New Jersey Department of Environmental Protection
Water Monitoring and Standards

FISH IBI REPORT
2008 SAMPLING
Round 2, Year 4 of 5

Volume 1 of 2

October 2010

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October 2010

FISH IBI REPORT
2008 SAMPLING
Round 2, Year 4 of 5

Volume 1 – Summary

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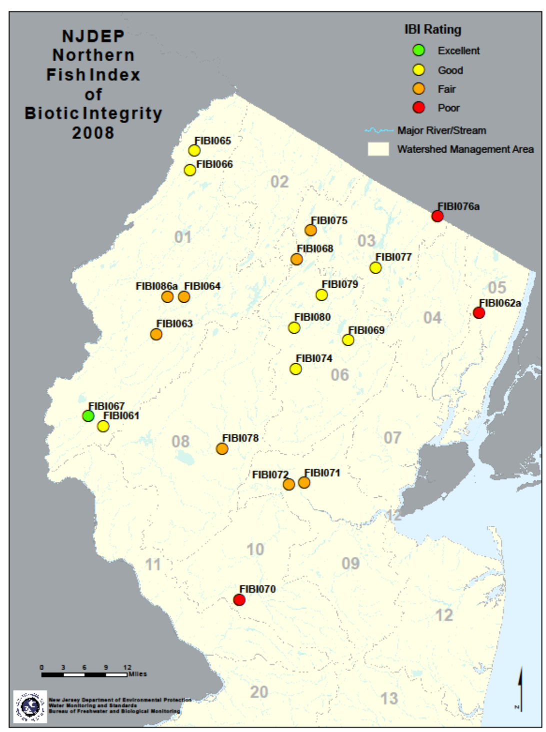
EXECUTIVE SUMMARY

Historically, the health of aquatic systems was monitored primarily through chemical means. However, chemical monitoring provides only a "snapshot" of conditions at the time of sampling and may fail to detect acute pollution events (e.g., runoff from heavy rain, spills), non-chemical pollution (e.g., habitat alteration) and non-point source pollution.

In order to address the limitations of chemical monitoring, DEP began supplementing its chemical monitoring with biological monitoring in 1992. Such monitoring is based on the premise that biological communities are shaped by the long-term conditions of their environment and more accurately reflect the health of an ecosystem for applications such as aquatic life use assessments. Originally, Water Monitoring and Standards' (WM&S) Bureau of Freshwater and Biological Monitoring (BFBM) only monitored benthic macroinvertebrate assemblages (aquatic insects, worms, clams, etc.) at stations throughout New Jersey. Benthic macroinvertebrate assemblages are generally reflective of short-term and local impairment.

The federal Clean Water Act (CWA) Title 40, section 130.4 requires states to monitor all waters, which includes using biological monitoring. The U.S. EPA's National Guidance on the 10 elements of a State Water Monitoring and Assessment Program suggests states should be using at least three (3) trophic levels, including fish, macroinvertebrates, and periphytic algae. Consequently, in order to assess environmental conditions on a larger spatial and temporal scale as envisioned by the CWA, in 2000 the state began to supplement benthic macroinvertebrate monitoring (AMNET program) with a new sampling program called the fish index of biotic integrity (FIBI). The FIBI is an index that measures the health of a stream based on multiple attributes of the resident fish assemblage. Each site sampled is scored based on its deviation from reference conditions (i.e., what would be found in an unimpacted stream) and is subsequently classified as "poor", "fair", "good" or "excellent". In addition, the habitat at each site is evaluated and later classified as "poor", "marginal", "suboptimal" or "optimal". Presently FIBI monitoring takes place only in northern New Jersey where a 100 station network has been established. Sites are sampled once every five (5) years, and in 2004, New Jersey completed the first 5 year round of sampling. Data are currently being collected for the planned extension of the network to include portions of southern New Jersey and the state's headwater streams, with the goal of having a statewide 200 station network.



Beginning in 2004, the collected Fish IBI data became a significant part of the intensive, data-driven, Category 1 (C-1) selection process (N.J.A.C. 7:9B). This selection process is used to identify State waterbodies of exceptional ecological significance that would then be entitled to an anti-degradation classification. Since 2004, this Fish IBI data has aided in the classification of some or all of an additional 229 river miles to a C-1 category.

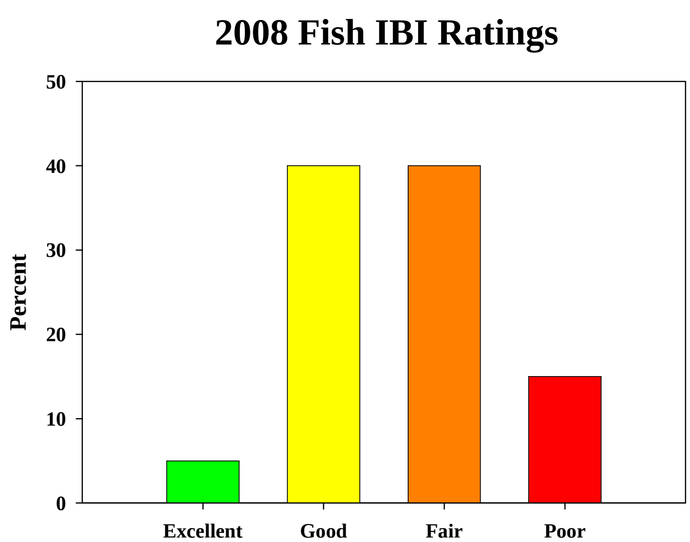
In addition to its inclusion in the C-1 evaluation process, the Fish IBI data has proven to be critical for other federally-required activities, including:

a) the assessment of aquatic life use in State waters, as required by the federal CWA under section 305(b); and
b) the identification of State impaired waters, under section 303(d) of the federal CWA.

These two latter efforts, as reported in New Jersey's biennial Integrated Water Quality Monitoring and Assessment Report, help measure the NJDEP's success in attainment of water quality uses as well as the CWA's goal of "fishable" waters.

The Fish IBI has also found utility in WM&S' Stressor Identification (SI) program as well, where it has been used to prioritize site selection, help identify the spatial extent of waterbody degradation, and to aid in the location and identification of potential stressors. An unexpected use that appears to be of some public importance, is the location of waterbodies with a high potential for successful fishing opportunities. The importance of the Fish IBI data to the public is exemplified in the average 2,800 website downloads WM&S receives per month.

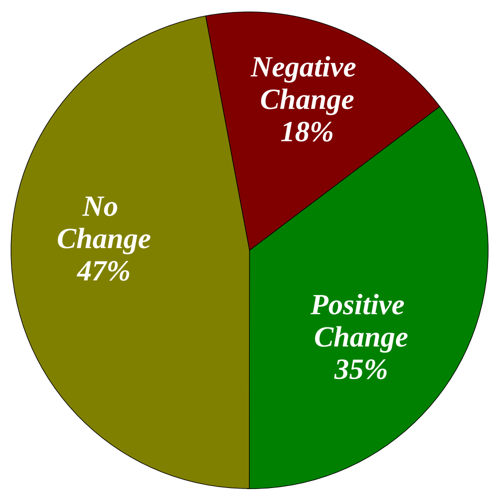
The 2008 season marked year four of the second round of sampling, in which the network sites originally sampled in 2003 were revisited. In an effort to ensure sensitivity to anthropogenic stressors, the Northern Fish IBI was re-evaluated in 2005 using Round 1 data (2000-2004). This recalibration resulted in modifications in scoring criteria and species lists for several metrics (see Table 3, in the full Summary Report, for list of refined metrics). Refinements also included the replacement of the proportional abundance of white suckers metric with the proportional abundance of tolerant species. These recalibrations have increased the overall sensitivity of the Fish IBI to anthropogenic stressors, as Round 2 scores exhibit a significant decreasing trend with an increase in urban land use. The 2008 season is the fourth year in which the revised metrics were utilized. Previous years' data (2000-2004) will be rescored only for the purposes of conducting trends analysis; not for the purpose of revisiting the listing process under the Integrated Water Monitoring and Assessment Report, as those sites will be revisited in this second round. In 2008, the ninth year of sampling, 20 sites were sampled. One site was rated "excellent", eight were "good", eight were "fair", and three sites received a "poor" rating.



It is worth noting that Beaver Brook (FIBI079) exhibited a decline in biological integrity from a score of 48 “Excellent” in Round 1 to a score of 42 “Good” in Round 2. An impounded tributary of the brook may be the cause of the decline in biological integrity, as fine sediment build-up and changes to the stream’s discharge and water chemistries were noted just below the recently impounded section. Several DEP programs were contacted with regard to this stream encroachment including the NJDEP’s Northern Region Enforcement Bureau within the Compliance and Enforcement Program. The TPC1 designation to this section of Beaver Brook was adopted in 2002, prior to the encroachment. Conversely at FIBI067 on Pohatcong Creek, a total of 86 wild trout were collected, including 21 young-of-the-year brown trout, making this a candidate stream for upgrade from “trout maintenance” to a “trout production” classification.

Overall, ratings from Rounds 1 and 2 for the same 17 sites were similar when Round 1 sites were rescored utilizing the new metrics. In Round 1 53% of sites were rated “fair” or “poor” compared to 47% in Round 2. The number of “excellent” sites remained the same, while sites receiving a “good” rating increased from 41% in Round 1 to 47% in Round 2. In addition, 35% of the sites exhibited a positive rating increase, while the ratings for 47% of sites remained unchanged. Three sites (Russia Brook, Stony Brook, and Beaver Brook) exhibited sharp declines in biological integrity, while scores from Pequest River, Troy Brook, Ambrose Brook, and Middle Brook increased significantly from 2002/2003 to 2008 (for further information see Trends Analysis section in the full Summary Report).

Percent Ratings Change Between Rounds 1 & 2



*Round 1 sites were re-scored using newly re-calibrated metrics for comparative analysis. These re-calculated Round 1 scores will only be used for the purposes of trends analysis.

INTRODUCTION

Monitoring the health of aquatic systems is a critical component of watershed management. Historically, aquatic systems were monitored primarily through chemical means. Unfortunately, chemical monitoring provides only a “snapshot” of conditions at the time of sampling and may fail to detect acute pollution events (e.g. runoff from heavy rain, spills) and chronic non-chemical pollution (e.g. habitat alteration). In order to address the shortcomings of chemical monitoring, the Department of Environmental Protection (NJDEP) supplements chemical monitoring with biological monitoring. Biological monitoring is based on the premise that biological communities are shaped by the long-term conditions of their environment and more accurately reflect the health of an ecosystem.

The monitoring of stream fish assemblages is an integral component of many water quality management programs for a variety of reasons (see Table 1), and its importance is reflected in the aquatic life use support designations adopted by many states. Narrative expressions such as "maintaining coldwater fisheries", "fishable", or "fish propagation" are prevalent in many state standards. In New Jersey, surface water quality criteria are closely aligned with descriptors such as *trout production, trout maintenance* and *non-trout* waterways. Fish assemblages can be stand-alone indicators of a waterbody’s health and/or fishability. In addition, they may be combined with other biological and chemical indicators to assist in the identification of waters for upgrade to Category One antidegradation classification (N.J.A.C. 7:9B) based on exceptional ecological significance.

The general methodology[1] currently employed in the compilation of these studies and reports is the Rapid Bioassessment Protocol described in Barbour et al. (1999) with some modifications for regional conditions (Kurtenbach 1994). The principal evaluation mechanism utilizes the technical framework of the *Index of Biotic Integrity (IBI),* a fish assemblage approach developed by Karr (1981). The IBI incorporates the zoogeographic, ecosystem, community and population aspects of the fish assemblage into a single ecologically based index. Calculation and interpretation of the IBI involves a sequence of activities including: fish sample collection, data tabulation, and regional modification[1] and calibration of metrics and expectation values. This concept has provided the overall multimetric index framework for rapid bioassessment in this document.

The Clean Water Act (CWA) Title 40, section 130.4 requires states to monitor all waters, which includes using biological monitoring. The U.S. EPA’s National Guidance on the 10 elements of a State Water Monitoring and Assessment Program suggest states should be using at least 3 trophic levels, including fish, macroinvertebrates, and periphytic algae. The Fish IBI data is used in concert with available macroinvertebrate data to assess the status of aquatic life designated use in state waters as required by the CWA section 305(b) (40 CFR: 130.8). These data are also used

[1] The IBI methodology presently being used in these studies was modified from Plafkin et al. (1989) to meet the regional conditions of New Jersey (not all of the state, however, is covered, see Fig. 1) based on work by Kurtenbach (1994). It should be noted, however, that an enumeration of fish assemblages, regardless of whether an IBI is calculated or not, is still a useful *environmental indicator* capable of providing stand alone information to determine whether the affected stream(s) are capable of providing some secondary contact recreation such as fishing.

to identify impaired waters under section 303(d) (40 CFR: 130.7). The data help to measure water quality use attainment and the Department's success in attaining the Clean Water Act goal of "fishable" waters as elaborated in the New Jersey Integrated Water Quality Monitoring and Assessment Report (Integrated Report). The Department has developed an assessment methodology that uses the results from the Fish IBI. This methodology was used in the 2008 Methods Document that was used to prepare the 2008 Integrated List and Report. Data provided by the IBI have become another component of the DEP's suite of environmental indicators.

Beginning in 2004, the Fish IBI data became a significant part of the intensive, data-driven, Category 1 (C-1) selection process (N.J.A.C. 7:9B). This selection process is used to identify State waterbodies of exceptional ecological significance that would then be entitled to an anti-degradation classification. Since 2004, this Fish IBI data has aided in the classification of some or all of an additional 229 river miles to a C-1 category.

The Fish IBI has also found utility in Water Monitoring and Standards' (WM&S') Stressor Identification (SI) program as well, where it has been used to prioritize site selection, help identify the spatial extent of waterbody degradation, and to aid in the location and identification of potential stressors. An unexpected use that appears to be of some public importance, is the location of waterbodies with a high potential for successful fishing opportunities. The importance of the Fish IBI data to the public is exemplified in the average 2,800 website downloads WM&S receives per month.

Table 1. Advantages of using fish as indicators of environmental health.

1. Fish are good indicators of long-term (several years) effects and broad habitat conditions because they are relatively long-lived and mobile (Karr et al. 1986).
2. Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, and piscivores). They tend to integrate effects of lower trophic levels; thus, fish assemblage structure is reflective of integrated environmental health.
3. Fish are at the top of the aquatic food chain and are consumed by humans, making them important subjects in assessing contamination.
4. Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field and released unharmed.
   - Environmental requirements of common fish are comparatively well known.
   - Life history information is extensive for most species.
   - Information on fish distributions is commonly available.
5. Aquatic life uses (water quality standards) are typically characterized in terms of fisheries (e.g. coldwater, coolwater, warmwater, sport, forage).
   - Monitoring fish assemblages provides direct evaluation of "fishability", which emphasizes the importance of fish to anglers and commercial fisherman.
6. Fish account for nearly half of the endangered vertebrate species and subspecies in the United States (Warren and Burr 1994).

METHODS

Field Sampling

Primary objectives of the fish collections are to obtain samples with representative species and abundances, at a reasonable level of effort. Sampling effort is standardized by using similar stream lengths, collection methods, and habitat types. Stream segments selected for sampling are representative of the habitat of the reach. In addition, sample sites will be representative of the habitat of the reach being sampled, and will have a riffle, run, and pool sequence where possible.

Table 2. Requirements for fish sampling based on stream size.

	A	B	C
Stream Size	Moderate to large streams and rivers (5th order or greater)	Wadeable streams (3rd and 4th order)	Headwater streams (1st and 2nd order)
Sampling Distance (meters)	500 m	150 m	150 m
Electrofishing Gear	12' boat	2 Backpacks or barge electrofishing unit	1-2 Backpack electrofisher(s)
Power Source	5000 watt generator	24 volt battery or 2500 watt generator	24 volt battery

Streams with drainage areas less than 5 square miles are presently excluded from IBI scoring because of naturally occurring low species richness. Often streams classified as trout production waters fall into this category. More appropriate assessment methods for these streams include the measurement of trout abundance and/or young of the year production. Benthic macroinvertebrate assessments are also a viable alternative. In addition, atypical habitats such as dams and mouths of tributaries are avoided, unless the intent of the study is to determine the influence these habitats have on the fish assemblage. Most often, sampling atypical habitats results in the collection of fish species not represented in typical stream reaches. Sampling intermittent streams is also avoided. These streams require the development of a separate set of IBI scoring criteria. The Fish IBI was developed for waters in northern New Jersey, from Trenton to Raritan Bay (Figure 1).

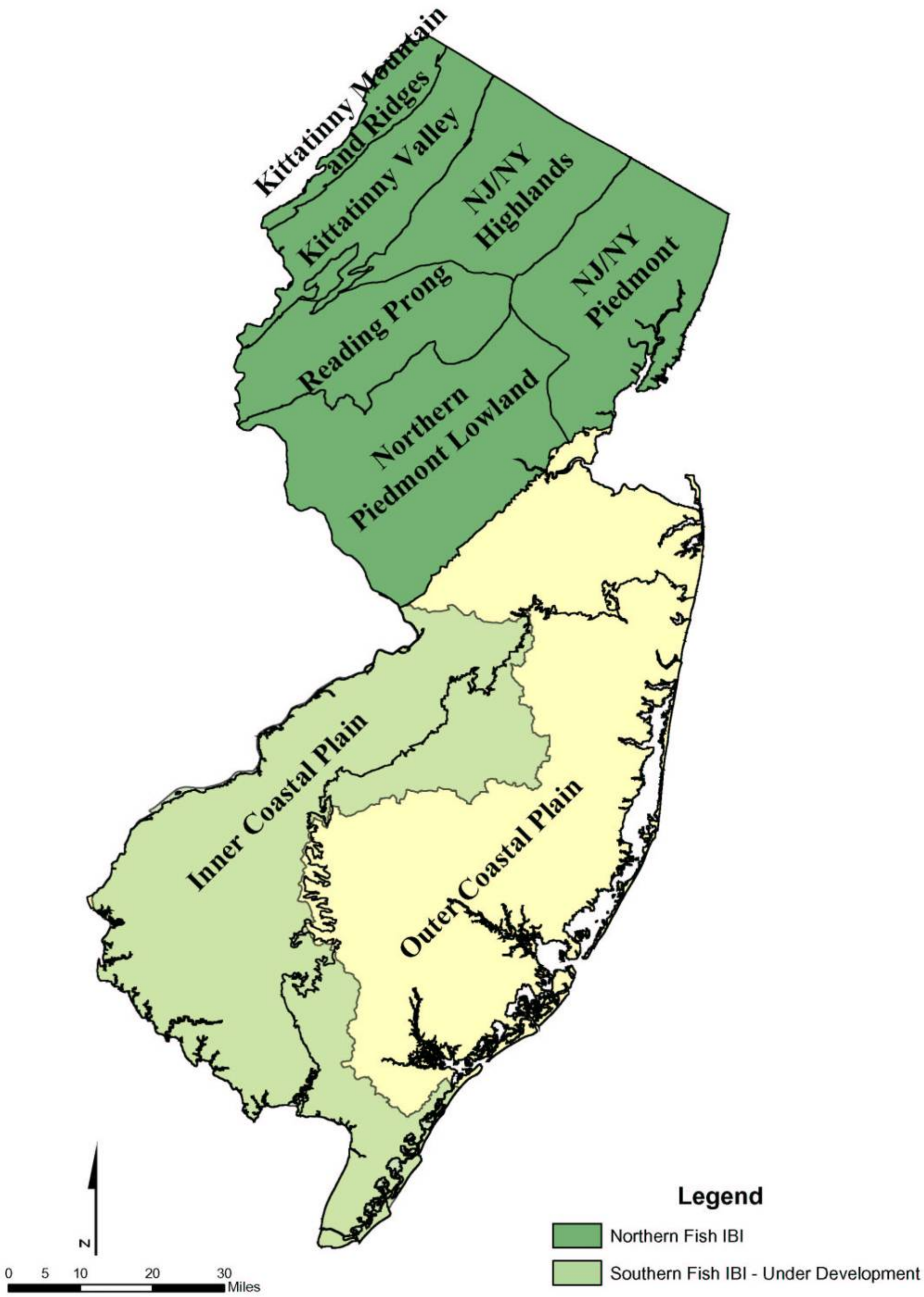


Figure 1. Map of New Jersey Ecoregions and region of Fish IBI applicability.

Electrofishing

Fish are sampled primarily with electrofishing gear using pulsed direct current (DC) output. This method of collection has proved to be the most comprehensive and effective single method for collecting stream fishes. Direct current is safer, more effective, especially in turbid water, and less harmful to the fish. In waters with low conductivity (less than 75 µmhos/cm) it may be necessary to use an AC unit (Lyons 1992). Selection of the appropriate electrofishing gear is dependent on stream size (Table 2). A typical sampling crew consists of four to seven people (Figure 2), depending on the gear being utilized. A minimum of two people are required for netting the stunned fish. Electrofishing is conducted by working slowly upstream for 150 meters and placing the electrodes in all available fish habitat. Stunned fish are netted at and below the electrodes as they drift downstream. Netters attempt to capture fish representing all size classes. All fish captured are immediately placed in water filled containers strategically located along the stream bank in order to reduce fish mortality.

Figure 2. A typical fish sampling operation using the backpack electrofishing.

Sampling time generally requires 4 to 5 hours per station. This includes the measurement of chemical and physical parameters. Sampling is conducted during daylight hours, June through early October, under normal or low flows, and never under atypical conditions such as high flows or excessive turbidity caused by heavy precipitation. Fish collections made in the summer and early fall are easier, safer and less likely to disturb spawning fish.

Sample Processing

Fish are identified to the species level, counted, examined for disease and anomalies, measured (game fish), released and recorded on fish data sheets in the field. The sampling protocol employed is ineffective in capturing a representative sample of smaller fish because they are difficult to see and tend to congregate. Consequently, only fish greater than 25 mm or 1″ in length are counted. Reference specimens and difficult to identify individuals are placed in jars containing 10 percent formaldehyde and later confirmed at the laboratory using taxonomic keys (Werner 1980; Eddy and Underhill 1983; Smith 1985; Page and Burr 1991; Jenkins and Burkhead 1993). Species particularly difficult to identify are forwarded to fisheries experts outside WM&S' Bureau of Freshwater and Biological Monitoring (BFBM) for confirmation (at present, Eco-Analysts, Inc).

Measurement of Physical and Chemical Parameters

Physical and chemical measurements (e.g. pH, conductivity, temperature, dissolved oxygen, depth, and flow) of existing stream conditions are recorded on physical characterization/water quality field data sheets and later summarized. Potential stressors, such as storm sewer outfalls, are identified and mapped using GPS.

Habitat Assessment

Habitat assessments are conducted at every sampling site and all information is recorded on field sheets (Barbour et al. 1999). Habitat assessments provide useful information on probable causes of impairment to instream biota when water quality parameters do not indicate a problem. The habitat assessment consists of an evaluation of the following physical features along the 150 meter reach: substrate, channel morphology, stream flow, bank stability, canopy, and stream side cover. Individual parameters within each of these groups are scored and summed to produce a total score, which is assigned a habitat quality category (see Appendix 3).

Quality Assurance/Quality Control

A Quality Assurance/Quality Control plan is approved by the DEP Office of Quality Assurance prior to sampling. A copy of this plan is available by contacting WM&S' BFBM.

IBI METRICS

Metric Refinement

In an effort to ensure sensitivity to common urban and agricultural stressors, the Northern Fish IBI metrics were re-evaluated using data from Round 1 (2000-2004). Metric refinements led to changes in scoring criteria, species lists, and the selection of a replacement metric (Table 3). Metric recalibration analysis mirrored those techniques used by Ohio EPA and Maryland Department of Natural Resources (Emery et al. 2003; Rankin and Yoder 1999; Roth et al. 2000). Each metric was examined individually to ensure sensitivity to urban and agricultural land uses, statistically significant separation between least impaired and most impaired sites, adequate scoring distribution, and correlation with habitat scoring. Linear regression models were used to assess drainage correlation and the need for scoring modification.

Table 3. Refined Fish IBI Metrics.

Metric	Recalibration Results
1. Total Number of Fish Species	Revised Maximum Species Richness Scoring Lines
2. Number of Benthic Insectivorous Species	Eliminated white sucker & bullheads
3. Number of Trout and/or Sunfish Species	Eliminated green sunfish & bluegill
4. Number of Intolerant Species	No refinement needed
5. Proportion of Tolerant Individuals	Replacement metric for Proportion White Suckers
6. Proportion of Generalists	Revised species list
7. Proportion of Insectivorous Cyprinids	No refinement necessary
8. Proportion of Piscivores	Removed size limits
8. Proportion of Trout	No refinement necessary
9. Number of Individuals in Sample	Removed Tolerant Species
10. Proportion of DELT Anomalies	No refinement at this time

Using surrounding watershed land use/land cover and site habitat scores from Round 1, a subset of sites were divided into least impaired and most impaired. The following criteria were used to classify sites: least impaired < 35% combined urban/agricultural land use and habitat score ≥ 160; most impaired > 65% urban land use. A total of 32 sites (17 least impaired; 15 most impaired) were analyzed using analysis of covariance (ANCOVA) and Mann-Whitney nonparametric U-test (Table 4).

In addition, each metric was analyzed for classification efficiency to ensure minimal overlap between least impaired and most impaired sites (Table 4). The classification efficiency was calculated as the proportion of least impaired sites with individual metric scores greater than or equal to 3 and the proportion of most impaired sites with individual metric scores less than 3 (Roth et al. 2000). Metric classification efficiencies ranged from 59 to 91 percent for Round 1 data and 54 to 90 percent using an independent dataset from USEPA. The mean classification efficiency for refined metrics was 66 percent compared to the 56 percent efficiency using previous metrics. Final metric refinements were validated using the USEPA Region 2 dataset and redundancy among metrics was examined using Pearson's correlation analysis (Table 5). Correlation among metrics ranged from 0.01 to 0.67 and although several metrics were statistically significant, values were below the 0.75-0.80 redundancy threshold (Mundahl and Simon 1999; Emery et al. 2003).

Table 4. Results of metric analysis and classification efficiency for impaired vs. non-impaired sites.

Fish IBI Metrics		ANCOVA (*p*-value)	Mann-Whitney (*p*-value)	Round 1 Classification Efficiency (%)	Independent Data Classification Efficiency (%)
Species Richness & Composition			--		
1.	Number of Species	0.042	--	59%	73%
2.	Number of Benthic Insectivorous Species	<0.001	--	69%	78%
3.	Number of Trout and/or Sunfish Species	0.036	--	59%	54%
4.	Number of Intolerant Species	<0.001	--	91%	90%
5.	Proportion of Tolerant Species	--	0.021	75%	73%
Trophic Composition					
6.	Proportion of Generalists	--	<0.001	75%	70%
7.	Proportion of Insectivorous Cyprinids	--	0.004	72%	73%
	Proportion of Trout	--	0.007		
8.	OR			63%	76%
	Proportion of Piscivores	--	0.61		
Fish Abundance & Condition					
9.	Number of Fish	--	0.14	59%	66%
10.	Proportion of Fish with anomalies	N/A	N/A	N/A	N/A

Table 5. Pearson Correlation matrix for revised Fish IBI metrics.

	No. Species	Abund-Tol	% Piscivores	% Trout	%Ins. Cyprinids	% Generalists	% Tolerants	No. Intolerants	No. Trout&Sun
No.Benthic Ins.	**0.52**	0.39	-0.29	0.07	0.42	-0.42	-0.23	**0.65**	0.28
No.Trout&Sun	**0.59**	-0.05	-0.008	0.21	-0.11	-0.04	-0.02	**0.55**	1
No.Intolerants	0.30	0.12	-0.04	0.29	0.26	-0.42	-0.29	1	
%Tolerants	0.10	-0.39	-0.18	-0.27	**-0.56**	**0.67**	1		
%Generalists	0.003	-0.33	-0.02	-0.26	**-0.66**	1			
%Ins.Cyprinids	0.02	**0.53**	-0.25	0.06	1				
%Trout	-0.11	0.01	0.06	1					
%Piscivores	-0.16	-0.22	1						
Abund-Tol	0.24	1							

Finally, Pearson's correlation analysis was used to evaluate the response of each metric to land use, habitat score, and IBI score (Table 6). Overall, each metric, with the exception of proportion of piscivores, exhibited a significant predicted response at $P < 0.05$. The number of benthic insectivores, number of intolerants, and proportion of insectivorous cyprinids metrics exhibited significant decreasing trends with urban and urban/agriculture land use and significant increasing trends with habitat score and IBI score. In contrast, proportion of tolerant and generalist species metrics exhibited significant predicted responses; both increased with urban and urban/agriculture land use and decreased with an increase in habitat and IBI score.

Table 6. Pearson correlation analysis of revised metrics with land use, habitat, and IBI scores. Correlations in bold are significant at $P < 0.05$.

Metric	Urban Land Use	Urban/Ag Land Use	Habitat Score	IBI Score
No. Species	**-0.32**	-0.15	0.11	**0.38**
No. Benthic Ins.	**-0.49**	**-0.33**	**0.40**	**0.67**
No. Trout&Sun	**-0.32**	**-0.32**	0.15	**0.38**
No. Intolerants	**-0.48**	**-0.48**	**0.37**	**0.62**
% Tolerants	**0.32**	**0.38**	**-0.30**	**-0.66**
% Generalists	**0.42**	**0.42**	**-0.52**	**-0.68**
% Ins Cyprinids	**-0.37**	**-0.28**	**0.37**	**0.67**
% Trout	-0.05	-0.14	**0.23**	**0.35**
% Piscivores	-0.09	-0.18	0.002	-0.04
Abund-Tol	**-0.25**	-0.01	0.11	**0.44**

Calculating the IBI[2]

Once the fish from each sample collection have been identified, counted, examined for disease and anomalies, and recorded, several biometrics are used to evaluate biological integrity. Fish assemblage analysis is accomplished using a regional modification of the original IBI (Karr 1981), developed by Kurtenbach (1994) and later recalibrated by WM&S' BFBM in 2005. Consistent with Karr et al. (1986), a theoretical framework is constructed of several biological metrics that are used to assess a fish assemblage's richness, trophic composition, abundance and condition, as compared to fish assemblages found in regional reference streams.[3, 4] The recent metric recalibration has resulted in the selection of a new metric proportion of tolerant individuals in place of the prior proportion of white suckers metric. The modified IBI uses the following 10 biometrics: 1) total number of fish species, 2) number of benthic insectivorous species, 3) number of trout and sunfish species, 4) number of intolerant species, 5) proportion of tolerant individuals, 6) proportion of individuals as generalists, 7) proportion of individuals as insectivorous cyprinids, 8) proportion of individuals as trout or proportion of individuals as piscivores (top carnivores), 9) number of individuals in the sample and 10) proportion of individuals with disease or anomalies, excluding blackspot disease (see Appendices 1 and 2).

Quantitative scoring criteria were developed for each biometric based upon the degree of deviation; 5 (none to slight), 3 (moderately), and 1 (significantly) from appropriate ecoregional reference conditions. Scores for the individual biometrics at each sampling location are summed to produce a total score, which is then assigned a condition category. The maximum possible IBI score is 50, representing excellent biological integrity. A score of less than 29 indicates a stream has poor biological integrity. 10 is the lowest score a site can receive. Further descriptions of all of the metrics used in the IBI calculations are presented below:

<u>Species Richness and Composition</u>

Four of the biometrics require the use of Maximum Species Richness (MSR) lines. MSR lines relate species richness to stream size and environmental quality. For streams with drainage areas over 5 square miles in northern New Jersey, species richness is expected to increase with higher environmental quality. Additionally, in a stream with a given level of environmental quality, species richness should increase with stream size. Thus, large sized streams with good water quality should have significantly more species than a small stream with good water quality. MSR lines (See Appendix 3) were developed to show the relationship between species richness and waterbody size in New Jersey. Using the procedure described in Karr et al. (1986), MSR lines for each richness metric were drawn by Kurtenbach (1994) with slopes fit by eye to include 95% of the data points. These MSR lines have recently been evaluated and modified when necessary as part of WM&S' BFBM's Fish IBI refinement. The area under the MSR line is trisected by

[2] Narrative for this section taken largely from Kurtenbach (1994)
[3] For regional reference conditions Kurtenbach (1994) used historical fisheries data collected by the New Jersey Division of Fish, Game and Wildlife (unpublished) at 126 stream sites located in the Delaware, Passaic, and Raritan River watersheds. The fish collection methods and the stream lengths sampled in these historical studies were compatible with Kurtenbach's work.
[4] Trophic guilds, pollution tolerances and origins (native or introduced) of each fish species utilized by Kurtenbach to calculate the IBI were assigned using several fisheries publications (Stiles, 1978: Smith, 1985; Hocutt et al. 1986; Karr et al. 1986; Ohio EPA, 1987; Miller et al. 1988).

two diagonal lines.

Points located near the MSR line represent species richness approaching that expected for an unimpacted stream. Points falling within the lowest trisected area, furthest from the MSR line, represent the greatest deviation from an ecoregional reference condition. For example, using the “total number of fish species” graph in Appendix 3, a sample collection resulting in the capture of ten total fish species in a stream with a drainage area of 10 square miles, would receive a score of three and have an intermediate deviation from the expected condition.

1. Total number of fish species:

This metric is simply a measure of the total number of fish species identified from a sample collection. A reduction of taxonomic richness may indicate a pollution problem (e.g., organic enrichment, toxicity) and/or physical habitat loss. Fish species with the least tolerance to environmental change, typically are the first to become absent when water degradation occurs. Although freshwater fish species richness in New Jersey is less than half that of the Midwest region where the IBI was first developed (Karr et al. 1986; Ohio EPA 1987; Lyons 1992), effectiveness of this metric is comparable to regions with richer fish faunas.

2. Number of benthic insectivorous species:

This metric is a modification of several metrics used in the original IBI (Karr 1981). Darter species make up a relatively small component of the New Jersey fish fauna. However, several other benthic species require clean gravel or cobble substrate for reproduction and/or living space. Degradation of this habitat from siltation is often reflected by a loss of benthic species richness (Karr et al. 1986) and abundance (Berkman and Rabeni 1987). Several benthic fish require quiet pool bottoms and may decline when benthic oxygen depletion occurs (Ohio EPA 1987). Further, reductions of some benthic insectivorous fish may indirectly indicate a toxics problem. Benthic macroinvertebrates are an important food source for benthic insectivorous fish and their sessile mode of life make them particularly susceptible to toxicant effects. Metric recalibration has resulted in the elimination of white suckers and bullheads, as these species are designated as tolerant by the USEPA (Plafkin et al 1989).

3. Number of trout and sunfish species:

This metric was adopted as a hybrid for warmwater and coldwater streams. The metric is similar to that used in a combined coldwater-warmwater version of an IBI developed in Ontario (Steedman 1988), but designed for high-gradient rather than low gradient streams. Both sunfish and trout are water-column species sensitive to habitat degradation and loss of instream cover (Gammon et al. 1981; Angermeier 1983). In coldwater streams where sunfish are typically absent, trout fill a similar ecological niche and may be used to replace sunfish. Trout are equally, if not more sensitive to habitat degradation. The relationship between trout populations and habitat is well documented (Peters 1967; Hunt 1969; Meehan 1991). Metric recalibration has resulted in the elimination of green sunfish and bluegill, as these species are designated as tolerant by the USEPA (Plafkin et al 1989).

4. Number of intolerant species:

This metric provides a measure of fish species most sensitive to environmental degradation. The absence of some fish species occurs with subtle environmental changes caused by anthropogenic disturbances. Fish species assigned as intolerant should have historical distributions significantly greater than presently occurring populations and be restricted to streams that have exceptional water quality (Karr et al. 1986).

5. Proportion of tolerant individuals:

This metric was selected as a replacement for the percentage of white sucker as a more regionally appropriate tolerant group in the northeast (Miller et al. 1988; Langdon 1992). In New Jersey, a number of tolerant species are commonly found in small and large streams representing a wide range of water quality conditions. These tolerant species adapt well to changing environmental conditions and often become dominant at disturbed sites. This metric is generally useful in distinguishing moderately and severely impaired conditions.

Trophic Composition

Trophic composition metrics, unlike the richness metrics, are scored based on a percentage of the total numbers of individual fish captured. The influence of stream size on trophic composition has not been determined for New Jersey streams. However, in Illinois and Wisconsin streams (Karr 1981; Lyons 1992), trophic composition was not strongly influenced by stream size. Based on these findings, fixed scoring criteria are used on all stream sizes found in New Jersey, with the exception of large rivers.

6. Proportion of individuals as generalists:

This metric replaces the omnivore metric used in the original IBI (Karr 1981). Use of the omnivore metric was determined to be inappropriate in New Jersey because omnivores are naturally depauperate. Generalists, as defined here, are species with flexible feeding strategies and broad habitat requirements. Often a shift from predominantly specialist groups to generalist groups occurs as water quality becomes degraded (Leonard and Orth 1986; Ohio EPA 1987). Due to broad feeding and habitat requirements, species included for use in this metric are considered tolerant of environmental degradation.

7. Proportion of individuals as insectivorous cyprinids:

Like many streams found in North America, cyprinids are the dominant insectivorous fish in New Jersey (excluding Pineland streams). A shift from specialized invertebrate feeders to generalists with flexible foraging behaviors often indicates poor conditions associated with water quality and/or physical habitat degradation (Karr et al. 1986). Similar to the benthic insectivore metric, insectivorous cyprinids in some instances, may indirectly measure the effects of toxicity.

8. Proportion of individuals as trout or proportion of individuals as piscivores (top carnivores) - excluding American eel (whichever gives higher score):

Streams with slight or moderate water quality impairment generally contain several top predator fish species. In cold water streams of New Jersey, predator fish such as bass and pickerel are depauperate and typically replaced by trout. Thus, a metric is required which measures both groups of top carnivores. A metric fulfilling this requirement is currently used on Vermont streams (Langdon 1992) and has been adopted for use in New Jersey. American eels are excluded from use in this metric. The ubiquity of American eels in streams that have a wide range of water quality and habitat conditions limits their use as an indicator of aquatic health.

Fish Abundance and Condition

9. Numbers of individuals in the sample – excluding tolerant species:

This metric measures the abundance of fish captured from a specified area or stream reach and is used to distinguish streams with severe water quality impairment. Like the original IBI (Karr 1981), catch per unit effort is used to score this metric. Severe toxicity and oxygen depletion are examples of perturbations often responsible for extremely low fish abundance. Tolerant species have been excluded from this metric, as often these species thrive and are numerous under degraded conditions (Ohio EPA 1988).

10. Proportion of individuals with disease or anomalies (excluding blackspot disease):

This metric provides a relative measure of the condition of individual fish (Figure 3). Similar to metric nine, this metric is especially useful in distinguishing streams with serious water quality impacts. This metric is intended to detect impacts in streams highly contaminated by chemicals. A significant relationship between the incidence of blackspot disease and environmental quality has not been established for New Jersey streams. As a result, blackspot disease is excluded from use in this metric. The acronym DELT is used for the types of anomalies: **D**=deformity; **E**=eroded fins; **L**=lesion; **T**=tumor.

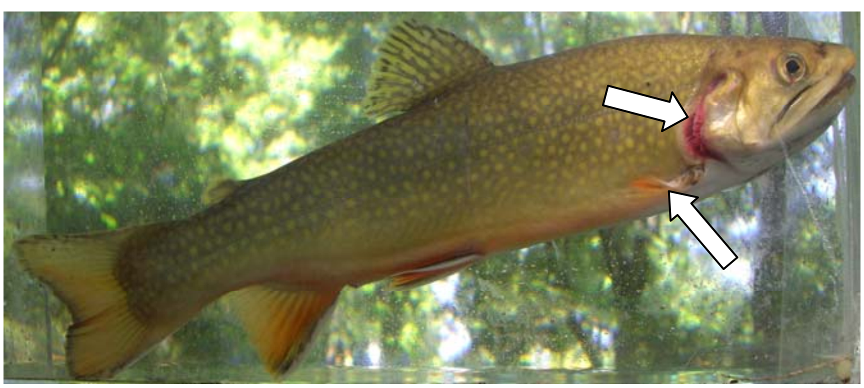


Figure 3. Stocked brook trout with multiple deformities.

RESULTS

In 2008, the fourth year of Round 2 of sampling, 20 sites were sampled. One site was rated "excellent", eight were "good", eight were "fair" and three were "poor" (Figure 4). The habitat ratings for the 2008 sites consisted of seven sites with "optimal" habitat, ten "sub-optimal", and three with "marginal" habitat.

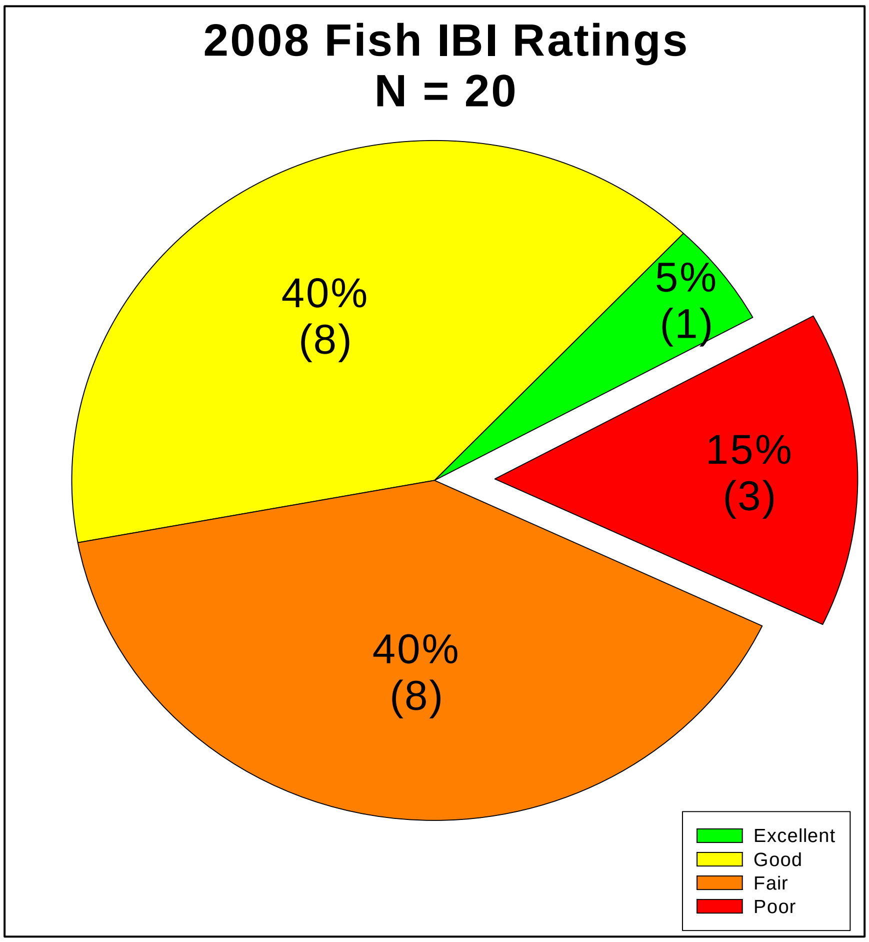


Figure 4. Summary of the 2008 ratings for 20 sites in northern New Jersey.

DISCUSSION

The fish IBI monitoring network is one of the Department's newer rapid bioassessment protocols, designed to detect impacts to biological communities - in this case, fish assemblages. When impacts are suspected, additional investigation would be warranted. This can be accomplished with either more intensive field surveys and sampling, or a desk review of other Department records, or a combination of both. For purposes of discussion here, impacts are suspected at sites with a FIBI rating of "fair". Sites with an FIBI rating of "poor" are considered to be impacted significantly enough that, for purposes of the Department's Water Quality Monitoring and Integrated Assessment Report [IA](40 CFR 130.7 and N.J.A.C. 7:15-6 f), they will be categorized as "impaired". It is important to note that the use attainment status of the overall biological community is based upon a suite of indicators which include fish and benthic macroinvertebrate communities, and associated physical/chemical data.

In this round of sampling, a total of three (3) impaired sites were identified (FIBI062a, FIBI070, FIBI076a) (Figure 5; Table 7). Of these three sites, Van Saun Mill Brook (FIBI062a) and Mahwah Brook (FIBI076a) were identified as having water quality impairments, likely a result of anthropogenic stressors. Poor biotic integrity at Stony Brook (FIBI070), however, is unclear. In addition, eight (8) sites were classified as "fair" and are suspected of having impacts.

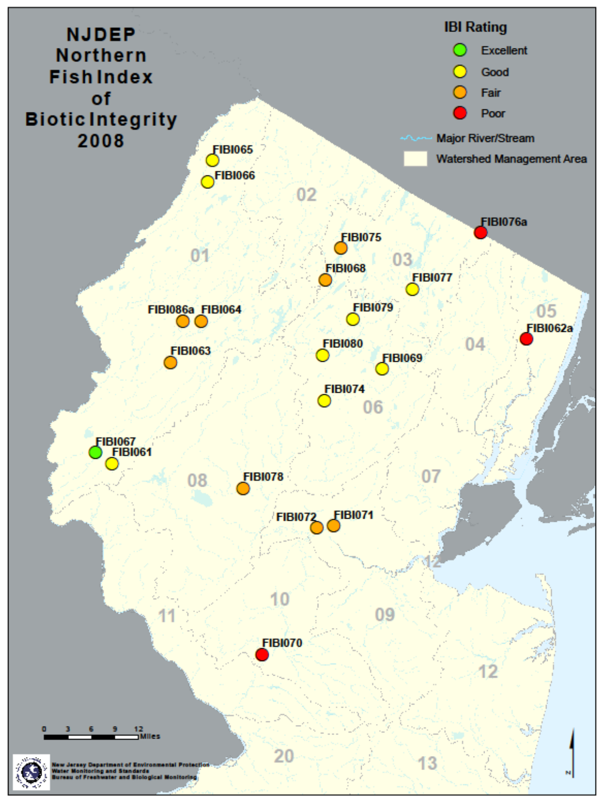


Figure 5. Location of 2008 Fish IBI sites.

Except for Pequannock River (FIBI075) and Lamington River (FIBI078), those sites classified as "impaired" and "potentially impaired" all had "marginal" or "sub-optimal" habitat ratings and many have high percent urban land cover/use within their contributing watershed. Increasing urbanization has been shown to result in a reduction, and even loss, of sensitive fish species, an increased rate of native species replacement by introduced species, as well as a general decline in species richness and abundance (Wang & Lyons, 2003). The following is a discussion of possible causes for the suspected impacts.

Table 7. Results of 2008 Round 2 Fish IBI sampling[1].

FIBI Site	Waterbody	County	Habitat Rating	IBI Score	IBI Rating
FIBI061	Musconetcong River	Warren	Optimal	38	Good
FIBI062a	Van Saun Mill Brook	Bergen	Marginal	26	Poor
FIBI063	Pequest River	Sussex	Suboptimal	36	Fair
FIBI064	Pequest River	Warren	Suboptimal	36	Fair
FIBI065	Little Flat Brook	Sussex	Optimal	38	Good
FIBI066	Big Flat Brook	Sussex	Optimal	40	Good
FIBI067	Pohatcong Creek	Warren	Suboptimal	46	Excellent
FIBI068	Russia Brook	Morris	Suboptimal	32	Fair
FIBI069	Troy Brook	Morris	Suboptimal	38	Good
FIBI070	Stony Brook	Mercer	Suboptimal	26	Poor
FIBI071	Ambrose Brook	Middlesex	Marginal	34	Fair
FIBI072	Middle Brook	Somerset	Suboptimal	32	Fair
FIBI086a	Bear Creek	Warren	Suboptimal	34	Fair
FIBI074	Whippany River	Morris	Suboptimal	42	Good
FIBI075	Pequannock River	Passaic	Optimal	34	Fair
FIBI076a	Mahwah Brook	Bergen	Marginal	28	Poor
FIBI077	Pequannock River	Morris	Optimal	42	Good
FIBI078	Lamington River	Somerset	Optimal	32	Fair
FIBI079	Beaver Brook	Morris	Optimal	42	Good
FIBI080	Rockaway River	Morris	Suboptimal	38	Good

[1]Sampling maps and data for each site can be found in volume 2 of this report.

Potentially Impaired Sites

Pequest River - FIBI063

FIBI063 was relocated approximately 13 miles downstream of the original sampling location to avoid channel braiding. This new location on the Pequest River in Independence Township received a “fair” rating (36) mainly as a result of the proportionally high abundance of tolerant species in the collection. American eel and white sucker were the most abundant tolerant species collected, together representing almost 40% of the total catch. The overall fish community was diverse (H` = 2.4) and species rich (22) despite the homogeneous habitat consisting of mainly slow moving runs and with a high percentage of fine sediments. Throughout the stretch there was ample large woody debris which provided excellent habitat for numerous game species such as bluegill, redbreast sunfish, largemouth bass, redfin pickerel, green sunfish, rockbass, and pumpkinseed.

Pequest River - FIBI064

The habitat at FIBI064 exhibited signs of impairment, and received a “fair” rating with a score of 36. This is likely a result of agriculture surrounding this section of the Pequest River. The left descending bank has been severely impacted, most likely a result of unrestricted livestock access to the stream. The wetted width increases from 30 feet at the start of the reach to 69 feet at the 100-meter point. In addition, the conductivity was relatively high (589 μmhos/cm) and heavy periphyton/macrophyte growth was observed. Livestock access to streams increases nutrient loading and bank erosion/stream widening. This section of the Pequest River has few trees along the bank, likely a result of bank erosion. The mean percent open canopy increases from 22 percent downstream of the livestock access to 99 percent at the access point.

Although fish abundance (1,131) and richness (20) were high, only one top predator was collected, representing less than one percent of the total fish collected. In the previous survey in 2003, predatory fish represented 5% of the fish collected and included chain pickerel, redfin pickerel, largemouth bass, and yellow perch. Numerous fish typically preyed upon by piscivores were abundant in 2008 including banded killifish (241), spottail shiner (95), common shiner (129), and blacknose dace (56).

Russia Brook - FIBI068

The overall score of ‘fair’ (32) for this site indicates some impacts to the aquatic community are occurring. The habitat in the downstream section of the reach is characterized by mainly fine sediments, heavy embeddedness, uniform channel, and a lack of adequate fish habitat. As a result, insectivorous cyprinids such as fallfish and blacknose dace were only collected in the upper portion of the reach which contained cleaner cobble/gravel substrate, higher flow, and better fish habitat. Impacts to the stream have resulted in trophic imbalance, as generalist species were overly abundant, while few specialized feeders such as insectivorous cyprinids were collected.

Ambrose Brook - FIBI071

A Fish IBI rating of ‘fair’ (34) may underestimate the numerous habitat and water quality impairments noted at this site, which have likely impacted resident fish communities. These impairments include low dissolved oxygen for early June (4.8 mg/l), high conductivity (489 μmhos/cm), large composition of fine sediment (25%), numerous storm water outfalls, a lot of debris/garbage, and a lack of habitat/flow complexity. A storm water outfall on the right descending bank approximately 50-m from the start was the source of cloudy gray water entering the stream and anoxic sediments in the stream around the outfall. In addition, yard wastes were being dumped into the stream near the start of the sampling reach. As result of channelization and low flow, it is unlikely this material is dispersed and, instead, is decomposing in one area of the stream, which can impact nearby aquatic organisms.

Middle Brook - FIBI072

Middle Brook received a "fair" rating (32) in 2008 and is likely a result of impairments to the natural substrate, habitat, and water temperature. Although the substrate throughout the stretch is made-up of cobble and gravel/sand, most are severely embedded by fine sediments. The left descending bank is bordered by a flood control levee with no trees to provide overhead cover. The section of the stream from the start to 100-m had an average open canopy of 81.5%, thus allowing a great deal of sunlight penetration leading to the high water temperature (25.5° C) for early June.

Natural substrates embedded by fine sediments smother aquatic macroinvertebrates and, therefore, impact the specialized insectivorous cyprinidae feeding group, whose abundance was proportionally low. The high water temperature measured in early June can be detrimental to those sensitive fish in the intolerant species metric, none of which were collected here. In contrast, tolerant species able to tolerate high water temperatures and habitat degradation comprised more than half (54%) of the total fish collected.

Bear Creek - FIBI086a

A total of 12 wild brook trout were collected from this FW2-TMC2 stream. Although the habitat was rated as "sub-optimal" (154), the stream was more typical of a low gradient waterbody. The stream lacked adequate riffle habitat, as the majority of the stream was run and pool habitat. As a result, few riffle species were collected and richness of several fish groups was relatively low, resulting in a Fish IBI score of "fair" (34). The left descending bank contained little overhead cover as the bank was meadow, providing little shade to the stream. Although Bear Creek receives a lot of direct sunlight, springs keep the stream cool (18.3° C) and oxygenated (101%) during summer months enabling sensitive wild brook trout survival.

Pequannock River - FIBI075

Although the habitat was rated "optimal" (176), no trout were collected at this FW2-TPC1 stream and the resulting Fish IBI score was rated "fair" (34). The stream flattens 100-meters above the Route 23 crossing and becomes low gradient. Communication with NJ Fish & Wildlife indicated the upper sections of the Pequannock River have been altered by beaver ponds which have modified the gradient of downstream sections and limited available trout production habitat. This is apparent from the two rounds of sampling in which no trout have been collected and the fish assemblages consist of a mix of high gradient and low gradient species. The only other possible impairment to the stream was a plume of foamy gray water following the thalweg from an unidentified source. Two NJPDES permitted outfalls are located several miles upstream, on a tributary to the Pequannock River, but it is unclear if these were the source.

Lamington River - FIBI078
In 2008, FIBI078 was moved approximately 1.5 miles downstream to eliminate a braided channel around the previous sample location. This new site, which received a "fair" rating (32), is downstream and adjacent to a large golf course which borders both banks for more than a kilometer below Interstate 78 (Figure 6). Several outfalls were observed coming from the golf course property, which provides a pathway to transport fertilizers and herbicides sprayed on the fairways and greens. Although periphyton growth was minimal while sampling in late June, growth may be more significant later in the summer, especially if allochthonous nutrients enter the stream. In addition, throughout much of this section there is no riparian buffer between the river and golf course which not only eliminates natural filtering processes, but also reduces natural shading to the stream. As a result, periphyton growth was higher in sections of the Lamington River which had an open canopy (Figure 7).

Figure 6. Proximity of golf course to Fish IBI station.

Figure 7. Periphyton growth in Lamington River.

Although three species of intolerant fish were collected, shield darter, brook lamprey, and margined madtom, overall fish abundance and richness were relatively low for a river this size. In addition, proportional abundance of specialized feeders such as insectivorous cyprinids and piscivores were low.

Fish IBI station FIBI032, located approximately 3.5 miles upstream of FIBI078 was sampled in 2006 and received a “good” rating. The fish assemblage from this upstream location (FIBI032) contained 7 insectivorous cyprinid species which comprised almost 24% of the fish collected compared to just 3 insectivorous cyprinids comprising only 14% of the total at the downstream location (FIBI078).

Impaired Sites

Van Saun Mill Brook - FIBI062a

The habitat of Van Saun Mill Brook was rated “marginal” (89) with numerous signs of stress and degradation. The conductivity was relatively high (455 μmhos/cm), a likely result of the large amount of run-off from surrounding parking lots and roads, but other water chemistry parameters were relatively normal. Large amounts of concrete, cinder blocks, and debris were observed throughout the stretch. Several failing retaining walls were noted which likely adds to the artificial substrate of the stream (Figure 8). The stream provides little natural fish habitat, with most of the fish concentrated in and around concrete slabs in the deeper pools (Figure 9). Although hydrology and run-off have severely impacted the stream’s biota, the stretch did exhibit good overhead cover, flow regime, and water clarity.

Figure 8. Failing retaining walls along Van Saun Mill Brook.

Figure 9. Concrete debris in Van Saun Mill Brook.

Although fish were abundant in the stretch, over half of the fish collected (~52%) are considered tolerant species. In addition, proportional abundance of specialized feeding insectivorous cyprinids was low (3.4%), an indication of impairments to the benthic community, and just one top predatory fish was collected. Surprisingly, just two green sunfish were collected compared to 105 pumpkinseed, a trend which is likely to reverse in future years.

Ratings for AMNET site AN0211, 0.2 miles upstream of FIBI062a, have steadily increased over time from "poor" (16.86) in 1998 to "fair" (23.39) in 2008.

Stony Brook - FIBI070

Stony Brook received a "suboptimal" (144) habitat score and although there were no obvious signs of impairment, the stream lacked adequate riffle habitat, as the stretch was relatively flat (Figure 10). In addition, the substrate consisted mainly of sand/gravel with little cobble or larger substrate for macroinvertebrate assemblages and the fish species which rely on these organisms. The flow throughout much of the stretch was low (3cfs), as the stream widened above the halfway point in the stretch, as the wetted width increased from 22.4 feet at 50-meters to 45.4 feet at 100-meters. Several large macrophyte beds were present in the wide flat sections, including duckweed and Eurasian Watermilfoil (Figure 11). The stretch contained several deep pools with ample large woody debris providing suitable habitat for lentic species like many centrarchids, but little habitat for lotic fish species.

Figure 10. Flat sections of Stony Brook.

Figure 11. Duckweed in sections of Stony Brook.

The fish community was made-up of mostly Centrarchid species with few benthic or cyprinid species. A few margined madtoms and tessellated darters comprised the benthic community, while just seven total cyprinids were collected. As a result, generalist feeders were the most abundant (65%) feeding guild, while the proportion of specialized feeders such as insectivorous cyprinids and top predators was low (2.8% and 0.8% respectively). Despite being stocked with trout just a few weeks prior to the July 11, 2008 sampling event, no trout were collected confirming the stream's FW2-NT status.

Mahwah Brook - FIBI076a

The habitat was rated “marginal” (96) with abundant debris throughout the stretch. The stream lacks a riparian buffer, as it is bordered by numerous parking lots, buildings, and houses. The right descending bank from the road crossing upstream 100 meters is lined with riprap, while the left descending bank above the mid-point of the stretch is bordered by large retaining walls (Figure 12). The stream is prone to flash flooding from run-off from the surrounding impervious surfaces and outfalls. There are a total of 11 outfalls within the 150-meter sample reach, including a NJPDES permitted outfall near the start. In addition, the conductivity was very high (733 µmhos/cm), a likely result of run-off, and the dissolved oxygen concentration was low (5.65 mg/l). In addition, the substrate is covered in a layer of fine sediments.

Figure 12. Failing retaining wall on Mahwah Brook.

The fish community was dominated by green sunfish, as this invasive species comprised almost 29% of the total sample (Figure 13). The trophic status of the fish community was skewed toward generalist feeders (60%), while proportional abundance of specialized feeders such as insectivorous cyprinids and piscivores were relatively low, 11 and 2.6 percent respectively. Despite the numerous habitat and water quality impairments, a number of cyprinid species were collected including fallfish, common shiner, creek chub, and the intolerant cutlips minnow. Typically impairments to the benthic community will result in fish community shifts from cyprinids to tolerant/generalist species. A number of abnormalities were noted within the fish community, primarily consisting of lesions on white suckers (Figure 14).

Figure 13. Green sunfish collected from Mahwah Brook.

Figure 14. Caudal fin lesion on white sucker collected from Mahwah Brook.

Other Important Findings

Pohatcong Creek - FIBI067

A total of 86 wild trout were collected from this FW2-TMC1 stream, which included 84 wild brown trout and 2 wild brook trout. In addition, 21 of the wild brown trout were young-of-the-year making this a candidate stream for upgrade to a "trout production" classification (Figure 15).

Figure 15. Young-of-the-year brown trout collected from Pohatcong Creek.

Whippany River - FIBI074

Twelve wild brown trout, including one young-of-the-year, were collected from this FW2-TPC1 stream. In addition, 86 American brook lamprey were collected which is the highest abundance of these sensitive species found at a site since the start of the Fish IBI Program in 2000.

Pequannock River - FIBI077

Eight wild brown trout and two wild brook trout were collected from this FW2-TPC1 stream, including four young-of-the-year brown trout and one young-of-the-year brook trout. The stream habitat was rated "optimal" (181) and exhibited good fish habitat, overhead cover, substrate, and flow regime. The only potential impairment was the relatively high conductivity (413 µmhos/cm), likely a result of the run-off from the Paterson-Hamburg Turnpike, which closely parallels the stream.

Beaver Brook - FIBI079

A total of 33 wild brook trout, including eight young-of-the-year, were collected from this FW2-TPC1 stream. Although the habitat was rated "optimal" (162), the recent construction of a private pond has changed the water chemistry, substrate, and discharge of the stream (Figures 16 and 17). The pond appears to be an encroachment of the stream, as a branch of Beaver Brook has been dammed to create the pond. The substrate in a large pool just below the pond outfall consists of fine sediments which contrasts the gravel/cobble/boulder substrate of the rest of the stretch. In addition, the water temperature was higher and the pH was much lower at the pond outfall compared to the section just upstream. The warm surface water run-off from the pond could quickly increase the water temperature of the stream and could impact the wild brook trout population. Several state agencies were contacted with regard to this stream encroachment including the NJDEP's Northern Enforcement Bureau within the Compliance and Enforcement Element. The TPC1 designation to this section of Beaver Brook upstream of Meridan Road was adopted in 2002, prior to the encroachment.

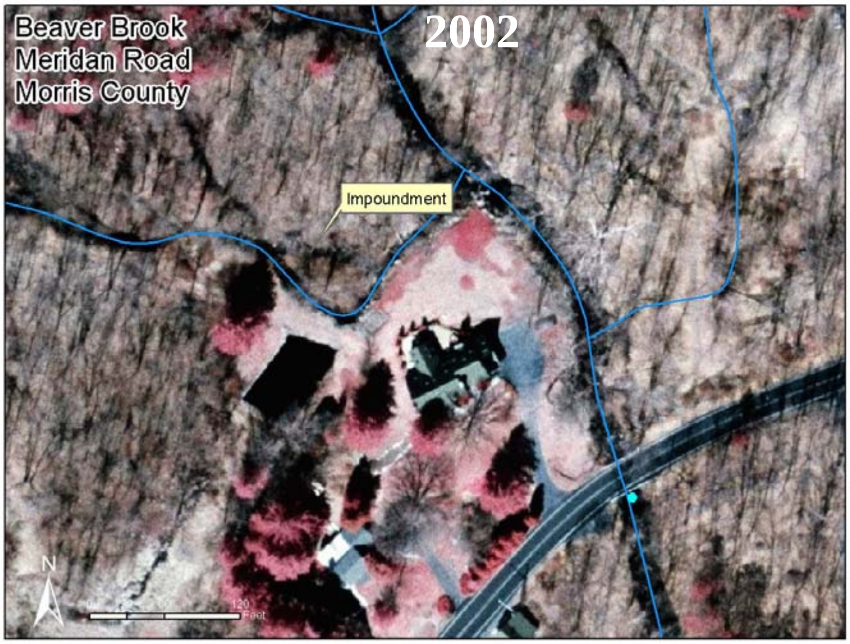


Figure 16. 2002 aerial photo of Beaver Brook.

Figure 17. 2007 aerial photo of Beaver Brook.

Rockaway River - FIBI080

Despite numerous man-made impacts to this section of the Rockaway River which include high conductivity, floatables, several storm water outfalls, marginal overhead canopy, and no riparian buffer along the left descending bank, one wild brown trout was collected in this FW2-NTC1 stream. The stream was littered with garbage and debris and contained little fish habitat, but this has had minimal impact on the resident fish community as the site was rated "good" (38). The fish community was healthy and balanced. These anthropogenic impacts may not be impacting the fish community at FIBI080, but biotic integrity steadily decreases downstream. FIBI080 is the uppermost Fish IBI site on the Rockaway River and has received recalibrated metric ratings of "good" in both Rounds 1 and 2. However, biotic integrity steadily decreases downstream to a "fair" rating at FIBI083 (~5 miles downstream of FIBI080) and "poor" ratings in both Rounds 1 and 2 at FIBI021, the furthest downstream Fish IBI location on the Rockaway River (~13.5 miles downstream of FIBI080).

SUMMARY

The observed impacts and potential impacts often appear related to the habitat/water quality and the land use/land cover of the surrounding watershed. Vegetative cover and riparian buffers are important in maintaining natural stream function necessary to sustain a healthy stream community. Studies have demonstrated the adverse impacts to fish community structure and function as a result of loss of riparian cover due to agriculture and urbanization (Roth et al. 1996; Goldstein et al. 2002; Talmage et al. 2002). Linear regression analysis of NJ Fish IBI Round 2 data indicates a positive linear relationship between Fish IBI and habitat scores (Figure 18). Similarly, Roth et al. (1996) found a direct correlation between fish IBI and habitat quality in the Midwest.

In addition, there is a significant inverse relation between the percent urban land use and Round 2 Fish IBI score (Figure 19). Stream impacts resulting from urban land use can be complex in nature and difficult to discern. Urban impacts to a stream are wide ranging and include changes to stream hydrology, geomorphology, water temperature, water chemistry, fish communities, and macroinvertebrate communities. Analysis of data on the effects of urbanization on New England streams indicated degradation was most apparent in the following biotic metrics: EPT taxa for macroinvertebrates, cyprinid taxa for fish, and diatom taxa for periphyton (Coles et al. 2004). Water chemistry and stream habitat impacts were most apparent in levels of alkalinity, conductivity, nitrogen, water depth, and water temperature.

Preliminary analysis of the NJ Fish IBI data suggests several community metrics appear responsive to urbanization, including loss of trophic guilds and intolerant species. The most common trophic level changes include loss and often absence of top carnivores (piscivores) and insectivorous cyprinids.

Although an index of biotic integrity provides valuable input into the health of a lotic ecosystem, accurate interpretation of the data is essential. According to Angermeier and Karr (1986) “ the IBI cannot be used in a “cookbook” fashion…When used in conjunction with measures of physical and chemical quality, it can provide a comprehensive evaluation of ecological integrity.”

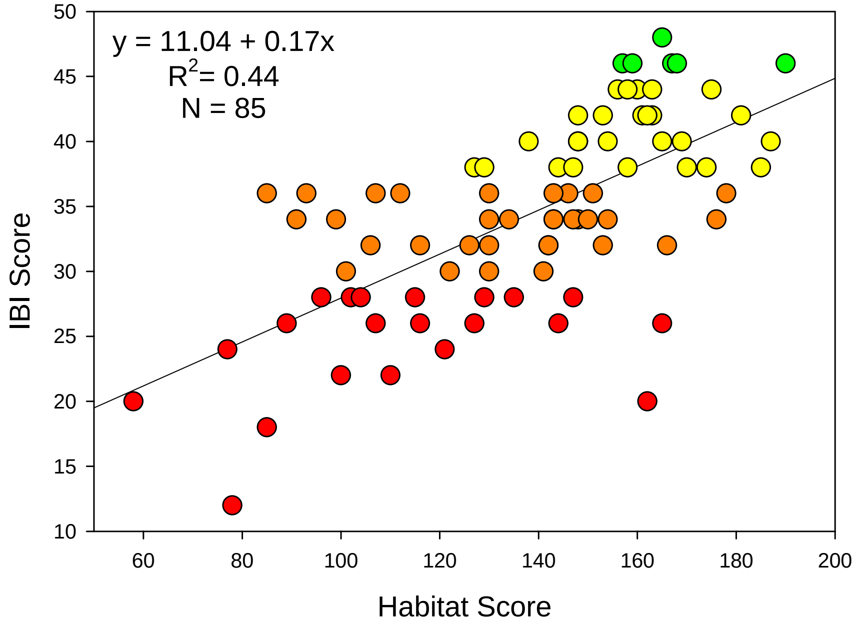


Figure 18. Linear regression comparing IBI and habitat scores.

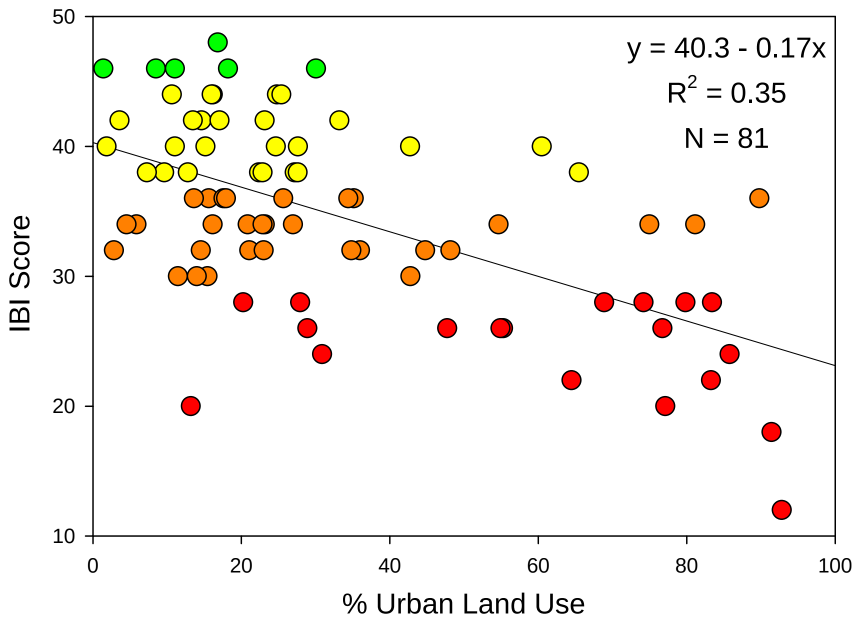


Figure 19. Linear regression comparing urban land use and IBI score.

TRENDS ANALYSIS

The completion of the 2008 sampling season marks the fourth year of the second round of Fish IBI sampling. The sites sampled in 2008 were originally sampled in 2003. Those sites sampled in 2003 were re-scored using the re-calibrated metrics in order to compare results over time (Table 8).

Table 8. Comparison of Round 1 and 2 results using newly calibrated metrics.

		Round 1 Results*		2008 Results		
FIBI Site	**Waterbody**	**IBI Score**	**IBI Rating**	**IBI Score**	**IBI Rating**	
FIBI061	Musconetcong River†	34	Fair	38	Good	
FIBI062a	Van Saun Mill Brook	N/A	N/A	26	Poor	
FIBI063	Pequest River	26	Poor	36	Fair	
FIBI064	Pequest River	32	Fair	36	Fair	
FIBI065	Little Flat Brook	44	Good	38	Good	
FIBI066	Big Flat Brook	42	Good	40	Good	
FIBI067	Pohatcong Creek	42	Good	46	Excellent	
FIBI068	Russia Brook	40	Good	32	Fair	
FIBI069	Troy Brook	32	Fair	38	Good	
FIBI070	Stony Brook	32	Fair	26	Poor	
FIBI071	Ambrose Brook	24	Poor	34	Fair	
FIBI072	Middle Brook	26	Poor	32	Fair	
FIBI086a	Bear Creek	N/A	N/A	34	Fair	
FIBI074	Whippany River	38	Good	42	Good	
FIBI075	Pequannock River	36	Fair	34	Fair	
FIBI076a	Mahwah Brook	N/A	N/A	28	Poor	
FIBI077	Pequannock River	44	Good	42	Good	
FIBI078	Lamington River	34	Fair	32	Fair	
FIBI079	Beaver Brook	48	Excellent	42	Good	
FIBI080	Rockaway River	44	Good	38	Good	

*Round 1 sites were re-scored using newly re-calibrated metrics for comparative analysis. These re-calculated Round 1 scores will only be used for the purposes of trends analysis and will not be used for regulatory uses.
†Round 1 results are from resample in 2005.

The proportion of sites rated as "fair" and "poor" decreased slightly from Round 1 (53%) to Round 2 (47%) (Figure 20). The number of "excellent" sites remained constant, while the proportion of "good" sites increased slightly from 41% in Round 1 to 47% in Round 2. Overall, scores between rounds differed by less than one point, as the average score in 2003 was 36.4 compared to 35.7 in 2008.

Fish IBI scores can fluctuate temporally at a station due to natural variation, and as a result it is not uncommon for site scores to differ by a few points over time (Karr et al. 1986). Anthropogenic stress, on the other hand, can result in larger fluctuations in scoring over time, and for the purposes of the NJ Fish IBI, sites with scoring differences greater than four points in addition to a change in rating are considered significant. Significant scoring/rating changes occurred at several sites including the following: Pequest River (063), Russia Brook (068), Troy Brook (069), Stony Brook (070), Ambrose Brook (071), Middle Brook (072), and Beaver Brook (079) (Figure 21). Four of these changes were positive changes and three indicated degradation in biological integrity. The following is a description of trends at these individual sites over time.

Pequest River – FIBI063

The location of FIBI063 on the Pequest River was moved in 2008 due to a braided channel and difficulty in collecting a representative sample from the original sampling location on Pequest Road in Green Township. The new site is located approximately 13 miles south of the Green Township site and is likely the reason for significant scoring and rating differences.

Russia Brook – FIBI068

The biological integrity of Russia Brook decreased from 40 "Good" in Round 1 to 32 "Fair" in Round 2. The number and proportion of insectivorous cyprinids decreased significantly between rounds. Within this group of specialized feeders, creek chub, blacknose dace, and fallfish represented 49% of the total catch in Round 1compared to just 19% in the second round. Subsequently, as the proportional abundance of specialized feeders decreased, the proportion of generalist feeders increased between rounds. These generalist feeders included redbreast sunfish, white sucker, bluegill, Eastern mudminnow, and brown bullhead all of which comprised almost 46% of the total catch.

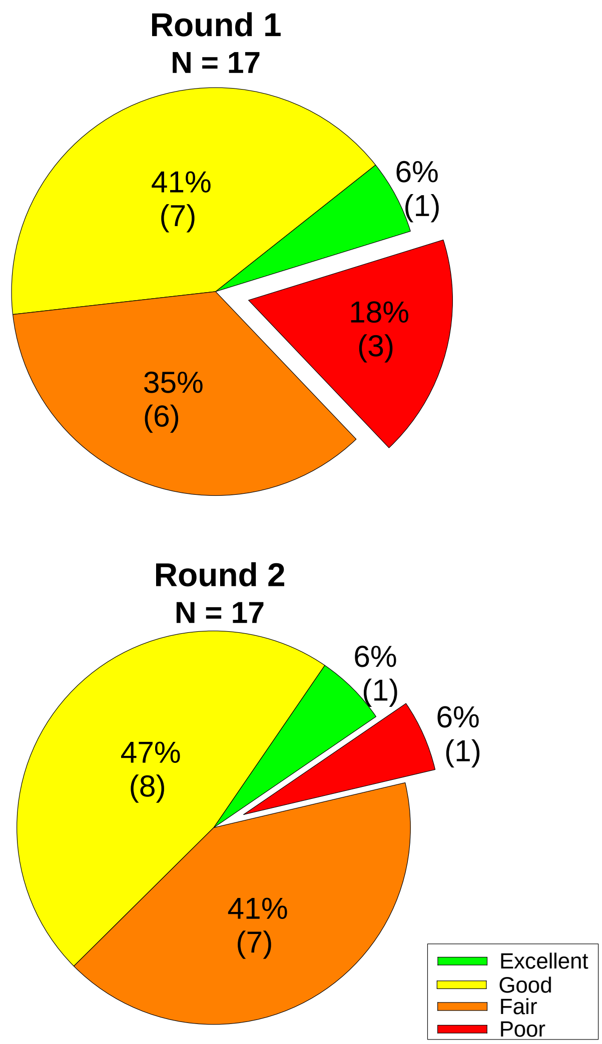


Figure 20. Ratings comparison for Rounds 1 and 2.

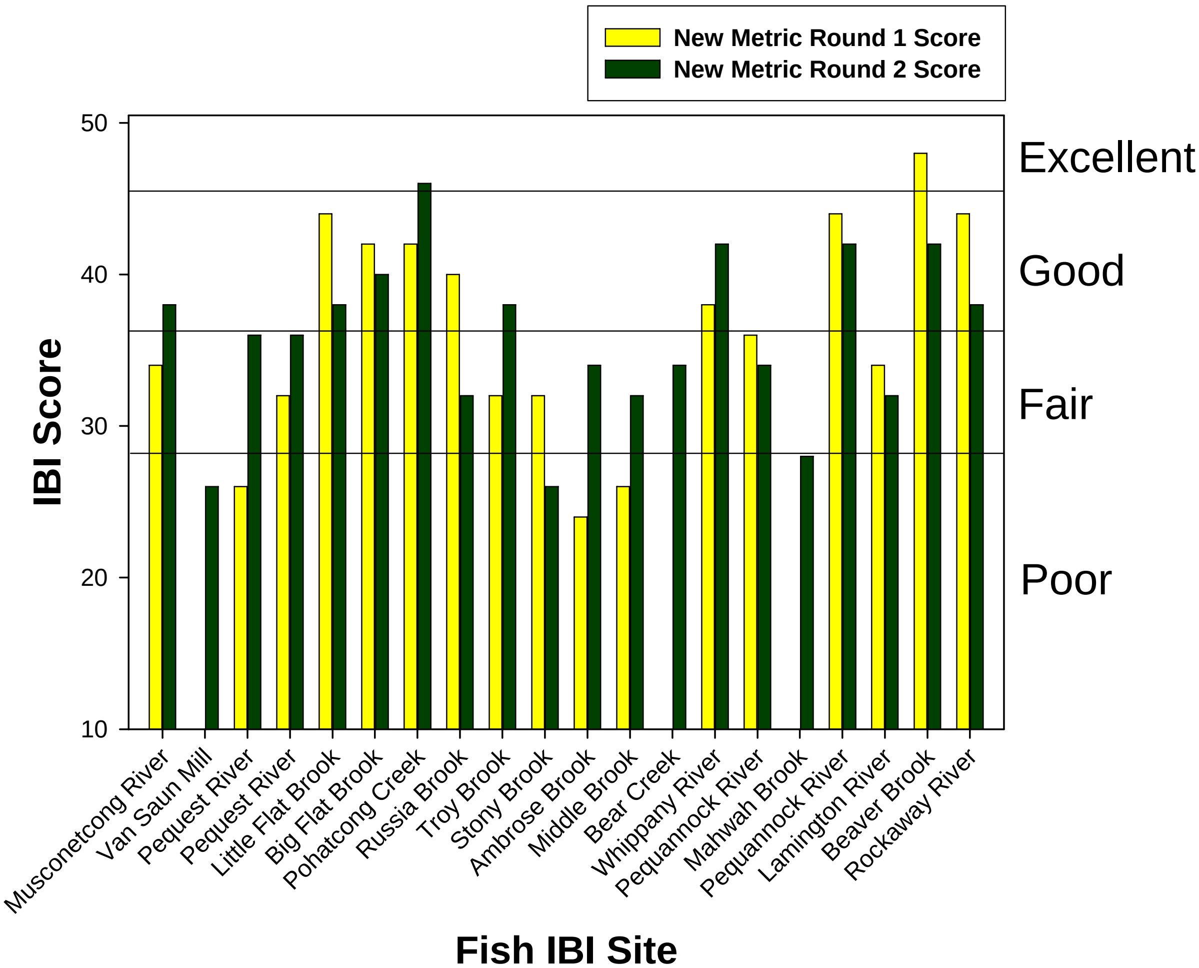


Figure 21. Comparison of ratings for Rounds 1 and 2 at individual sites.

<u>Troy Brook – FIBI069</u>

The 2008 fish community lacked diversity (H` = 1.67) and no intolerant species were collected, but did exhibit good trophic balance. The biotic integrity of Troy Brook increased from “fair” (32) in 2003 to “good” (38) in 2008. Despite high turbidity, high conductivity, and possible impacts from a storm water detention basin, the substrate, flow, habitat, and overhead cover in 2008 were indicative of a healthy stream community. The detention basin is likely outdated and was not designed to handle the current run-off from surrounding impervious cover. As a result, a deeply scoured channel has been carved from the outlet to the entrance into Troy Brook (Figure 22).

Figure 22. Channel scouring at storm water detention basin outlet.

Stony Brook – FIBI070
The biotic integrity of Stony Brook decreased from 32 “fair” in Round 1 to 26 “poor” in Round 2. In 2003, two stocked rainbow and one stocked brook trout were collected which resulted in higher scores for metric 3 (Trout/Sunfish Richness) and metric 4 (Intolerant Richness). Without these stocked fish, results between rounds were the same. The collection of stocked trout is dependent on many factors not related to biotic integrity including stocking allocations, fishing pressure, and condition of the fish at the time of stocking.

Ambrose Brook – FIBI071
Despite numerous signs of habitat and water quality degradation, the biotic integrity increased from 24 “poor” in Round 1 to 34 “fair” in Round 2. The fish community collected in 2008 exhibited better trophic balance and was not dominated by tolerant individuals, as was the collection in 2003. Although certain fish groups, such as the benthic insectivorous tessellated darter and the insectivorous cyprinid spottail shiner were more abundant in 2008, overall species diversity was poor (H` = 1.58).

Middle Brook – FIBI072
The biotic integrity increased from “poor” (26) in 2003 to “fair” (32) in 2008. Although the overall proportion of tolerant species was high for both years surveyed, the percentage decreased from 79% in 2003 to 54% in 2008. In addition, specialized feeders and overall fish abundance were slightly higher in this second round of sampling.

Beaver Brook – FIBI079
Biological integrity decreased from 48 “Excellent” in Round 1 to 42 “Good” in Round 2. An impounded tributary of the brook may be the cause of the decline in biological integrity, as fine sediment build-up and changes to the stream’s discharge and water chemistries were noted just below the impounded section. Species richness declined

from 15 in Round 1 to 10 in this second round with several benthic species absent from this recent sampling event including margined madtom, yellow bullhead, and brown bullhead.

FURTHER INFORMATION

The current report summarizes the ninth year of IBI sampling. The network established a total of 100 stations in northern New Jersey. An IBI for southern New Jersey is currently being evaluated. Stations will be visited every five years as part of the WM&S/BFBM's monitoring efforts.

Reports and data for the first eight years of the IBI can be obtained on the WM&S Bureau of Freshwater and Biological Monitoring's web page: http://www.state.nj.us/dep/wms/bfbm/fishibi.html or by calling 609-292-0427.

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APPENDIX 1
Second Revised List of New Jersey Freshwater Fishes

	Trophic Guild	Tolerance	Historical Presence
Petromyzontidae:			
American Brook Lamprey (*Lampetra appendix*)	NF	IS	N
Sea Lamprey (*Petromyzon marinus*)	PF	--	N
Acipenseridae:			
Atlantic Sturgeon (*Acipenser oxyrhynchus*)	BI	--	N
Shortnose Sturgeon (*A. brevirostrum*)	BI	IS	N
Lepisosteidae:			
Longnose Gar (*Lepisosteus osseus*)	P	--	EX
Amiidae:			
Bowfin (*Amia calva*)	P	--	NN
Anguillidae:			
American Eel (*Anguilla rostrata*)	P	TS	N
Clupeidae:			
Blueback Herring (*Alosa aestivalis*)	PL	--	N
Hickory Shad (*A. mediocris*)	I/P	--	N
Alewife (*A. pseudoharengus*)	PL	--	N
American Shad (*A. sapidissima*)	PL	--	N
Gizzard Shad (*Drosoma cepedianum*)	O	--	N
Salmonidae:			
Rainbow Trout (*Oncorhynchus mykiss*)	I/P	IS	NN
Brown Trout (*Salmo trutta*)	I/P	IS	E
Brook Trout (*Salvelinus fontinalis*)	I/P	IS	N
Lake Trout (*S. namaycush*)	P	--	NN
Osmeridae:			
Rainbow Smelt (*Osmerus mordax*)	I	--	N
Umbridae:			
Eastern Mudminnow (*Umbra pygmaea*)	G	--	N
Esocidae:			
Redfin Pickerel (*Esox americanus*)	P	--	N
Northern Pike (*E. lucius*)	P	--	NN
Muskellunge (*E. masquinongy*)	P	--	NN
Chain Pickerel (*E. niger*)	P	--	N
Cyprinidae:			
Goldfish (*Carassius auratus*)	G	--	E
Grass Carp (*Ctenopharyngodon idella*)	H	--	E
Satinfin Shiner (*Cyprinella analostana*)	I	--	N
Spotfin Shiner (*C. spiloptera*)	I	--	N
Common Carp (*Cyprinus carpio*)	G	--	E
Cutlips Minnow (*Exoglossum maxillingua*)	BI	IS	N
Eastern Silvery Minnow (*Hybognathus regius*)	H	--	N
Common Shiner (*Luxilis cornutus*)	I	--	N
Golden Shiner (*Notemigonus crysoleucas*)	O	--	N
Comely Shiner (*Notropis amoenus*)	I	--	N

	Trophic Guild	Tolerance	Historical Presence
Bridle Shiner (*N. bifrenatus*)	I	--	N
Ironcolor Shiner (*N. chalybaeus*)	I	--	N
Spottail Shiner (*N. husdonius*)	I	--	N
Swallowtail Shiner (*N. procne*)	I	--	N
Bluntnose Minnow (*Pimephales notatus*)	O	--	NN
Fathead Minnow (*P. promelas*)	O	--	NN
Blacknose Dace (*Rhinichthys atratulus*)	BI	--	N
Longnose Dace (*R. cataractae*)	BI	--	N
Creek Chub (*Semotilus atromaculatus*)	I	--	N
Fallfish (*S. corporalis*)	I	--	N
Cobitidae:			
Oriental Weatherfish *(Misgurnus anguillicaudatus)*	BI	--	E
Catostomidae:			
Quillback *(Carpiodes cyprinus)*	O	--	N
White Sucker (*Catostomus commersoni*)	G	TS	N
Creek Chubsucker (*Erimyzon oblongus*)	BI	--	N
Northern Hog Sucker (*Hypentelium nigricans*)	BI	IS	N
Ictaluridae:			
White Catfish (*Ameiurus catus*)	I/P	--	N
Black Bullhead (*A. melas*)	G	--	NN
Yellow Bullhead (*A. natalis*)	G	--	N
Brown Bullhead (*A. nebulosus*)	G	--	N
Channel Catfish (*Ictalurus punctatus*)	I/P	--	NN
Tadpole Madtom (*Noturus gyrinus*)	BI	--	N
Margined Madtom (*N. insignis*)	BI	IS	N
Flathead Catfish *(Pylodictis olivaris)*	P	--	NN
Aphredoderidae:			
Pirate Perch (*Aphredoderus sayanus*)	I	--	N
Cyprinodontidae:			
Banded Killifish (*Fundulus diaphanus*)	G	TS	N
Mummichog (*F. heteroclitus*)	G	TS	N
Poeciliidae:			
Western Mosquitofish (*Gambusia affinis*)	I	--	NN
Eastern Mosquitofish (*G. holbrooki*)	I	--	N
Gasterosteidae:			
Fourspine Stickleback (*Apeltes quadracus*)	I	--	N
Threespine Stickleback (*Gasterosteus aculeatus*)	I	--	N
Ninespine Stickleback (*Pungitius pungitius*)	I	--	N
Moronidae:			
White Perch (*Morone americana*)	I/P	--	N
Striped Bass (*M. saxatilis*)	P	--	N
Centrarchidae:			
Mud Sunfish (*Acantharchus pomotis*)	I	--	N
Rock Bass (*Ambloplites rupestris*)	I/P	--	NN
Warmouth *(Chaenobryttus gulosus)*	I/P	--	NN

	Trophic Guild	Tolerance	Historical Presence
Blackbanded Sunfish (*Enneacanthus chaetodon*)	I	--	N
Bluespotted Sunfish (*E. gloriosus*)	I	--	N
Banded Sunfish (*E. obesus*)	I	--	N
Redbreasted Sunfish (*Lepomis auritus*)	G	--	N
Green Sunfish (*L. cyanellus*)	G	TS	NN
Pumpkinseed (*L. gibbosus*)	G	--	N
Bluegill (*L. macrochirus*)	G	TS	NN
Smallmouth Bass (*Micropterus dolomieu*)	P	--	NN
Largemouth Bass (*M. salmoides*)	P	--	NN
White Crappie (*Pomoxis annularis*)	I/P	--	NN
Black Crappie (*P. nigromaculatus*)	I/P	--	NN
Percidae:			
Swamp Darter (*Etheostoma fusiforme*)	BI	IS	N
Tessellated Darter (*E. olmstedi*)	BI	--	N
Yellow Perch (*Perca flavescens*)	P	--	N
Shield Darter (*Percina peltata*)	BI	IS	N
Walleye (*Sander vitreus*)	P	IS	NN
Cottidae:			
Slimy Sculpin (*Cottus cognatus*)	BI	IS	N

Abbreviations:

BI	Benthic Insectivore or Invertivore	IS	Intolerant Species
E	Exotic	N	Native
EX	Extirpated (no longer found in NJ)	O	Omnivore
NF	Nonparasitic filterer	P	Piscivore (top carnivore)
PF	Parasitic / Filterer	PL	Planktivore
H	Herbivore	NN	Non Native (introduced)
I	Insectivore	TS	Tolerant Species
G	Generalist		

APPENDIX 2
IBI for Northern New Jersey
(Metrics and Scoring Criteria)

	SCORING CRITERIA		
	5	**3**	**1**
SPECIES RICHNESS AND COMPOSITION:			
1) Total Number of Fish Species	VARIES WITH STREAM SIZE		
2) Number and Identity of benthic insectivorous species	VARIES WITH STREAM SIZE		
3) Number and identity of trout and/or sunfish species	VARIES WITH STREAM SIZE		
4) Number and identity of intolerant species	VARIES WITH STREAM SIZE		
5) Proportion of tolerant individuals	<20%	20-45%	>45%
TROPHIC COMPOSITION:			
6) Proportion of individuals as generalists	<20%	20-45%	>45%
7) Proportion of individuals as insectivorous cyprinids	>45%	20-45%	<20%
8) Proportion of individuals as trout	>10%	3-10%	<3%
OR (whichever gives better score)			
Proportion of individuals as piscivores (excluding American eel)	>5%	1-5%	<1%
FISH ABUNDANCE AND CONDITION:			
9) Number of individuals in the sample	>250	75-250	<75
10) Proportion of individuals with disease and anomalies (excluding blackspot disease)	<2%	2-5%	>5%

Condition Categories (modified from Karr et al. 1986)

45-50 Excellent Comparable to the best situations with minimal human disturbance: all regionally expected species for the habitat and stream size, most intolerant forms are present and there is a balanced trophic structure.

37-44 Good Species richness somewhat below expectation, especially due to the loss of some intolerant species; some species present with less than optimal abundances or size distributions; trophic structure shows some signs of stress (increasing frequency of generalists and tolerant species).

29-36 Fair Signs of additional deterioration include fewer species, loss of most intolerant species, highly skewed trophic structure (high frequency of generalists and tolerant species); older age classes of trout and/or top carnivores may be rare.

10-28 Poor Low species richness, dominated by generalists and tolerant species, few (if any) trout or top carnivores, individuals may show signs of disease/parasites and site may have overall low abundance of fish.

Species to be included in each of the metrics used by the NJDEP:

Benthic Insectivores (Metric 2) – Sturgeon, Cutlips Minnow, Dace, Suckers, Madtoms, Darters and Sculpins **(Not including white sucker or bullheads)**

Trout* and Sunfish (Metric 3, 8) – All species in the families Salmonidae and Centrarchidae **(Not including green sunfish or bluegill)**

Intolerant Species (Metric 4) – American Brook Lamprey, Shortnose Sturgeon, All Trout species, Cutlips Minnow, Northern Hog Sucker, Margined Madtom, Swamp Darter, Shield Darter, Walleye and Slimy Sculpin

Proportion of Tolerant Individuals (Metric 5) – Green Sunfish, Bluegill, White Sucker, Banded Killifish, Mummichog, American Eel

Proportion of Generalist Individuals (Metric 6) – Redbreast Sunfish, Green Sunfish, Banded Killifish, Pumpkinseed, Bluegill, Mummichog, Eastern Mudminnow, Yellow Bullhead, Brown Bullhead, White Sucker, Common Carp, Goldfish

Insectivorous Cyprinids (Metric 7) – All minnows (Family Cyprinidae) in the following genera: *Cyprinella, Exoglossum, Luxilus, Notropis, Rhinichthys* and *Semotilus*

Piscivores (Metric 8) – Largemouth Bass, Smallmouth Bass, Yellow Perch, Walleye, Chain Pickerel, Redfin Pickerel, Northern Pike, Bowfin

- Streams that have been stocked with trout are sampled during July and August. Both stocked and resident trout found during these months are counted in the IBI scoring. The ability of a stream to support trout during these harsh months (high temperature, low dissolved oxygen) is indicative of good water quality and habitat.

Number of Individuals (Metric 9) – (Not including Tolerant Species – Green Sunfish, Bluegill, White Sucker, Banded Killifish, Mummichog, American Eel)

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APPENDIX 3

IBI AND HABITAT SCORING SHEETS/GRAPHS

LABEL

IBI SCORING SHEET

			Excellent	Good	Fair	Poor
Scorer 1						
Date						
Scorer 2			Excellent	Good	Fair	Poor
Date						

	Scorer 1	Scorer 2
# of Fish Species		
# of Benthic Insectivorous Species (BI)		
# of Trout and Centrarchid Species (trout, bass, sunfish, crappie)		
# of Intolerant Species (IS)		
Proportion of Tolerant Individuals		
Proportion of Individuals as Generalists		
Proportion of Individuals as Insectivorous **Cyprinids** (I and BI)		
Proportion of Individuals as Trout OR Proportion of Individuals as Piscivores (Excluding American Eel)*		
Number of Individuals in Sample		
Proportion of Individuals w/disease/anomalies (excluding blackspot)		
Total		

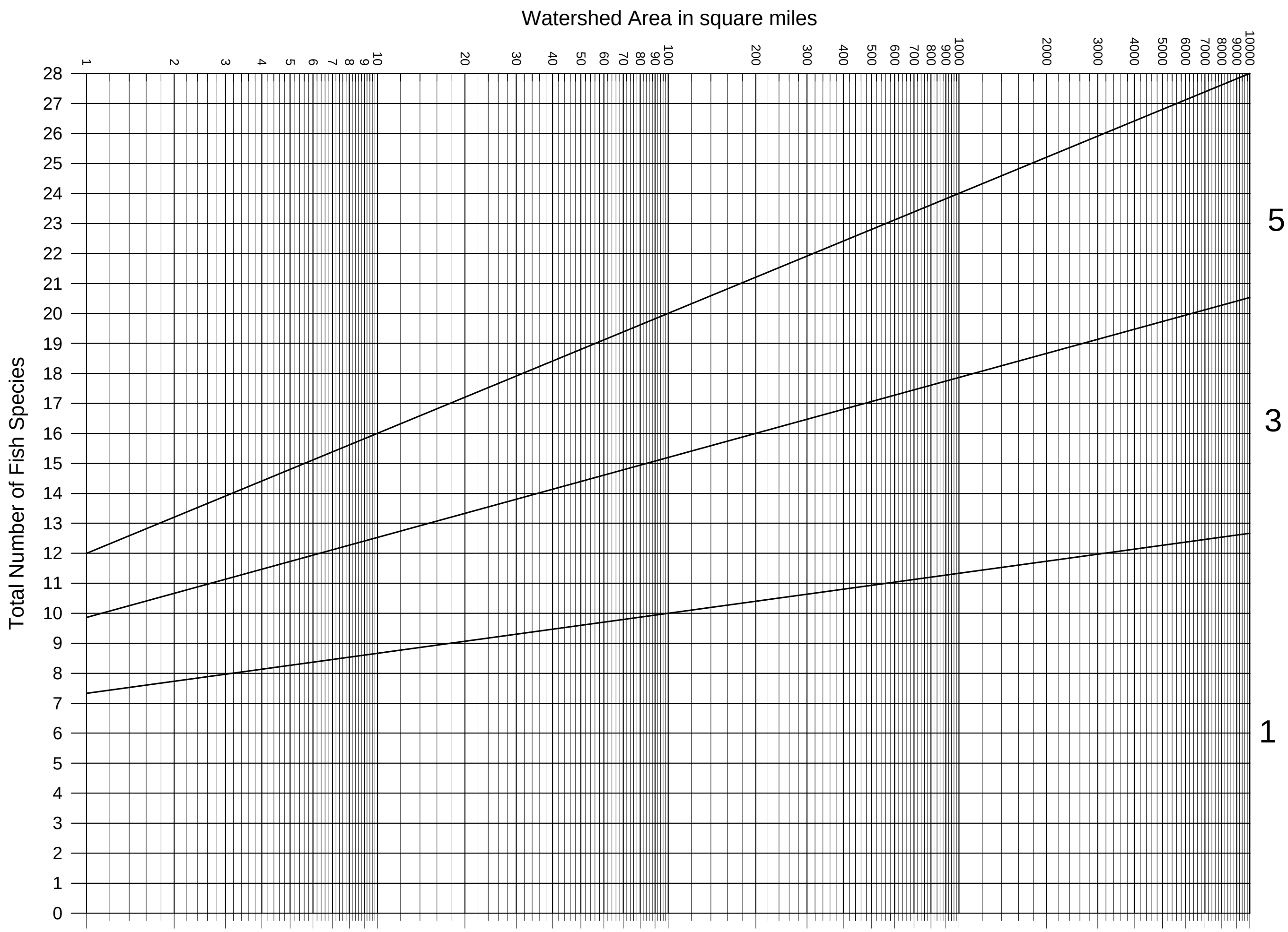
*whichever gives better score

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate /Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regimes	All 4 velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (slow is <0.3 m/s, deep is >0.5 m)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity / depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. In stream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ______ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ______ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Bank Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, under story shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ______ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ______ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ______ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ______ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

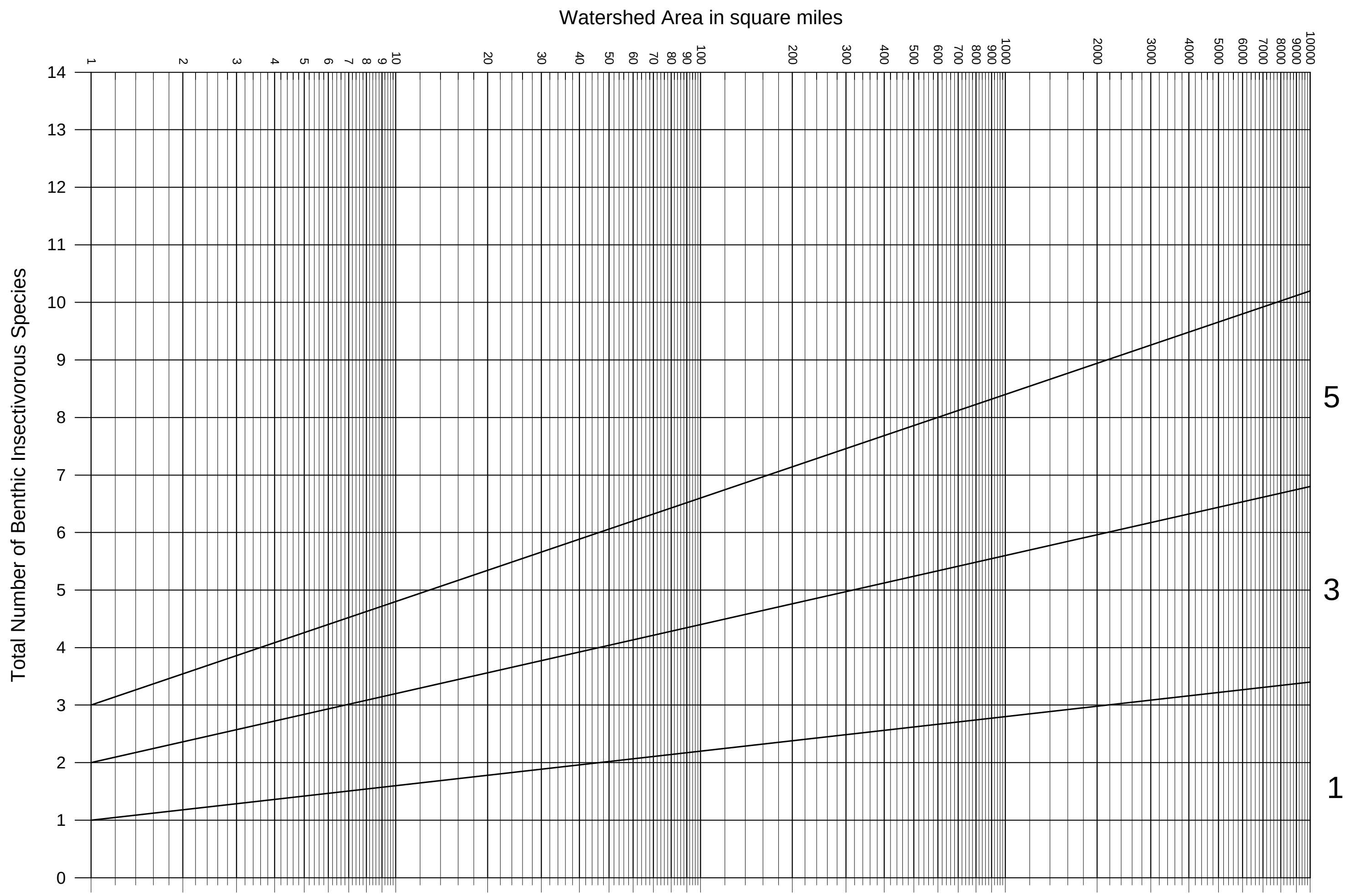
HABITAT SCORE

HABITAT SCORES	VALUE
OPTIMAL	160 X 200
SUB-OPTIMAL	110 X 159
MARGINAL	60 X 109
POOR	< 60

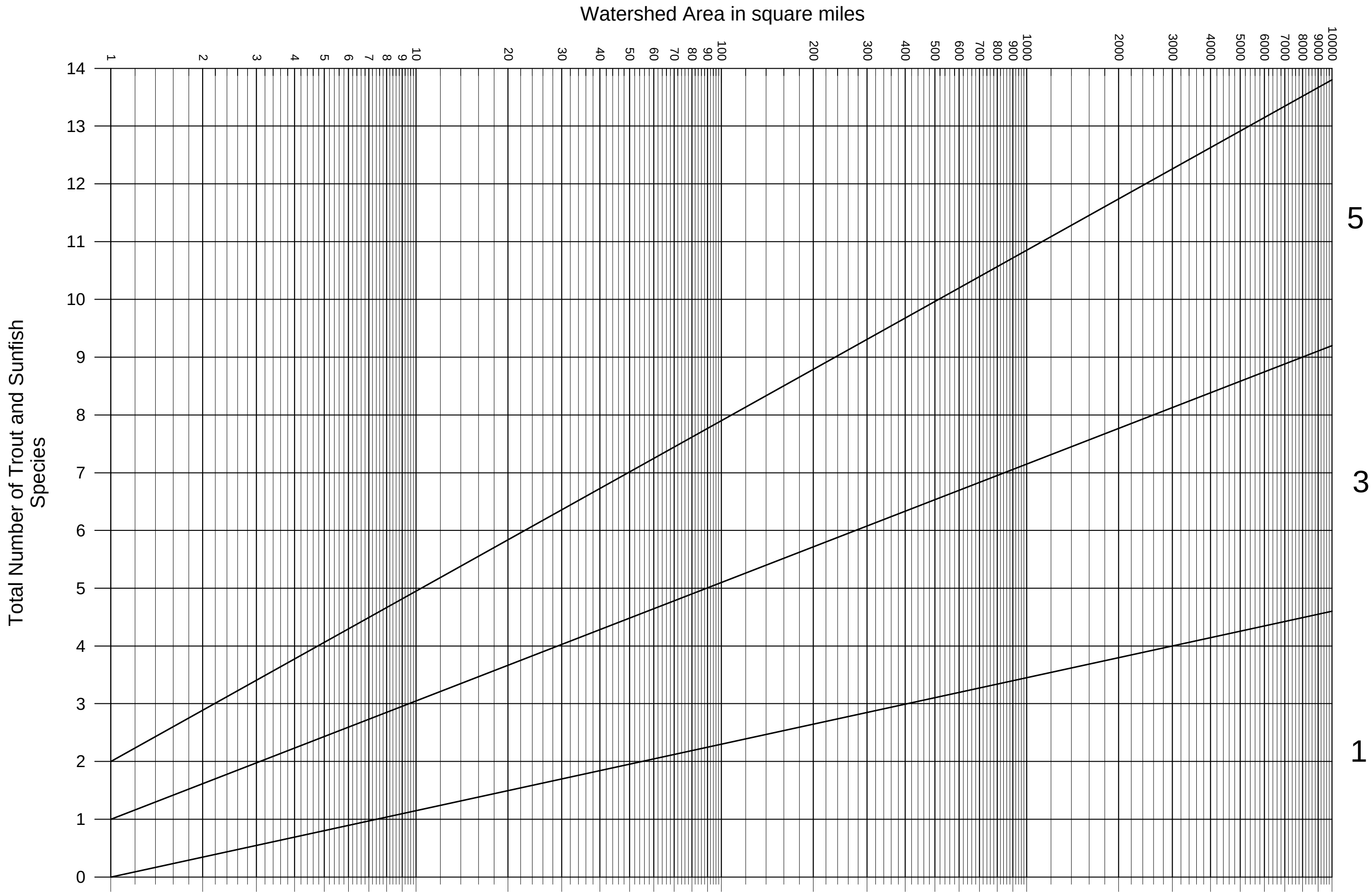
Total number of fish species versus watershed area for New Jersey ecoregion reference sites



Total number of benthic insectivorous fish species versus watershed area for New Jersey ecoregion reference sites



Total number of trout and sunfish species versus watershed area for New Jersey ecoregion reference sites



Total number of intolerant fish species versus watershed area for New Jersey ecoregion reference sites