Appendix 1

Development and Analysis of Reference Fish Community Models to Evaluate the Existing Fish Communities of the Pomperaug River Watershed, Connecticut

Overview

Target Fish Community (TFC) models have been developed for instream flow related studies on multiple rivers in Southern New England since Bain and Meixler's initial development and application of the methodology on the Quinnebaug River (2000). Successful applications of such models to assess the status of native fish communities on the Quinnebaug, Ipswich, Assabet, Charles, Housatonic, and Souhegan Rivers (Bain and Meixler 2000, Armstrong et al. 2001, Parker et al. 2004, Meixler 2005, Kearns et al. 2005, Legros 2006) have led to increasing use and acceptance of the TFC methodology by the scientific fisheries community. As part of the development of a comprehensive watershed management plan for the Pomperaug River Watershed, Connecticut, the Northeast Instream Habitat Program (NEIHP) developed TFC models for the Upper and Lower Pomperaug River Watershed to assess current habitat and fish community conditions and guide future restoration measures.

The development of a TFC is dependent upon the use of fish data from several ecologically healthy Reference Rivers that are physically and zoo-geographically similar to a study river. While it is essential that the ecological condition of these rivers exceeds that of the study river, most still exhibit a certain degree of habitat degradation. Populations of some native fish species that were once common have declined or become extirpated from many of New England's rivers and streams as a result of the ecological effects of centuries of anthropogenic impacts. In other words, neither "pristine rivers" nor "pristine fish assemblages" currently exist throughout much of New England. Consequently, many potential Reference Rivers within this region exhibit incomplete fish communities. Do to the absence or under-representation of some species within many Reference Rivers, TFC models are not always able to account for appropriate proportions of all species.

The necessity to account for such species within a TFC model is dependent upon watershed or fisheries management objectives. In order to completely evaluate the existing habitat and fish community conditions and guide future restoration efforts within the Pomperaug River Watershed, it was critical that TFC models developed for the Watershed accounted for appropriate proportions of all fish species which were historically present within the Watershed. Two fish species which were historically present within the Pomperaug Watershed were either missing or under-represented within the TFC models. American eel *Anguilla rostrata* was under-represented while Atlantic salmon *Salmo salar* was missing completely. NEIHP, using data provided by the Connecticut Department of Environmental Protection (CTDEP), simulated proportions of American eel and Atlantic salmon to account for their under-representations or absences within the Pomperaug Watershed TFC models. The TFC models were adapted to include simulated proportions of American eel and Atlantic salmon. The modified models, referred to as Reference Fish Community (RFC) models, provided a reference template to guide future restoration efforts within the Pomperaug Watershed.

Simulations were calculated based on abundance data for each of these species collected from several high quality index sites by the CTDEP within Connecticut. The average number of individuals per sample was determined by CTDEP for 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} order streams for each species (Gephard and Wildman 2005). This number was then applied to each of the Reference River samples after being individually weighted for each river. The new Reference River data, including the estimated abundances of Atlantic salmon and American eel, were then re-applied to the TFC framework to create the RFC models for the Upper and Lower Watershed.

Defining the RFC models was an interactive process that required direct input from local fisheries experts to assure that the species compositions of the proposed fish community models were conducive to watershed management objectives and consistent with the zoogeography of the Pomperaug River Watershed. CTDEP provided the fisheries data, including Atlantic salmon and American eel abundances, used to calculate the models and was instrumental in their development. These models provided us with the minimal amount of information needed to evaluate the existing fish communities within the Pomperaug River Watershed. Comparisons between the RFC models and the existing fish communities allowed us to identify deviations from reference conditions and make inferences on potential reasons for such deviations with regard to instream habitat and flow conditions, water quality, and thermal regime. This information may then be used to aid in the development of a comprehensive watershed management plan for the Pomperaug River Watershed.

Introduction

The Northeast Instream Habitat Program (NEIHP), in an effort to identify and define the flow dependency of the native fish fauna within the Pomperaug River Watershed, conducted an analysis of fish habitat within the Pomperaug, Nonnewaug and Weekeepeemee Rivers. This analysis entailed using multivariate statistics to determine which physical habitat characteristics were most suitable for individual fish species (or species groups) and assessing changes in fish habitat availability at various stream flow scenarios. A habitat simulation model, MesoHABSIM (Parasiewicz 2001), was used to determine the relationship between instream flow conditions and instream habitat availability for selected fish species. Reference Fish Community (RFC) models, developed using an approach known as Target Fish Community (TFC) modeling (Bain and Meixler 2000), were created to identify the native fluvial fish species considered within the MesoHABSIM modeling process and evaluate the existing fish communities of the Pomperaug River Watershed.

Developing RFC models consisted of multiple steps. First, a list of species expected or with the potential to occur within the project river was compiled. Next, a group of rivers, physically and zoo-geographically[1] similar to the investigated rivers and in relatively un-impacted condition, were chosen as references. Existing fish collection data from these Reference Rivers, including simulated abundances of missing or under-represented species, were then used to generate RFC models. To calculate the models, a weighted-ranking procedure was applied to these data sets to determine compositions and proportions of fish species expected to occur within the Pomperaug, Nonnewaug, and Weekeepeemee Rivers under un-impaired conditions. The computational framework of the RFC models accounted for spatial and temporal variations as well as missing or under-represented fish species within the Reference Rivers and created robust representations of the expected native fish communities of the Upper and Lower Pomperaug River Watershed. The resulting RFC models were then compared to the

[1] Determination of the zoogeographic similarity of areas, or Ecoregions, is based on an analysis of geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology (Omernik 1987).

existing fish communities of the Pomperaug River Watershed assess their current condition.

We present here two RFC models, created for the Upper and Lower portions of the Pomperaug River Watershed, Connecticut. Their development processes are outlined, the resulting communities are presented, and comparisons are made between the RFC models and the existing fish communities to identify deviations from target conditions.

Methods

Study Area

The study area encompassed a majority of the 90 square mile Pomperaug River Watershed, Connecticut. The focus of this study was on the mainstems of the Pomperaug, Nonnewaug and Weekeepeemee rivers within the towns of Southbury (New Haven County), Woodbury and Bethlehem (Litchfield County). The Pomperaug River Watershed is a sub-basin of the Housatonic River basin. Based on an initial reconnaissance survey and MesoHABSIM habitat mapping of the watershed in 2001, the watershed was divided into ten representative sites (Figure 1). Due to geo-morphological differences between the Upper and Lower Watershed (e.g. stream order, gradient, land use/ land cover), separate target fish communities are being developed for both the Nonnewaug/Weekeepeemee and Pomperaug Rivers.

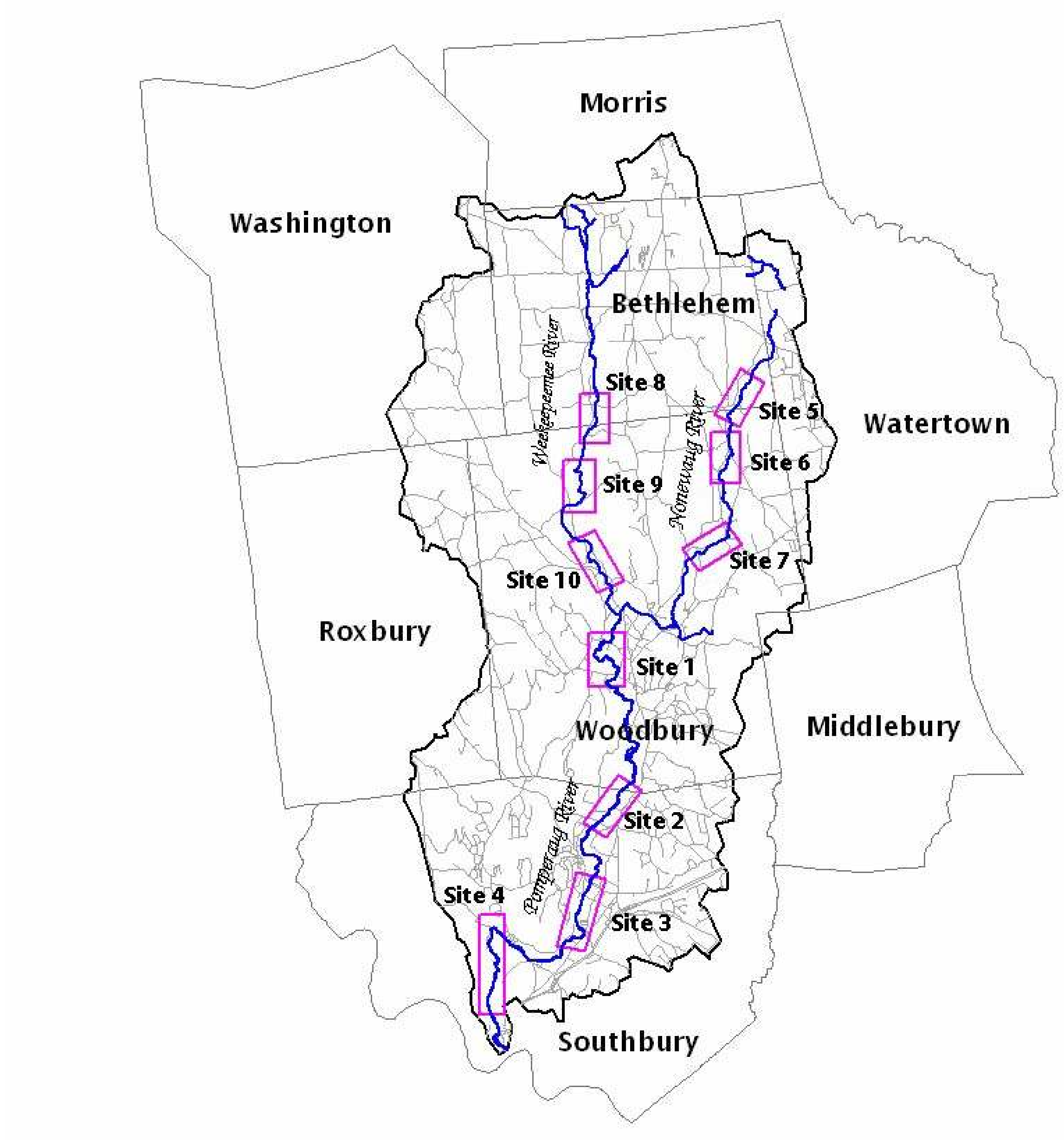

Figure 1. Pomperaug Watershed and designated representative study sites

Fish List

A list of species currently or historically found or with the potential to exist within the Pomperaug River Watershed was compiled using fish distribution references, historical records, and recent collection records (Schmidt 1986, Witworth 1996, CTDEP).

Fish species habitat use and pollution tolerance classifications assigned by Bain (2000) through an extensive literature review (Scott and Crossman 1973, Pflieger 1975, Lee et al. 1980, Trautman 1981, Becker 1983, Burr and Warren 1986, Robinson and Buchanon 1988, Jenkins and Burkhead 1994, Halliwell et al. 1999) were reviewed with regard to regional differences in species habitat-use preferences. Creek chub, fallfish, longnose dace, and slimy sculpin were reclassified as fluvial specialists in this study, as in previous target fish community studies within this region, based on their local habitat use patterns (Lang et al. 2001, Kearns et al. 2005). Fish species were also classified based on thermal tolerances, determined from a review of the literature pertinent to the fishes of the northeast region (Scarola 1987, Witworth 1996, Halliwell et al. 1999, Langdon 2001, Hartel et al. 2002).

Reference River Selection

The first step in this process was to compile a list of quality rivers that were physically similar to either the Pomperaug, Nonnewaug, or Wekeepeemee Rivers. In a similar analysis on the Housatonic River (Kearns et al. 2005), quality rivers were defined as being *"similar in geological characteristics to the study reach, relatively unimpaired, undammed, and undeveloped, with few water withdrawals, good water quality and a similar temperature regime."* Recognizing that potential Reference Rivers in Connecticut did not fully meet the criteria developed for the Housatonic, we relied on the professional judgment of Neal Hagstrom of the CTDEP to provide the initial list of rivers to be considered as potential references.

To determine the geo-physical and zoogeographic similarity of the initial rivers list, we reviewed draft Stream and Lake Classification GIS layers generated by The Nature Conservancy (TNC). Stream order, drainage area at the sampling locations, percent of calcareous geological formations, gradient, and Level III ecoregion (Omernik 1987) were chosen as the parameters having the greatest effect on the distribution of fish populations in the Pomperaug River Watershed. Next, acceptable ranges for each of these parameters were selected for comparison to our study sites. Rivers that did not fall into the acceptable ranges for all four parameters were eliminated from consideration. At the recommendation of Hagstrom, all sites to the east of the Connecticut River were also eliminated from the original list of quality rivers due to regional differences in the native fauna compositions of eastern and western Connecticut. Upon removal of all rivers east of the Connecticut River, and those deemed dissimilar to the study rivers, the list was re-submitted to Hagstrom for further review. This list of rivers was cross-referenced with CTDEP fish survey data. Those rivers lacking, or containing insufficient fish data (less than 20 fish collected), containing fish data collected from degraded habitats, or possessing unique geologic or biologic conditions dissimilar to those of the study area were eliminated. The remaining quality rivers, containing adequate fish data and similar physical characteristics to the study area, were selected as Reference Rivers.

It was found that Reference Rivers that matched the physical criteria of the Pomperaug were much larger than those that matched the Nonnewaug and Weekeepeemee rivers. Those that matched the Nonnewaug and Weekeepeemee were found to be physically similar to each other. Therefore, a separate RFC was generated as a single representation of both the Nonnewaug and Weekeepeemee Rivers combined while another RFC was developed to serve as a reference community for the mainstem of the Pomperaug River. Fish data from the Reference Rivers that were similar to the Nonnewaug and Weekeepeemee Rivers were used to calculate the RFC for the Upper Watershed (Nonnewaug/Weekeepeemee RFC), while those from Reference Rivers similar to the Pomperaug Rivers were used to develop the RFC for the Lower Watershed (Pomperaug RFC).

Reference Fish Community Development

Following the methods of Bain and Meixler (2000), the total number of fish at each site was summed. The totals of each species were divided by this sum, yielding a proportion of the total catch. These proportions were summed for all sites. The sums of the proportions were then ranked, with the species having the greatest sum ranked “1”. At this point all non-native species were removed from the calculation. Although these species were removed, all of the species remaining on the list maintained the same numerical rank. Then, the reciprocal of each species’ rank was taken, and these reciprocals were summed. The reciprocal rank of any given species divided by the sum of the reciprocal ranks yielded that species’ expected proportion in the Pomperaug River. All of these calculations were done on a spreadsheet created by Mark Bain (2000).

Atlantic salmon and American eel abundance numbers were simulated for each Reference River and then subjected to the rank-weighted technique (Bain and Meixler 2000) along with all other species within the Reference River samples to calculate their expected proportions within the RFC. Numbers were simulated by dividing the sum of fish caught (all species) within each Reference River by the total sum of fish caught from all Reference Rivers to calculate the average number of fish per Reference River. The total number of fish caught within an individual Reference River was then divided by the average number of fish per Reference River. This proportion was then multiplied by a previously generated average number of Atlantic salmon or American eel per sampling unit to yield the simulated number of salmon or eel for each Reference River. Average numbers of Atlantic salmon and American eel were calculated and provided by the CTDEP using fish collection data from several high quality index sites containing "healthy" populations of Atlantic salmon or American eel. An average number of each species per sample was generated for first, second, third, and fourth order streams (Gephard and Wildman 2005).

Pomperaug River Watershed Fish Sampling

To evaluate the current status of the instream fauna of the Nonnewaug, Weekeepeemee, and Pomperaug Rivers, instream surveys were conducted to determine the fish communities within the designated study area of these rivers.

Fish were sampled using pre-positioned electrofishing grids (Bain 1985), within previously selected representative sites throughout the study area. Grids were placed within hydromorphologic units (HMU) or habitat types that were representative of the distribution of habitats within each site. Using this method we were able to sample a variety of habitat types, document and map the habitat attributes present within each grid, and collect hydraulic depth and current velocity data within each grid. This allowed us to determine the distribution of the existing fish community with regard to instream habitat and hydraulic conditions.

Fish Community Evaluation

Evaluation of the status of the fish fauna in the Pomperaug and Nonnewaug/Weekeepeemee Rivers was accomplished by comparing the similarity between the two RFC and the Nonnewaug/Weekeepeemee and Pomperaug River existing fish communities as sampled in 2004. To make this comparison, we used the percent model affinity procedure developed by Novak and Bode (1992). This procedure yields values from 0 to 100 to describe the extent to which the study rivers' fish communities are similar to the RFC. Higher percent model affinity values indicate higher degrees of similarity between the communities. These values are calculated as:

Percent similarity = 100 – 0.5 (Sum | target P – observed P |) where: P = proportions of each species in the community or collection.

Additional comparisons were also made between the proportions of habitat use, pollution tolerance, and thermal regime tolerance classification guilds within the reference and existing fish communities of the Nonnewaug/Weekeepeemee and Pomperaug Rivers.

A comparison of the proportions of individual species within the RFC and existing fish communities of the Nonnewaug/Weekeepeeme Rivers and the Pomperaug Rivers documented under-represented species, over-represented species and species found proportions close to expected proportions. Species with proportions differing by more than 50% less or greater than expected were considered under-represented or overly abundant, respectively. Native species, identified in the RFC that were missing from the existing fish communities, and non-native species occurring within the existing communities were also identified.

Results

Fish List

Based on our review of fish distribution references, historical records, and recent collection records, 37 different fish species, from 12 families, were found to occur either historically or currently within the Pomperaug River Watershed (**Table 1**). The list contains a variety of species, both native and introduced, with a full range of habitat use, pollution tolerance, and thermal regime classifications.

Reference Rivers

Connecticut's quality rivers which were physically similar to the three study rivers and located within Ecoregion 59 (The Northeastern Coastal Zone) were compiled into an initial list of potential Reference Rivers. After all the rivers found to be geo-physically dissimilar to those in the Pomperaug Watershed were eliminated from the initial list, 22 sites remained. Thirteen of these rivers were similar to the Nonnewaug/Weekeepeemee Rivers, while the other Eight were similar to the Pomperaug. After further review by Hagstrom, based on the availability and suitability of fish data, and the ecological integrity of sample sites, the list was narrowed to six Reference Rivers for the Nonnewaug/Weekeepeemee, and five for the Pomperaug. **Table 2** lists the Nonnewaug/Weekeepeemee and Pomperaug Reference Rivers and their geo-physical parameters. Initially the list of Pomperaug Reference Rivers only included three rivers but was expanded to include the Mad and Saugatuck Rivers, which were originally eliminated because of impacted habitat conditions. Fish community data from these rivers did not reflect those conditions and included three important species, creek chub *Semotilus atromaculatus*, cutlips minnow *Exoglossum maxillingua*, and redfin pickerel *Esox americanus* which were not present within the other three rivers.

Table 1. Species expected or with potential to occur within the Pomperaug River Watershed. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate/intermediate (M), or tolerant (T) pollution tolerances, and Cold, Cool, or Warm water thermal regime tolerances are given for each species.

FAMILY Common name	Genus	Species	Native or Introduced	Habitat use classification	Pollution tolerance	Thermal regime
Petromyzontidae						
Sea lamprey	*Petromyzon*	*marinus*	N	FD		
Anguillidae						
American eel	*Anguilla*	*rostrata*	N	FD	T	Cool
Clupeidae						
Blueback herring	*Alosa*	*aestivalis*	N	FD		
Alewife	*Alosa*	*pseudoherangus*	N	FD		
American shad	*Alosa*	*sapidissima*	N	FD		
Salmonidae						
Rainbow trout	*Oncorhynchus*	*mykiss*	I	FD	I	Cold
Atlantic salmon	*Salmo*	*salar*	N	FS	I	Cold
Brown trout	*Salmo*	*trutta*	I	FD	I	Cool
Brook trout (char)	*Salvelinus*	*fontinalis*	N	FS	I	Cold
Escocidae						
Redfin pickerel	*Esox*	*americanus*	N	MG	M	Warm
Chain pickerel	*Esox*	*niger*	N	MG	M	Warm
Cyprinidae						
Gold fish	*Carassius*	*auratus*	I	MG	T	Warm
Common carp	*Cyprinus*	*carpio*	I	MG	T	Warm
Cutlips minnow	*Exoglossum*	*maxillingua*	N	FS	I	Warm
Common shiner	*Luxilus*	*cornutus*	N	FD	M	Cool
Golden shiner	*Notemigonus*	*crysoleucas*	N	MG	T	Cool
Bridle shiner	*Notropis*	*bifrenatus*	N	MG	I	Warm
Spottail shiner	*Notropis*	*hudsonius*	N	MG	M	Cool
Fathead minnow	*Pimephales*	*promelas*	I	MG	T	Warm
Blacknose dace	*Rhinichthys*	*atratulus*	N	FS	T	Cool
Longnose dace	*Rhinichthys*	*cataractae*	N	FS	M	Cool
Creek chub	*Semotilus*	*atromaculatus*	N	FS	T	Cool
Fallfish	*Semotilus*	*corporalis*	N	FS	M	Cool
Catostomidae						
White sucker	*Catostomus*	*commersoni*	N	FD	T	Cool
Creek chubsucker	*Erimyzon*	*oblongus*	N	FS	I	Cool
Ictaluridae						
Brown bullhead	*Ameiurus*	*nebulosus*	N	MG	T	Warm
Cyprinodontidae						
Banded killifish	*Fundulus*	*diaphanus*	N	MG	T	Warm
Centrarchidae						
Rock bass	*Amblopites*	*rupestris*	I	MG	M	Warm
Redbreast sunfish	*Lepomis*	*auritus*	N	MG	M	Warm
Pumpkinseed	*Lepomis*	*gibbosus*	N	MG	M	Warm
Bluegill	*Lepomis*	*macrochirus*	I	MG	T	Warm
Smallmouth bass	*Micropterus*	*dolomieu*	I	MG	M	Warm
Largemouth bass	*Micropterus*	*salmoides*	I	MG	M	Warm
Black crappie	*Pomoxis*	*nigromaculatus*	I	MG	M	Warm
Percidae						
Tessellated darter	*Etheostoma*	*olmstedi*	N	FS	M	Cool
Yellow perch	*Perca*	*flavescens*	N	MG	M	Cool
Cottidae						
Slimy sculpin	*Cottus*	*cognatus*	N	FS	I	Cold

Table 2. The list of selected quality Reference Rivers including fish data site identification numbers and physical and zoogeographic parameters.

Nonnewaug and Weekeepeemee Reference Rivers	CTDEP Site Number	Stream Order	Drainage Area	Level III Ecoregion	Gradient m/m
Beacon Hill Brook	3049	2	11	59	0.0118
Eightmile River	2014	2	16	59	0.0042
Leadmine Brook	4112	3	21	59	0.0084
Pootatuck River	3008	3	14	59	0.0101
West River	2010	3	15	59	0.0052
Willow Brook	2022	2	10	59	0.0065
Pomperaug Reference Rivers	**CTDEP Site Number**	**Stream Order**	**Drainage Area**	**Level III Ecoregion**	**Gradient m/m**
Coginchaug River	1044	3	33	59	0.0066
Mad River	3044	3	26	59	0.0063
Rippowam River	2048	4	33	59	0.0012
Saugatuck River	2037	3	43	59	0.0052
Saugatuck River	2073	4	80	59	0.0066
Quinnipiac River	2060	4	76	59	0.0002

Fish Species Abundance Simulations

Mean abundances per hectare of Atlantic salmon and American eel were calculated using data from several high quality index sites within Connecticut (**Table 3**). The average number of each species per hectare within third order streams was used to simulate proportions for the Nonnewaug/Weekeepeemee RFC while the values for fourth order streams were used for the Pomperaug RFC simulations.

Table 3: Mean values of Atlantic salmon and American eel per hectare within high quality index sites. Values are given for first, second, third and fourth order streams in Connecticut (Gephard and Wildman 2005).

Reference Fish Community Density Value Recommendations				
	Stream Order Category			
Species	*First*	*Second*	*Third*	*Fourth*
Atlantic salmon	1,900	2,200	1,600	300
American eel	1,400	1,450	1,250	800

Nonnewaug/Weekeepeemee Reference Fish Community

The RFC for the Nonnewaug and Weekeepeemee Rivers consisted of a diverse fish fauna of 16 species, dominated by Atlantic salmon (30%), American eel (15%), blacknose dace (10%), longnose dace (8%), tessellated darter (6%), and white sucker (4%). The remaining 11 species comprised between 1% and 4% of the fauna, and included brook trout, common shiner, fallfish, redbreast sunfish, creek chub, pumpkinseed, brown bullhead, yellow perch, redfin pickerel, chain pickerel, and golden shiner. A chart of the RFC species and their expected proportions is shown in **Figure 2**. The Nonnewaug/Weekeepeemee RFC consisted of 63% fluvial specialist, 23% fluvial dependent, and 14% macrohabitat generalist species (**Figure 3**). The Reference River fish data used to calculate the mean ranks and expected proportions of species within the RFC developed for the Nonnewaug and Weekeepeemee Rivers are presented in **Table 4**. Prior to Atlantic salmon and American eel simulations, Atlantic salmon were absent from the RFC and American eel were ranked fourth (8%). The addition of Atlantic salmon as the first ranking species, and the change in ranking of American eel from fourth to second, affected the expected proportions of other species within the RFC, but did not change their ranking order.

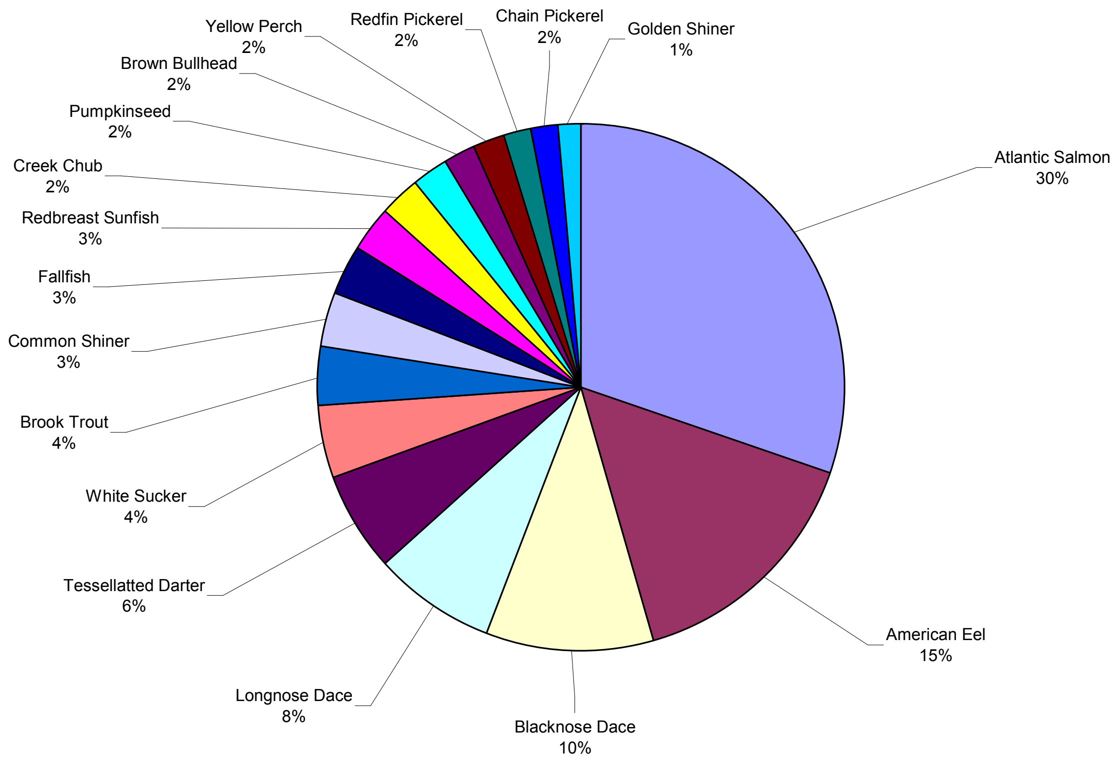

Figure 2. Nonnewaug/Weekeepeemee Reference Fish Community

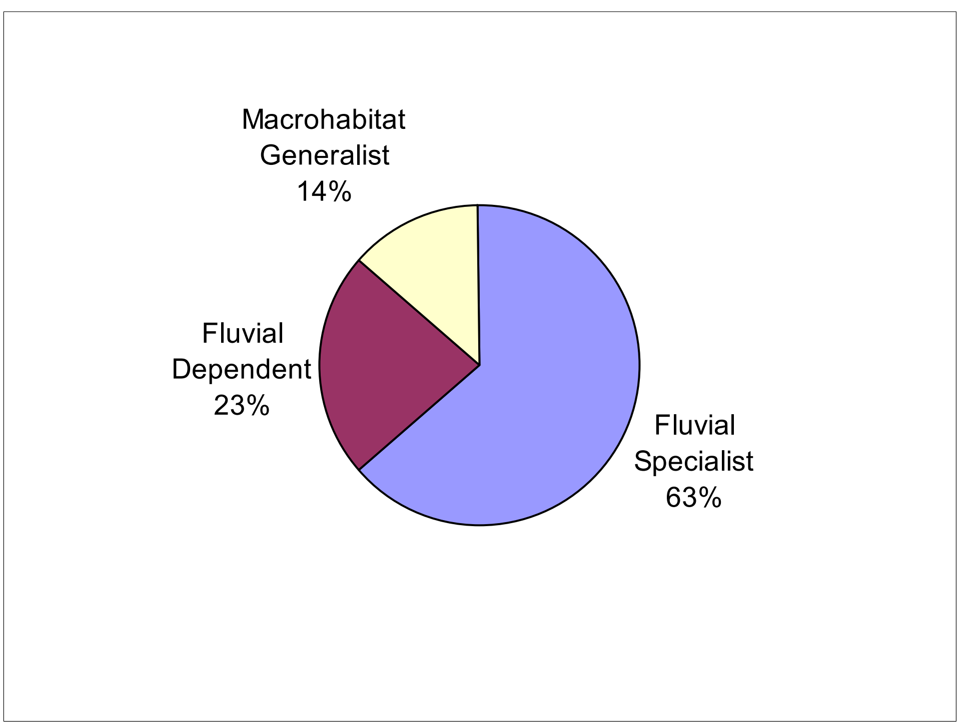

Figure 3. Nonnewaug/Weekeepeemee RFC based on species habitat use classification guilds

Table 4. Reference River fish data and calculated mean ranks and expected proportions of fish species within the Nonnewaug/Weekeepeemee Reference Fish Community.

	Beacon Hill Brook CTDEP Site # 3049	Eightmile River CTDEP Site # 2014	Leadmine Brook CTDEP Site # 4112	Pootatuck River CTDEP Site # 3008	West River CTDEP Site # 2010	Willow Brook CTDEP Site # 2022	Mean Rank	Expected Proportion
Atlantic Salmon	3705	3727	3922	2162	1380	1101	1	30%
American Eel	2895	2912	3064	1689	1078	860	2	15%
Blacknose Dace	1493	3606	1653	1289		820	3	10%
Longnose Dace	807	1963	2440	191	20	100	4	8%
Tessellatted Darter	3087	129	93	230		73	5	6%
Brown Trout	73	45	153	1029	113	187	6	
White Sucker	560	123	460	204	200	193	7	4%
Brook Trout	47	19		388	113	253	8	4%
Common Shiner		142	1480	20	13		9	3%
Fallfish		116			225	60	10	3%
Redbreast Sunfish					275		11	3%
Bluegill		6		26	181	7	12	
Creek Chub	73		227	105			13	2%
Pumpkinseed	7			20	56		14	2%
Brown Bullhead				39	13	20	15	2%
Yellow Perch					25		16	2%
Largemouth Bass				39			17	
Redfin Pickerel						7	18	2%
Chain Pickerel					6		19	2%
Rainbow Trout				7			20	
Golden Shiner		6					21	1%
Totals:	12747	12794	13492	7438	3698	3681		100%

Pomperaug Reference Fish Community

The RFC for the mainstem of the Pomperaug River also consisted of a diverse array of 16 native fluvial species, dominated by American eel (32%), longnose dace (16%), blacknose dace (10%), white sucker (8%), common shiner (6%), tessellated darter (5%), and Atlantic salmon (4%). The remaining ten species comprised between 1% and 4% of the community and included fallfish, redbreast sunfish, cutlips minnow, pumpkinseed, yellow perch, brook trout, redfin pickerel, golden shiner, and creek chub. **Figure 4** shows the composition of fish species within the Pomperaug River RFC. The community included 46% fluvial specialist, 44% fluvial dependent, and 10% macrohabitat generalist species (**Figure 5**). The Reference River fish data used to calculate the mean ranks and expected proportions of species within the RFC developed for the mainstem of the Pomperaug River are presented in **Table 5**. Prior to simulations, Atlantic salmon were absent from the Pomperaug RFC while American eel were ranked first, comprising 32% of the community. Subsequent to simulations, Atlantic salmon ranked seventh in the community (4%), while American eel maintained the same rank and proportion. Species proportions experienced only slight adjustments as a result of simulations and species ranks remained the same with the exception of white sucker and blacknose dace switching positions.

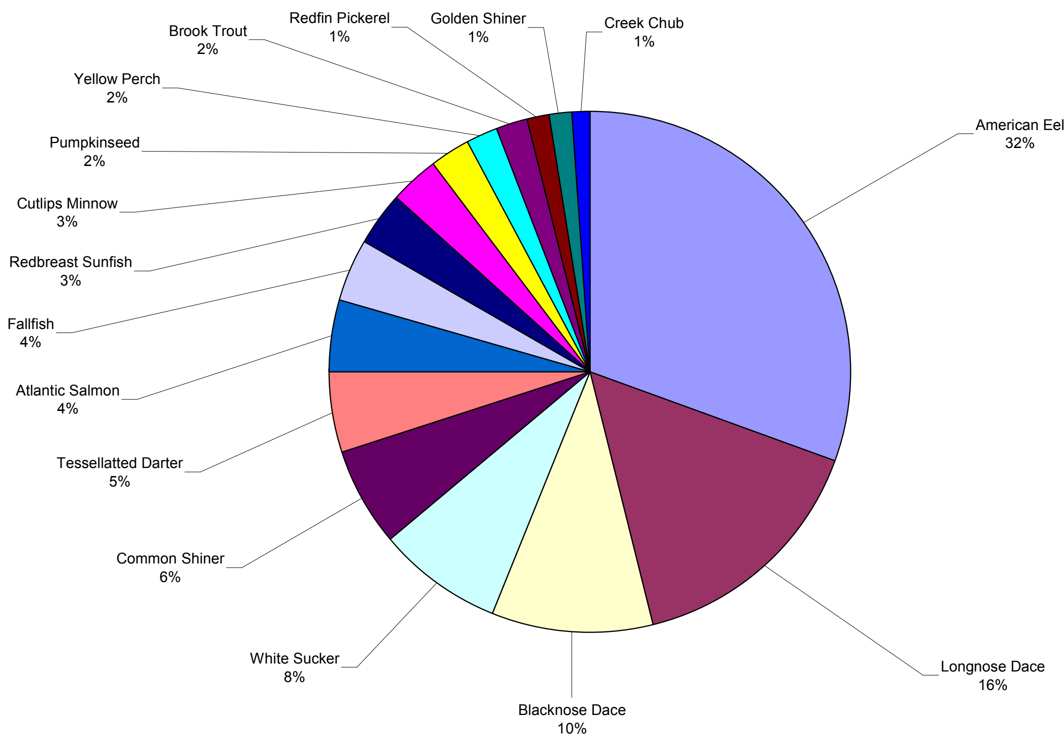

Figure 4. Pomperaug River Reference Fish Community

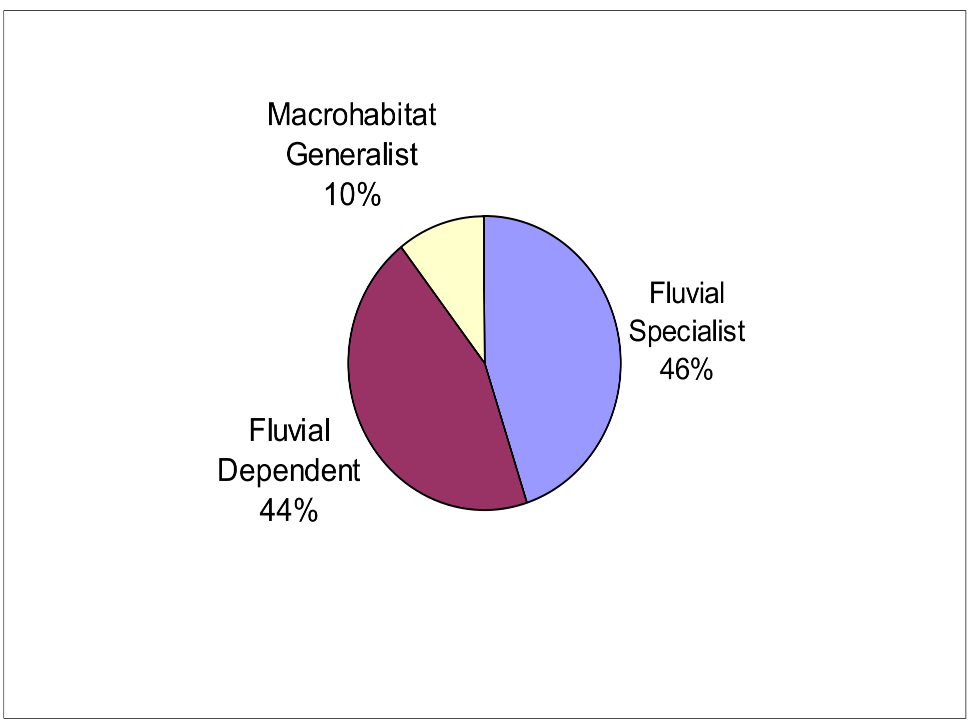

Figure 5. Pomperaug River RFC based on species habitat use classification guilds

Table 5. Reference River fish data and calculated mean ranks and expected proportions of fish species within the Pomperaug Reference Fish Community.

	Coginchaug River CTDEP Site # 1044	Saugatuck River CTDEP Site # 2037	Saugatuck River CTDEP Site # 2073	Rippowam River CTDEP Site # 2048	Quinnipiac River CTDEP Site # 2060	Mad River CTDEP Site # 3004	Mean Rank	Expected Proportion
American Eel	2820	2660	7140	809	243	935	1	31%
Longnose Dace	2407	1087	1025	647	225	153	2	15%
Blacknose Dace	160	3260	805	427		1827	3	10%
White Sucker	40	1173	60	507	625	780	4	8%
Common Shiner		973	1110	833		1087	5	6%
Tessellatted Darter	287	200	280	667	135	747	6	5%
Atlantic Salmon	441	727	785	303	91	350	7	4%
Fallfish	280		5	587	95	47	8	4%
Redbreast Sunfish	233	13	610	413		173	9	3%
Cutlips Minnow		1293	205				10	3%
Brown Trout	27	53	175	7	80	107	11	
Bluegill	53		15	7	40	27	12	
Pumpkinseed	153	7	40	20	10	20	13	2%
Largemouth Bass	20	13	100	40	15		14	
Yellow Perch			5	7	30		15	2%
Brook Trout	20	7			5	73	16	2%
Green Sunfish				53			17	
Smallmouth Bass						53	18	
Carp					10		19	
Rainbow Trout	27		5			7	20	
Black Crappie			35	7			21	
Rock Bass					5		22	
Redfin Pickerel		20					23	1%
Golden Shiner						7	24	1%
Creek Chub		7					25	1%
Totals:	6968	11493	12400	5334	1609	6393		100%

Nonnewaug/Weekeepeemee Existing Fish Community

The existing fish community of the Nonnewaug and Weekeepeeme Rivers in the upper portion of the Pomperaug River Watershed, as sampled in the summer of 2004, consisted of blacknose dace (31%), white sucker (16%), longnose dace (11%), brown trout (8%), creek chub (6%), brook trout (5%), tessellated darter (4%), largemouth bass (4%), smallmouth bass (4%), fallfish (3%), yellow perch (3%), common shiner (3%), and golden shiner (2%) (**Figure 6**). The fish community of the Nonnewaug and Weekeepeemee Rivers was dominated by native fluvial species (61% fluvial specialist, and 26% fluvial dependent), and included a smaller proportion of macrohabitat generalists (13%). A total of 13 different fish species were sampled from the Nonnewaug and Weekeepeemee Rivers, 10 of which were native. The three non-native fish species sampled in the Upper Watershed, brown trout, largemouth bass and smallmouth bass, accounted for a combined 16% of the community.

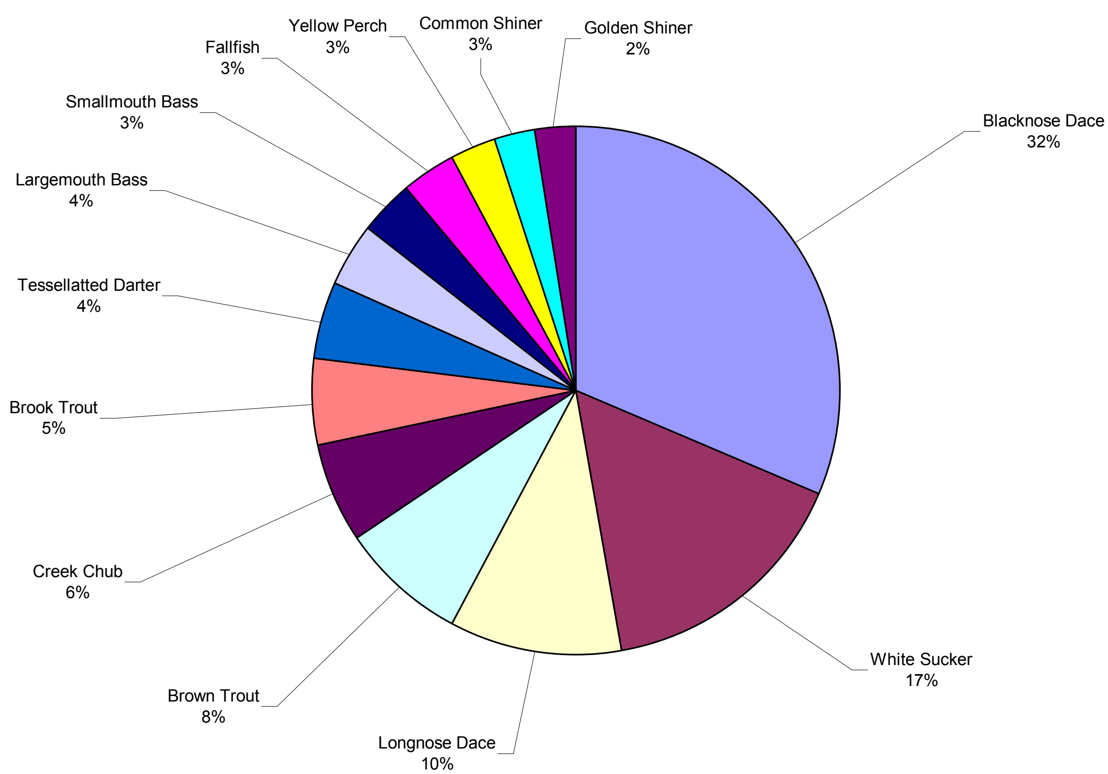

Figure 6. Nonnewaug/Weekeepeemee Rivers existing fish community

Pomperaug Existing Fish Community

The existing fish community of the Pomperaug River, also surveyed in the summer of 2004, consisted of white sucker (29%), creek chub (14%), blacknose dace (10%), cutlips minnow (7%), tessellated darter (6%), longnose dace (5%), fallfish (4%), bluegill (4%), rock bass (3%), common shiner (3%), largemouth bass (3%), smallmouth bass (2%), brook trout (2%), redbreast sunfish (2%), pumpkinseed (2%), redfin pickerel (2%), and American eel (2%) (**Figure 7**). The Pomperaug fish community was dominated by native fluvial species (49% fluvial specialist, and 34% fluvial dependent), and contained a considerably lesser proportion of macohabitat generalists (18%). A total of 17 different fish species were sampled in the Pomperaug River, 13 of which were native. The four non-native species sampled in the Pomperaug, bluegill, rock bass, largemouth bass and smallmouth bass, accounted for a combined 12% of the community.

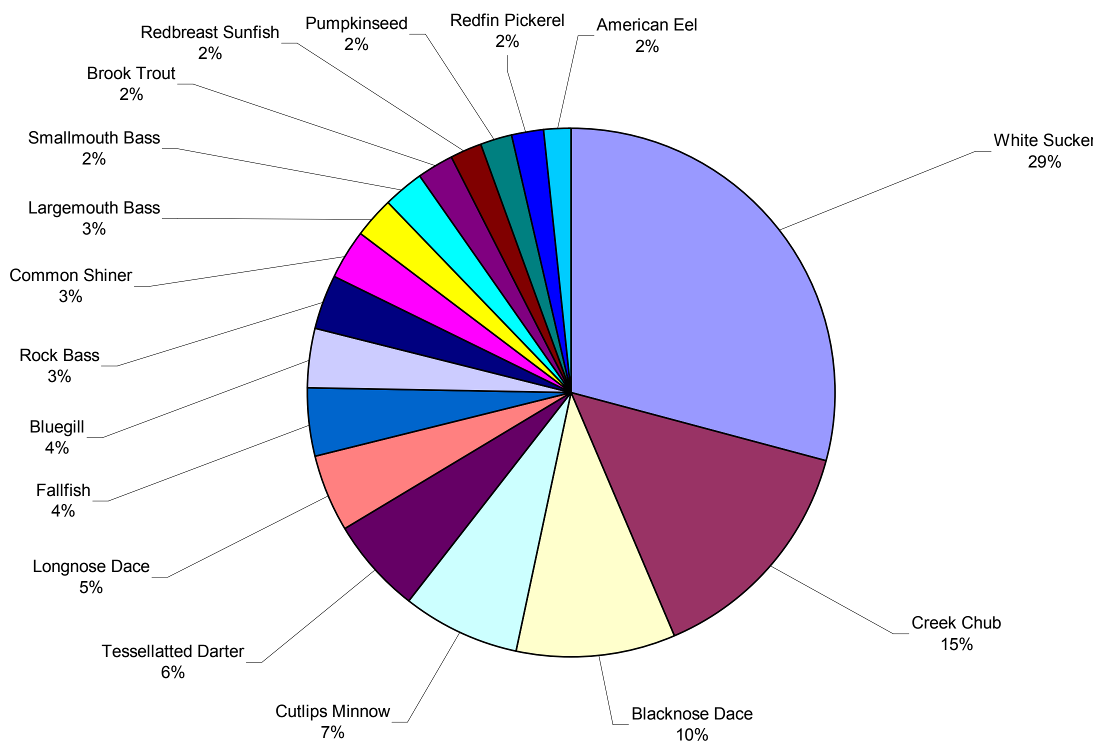

Figure 7. Pomperaug River existing fish community

Fish Community Evaluation – Nonnewaug/Weekeepeemee

The overall affinity of the Nonnewaug/Weekeepeemee existing fish community to the Nonnewaug/Weekeepeemee RFC model was 42%. Prior to simulated proportions of Atalantic salmon and American eel, the affinity between these two communities was 68%.

Comparison of the Nonnewaug/Weekeepeemee existing fish community and RFC based on habitat use guilds showed an almost perfect match between the two communities (**Figure 8**). Specific proportions of these guilds within the communities were given previously in the sections describing the Nonnewaug/Weekeepeemee RFC and existing fish community, respectively and can be viewed within Figure 8. The percent model affinity similarity calculation for the two communities based on species habitat use classifications yielded a value of 97% similarity.

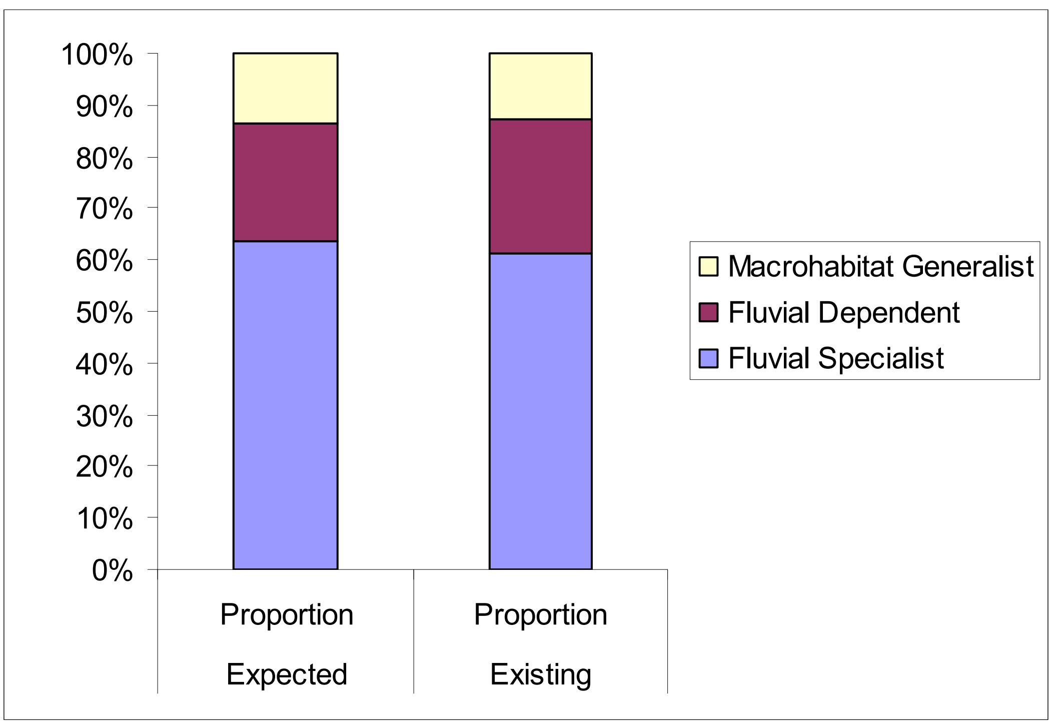

Figure 8. Comparison of Nonnewaug/Weekeepeemee existing and reference fish communities based on habitat use classification guilds

The comparison of the proportions of fish species pollution tolerance classification guilds within the Nonnewaug/Weekeepeemee Rivers existing fish community (56% tolerant, 31% moderately tolerant or intermediate, and 13% intolerant species) to those of the RFC (36% tolerant, 30% moderately tolerant, and 34% intolerant species) showed considerable differences. Most notable of these were the low proportion of pollution intolerant species and the overabundance of pollution tolerant species within the existing fish community (**Figure 9**). Overall, the communities scored a 79 percent model affinity value based on the similarity between the proportions of pollution tolerance guilds within each community.

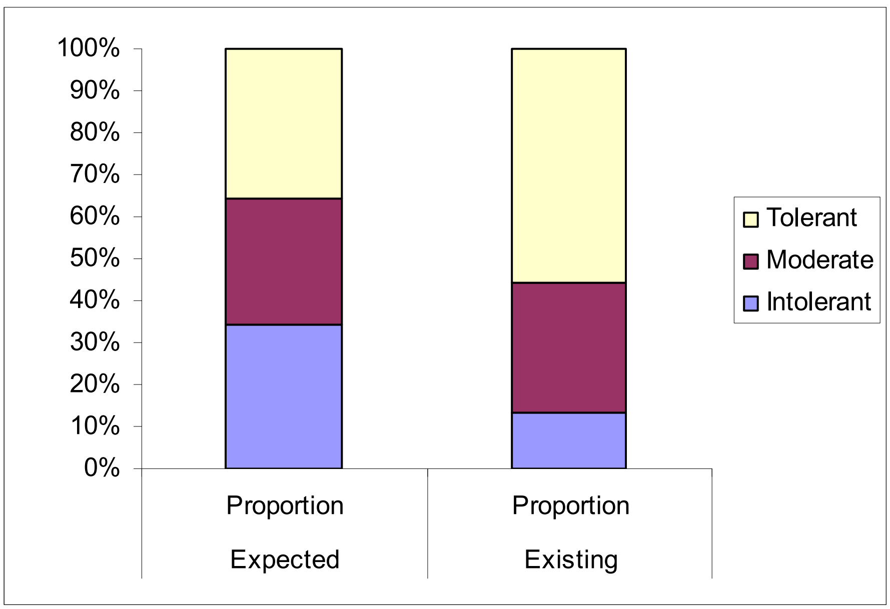

Figure 9. Comparison of Nonnewaug/Weekeepeemee existing and reference fish communities based on pollution tolerance classification guilds

When the RFC and existing community of the Nonnewaug/Weekeepeemee Rivers were compared based on the proportions of fish species thermal regime tolerance guilds, considerable differences were observed (**Figure 10**). The existing fish community consisted of 7% warm, 87% cool*, and 5% cold-water fish species. While warm-water fish species existed in a proportion similar to the expected proportion of the

* Species tolerating a wide range of water temperatures from cold to warm (eurythermal).

Nonnewaug/Weekeepeemee RFC (10%), proportions of cool-water species were expected to be considerably lower (56%), and cold-water species were expected to account for a much greater proportion (34%). When a percent model affinity similarity measurement was applied to the Nonnewaug/Weekeepeemee existing fish community and RFC pollution tolerance guild proportions a value of 68% was calculated.

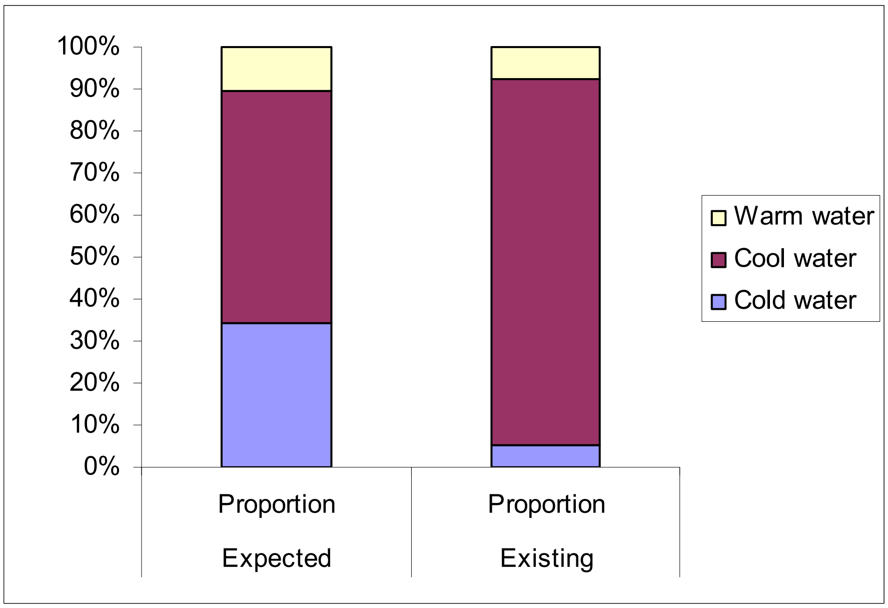

Figure 10. Comparison of Nonnewaug/Weekeepeemee existing and reference fish communities based on thermal regime classification guilds

In the Nonnewaug and Weekeepeemee Rivers there were no individual species that were considered as under-represented. However, seven species that were present within the RFC were absent from the Nonnewaug/Weekeepeemee existing fish community. Four native species were found to exist in abundances considerably higher than expected and were considered overly abundant. Six native species were found in proportions similar to those in the RFC. Three non-native fish species were found to occur within the Nonnewaug/Weekeepeemee Rivers' existing fish community. Individual fish species are listed in **Table 6** based on their designations as under-represented, overly abundant, missing, introduced, or occurring as expected within the Nonnewaug/Weekeepeemee Rivers.

Table 6. Comparison of proportions of fish species between the RFC and the Nonnewaug/Weekeepeemee Rivers existing fish community identifying under-represented, existing as expected, overly abundant, missing, and introduced species in the Nonnewaug and Weekeepeemee Rivers. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerance classifications, and Cold, Cool, or Warm water thermal regime classifications are given for each species.

Species	Proportion of Reference Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Missing native reference fish species						
American eel	15%	0%	N	FD	T	Cool
Atlantic salmon	30%	0%	N	FS	I	Cold
Brown bullhead	2%	0%	N	MG	T	Warm
Chain pickerel	2%	0%	N	MG	M	Warm
Pumpkinseed	2%	0%	N	MG	M	Warm
Redbreast sunfish	3%	0%	N	MG	M	Warm
Redfin pickerel	2%	0%	N	MG	M	Warm
Underrepresented native reference fish species						
N/A						
Native reference fish species recorded as expected						
Brook trout	4%	5%	N	FS	I	Cold
Common shiner	3%	3%	N	FD	M	Cool
Fallfish	3%	3%	N	FS	M	Cool
Longnose dace	8%	10%	N	FS	M	Cool
Tessellated darter	6%	4%	N	FS	M	Cool
Yellow perch	2%	3%	N	MG	M	Cool
Overly abundant native reference fish species						
Blacknose dace	10%	31%	N	FS	T	Cool
Creek chub	2%	6%	N	FS	T	Cool
Golden shiner	1%	2%	N	MG	T	Cool
White sucker	4%	16%	N	FD	T	Cool
Overly abundant non-native/Introduced fish species						
Brown trout	0%	8%	I	FD	I	Cool
Largemouth bass	0%	4%	I	MG	M	Warm
Smallmouth bass	0%	3%	I	MG	M	Warm

Fish Community Evaluation – Pomperaug

The overall affinity between the Pomperaug existing fish community and the Pomperaug RFC was 47%. When a comparison was made between the two communities prior to the calculation of simulated proportions of Atlantic salmon and American eel, the communities exhibited a 50% affinity.

Habitat use guild proportions in the Pomperaug River RFC were similar to those of the Pomperaug River existing fish community (**Figure 11**). The two communities exhibited an affinity of 89%. Specific proportional compositions of each habitat use guild within the Pomperaug RFC and existing fish community were defined earlier in this report in the sections describing the Pomperaug RFC and existing fish community, respectively and can be viewed within Figure 11.

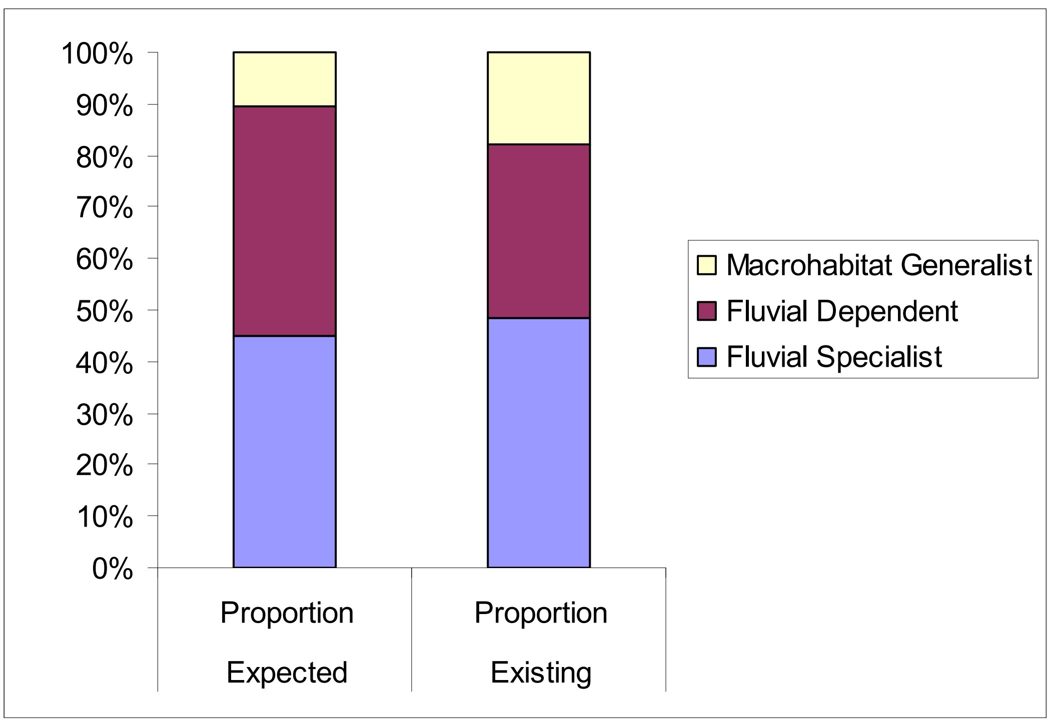

Figure 11. Comparison of Pomperaug River existing and reference fish communities based on habitat use classification guilds

The Pomperaug River existing fish community was also compared to its respective RFC based on fish species pollution and thermal regime tolerance classification guilds. The Pomperaug existing fish community exhibited a strong similarity to the Pomperaug RFC when the communities were compared based on pollution tolerance guilds (**Figure 12**). The existing proportion of pollution tolerant species (59%) was slightly higher than expected (51%), and the existing proportion of moderately tolerant (32%), was slightly lower than the expected proportion (40%). However, these differences were minor. Pollution intolerant species existed in proportions (9%) almost identical to expected proportions (10%). The percent model affinity value for the two communities based on pollution tolerance guilds was 92%.

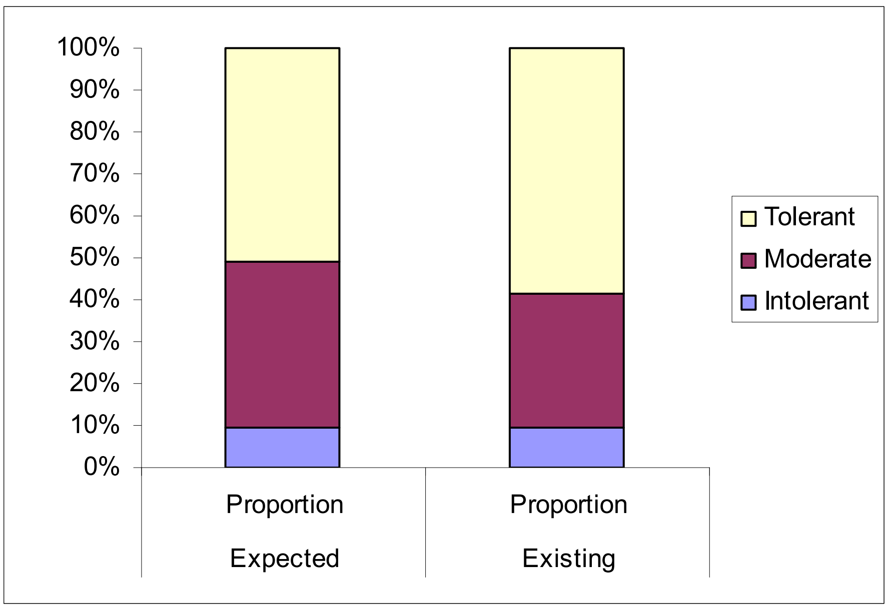

Figure 12. Comparison of Pomperaug River existing and reference fish communities based on pollution tolerance classification guilds

When the existing and expected communities for the Pomperaug were compared based on fish species thermal regime tolerance classification guilds (**Figure 13**), the communities were slightly less similar, having an affinity value of 85%. The existing fish community consisted of warm water (10%), cool water (84%), and cold water (6%) species. Proportions in the Pomperaug RFC were 25%, 73%, and 2%, respectively. The most drastic difference between the two communities was in the proportions of warm water species, which existed in proportions more than double those of the RFC. Cold water species were slightly under-represented within the existing fish community of the Pomperaug River.

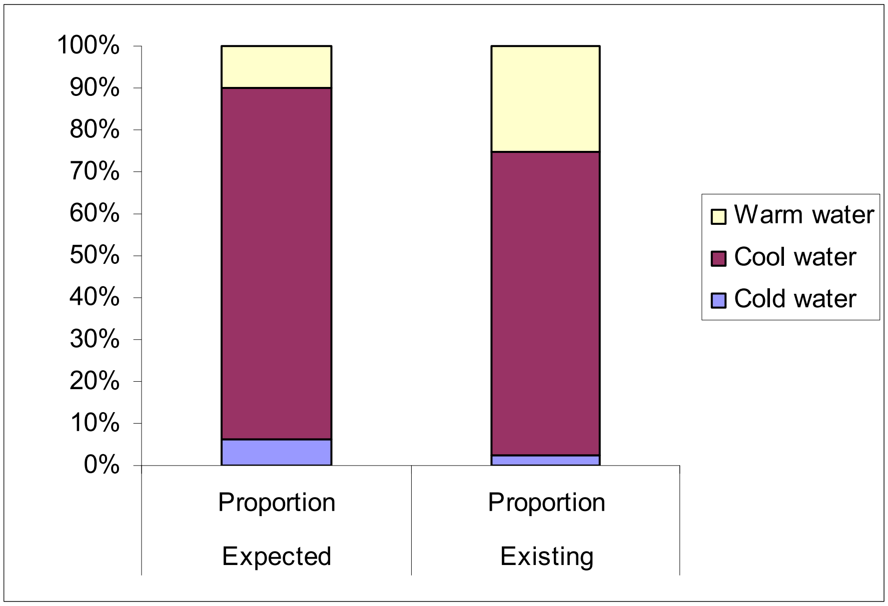

Figure 13. Comparison of Pomperaug River existing and reference fish communities based on thermal regime classification guilds

When comparing the proportions of individual species in the Pomperaug River existing fish community to the expected proportions defined in the Pomperaug RFC, three native species were considered underrepresented, seven were recorded as expected, three were classified as overly abundant, and seven were missing. Four introduced fish species occurred within the Pomperaug River. **Table 7** lists the individual fish species of the Pomperaug River existing fish community based on their designations as under-represented, overly abundant, missing, introduced, or occurring as expected.

Table 7. Comparison of proportions of fish species between the RFC and the Pomperaug River existing fish community identifying under-represented, existing as expected, overly abundant, missing, and introduced species in the Pomperaug River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerance classifications, and Cold, Cool, or Warm water thermal regime classifications are given for each species.

Species	Proportion of Reference Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Missing native reference fish species						
Atlantic salmon	4%	0%	N	FS	I	Cold
Golden Shiner	1%	0%	N	MG	T	Cool
Yellow perch	2%	0%	N	MG	M	Cool
Underrepresented native reference fish species						
American eel	31%	2%	N	FD	T	Cool
Common shiner	6%	3%	N	FD	M	Cool
Longnose dace	15%	5%	N	FS	M	Cool
Native reference fish species recorded as expected						
Blacknose dace	10%	10%	N	FS	T	Cool
Brook trout	2%	2%	N	FS	I	Cold
Fallfish	4%	4%	N	FS	M	Cool
Pumpkinseed	2%	2%	N	MG	M	Warm
Redbreast sunfish	3%	2%	N	MG	M	Warm
Redfin pickerel	1%	2%	N	MG	M	Warm
Tessellated darter	5%	6%	N	FS	M	Cool
Overly abundant native reference fish species						
Creek chub	1%	15%	N	FS	T	Cool
Cutlips minnow	3%	7%	N	FS	I	Warm
White sucker	8%	29%	N	FD	T	Cool
Overly abundant non-native/introduced fish species						
Bluegill	0%	4%	I	MG	T	Warm
Largemouth bass	0%	3%	I	MG	M	Warm
Rock bass	0%	3%	I	MG	M	Warm
Smallmouth bass	0%	2%	I	MG	M	Warm

Discussion

The RFC model is a useful management tool which, similar to TFC models applied to rivers elsewhere in New England, was used to evaluate the existing fish communities, assess the current instream habitat conditions and set goals for future restoration efforts of the Pomperaug River Watershed. The only difference between a TFC and a RFC model is that RFC models attempt to account for species which, as a result of historical extirpations or range-wide declines, are either missing or underrepresented within the Reference Rivers used to develop the models. These species were accounted for in the Pomperaug Watershed RFC models by the use of data from high quality index sites within Connecticut where these species were unaffected by the historic factors contributing to their extirpation and declines, or have either recovered or been restored.

The initial list of fish species with known current or historic distributions within the Pomperaug River Watershed was established through a review of Whitworth's, *Freshwater Fishes of Connecticut* (1996) and recent Pomperaug River Watershed fish survey data (CTDEP). Further review of Schmidt's, *Zoogeography of the Northern Appalachians* (1986) yielded a comprehensive list of fish species with known distributions within the Housatonic River drainage basin and supplemented the initial list. This comprehensive list was then reviewed by local fisheries biologists familiar with the fish fauna of the Pomperaug Watershed, and species were added or removed accordingly. It was determined that the Pomperaug River Watershed was not included in the local range of central mudminnow *Umbra limi*, northern pike *Esox lucius*, longnose sucker *catostomus catostomus*, margined madtom *Noturus insignis*, burbot *Lota lota*, banded sunfish *Enneacanthus obesus*, swamp darter *Etheostoma fusiforme*, and walley *Stizostedium vitreum* (N. Hagstrom, Personal Communication). These species were removed from the list. Diadromous species were considered due to the importance of maintaining and restoring populations of these fish within the state of Connecticut. American eel currently existed in low proportions within the Pomperaug River and, hence, remained on the list. It was determined that the historical distributions of alewife, American shad, Atlantic salmon, blueback herring, and sea lamprey within Connecticut included the Pomperaug Watershed (S. Gephard, Personal Communication). These species were also included in the list. The final list includes a wide range of species and families that are indicative of the fish fauna of the Northeastern Coastal Zone ecoregion. However some local differences were found. For instance, the distributions of banded sunfish and swamp darter, two species associated with the Northern Coastal Zone, did not include the Pomperaug Watershed and were excluded from the list. Despite these minor differences, the final list provided a feasible and comprehensive summary of the current, historic, or potential fish fauna of the Pomperaug River Watershed.

The major difficulty of this analysis was in the selection of suitable Reference Rivers. There were a limited number of low impact stream sections available to serve as references and provide adequate fish data for computation of the RFC models. Finding low impact Reference River sections was less problematic for the Upper Watershed (Nonnewaug and Weekeepeemee Rivers) than it was for the Lower Watershed (Pomperaug River). Smaller streams, similar to those of the Upper Watershed, were generally exposed to less human development and alteration than larger ones and as a result are often less impacted than larger streams. Many potential Reference Rivers for the Lower Watershed exhibited such impacts and could not be used, while only a few of the potential references for the Upper Watershed had to be eliminated for this reason.

While this problem did not affect our selection of suitable Reference Rivers for the Nonnewaug/ Weekeepeemee RFC, it limited us to only three suitable Reference Rivers for the Pomperaug River RFC. The composition of species within a RFC developed for the Pomperaug using only these three rivers was not sufficient to represent the potential community of the Pomeraug River. As a result, the fish data of the impacted streams was investigated to determine whether any impacted streams contained relatively "healthy" fish communities and could be used as Reference Rivers to complete the RFC. Through this investigation, it was realized that the fish data of the Mad River and Saugatuck River did not appear to be affected by the impacted habitat conditions of those rivers. It was also realized that the fish data from these rivers included two native species, creek chub and cutlips minnow, which were present within recent Pomperaug River fish surveys (CTDEP, Gallagher 2003) but were missing from the RFC developed using only the three "healthy" reference rives. It was concluded that the addition of these data to the Pomperaug RFC would result in a more robust, complete, and feasible representation of the Pomperaug River fish community. As a result, the Mad River and Saugatuck River were included, along with the three "healthy" rivers, as references for the development of the Pomperaug RFC.

Prior to the development of the RFC models for the Pomperaug River Watershed it was concluded that diadromous fish species were an important component of the Watershed's historic fish community and should be considered when creating a RFC. Among, the historically present species considered, it was recommended that alwife, American shad and blueback herring not be included within the RFC due to the fact that these species are only present within rivers for a short period of time. Another diadromous species, sea lamprey, was also eliminated from consideration as a RFC member due to this species habitat-use behavior during its freshwater juvenile life-stages. Given that this species burrows into the sediment and filter-feeds from this stationary position, in a fashion more similar to a freshwater mussel than a fish, sampling of this species can be difficult resulting in limited or inaccurate data and making the identification of appropriate proportions of these species within a RFC difficult. The inclusion Atlantic salmon and American eel within the Pomperaug Watershed RFC models was determined to be necessary to consider the habitat and flow needs of these two species. The fact both of these species spend multiple years of their life history cycle within freshwater and are considered to have been present within the Watershed historically, combined with actions or concerns to maintain and/or restore populations of these species throughout Connecticut, resulted in our decision to include them within the RFC (S. Gephard, Personal Communication).

The under-representation of eels and absence of Atlantic salmon within the Reference Rivers led to the need to simulate abundances of these species within each Reference River in order to calculate their expected proportions within the RFC models. This task may not have been possible had it not been for the data provided by CTDEP for these species from several high quality index sites. The average abundances of these species per sample area generated by CTDEP for varying stream orders were essential to our simulations. The simulated proportions of these species within both the Nonnewaug/Weekeepeemee and Pomperaug RFC models seemed appropriate and provided a reference for the historical ranks and proportions of these species within the Pomperaug River Watershed. Such a reference would not have been possible through the use of Reference River fish data alone. The method applied here seems to be a reasonable approach to attaining a reference for historical fish community conditions when pristine reference rivers are not available.

Comparisons between the RFC models and the existing fish communities at both the individual species level and the species group, or guild classification level allowed for a complete assessment of the existing fish communities. A comparison of species specific differences alone may have been affected by the natural variation of species compositions between the Reference Rivers, while a more generalized comparison of species classification guilds, when considered alone, would not have specified missing, under-represented, over-abundant, or non-native species within the existing fish communities. An evaluation of the existing fish communities, which took into consideration comparisons between RFC models and the existing fish communities at both the species specific *and* species guild levels accounted for the deficiencies that either single comparison would have exhibited. These comparisons at multiple levels provided the full range of information required to make logical inferences of potential reasons for differences between the RFC models and the existing fish communities. When both comparisons between specific species and guilds of species groups are considered together, an evaluation of the status of a fish community may be more accurately assessed than if either comparison were considered alone.

When the composition of fish species within the existing fish community of the Nonnewaug and Weekeepeemee Rivers, or the Upper Watershed, was compared to the species composition of the Nonnewaug/Weekeepeemee RFC, there were many obvious differences. Seven species (American eel, Atlantic salmon, brown bullhead, chain pickerel, pumpkinseed, redbreast sunfish, and redfin pickerel) were missing from the existing fish community, while four others (blacknose dace, creek chub, golden shiner, and white sucker) were found in overly abundant proportions. Six other species were recorded in similar proportions as those of the RFC. There were only three non-native fish species, brown trout (8%), largemouth bass (4%), and smallmouth bass (3%), recorded within the Nonnewaug and Weekeepeemee Rivers. While there proportions were relatively low, non-native fish are never included within RFC (or TFC) models and are, as a result, always considered as overly abundant. There were no species found to be under-represented within the Upper Watershed (aside from those that were missing outright). Many fluvial species (brook trout, common shiner, fallfish, longnose dace, and tessellated darter) were recorded as expected, as was yellow perch.

Aside from American eel and Atlantic salmon, all of the missing species were macrohabitat generalist, warm-water fish. Typically warm-water macrohabitat generalist species are associated with pond habitats and fluvial species are generally associated with rivers and streams. While this may indicate that the Nonnewaug and Weekeepeemee have less "pond" fish and potentially cooler water conditions than the Reference Rivers, it may also indicate a lack of physical cover and pool-habitat, two critical habitat attributes. Given the fact that all of the fish species that were recorded as expected were cool or cold-water species, fluvial species (except yellow perch), and habitat observations and mappings of the Upper Watershed both of these theories may be accurate. Increasing physical cover (e.g. course woody debris) within the Upper Watershed could result in geo-morphological changes in the river that would increase pool habitat and provide physical cover for the under-represented macrohabitat generalist species without negatively affecting fluvial conditions or species. It is also possible that non-native introduced macrohabitat generalist species (largemouth bass and smallmouth bass) are out-competing the native macrohabitat generalist species, explaining the numerous native macrohabitat generalist species missing from the existing fish community.

The absence of Atlantic salmon and American eel within the Upper watershed can be explained by the presence of multiple dams between the study area and Long Island sound which have prevented the migrations of these fish between freshwater and the sea for hundreds of years. The fact that all of the overly abundant species are pollution tolerant could suggest that at some point the Upper Watershed may have experienced some form of pollution. However, the theoretical inference approach of this analysis does not provide direct evidence to support that suggestion. Furthermore, the overabundance of pollution tolerant should be considered with respect to simulated proportions of Atlantic salmon and American eel. Prior to simulating proportions of these species within the RFC blacknose dace existed in proportions as expected. While the other three species were still over-abundant prior to simulations, the difference between the pollution tolerant guilds of the two communities was slightly less. Overall, the two communities were much more similar (68%) prior to simulations. The under-representation of cold-water species within the Upper Watershed can be explained by the absence of Atlantic salmon alone, as the only other cold-water-dependent species, brook trout, existed in expected proportions. It should be acknowledged though, that brook trout have experienced regional population declines (Karas 1997, TU 2004) and may have been under-represented within the Reference Rivers.

The comparison of the habitat use guild proportions between the two communities of the Upper Watershed illustrated remarkably similar guild proportions. The existing fish community of the Upper Watershed contained 87% fluvial species (61% fluvial specialist and 26% fluvial dependent). This high proportion of fluvial species within the existing fish community exceeds the proportions found in many similar fish community investigations (Armstrong et al. 2001, Parker et al. 2004, Kearns et al. 2005) and indicates highly favorable habitat conditions for fluvial species within the Nonnewaug and Weekeepeemee Rivers. This analysis implies that if Atlantic salmon and American eel were to recover within the Nonnewaug and Weekeepeemee, the fish community of the Upper Watershed could expect to exhibit a high affinity to reference conditions.

The evaluation of the Pomperaug River, or Lower Watershed existing fish community revealed three fish species (Atlantic salmon, golden shiner, and yellow perch) that were present within the Pomperaug RFC but missing from the existing fish community. Another three species (American eel, common shiner, and longnose dace) were under-represented within the Pomperaug River based on the proportions specified by the RFC. Seven species were recorded in proportions similar to the RFC and three (creek chub, cutlips minnow, and white sucker) were overly abundant. Four non-native species, bluegill (4%), largemouth bass (3%), rock bass (3%), and smallmouth bass (2%), were present within the Lower Watershed.

The most striking differences between the Pomperaug RFC and existing fish communities are the under-abundance of American eel and the absence of Atlantic salmon. The proportion of eels within the RFC was not affected by the simulated abundances of these species within the Reference Rivers. The same under-representation existed prior to simulations. The cause of these species absence or low abundance within the Pomperaug River is attributed to multiple migratory passage barriers downstream of the study area. The presence of eels within the Pomperaug River is evidence that some are able to negotiate these barriers, and suggests that historical abundances within the Watershed may have been higher prior to the building of dams.

Two pollution tolerant species, creek chub and white sucker were present in proportions considerably higher than expected. However, one pollution *intolerant* species, cutlips minnow was also overly abundant, and another, brook trout, was recorded as expected. The over-abundance of pollution tolerant species alone does not provide the information necessary to imply that pollution may be a factor affecting the fish community of the Pomperaug River. Furthermore, the over abundance of a pollution intolerant species (cutlips minnow) and the presence of the highly pollution sensitive brook trout suggest that pollution is not a factor. Again, as in the Upper Watershed, the under abundance of cold-water species can be explained by the absence of Atlantic salmon, a species which was eliminated from the region for reasons other than the thermal conditions of the Pomperaug River. Temperature does not explain the absence of this species and should not be considered a problem within the Pomperaug River based on this analysis. The presence of brook trout, again, illustrates this point. The slight overabundance of warm-water species and macrohabitat generalists do not seem to be explained by water temperature conditions or habitat conditions given that the Lower watershed includes the expected proportion of cold-water species (excepting Atlantic salmon as explained above) and 90% fluvial species. Perhaps the over abundance of macrohabitat generalists and warm water fish is better explained when considering the status of non-native species within the community. The presence of the four non-native fish species (which are all warm-water macrohabitat generalists) accounts for these over abundances. It is also highly likely that the non-native macrohabitat generalist species which have been introduced to the Pomperaug River are out-competing the native macrohabitat generalist species of the Pomperaug River. The only species missing from the Pomperaug River, other than Atlantic salmon, golden shiner and yellow perch are both native macrohabitat generalist species.

Overall, the Pomperaug River exhibits relatively healthy fish community dominated by fluvial species. The recovery of American eel alone would substantially increase the affinity of the community to the RFC. The over abundance of white sucker within the Pomperaug River was substantial even prior to Atlantic salmon and American eel simulations and had a considerable affect on the affinity of the two communities. Had proportions of eel and white sucker been not been so different from the RFC, the communities would have been highly similar.

This analysis illustrated the impacts that non-native fish species may be having on native stream fish communities and particularly on the native macrohabitat generalists of the Pomperuag River Watershed. Investigating this matter further may be critical to the preservation of native fish communities. In particular the fish communities of the Pomperaug River watershed should be monitored with regard to this theory to assess the changes in fish community composition over time and in an effort to maintain native fish communities.

The RFC models developed for the Pomperaug Watershed provided information that was crucial to the MesoHABSIM modeling process. The models identified the core groups of native fish species expected to dominate the Upper and Lower portions of the Pomperaug River Watershed under un-impacted conditions. These species then served as indicator species for the MesoHABSIM. Their habitat requirements provided a baseline template used to quantify stream flows necessary to maintain the biological integrity of aquatic habitat throughout the year. In other words, fish were used as an indicator of the biological integrity of aquatic habitat, providing important information used to determine the necessary amount of instream flow required within the river to provide and maintain sufficient amounts of habitat to support the biological needs of the existing fish community. Methods of identifying habitat-related instream flow thresholds are crucial to sustaining “healthy” ecological communities in the face of the numerous competing needs for limited regional water resources. The RFC and MesoHABSIM approaches proved to be highly effective methods of accomplishing this task for the Pomperaug River Watershed.

The same core group of species ranked among the top seven or eight positions within both RFC models. The differences in positions of these species between the two communities were appropriate considering the geo-morphologic and hydro-morphologic differences between the Upper and Lower Watershed. Brook was ranked seventh within the Upper Watershed, replacing common shiner among the group of species which were dominant within the Lower Watershed. Common shiner was ranked eighth within the Upper Watershed and was still considered among the core group of dominant species for the Upper Watershed. Brook trout, however, was not a dominant species within the Lower Watershed. The difference between the two communities, with respect to brook trout is easily explained by the differences between the Upper and Lower Watershed and the habitat requirements of this species, and is appropriate given these circumstances. The consistency of the top ranking species within both communities (with the exception of brook trout) suggests that appropriate Reference Rivers were selected for both the Upper and Lower Pomperaug Watershed RFC models.

Based on the species dominating the two RFC communities, American eel, Atlantic salmon, blacknose dace, brook trout, common shiner, longnose dace, tessellated darter, and white sucker were selected as indicator species for the MesoHABSIM modeling process. The habitat suitability requirements (based on linear regression coefficients developed from empirical fish capture data, see Appendix 3) and weighted proportions of these species within the RFC models were used to calibrate the model for the Upper and Lower portions of the Watershed, respectively. Brook trout was not a dominant species within the Pomperaug River RFC, and was not included as an indicator species for the Lower Pomperaug Watershed. The habitat suitability and proportions of brook trout *were* factors in the MesoHABSIM modeling of the Upper Watershed.

In addition to providing the indicator species used for habitat modeling, the RFC models served as evaluation tools to assess the existing fish communities of the Upper and Lower Pomperaug River Watershed. An inference approach, based on comparisons between fish species habitat use, pollution tolerance, and thermal regime guilds, was used to identify potential causes for deviations of fish species-proportions from those specified within the RFC models. This analysis and report provide a gauge to guide watershed management objectives and measure the results of any physical or biological rehabilitation efforts that may occur within the Pomperaug River Watershed.

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