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Jon S. Corzine, Governor

FISH IBI REPORT
2005 SAMPLING
Round 2, Year 1 of 5

Volume 1 of 2

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FISH IBI REPORT 2005 SAMPLING Round 2, Year 1 of 5

Volume 1 – Summary

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EXECUTIVE SUMMARY

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

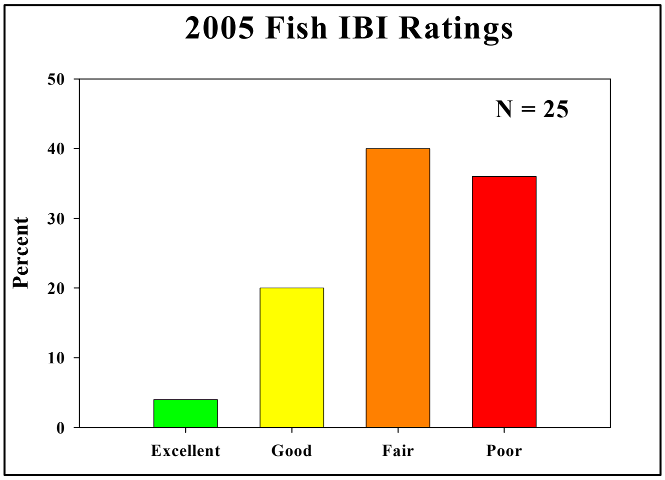
In order to address the limitations of chemical monitoring, DEP supplemented its chemical monitoring with biological monitoring which is based on the premise that biological communities are shaped by the long-term conditions of their environment and more accurately reflect the health of an ecosystem. Originally, the Bureau of Freshwater and Biological Monitoring (BFBM), within Water Monitoring and Standards (WM&S), only monitored benthic macroinvertebrate assemblages (aquatic insects, worms, clams, etc.) at over 800 stream stations throughout New Jersey. Benthic macroinvertebrate assemblages are generally reflective of short-term and local impairment.

In order to assess environmental conditions on a larger spatial and temporal scale, BFBM in 2000 began to supplement benthic macroinvertebrate monitoring with a new sampling program called the fish index of biotic integrity (FIBI). A 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 classified as “poor”, “fair”, “good” or “excellent”. In addition, habitat is evaluated at each site and classified as “poor”, “marginal”, “suboptimal” or “optimal”.

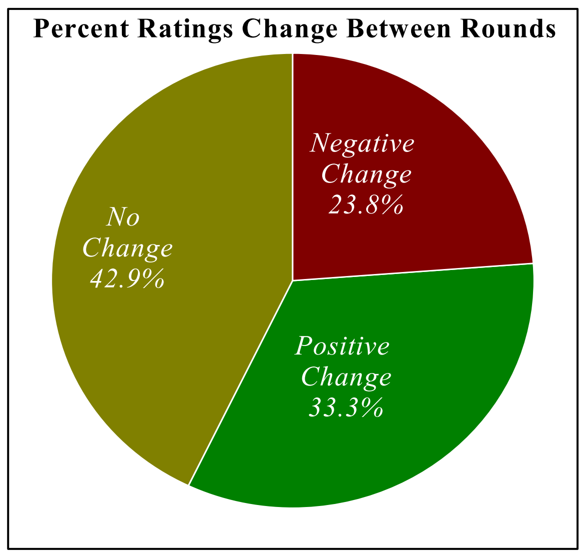
The data provided by the FIBI has become another component of the DEP's suite of environmental indicators. The data help to measure water quality use attainment and the Department's success in attaining the Clean Water Act goal of "fishable" waters as elaborated in the New Jersey Integrated Water Quality Monitoring and Assessment Report. IBI data will also be used to develop biological criteria, prioritize sites for further studies, provide biological impact assessments, and assess status and trends of the state's freshwater fish assemblages. Currently, FIBI data collected from northern New Jersey is used in an approach to identify candidate waters for upgrade to a Category One antidegradation classification (NJAC 7:9B) based on exceptional ecological significance.

With the completion of the 2004 sampling season, the DEP finalized a 100 station Fish IBI monitoring network in northern New Jersey. Stations will be visited once every five years as part of the BFBM’s ambient monitoring efforts. Data are currently being collected for the planned expansion 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.

The 2005 season marked the start of the second round of sampling, in which we returned to those network sites originally sampled in 2000. 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. Refinements also included the replacement of the proportional abundance of white suckers metric with the proportional abundance of tolerant species. The 2005 season is the first year in which the revised metrics will be utilized. Previous year's 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 2005, the sixth year of sampling, 25 sites were sampled. One site was rated "excellent", five were "good", ten were "fair", and nine sites received a "poor" rating.



Overall, ratings from Rounds 1 and 2 for the same 20 sites originally sampled in the year 2000 were similar when Round 1 sites were rescored utilizing the new metrics. In Round 1, 80% of sites were rated "fair" or "poor" compared to 70% in Round 2. In addition, the number of "excellent" sites dropped from 15% to just 5% in 2005 with a subsequent increase in the proportion of "good" sites from 5% in Round 1 to 25% in 2005. As a result, a third of the sites exhibited a positive ratings increase, while the ratings for nearly 43% of sites remained unchanged (for further information see Trends Analysis section).



INTRODUCTION

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

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

Data provided by the IBI have become another component of the DEP's suite of environmental indicators. 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 is used to prepare the 2006 Integrated List and

[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.

Report.

IBI data will also be used to develop biological criteria, provide biological impact assessments, and assess status and trends of the state's freshwater fish assemblages. Current uses of IBI data collected from northern New Jersey include prioritizing sites for further studies and identifying candidate waters for upgrade to a Category One antidegradation classification (NJAC 7:9B) based on exceptional ecological significance.

Table 1. Advantages of using fish as indicators of environmental health (Barbour et al. 1999).

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

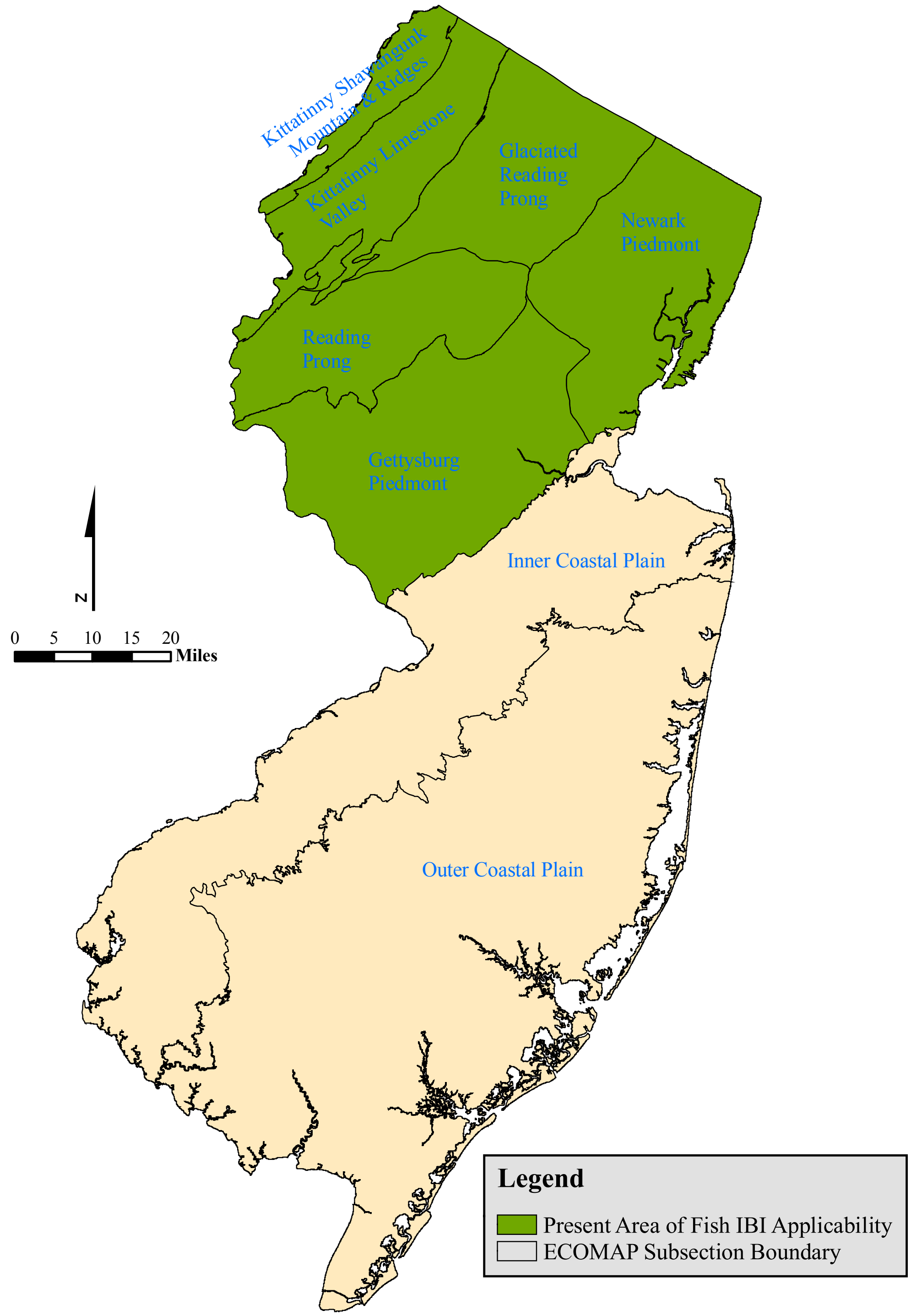


Figure 1. Map of New Jersey Ecoregions and region of Fish IBI applicability.

Electrofishing

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

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

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 the Bureau of Freshwater and Biological Monitoring for confirmation (at present, the 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 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 the 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). The analysis and final results were reviewed by members of the NJ Fish IBI Workgroup which includes members from WM&S, NJ Fish and Wildlife, USEPA Region 2, USGS, and the Philadelphia Academy of Natural Sciences. Each metric was examined individually to ensure sensitivity to urban and agricultural land uses, statistically significant separation between least impaired and most impaired sites, adequate scoring distribution, and correlation with habitat scoring. Linear regression models were used to assess drainage correlation and the need for scoring modification.

Table 3. Refined Fish IBI Metrics.

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

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

In addition, each metric was analyzed for classification efficiency to ensure minimal overlap between least impaired and most impaired sites (Table 4). The classification efficiency was calculated as the proportion of least impaired sites with individual metric scores greater than or equal to 3 and the proportion of most impaired sites with individual metric scores than less 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. Correlation among metrics ranged from 0.01 to 0.67 (Table 5) 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 the 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, and 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

[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 Bureau's Fish IBI refinement. The area under the MSR line is trisected by two diagonal lines.

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

1. Total number of fish species:

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

2. Number of benthic insectivorous species:

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

3. Number of trout and sunfish species:

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

4. Number of intolerant species:

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

5. Proportion of tolerant individuals:

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

Trophic Composition

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

6. Proportion of individuals as generalists:

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

7. Proportion of individuals as insectivorous cyprinids:

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

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

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

Fish Abundance and Condition

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

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

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

This metric provides a relative measure of the condition of individual fish (Figure 3). Similar to metric nine, this metric is especially useful in distinguishing streams with serious water quality impacts. This metric is intended to detect impacts in streams highly contaminated by chemicals. A significant relationship between the incidence of blackspot disease and environmental quality has not been established for New Jersey streams. As a result, blackspot disease is excluded from use in this metric.

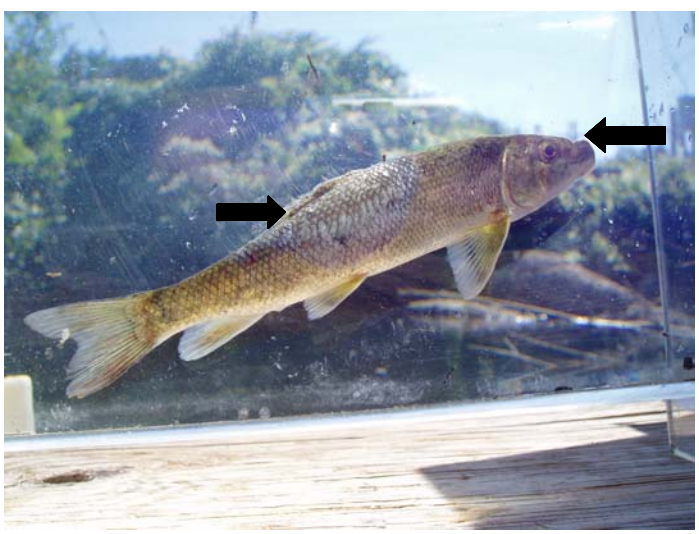


Figure 3. White sucker with multiple anomalies.

RESULTS

In 2005, the first year of the second round of sampling, 25 sites were sampled. One site was rated "excellent", five were "good", ten were "fair" and nine were "poor" (Figure 4). The habitat ratings for the 2005 sites consisted of two sites with "optimal" habitat, seventeen "sub-optimal", and six sites with "marginal" habitat.

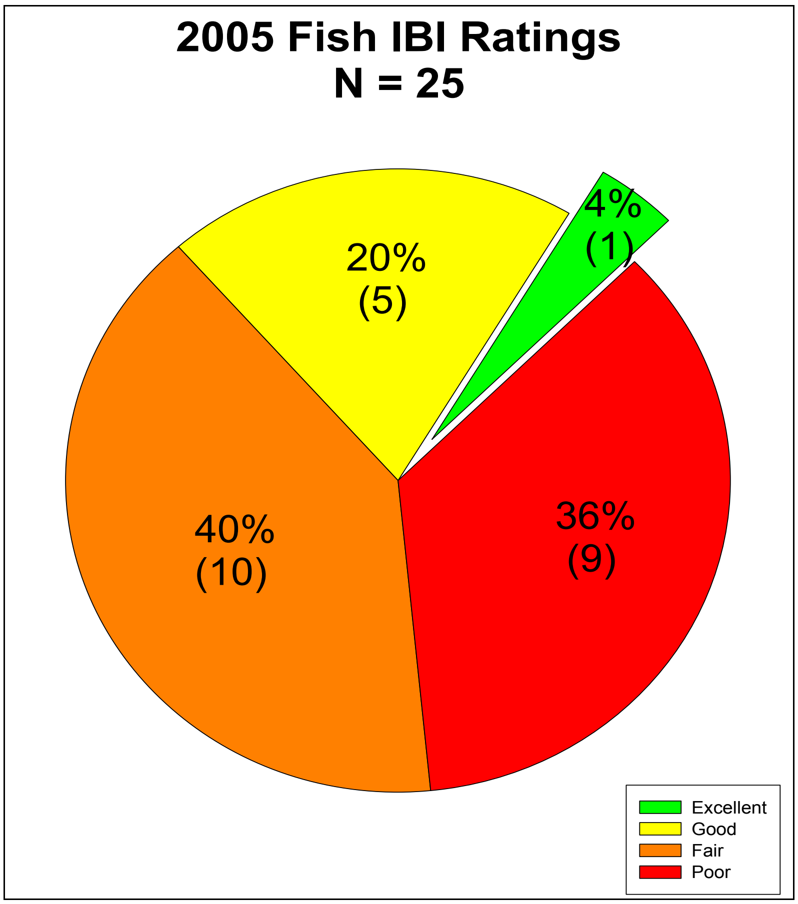


Figure 4. Summary of the 2005 ratings for 25 sites in northern New Jersey.

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 nine (9) impaired sites were identified (FIBI 006, 009, 014, 016, 017a, 019, 020, 085a, 097a) (Figure5; Table 3). In addition, ten sites were classified as “fair” and are suspected of having impacts. The drainage size calculation was revised using GIS following the 2004 sampling season. This resulted in the elimination of 1 site, classified as “fair” (FIBI017), due to a drainage size less than 5 square miles. The data from this site has been included in the report, but will not be used in future analysis or monitoring.

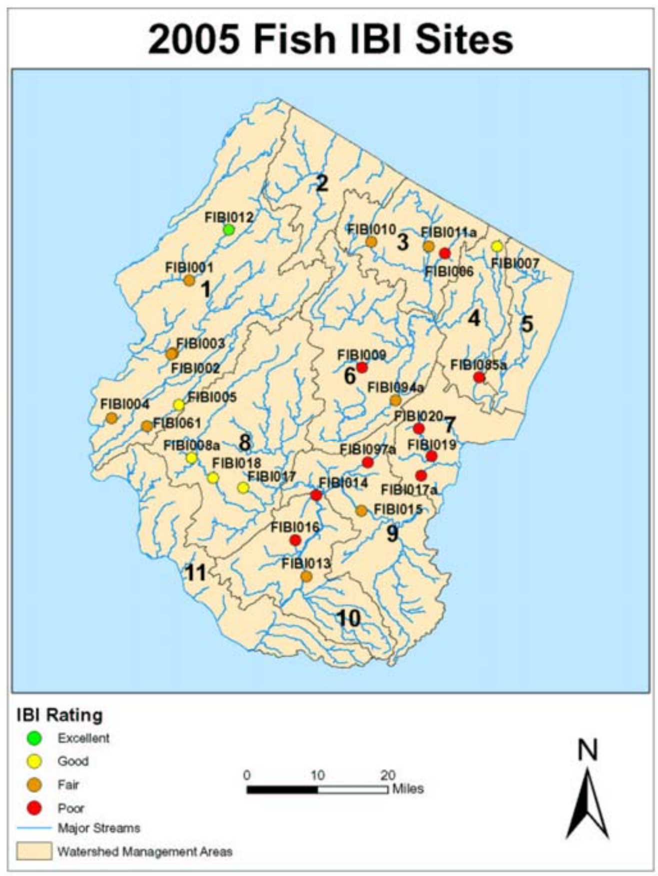


Figure 5. Location of 2005 Fish IBI sites.

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

Table 7. Results of 2005 Round 2 Fish IBI sampling[1].

FIBI Site	Waterbody	County	Habitat Rating	IBI Score	IBI Rating
FIBI001	Paulins Kill	Warren	Suboptimal	34	Fair
FIBI002	Furnace Brook	Warren	Suboptimal	36	Fair
FIBI003	Pequest River	Warren	Suboptimal	30	Fair
FIBI004	Lopatcong Creek	Warren	Suboptimal	34	Fair
FIBI005	Musconetcong River	Hunterdon/Warren	Optimal	42	Good
FIBI006	Ramapo River	Bergen	Suboptimal	28	Poor
FIBI007	Saddle River	Bergen	Suboptimal	40	Good
FIBI008a	Sidney Brook	Hunterdon	Optimal	44	Good
FIBI009	Whippany River	Morris	Suboptimal	26	Poor
FIBI010	Clinton Brook	Passaic	Suboptimal	32	Fair
FIBI011a	Meadow Brook	Passaic	Marginal	36	Fair
FIBI012	Neldon Brook	Sussex	Suboptimal	46	Excellent
FIBI013	Heathcote Brook	Middlesex	Suboptimal	32	Fair
FIBI014	Royce Brook	Somerset	Suboptimal	26	Poor
FIBI015	Mile Run	Middlesex	Marginal	36	Fair
FIBI016	Pike Run	Somerset	Suboptimal	28	Poor
FIBI017*	Pleasant Run	Hunterdon	Suboptimal	42	Good
FIBI017a	Rahway River S.B.	Middlesex	Marginal	24	Poor
FIBI018	Raritan River S.B.	Hunterdon	Suboptimal	40	Good
FIBI019	Rahway River	Union	Suboptimal	28	Poor
FIBI020	Rahway River	Union	Marginal	26	Poor
FIBI061	Musconetcong River	Warren	Suboptimal	34	Fair
FIBI085a	Second River	Essex	Marginal	18	Poor
FIBI094a	Passaic River	Morris	Suboptimal	32	Fair
FIBI097a	Green Brook	Union	Marginal	22	Poor

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

*Site was dropped from future FIBI monitoring due to drainage < 5 sq. miles.

Potentially Impaired Sites

Paulins Kill - FIBI001

The conductivity was relatively high (516µmhos) likely a result of upstream land use practices. The flow and overall discharge (11.3 cfs) were low, as much of the sample stretch consisted of slow moving run and pool habitat with few riffles.

Figure 6. Lack of flow and habitat complexity on Paulins Kill.

The fish assemblage consisted of a large proportion of generalist species with redbreast sunfish, white sucker, and bluegill comprising the bulk of the catch. The substrate at the site was mainly bedrock with little gravel or cobble for macroinvertebrate colonization. This combined with the lack of riffle habitat and the fine sediment load is likely the cause for low insectivorous cyprinid abundance (Figure 6).

Ambient Biological Monitoring Station AN0025 located 1.2 miles upstream of the Fish IBI station, received “non-impaired” ratings in 1992 and 1997 and a “moderately” impaired rating in 2002. The percent EPT taxa dropped from 41 and 48 percent in 1992 and 1997, respectively to 7 percent in 2002.

Furnace Brook - FIBI002

The source of the potential impairment at the Furnace Brook (FIBI002) is unclear and difficult to pinpoint based this single sampling event. Siltation was noted in the lower portion of the sampling stretch, but the substrate in the upper portion was relatively clean. The site has good overhead cover, bank vegetation, riparian buffer, and does not appear prone to major flooding and erosion. Oxford Textile located approximately 2 miles upstream of the sample location has had numerous operational violations and has been implicated as the cause of several fish kills in Furnace Brook. From 2001 through 2003, the plant was cited for 18 violations including the following: Bioassay, Phenols, Phosphorous, Oil and Grease, MBAS/Surfactants, and BOD/COD (NJPDES No. NJ0004901).

The fish assemblage lacked intolerant species and the proportional abundance of insectivorous cyprinids was low. In addition, the sample consisted mainly of tolerant and generalist species adapted to survive under adverse conditions.

Ambient Biological Monitoring site AN0042, located approximately 0.6 miles downstream, received a "severe" impairment rating in 1992 and "moderate" impairment ratings in 1997 and 2002. In 1997, 93% of the sample consisted of worms, while the 2002 sample consisted mainly of blood red chironomids typically found in oxygen devoid and degraded environments.

Pequest River – FIBI003

This stretch of the Pequest River is characterized by a high silt load, high conductivity, and lack of habitat complexity, as only a small proportion of riffle habitat was available in the stretch. Although the water temperature was low and dissolved oxygen concentration was high, only two trout were collected in this stretch. The Pequest River is heavily stocked in this region which is just downstream of the Pequest Hatchery and the "No Kill" fly-fishing only stretch. The substrate throughout the stretch was characterized by heavy silt/mud deposition in runs and pools along with severe substrate embeddedness in runs. Although bank erosion was noted for both banks, the sediment loading is likely coming from upstream land use activities, as the conductivity was also relatively high (546 µmhos). In addition to the aforementioned habitat impairments, a strong smell of sewage was noted and a small tributary with foamy water entered the Pequest River just upstream of the start (Figure 7).

Figure 7. Small tributary with foam entering Pequest River.

The fish assemblage consisted mainly of white suckers, tessellated darters, and American eels. A trophic imbalance was evident, as insectivorous cyprinid proportional abundance and richness were low and trout or piscivores were lacking, while the portion of generalist feeders represented almost half (48%) of the fish collected. In addition, the proportion of tolerant species was high (58%) and a number of fish had external deformities including fin erosion and lesions.

Lopatcong Creek - FIBI003

The surrounding land use consists of agriculture with some new housing developments upstream of the sample location. It is unclear whether these land use practices are adversely impacting the resident fish population. The substrate mainly consists of sandy substrate with few boulders and few snags which provide fish habitat (Figure 8). The stream is likely prone to severe flooding, as there is evidence of new gravel bar formation and bank scouring. The banks along the bridge crossing have been armored with riprap to stabilize the banks.

The fish community was dominated by riffle species and white suckers. Except for the large boulders and undercut banks in the first 20-30 meters, most of the stream lacked adequate habitat for larger piscivorous fish. Although 12 wild brown trout were collected, the overall proportion of top predatory fish was low, as was the number of trout and sunfish species. In addition, the proportion of generalist and tolerant species were relatively high. The combined impairment in the resident fish community may be an indication the system is in a state of transition or decline.

Figure 8. Lack of habitat complexity and overhead cover at Lopatcong Creek.

Ambient Biological Monitoring station AN0052, located 0.7 miles downstream of the Fish IBI site received "non-impaired" ratings in 1992 and 1997 and a "moderately" impaired rating in 2002.

Clinton Brook – FIBI010

The naturally low conductivity of the upstream reservoir and brook make this a low productivity stream which is difficult to sample. The conductivity at the time of sampling was relatively low (48 μmhos/cm) which made electrofishing problematical. In contrast to previous sampling events, barge electrofishing was employed to maximize power and efficiency. The site had substrate comprised mainly of silt with few riffles enabling fine sediments to settle in the numerous runs and pools.

Overall the fish community lacked trout or sunfish species, no intolerant species were collected, and overall fish abundance was relatively low. It is unclear whether the fish community is exhibiting sign of impairment or the stream's productivity is naturally low.

Ambient Biological Monitoring site AN0261 received a "severely" impaired rating in 1993, "non-impaired" in 1998, and "moderately" impaired in 2003.

Meadow Brook – FIBI011a

This stretch of Meadow Brook has good overhead cover, but lacks riparian buffer with numerous houses built to the streams edge. The stream bank consists of concrete walls, bulkheads, and residential retaining walls throughout much of the sample reach (Figure 9). Large amounts of debris and garbage were present just downstream of the sample area indicating the area is prone to severe flooding. A layer of silt covers most of the substrate with heavier deposition in the slower runs and pools. As a result of these impacts, the site received a “marginal” habitat rating (107).

Despite the degradation to instream and surrounding habitat, 65 wild brown trout were collected. The stream has adequate water temperature and dissolved oxygen to sustain wild trout population, but human encroachment is likely stressing the population. The remaining assemblage consists mainly of tolerant and generalist species adapted to survive under stressed conditions. Although siltation and embeddedness were evident in pools and runs, two benthic insectivorous species, blacknose dace and tessellated darter, were relatively common.

Ambient Biological Monitoring site AN0265a, located 0.81 miles upstream of the Fish IBI site has received “moderately” impaired ratings in 1998 and 2003.

Figure 9. Human encroachment at Meadow Brook.

__Heathcote Brook - FIBI013__

The stressors causing the potentially impaired fish community in Heathcote Brook are not evident. Some human and hydrologic impacts are evident, with bank erosion, lack of bank vegetation, and inadequate riparian buffer noted on the right descending bank. A landscape/nursery located on the right descending bank has removed most bank vegetation leaving the stream vulnerable to run-off of sediments.

__Mile Run – FIBI015__

The surrounding land use and impervious surfaces are impairing the habitat and fish community in Mile Run at the Easton Avenue crossing. The left descending shale bank has been severely eroded by flash flooding and has created a substrate which largely consists of red shale. In addition, riprap has been used to secure the left descending bank near the Easton Avenue crossing. The right descending bank exhibits some evidence of erosion and was littered with debris and garbage likely from a past storm event. The stream is prone to severe flash flooding which was observed while sampling on July 13, 2005. Shortly after electrofishing had concluded, a moderate rainfall caused stream levels to quickly rise. The numerous outfalls draining Easton Avenue and a nearby parking lot flooded the stream and raised stream levels 1-2 feet in just a few minutes (Figure 10).

In addition, the habitat was rated as “marginal”, floatables were observed, and the conductivity was relatively high (548 μmhos/cm). Throughout much of the sample reach a petroleum sheen was observed on the surface along with a strong smell of heating fuel near the end of the sample reach. The source of the heating fuel smell appeared to come from a large outfall on the left descending bank which drained a nearby parking lot (Figure 11). A follow-up visit was made on September 26, 2006 to determine the presence and possible source of the spill, but no fuel was detected.

The fish assemblage was not indicative of the impairments observed at the time of sampling. Although species richness and benthic insectivores were relatively low and no intolerant species were collected, the fish community did not represent a “severe” impairment. The intermittent presence of petroleum in the stream and run-off from nearby roads, therefore, may not have immediate impacts to the fish community.

Ambient Biological Monitoring site AN0429 received “moderately” impaired ratings in 1993 and 2004 and a “severely” impaired rating in 1998.

Figure 10. Active storm sewer outfall during storm event at Mile Run.

Figure 11. Concrete slabs below large storm sewer outfall on Mile Run.

Musconetcong River - FIBI061

The Musconetcong River site located in Franklin Township was re-sampled in 2005 after the site received a “poor” rating in 2003. Based on the hydrology and sampling difficulty at this site, along with the low species richness and overall fish abundance from the 2003 sample, the determination was made to re-sample using a more effective gear.

The barge electrofishing employed on July 12, 2005 was far more effective than the previous year’s sampling method (backpack electrofishing), but the high flows due to the natural hydrology and geology likely reduced sampling efficiency, as the discharge in 2003 and 2005 was 422.5 and 265 cfs, respectively. Benthic species, such as bullheads and madtoms are often missed when sampling in higher flows. The 2005 “fair” rating is not indicative of the surrounding habitat and is likely slightly underestimating the true biological integrity of the site. In addition, the inclusion of stocked trout in the DELT anomaly metric has reduced the score slightly. Stocked trout typically have numerous deformities as a result of being raised in concrete hatchery raceways. These deformities in stocked fish may not be indicative of poor water quality, but merely a result of the environment in which they are raised. In addition, several young-of-the-year brown trout were collected in the mainstem Musconetcong River, but likely originated from one of the numerous trout production tributaries in the area, such as West Portal Creek.

Passaic River – FIBI094a

The river level at the Passaic River site was low, with low flow during the sampling event in late August 2005. The discharge measured 11.7 cfs which is far below the median discharge of 36 cfs at the Chatham USGS gauging station for mid-August (USGS 2006). The conductivity was relatively high (586 μmhos) and fine sediments comprised a large proportion (25%) of the sediments, especially in pools and near the rivers edge. In addition, the stream receives a lot of direct sunlight, as 70.1% of the stretch was open canopy with sporadic bank vegetation and little riparian buffer.

The site received a "sub-optimal" (116) habitat rating and, overall, the stretch lacked adequate fish habitat. The low abundance of top predatory fish is likely a result of poor fish habitat, as few snags or undercut banks were present. Although the stream is trout stocked in the spring, no trout were collected.

Ambient Biological Monitoring site AN0230 located 0.09 miles downstream of the Fish IBI station received "moderately" impaired ratings in 1998 and 2003.

Impaired Sites

Ramapo River – FIBI006

The fish assemblages, water quality, and hydrology of this stretch of the Ramapo River are likely influenced by upstream and surrounding housing developments. Although the surrounding watershed landuse consists of only 15% urban, much of this stretch is within close proximity to large developments. The river has some bank vegetation and riparian buffer on the right descending bank, but lacks overhead cover (75.4% open canopy). This section of the Ramapo River is relatively wide and slow moving with few riffles. An excessive nutrient load is likely impacting the water quality, as the conductivity was relatively high (619 μmhos), moderate periphyton growth was observed, along with slight turbidity. The large amount of sunlight hitting the stream has likely influenced the relatively high water temperature (25.2°C), with a low dissolved oxygen concentration (6.74 mg/l). In addition, a strong chlorine smell was noted while sampling in mid-August.

Overall the site lacked adequate fish habitat, as the majority of specimens were collected in a couple of deep pools with structure or overhanging cover. Most of the stream was devoid of fish habitat or refugia for young fish. A number of specimens were inflicted with external anomalies including 6 of the 8 rockbass collected. In addition, two dead bullheads were discovered while sampling.

Whippany River – FIBI009

The fish community in the Whippany River has likely been impacted as a result of anthropogenic impacts. The land use of the surrounding watershed consists of 47% urban. Habitat surveys, conducted on 9/06/2005, noted many habitat impairments including inadequate buffer zone, numerous outalls, bank erosion and lack of fish habitat (Figure 12). A large proportion of the stream banks have been armored with large concrete blocks in an effort to reduce erosion. In addition, the stream consists largely of impervious surfaces, with several parking lots and a landscape company surrounding the sample reach, which has likely led to the relatively high conductivity (666 μmhos/cm) (Figure13).

Figure 12. Multiple outfalls on Whippany River.

Figure 13. Mulch pile on bank of Whippany River.

Almost 58% of the fish collected are considered generalists, while no insectivorous cyprinids were collected. The aforementioned impacts to the river have likely affected the benthic fish community and those species which rely on benthic macroinvertebrates for food. The impacts to the benthic community do not appear related to sediment loading, as the majority of the substrate was relatively clean boulder and cobble. In addition, no intolerant species were collected, richness and abundance were low, and a number of anomalies were noted.

Royce Brook - FIBI014

The "poor" rating for Royce Brook is likely related to anthropogenic impacts. With almost 49% of the surrounding watershed consisting of urban land use, the stream lacks adequate riparian buffer and bank vegetation, which has led to a "sub-optimal" (116) habitat rating. Several storm sewer outfalls drain nearby commercial and residential parking lots and impervious surfaces have likely caused an increase in flooding and bank erosion (Figure 14). Both banks consist mainly of mud with very little bank vegetation; the right descending bank has been lined with numerous concrete slabs to stabilize the bank and prevent further erosion. The use of concrete is unnatural, decreases bank vegetation, and often reduces habitat complexity. In addition, chemical analysis conducted on June 28, 2005 indicated a relatively low dissolved oxygen concentration which measured 63 percent saturation.

The water clarity was turbid and some sampling difficulty was noted due to the poor visibility. Although species richness was high, overall abundance was relatively low. Benthic and insectivorous species were not well represented, as a single benthic insectivorous species was collected and insectivorous cyprinds only represented 12 % of the overall catch.

The macroinvertebrate assemblage through the first three rounds of sampling were composed of Gammaridae and blood red chironomids. Blood red chironomids are typically found in environments devoid of oxygen, which supports the low dissolved oxygen concentration measured June 28, 2005. In addition, through three years of monitoring, only one EPT taxa has been collected. This Ambient Biological Monitoring site (AN0413) received "moderately" impaired ratings in 1993 and 2004 and a "severely" impaired rating in 1998.

Figure 14. Debris, concrete slabs, and storm sewer outfall on Royce Brook.

Pike Run - FIBI016

The impacts to the fish community of Pike Run are unclear. The surrounding watershed consists of a combination of urban, agricultural, and forested land use/land cover. The substrate consists of mainly bedrock covered with some silt and filamentous algae (Figure 15). The high conductivity (533 μmhos) and moderate periphyton growth is an indication of excess nutrients entering the stream. The banks showed signs of erosion with numerous erosion scars throughout the stretch.

The fish community is dominated by tolerant and generalist species comprising 52 and 55 percent of the overall catch respectively. Trophic imbalance was evident by the low proportion of insectivorous cyprinids and piscivores. The stream lacks adequate fish habitat for larger centrarchids and predators, as the stream consists mostly of slow moving runs.

An Ambient Biological Monitoring site, located 2.2 miles upstream received "moderately" impaired ratings in 1994 and 2004 and a "severely" impaired rating in 1999. The macroinvertebrate community in 1999 consisted mainly of worms while members of

Gammaridae dominated the 2004 sample. Both groups of taxa are relatively tolerant of disturbance and water quality degradation. In addition, the substrate is mainly bedrock which provides little habitat for macroinvertebrate colonization.

Figure 15. Periphyton growth in Pike Run.

Rahway River, South Branch - FIBI017a

The heavy urbanization (84%) of the surrounding watershed has led to numerous habitat and water quality impairments which have likely impacted the resident fish community. The stream is characterized by having a heavy fine sediment load which has led to slightly turbid water clarity, unstable substrate, and a high degree of embeddedness. The stream likely receives excess nutrients from the surrounding watershed, as the conductivity was relatively high (605 μmhos). A few pools contained substrates devoid of oxygen, as a strong smell of organic decomposition was noted while sampling. Much of the stream is shaded with good overhead cover, but riparian buffer and bank vegetation are insufficient, which has led to increased run-off and bank erosion. The right descending bank is severely eroded with undercut banks and little buffer from run-off from Chain O'Hills Road and other local roadways. The left descending bank is bordered by mowed grass from Merrill Park. A single storm water outfall is located at the 50 meter mark and appears to drain the parking lot. A number of snags and large woody debris along the right descending bank provide excellent habitat for fish such as centrarchids.

Warmwater species were well represented in the sample, as a number of pumpkinseed sunfish and largemouth bass were collected around snags and large woody debris. Trophic imbalance is apparent by the large proportion of generalist feeders (~82%) and low abundance of insectivorous cyprinids (4%). The heavy fine sediment load and unstable substrate has likely impacted insectivorous cyprinids and benthic insectivores which depend on a healthy benthic macroinvertebrate community for food. A large proportion of the overall catch was made-up of tolerant species (~48%), with white sucker and banded killifish being the most abundant members of the group.

Ambient Biological Monitoring site AN0201 is located 140-m upstream of the Fish IBI site. The

AMNET station received a “severely” impaired rating in 1993 and “moderately” impaired ratings in 1999 and 2004.

Rahway River - FIBI019

The land surrounding the river is largely urban (79%) with evidence of anthropogenic impacts. The sample reach is closely bordered by River Road and numerous housing developments which have reduced the riparian buffer. Bank erosion was noted on both banks and concrete slabs have been used to armor the left descending bank along River Road (Figure 16). As a result of the bank erosion and concrete, much of the left descending bank is devoid of vegetation. In addition, the sample stretch contains three storm sewer outfalls which drain the surrounding impervious surface and a strong sewage smell was emitted from the river. The water chemistry measurements indicated a high water temperature for mid-July (25.58°C), relatively low dissolved oxygen concentration (6.5 mg/l), and high conductivity (420 µmhos). The river’s nutrient load, water chemistry, aquatic macrophytes, and fish assemblages are also influenced by upstream impoundments, such as Rahway River Park Lake located 1/3 mile upstream of the start (Figure 17). Duckweed and other aquatic macrophytes, likely introduced from one of the nearby impoundments, were observed in slower sections of the river. The stretch lacked adequate fish habitat and the overall habitat received a “sub-optimal” (115) rating.

American eel, a tolerant species were the most numerous fish collected representing 55 % of the overall catch. Impairments within the benthic fish community were noted, as benthic insectivores were represented by just one species and insectivorous cyprinid abundance was low. Although fish abundance was high, species diversity and richness were relatively low. A number of blue claw crabs were observed in this section of the river.

Ambient Biological Monitoring site AN0195 received “moderate” ratings in 1992 and 2004 and a “severely” impaired rating in 1999. Almost 48% of the 2004 sample consisted of Gammaridae which are typically found below impoundments and are tolerant of organic pollution.

Figure 16. Storm sewer outfall and concrete slabs on Rahway River.

Figure 17. Aquatic macrophyte density on Rahway River Park Lake.

Rahway River - FIBI020

The surrounding land use is heavily urbanized (~76%), but the sample reach has an adequate riparian buffer and bank vegetation in the form of wetlands and forested areas as the river winds through a county park. The river likely receives large amounts of run-off during storm events, as many of the banks have erosion scars and most of the substrate is unstable. Fine sediments comprise the substrate which has led to slightly turbid water clarity, substantial embeddedness, and sediment deposition in pools and runs. The dissolved oxygen was low (4.76 mg/l) while the conductivity was relatively high (487 µmhos). An oily sheen was observed at the stream surface and along the right descending bank near the head of the sample reach (Figure 18). Overall, the habitat was rated as "marginal" (107) mainly a result of poor substrate, lack of habitat complexity, and bank erosion.

The fish assemblage within the sample reach consists of a large percentage (51%) of tolerant species able to survive under adverse river conditions. Trophic imbalance is apparent by the disproportionately high percentage of generalists and low percent insectivorous cyprinids. Insectivorous cyprinids, which rely on benthic macroinvertebrates for food, accounted for 12% of the fish collected and were represented by just two species. Most of the cyprinid species and tessellated darters were collected in the only riffle at the head of the sample reach. The runs and pools contained little fish habitat, as there were no undercut banks, few snags, and no overhanging vegetation.

Ambient Biological Monitoring site AN0194, located approximately 150-m downstream of the Fish IBI site, received a “severely” impaired rating in 1999 and “moderately” impaired ratings in 1992 and 2004. The macroinvertebrate assemblage throughout this period consisted of worms, midges, and scuds. In 1999, tubificid worms, an indicator of organic pollution, comprised 65% of the sample.

Figure 18. Oily sheen on surface of Rahway River.

Second River - FIBI085a

The severe impairments noted at Second River are likely a combination of water quality and anthropogenic impacts, as 91.8% of the land use in the surrounding watershed is urban. The habitat of this stretch of river is severely impaired with almost no bank vegetation, riparian buffer, or fish habitat, as evident by the “marginal” habitat rating (85). Throughout much of the sampling stretch, the river bank and substrate is comprised mainly of concrete and other artificial materials providing little substrate for macroinvertebrate colonization or refugia for fish (Figure 19). Four dead fish (3 striped bass and 1 brown trout) discovered while sampling are an indication of water quality impairment, possibly caused by runoff from the adjacent parking lot or inputs from the numerous outfalls present within the stretch (Figure 20).

The conductivity was high (883 µmhos) and the stream emitted a strong smell of sewage, petroleum, and chemical solvents. There were a total of seven outfalls within the sample reach, several of which were from windows of factories bordering the river. The stretch is prone to severe flooding with a lot of erosion scars and debris along the banks. Most of the left descending bank has been reinforced with concrete slabs.

American eels, a tolerant species, were the dominant fish collected comprising over 90% of the overall sample. A large percentage of the resident fish exhibited some anomalies; nine of the 26 white suckers collected had either eroded fins or lesions, an indication of severe water quality impairment.

Ambient Biological Monitoring site AN0293, located at the Fish IBI station, received “moderately” impaired ratings in 1998 and 2004. The 1998 and 2004 samples were dominated by midges and worms, with few EPT taxa collected. Tubificidae, commonly found in organically polluted environments, were the dominant worm collected in 2004. The habitat was rated as “sub-optimal” in 1998 and “marginal” in 2003 and 2004. Field staff collecting the 2004 macroinvertebrate samples also noted sewage and chemical odors in the stream.

Figure 19. Factory with numerous outfalls and concrete armored bank along Second River.

Figure 20. Fish kill at Second River.

Green Brook - FIBI097a

Impacts to the fish assemblage of Green Brook are likely anthropogenic, as 65.1% of the surrounding watershed is urban. The habitat was rated as "marginal" (100) and was prone to severe flooding which has severely scoured the stream banks and left debris in the stream and in the surrounding bank vegetation (Figure 21). The streambed lacked stable substrate with a high degree of embeddedness, along with sediment deposition in the form of sand and fine sediment bars. There was insufficient bank vegetation and riparian buffer to limit bank erosion and flash flooding, as the left descending bank was bordered by a township park with mowed grass to the streams edge. The dissolved oxygen was relatively low (5.3 mg/l) for early June an indication oxygen may be low during the summer months. In addition, the conductivity was relatively high (484 µmhos) and large amounts of garbage and debris were observed along both banks and the streambed.

The fish assemblage consisted mainly of tolerant species and generalists typically abundant in degraded systems. Tolerant species comprised 54% of the total specimens collected while 64% of the fish were classified as generalists. Trophic imbalance was observed in two of the three trophic composition metrics, as not only was there an overpopulation of generalists, but no top carnivores were collected. The fine sediment load and embeddedness have likely impacted the benthic fish community, as 3 benthic insectivores represented only 7% of the total abundance. A number of fish species exhibited external anomalies, with white sucker being the species most commonly inflicted. The type of external abnormality varied with fungus, lesions, and fin erosion the most common.

Figure 21. Severe bank erosion at Green Brook.

Other Important Findings

Musconetcong River - FIBI005

This region of the Musconetcong River is classified as FW2-TM indicating a trout maintenance stream. Although young-of-the-year trout were not collected a number of wild and stocked trout were collected including 14 wild brown trout, 3 stocked brown trout, and 4 wild brook trout. In addition, several other intolerant species were collected including cutlips minnows (19) and margined madtoms (3) which also indicate good water quality and fish habitat. These results, along with "optimal" habitat scores in Rounds 1 and 2 and a recent "non-impaired" AMNET rating in 2002, makes this stretch of the Musconetcong River a likely candidate for upgrade to Category One antidegradation classification (NJAC 7:9B).

Saddle River - FIBI007

The Saddle River in the vicinity of the Fish IBI sample location is classified as FW2-TM indicating a trout maintenance stream. Although the surrounding land use is mainly urban (79.9%) and a number of habitat impairments were noted within and upstream of the sample stretch, 80 wild brown trout were collected including several young-of-the-year (Figure 22).

Figure 22. Young-of-the-year brown trout from Saddle River.

Sidney Brook (Grandin Stream) - FIBI008a

This stretch of Sidney Brook is classified as FW2-NTC1 indicating a non-trout waterbody. Although no young-of-the-year were noted while sampling in July 2005, four adult wild brown trout were collected. The site received a "good" (44) rating in Round 2 in addition to an "optimal" (160) habitat rating. A total of 1,179 fish were collected from the stream which exhibited good cyprinid and benthic insectivore abundance.

Neldon Brook - FIBI012

This site received "Excellent" ratings and scores of 48 and 46 in Rounds 1 and 2 respectively. Habitat scores ranged from 179 "optimal" in 2000 to 157 "sub-optimal" in 2005. The surrounding land use/land cover is mainly forest, which provides essential stream buffer and overhead cover. The stream is currently classified as FW2-TM (Trout Maintenance) which is appropriate as stocked brook, brown, and rainbow trout were collected. The only impairment noted in the 2005 results was the high proportion of DELT anomalies observed. A total of ten anomalies were noted, of which seven were from stocked trout which usually have some form of deformity as a result of being raised in concrete raceways. Ambient Biological Monitoring station AN0023a received "non-impaired" ratings in 1997 and 2002. Neldon Brook should be viewed as a candidate stream for upgrading to Category One antidegradation classification (NJAC 7:9B) based on Fish IBI scores and ratings, habitat scores, and Ambient Biological Monitoring ratings.

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 data indicates a significant positive linear relationship between Fish IBI and habitat scores ($R^2 = 0.46$; Figure 23). 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 Fish IBI score ($R^2 = 0.23$; Figure 24). 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.”

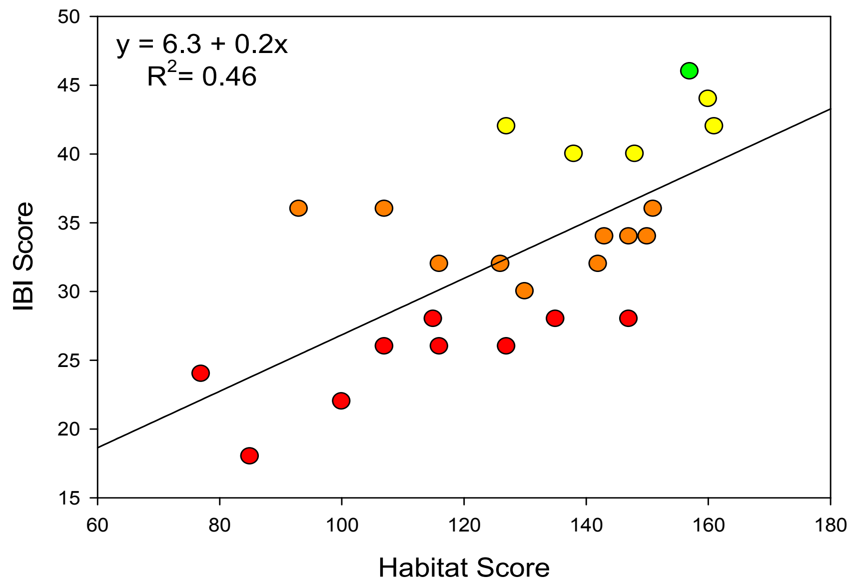


Figure 23. Linear regression comparing IBI and habitat scores.

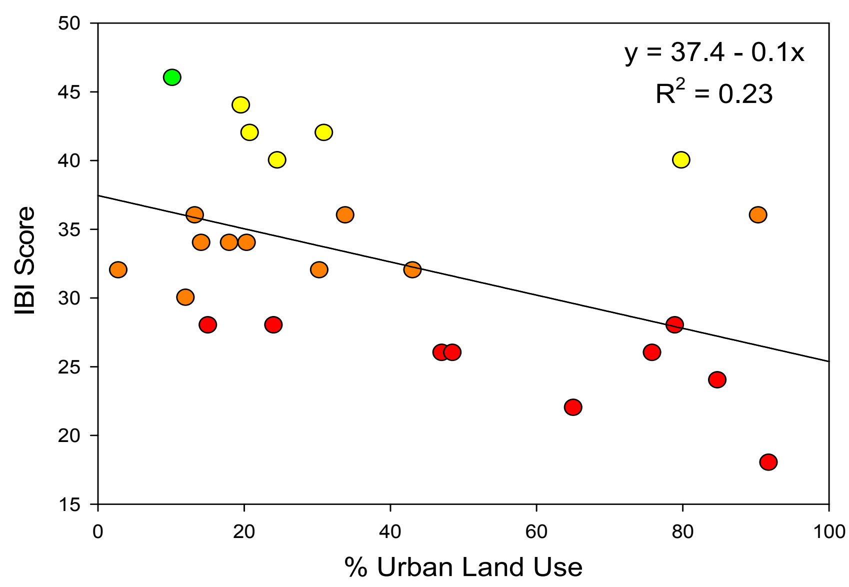


Figure 24. Linear regression comparing urban land use and IBI score.

TRENDS ANALYSIS

The completion of the 2005 sampling season marks the start of the second round of Fish IBI sampling. The majority of those sites sampled in 2005 were originally sampled in 2000 with the exception of Sidney Brook (FIBI008a) and Meadow Brook (FIBI011a), which were sampled in 2001 and Musconetcong River (FIBI061) which was sampled in 2003. In addition, several new sites were added to the network of 100 sites including: Rahway River S.B. (FIBI017a), Second River (85a), Passaic River (94a), and Green Brook (97a). Those sites sampled in 2000, 2001, and 2003 were re-scored using the re-calibrated metrics in order to compare results over time (Table 4).

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

		Round 1 Results*			2005 Results		
FIBI Site	**Waterbody**	**IBI Score**	**IBI Rating**		**IBI Score**	**IBI Rating**	
FIBI001	Paulins Kill	28	Poor		34	Fair	
FIBI002	Furnace Brook	34	Fair		36	Fair	
FIBI003	Pequest River	32	Fair		30	Fair	
FIBI004	Lopatcong Creek	38	Good		34	Fair	
FIBI005	Musconetcong River	34	Fair		42	Good	
FIBI006	Ramapo River	32	Fair		28	Poor	
FIBI007	Saddle River	36	Fair		40	Good	
FIBI008a	Sidney Brook	46	Excellent		44	Good	
FIBI009	Whippany River	20	Poor		26	Poor	
FIBI010	Clinton Brook	34	Fair		32	Fair	
FIBI011a	Meadow Brook	46	Excellent		36	Fair	
FIBI012	Neldon Brook	46	Excellent		46	Excellent	
FIBI013	Heathcote Brook	30	Fair		32	Fair	
FIBI014	Royce Brook	30	Fair		26	Poor	
FIBI015	Mile Run	24	Poor		36	Fair	
FIBI016	Pike Run	28	Poor		28	Poor	
FIBI017**	Pleasant Run	26	Poor		42	Good	
FIBI017a	Rahway River S.B.	N/A	N/A	N/A	24	Poor	
FIBI018	Raritan River S.B.	32	Fair		40	Good	
FIBI019	Rahway River	20	Poor		28	Poor	
FIBI020	Rahway River	22	Poor		26	Poor	
FIBI061	Musconetcong River	22	Poor		34	Fair	
FIBI085a	Second River	N/A	N/A	N/A	18	Poor	
FIBI094a	Passaic River	N/A	N/A	N/A	32	Fair	
FIBI097a	Green Brook	N/A	N/A	N/A	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.
**Site was dropped from future FIBI monitoring due to drainage < 5 sq. miles.

The proportion of sites rated as "fair" and "poor" remained relatively constant from Round 1 to Round 2 (Figure 25). The number of "excellent" sites dropped from 15% to just 5% in 2005 with a subsequent increase in the proportion of "good" sites from 5% in Round 1 to 20% in 2005.

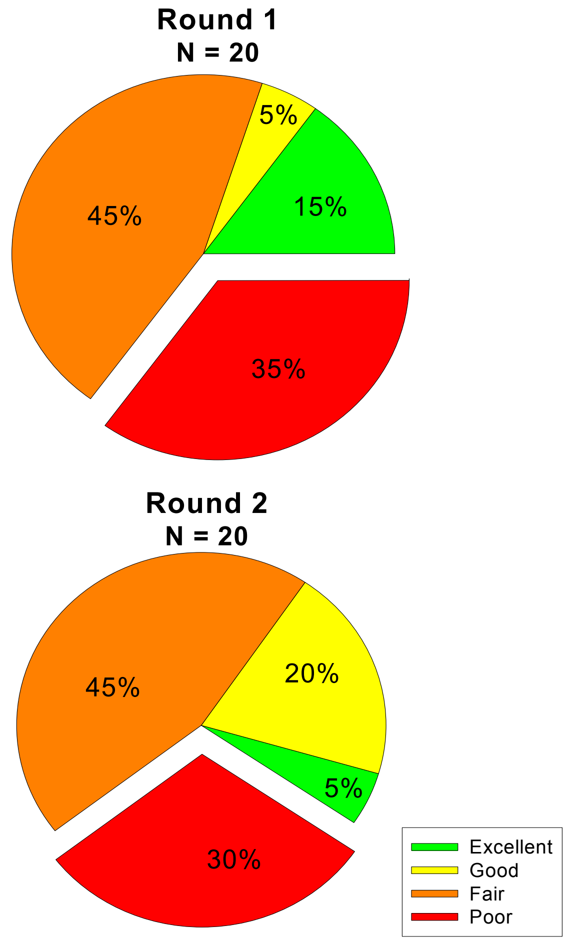


Figure 25. Ratings comparison for Rounds 1 and 2.

Significant scoring and rating changes occurred at several sites including the following: Paulins Kill (001), Musconetcong River (005), Ramapo River (006), Meadow Brook (011a), Mile Run (015), Pleasant Run (017), Raritan River South Branch (018), Rahway River (019), and Musconetcong River (061)(Figure 26). The majority of these changes were positive changes in biological integrity. The following is a description of trends at these individual sites over time.

Meadow Brook – FIBI011a

Meadow Brook exhibited a sharp decline in biological integrity from 2001 to 2005. Utilizing the newly re-calibrated metrics, this site would have received a score of 46-"excellent" based on 2001 data, but recently declined sharply in 2005 with a score of 36-"fair". The river has a history of severe run-off of fine sediments near the confluence of the Pompton River. While sampling in mid-June 2005, moderate to heavy siltation was noted along with embeddedness of cobble and gravel substrates. Site visits and sampling by biologists from NJ Fish & Wildlife have identified siltation run-off into the river which have severely impacted the wild brown trout fishery near the confluence with the Pompton River (Personal Communication 2005). At this confluence, F&W biologists observed siltation levels several feet deep.

The brook currently sustains a wild brown trout fishery, but no young-of-the-year fish were collected. The absence of young-of-the-year trout is a likely indication the reach lacks clean substrate to support spawning and lacks adequate refugia for young fish; spawning may occur further upstream above the impacts of siltation. The 2001 sample contained several species not found in the 2005 collection including: bluegill, fallfish, brook trout, and yellow perch.

In addition to a decrease in biological integrity, the habitat score and parameters indicate possible impairments since 2001. The habitat, rated "sub-optimal" (130) in 2001, declined to "marginal" (107) in 2005. In addition, the substrate composition was estimated to have 5% silt in 2001 with no significant embeddedness. In 2005 however, silt was estimated to comprise 20% of the substrate with moderate embeddedness.

Mile Run – FIBI015
The fish assemblage and overall Fish IBI score differed significantly between Rounds 1 and 2. Using the recalibrated metric, the site would receive a "poor" rating in 2000 which is attributable to an overabundance of tolerant and generalist species and the lack of cyprinid species. In Round 1 just five blacknose dace, representing less than 2 percent of the overall catch were collected compared to 181 blacknose dace representing 38 percent of the 2005 catch. The overall fish abundance was lower in Round 1, but proportions of both tolerant and generalist species were much higher compared to Round 2.

The change in fish assemblages and composition is unclear, as habitat scores remained relatively constant between rounds (Round 1=88; Round 2=93). In addition, a number of impairments to the water quality and surrounding habitat were noted in 2005 including: severe bank erosion, red shale substrate from eroded banks, severe flash flooding, numerous outfalls, high conductivity, presence of large amounts of debris and garbage, petroleum slick, and a strong smell of heating fuel.

The aforementioned impairments are likely impacting the benthic macroinvertebrate community, which in turn is impacting insectivorous fish species. Ambient Biological Monitoring site AN0429 received "moderately" impaired ratings in 1993 and 2004 and a "severe" rating in 1998.

Pleasant Run – FIBI017
A significant increase in score and subsequent rating occurred between the 2000 and 2005 sampling season at the Pleasant Run station. Recent updates to the drainage size calculation have revealed this site is below the 5-square mile threshold and is therefore not an appropriate site to apply the NJ Fish IBI. This site will subsequently be removed from the monitoring network and any variations in scoring can be attributed to the small drainage size and anomalies which naturally occur in these small systems.

Raritan River S.B. – FIBI018
The score and rating for the Raritan River South Branch changed from 32 "fair" in 2000 to 40 "good" in 2005. Although some temporal variation is likely influencing the scoring change, the main reason for the change is due to the large number of DELT anomalies observed in the 2000 sample. The Round 1 sample contained twenty-one margined madtoms with an acute trematode infection, which was not present in Round 2. Necropsies were performed on infected specimens, but the type of trematode and cause of the infection could not be determined. Only three anomalies were observed in the 2005 sample, of which one was from a margined madtom.

Common riffle cyprinids, such as spottail shiner, common shiner, and longnose dace were relatively abundant in 2005, but were not as common in 2000. Differences in flow between years is the likely cause, as only 10% of the available habitat was estimated to be riffles in 2000, while riffles comprised 85% of the habitat in 2005.

Rahway River – FIBI019
The score for the Rahway River in Rahway increased from 20 in the year 2000 to 28 in 2005, but the rating remained "poor". Overall the fish assemblage changed little, as both sampling events were dominated by American eels and tessellated darters. The fish assemblage did exhibit better trophic balance and species richness in 2005. Several species including spottail shiner, largemouth bass, black crappie, and striped bass were collected in 2005, but were not present in

2000.

Musconetcong River – FIBI061

The scoring and rating change from 2003 to 2005 is largely a result of changes in sampling gear and sampling error. The 2003 sampling was conducted using 2 backpack electrofishers which is ineffective on medium-sized rivers with high flows, such as the Asbury section of the Musconetcong River. The follow-up sampling in 2005 utilized barge electrofishing, a more effective gear-type, which resulted in higher catch rates and species richness. Subsequently, the score and rating changed from 22-"poor" to 34-"fair". The difficult conditions encountered in this section of river likely creates a high sampling error, as fish are able to escape in the swift current and benthic species such as madtoms and bullheads are not visible to collectors.

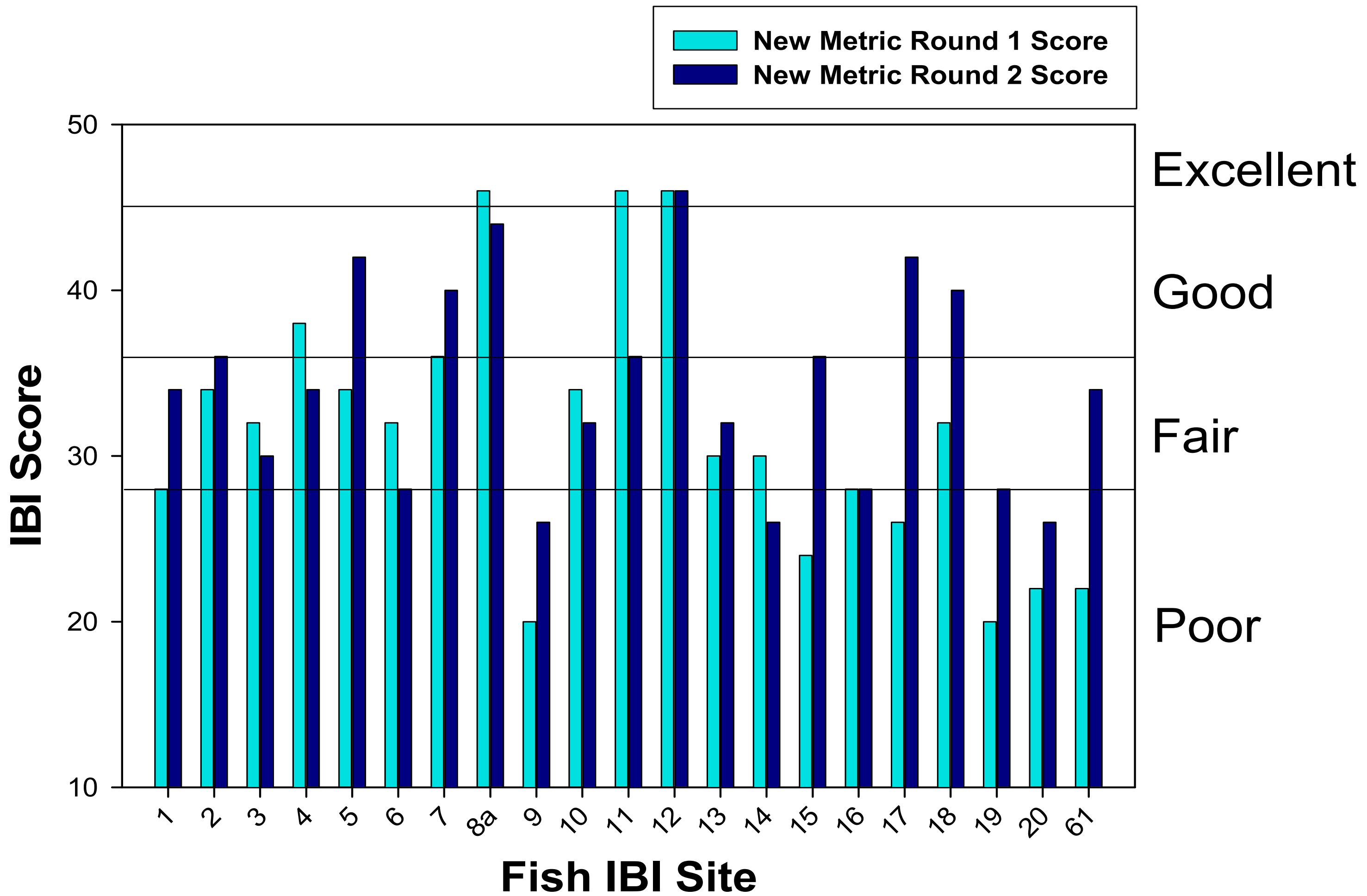


Figure 26. Comparison of ratings for Rounds 1 and 2 at individual sites.

FURTHER INFORMATION

The current report summarizes the fifth year of IBI sampling. The network established includes 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 four years of the IBI can be obtained on the WM&S Bureau of Freshwater and Biological Monitoring's web page:
http://www.state.nj.us/dep/wms/bfbm/fishibi.html or by calling 609-292-0427.

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APPENDIX 1
Second Revised List of New Jersey Freshwater Fishes

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

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

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

Abbreviations:

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

APPENDIX 2
IBI for Northern New Jersey

(Metrics and Scoring Criteria)

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

Condition Categories (modified from Karr et al. 1986)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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APPENDIX 3

IBI AND HABITAT SCORING SHEETS/GRAPHS

LABEL

IBI SCORING SHEET

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

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

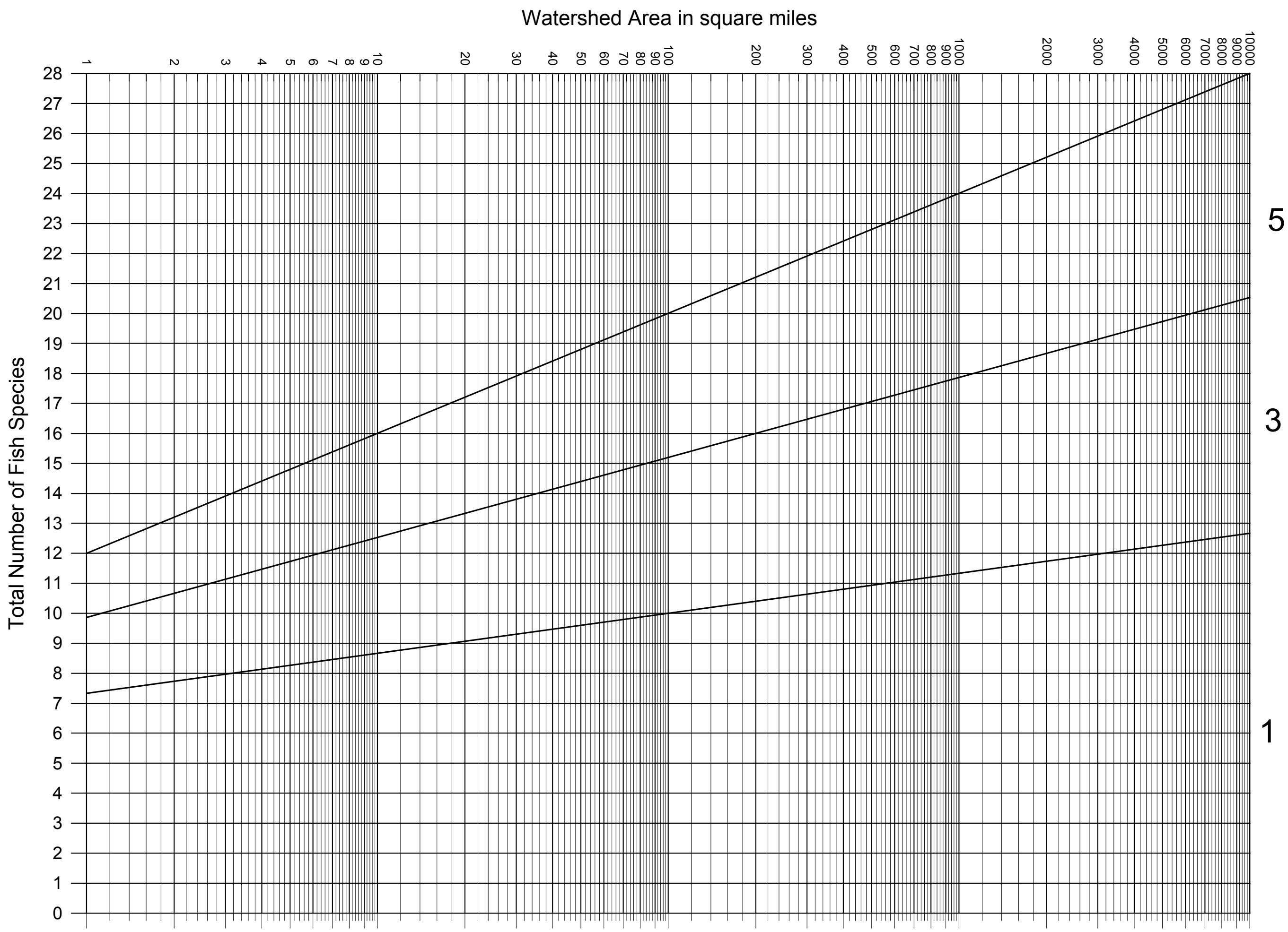
*whichever gives better score

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

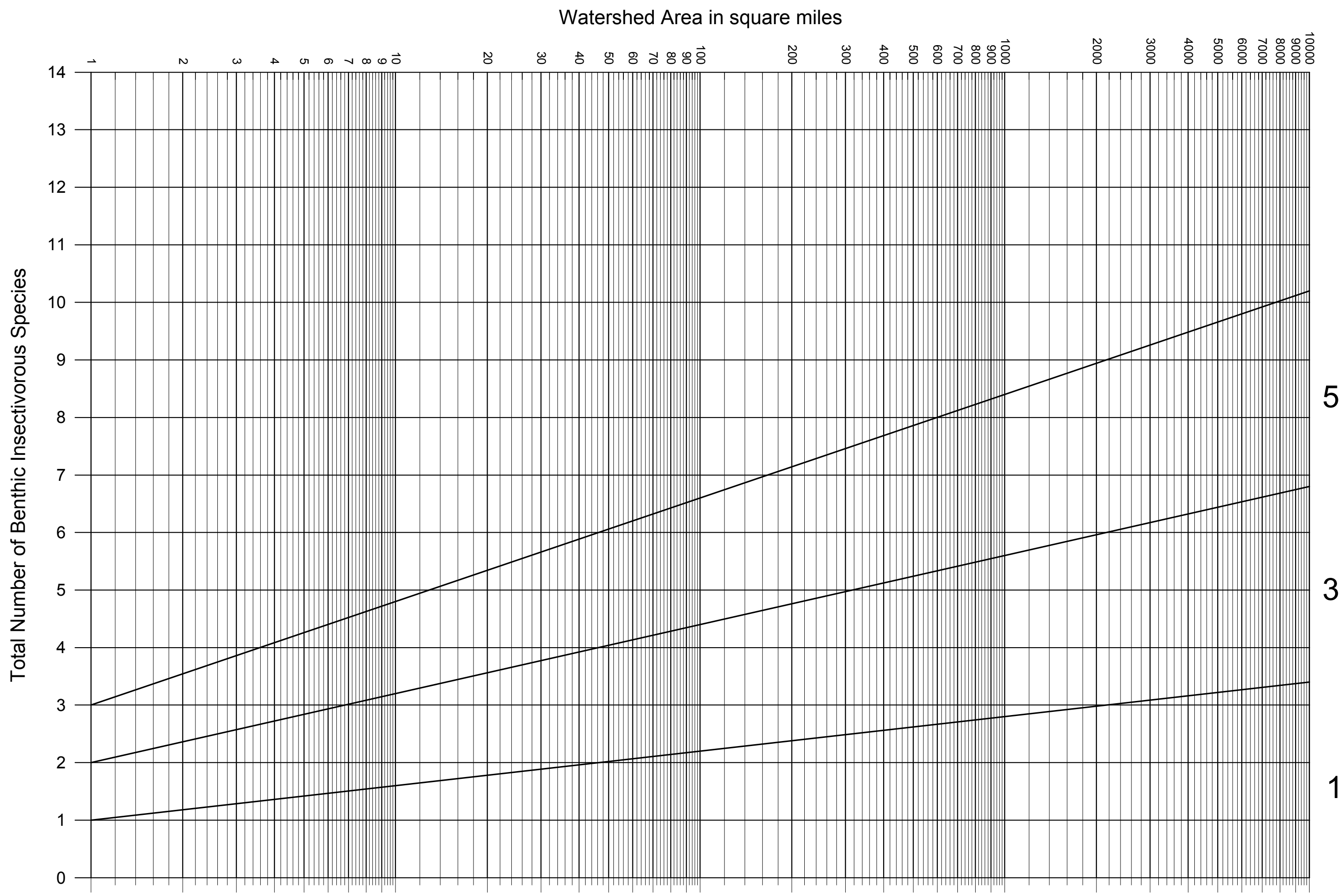
HABITAT SCORE

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

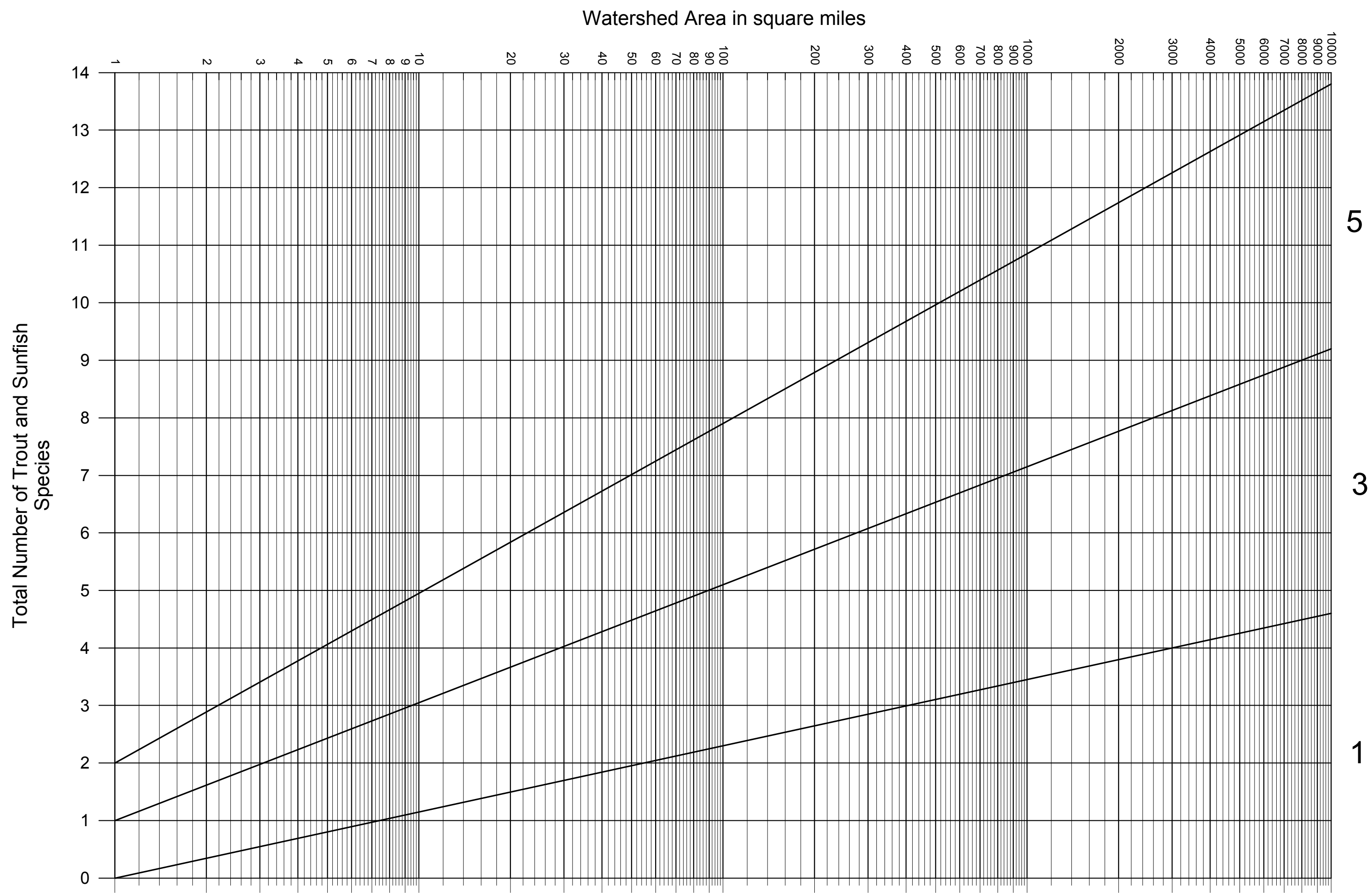
Total number of fish species versus watershed area for New Jersey ecoregion reference sites



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