Development of Target Fish Community Models for Massachusetts Mainstem Rivers

Technical Report

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Department of Fish and Game
Division of Fisheries and Wildlife

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Executive Summary

In 2005, the Massachusetts Division of Fisheries and Wildlife (MDFW) received funding from the Executive Office of Energy and Environmental Affairs (EOEEA) to apply the Target Fish Community (TFC) approach to the majority of Massachusetts mainstem rivers. The method sets a template for defining a fish community that is appropriate for a river in southern New England (Meixler, 2006). TFCs describe expected fish community composition. This allows us to compare an expectation to what we currently find in our mainstem rivers. While impairments to aquatic habitat have been well documented within the Commonwealth, only now using this tool can we begin to understand the affect these impairments have had on fish communities in each major river and begin to prioritize restoration actions.

Each mainstem river TFC is constructed using fish community data from several relatively high quality rivers (e.g. few or no impoundments, withdrawals, low impervious surface) that have similar physical and zoo-geographical characteristics (e.g. watershed size, geology, gradient). For the purposes of this report, these high quality rivers will be called reference rivers.

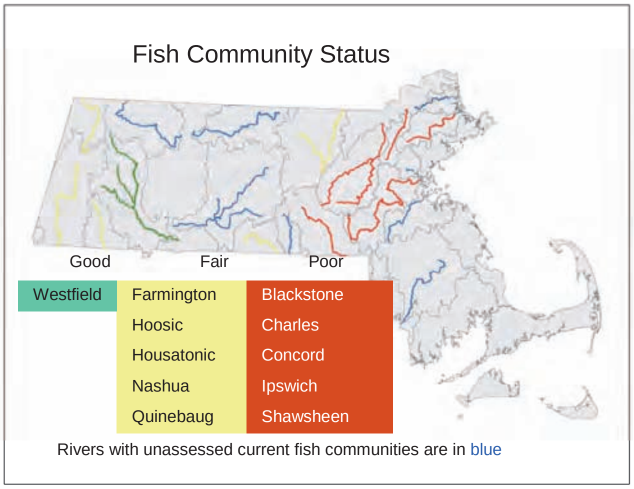
This report followed the methodology of previous Massachusetts applications (Quinebaug, Housatonic, and Charles Rivers) to develop Target Fish Communities for mainstem reaches of the Blackstone, Chicopee, Concord, Deerfield, Farmington, French, Hoosic, Ipswich, Millers, Mystic, Nashua, Neponset, Parker, Shawsheen, Taunton, and Westfield Rivers. Results from the Quinebaug, Housatonic, and Charles are also summarized in this document. Those basins for which TFCs are not developed (Connecticut River, Merrimac River, North Coastal, South Coastal, Buzzards Bay, Cape Cod, Ten Mile and Islands) are also discussed and suggestions are made for their evaluation.

TFCs were consistently dominated by riverine species. Species that were predicted to be abundant included fallfish, common shiner, white sucker, blacknose dace, longnose dace, and tesselated darter. Riverine species made up between 67 percent and 93 percent of each Target Fish Community.

In cases where comprehensive fish community data were available (based on number of samples, number of fish captured, data quality, and representative habitat sampled) on the existing fish community, TFCs were compared to existing fish communities. These comparisons are currently available for eleven mainstem rivers. The mainstem fish communities were compared to their respective TFCs by a percent similarity index (Novak and Bode, 1992). This index measures, on a scale of zero (no similarity) to 100 percent (complete similarity), the degree to which the current and Target Fish Communities coincide based on species presence and relative abundance. Mainstem rivers lacking sufficient sampling to determine similarity scores will be

prioritized for sampling in the future. We used the percent similarity scores, in conjunction with species scarcity measures to categorize the studied rivers into good, fair, or poor condition.

Only the Westfield River fish community is considered to be in good condition (similarity score > 75% and no scarce species). Rivers in good condition maintain a diverse fish



community that is dominated by the same species predicted to be in their respective TFC. The Farmington, Hoosic, Housatonic, Nashua, and Quinebaug River fish communities are considered to be in fair condition (similarity scores between 50 and 75% and few or no scarce species, with some exceptions explained fully in the text). These rivers maintain a fish community with many of the same fluvial fish species predicted by their respective TFC and most of these species are relatively abundant. The Blackstone, Charles, Concord, Ipswich, and Shawsheen River fish communities are considered to be in poor condition. These rivers are no longer dominated by the fluvial species predicted by their respective TFC. Many of the predicted species are either scarce or entirely absent.

Of the five species predicted to be most abundant in each mainstem, only two rivers (Westfield and Housatonic Rivers) retain those five species in abundance (10% or greater of the predicted percentage).

The deviation of the TFC from the current fish community is also described in this report using two variables: 1) habitat-use categories, and 2) tolerances. Habitat Use Categories were adopted as in Bain and Meixler (2008) with minor modification: fluvial specialist (FS) species that require flowing water for all of their life-history requirements; fluvial dependent (FD) species that require flow for at least come portion of their life history; and macrohabitat generalist (MG) species that can meet all of their life-history requirements in lentic conditions. Rivers that are dominated by macrohabitat generalist species likely have impairments to stream flow or are dominated by impounded habitat. Three tolerance categories following Plafkin et al. (1989): intolerant (I), moderately tolerant (M), and tolerant (T), reflect the species observed tolerance to environmental degradation. Rivers that are dominated by tolerant individuals or have lost intolerant species entirely are likely impacted by water quality impairments.

Based on habitat use categories, the similarity scores ranged from 95 percent (Westfield River) to 31 percent (Ipswich

River). Based on tolerances, the similarity scores ranged from 95 percent (Westfield River) to 54 percent (Shawsheen River).

Only the Westfield River maintains a diverse riverine fish community. The fish communities in the other mainstem rivers examined reflect considerable impairments to habitat. Impairment of some rivers appears to be driven by water quantity and physical habitat alteration while others are primarily driven by water quality. Many, however, are severely impacted by both measures. These measures of degradation can be used to prioritize restoration actions and can be incorporated into natural resource allocation and protection frameworks like land acquisition, reclassification of basin stress and the development of Index Stream Flows.

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1.0 Introduction

There are multiple fish community-based techniques that are used to assess the health of aquatic ecosystems (Karr 1981, Simon 1999, Yoder and Kulik 2003). One method that has been successfully developed and applied in the northeast region is the Target Fish Community (TFC) model. The TFC was first developed by Bain and Meixler (2008) for use on the Quinebaug River in Massachusetts. The method set a template for defining a fish community that is appropriate for a river in southern New England (Meixler, 2006) and a broad management objective of providing direction and progress assessment for restoration activities (Bain and Meixler, 2008).

The Quinebaug TFC model was constructed using fish community data from several relatively unimpacted rivers that were similar physically and zoo-geographically to the Quinebaug. These relatively unimpacted rivers, while called reference rivers in this context, are more accurately described as rivers that currently maintain a diverse riverine fish community in a human dominated landscape (Bain and Meixler, 2008). They are not considered to be in pre-colonial or pristine condition.

Subsequent TFCs were developed for the Housatonic (Kearns et al. 2004) and Charles Rivers (Meixler, 2006) in Massachusetts and the Souhegan (Legros, 2006) and Lamprey Rivers (Legros and Paraciewicz, 2007) in New Hampshire. Each TFC study advanced the method in some measurable way. Kearns (2004) developed a list of mainstem criteria for selecting reference rivers; Legros (2006) developed a GIS utility to create a region-wide list of potential reference rivers, and Legros (2006) and Meixler (2006) incorporated both of these elements.

To date, the TFC method have been applied by a wide range of parties (academic, state agency, watershed organizations) and have been completed at the rate of one or two mainstem rivers each year. In order to facilitate statewide method completion in a timely and consistent fashion, funding was provided as part of the Massachusetts Water Policy. The Water Policy was created in 2004 by the Secretary of the EOEEA. The Secretary appointed a Task Force with representatives from environmental groups, industry, public works, local, state and federal government. The Task Force discussed key water-related issues and made recommendations for protecting water resources. One of the key principles of the Water Policy is to protect fish and wildlife habitat. One of the Water Policy recommendations was to conduct Target Fish Community assessments.

The goal for this project was to develop TFC models for the remaining large rivers in Massachusetts for which the method is applicable. Having a statewide and consistent method for assessing the integrity of large streams and rivers will facilitate water resource allocation and restoration decisions.

This report does not describe TFCs for the Connecticut or Merrimack Rivers. Both of these rivers are large (6^{th} order) and reside primarily outside Massachusetts jurisdiction. The extreme size of these rivers makes reference river selection impractical. In addition, methods to determine the existing community structure of large rivers are currently under development (Yoder and Kulik 2003) and will be employed in the future.

Other geographical areas not covered by river-specific target fish communities include the North and South Coastal basins, Buzzards Bay, and Cape and Islands. The streams and rivers within these boundaries are smaller than the mainstem rivers covered by the TFC methodology and would be better served by the development of an Index of Biotic Integrity.

2.0 Methods

2.1 Reference River Selection

Reference rivers are defined in this context as systems that have relatively few significant human impacts in their watersheds. While these reference rivers are not unimpacted or pristine, they currently have the water quantity, water quality and physical habitat to maintain a diverse riverine fish community in a human dominated landscape.

The first step in the reference river selection process was to compile a list of rivers physically and zoo-geographically similar to each river for which a TFC was to be developed. A program written by the Northeast Instream Habitat Program was used to select potential reference rivers from a stream data layer created by The Nature Conservancy in 2003. The TNC data layer is unique in that it is multi-state and has the appropriate variables to determine physical and zoo-geographic similarity between study-rivers and potential reference rivers. The program selected rivers or river reaches that most closely approximated the following basin characteristics for each of the sixteen TFC rivers: drainage area, stream order, gradient class, elevation class, calcareous geology, and Ecoregion (EPA Level III, Omernick, 1987).

These rivers were further scrutinized in a process described by Kearns et al. (2004), Bain and Meixler (2008), and Legros (2006) that incorporates consultation with regional state and federal fisheries biologists to determine the suitability of the river for use as a reference based on the presence of dams, water withdrawals, channelization, and extent of watershed in non-natural (e.g. impervious) land use. Those rivers considered to be in poor ecological condition were removed from consideration as reference rivers. Again using best professional judgment, additional rivers of similar physical and zoo-geographic characteristics were suggested by regional fisheries experts and incorporated in to the analysis.

Finally, only reference rivers with suitable fishery information could be included in the analysis. Fishery data was provided by regional biologists. As in other TFC development publications (Kearns et al. 2004, Meixler 2006), suitable fishery information was defined as at least two sampling events from free-flowing reaches of river with at least 10 individuals of the most abundant species. A total of 32 rivers in the northeast region were identified and used as reference rivers (Table 1).

2.2 Target Fish Community Models

Community level fish data from the respective reference rivers for each mainstem were collected, organized and used to develop TFC models. For each reference river, the total abundance for each species was calculated by summing fish counts from multiple sample sites. Species abundances were then converted into percentages by dividing the total number of fish of each species by the total number of fish.

The TFC methodology is used to determine expected proportions of freshwater species that occur year-round in Massachusetts rivers and are present in multiple age classes. For this reason, several fish species were removed from the analysis. Atlantic salmon were excluded from the analysis as all current populations are maintained by an annual stocking effort. Most migratory species were removed from the analysis as they are only present in freshwater systems for short periods and might not be captured during sampling events. Unlike the other migratory species, American eel spend the majority of their adult lives (often for several years) in freshwater systems and were included in the analysis.

Percent compositions of each species were summed across the selected reference rivers for each mainstem model. The summed percentages were ranked, creating a species list in rank order of expected abundance. Ranks for non-native, out of distribution range, and stocked fish species were removed at this point. The native and non-native species classification by Hartel et al. (2002, Table 2) was used to determine a species inclusion in the ranking procedure. Species that were considered out of their distribution range for a specific mainstem were excluded using species distribution maps created by Hartel et al. (2002). The remaining ranks were converted to expected proportions using a rank-weighting technique as outlined by Bain and Meixler (2008). Species ranks were converted to reciprocals (1/rank) and then summed in decimal form. Expected proportions for each species were calculated by dividing the reciprocal rank by the sum of all reciprocal ranks. Model calculations and expected proportions were calculated for all mainstem TFC models (Appendix A).

Table 1. Physical characteristics of the 32 reference rivers used in the development of Massachusetts target fish community models.

0River	State	Drainage Area (km^2)	Stream Order	Calcareous Geology[a]	Gradient Class[b]	Elevation Class[c]	EPA Level III Ecoregion[d]	Data Source[e]
Third Branch White River	VT	280	4	Acidic	1	1	58	VT DEC
Ammonoosuc River	NH	842	4	Acidic	2	1	58	NH DES
Ashuelot River	NH	241	4	Acidic	2	1	58	NH DES
Ashuelot River	NH	904	5	Acidic	1	1	58	NH DES
Batten Kill	NY	391	4	-	1	1	58	NYSDEC
Black Creek	NY	161	3	-	1	1	58	NYSDEC
Cold River	NH	251	4	Acidic	2	1	58	NH DES
East Branch Westfield River	MA	373	5	Acidic	1	1	58	MA DFW
Eightmile River	CT	145	4	Acidic	1	1	59	NEIHP
Green River	MA	150	3	Neutral	2	1	58/59	MA DFW
Hollenbeck River	CT	109	4	Acidic	1	1	58	CT DEP
Isinglass River	NH	166	4	Acidic	1	1	59	NH DES
Kinderhook River	NY	389	3	-	1	1	58	NYSDEC
Lamprey River	NH	350	4	Acidic	1	1	59	NH DES
Little Hoosic River	NY	194	3	-	1	1	58	NYSDEC
Little River	ME	132	3	Neutral	1	1	58/59	USGS
Mt Hope Brook	CT	91	3	Acidic	1	1	59	CT DEP
North Branch Sugar River	NH	231	4	Acidic	2	1	58	NH DES
Nissitissit River	MA	145	4	Acidic	1	1	58/59	MA DFW
North River	NH	339	4	Acidic	1	1	59	NH DES
North River	MA	233	4	Neutral	2	1	58	MA DFW
Pawcatuck River	RI	712	5	Acidic	1	1	59	WPWA, RI DEM
Piscataquog River	NH	559	5	Acidic	1	1	58	NH DES
Queen River	RI	93	3	Acidic	1	1	59	RI DEM
Salmon Brook	CT	179	4	Acidic	1	1	58/59	CT DEP
Salmon River	CT	290	4	Acidic	1	1	59	CT DEP
South Branch Piscataquog River	NH	267	4	Acidic	1	1	58	NH DES
Tenmile River	NY	539	5	Neutral	1	1	58	USGS, CT DEP

Table 1. Reference Rivers (continued).

River	State	Drainage area (sq miles)	Stream order	Calcareous geology[a]	Gradient class[b]	Elevation class[c]	EPA Level III Ecoregion[d]	Data source[e]
West Branch Westfield River	MA	249	3	Acidic	1	1	58	MA DFW
Willimantic River	CT	321	4	Acidic	1	1	59	CT DEP
Wood River	RI	231	4	Acidic	1	1	59	RI DEM
Yantic River	CT	259	3	Acidic	1	1	59	CT DEP

[a]Calcareous Geology: Neutral = >40% calcareous for watersheds < 518 km^2; > 30% for watersheds > 518 km^2; otherwise Acidic;
"-" = undetermined
[b]Gradient Class: 1 = 0-0.5%, 2 = 0.5-2.0%
[c]Elevation Class: 1 = 0-800 ft
[d]EPA Level III Ecoregions: following Omernick, 1987; 58 = Northeastern Highlands, 59 = Northeastern Coastal Zone

[e]Data Sources
CT DEP – Connecticut Department of Environmental Protection-Fisheries
MA DFW – Massachusetts Division of Fisheries and Wildlife
NEIHP – Northeast Instream Habitat Program
NH DES – New Hampshire Department of Environmental Services
NYSDEC – New York State Department of Environmental Conservation
RI DEM – Rhode Island Department of Environmental Management, Division of Fish and Wildlife
USGS – U.S. Geological Survey National Water-Quality Assessment Program (NAWQA)
VT DEC – Vermont Department of Environmental Conservation
WPWA – Wood-Pawcatuck Watershed Association

Table 2. Massachusetts fish species with their Origin (Hartell et al. 2002), habitat-use categories (HUC) based on Bain (1992 – and modified for regional application), and tolerance (Plafkin et al. 1989).

Species	Scientific Name	Origin[a]	Habitat-Use Category[b]	Tolerance[c]
American eel	*Anguilla rostrata*	N	MG	T
Atlantic salmon	*Salmo salar*	N	FS	I
Banded killifish	*Fundulus diaphanus*	N	MG	T
Banded sunfish	*Enneacanthus obesus*	N	MG	I
Black crappie	*Pomoxis nigromaculatus*	I	MG	M
Blacknose dace	*Rhinichthys atratulus*	N	FS	T
Bluegill	*Lepomis macrochirus*	I	MG	T
Bluntnose Minnow	*Pimephales notatus*	I	MG	T
Bridle shiner	*Notropis bifrenatus*	N	MG	I
Brook trout	*Salvelinus fontinalis*	N	FS	I
Brown bullhead	*Ameiurus nebulosus*	N	MG	T
Brown trout	*Salmo trutta*	I	FS	I
Chain pickerel	*Esox niger*	N	MG	M
Channel catfish	*Ictalurus punctatus*	I	MG	M
Common carp	*Cyprinus carpio*	I	MG	T
Common shiner	*Notropis cornutus*	N	FD	M
Creek chub	*Semotilus atromaculatus*	N	FS	T
Creek chubsucker	*Erimyzon oblongus*	N	FS	I
Cutlip Minnow	*Exoglossum maxillingua*	I	FS	I
Fallfish	*Semotilus corporalis*	N	FS	M
Golden shiner	*Notemigonus crysoleucas*	N	MG	T
Green sunfish	*Lepomis cyanellus*	I	MG	T
Landlocked salmon	*Salmo salar*	I	FD	
Largemouth bass	*Micropterus salmoides*	I	MG	M
Longnose dace	*Rhinicthys cataractae*	N	FS	M
Longnose Sucker	*Catostomus catostomus*	N	FD	I
Northern pike	*Esox lucius*	I	MG	I
Pumpkinseed	*Lepomis gibbosus*	N	MG	M
Rainbow trout	*Oncorhynchus mykiss*	I	FS	I
Redbreast sunfish	*Lepomis auritus*	N	MG	M
Redfin pickerel	*Esox americanus americanus*	N	MG	M

Table 2. (Continued)

Species	Scientific Name	Origin[a]	Habitat-Use Category[b]	Tolerance[c]
Rock bass	*Ambloplites rupestris*	I	MG	M
Slimy sculpin	*Cottus cognatus*	N	FS	I
Smallmouth bass	*Micropterus dolomieu*	I	MG	M
Spottail shiner	*Notropis hudsonius*	N	MG	M
Swamp Darter	*Etheostoma fusiforme*	N	MG	I
Tesselated darter	*Etheostoma olmstedi*	N	FS	M
White perch	*Morone americana*	N	MG	M
White sucker	*Catostomus commersoni*	N	FD	T
Yellow bullhead	*Ameiurus natalis*	I	MG	T
Yellow perch	*Perca flavescens*	N	MG	M

[a]- Origin categories: N = Native, I = Introduced
[b]- Habitat-use categories: FS = fluvial specialist, FD = fluvial dependent, MG = macrohabitat generalist
[c]-Tolerance categories: T = Tolerant, M = Moderately Tolerant, I = Intolerant

2.3 Similarity Testing

Comparisons were made between the TFC and the existing fish community where possible. Mainstems were considered adequately sampled if they had multiple sample sites from free flowing sections along the longitudinal length of the river and a range of available habitat types (e.g. riffle, pool, and run) within the mainstem. To maintain method consistency, only sites that were sampled by either backpack or barge electroshocking were used. Sites with obviously impacted habitat (based on field notes), poor efficiency (e.g. high water or poor visibility due to silt), low fish sample size, or within impounded reaches were excluded. A list of all sample sites used for each river and the proportions of each species sampled at each site is found in Appendix B.

Percent similarity between TFC and current fish communities was calculated using a similarity measure developed by Novak and Bode (1992).

Percent similarity = 100 – 0.5 (sum | target P – observed P |)

where: P = proportions of each species in the community

The percent similarity scores range from 0 to 100, with high scores corresponding to a high degree of similarity between the TFC and current fish community.

2.4 Species Scarcity

To supplement the similarity scores provided for each mainstem, a measure of species scarcity was developed to illustrate mainstem-wide biological disturbances. For this procedure, those species that were predicted to be most abundant (ranks 1-5) were examined in detail.

Species were considered scarce is they were found in the current fish community at less than 10 percent of the predicted (TFC) proportion. For example, a species that was predicted to make up 30 percent of the fish community would be considered scarce if it made up less than 3 percent current fish community. While 10 percent is subjective, it is intended to reflect that a species is missing or nearly so. Species scarcity is indicative of degradation of environmental conditions severe enough to eliminate or nearly eliminate a given species that is predicted to be among the most abundant in a river.

We used the percent similarity scores and species scarcity measures to categorize the studied rivers into good, fair, or poor condition. Rivers that have percent similarity scores greater than 75 percent were considered to be in good condition. Rivers that have percent similarity scores between 50 percent and 75 percent were considered to be in fair condition. Rivers that scored below 50 percent similarity were considered to be in poor condition. While the majority of the weight of the categorization stems from the similarity score, species scarcity was useful to categorize rivers that were on the edge of the category demarcations or had unique fish community attributes worthy of further clarification.

2.5 Habitat-Use Categories and Tolerances

Species were classified into three habitat-use categories and three tolerance categories. Habitat Use Categories were adopted as in Bain and Meixler (2008) with regional modification: fluvial specialist (FS) species that require flowing water for all of their life-history requirements; fluvial dependent (FD) species that require flow for at least some portion of their life history; and macrohabitat generalist (MG) species that can meet all of their life-history requirements in lentic conditions. Rivers that are dominated by macrohabitat generalist species likely have impairments to stream flow or are dominated by impounded habitat.

Three tolerance categories following Plafkin et al. (1989) (Table 2): intolerant (I), moderately tolerant (M), and tolerant (T), reflect the species observed tolerance to environmental degradation. Water quality concerns should likely be addressed in rivers that are dominated by tolerant individuals or have lost intolerant species entirely.

Just as was done for the proportions of each fish species in a fish community, similarity scores were calculated, for the proportions of the fish community in each macrohabitat and tolerance category in the target and current fish communities.

3.0 Results

Statewide results will be presented here for similarity scores, species scarcity, river condition, habitat use categories, and tolerances in section 3.1. The details of each river-specific TFC will be described section 3.2.

3.1 Statewide TFC Results

Target fish communities were developed for 16 mainstems during the course of this project. Three TFCs, previously developed, are also presented and referenced in this document, bringing the total number of TFCs to 19 statewide (Figure 1).

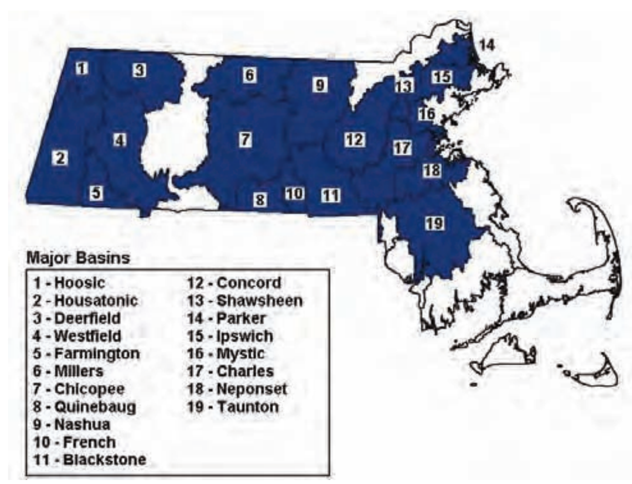

Figure 1. Map of major river basins in Massachusetts that have target fish community models. Major basins that have target fish community models from previous studies include: Housatonic (Kearns et al. 2004), Quinebaug (Bain and Meixler 2008), and Charles (Meixler 2005).

3.1.1 Similarity and Species Scarcity

Similarity testing was conducted on the eleven rivers for which sufficient data was available to compare the TFCs to the current fish communities (figure 2). The similarities ranged from a low of 22% similarity (Blackstone) to a high of 76% similarity (Westfield). The results of the species scarcity analysis also varied among mainstems and ranged from 4 species scarce or absent (Blackstone) to zero species scarce or absent (Westfield and Housatonic) (Figure 2).

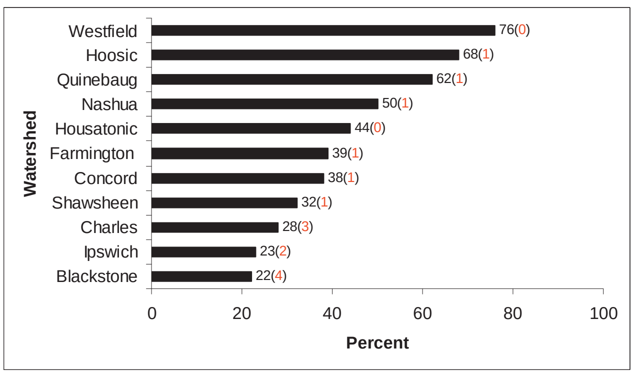

Figure 2. Percent similarity based on species percent abundance values for select Massachusetts watersheds. Charles, Housatonic and Quinebaug results are from Meixler (2005), Kearns et al. (2004), and Bain and Meixler (2008) respectively. Number in parenthesis represents the species predicted to be in the TFC that were either scarce (10% or less of the PREDICTED abundance) or absent in the current community.

3.1.2 River Condition

Percent similarity and species scarcity were used to categorize the rivers broadly into good, fair and poor condition (Figure 3). While the majority of the weight of the categorization stems from the similarity score, species scarcity was useful to categorize rivers that were on the edge of the category demarcations or had unique fish community attributes worthy of further clarification.

Only the Westfield River was categorized as having a fish community in good condition (similarity score > 75%; species scarcity = 0). The Westfield River maintains a diverse fish community that is dominated by the same species predicted to be in the TFC.

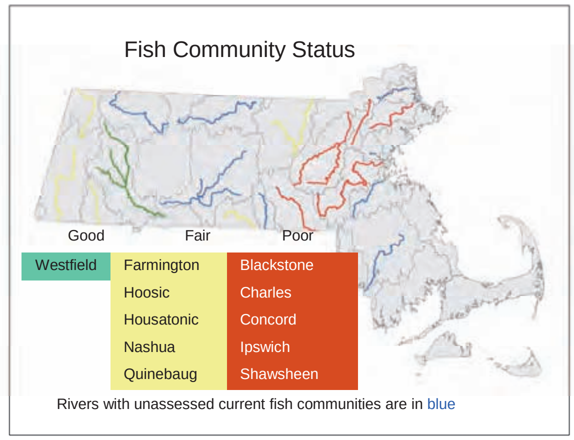

Figure 3. River condition for the 11 watersheds where TFC and existing fish community comparisons can be made. Assessments are underway for the remaining rivers (shown in blue).

Rivers with fish communities considered to be in fair condition (similarity score of 50 to 75% inclusive) included the Hoosic, Quinebaug, and Nashua. In addition, the Housatonic River (similarity score of 44%) and Farmington River (similarity score of 39%) were also categorized as having fish communities in fair condition. The Housatonic River was considered fair as it had a similarity score of 49, very close to the 50% cut-off for categorization, and had a species scarcity of zero. The Farmington River was considered in fair condition for fish community attributes that are explained in the river-specific account in section 3.2.6. Rivers with fish communities considered to be in fair condition maintain many of the same fluvial fish species predicted by the TFC model and most of these species are relatively abundant.

The Blackstone, Charles, Concord, Ipswich, and Shawsheen Rivers were all categorized as having fish communities in poor condition as they all had similarity scores well under 50% and all had one or more species that qualified as scarce or absent. These rivers are no longer dominated by the same species predicted by the TFC model.

3.1.3 Similarity Scores for Habitat Use Categories and Tolerances

Similarities were calculated for habitat use categories and tolerances. While similarity scores based on species proportions describe how close the target is to the current community, similarity scores for habitat use categories and tolerances lend insight into the reasons behind the similarity or dissimilarity.

Similarity scores for habitat use category proportions ranged from 31% (Ipswich) to 95% (Westfield) (Figure 4). Rivers that scored the lowest for this variable included the Ipswich, Charles, and Shawsheen. These rivers all have water quantity impairments or are impacted directly by physical habitat alteration.

Similarity scores for tolerances ranged from 54% (Shawsheen) to 95% (Westfield) (Figure 5). Low similarity scores were generally caused by the reduction of loss of moderately tolerant or intolerant species. The lowest values for this variable occurred in the Charles, Shawsheen, and Blackstone Rivers.

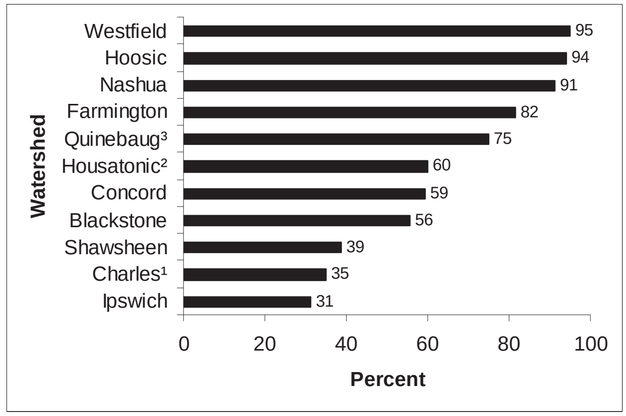

Figure 4. Similarity scores based on habitat-use categories for select Massachusetts watersheds.[1]Meixler (2005), [2] Kearns et al. (2004), [3]Bain and Meixler (2008).

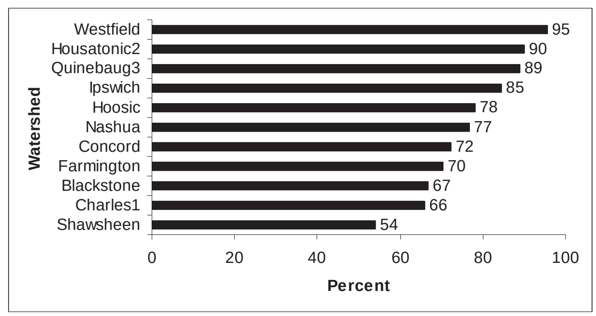

Figure 5. Similarity scores based on tolerance categories for select Massachusetts watersheds.[1]Meixler (2005), [2] Kearns et al. (2004), [3]Bain and Meixler (2008).

3.2 River-Specific Results

Individual river-specific summaries are presented here to provide background information on the river, reference rivers selection, and details on each target fish community. Summaries for the current fish communities and comparisons to the target fish communities are provided for the eleven mainstems for which sufficient information was available. Habitat use categories and tolerances are summarized to provide the most efficient restoration alternatives for each river.

3.2.1 Blackstone River

The Blackstone River begins south of the City of Worcester and flows southeast into Rhode Island. The river is a 4th order system (generally the larger the stream order, the larger the river) with a drainage area of 842 km² located in southern Worcester County. The Massachusetts section of the river is located entirely in Ecoregion 59, is 47.1 km in length, and has a gradient ranging from 0.0004 m/m to 0.028 m/m. Based on these mainhstem characteristics, five reference rivers (Figure 6, Table 3) were used to develop the TFC model.

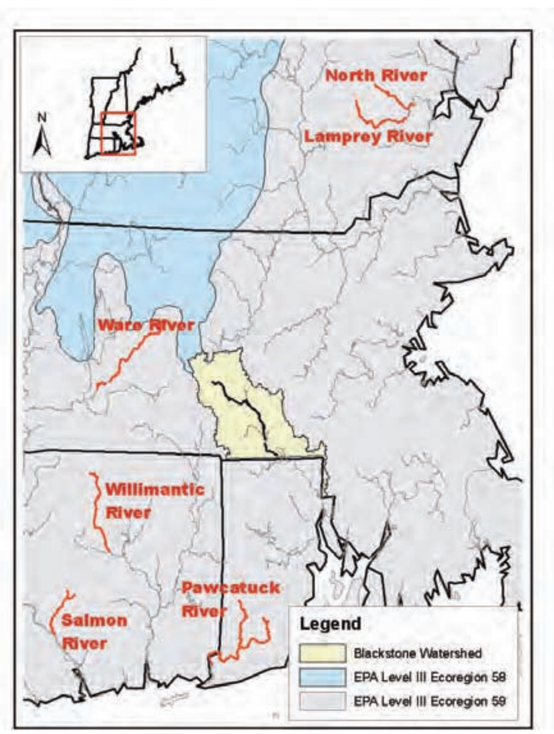

Figure 6. Reference rivers (labeled) used to develop the Blackstone River target fish community.

The five most abundant species in the TFC model are fallfish (32%), common shiner (16%), white sucker (11%), longnose dace (8%), and redbreast sunfish (5%) (Figure 7).

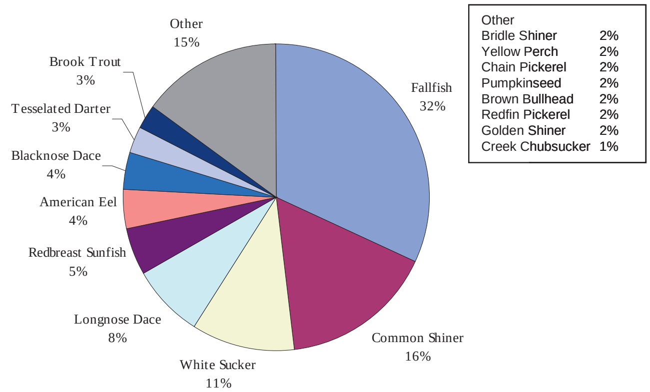

Figure 7. Target fish community composition for the mainstem of the Blackstone River.

Seven sampling locations from the Blackstone River were used to describe the fish community. These samples resulted in the capture of 928 fish of 19 species. The five most abundant species in the current community are white sucker (49%), yellow perch (19%), largemouth bass (9%), bluegill (5%), and tessellated darter (4%). Four of the five species predicted to be most abundant in the TFC are scarce or absent in the current community (Table 4). Based on species habitat-use categories, the community composition of the mainstem river section should contain 51 percent fluvial specialists, 26 percent fluvial dependents, and 23 percent macrohabitat generalists. The current community consists of 44 percent macrohabitat generalists and only 6 percent fluvial specialists (Figure 8). While individuals of tolerant species make up 22 percent of the TFC, they make up more than 50 percent of the current fish community (Figure 9).

Table 3. Physical characteristics of the Blackstone River and the reference rivers used to develop the Blackstone River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Blackstone River	MA	842	4	Acidic	1	1	59
Lamprey River	NH	350	4	Acidic	1	1	59
North River	NH	339	4	Acidic	1	1	59
Pawcatuck River	RI	712	5	Acidic	1	1	59
Salmon River	CT	290	4	Acidic	1	1	59
Willimantic River	CT	321	4	Acidic	1	1	59

Table 4. Blackstone River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish species	**TFC Percentage**	**Current Community Percentage**	**Absolute Difference**
Fallfish	31.8	1.3	30.5
Common shiner	15.9	1.0	14.9
White sucker	10.6	49.4	38.8
Longnose dace	8.0	0.3	7.7
Redbreast Sunfish	5.3	-	5.3
American eel	4.5	-	4.5
Blacknose dace	4.0	0.1	3.9
Tesselated Darter	2.9	4.0	1.1
Brook trout	2.7	0.1	2.6
Bridle shiner	2.4	-	2.4
Yellow Perch	2.1	18.9	16.8
Chain pickerel	2.0	0.2	1.8
Pumpkinseed	1.9	2.1	0.2
Brown bullhead	1.7	0.1	1.6
Redfin pickerel	1.6	-	1.6
Golden shiner	1.4	1.9	0.5
Creek chubsucker	1.3	-	1.3
Largemouth bass*	-	9.0	9
Bluegill*	-	5.3	5.3
Yellow bullhead*	-	2.3	2.3
White catfish*	-	2.0	2
Carp*	-	1.5	1.5
Smallmouth bass*	-	0.5	0.5
Total			156.1
Percent Similarity			**22.0**

* - non-native species

The similarity scores were among the lowest calculated for species proportions (22%, Figure 2) habitat-use category proportions (56%, Figure 4), and tolerance proportions (67%, Figure 5).

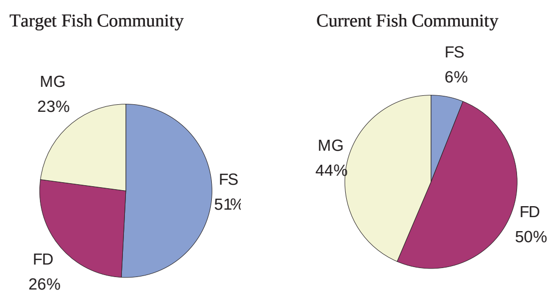

Figure 8. Blackstone River habitat-use category percentages for target fish community and current fish community composition (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

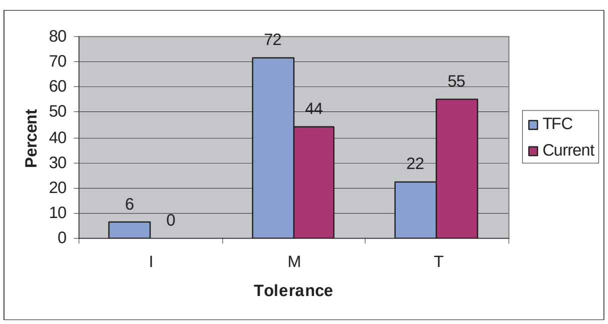

Figure 9. Proportion of individuals in the Blackstone River current and target fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

This analysis documents the strong deviation of the current fish community from the TFC. Although water quality in the Blackstone has improved markedly in the last few decades, water quality issues, exacerbated by growing stream flow problems and numerous impoundments likely result in fish community degradation. In addition to the industrial legacy impacts evident on what was once "the world's busiest River" more than 100 years ago (Tennant et al. 1975), a summary of the impairments that contribute to the deviation of the current fish community from the TFC is as follows:

> "The entire 28.8 mile length of the mainstem Blackstone River in Massachusetts was assessed as non-support for the Aquatic Life Use. Habitat alteration, organic enrichment, elevated nutrients, instream and whole effluent toxicity, sediment contamination (heavy metals), and flow alteration were identified as causes of impairment. Sources, when known, included municipal point source and combined sewer overflow discharges, urban runoff/storm water, contaminated sediments and hydromodification (hydropower operations) (Weinstein et al. 1998)."

3.2.2 Charles River

The Charles River begins in the Town of Milford and flows northeast into Boston Harbor. The river is a 4th order system in Ecoregion 59 with a drainage area of 780 km² and a mainstem river length of 129 km. Based on these mainstem characteristics, seven reference rivers (Figure 10, Table 5) were used to develop the TFC model. The Charles River was the source of an independent TFC determination conducted by Cornell University (Meixler, 2006).

Table 5. Physical characteristics of the Charles River and the reference rivers used to develop the Charles River target fish community (from Meixler, 2006).

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Charles River	**MA**	**780**	**4**	**Acidic**	**1**	**1**	**59**
Pawcatuck	RI	259	5	Acidic	1	1	59
Exeter River	NH	164	3		1	1	59
Lamprey River	NH	474	4	Acidic	1	1	59
Piscataquog River	NH	523	5	Acidic	1	1	58
Salmon River	CT	259	4	Acidic	1	1	59
Souhegan River	NH	443			1		58/59
Yantic River	CT	233	3	Acidic	1	1	59

Table 6. Charles River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish species	TFC Percentage[1]	Current Community Percentage[1]	Absolute Difference
Common shiner	34	-	35
Fallfish	17	-	17
Redbreast Sunfish	11	12	1
White Sucker	8	1	7
American eel	7	17	10
Brown Bullhead	4	-	4
Pumpkinseed	3	5	2
Chain pickerel	2	1	1
Golden Shiner	2	5	3
Redfin pickerel	2	-	2
Banded Killifish	1	-	1
Banded sunfish	1	-	1
Bridle shiner	1	-	1
Creek chubsucker	1	-	1
Spottail shiner	1	-	1
Yellow perch	1	8	7
Bluegill*	-	31	31
Black crappie*	-	3	3
Common carp*	-	3	3
Largemouth bass*	-	8	8
Smallmouth bass*	-	1	1
White perch	-	3	3
Yellow bullhead*	-	1	1
Total			144
Percent Similarity			**28**

* - non-native species

1 – From Meixler 2006

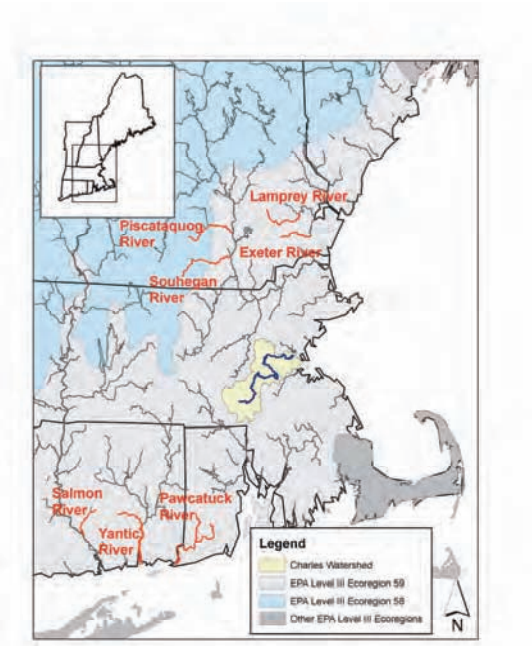

Figure 10. Reference rivers (labeled) used to develop the Charles River target fish community.

The five most abundant species in the TFC are common shiners (34%), fallfish (17%) redbreast sunfish (11%), white suckers (8%), and American eel (7%) (Figure 11).

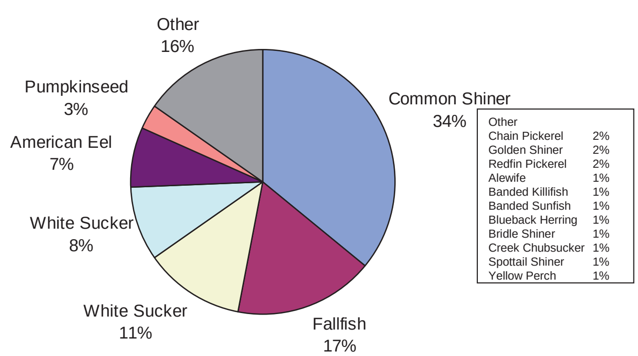

Figure 11. Target fish community composition for the Charles River (Meixler, 2006)

The fish sampling locations used by Meixler (2006) to describe the fish population indicated that the five most abundant species in the current community are bluegill (31%), American eel (17%), redbreast sunfish (12%), largemouth bass (8%), and yellow perch (8%). Three of the five species predicted to be most abundant in the TFC are scarce or absent in the current community (Table 6).

Meixler (2006) reported the river to be dominated by macrohabitat generalists (99%). Using habitat-use categories, the composition of TFC is predicted to contain 19 percent fluvial specialist species, 48 percent fluvial dependent species, and 33 percent macrohabitat generalist species (Figure 12). In addition, while the target community is dominated by moderately tolerant fish (71%), the current fish community is dominated by tolerant individuals (59%) and has lost all species expected in the TFC that are intolerant (Figure 13). Similarity scores for species (28%, Figure 2), habitat-use categories (35%, Figure 4), and tolerance categories (66%, Figure 5) were all among the lowest calculated in Massachusetts.

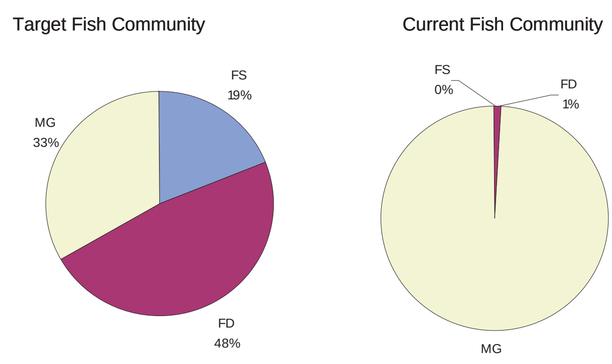

Figure 12. Charles River habitat-use category percentages for target fish community and current community composition (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

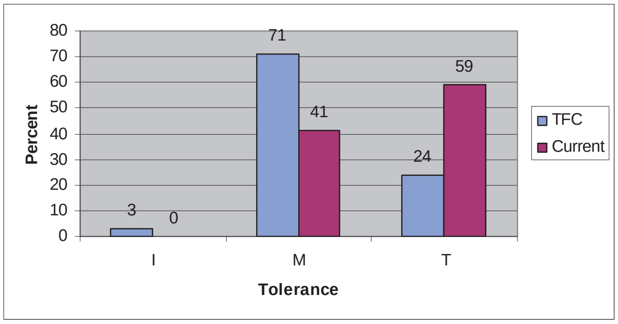

Figure 13. Proportion of individuals in the Charles River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

The TFC analysis documents the strong deviation of the current fish community from the TFC. This deviation is not unexpected. Long one of the most developed Rivers in the State, impairments in the Charles have been studied extensively. More than 80 percent of the river miles in the watershed are listed as impaired for Aquatic Life Use. The causes of impairment include barriers to fish passage, nutrient enrichment, and elevated temperature attributed to municipal discharges, habitat alteration caused by impoundments and non-point pollution. These impairments are also illustrated in widespread consumption advisories for elevated levels of PCBs, mercury, and DDT (DEP, 2007).

3.2.3 Chicopee River

The Chicopee River is a 5th order system that flows through central Massachusetts, emptying into the Connecticut River near Springfield, MA. The Swift, Ware, and Quaboag Rivers combine to form the Chicopee River. These three rivers have a combined mainstem length of 123.7 km and drain an area of 1870 km^2 in Hampden, Hampshire, and Worcester Counties. The gradient of the three rivers ranges from 0.0003 m/m to 0.033 m/m. The majority of the Chicopee watershed is in Ecoregion 59, with small sections crossing over into Ecoregion 58. Based on these mainstem characteristics, four reference rivers (Figure 14, Table 7) were used to develop the TFC model. The five most abundant species in the TFC are fallfish (31%), common shiner (16%), blacknose dace (10%), white sucker (8%), and longnose dace (6%) (Figure 15).

While 18 fish community surveys have been conducted on the Ware, Swift and Quaboag Rivers within the study reach, only two met the criteria for inclusion in the TFC analysis. These samples do not have the geographic distribution to adequately characterize the entire mainstem study reach. Full analysis of this system is currently in progress and should be completed within the next five years as part of the basin assessment cycle.

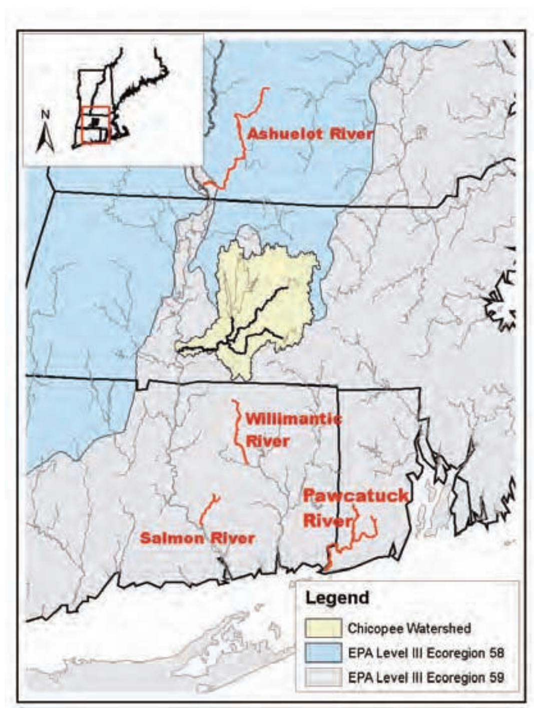

Figure 14. Reference rivers (labeled) used to develop the Chicopee River target fish community.

Table 7. Physical characteristics of the Chicopee River and the reference rivers used to develop the Chicopee River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Chicopee River	**MA**	**1870**	**5**	**Acidic**	**1**	**1**	**58/59**
Ashuelot River	NH	904	5	Acidic	1	1	58
Pawcatuck River	RI	712	5	Acidic	1	1	59
Salmon River	CT	290	4	Acidic	1	1	59
Willimantic	CT	321	4	Acidic	1	1	59

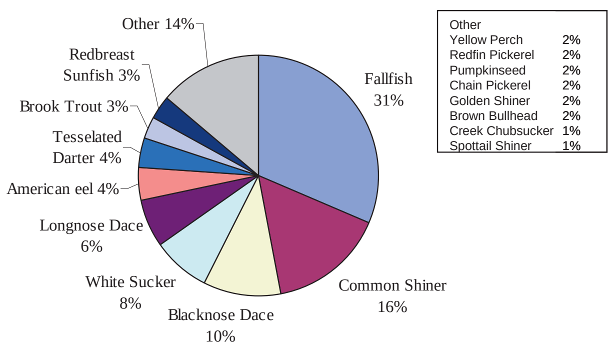

Figure 15. Target fish community composition for the Chicopee River.

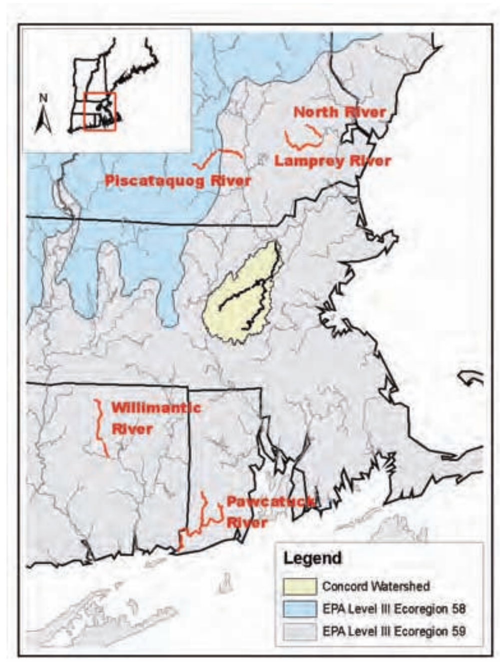

Figure 16. Reference rivers (labeled) used to develop the Concord River target fish community.

3.2.4 Concord River

The Concord River begins at the confluence of the Sudbury and Assabet Rivers in the town of Concord, and flows northeast into the Merrimack River in the city of Lowell, Massachusetts. This basin is typically referred to as the SuAsCo basin reflecting the importance of the Sudbury, Assabet and Concord. This system has 131 km of mainstem river, a drainage area of 1036 km² and range of gradients from 0.0002 m/m to 0.0169 m/m. Based on these mainstem characteristics, five reference rivers (Figure 16, Table 8) were used to develop the TFC model.The five most abundant fish species identified by the target fish model are fallfish (37%), common shiner (19%), white sucker (9%), redbreast sunfish (6%), and American eel (4%) (Figure 17).

Table 8. Physical characteristics of the Concord River and the reference rivers used to develop the Concord River target fish community.

River	State	Drainage area (km^2)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Concord River	**MA**	**1036**	**5**	**Acidic**	**1**	**1**	**59**
Lamprey River	NH	350	4	Acidic	1	1	59
North River	NH	339	4	Acidic	1	1	59
Pawcatuck River	RI	712	5	Acidic	1	1	59
Piscataquog River	NH	559	5	Acidic	1	1	58
Willimantic River	CT	321	4	Acidic	1	1	59

Table 9. Concord River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish species	TFC Percentage	Current Community Percentage	Absolute Difference
Fallfish	37.3	9.4	27.9
Common shiner	18.7	0	18.7
White sucker	9.3	22.6	13.3
Redbreast sunfish	6.2	4.7	1.5
American eel	4.1	4.7	0.6
Tesselated darter	3.7	0	3.7
Brook trout	3.4	0	3.4
Bridle shiner	2.9	0	2.9
Yellow perch	2.7	1.1	1.6
Pumpkinseed	2.5	7	4.5
Chain pickerel	2.3	1.6	0.7
Brown bullhead	2.1	1	1.1
Redfin pickerel	2	18.5	16.5
Golden shiner	1.6	6.8	5.2
Creek chubsucker	1.4	1	0.4
Largemouth bass*	-	9.5	9.5
Yellow bullhead*	-	6.3	6.3
Bluegill*	-	3	3
Brown trout*	-	1.1	1.1
Rock bass*	-	1.1	1.1
Rainbow trout*	-	0.3	0.3
Blacknose dace	-	0.2	0.2
Banded sunfish	-	0.1	0.1
Total			123.6
Percent Similarity			**38.2**

* - non-native species

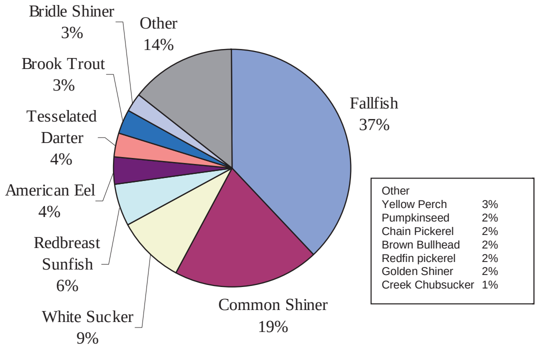

Figure 17. Target fish community composition for the Concord River.

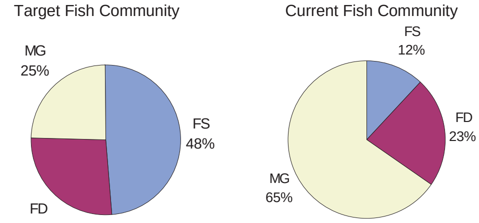

Figure 18. Concord River habitat-use category percentages for target fish community and current fish community composition (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

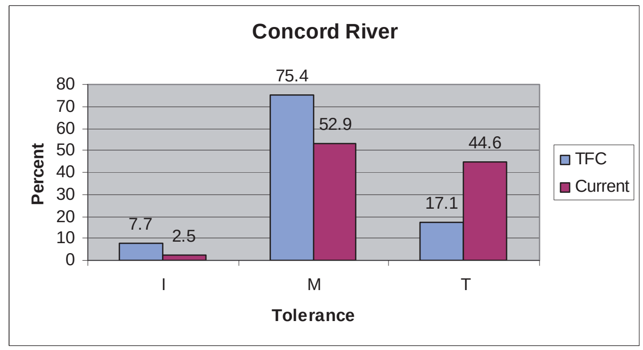

Figure 19. Proportion of individuals in the Concord River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

Eight sampling locations from the Sudbury and Assabet Rivers were used to describe the fish community. These samples resulted in the capture of 915 fish of 19 species. The current community is dominated by white suckers (23%), redfin pickerel (18%), largemouth bass (10%), fallfish (9%), and golden shiner (7%). One of the five species predicted to be most abundant in the TFC (common shiner) was entirely absent from the current community (Table 9). The differences between the TFC and current fish community proportions result in a low similarity score of 38 percent (Figure 2).

Grouped by habitat-use categories, the TFC consisted of 48 percent fluvial specialist species, 27 percent fluvial dependent species, and 25 percent macrohabitat generalist species. The current fish community consists of more than twice the expected proportion of macrohabitat generalists (Figure 18), resulting in a low similarity of 59 percent (Figure 4) for habitat use categories. Examination of tolerances reveals a current fish community with more than twice the expected proportion of tolerant individuals (Figure 19).

The TFC analysis documents considerable deviation from an expected fish community. The deviation can likely be attributed to many well known anthropogenic impairments that have been identified throughout the mainstem rivers studied here. Causes of impairment in the Assabet include flow regime alterations, and high total phosphorus levels. Non-native aquatic plants, present for the most part due to the presence of impoundments, also cause impairments. The major known sources of impairment are municipal point source discharges and alteration of the natural flow regime. Also suspected as impairments are stormwater from municipal separate storm sewers, internal nutrient recycling, golf courses, and yard maintenance. Causes of impairment in the in the Sudbury and Concord Rivers are similar but include known contamination by mercury resulting in fish consumption advisories (O'Brien-Clayton et al. 2005).

3.2.5 Deerfield River

The Deerfield River flows from southern Vermont into Massachusetts, eventually emptying into the Connecticut River. The 5th order river in Ecoregion 58 drains an area of 899 km², is 68.5 km long and has a gradient ranging from 0.0006 m/m to 0.041 m/m. Based on these mainstem characteristics, six reference rivers (Figure 20, Table 10) were used to develop the TFC model.

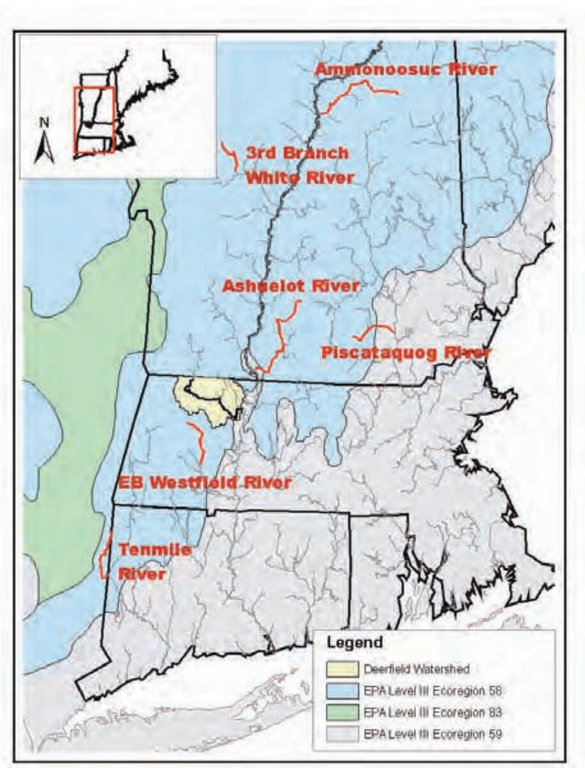

Figure 20. Reference rivers (labeled) used to develop the Deerfield target fish community.

The five most abundant species in the TFC model are blacknose dace (32%), longnose dace (16%), common shiner (11%), slimy sculpin (8%), and fallfish (6%) (Figure 21).

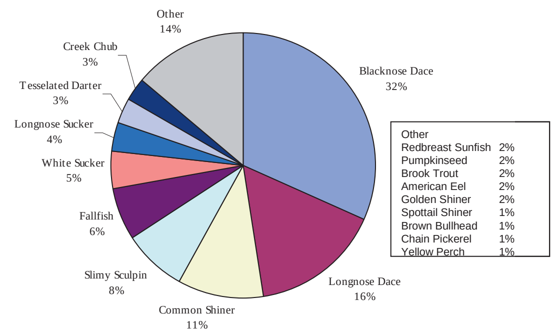

Figure 21. Target fish community composition for the Deerfield River.

Samples in the Deerfield River, a large, high gradient system, are inadequate to describe the current status of the fish community. Assessment of this system is currently in progress and should be completed within the next five years as part of the basin assessment cycle. Previous research in the mainstem has, however, examined the impact of hydropower-induced flow alteration and documented the reduction of many of the same species, like blacknose and longnose dace, that are impacted statewide by other habitat and flow alterations (Bain 1985).

3.2.6 Farmington River

The Farmington River (technically the West Branch) starts in Otis Massachusetts and flows southerly into Connecticut. The river is a 4th order system with a drainage area of 404 km² located in southeastern Berkshire County. The mainstem section of the river in Massachusetts is found in Ecoregion 58 and is 24.9 km in length. River gradient

Table 10. Physical characteristics of the Deerfield River and the reference rivers used to develop the Deerfield River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Deerfield River	**MA**	**899**	**5**	**Acidic**	**1**	**1**	**59**
Ammonoosuc River	NH	842	4	Acidic	2	1	58
Ashuelot River	NH	904	5	Acidic	1	1	58
E.B. Westfield River	MA	373	5	Acidic	1	1	58
Piscataquog River	NH	559	5	Acidic	1	1	58
Tenmile River	NY	539	5	Neutral	1	1	58
3rd Branch White River	VT	280	4	Acidic	1	1	58

ranged from 0.0018 m/m to 0.011 m/m. Based on these mainstem characteristics, six reference rivers (Figure 22, Table 11) were used to develop the TFC model.

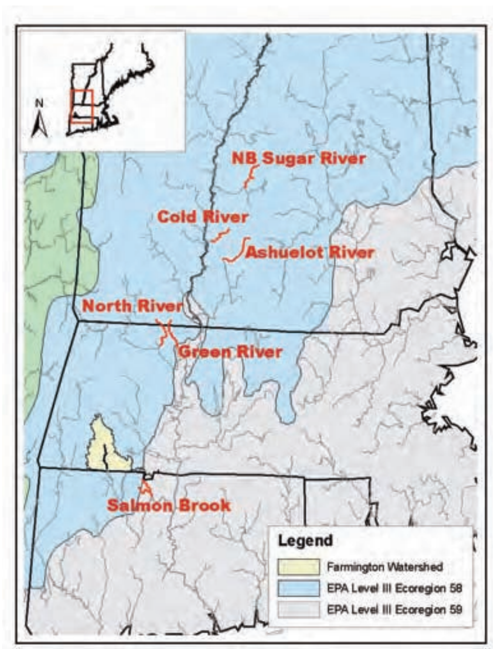

Figure 22. Reference rivers (labeled) used to develop the Farmington River target fish community.

The five most abundant species in the TFC model are blacknose dace (34%), longnose dace (17%), slimy sculpin (8%), common shiner (7%), and fallfish (6%) (Figure 23).

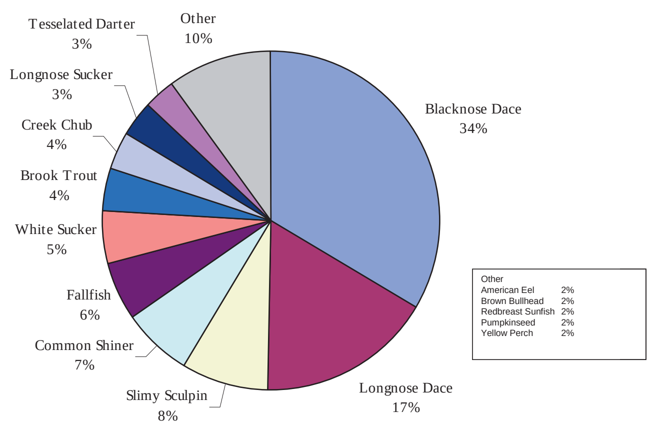

Figure 23. Target fish community composition for the Farmington River.

Four sampling locations from the Farmington River were used to describe the fish community. This relatively small number of samples was used to describe the current fish community as they were taken in a wide range of habitat types throughout the geographic extent of the mainstem study reach. Future efforts will prioritize additional samples in the Farmington to increase the sample size. These samples resulted in the capture of 450 fish of 9 species. The five most abundant species in the current fish community are common shiner (28%), cutlip minnow (25%), smallmouth bass (14%), blacknose dace (10%), and longnose dace (10%). One of the

Table 11. Physical characteristics of the Farmington River and the reference rivers used to develop the Farmington River target fish community.

River	State	Drainage area (km^2)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Ashuelot River	NH	241	4	Acidic	2	1	58
Cold River	NH	251	4	Acidic	2	1	58
Green River	MA	150	3	Neutral	2	1	58/59
NB Sugar River	NH	231	4	Acidic	2	1	58
North River	MA	233	4	Neutral	2	1	58
Salmon Brook	CT	179	4	Acidic	1	1	58/59

Table 12. Farmington River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish Species	TFC Percentage	Current Community Percentage	Absolute Difference
Blacknose dace	33.7	10.0	23.7
Longnose dace	16.8	9.6	7.2
Slimy sculpin	8.4	-	8.4
Common shiner	6.7	28.2	21.5
Fallfish	5.6	6.0	0.4
White sucker	4.8	3.8	1.0
Brook trout	4.2	-	4.2
Creek chub	3.7	3.1	0.6
Longnose sucker	3.4	-	3.4
Tessellated darter	3.1	-	3.1
American eel	2.2	-	2.2
Brown bullhead	2.1	-	2.1
Redbreast sunfish	1.9	-	1.9
Pumpkinseed	1.8	-	1.8
Yellow perch	1.7	-	1.7
Cutlip minnow*	-	25.3	25.3
Smallmouth bass*	-	13.8	13.8
Rock bass*	-	0.2	0.2
Total			122.5
Percent Similarity			**38.7**

* - non-native species

five species expected to be most abundant in the TFC (slimy sculpin) was completely absent from the samples (Table 12).

The current community and TFC are both composed mainly of fluvial specialists and fluvial dependents (Figure 24). The species that make up those categories are considerably different in the two communities (Table 12), resulting in a low similarity score of 39 percent (Figure 2).

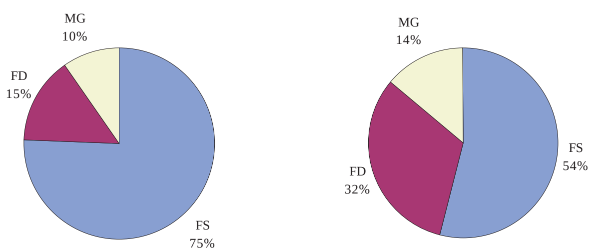

Figure 24. Farmington River habitat-use category percentages for target fish community and current fish community composition.

Based on habitat-use categories, the similarity between the current and TFC is 82 percent (Figure 4). Tolerance information reveals a current population that consists of more intolerant and moderately tolerant species than the TFC and consequently, fewer tolerant individuals than the model (Figure 25), resulting in a tolerance similarity of 70 percent (Figure 5).

In the case of the Farmington River, the low similarity between the TFC and the current fish community is due to the presence of an exotic species (cutlip minnow) which is both a fluvial species and considered intolerant. Consequently it is difficult to attribute the discrepancy in

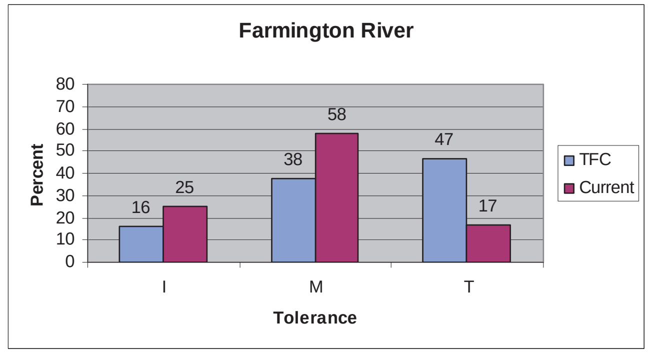

Figure 25. Proportion of individuals in the Farmington River current and target fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

fish community composition to degradations in water quality, quantity or physical habitat. Most introduced species which are macrohabitat generalists and are moderately tolerant or tolerant of water quality impacts. While there are habitat concerns along the mainstem of the Farmington River, including riparian encroachment from roads with the potential for sedimentation and impacts from road salt, and minimum flow releases from upstream reservoirs, it is characterized largely by natural cover types and low human population density. The mainstem is a designated cold water in the Massachusetts Surface Water Quality Standards (314 CMR 4.00) and consequently any exceedance of the 20°C standard is considered impaired (Duerring, 2005). As indicated by the TFC, the Farmington River is expected to maintain a component of the fish community as coldwater individuals, so concern over the temperature exceedance is warranted. The river does currently, however, maintain a diverse riverine fish community. Consequently, while the similarity score is well below the 50 percent cutoff typically used in this report to separate fair from poor fish communities, the Farmington community is considered to be in fair condition.

3.2.7 French River

The French River flows south from Massachusetts into Connecticut. This 4th order river in Worcester County drains an area of 168 km² in Ecoregion 59. The mainstem in Massachusetts is 21.7 km long with a gradient of between 0.0006 m/m and 0.029 m/m. Based on these mainstem characteristics, six reference rivers (Figure 26, Table 13) were used to develop the TFC model.

The five most abundant species in the TFC model are common shiner (31%), fallfish (16%), tessellated darter (10%), redbreast sunfish (8%), and longnose dace (6%) (Figure 27).

Samples collected on free-flowing reaches of the French River are limited to the upper third of the mainstem and do not have the sufficient geographic distribution to adequately characterize the fish community throughout the mainstem study reach. The majority of the French River mainstem downstream of the existing samples is impounded. While the samples in the free-flowing reaches of the headwaters indicate that habitat is still capable of supporting fluvial species, this habitat is limited in extent. Fish community surveys will be conducted with in the next five years as part of the basin assessment cycle that will allow an adequate comparison of the Target and current fish communities.

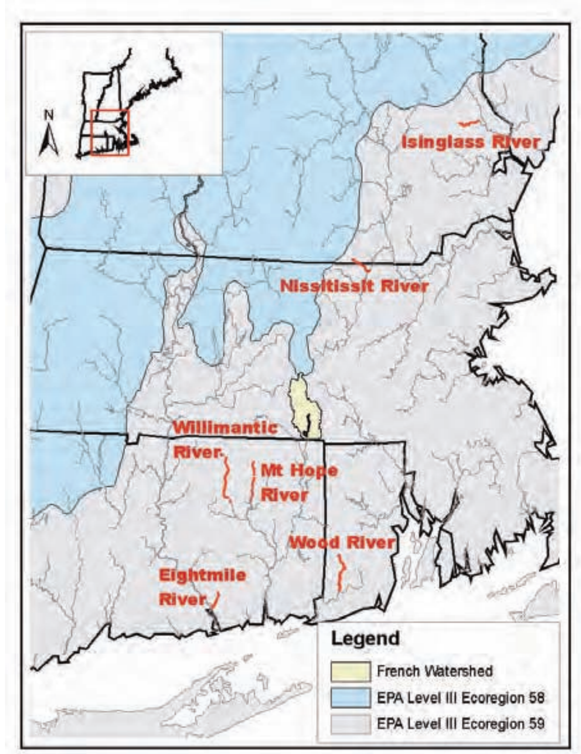

Figure 26. Reference rivers (labeled) used to develop the French River target fish community.

Table 13. Physical characteristics of the French River and the reference rivers used to develop the French River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
French River	**MA**	**168**	**4**	**Acidic**	**1**	**1**	**59**
Eightmile River	CT	145	4	Acidic	1	1	59
Isinglass River	NH	166	4	Acidic	1	1	59
Mt Hope Brook	CT	91	3	Acidic	1	1	59
Nissitissit River	MA	145	4	Acidic	1	1	58/59
Willimantic River	CT	321	4	Acidic	1	1	59
Wood River	RI	231	4	Acidic	1	1	59

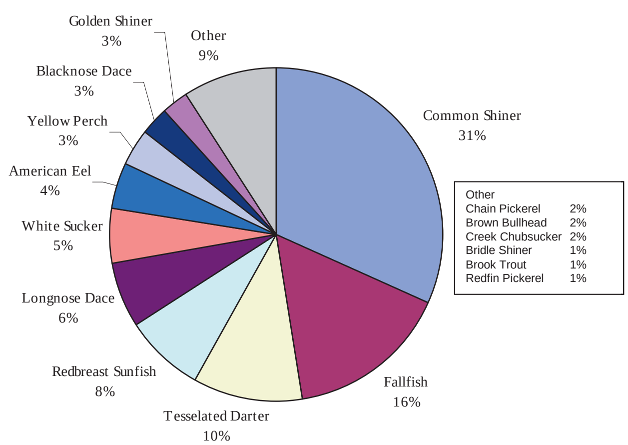

Figure 27. Target fish community composition for the French River.

3.2.8 Hoosic River

The Hoosic River flows northerly from the northwest corner of Berkshire County into Vermont and New York, eventually emptying into the Hudson River. This river is a 4th order system with a drainage area of 487 km². Located entirely in Ecoregion 58, the mainstem section is 33.4 km long with a gradient ranging from 0.0001 m/m to 0.008 m/m. Based on these mainstem characteristics, seven reference rivers (Figure 28, Table 14) were used to develop the TFC model.

The five most abundant species in the TFC are blacknose dace (34%), longnose dace (17%), slimy sculpin (11%), white sucker (8%), and common shiner (7%)(Figure 29). Eight sampling locations from the Hoosic River were used to describe the fish community from the mainstem study reach. These samples resulted in the capture of 2088 fish of 12 species. The five most abundant species in the current Hoosic River mainstem were blacknose dace (47%),

Table 14. Physical characteristics of the Hoosic River and the reference rivers used to develop the Hoosic River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Hoosic River	**MA**	**487**	**4**	**Acidic**	**1**	**1**	**58**
Batten Kill	NY	391	4	-	1	1	83
Black Creek	NY	161	3	-	1	1	83
Hollenbeck River	CT	109	4	Acidic	1	1	58
Kinderhook River	NY	389	3	-	1	1	58
Little Hoosic River	NY	194	3	-	1	1	58
3rd Branch White River	VT	280	4	Acidic	1	1	58
W.B. Westfield River	MA	249	3	Acidic	1	1	58

Table 15. Hoosic River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish Species	TFC Percentage	Current Community Percentage	Absolute Difference
Blacknose dace	34.1	46.5	12.4
Longnose dace	17.1	19.1	2.0
Slimy sculpin	11.4	1.0	10.4
White sucker	8.5	15.5	7.0
Common shiner	6.8	0.9	5.9
Brook trout	4.5	-	4.5
Fallfish	4.3	-	4.3
Creek chub	2.8	6.4	3.6
Longnose sucker	2.6	2.0	0.6
Troutperch	2.1	-	2.1
Pumpkinseed	2.0	2.0	0.0
Golden shiner	1.8	0.3	1.5
Yellow perch	1.7	-	1.7
American eel	-	-	0.0
Brown trout*	-	5.1	5.1
Bluegill*	-	0.8	0.8
Bluntnose minnow*	-	0.6	0.6
Total			62.6
Percent Similarity			**68.7**

* - non-native species

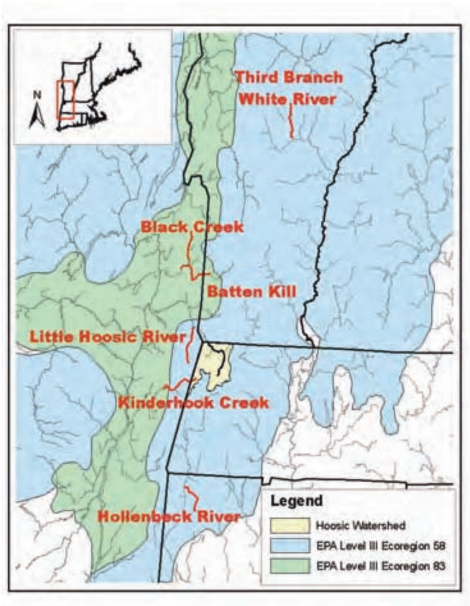

Figure 28. Reference rivers (labeled) used to develop the Hoosic River target fish community.

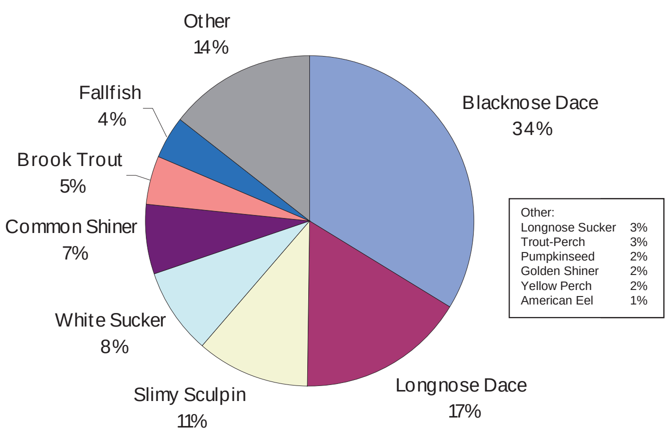

Figure 29. Target fish community composition for the Hoosic River.

longnose dace (19%), white sucker (16%), creek chub (6%), and brown trout (5%). Slimy sculpin, expected to be one of the 5 most abundant species in the TFC, was scarce in the current community (Table 15). Expected species missing from the current fish assemblage include brook trout, fallfish, trout-perch, and yellow perch. Trout perch have been extirpated within the borders of the Commonwealth, but are still a component of the fish community in the Hudson watershed in New York to which the Hoosic River is tributary (Hartel et al. 2002).

Both the TFC and current fish communities are dominated by fluvial fish (Figure 30). The similarity between the current and target fish communities is among the highest calculated for species proportions (68%) (Figure 2). The similarity score for habitat-use categories was also very high (94%)(Figure 4). Tolerance similarity was lower (78%, Figure 5), as the current community has more tolerant individuals than the TFC (Figure 31).

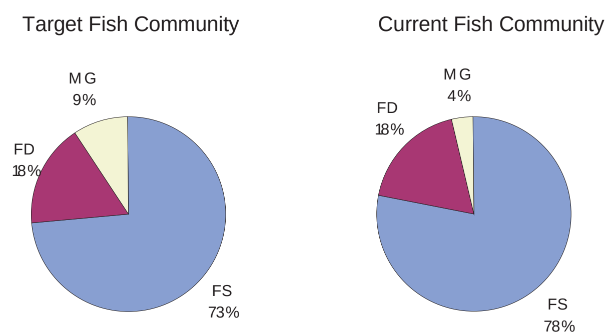

Figure 30. Hoosic River habitat-use category percentages for target fish community and current fish community composition (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

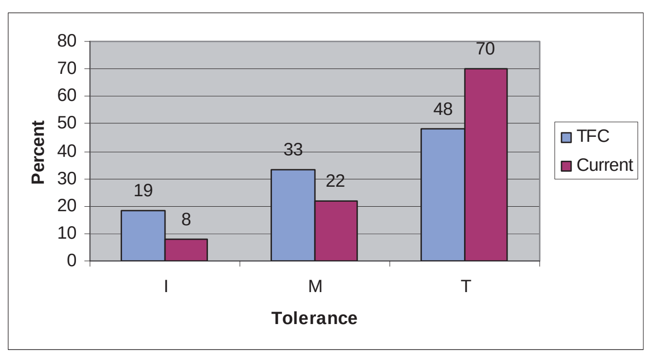

Figure 31. Proportion of individuals in the Hoosic River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

Differences between the TFC and current fish communities, while more subtle than many other Massachusetts mainstems, are likely caused by physical habitat alteration and degraded water quality. Roughly 5 kilometers of the Hoosic River have been converted to concrete flood control devices that are virtually devoid of fish habitat (O'Brien-Clayton, 2006). These structures not only alter the stream channel structure, but also result in temperature impairments as the water flows through wide, flat, exposed river reaches. Fish communities were not sampled within these obviously altered sections. Impairments downstream of the flood chutes include PCB-contaminated sediments caused by historical industrial use and nutrient enrichment caused by non-point discharges, municipal stormwater, crop production, and unrestricted cattle access/managed pasture grazing.

3.2.9 Housatonic River

The Housatonic River begins in the Town of Pittsfield and flows south into Connecticut before entering Long Island Sound. The river is a 4th order system in Ecoregion 58 with a drainage area of 1181 km² and a mainstem river length of 63 km. Five reference rivers (Figure 32, Table 16) were used to develop the TFC model. The Housatonic River was the subject of a TFC report authored by the Riverways Program of the Massachusetts Department of Fish and Game (Kearns et al. 2004).

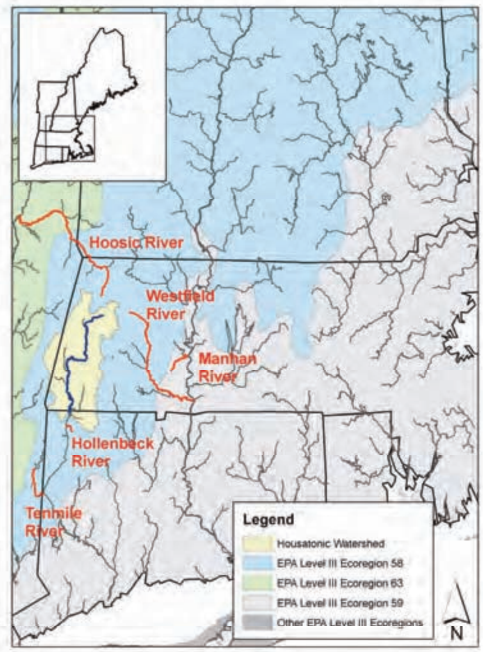

Figure 32. Reference rivers (labeled) used to develop the Housatonic River target fish community

The five most abundant species in the TFC are blacknose dace (31%), longnose dace (15%), common shiners (10%), white suckers (8%), and fallfish (6%) (Figure 33).

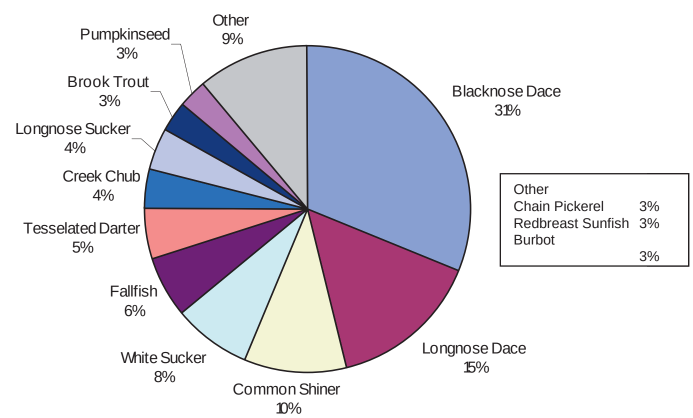

Figure 33. Housatonic River Target Fish Community (from Kearns et al. (2004)).

The fish sampling locations used by Kearns (2004) to describe the fish population indicated that the current community is dominated by bluntnose minnow (23%), white

Table 16. Physical characteristics of the Housatonic River and the reference rivers used to develop the Housatonic River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Housatonic River	**MA**	**1181**		**Neutral**	**1**	**1**	**58**
Hollenbeck River	CT	109	4	Acidic	1	1	58
Hoosic River	MA/NY	1637		Acidic			58/83
Manhan River	MA	220		Acidic			58/59
Tenmile River	NY	539	5	Neutral	1	1	58
Westfield River	MA	1339		Acidic	1		58

Table 17. Housatonic River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity.

Fish species	TFC Percentage[1]	Current Community Percentage[1]	Absolute Difference
Blacknose dace	31	10	21
Longnose dace	15	15	0
Common shiner	10	3	7
White sucker	8	17	9
Fallfish	6	2	4
Tessellated darter	5	1	4
Creek chub	4	1	3
Longnose sucker	4	1	3
Brook trout	3	-	3
Burbot	3	-	3
Chain pickerel	3	-	3
Pumpkinseed	3	1	2
Redbreast sunfish	3	-	3
Bluegill	-	3	3
Bluntnose minnow	-	23	23
Largemouth bass	-	1	1
Rock bass	-	11	11
Smallmouth bass	-	3	3
Spottail shiner	-	2	2
Yellow perch	-	3	3
Total			111
Percent Similarity			**44.5**

* - non-native species

1 – From Kearns et al. 2004

sucker (17%), longnose dace (15%), rock bass (11%), and blacknose dace (10%), resulting in a similarity index of 44% (Table 17). Using habitat-use categories, the composition of TFC should contain 70 percent fluvial specialist species, 18 percent fluvial dependent species, and 12 percent macrohabitat generalist species. The current community has four times the proportion (48%) of macrohabitat generalists as the TFC (Figure 34).

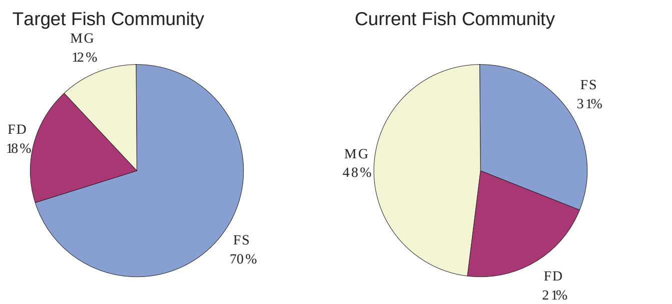

Figure 34. Housatonic River habitat-use category percentages for target fish community and current fish community composition (from Kearns et al. 2004) (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

Similarity scores for species (Figure 2) and habitat-use categories (Figure 4) indicate impaired water quantity and physical habitat issues within the mainstem. Tolerance information, on the other hand, had a relatively high similarity score (Figure 5) with only very modest differences in the proportions of tolerant and intolerant species (Figure 35).

The TFC analysis illustrates some significant differences between the current and target fish communities. These differences are likely due to well known and documented impairments within the watershed generally and the mainstem specifically. Numerous impoundments, with

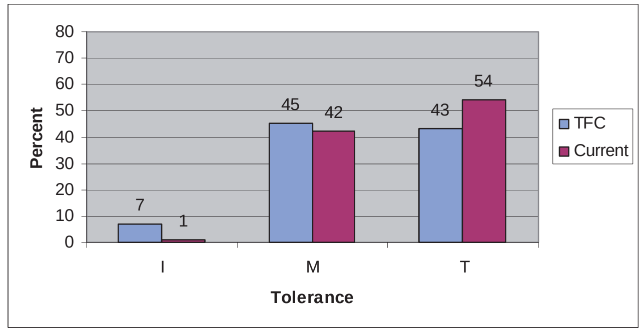

Figure 35. Proportion of individuals in the Housatonic River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T) (From Kearns et al. 2004).

habitats favoring generalist species, are recognized as sources impairment as are wastewater treatment discharges that, in conjunction with increased resident time provided by impoundments, are suspected to result in nutrient (phosphorous) enrichment (Carr and Kennedy, 2007).

3.2.10 Ipswich River

While the Ipswich River was the subject of a TFC report by Lang et al. (2001), this report repeats the exercise in the interest of method consistency. The original Ipswich TFC used fewer reference rivers and fewer criteria for reference river selection. The result of the original work is a product that relies heavily on one reference river (Lamprey River, NH). In addition, the 2001 TFC was developed for the mainstem and its major tributaries, while the TFC presented here, like all others in this document, focuses on the mainstem study reach only.

The Ipswich River is a coastal system that flows through Middlesex and Essex Counties in northeast Massachusetts.

The mainstem of this 4th order river is located in Ecoregion 59, is 48.9 km long and has a drainage area of 396 km². The river's gradient ranges from 0.0003 m/m to 0.0024 m/m. Based on these mainstem characteristics, five reference rivers (Figure 36, Table 18) were used to develop the TFC model.

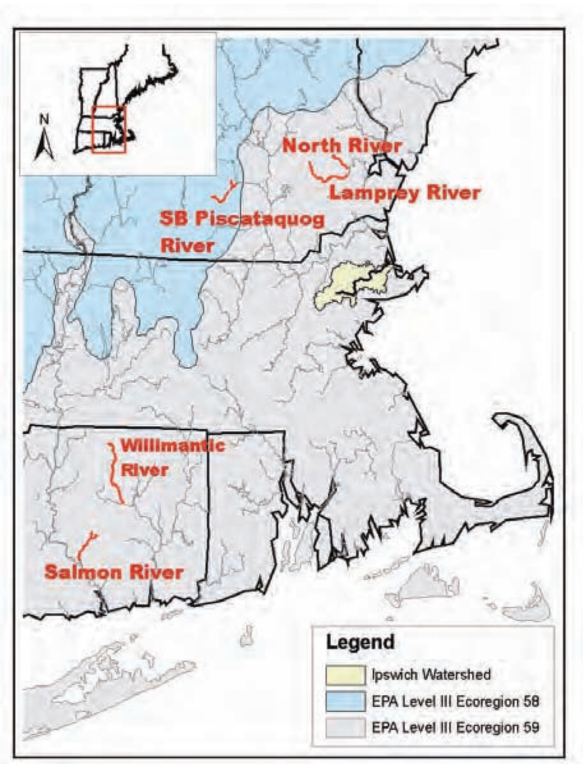

Figure 36. Reference rivers (labeled) used to develop the Ipswich River target fish community.

The five most abundant fishes expected in the target fish model are common shiner (41%), fallfish (20%), white sucker (7%), redbreast sunfish (6%), and American eel (4%) (Figure 37).

Twenty-five sampling locations from the Ipswich River were used to describe the fish community from the mainstem study reach. These samples resulted in the capture of 4290

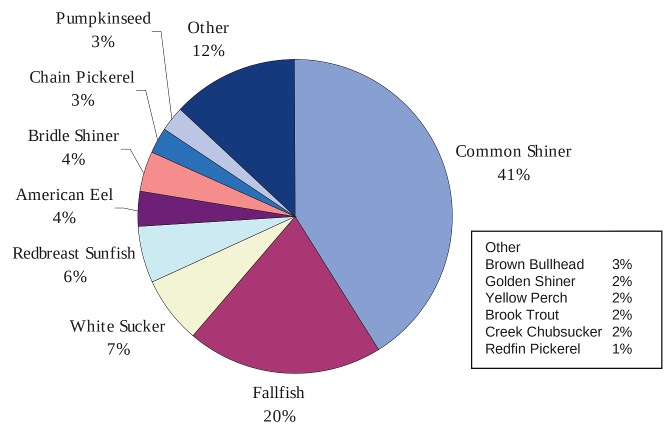

Figure 37. Target fish community composition for the Ipswich River.

fish of 21 species. The five most abundant species in the current community are redfin pickerel (45%), American eel (24%), pumpkinseed (10%), redbreast sunfish (6%), and chain pickerel (4%). Two of the 5 species expected to be most abundant in the TFC were scarce (fallfish) or absent (common shiner) (Table 19). Bridle shiner and brook trout were two other expected species that were missing from the current fish community.

The current fish community is dominated by macrohabitat generalist species. These species comprise 96 percent of the mainstem fish assemblage. The TFC model predicts a community containing 26 percent fluvial specialist, 46 percent fluvial dependents, and only 28 percent macrohabitat generalists (Figure 38). Similarity scores for both species (Figure 2) and habitat-use categories (Figure 4) were among the lowest of any mainstem river examined. Tolerances of

Table 18. Physical characteristics of the Ipswich River and the reference rivers used to develop the Ipswich River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Ipswich River	**MA**	**396**	**4**	**Acidic**	**1**	**1**	**59**
Lamprey River	NH	350	4	Acidic	1	1	59
North River	NH	339	4	Acidic	1	1	59
Salmon River	CT	290	4	Acidic	1	1	59
SB Piscataquog River	NH	267	4	Acidic	1	1	58
Willimantic River	CT	321	4	Acidic	1	1	59

Table 19. Ipswich River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish Species	TFC Percentage	Current Community Percentage	Absolute Difference
Common shiner	40.6	-	40.6
Fallfish	20.3	0.3	20.0
White sucker	6.7	1.5	5.2
Redbreast sunfish	5.8	5.5	0.3
American eel	4.1	23.8	19.5
Bridle shiner	3.7	-	3.7
Chain pickerel	3.1	3.6	0.5
Pumpkinseed	2.8	9.5	6.7
Brown bullhead	2.7	0.3	2.4
Golden shiner	2.5	0.5	2.0
Yellow perch	2.3	1.5	0.8
Brook trout	1.7	-	1.7
Creek chubsucker	1.7	1.1	0.6
Redfin pickerel	1.5	44.9	43.4
Bluegill*	-	3.3	3.3
Yellow bullhead*	-	1.7	1.7
Swamp darter	-	0.7	0.7
Largemouth bass*	-	0.6	0.6
Banded sunfish	-	0.3	0.3
Green sunfish*	-	0.3	0.3
Brown trout*	-	0.1	0.1
Total			154.3
Percent Similarity			**23**

* - non-native species

species found in the Ipswich River are, however, relatively similar to those expected in the TFC (Figure 39).

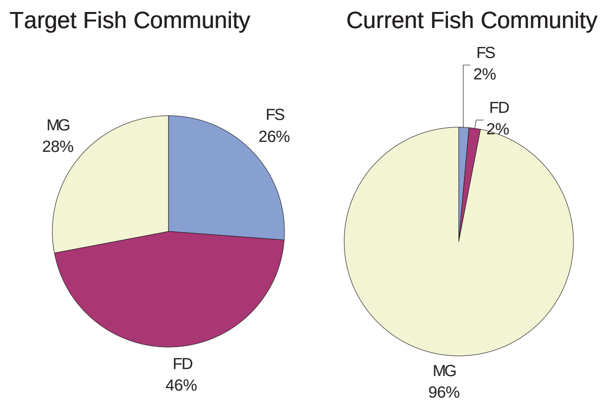

Figure 38. Ipswich River habitat-use category percentages for target fish community and current fish community composition. (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

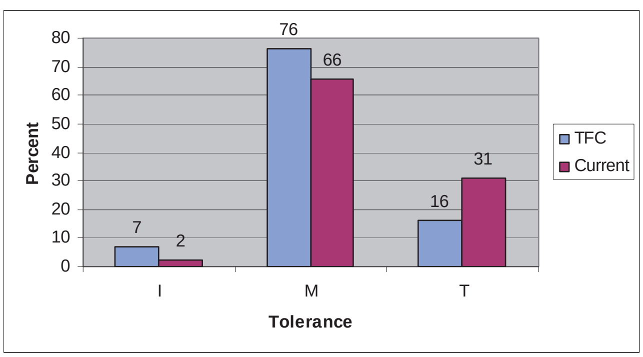

Figure 39. Proportion of individuals in the Ipswich River current and target fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

The Ipswich River has been studied extensively with regard to impacts caused by water withdrawal and water quality. A series of publications by the US Geological Survey examined the effect of water use and land use patterns on stream flow (Zarriello and Ries, 2000), stream flow requirements for habitat protection (Armstrong et al., 2001), and the effects of hypothetical water-management alternatives on stream flow (Zarriello, 2002). The impetus for these studies was the severe stream flow depletion due largely to the municipal water withdrawal (surface and groundwater) by more than 21 communities all or partly within the basin and 2 municipalities entirely outside the basin (Zarriello and Ries, 2000). These reports documented the severe impact of water withdrawals on stream flows and stream habitat. The TFC analysis documents the severe impact of these stream flow and habitat reductions on the fish community.

3.2.11 Millers River

The Millers River flows west across northern Franklin and Worcester Counties into the Connecticut River. This 5^{th} order river in Ecoregion 58 has a drainage area of 803 km^2. The mainstem section is 62 km long with a gradient ranging from 0.0004 m/m to 0.0137 m/m. Based on these mainstem characteristics, six reference rivers (Figure 40, Table 20) were used to develop the TFC model.

Table 20. Physical characteristics of the Millers River and the reference rivers used to develop the Millers River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Millers River	**MA**	**803**	**5**	**Acidic**	**1**	**1**	**58/59**
E.B. Westfield River	MA	373	5	Acidic	1	1	58
Ammonoosuc River	NH	842	4	Acidic	2	1	58
Piscataquog River	NH	559	5	Acidic	1	1	58
Ashuelot River	NH	904	5	Acidic	1	1	58
Tenmile River	NY	539	5	Neutral	1	1	58
3rd Branch White River	VT	280	4	Acidic	1	1	58

Table 21. Physical characteristics of the Mystic River and the reference rivers used to develop the Mystic River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Mystic River	**MA**	**197**	**3**	**Acidic**	**1**	**1**	**59**
Eightmile River	CT	145	4	Acidic	1	1	59
Isinglass River	NH	166	4	Acidic	1	1	59
Little River	ME	132	3	Neutral	1	1	58/59
Mt Hope Brook	CT	91	3	Acidic	1	1	59
Nissitissit River	MA	145	4	Acidic	1	1	58/59
Queen River	RI	93	3	Acidic	1	1	59
Wood River	RI	231	4	Acidic	1	1	59

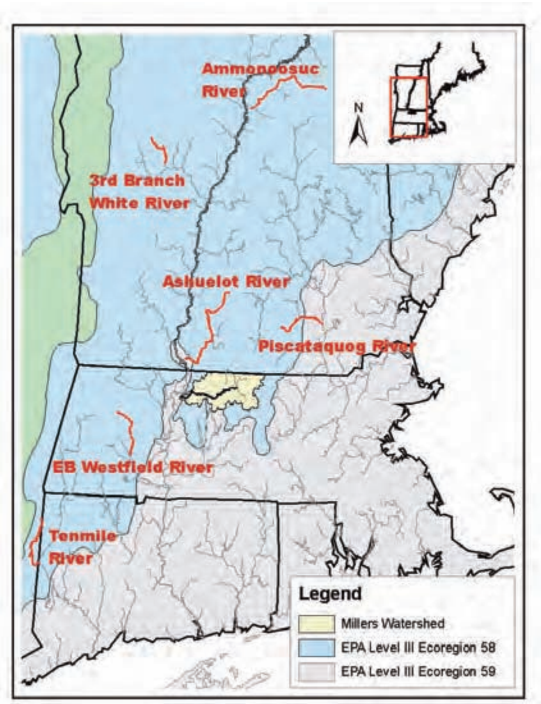

Figure 40. Reference rivers (labeled) used to develop the Millers River target fish community.

The five most abundant species in the TFC are blacknose dace (33%), longnose dace (16%), common shiner (11%), fallfish (8%), and slimy sculpin (5%) (Figure 41).

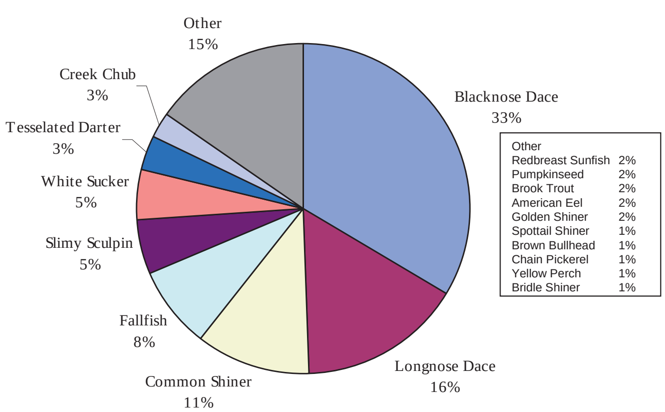

Figure 41. Target fish community composition for the Millers River.

The Millers River, contains habitat that has not been adequately sampled to allow the current fish community to be compared to the TFC. This river will be assessed as part of the basin assessment cycle within the next five years to allow for a more appropriate comparison of the target and current fish communities.

3.2.12 Mystic River

The Mystic River is a coastal system located in the Boston metropolitan area. This 3rd order river in Middlesex County has a drainage area of 197 km². The mainstem section is found in Ecoregion 59 and measures 7.9 km in length with a gradient range of 0.0004 m/m to 0.0007 m/m. Based on these mainstem characteristics, seven reference rivers (Figure 42, Table 21) were used to develop the TFC model.

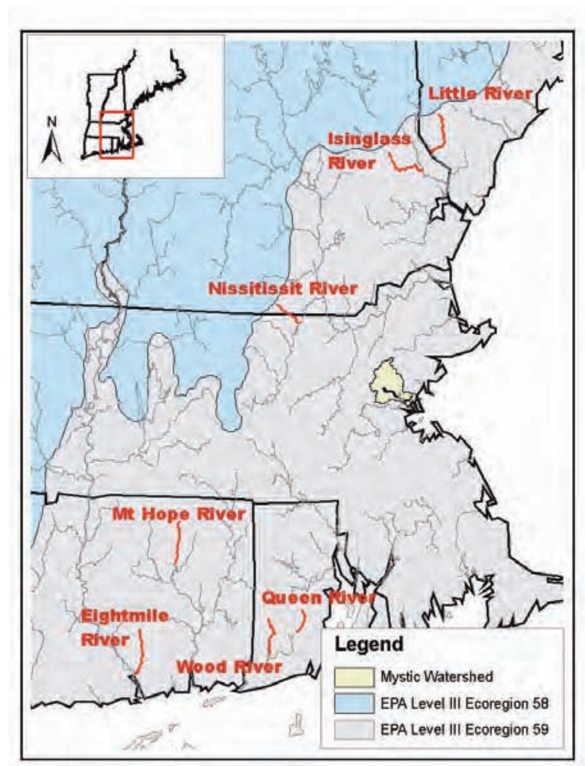

Figure 42. Reference rivers (labeled) used to develop the Mystic River target fish community.

The five most abundant species in the TFC are common shiner (38%), fallfish (19%), white sucker (10%), American eel (8%), and redbreast sunfish (6%) (Figure 43).

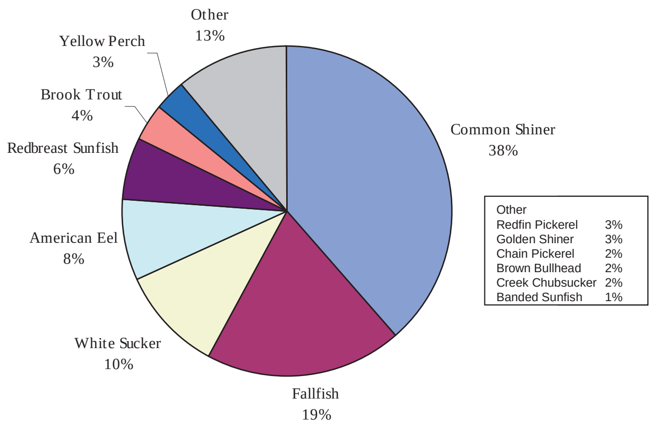

Figure 43. Target fish community composition for the Mystic River TFC.

Seventeen samples have been collected in the Mystic watershed (primarily on tributaries). Only one sample was collected in the Mystic River and it was in an impounded reach. Most of the mainstem Mystic is impounded or under tidal influence, making an adequate assessment difficult. Samples within the mainstem will be prioritized in future sampling efforts.

3.2.13 Nashua River

The Nashua River flows into the Merrimack River after passing through Middlesex and Worcester Counties in north-central Massachusetts. The mainstem of this 5th order river has a length of 65.3 km and a gradient of between 0.0003 m/m and 0.0029 m/m. The watershed has an area of 1155 km², with sections located in both Ecoregions 58 and 59. Based on these mainstem characteristics, four reference rivers were used to develop the TFC model (Figure 44, Table 22).

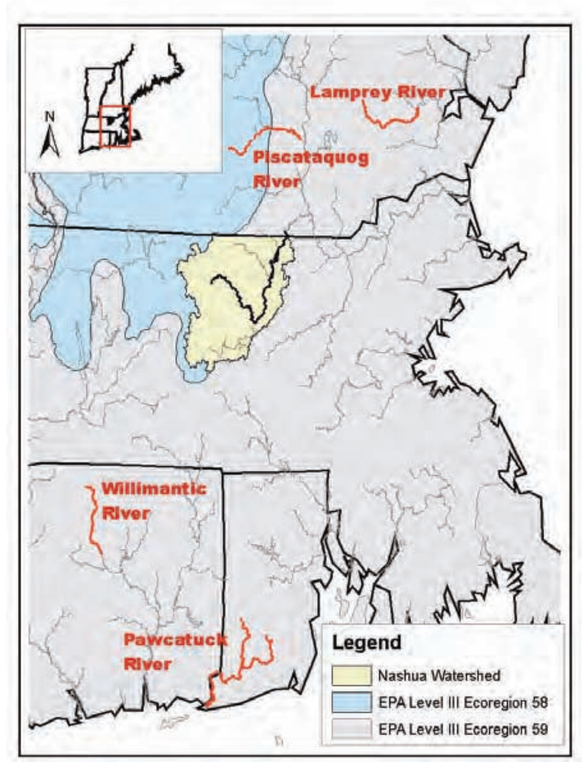

Figure 44. Reference rivers (labeled) used to develop the Nashua River target fish community.

The five most abundant species in the TFC model are common shiner (31%), fallfish (15%), white sucker (10%), blacknose dace (8%), and redbreast sunfish (6%) (Figure 45).

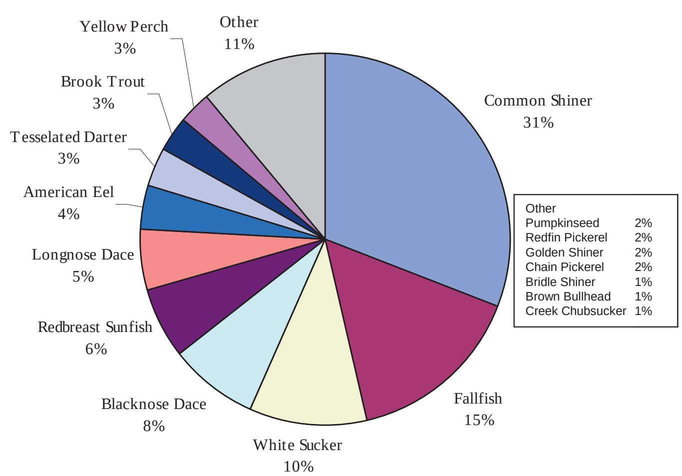

Figure 45. Target fish community composition for the Nashua River.

Table 22. Physical characteristics of the Nashua River and the reference rivers used to develop the Nashua River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Nashua River	**MA**	**1155**	**5**	**Acidic**	**1**	**1**	**59**
Lamprey River	NH	350	4	Acidic	1	1	59
Pawcatuck River	RI	712	5	Acidic	1	1	59
Piscataquog River	NH	559	5	Acidic	1	1	58
Willimantic River	CT	321	4	Acidic	1	1	59

Table 23. Nashua River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish Species	TFC Percentage	Current Community Percentage	Absolute Difference
Common shiner	30.8	6.4	24.4
Fallfish	15.4	12.4	3.0
White sucker	10.3	25.7	15.4
Blacknose dace	7.7	18.2	10.5
Redbreast sunfish	6.2	-	6.2
Longnose dace	5.1	5.4	0.3
American eel	3.8	-	3.8
Tesselated darter	3.4	2.0	1.4
Brook trout	3.1	-	3.1
Yellow perch	2.8	5.7	2.9
Pumpkinseed	2.4	2.1	0.3
Redfin pickerel	2.1	-	2.1
Golden shiner	1.7	0.2	1.5
Chain pickerel	1.5	0.4	1.1
Bridle shiner	1.4	-	1.4
Brown bullhead	1.3	-	1.3
Creek chubsucker	1.2	-	1.2
Bluegill*	-	1.3	1.3
Spottail shiner	-	13.2	13.2
Largemouth bass*	-	3.4	3.4
Yellow bullhead*	-	3.6	3.6
Total			101.2
Percent Similarity			**49.9**

* - non-native species

Eleven fish surveys conducted in the North Nashua and mainstem Nashua were used to determine the characteristics of the current fish community. These samples resulted in the capture of 2812 fish of 16 species. The five most abundant species in the Nashua River are white sucker (26%), blacknose dace (18%), spottail shiner (13%), fallfish (12%), and common shiner (6%). The comparison of species proportions in the current and TFC model resulted in a similarity of 50 percent (Table 23).

When grouped by habitat-use category, the current community consists of 32 percent fluvial specialists, 38 percent fluvial dependents, and 30 percent macrohabitat generalists. The TFC model predicts 36 percent fluvial specialists, 41 percent fluvial dependents, and 23 percent macrohabitat generalists (Figure 46), resulting in a similarity of 91 percent (Figure 4).

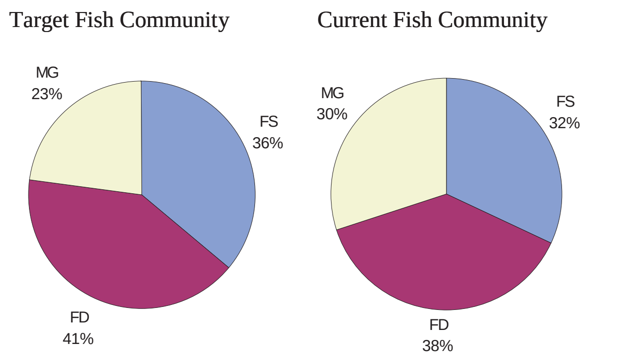

Figure 46. Nashua River habitat-use category percentages for target and current fish community composition (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

While the Nashua still retains fluvial species in relatively high proportion to other species, the two most dominant species (white sucker and blacknose dace) are tolerant to water quality degradation, resulting in a fish community with twice the proportion of tolerant individuals as the TFC (Figure 47).

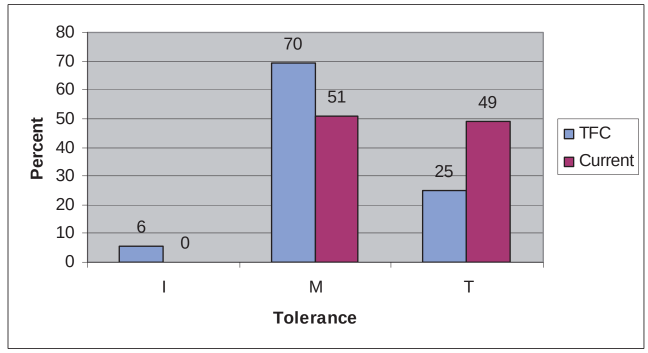

Figure 47. Proportion of individuals in the Nashua River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

Water quality in the Nashua River basin is much improved from decades past. Pollution issues have been addressed by modern permitting solutions and upgrades to treatment facilities. Some water quality impairment still exists, however. Organic enrichment, elevated nutrients and contaminated sediments likely play a role in determining the extent to which the TFC and current fish community match. The sources of impairment include municipal and industrial point sources, combined sewer overflows, and urban runoff (Weinstein et al. 2001).

3.2.14 Neponset River

The Neponset River is a coastal system that flows into Boston Harbor through Norfolk County. This 4th order river has a 44 km mainstem section with a gradient range of 0.0004 m/m to 0.0037 m/m. The 295 km² drainage area is

Table 24. Physical characteristics of the Neponset River and the reference rivers used to develop the Neponset River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Neponset River	**MA**	**295**	**4**	**Acidic**	**1**	**1**	**59**
Lamprey River	NH	350	4	Acidic	1	1	59
North River	NH	339	4	Acidic	1	1	59
Salmon River	CT	290	4	Acidic	1	1	59
SB Piscataquog River	NH	267	4	Acidic	1	1	58
Willimantic River	CT	321	4	Acidic	1	1	59
Wood River	RI	231	4	Acidic	1	1	59

Table 25. Physical characteristics of the Parker River and the reference rivers used to develop the Parker River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Parker River	**MA**	**212**	**3**	**Acidic**	**1**	**1**	**59**
Eightmile River	CT	145	4	Acidic	1	1	59
Isinglass River	NH	166	4	Acidic	1	1	59
Little River	ME	132	3	Neutral	1	1	58/59
Mt Hope Brook	CT	91	3	Acidic	1	1	59
Nissitissit River	MA	145	4	Acidic	1	1	58/59
Queen River	RI	93	3	Acidic	1	1	59
Wood River	RI	231	4	Acidic	1	1	59

located within Ecoregion 59. Based on these mainstem characteristics, six reference rivers were used to develop the TFC model (Figure 48, Table 24).

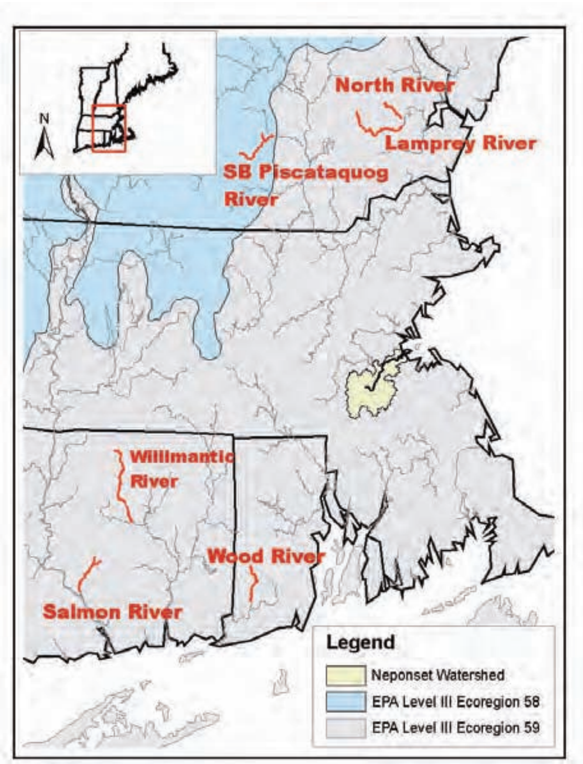

Figure 48. Reference rivers (labeled) used to develop the Neponset River target fish community.

The five most abundant species in the TFC model are common shiner (40%), fallfish (20%), redbreast sunfish (7%), white sucker (6%), and American eel (5%) (Figure 49).

While many of the tributaries to the Neponset River have been sampled recently, the mainstem has not been adequately sampled since 1988. At that time it was dominated by macrohabitat generalists and one fluvial dependant species (white sucker). An effort will be made in the near future to repeat the 1988 survey and compile the Neponset River current fish community information.

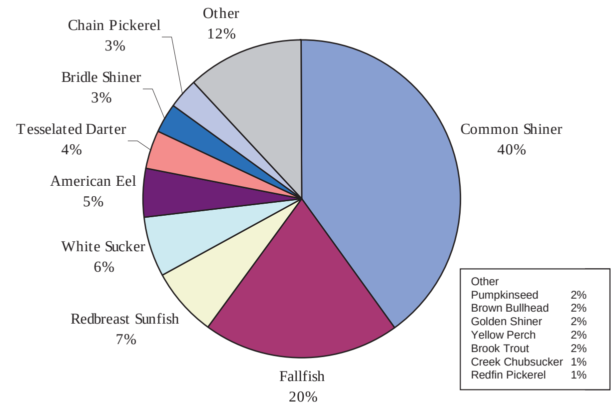

Figure 49. Target fish community composition for the Neponset River.

3.2.15 Parker River

The Parker River is a coastal system located along the North Shore in Essex County. This 3[rd] order river is 30.7 km long, with a drainage area of 212 km². Located in Ecoregion 59, the mainstem river has a gradient range of 0.0017 m/m to 0.004 m/m. Based on these mainstem characteristics, seven reference rivers were used to develop the TFC model (Figure 50, Table 25).

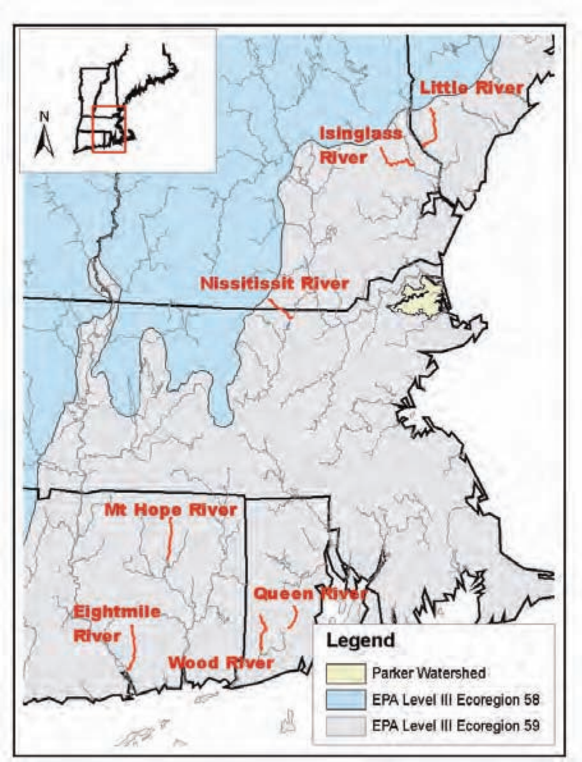

Figure 50. Reference rivers (labeled) used to develop the Parker River target fish community.

The five most abundant species in the TFC are common shiner (38%), fallfish (19%), white sucker (10%), American eel (8%), and redbreast sunfish (6%) (Figure 51).

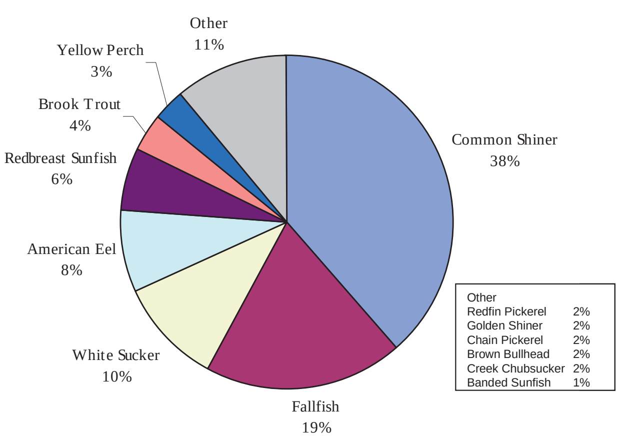

Figure 51. The fish species and proportions expected in the Parker River TFC.

The Parker River was sampled in 5 locations in 2005. Most of these samples were not suitable for inclusion in the description of the current fish community. Most samples had very low fish density which could also be an indicator of degradation. Fish density and biomass are two variables that will likely be included in the development of statewide indexes of biotic integrity.

3.2.16 Quinebaug River

The Quinebaug River begins in the Town of Brimfield, MA and flows southeast into Connecticut. The TFC was developed for a 38 km reach between East Brimfield Reservoir (MA) and West Thompson Lake (CT). The river is a 3rd order system in Ecoregion 59 with a drainage area of 404 km². Based on these mainstem characteristics, five reference rivers (Figure 52, Table 26) were used to develop the TFC model. The Quinebaug River was the subject of a TFC report authored by Cornell University (Bain and Meixler, 2008).

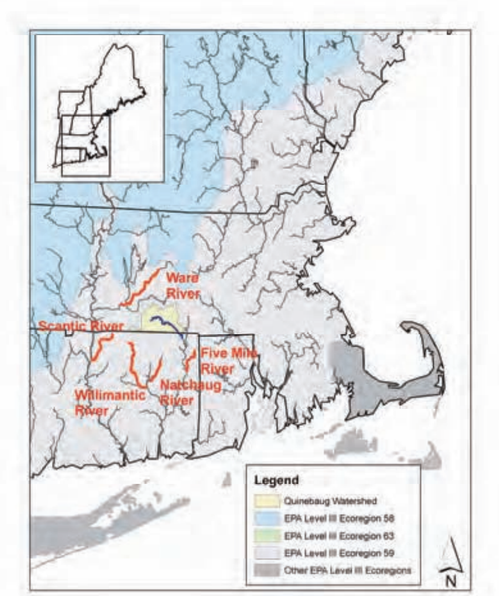

Figure 52. Reference rivers (labeled) used to develop the Quinebaug River target fish community.

Table 26. Reference rivers used to develop the Quinebaug River target fish community (Bain and Meixler, 2008).

River	State
Fivemile River	CT
Natchaug River	CT
Scantic River	CT
Ware River	MA
Willimantic	CT

Table 27. Quinebaug River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish Species	TFC Percentage[1]	Current Community Percentage[1]	Absolute Difference
Fallfish	29	22.2	8.79
Common shiner	15	19.0	4.01
White sucker	10	7.0	3.04
Longnose dace	7	2.7	5.35
Blacknose dace	6	0.6	5.45
Tessellated darter	5	0.4	4.56
American eel	3	0.1	2.89
Redbreast sunfish	3	11.5	8.49
Yellow perch	3	3.1	0.09
Chain pickerel	2	0.2	1.78
Golden shiner	2	0.6	1.45
Pumpkinseed	2	3.1	1.09
Spottail shiner	2	7.7	5.73
Creek chub	2	-	2.00
Brown bullhead	1	0.1	0.89
Brook trout	1	-	1.00
Creek chubsucker	1	-	1.00
Bluegill		2.9	2.87
Black crappie		0.1	0.11
Largemouth bass		2.3	2.32
Smallmouth bass		11.2	11.16
Yellow bullhead		5.3	5.30
Total			79.4
Percent Similarity			**60.3**

* - non-native species
1 – From Bain and Meixler, 2008

The species that make up the majority of the TFC are fallfish (29%), common shiners (15%), white sucker (10%), longnose dace (7%), and blacknose dace (6%) (Figure 53).

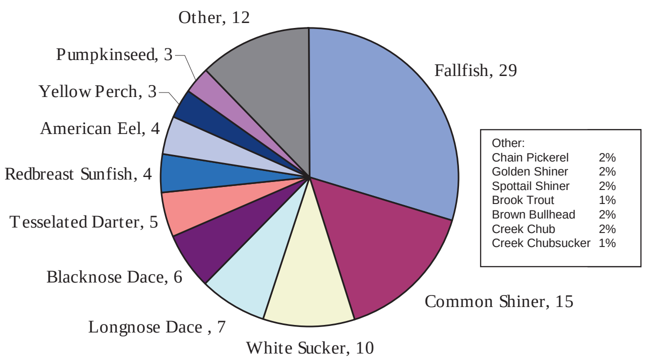

Figure 53. Quinebaug River Target Fish Community (From Bain and Meixler, 2008).

The fish sampling locations used by Bain and Meixler (2008) to describe the fish population indicated that the current community is dominated by fallfish (22%), common shiner (19%), redbreast sunfish (12%), smallmouth bass (11%), and spottail shiner (8%) (Table 27). Using habitat-use categories, the composition of the TFC is 50 percent fluvial specialist species, 25 percent fluvial dependent species, and 23 percent macrohabitat generalist species. The current community is nearly half (48%) macrohabitat generalists (Figure 54).

Similarity scores for species (60%, Figure 2) and habitat-use categories (75%, Figure 4) likely indicate impaired water quantity and physical habitat issues within the mainstem. Tolerance information illustrates a TFC and current community dominated by moderately tolerant individuals

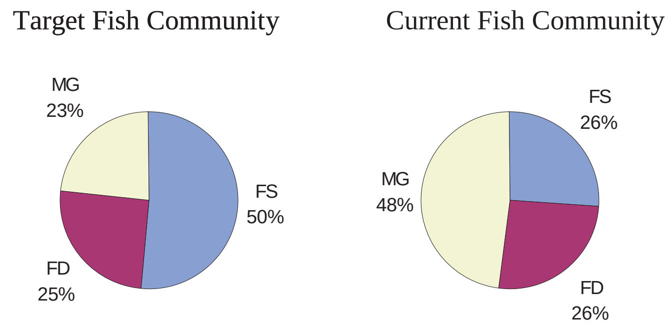

Figure 54. Quinebaug River habitat-use category percentages for target fish community and current community composition (from Bain and Meixler, 2008) (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist). Target fish community percentages do not add up to 100% due to the expected presence of an uncategorized species (sea lamprey, 2%).

(Figure 55) and a relatively high similarity score (89%, Figure 5).

The differences between the current and target fish communities have been attributed to the presence of impoundments, a lack of flood plain dynamics (e.g. incised channels not being able to reach floodplains), channel modification and temperature pollution (Paraciewicz and Gallagher, 2002). The same authors recommend dam removal, floodplain connectivity and natural flow regime restoration as top priorities.

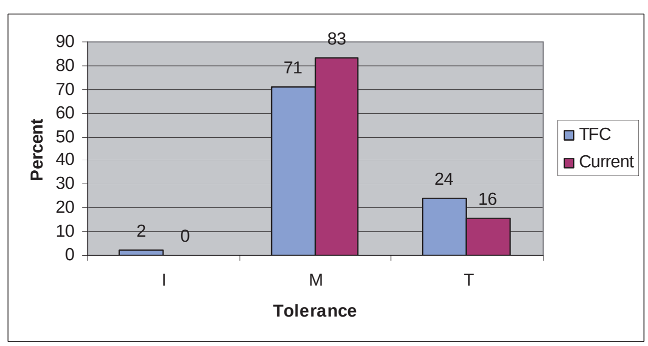

Figure 55. Proportion of individuals in the Quinebaug River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T) of pollution.

3.2.17 Shawsheen River

The Shawsheen River flows through Middlesex and Essex Counties before emptying into the Merrimack River near Lawrence, MA. This 37.3 km long, 4^{th} order river has a drainage area of 202 km². The river is located in Ecoregion 59 and has a gradient ranging from 0.0004 m/m to 0.0042 m/m. Based on these mainstem characteristics, six reference rivers (Figure 56, Table 28) were used to develop the TFC model.

The five most abundant species expected in the TFC are common shiner (38%), fallfish (19%), tessellated darter (8%), redbreast sunfish (6%), and American eel (5%) (Figure 57).

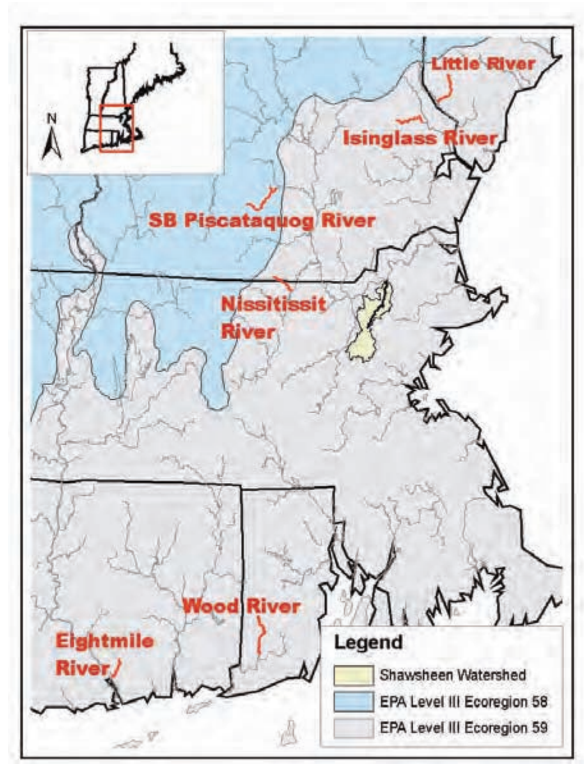

Figure 56. Reference rivers (labeled) used to develop the Shawsheen River target fish community.

Twelve samples from the mainstem of the Shawsheen River were used to describe the current fish community. These samples resulted in the capture of 1365 fish of 22 species. The five most abundant species collected from the mainstem of the river were American eel (46%), redbreast sunfish (11%), redfin pickerel (11%), Bluegill (9%), and fallfish (5%). Common shiner, the most abundant species in the model, is completely absent from mainstem samples (Table 29). Other under-represented or absent species include brook trout, fallfish, tessellated darter and white sucker (all fluvial species). Overly abundant species include American eel, bluegill, and redbreast sunfish (all generalist species). Similarity scores for the Shawsheen River were low (32%, Figure 2).

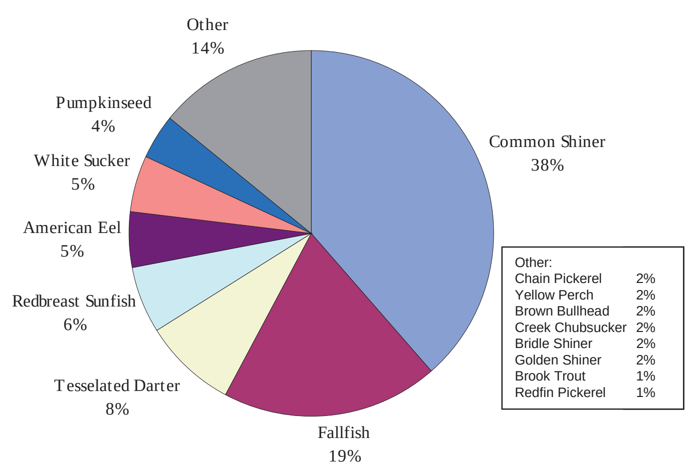

Figure 57. Target fish community composition for the Shawsheen River TFC.

The current assemblage is dominated by macrohabitat generalists (88%), while the TFC has only 28 percent macrohabitat generalists (Figure 58). As a result, the mainstem of the Shawsheen River had low similarity scores for habitat-use categories (39%, Figure 4).

Table 28. Physical characteristics of the Shawsheen River and the reference rivers used to develop the Shawsheen River target fish community.

River	State	Drainage area (km^2)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Shawsheen River	**MA**	**202**	**4**	**Acidic**	**1**	**1**	**59**
Eightmile River	CT	145	4	Acidic	1	1	59
Isinglass River	NH	166	4	Acidic	1	1	59
Little River	ME	132	3	Neutral	1	1	58/59
Nissitissit River	MA	145	4	Acidic	1	1	58/59
SB Piscataquog River	NH	267	4	Acidic	1	1	58
Wood River	RI	231	4	Acidic	1	1	59

Table 29. Shawsheen River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity. Highlighted rows indicate dominant species in the TFC that are scarce in the current community.

Fish Species	TFC Percentage	Current Community Percentage	Absolute Difference
Common shiner	37.6	-	37.6
Fallfish	18.8	5.2	13.6
Tessellated darter	7.5	2.6	4.9
Redbreast sunfish	6.3	11.1	4.8
American eel	5.4	45.6	40.2
White sucker	4.7	1.3	3.4
Pumpkinseed	4.2	4.2	0.0
Chain pickerel	2.5	1.0	1.5
Yellow perch	2.2	0.1	2.1
Brown bullhead	2.1	2.8	0.7
Creek chubsucker	2.0	0.6	1.4
Bridle shiner	1.8	0.1	1.7
Golden shiner	1.7	0.7	1.0
Brook trout	1.6	-	1.6
Redfin pickerel	1.6	10.6	9.0
Bluegill*	-	9.3	9.3
Largemouth bass*	-	1.8	1.8
Yellow bullhead*	-	0.4	0.4
Banded sunfish	-	0.4	0.4
Brown trout*	-	0.2	0.2
Total			135.7
Percent Similarity			**32.2**

* - non-native species

Also, while the TFC is dominated by moderately tolerant individuals, the current fish community is dominated by tolerant fish (Figure 59) and had the lowest tolerance similarity score of any mainstem (Figure 5).

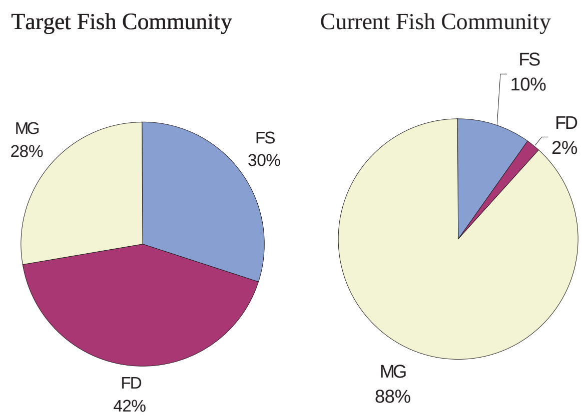

Figure 58. Shawsheen River habitat-use category percentages for target fish community and current community composition (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

The TFC analysis demonstrates the considerable deviation of the current fish community from the target. In addition to several impoundments on the mainstem, the primary impairment in the watershed has been described as "anthropogenic substrate alterations" such as channelization although other potential sources include post development erosion, sedimentation and industrial/commercial site stormwater discharges (Kiras, 2003).

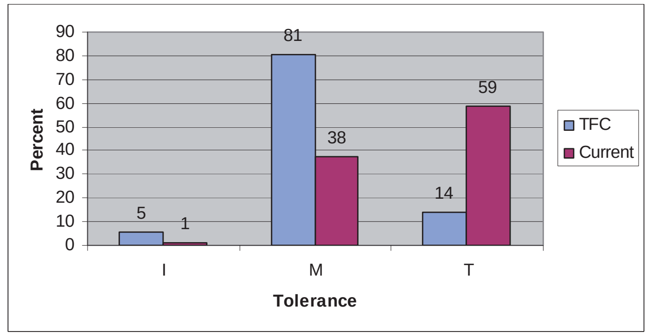

Figure 59. Proportion of individuals in the Shawsheen River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

3.2.18 Taunton River

The non-tidal mainstem section of the Taunton River is 38.9 km in length, flowing through Plymouth and Bristol counties in southeastern Massachusetts and emptying into Narragansett Bay along the border with Rhode Island. This 5th order system has a drainage area of 803 km² and is in Ecoregion 59. Gradient ranges from 0.0002 m/m to 0.0043 m/m. The Taunton River empties in Narragansett Bay in along the border with Rhode Island. Based on these mainstem characteristics, six reference rivers (Figure 60, Table 30) were used to develop the TFC model.

Table 30. Physical characteristics of the Taunton River and the reference rivers used to develop the Taunton River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Taunton River	**MA**	**803**	**5**	**Acidic**	**1**	**1**	**59**
Salmon River	CT	290	4	Acidic	1	1	59
Willimantic River	CT	321	4	Acidic	1	1	59
Yantic River	CT	259	3	Acidic	1	1	59
SB Piscataquog River	NH	267	4	Acidic	1	1	58/59
Tenmile River	NY	539	5	Neutral	1	1	58
Pawcatuck River	RI	712	5	Acidic	1	1	59

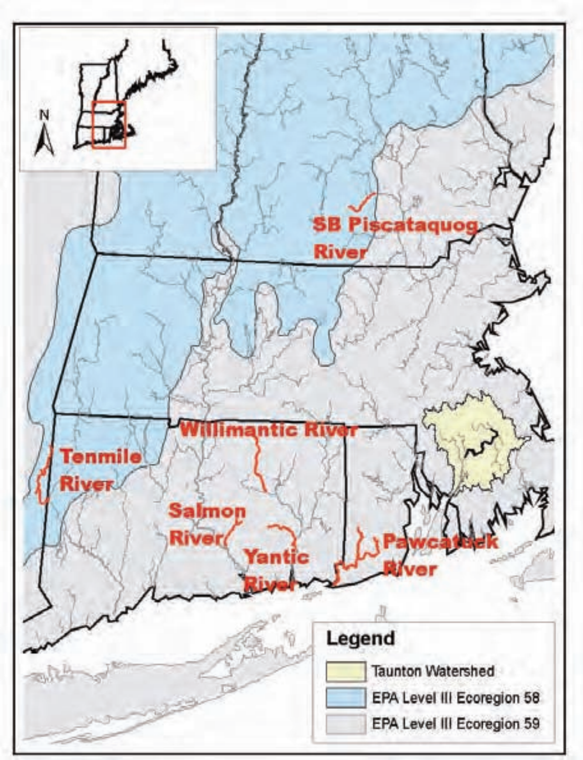

Figure 60. Reference rivers (labeled) used to develop the Taunton River target fish community.

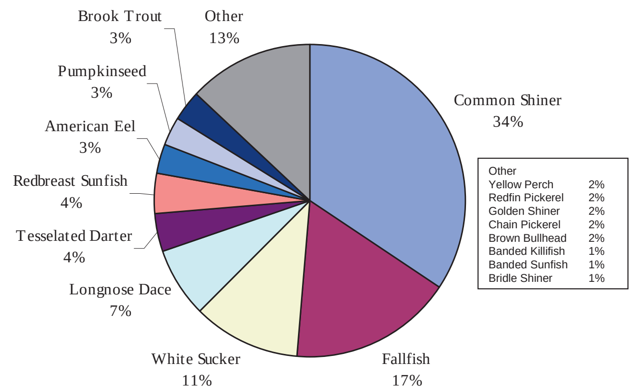

Figure 61. Target fish community composition for the Taunton River.

The five most abundant species from the TFC model are common shiner (34%), fallfish (17%), white sucker (11%), longnose dace (7%), and tessellated darter (4%) (Figure 61). According to Hartel et al. (2002), longnose dace are absent from the Taunton River drainage except for one undocumented record. Recent sampling in that same area resulted in the capture of the species. Longnose dace were collected by MDFW staff in a tributary stream to the Taunton River (Rumford River, 7/6/2006). For this reason, longnose dace were retained in the model even though they have been classified as outside their geographic range in the Taunton watershed.

The Taunton River mainstem has not been sampled sufficiently to determine the current composition of the fish community. The mainstem and major tributaries will be added to the MDFW sampling priorities in the upcoming sampling season.

3.2.19 Westfield River

The Westfield River is a 5th order system in western Massachusetts, flowing through Hampshire and Hampden Counties, eventually emptying into the Connecticut River near West Springfield, MA. The Westfield River basin drains an area of 1336 km² and is in Ecoregion 58. The main section of this river is formed by three separate rivers: the West Branch, Middle Branch, and East Branch. The combined mainstem length of these three rivers is 114.1 km. River gradients for these mainstem sections range from 0.0005 m/m to 0.0643 m/m. Based on these mainstem characteristics, eight reference rivers (Figure 62, Table 31) were used to develop the TFC model.

Table 31. Physical characteristics of the Westfield River and the reference rivers used to develop the Westfield River target fish community.

River	State	Drainage area (km²)	Stream order	Calcareous geology	Grad. class	Elv. class	Level III Ecoregion
Westfield River	MA	1336	5	Acidic	2	1	58
Ashuelot River	NH	904	5	Acidic	1	1	58
Ammonoosuc River	NH	842	4	Acidic	2	1	58
Cold River	NH	251	4	Acidic	2	1	58
NB Sugar River	NH	231	4	Acidic	2	1	58
North River	MA	233	4	Neutral	2	1	58
Piscataquog River	NH	559	5	Acidic	1	1	58
Tenmile River	NY	539	5	Neutral	1	1	58
3rd Branch White River	VT	280	4	Acidic	1	1	58

The five most abundant species in the TFC model are:

blacknose dace (32%), longnose dace (16%), common shiner (11%), slimy sculpin (6%), and fallfish (5%) (Figure 63).

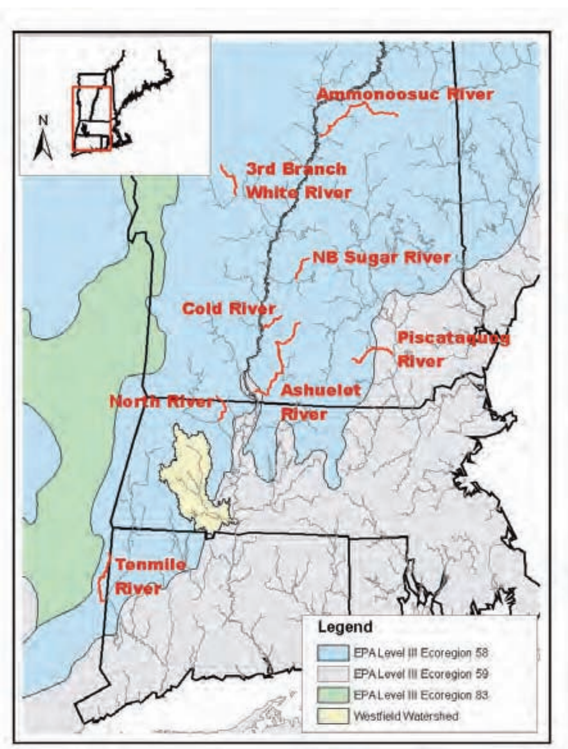

Figure 62. Reference rivers (labeled) used to develop the Westfield River target fish community.

Ten fish surveys from the mainstem and main branches of the Westfield River were used to construct the current fish community. These surveys resulted in the capture of more than 3,000 fish of 19 species. Atlantic salmon, stocked as part of the Atlantic salmon restoration effort were removed from the analysis in both the TFC and current fish community. The five most abundant species in the Westfield River are blacknose dace (36%), longnose dace (24%), common shiner (13%), slimy sculpin (8%), and smallmouth bass (5%) (Table 32). Both the TFC and current fish community are dominated by fluvial fish (Figure 64) and a mix of moderate and tolerant species (Figure 65). Four of the top five species in the TFC are also in the top five of the current community (Table 32). Corresponding similarity scores for species (80%, Figure 2), habitat-use categories (95%, Figure 4), and tolerance categories (95%, Figure 5) were high.

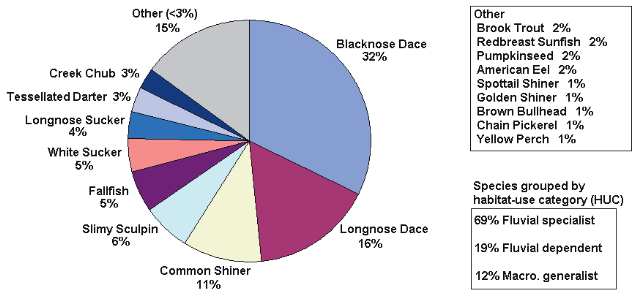

Figure 63. Target fish community composition for the Westfield River.

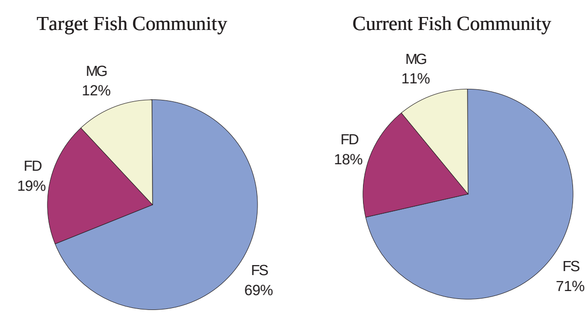

Figure 64. Westfield River habitat-use category percentages for target fish community and current community composition (FS, fluvial specialist; FD, fluvial dependent; MG, macrohabitat generalist).

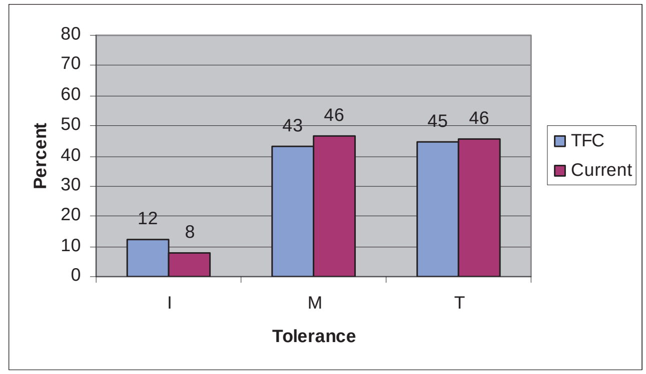

Figure 65. Proportion of individuals in the Westfield River target and current fish community that are considered intolerant (I), moderately tolerant (M), and tolerant (T).

The similarity between the current and target fish communities is an indication of the relative integrity of the system. The Westfield River provides an environment suitable for native riverine species predicted by the TFC model. Assessments of water quality support the same basic conclusion. Except for the 1-mile reach of the Westfield River near the Westfield Wastewater Treatment Plant, the assessed portions of the river supports the Aquatic Life Use Standard (Dunn and Kennedy, 2005). The river does still have impairments to habitat including impoundments and hydromodification that alter temperature and flow regimes, but these impairments also affect aspects of the fish community not directly studied in this report (e.g. anadromous fish species).

Table 32. Westfield River species percentages for target fish community model and current community composition. Absolute difference values between model expected and current community percentages were used to calculate percent similarity.

Fish Species	TFC Percentage	Current Community Percentage	Absolute Difference
Blacknose dace	32.4	36.2	3.9
Longnose dace	16.2	24.5	8.3
Common shiner	10.8	12.7	2.0
Slimy sculpin	6.5	7.5	1.0
Fallfish	5.4	0.8	4.6
White sucker	4.6	5.0	0.4
Longnose sucker	3.6	0.0	3.6
Tessellated darter	3.2	0.9	2.3
Creek chub	2.9	1.1	1.8
Brook trout	2.3	0.2	2.1
Redbreast sunfish	1.9		1.9
Pumpkinseed	1.8	0.1	1.7
American eel	1.7	3.0	1.3
Golden shiner	1.5	0.4	1.1
Spottail shiner	1.5		1.5
Brown bullhead	1.4		1.4
Chain pickerel	1.2		1.2
Yellow perch	1.2		1.2
Lake chub		0.5	0.5
Rock bass*		1.4	1.4
Rainbow trout*		0.1	0.1
Smallmouth bass*		5.4	5.4
Yellow bullhead*		0.1	0.1
Total			48.7
Percent Similarity			**75.7**

* - non-native species

3.3 Addressing Gaps in Target Fish Community Development

As mentioned in the introduction, there are several mainstem rivers for which a river-specific TFC was not developed, namely the large inter-jurisdictional rivers (Connecticut and Merrimack) and certain coastal planning basins that lack large mainstem rivers (North Coastal, South Coastal, Cape Cod, Islands, Buzzards Bay). In both cases, the rivers are more extreme in size (larger or smaller) than other rivers for which TFCs have been developed. Both larger and smaller systems will require an alternative assessment methodology. Larger Rivers will need to be assessed through interstate agency cooperative efforts (underway). Coastal basins and tributaries to mainstem rivers with existing TFCs will be assessed in the future using site-specific methodologies like Indexes of Biotic Integrity described by Karr (1981). These methodologies will allow the establishment of restoration goals and measures of current condition for these waters.

4.0 Conclusions

Comparisons of TFCs to current fish communities document that most Massachusetts mainstems have been measurably degraded to some degree. High quality rivers, as determined through the reference river selection process, are dominated by riverine species with a mix of tolerant, moderately tolerant, and intolerant species.

Based on species percent abundance, the Westfield mainstem had the greatest degree of similarity between the TFC and current fish community. The similarity score of 76 percent suggests that the current fish assemblage in the Westfield River closely matches conditions expected by the TFC model. The Blackstone, Ipswich, and Charles mainstems had the lowest species similarity scores. These low scores indicate that the current fish assemblages in these mainstem sections differ greatly from the expected communities predicted by the TFC models.

These similarity scores should be considered a very rudimentary assessment of biotic integrity. Many methods of the assessment of biotic integrity following Karr (1981) address not only species diversity but also characteristics such as trophic status, individual fish health and the presence of indicator or sensitive species. All these variables are then compared to the same variables measured at reference sites.

Habitat-use and tolerance similarity scores help us to determine the primary factors affecting the fish community and in tern the most efficient restoration actions to take. Those rivers that scored poorly based on habitat-use category similarity (Figure 4) are most likely to be impaired directly by alteration of some or many components of the natural flow regime or physical habitat (e.g. water withdrawal, channelization or impoundment). The lowest habitat-use category similarity scores were found in the Ipswich, Charles, Shawsheen, Blackstone and Concord

Rivers. The Charles, Blackstone, and Concord Rivers are considerably impounded and this condition likely acts in concert with extensive reach-specific stream flow alterations to impact physical habitat and the natural flow regime. The Shawsheen and Ipswich Rivers both have considerable flow alteration though fewer impoundments.

The rivers that scored poorly based on tolerance similarity (Figure 5) are most likely to be impaired directly by water quality alteration. Tolerance similarity scores were lowest for the Shawsheen, Charles, Blackstone, Farmington, and Concord. Many of these systems are known to be effluent dominated in the summer months and have other water quality impairments. Through this research, it becomes evident that these water quality impairments manifest themselves in the fish community.

The target fish community approach is an excellent tool to describe restoration goals. Some of the limitations inherent to a broad-brush approach like this should be recognized, however. First, this approach addresses resident freshwater fish species and does not include assessments of anadromous species that are in range-wide decline and in need of restoration. Second, this is not a site-by site analysis based on extensive scrutiny of fish community attributes, but a simple measure of the relative abundance of the species present in the current community relative to that predicted in the TFC. Measures of biomass, density, or individual fish health that are often used as indicators of biotic integrity are not here addressed. Finally, even in waters that do not currently have a TFC, fish community attributes can be measured and examined to determine potential restoration options.

This is the first state-wide effort to characterize the condition of the fish communities in Massachusetts' mainstem river systems and will be useful for guiding restoration, protection, and management efforts. This work focuses on the species that are expected to be most common, rather than other methodologies of assessment based on the needs of only rare or sensitive species. This attribute of the approach makes the evaluation of success or failure of each individual restoration action far more possible and will increase the success of adaptive management strategies.

In addition to site-specific fish community assessment tools like the Index of Biotic Integrity (Karr, 1981), specific restoration objectives within each mainstem river need to be mapped out and prioritized for action. The Target Fish Community method provides a biological foundation on which to make ecologically-based policy and management decisions like the basin stress reclassification, the establishment of instream flow criteria, and biological monitoring for restoration activities.

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Appendix A.

Species percent composition for reference rivers used to develop target fish community models for statewide application.

Table A1. Species percent composition for reference rivers used to develop the Blackstone River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Willimantic River	Salmon River	North River	Lamprey River	Pawcatuck River	Total	Rank	Expected Proportion
Fallfish	44.3	0.3	28.6	15.4	8.7	97.3	1	31.8
Common shiner	21.6	13.9	9.0	42.1	9.2	95.8	2	15.9
White sucker	14.6	5.1	5.3	3.7	9.3	38.1	3	10.6
Longnose dace	0.0	15.2	10.6	5.4	6.6	37.8	4	8.0
Atlantic salmon	0.0	21.7	3.1	0.3	3.3	28.3		
Redbreast sunfish	2.1	0.0	0.0	18.3	6.8	27.2	6	5.3
American eel	0.2	10.1	2.0	5.3	7.6	25.2	7	4.5
Blacknose dace	7.9	11.1	0.0	0.0	0.0	19.0	8	4.0
Spottail shiner	0.2	0.0	17.9	0.0	0.0	18.1		
Smallmouth bass	2.9	9.5	0.0	1.6	0.0	14.0		
Tessellated darter	1.3	1.8	0.0	0.0	10.1	13.2	11	2.9
Brook trout	0.0	1.0	0.0	0.0	11.1	12.2	12	2.7
Bridle shiner	0.0	0.0	7.8	1.4	0.1	9.3	13	2.4
Brown trout	0.6	5.2	1.4	0.1	1.7	9.0		
Yellow perch	2.6	0.0	0.0	0.6	4.8	8.1	15	2.1
Chain pickerel	0.1	0.2	5.6	0.2	1.6	7.6	16	2.0
Pumpkinseed	0.7	0.2	1.4	2.4	2.1	6.9	17	1.9
Largemouth bass	0.3	0.6	0.8	0.5	3.8	5.9		
Brown bullhead	0.0	0.0	4.8	0.0	0.8	5.6	19	1.7
Redfin pickerel	0.0	0.0	0.0	0.0	5.1	5.1	20	1.6
Bluegill	0.1	0.9	0	0.0	3.8	4.9		
Golden shiner	0.3	0.0	0.0	1.7	1.3	3.3	22	1.4
Rainbow trout	0.0	0.6	0.6	0.0	0.0	1.2		
Yellow bullhead	0.0	0.0	0.0	1.0	0.0	1.0		
Creek chubsucker	0.0	0.0	0.0	0.2	0.5	0.6	25	1.3
Black crappie	0.0	0.0	0.0	0.0	0.5	0.5		
Rock bass	0.1	0.0	0.0	0.0	0.0	0.1		

Table A2. Species percent composition for reference rivers used to develop the Chicopee River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Willimantic River	Salmon River	Pawcatuck River	Ashuelot River	Total	Rank	Expected Proportion
Fallfish	44.3	0.3	8.7	26.8	80.2	1	31.4
Common shiner	21.6	13.9	9.2	22.3	67.1	2	15.7
Blacknose dace	7.9	11.1	0.0	19.8	38.8	3	10.5
White sucker	14.6	5.1	9.3	7.9	36.9	4	7.8
Longnose dace	0.0	15.2	6.6	12.7	34.5	5	6.3
Atlantic salmon	0.0	21.7	3.3	2.2	27.2		
American eel	0.2	10.1	7.6	0.2	18.1	7	4.5
Tessellated darter	1.3	1.8	10.1	3.8	17.0	8	3.9
Smallmouth bass	2.9	9.5	0.0	1.3	13.7		
Brook trout	0.0	1.0	11.1	0.0	12.2	10	3.1
Redbreast sunfish	2.1	0.0	6.8	0.0	8.9	11	2.9
Brown trout	0.6	5.2	1.7	0.3	7.9		
Yellow perch	2.6	0.0	4.8	0.3	7.7	13	2.4
Redfin pickerel	0.0	0.0	5.1	0.0	5.1	14	2.2
Bluegill	0.1	0.9	3.8	0.0	4.9		
Largemouth bass	0.3	0.6	3.8	0.0	4.6		
Pumpkinseed	0.7	0.2	2.1	0.3	3.3	17	1.8
Chain pickerel	0.1	0.2	1.6	0.1	1.9	18	1.7
Golden shiner	0.3	0.0	1.3	0.0	1.6	19	1.7
Brown bullhead	0.0	0.0	0.8	0.2	1.0	20	1.6
Yellow bullhead	0.0	0.0	0.0	1.0	1.0		
Rainbow trout	0.0	0.6	0	0.0	0.6		
Black crappie	0.0	0.0	0.5	0.0	0.5		
Creek chubsucker	0.0	0.0	0.5	0.0	0.5	24	1.3
Rock bass	0.1	0.0	0.0	0.1	0.2		
Spottail shiner	0.2	0.0	0.0	0.0	0.2	26	1.2

Table A3. Species percent composition for reference rivers used to develop the Concord River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Willimantic River	Lamprey River	North River	Pawcatuck River	Piscataquog River	Total	Rank	Expected Proportion
Fallfish	44.3	15.4	28.6	8.7	2.8	99.8	1	37.3
Common shiner	21.6	42.1	9.0	9.2	15.8	97.6	2	18.7
Longnose dace	0.0	5.4	10.6	6.6	15.2	37.9		
White sucker	14.6	3.7	5.3	9.3	2.8	35.7	4	9.3
Blacknose dace	7.9	0.0	0.0	0.0	22.5	30.3		
Redbreast sunfish	2.1	18.3	0.0	6.8	2.7	29.9	6	6.2
Spottail shiner	0.2	0.0	17.9	0.0	0.5	18.6		
Smallmouth bass	2.9	1.6	0.0	0.0	12.0	16.5		
American eel	0.2	5.3	2.0	7.6	1.4	16.5	9	4.1
Tessellated darter	1.3	0.0	0.0	10.1	0.0	11.4	10	3.7
Brook trout	0.0	0.0	0.0	11.1	0.0	11.1	11	3.4
Atlantic salmon	0.0	0.3	3.1	3.3	3.4	10.0		
Bridle shiner	0.0	1.4	7.8	0.1	0.0	9.3	13	2.9
Yellow perch	2.6	0.6	0.0	4.8	0.0	8.1	14	2.7
Pumpkinseed	0.7	2.4	1.4	2.1	1.4	8.0	15	2.5
Chain pickerel	0.1	0.2	5.6	1.6	0.2	7.6	16	2.3
Largemouth bass	0.3	0.5	0.8	3.8	1.4	6.8		
Brown bullhead	0.0	0.0	4.8	0.8	0.2	5.7	18	2.1
Redfin pickerel	0.0	0.0	0.0	5.1	0.2	5.3	19	2.0
Brown trout	0.6	0.1	1.4	1.7	0.4	4.2		
Bluegill	0.1	0.0	0.0	3.8	0.0	4.0		
Yellow bullhead	0.0	1.0	0.0	0.0	3.0	4.0		
Golden shiner	0.3	1.7	0.0	1.3	0.5	3.8	23	1.6
Longnose sucker	0.0	0.0	0.0	0.0	2.8	2.8		
Rainbow trout	0.0	0.0	0.6	0.0	1.1	1.7		
Creek chubsucker	0.0	0.2	0.0	0.5	0.0	0.6	26	1.4
Black crappie	0.0	0.0	0.0	0.5	0.0	0.5		
Rock bass	0.1	0.0	0.0	0.0	0.0	0.1		

Table A4. Species percent composition for reference rivers used to develop the Deerfield River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	EB Westfield River	Third Branch White River	Tenmile River	Ashuelot River	Ammonoosuc River	Piscataquog River	Total	Rank	Expected Proportion
Blacknose dace	41.3	25.0	14.9	19.8	24.1	22.5	147.6	1	31.8
Longnose dace	18.7	19.9	9.3	12.7	38.5	15.2	114.2	2	15.9
Common shiner	7.8	2.6	13.8	22.3	1.4	15.8	63.7	3	10.6
Slimy sculpin	9.6	33.1	0.0	0.0	6.0	0.0	48.8	4	7.9
Fallfish	0.5	0.0	18.7	26.8	0.0	2.8	48.8	5	6.4
Atlantic salmon	9.7	0	0	2.2	24.1	3.4	39.4		
White sucker	8.2	0.3	15.8	7.9	0.5	2.8	35.5	7	4.5
Smallmouth bass	0.0	0.0	12.2	1.3	0.0	12.0	25.5		
Longnose sucker	0.0	5.6	0.0	0.0	4.8	2.8	13.2	9	3.5
Tessellated darter	0.0	0.1	7.3	3.8	0.2	0.0	11.4	10	3.2
Rainbow trout	0.1	7.5	0.1	0.0	0.0	0.2	7.8		
Creek chub	2.7	1.4	0.6	0.2	0.0	0.0	4.9	12	2.6
Cutlips minnow	0.0	0	4.6	0	0.0	0	4.6		
Brown trout	0.0	3.3	0.1	0.3	0.0	0.4	4.1		
Yellow bullhead	0.0	0.0	0.0	1.0	0.0	3.0	4.0		
Redbreast sunfish	0.0	0.0	0.0	0.0	0.0	2.7	2.7	16	2.0
Pumpkinseed	0.1	0.0	0.6	0.3	0.0	1.4	2.4	17	1.9
Brook trout	0.5	1.2	0.1	0.0	0.6	0.0	2.3	18	1.8
American eel	0	0	0	0.2	0	1.4	1.6	19	1.7
Bluegill	0.2	0	1.3	0	0.0	0	1.5		
Largemouth bass	0.0	0.0	0.0	0.0	0.0	1.4	1.4		
Golden shiner	0.1	0.0	0.3	0.0	0.0	0.5	0.9	22	1.4
Lake chub	0.6	0.0	0.0	0.0	0.0	0.0	0.6		
Spottail shiner	0.0	0.0	0.0	0.0	0.0	0.5	0.5	24	1.3
Brown bullhead	0.0	0	0.0	0.2	0.0	0.2	0.4	25	1.3
Bluntnose minnow	0.0	0	0.4	0	0.0	0	0.4		
Rock bass	0.0	0.0	0.3	0.1	0.0	0.0	0.4		
Chain pickerel	0.0	0.0	0.0	0.1	0.0	0.2	0.3	28	1.1
Yellow perch	0.0	0.0	0.0	0.3	0.0	0.0	0.3	28	1.1

Table A5. Species percent composition for reference rivers used to develop the Farmington River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	North River	Green River	Cold River	NB Sugar River	Ashuelot River	Salmon Brook	Total	Rank	Expected Proportion
Blacknose dace	38.4	41.9	53.8	6.9	29.0	38.9	208.9	1	33.7
Longnose dace	29.1	23.2	16.9	44.6	14.1	5.6	133.5	2	16.8
Atlantic salmon	15.1	18.8	6.5	0.0	3.2	18.7	62.2		
Slimy sculpin	8.9	12.0	2.7	0.0	0.0	16.9	40.5	4	8.4
Common shiner	1.1	0.7	6.5	20.8	8.2	1.4	38.7	5	6.7
Fallfish	0.3	0.0	0.0	1.0	30.4	0.0	31.6	6	5.6
White sucker	1.9	0.1	6.2	10.9	9.4	1.9	30.4	7	4.8
Brook trout	0.6	1.9	2.4	0.0	0.1	9.3	14.4	8	4.2
Creek chub	0.8	0.9	2.8	5.0	0.3	1.0	10.8	9	3.7
Longnose sucker	2.9	0.0	0.6	4.0	0.0	0.0	7.6	10	3.4
Tessellated darter	0.3	0.2	0.6	0.0	1.5	4.3	6.8	11	3.1
Brown trout	0.3	0.2	0	5	0.3	0.0	5.8		
Yellow bullhead	0.0	0.0	0.0	0.0	1.5	0.0	1.5		
Smallmouth bass	0.0	0.0	0.4	0.0	0.9	0.1	1.4		
American eel	0	0	0	0	0	1	1.0	15	2.2
Brown bullhead	0.2	0	0	0	0.3	0	0.4	16	2.1
Rainbow trout	0.2	0.0	0.2	0.0	0.1	0.0	0.4		
Redbreast sunfish	0.0	0.0	0.0	0.0	0.3	0.0	0.3	18	1.9
Pumpkinseed	0.0	0.0	0.1	0.0	0.2	0.0	0.3	19	1.8
Yellow perch	0.0	0.0	0.0	0.0	0.1	0.0	0.1	20	1.7
Largemouth bass	0.0	0.0	0.0	0.0	0.1	0.0	0.1		

Table A6. Species percent composition for reference rivers used to develop the French River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outline by Bain and Meixler (2008).

Species	Wood River	Nissitissit River	Eightmile River	Willimantic River	Isinglass River	Mt Hope River	Total	Rank	Expected Proportion
Common shiner	32.3	5.4	18.6	21.6	36.8	4.6	119.3	1	31.5
Fallfish	4.1	26.7	3.1	44.3	18.1	20.7	117.0	2	15.7
Tessellated darter	13.6	9.7	17.3	1.3	0.0	0.5	42.6	3	10.5
Redbreast sunfish	16.1	1.0	10.9	2.1	9.2	0.0	39.2	4	7.9
Longnose dace	12.5	12.6	1.0	0.0	12.1	0.0	38.2	5	6.3
White sucker	2.1	0.8	5.0	14.6	0.5	13.2	36.1	6	5.2
American eel	5.9	2.3	8.9	0.2	10.8	0.4	28.4	7	4.5
Largemouth bass	0.2	5.4	6.0	0.3	0.9	12.1	24.8		
Yellow perch	0.0	0.0	4.3	2.6	0.0	17.4	24.3	9	3.5
Pumpkinseed	0.3	11.0	3.3	0.7	2.7	5.7	23.7		
Blacknose dace	0.0	6.2	3.4	7.9	0.0	4.8	22.2	11	2.9
Golden shiner	0.0	0.0	0.0	0.3	0.0	11.5	11.8	12	2.6
Spottail shiner	0.0	0.0	11.3	0.2	0.0	0.0	11.5		
Bluegill	4.9	3.8	0.4	0.1	0.0	2.0	11.4		
Yellow bullhead	0.0	10.3	0.0	0.0	0.0	0.0	10.3		
Chain pickerel	1.1	3.3	0.1	0.1	0.2	3.7	8.6	16	2.0
Smallmouth bass	0.0	0.0	1.3	2.9	0.5	3.5	8.2		
Atlantic salmon	2.8	0.0	1.4	0.0	3.9	0.0	8.1		
Brown bullhead	0.8	0.0	0.1	0.0	1.4	0.0	2.4	19	1.7
Creek chubsucker	1.3	0.8	0.0	0.0	0.0	0.0	2.1	20	1.6
Bridle shiner	0.0	0.0	0.0	0.0	1.8	0.0	1.8	21	1.5
Brown trout	0.7	0.0	0.3	0.6	0.0	0.0	1.6		
Brook trout	0.8	0.3	0.0	0.0	0.0	0.0	1.1	23	1.4
Redfin pickerel	0.0	0.0	0.9	0.0	0.0	0.0	0.9	24	1.3
Rock bass	0.0	0.5	0.0	0.1	0.0	0.0	0.6		
Black crappie	0.2	0.0	0.0	0.0	0.0	0.0	0.2		
Rainbow trout	0.2	0.0	0.0	0.0	0.0	0.0	0.2		

Table A7. Species percent composition for reference rivers used to develop the Hoosic River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Third Branch White River	Batten Kill	Little Hoosic River	Kinderhook River	Black Creek	Hollenbeck River	WB Westfield River	Sum	Rank	Expected Proportion
Blacknose dace	36.7	31.3	30.0	11.5	8.4	42.1	32.4	192.4	1	34.1
Longnose dace	28.4	11.6	11.1	5.7	23.6	34.1	31.4	145.9	2	17.1
Slimy sculpin	21.2	13.7	24.7	21.6	4.1	0.0	0.2	85.5	3	11.4
White sucker	0.9	0.4	19.3	7.9	16.5	1.2	3.3	49.5	4	8.5
Common shiner	0.0	0.0	1.0	11.1	12.1	2.2	10.4	36.8	5	6.8
Brown trout	4.0	15.5	2.1	10.1	1.7	0.0	0.5	33.9		
Brook trout	0.1	25.3	0.6	0.1	0.0	3.5	0.1	29.7	7	4.5
Fallfish	0.0	0.0	0.0	16.0	0.0	4.8	0.0	20.8	8	4.3
Tessellated darter	0.3	0.0	0.0	1.2	11.0	2.3	3.1	17.9		
Cutlips minnow	0.0	0.0	0.0	9.4	4.9	0.0	0.0	14.3		
Bluntnose minnow	0.0	0.0	0.0	0.0	13.8	0.0	0.0	13.8		
Creek chub	1.1	0.0	2.8	0.5	3.5	2.9	0.3	11.1	12	2.8
Longnose sucker	4.7	2.1	0.4	0.9	0.0	0.0	0.0	8.1	13	2.6
Rainbow trout	2.6	0.0	3.9	0.0	0.0	0.0	0.4	6.9		
Rock bass	0.0	0.0	0.0	0.1	0.2	5.0	0.1	5.4		
Trout-perch	0.0	0.0	3.8	0.0	0.0	0.0	0.0	3.8	16	2.1
Pumpkinseed	0.0	0.0	0.0	1.7	0.1	1.4	0.0	3.2	17	2.0
Smallmouth bass	0.0	0.0	0.0	1.2	0.0	0.4	1.1	2.7		
Golden shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	19	1.8
Yellow perch	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	20	1.7
American eel	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.4		
Bluegill	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3		
Spottail shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2		

Table A8. Species percent composition for reference rivers used to develop the Ipswich River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Lamprey River	North River	SB Piscataquog River	Willimantic River	Salmon River	Total	Rank	Expected Proportions
Common shiner	42.1	9.0	20.6	21.6	13.9	107.2	1	40.6
Fallfish	15.4	28.6	3.0	44.3	0.3	91.6	2	20.3
Blacknose dace	0.0	0.0	33.4	7.9	11.1	52.4		
Longnose dace	5.4	10.6	19.0	0.0	15.2	50.2		
Atlantic salmon	0.3	3.1	9.4	0.0	21.7	34.4		
White sucker	3.7	5.3	0.9	14.6	5.1	29.6	6	6.7
Redbreast sunfish	18.3	0.0	0.0	2.1	0.0	20.4	7	5.8
Spottail shiner	0.0	17.9	0.5	0.2	0.0	18.6		
Smallmouth bass	1.6	0.0	3.6	2.9	9.5	17.6		
American eel	5.3	2.0	0.0	0.2	10.1	17.5	10	4.1
Bridle shiner	1.4	7.8	0.0	0.0	0.0	9.2	11	3.7
Brown trout	0.1	1.4	0.4	0.6	5.2	7.7		
Chain pickerel	0.2	5.6	0.2	0.1	0.2	6.2	13	3.1
Pumpkinseed	2.4	1.4	0.5	0.7	0.2	5.2	14	2.8
Brown bullhead	0.0	4.8	0.0	0.0	0.0	4.8	15	2.7
Golden shiner	1.7	0.0	1.6	0.3	0.0	3.5	16	2.5
Yellow perch	0.6	0.0	0.0	2.6	0.0	3.2	17	2.3
Tessellated darter	0.0	0.0	0.0	1.3	1.8	3.1		
Largemouth bass	0.5	0.8	0.7	0.3	0.6	2.9		
Yellow bullhead	1.0	0.0	1.8	0.0	0.0	2.8		
Rainbow trout	0.0	0.6	0.2	0.0	0.6	1.4		
Bluegill	0.0	0.0	0.0	0.1	0.9	1.1		
Brook trout	0.0	0.0	0.0	0.0	1.0	1.0	23	1.7
Creek chubsucker	0.2	0.0	0.0	0.0	0.0	0.2	24	1.7
Rock bass	0.0	0.0	0.0	0.1	0.0	0.1		
Redfin pickerel	0.1	0.0	0.0	0.0	0.0	0.1	26	1.5

Table A9. Species percent composition for reference rivers used to develop the Millers River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	EB Westfield River	Third Branch White River	Tenmile River	Ashuelot River	Ammonoosuc River	Piscataquog River	Total	Rank	Expected Proportions
Blacknose dace	41.3	25.0	14.9	19.8	24.1	22.5	147.6	1	32.6
Longnose dace	18.7	19.9	9.3	12.7	38.5	15.2	114.2	2	16.3
Common shiner	7.8	2.6	13.8	22.3	1.4	15.8	63.7	3	10.9
Fallfish	0.5	0.0	18.7	26.8	0.0	2.8	48.8	4	8.1
Atlantic Salmon	9.7	0.0	0.0	2.2	24.1	3.4	39.4		
Slimy sculpin	0.0	33.1	0.0	0.0	6.0	0.0	39.1	6	5.4
White sucker	8.2	0.3	15.8	7.9	0.5	2.8	35.5	7	4.7
Smallmouth bass	9.6	0.0	12.2	1.3	0.0	12.0	35.1		
Longnose sucker	0.0	5.6	0.0	0.0	4.8	2.8	13.2		
Tessellated darter	0.0	0.1	7.3	3.8	0.2	0.0	11.4	10	3.3
Rainbow trout	0.1	7.5	0.1	0.0	0.0	0.2	7.8		
Creek chub	2.7	1.4	0.6	0.2	0.0	0.0	4.9	12	2.7
Cutlips minnow	0.0	0.0	4.6	0.0	0.0	0.0	4.6		
Brown trout	0.0	3.3	0.1	0.3	0.0	0.4	4.1		
Yellow bullhead	0.0	0.0	0.1	1.0	0.0	3.0	4.1		
Redbreast sunfish	0.0	0.0	0.0	0.0	0.0	2.7	2.7	16	2.0
Pumpkinseed	0.1	0.0	0.6	0.3	0.0	1.4	2.4	17	1.9
Brook trout	0.5	1.2	0.1	0.0	0.6	0.0	2.3	18	1.8
American eel	0.0	0.0	0.0	0.2	0.0	1.4	1.6	19	1.7
Bluegill	0.2	0.0	1.3	0.0	0.0	0.0	1.5		
Largemouth bass	0.0	0.0	0.0	0.0	0.0	1.4	1.4		
Golden shiner	0.1	0.0	0.3	0.0	0.0	0.5	0.9	22	1.5
Spottail shiner	0.0	0.0	0.0	0.0	0.0	0.5	0.5	23	1.4
Brown bullhead	0.0	0.0	0.0	0.2	0.0	0.2	0.4	24	1.4
Bluntnose minnow	0.0	0.0	0.4	0.0	0.0	0.0	0.4		
Rock bass	0.0	0.0	0.3	0.1	0.0	0.0	0.4		
Chain pickerel	0.0	0.0	0.0	0.1	0.0	0.2	0.3	27	1.2
Yellow perch	0.0	0.0	0.0	0.3	0.0	0.0	0.3	28	1.2
Bridle shiner	0.1	0.0	0.0	0.0	0.0	0.0	0.1	29	1.1

Table A10. Species percent composition for reference rivers used to develop the Mystic River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Queen River	Little River	Mount Hope River	Wood River	Isinglass River	Eightmile River	Nissitissit River	Total	Rank	Expected Proportion
Common shiner	0.0	14.9	4.6	32.3	36.8	18.6	5.4	112.6	1	38.3
Fallfish	15.4	16.2	20.7	4.1	18.1	3.1	26.7	104.3	2	19.2
Tessellated darter	12.8	0.0	0.5	13.6	0.0	17.3	9.7	54.0		
White sucker	8.6	12.2	13.2	2.1	0.5	5.0	0.8	42.3	4	9.6
American eel	7.6	4.7	0.4	5.9	10.8	8.9	2.3	40.5	5	7.7
Longnose dace	0.0	0.0	0.0	12.5	12.1	1.0	12.6	38.2		
Redbreast sunfish	0.0	0.0	0.0	16.1	9.2	10.9	1.0	37.1	7	5.5
Blacknose dace	0.0	22.3	4.8	0.0	0.0	3.4	6.2	36.6		
Brook trout	29.7	0.0	0.0	0.8	0.0	0.0	0.3	30.7	9	4.3
Largemouth bass	0.9	0.0	12.1	0.2	0.9	6.0	5.4	25.5		
Pumpkinseed	2.1	0.0	5.7	0.3	2.7	3.3	11.0	25.1		
Yellow perch	1.4	0.0	17.4	0.0	0.0	4.3	0.0	23.1	12	3.2
Atlantic salmon	5.6	0.0	0.0	2.8	3.9	1.4	0.0	13.8		
Redfin pickerel	12.3	0.0	0.0	0.0	0.0	0.9	0.0	13.2	14	2.7
Golden shiner	0.9	0.0	11.5	0.0	0.0	0.0	0.0	12.4	15	2.6
Bluegill	0.8	0.0	2.0	4.9	0.0	0.4	3.8	12.0		
Spottail shiner	0.0	0.0	0.0	0.0	0.0	11.3	0.0	11.3		
Yellow bullhead	0.0	0.0	0.0	0.0	0.0	0.0	10.3	10.3		
Chain pickerel	0.6	0.7	3.7	1.1	0.2	0.1	3.3	9.8	19	2.0
Smallmouth bass	0.0	0.0	3.5	0.0	0.5	1.3	0.0	5.2		
Brown bullhead	0.6	0.0	0.0	0.8	1.4	0.1	0.0	3.0	21	1.8
Creek chubsucker	0.1	0.0	0.0	1.3	0.0	0.0	0.8	2.2	22	1.7
Bridle shiner	0.1	0.0	0.0	0.0	1.8	0.0	0.0	2.0		
Brown trout	0.0	0.7	0.0	0.7	0.0	0.3	0.0	1.6		
Banded sunfish	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	26	1.5
Black crappie	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2		

Table A11. Species percent composition for reference rivers used to develop the Nashua River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Willimantic River	Lamprey River	Pawcatuck River	Piscataquog River	Total	Rank	Expected Proportion
Common shiner	21.6	42.1	9.2	15.8	88.7	1	30.8
Fallfish	44.3	15.4	8.7	2.8	71.2	2	15.4
White sucker	14.6	3.7	9.3	2.8	30.4	3	10.3
Blacknose dace	7.9	0.0	0.0	22.5	30.3	4	7.7
Redbreast sunfish	2.1	18.3	6.8	2.7	29.9	5	6.2
Longnose dace	0.0	5.4	6.6	15.2	27.2	6	5.1
Smallmouth bass	2.9	1.6	0.0	12.0	16.5		
American eel	0.2	5.3	7.6	1.4	14.5	8	3.8
Tessellated darter	1.3	0.0	10.1	0.0	11.4	9	3.4
Brook trout	0.0	0.0	11.1	0.0	11.1	10	3.1
Yellow perch	2.6	0.6	4.8	0.0	8.1	11	2.8
Atlantic salmon	0.0	0.3	3.3	3.4	6.9		
Pumpkinseed	0.7	2.4	2.1	1.4	6.6	13	2.4
Largemouth bass	0.3	0.5	3.8	1.4	5.9		
Redfin pickerel	0.0	0.0	5.1	0.2	5.3	15	2.1
Bluegill	0.1	0.0	3.8	0.0	4.0		
Yellow bullhead	0.0	1.0	0.0	3.0	4.0		
Golden shiner	0.3	1.7	1.3	0.5	3.8	18	1.7
Longnose sucker	0.0	0.0	0.0	2.8	2.8		
Brown trout	0.6	0.1	1.7	0.4	2.8		
Chain pickerel	0.1	0.2	1.6	0.2	2.0	21	1.5
Bridle shiner	0.0	1.4	0.1	0.0	1.5	22	1.4
Rainbow trout	0.0	0.0	0.0	1.1	1.1		
Brown bullhead	0.0	0.0	0.8	0.2	1.0	24	1.3
Spottail shiner	0.2	0.0	0.0	0.5	0.7		
Creek chubsucker	0.0	0.2	0.5	0.0	0.6	26	1.2
Black crappie	0.0	0.0	0.5	0.0	0.5		

Table A12. Species percent composition for reference rivers used to develop the Neponset River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Wood River	Lamprey River	North River	SB Piscataquog River	Willimantic River	Salmon River	Total	Rank	Expected Proportion
Common shiner	32.3	42.1	9.0	20.6	21.6	13.9	139.5	1	39.5
Fallfish	4.1	15.4	28.6	3.0	44.3	0.3	95.7	2	19.8
Longnose dace	12.5	5.4	10.6	19.0	0.0	15.2	62.7		
Blacknose dace	0.0	0.0	0.0	33.4	7.9	11.1	52.4		
Atlantic salmon	2.8	0.3	3.1	9.4	0.0	21.7	37.2		
Redbreast sunfish	16.1	18.3	0.0	0.0	2.1	0.0	36.5	6	6.6
White sucker	2.1	3.7	5.3	0.9	14.6	5.1	31.8	7	5.6
American eel	5.9	5.3	2.0	0.0	0.2	10.1	23.5	8	4.9
Spottail shiner	0.0	0.0	17.9	0.5	0.2	0.0	18.6		
Smallmouth bass	0.0	1.6	0.0	3.6	2.9	9.5	17.6		
Tessellated darter	13.6	0.0	0.0	0.0	1.3	1.8	16.7	11	3.6
Bridle shiner	0.0	1.4	7.8	0.0	0.0	0.0	9.2	12	3.3
Brown trout	0.7	0.1	1.4	0.4	0.6	5.2	8.4		
Chain pickerel	1.1	0.2	5.6	0.2	0.1	0.2	7.4	14	2.8
Bluegill	4.9	0.0	0.0	0.0	0.1	0.9	6.1		
Brown bullhead	0.8	0.0	4.8	0.0	0.0	0.0	5.6	16	2.5
Pumpkinseed	0.3	2.4	1.4	0.5	0.7	0.2	5.6	17	2.3
Golden shiner	0.0	1.7	0.0	1.6	0.3	0.0	3.5	18	2.2
Yellow perch	0.0	0.6	0.0	0.0	2.6	0.0	3.2	19	2.1
Largemouth bass	0.2	0.5	0.8	0.7	0.3	0.6	3.0		
Yellow bullhead	0.0	1.0	0.0	1.8	0.0	0.0	2.8		
Brook trout	0.8	0.0	0.0	0.0	0.0	1.0	1.9	22	1.8
Rainbow trout	0.2	0.0	0.6	0.2	0.0	0.6	1.6		
Creek chubsucker	1.3	0.2	0.0	0.0	0.0	0.0	1.5	24	1.6
Black crappie	0.2	0.0	0.0	0.0	0.0	0.0	0.2		
Rock bass	0.0	0.0	0.0	0.0	0.1	0.0	0.1		
Redfin pickerel	0.0	0.1	0.0	0.0	0.0	0.0	0.1	27	1.5

Table A13. Species percent composition for reference rivers used to develop the Parker River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Queen River	Little River	Mount Hope River	Wood River	Isinglass River	Eightmile River	Nissitissit River	Total	Rank	Expected Proportion
Common shiner	0.0	14.9	4.6	32.3	36.8	18.6	5.4	112.6	1	38.3
Fallfish	15.4	16.2	20.7	4.1	18.1	3.1	26.7	104.3	2	19.2
Tessellated darter	12.8	0.0	0.5	13.6	0.0	17.3	9.7	54.0		
White sucker	8.6	12.2	13.2	2.1	0.5	5.0	0.8	42.3	4	9.6
American eel	7.6	4.7	0.4	5.9	10.8	8.9	2.3	40.5	5	7.7
Longnose dace	0.0	0.0	0.0	12.5	12.1	1.0	12.6	38.2		
Redbreast sunfish	0.0	0.0	0.0	16.1	9.2	10.9	1.0	37.1	7	5.5
Blacknose dace	0.0	22.3	4.8	0.0	0.0	3.4	6.2	36.6		
Brook trout	29.7	0.0	0.0	0.8	0.0	0.0	0.3	30.7	9	4.3
Largemouth bass	0.9	0.0	12.1	0.2	0.9	6.0	5.4	25.5		
Pumpkinseed	2.1	0.0	5.7	0.3	2.7	3.3	11.0	25.1		
Yellow perch	1.4	0.0	17.4	0.0	0.0	4.3	0.0	23.1	12	3.2
Atlantic salmon	5.6	0.0	0.0	2.8	3.9	1.4	0.0	13.8		
Redfin pickerel	12.3	0.0	0.0	0.0	0.0	0.9	0.0	13.2	14	2.7
Golden shiner	0.9	0.0	11.5	0.0	0.0	0.0	0.0	12.4	15	2.6
Bluegill	0.8	0.0	2.0	4.9	0.0	0.4	3.8	12.0		
Spottail shiner	0.0	0.0	0.0	0.0	0.0	11.3	0.0	11.3		
Yellow bullhead	0.0	0.0	0.0	0.0	0.0	0.0	10.3	10.3		
Chain pickerel	0.6	0.7	3.7	1.1	0.2	0.1	3.3	9.8	19	2.0
Smallmouth bass	0.0	0.0	3.5	0.0	0.5	1.3	0.0	5.2		
Brown bullhead	0.6	0.0	0.0	0.8	1.4	0.1	0.0	3.0	21	1.8
Creek chubsucker	0.1	0.0	0.0	1.3	0.0	0.0	0.8	2.2	22	1.7
Bridle shiner	0.1	0.0	0.0	0.0	1.8	0.0	0.0	2.0		
Brown trout	0.0	0.7	0.0	0.7	0.0	0.3	0.0	1.6		
Banded sunfish	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	26	1.5
Black crappie	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2		

Table A14. Species percent composition for reference rivers used to develop the Shawsheen River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Wood River	Nissitissit River	Eightmile River	Isinglass River	SB Piscataquog River	Little River	Total	Rank	Expected Proportions
Common shiner	32.3	5.4	18.6	36.8	20.6	14.9	128.6	1	37.6
Fallfish	4.1	26.7	3.1	18.1	3.0	16.2	71.2	2	18.8
Blacknose dace	0.0	6.2	3.4	0.0	33.4	22.3	65.3		
Longnose dace	12.5	12.6	1.0	12.1	19.0	0.0	57.2		
Tessellated darter	13.6	9.7	17.3	0.0	0.0	0.0	40.7	5	7.5
Redbreast sunfish	16.1	1.0	10.9	9.2	0.0	0.0	37.1	6	6.3
American eel	5.9	2.3	8.9	10.8	0.0	4.7	32.6	7	5.4
White sucker	2.1	0.8	5.0	0.5	0.9	12.2	21.4	8	4.7
Pumpkinseed	0.3	11.0	3.3	2.7	0.5	0.0	17.9	9	4.2
Atlantic salmon	2.8	0.0	1.4	3.9	9.4	0.0	17.5		
Largemouth bass	0.2	5.4	6.0	0.9	0.7	0.0	13.2		
Yellow bullhead	0.0	10.3	0.0	0.0	1.8	0.0	12.1		
Spottail shiner	0.0	0.0	11.3	0.0	0.5	0.0	11.8		
Bluegill	4.9	3.8	0.4	0.0	0.0	0.0	9.2		
Chain pickerel	1.1	3.3	0.1	0.2	0.2	0.7	5.7	15	2.5
Smallmouth bass	0.0	0.0	1.3	0.5	3.6	0.0	5.4		
Yellow perch	0.0	0.0	4.3	0.0	0.0	0.0	4.3	17	2.2
Brown bullhead	0.8	0.0	0.1	1.4	0.0	0.0	2.3	18	2.1
Creek chubsucker	1.3	0.8	0.0	0.0	0.0	0.0	2.1	19	2.0
Brown trout	0.7	0.0	0.3	0.0	0.4	0.7	2.0		
Bridle shiner	0.0	0.0	0.0	1.8	0.0	0.0	1.8	21	1.8
Golden shiner	0.0	0.0	0.0	0.0	1.6	0.0	1.6	22	1.7
Brook trout	0.8	0.3	0.0	0.0	0.0	0.0	1.1	23	1.6
Redfin pickerel	0.0	0.0	0.9	0.0	0.0	0.0	0.9	24	1.6
Rock bass	0.0	0.5	0.0	0.0	0.0	0.0	0.5		
Rainbow trout	0.2	0.0	0.0	0.0	0.2	0.0	0.4		
Black crappie	0.2	0.0	0.0	0.0	0.0	0.0	0.2		

Table A15. Species percent composition for reference rivers used to develop the Taunton River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. Taunton River model developed in conjunction with Joe Smith from the University of Massachusetts. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Pawcatuck River	SB Piscataquog River	Salmon River	Yantic River	Willimantic River	Tenmile River	Total	Rank	Expected Proportion
Common shiner	9.2	19.3	30.9	5.9	20.8	16.4	102.6	1	34.0
Fallfish	8.7	2.8	5.6	12.8	34.3	20.8	85.0	2	17.0
White sucker	9.3	0.8	2.6	30.0	16.1	16.7	75.5	3	11.3
Blacknose dace	0.0	31.3	0.0	4.5	0.2	17.3	53.3		
Longnose dace	6.6	17.8	19.3	0.0	0.0	6.7	50.4	5	6.8
Smallmouth bass	0.0	3.3	2.4	6.3	9.9	10.3	32.2		
Atlantic Salmon	3.3	8.8	17.9	0.0	0.0	0.0	30.1		
Tessellated darter	10.1	0.0	0.3	4.9	2.5	5.3	23.1	8	4.3
Redbreast sunfish	6.8	0.0	0.0	11.1	4.4	0.2	22.5	9	3.8
American eel	7.6	0.0	10.1	0.8	0.1	0.0	18.6	10	3.4
Pumpkinseed	2.1	0.5	0.0	11.3	2.0	0.6	16.5	11	3.1
Bluegill	3.8	0.0	0.0	7.8	1.8	1.0	14.4		
Brook Trout	11.1	0.0	0.0	0.1	0.0	0.0	11.2	13	2.6
Yellow perch	4.8	0.0	0.0	0.3	3.7	0.0	8.8	14	2.4
Brown trout	1.7	0.3	1.5	1.8	1.6	0.0	6.9		
Largemouth bass	3.8	0.7	0.0	1.3	0.9	0.0	6.6		
Longnose sucker	0.0	6.3	0.0	0.0	0.0	0.0	6.3		
Redfin pickerel	5.1	0.0	0.0	0.0	0.0	0.0	5.1	18	1.9
Cutlips Minnow	0.0	0.0	0.0	0.0	0.0	3.3	3.3		
Golden shiner	1.3	1.5	0.2	0.0	0.0	0.3	3.3	20	1.7
Chain pickerel	1.6	0.2	0.0	0.3	0.6	0.0	2.6	21	1.6
Brown bullhead	0.8	0.0	0.0	0.8	0.1	0.0	1.7	22	1.5
Yellow bullhead	0.0	1.7	0.0	0.0	0.0	0.0	1.7		
Alewife	0.7	0.0	0.0	0.0	0.0	0.0	0.7		
Creek chub	0.0	0.0	0.0	0.0	0.0	0.5	0.5		
Spottail shiner	0.0	0.5	0.0	0.0	0.0	0.0	0.5		
Black crappie	0.5	0.0	0.0	0.0	0.0	0.0	0.5		

Table A15. Taunton watershed continued.

Species	Pawcatuck River	SB Piscataquog River	Salmon River	Yantic River	Willimantic River	Tenmile River	Total	Rank	Expected Proportion
Rainbow trout	0.0	0.2	0.2	0.1	0.0	0.0	0.4		
Banded killifish	0.4	0.0	0.0	0.0	0.0	0.0	0.4	30	1.1
Sea lamprey	0.0	0.0	0.3	0.0	0.0	0.0	0.3		
Bluntnose minnow	0.0	0.0	0.0	0.0	0.0	0.3	0.3		
Banded sunfish	0.1	0.0	0.0	0.0	0.0	0.0	0.1	33	1.0
Bridle shiner	0.1	0.0	0.0	0.0	0.0	0.0	0.1	34	1.0

Table A16. Species percent composition for reference rivers used to develop the Westfield River target fish community model. Species are ordered by mean rank. Non-native, stocked, and out-of-range species were deleted from the ranking and calculation of expected proportion in the target fish model. The ranks were converted to expected proportions (as a percent) using a rank-weighting technique as outlined by Bain and Meixler (2008).

Species	Third Branch White River	Tenmile River	Ashuelot River	Ammonoosuc River	Piscataquog River	Cold River	NB Sugar River	North River	Total	Rank	Expected Proportion
Blacknose dace	25.0	14.9	19.8	24.1	22.5	53.8	6.9	38.4	205.4	1	32.4
Longnose dace	19.9	9.3	12.7	38.5	15.2	16.9	44.6	29.1	186.2	2	16.2
Common shiner	2.6	13.8	22.3	1.4	15.8	6.5	20.8	1.1	84.3	3	10.8
Atlantic salmon	0.0	0.0	2.2	24.1	3.4	6.5	0.0	15.1	51.3		
Slimy sculpin	33.1	0.0	0.0	6.0	0.0	2.7	0.0	8.9	50.6	5	6.5
Fallfish	0.0	18.7	26.8	0.0	2.8	0.0	1.0	0.3	49.5	6	5.4
White sucker	0.3	15.8	7.9	0.5	2.8	6.2	10.9	1.9	46.1	7	4.6
Smallmouth bass	0.0	12.2	1.3	0.0	12.0	0.4	0.0	0.0	25.9		
Longnose sucker	5.6	0.0	0.0	4.8	2.8	0.6	4.0	2.9	20.8	9	3.6
Tessellated darter	0.1	7.3	3.8	0.2	0.0	0.6	0.0	0.3	12.3	10	3.2
Creek chub	1.4	0.6	0.2	0.0	0.0	2.8	5.0	0.8	10.8	11	2.9
Brown trout	3.3	0.1	0.3	0.0	0.4	0.0	5.0	0.3	9.4		
Rainbow trout	7.5	0.1	0.0	0.0	0.2	0.2	0.0	0.2	8.1		
Brook trout	1.2	0.1	0.0	0.6	0.0	2.4	0.0	0.6	4.9	14	2.3
Cutlips minnow	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	4.6		
Yellow bullhead	0.0	0.0	1.0	0.0	3.0	0.0	0.0	0.0	4.0		
Redbreast sunfish	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	2.7	17	1.9
Pumpkinseed	0.0	0.6	0.3	0.0	1.4	0.1	0.0	0.0	2.4	18	1.8
American eel	0.0	0.0	0.2	0.0	1.4	0.0	0.0	0.0	1.6	19	1.7
Largemouth bass	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.4		
Bluegill	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3		
Spottail shiner	0.0	0.0	0.0	0.0	0.5	0.3	0.0	0.0	0.8	22	1.5
Golden shiner	0.0	0.3	0.0	0.0	0.5	0.0	0.0	0.0	0.8	22	1.5
Brown bullhead	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.2	0.6	23	1.4
Bluntnose minnow	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4		
Rock bass	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.4		
Chain pickerel	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.3	26	1.2
Yellow perch	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	26	1.2

Appendix B.

Sample information from current MA Division of Fisheries and Wildlife databases used to develop the description of the current fish communities.

Table B1. Blackstone River sample site information

River	SARIS	Sample ID	Date	Sampling Method
Blackstone	5131000	298	8/22/2001	Barge Shocking
		299	8/22/2001	Barge Shocking
		321	8/28/2001	Barge Shocking
		324	8/28/2001	Barge Shocking
		441	9/20/2001	Barge Shocking
		446	8/27/2001	Barge Shocking
		466	9/20/2001	Backpack Shocking

Table B2. Fish species counts for Blackstone River sample sites

	Sample ID								Percent
Species	**298**	**299**	**321**	**324**	**441**	**446**	**466**	**Total**	**Composition**
Bluegill		28		7		15		50	5.3
Brown bullhead		1						1	0.1
Blacknose dace	1							1	0.1
Brown trout		1						1	0.1
Carp			14					14	1.5
Chain pickerel			2					2	0.2
Common shiner	5	5						10	1.1
Brook trout							1	1	0.1
Fallfish		12						12	1.3
Golden shiner			6	10		2		18	1.9
Largemouth bass	5	1	2	7	27	34	7	83	9.0
Longnose dace		3						3	0.3
Pumpkinseed	1	1	7	2	2	7		20	2.1
Smallmouth bass		5						5	0.5
Tessellated darter	35	3						38	4.0
White sucker	27	13	59	81	1	180	110	471	49.8
Yellow bullhead	3	2		3	11	3		22	2.3
Yellow perch	1			27	29	105	14	176	18.9
Total	78	75	90	137	70	346	132	**928**	

Table B3. Concord River sample site information

River	SARIS	Sample ID	Date	Sampling Method
Assabet	8246775	91	8/31/1999	Barge Shocking
		308	6/7/2001	Barge Shocking
		433	8/24/2001	Barge Shocking
		500	8/24/2001	Barge Shocking
		501	8/24/2001	Barge Shocking
Sudbury	8247650	309	8/2/2001	Backpack Shocking
		310	8/2/2001	Backpack Shocking
		399	7/31/2001	Barge Shocking

Table B4. Fish species counts for Concord River sample sites

Species	Sample ID 91	308	309	310	399	433	500	501	Total	Percent Composition
American eel	17	9					12	5	43	4.7
Banded sunfish	1								1	0.1
Blacknose dace	2								2	0.2
Bluegill		9	3	1	2	3	9		27	3.0
Brown bullhead					3	4	1	1	9	1.0
Brown trout	2	8							10	1.1
Chain pickerel			3	2		7	2	1	15	1.6
Creek chubsucker	9								9	1.0
Fallfish	7		14	53	3	4	5		86	9.4
Golden shiner	4				1	53	4		62	6.8
Largemouth bass	54		12	10	2	2	7		87	9.5
Pumpkinseed	5	3	1	5	1	14	34	1	64	7.0
Rainbow trout		3							3	0.3
Redbreast sunfish	11		16				16		43	4.7
Redfin pickerel	14	6	1		114	30	3	1	169	18.5
Rock bass				10					10	1.1
White sucker	66	12	10	3		97	5	14	207	22.6
Yellow bullhead	17		4	8	1	2	19	7	58	6.3
Yellow perch				9			1		10	1.1
Total	209	50	64	101	127	216	118	30	**915**	

Table B5. Farmington River sample site information

River	SARIS	Sample ID	Date	Sampling Method
Farmington	3106850	557	8/13/2001	Backpack Shocking
		558	8/13/2001	Backpack Shocking
		1113	7/29/2005	Backpack Shocking
		1232	7/27/2005	Backpack Shocking

Table B6. Fish species counts for Farmington River sample sites

	Sample ID					Percent
Species	**557**	**558**	**1113**	**1232**	**Total**	**Composition**
Blacknose dace	7	17	5	16	45	10.0
Cutlips minnow	6	22	19	67	114	25.3
Creek chub	14				14	3.1
Common shiner	39	58		30	127	28.2
Fallfish	18	6	3		27	6.0
Longnose dace	9	13	8	13	43	9.6
Rock bass			1		1	0.2
Smallmouth bass	11	14	12	25	62	13.8
White sucker	9	2	4	2	17	3.8
Total	113	132	52	153	**450**	

Table B7. Hoosic River sample site information

River	SARIS	Sample ID	Date	Sampling Method
Hoosic	1100500	795	7/23/2002	Barge Shocking
		798	8/14/2002	Barge Shocking
		904	7/17/2003	Barge Shocking
		905	7/17/2003	Barge Shocking
		906	7/17/2003	Barge Shocking
		907	7/18/2003	Backpack Shocking
		908	7/18/2003	Barge Shocking
		1883	11/5/1998	Backpack Shocking

Table B8. Fish species counts for Hoosic River sample sites

	Sample ID									Percent
Species	**795**	**798**	**904**	**905**	**906**	**907**	**908**	**1883**	**Total**	**Composition**
Bluegill	1		5		3			8	17	0.8
Blacknose dace	92	91	170	198	44	90	271	16	972	46.5
Bluntnose minnow		9			3				12	0.6
Brown trout	11	1	19	15	3	16	29	10	104	5.1
Creek chub	49	60	12	4	7			1	133	6.4
Common shiner			13	2	2		1		18	0.9
Golden shiner	1							5	6	0.3
Longnose dace	88	36	108	45	13	49	57	4	400	19.1
Longnose sucker	29	1		5			6		41	2.0
Pumpkinseed	24	5	10		1		1		41	2.0
Slimy sculpin	14			3	1			2	20	1.0
White sucker	32	92	15	25	9	25	113	13	324	15.5
Total	341	295	352	297	86	180	478	59	**2088**	

Note – Brown trout >160 mm were removed from the calculations. These larger fish may be hatchery stocked individuals

Table B9. Ipswich River sample site information

River	SARIS	Sample ID	Date	Sampling Method
Ipswich	9253500	1	8/19/1998	DEP Backpack Shocking
		2	8/19/1998	Backpack Shocking
		3	8/20/1998	Backpack Shocking
		4	8/20/1998	Backpack Shocking
		5	8/21/1998	Backpack Shocking
		6	8/27/1998	Backpack Shocking
		7	8/27/1998	Backpack Shocking
		8	8/28/1998	Backpack Shocking
		9	8/28/1998	Backpack Shocking
		10	8/31/1998	Backpack Shocking
		11	8/31/1998	Backpack Shocking
		12	9/1/1998	Backpack Shocking
		13	9/1/1998	Backpack Shocking
		14	9/3/1998	Backpack Shocking
		15	9/3/1998	Backpack Shocking
		16	9/4/1998	Backpack Shocking
		17	9/4/1998	Backpack Shocking
		18	9/15/1998	Backpack Shocking
		19	9/15/1998	Backpack Shocking
		20	9/16/1998	Backpack Shocking
		21	9/16/1998	Backpack Shocking
		22	9/17/1998	Backpack Shocking
		24	9/29/1998	Backpack Shocking
		25	9/29/1998	Backpack Shocking
		42	7/20/1999	Backpack Shocking

Table B10. Fish species counts for samples on the Ipswich River

	Sample ID													
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
American eel	2	3	3	2	24	15	9	54	41	42		35	56	11
Bluegill					6	6	6	22	41	42		3	1	5
Brown bullhead	1							6		2			1	
Banded sunfish								2			2			
Brown trout														
Creek chubsucker	1	2			1			5	4	2		1		8
Chain pickerel	2	2	5	1	5	1	4	1	3	18			6	2
Fallfish														
Golden shiner	1							11		1				
Green sunfish					2			1					7	
Largemouth bass			1		2		1	2				3		
Northern pike														
Pumpkinseed	15	2	7	3	35	19	5	76	7	2	1	1	2	29
Redbreast sunfish					10			7	11	2		10	12	
Redfin pickerel	131	22	77	28	31	12	40	22	58	156	186	157	79	52
Rainbow trout														
Swamp darter	2	4	2	1		1	6		2	1		1	1	3
Sea lamprey					3				2					
White sucker	5		18	4	4	10		9						1
Yellow bullhead					2			19	6	2	1	1	2	
Yellow perch	2		1	1	7		5	13		2		2	1	9
Total	162	35	114	40	132	64	76	250	134	231	190	214	168	120

Table B10. Fish species counts for samples on the Ipswich River (continued)

	Sample ID												
Species	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**24**	**25**	**42**	**Total**	**Percent Composition**
American eel	78	26	87	100	58	25	109	43	75	105	17	1019	23.8
Bluegill	1	2	9		25	2		6	3	3	41	142	3.3
Brown bullhead						1				1	1	13	0.3
Banded sunfish	2		1	2			1	1	1		1	13	0.3
Brown trout				4			2					6	0.1
Creek chubsucker	2			4			2	2		11	1	46	1.1
Chain pickerel	13	11	18		6		9	23	7	9	9	155	3.6
Fallfish				3			2		4		2	11	0.3
Golden shiner											7	20	0.5
Green sunfish			2							1	1	14	0.3
Largemouth bass			2	1					1		13	26	0.6
Northern pike												0	0.0
Pumpkinseed	1	9	14	24	58	14		5	24	32	21	406	9.5
Redbreast sunfish	16	1	3	51	9	16	23	5	2	58		236	5.5
Redfin pickerel	163	374	72	13	19	2	10	138	46	27	11	1926	44.9
Rainbow trout							1					1	0.0
Swamp darter			1	1	1						2	29	0.7
Sea lamprey	4	3	1	1	1	1	8					24	0.6
White sucker				4			2		1		5	63	1.5
Yellow bullhead	1		3	15	4	2		1	1	4	10	74	1.7
Yellow perch	11		2	3	1				2	2	2	66	1.5
Total	292	426	215	226	182	63	169	224	167	253	144	4290	

Table B11. Nashua River sample site information

River	SARIS	Sample ID	Date	Sampling Method
Nashua	8143500	92	8/31/1999	Barge Shocking
		666	9/12/2002	Barge Shocking
		667	9/12/2002	Barge Shocking
North Branch Nashua	8144650	93	9/2/1999	Barge Shocking
		94	9/2/1999	Barge Shocking
		588	7/30/2002	Barge Shocking
		589	7/31/2002	Barge Shocking
		594	7/31/2002	Barge Shocking
		657	8/9/2002	Barge Shocking
		663	8/15/2002	Backpack Shocking
		664	8/15/2002	Backpack Shocking

Table B12. Fish species counts for samples on the Nashua River

	Sample ID												Percent Composition
Species	**92**	**93**	**94**	**588**	**589**	**594**	**657**	**663**	**664**	**666**	**667**	**Total**	
Banded sunfish	1											1	1.3
Blacknose dace		6		4	62	79	49	10	289	13		512	18.2
Bluegill	25		9				1	2				37	0.0
Brown trout								1				1	0.0
Chain pickerel	1		2			1					7	11	0.4
Common shiner	65	53			1	6	21	32	2			180	6.4
Fallfish	15	39	4		5	3		193			89	348	12.4
Golden shiner		1		1				1		4		7	0.2
Largemouth bass	7	10	5			1	4	70				97	3.4
Longnose dace		32		5	20	27	55	4		8		151	5.4
Pumpkinseed	55		3									58	2.1
Spottail shiner	91	93		2	2					183		371	13.2
Tesselated darter	45		9							3		57	2.0
White sucker	135	179	65	2	90	93	91	6	12	22	27	722	25.7
Yellow bullhead	5	16	23	3	2	4	20	4	18	3	2	100	3.6
Yellow perch	45	39	7	1	18					2	47	159	5.7
Total	490	468	127	18	200	214	241	323	321	238	172	**2812**	100.0

Table B13. Shawsheen River sample site information.

River	SARIS	Sample ID	Date	Sampling Method
Shawsheen	8349000	27	9/9/1998	Backpack Shocking
		28	9/9/1998	Backpack Shocking
		29	9/10/1998	Backpack Shocking
		30	9/10/1998	Backpack Shocking
		31	9/11/1998	Backpack Shocking
		33	9/30/1998	Backpack Shocking
		34	10/1/1998	Backpack Shocking
		153	7/10/2000	Backpack Shocking
		244	9/11/1998	Backpack Shocking
		1195	7/26/2005	Backpack Shocking
		1196	7/21/2005	Backpack Shocking
		1237	7/26/2005	Backpack Shocking

Table B14. Fish species counts for Shawsheen River sample sites.

	Sample ID													Percent
Species	**27**	**28**	**29**	**30**	**31**	**33**	**34**	**153**	**244**	**1195**	**1196**	**1237**	**Total**	**Composition**
American eel	61	77	61	101	46	36	134	26	43	7	21	10	623	45.6
Atlantic salmon										5			5	0.4
Bluegill	8	25	24	18		3	16	2	1		25	5	127	9.3
Brown bullhead								1			8	29	38	2.8
Bridle shiner						1							1	0.1
Banded sunfish								2	1		2		5	0.4
Brown trout						1	1	1					3	0.2
Creek chubsucker						7			1				8	0.6
Chain pickerel			4	1		4			3		1	1	14	1.0
Fallfish		5		1	1		25			1	32	6	71	5.2
Golden shiner												9	9	0.7
Largemouth bass	2		1		7	4	7	2	2				25	1.8
Pumpkinseed		5		1	3	12	20	3	3	1	2	8	58	4.2
Redbreast sunfish	20		18	23	15	6	6		31	12	19	2	152	11.1
Redfin pickerel		4		4	16	75	4	6	29		4	3	145	10.6
Rainbow trout						1			1				2	0.1
Swamp darter						1							1	0.1
Sea lamprey	5	10											15	1.1
Tessellated darter	4	29								2		2	37	2.7
White sucker		7		1				4	1	4		1	18	1.3
Yellow bullhead	1				1						4		6	0.4
Yellow perch												2	2	0.1
Total	101	162	108	150	89	151	213	47	116	32	118	78	**1365**	

Table B15. Westfield River sample site information.

River	SARIS	Sample ID	Date	Sampling Method
Westfield	3208250	335	8/8/2001	Barge Shocking
		356	8/8/2001	Barge Shocking
		547	8/7/2001	Backpack Shocking
		548	9/13/2001	Backpack Shocking
		900	7/10/2003	Barge Shocking
		1070	8/24/2004	Backpack Shocking
		1248	8/10/2005	Backpack Shocking
West Branch Westfield	3210075	378	8/9/2001	Backpack Shocking
		1249	8/9/2005	Backpack Shocking
East Branch Westfield	3211030	336	8/7/2001	Backpack Shocking

Table B16. Fish species counts for Westfield River sample sites

	Sample ID											Percent Composition
Species	**335**	**336**	**356**	**378**	**547**	**548**	**900**	**1070**	**1248**	**1249**	**Total**	
American eel	48						41				89	3.0
Blacknose dace		136		37	217	22		103	319	250	1084	36.2
Creek chub	6	9						15	3		33	1.1
Common shiner	5	7	100	10	87	49		10	42	71	381	12.7
Brook trout								4	2		6	0.2
Fallfish	12								13		25	0.8
Golden shiner								1	10		11	0.4
Lake chub					8	6		2			16	0.5
Longnose dace		123	22	115	89	40		46	93	204	732	24.5
Longnose sucker								1			1	0.0
Pumpkinseed	3		1								4	0.1
Rock bass	11						31				42	1.4
Rainbow trout						2					2	0.1
Slimy sculpin		94		1	2			43	83		223	7.5
Smallmouth bass	82	47		1			32				162	5.4
Tesselated darter	6		3	1		1	7			10	28	0.9
White sucker	4	4	1		12	11		6	101	11	150	5.0
Yellow bullhead							2				2	0.1
Total	177	420	127	165	415	131	113	231	666	546	**2991**	