 14 | | | | | | | | | | | | 14 |
| Fallfish | 26 | | | | | | | | | | | | 26 |
| Golden Shiner | 6 | | 10 | 7 | 3 | 5 | 3 | | | | 1 | | 35 |
| Largemouth Bass | | 17 | | | | 5 | 6 | | | 16 | 22 | 10 | 77 |
| Margined Madtom | 14 | | 18 | 18 | 8 | 21 | 2 | | | 2 | | | 83 |
| Pumpkinseed | | | 6 | | 18 | 14 | | | | 17 | 9 | 15 | 79 |
| Rainbow Smelt | 19 | 22 | | | | | | | | | | 36 | 77 |
| Redbreast Sunfish | | | 6 | | 3 | 5 | | | 6 | | | | 20 |
| Rock Bass | | | | | | 6 | | | | | | 8 | 14 |
| Smallmouth Bass | | | 6 | | | 2 | 7 | 3 | | | 3 | 3 | 24 |
| Spottail Shiner | 48 | 22 | 5 | | 3 | 9 | 11 | | | 2 | 1 | 195 | 296 |
| Tessellated Darter | | | 32 | | | | 2 | | | | | | 35 |
| White Perch | 5 | | | | | | | | | | 1 | | 6 |
| White Sucker | | | | | | 2 | 8 | | | | | | 10 |
| Yellow Bullhead | | | 11 | | | | 3 | | | | | | 14 |
| Yellow Perch | 27 | | 45 | | 5 | 8 | | | | | | 94 | 180 |
| Total | 164 | 66 | 171 | 41 | 135 | 993 | 105 | 9 | 22 | 62 | 83 | 435 | 2,285 |

**10-year AIF, 3-mm WWS**

| Species | Jan | Feb | Mar | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 5 | | | | | | | 5 |
| Black Crappie | | | | | 10 | 17 | 25 | 19 | 72 |
| Bluegill | 5 | | 31 | 6 | 7 | 7 | 21 | 55 | 132 |
| Chain Pickerel | 14 | | | | | | | | 14 |
| Fallfish | 26 | | | | | | | | 26 |
| Golden Shiner | 6 | | 10 | | | | 1 | | 17 |
| Largemouth Bass | | 17 | | | | 16 | 22 | 10 | 66 |
| Margined Madtom | 14 | | 18 | | | 2 | | | 34 |
| Pumpkinseed | | | 6 | | | 17 | 9 | 15 | 47 |
| Rainbow Smelt | 19 | 22 | | | | | | 36 | 77 |
| Redbreast Sunfish | | | 6 | | 6 | | | | 12 |
| Rock Bass | | | | | | | | 8 | 8 |
| Smallmouth Bass | | | 6 | 3 | | | 3 | 3 | 15 |
| Spottail Shiner | 48 | 22 | 5 | | | 2 | 1 | 195 | 273 |
| Tessellated Darter | | | 32 | | | | | | 32 |
| White Perch | 5 | | | | | | 1 | | 6 |
| Yellow Bullhead | | | 11 | | | | | | 11 |
| Yellow Perch | 27 | | 45 | | | | | 94 | 166 |
| Total | 164 | 66 | 171 | 9 | 22 | 62 | 83 | 435 | 1,012 |

**10-year AIF, Cooling Towers**

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | <1 | | | | | | | | | | | <1 |
| Banded Sunfish | | | | <1 | <1 | | | | | | | | 1 |
| Black Crappie | | | | <1 | 1 | <1 | | | <1 | 1 | 1 | 1 | 5 |
| Bluegill | <1 | | 2 | | 3 | 45 | 3 | <1 | <1 | <1 | 1 | 3 | 58 |
| Brown Bullhead | | | | | | <1 | <1 | | | | | | 1 |
| Chain Pickerel | 1 | | | | | | | | | | | | 1 |
| Fallfish | 1 | | | | | | | | | | | | 1 |
| Golden Shiner | <1 | | <1 | <1 | <1 | <1 | <1 | | | | <1 | | 2 |
| Largemouth Bass | | 1 | | | | <1 | <1 | | | 1 | 1 | 1 | 4 |
| Margined Madtom | 1 | | 1 | 1 | <1 | 1 | <1 | | | <1 | | | 4 |
| Pumpkinseed | | | <1 | | 1 | 1 | | | | 1 | <1 | 1 | 4 |
| Rainbow Smelt | 1 | 1 | | | | | | | | | | 2 | 4 |
| Redbreast Sunfish | | | <1 | | <1 | <1 | | | <1 | | | | 1 |
| Rock Bass | | | | | | <1 | | | | | | <1 | 1 |
| Smallmouth Bass | | | <1 | | | <1 | <1 | <1 | | | <1 | <1 | 1 |
| Spottail Shiner | 2 | 1 | <1 | | <1 | <1 | 1 | | | <1 | <1 | 10 | 15 |
| Tessellated Darter | | | 2 | | | | <1 | | | | | | 2 |
| White Perch | <1 | | | | | | | | | | <1 | | <1 |
| White Sucker | | | | | | <1 | <1 | | | | | | 1 |
| Yellow Bullhead | | | 1 | | | | <1 | | | | | | 1 |
| Yellow Perch | 1 | | 2 | | <1 | <1 | | | | | | 5 | 9 |
| Total | 8 | 3 | 9 | 2 | 7 | 50 | 5 | <1 | 1 | 3 | 4 | 22 | 114 |

**100% DIF, Existing CWIS**

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 7 | | | | | | | | | | | 7 |
| Banded Sunfish | | | | 27 | 11 | | | | | | | | 38 |
| Black Crappie | | | | 23 | 79 | 4 | | | 36 | 84 | 65 | 31 | 323 |
| Bluegill | 7 | | 46 | | 242 | 2,032 | 92 | 15 | 26 | 35 | 54 | 87 | 2,637 |
| Brown Bullhead | | | | | | 17 | 11 | | | | | | 28 |
| Chain Pickerel | 20 | | | | | | | | | | | | 20 |
| Fallfish | 38 | | | | | | | | | | | | 38 |
| Golden Shiner | 9 | | 15 | 23 | 9 | 12 | 5 | | | | 3 | | 75 |
| Largemouth Bass | | 24 | | | | 12 | 10 | | | 80 | 56 | 17 | 197 |
| Margined Madtom | 20 | | 27 | 57 | 29 | 47 | 4 | | | 11 | | | 195 |
| Pumpkinseed | | | 10 | | 62 | 32 | | | | 81 | 23 | 24 | 232 |
| Rainbow Smelt | 28 | 31 | | | | | | | | | | 57 | 115 |
| Redbreast Sunfish | | | 10 | | 10 | 12 | | | 21 | | | | 52 |
| Rock Bass | | | | | | 14 | | | | | | 12 | 26 |
| Smallmouth Bass | | | 9 | | | 4 | 11 | 6 | | | 9 | 5 | 44 |
| Spottail Shiner | 68 | 31 | 8 | | 10 | 19 | 19 | | | 10 | 3 | 312 | 480 |
| Tessellated Darter | | | 48 | | | | 4 | | | | | | 52 |
| White Perch | 7 | | | | | | | | | | 3 | | 10 |
| White Sucker | | | | | | 6 | 13 | | | | | | 19 |
| Yellow Bullhead | | | 17 | | | | 5 | | | | | | 22 |
| Yellow Perch | 39 | | 68 | | 17 | 19 | | | | | | 150 | 293 |
| Total | 235 | 91 | 256 | 131 | 468 | 2,231 | 174 | 21 | 82 | 302 | 214 | 695 | 4,902 |

**100% DIF, 3-mm WWS**

| Species | Jan | Feb | Mar | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 7 | | | | | | | 7 |
| Black Crappie | | | | | 36 | 84 | 65 | 31 | 216 |
| Bluegill | 7 | | 46 | 15 | 26 | 35 | 54 | 87 | 270 |
| Chain Pickerel | 20 | | | | | | | | 20 |
| Fallfish | 38 | | | | | | | | 38 |
| Golden Shiner | 9 | | 15 | | | | 3 | | 26 |
| Largemouth Bass | | 24 | | | | 80 | 56 | 17 | 176 |
| Margined Madtom | 20 | | 27 | | | 11 | | | 58 |
| Pumpkinseed | | | 10 | | | 81 | 23 | 24 | 138 |
| Rainbow Smelt | 28 | 31 | | | | | | 57 | 115 |
| Redbreast Sunfish | | | 10 | | 21 | | | | 30 |
| Rock Bass | | | | | | | | 12 | 12 |
| Smallmouth Bass | | | 9 | 6 | | | 9 | 5 | 29 |
| Spottail Shiner | 68 | 31 | 8 | | | 10 | 3 | 312 | 432 |
| Tessellated Darter | | | 48 | | | | | | 48 |
| White Perch | 7 | | | | | | 3 | | 10 |
| Yellow Bullhead | | | 17 | | | | | | 17 |
| Yellow Perch | 39 | | 68 | | | | | 150 | 257 |
| Total | 235 | 91 | 256 | 21 | 82 | 302 | 214 | 695 | 1,898 |

**100% DIF, Cooling Towers**

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | <1 | | | | | | | | | | | <1 |
| Banded Sunfish | | | | 1 | 1 | | | | | | | | 2 |
| Black Crappie | | | | 1 | 4 | <1 | | | 2 | 4 | 3 | 2 | 16 |
| Bluegill | <1 | | 2 | | 12 | 102 | 5 | 1 | 1 | 2 | 3 | 4 | 132 |
| Brown Bullhead | | | | | | 1 | 1 | | | | | | 1 |
| Chain Pickerel | 1 | | | | | | | | | | | | 1 |
| Fallfish | 2 | | | | | | | | | | | | 2 |
| Golden Shiner | <1 | | 1 | 1 | <1 | 1 | <1 | | | | <1 | | 4 |
| Largemouth Bass | | 1 | | | | 1 | <1 | | | 4 | 3 | 1 | 10 |
| Margined Madtom | 1 | | 1 | 3 | 1 | 2 | <1 | | | 1 | | | 10 |
| Pumpkinseed | | | <1 | | 3 | 2 | | | | 4 | 1 | 1 | 12 |
| Rainbow Smelt | 1 | 2 | | | | | | | | | | 3 | 6 |
| Redbreast Sunfish | | | <1 | | <1 | 1 | | | 1 | | | | 3 |
| Rock Bass | | | | | | 1 | | | | | | 1 | 1 |
| Smallmouth Bass | | | <1 | | | <1 | 1 | <1 | | | <1 | <1 | 2 |
| Spottail Shiner | 3 | 2 | <1 | | <1 | 1 | 1 | | | 1 | <1 | 16 | 24 |
| Tessellated Darter | | | 2 | | | | <1 | | | | | | 3 |
| White Perch | <1 | | | | | | | | | | <1 | | 1 |
| White Sucker | | | | | | <1 | 1 | | | | | | 1 |
| Yellow Bullhead | | | 1 | | | | <1 | | | | | | 1 |
| Yellow Perch | 2 | | 3 | | 1 | 1 | | | | | | 8 | 15 |
| Total | 12 | 5 | 13 | 7 | 23 | 112 | 9 | 1 | 4 | 15 | 11 | 35 | 245 |

**50% DIF, Existing CWIS**

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 3 | | | | | | | | | | | 3 |
| Banded Sunfish | | | | 14 | 5 | | | | | | | | 19 |
| Black Crappie | | | | 12 | 40 | 2 | | | 18 | 42 | 32 | 16 | 162 |
| Bluegill | 4 | | 23 | | 121 | 1,016 | 46 | 7 | 13 | 18 | 27 | 44 | 1,318 |
| Brown Bullhead | | | | | | 8 | 5 | | | | | | 14 |
| Chain Pickerel | 10 | | | | | | | | | | | | 10 |
| Fallfish | 19 | | | | | | | | | | | | 19 |
| Golden Shiner | 5 | | 7 | 12 | 4 | 6 | 3 | | | | 1 | | 38 |
| Largemouth Bass | | 12 | | | | 6 | 5 | | | 40 | 28 | 8 | 99 |
| Margined Madtom | 10 | | 13 | 29 | 14 | 24 | 2 | | | 6 | | | 97 |
| Pumpkinseed | | | 5 | | 31 | 16 | | | | 41 | 12 | 12 | 116 |
| Rainbow Smelt | 14 | 15 | | | | | | | | | | 28 | 58 |
| Redbreast Sunfish | | | 5 | | 5 | 6 | | | 10 | | | | 26 |
| Rock Bass | | | | | | 7 | | | | | | 6 | 13 |
| Smallmouth Bass | | | 5 | | | 2 | 6 | 3 | | | 4 | 2 | 22 |
| Spottail Shiner | 34 | 15 | 4 | | 5 | 10 | 9 | | | 5 | 1 | 156 | 240 |
| Tessellated Darter | | | 24 | | | | 2 | | | | | | 26 |
| White Perch | 4 | | | | | | | | | | 1 | | 5 |
| White Sucker | | | | | | 3 | 7 | | | | | | 9 |
| Yellow Bullhead | | | 8 | | | | 3 | | | | | | 11 |
| Yellow Perch | 20 | | 34 | | 9 | 9 | | | | | | 75 | 147 |
| Total | 118 | 46 | 128 | 65 | 234 | 1,115 | 87 | 10 | 41 | 151 | 107 | 348 | 2,451 |

**50% DIF, 3-mm WWS**

| Species | Jan | Feb | Mar | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|
| American Eel | | 3 | | | | | | | 3 |
| Black Crappie | | | | | 18 | 42 | 32 | 16 | 108 |
| Bluegill | 4 | | 23 | 7 | 13 | 18 | 27 | 44 | 135 |
| Chain Pickerel | 10 | | | | | | | | 10 |
| Fallfish | 19 | | | | | | | | 19 |
| Golden Shiner | 5 | | 7 | | | | 1 | | 13 |
| Largemouth Bass | | 12 | | | | 40 | 28 | 8 | 88 |
| Margined Madtom | 10 | | 13 | | | 6 | | | 29 |
| Pumpkinseed | | | 5 | | | 41 | 12 | 12 | 69 |
| Rainbow Smelt | 14 | 15 | | | | | | 28 | 58 |
| Redbreast Sunfish | | | 5 | | 10 | | | | 15 |
| Rock Bass | | | | | | | | 6 | 6 |
| Smallmouth Bass | | | 5 | 3 | | | 4 | 2 | 14 |
| Spottail Shiner | 34 | 15 | 4 | | | 5 | 1 | 156 | 216 |
| Tessellated Darter | | | 24 | | | | | | 24 |
| White Perch | 4 | | | | | | 1 | | 5 |
| Yellow Bullhead | | | 8 | | | | | | 8 |
| Yellow Perch | 20 | | 34 | | | | | 75 | 129 |
| Total | 118 | 46 | 128 | 10 | 41 | 151 | 107 | 348 | 949 |

**50% DIF, Cooling Towers**

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | | <1 | | | | | | | | | | | <1 |
| Banded Sunfish | | | | 1 | <1 | | | | | | | | 1 |
| Black Crappie | | | | 1 | 2 | <1 | | | 1 | 2 | 2 | 1 | 8 |
| Bluegill | <1 | | 1 | | 6 | 51 | 2 | <1 | 1 | 1 | 1 | 2 | 66 |
| Brown Bullhead | | | | | | <1 | <1 | | | | | | 1 |
| Chain Pickerel | <1 | | | | | | | | | | | | <1 |
| Fallfish | 1 | | | | | | | | | | | | 1 |
| Golden Shiner | <1 | | <1 | 1 | <1 | <1 | <1 | | | | <1 | | 2 |
| Largemouth Bass | | 1 | | | | <1 | <1 | | | 2 | 1 | <1 | 5 |
| Margined Madtom | <1 | | 1 | 1 | 1 | 1 | <1 | | | <1 | | | 5 |
| Pumpkinseed | | | <1 | | 2 | 1 | | | | 2 | 1 | 1 | 6 |
| Rainbow Smelt | 1 | 1 | | | | | | | | | | 1 | 3 |
| Redbreast Sunfish | | | <1 | | <1 | <1 | | | 1 | | | | 1 |
| Rock Bass | | | | | | <1 | | | | | | <1 | 1 |
| Smallmouth Bass | | | <1 | | | <1 | <1 | <1 | | | <1 | <1 | 1 |
| Spottail Shiner | 2 | 1 | <1 | | <1 | <1 | <1 | | | <1 | <1 | 8 | 12 |
| Tessellated Darter | | | 1 | | | | <1 | | | | | | 1 |
| White Perch | <1 | | | | | | | | | | <1 | | <1 |
| White Sucker | | | | | | <1 | <1 | | | | | | <1 |
| Yellow Bullhead | | | <1 | | | | <1 | | | | | | 1 |
| Yellow Perch | 1 | | 2 | | <1 | <1 | | | | | | 4 | 7 |
| Total | 6 | 2 | 6 | 3 | 12 | 56 | 4 | 1 | 2 | 8 | 5 | 17 | 123 |