New Jersey Department of Environmental Protection
Water Monitoring and Standards

FISH IBI REPORT
2007 SAMPLING
Round 2, Year 3 of 5

Volume 1 of 2

July 2009

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Volume 1 – Summary

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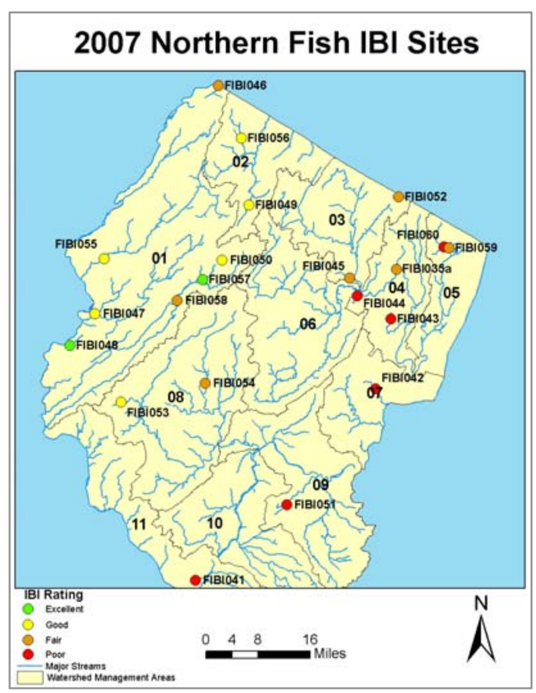
EXECUTIVE SUMMARY

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.

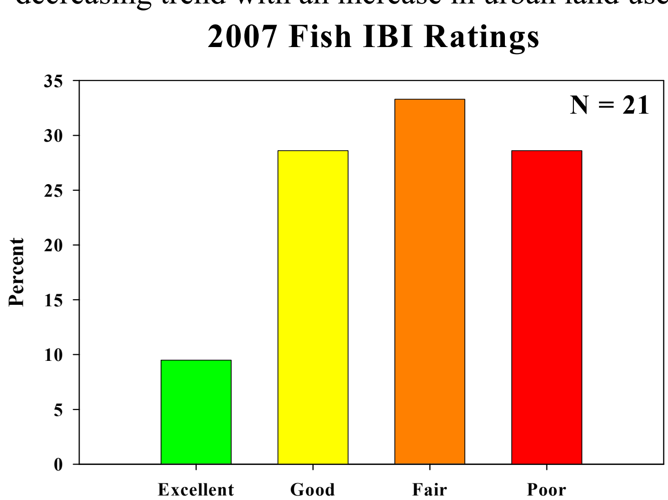
In addition to its inclusion in the C-1 evaluation process, the Fish IBI data has proven its usefulness for other programs, including:

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.

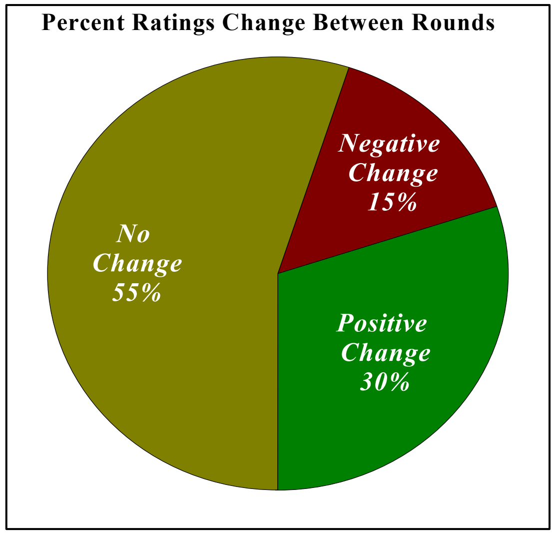
The Fish IBI has also found utility in WM&S's Stressor Identification (SI) program as well, where it has been used to prioritize site selection, help identify the spatial extent of waterbody degradation, and to aid in the location and identification of potential stressors. An unexpected use, that appears 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 1,800 website downloads WM&S receives per month.

The 2007 season marked year three of the second round of sampling, in which the network sites originally sampled in 2002 and 2003 were revisited. In an effort to ensure sensitivity to anthropogenic stressors, the Northern Fish IBI was re-evaluated in 2005 using Round 1 data (2000-2004). This recalibration resulted in modifications in scoring criteria and species lists for several metrics (see Table 3, 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 2007 season is the third 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 2007, the eighth year of sampling, 21 sites were sampled. Two sites were rated "excellent", six were "good", seven were "fair", and six sites received a "poor" rating.



Of the sites sampled in 2007, one (Elizabeth River) received the lowest FIBI score since the inception of the program in 2000, while another (Deepavaal Brook) received the lowest ever habitat score. There are a variety of factors which may be contributing to these low ratings including low dissolved oxygen, channelization, heavy sediment loading, and Surface water Quality Standards violations for copper and lead. Conversely, one site (Beaver Brook) had sufficient fish assemblage and water chemistry scores and as a result has been nominated for classification upgrade from FW2-NT (non-trout) to FW2-TM (trout maintenance).

Overall, ratings from Rounds 1 and 2 for the same 20 sites were similar when Round 1 sites were rescored utilizing the new metrics. In both Rounds 1 and 2, 60% of sites were rated "fair" or "poor". There were no "excellent" sites in Round 1, but 10% of the 2007 sites received an "excellent" rating. The proportion of "good" sites dropped slightly from 40% in Round 1 to 30% in 2007. In addition, 30% of the sites exhibited a positive rating increase, while the ratings for 55% of sites remained unchanged. One site Shabakunk Creek exhibited a sharp decline in biological integrity, while scores from Beaver Dam Brook, Buckhorn Creek, and two sites on the Musconetcong River increased significantly from 2001 to 2007 (for further information see Trends Analysis section).



*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 2006 Methods Document that was used to prepare the 2006 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 1,800 website downloads WM&S receives per month.

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

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

METHODS

Field Sampling

Primary objectives of the fish collections are to obtain samples with representative species and abundances, at a reasonable level of effort. Sampling effort is standardized by using similar stream lengths, collection methods, and habitat types. Stream segments selected for sampling are representative of the habitat of the reach. In addition, sample sites will be representative of the habitat of the reach 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 Fish IBI scoring because of naturally occurring low species richness and fish abundance. Often streams classified as trout production waters fall into this category. Current assessment methods for these streams include the measurement of trout abundance and/or young of the year production. The department is completing the development of biological criteria to assess these headwater streams. This Headwaters IBI uses fish, salamanders, and crayfish as biological monitors of stream health. 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. The Fish IBI was developed for waters in northern New Jersey from Trenton to Raritan Bay (Figure 1).

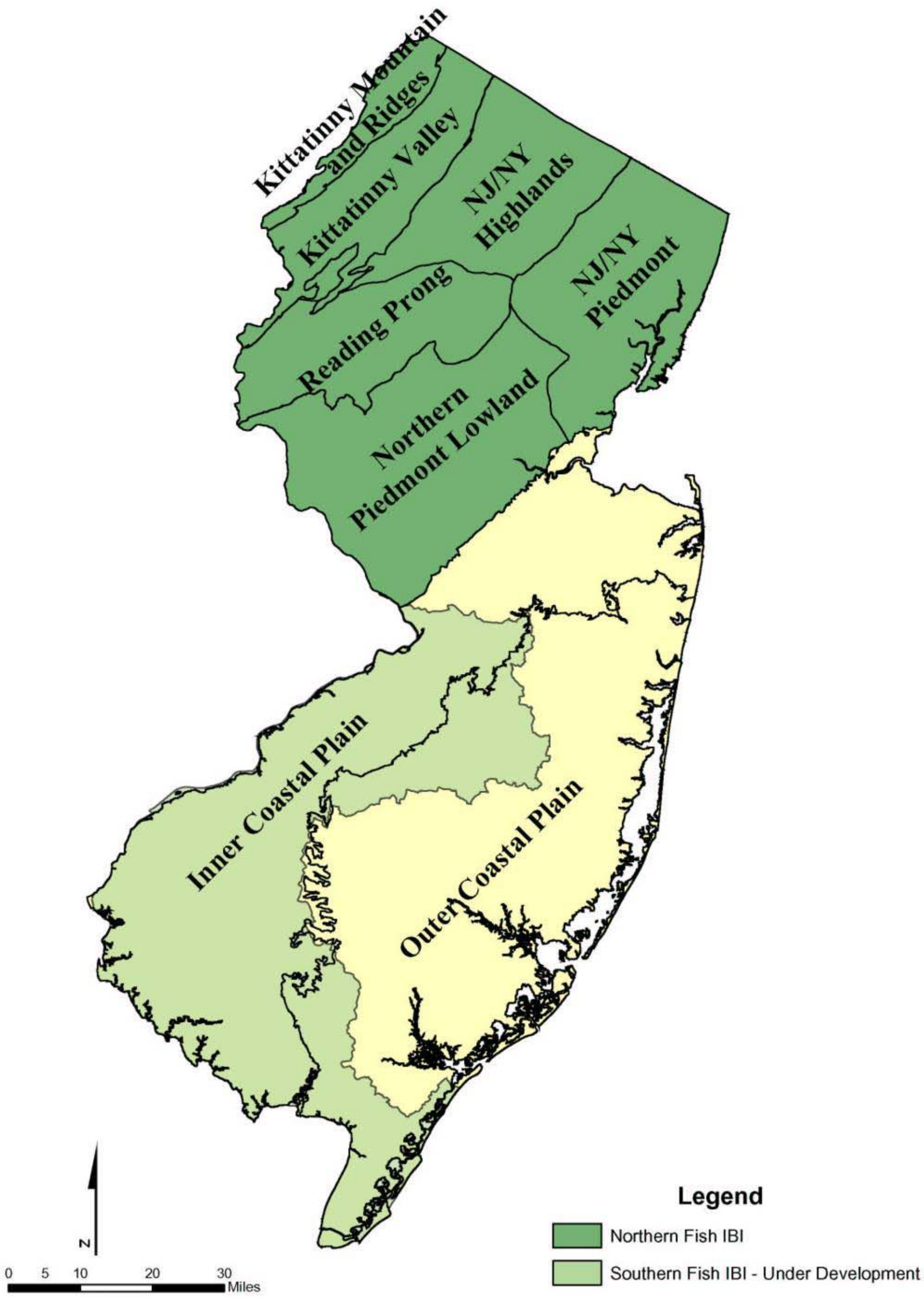


Figure 1. Map of New Jersey Ecoregions and region of Fish IBI applicability.

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 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, Eco-Analysts, Inc).

Measurement of Physical and Chemical Parameters

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

Habitat Assessment

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

Quality Assurance/Quality Control

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

IBI METRICS

Metric Refinement

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

Table 3. Refined Fish IBI Metrics.

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

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

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

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

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

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

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

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

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

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

Calculating the IBI[2]

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

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

Species Richness and Composition

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

[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).

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. Stocked brook trout with multiple deformities.

RESULTS

In 2007, the third year of Round 2 of sampling, 21 sites were sampled. Two sites were rated "excellent", six were "good", seven were "fair" and six were "poor" (Figure 4). The habitat ratings for the 2007 sites consisted of six sites with "optimal" habitat, nine "sub-optimal", five "marginal", and one site with "poor" habitat.

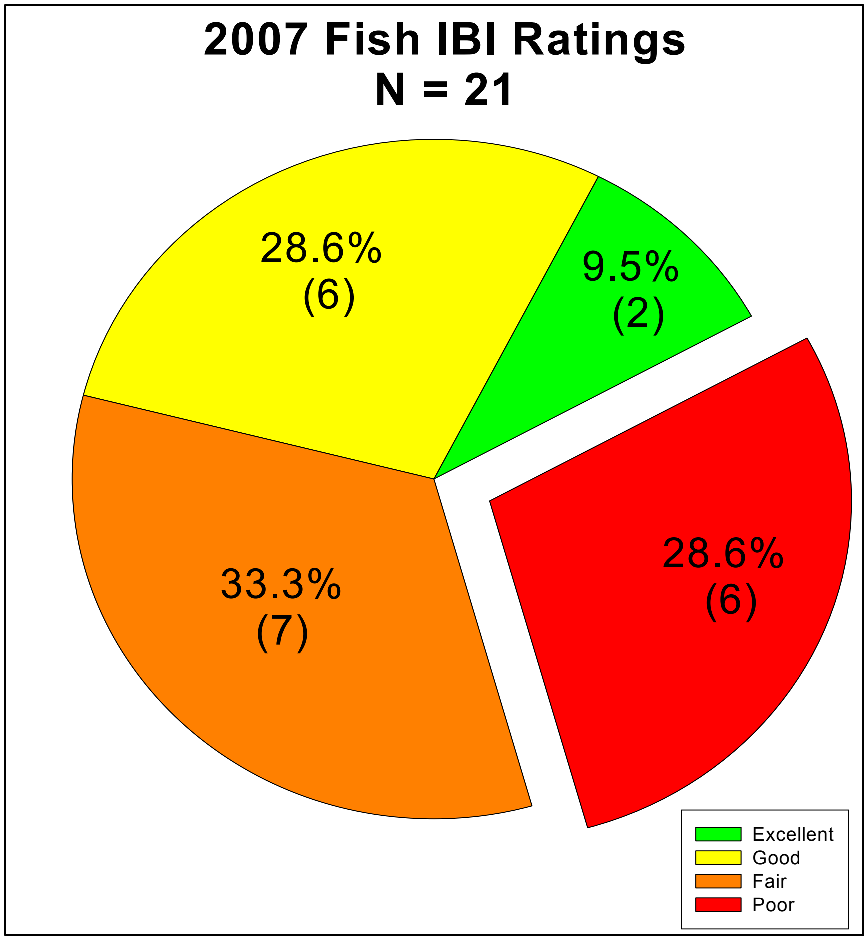


Figure 4. Summary of the 2007 ratings for 21 sites in northern New Jersey.

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 six (6) impaired sites were identified (FIBI 041, 042, 043, 044, 051, 060) (Figure 5; Table 7). Of these six sites Shabakunk Creek (FIBI041), Elizabeth River (FIBI042), Third River (FIBI043), Deepavaal Brook (FIBI044), and Musquapsink Brook (FIBI060) were identified as having water quality impairments, likely a result of anthropogenic stressors. Poor biotic integrity at Ireland Brook (FIBI051), however, is unclear. In addition, seven (7) sites were classified as "fair" and are suspected of having impacts.

Except for Ireland Brook (FIBI051) and Lamington River (FIBI054), those sites classified as "impaired" and "potentially impaired" all had "poor", "marginal" or "sub-optimal" habitat ratings and many have high percent urban land cover/use within their contributing watershed. Increasing urbanization has been shown to result in a reduction, and even loss, of sensitive fish species, an increased rate of native species replacement by introduced species, as well as a general decline in species richness and abundance (Wang & Lyons, 2003). The following is a discussion of possible causes for the suspected impacts at the sites with "fair" or "poor" ratings.

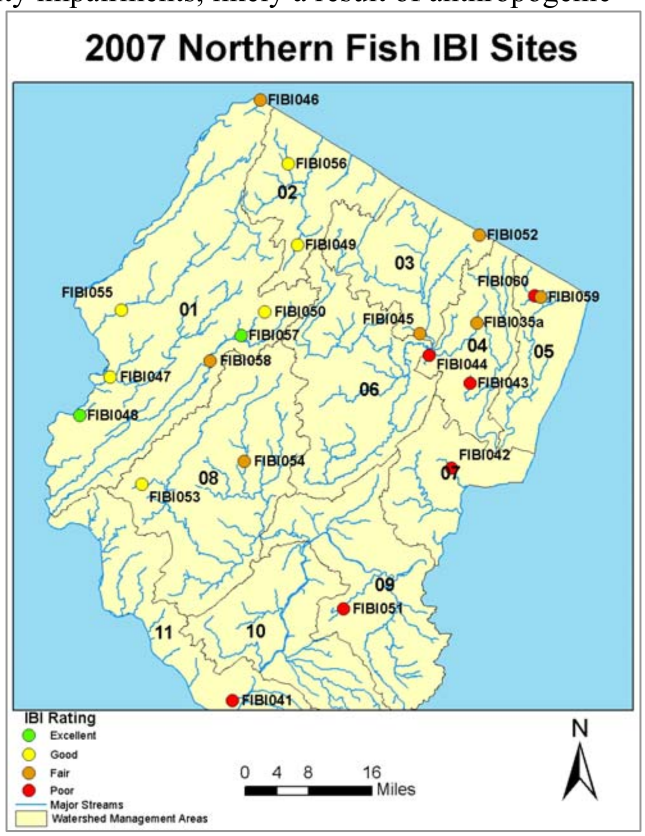


Figure 5. Location of 2007 Fish IBI sites.

Table 7. Results of 2007 Round 2 Fish IBI sampling[1].

FIBI Site	Waterbody	County	Habitat Rating	IBI Score	IBI Rating	
FIBI041	Shabakunk Creek	Mercer	Suboptimal	28	Poor	
FIBI042	Elizabeth River	Union	Marginal	12	Poor	
FIBI043	Third River	Essex	Marginal	28	Poor	
FIBI044	Deepavaal Brook	Essex	Poor	20	Poor	
FIBI045	Beaver Dam Brook	Morris	Marginal	30	Fair	
FIBI046	Clove Brook	Sussex	Suboptimal	34	Fair	
FIBI047	Beaver Brook	Warren	Suboptimal	40	Good	
FIBI048	Buckhorn Creek	Warren	Optimal	46	Excellent	
FIBI049	Wallkill River	Sussex	Suboptimal	38	Good	
FIBI050	Lubbers Run	Sussex	Optimal	38	Good	
FIBI051	Ireland Brook	Middlesex	Optimal	26	Poor	
FIBI052	Ramapo River	Bergen	Suboptimal	36	Fair	
FIBI053	Mulhockaway Creek	Hunterdon	Optimal	44	Good	
FIBI054	Lamington River	Hunterdon	Optimal	36	Fair	
FIBI055	Paulins Kill	Warren	Suboptimal	44	Good	
FIBI056	Clove Brook	Sussex	Suboptimal	38	Good	
FIBI057	Musconetcong River	Sussex	Optimal	46	Excellent	
FIBI058	Musconetcong River	Warren	Suboptimal	32	Fair	
FIBI059	Pascack River	Bergen	Marginal	34	Fair	
FIBI060	Musquapsink Brook	Bergen	Suboptimal	22	Poor	
FIBI035a	Goffle Brook	Passaic	Marginal	36	Fair	

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

Potentially Impaired Sites

Beaver Dam Brook - FIBI045

Impacts to the fish community of Beaver Dam Brook are related to the hydrology and land use of the surrounding watershed. The stream was littered with garbage and debris, as the surrounding park and apartment complex provide little to no riparian buffer (Figure 6). The right descending bank was armored with fenced rock revetment and the stream exhibited signs of severe flash flooding and bank erosion (Figure 7). The upstream watershed of Beaver Brook consists of 43% urban land use, along with 12% impervious cover which have likely influenced the hydrology of the stream.

The substrate throughout much of the sample reach was covered in a thin layer of silt which has likely impaired the aquatic macroinvertebrate community and the specialized fish which feed on them. The stream provided little natural habitat, as many fish were collected in and around debris piles and shopping charts deposited in the stream.

Figure 6. Debris in the stream.

Figure 7. Gabion reinforced bank on Beaver Dam Brook

The fish community lacked insectivorous cyprinids and largely consisted of tolerant and generalist species (43% and 50% respectively). The invasive green sunfish increased in proportional abundance from almost 13% in 2002 to 27% in 2007.

<u>Clove Brook - FIBI046</u>

While performing site reconnaissance in mid-June and also while performing fish surveys on July 31, 2007 a strong gasoline smell was noted near several outfalls around the Route 23 bridge crossing. In addition, a strong petroleum/oil smell was emitted from the right descending bank around the 50-meter mark. DEP's Northern Enforcement Program was contacted to investigate the site for potential violations. The right descending bank from ~20 to 75-meters was severely eroded with portions of the gas station parking lot and retaining wall sloughing off into the stream (Figure 8). Sections of the stream with little canopy cover, especially near the start, exhibited heavy periphyton growth (Figure 9).

Figure 8. Collapsed retaining wall.

Figure 9. Heavy periphyton growth in Clove Brook.

The fish assemblage was dominated by blacknose dace (59%) and tolerant and generalist species. Overall, species richness (8) and species diversity (H' = 1.28) were relatively low. Although several wild brown trout including a few young-of-the-year were collected, many fish including redbreast sunfish and adult brown trout were thin and appeared to be in poor health.

Ramapo River - FIBI052

Despite the heavy bank erosion along the left descending bank, this stretch of the Ramapo River contained numerous snags and good fish habitat complexity (Figure 10). Several pools were fairly deep which made electrofishing difficult. The conductivity was high (551 μmhos/cm) and there was a strong smell of sewage throughout the stretch. The overall habitat was rated "sub-optimal" (112) as the stream lacked adequate bank vegetation and riparian buffer on the left descending bank and few riffles were encountered within the stretch.

Figure 10. Sandbags used to reinforce bank.

The fish community was relatively healthy and exhibited good species richness and diversity. Several intolerant species were collected including 29 cutlips minnow and 1 brown trout. Results indicated some trophic imbalance, with generalist feeders comprising almost half of the total fish collected.

Lamington River - FIBI054

The instream and surrounding habitat for this stretch was rated "optimal" (178) with no obvious indicators of impairment. The river is very wide, but too shallow in several spots to employ barge electrofishing typically a more appropriate gear type for rivers this size. Although backpack electrofishing was difficult, 495 fish were effectively collected. The proportion of top predatory fish was low and resulted in a low metric score, but sampling gear may have attributed to the low catch of these species. Top predatory fish, such as smallmouth bass and trout can easily escape capture when sampling larger deeper streams.

A large proportion of fish had fin deformities which were most likely related to the abundant crayfish population in the river. Most fish with damaged fins were benthic species, such as white sucker, which are in contact with bottom dwelling crayfish. Several intolerant fish species were collected including brown trout, brook lamprey, and shield darter. A total of seven wild brown trout, including five young-of-the-year were collected in this FW2-TPC1 stream (Figure 11).

Figure 11. Wild brown trout collected on the Lamington River.

<u>Musconetcong River - FIBI058</u>

This section of the Musconetcong River received a “Fair” (32) Fish IBI rating along with a “Sub-optimal” (153) habitat rating. Although there were no obvious signs of impairment, the sample stretch lacked adequate fish habitat. Most fish were collected in eddies behind large boulders, as only a few snags and limited bank habitat was present. Although a large percentage of the habitat sampled was riffles, few insectivorous cyprinids were collected. Overall, the diversity was low (H` = 1.28) with American eel comprising 64% of the total. Common benthic species such as longnose dace and tessellated darter were low in abundance and species richness was generally low for all four richness metrics.

<u>Pascack River - FIBI059</u>

This reach of the Pascack River is characteristic of a stream impacted from alterations to the stream’s natural hydrology as a result of surrounding land use. The surrounding watershed consists of 81% urban land use based on 2002 GIS data and aerial photography. This high proportion of urbanization provides little riparian buffer and protection to the river from run-off from the abundant impervious cover in the area. Overall, the conductivity was relatively high (596 μmhos/cm), the stream was slightly turbid, a high proportion of the substrate consisted of fine sediments (40%), and several outfalls were present within the sample stretch. The fine sediments comprising a large proportion of the substrate is frequently disturbed and likely smothers benthic species (Figure 12).

Figure 12. Safety cone buried in the shifting sediments of the Pascack River.

<u>Goffle Brook - FIBI035a</u>

Goffle Brook suffers from severe flash flooding which deposits garbage/debris and frequently shifts the substrate as evidenced by the newly formed gravel bars. Overall, the habitat was rated "marginal" (85) mainly as a result of poor substrate, bank erosion, and lack of bank vegetation and riparian buffer. The right descending bank is bordered by Goffle Park with mowed grass to the edge of the bank, while the left descending bank is bordered by an industrial park. Several storm water outfalls present along the left descending bank drain run-off from the industrial park and road which has likely led to the high conductivity measured and the oily sheen observed in several sections of the stream (Figure 13).

Figure 13. Storm water outfall on Goffle Brook.

Impaired Sites

Shabakunk Creek - FIBI041

The habitat of Shabakunk Creek was rated "sub-optimal" (129) with some obvious sign of stress and degradation. The dissolved oxygen concentration was rather low (6.18 mg/L) for early June and the stream had a strong sewage smell which may have increased the stream's biological oxygen demand (BOD). The substrate of runs and pools was covered with a silt layer likely resulting from erosion, as erosion scars and sediment bars were present throughout the stretch (Figure 14). The stream was littered with bottles and garbage throughout the stretch. Despite many impairments, the stream did possess many snags, large woody debris, and undercut banks which provide good habitat for fish. In addition, the stream was well shaded with abundant overhead cover and a good riparian buffer along the left descending bank.

Figure 14. Bank erosion and scouring on Shabakunk Creek.

The fish community showed signs of impairment, as insectivorous cyprinids declined from previous sampling events, top predators were scarce (0.9%), but generalist species were overly abundant (54%) - all indicators of trophic imbalance. In addition, a number of individuals had some form of external deformity which is typically a result of severe organic pollution (Figure 15). In addition, green sunfish, an invasive species, was abundant and had hybridized with native *Lepomis* species.

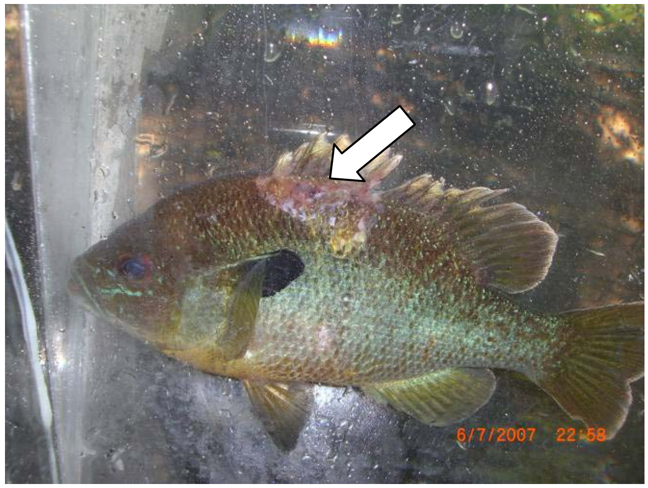


Figure 15. External deformity on a redbreast sunfish.

The most recent AMNET sampling event in 2003 resulted in a “poor” rating for site AN0114, located 0.5 miles downstream of the Fish IBI site. The habitat for this site was rated “marginal” (100). The macroinvertebrate community was dominated by Naididae, a family of relatively tolerant worms. In addition, no EPT taxa were collected.

Elizabeth River - FIBI042

The Elizabeth River received the lowest Fish IBI score (12) since the program was initiated in 2000. The banks were severely eroded with little vegetation to provide protection (Figure 16). The substrate consisted of a high proportion of clay and silt providing limited fish and macroinvertebrate habitat. 2005 sampling of the river for various chemical parameters indicated Surface Water Quality Standards violations for dissolved oxygen, copper, and lead. The dissolved oxygen concentration for the mid-August water quality sampling event was 3.55 mg/L with a saturation level of just 42.8%. Low dissolved oxygen concentrations, especially at night when oxygen is no longer produced, limit the fish species and number of fish capable of surviving in a system. Copper concentrations (23.9 µg/L) were above the criteria for aquatic life.

Figure 16. Severe bank erosion on Elizabeth River

Fish sampling in mid-June 2007 resulted in the collection of just 28 fish, the lowest fish total recorded in the history of the program. In addition, just three species were collected, mummichog, banded killifish, and green sunfish. All three fish species are designated as tolerant/generalist species and are able to adapt and survive under harsh environmental conditions. Mummichog, representing 82% of the fish collected, are a species extremely tolerant of low dissolved oxygen concentrations and chemical/heavy metal contamination (Figure 17). Studies have shown the mummichog to sustain growth at dissolved oxygen concentrations as low as 1 mg/L, mainly as a result of surface respiration (Stierhoff et al. 2003).

Figure 17. Mummichog collected on the Elizabeth River.

The fish collected exhibit no signs of a balanced fish community, but instead appear to be those specimens able to survive in the river. Overall, 3.6% of the fish collected had external deformities, which, as a result, was the only metric which did not receive a score of “1”. Subsequently, this metric was the reason the Elizabeth River site received a total score of “12” instead of “10”, the lowest possible Fish IBI score.

The most recent AMNET sampling event was 2004, prior to the surface water quality violation in 2005. This monitoring resulted in a “fair” rating with limited impairments to the macroinvertebrate community.

<u>Third River - FIBI043</u>

The habitat was rated “marginal” (104) with abundant debris throughout the stretch. The stream lacks a riparian buffer, as it is bordered to the east by the Garden State Parkway and to the west by numerous parking lots (Figure 18). The stream is prone to flash flooding from run-off from the surrounding impervious surfaces. In addition, the conductivity was very high (728 μmhos/cm), a likely result of run-off. The substrate of the lower section near the start consisted mainly of sand/gravel covered with silt, while the upper section contained more cobble.

Figure 18. Proximity of NJ Garden State Parkway to Third River.

The fish community consisted mainly of tolerant and generalist species with the invasive green sunfish the most abundant member of these two metrics. The 305 green sunfish collected at Third River on June 12, 2007 is the largest total ever collected since the program was initiated in 2000. Five of the six fish designated as tolerant in New Jersey were collected, including green sunfish, mummichog, banded killifish, white sucker, and American eel. The fish community was characterized by low species richness, no intolerant species were collected, and the trophic community was imbalanced. A single largemouth bass was collected which represented the only top predator and proportionally represented only 0.08% of the fish collected.

In 2003, AN0292A received a "poor" AMNET rating and "marginal" habitat (101). The macroinvertebrate community largely consisted of the freshwater crustacean Gammaridae, while just one EPT was collected.

<u>Deepavaal Brook - FIBI044</u>

This sampling site received the lowest habitat score "poor" (58) since the program was initiated in 2000. The stretch was characterized by limited fish habitat, channelization, heavy bank scouring, little to no bank vegetation, heavy fine sediment loading, relatively high conductivity (604 μmhos/cm), and numerous outfalls (Figure 19). In addition, a milky white effluent was entering the stream as a result of run-off from the parking lot of a stone cutting operation (Figure 20).

Figure 19. Storm water outfalls on Deepavaal Brook.

Figure 20. Effluent discharging into Deepavaal Brook.

A total of just 89 fish were collected which consisted mainly of tolerant and generalist species. Tessellated darters were the only benthic insectivores collected and no insectivorous cyprinids were collected. The lack of insect feeding minnows is an indication of trophic imbalance and potential impairment to the benthic macroinvertebrate community and those fish which prey upon them. These organisms may be impacted by the high composition of fine sediments (65%) which can fill interstitial spaces and smother benthic communities (Figure 21).

Figure 21. Fine sediment bar deposited in Deepavaal Brook.

AMNET site AN0271 has been rated "poor" in each of the two rounds of sampling in 1998 and 2003. In 2003, the macroinvertebrate assemblage consisted mainly of Tubificidae, an extremely tolerant family of worms. The habitat for this site, located three quarters of a mile downstream of the Fish IBI site, was rated "marginal" (99) in 2003.

Musquapsink Brook - FIBI060

The habitat was rated "sub-optimal" (110) and lacked habitat complexity, as 75% of the stream was classified as run habitat. The large amount of impervious cover (26%) and subsequent storm water run-off has channelized this section of stream, resulting in a lack of natural sinuosity and flow regime. The substrate was mainly sand/gravel covered by a layer of silt. In addition, the stream was littered with garbage/debris, along with yard wastes which had been dumped into the stream by local residents (Figure 22). The conductivity was high (657 µmhos/cm) and a strong petroleum/chemical smell appeared to come from in and around the stream near several manholes on the right descending bank.

Figure 22. Lawn clippings dumped into Musquapsink Brook.

Overall, fish abundance and richness were low, as just 147 fish representing 7 species were collected. No cyprinids were collected, while generalist feeders were abundant, an indication of trophic imbalance and impairments to the benthic macroinvertebrate community. Over one quarter of the fish collected were green sunfish, a nonnative invasive sunfish able to tolerate harsh conditions and out-compete other native sunfish species.

Ireland Brook - FIBI051

The impairment at Ireland Brook is unclear. The habitat did not indicate any degradation, as the reach was rated "optimal" (165). The sample stretch had good depth/velocity regimes and good habitat complexity. The bank vegetation provided sufficient overhead cover and riparian buffer. The substrate, water chemistry, and fish community was more representative of a low gradient system. Although the area surrounding the sample stretch is mostly wooded, the watershed is mainly urban (55%). The headwaters of Ireland Brook are located in a heavy urbanized area which is likely influencing the downstream water quality and biotic integrity. The upstream watershed contains almost 19% impervious cover, which has likely impacted the downstream fish community. The headwaters of Ireland Brook is heavily influenced by stormwater run-off which is evidenced by large areas of sediment deposition and debris present throughout the headwaters and middle sections of the brook (Figures 23 and 24).

Figure 23. Garbage and debris accumulated in headwaters of Ireland Brook.

Figure 24. Numerous sediment bars formed in headwaters of Ireland Brook.

Similarly, AMNET site AN0433 was rated "fair' in both 1998 and 2005 while the habitat and water chemistry did not indicate a potential impairment. The habitat rating for this site ranged from "sub-optimal" (157) to "optimal" (183) over this time period.

Other Important Findings

Beaver Brook - FIBI047

Beaver Brook received a "Good" (40) Fish IBI rating along with a "sub-optimal" (154) habitat rating. The habitat did not score in the "optimal" range mainly as a result of old shoring structures along both banks and the close proximity of CR 618 to the stream. Two stocked rainbow trout were collected in this FW2-NT waterbody, which was sampled in mid-September (Figure 25). The ability to survive throughout summer months is an indication the stream has adequate flow, dissolved oxygen, and water temperatures for trout survival. In addition, several other intolerant species were collected including cutlips minnow and margined madtom. Based on water chemistry and the fish assemblage this stream has been nominated for upgrade to "trout maintenance".

Figure 25. Stocked rainbow trout collected in Beaver Brook.

Buckhorn Creek - FIBI048

Buckhorn Creek was rated “Excellent” (46) with “Optimal” (167) habitat rating. A total of 20 wild brown trout and three wild rainbow trout (Figure 26) were collected which included 12 young-of-the-year brown trout. The stream is already classified FW2-TPC1, but this data is important to monitoring the health of the stream over time.

Figure 26. Wild rainbow trout collected in Buckhorn Creek.

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 27). 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 28). 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.”

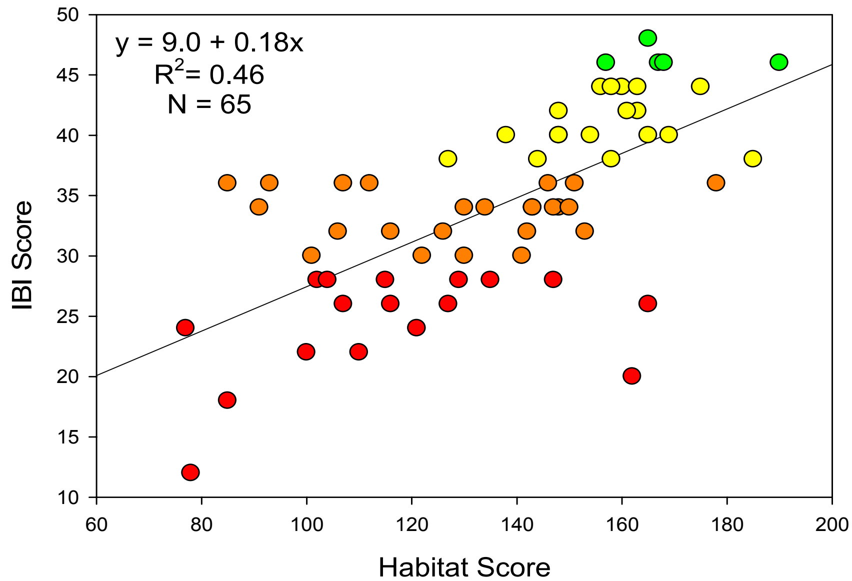


Figure 27. Linear regression comparing IBI and habitat scores.

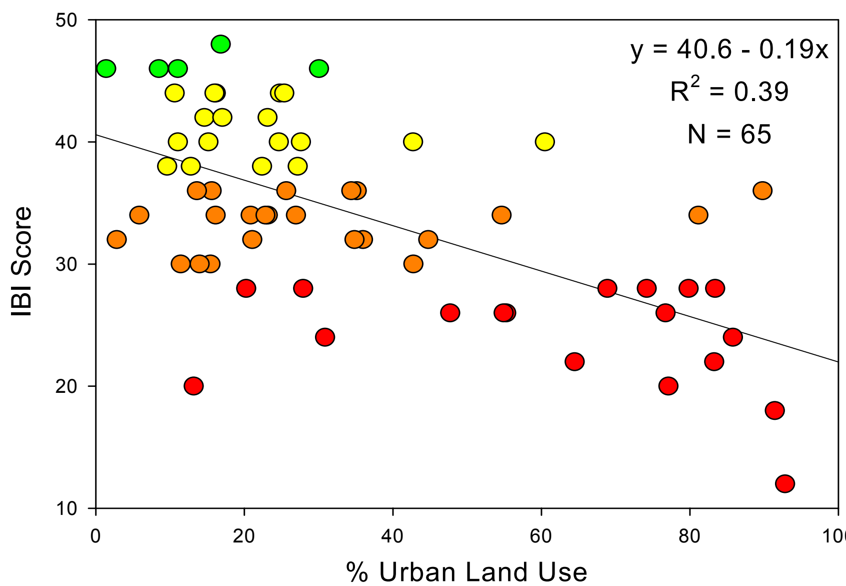


Figure 28. Linear regression comparing urban land use and IBI score.

TRENDS ANALYSIS

The completion of the 2007 sampling season marks the third year of the second round of Fish IBI sampling. The sites sampled in 2007 were originally sampled in 2002 and 2003. Those sites sampled in 2002 and 2003 were re-scored using the re-calibrated metrics in order to compare results over time (Table 8).

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

		Round 1 Results*		2007 Results		
FIBI Site	**Waterbody**	**IBI Score**	**IBI Rating**	**IBI Score**	**IBI Rating**	
FIBI041	Shabakunk Creek	34	Fair	28	Poor	
FIBI042	Elizabeth River	14	Poor	12	Poor	
FIBI043	Third River	22	Poor	28	Poor	
FIBI044	Deepavaal Brook	20	Poor	20	Poor	
FIBI045	Beaver Dam Brook	22	Poor	30	Fair	
FIBI046	Clove Brook	38	Good	34	Fair	
FIBI047	Beaver Brook	36	Fair	40	Good	
FIBI048	Buckhorn Creek	38	Good	46	Excellent	
FIBI049	Wallkill River	34	Fair	38	Good	
FIBI050	Lubbers Run	40	Good	38	Good	
FIBI051	Ireland Brook	24	Poor	26	Poor	
FIBI052	Ramapo River	32	Fair	36	Fair	
FIBI053	Mulhockaway Creek	44	Good	44	Good	
FIBI054	Lamington River	40	Good	36	Fair	
FIBI055	Paulins Kill	38	Good	44	Good	
FIBI056	Clove Brook	44	Good	38	Good	
FIBI057	Musconetcong River	38	Good	46	Excellent	
FIBI058	Musconetcong River	24	Poor	32	Fair	
FIBI059	Pascack River	30	Fair	34	Fair	
FIBI060	Musquapsink Brook	24	Poor	22	Poor	

*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 "fair" and "poor" remained relatively constant from Round 1 to Round 2 (Figure 29). The number of "excellent" sites increased to 10% in 2007 with a subsequent decrease in the proportion of "good" sites from 40% in Round 1 to 30% in Round 2. Overall, scores between rounds differed by less than two points, as the average score in 2002/2003 was 31.8 compared to 33.6 in 2007.

Significant scoring/rating changes occurred at several sites including the following: Shabakunk Creek (041), Beaver Dam Brook (045), Buckhorn Creek (048), Musconetcong River (057), and Musconetcong River (058) (Figure 30). Four 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.

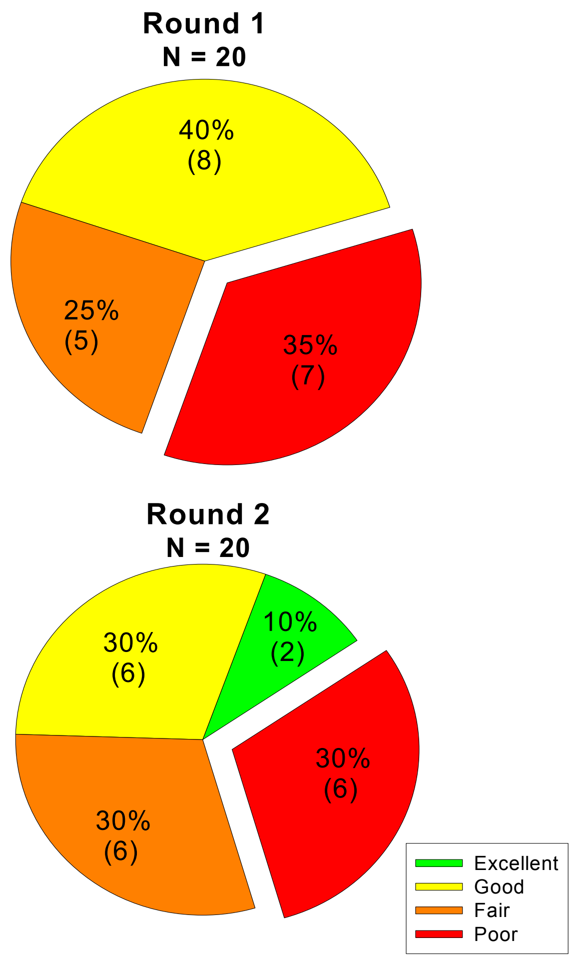


Figure 29. Ratings comparison for Rounds 1 and 2.

<u>Shabakunk Creek – FIBI041</u>

Shabakunk Creek exhibited a sharp decline in biological integrity from the year 2001 to 2007. Utilizing the newly re-calibrated metrics, this site would have received a score of 34 "fair" based on 2001 data, but recently declined sharply in 2007 with a score of 28 "poor".

The changes in biological integrity are likely related to the surrounding land use/land cover and hydrology. Increased sediment loading in the stream has impacted specialized feeders, such as insectivorous cyprinds, which have decreased from 54% in Round 1 to 25% in Round 2. Spottail and shallowtail shiners both exhibited a sharp decrease in abundance between rounds and satinfin shiner were not collected in this second round of sampling.

In contrast, generalist feeders increased in proportional abundance from 35% to 54%. This trophic change, from specialized feeding groups to more generalized feeders, is a common response usually related to degradation of riffle habitat, substrate composition, or impairments within the macroinvertebrate community. In addition, the invasive green sunfish increased in proportional abundance from 3% to 9% between rounds. Impacts to the resident fish community from green sunfish were even more evidenced by hybridization with native *Lepomis* sp., as two green sunfish/redbreast sunfish hydrids were collected. A large proportion of the fish collected had external deformities (DELT anomalies), usually an indication of stressful environmental conditions or organic pollution.

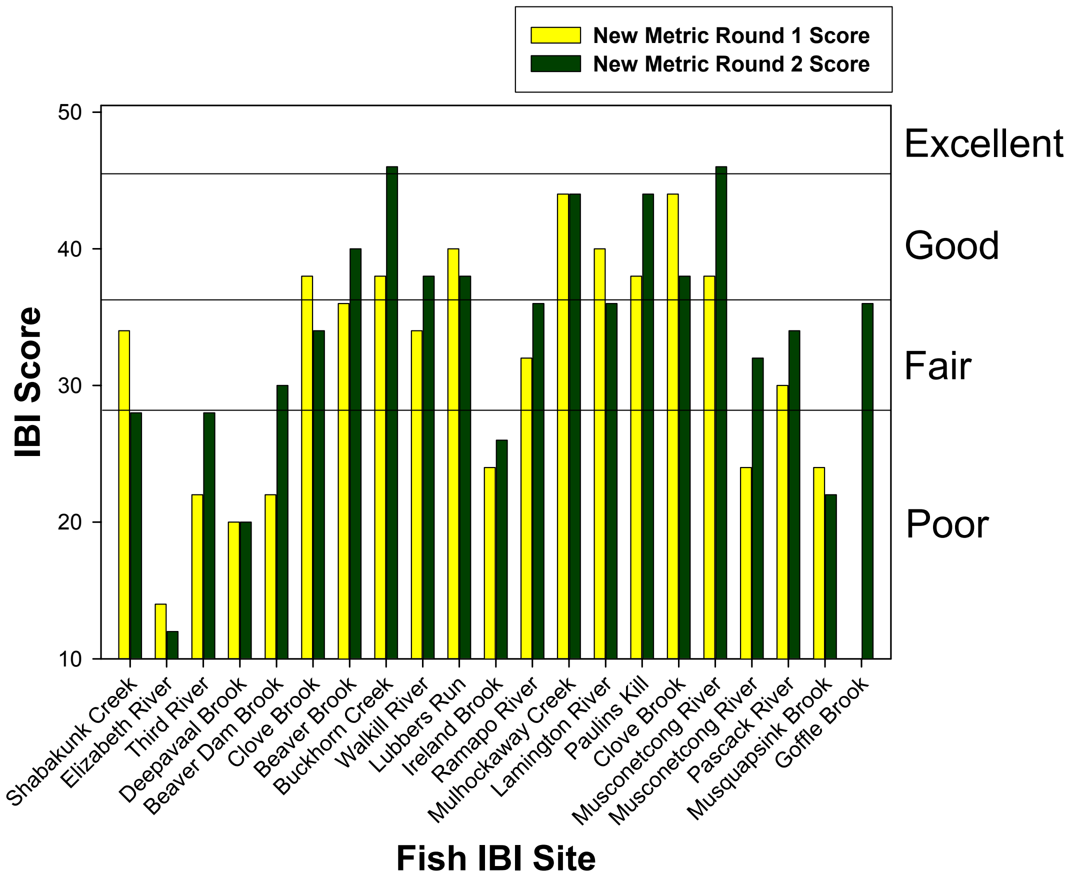


Figure 30. Comparison of ratings for Rounds 1 and 2 at individual sites.

<u>Beaver Dam Brook – FIBI045</u>

The biological integrity of Beaver Dam Brook increased from 22 "Poor" in Round 1 to 30 "Fair" in Round 2. Species richness in Round 1 was low, as just 8 species were captured, compared to 15 species collected in Round 2. Overall, the Round 2 sample exhibited better trophic balance and diversity. In 2002, almost 62% of the sample consisted of tessellated darters resulting in a low diversity (H` = 1.2), compared to 2007 (H` = 2.0). In addition, several specialized insect feeding minnows were only collected in Round 2 including satinfin shiner, blacknose dace, and fallfish.

<u>Buckhorn Creek – FIBI048</u>

The Fish IBI score and rating increased from 38 "Good" in 2002 to 46 "Excellent" in 2007. In 2002, diversity and species richness were low, as 60% of the fish collected were blacknose dace (H` = 1.4) and just 10 species were captured. In contrast, 19 species were collected in 2007 which also exhibited a higher diversity (H` = 2.1). In Round 1, the fish community lacked trophic balance, as no top predators and just one intolerant species were collected compared to the following top predators and intolerant species collected in Round 2: brown trout, smallmouth bass, rainbow trout, brook trout, largemouth bass, and margined madtom. A total of 31 stocked and wild brook, brown, and rainbow trout were collected in mid-July 2007 (Round 2), while one dead rainbow trout was observed and none were collected in early July 2002 (Round 1). Personal communications with biologists from the Bureau of Freshwater Fisheries indicated in recent years Buckhorn Creek had been impacted from an upstream quarry. It is unclear whether the fish community was impacted in Round 1 and is now in a state of recovery, but the most recent sampling event is more representative of the FW2-TPC1 classification.

Musconetcong River – FIBI057

The Fish IBI score and rating increased from 38 "Good" in 2002 to 46 "Excellent" in 2007. Although the fish community was similar between years, the 2007 sample exhibited better trophic balance, as proportional abundance of piscivores and insectivorous cyprinids were higher in Round 2 compared to Round 1. Although several intolerant species were collected in 2007, the four brown trout collected were stocked fish.

Musconetcong River – FIBI058

Biological integrity increased from 24 "Poor" in Round 1 to 32 "Fair" in Round 2. Although both sample rounds were dominated by American eel, the fish community collected in Round 2 was more diverse and balanced compared to Round 1. In Round 1, just 2 top predatory fish were collected compared to 28 in Round 2. Overall discharge was significantly lower in Round 2 (25.6 cfs) compared to Round 1 (318.6 cfs) which may have enabled a more efficient collection.

FURTHER INFORMATION

The current report summarizes the seventh 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 five years of the IBI can be obtained on the WM&S BFBM's web page: http://www.state.nj.us/dep/wmm/bfbm/fishibi.html or by calling 609-292-0427.

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APPENDIX 1
Second Revised List of New Jersey Freshwater Fishes

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

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

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

Abbreviations:

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

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

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

Condition Categories (modified from Karr et al. 1986)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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APPENDIX 3

IBI AND HABITAT SCORING SHEETS/GRAPHS

LABEL

IBI SCORING SHEET

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

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

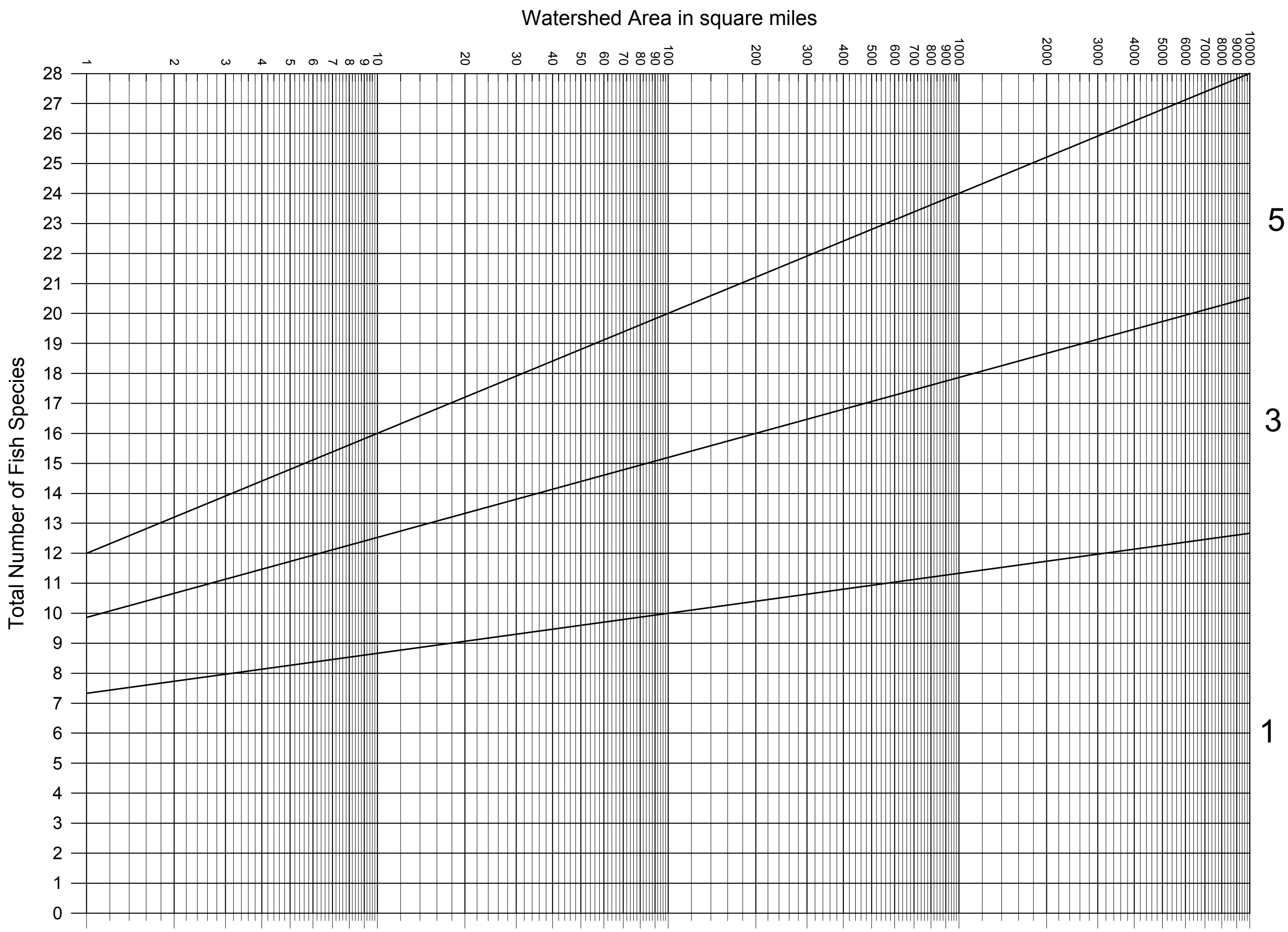
*whichever gives better score

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

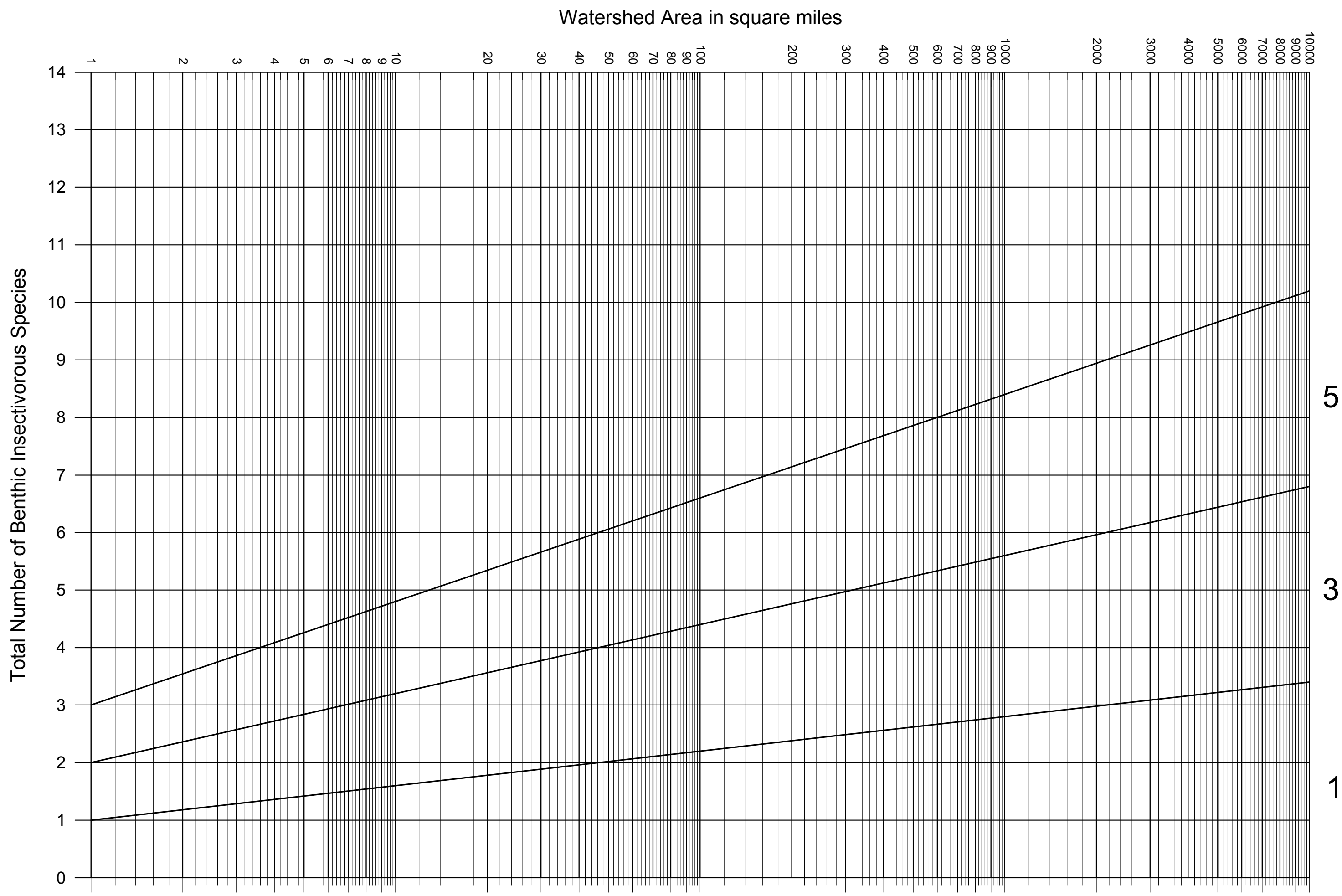
HABITAT SCORE

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

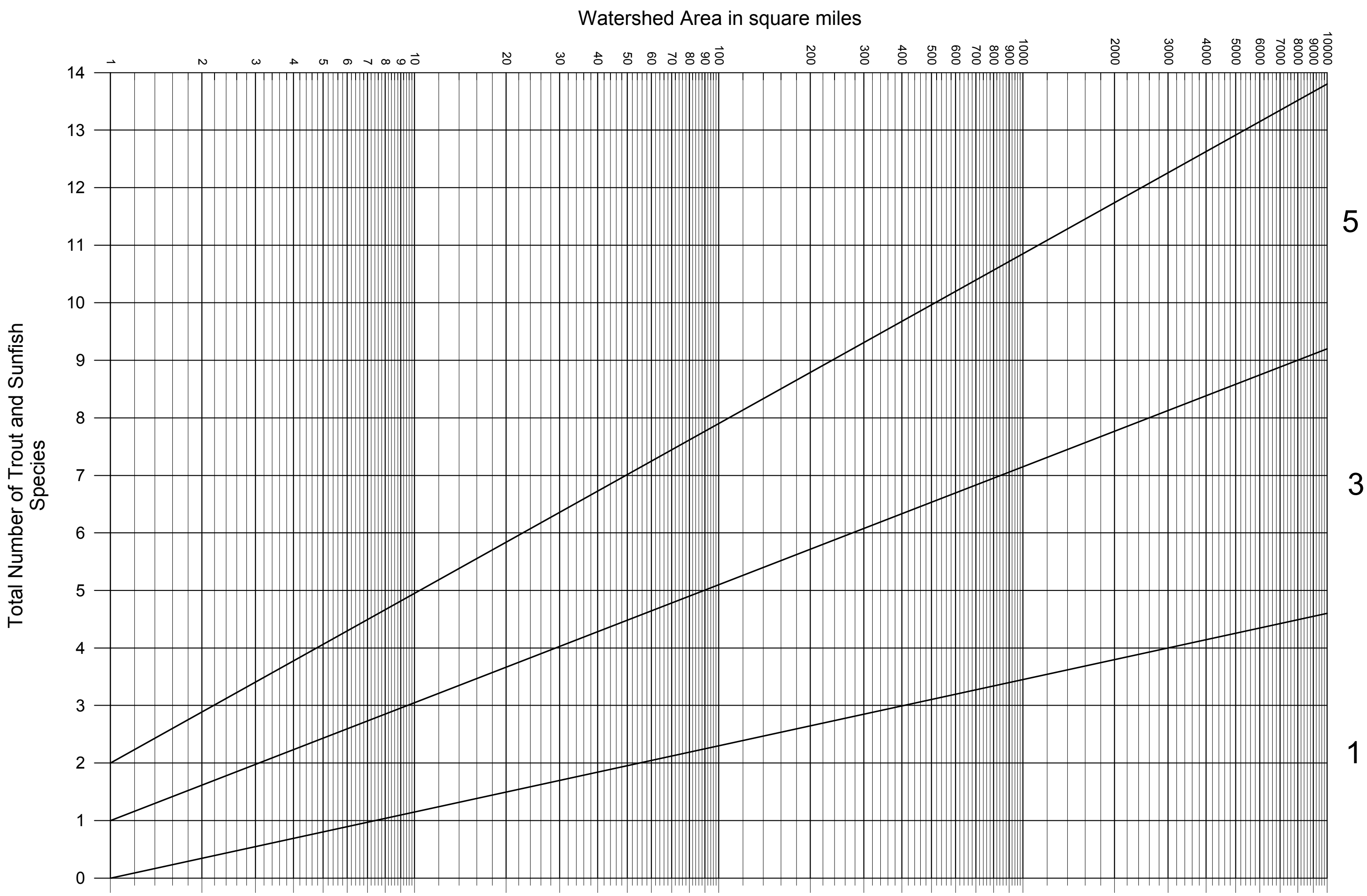
Total number of fish species versus watershed area for New Jersey ecoregion reference sites



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



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



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