Warmwater Fish Assemblage Indices of Biotic Integrity for New Hampshire Wadeable Streams

Moose Meadow Brook, Hooksett, NH

Beaver Brook, Pelham, NH

Hackett Brook, Concord, NH

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

July 2021

R-WD-21-10

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July 2021

ACKNOWLEDGEMENTS

Development of the Warmwater Fish Assemblage Indices of Biotic Integrity for New Hampshire wadeable streams would not have been possible without the previous work, expertise and guidance of David Neils, NHDES Chief Aquatic Biologist. This report was also made possible by the following two NHDES field crews that assisted with site reconnaissance and collected fish survey data: Colby Denison and Justin Sherman during the summer/fall of 2016 and 2017, and Maxwell Maynard and Brendan Polichronopoulos during the summer/fall of 2018 and 2019. NHDES also appreciates and thanks New Hampshire Fish and Game (NHFG) for sharing fish survey data, and John Magee (NHFG), Aaron Moore (Vermont Department of Environmental Conservation) and Tom Danielson (Maine Department of Environmental Protection) for their review of this report prior to publication.

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1. INTRODUCTION

An index of biotic integrity (IBI) is a method of evaluating biological condition of an aquatic resource. IBIs combine multiple metrics that measure how an aquatic resource, such as stream fish, responds to pollution and human disturbance. Stream fish assemblages are shaped, in part, by water temperature. Coldwater streams support trout and sculpins. Warmwater streams are too warm for trout or sculpins but have a variety of other fish. Coolwater streams could also be described as “transitional waters” with temperatures between coldwater and warmwater. The New Hampshire Department of Environmental Services (NHDES) previously developed IBIs for coldwater fish assemblages (NHDES 2007) and coolwater (transitional water) fish assemblages (NHDES 2011) of the state. The objective of this project was to develop IBIs for warmwater streams in New Hampshire.

NHDES created an IBI for high gradient warmwater streams and another IBI for low gradient warmwater streams because high gradient and low gradient streams can have different fish assemblages. High gradient and low gradient sites refer to basin or watershed gradients, not stream gradient, referenced as mean basin slope as defined by the United States Geological Survey (USGS). NHDES proposes the use of logistic regression to assign likely membership of a site to each group (i.e., high gradient and low gradient). Sites were scored separately for each of the warmwater IBIs with a final score represented through a weighted warmwater IBI (WWIBI) score. Score weights were based on predicted membership to each group, thereby acknowledging and accounting for the known continuum across all warmwater sites from high gradient to low gradient. Typical indicator fish species found in warmwater high gradient sites include blacknose dace, longnose dace and creek chub. Typical warmwater low gradient indicator species include fallfish, common sunfish (pumpkinseed), margined madtom, golden shiner, yellow bullhead, and bluegill. Fish species found in both high gradient and low gradient systems include common shiner and common white sucker.

Basin gradients for warmwater high gradient and low gradient systems within the calibration dataset generally ranged from 8% to 18% and 5% to 12%, respectively. Seventy-five percent of warmwater high gradient calibration sites had basin gradients greater than 11.2% while, 75% of warmwater low gradient calibration sites had basin gradients less than 8.6%. Application of the WWIBIs to sites with basin gradients less than 3%, typically found adjacent to New Hampshire’s tidal waters, is not appropriate, and caution should be applied for sites with basin gradients between 3% and 5%.

The WWIBIs developed herein are a numeric interpretation of the narrative water quality criteria as stated in NHDES Administrative Rules Env-Wq 1700 covered under the statutory authority given in RSA 485-A:8, VI. Specifically, the narrative standard is detailed in section Env-Wq 1703.19 as:

Env-Wq 1703.19 Biological and Aquatic Community Integrity

> **(a)** The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and

functional organization comparable to that of similar natural habitats of a region.

(b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.

NHDES will use the WWIBIs to assess, in part, the condition of applicable aquatic communities. Specifically, assessments under this authority will be made for aquatic life use determinations as required for 305(b)/303(d) reporting to the U.S. Environmental Protection Agency (EPA). Additional applications include, but are not limited to, the establishment of permit limits, determination of non-point source water quality impacts, water quality planning and ecological risk assessment (Barbour et al. 1999).

As a two-part narrative criterion, the goal of index development was to first identify the natural structure and function of the fish assemblages residing in the pertinent natural habitats [1703.19(a)], and second, to determine when a detrimental departure from the natural condition has occurred [1703.19(b)]. The basic approach taken for developing the WWIBIs was the identification of a suitable reference condition and establishment of a natural range of variation within this reference condition (= identification of natural structure and function). Once identified, a reference condition threshold was established below which the biological condition includes detrimental changes in overall aquatic community structure and function (= departure from natural condition). If a warmwater fish assemblage did not meet the reference condition threshold, then the stream would not attain narrative criteria for aquatic life use as outlined in Env-Wq 1703.19.

2. GENERAL PROCESS FOR IBI DEVELOPMENT

Indices of biological integrity for fish assemblages have been developed using a variety of approaches over the past 40 years (Karr 1981; Leonard and Orth 1986; Lyons et al. 1996; Mundahl and Simon 1999; Langdon 2001; Daniels et al. 2002; Hughes et al. 2004, and Whittier et al. 2007). While these approaches differ in their objectivity, data analysis approaches and final index evaluation system, most follow the same basic developmental principles to arrive at a final condition index to characterize the overall structure and function of the fish assemblage. NHDES chose a multimetric index approach to developing a WWIBI for wadeable streams in New Hampshire.

The process of developing a numeric index that interprets the biological condition of warmwater fish assemblages was similar to that described by Barbour et al. (1995) and included five basic steps:

1) ***Reference sites selection***: An *a-priori* process used to select sites with minimal human impacts in order to establish the minimally impacted biological condition.

2) ***Warmwater fish assemblage identification***: The determination of indicator species, assemblage diversity, applicable area and non-biological factors that describe this assemblage type.

3) ***Identification of biological response indicators (metrics)***: The selection of the best ecological measures of community structure and function. Generally known as metric selection.

4) ***Establishment of index scoring criteria and thresholds***: A comparison of reference and non-reference biological conditions for the purpose of determining when substantial unnatural impacts to ecological structure and function have occurred.

5) ***Validation of index:*** Testing of metric responses, comparison of reference and non-reference conditions, and testing of the proposed threshold with an independent dataset.

The resulting WWIBIs included multiple response indicators (i.e. multi-metric) that were considered to quantify the biological condition of applicable streams. Separate high gradient and low gradient warmwater indices were comprised of different metrics to reflect different structure and function of high and low gradient fish assemblages. Each index was developed to be sensitive to human disturbance in that it demonstrates declining biological conditions in response to increasing anthropogenic impacts. A singular weighted WWIBI score accounts for the predicted membership to warmwater high gradient and warmwater low gradient assemblages based on physical, environmental variables that do not change.

3. METHODS

3.1 Identification of Expected Warmwater Fish Assemblage Areas

Geographic boundaries of streams and rivers expected to support coldwater fish species [coldwater (CW) and transitional water (TW) assemblages] year round were delineated using predictions from a logistic regression model based on latitude, longitude, and upstream drainage area (NHDES, 2007a). The area not contained within the predicted geographic areas (Figure 1) was expected to contain warmwater fish assemblages and subsequently included in development of the WWIBIs. See Appendix A describing the process for identifying New Hampshire fish assemblages (CW, TW and WW). On occasion, sites within the predicted warmwater area were found to hold coldwater fish species. These sites were removed from the warmwater assemblage dataset.

3.2 Dataset

The development of condition indices for warmwater fish assemblages included fish survey data collected from 1983 through 2019 from 285 sites located in wadeable 1st to 6th order streams and rivers. Data included in the development process originated from sampling performed by NHDES and the New Hampshire Fish and Game Department (NHFG). For all sites, as many fish as possible were collected during active sampling. After sampling was complete all fish were identified, enumerated, recorded and returned to the river or stream from which they were collected.

Each of the 285 sites met the following conditions:

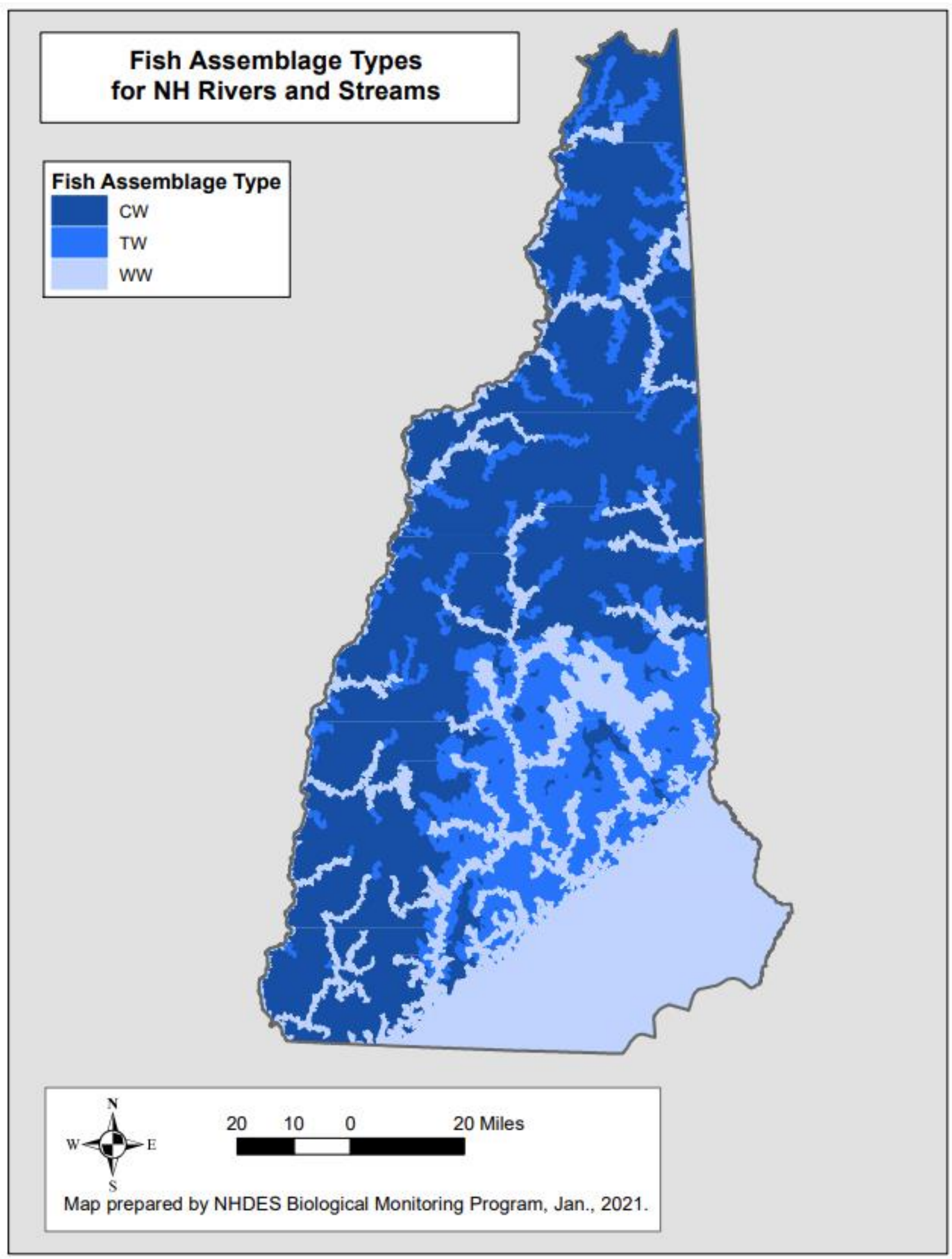
a) Percent coldwater probability ≤50 (based on CW logistic regression model).
b) Stream order ≤6.
c) Backpack electrofishing length ≥100 meters, single pass.
d) ≥ 30 individuals (with exception of 3 validation sites).
e) Percent warmwater and eurythermal individuals ≥85.
f) No presence of slimy sculpin.
g) No presence of wild brook trout, brown trout, or rainbow trout (hatchery fish were removed from the dataset).

Of the 285 sites, 128 were NHFG sites and 157 were NHDES sites. Of the 128 NHFG sites, 63 (49%) sites were placed in the calibration dataset and 65 (51%) sites were placed in the validation dataset. Of the 157 NHDES sites, 122 (78%) sites were placed in the calibration dataset and 35 (22%) were placed in the validation dataset. See Appendix B for a list of sites in the calibration dataset (185 sites) and Appendix C for a list of sites in the validation dataset (100 sites). Site attribute descriptions can be found in Appendix D. See Appendix E for a map of calibration and validation sites.

The calibration dataset included 185 sites (43 reference, 142 non-reference) sampled from 1997 through 2017. While there were no data quality concerns preventing the use of older data, sites with data collected prior to 1997 were removed from the calibration dataset to allow IBI calibration based on most recent data of robust data quality. Sites considered reference had minimal watershed disturbance with less than 5% watershed development as defined by 2011 National Land Cover Dataset (2011 NLCD, classes 21-24). Each of the 43 reference sites was also evaluated for additional disturbances through satellite imagery inspection not revealed by the land cover data. The remaining 142 non-reference sites were set aside to test the performance of candidate biologic metrics by comparing reference and non-reference sites. Watershed and waterbody physical characteristics of the reference and non-reference populations of the calibration set were evaluated for differences.

Land use variables and alternative watershed development percentages were considered when defining site reference conditions. New Hampshire does not have a large amount of land use activities other than developed or forested, such as intense agriculture or other industry, that would substantially alter water quality. Therefore, applying watershed development was an appropriate land use variable for defining reference condition. Further, adjusting the percent development cutoff for defining a site's reference condition was also evaluated. Ideally, an IBI could be developed based on fully forested sites with no watershed development. However, selecting sites with less than 5% watershed development to calibrate the IBI would have greatly limited the number of reference sites available to develop the IBI. Applying a percent development threshold greater than 5% tended to include non-reference site conditions based upon site evaluations. Therefore, selecting 5% watershed development was considered to be an appropriate and realistic threshold for defining a site's reference condition.

Figure 1. Map of NH cold water (CW), transitional water (TW), and warmwater (WW) fish assemblage types.



The validation dataset consisted of 100 sites to test the performance of selected metrics. This included sites where survey data was collected either prior to 1997 (65 sites) or in 2018-2019 (35 sites). Percent watershed development for each site relied the most relevant NLCD dataset: the 2001 National Land Cover Dataset (2001 NLCD) for sites with fish survey data prior to 1997 or the 2011 NLCD, for sites with fish survey data collected in 2018-2019.

Table 1 provides a summary of calibration and validation sites, indicating the agency responsible for collecting the fish survey data according to watershed development category.

Table 1. Summary of sites by calibration/validation dataset, agency and watershed development category. Watershed development categories included reference (<5% development), moderate (5-15% development) and high (>15% development).

Calibration Sites				
	Reference	Moderate	High	Totals
NHDES	31	65	26	122
NHFG	12	41	10	63
Total	43	106	36	185
Validation Sites				
	Reference	Moderate	High	Totals
NHDES	10	14	11	35
NHFG	54	10	1	65
Total	64	24	12	100
Grand Total	107	130	48	285

3.3 Site Classification

A cluster analysis [Sorensen (Bray-Curtis) distance measure] based on the number of individuals for each species across each of the 43 references sites was performed. No fish species were removed from the dataset based on rarity. Sites were categorized in one of two groups in accordance with the resulting dendrogram. Next, an NMDS ordination plot for each of the 43 references sites (primary matrix) was developed. Cluster analysis group assignments were overlayed on the NMDS plot. Finally, watershed physical parameter data (secondary matrix) was evaluated (joint plot vector) to determine which watershed characteristics were most important in describing the sites.

Several steps were taken to assist with determining which of the physical watershed characteristics best predicted the warmwater site group category. Frequency distributions of non-changeable watershed characteristics were compared between the two groups. Ultimately, this lead to development of a logistic regression equation using the most important physical characteristics to predict assignment to one of two fish assemblage groups. A probability threshold of 0.50 was used to assign predicted membership to one assemblage group or the other.

3.4 Species Analysis

Patterns of fish species occurrence and abundance were evaluated to identify species affiliated with one or both assemblage groups. This information can help the process of developing and understanding potential fish metrics for each assemblage group. Indicator species analysis assigned each species to one group or the other based on patterns of both occurrence and abundance. For example, a species that primarily occurred in and was most abundant in one group of streams could be an indicator species. A species that was common and had similar abundances in both groups of streams would not be an indicator species. Indicator species analysis also computed the probability of a species reliably occurring in one group of streams and not the other group of streams. Species with a probability (p-value) less than 0.05 were determined to be reliable indicators of one or the other assemblage group. A table of species frequency of common species was created. Tables of species frequency and abundance were created identifying for each assemblage group. Species were ranked in terms of number of sites, total number of individuals, and relative abundance. For example, the most abundant species received the highest rank (1) and the least abundant species received the lowest rank. An overall rank was assigned to each species based on their ranks for the following categories: 1) number of sites present; 2) percent of all individuals; and 3) average number of individuals/ site. Finally, species richness of each warmwater group were compared to the number of species that occurred in coldwater and transitional water reference sites.

3.5 Biological Response Indicators (Fish Metrics)

Metrics are measurable attributes of a biological community that show a predictable response to human disturbance, such as alteration of forest and wetlands to urban and agricultural land. A list of potential candidate metrics was started by selecting metrics from previously developed fish indices (Hughes et al. 2004; Karr 1981; Langdon 2001; Leonard and Orth 1986; Lyons et al. 1996; Mundahl and Simon 1999; Daniels et al. 2002; Whittier et al. 2007, and D. Peck, personal communication, 2017). Other candidate metrics were added to the list based on analysis of New Hampshire data, such as individual species or species groupings as a result of indicator species analysis, frequency analysis, or other evaluations based on professional observations and experience. Candidate metrics considered trophic class, tolerance to pollution, thermal preference, streamflow preference, species richness, reproductive strategy and success, species composition, and origin (native or introduced). Candidate metrics were based upon autecological characteristics either as defined by NHDES or by the 2018 National Rivers and Streams Assessment (NRSA 2018). Species common names and scientific names, along with the respective ecological, pollution tolerances, thermal preferences, reproductive strategies and origin for the most commonly encountered species as defined by NHDES and the NRSA, can be found in Appendix F and G. Autecological characteristics as defined by NHDES and the NRSA can be found in Appendix H and I. For each metric within each warmwater group, an *a priori* expected response to impact was determined and applied in the metric evaluation process. Expected responses were either positive (i.e. higher for reference than sites with watershed development) or negative (lower for reference than sites with watershed development).

A total of 153 candidate metrics based upon autecological groupings and single species percentage of total individuals were considered for testing their ability to respond to varying levels of human disturbance for each of the two groups. Twenty-eight of the 153 metrics were removed from consideration as they could not be considered as either a positive or negative metric for either group. The remaining 125 metrics were selected for testing for each group. Expected responses were the same for both warmwater groups with a few exceptions as noted in the appendices.

Candidate metrics were evaluated separately for each group. Candidate metrics were evaluated and ranked based on their ability to distinguish reference sites from impacted sites. This analysis included reference sites (<5% watershed development), moderately impacted sites (5-15% watershed development), and highly impacted sites (>15% watershed development). For Group A sites, metrics were evaluated by comparing metric values from reference sites to highly developed sites. For Group B sites, metrics were evaluated by comparing metric values from reference sites to moderately developed sites, because there were no highly developed Group B sites in the study. The strength of a metric was computed with equations in Table 2, depending on if the candidate metric was a positive or negative metric.

Three measures of metric performance were first considered: 1) summation of metric scoring equations; 2) a tally of the total number of positive or negative equation scores (depending on expected response); and 3) visual inspection of the box and whisker plots on the metrics having the greatest potential for IBI development. Performance measures 1 and 2 relate to the metric scoring equations provided in Table 2. For performance measure 1, candidate metrics having the greatest positive values for positive metrics or greatest negative values for negative metrics were considered the strongest candidate metrics. For performance measure 2, equation tallies ranged from 0 to 3. Candidate metrics having equation tallies at or near 3 were considered the strongest candidate metrics. When possible, candidate metrics were also selected to balance the index with regards to the number of positive and negative response metrics, major metric categories, and important fish assemblage characteristics. Pearson's correlation coefficient was performed to test metric redundancy. A target maximum correlation coefficient of 0.70 was established whereby metrics with correlation coefficients greater than this value were considered excessively redundant requiring the selection of one or the other or justification for further inclusion. Final metrics for inclusion in the index were based on metric performance measures, selecting metrics that balanced metric response, metric categories and importance fish assemblage characteristics, redundancy testing, and best professional judgement.

Table 2. Scoring equations for positive and negative metrics. Reference (ref) = sites with <5% watershed development. Developed (dev) = sites with >15% development (Group A) or >5% development (Group B).

Positive Metric Scoring Equations (Positive score = strong metric signal)
Level 1 = (Median (ref) – Median (dev))/ Median (ref)
Level 2 = (Median (ref) -75th (dev))/Median (ref)
Level 3 = (25th (ref) – 75th (dev))/25th (ref)
Negative Metric Scoring Equations (Negative score = strong metric signal)
Level 1 = (Median (ref)- Median (dev))/ Median (dev)
Level 2 = (75th(ref) – Median(dev))/Median(dev)
Level 3 = (75th (ref) – 25th (dev))/25th (dev)

3.6 WWIBI Point Assignment, Scoring and Threshold Identification

Point assignment for individual metrics were established by reviewing the frequency distributions of raw metric values of reference and impacted sites of the calibration dataset. Specifically, three scoring categories for each metric were established to be consistent with previously developed fish indices in Vermont by the Vermont Department of Environmental Conservation (VTDEC) (VTDEC 2004) and in New Hampshire by NHDES for the coldwater assemblage (NHDES 2007) and transitional water (coolwater) assemblage (NHDES 2011), with higher scores representing better condition. For each metric, percentiles and median values of reference sites (25^{th} percentile and median for positive response metrics or 75^{th} percentile and median for negative response metrics) were evaluated in order to assign logical breakpoints. For each metric, points were assigned to the respected categories based on the breakpoints. For each site, a final score was computed for each index by summing individual metric points. Recognizing fish assemblages do not always fit into distinct categories, a final weighted WWIBI score was calculated. The weighted score was calculated for each site by summing the final index scores multiplied by their respective group membership as determined by the logistic regression equation using latitude and basin slope.

A threshold for aquatic life use attainment was selected based on the 25^{th} percentile of the weighted WWIBI reference site scores rounded up to the nearest whole number.

3.7 Final Index Score Performance Evaluation

As a visual check on the ability of the index to discriminate along a human disturbance gradient, all weighted WWIBI scores of the validation sites were plotted against the respective percent watershed development for each site. Sites that had high watershed development and high scores or low watershed development and low scores were further evaluated. Lastly, a site's weighted

WWIBI score was evaluated against the weighted WWIBI threshold. The number of sites meeting and failing to meet this threshold was determined.

4. RESULTS

4.1 Warmwater Fish Assemblage Area

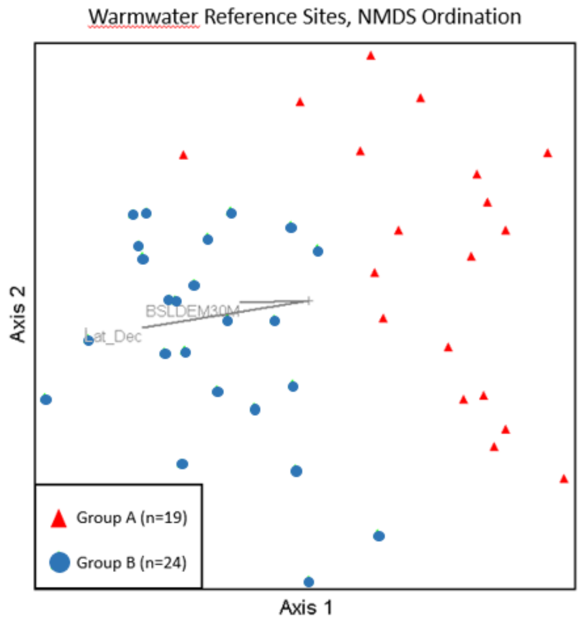
Riverine fish assemblages in New Hampshire are dependent on latitude, longitude, elevation, and drainage basin size. The applicable warmwater fish assemblage area is primarily located in the southern part of the state. The area identified to contain warmwater fish assemblages and subsequently applicable to the WWIBIs was 2,543 square miles (27.2%) of the New Hampshire landscape (Figure 1), noting that many larger rivers and streams within this area are not considered wadeable, and not applicable to the WWIBIs.

4.2 Site Classification

The cluster analysis based on species abundance resulted in two fish assemblage groups (Appendix J). An NMDS ordination plot coupled with an overlay of cluster analysis outcomes for the 43 reference sites confirmed sites separated in two distinct groups (Figure 2) with minimal overlap. Watershed physical parameter data was evaluated (joint plot vector) and showed that two watershed characteristics; site latitude (dd.dddd) and watershed basin gradient (percent) were most important in describing the differences between the two groups and were most closely correlated to axis 1 on the NMDS plot.

To further investigate the differences between Group A and Group B reference site physical characteristics an expanded suite of variables including latitude and basin gradient were evaluated and compared (Table 3). Five of the nine watershed characteristics, including latitude and basin slope, were significantly different ($p<=0.05$). Latitude had a median 0.19 decimal degree difference between group A and group B, which equates to approximately 13 miles. Average basin gradient ranged from 5.8-12.0% for group A sites and 8.0-17.3% for group B sites. Due to the difference in basin gradient between the two groups, group A sites were defined as warmwater low gradient (WWLG) and group B sites were defined as warmwater high gradient (WWHG).

Figure 2. NMDS ordination plot of 43 warmwater fish assemblage reference sites. Red triangles = Group A; Blue circles = Group B; as identified through cluster analysis. Vectors for a site's mean basin gradient (BSLDEM30M) and site latitude (Lat_Dec) represent environmental characters with greatest NMDS axes correlation.



To predict a site's membership to WWLG or WWHG a logistic regression analysis was performed that included the five watershed characteristics that were significantly different ($p<=0.05$) according to Mann-Whitney U tests. Three of the five watershed characteristics, (drainage area, maximum drainage area elevation and percent wetland) explained minimal variation in the logistic regression model and were therefore excluded from further consideration. A final logistic regression model to that predicted a site's probability to the WWLG group was developed using the remaining watershed characteristics, latitude and mean basin slope described as:

Probability Equation that site belongs to WWLG =

1/(1+EXP(-(276.423+(-6.288*(latitude)) + (-0.525*(mean basin gradient)))))

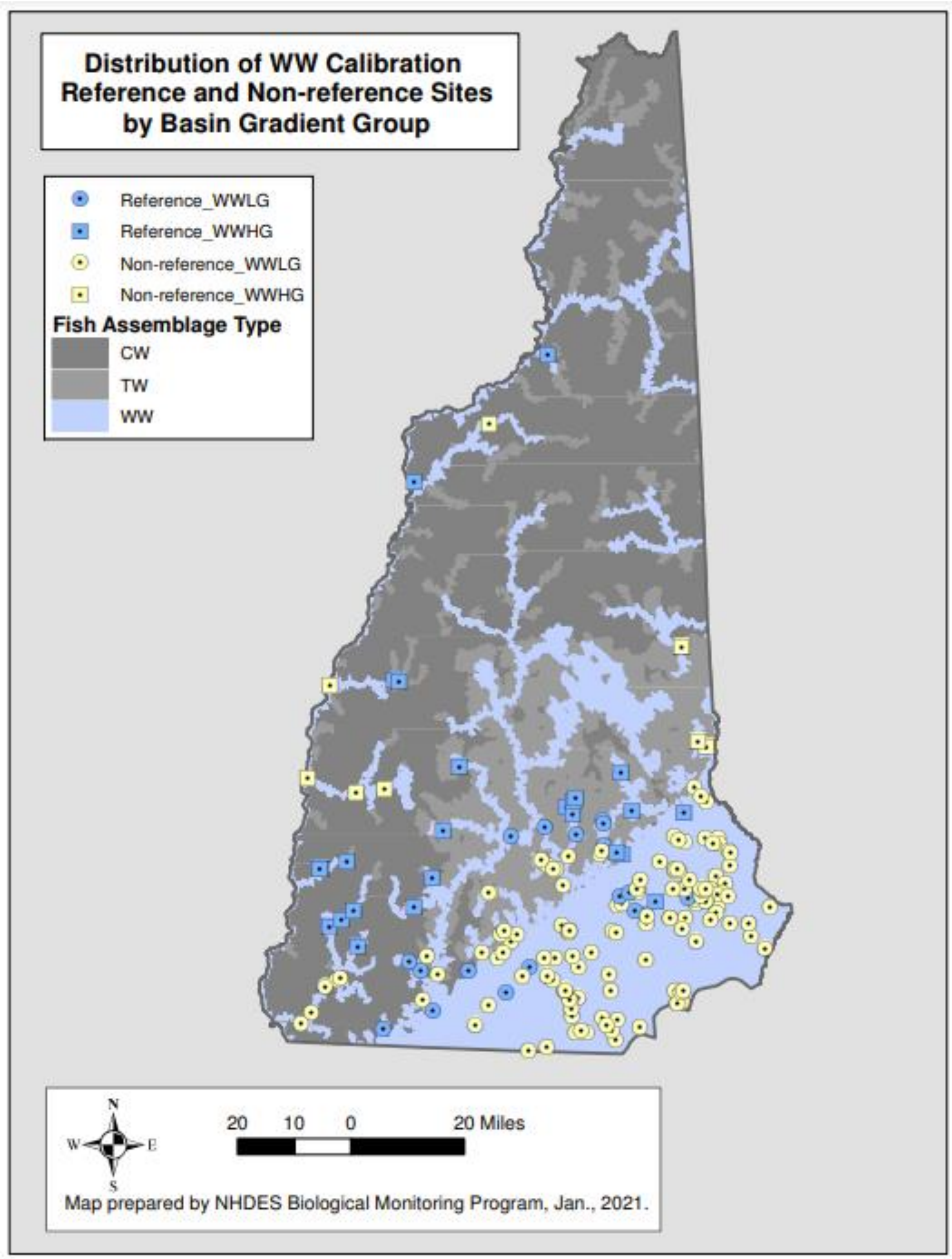
"Latitude" equals a site's latitude in decimal degrees and "mean basin gradient" is the mean basin gradient (slope) as percent, which is an area weighted mean computed from 30 meter DEM and abbreviated as BSLDEM30M (U.S. Geological Survey, 2016, The StreamStats program for New Hampshire).

Sites with a resulting probability greater than or equal to 0.50 were assigned to the WWLG group. Sites with a resulting probability less than 0.50 were assigned to the WWHG group. Predictions of group membership from the logistic regression equation were inconsistent with the cluster analysis results for only 5 of the 43 reference sites. The model predicted the appropriate reference warmwater group almost 90% of the time. The logistic regression equation was used to assign the expected warmwater assemblage group to the non-reference sites (Figure 3) to complete the index development process. Additionally, the model is considered suitable for use in classifying sites along a continuous scale from low to high gradient warmwater fish assemblages.

Table 3. Summary of physical characteristics differences between group A (WWLG) and group B (WWHG) reference sites.

Watershed Characteristic	Mann-Whitney U test result significance (p<=0.05) (Yes/No)	Statistic	Calibration Reference Sites (n=43)	
			Group A (n=18)	Group B (n=25)
Latitude (dd.dddd)	Yes	Median	43.0773	43.2675
		Min	42.7589	42.9713
		Max	43.2927	44.4817
Longitude (dd.dddd)	No	Median	-71.5094	-71.9188
		Min	-72.1241	-72.3498
		Max	-71.0637	-71.0781
Station Elevation (ft.)	No	Median	351.8	626.6
		Min	118.1	269.0
		Max	1075.3	1062.4
Dam Density (dams/ sq. mi.)	No	Median	0.3	0.3
		Min	0.1	0.0
		Max	0.7	0.8
Drainage Area (sq. mi.)	Yes	Median	10.4	51.1
		Min	2.5	2.0
		Max	161.2	401.9
Change in Main Stem Slope (USGS CSL10_85, ft./mile)	No	Median	39.5	50.1
		Min	18.2	19.3
		Max	171.7	139.1
Mean Basin Gradient (USGS BSLDEM30M, %)	Yes	Median	7.9	12.0
		Min	5.8	8.0
		Max	12.0	17.3
Max Drainage Area Elevation (ft.)	Yes	Median	1221.3	2161.6
		Min	494.2	971.1
		Max	2339.3	6283.8
Drainage Area, % Wetland	Yes	Median	7.1	5.3
		Min	2.4	1.5
		Max	16.6	10.1

Figure 3. Map of reference and non-reference calibration sites identified as either warmwater low gradient (WWLG) or warmwater high gradient (WWHG) by logistic regression.



4.3 Indicator Species Analysis

A total of 50 fish species exist in New Hampshire (Table 4) that prefer or can survive warm water temperatures based upon species profiles detailed in Freshwater Fishes of New Hampshire (Scarola 1973), Fishes of Vermont (Langdon et al. 2006), and best professional judgment. However, of those 50 species, many primarily inhabit large rivers and lentic waterbodies or have low population densities and are therefore rarely captured during electrofishing surveys of wadeable streams. As a result, 22 out of the 50 species did not have a single individual recorded for any of the 43 wadeable stream and river reference sites. Ten of the remaining 28 species found in the 43 reference sites were identified as indicator species (Table 5). Seven species [bluegill, creek chubsucker, common sunfish (pumpkinseed), fallfish, golden shiner, margined madtom, and yellow bullhead] were associated with WWLG sites. Three species (blacknose dace, creek chub and longnose dace) were associated with WWHG sites.

Table 4. Warmwater and eurythermal fish species abbreviations, common names and scientific names found in New Hampshire.

Species Abbr.	Common Name	Scientific Name	Species Abbr.	Common Name	Scientific Name
ABL	AMER. BROOK LAMPREY	*Lampetra appendix*	GS	GOLDEN SHINER	*Notemigonus crysoleucas*
AE	AMERICAN EEL	*Anguilla rostrata*	LMB	LARGEMOUTH BASS	*Micropterus salmoides*
ASH	AMERICAN SHAD	*Alosa sapidissima*	LND	LONGNOSE DACE	*Rhinichthys cataractae*
AW	ALEWIFE	*Alosa pseudoharengus*	MMG	MUMMICHOG	*Fundulus Heteroclitus*
BBH	BROWN BULLHEAD	*Ameiurus nebulosus*	MMT	MARGINED MADTOM	*Noturus insignis*
BC	BLACK CRAPPIE	*Pomoxis nigromaculatus*	MS	MIMIC SHINER	*Notropis volucellus*
BDK	BANDED KILLIFISH	*Fundulus diaphanus*	NP	NORTHERN PIKE	*Esox lucius*
BDS	BANDED SUNFISH	*Enneacanthus obesus*	NRD	NORTHERN REDBELLY	*Phoxinus eos*
BG	BLUEGILL	*Lepomis macrochirus*	NSS	NINESPINE	*Pungitius*
BND	EASTERN BLACKNOSE	*Rhinichthys atratulus*	RB	ROCK BASS	*Ambloplites rupestris*
BNM	BLUNTNOSE MINNOW	*Pimephales notatus*	RBS	REDBREAST SUNFISH	*Lepomis auritus*
BNS	BLACKNOSE SHINER	*Notropis heterolepis*	RFP	REDFIN PICKEREL	*Esox americanus*
BS	BRIDLE SHINER	*Notropis bifrenatus*	RFS	ROSYFACE SHINER	*Notropis rubellus*
CC	CREEK CHUB	*Semotilus atromaculatus*	RSD	ROSYSIDE DACE	*Clinostomus funduloides*
CCS	CREEK CHUBSUCKER	*Erimyzon oblongus*	SD	SWAMP DARTER	*Etheostoma fusiforme*
CLM	CUTLIP MINNOW	*Exoglossum maxillingua*	SL	SEA LAMPREY	*Petromyzon marinus*
CRP	COMMON CARP	*Cyprinus carpio*	SM	EASTERN SILVERY	*Hybognathus regius*
CS	COMMON SHINER	*Luxilus cornutus*	SMB	SMALLMOUTH BASS	*Micropterus dolomieu*
CSF	PUMPKINSEED	*Lepomis gibbosus*	STK	STRIPED KILLIFISH	*Fundulus majalis*
CWS	WHITE SUCKER	*Catostomus commersoni*	STS	SPOTTAIL SHINER	*Notropis hudsonius*
ECP	CHAIN PICKEREL	*Esox niger*	TD	TESSELLATED DARTER	*Etheostoma olmstedi*
ES	EMERALD SHINER	*Notropis atherinoides*	WLE	WALLEYE	*Stizostedion vitreum*
FF	FALLFISH	*Semotilus corporalis*	WP	WHITE PERCH	*Morone americana*
FHM	FATHEAD MINNOW	*Pimephales promelas*	YBH	YELLOW BULLHEAD	*Ameiurus natalis*
GF	GOLDFISH	*Carassius auratus*	YP	YELLOW PERCH	*Perca flavescens*

Table 5. Indicator species analysis of 43 calibration reference sites categorized by NMDS cluster analysis; 19 WWLG and 24 WWHG. Of 28 New Hampshire WW fish species, 10 were found to be potential indicator species for one of the two groups (p<0.05) as highlighted in yellow and marked with an asterisk (*).

Species Abbreviation	Indicator Group	Observed Indicator Value (IV)	Mean	Std. Dev.	p
ABL	WWHG	4.2	4.7	0.55	1.0000
AE	WWLG	15.8	8.0	3.42	0.0774
BBH	WWLG	13.7	18.6	5.87	0.7978
BC	WWLG	5.3	4.7	0.55	0.4489
BDS	WWLG	5.3	4.7	0.55	0.4453
BG*	WWLG	24.8	12.5	4.74	0.0430
BND*	WWHG	78.2	43.6	6.83	0.0002
BNS	WWHG	4.2	4.6	0.55	1.0000
BS	WWHG	4.2	4.6	0.55	1.0000
CC*	WWHG	37.5	20.2	6.08	0.0050
CCS*	WWLG	21.1	9.6	4.1	0.0312
CS	WWLG	49.0	42.4	6.83	0.1628
CSF*	WWLG	56.0	30.4	7.6	0.0016
CWS	WWHG	46.0	49.7	6.01	0.6725
ECP	WWLG	29.8	28.6	6.2	0.3465
FF*	WWLG	80.4	45.3	7.48	0.0002
GS*	WWLG	31.3	14.6	5.42	0.0068
LC	WWLG	5.3	4.6	0.55	0.4289
LMB	WWLG	28.2	19.4	5.54	0.0896
LND*	WWHG	70.8	43.3	6.71	0.0016
MMT*	WWLG	52.6	18.6	5.8	0.0002
RBS	WWLG	9.7	11.3	4.72	0.5407
RFP	WWLG	5.3	4.6	0.55	0.4271
SMB	WWLG	14.6	13.0	5.01	0.3291
STS	WWHG	8.3	6.0	3.22	0.4897
TD	WWLG	12.4	17.3	5.72	0.7962
YBH*	WWLG	26.9	14.5	5.23	0.0292
YP	WWLG	12.4	12.8	4.87	0.4137

p = proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
Indicator Group = Group identifier for the group with maximum observed indicator value (IV).
Observed Indicator Value (IV) = frequency of occurrence a given species was found in the Max Group (low gradient, n=19, high gradient, n=24)
Mean = frequency of occurrence a given species was found across all reference calibration sites (n=43).

4.4 Fish Species Frequencies of Occurrence

Twelve fish species were routinely found at warmwater calibration sites (Table 6). Two species, common shiner and common white sucker were frequently found at both WWLG and WWHG sites. Common shiner had similar site frequencies of 67% and 68% for WWLG and WWHG sites, respectively. Common white sucker also had similar site frequencies of 89% and 80% for WWLG and WWHG sites, respectively. Neither species was identified as an indicator species because they were just as likely to occur in low gradient and high gradient streams.

The remaining 10 species were identified as indicator species of either the WWLG or WWHG groups in the indicator species analysis (Table 6). The seven indicator species for the WWLG streams were more frequently captured in the low gradient streams than the high gradient streams. Four of those species (pumpkinseed, fallfish, margined madtom and yellow bullhead) had frequencies greater than 30%. The three indicator species (blacknose dace, creek chub and longnose dace) for the WWHG group were more frequently captured in high gradient streams than low gradient streams. Of the high gradient sites, 84% had blacknose dace, 36% had creek chub, and 76% had longnose dace. The greatest differences in relative abundance between WWLG and WWHG groups were for fallfish, margined madtom, blacknose dace and longnose dace.

Table 6. Species frequency analysis and species relative abundance (average number of individuals per site) of 43 calibration reference sites (18 WWLG and 25 WWHG) categorized by logistic regression output (predictor of WW group). Ten of the 12 species associated with either WWLG or WWHG per the indicator species analysis. WWLG indicator species analysis group and species shaded red. WWHG indicator species analysis group shaded blue.

	Species Frequency (percent of sites)											
Indicator Species Analysis Group	WWLG							WWHG			----	
	BG	CCS	CSF	FF	GS	MMT	YBH	BND	CC	LND	CS	CWS
WWLG (n=18)	28%	22%	61%	83%	28%	44%	33%	50%	0%	61%	67%	89%
WWHG (n=25)	4%	0%	16%	60%	8%	8%	4%	84%	36%	76%	68%	80%
	Species Relative Abundance (Average Number of Individuals per Site)											
WWLG (n=18)	0.7	2.8	6.5	39.1	4.3	15.4	2.0	11.5	0.0	8.6	26.3	12.9
WWHG (n=25)	0.0	0.0	0.2	6.9	0.2	0.8	0.3	37.9	3.0	26.9	13.6	11.0

4.5 Coldwater and Transitional Assemblages vs. Warmwater Assemblages

Coldwater and transitional water fish assemblages greatly differ from warmwater assemblages in that they occur where coldwater fish can survive year round. Development of the Coldwater IBI (CWIBI) utilized 33 calibration dataset reference sites and included 3,008 individuals from 10 species (NHDES, 2007a). The five species with the highest relative frequency, in decreasing order, from CWIBI reference sites were brook trout (94% of sites), slimy sculpin (76%), blacknose dace (37%), longnose dace (24%) and rainbow trout (12%). Brook trout, slimy sculpin and rainbow trout are all considered coldwater species. Transitional water fish assemblages still contain coldwater species such as brook trout and slimy sculpin, but also see an increase in frequency of other species, such as blacknose dace, longnose dace and longnose sucker. Development of the transitional Water IBI (TWIBI) from 31 calibration dataset reference sites included 3,318 individuals from 14 species (NHDES, 2011). Overall, blacknose dace was the most commonly collected species (87% of sites), followed by brook trout (77%), longnose dace (65%), longnose sucker (58%) and slimy sculpin (58%).

Development of the high gradient WWIBI from 25 WWHG calibration reference sites included 2,692 individuals from 23 species. Similar to transitional water fish assemblages, blacknose dace was the most commonly collected species (84% of sites). The other most commonly collected species were common white sucker (80%), longnose dace (76%), common shiner (68%) and fallfish (60%) (Table 7). Species with the highest percent of all individuals included the same five species; blacknose dace (35%), longnose dace (25%), common shiner (13%), common white sucker (10%) and fallfish (6%). Fifteen of the remaining 18 species had a relative abundance less than 1%.

The development of the low gradient WWIBI from 18 WWLG calibration reference sites included 2,512 individuals from 23 species. Overall, common white sucker was the most commonly collected species (89% of sites), followed by fallfish (83%), common shiner (68%), longnose dace (61%) and blacknose dace (50%) (Table 8). Species with the highest percent of all individuals included fallfish (28%), common shiner (19%), margined madtom (11%), common white sucker (9%) and blacknose dace (8%). Ten of the remaining 18 species had average number of individuals per site present values less than 1%.

Table 7. Frequency of occurrence, total number of individuals, and average number of individuals per sites present of fish species collected at WWHG fish assemblage reference sites (n=25). Rank of ranks is inverse ranking of sum of ranks for # sites present, percent of all individuals, and average # individuals/sites present. Top five ranked species for each category, sum of ranks, and final rank of ranks shaded grey.

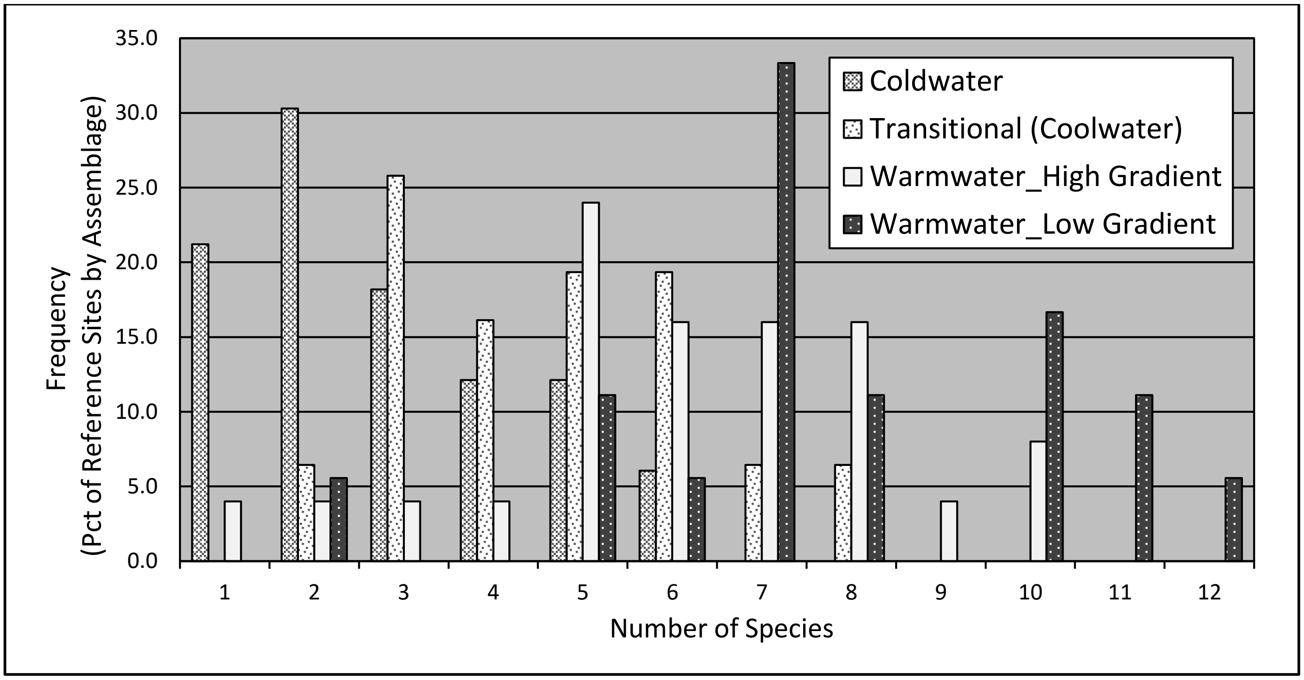
Species	# Sites Present	% of Sites Present	Rank	Total Number Individuals	% of All Individuals	Rank	Avg. # Individuals / Sites Present	Rank	Sum of Rank	Rank of Ranks
ABL	1	4.0	19	1	0.0	21	1.0	21	61	21
AE	0	0.0	24	0	0.0	24	0.0	24	72	24
BBH	5	20.0	9	18	0.7	10	3.6	14	33	10
BC	0	0.0	24	0	0.0	24	0.0	24	72	24
BDS	0	0.0	24	0	0.0	24	0.0	24	72	24
BG	1	4.0	19	1	0.0	21	1.0	21	61	21
BND	21	84.0	1	948	35.2	1	45.1	1	3	1
BNS	1	4.0	19	32	1.2	8	32.0	3	30	8
BRB	0	0.0	24	0	0.0	24	0.0	24	72	24
BS	1	4.0	19	1	0.0	21	1.0	21	61	21
CC	9	36.0	6	75	2.8	6	8.3	8	20	6
CCS	0	0.0	24	0	0.0	24	0.0	24	72	24
CS	17	68.0	4	341	12.7	3	20.1	4	11	3
CSF	4	16.0	10	5	0.2	18	1.3	20	48	18
CWS	20	80.0	2	274	10.2	4	13.7	5	11	3
ECP	9	36.0	6	34	1.3	7	3.8	13	26	7
FF	15	60.0	5	172	6.4	5	11.5	6	16	5
GS	2	8.0	16	4	0.1	19	2.0	18	53	19
LC	0	0.0	24	0	0.0	24	0.0	24	72	24
LMB	6	24.0	8	14	0.5	13	2.3	17	38	13
LND	19	76.0	3	673	25.0	2	35.4	2	7	2
LNS	3	12.0	13	9	0.3	16	3.0	15	44	16
MMT	2	8.0	16	19	0.7	9	9.5	7	32	9
RBS	3	12.0	13	13	0.5	14	4.3	11	38	13
RFP	0	0.0	24	0	0.0	24	0.0	24	72	24
SMB	3	12.0	13	18	0.7	10	6.0	10	33	10
STS	2	8.0	16	4	0.1	19	2.0	18	53	19
TD	4	16.0	10	16	0.6	12	4.0	12	34	12
YBH	1	4.0	19	8	0.3	17	8.0	9	45	17
YP	4	16.0	10	12	0.4	15	3.0	15	40	15

Table 8. Frequency of occurrence, total number of individuals, and average number of individuals per sites present of fish species collected at WWLG fish assemblage reference sites (n=18). Rank of ranks is inverse ranking of sum of ranks for # sites present, percent of all individuals, and average # individuals/sites present. Top five ranked species for each category, sum of ranks, and final rank of ranks shaded grey.

Species	# Sites Present	% of Sites Present	Rank	Total Number Individuals	% of All Individuals	Rank	Avg. # Individuals /Sites Present	Rank	Sum of Ranks	Rank of Ranks
ABL	0	0.0	24	0	0.0	24	0.0	24	72	24
AE	3	16.7	16	3	0.1	20	1.0	21	57	20
BBH	5	27.8	10	58	2.3	9	11.6	9	28	9
BC	1	5.6	20	1	0.0	22	1.0	21	63	22
BDS	1	5.6	20	5	0.2	18	5.0	14	52	18
BG	5	27.8	10	13	0.5	15	2.6	16	41	14
BND	9	50.0	6	207	8.2	5	23.0	4	15	5
BNS	0	0.0	24	0	0.0	24	0.0	24	72	24
BRB	0	0.0	24	0	0.0	24	0.0	24	72	24
BS	0	0.0	24	0	0.0	24	0.0	24	72	24
CC	0	0.0	24	0	0.0	24	0.0	24	72	24
CCS	4	22.2	15	50	2.0	10	12.5	8	33	10
CS	12	66.7	3	474	18.9	2	39.5	2	7	2
CSF	11	61.1	4	117	4.7	7	10.6	10	21	7
CWS	16	88.9	1	232	9.2	4	14.5	6	11	3
ECP	9	50.0	6	31	1.2	12	3.4	15	33	10
FF	15	83.3	2	704	28.0	1	46.9	1	4	1
GS	5	27.8	10	78	3.1	8	15.6	5	23	8
LC	1	5.6	20	1	0.0	22	1.0	21	63	22
LMB	5	27.8	10	11	0.4	16	2.2	19	45	16
LND	11	61.1	4	154	6.1	6	14.0	7	17	6
LNS	0	0.0	24	0	0.0	24	0.0	24	72	24
MMT	8	44.4	8	278	11.1	3	34.8	3	14	4
RBS	2	11.1	18	14	0.6	14	7.0	11	43	15
RFP	1	5.6	20	2	0.1	21	2.0	20	61	21
SMB	3	16.7	16	7	0.3	17	2.3	18	51	17
STS	0	0.0	24	0	0.0	24	0.0	24	72	24
TD	5	27.8	10	31	1.2	12	6.2	12	34	13
YBH	6	33.3	9	36	1.4	11	6.0	13	33	10
YP	2	11.1	18	5	0.2	18	2.5	17	53	19

When comparing the species richness of the four New Hampshire fish assemblage types, differences were evident. Coldwater assemblages have the fewest average number of species per site (2.6), followed by transitional assemblages (4.6), warmwater high gradient assemblages (6.1) and warmwater low gradient assemblages (7.8) having the most (Figure 4).

Figure 4. Frequency (normalized by percent) of the number of fish species at cold (n=33), transitional (n=31), warmwater high gradient (n=25), and warmwater low gradient (n=18) reference sites.



4.6 Biological Response Indicators (Fish Metrics)

A total of 125 metrics were selected for final testing (Appendix K). Many of the highest ranking metrics for low gradient and high gradient sites were related to trophic class, streamflow preference, origin (native or introduced), or species composition without a specific autecological characteristic (Table 9).

Metrics for the WWLG IBI included six metrics; two positive and four negative (Table 10). The two positive metrics included percent fallfish individuals and percent benthic insectivore taxa. Negative metrics included percent carnivore individuals, percent bluegill and common sunfish (pumpkinseed) individuals, percent pool individuals and percent golden shiner individuals. The positive metrics ranked in the top 11 while the negative metrics all ranked 7th or better. All metrics had good separation between reference and non-reference (moderate and high watershed development) sites (Figure 5). In addition, there was minimal redundancy, with Pearson correlation coefficients less than 70% with the exception of the percent pool individuals and percent bluegill and common sunfish (pumpkinseed) individuals where the correlation was 75% (Appendix L). Metrics that revolved around feeding group (carnivore vs benthic insectivore) and stream flow, species that favor pools (golden shiner, bluegill, pumpkinseed) versus more fluvial species (fallfish) were the strongest metrics for distinguishing between reference and non-reference sites. Metrics related to pollution tolerance, thermal preference, and reproductive strategy did not score well.

Table 9. Metrics with the highest rank for WWLG and WWHG sites by metric type. Metrics ranked within each group and metric type by summing scoring equations in Table 3. A tally of the number of scoring equations greater than 0 (positive metrics) or less than 0 (negative metrics) from Table 3 is provided. Metric abbreviations noted with and asterisk (*) were the final metrics selected.

WWLG

Group	Metric Abbreviation	Metric Description	Sum of Metric Score Categories	Metric Rank by Metric Type	Number of Score Equations >0 (Pos) or <0 (Neg)	Metric Type
WWLG	SP22_LND_PIND	Percent LND Individuals	2.0000	1	2	POS
WWLG	FF_MMT_PIND	Percent FF, MMT Individuals	1.4624	2	3	POS
WWLG	FF_LND_MMT_PIND	Percent FF, LND, MMT Individuals	1.3885	3	3	POS
WWLG	BENTINVNTAX	Number Benthic Invertivore Taxa	1.3333	4	2	POS
WWLG	BI_NTAX	Number Benthic Insectivore Taxa	1.3333	4	2	POS
WWLG	BENTINVPTAX	Percent Benthic Invertivore Taxa	1.3005	6	2	POS
WWLG	BI_PTAX*	Percent Benthic Insectivore Taxa	1.3005	6	2	POS
WWLG	ECP_FF_LND_SMB_PIND	Percent ECP, FF, LND, SMB Individuals	1.0894	8	3	POS
WWLG	FS_PTAX	Percent Fluvial Specialist Taxa	1.0483	9	3	POS
WWLG	FF_LND_PIND	Percent FF and LND Individuals	0.9001	10	3	POS
WWLG	SP18_FF_PIND*	Percent FF Individuals	0.8751	11	2	POS
WWLG	FF_MMT_GS_YBH_PIND	Percent FF, MMT, GS, YBH Individuals	0.8014	12	2	POS
WWLG	SP15_CSF_PIND	Percent CSF Individuals	-1.4897	1	2	NEG
WWLG	CARNPIND	Percent Carnivore Individuals	-1.1963	2	2	NEG
WWLG	TC_PIND*	Percent Carnivore Individuals	-1.1358	3	2	NEG
WWLG	BG_CSF_GS_PIND	Percent BG_CSF_GS Individuals	-1.1006	4	2	NEG
WWLG	BG_CSF_PIND*	Percent BG and CSF Individuals	-1.0822	5	2	NEG
WWLG	POOLPIND*	Percent Pool Individuals	-1.0609	6	2	NEG
WWLG	SP19_GS_PIND*	Percent GS Individuals	-0.9141	7	1	NEG
WWLG	CARNNTAX	Number Carnivore Taxa	-0.7500	8	3	NEG
WWLG	TC_NTAX	Number Carnivore Taxa	-0.7500	8	3	NEG
WWLG	CARNPTAX	Percent Carnivore Taxa	-0.2481	10	1	NEG
WWLG	TC_PTAX	Percent Carnivore Taxa	-0.2481	10	1	NEG
WWLG	HD_PTAX	Percent Hole and Digger Taxa	-0.1578	12	2	NEG

WWHG

Group	Metric Abbreviation	Metric Description	Sum of Metric Score Categories	Metric Rank by Metric Type	Number of Score Equations >0 (Pos) or <0 (Neg)	Metric Type
WWHG	BND_CS_CWS_PIND*	Percent BND, CS, CWS Individuals	1.1717	1	3	POS
WWHG	SP14_CS_PIND	Percent CS Individuals	0.9991	2	2	POS
WWHG	OMNIPIND	Percent Omnivore Individuals	0.9431	3	3	POS
WWHG	GF_OI_PIND	Percent Generalist Feeder & Omnivore Insectivore Individuals	0.4609	4	2	POS
WWHG	NATPIND	Percent Native Individuals	0.0516	5	1	POS
WWHG	RHEOPTAX*	Percent Rheophilic Taxa	0.0107	6	1	POS
WWHG	INTLINVPIND	Percent Intolerant Invertivore Individuals	0.0000	7	0	POS
WWHG	INTLINVPTAX	Percent Intolerant Invertivore Taxa	0.0000	7	0	POS
WWHG	INTLLOTNTAX	Number Intolerant Lotic Taxa	0.0000	7	0	POS
WWHG	INTLLOTPIND	Percent Intolerant Lotic Individuals	0.0000	7	0	POS
WWHG	INTLLOTPTAX	Percent Intolerant Lotic Taxa	0.0000	7	0	POS
WWHG	INTLNTAX	Number Intolerant Taxa	0.0000	7	0	POS
WWHG	SP34_SMB_PIND*	Percent SMB Individuals	-2.0000	1	2	NEG
WWHG	ALIENPIND	Percent Introduced Individuals	-1.7076	2	2	NEG
WWHG	ALIENNTAX	Number Introduced Taxa	-1.0000	3	1	NEG
WWHG	ALIENPTAX*	Percent Introduced Taxa	-0.6071	4	1	NEG
WWHG	ECP_FF_LND_SMB_PIND	Percent ECP, FF, LND, SMB Individuals	-0.4733	5	2	NEG
WWHG	CSF_FF_LND_SMB_PIND	Percent CSF, FF, LND and SMB Individuals	-0.4093	6	2	NEG
WWHG	MODTOL_PIND	Percent Mod Tolerant Individuals	-0.1452	7	1	NEG
WWHG	MODTOL_PTAX	Percent Tolerant Mod Taxa	-0.1307	8	2	NEG
WWHG	INTLINVNTAX	Number Intolerant Invertivore Taxa	0.0000	9	0	NEG
WWHG	BG_CCS_CSF_GS_YBH_PIND	Percent BG, CCS, CSF, GS, YBH Individuals	0.0000	9	0	NEG
WWHG	BG_BBH_CSF_YBH_PIND	Percent BG, BBH, CSF, and YBH Individuals	0.0000	9	0	NEG
WWHG	BG_CSF_PIND	Percent BG and CSF Individuals	0.0000	9	0	NEG

Metrics for the WWHG IBI included four metrics: two positive and two negative (Table 10). Positive metrics included percent blacknose dace, common shiner and common white sucker individuals, and percent rheophilic taxa. The two negative metrics included percent smallmouth bass individuals, and percent introduced fish taxa. The positive metrics ranked in the top six, while negative metrics ranked in the top four. As with the low gradient metrics, the high gradient metrics had decent separation between reference and non-reference sites (moderate watershed development between 5 and 15%) (Figure 5). No high development watershed sites (>15%

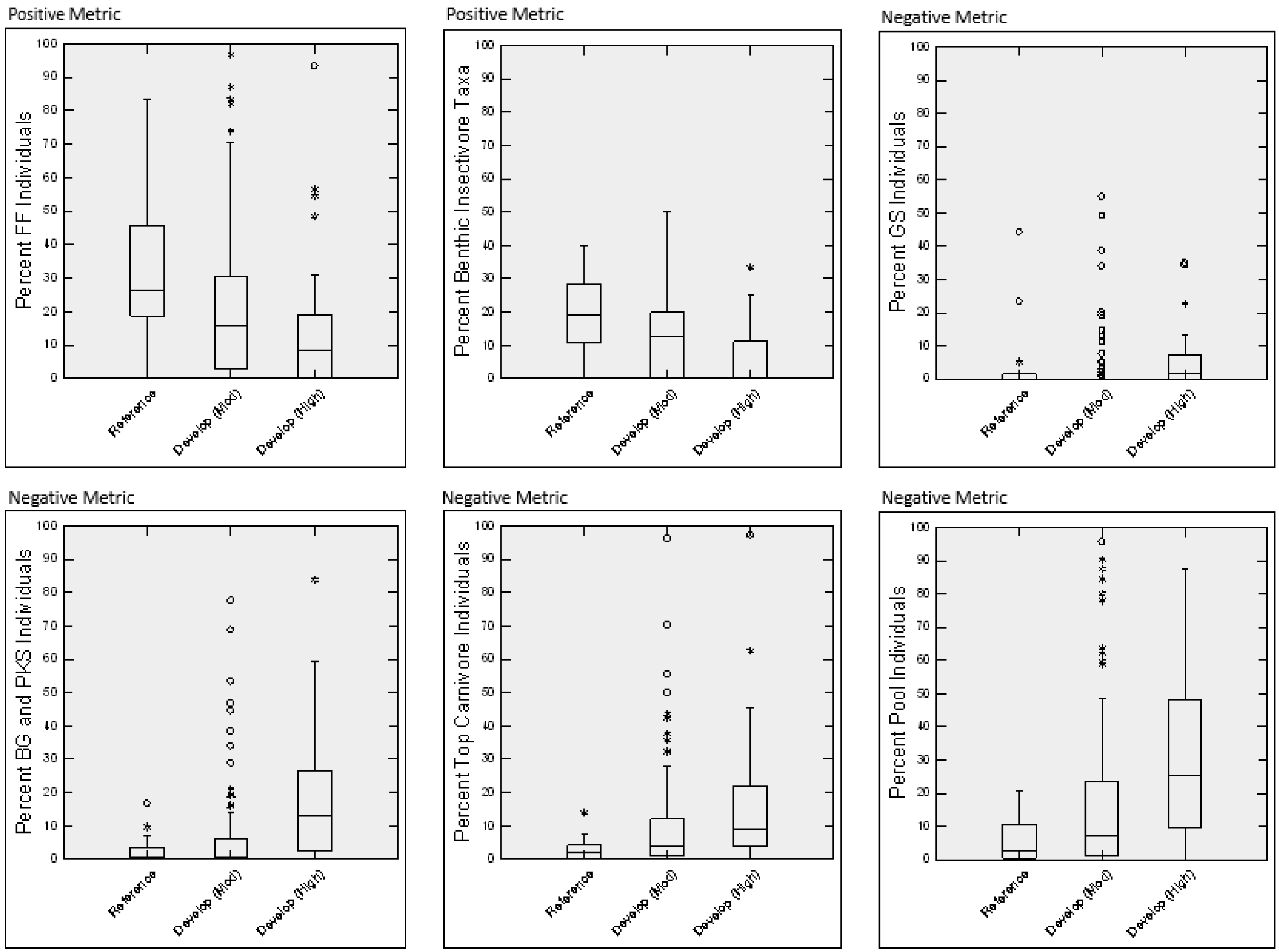
watershed development) were part of the high gradient calibration dataset as this part of the state has much less development than south and southeastern New Hampshire. All Pearson correlation coefficients were less than 70% and therefore showed minimal redundancy (Appendix L). Metrics demonstrating degraded conditions relied on the presence of introduced fish species.

Table 10. Final WWLG and WWHG metrics selected for testing.

Group A (WW Low Gradient)	
Metric	Metric Type
Percent Fallfish Individuals	POS
Percent Benthic Insectivore Taxa (blacknose shiner, cutlip minnow, longnose dace, margined madtom, swamp darter, tessellated darter)	POS
Percent Golden Shiners Individuals	NEG
Percent Bluegill and Common Sunfish (Pumpkinseed) Individuals	NEG
Percent Top Carnivore Individuals (black crappie, eastern chain pickerel, largemouth bass, northern pike, rock bass, redfin pickerel, smallmouth bass, walleye, white crappie, yellow perch) Note: excludes American eel	NEG
Percent pool individuals [black crappie, banded sunfish, bluegill, brown bullhead, common sunfish (pumpkinseed), eastern chain pickerel, green sunfish, largemouth bass, mummichog, northern pike, ninespine stickleback, rock bass, redbreast sunfish, redfin pickerel, swamp darter, smallmouth bass, striped killifish, white perch, yellow bullhead, yellow perch]	NEG
Group B (WW High Gradient)	
Metric	Metric Type
Percent blacknose dace, common shiner and common white sucker Individuals (blacknose dace, common shiner, common white sucker)	POS
Percent Rheophilic Taxa (blacknose dace, common white sucker, longnose dace, longnose sucker)	POS
Percent Smallmouth Bass Individuals	NEG
Percent Introduced Taxa (black crappie, bluegill, golden shiner, goldfish, green sunfish, largemouth bass, rock bass, rosyface shiner, rosyside dace, smallmouth bass, spottail shiner)	NEG

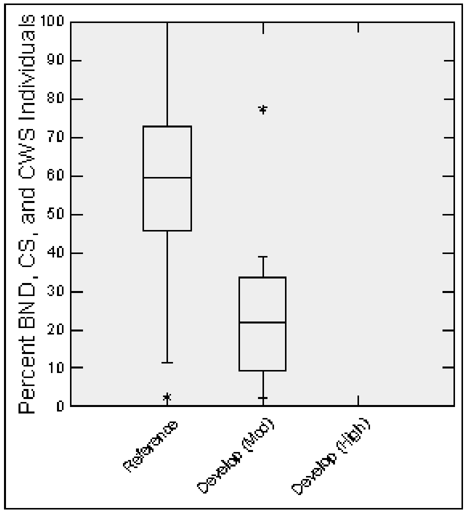
Figure 5. Box and whisker plots of WWIBI metrics for WWLG and WWHG reference and impacted sites from the calibration dataset. Upper extent of box is 75th percentile. Lower extent of box is 25th percentile. Line inside box is median. Upper whisker = [1.5 x (75th – 25th percentile] + 75th percentile. Lower whisker = [1.5 x (75th – 25th percentile] – 25th percentile. Asterisks (*) indicate mild outliers (0-1.5x interquartile range). Circles (○) indicate extreme outlier points (1.5-3x interquartile range). Includes reference sites (<5% watershed development), moderately developed watersheds (5-15%) and highly developed watersheds (>15%). The dataset did not include any highly developed WWHG watersheds.

WWLG

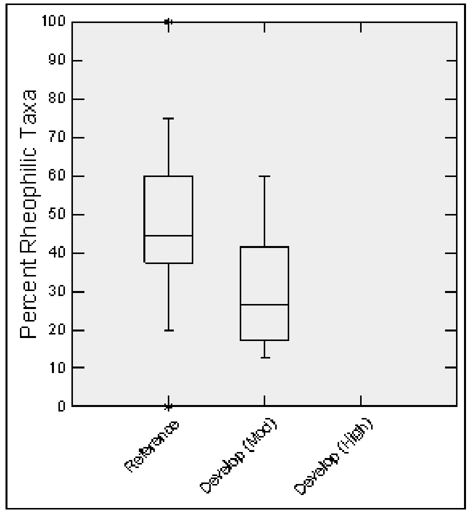


WWHG

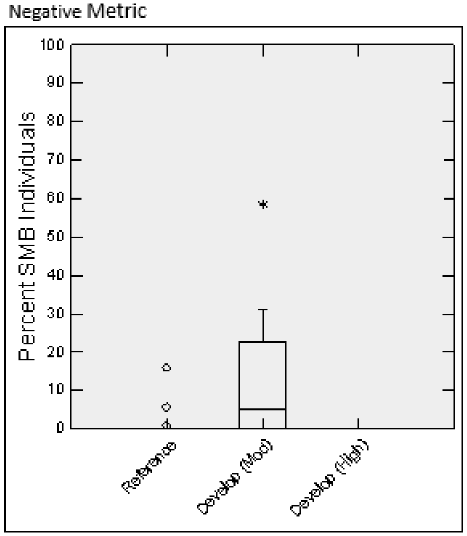
Positive Metric



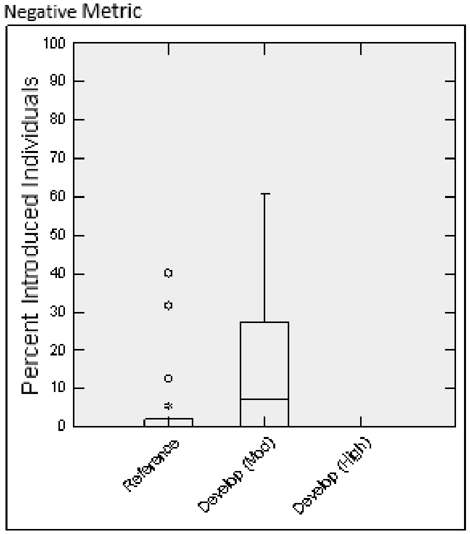
Positive Metric



Negative Metric



Negative Metric



4.7 Metric and WWIBI Scoring

Raw metric values (percentages) were converted to a numeric score by placing them into one of three scoring bins. Break points for scoring bins were developed based upon the raw metric values of reference sites in each gradient category (25th percentile and median for positive metrics and median and 75th percentile for negative metrics). Breakpoints were rounded to the nearest whole number for percentages <5% and either nearest 5% or 10% for greater percentages. A few adjustments were also made to the breakpoints, limiting the number of non-reference sites scoring “moderate” or “high” to no more than 25% of all non-reference sites. In addition, two of the metrics, percent golden shiners and percent smallmouth bass had very low raw metric percentages (<2%) for each breakpoint. Scoring bins were adjusted to prevent a relatively low percent raw metric value from scoring poorly by shifting the medium score breakpoint to 1% and low score breakpoint to >5%. This is a conservative adjustment, assuring that a site does not score poorly based on very few individuals of those species captured during a fish survey.

Points for the WWLG group bins were 1.5, 4.5, and 7.5 while points for the WWHG group bins were 2.25, 6.75 and 11.25. Scoring bin values were assigned based on the number of metrics for each IBI group and to achieve a final total score of 9 to 45 comparable with previously developed CW and TW IBIs. For each site, points were assigned to individual metrics dependent on the metric values (Table 12). Low metric scores reflected poorer assemblage condition while higher metric scores indicated better assemblage condition. The metric scores within each group were then summed for an overall WWLG IBI and WWHG IBI score. Then, the final WWIBI score was computed by summing the WWLG IBI and WWHG IBI scores multiplied by their respective predicted membership in each warmwater gradient category using the following equation:

WWIBI = (Probability of WWLG * WWLG IBI score) + ((1 – Probability of WWLG) * WWHG IBI Score)

4.8 WWIBI Thresholds Determination

The 25th percentile of the IBI scores for both the WWLG and WWHG reference sites was 27. In addition, a weighted WWIBI threshold for each reference site was calculated based upon predicted membership to the low gradient and high gradient groups. The 25th percentile of the reference site weighted WWIBI scores was also 27 and applied as the threshold for determining if a site passed or failed the WWIBI (Figure 6). A score equal to or greater than 27 indicated the fish assemblage met the aquatic life use threshold. A score less than 27 indicated the site did not meet the aquatic life use threshold. Site scores were further compared by watershed development. Reference sites being equivalent to those with less than 5% (low) watershed development and non-reference sites having either 5-15% (moderate) or >15% (high) watershed development (Figure 7).

Figure 6. Box and whisker plot for warmwater, reference (n=43) and non-reference (n=142) calibration sites. Dashed line represents WWIBI threshold. Upper extent of box is 75th percentile. Lower extent of box is 25th percentile. Line inside box is median. Upper whisker = [1.5 x (75th – 25th percentile] + 75th percentile. Lower whisker = [1.5 x (75th – 25th percentile] – 25th percentile.

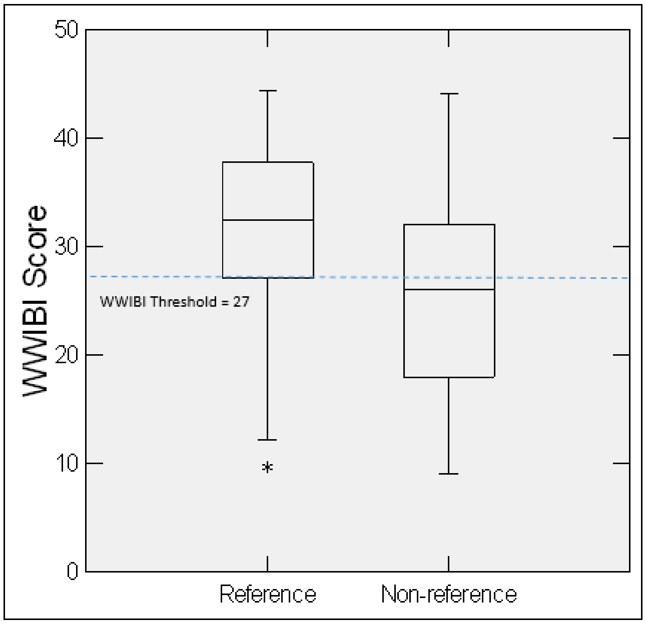


Figure 7. Box and whisker plot for warmwater, low development (n=43), moderate development (n=116), and high development (n=36) calibration sites. Dashed line represents WWIBI threshold. Upper extent of box is 75th percentile. Lower extent of box is 25th percentile. Line inside box is median. Upper whisker = [1.5 x (75th – 25th percentile] + 75th percentile. Lower whisker = [1.5 x (75th – 25th percentile] – 25th percentile.

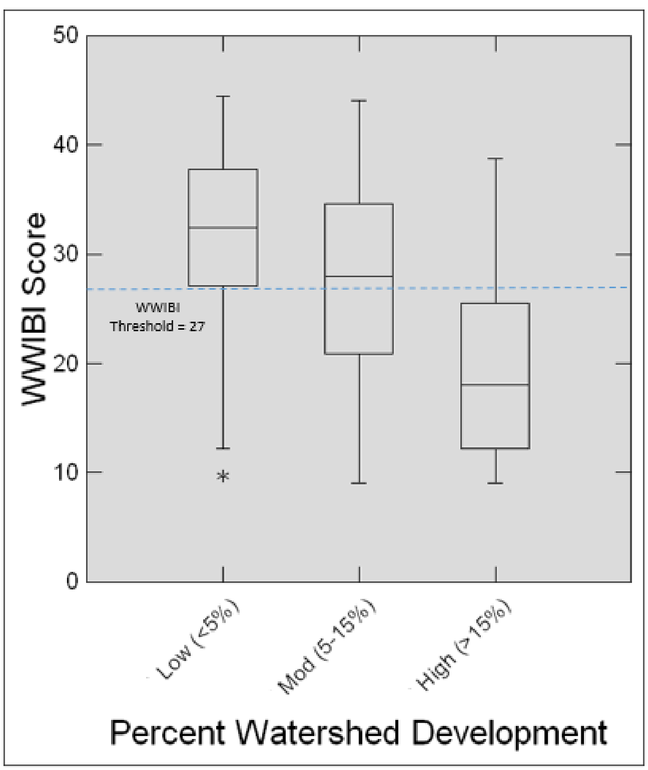


Table 11. Metric scoring and point assignment bins for low gradient and high gradient sites.

WW Low Gradient											
Metrics		**Preliminary Metric Breakpoints Relative to WWLG Percentiles of Reference Sites**			**Final Metric Breakpoints/ Assigned Scores**						
Metric	Metric Type	<25th (Low %)	25th-Median (Med %)	>Median (High %)	Low %	Score	Med %	Score	High %	Score
Percent Fallfish	POS (high % scores higher)	21.8	21.8-28.4	28.4	< 20	1.5	20-30	4.5	>30	7.5
Percent Benthic Insectivore Taxa	POS (high % scores higher)	4.5	4.5-14.3	14.3	<5	1.5	5-15	4.5	>15	7.5
Metric	Metric Type	<Median (Low %)	Median to 75th (Med %)	>75th (High %)	Low %	Score	Med %	Score	High %	Score
Percent Golden Shiners	NEG (low % scores higher)	0.0	0.0-1.4	1.4	<1	7.5	1-5	4.5	>5	1.5
Percent Bluegill and Pumpkinseed	NEG (low % scores higher)	0.8	0.8-7.6	7.6	<1	7.5	1-5	4.5	>5	1.5
Percent Top Carnivore Individuals	NEG (low % scores higher)	2.3	2.3-4.8	4.8	<2	7.5	2-5	4.5	>5	1.5
Percent Pool Individuals	NEG (low % scores higher)	3.5	3.5-15.7	15.7	<3	7.5	3-10	4.5	>10	1.5
WW High Gradient											
Metrics		**Preliminary Metric Breakpoints Relative to WWHG Percentiles of Reference Sites**			**Final Metric Breakpoints/ Assigned Scores**						
Metric	Metric Type	<25th (Low %)	25th-Median (Med %)	>Median (High %)	Low %	Score	Med %	Score	High %	Score
Percent Blacknose Dace, Common Shiner and Common White Sucker	POS (high % scores higher)	42.8	42.8-59.4	59.4	<40	2.25	40-60	6.75	>60	11.25
Percent Rheophilic Taxa	POS (high % scores higher)	33.8	33.8-44.4	44.4	<40	2.25	40-60	6.75	>60	11.25
Metric	Metric Type	<Median (Low %)	Median to 75th (Med %)	>75th (High %)	Low %	Score	Med %	Score	High %	Score
Percent Smallmouth Bass	NEG (low % scores higher)	0.0	0.0-0.0	0.0	<1	11.25	1-5	6.75	>5	2.25
Percent Introduced Taxa	NEG (low % scores higher)	0.0	0.0-15.5	15.5	<1	11.25	1-15	6.75	>15	2.25

4.9 Validation Testing

A total of 100 sites were utilized for the purpose of validating the performance of the WWIBI, weighted by predicted membership to warmwater low gradient and high gradient assemblages. With a proposed pass-fail threshold of 27, 50 of 64 (78%) of validation reference sites (<5% watershed development) exceeded the criterion, while 19 of 36 (52%) of validation non-reference (>5% development) sites failed to achieve the criterion as shown in the box and whisker plot (Figure 8). The average WWIBI score for validation sites with low watershed development (<5%) was 32.9 (n=64), while the average WWIBI scores for sites with moderately developed watersheds (5-15%) and highly developed watersheds (>15%) were 26.8 (n=24) and 20.7 (n=12), respectively. Box plots for each of the development categories are provided in Figure 9.

As a final check on the ability of the index to discriminate along a human disturbance gradient, all reference and non-reference sites were plotted (Figure 10). Sites that had high watershed development and high scores or low watershed development and low scores were further evaluated. Humphrey Brook, Manchester, has a watershed development that exceeded 90%, but scored somewhat high, although well under the threshold. However, the number of individuals and species diversity documented during the fish survey was limited. There were only 11 individuals collected across three species: goldfish, golden shiner and brown bullhead. Goldfish, being tolerant to pollution, are an indicator of poor water quality. A lack of other species and individuals overall demonstrates poor biological integrity. Therefore, the somewhat high IBI score for a site with watershed development exceeding 90% did not reflect the very poor water quality of the stream. Further, it is recommended that the index use at least 30 individuals as the metrics were developed based on sites having at least 30 individuals. Other sites, including Bowman Brook, Patten Brook and Messer Brook with watershed development exceeding 50% also scored much better than expected. However, these three brooks are tributaries to the Merrimack River and within an area of the state that is documented to have streams with coolwater thermal regimes and provide cold water fish habitat year-round. Therefore, steps, such as collection of summer temperature data with data loggers should be taken to confirm these sites have a coolwater thermal regime and if confirmed, should be evaluated using the transitional water IBI. Lastly, Little River in Plaistow with a WWIBI score of almost 39 scored much better than expected considering a high level of watershed development (19%). This section of the river is characterized by modest stream gradients and habitat favorable to blacknose dace which comprised nearly 50% of the individuals from the survey. In addition, this site may also have a coolwater thermal regime. Higher stream velocities and possible cooler water temperatures may be negating the pollutant stressors associated with watershed development and allowing fish species such as blacknose dace, typical of sites with high gradient watersheds and frequently found in transitional water fish assemblages to survive. American eel was also found in high numbers, representing almost 50% of survey individuals. However, American eels, even though tolerant of poor water quality, are removed from any of the negative IBI metrics as they are catadromous and a good indicator of stream connectivity. As a result, the presence of blacknose dace and American eels which together accounted for more than 90% of the individuals from the survey, may be altering the IBI score and therefore may not be a good representation of overall stream water quality condition.

Figure 8. Box and whisker plot for warmwater, reference (n=64) and non-reference (n=36) validation sites. Dashed line represents WWIBI threshold. Upper extent of box is 75th percentile. Lower extent of box is 25th percentile. Line inside box is median. Upper whisker = [1.5 x (75th – 25th percentile] + 75th percentile. Lower whisker = [1.5 x (75th – 25th percentile] – 25th percentile.

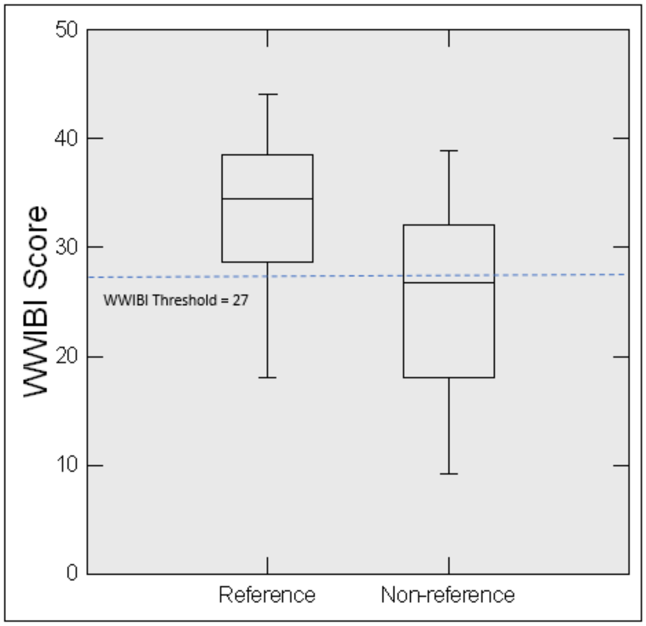


Figure 9. Box and whisker plot for warmwater, low development (n=64), moderate development (n=24), and high development (n=12) validation sites. Dashed line represents WWIBI threshold. Upper extent of box is 75th percentile. Lower extent of box is 25th percentile. Line inside box is median. Upper whisker = [1.5 x (75th – 25th percentile] + 75th percentile. Lower whisker = [1.5 x (75th – 25th percentile] – 25th percentile.

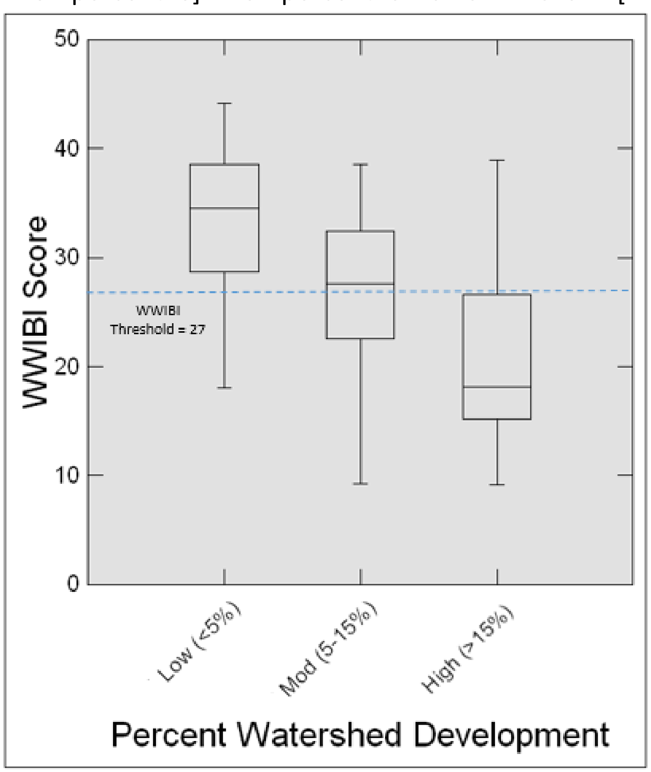
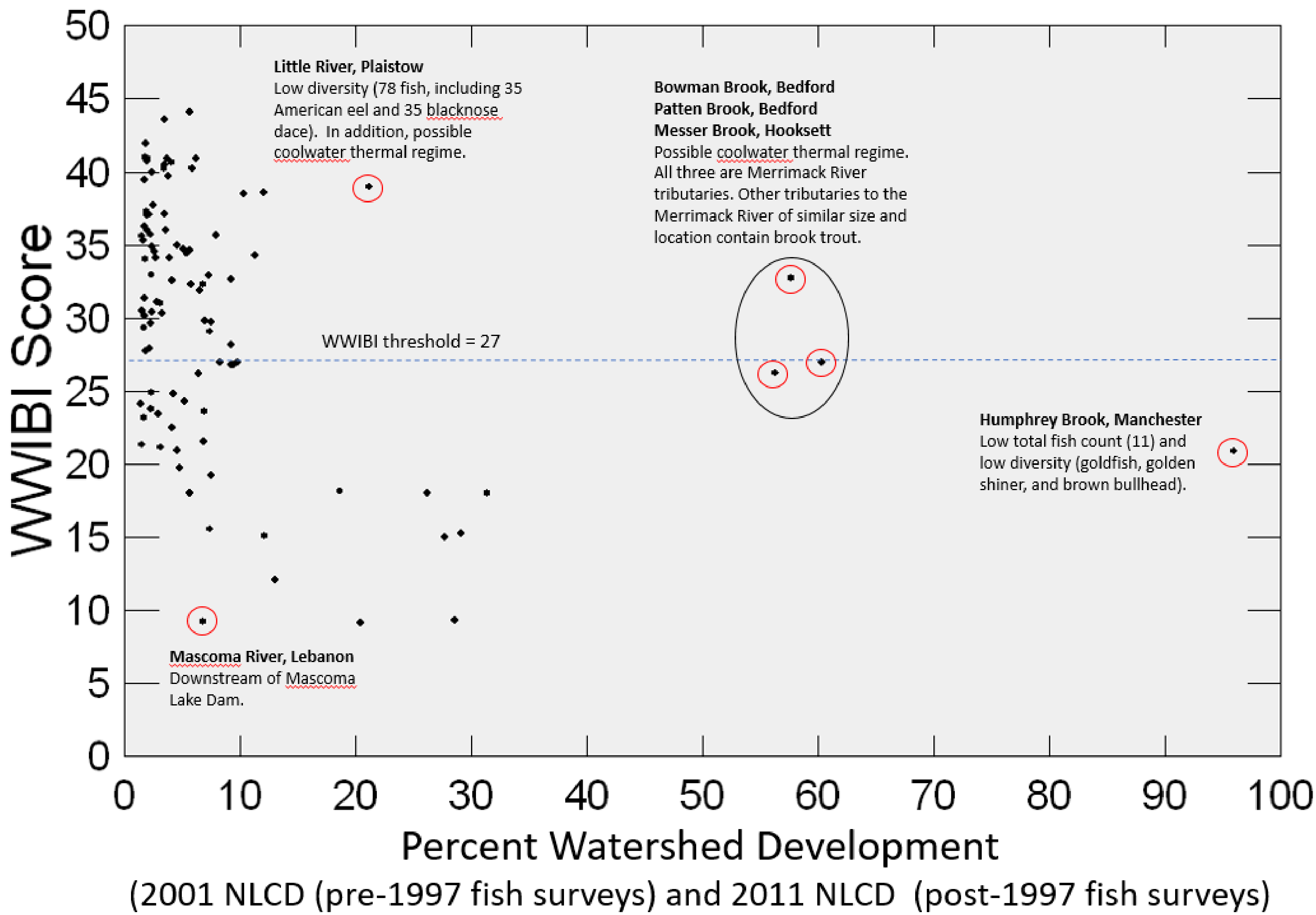


Figure 10. WWIBI scores versus percent watershed development of validation sites (n=100).



5. SUMMARY AND RECOMMENDATIONS

New Hampshire's Biomonitoring Program has developed fish IBIs for coldwater assemblages (CWIBI) (NHDES, 2007) and transitional fish assemblages (TWIBI) (NHDES, 2011) in riverine systems. However, roughly 27% of the state's area, is comprised of rivers and streams that naturally contain warmwater fish communities and therefore did not have an applicable IBI to appropriately assess the biotic integrity of the fish community. Warmwater fish assemblages occur statewide, yet their natural expected area of occurrence is focused in the south and southeastern half of the state (Figure 1). The expected area of occurrence of warmwater fish assemblages is dependent primarily geographic position (longitude/latitude), drainage area, elevation, and basin slope. New Hampshire's warmwater fish assemblages differ from coldwater and transitional water fish assemblages in that they do not hold coldwater species year round. In order to fill this gap, a WWIBI for wadeable rivers and streams, based on predicted membership to low basin and high basin gradient fish assemblages provides the capability to assess the integrity of nearly all the riverine fish assemblage types in the state, excluding large, non-wadeable systems. Further, due to a lack of reference sites with basin gradients between 3% and 5%, caution should be applied when assessing these sites. The WWIBI may not be appropriate, especially when supportive evidence, such as rocky substrate, absence of tidal species, relatively steep stream slope, and a large number of individuals (>30) does not exist. The WWIBI should not be applied to wadeable rivers and streams with basin gradients less than 3%, largely located in areas near New Hampshire's coast.

The analysis of fish species relative abundance and frequency of occurrence from 285 warmwater, wadeable streams in New Hampshire indicated that two additional fish assemblage types, warmwater low gradient (WWLG) and warmwater high gradient (WWHG), are found throughout southern and southeastern New Hampshire. WWLG fish assemblages typically occur when basin gradients are less than 8%. WWHG fish assemblages typically occur when basin gradients exceed 12%, and rarely greater than 16%. Fish assemblages of sites with basin gradient between 8% and 12% are a mix of species found in both low gradient and high gradient systems, and favor low gradient assemblages further south and high gradient assemblages, further north within the state. Percent membership of a given fish survey site to each of these warmwater assemblages can be predicted using a logistic regression equation based on the site's latitude and basin slope. A weighted WWIBI score, based on the predicted membership, is then used to assess the biological health of the warmwater fish community.

Natural, non-impacted, warmwater sites in New Hampshire will frequently have blacknose dace, common shiner, common white sucker, fallfish and longnose dace, and were found more than 50% of the time in calibration reference sites. WWHG reference sites with basin gradients greater than 12% naturally contain blacknose dace, longnose dace, common shiner, common white sucker, fallfish and creek chub in descending order of percent individuals per site across calibration reference sites. WWLG reference sites with basin gradients less than 8% naturally contain fallfish, common shiner, margined madtom, common white sucker, and blacknose dace, in descending order of percent individuals per site across calibration reference sites.

Species richness also shifts between coldwater and warmwater sites. In comparison to coldwater and transitional water fish communities, warmwater fish communities in New Hampshire have higher species richness (Figure 4). Average number of species per site for New Hampshire's coldwater assemblages was approximately 2.8 species, while New Hampshire's low gradient warmwater assemblages averaged 7.8 species. This may be due to the habitat diversity and habitat volume differences between streams supporting coldwater versus warmwater fish assemblages. As stated by Karr (1983), habitat diversity is a complex integration of depth, current velocity, and substrate attributes. Habitat volume is a measurement of stream area by depth. Although Karr's 1983 study focused on warmwater streams, both habitat diversity and habitat volume increased from upstream to downstream and riffle to pool habitats, with increased species richness as a result. Greater habitat diversity and volume possibly provides a greater number of potential niche habitats, and therefore increases the potential for greater species diversity, when comparing coldwater and warmwater streams.

Distinct boundaries in biological assemblages rarely exist and there may be instances when best professional judgement must be used before making a final decision of the most appropriate fish condition index to be applied in making an aquatic life use determination. In particular, special attention must be paid to sites where known or suspected groundwater inputs, provide cooler water habitat and may rely on groundwater or water temperature data. GIS data layers showing locations of sandy aquifers, which often provide cool water to streams during the summer could assist with identifying these locations. In addition, when fish data is available, the number of species per site may prove helpful for determining the site's fish assemblage type and thereby evaluating it using the most appropriate New Hampshire fish IBI.

A WWIBI where two separate IBIs were scored and weighted according to a site's likely membership to high gradient and low gradient fish assemblage categories proved useful in discriminating between reference and presumed impacted sites with overall index scores displaying an inverse relationship to the level of human disturbance. The selection of four metrics for the WWHG IBI and six metrics for the WWLG IBI was within the range of previously developed fish IBIs (Leonard and Orth 1986; Lyons et al. 1996; Langdon 2001; Daniels et al. 2002; Hughes et al. 2004; Whittier et al. 2007), yet lower than the classic biotic index developed by Karr (1981). A predetermined number of metrics was not targeted prior to index development; rather the number included in the index was based on performance and redundancy testing for individual metrics. Overall, metrics associated with species specific composition, habitat, trophic class, origin and streamflow preference were most successful at differentiating between reference and impacted sites.

Of the six WWLG and four WWHG metrics, the metric category of streamflow preference was found in each; percent pool individuals for WWLG and percent rheophilic for WWHG. Several of the other metrics in the WWLG category gravitated towards metrics depicting species such as largemouth bass, pickerel, golden shiners and sunfish, favoring slower velocities or "pond-like" conditions. Whereas, several of the metrics in the WWHG category included species such as dace, suckers, and even smallmouth bass favoring swifter flowing conditions. Particular attention will be needed when assessing sites that may be related to altered stream flows, either through damming (natural or human induced), water withdrawal, or stormwater runoff typical of urban landscapes with reduced stream buffers, impervious surfaces, and direct stormwater discharges. Sites downstream of wetland complexes, either natural or created, supporting lentic fish communities may see an increase in those species as they drop out of the wetland complex system and move downstream. Sites within highly developed watershed, with water withdrawals or changes to a river or stream's natural stormwater runoff hydrograph may favor species preferring lower stream velocities or that can survive short periods of increased stream water volume and velocities related to stormwater runoff spikes over species that rely on longer durations of moderate to high, steady base flow volume and velocities typical of watersheds with natural stream systems with minimal human induced impacts. There may also be natural stream systems with low flow and low stream velocities, such as those with extensive wetland complexes. This may be reflected in low watershed slopes (<5%), but should be considered when evaluating a site's fish community.

Several established IBIs (Leonard and Orth 1986; Lyons et al. 1996; Langdon 2001; Daniels et al. 2002), included species richness metrics. However, for New Hampshire's WWIBIs, species richness did not prove useful in discriminating between reference and impacted sites; similar to that documented by Whittier et al. (2007). The exclusion of overall richness as a metric in the WWIBIs for New Hampshire was, in part, believed to be a reflection of the naturally low fish species diversity statewide and the majority of the dataset was comprised of tolerant warmwater species that could be found within streams of both reference and impacted watersheds. Further, of the impacted watersheds, conditions were not substantially degraded to reduce species richness.

Metrics related to pollution tolerance, thermal preference, and reproductive strategy also did not score well and were therefore not selected for the IBIs. Unlike New Hampshire's coldwater and transitional water IBIs, there is a lack of metrics reflective of fish tolerance to water pollution. This is likely because there are only six intolerant warmwater and eurythermal species (American brook lamprey, banded sunfish, blacknose shiner, rainbow smelt, walleye, and white perch) in New Hampshire. Of those six species, only three of them (American brook lamprey, banded sunfish and blacknose shiner) had at least one individual recorded and the total individuals comprised <1% of the calibration dataset. As a result, an evaluation of metrics identifying intolerant species are not easily identified. Additional assessments of water quality, habitat and summer long water temperature datasets should be considered during the stream assessment process as suggested by James Karr (1981) to help assess the impacts of water pollution on a site's fish community. Thermal preference and reproductive strategy likely didn't score well as most species within the dataset prefer or tolerate warmwater conditions, and do not require highly specific conditions for reproductive success.

The indices, as constructed, minimize inter-metric redundancy. Of the final 10 metrics (six low gradient metrics and four high gradient metrics), all but one metric combination included in the WWIBIs had a correlation coefficient less than 0.70. The percent pool individuals and percent bluegill and common sunfish (pumpkinseed) individuals had a correlation coefficient of 75%. However, these two metrics were both retained as they are considered important indicators of impacted fish communities. Impacted sites will often be accompanied by a high percentage of bluegill and common sunfish (pumpkinseed). However, this metric is somewhat limited as it only includes two species. The percent pool individuals metric includes 20 species and therefore accounts for instances when impacted sites do not have a high percentage of percent bluegill and common sunfish (pumpkinseed) individuals. Two examples of this are for sites 06T-ISG on the Isinglass River in Barrington and 01-BWB on Bowman Brook in Bedford. Site 06T-ISG was surveyed on July 24, 2019 and had zero records of bluegill and common sunfish (pumpkinseed). However, other "pool" species present included banded sunfish (n=11), eastern chain pickerel (n=2), largemouth bass (n=10), and redbreast sunfish (n=14). The percent pool individuals for this site was 18% and it received a score of 1.5 for this metric. Including this negative metric resulted in a WWIBI score of 27.4, only slightly above the threshold of 27. The fish survey for 01-BWB occurred on August 20, 2018 had zero records for bluegill and only one individual for common sunfish (pumpkinseed). As with 06T-ISG there were several pool species including brown bullhead (n=2), largemouth bass (n=6), smallmouth bass (n=9), striped killifish (n=1) and yellow bullhead (n=2). The percent pool individuals for this site was almost 11% and it received a score of 4.5. Including the percent pool individuals metric resulted in a score of 26.2, slightly below the threshold of 27. For both cases, use of the percent pool individuals metric provided useful information that was not redundant to the bluegill/common sunfish (pumpkinseed) metric and effectively reflected on the deviation of the warmwater fish community structure from the natural condition.

The overall lack of redundancy across the majority of the 10 metrics indicate that the index components represent a unique expression of the ecological characteristics of the fish assemblage. Further, the individual metrics selected for inclusion into the index proved to be responsive to increases in environmental stressors based on the narrative impact rating categories. Of the four metrics selected for the high gradient warmwater index and six metrics selected for the warmwater low gradient index, most were able to clearly separate reference and impacted sites and were among the strongest indicators in doing so based on an objective testing process. One of the warmwater high gradient metrics (percent smallmouth bass individuals) did not show a large amount of separation. This is likely due to the overall low number of smallmouth bass individuals at both reference and impacted sites. Collectively metric selection focused on the inclusion of metrics across broad ecological categories, that combine to represent the important qualities of a minimally impacted biological community and capable of detecting a departure from the reference condition.

Overall, the individual WWIBIs developed for New Hampshire have equal or fewer metrics than New Hampshire's CWIBI (six metrics) and TWIBI (eight metrics). New Hampshire's WWLG IBI has six metrics while the WWHG IBI has just four metrics. There are likely several factors that limit the number of metrics that meet the criteria for selection in WWHG streams. First off, New Hampshire has very few fish species, comparative to other parts of the country. As a result, there are fewer combinations of species that might yield a metric for potential inclusion in an index. Second, there were only 43 calibration reference sites. While the number of sites is adequate for developing an index, including more calibration references sites may have been useful in identifying additional candidate metrics for evaluation. Further, of the 43 reference sites, 18 were used for development of the WWLG IBI and 25 for the WWHG IBI. However, by weighting a site's membership as WWLG and WWHG, all 10 metrics are utilized for determining a site's score.

Scores for the WWLG, WWHG and weighted WWIBIs range from 9-45. The recommended index threshold of 27 for the WWLG IBI, WWHG IBI, and the weighted WWIBI was based on the 25th percentile of reference site scores. The use of the 25th percentile of the index score as a threshold for evaluating community condition corresponds to previous New Hampshire fish IBIs. As mentioned by Neils (NHDES, 2011), Hughes et al. 2004 provided examples of how manipulating threshold criteria can lead to varying amounts of stream miles considered to be impaired. Without a doubt the selection of any statistical threshold (i.e., x-percentile, # standard deviations) is a subjective decision that implies a level of confidence in the index's performance, natural variability, sampling efficiency, and an acceptable reduction in biological condition. For the WWIBIs, and other biological indices developed by the NHDES, it is believed that a 25th percentile threshold is acceptable for the determination of aquatic life use. A lower or higher threshold would likely be under- or overprotective of the resource, respectively. Thus, the selection of this threshold is an attempt to balance an acceptable biological condition while concurrently taking into account largely uncontrollable sources of index variability such as sampling effectiveness, unmeasured components of ecosystem health (i.e. trophic dynamics) and regional environmental impacts. Mean index scores from the weighted WWIBI calibration dataset were 29.6 for reference (<5% watershed development) sites, 25.7 for moderately developed watershed sites, and 22.2 for highly developed watershed sites. Mean index scores from the weighted WWIBI validation dataset were 33.1 for low developed watershed sites, 26.4 for moderately developed watershed sites and 21.2 for highly developed watershed sites. Based on the results from both the calibration and validation datasets, it can be concluded that the index was capable of clearly distinguishing changes in fish assemblage structure and function as the level of disturbance from watershed development increased.

The selection of the 25th percentile of the weighted WWIBI threshold translated to 59 of the 106 (56%) moderately developed watershed sites from the calibration set failing to achieve the threshold of 27. Likewise, for highly developed sites, 29 of 36 (81%) sites from the calibration dataset failed to achieve the threshold of 27. Further, of the reference sites in the calibration dataset with WWIBI scores less than the 25th percentile (score = 27), the median WWIBI score was 18.22 and the median percent watershed development was 4.5%. Reference sites in the calibration dataset with WWIBI scores equal to or greater than the 25th percentile (score = 27) had a median WWIBI score of 36.0 and median percent watershed development of 3.3%. This demonstrates that sites of marginal reference quality approaching 5% watershed development scored poorer while sites with less watershed development scored better, demonstrating that the sensitivity of the IBI performs well even with sites with minimal (<5%) watershed development.

Overall, the threshold chosen for the weighted WWIBI was determined to be appropriate in defining an acceptable versus unacceptable level of departure from the "natural" condition. However, as with any biological index, an "attainment" threshold is a human-imposed decision criterion along a gradient of ecological structure and function. As a result, a single numeric representation of overall assemblage condition should be considered in concert with the actual raw data when making final impairment or regulatory decisions.

The WWIBIs establish a proposed set of guidelines to define two unique fish assemblages, metrics to measure biological condition, and criterion to determine the level of departure from minimally impacted sites. These guidelines, measures and associated thresholds are, however, based on current environmental conditions. In evaluating the data, geographically widespread unnatural perturbations to these conditions include regional and global impacts such as acid deposition and climate change, respectively. The effects of these impacts are difficult, if not impossible, to account for, and therefore, should be considered as unknown elements that may have contributed to the geographic boundaries of the warmwater water fish assemblage defined herein, as well as metric selection and threshold determination. Further, as these impacts are likely to continue, and perhaps worsen, modifications to the index will be necessary to account for changes in natural fish distributions, assemblage structure and function, and expectations in biological condition.

The WWIBIs will serve as a partial numeric interpretation of the NHDES' current narrative water quality criteria relating to the biological integrity (Env-Wq 1703.19) of aquatic communities for 1st through 6th order wadeable streams meeting the definition of a warmwater fish assemblage. The indices, low gradient, high gradient and weighted, based on predicted membership, are designed to accurately and precisely describe the biological condition of these assemblage types through unique ecological measures (metrics). Other indices, such as the NHDES' benthic IBI, or physical and chemical water quality measures may be coupled with the WWIBIs for the determination of aquatic life use and used in completing federally-required water quality reports, state-level regulatory actions, permit limits, and general water quality planning activities.

Southern and southeastern New Hampshire have the greatest land development in New Hampshire. Therefore, reference sites are largely concentrated in more northern and western New Hampshire relative to non-reference sites which are located in southern and eastern New Hampshire. These regions are geographically different. Northern/western New Hampshire is characterized by hills and mountains with steeper gradients whereas southern/eastern New Hampshire is mostly characterized by gentle gradients within the Merrimack River valley and coastal plain. This was also evident when evaluating the physical site and watershed characteristics; reference and non-reference sites were similar for the WWHG group but different for WWLG group (Mann-Whitney U test, $p<0.05$). In 2019, a concerted effort was made to locate reference sites in southeast New Hampshire, within the coastal plain and includes areas with watershed basin slopes less than 5%. Unfortunately, due to landscape development in this part of the state, very few potential reference sites with less than 5% watershed development exist. Further, of the sites that met this criteria, most had watershed areas less than a few square miles and did not represent a complete range of drainage areas, upwards of 100 square miles, for wadeable, warmwater sites in the state. Therefore, caution should be used when applying the WWIBI to sites in this part of the state, having watershed basin slopes less than 5%. Further, the WWIBI is not considered applicable to sites with watershed basin slopes less than 3% without substantial justification. For all sites, and especially those with watershed basin slopes less than 5%, it is recommended that that with each warmwater stream assessment of biotic integrity, the WWIBI score be evaluated with the support of other abiotic chemical and physical factors. Sites which do not score as anticipated should be further scrutinized to understand the cause, with evidence tracked in the NHDES biomonitoring database, allowing for future WWIBI adjustments and formal revisions.

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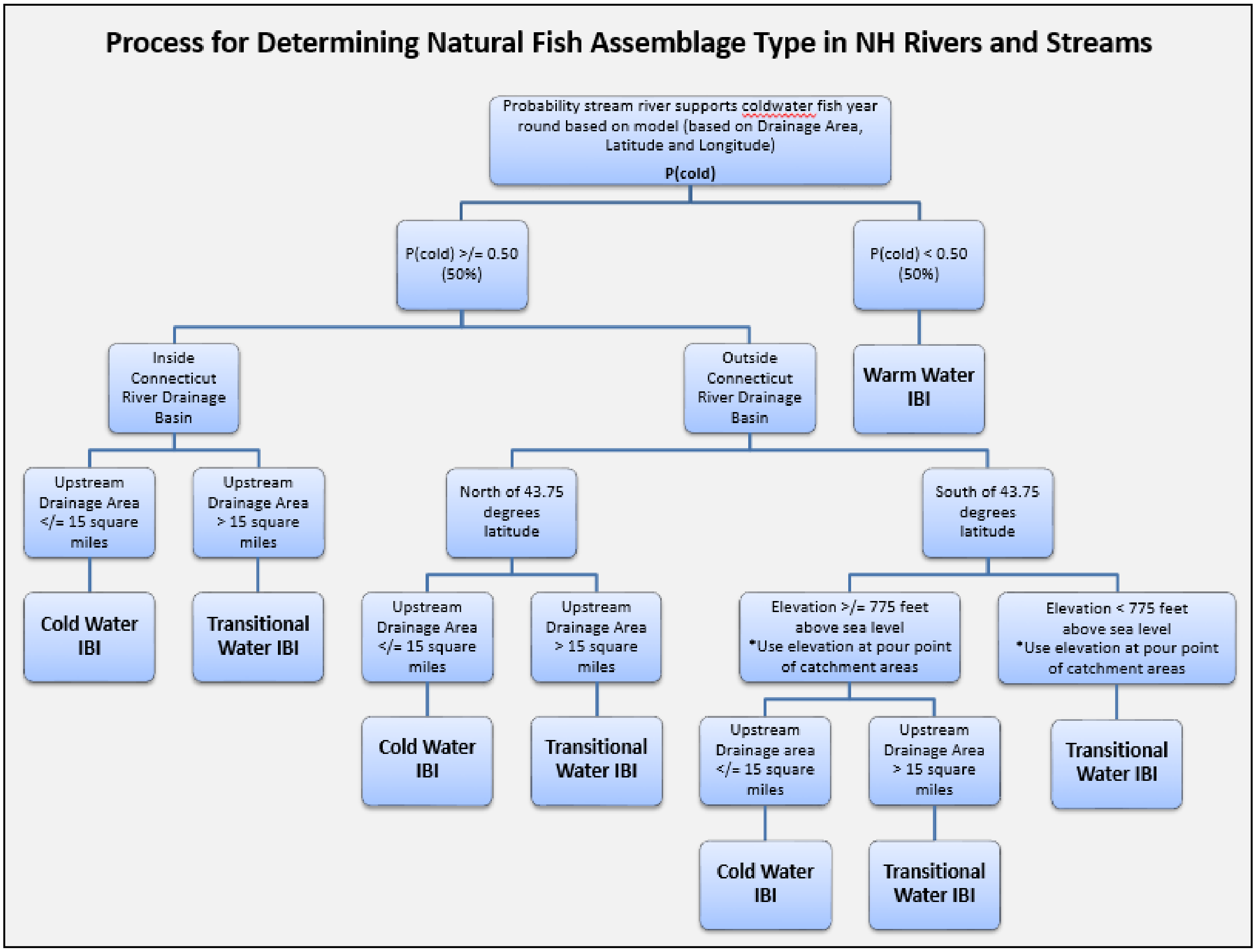
7. APPENDICES

Appendix A. Fish Assemblage Flow Chart

Process for determination of natural fish community Assemblages in NH Rivers and Streams



Appendix B. Warmwater Calibration Sites

Warmwater site list identifying calibration sites (n=185). General site information in Table 1. Detailed site information in Table 2.

Table 1, General Site Information

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
00M-BRA	Branch River	Milton	43.480096	-70.997192	NHRIV600030402-06	Sort003	NHDES	19980821
01C-KLY	Kelly Brook	Hampstead	42.857781	-71.11333	NHRIV700061401-04	Sort004	NHDES	20170725
01C-PRG	Purgatory Brook	Roxbury	42.855447	-71.699339	NHRIV700060904-07	Sort005	NHDES	20020719
01-HYW	Hayward Brook	Concord	43.274392	-71.564221	NHRIV700060302-08	Sort008	NHDES	20170706
01K-HOB	Hodgson Brook	Portsmouth	43.069322	-70.778485	NHRIV600031001-04	Sort009	NHDES	20170928
01M-NEG	Nesenkeag Brook	Litchfield	42.841883	-71.449954	NHRIV700061002-05	Sort011	NHDES	20170620
01-MSC	Mascoma River	Lebanon	43.633831	-72.317386	NHRIV801060106-20	Sort012	NHDES	20150825
01-NCB	Nicholls Brook	Deerfield	43.115559	-71.237412	NHRIV600030701-11	Sort014	NHDES	20160613
01-NEG	Nesenkeag Brook	Litchfield	42.835731	-71.473669	NHRIV700061002-05	Sort015	NHDES	20000703
01-NIS	Nissitissit R	Hollis	42.7052	-71.621	NHRIV700040401-20	Sort016	NHDES	20160728
01-PEN	Pennichuck Brook	Merrimack	42.793503	-71.470755	NHRIV700061001-10	Sort017	NHDES	20150806
01-RND	Rand Brook	Francestown	42.956759	-71.78401	NHRIV700060604-11	Sort018	NHDES	20050630
01-SBA	South Branch Ashuelot River	Swanzey	42.888941	-72.275978	NHRIV802010303-23	Sort019	NHDES	20150804
01-SGR	Sugar River	Claremont	43.398329	-72.393798	NHRIV801060407-16	Sort020	NHDES	20160808
01-SMN	Salmon Brook	Nashua	42.749592	-71.457133	NHRIV700061201-06	Sort022	NHDES	20170811
01S-SAN	Sanborn Brook	Chichester	43.284363	-71.358367	NHRIV700060501-22	Sort023	NHDES	20040727
01-TKR	Turkey River	Bow	43.169031	-71.524747	NHRIV700060301-13	Sort025	NHDES	20000714
01T-SOP	Piscataquog River-South Branch	New Boston	42.982247	-71.682594	NHRIV700060606-05	Sort026	NHDES	20160725
01X-OTB	Otter Brook	Roxbury	42.971142	-72.214519	NHRIV802010201-19	Sort028	NHDES	20150731
02-BKB	Black Brook	Manchester	43.02538	-71.504638	NHRIV700060801-05-02	Sort030	NHDES	20000706
02-ISG	Isinglass River	Rochester	43.233476	-70.955424	NHRIV600030607-10	Sort034	NHDES	19980826
02-LCH	Little Cohas Brook	Manchester	42.919813	-71.445941	NHRIV700060804-05	Sort036	NHDES	20000628
02L-GRD	Gridley River	Sharon	42.80518	-71.9523	NHRIV700030104-29	Sort037	NHDES	20170711
02-SEC	Second Brook	Hudson	42.751649	-71.41934	NHRIV700061206-10	Sort039	NHDES	20000703
02-SKR	Shaker Brook	Loudon	43.327711	-71.488206	NHRIV700060202-09	Sort040	NHDES	20000711
02V-LLR	Little River	Plaistow	42.824835	-71.105532	NHRIV700061401-04	Sort043	NHDES	20170801
03-BVR	Beaver Brook	Pelham	42.733092	-71.318344	NHRIV700061205-01	Sort045	NHDES	19990619
03-LLR	Little River	Plaistow	42.826387	-71.103943	NHRIV700061401-04	Sort049	NHDES	20170801

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
03P-103	Lamprey River	Lee	43.114312	-70.984675	NHRIV600020709-08	Sort051	NHDES	20030826
03-PIS	Piscassic River	Newmarket	43.068981	-70.961932	NHRIV600030708-07	Sort052	NHDES	20170619
03-POL	Porcupine Brook	Salem	42.76583	-71.23573	NHRIV700061102-18	Sort053	NHDES	20030924
03-SAN	Sanborn brook	Chichester	43.292649	-71.36072	NHRIV700060501-22	Sort054	NHDES	20040805
03X-MIP	Middle Branch Piscataquog	New Boston	43.012446	-71.704215	NHRIV700060605-08	Sort057	NHDES	19990616
04A-ISG	Isinglass River	Barrington	43.245592	-71.004109	NHRIV600030607-01	Sort058	NHDES	19980825
04-BRA	Branch River	Wakefield	43.494476	-71.026437	NHRIV600030402-05	Sort059	NHDES	20150709
04-COH	Cohas Brook	Manchester	42.954269	-71.402184	NHRIV700060703-05	Sort061	NHDES	20000628
04-COR	Cornelius Brook	North Hampton	42.995189	-70.846381	NHRIV600030901-01	Sort062	NHDES	20030813
04D-SOP	South Branch Piscataquog River	New Boston	42.954536	-71.708657	NHRIV700060606-03	Sort063	NHDES	20150616
04E-BVR	Beaver Brook	Pelham	42.754086	-71.332433	NHRIV700061203-21	Sort064	NHDES	20020716
04J-CLD	Cold River	Langdon	43.167797	-72.349905	NHRIV801070202-09	Sort066	NHDES	20020717
04M-CLD	Cold River	Langdon	43.169802	-72.345635	NHRIV801070202-09	Sort067	NHDES	19970820
04-PST	Preston Brook	Auburn	43.012037	-71.328552	NHRIV700060701-12	Sort069	NHDES	20170810
04-SKR	Sucker Brook	Hollis	42.71435	-71.557574	NHRIV700040402-02	Sort070	NHDES	20170921
04-TKR	Turkey River	Concord	43.169395	-71.533356	NHRIV700060301-13	Sort071	NHDES	20170710
05B-FER	Ferguson Brook	Hancock	42.945809	-71.973736	NHRIV700030106-05	Sort073	NHDES	20170712
05-BFG	Bumfagon Brook	Loudon	43.348727	-71.455733	NHRIV700060201-08	Sort074	NHDES	20170705
05F-SNK	Suncook River	Epsom	43.204026	-71.371522	NHRIV700060503-03-01	Sort076	NHDES	20130919
05-GOL	Golden Brook	Windham	42.784723	-71.312356	NHRIV700061204-03	Sort077	NHDES	20170621
05-ISR	Israel River	Lancaster	44.480435	-71.551967	NHRIV801010806-08	Sort078	NHDES	19980803
05M-BVR	Beaver Brook	Pelham	42.77015	-71.350657	NHRIV700061203-21	Sort080	NHDES	20170621
05-NBC	North Branch	Antrim	43.07318	-72.018542	NHRIV700030202-17	Sort082	NHDES	19990628
05-NOR	North River	Nottingham	43.11665	-71.083206	NHRIV600030706-02	Sort083	NHDES	19980825
05-PIS	Piscassic River	Newfields	43.036105	-70.987233	NHRIV600030708-02	Sort084	NHDES	20170619
05-SOP	South Branch Piscataquog River	New Boston	42.9422	-71.728369	NHRIV700060606-02	Sort086	NHDES	19990615
06-BRY	Berry's River	Farmington	43.3118	-71.078044	NHRIV600030606-03	Sort089	NHDES	20020711
06-CRN	Crooked Run	Barnstead	43.318275	-71.258382	NHRIV700060501-04	Sort090	NHDES	20170717
06-DMB	Deer Meadow Brook	Hopkinton	43.253096	-71.68298	NHRIV700030506-04	Sort091	NHDES	20170816
06-FPB	Scott Brook	Fitzwilliam	42.758918	-72.124086	NHRIV802020102-02	Sort092	NHDES	20170626
06F-SNK	Suncook River	Epsom	43.22704	-71.356978	NHRIV700060503-03	Sort093	NHDES	20130920
06-MIP	M. Br. Piscataquog	New Boston	43.003471	-71.718446	NHRIV700060605-12	Sort094	NHDES	20140902
06-NUB	Nubanusit Brook	Peterborough	42.911222	-71.995887	NHRIV700030103-12	Sort096	NHDES	20140617

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
06-OYS	Oyster River	Durham	43.129454	-70.935312	NHRIV600030902-09	Sort097	NHDES	19980826
06-TKR	Turkey River	Concord	43.170769	-71.536487	NHRIV700060301-11	Sort098	NHDES	20170815
07A-BVR	Beaver Brook	Windham	42.79038	-71.364451	NHRIV700061203-21	Sort099	NHDES	19990617
07-BLM	Bellamy River	Madbury	43.17443	-70.91779	NHRIV600030903-08	Sort100	NHDES	20160811
07T-ISG	Isinglass River	Barrington	43.238821	-71.076626	NHRIV600030607-01	Sort105	NHDES	20160811
08-BRDS	Beards Brook	Hillsborough	43.143675	-71.955799	NHRIV700030204-14	Sort108	NHDES	20160804
08-RID	Baboosic Brook	Merrimack	42.942969	-71.528203	NHRIV700060905-19	Sort109	NHDES	20000703
08T-LMP	Lamprey River	Lee	43.115515	-71.003078	NHRIV600030709-08	Sort110	NHDES	20171004
09JM-PQG	Piscataquog River	Weare	43.108655	-71.752157	NHRIV700060602-02	Sort112	NHDES	20090908
09L-PQG	Piscataquog River	Weare	43.110211	-71.759092	NHRIV700060602-02	Sort113	NHDES	20020710
09-NOR	North River	Nottingham	43.163412	-71.110849	NHRIV600030705-13	Sort114	NHDES	19980825
09-NUB	Nubanusit Brook	Harrisville	42.932026	-72.035914	NHRIV700030103-07	Sort115	NHDES	19970730
09-OYS	Oyster River	Lee	43.148281	-70.965667	NHRIV600030902-04	Sort116	NHDES	20160811
09-SHB	Shields Brook	Londonderry	42.8993	-71.3422	NHRIV700061203-11	Sort117	NHDES	20170921
09-TKR	Turkey River	Concord	43.178584	-71.55313	NHRIV700060301-11	Sort118	NHDES	20170815
10-BBB	Bow Bog Brook	Bow	43.128251	-71.500986	NHRIV700060302-20	Sort120	NHDES	20170705
10-BVR	Beaver Brook	Windham	42.857639	-71.336136	NHRIV700061203-21	Sort121	NHDES	20000706
10-JOE	Joe English Brook	Amherst	42.917365	-71.616905	NHRIV700060905-06	Sort122	NHDES	20170719
10-LLR	Little River	Plaistow	42.852095	-71.091535	NHRIV700061401-01	Sort123	NHDES	20170614
10-WNR	Warner River	Bradford	43.267502	-71.918803	NHRIV700030302-12	Sort124	NHDES	20150713
11-BEA	Beaver Brook	Mont Vernon	42.895333	-71.643271	NHRIV700060906-01	Sort125	NHDES	20170718
11B-PST	Preston Brook	Auburn	43.004993	-71.314848	NHRIV700060701-12	Sort126	NHDES	20170810
12-TKR	Turkey River	Concord	43.184439	-71.563847	NHRIV700060301-11	Sort128	NHDES	20030909
13-BKW	Blackwater River	Andover	43.43132	-71.861828	NHRIV700030403-13	Sort129	NHDES	20170824
13-LLR	Little River	Plaistow	42.85764	-71.084352	NHRIV700061401-01	Sort131	NHDES	20170614
14A-LMP	Lamprey River	Epping	43.0411	-71.074475	NHRIV600030703-15	Sort132	NHDES	19980824
15A-LMP	Lamprey River	Epping	43.04113	-71.128779	NHRIV600030703-11	Sort134	NHDES	20171004
15-CCH	Cocheco River	Rochester	43.247538	-70.956625	NHRIV600030607-15	Sort135	NHDES	19980826
15-EXT	Exeter River	Brentwood	42.984705	-71.038343	NHRIV600030803-05	Sort136	NHDES	20161013
15P-AMM	Ammonoosuc River	Littleton	44.306984	-71.759462	NHRIV801030403-11	Sort137	NHDES	20030806
15-STY	Stony Brook	Lyndeborough	42.907586	-71.828561	NHRIV700060903-11	Sort138	NHDES	20170718
15-TKR	TURKEY RIVER	Concord	43.188913	-71.570715	NHRIV700060301-11	Sort139	NHDES	20100701
16-SGR	SUGAR RIVER	Sunapee	43.372966	-72.124968	NHRIV801060405-10	Sort141	NHDES	20170809

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
16-SHG	Souhegan River	Wilton	42.821707	-71.760484	NHRIV700060902-13	Sort142	NHDES	19990615
16-SNK	Suncook River	Gilmanton	43.414598	-71.296292	NHRIV700060402-05	Sort143	NHDES	20000711
17-MCQ	McQuade Brook	Bedford	42.943941	-71.567048	NHRIV700060905-12	Sort144	NHDES	20170719
17-MSC	Mascoma	Canaan	43.652076	-72.09335	NHRIV801060105-05	Sort145	NHDES	19970806
18-MSC	Mascoma River	Canaan	43.648519	-72.076229	NHRIV801060105-05	Sort146	NHDES	20140821
18-TKR	Turkey River	Concord	43.193442	-71.576238	NHRIV700060301-11	Sort147	NHDES	20170710
19P-SHG	Souhegan River	Greenville	42.772161	-71.806116	NHRIV700060902-05	Sort148	NHDES	20020808
21F-LMP	Lamprey River	Raymond	43.048193	-71.208354	NHRIV600030703-05	Sort149	NHDES	19980827
22-CCH	Cocheco River	Rochester	43.339194	-70.997128	NHRIV600030603-06	Sort151	NHDES	19980826
22J-CCH	Cocheco River	Farmington	43.352683	-71.017005	NHRIV600030603-01	Sort152	NHDES	20160811
22O-ASH	Ashuelot River (gorge)	Gilsum	43.03862	-72.271186	NHRIV802010104-13	Sort153	NHDES	20060818
23-CCH	Cocheco River	Farmington	43.375948	-71.041305	NHRIV600030603-01	Sort154	NHDES	19980826
23J-ASH	Ashuelot River	Gilsum	43.06044	-72.230945	NHRIV802010103-22	Sort155	NHDES	19970806
30-EXT	Exeter River	Sandown	42.936156	-71.213737	NHRIV600030802-03	Sort156	NHDES	20170725
31BO-CTC	Contoocook River	Jaffrey	42.833256	-71.987558	NHRIV700030101-16	Sort157	NHDES	19990614
ACPS12-U30	Little River	North Hampton	42.964449	-70.796993	NHRIV600031004-04	Sort158	NHDES	20000705
NHFG-1005	Green Hill Brook	Barrington	43.234496	-70.976143	NHRIV600030607-09	Sort159	NHF&G	20100628
NHFG-1014	Nippo Brook	Barrington	43.24222	-71.0972	NHRIV600030605-15	Sort160	NHF&G	20080729
NHFG-1031	Isinglass River	Strafford	43.251688	-71.11148	NHRIV600030605-11	Sort163	NHF&G	20080607
NHFG-1041	Soucook River Loudon	Loudon	43.255638	-71.454499	NHRIV700060202-18	Sort164	NHF&G	19990719
NHFG-1143	Soucook River	Loudon	43.310413	-71.465817	NHRIV700060202-11	Sort169	NHF&G	19990714
NHFG-1193	Soucook River	Loudon	43.34255	-71.464558	NHRIV700060202-10	Sort171	NHF&G	19990709
NHFG-122	Seaver Brook	Plaistow	42.829202	-71.087121	NHRIV700061401-02	Sort175	NHF&G	20130603
NHFG-131	Nesenkeag Brook	Litchfield	42.834249	-71.478778	NHRIV700061002-06	Sort183	NHF&G	20130718
NHFG-15	Second Brook	Hudson	42.75476	-71.438587	NHRIV700061206-10	Sort193	NHF&G	20130717
NHFG-169	Souhegan River	Merrimack	42.85799	-71.495112	NHRIV700060906-18	Sort197	NHF&G	20090820
NHFG-170	Souhegan River	Merrimack	42.858388	-71.494353	NHRIV700060906-18	Sort198	NHF&G	20130819
NHFG-1746	Pine River	Effingham	43.735736	-71.081542	NHRIV600020703-12	Sort199	NHF&G	20080714
NHFG-176	Souhegan River	Merrimack	42.86084	-71.49282	NHRIV700060906-18	Sort200	NHF&G	20090820
NHFG-178	Souhegan River	Merrimack	42.8611	-71.4923	NHRIV700060906-18	Sort202	NHF&G	20130819
NHFG-2023	Ammonoosuc River	Bath	44.156013	-72.025426	NHRIV801030506-10	Sort205	NHF&G	20110727
NHFG-215	Baboosic Brook	Merrimack	42.886096	-71.537176	NHRIV700060905-16	Sort211	NHF&G	20050804

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
NHFG-231	Baboosic Brook	Bedford	42.898133	-71.555499	NHRIV700060905-16	Sort213	NHF&G	20050804
02-PNB	Chandler Brook	Bedford	42.944971	-71.468426	NHRIV700060803-12	Sort224	NHF&G	20090803
NHFG-443	South Branch Piscataquog River	New Boston	43.001333	-71.662126	NHRIV700060606-06	Sort235	NHF&G	20020719
NHFG-453	Black Brook	Manchester	43.00858	-71.48212	NHRIV700060801-05-02	Sort237	NHF&G	20100727
NHFG-456	Black Brook	Manchester	43.009973	-71.477302	NHRIV700060801-05-02	Sort239	NHF&G	20090629
NHFG-458	Black Brook	Manchester	43.010263	-71.479209	NHRIV700060801-05-02	Sort240	NHF&G	20100727
NHFG-460	Black Brook	Manchester	43.010349	-71.477674	NHRIV700060801-05-02	Sort241	NHF&G	20100727
NHFG-461	Middle Branch Piscataquog River	New Boston	43.010869	-71.705647	NHRIV700060605-08	Sort242	NHF&G	20060912
NHFG-468	Piscassic River	Freemont	43.01702	-71.08563	NHRIV600030708-14	Sort244	NHF&G	20100809
NHFG-484	Thompson Brook	Greenland	43.025932	-70.85307	NHRIV600030901-02	Sort246	NHF&G	20110809
NHFG-485	Mill Brook	Stratham	43.02697	-70.920241	NHRIV600030806-11	Sort247	NHF&G	20130603
NHFG-488	Thompson Brook	Greenland	43.027336	-70.854424	NHRIV600030901-02	Sort248	NHF&G	20110809
NHFG-498	Unknown Brook	Raymond	43.03072	-71.209905	NHRIV600030703-02	Sort249	NHF&G	20100726
NHFG-517	Lamprey River	Epping	43.041378	-71.128259	NHRIV600030703-11	Sort251	NHF&G	20100805
NHFG-523	Dudley Brook	Raymond	43.050909	-71.212408	NHRIV600030703-04	Sort253	NHF&G	20100715
NHFG-531	Unknown Brook	Newmarket	43.05501	-70.96711	NHRIV600030708-06	Sort255	NHF&G	20100810
NHFG-550	North Branch River	Candia	43.063411	-71.248802	NHRIV600030702-07	Sort260	NHF&G	20070823
NHFG-582	Unknown	Candia	43.075869	-71.311155	NHRIV600030702-02	Sort262	NHF&G	20070813
NHFG-603	Unknown	Candia	43.079096	-71.29614	NHRIV600030702-02	Sort263	NHF&G	20070816
NHFG-605	North River	Epping	43.079364	-71.035769	NHRIV600030706-02	Sort264	NHF&G	20100727
NHFG-624	Unknown Brook	Nottingham	43.084842	-71.177713	NHRIV600030704-07	Sort267	NHF&G	20100721
NHFG-625	Unknown Brook	Lee	43.085921	-71.001851	NHRIV600030709-03	Sort268	NHF&G	20100804
NHFG-636	North River	Lee	43.09012	-71.047256	NHRIV600030706-02	Sort269	NHF&G	20100728
NHFG-638	Rollins Brook	Lee	43.0912	-71.063416	NHRIV600030706-04	Sort270	NHF&G	20100802
NHFG-645	Ellison Brook	Durham	43.09639	-70.924996	NHRIV600030709-12	Sort272	NHF&G	20080418
NHFG-651	North Branch River	Deerfield	43.09869	-71.30297	NHRIV600030702-06	Sort273	NHF&G	20070816
NHFG-654	Unknown Brook	Durham	43.099936	-71.020011	NHRIV600030709-05	Sort274	NHF&G	20100802
NHFG-674	Lamprey River	Deerfield	43.107394	-71.242219	NHRIV600030701-09	Sort275	NHF&G	20100707
NHFG-683	Hartford Brook	Deerfield	43.109404	-71.267942	NHRIV600030701-08	Sort277	NHF&G	20100629
NHFG-687	Little River	Lee	43.111334	-71.01187	NHRIV600030707-07	Sort279	NHF&G	20130815
NHFG-702	North River	Nottingham	43.116296	-71.077346	NHRIV600030706-02	Sort281	NHF&G	20100728
NHFG-706	Nicholls Brook	Deerfield	43.11806	-71.24423	NHRIV600030701-11	Sort282	NHF&G	20100713
NHFG-710	Little River	Lee	43.118715	-71.022125	NHRIV600030707-07	Sort283	NHF&G	20100720

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
NHFG-712	Unknown Brook	Nottingham	43.118887	-71.117432	NHRIV600030705-15	Sort285	NHF&G	20100707
NHFG-764	Little River	Nottingham	43.138419	-71.059248	NHRIV600030707-03	Sort288	NHF&G	20100728
NHFG-776	Lamprey River	Deerfield	43.14093	-71.230755	NHRIV600030701-09	Sort289	NHF&G	20100713
NHFG-850	Unnamed Stream	Nottingham	43.16322	-71.09584	NHRIV600030707-03	Sort292	NHF&G	20130818
NHFG-856	North River	Nottingham	43.167082	-71.110138	NHRIV600030705-13	Sort293	NHF&G	20100629
NHFG-861	Unknown Brook	Nottingham	43.1695	-71.10148	NHRIV600030707-03	Sort294	NHF&G	20100721
NHFG-895	Unknown Brook	Northwood	43.185758	-71.162152	NHRIV600030705-08	Sort296	NHF&G	20100706
NHFG-92	Chase Brook	Litchfield	42.814486	-71.472273	NHRIV700061002-09	Sort297	NHF&G	20130716
NHFG-928	Soucook River Pembroke	Pembroke	43.1997	-71.4818	NHRIV700060202-21	Sort298	NHF&G	19990719
NHFG-945	Giffin Brook	Deerfield	43.203882	-71.293429	NHRIV700060502-08	Sort299	NHF&G	20080805
NHFG-951	Cocheco River	Dover	43.207956	-70.915439	NHRIV600030608-05	Sort300	NHF&G	20080922
NHFG-954	Blake Brook	Epsom	43.209791	-71.311741	NHRIV700060502-16	Sort301	NHF&G	20080528
NHFG-959	Suncook River	Epsom	43.213223	-71.365404	NHRIV700060503-04	Sort302	NHF&G	20070827
NHFG-960	Cocheco River	Dover	43.213595	-70.922018	NHRIV600030608-05	Sort303	NHF&G	20080922
25Z-CTC	Contoocook River	Peterborough	42.899787	-71.93693	NHRIV700030104-17	Sort305	NHDES	20030910
07-SGR	Sugar River	Newport	43.362297	-72.22485	NHRIV801060406-30	Sort306	NHDES	19970806
10W-ASH	Ashuelot River	Winchester	42.800807	-72.375142	NHRIV802010401-19	Sort307	NHDES	19970813
05Q-ASH	Ashuelot River	Winchester	42.772645	-72.410078	NHRIV802010403-09	Sort309	NHDES	19970815
11-LMP	Lamprey River	Lee	43.091371	-71.007141	NHRIV600030709-07	Sort310	NHDES	19980824
16-ASH	Ashuelot River(up)	Swanzey	42.886195	-72.286546	NHRIV802010401-15	Sort311	NHDES	19990826
14T-ASH	Ashuelot River(down)	Swanzey	42.868086	-72.326997	NHRIV802010401-16	Sort312	NHDES	19990826
03P-101	Lamprey River	Lee	43.087731	-71.00078	NHRIV600030709-07	Sort313	NHDES	20030828
03P-104	Lamprey River	Durham	43.101762	-70.961768	NHRIV600030709-09	Sort314	NHDES	20030827
03P-105	Lamprey River	Durham	43.105861	-70.946829	NHRIV600030709-09	Sort315	NHDES	20030827
21G-ASH	Ashuelot River	Surry	43.021838	-72.31419	NHRIV802010104-13	Sort316	NHDES	20040709
06M-CLD	Cold River	Acworth	43.186765	-72.255272	NHRIV801070202-02	Sort317	NHDES	20060807

Table 2, Detailed Site Information

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC11DEV (PCT)
00M-BRA	53.76	430.64	4	Coastal	1.17	17.01	9.60	1824.96	7.26	1.35	6.88
01C-KLY	3.22	129.23	3	Merrimack	0.07	27.63	5.56	367.45	7.62	9.81	27.66
01C-PRG	12.01	266.97	3	Merrimack	16.86	67.43	8.48	1342.34	6.11	0.58	3.87

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC11DEV (PCT)
01-HYW	15.04	288.49	3	Merrimack	0.47	20.75	7.77	1161.76	10.55	0.55	3.32
01K-HOB	3.51	20.00	2	Coastal	0.07	22.95	1.33	101.07	7.06	40.22	80.27
01M-NEG	8.13	176.90	3	Merrimack	0.11	30.84	4.89	443.08	16.75	6.24	21.19
01-MSC	194.50	366.73	5	Connecticut	0.00	26.25	12.39	3217.65	6.68	1.57	5.56
01-NCB	4.03	272.37	3	Coastal	0.28	74.36	6.75	867.65	2.46	0.89	6.92
01-NEG	8.12	131.98	3	Merrimack	11.58	23.83	4.74	443.08	16.22	7.04	23.53
01-NIS	48.20	214.11	4	Merrimack	0.00	32.88	7.77	1095.31	6.18	1.17	5.79
01-PEN	26.80	133.57	4	Merrimack	0.02	15.21	5.62	809.32	10.65	11.50	29.08
01-RND	10.09	615.00	3	Merrimack	34.80	83.93	10.48	1723.94	3.90	0.45	5.06
01-SBA	75.10	503.67	5	Connecticut	0.40	36.86	11.07	3148.29	5.18	1.14	5.68
01-SGR	272.34	312.04	6	Connecticut	0.00	25.92	12.30	2766.18	7.18	1.85	7.52
01-SMN	30.64	115.32	4	Merrimack	0.01	7.95	5.83	495.28	15.07	13.36	30.83
01S-SAN	10.67	424.00	2	Merrimack	42.37	45.29	5.84	1056.76	6.85	0.47	3.53
01-TKR	37.44	215.74	4	Merrimack	0.00	11.66	6.41	905.37	11.29	4.55	14.96
01T-SOP	55.24	401.54	4	Merrimack	0.01	28.51	10.00	2025.43	5.14	0.85	6.10
01X-OTB	40.84	831.99	5	Connecticut	11.01	58.48	13.02	2148.83	5.08	0.61	4.73
02-BKB	20.72	284.98	4	Merrimack	10.60	37.14	8.14	920.38	8.18	1.06	5.70
02-ISG	73.76	121.48	4	Coastal	0.05	29.72	7.30	1401.81	9.28	1.14	7.70
02-LCH	8.74	143.43	3	Merrimack	15.21	23.07	4.86	533.38	10.13	18.67	44.17
02L-GRD	7.94	1075.32	2	Merrimack	0.33	31.69	7.96	1881.42	15.52	0.49	4.66
02-SEC	4.69	239.00	3	Merrimack	8.98	52.01	7.69	499.35	8.59	4.50	15.27
02-SKR	14.31	450.50	3	Merrimack	49.47	69.87	8.41	1493.34	4.67	0.10	0.92
02V-LLR	14.59	54.13	4	Merrimack	0.02	24.08	4.63	370.75	12.17	11.70	32.82
03-BVR	73.02	153.78	4	Merrimack	0.01	10.76	5.86	637.67	9.40	12.37	36.14
03-LLR	14.51	90.88	4	Merrimack	0.02	24.36	4.64	370.75	12.24	11.57	32.46
03P-103	183.01	58.07	1	Coastal	0.00	10.29	6.73	1144.55	7.83	1.78	9.17
03-PIS	19.50	60.45	4	Coastal	0.03	7.62	2.95	307.65	15.82	3.59	14.06
03-POL	5.29	122.84	2	Merrimack	5.39	35.64	4.36	370.02	14.19	19.83	47.23
03-SAN	10.14	450.30	2	Merrimack	44.81	46.64	5.88	1056.76	7.26	0.38	3.25
03X-MIP	17.50	441.82	4	Merrimack	13.55	49.63	9.28	1301.47	7.73	0.59	5.67
04A-ISG	66.35	188.74	4	Coastal	0.11	36.75	7.49	1401.81	9.79	0.72	6.30
04-BRA	35.60	482.38	3	Coastal	7.09	17.12	10.68	1824.96	8.57	1.21	6.85
04-COH	14.95	208.80	3	Merrimack	9.45	12.09	6.00	635.65	11.11	6.32	18.99

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC11DEV (PCT)
04-COR	0.56	52.68	2	Coastal	8.00	21.01	3.18	117.62	1.63	6.15	60.59
04D-SOP	46.73	489.79	4	Merrimack	1.35	32.48	9.82	2025.43	5.18	0.70	5.65
04E-BVR	52.49	139.84	3	Merrimack	0.09	11.32	5.85	637.67	7.41	13.49	37.57
04J-CLD	59.93	603.31	4	Connecticut	8.01	37.21	12.83	2161.57	2.79	0.41	4.40
04M-CLD	59.25	617.36	4	Connecticut	8.45	37.55	12.83	2161.57	2.81	0.41	4.39
04-PST	5.28	260.22	3	Merrimack	0.21	45.33	6.55	599.70	11.31	1.87	10.02
04-SKR	2.81	198.82	2	Merrimack	0.13	61.95	4.38	481.47	6.91	3.98	12.39
04-TKR	34.89	280.95	4	Merrimack	0.07	12.52	6.49	905.37	11.98	3.21	11.97
05B-FER	8.47	717.77	3	Merrimack	0.51	112.46	10.74	1986.87	3.87	0.62	6.41
05-BFG	29.25	422.41	4	Merrimack	0.20	70.97	8.14	1458.01	5.77	0.49	3.32
05F-SNK	205.20	307.28	5	Merrimack	0.00	15.07	8.62	2339.32	7.72	1.00	5.56
05-GOL	9.04	166.93	3	Merrimack	0.05	35.65	6.68	508.33	11.91	11.66	38.82
05-ISR	132.37	964.82	5	Connecticut	0.76	47.30	16.97	5694.50	3.41	0.50	2.74
05M-BVR	49.40	159.94	4	Merrimack	0.00	12.59	5.61	637.67	7.69	13.95	38.63
05-NBC	51.12	1030.20	5	Merrimack	4.17	19.28	11.78	2468.40	10.14	0.50	3.61
05-NOR	25.66	220.34	4	Coastal	3.15	22.17	6.23	1144.55	7.57	1.14	7.13
05-PIS	10.29	114.99	4	Coastal	0.06	6.15	2.74	307.65	14.95	4.44	16.88
05-SOP	41.62	518.96	3	Merrimack	2.15	34.37	9.96	2025.43	5.22	0.72	5.80
06-BRY	6.36	438.91	3	Coastal	34.75	77.67	9.46	1346.67	4.75	0.39	4.45
06-CRN	8.48	552.18	3	Merrimack	0.44	52.53	8.24	1240.90	6.72	0.38	3.49
06-DMB	18.05	373.53	3	Merrimack	0.46	32.24	7.46	959.49	9.94	0.36	2.67
06-FPB	7.62	1048.78	3	Connecticut	0.41	31.78	6.93	1889.13	16.58	0.47	3.90
06F-SNK	161.22	332.94	5	Merrimack	0.00	18.23	8.68	2339.32	7.01	0.84	4.89
06-MIP	15.80	496.20	4	Merrimack	24.48	51.63	9.31	1301.47	7.94	0.56	5.30
06-NUB	25.73	951.88	4	Merrimack	15.78	33.95	11.04	2215.50	14.06	0.26	3.05
06-OYS	17.48	44.73	4	Coastal	4.51	14.50	4.41	387.24	8.33	2.49	13.54
06-TKR	34.74	284.95	4	Merrimack	0.07	12.90	6.49	905.37	12.02	3.16	11.87
07A-BVR	42.83	207.08	4	Merrimack	0.29	11.78	5.36	637.67	7.70	14.35	39.48
07-BLM	22.90	92.89	4	Coastal	0.03	19.60	4.29	513.49	18.26	1.76	9.78
07T-ISG	57.52	236.68	4	Coastal	0.00	51.97	7.66	1401.81	9.59	0.67	5.68
08-BRDS	29.28	782.53	4	Merrimack	0.28	66.38	13.39	2459.87	7.37	0.18	2.50
08-RID	48.98	176.96	4	Merrimack	0.37	101.33	8.69	1318.29	3.38	5.27	24.47
08T-LMP	180.99	64.80	6	Coastal	0.00	10.81	6.76	1144.55	7.83	1.78	9.12

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC11DEV (PCT)
09JM-PQG	32.98	563.00	4	Merrimack	11.10	399.73	9.38	821.03	0.00	0.96	10.29
09L-PQG	30.79	586.39	4	Merrimack	13.63	31.37	10.08	1523.32	7.76	0.56	5.18
09-NOR	8.73	296.10	3	Coastal	17.78	40.83	6.74	976.63	6.28	2.21	11.44
09-NUB	15.96	1037.69	4	Merrimack	37.09	28.42	11.36	2215.50	15.65	0.26	2.84
09-OYS	12.26	72.08	4	Coastal	0.09	17.73	4.47	387.24	9.58	2.21	11.39
09-SHB	2.55	318.11	2	Merrimack	0.17	41.02	4.79	549.85	8.97	11.25	35.59
09-TKR	33.76	277.62	4	Merrimack	0.08	14.11	6.57	905.37	12.14	3.01	11.41
10-BBB	5.23	377.98	3	Merrimack	0.46	78.45	7.92	915.24	4.43	1.15	5.79
10-BVR	41.47	192.58	4	Merrimack	0.36	18.48	5.61	637.67	6.59	14.28	36.56
10-JOE	5.95	327.98	1	Merrimack	0.28	106.81	10.30	1280.79	4.72	0.27	1.40
10-LLR	7.93	136.02	4	Merrimack	0.04	29.18	4.48	370.75	16.46	7.92	23.51
10-WNR	58.31	639.70	3	Merrimack	4.28	77.15	13.58	2702.76	6.35	0.66	4.45
11-BEA	3.49	425.65	2	Merrimack	0.32	93.86	8.94	951.07	4.88	1.33	8.70
11B-PST	4.20	284.17	3	Merrimack	0.22	43.48	6.65	599.70	13.02	1.43	8.65
12-TKR	32.30	273.48	4	Merrimack	9.91	15.21	6.72	905.37	12.52	2.30	9.43
13-BKW	73.03	639.05	5	Merrimack	0.02	69.03	13.00	2913.57	4.92	0.76	4.59
13-LLR	4.26	111.02	3	Merrimack	0.06	35.13	4.96	370.75	13.24	6.45	16.86
14A-LMP	106.58	107.93	5	Coastal	0.00	18.06	7.50	1144.55	7.13	1.97	9.20
15A-LMP	76.11	131.24	4	Coastal	0.00	18.90	7.33	1144.55	6.32	2.40	10.10
15-CCH	84.68	115.50	4	Coastal	0.02	15.64	6.16	1357.85	6.11	4.60	16.27
15-EXT	63.47	82.00	4	Coastal	0.00	7.09	5.43	652.13	13.72	2.80	10.77
15P-AMM	125.01	819.90	4	Connecticut	1.16	43.58	18.16	6283.81	1.17	1.07	5.22
15-STY	8.09	839.23	2	Merrimack	0.36	171.74	11.96	2259.68	3.94	0.42	4.19
15-TKR	30.75	279.60	4	Merrimack	11.73	14.52	6.76	905.37	12.91	2.08	9.00
16-SGR	53.96	850.00	4	Connecticut	0.18	45.78	10.85	2715.07	19.01	1.80	8.78
16-SHG	63.75	489.73	4	Merrimack	0.16	39.10	10.79	2277.26	4.01	1.44	7.49
16-SNK	28.22	609.73	4	Merrimack	18.78	89.22	13.51	2339.32	8.88	0.19	1.76
17-MCQ	2.73	338.41	3	Merrimack	0.34	134.77	9.39	1318.29	3.31	2.43	13.58
17-MSC	81.02	812.04	5	Connecticut	6.31	44.17	12.01	3217.65	5.35	0.55	2.65
18-MSC	80.37	890.80	5	Connecticut	6.24	48.87	12.02	3217.65	5.35	0.54	2.59
18-TKR	30.50	313.19	4	Merrimack	0.12	11.96	6.77	905.37	12.98	1.99	8.79
19P-SHG	30.58	746.66	4	Connecticut	3.14	26.23	10.22	1872.68	5.63	1.77	8.06
21F-LMP	52.37	190.96	5	Coastal	0.28	28.99	7.65	1144.55	5.13	1.15	6.11

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC11DEV (PCT)
22-CCH	58.10	228.69	4	Coastal	0.38	26.87	6.74	1357.85	5.21	1.94	9.27
22J-CCH	52.53	231.40	4	Coastal	0.01	34.05	6.96	1357.85	5.27	1.92	9.39
22O-ASH	71.90	801.98	5	Connecticut	1.13	31.09	11.68	2521.63	7.12	0.41	3.34
23-CCH	48.28	251.05	4	Coastal	1.31	39.88	6.81	1357.85	5.40	1.87	9.59
23J-ASH	64.12	1062.42	5	Connecticut	2.28	28.26	11.43	2521.63	7.71	0.40	3.22
30-EXT	6.49	244.09	3	Coastal	0.10	28.98	6.82	598.11	6.70	2.11	7.52
31BO-CTC	37.11	897.57	4	Merrimack	4.04	19.72	8.01	3122.59	11.67	2.15	10.02
ACPS12-U30	6.15	18.16	3	Coastal	3.64	16.63	2.16	127.31	21.35	7.65	24.89
NHFG-1005	2.10	137.79	2	Coastal	27.86	36.59	6.43	352.81	6.42	3.00	13.77
NHFG-1014	9.04	265.75	4	Coastal	23.49	62.27	7.20	927.87	8.77	0.66	6.88
NHFG-1031	17.85	291.99	3	Coastal	12.90	43.15	7.01	1225.45	15.27	0.63	5.16
NHFG-1041	73.38	311.68	4	Merrimack	0.24	30.84	7.77	1493.34	5.81	0.99	4.59
NHFG-1143	53.81	377.30	2	Merrimack	2.05	48.54	8.06	1493.34	5.28	0.85	3.84
NHFG-1193	33.03	400.26	4	Merrimack	14.64	63.83	8.03	1458.01	5.48	0.99	3.98
NHFG-122	0.75	101.71	2	Merrimack	7.09	80.67	5.51	277.72	2.61	9.87	36.30
NHFG-131	9.32	98.42	3	Merrimack	10.57	22.29	4.73	443.08	16.04	7.15	23.74
NHFG-15	5.17	98.42	3	Merrimack	9.24	40.98	7.33	499.35	7.65	9.24	23.96
NHFG-169	171.19	127.95	5	Merrimack	0.00	25.29	9.66	2278.75	4.73	3.15	12.06
NHFG-170	171.19	124.67	5	Merrimack	0.00	25.26	9.66	2278.75	4.73	3.15	12.06
NHFG-1746	47.54	416.67	4	Coastal	9.37	19.69	7.97	1882.71	7.87	1.05	5.75
NHFG-176	171.20	104.99	5	Merrimack	0.00	25.14	9.66	2278.75	4.73	3.17	12.10
NHFG-178	171.20	98.42	5	Merrimack	0.00	25.12	9.66	2278.75	4.73	3.17	12.10
NHFG-2023	401.93	439.63	5	Connecticut	0.00	24.89	17.27	6283.81	1.46	1.01	4.93
NHFG-215	25.02	203.41	4	Merrimack	4.10	56.32	8.65	1280.79	8.26	1.96	9.66
NHFG-231	23.19	209.97	4	Merrimack	5.40	64.37	8.95	1280.79	8.28	1.81	8.93
02-PNB	3.00	157.48	3	Merrimack	0.19	41.10	4.98	480.50	3.28	16.02	59.09
NHFG-443	59.37	341.21	4	Merrimack	0.46	28.50	10.00	2025.43	4.89	0.88	6.11
NHFG-453	22.17	206.69	4	Merrimack	8.14	35.82	8.10	920.38	8.00	1.99	8.02
NHFG-456	22.27	180.45	4	Merrimack	8.01	34.28	8.10	920.38	7.99	2.13	8.26
NHFG-458	22.24	206.69	4	Merrimack	8.09	35.10	8.10	920.38	7.99	2.10	8.21
NHFG-460	22.27	177.16	4	Merrimack	8.05	34.59	8.10	920.38	7.99	2.12	8.24
NHFG-461	17.06	433.07	4	Merrimack	22.36	50.11	9.32	1301.47	7.54	0.59	5.64

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC11DEV (PCT)
NHFG-468	4.36	137.79	3	Coastal	12.52	10.50	3.78	307.65	14.81	2.65	13.49
NHFG-484	1.25	16.40	2	Coastal	8.89	67.67	3.90	256.83	8.30	4.56	26.48
NHFG-485	2.44	19.68	2	Coastal	9.76	39.54	3.44	279.72	9.01	5.18	20.79
NHFG-488	1.21	22.97	2	Coastal	9.01	71.44	3.85	256.83	8.12	4.58	26.63
NHFG-498	8.77	209.97	3	Coastal	13.00	37.79	7.03	730.69	10.88	2.69	10.01
NHFG-517	75.19	127.95	4	Coastal	0.02	18.86	7.33	1144.55	6.32	2.40	10.10
NHFG-523	2.47	200.13	2	Coastal	23.11	40.55	7.91	571.75	6.13	0.77	3.65
NHFG-531	0.63	78.74	1	Coastal	14.60	15.08	3.46	163.28	6.77	0.81	7.41
NHFG-550	14.56	216.53	3	Coastal	10.41	38.38	7.37	938.32	7.95	1.25	5.01
NHFG-582	0.35	410.10	1	Coastal	36.16	286.07	7.38	730.69	0.00	1.54	5.80
NHFG-603	5.72	377.30	3	Coastal	24.98	71.12	7.33	938.32	6.97	1.19	5.25
NHFG-605	35.66	98.42	5	Coastal	0.90	24.22	6.34	1144.55	7.01	1.00	6.87
NHFG-624	3.22	269.03	2	Coastal	23.11	50.12	12.62	971.08	4.24	0.07	3.02
NHFG-625	0.24	85.30	1	Coastal	18.78	30.64	2.28	141.82	11.22	0.29	6.60
NHFG-636	34.44	104.99	5	Coastal	1.11	23.70	6.36	1144.55	7.17	0.97	6.70
NHFG-638	7.44	118.11	3	Coastal	12.84	48.38	7.00	494.18	7.00	0.41	4.52
NHFG-645	0.54	39.37	1	Coastal	15.79	26.87	3.40	107.76	16.89	0.93	9.33
NHFG-651	2.89	370.73	2	Coastal	32.90	62.49	7.92	781.83	13.36	0.28	2.54
NHFG-654	0.60	95.14	1	Coastal	20.31	67.29	4.34	261.26	10.36	2.84	23.24
NHFG-674	16.00	252.62	4	Coastal	11.10	37.99	7.90	1144.55	3.42	0.85	5.93
NHFG-683	8.54	259.19	3	Coastal	21.54	105.49	7.81	1138.16	2.35	0.52	4.47
NHFG-687	20.44	78.74	3	Coastal	3.97	29.65	6.05	602.43	9.19	1.01	7.86
NHFG-702	25.69	196.85	1	Coastal	3.09	21.81	6.24	1144.55	7.51	1.14	7.10
NHFG-706	3.95	298.56	3	Coastal	29.04	71.11	6.77	867.65	2.44	0.85	6.80
NHFG-710	18.74	118.11	3	Coastal	4.94	31.84	6.03	602.43	9.31	0.93	7.59
NHFG-712	1.28	223.10	4	Coastal	26.28	57.85	5.86	460.16	7.15	0.52	6.69
NHFG-764	11.72	157.48	3	Coastal	11.06	49.19	6.21	602.43	9.08	0.79	7.28
NHFG-776	9.29	387.14	3	Coastal	21.16	39.68	8.37	1144.55	4.30	0.69	5.29
NHFG-850	1.91	301.84	1	Coastal	28.32	61.88	5.44	600.42	5.27	1.90	13.70
NHFG-856	8.34	298.56	4	Coastal	18.79	40.68	6.70	976.63	6.03	2.26	11.55
NHFG-861	1.23	318.24	1	Coastal	30.68	65.01	5.91	600.42	7.24	1.77	14.37
NHFG-895	1.27	390.42	2	Coastal	36.64	96.23	7.78	974.68	6.76	1.24	12.47
NHFG-92	7.36	98.42	3	Merrimack	11.17	18.38	4.16	408.39	17.38	12.67	34.93

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC11DEV (PCT)
NHFG-928	86.24	249.34	4	Merrimack	0.06	25.50	7.78	1493.34	5.48	1.86	6.59
NHFG-945	1.98	675.85	2	Merrimack	47.15	108.96	11.20	1339.75	5.98	0.43	3.28
NHFG-951	170.05	88.58	5	Coastal	0.00	15.13	6.47	1401.81	7.74	3.32	13.32
NHFG-954	2.28	626.64	2	Merrimack	0.00	139.11	14.72	1392.33	2.81	0.18	2.68
NHFG-959	205.49	305.12	5	Merrimack	0.00	15.83	8.65	2339.32	7.72	0.97	5.50
NHFG-960	169.72	101.71	5	Coastal	0.00	15.32	6.48	1401.81	7.75	3.31	13.29
25Z-CTC	126.50	701.93	6	Merrimack	2.28	34.15	9.33	3122.59	10.32	1.39	7.30
07-SGR	218.54	687.79	6	Connecticut	0.11	26.49	11.93	2766.18	8.48	1.43	6.85
10W-ASH	350.88	449.28	6	Connecticut	0.04	22.47	12.19	3148.29	5.94	1.67	6.93
05Q-ASH	389.64	446.52	6	Connecticut	0.06	20.30	12.20	3148.29	5.91	1.63	6.93
11-LMP	152.91	93.31	6	Coastal	0.22	11.55	7.05	1144.55	7.42	1.90	9.23
16-ASH	311.35	457.74	6	Connecticut	11.73	29.57	12.14	3148.29	6.15	1.74	7.22
14T-ASH	316.10	457.93	6	Connecticut	0.46	26.59	12.10	3148.29	6.11	1.75	7.24
03P-101	153.08	75.43	6	Coastal	0.16	11.56	7.04	1144.55	7.41	1.90	9.24
03P-104	184.32	43.82	6	Coastal	0.00	9.82	6.71	1144.55	7.81	1.77	9.13
03P-105	185.03	38.46	6	Coastal	0.00	9.63	6.70	1144.55	7.79	1.77	9.13
21G-ASH	95.27	528.07	6	Connecticut	0.28	35.84	12.94	2521.63	6.06	0.36	3.13
06M-CLD	34.67	914.58	6	Connecticut	0.00	43.32	11.73	2161.57	4.00	0.42	4.33

Appendix C. Warmwater Validation Sites

Warmwater site list identifying validation sites (n=100). General site information in Table 1. Detailed site information in Table 2. Note: One of the verification sites (05R-BKR) had two fish surveys on different dates. Developed land cover percent (LC01DEV/LC11DEV) based on either NLCD 2001 (pre-1997 fish survey) or NLCD 2011 (post-1997 fish survey).

Table 1, General Site Information

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
00F-SHW	Summer Brook (aka West Branch)	New Ipswich	42.7319	-71.8486	NHRIV700060901-05	Sort002	NHF&G	19870622
01-SHW	Summer Brook (aka West Branch)	New Ipswich	42.7314	-71.8544	NHRIV700060901-05	Sort021	NHF&G	19870622
03-BZZ	Buzzels Run	Strafford	43.2589	-71.2030	NHRIV600030604-01	Sort046	NHF&G	19850829
04-TNL	Townline Brook	Peterborough	42.8419	-71.9321	NHRIV700030104-04	Sort072	NHF&G	19870728
06-NIS	Nissitissit River	Brookline	42.7350	-71.6696	NHRIV700040401-20	Sort095	NHF&G	19870624
07-LLR	Little River	Plaistow	42.8439	-71.1013	NHRIV700061401-04	Sort103	NHF&G	19840920
09-BZZ	Buzzels Run	Strafford	43.2615	-71.2133	NHRIV600030604-01	Sort111	NHF&G	19850905
NHFG-1015	Isinglass River	Barrington	43.2424	-71.0822	NHRIV600030605-16	Sort161	NHF&G	19850827
NHFG-1022	Isinglass River	Strafford	43.2451	-71.1440	NHRIV600030605-11	Sort162	NHF&G	19850828
NHFG-109	Great Brook (Osgood)	Milford	42.8207	-71.6632	NHRIV700060906-12	Sort165	NHF&G	19860618
NHFG-1098	Ax Handle Brook	Rochester	43.2885	-71.0008	NHRIV600030602-03	Sort166	NHF&G	19850723
NHFG-1205	Cocheco River	Farmington	43.3524	-71.0167	NHRIV600030603-01	Sort173	NHF&G	19850712
NHFG-1251	Cocheco River	Farmington	43.3873	-71.0609	NHRIV600030601-09	Sort179	NHF&G	19850711
NHFG-1265	Ela River	Farmington	43.3979	-71.1000	NHRIV600030601-02	Sort180	NHF&G	19850709
NHFG-132	Souhegan River	Wilton	42.8343	-71.7513	NHRIV700060902-13	Sort184	NHF&G	19870626
NHFG-134	Beaver Brook	Amherst	42.8361	-71.6091	NHRIV700060906-03	Sort186	NHF&G	19870609
NHFG-136	Blood Brook	Wilton	42.8365	-71.8117	NHRIV700060902-09	Sort187	NHF&G	19860624
NHFG-1378	Jones Brook	Milton	43.4806	-71.0103	NHIMP600030402-04	Sort188	NHF&G	19850722
NHFG-1379	Branch River	Milton	43.4810	-71.0027	NHRIV600030402-06	Sort189	NHF&G	19850723
NHFG-143	Souhegan River	Milford	42.8427	-71.7081	NHRIV700060904-14	Sort190	NHF&G	19870611
NHFG-1431	Branch River	Wakefield	43.5221	-71.0228	NHRIV600030401-08	Sort191	NHF&G	19850718
NHFG-145	Contoocook River	Peterborough	42.8431	-71.9645	NHRIV700030104-03	Sort192	NHF&G	19870728
NHFG-154	Souhegan River	Milford	42.8470	-71.6978	NHRIV700060904-14	Sort194	NHF&G	19870610
NHFG-163	Contoocook River	Peterborough	42.8525	-71.9633	NHRIV700030104-03	Sort196	NHF&G	19870728
NHFG-177	South Branch Ashuelot River	Marlborough	42.8609	-72.2036	NHRIV802010303-20	Sort201	NHF&G	19880606

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
NHFG-202	Glass Factory Brook	Lyndeborough	42.8798	-71.7720	NHRIV700060903-13	Sort204	NHF&G	19860619
NHFG-205	Curtis Brook (Bremner)	Lyndeborough	42.8823	-71.7404	NHRIV700060904-05	Sort206	NHF&G	19860609
NHFG-206	Glass Factory Brook	Lyndeborough	42.8827	-71.7698	NHRIV700060903-13	Sort207	NHF&G	19860626
NHFG-211	Nubanusit River	Peterborough	42.8853	-71.9709	NHRIV700030103-15	Sort209	NHF&G	19870812
NHFG-214	Baboosic Brook	Merrimack	42.8858	-71.5369	NHRIV700060905-16	Sort210	NHF&G	19860610
NHFG-24	Spaulding Brook (Mitchell)	Brookline	42.7631	-71.6858	NHRIV700040401-05	Sort214	NHF&G	19860618
NHFG-263	Powwow River	East Kingston	42.9080	-71.0159	NHRIV700061403-16	Sort217	NHF&G	19841023
NHFG-264	Nubanusit River	Peterborough	42.9093	-71.9961	NHRIV700030103-12	Sort218	NHF&G	19870812
NHFG-293	Swindlehurst Brook	Peterborough	42.9166	-71.9166	NHIMP700030105-04	Sort219	NHF&G	19870730
NHFG-295	Swindlehurst Brook	Peterborough	42.9173	-71.9161	NHRIV700030105-05	Sort220	NHF&G	19870730
NHFG-331	Otter Brook	Keene	42.9374	-72.2414	NHRIV802010202-20	Sort222	NHF&G	19830914
NHFG-339	Taylor River	Hampton	42.9424	-70.8775	NHRIV600031003-25	Sort223	NHF&G	19850926
NHFG-365	Rand Brook	Greenfield	42.9564	-71.8260	NHRIV700060604-10	Sort225	NHF&G	19860619
NHFG-368	South Br. Piscataquog River	New Boston	42.9573	-71.7080	NHRIV700060606-03	Sort226	NHF&G	19870611
NHFG-375	Riddle Brook	Bedford	42.9593	-71.5441	NHRIV700060905-18	Sort227	NHF&G	19850702
NHFG-391	Towle Brook	Chester	42.9683	-71.2144	NHRIV600030802-10	Sort228	NHF&G	19841019
NHFG-404	Towle Brook	Chester	42.9793	-71.1960	NHRIV600030802-05	Sort230	NHF&G	19841018
NHFG-416	Moose Brook	Hancock	42.9870	-71.9571	NHRIV700030107-07	Sort231	NHF&G	19870731
NHFG-428	Otter Brook	Sullivan	42.9908	-72.1965	NHRIV802010201-18	Sort232	NHF&G	19830913
NHFG-437	Middle Br. Piscataquog River	New Boston	42.9966	-71.7296	NHRIV700060605-03	Sort234	NHF&G	19870611
NHFG-45	Souhegan River	Greenville	42.7768	-71.8065	NHRIV700060902-05	Sort236	NHF&G	19870618
NHFG-463	Piscataquog River	Goffstown	43.0118	-71.5295	NHRIV700060607-17	Sort243	NHF&G	19850626
NHFG-473	Middle Br. Piscataquog River	New Boston	43.0195	-71.6904	NHRIV700060605-08	Sort245	NHF&G	19870615
NHFG-527	Ashuelot River	Surry	43.0525	-72.3290	NHRIV802010104-13	Sort254	NHF&G	19830915
NHFG-546	West Br. Piscataquog River	Deering	43.0612	-71.7959	NHRIV700060601-04	Sort258	NHF&G	19870616
NHFG-549	Lamprey River	Raymond	43.0627	-71.2274	NHRIV600030701-14	Sort259	NHF&G	19840911
NHFG-572	North Branch River	Antrim	43.0732	-72.0185	NHRIV700030202-17	Sort261	NHF&G	19870812
NHFG-615	North Branch River	Antrim	43.0832	-71.9774	NHRIV700030202-18	Sort265	NHF&G	19870812
NHFG-675	Piscataquog River	Weare	43.1081	-71.7095	NHRIV700060602-07	Sort276	NHF&G	19870615
NHFG-684	Hartford Brook	Deerfield	43.1098	-71.2686	NHRIV600030701-08	Sort278	NHF&G	19840911
NHFG-692	Piscataquog River	Weare	43.1119	-71.7231	NHRIV700060602-07	Sort280	NHF&G	19870616
NHFG-711	Little River	Lee	43.1187	-71.0354	NHRIV600030707-07	Sort284	NHF&G	19860906
NHFG-718	Shedd Brook	Hillsboro	43.1248	-71.9530	NHRIV700030203-15	Sort286	NHF&G	19870811

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
NHFG-726	Oyster River	Durham	43.1294	-70.9356	NHRIV600030902-05	Sort287	NHF&G	19850816
NHFG-782	Lamprey River	Deerfield	43.1421	-71.2318	NHRIV600030701-09	Sort290	NHF&G	19830824
NHFG-801	Oyster River	Lee	43.1482	-70.9656	NHRIV600030902-04	Sort291	NHF&G	19850705
NHFG-883	Bellamy River	Madbury	43.1801	-70.9475	NHRIV600030903-08	Sort295	NHF&G	19850822
NHFG-535	Ashuelot River	Gilsum	43.0586	-72.2397	NHRIV802010103-22	VSort023	NHF&G	19880609
NHFG-642	Ashuelot River	Marlow	43.0923	-72.1997	NHIMP802010102-03	VSort028	NHF&G	19830914
NHFG-254	McQuade Brook	Bedford	42.9057	-71.5237	NHRIV700060905-17	VSort065	NHF&G	19860609
01B-BKB	Black Brook	Manchester	43.0084	-71.4818	NHRIV700060801-05-02	VSort001	NHDES	20190904
01-BKB	Black Brook	Manchester	43.0104	-71.4781	NHRIV700060801-05-02	VSort002	NHDES	20190904
01-BNB	Browns Brook	Hooksett	43.1058	-71.4626	NHRIV700060802-02	VSort003	NHDES	20180830
01-BWB	Bowman Brook	Bedford	42.9549	-71.4753	NHRIV700060803-05	VSort004	NHDES	20180820
01M-FTB	Flatrock Brook	Windham	42.8167	-71.2506	NHRIV700061102-13	VSort006	NHDES	20190624
01M-LITR	Little River	North Hampton	42.9644	-70.7970	NHRIV600031004-04	VSort007	NHDES	20190828
01-MSC	Mascoma River	Lebanon	43.6338	-72.3174	NHRIV801060106-20	VSort008	NHDES	20190911
01C-PEA	Pea Porridge Brook	Nottingham	43.1190	-71.0697	NHRIV600030707-05	VSort009	NHDES	20191007
01R-CLD	Cold River	Langdon	43.1376	-72.4049	NHRIV801070203-09	VSort010	NHDES	20190722
02-BNB	Browns Brook	Hooksett	43.1103	-71.4513	NHRIV700060802-02	VSort013	NHDES	20180830
02B-PNB	Patten Brook	Bedford	42.9450	-71.4690	NHRIV700060803-12	VSort014	NHDES	20180820
02C-FTB	Flatrock Brook	Windham	42.8236	-71.2513	NHRIV700061102-13	VSort015	NHDES	20190619
02-CLD	Cold River	Walpole	43.1321	-72.3904	NHRIV801070203-09	VSort016	NHDES	20180907
02-HTY	Hittytitty Brook	Salem	42.8053	-71.2183	NHRIV700061102-32	VSort018	NHDES	20190610
02-ISR	Israel River	Lancaster	44.4879	-71.5696	NHRIV801010806-09	VSort019	NHDES	20190918
02-MSR	Messer Brook	Hooksett	43.0433	-71.4469	NHRIV700060802-09	VSort021	NHDES	20181010
04A-ISG	Isinglass River	Barrington	43.2456	-71.0041	NHRIV600030607-01	VSort023	NHDES	20190725
04M-CLD	Cold River	Langdon	43.1698	-72.3456	NHRIV801070202-08	VSort024	NHDES	20190723
05-BER	Berrys Brook	Rye	43.0363	-70.7489	NHRIV600031002-01	VSort025	NHDES	20190828
05-SAG	Sagamore Creek	Portsmouth	43.0493	-70.7783	NHRIV600031001-03	VSort026	NHDES	20190829
05-WNR	Warner River	Warner	43.2769	-71.8112	NHRIV700030304-16	VSort028	NHDES	20190917
06T-ISG	Isinglass River	Barrington	43.2409	71.0508	NHRIV600030607-01	VSort030	NHDES	20190724
07G-ISG	Isinglass River	Barrington	43.2344	-71.0613	NHRIV600030607-01	VSort031	NHDES	20190725
07T-ISG	Isinglass River	Barrington	43.2382	-71.0766	NHRIV600030607-01	VSort032	NHDES	20190912
08-BIG	Big River	Barnstead	43.3244	-71.2022	NHRIV700060403-07	VSort033	NHDES	20190826
08-DRW	Drew Brook	Derry	42.8842	-71.2209	NHRIV700061101-01	VSort034	NHDES	20190619

STATION ID	WATERBODY	TOWN	LAT (DEC DEG)	LONG (DEC DEG)	AU_ID	SORT ID	AGENCY	DATE SURVEYED
08-ISG	Isinglass River	Barrington	43.2424	-71.0821	NHRIV600030605-16	VSort035	NHDES	20190724
08T-LMP	Lamprey River	Lee	43.1155	-71.0031	NHRIV600030709-08	VSort036	NHDES	20190916
11-HMY	Humphrey Brook	Manchester	42.9686	-71.4585	NHRIV700060803-08	VSort038	NHDES	20180821
15A-LMP	Lamprey River	Epping	43.0411	-71.1288	NHRIV600030703-11	VSort040	NHDES	20190916
15-EXT	Exeter River	Brentwood	42.9847	-71.0383	NHRIV600030803-05	VSort042	NHDES	20190912
28N-LMP	Lamprey River	Deerfield	43.1629	-71.2334	NHRIV600030701-01	VSort043	NHDES	20191009
05R-BKR	Baker River	Wentworth	43.8395	-71.8992	NHRIV700010305-04	VSort044	NHDES	20190716
05R-BKR	Baker River	Wentworth	43.8395	-71.8992	NHRIV700010305-04	VSort045	NHDES	20190731
04P-PAR	Pawtuckaway River	Nottingham	43.0716	-71.1422	NHRIV600030703-14	VSort046	NHDES	20190903

Table 2, Detailed Site Information

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC01DEV/ LC11DEV (PCT)
00F-SHW	8.32	928.47	3	Merrimack	19.32	63.38	11.07	1872.68	3.00	1.07	5.94
01-SHW	8.23	948.16	3	Merrimack	19.69	72.22	11.20	1872.68	2.92	1.06	5.88
03-BZZ	3.61	521.65	2	Coastal	43.52	122.84	8.33	1164.23	5.16	0.24	2.73
04-TNL	6.60	1000.65	3	Merrimack	0.07	134.32	12.93	2045.67	5.63	0.47	4.02
06-NIS	27.30	252.62	4	Merrimack	2.33	103.33	8.20	1040.44	6.53	0.35	3.70
07-LLR	12.32	82.02	4	Merrimack	0.11	24.34	4.65	370.75	13.38	9.86	28.24
09-BZZ	3.17	570.86	2	Coastal	45.65	161.61	8.00	1164.23	5.34	0.20	2.48
NHFG-1015	41.60	239.50	3	Coastal	1.39	43.28	7.65	1401.81	10.21	0.70	5.65
NHFG-1022	14.41	475.72	3	Coastal	17.91	41.76	7.06	1225.45	16.18	0.60	5.03
NHFG-109	5.24	269.03	2	Merrimack	22.17	64.41	8.92	809.78	5.85	2.72	10.19
NHFG-1098	25.42	223.10	3	Coastal	5.91	68.06	6.38	1201.08	8.10	1.22	7.99
NHFG-1205	52.29	239.50	4	Coastal	0.74	34.00	6.96	1357.85	5.26	1.92	9.38
NHFG-1251	35.83	259.19	4	Coastal	4.55	41.68	7.12	1357.85	6.20	1.52	8.50
NHFG-1265	10.22	364.17	3	Coastal	38.28	39.52	7.29	1122.29	9.12	1.55	7.83
NHFG-132	65.13	403.54	4	Merrimack	0.15	38.88	10.83	2277.26	3.96	1.50	7.68
NHFG-134	12.45	219.82	4	Merrimack	11.76	66.20	7.67	951.07	5.89	3.84	16.34
NHFG-136	6.38	761.15	2	Merrimack	30.54	133.61	13.04	2277.26	1.27	1.21	7.51
NHFG-1378	16.59	433.07	3	Coastal	28.48	48.34	7.65	1640.95	4.86	0.95	4.83
NHFG-1379	53.52	416.67	4	Coastal	1.23	16.87	9.61	1824.96	7.27	1.30	6.75

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC01DEV/ LC11DEV (PCT)
NHFG-143	101.78	269.03	5	Merrimack	0.00	39.64	11.20	2278.75	3.86	1.45	7.30
NHFG-1431	28.15	498.69	3	Coastal	14.85	18.61	9.72	1824.96	8.84	1.25	7.25
NHFG-145	65.87	793.96	5	Merrimack	0.28	19.44	8.46	3122.59	10.40	1.45	7.76
NHFG-154	102.01	259.19	5	Merrimack	0.00	39.54	11.19	2278.75	3.84	1.48	7.34
NHFG-163	66.54	767.71	5	Merrimack	0.28	21.56	8.46	3122.59	10.31	1.47	7.82
NHFG-177	32.99	771.00	4	Connecticut	12.27	70.11	10.66	3148.29	6.28	0.85	4.91
NHFG-202	4.91	643.04	2	Merrimack	35.81	85.84	11.10	1697.16	7.03	0.68	5.46
NHFG-205	3.78	574.15	2	Merrimack	36.29	107.93	9.17	1342.34	5.50	0.54	4.23
NHFG-206	4.82	682.41	2	Merrimack	36.21	92.97	11.15	1697.16	7.18	0.66	5.31
NHFG-211	47.18	784.12	5	Merrimack	2.02	29.91	10.78	2877.13	11.70	0.59	4.78
NHFG-214	25.03	200.13	4	Merrimack	4.08	56.09	8.65	1280.79	8.25	1.97	9.70
NHFG-24	14.45	278.87	4	Merrimack	8.76	70.15	8.91	1095.31	3.02	0.37	3.79
NHFG-263	30.32	114.83	4	Merrimack	0.58	10.70	3.91	400.39	24.31	4.86	16.81
NHFG-264	25.51	938.32	4	Merrimack	15.98	33.66	11.02	2215.50	14.02	0.27	3.05
NHFG-293	12.48	715.22	1	Merrimack	34.24	35.64	6.07	1561.96	14.25	0.95	5.12
NHFG-295	12.47	711.94	1	Merrimack	34.32	36.04	6.07	1561.96	14.25	0.94	5.10
NHFG-331	47.88	633.20	2	Connecticut	5.50	55.02	13.16	2148.83	5.00	0.63	4.80
NHFG-339	8.58	16.40	4	Coastal	3.33	6.67	3.51	229.27	14.01	5.87	21.20
NHFG-365	5.63	715.22	3	Merrimack	47.81	126.31	8.98	1597.23	4.25	0.59	5.50
NHFG-368	50.70	469.16	3	Merrimack	0.94	32.12	9.83	2025.43	5.18	0.69	5.64
NHFG-375	3.00	334.64	3	Merrimack	33.22	117.42	9.20	1318.29	1.64	4.01	19.10
NHFG-391	5.87	206.69	3	Coastal	12.58	42.35	5.85	599.70	7.08	2.56	11.54
NHFG-404	25.31	164.04	4	Coastal	2.29	11.20	5.75	598.11	14.69	2.83	11.39
NHFG-416	12.42	741.47	3	Merrimack	46.08	54.54	11.77	2030.37	6.59	0.43	4.44
NHFG-428	35.26	977.69	5	Connecticut	17.82	63.63	12.71	2148.83	5.63	0.63	4.61
NHFG-437	9.14	534.78	3	Merrimack	37.64	61.06	9.22	1301.29	9.31	0.50	4.82
NHFG-45	31.57	725.06	4	Merrimack	2.94	26.54	10.24	1872.68	5.54	1.86	8.25
NHFG-463	210.45	167.32	5	Merrimack	0.00	21.63	9.55	2025.43	5.95	1.24	6.60
NHFG-473	25.91	400.26	4	Merrimack	11.18	48.19	9.83	1301.47	6.49	0.65	5.86
NHFG-527	86.17	610.23	5	Connecticut	0.39	35.50	12.36	2521.63	6.41	0.38	3.16
NHFG-546	10.77	659.45	3	Merrimack	47.04	50.19	9.67	1523.32	8.47	0.56	4.80
NHFG-549	34.34	209.97	4	Coastal	1.68	31.99	7.78	1144.55	3.76	0.92	6.10

STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC01DEV/ LC11DEV (PCT)
NHFG-572	51.30	1023.62	1	Merrimack	4.11	322.33	8.86	1401.30	3.15	0.40	8.70
NHFG-615	54.26	879.26	5	Merrimack	2.93	22.55	11.86	2468.40	9.93	0.54	3.94
NHFG-675	41.98	439.63	4	Merrimack	4.50	33.47	9.91	1523.32	6.87	0.80	5.46
NHFG-684	8.53	265.75	3	Coastal	21.62	105.88	7.82	1138.16	2.36	0.51	4.43
NHFG-692	41.43	462.60	4	Merrimack	5.01	33.08	9.93	1523.32	6.94	0.81	5.46
NHFG-711	17.53	137.79	3	Coastal	5.72	34.10	6.03	602.43	9.45	0.88	7.40
NHFG-718	21.37	741.47	5	Merrimack	42.72	46.12	11.37	1921.59	8.30	0.37	3.17
NHFG-726	16.96	29.53	4	Coastal	4.73	14.50	4.41	387.24	8.33	2.49	13.54
NHFG-782	9.25	400.26	3	Coastal	21.39	39.71	8.36	1144.55	4.33	0.69	5.25
NHFG-801	12.29	72.18	4	Coastal	8.49	17.72	4.47	387.24	9.58	2.21	11.39
NHFG-883	21.59	121.39	4	Coastal	4.17	23.69	4.30	513.49	18.89	1.83	10.13
NHFG-535	65.18	967.84	5	Connecticut	2.11	28.31	11.42	2521.63	7.66	0.40	0.66
NHFG-642	45.75	1151.57	5	Connecticut	12.20	29.67	11.59	2521.63	8.27	0.44	0.75
NHFG-254	7.73	196.85	3	Merrimack	18.55	61.13	7.66	1318.29	7.15	4.35	5.55
01B-BKB	22.16	207.69	4	Merrimack	8.13	35.76	8.10	920.38	8.00	1.99	8.02
01-BKB	22.25	197.35	4	Merrimack	8.06	34.84	8.10	920.38	7.99	2.11	8.23
01-BNB	6.35	195.59	3	Merrimack	37.62	64.81	8.81	677.64	8.72	2.20	8.01
01-BWB	6.28	139.60	3	Merrimack	22.45	44.20	6.66	680.78	1.78	19.19	54.98
01M-FTB	6.92	180.94	3	Merrimack	6.25	24.06	7.50	509.25	9.30	7.70	27.91
01M-LITR	6.08	8.40	4	Coastal	3.67	16.53	2.16	127.31	21.35	7.65	24.89
01-MSC	194.50	366.73	5	Connecticut	0.00	26.25	12.39	3217.65	6.68	1.57	5.56
01C-PEA	1.40	176.30	2	Coastal	23.33	74.14	6.04	433.93	11.66	0.11	1.43
01R-CLD	98.58	990.02	5	Connecticut	0.24	40.96	12.94	2161.57	2.61	0.56	4.63
02-BNB	5.84	287.67	3	Merrimack	38.48	61.24	8.72	677.64	9.35	1.04	5.18
02B-PNB	2.89	169.52	3	Merrimack	27.00	41.42	4.97	480.50	3.28	16.03	59.13
02C-FTB	5.76	234.81	3	Merrimack	7.16	21.77	7.31	509.25	10.28	7.36	27.27
02-CLD	83.32	400.00	4	Connecticut	0.92	41.10	13.05	2161.57	2.83	0.54	4.66
02-HTY	9.53	147.41	3	Merrimack	4.27	26.67	7.09	509.25	10.90	9.39	30.14
02-ISR	133.26	860.00	5	Connecticut	0.76	42.39	16.94	5694.50	3.40	0.55	2.90
02-MSR	2.34	201.13	2	Merrimack	37.68	83.27	8.16	617.04	3.39	22.79	56.44
04A-ISG	66.35	188.74	4	Coastal	0.11	36.75	7.49	1401.81	9.79	0.72	6.30
04M-CLD	59.25	617.36	4	Connecticut	8.46	37.55	12.83	2161.57	2.81	0.41	4.39

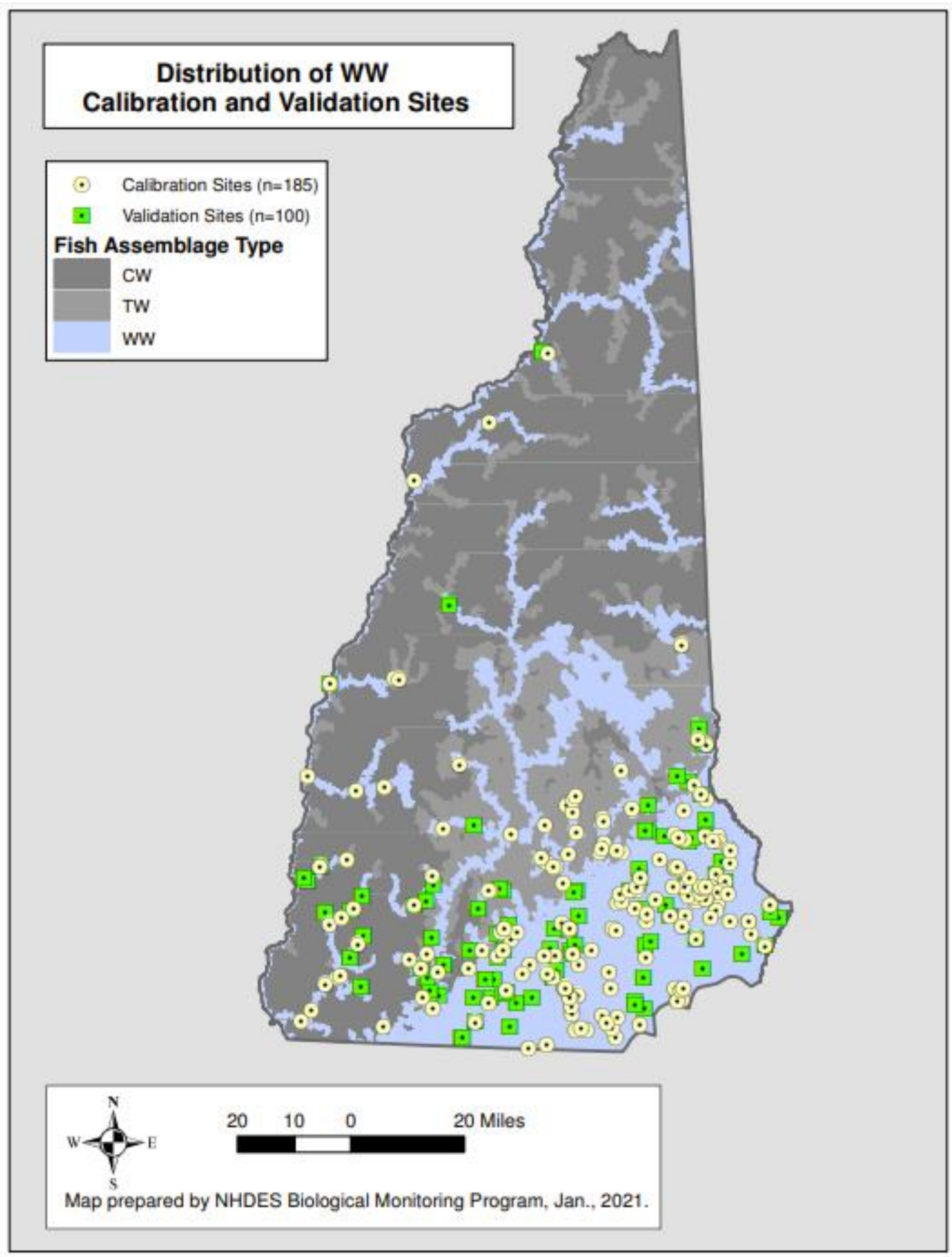
STATION ID	WSHED AREA (SQMI)	ELEV (FT.)	STREAM ORDER	BASIN	CW PROB (PCT)	CSL10_85	BSLDEM30M	WS_ELEV MAX (FT.)	WETLAND (PCT)	LC11IMP (PCT)	LC01DEV/ LC11DEV (PCT)
05-BER	5.39	20.13	2	Coastal	4.83	9.97	1.69	147.61	32.41	9.58	26.52
05-SAG	0.55	16.99	2	Coastal	8.54	22.30	2.42	84.72	12.10	8.53	19.19
05-WNR	118.30	400.05	5	Merrimack	0.01	41.03	13.46	2702.76	5.46	1.17	6.27
06T-ISG	62.44	203.86	4	Coastal	0.18	44.28	7.63	1401.81	9.75	0.70	6.12
07G-ISG	58.81	230.28	4	Coastal	0.25	46.21	7.68	1401.81	9.50	0.70	6.03
07T-ISG	57.52	236.68	4	Coastal	0.31	51.97	7.66	1401.81	9.59	0.67	5.68
08-BIG	13.77	572.44	3	Merrimack	29.47	45.37	7.63	1350.39	6.08	0.29	3.40
08-DRW	4.88	208.72	3	Merrimack	9.44	52.62	6.50	552.85	8.90	4.79	17.41
08-ISG	41.46	240.05	4	Coastal	1.40	43.25	7.65	1401.81	10.21	0.70	5.65
08T-LMP	180.99	64.80	6	Coastal	0.00	10.81	6.76	1144.55	7.83	1.78	9.12
11-HMY	3.51	220.14	2	Merrimack	27.63	22.29	5.48	577.33	1.13	52.64	94.43
15A-LMP	76.11	131.24	4	Coastal	0.02	18.90	7.33	1144.55	6.32	2.40	10.10
15-EXT	63.47	82.00	4	Coastal	0.04	7.09	5.43	652.13	13.72	2.80	10.77
28N-LMP	5.90	432.74	3	Coastal	29.38	54.30	9.40	1144.55	3.61	0.29	3.04
05R-BKR	85.17	535.50	4	Merrimack	6.20	132.36	18.30	4814.23	1.71	0.38	2.44
05R-BKR	85.17	535.50	4	Merrimack	6.20	132.36	18.30	4814.23	1.71	0.38	2.44
04P-PAR	21.16	172.69	4	Coastal	4.50	22.34	8.46	971.20	10.80	0.31	4.44

Appendix D. Site Attribute Descriptions

Attribute	Attribute Description
STATION ID	NHDES or NHFG Station ID
WATERBODY	River/Stream where the fish survey site is located
TOWN	Town where the fish survey site is located
LAT (DEC DEG)	Latitude in decimal degrees (dd.dddd)
LONG (DEC DEG)	Longitude in decimal degrees (dd.dddd)
AU_ID	Assessment Unit Identification Number
SORT ID	Additional identification number assigned to site
AGENCY	Agency that collected the fish survey data
DATE SURVEYED	Date of fish survey (YYYYMMDD)
WSHED AREA (SQMI)	Size of watershed (square miles)
ELEV (FT.)	Site elevation above sea level (feet)
STREAM ORDER	Strahler stream order
BASIN	Major NH river basin where site is located
CW PROB (PCT)	Percent coldwater fish assemblage probability prediction (NHDES, 2007)
CSL10_85	USGS, change instream slope (feet) between 10% and 85% of stream thread
BSLDEM30M	USGS, mean percent basin slope (%) of site, based on 30 meter DEM
WS_ELEV MAX (FT.)	Maximum elevation (feet) within the watershed
WETLAND (PCT)	Percent wetland land cover, National Land Cover Dataset, 2011
LC11IMP (PCT)	Percent impervious land cover, National Land Cover Dataset, 2011
LC11DEV (PCT)	Percent developed land cover, National Land Cover Dataset, 2011
LC01DEV/ LC11DEV (PCT)	Percent developed land cover, National Land Cover Dataset, 2001 or 2011

Appendix E. Map of Calibration and Validation Sites

285 warmwater calibration and validation sites used to develop and test the warmwater biotic indices.



Appendix F. NHDES Autecological Characteristics

Names, abbreviations, origin and autecological characteristics as defined by NHDES of fish species most commonly encountered at warmwater sampling locations. See Appendix H for explanation of abbreviations. Undefined (UND) characteristics for a species noted.

Common Name	Scientific Name	Abbreviation	Streamflow Preference (Velocity)	Trophic Class	Tolerance	Thermal Preference	Reproductive Strategy	Origin
AMERICAN BROOK LAMPREY	*Lampetra appendix*	ABL	UND	OTHER	I	ET	H_D	N
AMERICAN EEL	*Anguilla rostrata*	AE	mg	TC	T	WW	H_D	N
AMERICAN SHAD	*Alosa sapidissima*	ASH	UND	PL	M	WW	H_D	N
ALEWIFE	*Alosa pseudoharengus*	AW	UND	PL	M	ET	H_D	N
BROWN BULLHEAD	*Ameiurus nebulosus*	BBH	mg	GF	T	WW	H_D	N
BLACK CRAPPIE	*Pomoxis nigromaculatus*	BC	mg	BI	M	WW	H_D	I
BANDED KILLIFISH	*Fundulus diaphanus*	BDK	mg	OI	T	WW	H_D	N
BANDED SUNFISH	*Enneacanthus obesus*	BDS	mg	OI	I	WW	H_D	N
BLUEGILL	*Lepomis macrochirus*	BG	mg	GF	M	WW	H_D	I
EASTERN BLACKNOSE DACE	*Rhinichthys atratulus*	BND	fs	OI	T	ET	H_D	N
BLUNTNOSE MINNOW	*Pimephales notatus*	BNM	UND	OI	T	WW	H_D	I
BLACKNOSE SHINER	*Notropis heterolepis*	BNS	UND	BI	I	WW	H_D	N
BRIDLE SHINER	*Notropis bifrenatus*	BS	mg	OI	M	WW	H_D	N
CREEK CHUB	*Semotilus atromaculatus*	CC	fs	GF	T	ET	S_L	N
CREEK CHUBSUCKER	*Erimyzon oblongus*	CCS	fs	OI	M	WW	H_D	N
CUTLIP MINNOW	*Exoglossum maxillingua*	CLM	UND	BI	T	WW	H_D	I
COMMON CARP	*Cyprinus carpio*	CRP	mg	GF	T	WW	H_D	I
COMMON SHINER	*Luxilus cornutus*	CS	fd	GF	M	ET	S_L	N
PUMPKINSEED	*Lepomis gibbosus*	CSF	mg	OI	M	WW	H_D	I
WHITE SUCKER	*Catostomus commersoni*	CWS	fd	GF	T	ET	S_L	N
CHAIN PICKEREL	*Esox niger*	ECP	mg	TC	M	WW	H_D	N
EMERALD SHINER	*Notropis atherinoides*	ES	UND	GF	T	WW	H_D	I

Common Name	Scientific Name	Abbreviation	Streamflow Preference (Velocity)	Trophic Class	Tolerance	Thermal Preference	Reproductive Strategy	Origin
FALLFISH	*Semotilus corporalis*	FF	fs	GF	M	ET	S_L	N
FATHEAD MINNOW	*Pimephales promelas*	FHM	mg	GF	T	WW	H_D	I
GOLDEN SHINER	*Notemigonus crysoleucas*	GS	mg	GF	T	WW	H_D	I
LARGEMOUTH BASS	*Micropterus salmoides*	LMB	mg	TC	M	WW	H_D	I
LONGNOSE DACE	*Rhinichthys cataractae*	LND	fs	BI	M	ET	H_D	N
MUMMICHOG	*Fundulus Heteroclitus*	MMG	UND	GF	T	WW	H_D	N
MARGINED MADTOM	*Noturus insignis*	MMT	fs	BI	M	ET	H_D	N
MIMIC SHINER	*Notropis volucellus*	MS	UND	OI	M	WW	H_D	I
NORTHERN PIKE	*Esox lucius*	NP	mg	TC	M	ET	H_D	I
NORTHERN REDBELLY DACE	*Phoxinus eos*	NRD	mg	GF	M	ET	H_D	N
NINESPINE STICKLEBACK	*Pungitius pungitius*	NSS	mg	OI	M	WW	H_D	N
ROCK BASS	*Ambloplites rupestris*	RB	mg	TC	M	ET	S_L	I
REDBREAST SUNFISH	*Lepomis auritus*	RBS	mg	OI	M	WW	H_D	N
REDFIN PICKEREL	*Esox americanus*	RFP	mg	TC	M	WW	H_D	N
ROSYFACE SHINER	*Notropis rubellus*	RFS	UND	OI	M	WW	S_L	I
ROSYSIDE DACE	*Clinostomus funduloides*	RSD	UND	BI	M	ET	S_L	I
SWAMP DARTER	*Etheostoma fusiforme*	SD	mg	BI	M	WW	H_D	N
SEA LAMPREY	*Petromyzon marinus*	SL	UND	OTHER	M	ET	H_D	N
EASTERN SILVERY MINNOW	*Hybognathus regius*	SM	UND	GF	M	WW	H_D	N
SMALLMOUTH BASS	*Micropterus dolomieu*	SMB	mg	TC	M	ET	H_D	I
STRIPED KILLIFISH	*Fundulus majalis*	STK	UND	OI	T	WW	H_D	N
SPOTTAIL SHINER	*Notropis hudsonius*	STS	mg	OI	M	WW	H_D	I
TESSELLATED DARTER	*Etheostoma olmstedi*	TD	fs	BI	M	ET	H_D	N
WALLEYE	*Stizostedion vitreum*	WLE	UND	TC	I	ET	H_D	I
WHITE PERCH	*Morone americana*	WP	mg	TC	I	ET	H_D	I

Common Name	Scientific Name	Abbreviation	Streamflow Preference (Velocity)	Trophic Class	Tolerance	Thermal Preference	Reproductive Strategy	Origin
YELLOW BULLHEAD	*Ameiurus natalis*	YBH	mg	GF	T	WW	H_D	N
YELLOW PERCH	*Perca flavescens*	YP	mg	TC	M	ET	H_D	N

Appendix G. NRSA Autecological Characteristics

Names, abbreviations, origin, and autecological characteristics as defined by NRSA of fish species most commonly encountered at warmwater sampling locations. See Appendix I for explanation of abbreviations.

Common Name	Scientific Name	Abbreviation	Streamflow Preference (Velocity)	Trophic Class	Tolerance	Thermal Preference	Reproductive Strategy	Habitat Preference
AMERICAN BROOK LAMPREY	*Lampetra appendix*	ABL	O	O	I	WM	C	B
AMERICAN EEL	*Anguilla rostrata*	AE	O	C	T	CL	O	B
AMERICAN SHAD	*Alosa sapidissima*	ASH	O	I	I	CL	O	W
ALEWIFE	*Alosa pseudoharengus*	AW	O	I	I	CL	O	W
BROWN BULLHEAD	*Ameiurus nebulosus*	BBH	O	O	T	WM	G	B
BLACK CRAPPIE	*Pomoxis nigromaculatus*	BC	P	C	T	WM	G	W
BANDED KILLIFISH	*Fundulus diaphanus*	BDK	P	I	T	CL	O	W
BANDED SUNFISH	*Enneacanthus obesus*	BDS	P	I	S	WM	G	W
BLUEGILL	*Lepomis macrochirus*	BG	P	I	I	WM	G	W
EASTERN BLACKNOSE DACE	*Rhinichthys atratulus*	BND	R	O	T	CL	C	B
BLUNTNOSE MINNOW	*Pimephales notatus*	BNM	O	O	T	WM	G	W
BLACKNOSE SHINER	*Notropis heterolepis*	BNS	O	I	S	CL	O	W
BRIDLE SHINER	*Notropis bifrenatus*	BS	O	O	S	CL	O	W
CREEK CHUB	*Semotilus atromaculatus*	CC	O	O	I	CL	C	W
CREEK CHUBSUCKER	*Erimyzon oblongus*	CCS	O	O	I	WM	C	W
CUTLIP MINNOW	*Exoglossum maxillingua*	CLM	O	I	I	CL	C	B
COMMON CARP	*Cyprinus carpio*	CRP	O	O	T	WM	O	B
COMMON SHINER	*Luxilus cornutus*	CS	O	O	T	CL	C	W

Common Name	Scientific Name	Abbreviation	Streamflow Preference (Velocity)	Trophic Class	Tolerance	Thermal Preference	Reproductive Strategy	Habitat Preference
PUMPKINSEED	*Lepomis gibbosus*	CSF	P	I	I	WM	G	W
WHITE SUCKER	*Catostomus commersoni*	CWS	R	O	I	CL	C	B
CHAIN PICKEREL	*Esox niger*	ECP	P	C	I	CL	O	W
EMERALD SHINER	*Notropis atherinoides*	ES	O	O	I	CL	O	W
FALLFISH	*Semotilus corporalis*	FF	O	O	I	CL	C	W
FATHEAD MINNOW	*Pimephales promelas*	FHM	O	O	T	WM	G	W
GOLDEN SHINER	*Notemigonus crysoleucas*	GS	O	O	I	WM	O	W
LARGEMOUTH BASS	*Micropterus salmoides*	LMB	P	C	T	WM	G	W
LONGNOSE DACE	*Rhinichthys cataractae*	LND	R	I	I	CL	C	B
MUMMICHOG	*Fundulus Heteroclitus*	MMG	P	O	T*	WM	O	W
MARGINED MADTOM	*Noturus insignis*	MMT	O	I	S*	WM	G	B
MIMIC SHINER	*Notropis volucellus*	MS	O	O	S	CL	O	W
NORTHERN PIKE	*Esox lucius*	NP	P	C	T	CL	O	W
NORTHERN REDBELLY DACE	*Phoxinus eos*	NRD	O	O	I	CL	O	B
NINESPINE STICKLEBACK	*Pungitius pungitius*	NSS	P	I	S*	CL	G	W
ROCK BASS	*Ambloplites rupestris*	RB	P	C	T	WM	G	W
REDBREAST SUNFISH	*Lepomis auritus*	RBS	P	I	T	CL	G	W
REDFIN PICKEREL	*Esox americanus*	RFP	P	C	I	CL	O	W
ROSYFACE SHINER	*Notropis rubellus*	RFS	O	O	S	CL	C	W
ROSYSIDE DACE	*Clinostomus funduloides*	RSD	O	I	I	WM	C	W
SWAMP DARTER	*Etheostoma fusiforme*	SD	P	I	I	CL	O	B
SEA LAMPREY	*Petromyzon marinus*	SL	O	O	S*	CL	C	B
EASTERN SILVERY MINNOW	*Hybognathus regius*	SM	O	O	I	WM	O	B
SMALLMOUTH BASS	*Micropterus dolomieu*	SMB	P	C	I	CL	G	W
STRIPED KILLIFISH	*Fundulus majalis*	STK	P	I	T	CL	O	W

Common Name	Scientific Name	Abbreviation	Streamflow Preference (Velocity)	Trophic Class	Tolerance	Thermal Preference	Reproductive Strategy	Habitat Preference
SPOTTAIL SHINER	*Notropis hudsonius*	STS	O	O	T	CL	C	W
TESSELLATED DARTER	*Etheostoma olmstedi*	TD	O	I	T	CL	G	B
WALLEYE	*Stizostedion vitreum*	WLE	O	C	T	CL	C	W
WHITE PERCH	*Morone americana*	WP	P	C	I	WM	O	W
YELLOW BULLHEAD	*Ameiurus natalis*	YBH	O	O	I	WM	G	B
YELLOW PERCH	*Perca flavescens*	YP	O	C	I	CL	O	W
*Characteristic not assigned by NRSA, modified by NHDES								

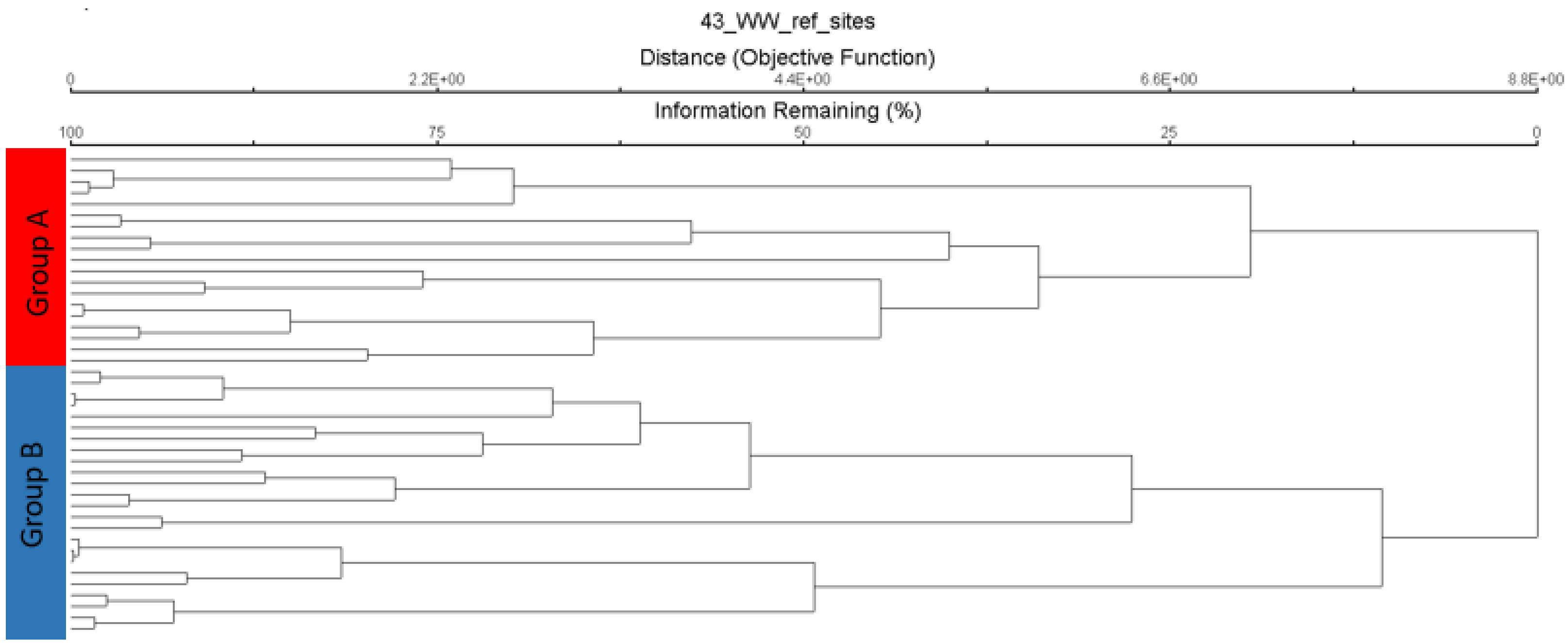
Appendix H. Autecological Fish Characteristics, NHDES Metrics

Streamflow Preference (Velocity)		Trophic Class		Tolerance		Thermal Preference		Reproductive Strategy		Origin		Composition	
Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type
fs	*fluvial specialist*	TC	*Top Carnivore*	I	*Intolerant*	WW	*Warmwater*	S_L	*Simple Lithophil (coarse substrate spawners, non-guarders)*	N	*Native*	P	*Present*
fd	*fluvial dependant*	BI	*Benthic Invertivore*	M	*Moderately Tolerant*	ET	*Eurythermal (Coolwater)*	H_D	*Hole Digger/ Nester*	I	*Introduced*	A	*Absent*
mg	*macro-habitat generalist*	OI	*Obligate Insectivore*	T	*Tolerant*	CW	*Coldwater*						
		GF	*Generalist Feeder*										
		PL	*Planktivore*										

Appendix I. Autecological Fish Characteristics, NRSA Metrics

Streamflow Preference (Velocity)		Trophic Class		Tolerance		Thermal Preference		Reproductive Strategy		Habitat Preference		Origin	
Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type	Abbrev.	Type
O	*Other*	C	*Carnivore*	S	*Sensitive/ Intolerant*	WM	*Warmwater*	C	*Clean/ coarse (lithophil)*	W	*Water Column*	N	*Native*
R	*Rheophil*	I	*Invertivore*	I	*Intermed-iate*	CD	*Coldwater*	D	*Drifter*	B	*Benthic*	I	*Introduced*
P	*Pool*	H	*Herbivore*	T	*Tolerant*	CL	*Coolwater*	G	*Guarder*	E	*Edge*		
		O	*Omnivore*					O	*Other*				

Appendix J. Cluster Analysis Dendogram



Appendix K. Candidate Fish Metrics

Candidate fish metrics for Group A (WW, Low Gradient) and Group B (WW, High Gradient) with abbreviation, and autecological characteristic reference, organized by category

Metric Description	Abbreviation	Metric Category	Autecological Characteristic Reference	Metric Direction (Group A, WWLG)	Metric Direction (Group B, WWHG)
Total NumberTaxa	TOTLNTAX	Composition	NHDES	NEG	NEG
Percent BG, CCS, CSF, GS, YBH Individuals	BG_CCS_CSF_GS_YBH_PIND	Composition	NHDES	NEG	NEG
Percent FF, MMT, GS, YBH Individuals	FF_MMT_GS_YBH_PIND	Composition	NHDES	POS*	NEG*
Percent FF, GS Individuals	FF_GS_PIND	Composition	NHDES	POS*	NEG*
Percent BND, CC and LND Individuals	BND_CC_LND_PIND	Composition	NHDES	POS	POS
Percent BND and LND Individuals	BND_LND_PIND	Composition	NHDES	POS	POS
Percent BG, BBH, CSF, and YBH Individuals	BG_BBH_CSF_YBH_PIND	Composition	NHDES	NEG	NEG
Percent BG and CSF Individuals	BG_CSF_PIND	Composition	NHDES	NEG	NEG
Percent BBH and YBH Individuals	BBH_YBH_PIND	Composition	NHDES	NEG	NEG
Percent BG_CSF_GS Individuals	BG_CSF_GS_PIND	Composition	NHDES	NEG	NEG
Percent BBH, YBH and GS Individuals	BBH_YBH_GS_PIND	Composition	NHDES	NEG	NEG
Percent CSF, FF, LND, and MMT Individuals	CSF_FF_LND_MMT_PIND	Composition	NHDES	POS*	NEG*
Percent BND, CS, CWS Individuals	BND_CS_CWS_PIND	Composition	NHDES	POS	POS
Percent ECP, FF, LND, SMB Individuals	ECP_FF_LND_SMB_PIND	Composition	NHDES	POS*	NEG*
Percent FF, MMT Individuals	FF_MMT_PIND	Composition	NHDES	POS*	NEG*
Percent 10 WW Species Individuals	BC_BG_BDS_CCS_CSF_GS_ LMB_RFP_YBH_YP_PIND	Composition	NHDES	NEG	NEG
Percent CSF_FF_MMT Individuals	CSF_FF_MMT_PIND	Composition	NHDES	NEG	NEG
Percent of One Specie (AE)	SP02_AE_PIND	Composition	NHDES	POS	POS
Percent of One Specie (BG)	SP08_BG_PIND	Composition	NHDES	NEG	NEG
Percent of One Specie (BND)	SP09_BND_PIND	Composition	NHDES	POS	POS
Percent of One Specie (CS)	SP14_CS_PIND	Composition	NHDES	POS	POS
Percent of One Specie (CSF)	SP15_CSF_PIND	Composition	NHDES	NEG	NEG
Percent of One Specie (CWS)	SP16_CWS_PIND	Composition	NHDES	POS	POS
Percent of One Specie (ECP)	SP17_ECP_PIND	Composition	NHDES	NEG	NEG
Percent of One Specie (FF)	SP18_FF_PIND	Composition	NHDES	POS*	NEG*
Percent of One Specie (GS)	SP19_GS_PIND	Composition	NHDES	NEG	NEG

Metric Description	Abbreviation	Metric Category	Autecological Characteristic Reference	Metric Direction (Group A, WWLG)	Metric Direction (Group B, WWHG)
Percent of One Specie (LND)	SP22_LND_PIND	Composition	NHDES	POS*	NEG*
Percent of One Specie (MMT)	SP25_MMT_PIND	Composition	NHDES	POS	POS
Percent of One Specie (SMB)	SP34_SMB_PIND	Composition	NHDES	NEG	NEG
Percent CSF, FF, LND and SMB Individuals	CSF_FF_LND_SMB_PIND	Composition	NHDES	POS*	NEG*
Percent BND, CS, CWS, LND and LNS Individuals	BND_CS_CWS_LND_LNS_PIND	Composition	NHDES	POS	POS
Percent FF, LND, MMT Individuals	FF_LND_MMT_PIND	Composition	NHDES	POS*	NEG*
Percent FF and LND Individuals	FF_LND_PIND	Composition	NHDES	POS*	NEG*
Number Benthic Invertivore Taxa	BENTINVNTAX	Habitat/Trophic	NRSA	POS	POS
Percent Benthic Invertivore Individuals	BENTINVPIND	Habitat/Trophic	NRSA	POS	POS
Percent Benthic Invertivore Taxa	BENTINVPTAX	Habitat/Trophic	NRSA	POS	POS
Number Native Taxa	NATNTAX	Origin	NHDES	POS	POS
Percent Native Individuals	NATPIND	Origin	NHDES	POS	POS
Percent Native Taxa	NATPTAX	Origin	NHDES	POS	POS
Number Introduced Taxa	ALIENNTAX	Origin	NRSA	NEG	NEG
Percent Introduced Individuals	ALIENPIND	Origin	NRSA	NEG	NEG
Percent Introduced Taxa	ALIENPTAX	Origin	NRSA	NEG	NEG
Number Lithophilic Taxa	LITHNTAX	Reproductive	NRSA	POS	POS
Percent Lithophilic Individuals	LITHPIND	Reproductive	NRSA	POS	POS
Percent Lithophilic Taxa	LITHPTAX	Reproductive	NRSA	POS	POS
Number Simple Lithophil Taxa	SL_NTAX	Reproductive	NHDES	POS	POS
Percent Simple Lithophil Individuals	SL_PIND	Reproductive	NHDES	POS	POS
Percent Simple Lithophil Taxa	SL_PTAX	Reproductive	NHDES	POS	POS
Number Hole and Digger Taxa	HD_NTAX	Reproductive	NHDES	NEG	NEG
Percent Hole and Digger Individuals	HD_PIND	Reproductive	NHDES	NEG	NEG
Percent Hole and Digger Taxa	HD_PTAX	Reproductive	NHDES	NEG	NEG
Number Lotic Taxa	LOTNTAX	Streamflow	NRSA	POS	POS
Percent Lotic Individuals	LOTPIND	Streamflow	NRSA	POS	POS
Percent Lotic Taxa	LOTPTAX	Streamflow	NRSA	POS	POS
Number Rheophilic Taxa	RHEONTAX	Streamflow	NRSA	POS	POS
Percent Rheophilic Individuals	RHEOPIND	Streamflow	NRSA	POS	POS

Metric Description	Abbreviation	Metric Category	Autecological Characteristic Reference	Metric Direction (Group A, WWLG)	Metric Direction (Group B, WWHG)
Percent Rheophilic Taxa	RHEOPTAX	Streamflow	NRSA	POS	POS
Number Fluvial Specialist Taxa	FS_NTAX	Streamflow	NHDES	POS	POS
Percent Fluvial Specialist Individuals	FS_PIND	Streamflow	NHDES	POS	POS
Percent Fluvial Specialist Taxa	FS_PTAX	Streamflow	NHDES	POS	POS
Number Fluvial DependantTaxa	FD_NTAX	Streamflow	NHDES	POS	POS
Percent Fluvial Dependant Individuals	FD_PIND	Streamflow	NHDES	POS	POS
Percent Fluvial Dependant Taxa	FD_PTAX	Streamflow	NHDES	POS	POS
Number Fluvial Specialist and Fluvial Dependant Taxa	FSFD_NTAX	Streamflow	NHDES	POS	POS
Percent Fluvial Specialist and Fluvial Dependant Individuals	FSFD_PIND	Streamflow	NHDES	POS	POS
Percent Fluvial Specialist and Fluvial Dependant Taxa	FSFD_PTAX	Streamflow	NHDES	POS	POS
Number Pool Taxa	POOLNTAX	Streamflow	NRSA	NEG	NEG
Percent Pool Individuals	POOLPIND	Streamflow	NRSA	NEG	NEG
Percent Pool Taxa	POOLPTAX	Streamflow	NRSA	NEG	NEG
Number Eurythermal Taxa	ET_NTAX	Thermal	NHDES	POS	POS
Percent Eurythermal Individuals	ET_PIND	Thermal	NHDES	POS	POS
Percent Eurythermal Taxa	ET_PTAX	Thermal	NHDES	POS	POS
Number Warmwater Taxa	WW_NTAX	Thermal	NHDES	POS	POS
Percent Warmwater Individuals	WW_PIND	Thermal	NHDES	POS	POS
Percent Warmwater Taxa	WW_PTAX	Thermal	NHDES	POS	POS
Number Eurythermal and Warmwater Taxa	EU_WW_NTAX	Thermal	NHDES	POS	POS
Percent Eurythermal and Warmwater Individuals	EU_WW_PIND	Thermal	NHDES	POS	POS
Percent Eurythermal and Warmwater Taxa	EU_WW_PTAX	Thermal	NHDES	POS	POS
Number Intolerant Taxa	INTLNTAX	Tolerance	NRSA	POS	POS
Percent Intolerant Individuals	INTLPIND	Tolerance	NRSA	POS	POS
Percent Intolerant Taxa	INTLPTAX	Tolerance	NRSA	POS	POS
Number Tolerant Taxa	TOLRNTAX	Tolerance	NRSA	NEG	NEG
Percent Tolerant Individuals	TOLRPIND	Tolerance	NRSA	NEG	NEG

Metric Description	Abbreviation	Metric Category	Autecological Characteristic Reference	Metric Direction (Group A, WWLG)	Metric Direction (Group B, WWHG)
Percent Tolerant Taxa	TOLRPTAX	Tolerance	NRSA	NEG	NEG
Number Tolerant Taxa	TOL_NTAX	Tolerance	NHDES	NEG	NEG
Percent Tolerant Individuals	TOL_PIND	Tolerance	NHDES	NEG	NEG
Percent Tolerant Taxa	TOL_PTAX	Tolerance	NHDES	NEG	NEG
Number Mod Tolerant Taxa	MODTOL_NTAX	Tolerance	NHDES	NEG	NEG
Percent Mod Tolerant Individuals	MODTOL_PIND	Tolerance	NHDES	NEG	NEG
Percent Tolerant Mod Taxa	MODTOL_PTAX	Tolerance	NHDES	NEG	NEG
Number Intolerant Lotic Taxa	INTLLOTNTAX	Tolerance/Streamflow	NRSA	POS	POS
Percent Intolerant Lotic Individuals	INTLLOTPIND	Tolerance/Streamflow	NRSA	POS	POS
Percent Intolerant Lotic Taxa	INTLLOTPTAX	Tolerance/Streamflow	NRSA	POS	POS
Number Intolerant Rheophilic Taxa	INTLRHEONTAX	Tolerance/Streamflow	NRSA	POS	POS
Percent Intolerant Rheophilic Individuals	INTLRHEOPIND	Tolerance/Streamflow	NRSA	POS	POS
Percent Intolerant Rheophilic Taxa	INTLRHEOPTAX	Tolerance/Streamflow	NRSA	POS	POS
Number Intolerant Invertivore Taxa	INTLINVNTAX	Tolerance/Trophic	NRSA	NEG	NEG
Percent Intolerant Invertivore Individuals	INTLINVPIND	Tolerance/Trophic	NRSA	POS	POS
Percent Intolerant Invertivore Taxa	INTLINVPTAX	Tolerance/Trophic	NRSA	POS	POS
Number Carnivore Taxa	CARNNTAX	Trophic	NRSA	NEG	NEG
Percent Carnivore Individuals	CARNPIND	Trophic	NRSA	NEG	NEG
Percent Carnivore Taxa	CARNPTAX	Trophic	NRSA	NEG	NEG
Number Invertivore Taxa	INVNTAX	Trophic	NRSA	POS	POS
Percent Invertivore Individuals	INVPIND	Trophic	NRSA	POS	POS
Percent Invertivore Taxa	INVPTAX	Trophic	NRSA	POS	POS
Number Omnivore Taxa	OMNINTAX	Trophic	NRSA	POS	POS
Percent Omnivore Individuals	OMNIPIND	Trophic	NRSA	POS	POS
Percent Omnivore Taxa	OMNIPTAX	Trophic	NRSA	POS	POS
Number Benthic Insectivore Taxa	BI_NTAX	Trophic	NHDES	POS	POS
Percent Benthic Insectivore Individuals	BI_PIND	Trophic	NHDES	POS	POS
Percent Benthic Insectivore Taxa	BI_PTAX	Trophic	NHDES	POS	POS
Number Generalist Feeder Taxa	GF_NTAX	Trophic	NHDES	POS	POS
Percent Generalist Feeder Individuals	GF_PIND	Trophic	NHDES	POS	POS
Percent Generalist Feeder Taxa	GF_PTAX	Trophic	NHDES	POS	POS

Metric Description	Abbreviation	Metric Category	Autecological Characteristic Reference	Metric Direction (Group A, WWLG)	Metric Direction (Group B, WWHG)
Number Omnivore Insectivore Taxa	OI_NTAX	Trophic	NHDES	NEG*	POS*
Percent Omnivore Insectivore Individuals	OI_PIND	Trophic	NHDES	NEG*	POS*
Percent Omnivore Insectivore Taxa	OI_PTAX	Trophic	NHDES	NEG*	POS*
Number Carnivore Taxa	TC_NTAX	Trophic	NHDES	NEG	NEG
Percent Carnivore Individuals	TC_PIND	Trophic	NHDES	NEG	NEG
Percent Carnivore Taxa	TC_PTAX	Trophic	NHDES	NEG	NEG
Number Generalist Feeder & Omnivore Insectivore Taxa	GF_OI_NTAX	Trophic	NHDES	POS	POS
Percent Generalist Feeder & Omnivore Insectivore Individuals	GF_OI_PIND	Trophic	NHDES	POS	POS
Percent Generalist Feeder & Omnivore Insectivore Taxa	GF_OI_PTAX	Trophic	NHDES	POS	POS
Number Omnivore Insectivore and Benthic Insectivore Taxa	OI_BI_NTAX	Trophic	NHDES	POS	POS
Percent Omnivore Insectivore and Benthic Insectivore Individuals	OI_BI_PIND	Trophic	NHDES	POS	POS
Percent Omnivore Insectivore and Benthic Insectivore Taxa	OI_BI_PTAX	Trophic	NHDES	POS	POS
* Metric direction difference between Group A (WWLG) and Group B (WWHG)					

Appendix L. Metric Correlations

Pearson's correlation coefficients for a) 6 candidate metrics within the WWLG group and b) 4 candidate metrics within the WWHG group.

a) Metric Correlation Coefficients, WWLG Group

WWLG			Metric Type					
			Negative				Positive	
			SP19_GS_PIND	*BG_CSF_PIND*	*TC_PIND*	*POOLPIND*	*BI_PTAX*	*SP18_FF_PIND*
Metric Type	Negative	SP19_GS_PIND	1.0000					
		BG_CSF_PIND	0.1464	1.0000				
		TC_PIND	0.0138	0.1329	1.0000			
		POOLPIND	0.1457	0.7514	0.4993	1.0000		
	Positive	BI_PTAX	-0.2416	-0.2995	-0.3557	-0.4207	1.0000	
		SP18_FF_PIND	-0.1092	-0.1771	-0.1878	-0.2336	0.0234	1.0000

b) Metric Correlation Coefficients, WWHG Group

WWHG			Metric Type			
			Negative		Positive	
			SP34_SMB_PIND	*ALIENPTAX*	*BND_CS_CWS_PIND*	*RHEOPTAX*
Metric Type	Negative	SP34_SMB_PIND	1.0000			
		ALIENPTAX	0.2810	1.0000		
	Positive	BND_CS_CWS_PIND	-0.1615	-0.4140	1.0000	
		RHEOPTAX	-0.0905	-0.4975	0.4859	1.0000