New Jersey Department of Environmental Protection
Water Monitoring and Standards

FISH IBI REPORT
2009 SAMPLING
Round 2, Year 5 of 5

Volume 1 of 2

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March 2011

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March 2011

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FISH IBI REPORT
2009 SAMPLING
Round 2, Year 5 of 5

Volume 1 – Summary

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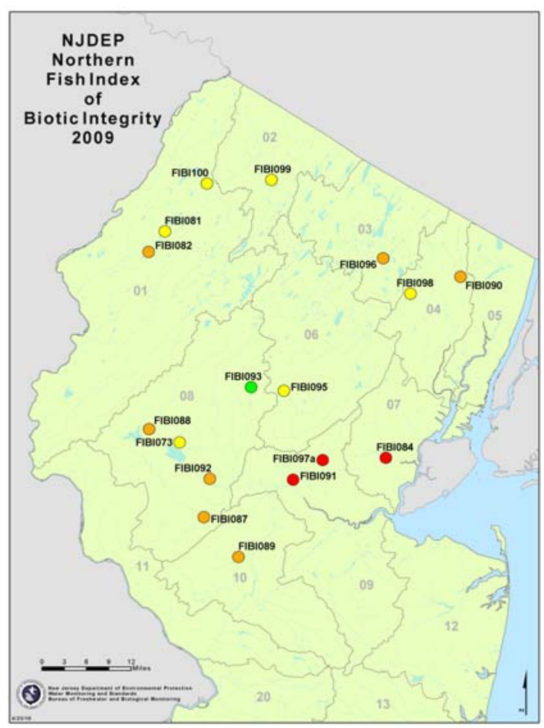
EXECUTIVE SUMMARY

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

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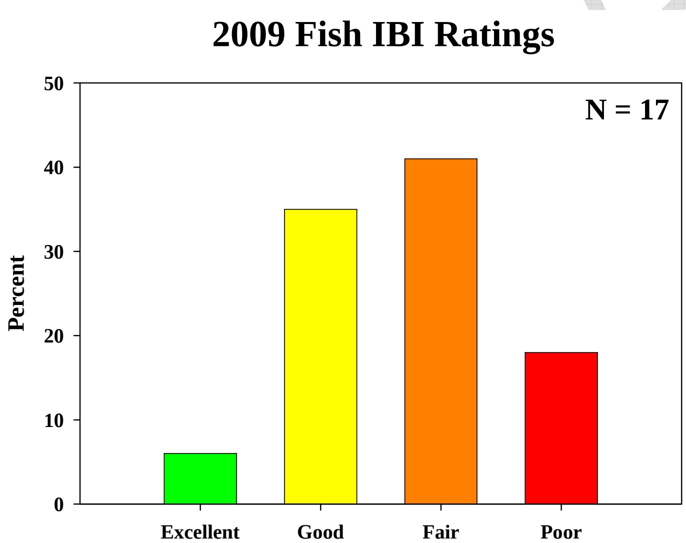
ecological significance that would then be entitled to an anti-degradation classification. Since 2004, this Fish IBI data has aided in the classification of some or all of an additional 229 river miles to a C-1 category.

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.

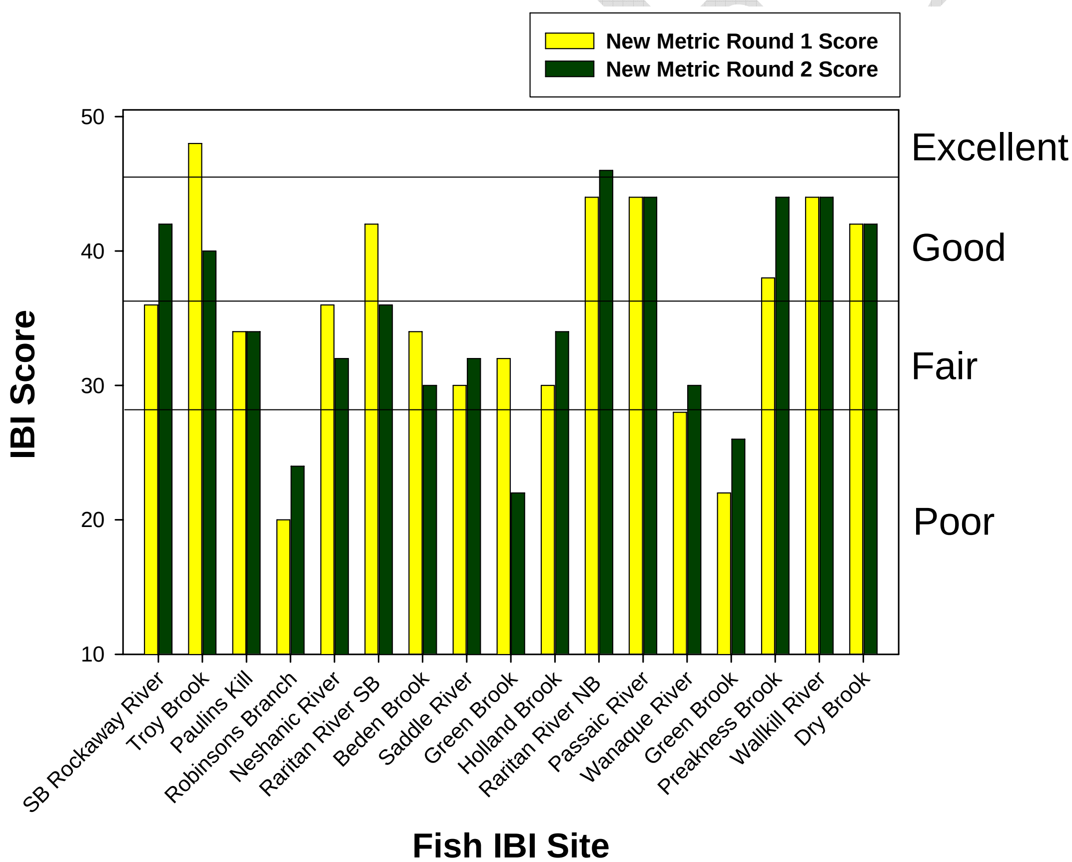
The Fish IBI has also found utility in WM&S' Stressor Identification (SI) program as well, where it has been used to prioritize site selection, help identify the spatial extent of waterbody degradation, and to aid in the location and identification of potential stressors. An unexpected use, that appears 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.



The 2009 season marked year five of the second round of sampling, in which the network sites originally sampled in 2004 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 2009 season is the fifth 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 2009, the tenth year of sampling, 17 sites were sampled. One site was rated "excellent", six were "good", seven were "fair", and three sites received a "poor" rating.

A total of 100 wild rainbow trout were collected from the Passaic River (FIBI095), a unique and rare occurrence, as just 13 naturally reproducing rainbow trout waterbodies exist in New Jersey (NJ F&W 2004). Conversely, a total of three hatchery brown trout and one hatchery rainbow trout were collected from the Wallkill River (FIBI099) in early October, prior to Fall trout stocking. The collection of trout indicates adequate water quality and habitat to enable survival through summer months and thus making this FW2-NTC1 stream a candidate for upgrade to "trout maintenance". In addition to trout, three other sensitive species were collected including cutlips minnow, American brook lamprey, and margined madtom.

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 both Rounds 1 and 2, 59% of sites were rated "fair" or "poor". In addition, the number of "excellent" and "good" sites remained the same between rounds. Three sites (Troy Brook, Raritan River SB, and Green Brook) exhibited sharp declines in biological integrity, while scores from SB Rockaway River increased significantly from 2004 to 2009.



*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 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).

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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 (5^{th} order or greater)	Wadeable streams (3^{rd} and 4^{th} order)	Headwater streams (1^{st} and 2^{nd} 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).

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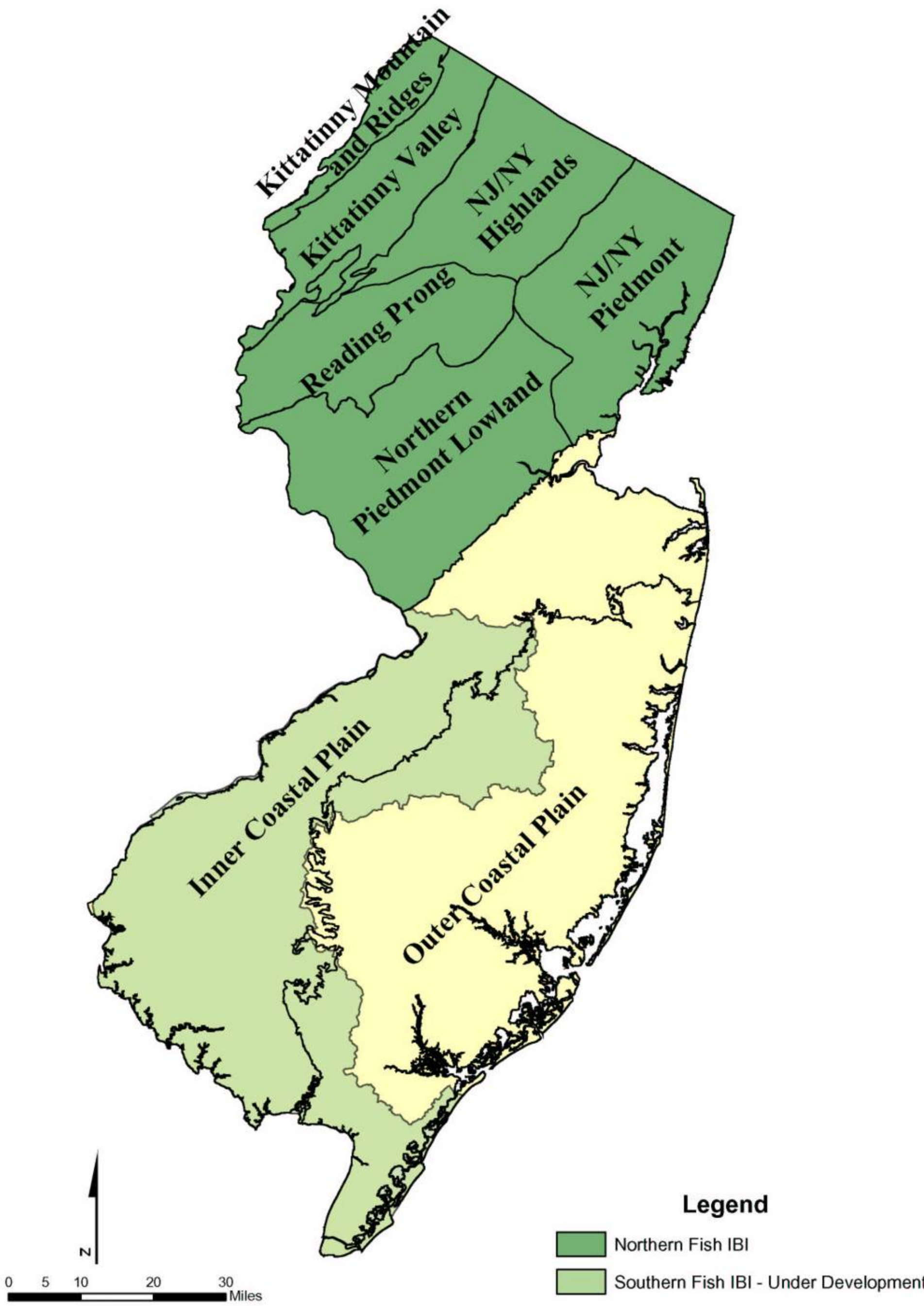

Figure 1. Map of New Jersey Ecoregions and region of Fish IBI applicability.

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.

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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

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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							

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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**

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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:

<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

[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).

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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) -

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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.

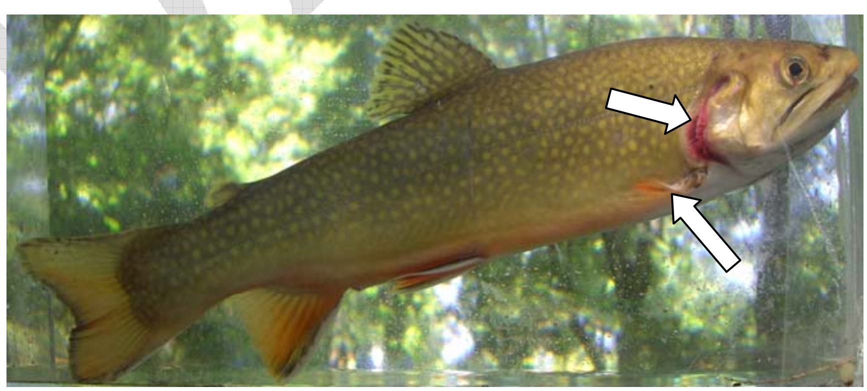

Figure 3. Hatchery brook trout with multiple deformities.

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RESULTS

In 2009, the fifth year of Round 2 of sampling, 17 sites were sampled. One site was rated "excellent", six were "good", seven were "fair" and three were "poor" (Figure 4). The habitat ratings for the 2009 sites consisted of five sites with "optimal" habitat and twelve with "sub-optimal" habitat.

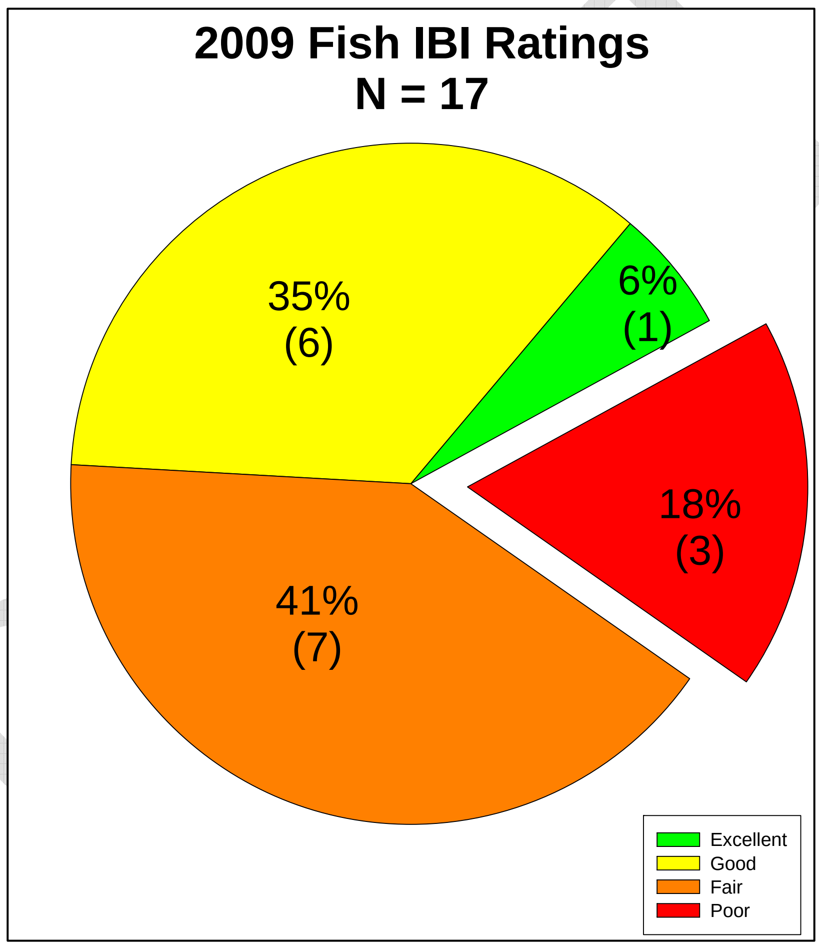

Figure 4. Summary of the 2009 ratings for 17 sites in northern New Jersey.

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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 (FIBI084, FIBI091, FIBI097a) (Figure 5; Table 7). These sites on Robinsons Branch (FIBI084) and Green Brook (FIBI091 and FIBI097a) 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.

Except for Wanaque River (FIBI096), those sites classified as "impaired" and "potentially impaired" all had "sub-optimal" habitat ratings and many have a high percent of 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.

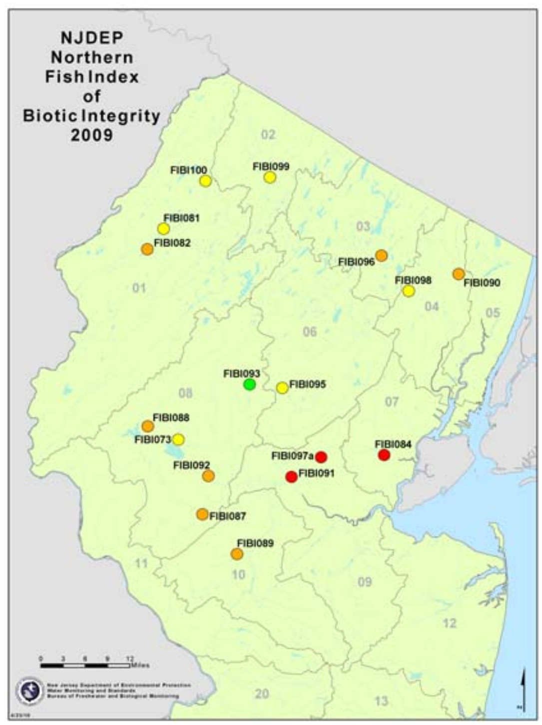

Figure 5. Location of 2009 Fish IBI sites.

Table 7. Results of 2009 Round 2 Fish IBI sampling[1].

FIBI Site	Waterbody	County	Habitat Rating	IBI Score	IBI Rating
FIBI073	SB Rockaway Creek	Hunterdon	Optimal	42	Good
FIBI081	Troy Brook	Sussex	Optimal	40	Good
FIBI082	Paulins Kill	Sussex	Sub-Optimal	34	Fair
FIBI084	Robinsons Branch	Union	Sub-Optimal	24	Poor
FIBI087	Neshanic River	Somerset	Sub-Optimal	32	Fair
FIBI088	SB Raritan River	Hunterdon	Sub-Optimal	36	Fair
FIBI089	Beden Brook	Somerset	Sub-Optimal	30	Fair
FIBI090	Saddle River	Bergen	Sub-Optimal	32	Fair
FIBI091	Green Brook	Middlesex/Somerset	Sub-Optimal	22	Poor
FIBI092	Holland Brook	Hunterdon	Sub-Optimal	34	Fair
FIBI093	NB Raritan River	Morris	Optimal	46	Excellent
FIBI095	Passaic River	Morris	Optimal	44	Good
FIBI096	Wanaque River	Passaic	Optimal	30	Fair
FIBI097a	Green Brook	Union	Sub-Optimal	26	Poor
FIBI098	Preakness Brook	Passaic	Sub-Optimal	44	Good
FIBI099	Wallkill River	Sussex	Sub-Optimal	44	Good
FIBI100	Dry Brook	Sussex	Sub-Optimal	42	Good

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

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Potentially Impaired Sites

Paulins Kill - FIBI082

The fish index of biotic integrity was rated "fair" (34) despite few habitat or water quality impairments. The overall habitat was rated "sub-optimal" (155), with a low frequency of riffles as the only habitat parameter which scored low. Saddleback Road, which runs along the Paulins Kill, along with local agricultural practices may have an influence on the elevated conductivity (444 μmhos/cm). Despite the "fair" rating for this FW2-TM site, a total of four hatchery brook trout were collected during this mid-August sampling event, providing evidence of sufficient dissolved oxygen, water temperature, and habitat for trout survival through summer months. Two additional sensitive fish species were collected at this site, including the cutlips minnow and the margined madtom.

Neshanic River - FIBI087

The invasive green sunfish was the dominant fish collected in 2009, comprising over 20% of the overall sample, a contrast to sampling from 2004 in which green sunfish represented 11% of the overall catch. The trophic structure was dominated by generalist feeders (56%), while specialized feeders were less common. In addition, the abundance of benthic species was low, which may be a result of infrequent riffles and the high degree of embeddedness of substrate in runs and pools throughout the stretch. The main channel and much of the reach lacked adequate fish habitat. Along the banks, those intermittent areas with large woody debris or undercut banks were inhabited by large numbers of fish.

SB Raritan River - FIBI088

The habitat along the left descending bank provided shade and more snags compared to the right descending bank which was almost devoid of fish habitat and overhead cover. Overall, few stressors were observed, except for areas of erosion along the left descending bank and a lack of optimal fish habitat and slack water from the swift current. The sample reach lacked a riparian buffer with Arch Street closely bordering the left descending bank and a park bordering the right descending bank.

The sample collected in late July was comprised mainly of American eel and as a result the percent composition of tolerant species was over 60% of the sample. Overall fish abundance, diversity (H'=1.64), and species richness were low. In addition, a large percentage of the catch, mainly white sucker, had external deformities. Over 14% of the white suckers collected had an external growth or deformity, typically an indication of stress within the resident fish community (Figure 6). Despite these impairments within the fish community, a total of four wild brown trout, four hatchery brown trout, and one hatchery rainbow trout were collected from this FW2-TM stream. One of the wild brown trout was a young-of-the-year (72-mm), making this a candidate stream for trout classification re-evaluation. In addition to hatchery and wild trout, shield darter and cutlips minnow were also collected.

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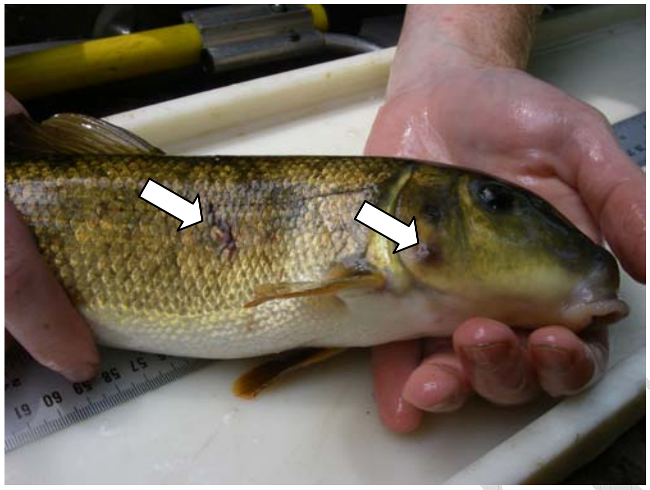

Figure 6. External deformities on white sucker.

Beden Brook - FIBI089

The habitat was rated sub-optimal (133) with evidence of stress related to the flow regime, bank stability, and riparian buffer. The stretch was relatively flat with very little riffle habitat. Severe bank erosion was evident on both banks mainly at outside bends in the river. A few snags were present along the banks, but overall the stream lacked complexity and sufficient fish habitat. Moderate to heavy periphyton growth was observed in several runs which lacked adequate overhead cover (Figure 7).

Figure 7. Filamentous algae growth in Beden Brook.

The fish community lacked sufficient predatory species, as only one redfin pickerel and no smallmouth bass were collected in contrast to the previous years' survey. No intolerant fish species were collected, while tolerant fish were dominant, totaling nearly 52% of the total collection. Despite habitat deficiencies and poor balance within the fish community, the fish collected in early July were healthy and in good condition, as just 1 DELT anomaly was observed.

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Saddle River - FIBI090

A number of habitat and water quality impairments were observed in mid-July 2009, which included high conductivity (663 μmhos/cm), channelization, sediment bar formation, and stagnant water flowing from a large detention basin. Overall, the habitat was rated "sub-optimal" (110) with deficient fish habitat throughout the stretch. The left descending bank was bordered by houses with erosion control structures lining the bank which included riprap, fabric, concrete, and other erosion control structures (Figure 8).

Figure 8. Fabric used to control bank erosion on Saddle River.

The riprap and other erosion control structures were mainly inhabited by the invasive green sunfish, which made-up almost 10% of the fish community. A total of 17 wild brown trout were collected from this FW2-NT stream, including 13 young-of-the-year (Figure 9). As a result, this section of the Saddle River is a candidate for upgrade to trout production, as the closest trout production water is more than 6.5 miles upstream. A majority of trout were collected in the fast flowing riffles with undercut banks near the start. Fewer trout were collected in the section above the 50-meter mark, as the river flattens and offers these sensitive fish little natural refugia.

Figure 9. Young-of-the-year brown trout collected in Saddle River.

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Holland Brook - FIBI092

This stretch of Holland Brook was relatively flat with little fish or riffle habitat. The substrate in riffles and flowing sections was relatively clean, while much of the slower run/pool sections had more embedded substrate and a layer of fine sediments. However, the substrate was cleaner in 2009 with less siltation, embeddedness, and periphyton growth in comparison to the 2004 sampling event. Both banks have little riparian buffer, although sections along the left descending bank were overgrown with vegetation rather than mowed grass to the stream bank. Numerous gravel/sand point and channel bars were formed throughout the stretch, an indication of high flows and frequently shifting sediments. In addition, the steep mostly shale right descending bank has been heavily eroded.

Despite habitat impairments, the fish assemblage exhibited good richness, diversity (H'=2.41), and abundance. Several attributes of the Fish IBI significantly improved since Round 1 sampling in 2004, despite the same rating between years. The 2004 sample consisted mainly of generalist feeders (53%) with few specialized feeders, such as insectivorous cyprinids (18%). Trophic structure was more balanced in 2009, with fewer generalist feeders (34%), while insectivorous cyprinids increased substantially (30%). In addition, the proportional abundance of tolerant fish decreased from 51% in 2004 to 26% in 2009.

Wanaque River - FIBI096

There were few signs of habitat or water quality impairments at FIBI096 in late September 2009, as the habitat was rated “optimal” (165). The only sign of stress to the system was heavy periphyton and filamentous algae growth in several slow moving sections.

Despite good overall habitat, overhead cover, substrate, and flow, the fish community was depauperate with very low species richness (6) and diversity (H'=1.09). No predatory fish species were collected despite the trout maintenance classification for this stretch and the close proximity of several trout production tributaries, including Jennings Creek. The intolerant cutlips minnow were dominant fish species, with a total of 262 collected in this stretch which is the greatest abundance of cutlips minnow of any stream sampled since the program’s inception.

Impaired Sites

Robinsons Branch - FIBI084

Impacts to Robinsons Branch are likely a result of the high impervious cover (26%) and heavy urbanization of the surrounding watershed leading to impairments within the fish community resulting in a “poor” rating (24). The stream lacks adequate riparian buffer and the banks and streambed were littered with debris and garbage.

Despite an abundance of snags and root wads to provide good habitat for piscivorous fish species, none were collected in the sample stretch. In addition, few specialized feeding insectivorous cyprinds were collected (5%), while generalist feeders dominated the sample (56%).

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Ambient Biological Monitoring station AN0199, located just upstream of the Fish IBI station received "poor" ratings in 2004 and 2009.

Green Brook - FIBI091

The habitat of this stretch of Green Brook contains good fish habitat with numerous snags, undercut banks, and deep pools with root wads, but overall fish abundance was low and few centrarchids were collected. In addition, there was a good mix of slow backwater habitat and fast flowing riffles. Despite these positive habitat attributes, the stretch contained numerous sediment bars and the banks exhibited signs of erosion, all a result of routine flooding (Figure 10). The upstream watershed is nearly 30% impervious cover.

Figure 10. Sediment bars formed from frequently shifting substrate.

Just two top predators were collected in this stretch representing less than 1 percent of the total fish collected. Specialized insect feeding minnow species represented just 15% of the fish assemblage and benthic species were poorly represented, an indication of impairments to the natural substrate and benthic macroinvertebrate community. Tolerant species able to adapt and thrive under harsh conditions represented over 55% of the fish community.

Ambient Biological Monitoring station AN0426, located just downstream of the Fish IBI station received a "poor" ratings in 2004 and a "fair" rating in 2009.

Green Brook - FIBI097a

This section of Green Brook contains more water quality and habitat impairments than the downstream site (FIBI091). The water temperature was higher at FIBI097a, a likely result of a lack of overhead cover throughout this stretch. The average open canopy was 55% for the upstream location (FIBI097a) compared to 9% open canopy at the downstream location (FIBI091). In addition, the conductivity was substantially higher (579 µmhos/cm) at this upstream location (FIBI097a). The stream banks have been severely scoured with large sections sloughing off into the stream, not only eroding the banks and changing the natural stream morphology, but also smothering benthic organisms. Large amounts of debris and garbage were distributed throughout the stretch with a large mass of garbage collected just downstream of the sampling stretch (Figure 11). In addition, large concrete slabs were deposited in the stream and on along the banks throughout the stretch most likely in an attempt to slow bank erosion.

Figure 11. Garbage/debris dam just downstream of sample stretch.

Despite the numerous habitat and water quality impairments, the biotic integrity improved slightly since 2005 and was slightly higher than the downstream location (FIBI091). Overabundance of white sucker and green sunfish resulted in trophic imbalance with the majority of fish classified as generalist feeders (60%) and high proportional abundance of tolerant species (58%).

Ambient Biological Monitoring station AN0423 received “fair” ratings in 2004 and 2009.

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Other Important Findings

Passaic River - FIBI095

A total of 169 wild trout were collected from this FW2-TPC1 waterbody, with 100 of these fish being rainbow trout (Figure 12). This is a rare occurrence, as just 13 naturally reproducing rainbow trout rivers exist in the state of New Jersey as of 2004 (NJ F&W 2004). However, there are some indications the community maybe changing, as brown trout represented 20% of the trout collected in 2004, but have more recently increased in proportional abundance representing 41% of the trout collected in 2009. In addition, just one tolerant species was collected in the first round compared to three in this latest round of sampling, which included the invasive green sunfish. The likely source of the additional tolerant species is Dreesen Pond located about 0.5 miles upstream of the sample location on Indian Grove Brook. In addition, some of the water chemistry parameters differed substantially between the sampling reach itself and the confluence of Indian Grove Brook with the Passaic River. The water temperature at the confluence was much warmer (19.76° C) compared to the Passaic River (17.85° C) and pH was also higher (7.49) at the confluence compared to the mainstem (6.77).

Figure 12. Young-of-the-year rainbow trout collected from Passaic River.

Wallkill River - FIBI099

A total of three hatchery brown trout and one hatchery rainbow trout were collected from this FW2-NTC1 stream in early October, prior to Fall trout stocking. The collection of trout indicates adequate water quality and habitat to enable survival through summer months and thus making this stream a candidate for upgrade to "trout maintenance". In addition to trout, three other sensitive species were collected including cutlips minnow, American brook lamprey, and margined madtom. Overall, the site was rated "good" (44), despite high conductivity (756 µmhos/cm), moderate siltation and embeddedness, and several NJPDES outfalls within the stretch and just upstream, including a Sussex County sewage treatment outfall.

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 13). 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 14). 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.”

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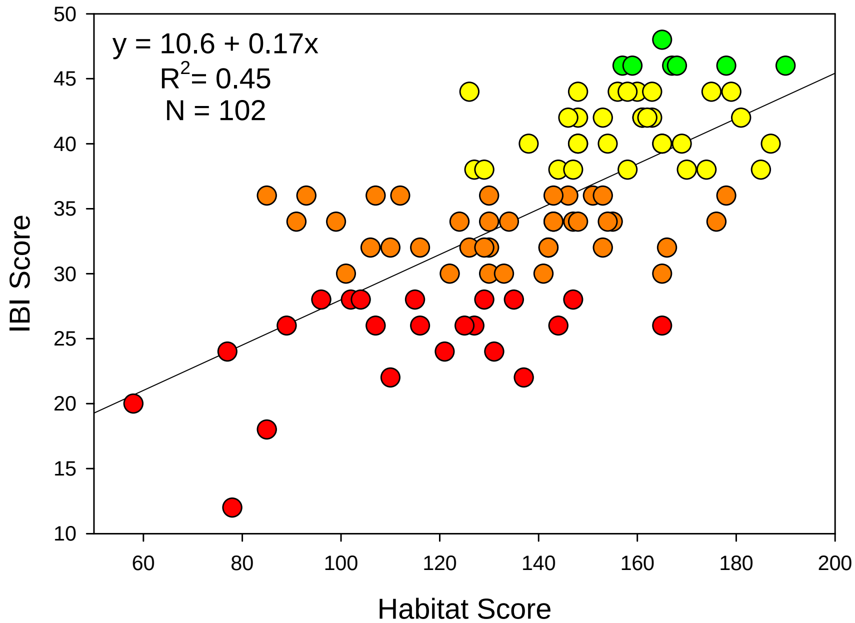

Figure 13. Linear regression comparing IBI and habitat scores.

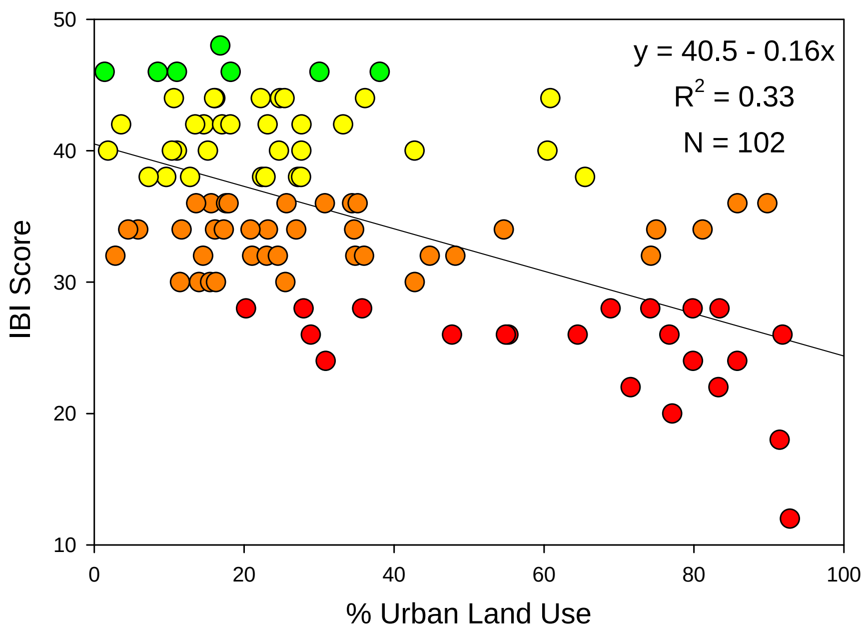

Figure 14. Linear regression comparing urban land use and IBI score.

TRENDS ANALYSIS

The completion of the 2009 sampling season marks the fifth and final year of the second round of Fish IBI sampling. The sites sampled in 2009 were originally sampled in 2004. Those sites sampled in 2004 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*		2009 Results	
FIBI Site	**Waterbody**	**IBI Score**	**IBI Rating**	**IBI Score**	**IBI Rating**
FIBI073	SB Rockaway Creek	36	Fair	42	Good
FIBI081	Troy Brook	48	Excellent	40	Good
FIBI082	Paulins Kill	34	Fair	34	Fair
FIBI084	Robinsons Branch	20	Poor	24	Poor
FIBI087	Neshanic River	36	Fair	32	Fair
FIBI088	SB Raritan River	42	Good	36	Fair
FIBI089	Beden Brook	34	Fair	30	Fair
FIBI090	Saddle River	30	Fair	32	Fair
FIBI091	Green Brook	32	Fair	22	Poor
FIBI092	Holland Brook	30	Fair	34	Fair
FIBI093	NB Raritan River	44	Good	46	Excellent
FIBI095	Passaic River	44	Good	44	Good
FIBI096	Wanaque River	28	Poor	30	Fair
FIBI097a	Green Brook†	22	Poor	26	Poor
FIBI098	Preakness Brook	38	Good	44	Good
FIBI099	Wallkill River	44	Good	44	Good
FIBI100	Dry Brook	42	Good	42	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 sample in 2005.

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The proportion of sites rated as "excellent", "good", "fair", and "poor" all remained the same between Rounds 1 and 2 (Figure 15). Overall, mean scores between rounds differed by just one tenth of a point, as the average score in 2004 was 35.5 compared to 35.4 in 2009.

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: SB Rockaway River (073), Troy Brook (081), SB Raritan River (088), and Green Brook (091) (Figure 16). One of these changes was positive and three indicated degradation in biological integrity. The following is a description of trends at these individual sites over time.

SB Rockaway River – FIBI073

Round 1 sampling in 2002 resulted in the collection of just six species with blacknose dace representing 47 percent of the sample. In 2009, a total of 10 species were collected, but the community was less diverse as 71 percent of the sample was comprised of blacknose dace. Despite the dominance of dace in the sample, the overall biotic integrity improved from "fair" (36) in 2002 to "good" (42) in 2009. The inclusion of several hatchery rainbow and brook trout resulted in the increase in biotic integrity.

Troy Brook – FIBI081

The biotic integrity of Troy Brook decreased from "excellent" (48) in Round 1 to "good" (40) in Round 2. The proportional abundance of specialized insect feeding minnows decreased from almost 60 percent in 2004 to 27 percent in 2009, mainly a result of a decreased abundance of longnose dace. Proportional abundance of longnose dace decreased between these sampling rounds from 53 percent to just 13 percent. Consequently, the proportional abundance of generalist feeders increased from only 7 percent in Round 1 to 41 percent in Round 2.

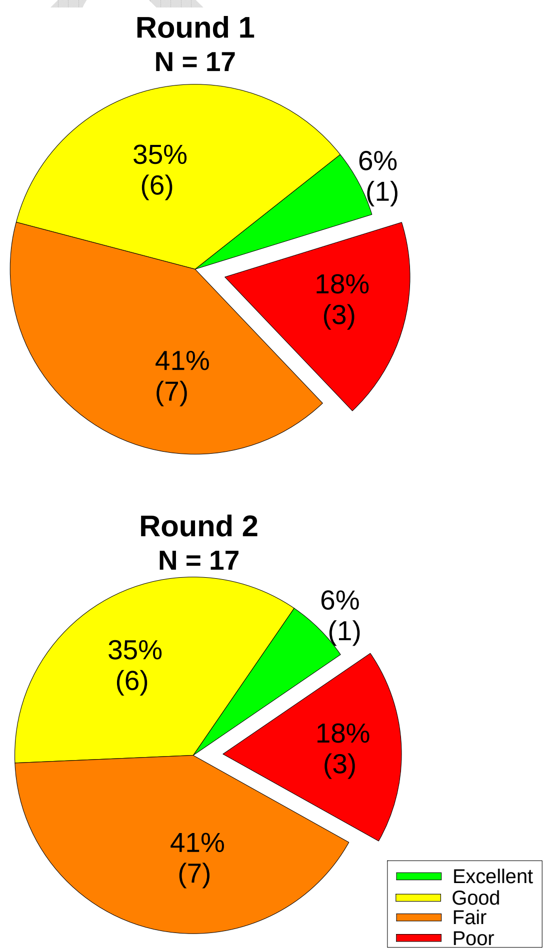

Figure 15. Ratings comparison for Rounds 1 and 2.

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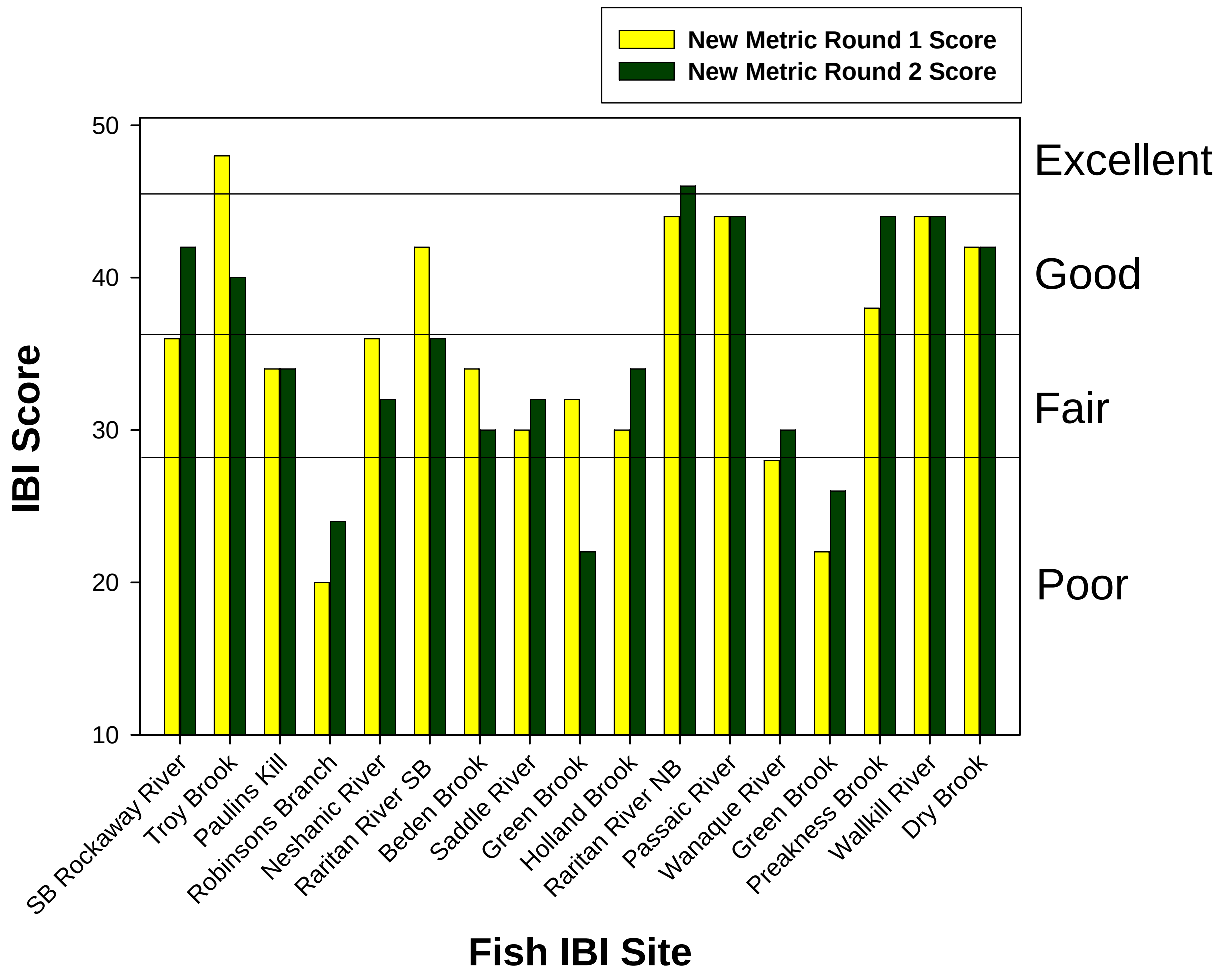

Figure 16. Comparison of ratings for Rounds 1 and 2 at individual sites.

SB Raritan River – FIBI088

The Fish IBI station was moved approximately 300-meters upstream in 2009 to avoid sampling around islands at the previous location. The score and rating decreased from “good” (42) in 2004 to “fair” (36) in 2009. The primary reason for this change is a result of the high abundance of American eel and white sucker in this Round 2 sample resulting in a high proportional abundance of tolerant species. Tolerant species represented 18 percent of the fish assemblage in 2004 compared to 61 percent in 2009.

Green Brook – FIBI091

Biotic integrity decreased from “fair” (32) in 2004 to “poor” (22) in 2009 mainly as a result of a shift from specialized feeders to generalists, along with an increase in the proportion of tolerant fish. Spottail shiner accounted for almost 37 percent of the fish community in 2004, but just 2 percent in 2009 with no replacement species filling this niche. Despite ample pools, root wads, and large woody debris, just two top predatory fish were collected in the 150-meter stretch. In addition, few native centrarchids were collected despite the suitable habitat. Also, fish abundance decreased significantly between rounds with just 268 fish collected in 2009.

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

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	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

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	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		

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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.

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<u>**Species to be included in each of the metrics used by the NJDEP:**</u>

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

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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)*		
Number of Individuals in Sample		
Proportion of Individuals w/disease/anomalies (excluding blackspot)		
Total		

*whichever gives better score

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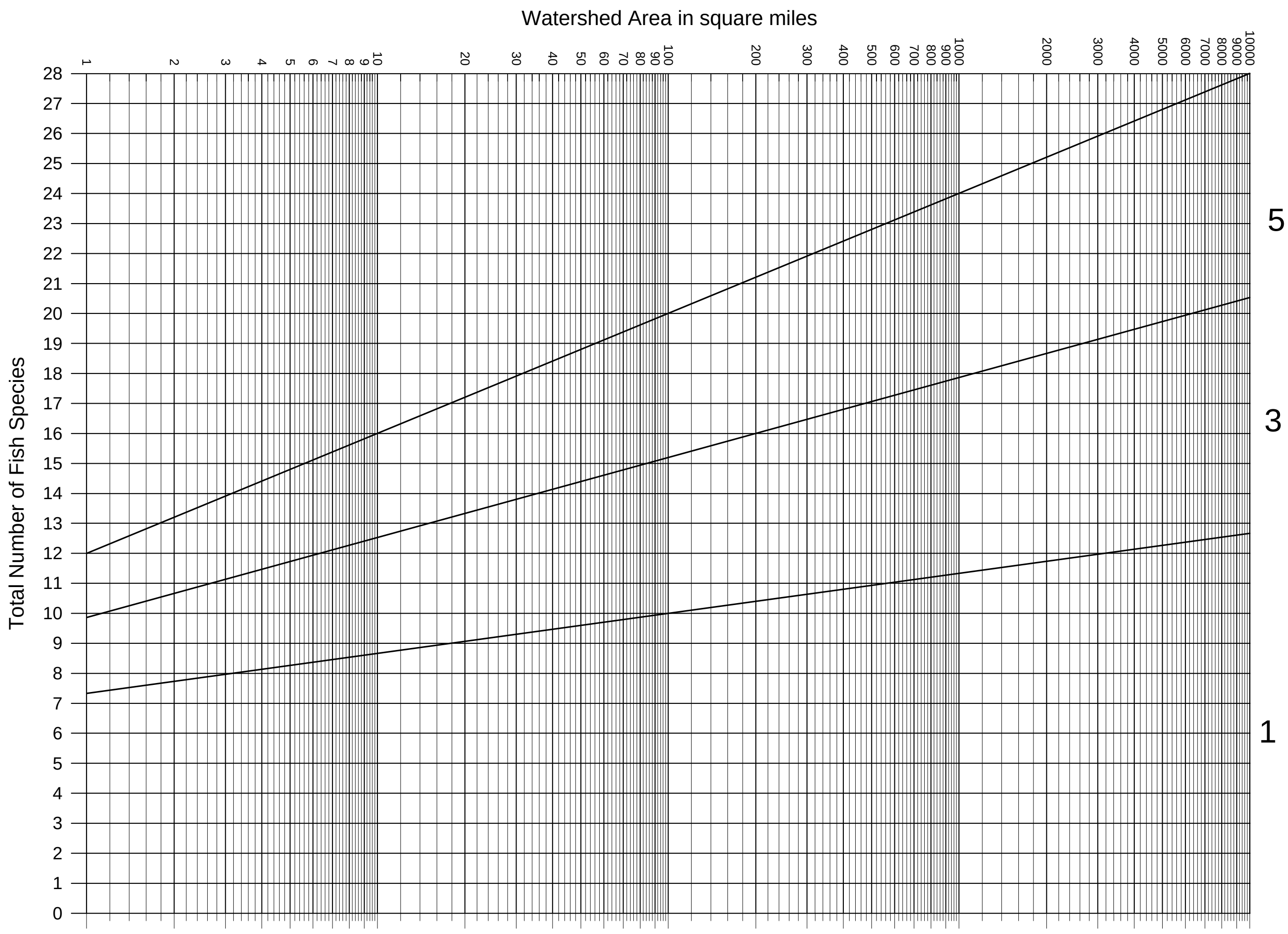
Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate /Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to 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

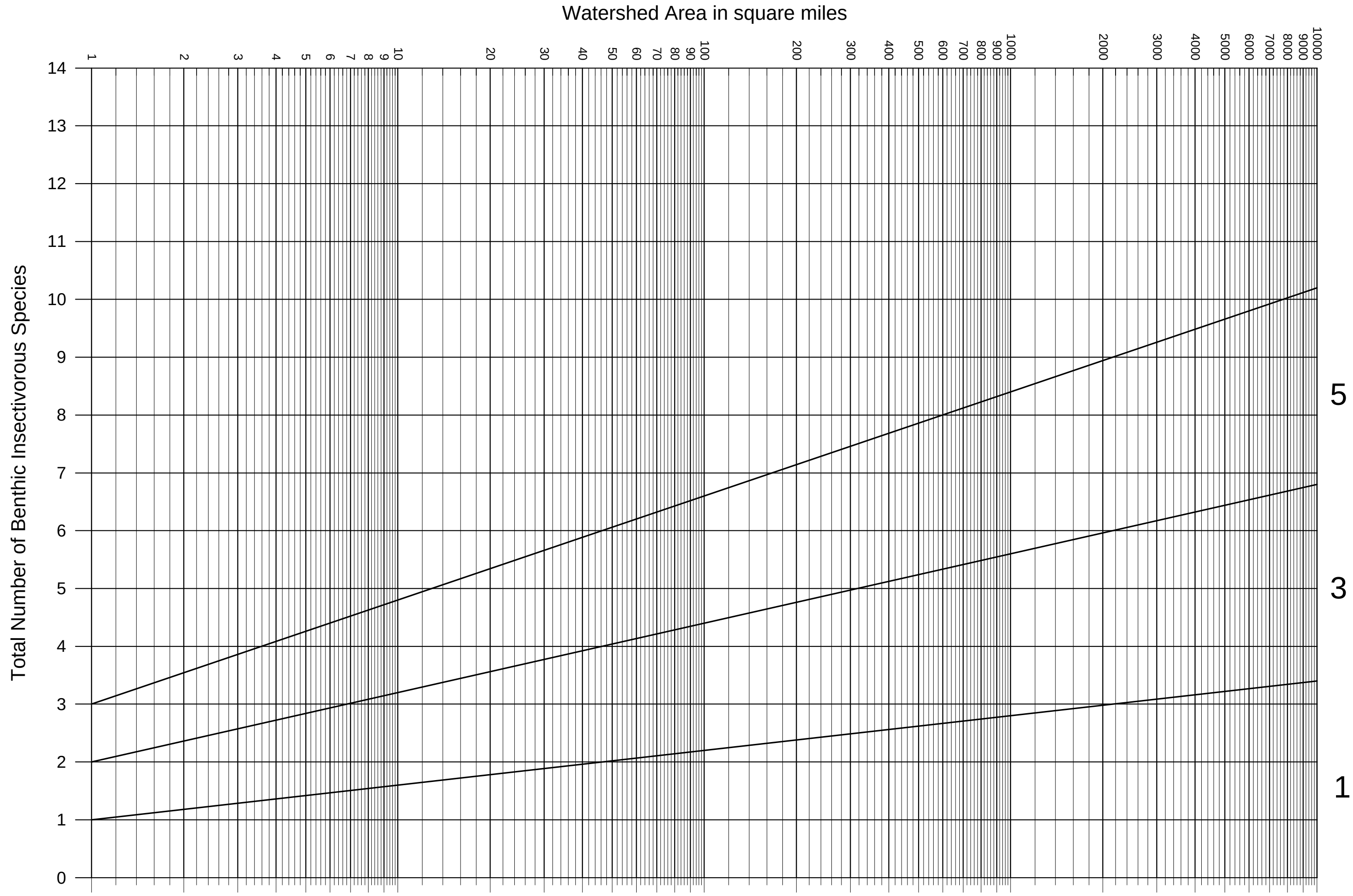
HABITAT SCORE

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

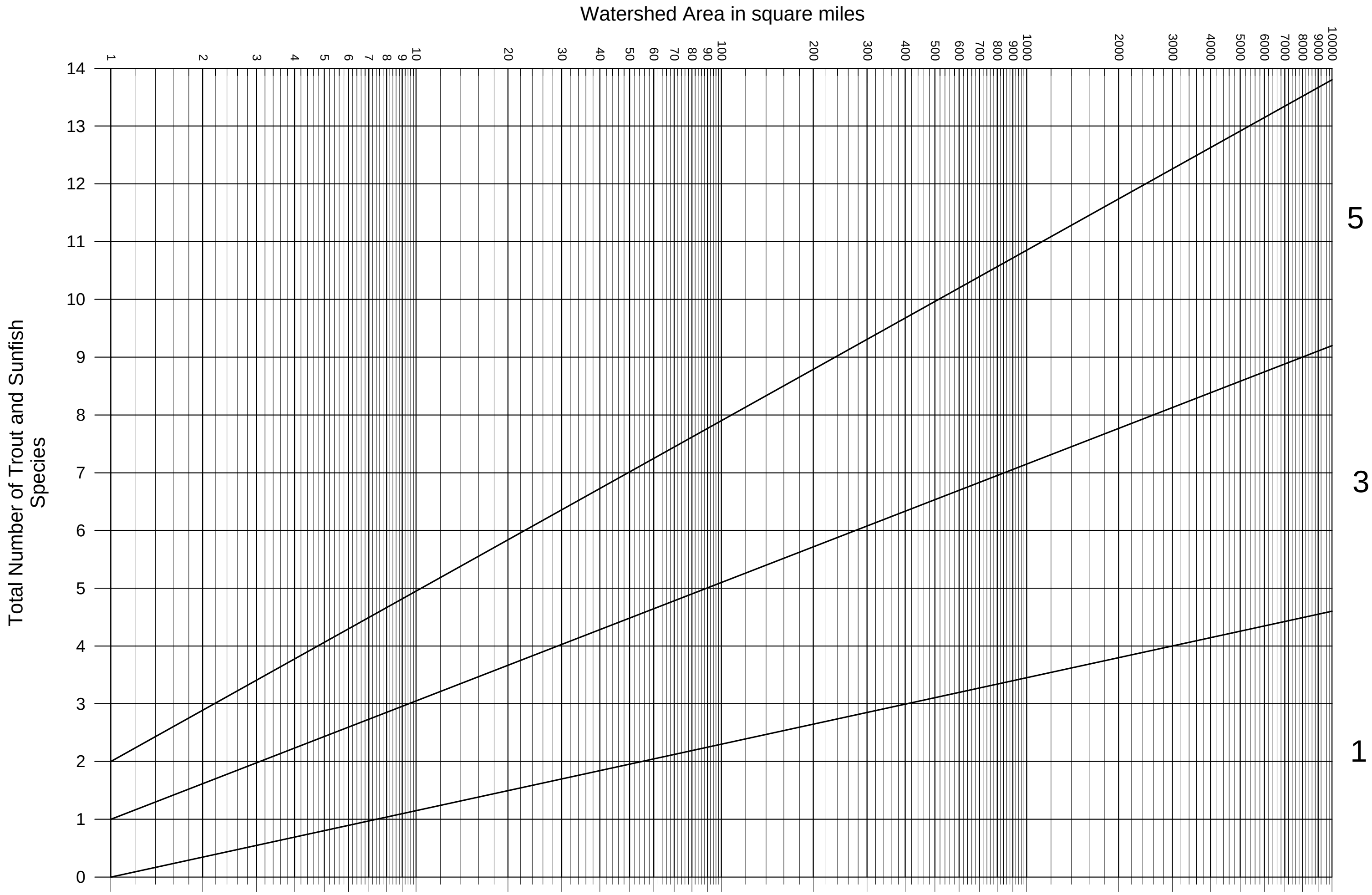
Total number of fish species versus watershed area for New Jersey ecoregion reference sites



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