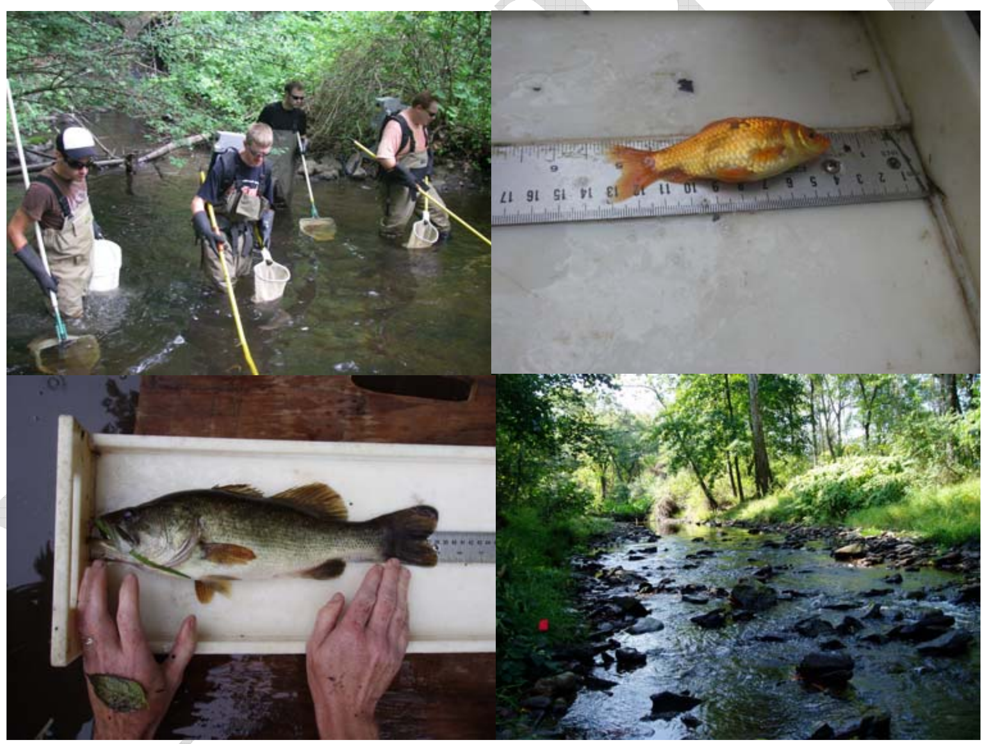
New Jersey Department of Environmental Protection
Water Monitoring and Standards

FISH IBI REPORT
2010 SAMPLING
Round 3, Year 1 of 5

Volume 1 of 2



September 2011

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September 2011

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2010 SAMPLING
Round 3, Year 1 of 5

Volume 1 – Summary

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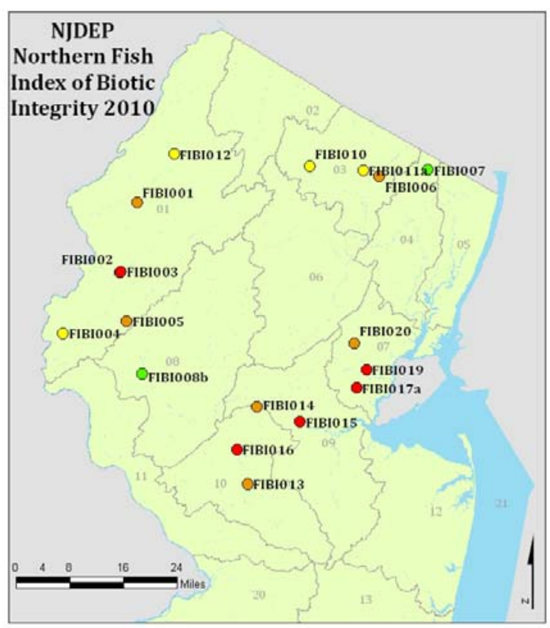
EXECUTIVE SUMMARY

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.



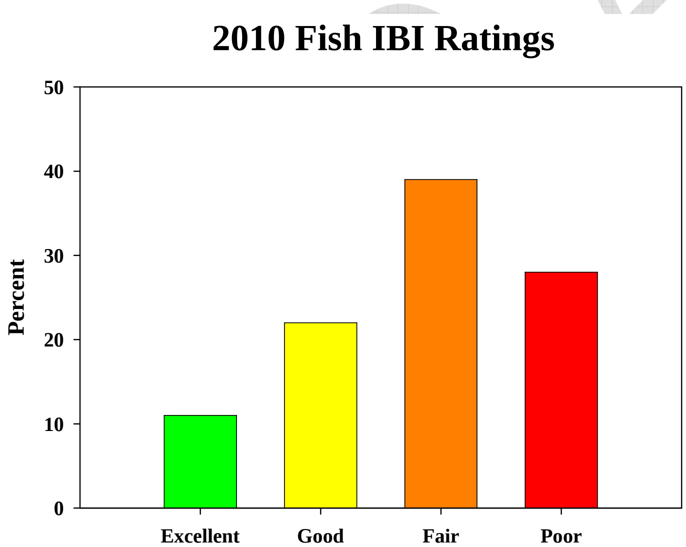
Beginning in 2004, the collected Fish IBI data became a significant part of the intensive, data-driven, Category 1 (C-1) selection process (N.J.A.C. 7:9B). This selection process is used to identify State waterbodies of exceptional ecological significance that would then be entitled to an anti-degradation 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 its usefulness for other programs, 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 programs, when combined 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.

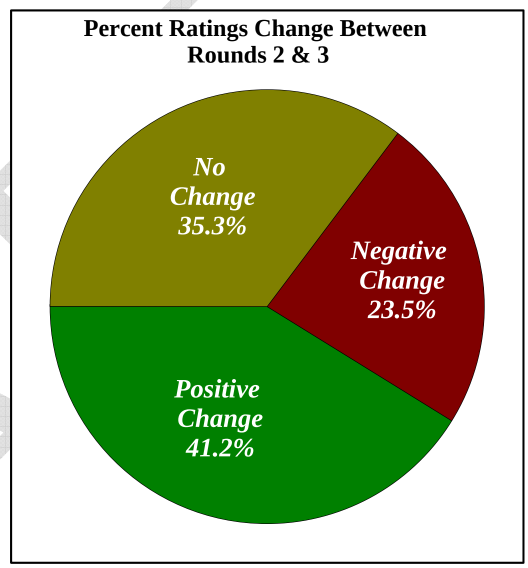
The Fish IBI has also found utility in WM&S's Stressor Identification (SI) program as well, where it has been used to prioritize site selection, help identify the spatial extent of waterbody degradation, and to aid in the location and identification of potential stressors. An unexpected use, that appears 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 3,500 report/data downloads WM&S receives per month since revising the webpage.



The 2010 season marked year one of the third round of sampling, in which the network sites originally sampled in 2000 and 2005 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) and an independent dataset. This recalibration resulted in modifications in scoring criteria and species lists for several metrics (see Table 3, later in this document, 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 2010 season is the sixth year in which the revised metrics were utilized. Round 1 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 third round. In 2010, the eleventh year of sampling, 18 sites were sampled. Two sites were rated "excellent", four were "good", seven were "fair", and five sites were "poor".

A total of six wild brown trout and one stocked rainbow trout were collected from Cakepoulin Creek (FIBI008b), but no young of the year were collected from this FW2-TPC1 stream. Conversely, 145 wild brown trout were collected from Meadow Brook (FIBI011a) and as a result this FW2-NTC1 stream was rated "good" (44). Of the trout collected, most were juvenile and young-of-the-year fish. The sampling location is just upstream of the trout production section of Meadow Brook and as a result, this stream should be re-evaluated to determine the extent of natural trout reproduction and the surface water quality standards should be adjusted accordingly.

Overall, biotic integrity increased between Rounds 2 and 3. In Round 2, 81% of sites were rated "fair" or "poor", compared to 69% in Round 3. In addition, the number of "good" sites increased from 13% to 25% between Rounds 2 and 3. Also, 41% of the sites exhibited a positive rating increase, while the ratings for 35% of sites remained unchanged. Three sites (Saddle River FIBI007, Clinton Brook FIBI010, and Rahway River FIBI020) exhibited increases in biological integrity, while scores from the Pequest River FIBI003 decreased significantly from 2005 to 2010 (for further information see Trends Analysis section).



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 New Jersey Department of Environmental Protection 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 used to

[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.

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. The Department has developed an assessment methodology that uses the results from the Fish IBI. The results of these decisions were 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 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.

The Fish IBI has also found utility in WM&S'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 3,500 report/data downloads WM&S receives per month since revising the webpage in 2009.

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).

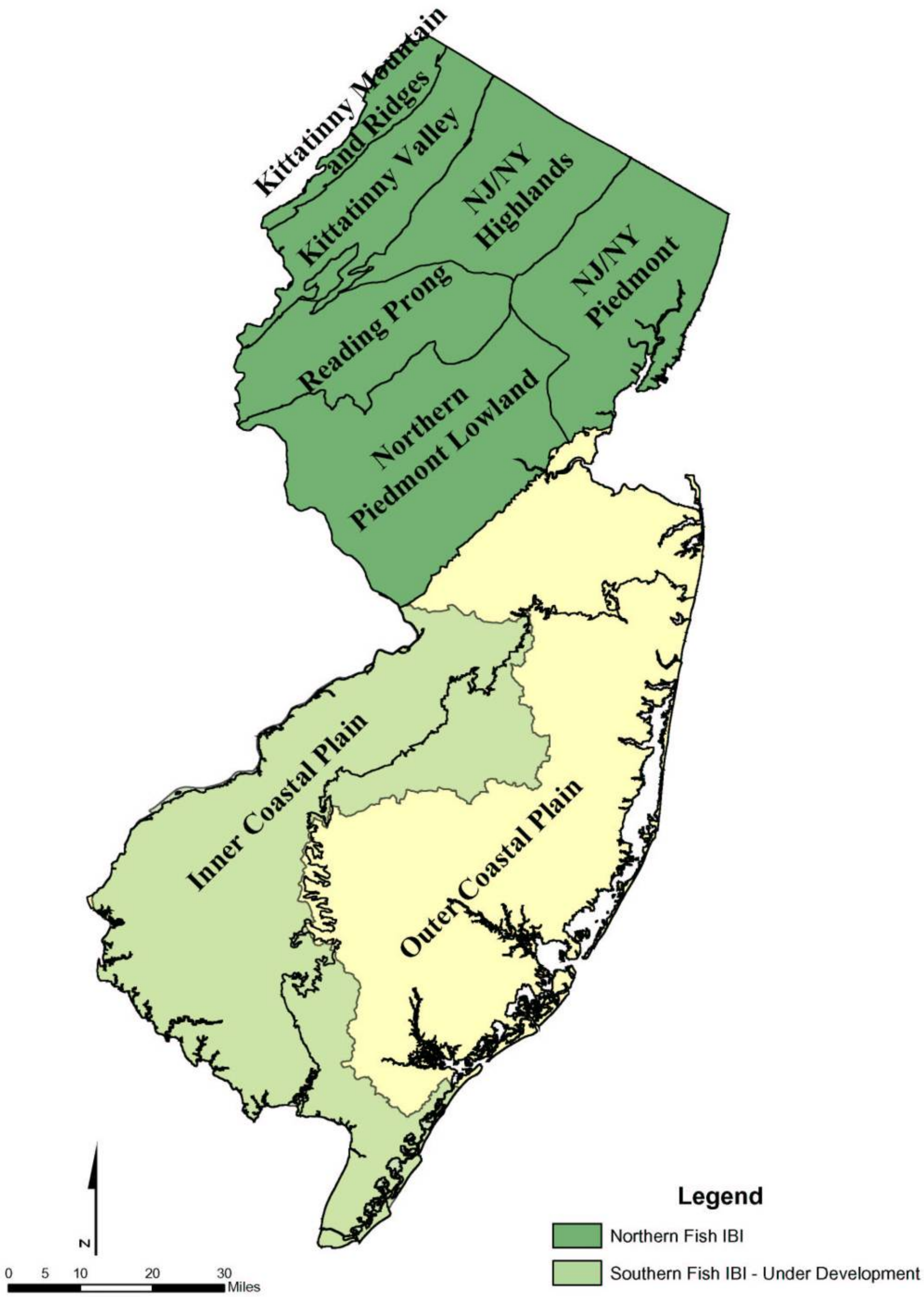


Figure 1. Map of New Jersey Ecoregions and region of Fish IBI applicability.

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 for confirmation (at present, Philadelphia Academy of Natural Sciences).

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) and an independent dataset. 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' Bureau of Freshwater and Biological Monitoring 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 which has poor biological integrity, with 10 being the lowest score a site can receive. Further descriptions of all of the metrics used in the IBI calculations are presented below:

Species Richness and Composition

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

[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).

as part of WM&S' Bureau of Freshwater and Biological Monitoring's Fish IBI refinement. The area under the MSR line is trisected by 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. Hatchery brook trout with multiple deformities.

RESULTS

In 2010, the first year of Round 3 sampling, 18 sites were sampled. Two sites were rated "excellent", four were "good", seven were "fair" and five were "poor" (Figure 4). The habitat ratings for the 2010 sites consisted of one site with "optimal" habitat, twelve with "sub-optimal" habitat, and five with "marginal" habitat.

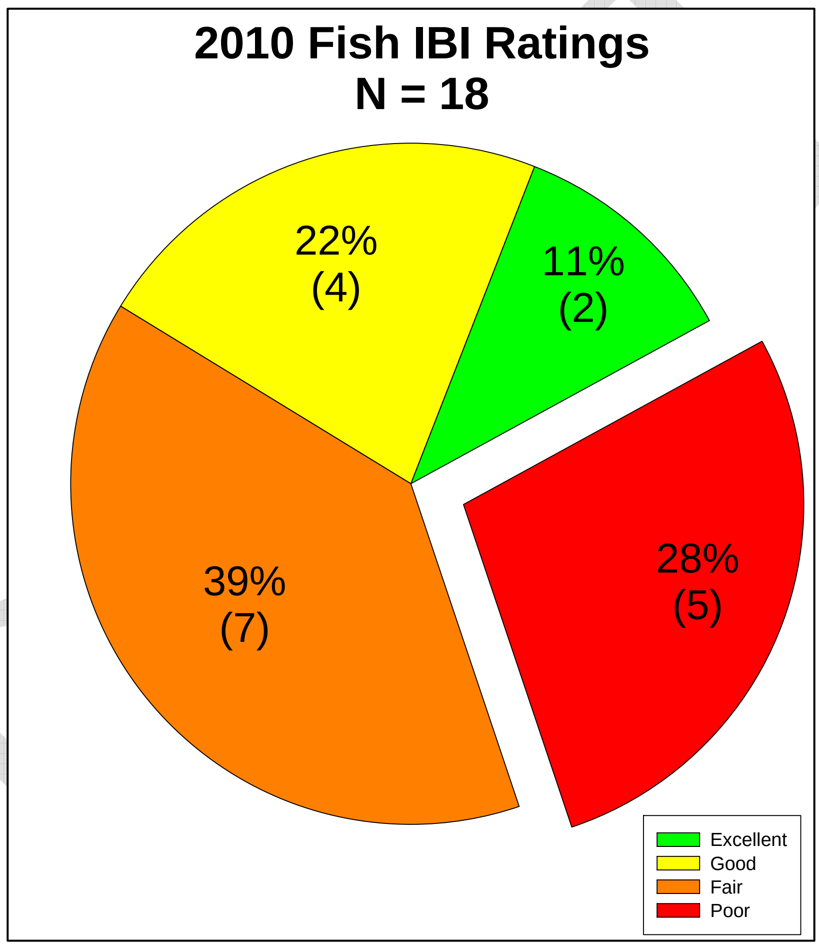


Figure 4. Summary of the 2010 ratings for 18 sites in northern New Jersey.

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 five (5) impaired sites were identified (FIBI003, FIBI015, FIBI016, FIBI017a, and FIBI019) (Figure 5; Table 7). These sites on Mile Run (FIBI015), Pike Run (FIBI016), South Branch of Rahway River (FIBI017a), and Rahway River (FIBI019) were identified as having water quality impairments, likely a result of anthropogenic stressors. In addition, seven (7) sites were classified as "fair" and are suspected of having impacts.

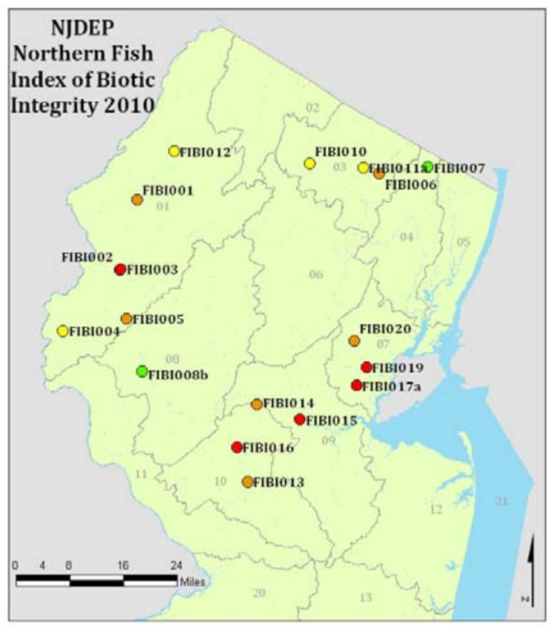


Figure 5. Location of 2010 Fish IBI sites.

Those sites classified as "impaired" and "potentially impaired" all had "sub-optimal" or "marginal" habitat ratings and many have a high impervious cover 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 2010 Round 3 Fish IBI sampling[1].

FIBI Site	Waterbody	County	Habitat Rating	IBI Score	IBI Rating
FIBI001	Paulins Kill	Warren	Sub-Optimal	34	Fair
FIBI002	Furnace Brook	Warren	Sub-Optimal	34	Fair
FIBI003	Pequest River	Warren	Sub-Optimal	24	Poor
FIBI004	Lopatcong Creek	Warren	Sub-Optimal	42	Good
FIBI005	Musconetcong River	Hunterdon/Warren	Sub-Optimal	36	Fair
FIBI006	Ramapo River	Bergen	Sub-Optimal	30	Fair
FIBI007	Saddle River	Bergen	Sub-Optimal	46	Excellent
FIBI008b	Cakepoulin Creek	Hunterdon	Optimal	46	Excellent
FIBI010	Clinton Brook	Passaic	Sub-Optimal	42	Good
FIBI011a	Meadow Brook	Passaic	Sub-Optimal	44	Good
FIBI012	Neldon Brook	Sussex	Sub-Optimal	42	Good
FIBI013	Heathcote Brook	Middlesex	Sub-Optimal	36	Fair
FIBI014	Royce Brook	Somerset	Marginal	32	Fair
FIBI015	Mile Run	Middlesex	Marginal	28	Poor
FIBI016	Pike Run	Somerset	Sub-Optimal	26	Poor
FIBI017a	SB Rahway River	Middlesex	Marginal	26	Poor
FIBI019	Rahway River	Union	Marginal	24	Poor
FIBI020	Rahway River	Union	Marginal	32	Fair

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

Potentially Impaired Sites

Paulins Kill - FIBI001

The habitat was rated "sub-optimal" (149) despite ample fish habitat in the form of large woody debris, boulders, and crevices in bedrock. This section was relatively flat with few riffles and the water levels appeared low, despite a similar discharge to previous rounds of sampling.

Overall, the fish community exhibited a shift in trophic structure with a high proportional abundance of generalist feeders (44%) and very low proportional abundance of specialized insectivorous cyprinids (6.5%). In addition, 5 of the 6 tolerant species for New Jersey were collected at this site including green sunfish, bluegill, white sucker, banded killifish, and American eel. Also, an abnormally high percentage of Centrarchids had external deformities in the form of lesions and fin erosion. All sunfish species, except green sunfish had external anomalies.

A total of ninety-eight western mosquitofish representing almost 19% of the total catch were collected in the sample reach. This species has not previously been collected at the site and were likely stocked in the river or nearby site as a form of mosquito control. This species not only consumes mosquitoes, but other aquatic and terrestrial insects as well, thus taking food away from native fish species. It is difficult to determine if the large decline in insectivorous cyprinids from 33% in Round 2 to just 6.5% in Round 3 or the poor condition of many sunfish species is a direct result of the introduction of mosquitofish, but anytime a nonnative fish species is introduced into a system a potential imbalance is created.

Furnace Brook - FIBI002

Despite an abundance of fish habitat, the fish community scored "fair" (34), an indication that habitat is not limiting fish community health, but perhaps water chemistry maybe impacting the stream. Overall, the fish community was rich (N=15), but not abundant (N=224) or diverse (H′=2.19). No intolerant fish species were collected, despite being trout stocked and located less than a quarter mile from the confluence of the Trout Maintenance section of the Pequest River.

Ambient biological monitoring station (AMNET) AN042 is located less than half a mile upstream of the Fish IBI station and has received "fair" and "poor" ratings in recent sampling rounds. In addition, results from Round 4 indicate no sensitive EPT taxa were collected at this upstream location.

Musconetcong River - FIBI005

The fish community was rated "fair" (36) with very few species collected (N=9) and low overall diversity (H′=1.51). Most of the fish collected (67%) were American eel and blacknose dace. Just one brook trout and one smallmouth bass were collected representing the only top predatory fish in this section. In addition, the smallmouth bass represented the only centrarchid species collected.

Ramapo River - FIBI006

The Ramapo River was rated "fair" (30) as a result of a lack of benthic and sensitive species and poor proportional abundance of insectivorous cyprinids. Just two benthic and one intolerant species were collected. Specialized insect feeding minnows represented less than 10% of the total catch, all an indication of impairments to the benthic fish and potentially the macroinvertebrate community.

Ambient biological monitoring station AN0267 is co-located with the Fish IBI station, scored “fair” in each of the four rounds of sampling.

Heathcote Brook - FIBI013

The biotic integrity of Heathcote Brook has steadily increased from “fair” (30) in 2000 to “fair” (36) in 2011. The only significant deviation from reference conditions was a lack of intolerant species. In Addition, this is the first sampling event in three rounds in which nonnative green sunfish were not collected.

Royce Brook - FIBI014

The habitat was rated “marginal” with numerous concrete slabs and debris throughout the stretch and little riparian buffer (Figure 6). As a result, most of the sediment was covered in a fine silt layer, numerous sediment bars were present, and little natural fish habitat exists.

Figure 6. Concrete slabs lining the banks of Royce Brook.

As a result of the numerous habitat impairments, the fish community was rated “fair” (32). Although the community exhibits some sign of degradation, there were positive attributes compared to previous sampling rounds. The 2010 sunfish community was dominated by native redbreast sunfish unlike Round 2 sampling which was dominated by nonnative green sunfish. The trophic structure improved slightly from Round 2, with several top predatory fish species collected, including smallmouth bass and chain pickerel.

Rahway River - FIBI020

The biological integrity for Rahway River (FIBI020) increased to “fair” (32) after “poor” ratings in each of the previous two rounds. Despite the increase, the fish community lacked intolerant species and few insectivorous cyprinids were collected, as these specialized insect feeding minnows accounted for just 12% of the total catch.

The habitat was rated “marginal” (103) with numerous signs of a stressed aquatic community, including a lack of stable substrate/cover, high embeddedness, moderate deposition of fine sediments, and unstable banks (Figure 7). Water chemistry indicated a relatively low dissolved oxygen concentration (5.37 mg/L; 63.4% saturation) and high conductivity (723 μmhos/cm). The substrate was estimated to consist of 50% fine sediments, which fills spaces between gravel and cobble and can impact macroinvertebrate communities and specialized insect feeding fish.

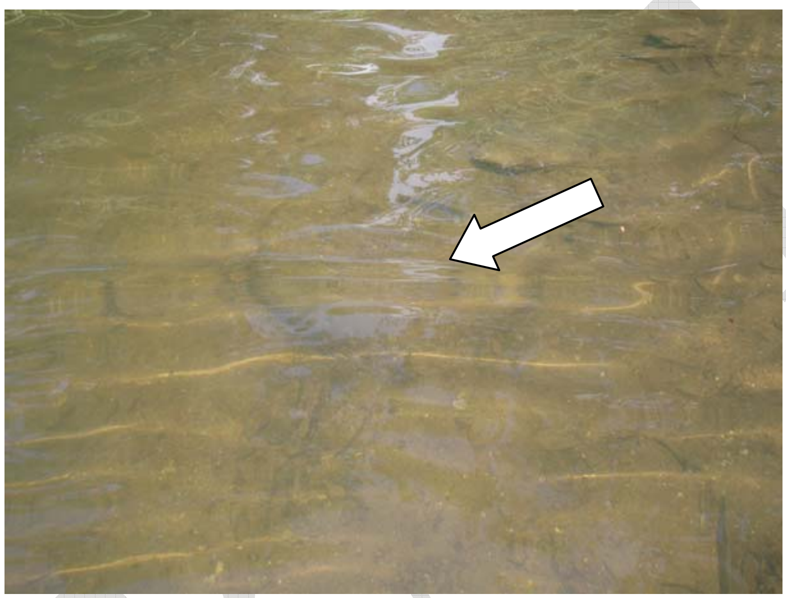


Figure 7. Embedded substrate in the Rahway River.

Impaired Sites

Pequest River - FIBI003

The Pequest River was rated "poor" (24) due to the loss of trophic structure and a high proportional abundance of tolerant species. The food web is out of balance and very simplistic, as specialized feeders such as insectivorous cyprinids and piscivores only represented 2% and 0.8% respectively, while generalist feeders made-up 57% of the sample. In addition, eighty-one percent of the sample was comprised of tolerant fish species, a percentage typically observed in very urban stressed systems. The proportional abundance of generalists has steadily increased from 37% in Round 1, to 49% in Round 2, to 57% in this third round. The collection of top predators, such as trout has historically been low, as only in Round 1 has the proportional abundance of trout been greater than 1 percent. Although this section is heavily stocked with trout and is designated Trout Maintenance, just eleven total stocked trout have been collected in three year of sampling.

Mile Run - FIBI015

The instream habitat, surrounding land use/land cover, and fish community are all indicative of an impaired system. The habitat was rated "marginal" (102) with numerous signs of degradation including severely eroded stream banks, inadequate fish habitat, numerous storm water and residential outfalls, poor flow regime, a lack of riparian buffer and bank vegetation, and excessive debris and garbage (Figure 8). These habitat impairments are typical of an urban stream with little buffering capacity, as the land use/land cover of the watershed upstream of Mile Run is over 43% impervious cover. As a result, few fish species were collected and over half of the fish collected are able to survive in stressed environments. One sensitive species was collected; a stray stocked brown trout which likely migrated upstream from the D&R Canal or the Raritan River. A total of just five Centrarchids were collected and most were nonnative green sunfish. Despite the numerous impairments, the specimens collected appeared healthy and exhibited few external deformities.

Figure 8. Garbage and debris from Mile Run.

Pike Run - FIBI016

The fish community at Pike Run was rated "poor" (26) after sampling in early August. Several attempts were made to sample this stretch in both June and July, but excessive turbidity caused sampling crews to postpone sampling until condition improved. Some in situ water chemistry parameters exhibited substantial changes from previous years' sampling events. Conductivity has progressively increased from 285 µmhos/cm in Round 1 to 533 in Round 2 to 749 in this last round of sampling. In 2000, the stream pH was 7.6 and has subsequently increased each successive round to 8.84 in 2010. A possible cause of the changes in water chemistry and excessive turbidity include the Pike Brook Waste Water Treatment Plant, located just 3 tenths of a mile upstream of the sample reach and run-off from a new housing development just upstream.

Although Pike Run has received "poor" fish IBI ratings in all three rounds of sampling, the 2010 fish community is indicative of a declining fish community. Changes in water chemistry may not only be a cause of the impairment rating, but may prevent recovery. While conducting reconnaissance in mid April 2010, a residential pool was being discharged into the stream just above the Fish IBI station. Foamy water with a chlorinated smell was being pumped directly into the stream (Figure 9). Central enforcement was contacted, but it was unclear if the pool water was indeed chlorinated. Although no fish kill was observed, chlorine has detrimental effects on fish even at very low concentrations.

Figure 9. Pool water discharging into Pike Run.

Overall, the community was dominated by just a few tolerant species and as a result, species diversity was low (H′=1.35) and the trophic structure was in disarray, with generalists comprising most of the food web. Tolerant fish species represented over 70% of the fish collected and few age classes of fish were collected, as most specimens were juveniles with very few adults collected. This community structure is common after a fish kill.

SB Rahway River - FIBI017a
The habitat for the South Branch Rahway River was rated “marginal” (91) with numerous impacts to the substrate, flow regime, bank stability, and riparian buffer. In addition, the conductivity was relatively high (751 µmhos/cm) which made electrofishing difficult, as the electrofishers frequently overloaded. Numerous point and channel bars were found throughout the stretch, an indication of frequently shifting substrates. Most of the substrate was heavily embedded with fine sediments and littered with debris. A large deep pool approximately 50-m upstream of the start contained grayish water with a strong smell of decomposition.

The fish community was typical of an urban stream which has been impacted as a result of 37% impervious cover. Species richness of several metrics was very low and no top predatory fish were collected. The condition of fish in this stretch was poor, as a number of white suckers had lesions and a number of pumpkinseed and bluegill sunfish had eroded fins.

Ambient Biological Monitoring Station AN0201, located just downstream of the IBI station received “poor” ratings in 3 of 4 rounds of sampling.

Rahway River - FIBI019
The habitat was rated “marginal” (109) with noted impacts from sediment deposition, channelization, severe bank erosion, poor flow regime, and no riparian buffer along left descending bank. Several storm water outfalls which drain Church Street and River Road were noted throughout the stretch. The left descending bank was severely sloughing into the stream due to the flashy nature of the stream from extensive surrounding impervious cover, severe bank erosion, and a lack of buffering capacity in this region (Figure 10).

Figure 10. Severe bank erosion along Rahway River.

Only ten species were collected from this stretch of the Rahway River, which included 5 of the 6 tolerant fish species in New Jersey. These tolerant species accounted for over 72% of the total catch resulting in poor species diversity (H' =1.31) and biotic integrity (24). Several hybrid sunfish were collected all of which were a result of nonnative green sunfish spawning with native sunfish species.

Ambient Biological Monitoring station AN0195 received "poor" ratings in 3 of 4 rounds of sampling. In addition, the macroinvertebrate community was dominated by tolerant Tubificid worms in 2 of these rounds.

Other Important Findings

Cakepoulin Creek - FIBI008b

Despite scoring "excellent" (46) and having "optimal" (165) habitat, we were unable to document natural trout reproduction from this FW2-TPC1 stream. Several adult trout were collected, including a hatchery raised rainbow trout and six wild brown trout, but no young-of-the-year.

Meadow Brook - FIBI011a

Despite the high impervious cover in the surrounding watershed and numerous signs of habitat and water quality impairments, 145 wild brown trout were collected from this FW2-NTC1 stream and as a result, the site was rated "good" (44). Of these, most were juvenile and young-of-the-year fish (Figure 11). The sampling location is just upstream of the trout production section of Meadow Brook and therefore, this stream should be re-evaluated to determine the extent of natural trout reproduction and the surface water quality standards should be adjusted accordingly.

Figure 11. Young-of-the-year brown trout collected at Meadow Brook.

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 Rounds 2 and 3 data indicates a positive linear relationship between Fish IBI and habitat scores (Figure 12). 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 Rounds 2 and 3 Fish IBI score (Figure 13). 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.”

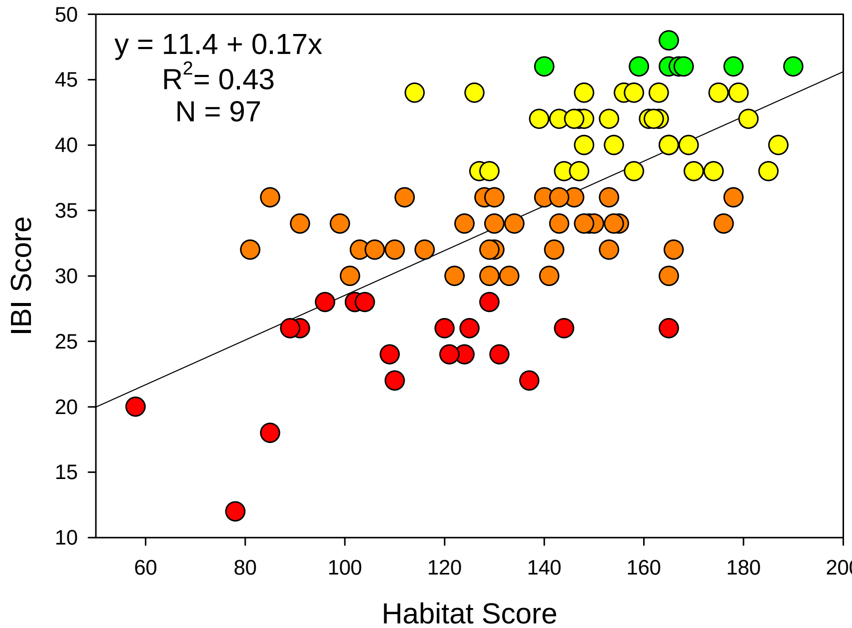


Figure 12. Linear regression comparing IBI and habitat scores.

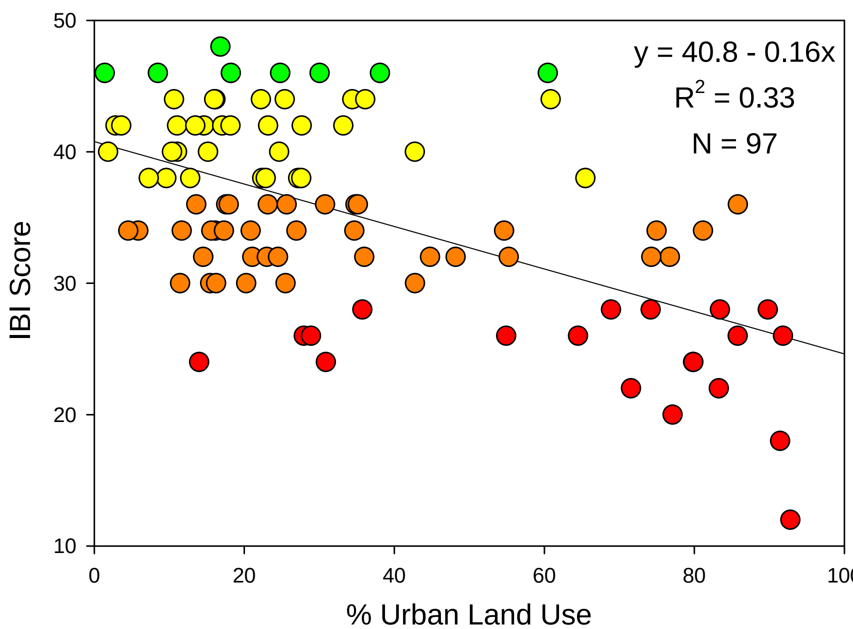


Figure 13. Linear regression comparing urban land use and IBI score.

TRENDS ANALYSIS

The completion of the 2010 sampling season marks the first year of the third round of Fish IBI sampling. The sites sampled in 2010 were originally sampled in 2000 and 2005. Those sites sampled in 2000 were re-scored using the re-calibrated metrics in order to compare results over time (Table 8).

Table 8. Comparison of Rounds 1, 2, and 3 results using newly calibrated metrics.

		Round 1 Results*		Round 2 Results		Round 3 Results	
FIBI Site	Waterbody	IBI Score	IBI Rating	IBI Score	IBI Rating	IBI Score	IBI Rating
FIBI001	Paulins Kill	28	Poor	34	Fair	34	Fair
FIBI002	Furnace Brook	34	Fair	36	Fair	34	Fair
FIBI003	Pequest River	32	Fair	30	Fair	24	Poor
FIBI004	Lopatcong Creek	38	Good	34	Fair	42	Good
FIBI005	Musconetcong R.	34	Fair	42	Good	36	Fair
FIBI006	Ramapo River	32	Fair	28	Poor	30	Fair
FIBI007	Saddle River	36	Fair	40	Good	46	Excellent
FIBI008b	Cakepoulin Creek	N/A	N/A	N/A	N/A	46	Excellent
FIBI010	Clinton Brook	34	Fair	32	Fair	42	Good
FIBI011a	Meadow Brook	46	Excellent	36	Fair	44	Good
FIBI012	Neldon Brook	46	Excellent	46	Excellent	42	Good
FIBI013	Heathcote Brook	30	Fair	32	Fair	36	Fair
FIBI014	Royce Brook	30	Fair	26	Poor	32	Fair
FIBI015	Mile Run	24	Poor	36	Fair	28	Poor
FIBI016	Pike Run	28	Poor	28	Poor	26	Poor
FIBI017a	SB Rahway River	N/A	N/A	24	Poor	26	Poor
FIBI019	Rahway River	20	Poor	28	Poor	24	Poor
FIBI020	Rahway River	22	Poor	26	Poor	32	Fair

***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.

The proportion of sites rated as “excellent”, “good”, “fair”, and “poor” was similar between rounds 1, 2, and 3 (Figure 14). Overall, mean scores between rounds increased slightly each successive round from 32 in the year to 34.5 in this last round of sampling.

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 a change in rating as a result of a large scoring change are considered significant. Significant scoring/rating changes occurred at several sites including the following: Pequest River (003), Saddle River (007), Clinton Brook (010), and Rahway River (020) (Figure 15). Three of these changes were positive changes and one indicated degradation in biological integrity. The following is a description of trends at these individual sites over time.

Pequest River – FIBI003

Scores have steadily decreased from 32 “fair” in Round 1 to the most recent score of 24 “poor” in Round 3. Overall, species richness metrics have remained relatively constant among rounds with slight decreases in 2010. Proportional abundance of generalist feeders have increased each survey year from 37% in 2000 to 58% in Round 3, mainly a result of changes in the white sucker population. White sucker proportion has steadily increased from almost 27% in Round 1 to 31% in Round 2 to 54% in Round 3. Specialized feeders such as insectivorous cyprinids and trout have consistently been low throughout all sapling rounds, despite ample trout stocking in this FW2-TMC1 waterbody.

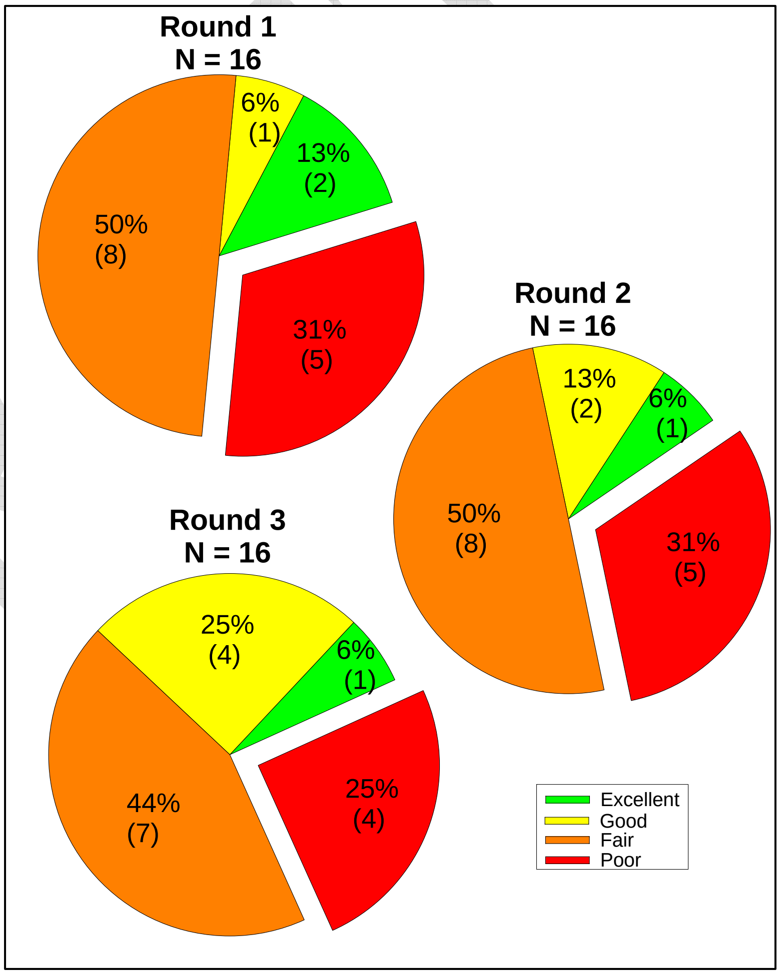


Figure 14. Ratings comparison for Rounds 1, 2, and 3.

Saddle River – FIBI007

Despite the high impervious cover in the watershed surrounding the Fish IBI station on Saddle River, the biotic integrity has steadily increased each sampling year from 36 “fair” in Round 1, 40 “good” in Round 2, and finally 46 “excellent” in this last round of sampling. In 2000, just nine wild brown trout were collected compared to 80 in 2005 and 85 in 2010. The only negative impact over time is the loss of redbreast sunfish, a native sunfish species which appears to have been replaced by nonnative bluegill and green sunfish. Although this stretched is stocked with trout, just three hatchery raised trout have been collected in the last two rounds of sampling.

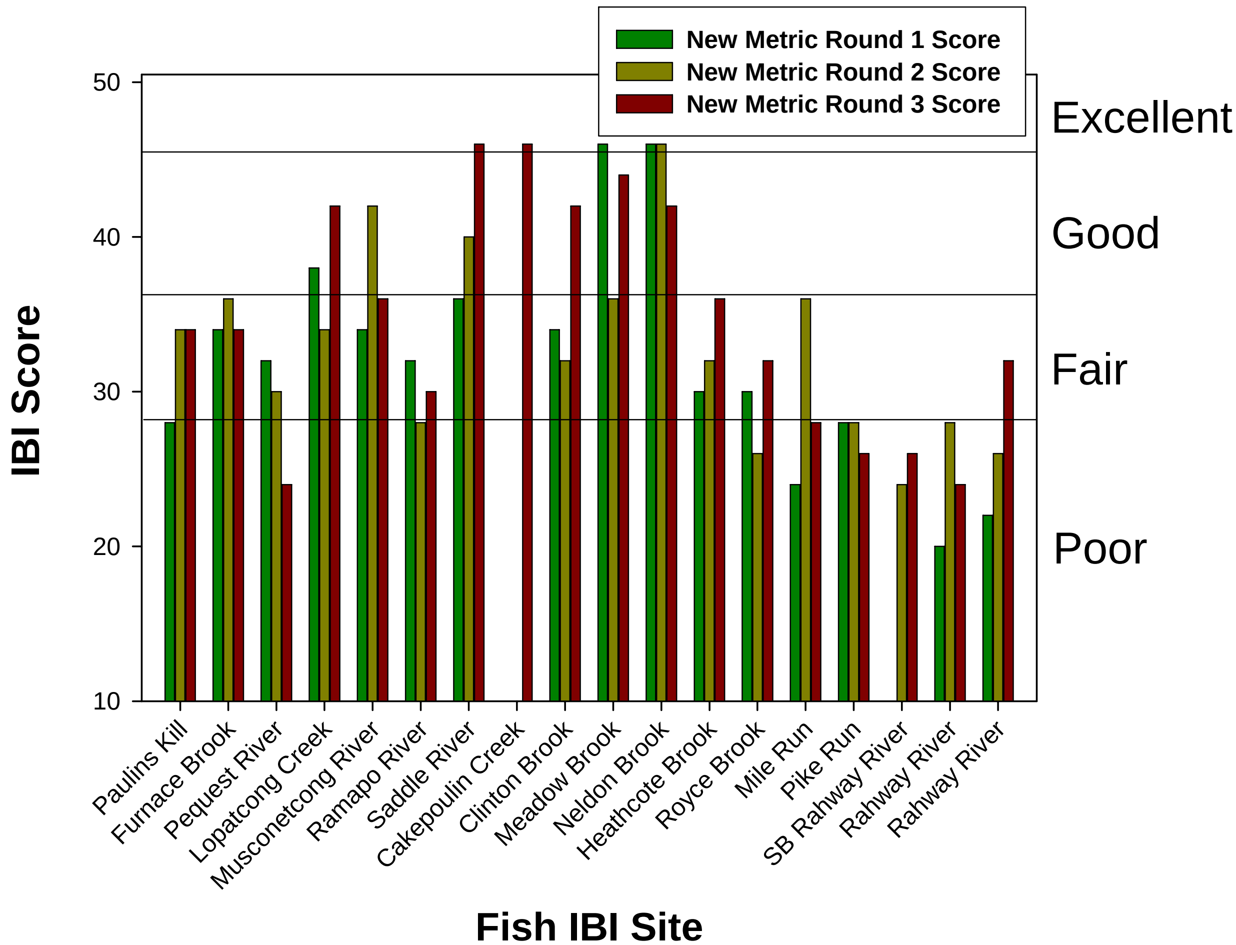


Figure 15. Comparison of ratings for Rounds 1, 2, and 3 at individual sites.

<u>Clinton Brook – FIBI010</u>

The biotic integrity was “fair” in Rounds 1 and 2, but increased in Round 3 to “good” (42), mainly as a result of a large increase in insectivorous cyprinids which increased in proportional abundance from 1.5% in Round 1 to 63% in Round 3. In addition, overall fish abundance was 135 and 120 in Rounds 1 and 2 respectively, but increased to 1,190 in Round 3. The reason for the large increase in abundance in unclear, but flow from Clinton Reservoir was cut in August 2010, which led to lower flows than previous sampling years. Also, conductivity was extremely low in 2005 (48 µmhos/cm) making electrofishing difficult, whereas the conductivity was higher in 2010 (121 µmhos/cm) and electrofishing was far more effective. Overall species richness increased each round of sampling from just 11 in round 1 to 16 fish species in Round 3. The only negative attribute to the current fish community is a lack of intolerant fish species. In 2000, 2 intolerant species were collected, 1 brown and 1 brook trout. These were most likely hatchery raised fish originating from Clinton Reservoir, which is annually stocked with trout each spring.

Rahway River – FIBI020
Since 2000, the biotic integrity, species richness, and overall fish abundance has increased. This site was rated "poor" in both Rounds 1 (22) and 2 (26), but recently received a "fair" rating (32). The number of fish species increased from 12 in Round 1, to 15 in Round 2, and 18 species were recently collected in this latest round of sampling. Despite an increase in species richness, the species diversity decreased in 2010 (H′=1.6). Overall the fish community in 2010 was healthier and was not dominated by tolerant fish species as in previous years.

FURTHER INFORMATION

The current report summarizes the tenth 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 Bureau's monitoring efforts.

Reports and data for the first nine 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

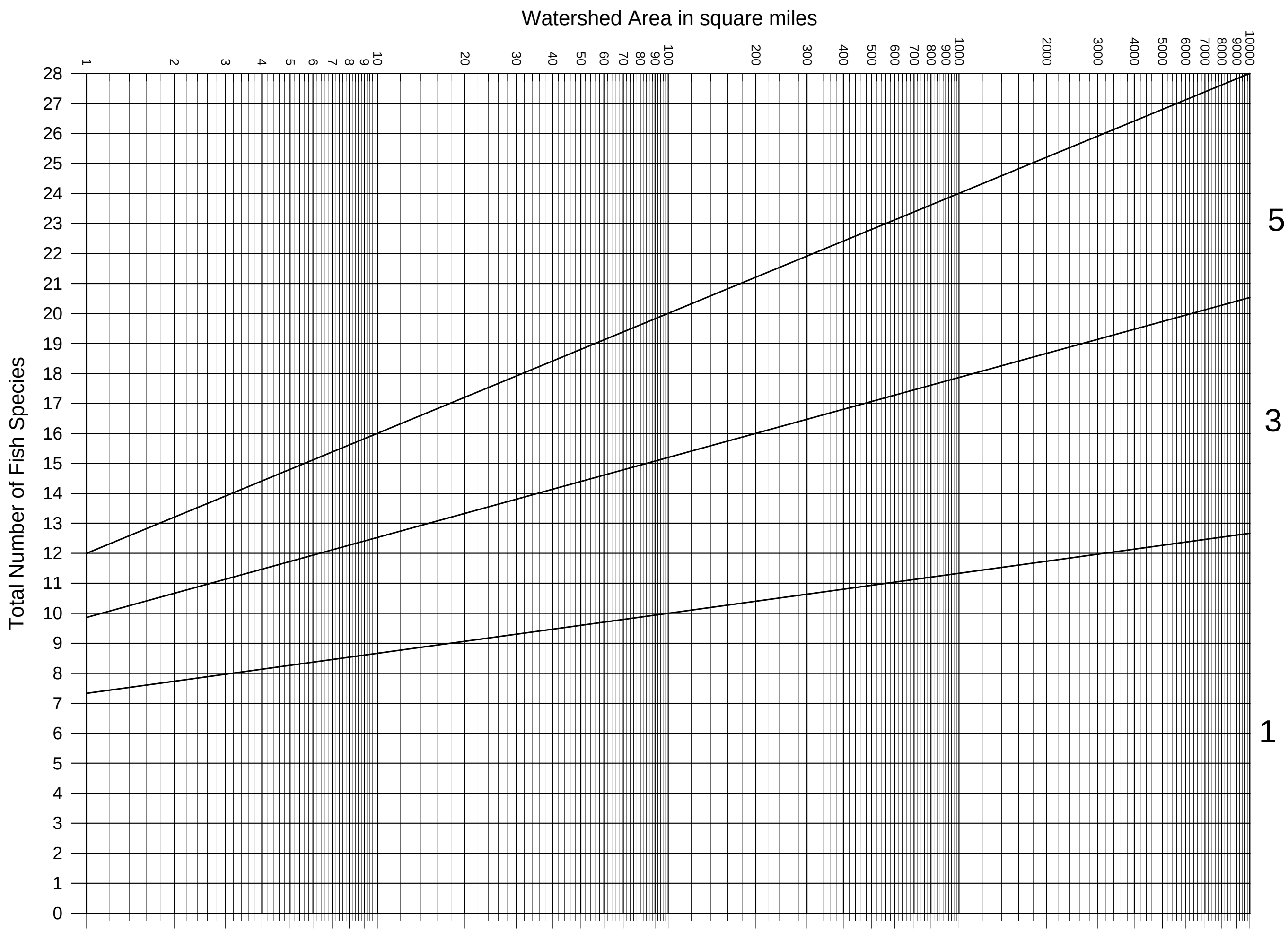
LABEL		IBI SCORING SHEET			
Scorer 1		Excellent	Good	Fair	Poor
Date					
Scorer 2		Excellent	Good	Fair	Poor
Date					
				Scorer 1	Scorer 2
# of Fish Species					
# of Benthic Insectivorous Species (BI)					
# of Trout and Centrarchid Species (trout, bass, sunfish, crappie)					
# of Intolerant Species (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)*			*whichever gives better score		
Number of Individuals in Sample					
Proportion of Individuals w/disease/anomalies (excluding blackspot)					
Total					

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

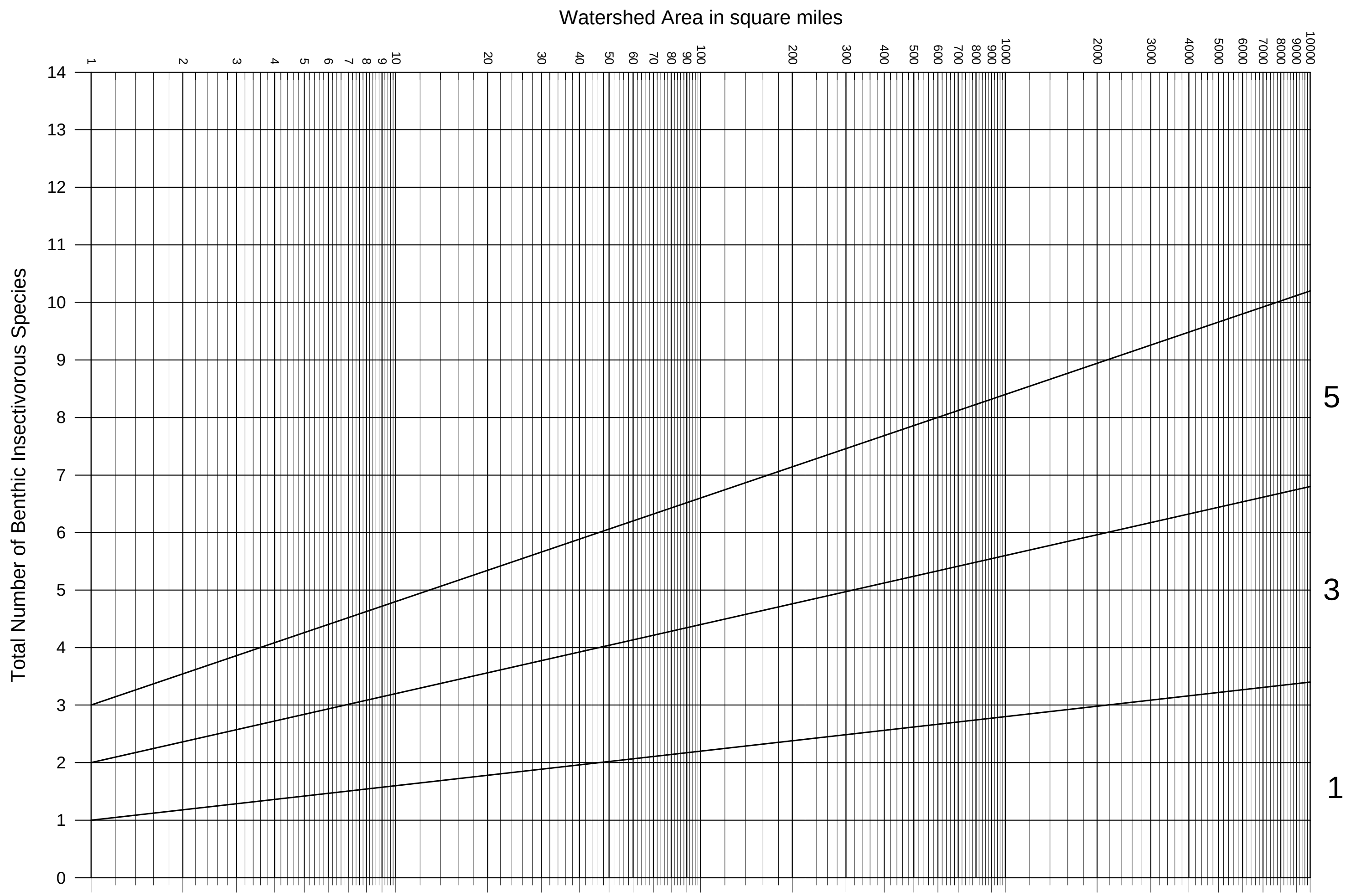
HABITAT SCORE

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

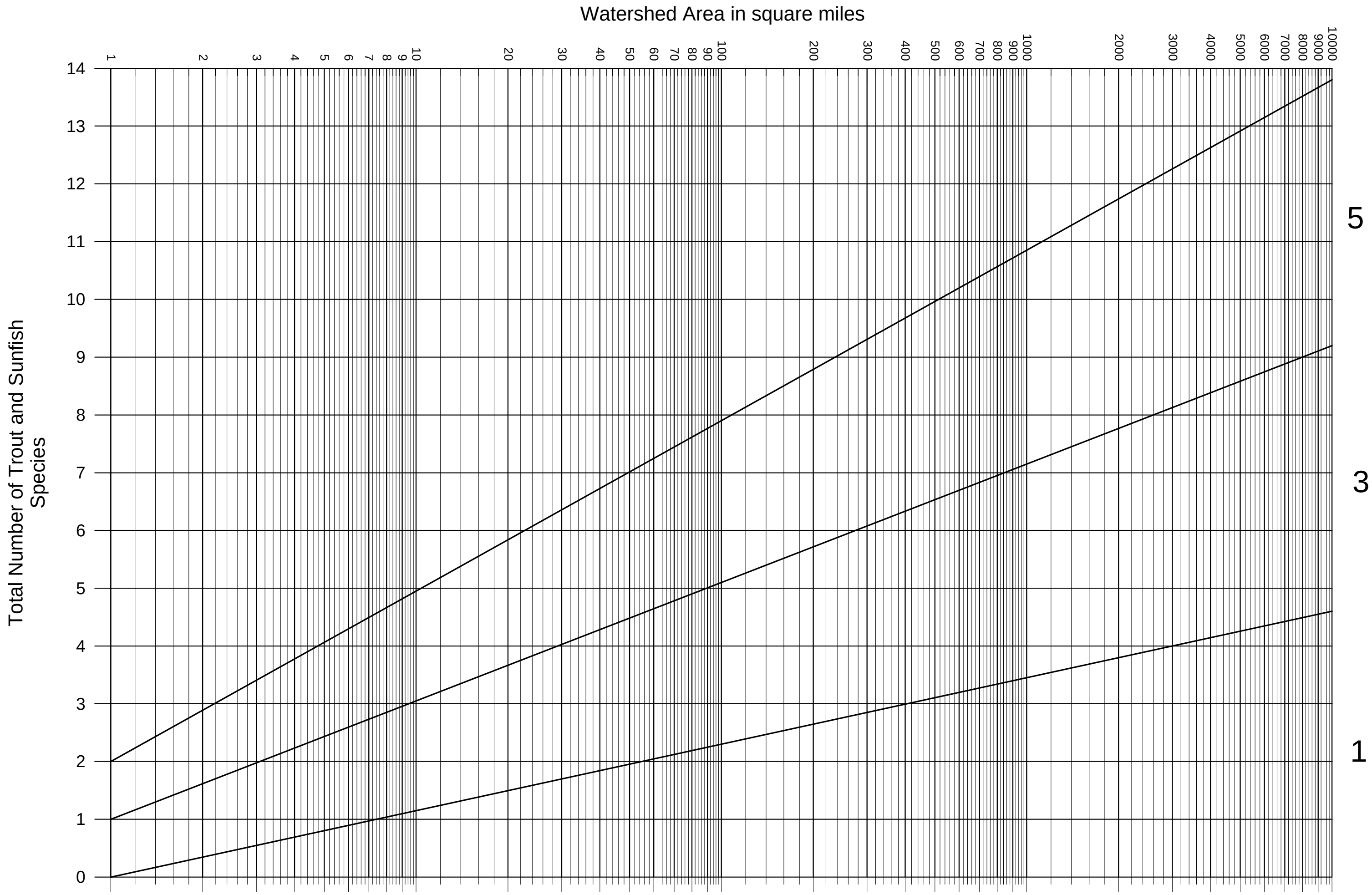
Total number of fish species versus watershed area for New Jersey ecoregion reference sites



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