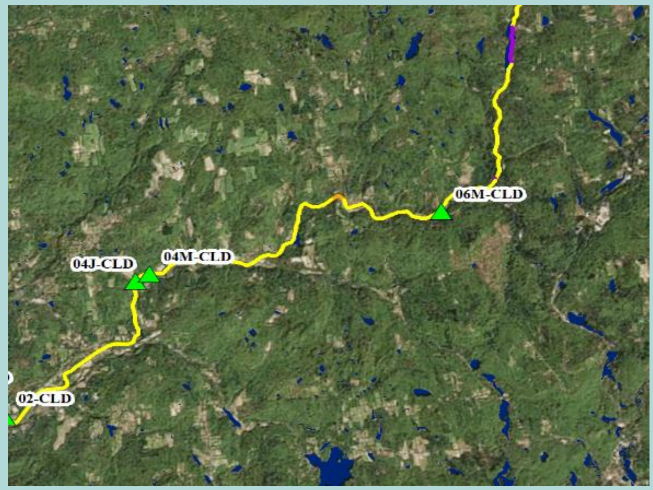
NEW HAMPSHIRE

STATEWIDE TARGET FISH COMMUNITY ASSESSMENT

PISCATAQUOG RIVER AND BRANCHES - FINAL REPORT



Prepared for:

New Hampshire Department of Environmental Services

Prepared by:

Gomez and Sullivan Engineers

July, 2018

Table of Contents

List of Tables

List of Figures

I. Introduction

Target Fish Community models have been developed for a number of instream flow related projects in the Northeast. The TFC development process, as defined by Bain and Meixler (2005), uses fish community data from the best available reference rivers that would characterize a feasible and currently relevant fish community. As such, the TFC model does not represent a historically "natural" community, but instead represents a community that would be expected to exist in the present time given relatively low direct anthropogenic impact on instream habitat. This approach has been useful for evaluating the biological integrity of streams and rivers by comparing the existing fish community with that of the predicted TFC. NHDES plans to use the TFC models in support of development of protected instream flows on Designated Rivers, and also as guidelines for evaluating the biological integrity.

Across the State, there is the potential for wide variability in hydromorphologic and geologic features that would have shaped the natural fish community. Additionally, sections of the Designated Rivers may be geomorphologically different from other sections, and may have naturally supported different fish communities. Therefore, the Designated Rivers must first be delineated prior to TFC development. The goal of the delineation was to segment Designated Rivers with the fewest possible breaks based on fish community shifts on a watershed scale that are relevant to NHDES management goals. After delineation, suitable fish community data from reference rivers that are geomorphologically similar to each delineated segment were selected for potential use in the TFC model using an iterative GIS and data screening process. Once reference river data were thoroughly screened, TFC models were developed using the Bain and Meixler (2005) methodology.

II. Designated River Delineation

Delineation Methods

Delineation of the Designated Rivers into segments was based on a combination of datasets, as described in more detail below, including current fish community data, predicted fish community types, and a variety of GIS layers that would allow for visualization of changes in stream geomorphology and overall character. The exact location of river segment delineation was based on a combination of factors that would lead to shifts in fish communities that may pertain to management of instream flow and habitat.

Fish Community Data Assessment

Fisheries sampling data, as provided from NHDES for the Designated River watersheds (including many sites that were not directly on Designated Rivers), were determined to be suitable for further comparative analysis if they were collected by electrofishing in non-impounded, riverine reaches. These sites were used to develop a site-species matrix for Nonmetric Multidimensional Scaling (NMDS) ordination. NMDS ordination provides a visual display of sites, with the locations of the sites in ordination space based on the community of species present; this is useful for determining similarities and differences of fish communities among sites.

Species captured at fewer than five locations within the entire dataset were removed from this matrix (Table - 1). This was found to be necessary for the NMDS ordination to reach a solution. In general, first-pass count data were used for further analysis for sites with greater than 50 individual fish captured, and more than six species present. However, all sites from within the Designated River segments were kept in the dataset, even if they did not meet the individual or species criteria. These data were used with caution and were only used to visualize differences in the ordination results. The final matrix included 157 site locations and 35 species.

The matrix was converted to catch per unit of effort (CPUE) at each location prior to NMDS development using ratio estimation techniques from Hansen et al. (2007), which is represented as:

$$CPUE = \hat{R} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i}$$

Where the CPUE ratio estimator ($\hat{R}$) equals the sum of the catch (y_i) at all sites sampled, divided by the sum of the effort (seconds of electrofishing) at all sites sampled (x_i).

The NMDS ordination was developed using the Statistical Package R and the metaMDS function. The metaMDS function was set to automatically transform the data matrix, which optimizes data standardization based on the data structure. The ordination was based on Bray-Curtis dissimilarity, which calculates how different community data from various sites are based on proportional abundance, and is considered to be the most reliable distance measure for NMDS ordination of community structure (Clarke 1993).

Table - 1: Fish species removed from the NMDS delineation analysis.

Scientific Name	Common Name	Locations in Dataset
Chrosomus neogaeus	Finescale Dace	1
Clinostomus funduloides	Rosyside Dace	1
Coregonus clupeaformis	Lake Whitefish	1
Fundulus heteroclitus	Mummichog	1
Notropis heterolepis	Blacknose Shiner	1
Pimephales notatus	Bluntnose Minnow	1
Pimephales promelas	Fathead Minnow	1
Pomoxis annularis	White Crappie	1
Prosopium cylindraceum	Round Whitefish	1
Alosa aestivalis	Blueback Herring	2
Alosa pseudoharengus	Alewife	2
Alosa sapidissima	American Shad	2
Fundulus diaphanus	Banded Killifish	2
Morone americana	White Perch	2
Notropis volucellus	Mimic Shiner	2
Esox lucius	Northern Pike	3
Petromyzon marinus	Sea Lamprey	3
Sander vitreus	Walleye	3
Pomoxis nigromaculatus	Black Crappie	4

Note: Only includes data from NH Designated River Watersheds

GIS Analysis

In addition to the fish community analysis, several physical and biological factors were evaluated to determine if river delineation was appropriate. Break locations were identified at areas where significant changes in stream character, based on available data, occur. Datasets utilized for these analyses are shown in Table - 2. In general, the greatest weight was given to data that are more easily quantifiable, such as Stream Order, Gradient, and Watershed Size, with the other types of data used secondarily to provide any additional support for break locations.

Table - 2: GIS layers used in the delineation analysis.

GIS Layer	Source	Uses
Designated Rivers	NHDES	Stream Order
Northeast Aquatic Habitat Classification	TNC	Gradient Size Class (Watershed Size) Water Chemistry
Level III Ecoregion	USEPA	Ecoregion
NH Fish Community Types	NHDES	Predicted Fish Community Type (cold, warm, transitional)
Soils	GRANIT	General Soil/Geology
Lithology	USGS/GRANIT	General Bedrock Geology
Orthoimagery	ESRI[1]	Visual Assessment of Character; Map Background

The Designated River layer was used to determine the extent of the Designated River, and to determine the locations at which the rivers increased in stream order. Changes in gradient and watershed size class were evaluated using the Northeast Aquatic Habitat Classification layer (Table - 3). This layer was developed by The Nature Conservancy (TNC) via the Northeast Aquatic Habitat Classification System Project (Olivero and Anderson 2008).

Table - 3: Gradient and watershed size class categories from the Northeast Aquatic Habitat Classification System layer.

Gradient Class	Gradient (%)		Size Class	Watershed Size (mi^2)
Very Low	< 0.02		Headwater	0 < 3.861
Low	>= 0.02 < 0.1		Creek	>= 3.861 < 38.61
Low-Moderate	>= 0.1 < 0.5		Small River	>= 38.61 < 200
Moderate-High	>= 0.5 < 2		Medium Tributary River	>= 200 < 1,000
High	>= 2 < 5		Medium Mainstem River	>= 1,000 < 3,861
Very High	> 5		Large River	>= 3,861 < 9,653

Though the NEAHC dataset also includes a temperature classification, for delineation, temperature criteria were evaluated based on the modeled NH Fish Community types, which predicts general fish

[1] The source for the imagery used is cited as: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community. The source for topographic background is cited as: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.

community types based on drainage basin, latitude, elevation, and upstream drainage area. As such, TFC Breaks based on predicted coldwater, transitional, and warmwater communities were examined.

Changes in soils and bedrock geology can result in changes in general substrate types and water quality conditions along the stream gradient. The soils layer was examined spatially, using the generic groups provided in the data layer as described in Table - 4.

Table - 4: Soil types used in the delineation analysis.

Group	Definition
IA	Deeper, loamy textured, moderately well and well-drained soils
IB	Sandy or loamy over sandy textures; slightly less fertile than Group IA
IC	Outwash sands and gravels, somewhat excessively to excessively drained and moderately well drained
IIA	Similar to Groups IA and IB, except physically limited due to steep slopes, bedrock outcrops, etc.
IIB	Poorly drained soils, seasonal high water table, generally within 12 feet of surface

Similarly, patterns in bedrock geology were examined. Underlying bedrock can affect valley and stream shape. Bedrock type also affects the buffering capacity and pH of the stream, which can impact fish communities on a watershed scale. Weathering of different types of bedrock yields different shapes and sizes of material, which in turn could affect substrate and sediment types in the stream, affecting fish on a microhabitat scale. Because the effects on stream fish communities can occur over multiple spatial scales, this analysis focuses on whether general changes in bedrock geology occur along the stream length rather than to characterize specific changes that may occur within a fish community based on bedrock type. Additionally, the water chemistry layer classification of the NEAHC dataset was overlain over bedrock types. Classifications provided by the layer include: 1) Highly Buffered, Calcareous; 2) Moderately Buffered, Neutral; 3) Low Buffered, Acidic; and 4) Assumed Moderately Buffered for Size 3+ Rivers.

Ecoregions have been developed by the U.S. Environmental Protection Agency (EPA) to denote areas of similarity in biotic, abiotic, terrestrial and aquatic ecosystem components, with humans considered as part of the biota. Abiotic and biotic factors included in ecoregion development were geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. Only two Level III ecoregions are present in New Hampshire; the Northeastern Highlands (Ecoregion 58) and the Northeastern Coastal Zone (Ecoregion 59). Level III Ecoregions were used in the analysis as a broad descriptor of where a variety of changes may occur in the landscape, and therefore potentially along the stream length.

The Northeastern Highlands, according to the USEPA (2013) description is:

"The Northeastern Highlands cover most of the northern and mountainous parts of New England as well as the Adirondacks and higher Catskills in New York. It is a relatively sparsely populated region characterized by hills and mountains, a mostly forested land cover, nutrient-poor soils, and numerous high-gradient streams and glacial lakes. Forest vegetation is somewhat transitional between the boreal regions to the north in Canada and the broadleaf deciduous forests to the south. Typical forest types include northern hardwoods (maple-beech-birch), northern hardwoods/spruce, and northeastern spruce-fir forests. Recreation, tourism, and forestry are primary land uses. Farm-to-forest conversion began in the 19th century and continues today. In spite of this trend, alluvial valleys, glacial lake basins, and areas of limestone-derived soils are still farmed for dairy products, forage crops, apples, and potatoes. Many of the lakes and streams in this region have been acidified by sulfur depositions originating in industrialized areas upwind from the ecoregion to the west."

The Northeastern Coastal Zone, according to the USEPA (2013) description is:

"Similar to the Northeastern Highlands (58), the Northeastern Coastal Zone contains relatively nutrient poor soils and concentrations of continental glacial lakes, some of which are sensitive to acidification; however, this ecoregion contains considerably less surface irregularity and much greater concentrations of human population. Landforms in the region include irregular plains, and plains with high hills. Appalachian oak forests and northeastern oak-pine forests are the natural vegetation types. Although attempts were made to farm much of the Northeastern Coastal Zone after the region was settled by Europeans, land use now mainly consists of forests, woodlands, and urban and suburban development, with only some minor areas of pasture and cropland."

Delineation Results

The Piscataquog River watershed consists of three primary branches (South, Middle, North) and the main-stem, for a total of nearly 64 miles of river (South Branch = 20.75 miles; Middle Branch = 10.87 miles; North Branch = 21.48 miles; Main-stem = 10.27 miles). The Piscataquog River flows into the Merrimack River in Manchester, NH.

Table - 5: Delineation parameter descriptions and break justifications.

Parameter	Description and/or TFC Break Justifications
Fish Community (NMDS)	The fish community of the main-stem Piscataquog differs from most sites on the branches. The sites on the South Branch exhibit changes in fish community longitudinally, with the furthest sites downstream being more similar in fish community to the main-stem than those further upstream. The sites on the Middle Branch group between the North/South Branch sites in ordination space.
Stream Order	South Branch: 1st to 5th Order; most of length is 3rd/4th Order Middle Branch: 2nd to 4th Order; most of length is 4th Order North Branch: 2nd to 4th Order; most of length is 4th Order Main-stem: 5th Order
Gradient	All three branches begin at lakes and have moderate/high and low/moderate gradient in free-flowing areas. The North Branch is impounded by two lakes, resulting in more very low gradient areas than the other two branches. On the main-stem, very low gradients present in the upper reaches of the river appear to be due to impoundments. However, the impoundment in the lower sections of the river was not identified as an area of low gradient, indicating that the TNC layer may be incorrect in its general gradient assessment on this river. Therefore, though a shift in gradient appears to be present in the GIS data, there may not actually be a natural gradient shift overall.
Watershed Size	South Branch: Creek to Small River, with a very short Headwater portion. Middle Branch: Creek North Branch: Creek to Small River Main-stem: Small River to Medium Tributary River
NH Fish Community Types	Warmwater throughout, with the exception of furthest upstream areas of the North Branch which may have once been coldwater prior to lake

	development. The branches are surrounded by areas predicted to be transitional, and the main-stem is surrounded by areas predicted to be warmwater.
Soils/Bedrock Geology/Water Chemistry	Some shifts are present in soil/bedrock geology, but no broad scale patterns in the shift occur along the stream gradient. Most areas of the branches were classified as poorly buffered and acidic, and the Main-stem was assumed to be moderately buffered below the point where it becomes a medium tributary river.
Level III Ecoregion	The main-stem, approximately half of the lower North Branch, and a small portion of the lower South Branch are within Ecoregion 59. The remainder of the branches are within Ecoregion 58.
Other	Review of the orthoimagery suggests that the stream is considerably wider/larger below the confluence of the North and South Branches, despite there being no change in stream order or watershed size class.

TFC Break: At the confluence of the North and South Branches. Though the threshold for increasing from a small river to a medium tributary river was not reached until further downstream on the main-stem, and no change in stream order occurred, the confluence of the major branches of the Piscataquog results in a considerably larger stream with different character than the branches.

Table - 6: Information pertaining to reaches delineated by the TFC breaks.

TFC Reach	Length (miles)	Description
Upper	North Branch (21.5) South Branch (20.75) Middle Branch (10.9)	All portions of the branches, down to the confluence of the North and South Branch.
Lower	10.28	Confluence of the North and South Branches to Mouth

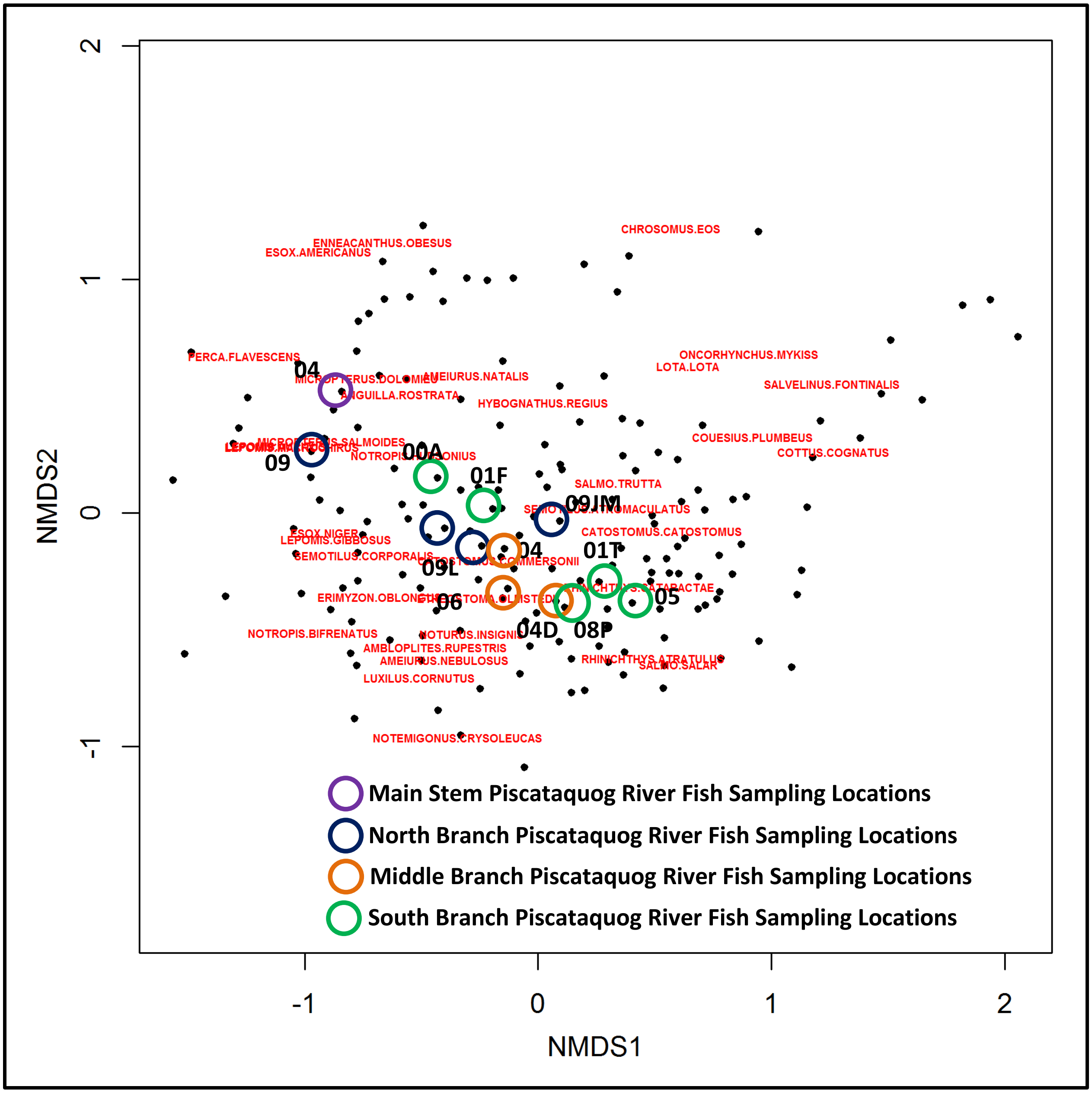


Figure - 1: NMDS ordination plots highlighting the locations fish sampling sites in ordination space, based on the fish community.

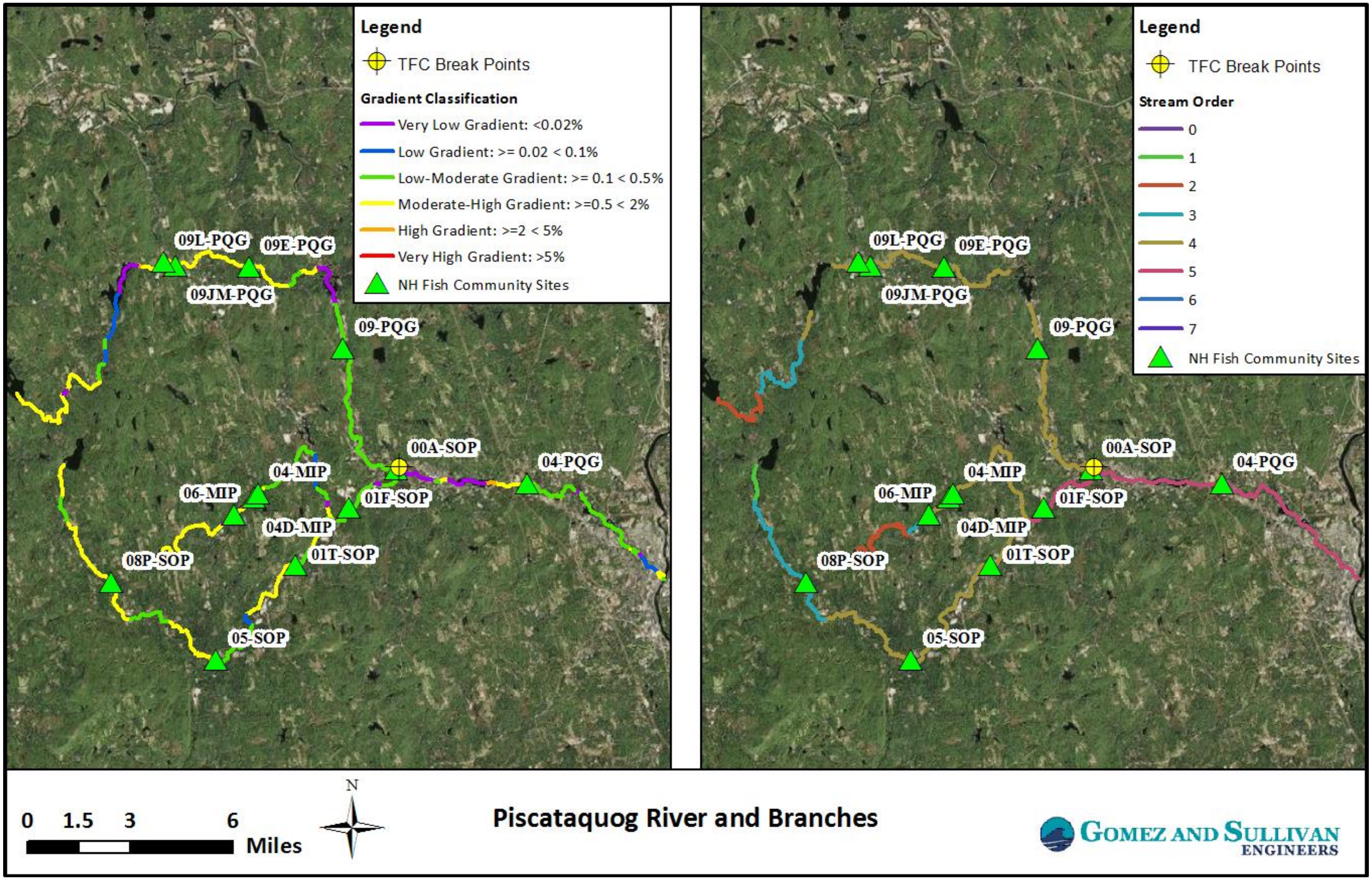


Figure - 2: Gradient (left panel) and stream order (right panel), along with fish sampling locations.

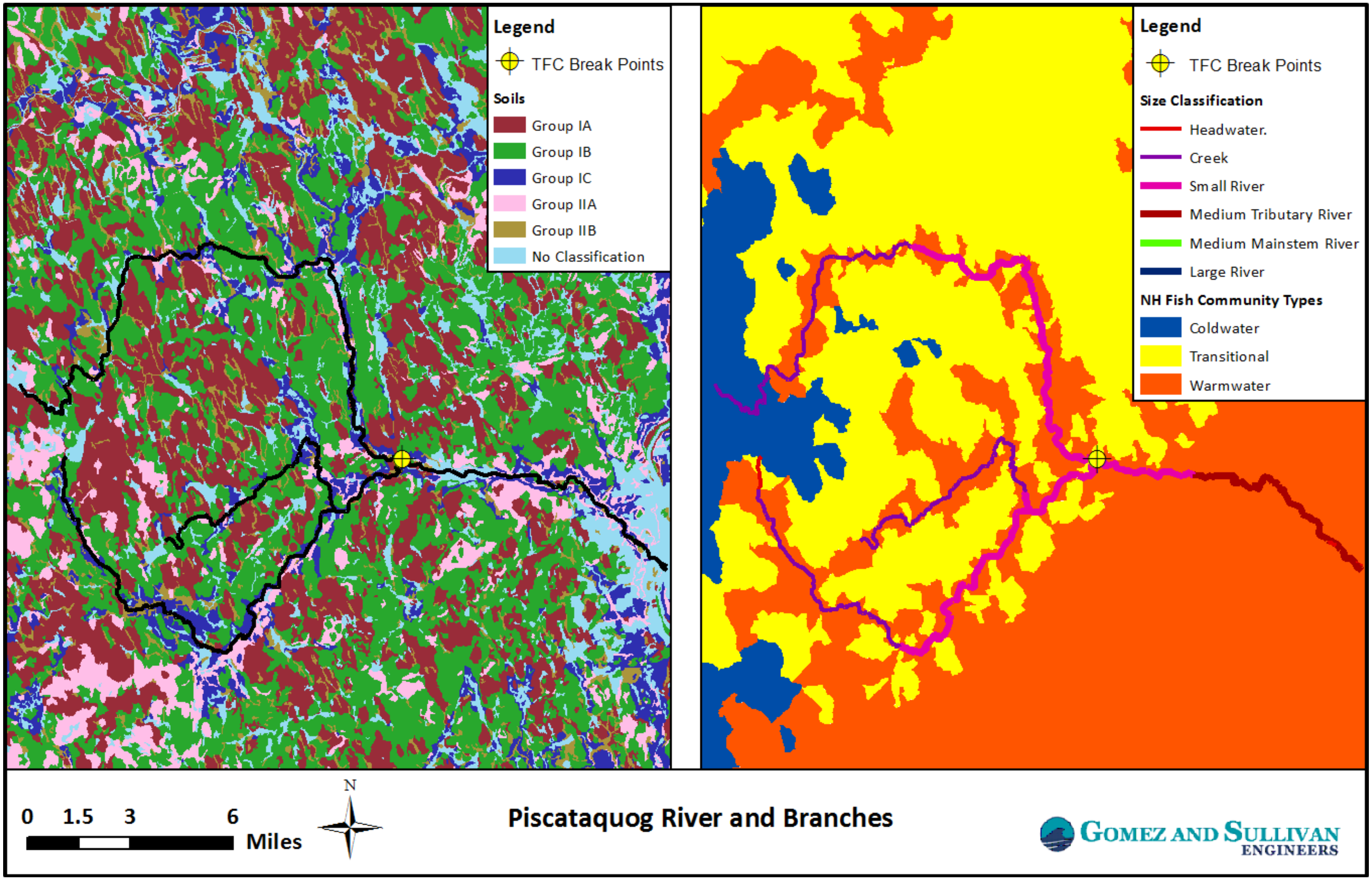


Figure - 3: Soils (left panel), watershed size-class (right panel), and NH predicted fish community types (right panel).

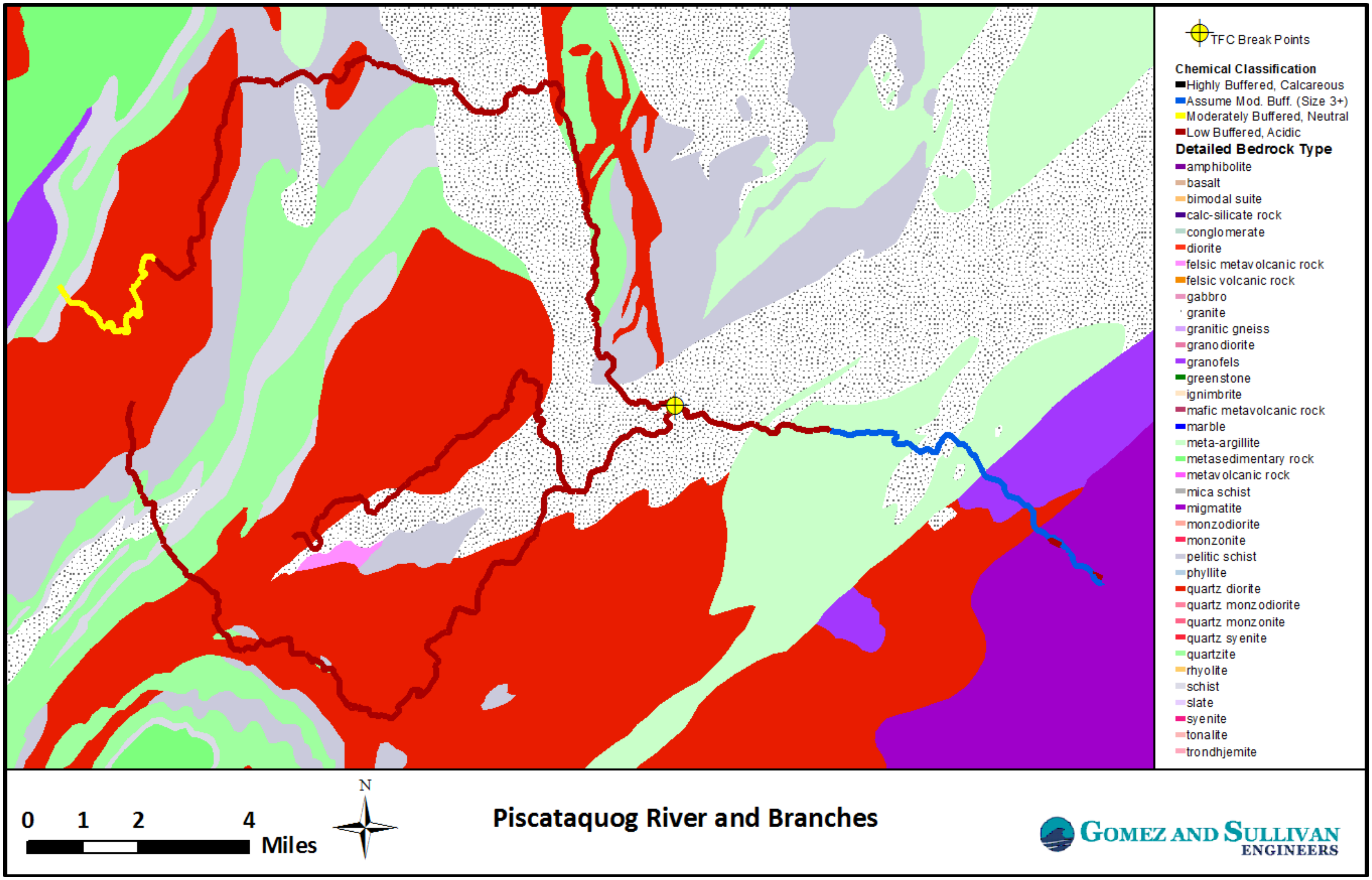


Figure - 4: Bedrock composition and water chemical classification.

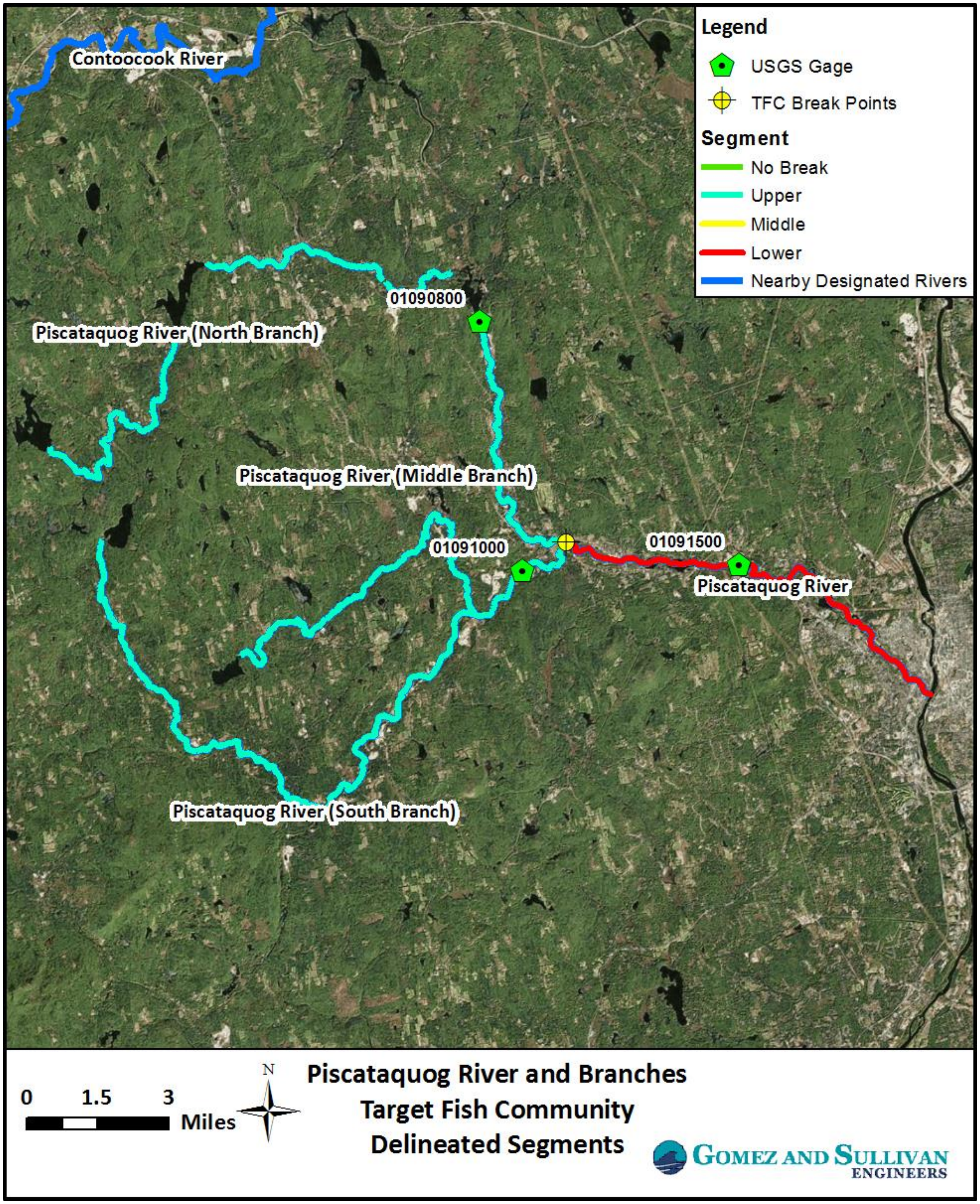


Figure - 5: Delineated segments derived from the TFC break points.

Upper reach (Branches): North Branch (21.5 miles), South Branch (20.75 miles) Middle Branch (10.9 miles) equals 53.15 miles; Lower (Main-stem) reach = 10.28 miles

III. Reference River Data Selection

Reference River Selection Methods

Reference river data were selected initially by using GIS tools, followed by a statistical screening evaluation.

GIS Analysis – Reference River and Fish Community Sample Selection

Segments of reference rivers were selected from the Northeast Aquatic Habitat Classification layer. The selection was based on a set of the following attributes[2] defined for each Designated River segment:

- Watershed Size Class (Table - 3)
- Gradient Class (Table - 3)
- Elevation Class (Table - 7)
- Chemical Class (Table - 8)
- Temperature Class (Table - 9)
- Level III Ecoregion

Table - 7: Elevation classes and descriptions from the Northeast Aquatic Habitat Classification System layer.

Elevation Class	Description	Elevation (ft)
1	Coastal Zone	< 20
2	Low Elevation	20 - 800
3	Mid-to-Lower Elevation Transitional	800 - 1,700
4	Mid-to-Upper Elevation Transitional	1,700 - 2,500
5	High Elevation	2,500 - 3,600
6	Subalpine/Alpine	> 3,600

Table - 8: Chemical classes and descriptions from the Northeast Aquatic Habitat Classification System layer.

Chemical Class	Description
1	Low Buffered, Acidic
2	Moderately Buffered, Neutral
3	Highly Buffered, Calcareous
0	Assume Moderately Buffered (Size 3+ Rivers)

[2] Though the initial intent was to include Stream Order as a variable, it was found that the Stream Order values from the Northeast Aquatic Habitat Classification layer were not consistent with the newer National Hydrography stream layer dataset (or the Stream Orders described during the Designated River delineation). It was determined that Watershed Size class was likely to be more influential on flow and fish communities than the Stream Order value over the spatial scale of the dataset.

Table - 9: Temperature classes and descriptions from the Northeast Aquatic Habitat Classification System layer. [3]

Temperature Class	Description
1	Cold
2	Transitional Cool
3	Transitional Warm
4	Warm

Electrofishing data from Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and New York were consolidated into a geodatabase. These data included only count data, as CPUE was not readily available from all states. A list of all species in the entire dataset is in Appendix A. Not all species are included in the reference river selection datasets.

From the segments of reference rivers identified, fish community samples were preliminarily selected in GIS. The initial sample selection included locations within a 200-meter buffer of the river segment, and were within areas classified as having a low to very low cumulative disturbance index based on the National Fish Habitat Disturbance Index layer.

If large numbers of samples were initially selected in GIS, then samples were retained based on a HUC4 watershed-level screening. This resulted in the removal of reference river data that were from distant watersheds. Data from more distant reference rivers were used if required to retain a sufficient sample size of fish community data from reference rivers.

The fish sample data were then screened to include only samples:

- Collected from 1990 to the present
- Containing 50 individuals or greater
- Collected using appropriate survey methods (i.e. General Biological Surveys vs. species-specific sampling), when this information was available
- Where more than two samples were present on a reference river

Further screening was performed later as described in the Statistical Analysis section.

[3] Note: The temperature classifications in the NAHCS dataset are from a different dataset than the NH fish community types, and the overall values may differ due to different calculation methods. However, the NAHCS data were used for reference river selection because their spatial extent covers the surrounding states.

Statistical Analysis

Fish community data from each reference river were evaluated for suitability using Multivariate Pseudo Standard Error (MultSE), as described by Anderson and Santana-Garcon (2015). This method was developed to measure precision for multivariate assemblage data. The concept of MultSE is similar to univariate standard error, but incorporates multivariate community data, with permutation-based means and bias-adjusted bootstrap-based error bars (Anderson and Santana-Garcon 2015). Though the method was developed to evaluate sufficiency of datasets being utilized subsequently for dissimilarity-based null hypothesis testing, it is also useful for determining whether the addition of samples to the dataset would result in considerable changes to the ecological community as a whole.

In this case, we evaluated whether enough samples were present in the fish community dataset to characterize each reference river fish community, and then went further and determined whether enough reference rivers were selected for developing a TFC model. An ideal number of sample sites or reference rivers would yield either a low MultSE value, or provide an asymptotic relationship, with additional sites or reference rivers providing relatively little decrease in MultSE and narrow confidence intervals (see theoretical example in Figure - 6). The calculations in the MultSE analyses were based on Bray-Curtis dissimilarity, incorporating the proportional abundance of species, which is directly pertinent to developing the TFC model using the Bain and Meixler (2005) method.

The adequacy of reference river fish community samples was evaluated by calculating MultSE of samples for each reference river (the number of samples per reference river = n). If the MultSE patterns indicated that more samples would have been necessary to characterize the fish community, those reference rivers were removed from further analyses.

After the MultSE screening, the counts from each reference river were summed, consistent with reported methods for the initial calculations in the TFC development used by Bain and Meixler (2005). Another MultSE analysis was performed in the same manner, but using tallied counts for each of the reference rivers (the number of reference rivers = n). If the MultSE analysis yielded an asymptotic function with low MultSE values and narrow error bars, it was determined that the use of these reference river data were sufficient for calculation of a TFC model.

The fish community data from the final selection of reference rivers was then provided in tables, ordered by the rank of mean proportional abundance, which is one of the first calculations for the TFC model development, per Bain and Meixler (2005). It should be noted that a number of species in the reference river data may not be expected to be present in the Designated River segment, due to potential data gathering from distant watersheds; these species are typically low in abundance, and will not be used in the TFC model development phase.

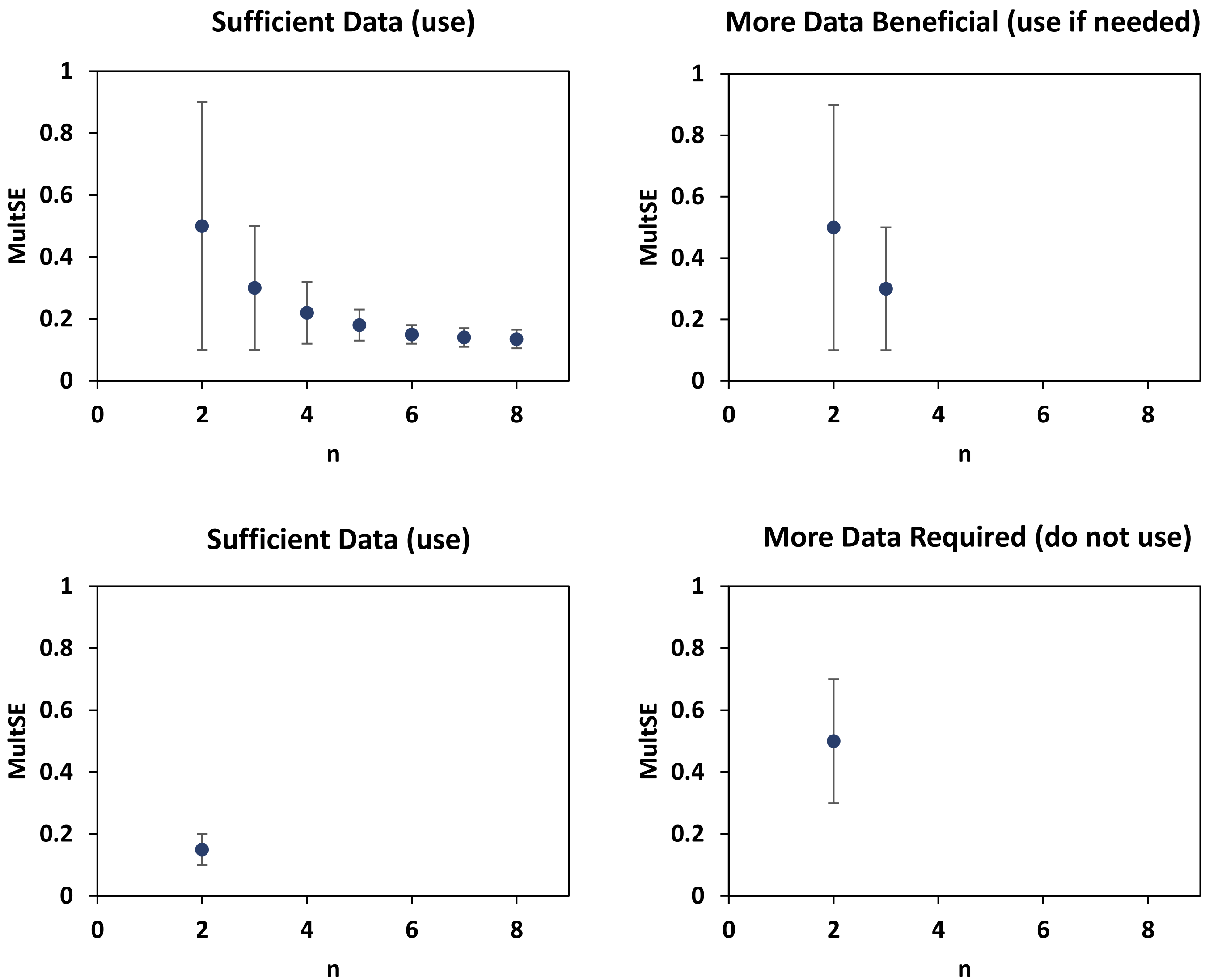


Figure - 6: Theoretical example of evaluating the number of samples (i.e. whether data are sufficient for further analysis) using MultSE.

Reference River Selection Results

Results are provided below for each delineated segment of the Designated River.

Upper Segment

Reference rivers were selected for the upper segment of the Piscataquog River using the characteristics shown in Table - 10.

Table - 10: Characteristics used to select reference rivers for the upper segment.

Characteristic	Class	Description
Size Class	1b-2	Creek to Small River
Elevation Class	2	20 - 800 feet
Gradient Class	3-4	Low Moderate to Moderate High
Chemical Class	1	Low Buffered (Acidic)
Temperature Class	1-2	Cold to Transitional Cool
Level III Ecoregion	58	Northeastern Highlands

Based on the amount of data selected initially, data from one watershed, the Merrimack River Watershed (HUC4 0107), was considered. From this selection and the available fish community data, twelve reference rivers[4] were identified (Figure – 7). The initial reference rivers identified were:

- Ames Brook (2 samples)
- Baker River (4 samples)
- Blackwater River (2 samples)
- East Wachusett Brook (2 samples)
- Middle Branch Piscataquog River (5 samples)
- North Branch Piscataquog River (4 samples)
- Phillips Brook (2 samples)
- Rand Brook (2 samples)
- Souhegan River (3 samples)
- South Branch Piscataquog River (8 samples)
- South Wachusett Brook (2 samples)
- Wiley Brook (3 samples)

Based on the MultSE analysis (Figure - 8), ten reference rivers provided either low MultSE values with relatively few site locations, or an asymptotic relationship when more sites were available. Two reference rivers (Souhegan River and South Wachusett Brook) were removed from further analysis because the high MultSE value using all samples for these rivers indicated that data may not be sufficient for accurate calculation of proportional abundance in these rivers.

The remaining ten reference rivers were then analyzed together using MultSE (Figure - 9). Low MultSE values, with narrow confidence intervals, and an asymptotic relationship with increasing numbers of reference rivers, indicated that these reference rivers would be suitable for development of a TFC model. The combined count data for each species and reference river is shown in Table - 11.

[4] Though technically the lower portions of the North Branch Piscataquog River are in the Northeastern Coastal Zone Ecoregion (59) according to the Ecoregion GIS Layer, the entire North Branch Piscataquog River was included in the search for reference river fish community data due to its relevance to the Designated River delineated segment.

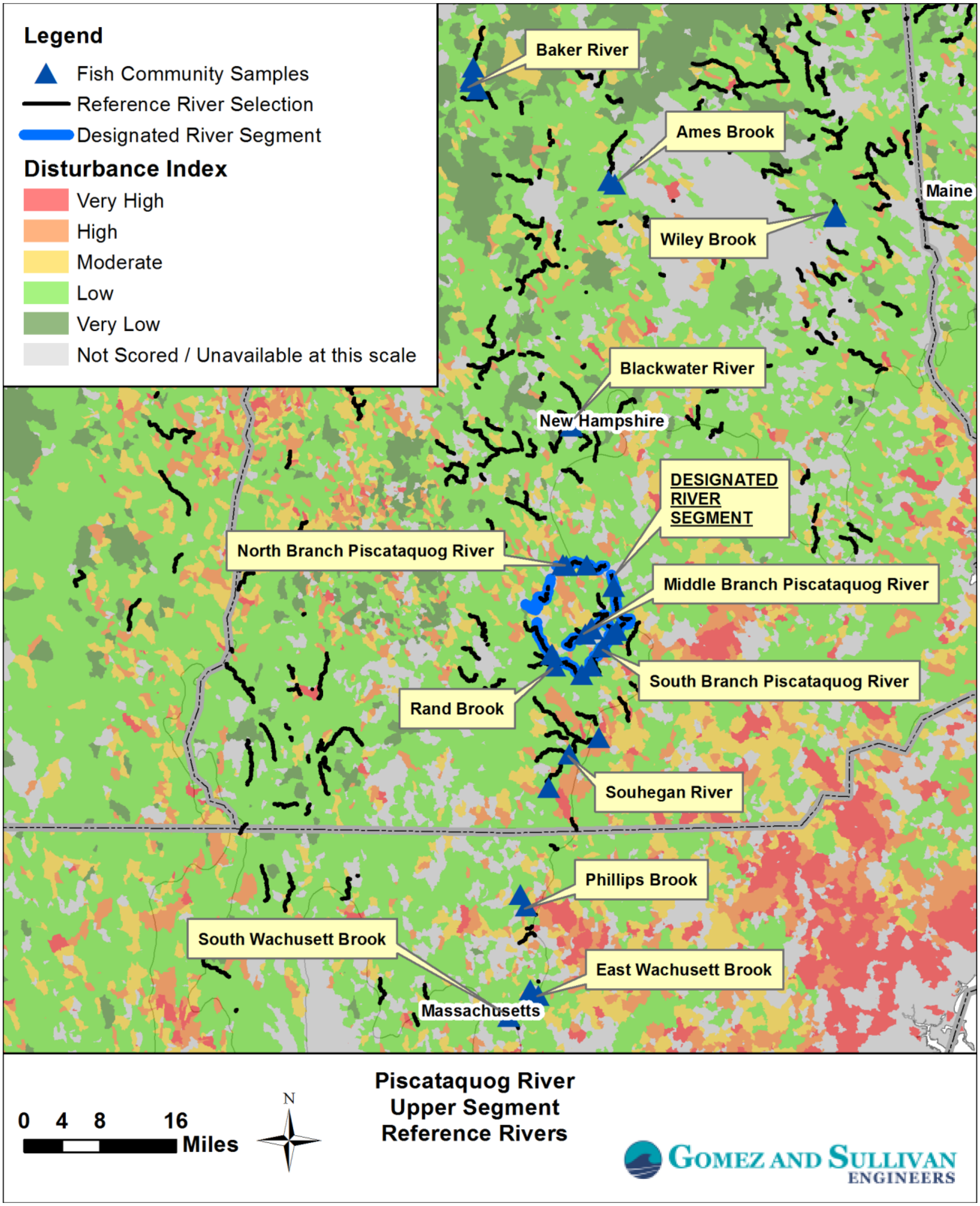


Figure - 7: Initial selection of reference river fish community samples for the upper segment.

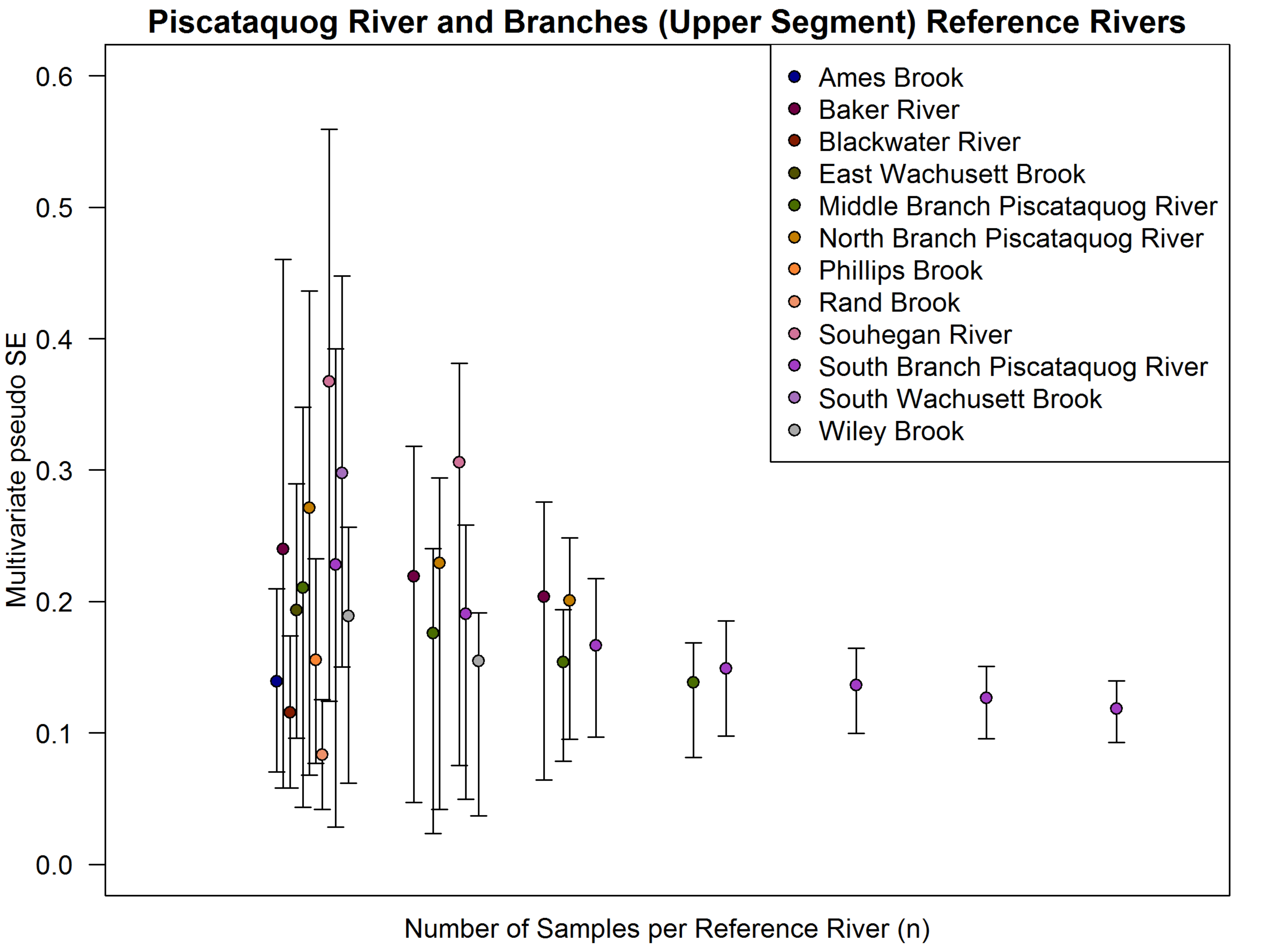


Figure - 8: MultSE (beginning at n=2) of fish community data for reference rivers initially selected for the upper segment.

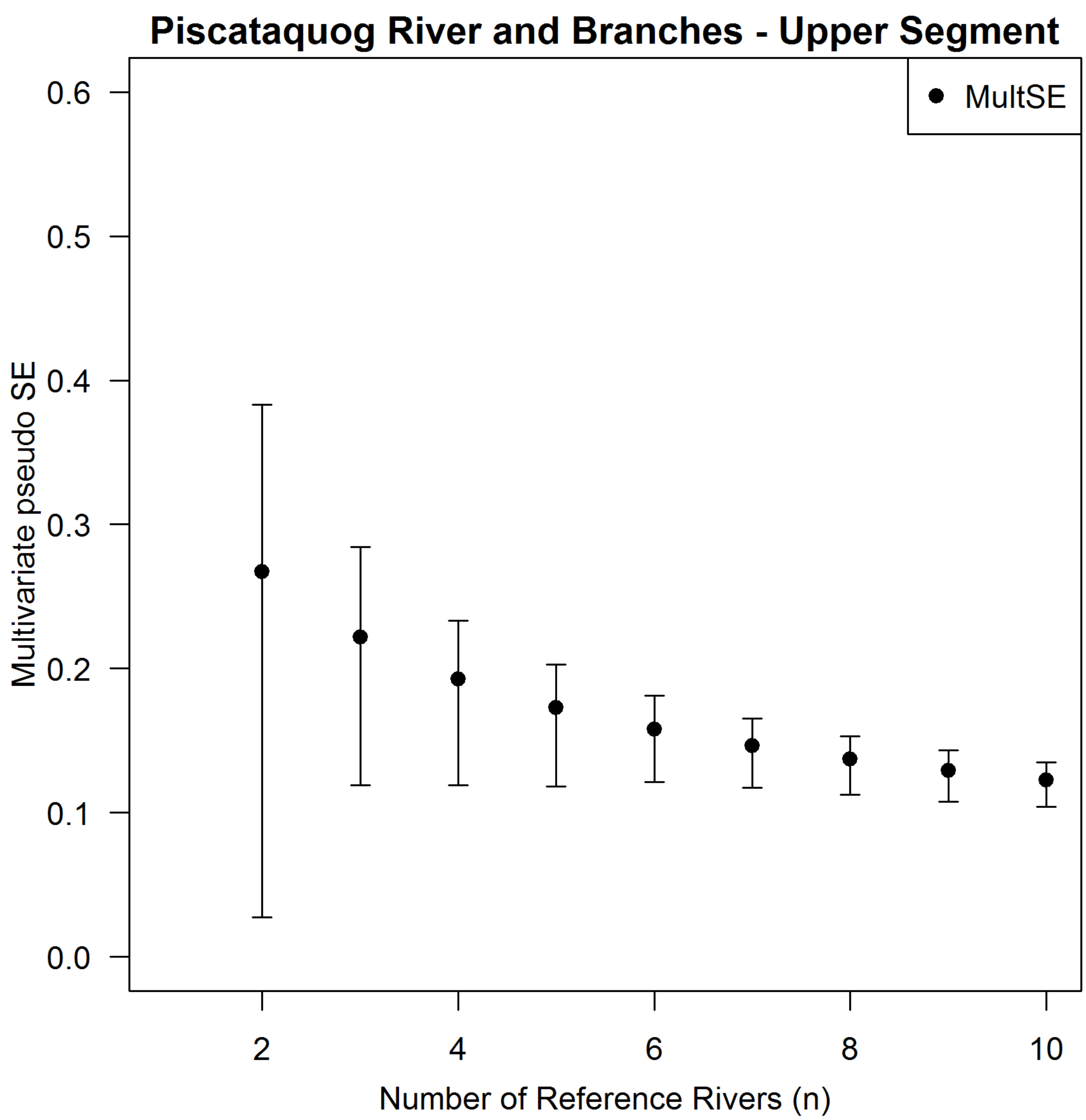


Figure - 9: MultSE for the final reference river selection for the upper segment.

Table - 11: Species counts for reference rivers for the upper segment.

Species	Ames Brook	Baker River	Blackwater River	East Wachusett Brook	Middle Branch Piscataquog River	North Branch Piscataquog River	Phillips Brook	Rand Brook	South Branch Piscataquog River	Wiley Brook	Mean Proportion	Rank of Mean Proportion
Blacknose Dace	147	57	41	119	130	45	156	150	562	144	0.420	1
Common Shiner	7	5	22	0	208	167	38	19	149	17	0.110	2
White Sucker	7	8	45	13	60	28	141	6	61	13	0.104	3
Longnose Dace	0	15	27	0	140	99	0	55	324	0	0.098	4
Atlantic Salmon	0	348	0	0	23	0	0	0	68	0	0.083	5
Fallfish	1	9	20	0	212	59	0	6	43	0	0.056	6
Brook Trout	30	0	0	5	0	1	24	21	15	10	0.038	7
Pumpkinseed	1	0	0	3	14	22	11	0	4	0	0.012	8
Yellow Perch	0	0	1	0	0	12	0	0	0	16	0.011	9
Slimy Sculpin	14	11	1	0	0	0	0	0	0	0	0.010	10
Margined Madtom	0	0	0	0	0	0	0	0	114	0	0.008	11
Golden Shiner	0	0	0	3	9	8	0	5	9	1	0.008	12
Smallmouth Bass	1	0	0	0	0	20	0	0	25	0	0.006	13
Largemouth Bass	0	0	1	0	18	10	2	0	8	0	0.006	14
Yellow Bullhead	0	0	0	0	5	13	0	0	27	0	0.005	15
Longnose Sucker	0	0	0	0	11	5	0	0	38	0	0.005	16
Burbot	0	8	3	0	0	3	0	0	0	1	0.005	17
Spottail Shiner	0	0	0	0	2	4	0	0	3	7	0.005	18
Chain Pickerel	0	0	0	0	3	17	0	0	2	0	0.004	19
Lepomis Sp	0	0	0	0	25	0	0	0	11	0	0.004	20
Brown Trout	0	0	0	0	1	2	5	0	2	0	0.002	21
Brown Bullhead	1	0	0	0	1	4	1	0	0	0	0.002	22
Bluegill	0	0	0	1	0	0	0	0	1	1	0.001	23
Redbreast Sunfish	0	0	1	0	3	0	0	0	0	0	0.001	24
Rainbow Trout	0	1	0	0	0	0	0	0	3	0	0.000	25
American Eel	0	0	0	0	0	1	0	0	0	0	0.000	26.5
Redfin Pickerel	0	0	0	0	0	1	0	0	0	0	0.000	26.5

Lower Segment

Reference rivers were selected for the Lower segment of the Piscataquog River using the characteristics shown in Table - 12.

Table - 12: Characteristics used to select reference rivers for the lower segment.

Characteristic	Class	Description
Size Class	2-3a	Small River to Medium Tributary River
Elevation Class	2	20 - 800 feet
Gradient Class	3-4	Low Moderate to Moderate High
Chemical Class	1-0	Low Buffered (Acidic) to Assume Mod. Buff (Size 3+)
Temperature Class	2	Transitional Cool
Level III Ecoregion	59	Northeastern Coastal Zone

Based on the amount of data selected initially, data from two watersheds, the Merrimack River Watershed (HUC4 0107), and the Saco River/Coastal Watershed (HUC4 0106) were considered. From this selection and the available fish community data, nine reference rivers were identified (Figure 10). The initial reference rivers identified were:

- Isinglass River (4 samples)
- Lamprey River (16 samples)
- North Branch Piscataquog River (2 samples)
- North River (2 samples)
- Quinapoxet River (2 samples)
- Soucook River (4 samples)
- South Branch Piscataquog River (2 samples)
- Squannacook River (6 samples)
- Suncook River (2 samples)

Based on the MultSE analysis (Figure - 11) four reference rivers provided either low MultSE values with relatively few site locations, or an asymptotic relationship when more sites were available. Five reference rivers (North Branch Piscataquog River, North River, Quinapoxet River, South Branch Piscataquog River, and Suncook River) were removed from further analysis because the high MultSE value using all samples for these rivers indicated that data was not sufficient for accurate calculation of proportional abundance in these rivers.

The remaining four reference rivers were then analyzed together using MultSE (Figure - 12). Though additional reference rivers would have beneficial for this model, low MultSE values, with narrow confidence intervals, indicated that these reference rivers would be suitable for development of a TFC model. The combined count data for each species and reference river is shown in Table - 13.

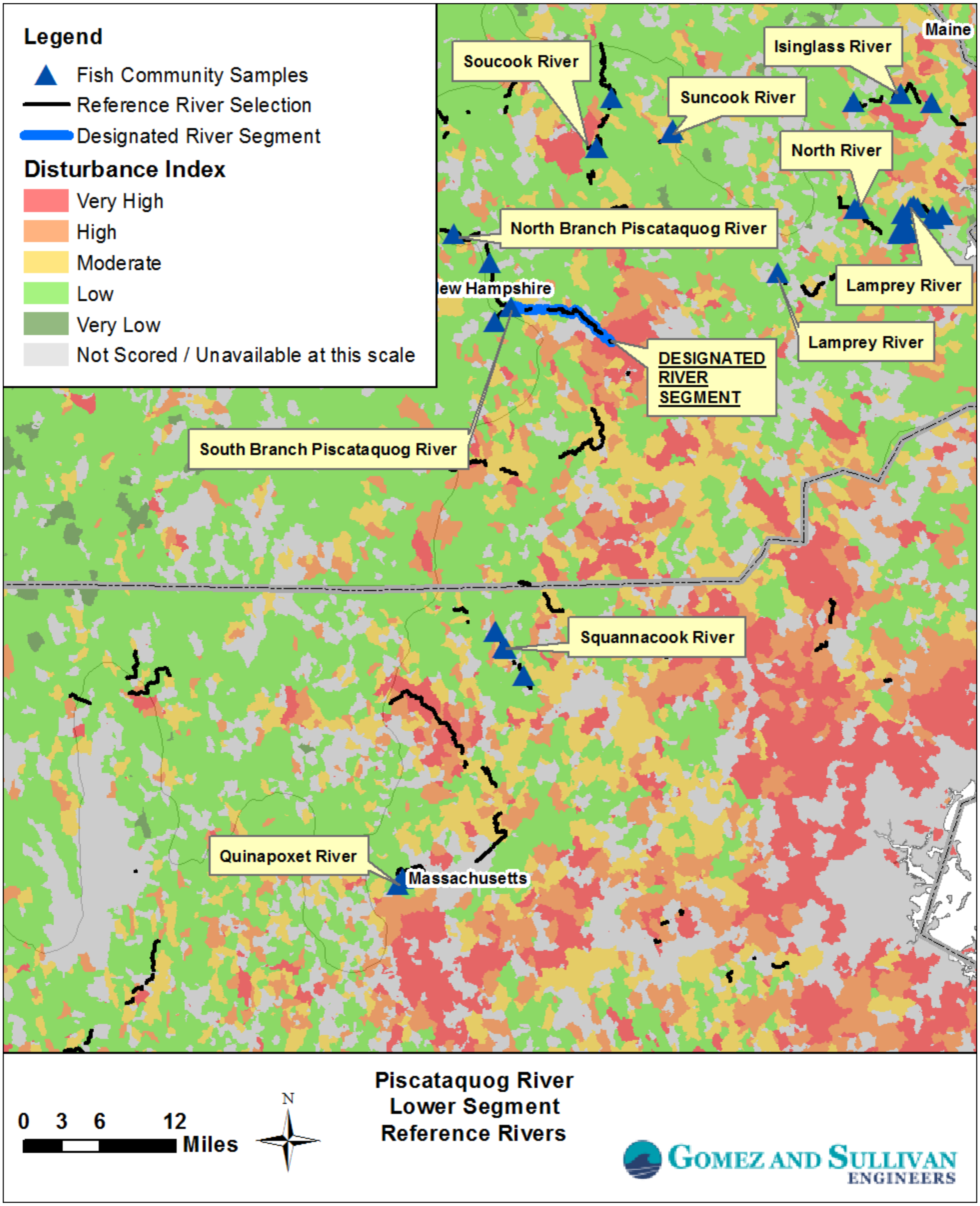


Figure - 10: Initial selection of reference river fish community samples for the lower segment.

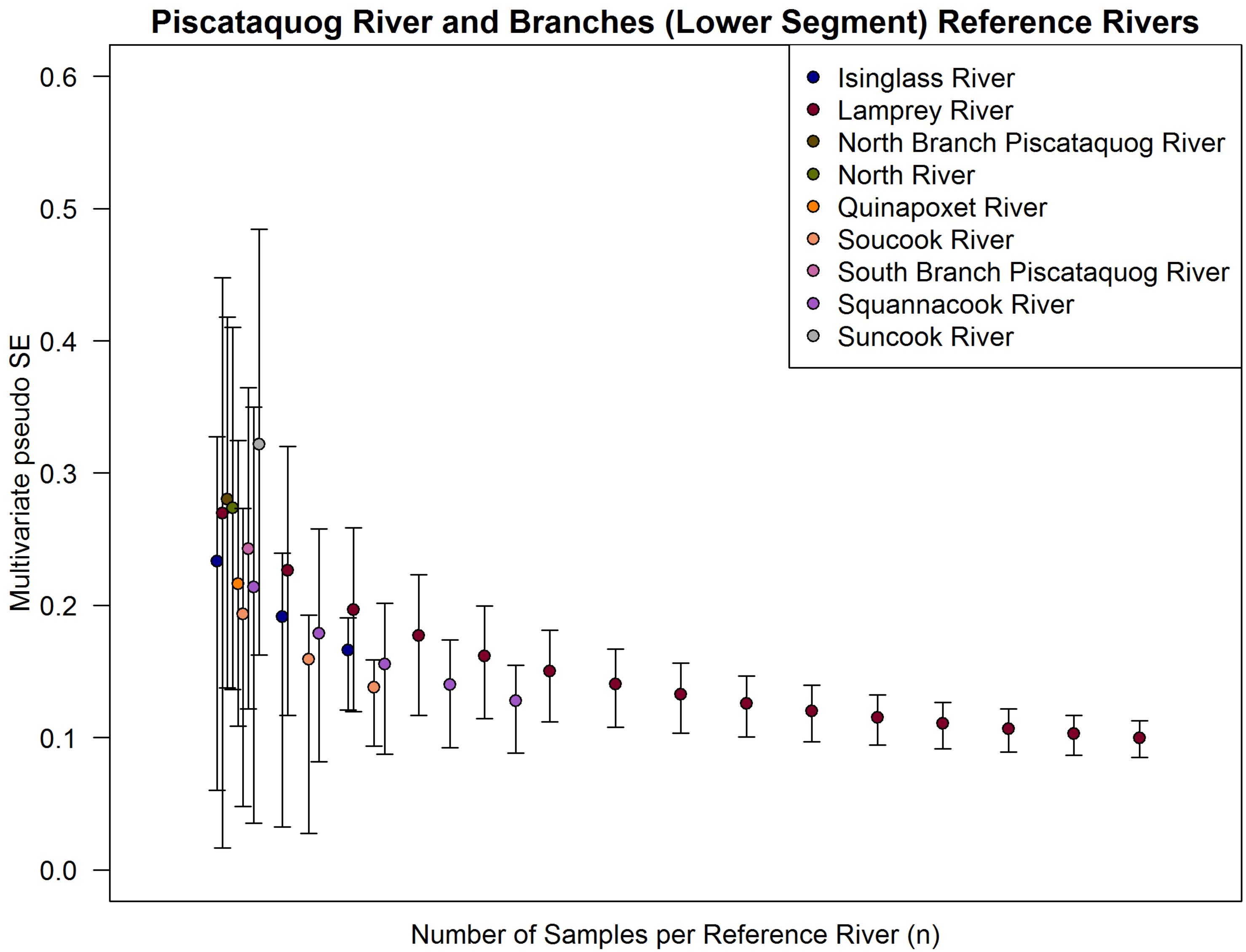


Figure - 11: MultSE (beginning at n=2) of fish community data for reference rivers initially selected for the lower segment.

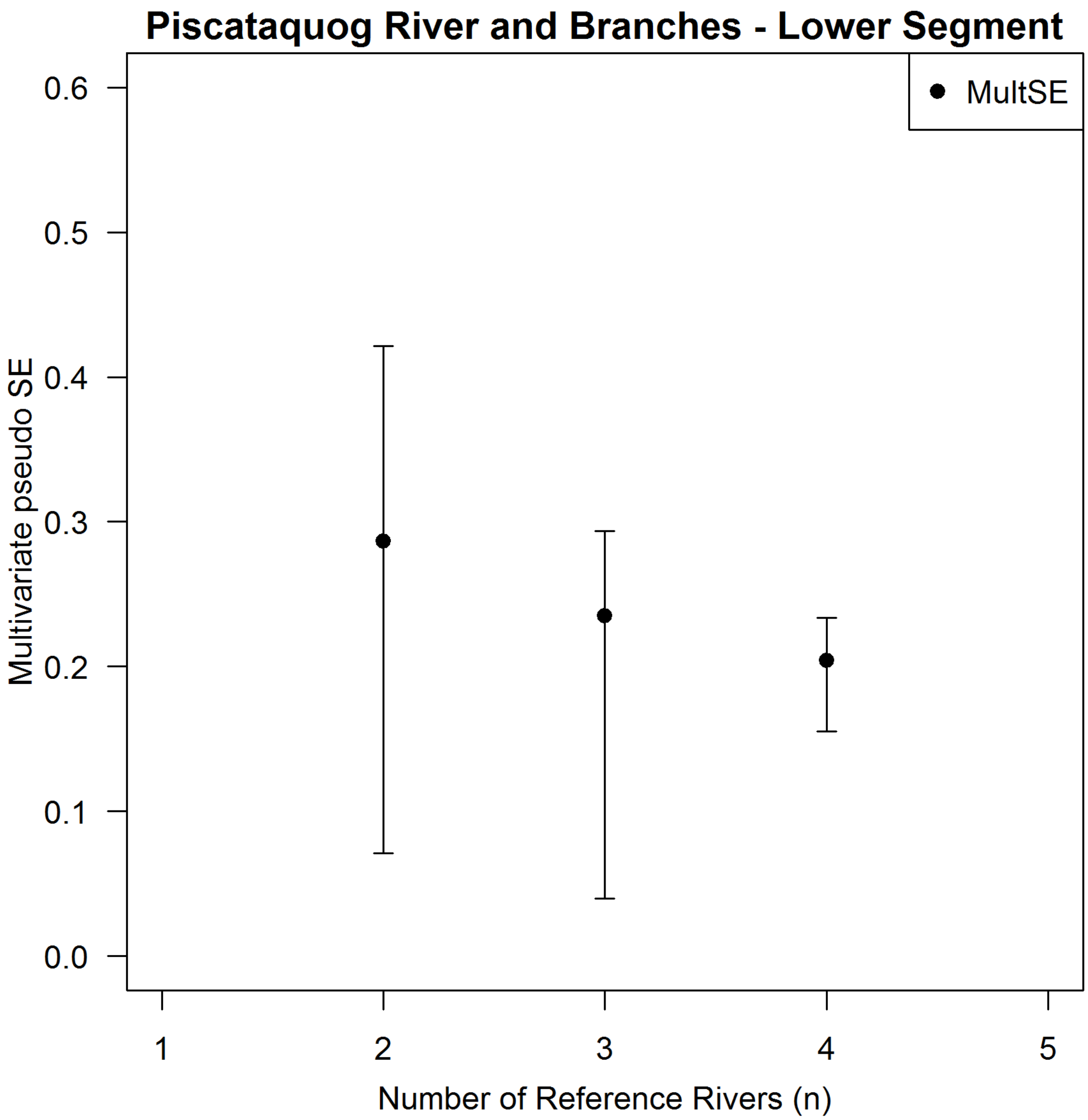


Figure - 12: MultSE for the final reference river selection for the lower segment

Table - 13: Species counts for reference rivers for the lower segment.

Species	Isinglass River	Lamprey River	Soucook River	Squannacook River	Mean Proportion	Rank of Mean Proportion
Common Shiner	175	1384	170	103	0.259	1
Fallfish	104	852	1	266	0.179	2
Blacknose Dace	0	19	174	0	0.077	3
Redbreast Sunfish	69	773	0	0	0.072	4
Longnose Dace	55	228	76	7	0.071	5
Largemouth Bass	5	47	4	186	0.067	6
American Eel	69	324	2	1	0.048	7
White Sucker	5	247	42	36	0.046	8
Pumpkinseed	26	153	0	35	0.031	9
Margined Madtom	39	0	28	0	0.029	10
Yellow Bullhead	0	48	23	41	0.026	11
Bluegill	11	1	0	61	0.025	12
Brown Bullhead	7	5	31	2	0.017	13
Smallmouth Bass	2	130	0	1	0.008	14
Atlantic Salmon	18	9	0	0	0.008	15
Bridle Shiner	8	61	0	0	0.007	16
Tessellated Darter	0	0	10	5	0.006	17
Chain Pickerel	1	12	3	9	0.005	18
Golden Shiner	0	83	0	1	0.005	19
Yellow Perch	1	24	0	4	0.003	20
Spottail Shiner	0	0	6	0	0.003	21
Brown Trout	0	5	0	6	0.002	22
Rock Bass	0	18	0	2	0.002	23
Brook Trout	0	0	3	0	0.001	24
Banded Sunfish	0	0	0	2	0.001	25
Creek Chub	0	10	0	0	0.001	26.5
Creek Chubsucker	0	10	0	0	0.001	26.5
Rainbow Trout	0	0	1	0	0.000	28
Lepomis Sp	0	5	0	0	0.000	29
Redfin Pickerel	0	3	0	0	0.000	30
Alewife	0	1	0	0	0.000	31.5
Blueback Herring	0	1	0	0	0.000	31.5

IV. TFC Model Development

TFC Model Development Methods

The TFC model development process included the following steps for each of the Designated River segments:

Develop Fish Species List

A comprehensive list of native fish species known to have inhabited the larger-scale basins for each of the Reference Rivers was developed collaboratively between Gomez and Sullivan, NHDES, and NH Fish and Game biologists. These lists were then matched to the Designated River segments that reside within those basins to remove non-native species, and species deemed to be native to the basin were retained for inclusion in the TFC model. Though anadromous species were included initially in the reference river data, and are considered native to most rivers, their abundances would not often be adequately represented by most sampling efforts due to immigration/emigration of individuals. Therefore, anadromous fish (Sea Lamprey; Alewife; Blueback Herring) were removed from TFC model development, consistent with Bain and Meixler (2005). Atlantic Salmon were retained in the analysis because juveniles of this species would typically reside in streams as parr and smolts for at least one year.

Remove Stocked Fish

The dataset developed during the reference river data selection phase was evaluated in detail to determine whether stocked fish of native species were present in the catch data. The objective was to remove stocked individuals from the reference river dataset. Removing these individuals was accomplished by using the available metadata and consulting with the state agencies that manage the original fish sample data. Sample-specific information varied among the State datasets; therefore methods for stocked fish removal varied, and included:

- Evaluation of length distributions (NH)
- Removal of Brook Trout over 200mm (MA)
- Removal of Brook Trout and Atlantic Salmon where no natural reproduction of these species occurs
- Removal based on wild/stocked information as available in the dataset

Develop the TFC Models

The TFC models were developed from the final dataset using steps adapted from Bain and Meixler (2005), which included:

1. The catch for each species from each sample within a reference river was summed across all samples.
2. Proportions of catch for each species was then summed across Reference Rivers.
3. The summed proportions were ranked by dominance, with a value of "1" being assigned to the most commonly dominant species. Ranks increased with decreasing dominance.
4. The expected proportions of species was calculated by converting the species ranks to reciprocals (1/rank), summing the reciprocal ranks, and then dividing the reciprocal rank by the sum of all of the reciprocal ranks.

The habitat use classification, pollution tolerance, and preferred thermal regime was also shown for each species based on Bain and Meixler (2000) and Yoder et al. (2016).

TFC Model Results

Species List

The comprehensive list of native, resident fish species list for this Designated River, as determined from the Merrimack River watershed, is shown in Table 14.

Table - 14: Comprehensive list of native species used for the Designated River watershed, as determined from the greater basin area.

Species	Habitat Use Classification	Pollution Tolerance	Thermal Regime
American Eel	MG	T	Eurythermal
Atlantic Salmon	FS	I	Cold
Banded Killifish	MG	T	Warm
Banded Sunfish	MG	M	Warm
Blacknose Dace	FS	T	Eurythermal
Bridle Shiner	MG	I	Warm
Brook Trout	FS	I	Cold
Brown Bullhead	MG	T	Warm
Burbot	FD	S	Cold
Chain Pickerel	MG	M	Warm
Common Shiner	FD	M	Eurythermal
Creek Chub	FS	T	Eurythermal
Creek Chubsucker	FS	I	Eurythermal
Fallfish	FS	M	Eurythermal
Golden Shiner	MG	T	Eurythermal
Lake Chub	FD	I	Cold
Longnose Dace	FS	M	Eurythermal
Longnose Sucker	FD	I	Cold
Northern Redbelly Dace	MG	I	Warm
Pumpkinseed	MG	M	Warm
Redbreast Sunfish	MG	M	Warm
Redfin Pickerel	MG	M	Warm
Slimy Sculpin	FS	I	Cold
Spottail Shiner	MG	M	Eurythermal
Tessellated Darter	FS	M	Eurythermal
White Perch	MG	M	Eurythermal
White Sucker	FD	T	Eurythermal
Yellow Perch	MG	M	Eurythermal

*Note: For Habitat Use Classification – MG = Macrohabitat Generalist; FD = Fluvial Dependent; FS = Fluvial Specialist; E = Estuarine. For Pollution Tolerance – I = Intolerant; S = Sensitive (Moderately Intolerant); M =

Moderate Tolerance; T = Tolerant. Information in brackets was not found in Bain and Meixler (2000) or Yoder et al. (2016), and was inserted based on relevant species information.

TFC model results are provided below for each delineated segment of the Designated River.

Upper Segment

The Target Fish Community of the upper delineated segment of the Designated River is shown in Figure 13 and Table 15.

Figure - 13: Graphical representation of the TFC Model for the upper segment.

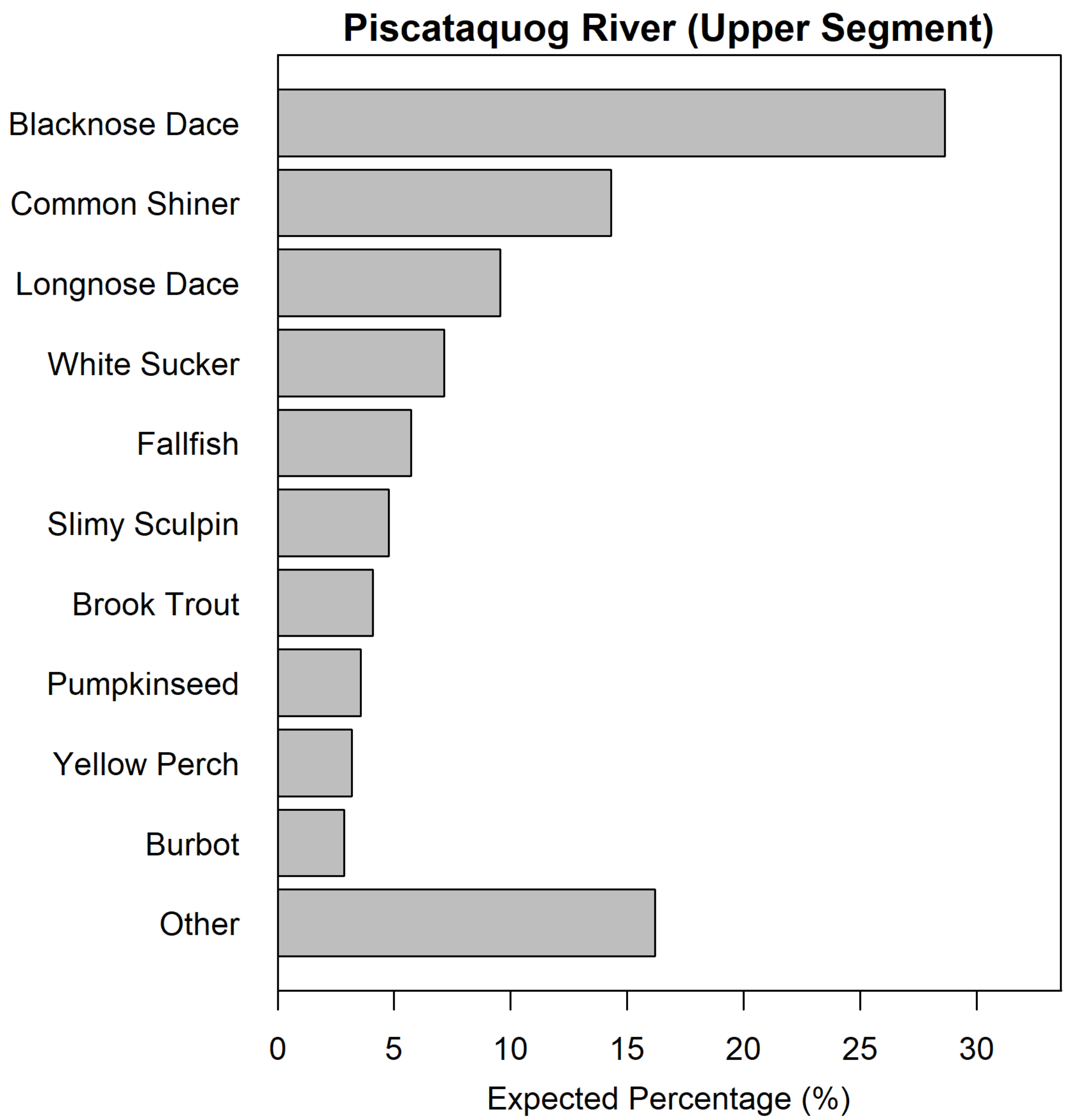


Table - 15: Count of fish from reference river data and expected percentage (TFC Model) of species for the upper segment.

Species	Ames Brook	Baker River	Blackwater River	East Wachusett Brook	Middle Branch Piscataquog River	North Branch Piscataquog River	Phillips Brook	Rand Brook	South Branch Piscataquog River	Wiley Brook	Mean Proportion	Rank of Mean Proportion	Expected Percentage
Blacknose Dace	147	57	41	119	130	45	156	150	562	144	0.48798	1	28.6%
Common Shiner	7	5	22	0	208	167	38	19	149	17	0.12207	2	14.3%
Longnose Dace	0	15	27	0	140	99	0	55	324	0	0.11830	3	9.5%
White Sucker	7	8	45	13	60	28	141	6	61	13	0.11343	4	7.2%
Fallfish	1	9	20	0	212	59	0	6	43	0	0.06615	5	5.7%
Slimy Sculpin	14	11	1	0	0	0	0	0	0	0	0.01822	6	4.8%
Brook Trout	0	0	0	5	0	1	23	0	6	9	0.01475	7	4.1%
Pumpkinseed	1	0	0	3	14	22	11	0	4	0	0.01235	8	3.6%
Yellow Perch	0	0	1	0	0	12	0	0	0	16	0.01083	9	3.2%
Burbot	0	8	3	0	0	3	0	0	0	1	0.01005	10	2.9%
Golden Shiner	0	0	0	3	9	8	0	5	9	1	0.00822	11	2.6%
Longnose Sucker	0	0	0	0	11	5	0	0	38	0	0.00560	12	2.4%
Spottail Shiner	0	0	0	0	2	4	0	0	3	7	0.00471	13	2.2%
Chain Pickerel	0	0	0	0	3	17	0	0	2	0	0.00412	14	2.0%
Brown Bullhead	1	0	0	0	1	4	1	0	0	0	0.00180	15	1.9%
Redbreast Sunfish	0	0	1	0	3	0	0	0	0	0	0.00100	16	1.8%
American Eel	0	0	0	0	0	1	0	0	0	0	0.00021	17.5	1.6%
Redfin Pickerel	0	0	0	0	0	1	0	0	0	0	0.00021	17.5	1.6%

Lower Segment

The Target Fish Community of the lower delineated segment of the Designated River is shown in Figure 14 and Table 16.

Figure - 14: Graphical representation of the TFC Model for the lower segment.

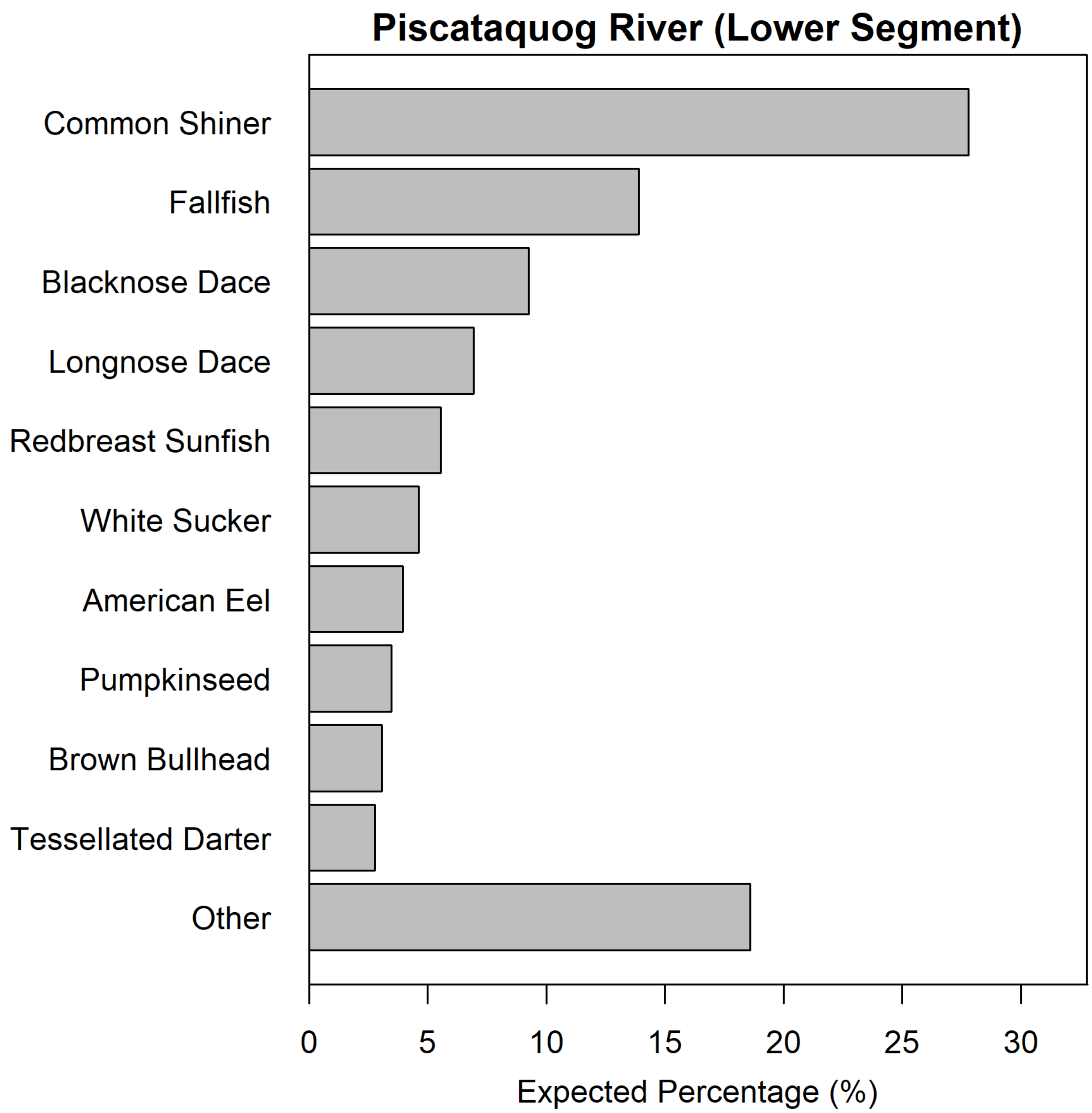


Table - 16: Count of fish from reference river data and expected percentage (TFC Model) of species for the lower segment.

Species	Isinglass River	Lamprey River	Soucook River	Squannacook River	Mean Proportion	Rank of Mean Proportion	Expected Percentage
Common Shiner	175	1384	170	103	0.30393	1	27.8%
Fallfish	104	852	1	266	0.24252	2	13.9%
Blacknose Dace	0	19	174	0	0.08560	3	9.3%
Longnose Dace	55	228	76	7	0.08066	4	6.9%
Redbreast Sunfish	69	773	0	0	0.07931	5	5.6%
White Sucker	5	247	42	36	0.05664	6	4.6%
American Eel	69	324	2	1	0.05401	7	4.0%
Pumpkinseed	26	153	0	35	0.04021	8	3.5%
Brown Bullhead	7	5	31	2	0.01977	9	3.1%
Tessellated Darter	0	0	10	5	0.00751	10	2.8%
Bridle Shiner	8	61	0	0	0.00749	11	2.5%
Chain Pickerel	1	12	3	9	0.00743	12	2.3%
Golden Shiner	0	83	0	1	0.00548	13	2.1%
Yellow Perch	1	24	0	4	0.00404	14	2.0%
Spottail Shiner	0	0	6	0	0.00291	15	1.9%
Banded Sunfish	0	0	0	2	0.00106	16	1.7%
Creek Chub	0	10	0	0	0.00060	17.5	1.6%
Creek Chubsucker	0	10	0	0	0.00060	17.5	1.6%
Redfin Pickerel	0	3	0	0	0.00018	19	1.5%
Blueback Herring	0	1	0	0	0.00006	20	1.4%

V. References Cited

Anderson, M.J. and J. Santana-Garcon. 2015. Measures of precision for dissimilarity-based multivariate analysis of ecological communities. Ecology Letters 18: 66-73.

Bain, M.B. and M.S. Meixler. 2000. Defining a target fish community for planning and evaluating enhancement of the Quinebaug River in Massachusetts and Connecticut. Developed for Quinebaug River Instream Flow Study Agencies, July 2000.

Bain, M.B. and M.S. Meixler. 2005. Defining a target fish community for planning and evaluating river rehabilitation. Manuscript submitted to *Environmental Biology of Fishes* in April 2005.

Clarke, K.R. 1993. Nonparametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18(1): 117-143.

Hansen, M.J., T.D. Beard, and D.B. Hayes. 2007. Sampling and experimental design. Pages 51-120 in C.S. Guy and M.L. Brown, editors. Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society, Bethesda, MD.

Olivero, A.P. and M.G. Anderson. 2008. Northeast Aquatic Habitat Classification System. The Nature Conservancy, Eastern Regional Office. September 30, 2008.

U.S. Environmental Protection Agency (USEPA). 2013. Primary distinguishing characteristics of Level III Ecoregions of the continental United States. September, 2013. ftp://newftp.epa.gov/EPADataCommons/ORD/Ecoregions/us/Eco_Level_III_descriptions.doc

Yoder, C.O., Thoma, R.F., and L.E. Hersha. 2016. Maine Rivers Fish Assemblage Assessment: Development of an Index of Biotic Integrity for Non-Wadeable Rivers. MBI Technical Report MBI/2008-22—2. March 8, 2009, Addendum March 31, 2016.

Appendix A

Table – A1: List of common and scientific names for fish species in the fish community sample dataset (includes samples from NY, CT, RI, MA, VT, NH, and ME).

Common Name	*Scientific Name*
Alewife	*Alosa pseudoharengus*
Allegheny Pearl Dace	*Margariscus margarita*
American Brook Lamprey	*Lampetra appendix*
American Eel	*Anguilla rostrata*
American Shad	*Alosa sapidissima*
Atlantic Salmon	*Salmo salar*
Banded Darter	*Etheostoma zonale*
Banded Killifish	*Fundulus diaphanus*
Banded Sunfish	*Enneacanthus obesus*
Bigeye Chub	*Hybopsis amblops*
Bigmouth Buffalo	*Ictiobus cyprinellus*
Bigmouth Shiner	*Notropis dorsalis*
Black Bullhead	*Ameiurus melas*
Black Crappie	*Pomoxis nigromaculatus*
Black Redhorse	*Moxostoma duquesnei*
Blackchin Shiner	*Notropis heterodon*
Blacknose Dace	*Rhinichthys atratulus*
Blacknose Shiner	*Notropis heterolepis*
Blackside Darter	*Percina maculata*
Blueback Herring	*Alosa aestivalis*
Bluebreast Darter	*Etheostoma camurum*
Bluegill	*Lepomis macrochirus*
Bluespotted Sunfish	*Enneacanthus gloriosus*
Bluntnose Minnow	*Pimephales notatus*
Bowfin	*Amia calva*
Brassy Minnow	*Hybognathus hankinsoni*
Bridle Shiner	*Notropis bifrenatus*
Brindled Madtom	*Noturus miurus*
Brook Silverside	*Labidesthes sicculus*
Brook Stickleback	*Culaea inconstans*
Brook Trout	*Salvelinus fontinalis*
Brown Bullhead	*Ameiurus nebulosus*
Brown Trout	*Salmo trutta*
Burbot	*Lota lota*
Central Mudminnow	*Umbra limi*
Central Stoneroller	*Campostoma anomalum*

Common Name	*Scientific Name*
Chain Pickerel	*Esox niger*
Channel Catfish	*Ictalurus punctatus*
Channel Darter	*Percina copelandi*
Chinook Salmon	*Oncorhynchus tshawytscha*
Coho Salmon	*Oncorhynchus kisutch*
Comely Shiner	*Notropis amoenus*
Common Carp	*Cyprinus carpio*
Common Shiner	*Luxilus cornutus*
Creek Chub	*Semotilus atromaculatus*
Creek Chubsucker	*Erimyzon oblongus*
Cutlips Minnow	*Exoglossum maxillingua*
Eastern Mudminnow	*Umbra pygmaea*
Eastern Sand Darter	*Ammocrypta pellucida*
Eastern Silvery Minnow	*Hybognathus regius*
Emerald Shiner	*Notropis atherinoides*
Fallfish	*Semotilus corporalis*
Fantail Darter	*Etheostoma flabellare*
Fat Sleeper Goby	*Dormitator maculatus*
Fathead Minnow	*Pimephales promelas*
Finescale Dace	*Phoxinus neogaeus*
Fourspine Stickleback	*Apeltes quadracus*
Freshwater Drum	*Aplodinotus grunniens*
Gizzard Shad	*Dorosoma cepedianum*
Golden Redhorse	*Moxostoma erythrurum*
Golden Shiner	*Notemigonus crysoleucas*
Goldfish	*Carassius auratus*
Grass Carp	*Ctenopharyngodon idella*
Grass Pickerel	*Esox americanus vermiculatus*
Gravel Chub	*Erimystax x-punctatus*
Greater Redhorse	*Moxostoma valenciennesi*
Green Sunfish	*Lepomis cyanellus*
Greenside Darter	*Etheostoma blennioides*
Hickory Shad	*Alosa mediocris*
Hogchoker	*Trinectes maculatus*
Hornyhead Chub	*Nocomis biguttatus*
Inland Silverside	*Menidia beryllina*
Iowa Darter	*Etheostoma exile*
Johnny Darter	*Etheostoma nigrum*

Common Name	***Scientific Name***
Koi	*Cyprinus rubrofuscus*
Kokanee/Sockeye Salmon	*Oncorhynchus nerka*
Lake Chub	*Couesius plumbeus*
Lake Chubsucker	*Erimyzon sucetta*
Lake Sturgeon	*Acipenser fulvescens*
Lake Trout	*Salvelinus namaycush*
Landlocked Salmon	*Salmo salar*
Largemouth Bass	*Micropterus salmoides*
Logperch	*Percina caprodes*
Longhead Darter	*Percina macrocephala*
Longnose Dace	*Rhinichthys cataractae*
Longnose Gar	*Lepisosteus osseus*
Longnose Sucker	*Catostomus catostomus*
Margined Madtom	*Noturus insignis*
Mimic Shiner	*Notropis volucellus*
Mooneye	*Hiodon tergisus*
Mottled Sculpin	*Cottus bairdii*
Mountain Brook Lamprey	*Ichthyomyzon greeleyi*
Mud Sunfish	*Acantharchus pomotis*
Mummichog	*Fundulus heteroclitus*
Muskellunge	*Esox masquinongy*
Ninespine Stickleback	*Pungitius pungitius*
Northern Brook Lamprey	*Ichthyomyzon fossor*
Northern Hog Sucker	*Hypentelium nigricans*
Northern Pike	*Esox lucius*
Northern Redbelly Dace	*Phoxinus eos*
Northern Snakehead	*Channa argus*
Northern Sunfish	*Lepomis megalotis*
Ohio Lamprey	*Ichthyomyzon bdellium*
Oriental Weatherfish	*Misgurnus anguillicaudatus*
Pearl Dace	*Margariscus sp*
Pirate Perch	*Aphredoderus sayanus*
Pugnose Shiner	*Notropis anogenus*
Pumpkinseed	*Lepomis gibbosus*
Quillback	*Carpiodes cyprinus*
Rainbow Darter	*Etheostoma caeruleum*
Rainbow Smelt	*Osmerus mordax*
Rainbow Trout	*Oncorhynchus mykiss*

Common Name	*Scientific Name*
Redbreast Sunfish	*Lepomis auritus*
Redear Sunfish	*Lepomis microlophus*
Redfin Pickerel	*Esox americanus americanus*
Redfin Shiner	*Lythrurus umbratilis*
Redside Dace	*Clinostomus elongatus*
River Chub	*Nocomis micropogon*
River Redhorse	*Moxostoma carinatum*
Rock Bass	*Ambloplites rupestris*
Rosyface Shiner	*Notropis rubellus*
Rosyside Dace	*Clinostomus funduloides*
Round Goby	*Neogobius melanostomus*
Round Whitefish	*Prosopium cylindraceum*
Rudd	*Scardinius erythrophthalmus*
Sand Shiner	*Notropis stramineus*
Satinfin Shiner	*Cyprinella analostana*
Sauger	*Sander canadensis*
Sea Lamprey	*Petromyzon marinus*
Sheepshead Minnow	*Cyprinodon variegatus*
Shield Darter	*Percina peltata*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Shortnose Sturgeon	*Acipenser brevirostrum*
Silver Lamprey	*Ichthyomyzon unicuspis*
Silver Redhorse	*Moxostoma anisurum*
Silver Shiner	*Notropis photogenis*
Silverjaw Minnow	*Notropis buccatus*
Slimy Sculpin	*Cottus cognatus*
Smallmouth Bass	*Micropterus dolomieu*
Smallmouth Redhorse	*Moxostoma breviceps*
Splake	*Salvelinus fontinalis x namaycush*
Spotfin Shiner	*Cyprinella spiloptera*
Spottail Shiner	*Notropis hudsonius*
Spotted Darter	*Etheostoma maculatum*
Spotted Sucker	*Minytrema melanops*
Stonecat	*Noturus flavus*
Streamline Chub	*Erimystax dissimilis*
Striped Bass	*Morone saxatilis*
Striped Killifish	*Fundulus majalis*

Common Name	*Scientific Name*
Striped Mullet	*Mugil cephalus*
Striped Shiner	*Luxilus chrysocephalus*
Summer Sucker	*Catostomus Utawana*
Swallowtail Shiner	*Notropis procne*
Swamp Darter	*Etheostoma fusiforme*
Tadpole Madtom	*Noturus gyrinus*
Tench	*Tinca tinca*
Tessellated Darter	*Etheostoma olmstedi*
Threespine Stickleback	*Gasterosteus aculeatus*
Tidewater Silverside	*Menidia beryllina*
Tiger Muskellunge	*Esox lucius x masquinongy*
Tiger Trout	*Salmo trutta x Salvelinus fontinalis*
Tonguetied Minnow	*Exoglossum laurae*
Trout Perch	*Percopsis omiscomaycus*
Variegate Darter	*Etheostoma variatum*
Walleye	*Sander vitreus*
Warmouth	*Lepomis gulosus*
Western Blacknose Dace	*Rhinichthys obtusus*
Western Mosquitofish	*Gambusia affinis*
White Bass	*Morone chrysops*
White Catfish	*Ameiurus catus*
White Crappie	*Pomoxis annularis*
White Mullet	*Mugil curema*
White Perch	*Morone americana*
White Sucker	*Catostomus commersonii*
Wreckfish	*Polyprion americanus*
Yellow Bullhead	*Ameiurus natalis*
Yellow Perch	*Perca flavescens*