State of New Jersey
Richard J. Codey, Acting Governor

2003 FISH IBI REPORT

Volume 1 of 2

New Jersey Department of Environmental Protection
Bradley M. Campbell, Commissioner

July 2005

NJ Department of Environmental Protection
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July 2005

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Volume 1of 2

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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 supplements 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. Currently, the Bureau of Freshwater and Biological Monitoring (BFBM), within the Water Monitoring and Standards program, monitors benthic macroinvertebrate assemblages (insects, worms, clams, etc.) at over 800 stream stations throughout New Jersey.

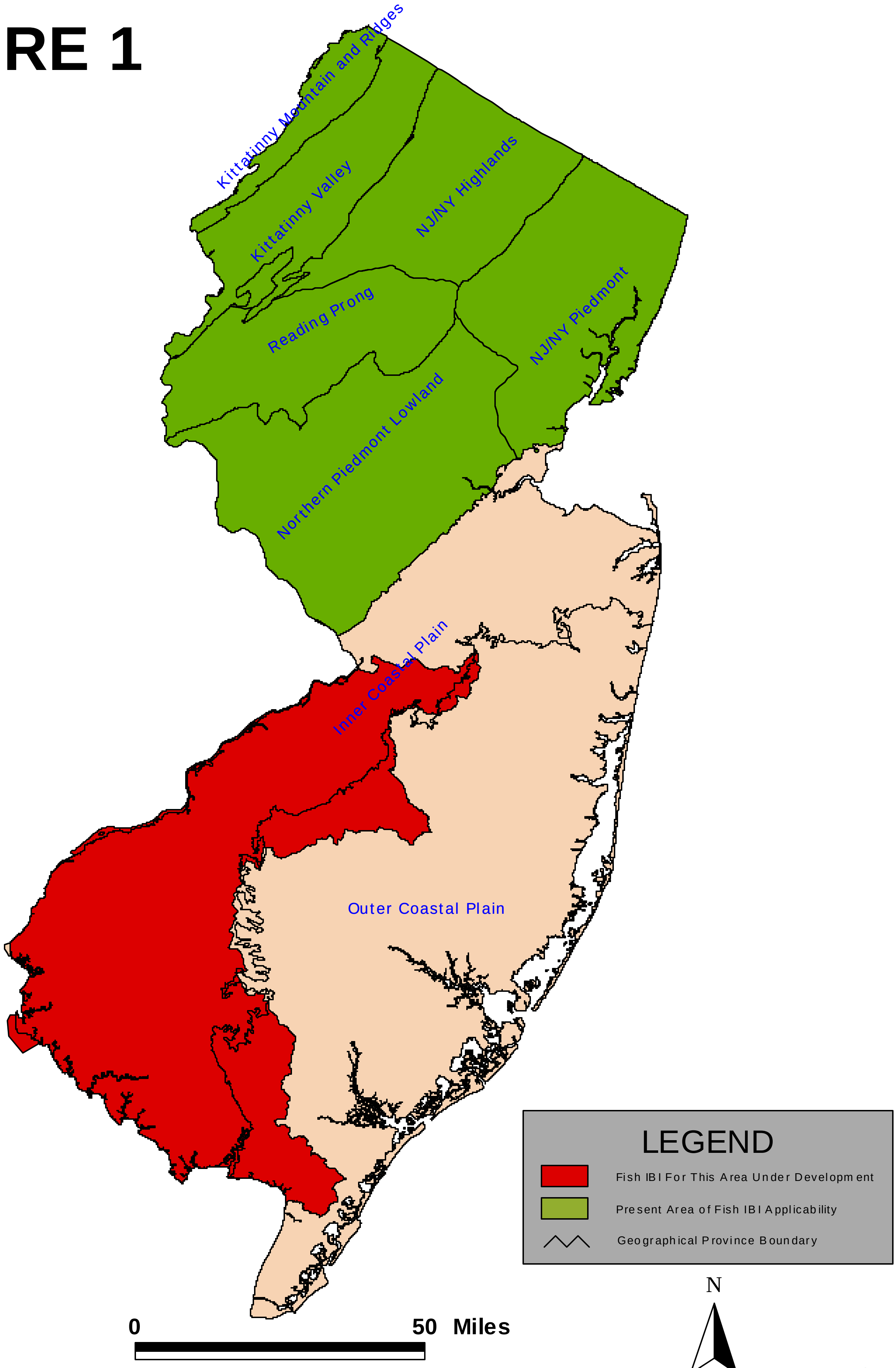
Benthic macroinvertebrate assemblages are generally reflective of short-term and local impairment. In order to assess environmental conditions on a larger spatial and temporal scale, BFBM began to supplement benthic macroinvertebrate monitoring with a fish index of biotic integrity (FIBI) during summer 2000. 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 is becoming another component of the DEP's suite of environmental indicators. The data will 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 nominate candidate waters for upgrade to a Category One antidegradation classification (NJAC 7:9B) based on exceptional ecological significance.

In 2003, the fourth year of sampling, 25 sites were sampled. Seven sites were rated “excellent”, eleven were “good”, six were “fair” and one (Musconetcong River, FIBI061) was “poor”.

The final FIBI network will have 100 established sampling stations in northern New Jersey (see Figure 1). Thereafter 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 both portions of southern New Jersey and the state’s headwater streams with the goal of having a statewide 200 station network.

FIGURE 1


Kittatinny Mountain and Ridges
Kittatinny Valley
NJ/NY Highlands
Reading Prong
NJ/NY Piedmont
Northern Piedmont Lowland
Inner Coastal Plain
Outer Coastal Plain
LEGEND
Fish IBI For This Area Under Development
Present Area of Fish IBI Applicability
Geographical Province Boundary
0
50 Miles
N

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 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 nomination 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 are becoming another component of the DEP's suite of environmental indicators or lines of evidence. 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 anticipates developing an assessment methodology that uses the results from the Fish IBI. The results of these decisions will be reflected in the 2006 Methods Document that is used to prepare

[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.

the 2006 Integrated List and 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, IBI data collected from northern New Jersey are used in an approach to nominate 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

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).

FIELD COLLECTION PROCEDURES

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 must have a minimum of one riffle, run, and pool sequence to be considered representative.

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.

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 (Fig. 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

TYPICAL ELECTROSHOCKING OPERATION

Sampling time generally requires 1.5 to 2 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, depth and flow) of existing stream conditions are recorded on physical characterization/water quality field data sheets and later summarized.

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, 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.

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). 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 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 individuals as white suckers, 6) proportion of individuals as generalists (carp, creek chub, goldfish, fathead minnow, green sunfish and banded killifish), 7) proportion of individuals as insectivorous cyprinids, 8) proportion of individuals as trout or proportion of individuals as piscivores (top carnivores) - excluding American eels, 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. The area under the MSR line is trisected by two diagonal lines.

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[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).

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 five 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 and sucker 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.

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).

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 individuals as white suckers:

The white sucker has been chosen to replace green sunfish as a more regionally appropriate tolerant species in the northeast (Miller et al. 1988; Langdon 1992). In New Jersey, the white sucker is commonly found in small and large streams representing a wide range of water quality conditions. White suckers 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 (carp, creek chub, goldfish, fathead minnow, green sunfish and banded killifish):

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:

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 abundances.

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

This metric provides a relative measure of the condition of individual fish. 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.

Multiple fish species from the same stream affected by blackspot disease.

RESULTS

In 2003, the fourth year of sampling, 25 sites were sampled. Seven sites were rated "excellent", eleven were "good", six were "fair" and one was "poor" (see Figure 4a). A total of 80 sites were sampled from 2000-2003. Fourteen sites were rated "excellent", forty-two were "good", twenty-two were "fair" and two were "poor" (see Figure 4b).

FIGURE 4a

IBI RATINGS FOR THE 2003 SAMPLING ROUND

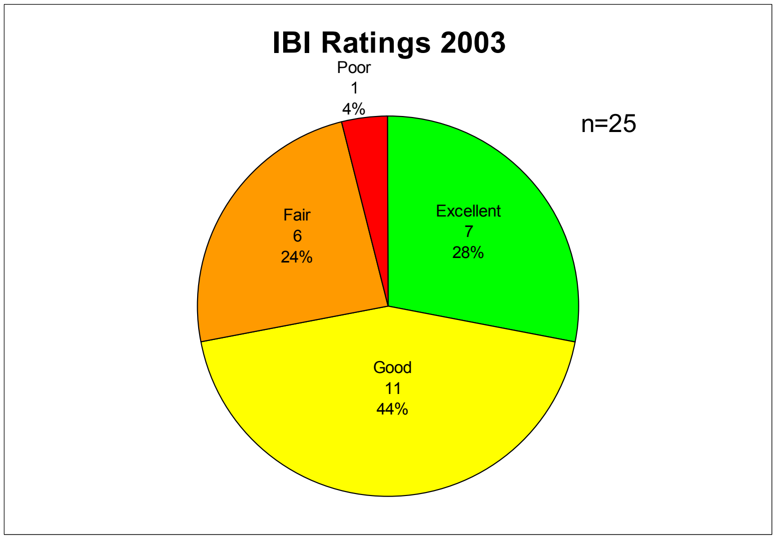
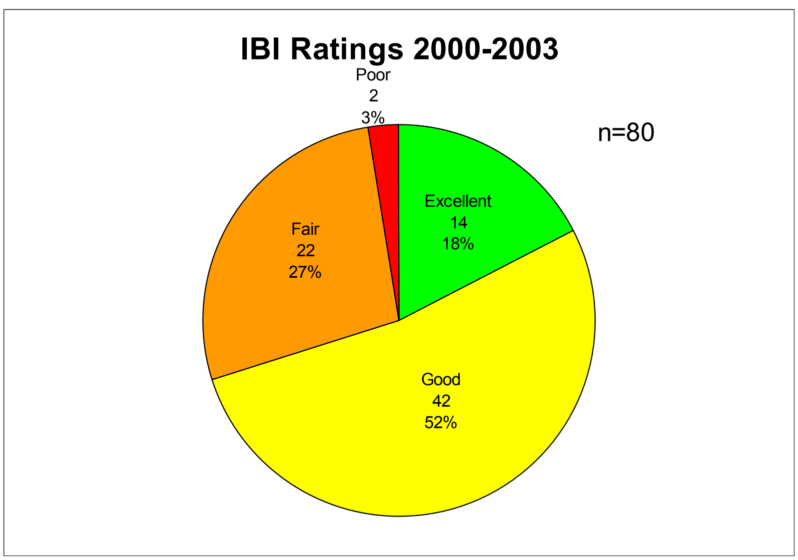


FIGURE 4b

IBI RATINGS FOR THE 2000-2003 SAMPLING ROUNDS



DISCUSSION OF 2003 RESULTS

The fish IBI (FIBI) 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 is warranted. This can be accomplished with either more intensive field surveys and biological and chemical sampling, or a desk review of other Department records, or a combination of all of the above. For purposes of discussion here, impacts are suspected at sites with an 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 Integrated Water Quality Monitoring and Assessment Report [IA] (40 CFR 130.7 and N.J.A.C. &:15-6f), they are 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, benthic macroinvertebrate communities, and associated physical and chemical data.

In this round of sampling, suspected impacts (fair rating) were found at six (6) sites (FIBI 059, 060, 069, 071, 058, and 063) and impairment (poor rating) was found at one (1) site (FIBI 061). The following is a discussion of possible causes for these suspected impacts, and in one case, impairment.

Suspected impacts at four (4) of the six (6) sites (FIBI 059, 060, 069, and 071) were likely the result of stressors brought about by a high percentage of urban land uses (estimated to be between 65% and 83%) and the concomitant impervious surfaces found within their respective, contributing watersheds. These stressors can include some or all of the following:

1) <u>Instream hydrological and morphological changes</u> (i.e. stream bank and stream channel erosion, excessive sedimentation, channel realignment, and excessive turbidity) all caused by the direct discharge of increased and sustained amounts of stormwater runoff from impervious surfaces such as rooftops, sidewalks, driveways, streets and parking lots.
2) <u>Excessive amounts of nutrients (nitrogen and phosphorus)</u> and fecal coliform bacteria from piped stormwater discharges, regulated publicly owned treatment works (POTWs) and indirect non-point sources (lawns, ballfields, agricultural fields etc.).
3) <u>Temperature increases in stream water caused by sunlight-heated impervious surfaces or heated latent water held in wet retention ponds.</u> (Elevated water temperatures increase the metabolism, respiration and oxygen demand of fish and aquatic life, approximately doubling respiration for an 18 degree Fahrenheit temperature rise.)
4) <u>Excessive amounts of turbidity</u>.
5) <u>Increased frequency and magnitude of stormwater runoff events.</u> Maxted (1999), for example, found that urbanized watersheds with 20% -30% impervious cover had 10 to 15 times the frequency of small flood events (1 year recurrence interval) compared to non-urban watersheds. Similarly, Hollis (1975) found that large flood events (100 year recurrence interval) occurred twice as often after urbanization – all of which can produce the stressors previously described above in item 1.

It should also be noted that even in the absence of high percentages of urban land use, sub-optimal fish communities may result from the influence of natural factors such as, on stream impoundments within the subwatershed sampled, or varying ratios of pool to riffle either within or proximal to the reach sampled.

Such high percentages of urban land use, along with its associated impervious cover, have been consistently found, by various researchers, to be a key element in the degradation of stream biota and water quality. Horner et al., for example, concluded, "*……comparatively high urbanization and natural cover loss make poor biological health (in stream) inevitable*". Brabec et al. (2002), in their comprehensive review of current literature on impervious cover impacts, found threshold values at which fish population health was detrimentally impacted, ranged from 3.6 to 12 percent impervious cover. Similarly Booth (1991) found that channel stability and fish habitat quality deteriorated rapidly after 10% imperviousness. Limburg and Schmidt, (1990) found resident and anadromous fish eggs and larvae declined sharply in 16 tributary streams that were more than 10% urban. Wang and others (2000 and 2001) indicate that streams in watersheds with more than 12% imperviousness have consistently poor fish communities.

In examining the data collected at FIBI sites 059, 060, 069, and 071 there are indications that urbanization is impacting all of these sites to some degree. FIBI site 059(Pascack River at Emerson Road, Bergen County) for example, is directly impacted by a sizeable stormwater outfall (Figure A) located immediately upstream of the sampled reach. Erosion and sediment deposition around the headwall and in front of the pipe outlet is clearly evident.

Figure A - Stormwater outfall discharging directly into Pascack River at upstream end of sampled reach at site FIBI059.

The sub-optimal habitat rating (Score 120) at FIBI site 059 reflects some of the stressors produced by what are most likely increased amounts of stormwater runoff. For instance an increased embeddedness (25%-50%) by fine sediment, of the stream substrate was noted, as was the moderate instability of the stream banks, observed to be, in some instances, as much as 30% to 60% eroded. It was also observed that human activities had narrowed and removed much of the vegetation in the riparian zone on the stream's right bank. The slight turbidity noted in the stream, on the day of sampling, despite the absence of a recent rainfall, may be further evidence that suspended sediment may also be a chronic problem. Excessive and protracted levels of suspended sediment can have deleterious effects on fish life including: avoidance and/or abandonment of a stream reach; reduction in feeding rates; increased rates of coughing and unsuccessful hatching (Newcombe, 1996). The further fact that the sampled reach was 90% run, as compared to a more desirable equal distribution of riffle, run and pool, may have also influenced the fish community population, and the resultant IBI score.

FIBI Site 060 (Musquapsink Creek at Harrington Avenue, Bergen County), similar to FIBI059, has high percentage (60%) of relatively shallow (0.80 ft. max. depth) run. The stream habitat was rated as sub-optimal, due primarily to existing erosion on both banks and narrowed riparian zones that have been impacted (particularly the right bank) by human activities. This site is also being influenced by direct discharges from storm drains, which are the most likely reason for the eroded and unstable stream banks that were noted. The dissolved oxygen content of the stream (6.7mg/L) was at 76% saturation, which may have been caused by the elevated temperature noted on the day of sampling, 21.7degrees C (71.0 degrees F), or a combination of shallow depth and temperature. The small number of species present (8), as well as the number of fish overall, reflects stream conditions (i.e. elevated temperature, lowered dissolved oxygen, shallow depth and fewer than desired riffle areas) that many fish species would find particularly inhospitable.

At FIBI site 069 (Troy Brook at Beaverwyck Road, Morris County) the stream habitat was rated as optimal – this despite the reduced width of the riparian zone due to human activities. The high percentage of riffle areas (60%) most likely helped sustain the higher levels of dissolved oxygen recorded at the time of sampling (93% saturation), even with a stream temperature of 22.5 degrees C (72.5 degrees F). The stream's shallow depth (0.45 feet max.), reduced wetted perimeter width, and reduced percentage of pools (25%), may have discouraged some fish species, from occupying this stream reach at the time of sampling. Larger fish species, piscivores for example, would have had some difficulty in successfully pursuing prey and would have been more susceptible to predation themselves. Similar to FIBI sites 059 and 060, this stream is also impacted by direct stormwater discharges.

FIBI site 071 (Ambrose Brook at Raritan Avenue, Middlesex County), is likely receiving an excess amount of nutrients (nitrogen and phosphorus) based on the presence of substantial growths of attached, filamentous algae (periphyton) on the stream substrate (See Figure B).

Figure B – Attached heavy algal growth on stream bottom

Human activities are heavily influencing this stream. The riparian zone is diminished both in quality and size. The stream channel itself, shows signs of channelization including the installation of a retaining wall and the armoring (rock rip-rap) of the retaining wall base and portions of the bank itself. That some of this extremely large rock rip-rap has been moved downstream from its original location and into the stream channel itself (See Figure C) indicates that stormwater runoff, both volume and velocity, is probably considerable at times. A number of stormwater outlet pipes were observed in the sampled stream reach. The stream reach had 90% pool habitat with low velocity. Despite this, the dissolved oxygen saturation was at 91%, an indication that the excess algal growth was putting considerable oxygen into the system during daylight – a situation that could be reversed during the hours of darkness. There were no pollution intolerant species present.

Figure C – Retaining wall and displaced rock rip-rap.

The source(s) of the suspected impact at the Musconetcong River site FIBI 058 at Stephens State Park, Warren County, remains unclear. High ambient stream temperature, 25.5 degrees C (77.9 degrees F) may be a factor influencing both the type and number of fish species present, despite the presence of optimal habitat. The absence of, or minimal numbers of, predatory piscivore species, except for the American eel, is noteworthy. It may be that the American eel is outcompeting other piscivores or can tolerate higher temperatures or a combination of both. It may also be possible that the section of stream sampled, because of its proximity to Stephens State Park is reflecting the impact of heavy use by fishermen (prone to harvest more piscivores) due to the easy access provided by the park roads and trails which directly abut the river. It should also be noted that in the time period from August 12 – 14, 2000 a series of localized severe storm cells, some with an intensity of 2.5 inches per hour, moved across northern New Jersey, causing severe property damage (estimated at $166 million) due to severe flooding. At the headwaters of the Musconetcong River, near the outlet of Lake Hopatcong, which is upstream of FIBI 058, a new flood peak of record was recorded at the U.S. Geological Survey (USGS) stream gage at that site. The previous peak gage height at the Lake Hopatcong site was set on August 20, 1955, with a height of 3.85 feet, equivalent to a flow of 795 cf/sec. The August 13, 2000 measured peak height at that gage was 10.74 feet, the equivalent of 1,900 cf/sec.. At Hackettstown, downstream of FIBI 058, another USGS gaging station recorded a peak gage height of 3.50 feet, which was close to the gage height of record of 3.97 feet set on August 19, 1955. Damages from the August 12-14, 2000 storm, to stream channels, roadways and bridges, was substantial (estimated at or around $80 million. Whether there are lingering, long term impacts of this 2000 flooding on the fishlife in the Musconetcong River, at FIBI 058, cannot be determined at this time. However, severe floods, such as described above, have been known to alter channel gradients, in some instances steepening it, such that there is a subsequent increase in the velocity of flow. That this particular reach has 50% riffles with rather high stream velocities (3.5 ft/sec. avg.) may be an important clue as to the site's fair rating despite an optimal habitat rating. Few species will tolerate high current velocities of channel areas very long and will relocate to more quiescent areas of the stream, particularly pooled areas. With pools occupying only 10% of the sampled reach, these areas of refugia may be insufficient.

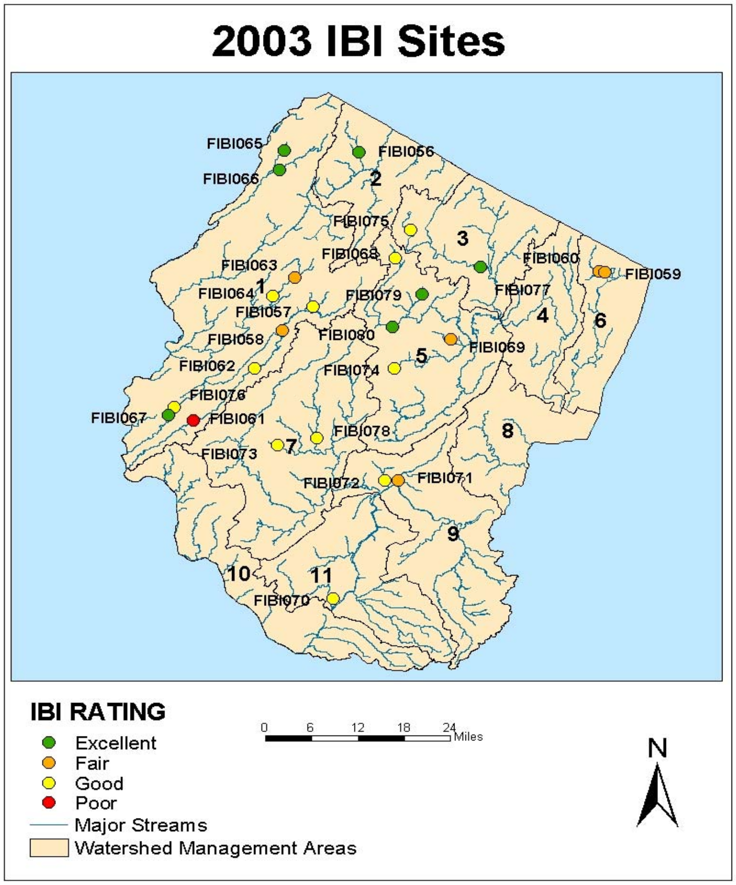
Despite the optimal habitat and moderately sized drainage area (30.3 square miles) at FIBI site 063 (Pequest River at Pequest Rd., Sussex County), the number of species found (7 total) is quite low. The routine water chemistries collected at the site show no unusual conditions, except for the pH value of 8.8 which violates the Surface Water Quality Standard of 6.5 – 8.5 Standard Units. The dissolved oxygen concentration of 9.14 mg/L was at 93.5% saturation with a water temperature at 16.4 degrees C (67.8 degrees F). It should be noted that FIBI 063 is located downstream from two (2) airport complexes - the Aeroflex-Andover Airport located on an unnamed tributary to the Pequest approximately 1.9 miles to the northeast, and the Newton Airport located on the Pequest mainstem approximately 2.5 miles to the northwest. In addition, storm drains from State Highway 206 and County Route 603, also located upstream of FIBI 063, discharge to the Pequest mainstem, and the unnamed tributary. FIBI 063 is also downstream of large agricultural areas. These airport sites, agricultural areas, and storm drainage systems, could be contributing water borne pollutants to the Pequest River which are not normally measured as part of the fish IBI, (including sodium, chloride, nitrate-nitrogen, phosphorus, turbidity, volatile organics, PAHs, and certain heavy metals such as zinc, lead and copper). These potential pollutants, though presently undocumented could, if present, affect overall fish fecundity. The Pequest River mainstem at Route 206 in Springdale has been listed in the Department's Integrated Water Quality Monitoring and Assessment Report (IA) for fecal coliform violations. Two Ambient Biological Monitoring (AMNET) sites, AN0036 and AN0035 are also located upstream of FIBI063. AN0036 is located on the aforementioned unnamed tributary to the Pequest, approximately 0.71 miles upstream of FIBI063. AN0035 is located on the Pequest mainstem branch at Route 206, a location that is 0.51 miles downstream from the Newton Airport site, and 2.5 miles upstream from FIBI site 063. Site AN0035 was rated Moderately Impaired in the 1997 and 2002 samplings. AN0036 was also rated as Moderately Impaired during the 1997 and 2002 samplings. At these sites the impairment has been attributed to both degraded habitat and nutrient enrichment, caused possibly by non point surface runoff from adjacent agricultural areas. In any event, more intensive sampling would be required to assess what may be producing the impact on fishlife at FIBI site 063, however, no additional sampling is planned at this time for this specific site.

The cause(s) of the depauperate fish population at site FIBI 061 on the Musconetcong River off Route 632 in Asbury, Warren County, (the poor site) remains unclear, especially since a sampling of the stream benthic macroinvertebrate population immediately downstream of the site, post FIBI sampling, indicates an nonimpaired benthic macroinvertebrate population. The habitat in the sampled reach was rated as sub-optimal, with deficiencies noted in the excessive amount of embeddedness of the stream substrate by fine sediment (estimated at between 50% and 75%) and the diminished riparian zone. Moderate amounts of periphyton on the stream substrate was also observed. This generally indicates nutrient enrichment. The sampled section of stream lies in an area that is predominantly agricultural, where both grain crops and hay are grown. In addition, there are several horse pasture areas draining to the sampled reach, as well as a horse riding trail along the stream itself. In addition a large population of canadian geese were present on the stream. The fine sediment observed on the stream substrate is likely the result of agricultural runoff from adjacent fields, because the riparian corridors along the stream lack sufficient width and vegetative cover to effectively trap or remove stormwater-borne, pesticide and fertilizer laden, sediments, from tilled fields. However, located upstream of the site (approximately 1.1 miles), there is an industrial facility that has been cited in the past for poor housekeeping practices which has resulted in solids and dust (primarily as graphite) being washed off the site by stormwater. This likely also contributed to the excessive embeddedness of the stream substrate that was observed. In addition the long term construction of new bridge piers across the Musconetcong at Wolverton Road may have also contributed to the loading of fine sediment. It should also be noted that similar to other sections of the Musconetcong River, this reach had rather high stream velocities (3.7 ft./sec. avg.). Few species as noted previously, will tolerate high current velocities of channel areas very long, and will relocate to more quiescent pooled areas. With pools occupying only 10% of the sampled reach, these areas of refugia may be insufficient. A follow up FIBI sampling will be conducted at this site in 2005.

FURTHER INFORMATION

The final FIBI network will have 100 established sampling 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 three years of the IBI can be obtained on the Bureau of Freshwater and Biological Monitoring's web page: http://www.state.nj.us/dep/wmm/bfbm/fishibi.html or by calling 609-292-0427.

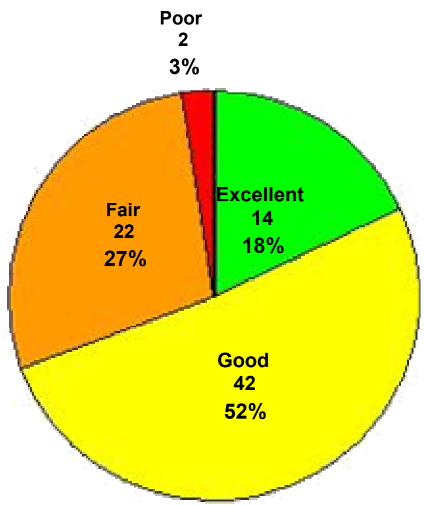


2003 IBI RESULTS[1]

FIBI site	Waterbody	County	Habitat Rating	IBI Score	IBI Rating
FIBI056	Clove Bk	Sussex	Optimal	46	Excellent
FIBI057	Musconetcong River	Sussex	Optimal	42	Good
FIBI058	Musconetcong River	Warren	Optimal	34	Fair
FIBI059	Pascack River	Bergen	Suboptimal	36	Fair
FIBI060	Musquapsink Creek	Bergen	Suboptimal	34	Fair
FIBI061	Musconetcong River	Warren	Suboptimal	28	Poor
FIBI062	Musconetcong River	Morris	Suboptimal	40	Good
FIBI063	Pequest River	Sussex	Optimal	32	Fair
FIBI064	Pequest River	Warren	Suboptimal	40	Good
FIBI065	Little Flat Brook	Sussex	Optimal	46	Excellent
FIBI066	Big Flat Brook	Sussex	Optimal	46	Excellent
FIBI067	Pohatcong Creek	Warren	Suboptimal	46	Excellent
FIBI068	Russia Brook	Morris	Suboptimal	40	Good
FIBI069	Troy Brook	Morris	Optimal	36	Fair
FIBI070	Stony Brook	Mercer	Suboptimal	42	Good
FIBI071	Ambrose Brook	Middlesex	Suboptimal	36	Fair
FIBI072	Middle Brook	Middlesex	Optimal	38	Good
FIBI073	S.B. Rockaway Creek	Hunterdon	Optimal	38	Good
FIBI074	Whippany River	Morris	Suboptimal	42	Good
FIBI075	Pequannock River	Passaic	Optimal	42	Good
FIBI076	Pohatcong Creek	Warren	Suboptimal	40	Good
FIBI077	Pequannock River	Morris	Suboptimal	46	Excellent
FIBI078	Lamington River	Somerset	Suboptimal	40	Good
FIBI079	Beaver Brook	Morris	Optimal	46	Excellent
FIBI080	Rockaway River	Morris	Suboptimal	48	Excellent

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

IBI Ratings 2000-03



Summary of 1st round IBI ratings to date for 80 sites in northern New Jersey. It is anticipated that approximately 100 sites will be sampled by the end of the 1st Round (Summer 2004).

REFERENCES

1. Angermeier, P.L. 1983. "*The importance of cover and other habitat features to the distribution and abundance of Ilinois stream fishes*" Ph.D. Dissertation, University of Illinois, Urbana.
2. Berkman, H.E., and C.F. Rabeni. 1987. "*Effect of siltation on stream fish communities*" Environmental Biology of Fishes 18:285-294
3. Booth, D. 1991. "*Urbanization and the natural drainage system – impacts, solutions and prognoses."* Northwest Environmental Journal, 7(1); 93-118.
4. Brabec, E. S. Schultz and P.L. Richards. (2002 May). "*Impervious surfaces and water quality: A review of current literature and its implications for watershed planning."* Journal of Planning Literature, 16(4). Sage Publications.
5. Eddy, S., and J.C. Underhill. 1983. "*How to Know the Freshwater Fishes*" 3rd ed., William C. Brown Company, Dubque, Iowa.
6. Eklov AG, Greenberg LA, et al. (1998 Dec). "*Response of stream fish to improved water quality: A comparison between the 1960s and 1990s."* Freshwater Biology; 40(4):771 (12 pages).
7. Gammon, J.R., A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. "*Role of electrofishing in assessing environmental quality of the Walbash River*" in "*Ecological Assessments of Effluent Impacts on Communities of Indigenous Aquatic Organisms*" J.M. Bates and C.I. Weber (eds.). STP 730, pp. 307-324. American Society for Testing and Materials, Philadelphia, PA.
8. Hocutt, C.H., and E.O. Wiley (eds.). 1986. "*The Zoogeography of North American Freshwater Fishes*" 1986, John Wiley and sons, N.Y.
9. Hollis, F. 1975. *"The effects of urbanization on floods of different recurrence intervals."* Water Resources Research. 11:431-435.
10. Horner, R. C. May, et.al. (no date). "*Structural and non-structural BMP's for protecting streams."* Proceedings of the Conference on Linking BMPs and Their Ability to Mitigate Effects of Urbanization, ASCE, Renton, VA.
11. Hunt, R.L. 1969. "*Effects of habitat alteration on production, standing crops and yield of brook trout in Lawrence Creek, Wisconsin*" pp. 281-312. *In* Northcoat.
12. Jenkins, R.E. and N.M. Burkhead. 1993. "*Freshwater Fishes of Virginia*" American Fisheries Society, Bethesda, MD.
13. Karr, J.R. 1981. "*Assessment of biotic integrity using fish communities*" Fisheries 6(6):21-27.
14. Karr, J. R., K.D. Fausch, P.L. Angermeier, P. R. Yant, and I.S. Schlosser. 1986. "*Assessing biological integrity in running waters: a method and its rationale"* Illinois Natural History Survey, Champaigne, IL, Special Publication 5.
15. Kurtenbach, J. P. 1994. "*Index of Biotic Integrity Study of Northern New Jersey Drainages*" U.S.EPA, Region 2, Div. Of Environmental Assessment, Edison, N. J. (Last revised April, 2000).
16. Langdon, R.W. 1992 "*Adapting an index of biological integrity to Vermont streams*" Presented at the 16th annual meeting of the New England Assoc. of Environmental Biologists at Laconia, New Hampshire, 4-6 March, 1992.
17. Leonard, P.M., and D.J. Orth. 1986. "*Application and testing of an index of biotic integrity in small, coolwater streams*" Transactions of the American Fisheries Society 115:401-415.
18. Limburg, K. and R. Schnidt. 1990. "*Patterns of fish spawning in Hudson river tributaries – response to an urban gradient?."* Ecology 71(4); 1231-1245.
19. Lyons, J. 1992. "*Using the index of biological integrity (IBI) to measure environmental quality in warmwater streams of Wisconsin*" U.S. Dept. of Agriculture, Forest Service,

General Technical Report NC 149.
20. Maxteo, J.R. 1999. “*The effectiveness of retention basins to protect aquatic life and physical habitat in three regions of the United States.*” Comprehensive Stormwater and Aquatic Ecosystem 1999 – Conference Vol.1, page 215.
21. Meehan, W.R. (ed.) 1991. “*Influences of forest and rangeland management on salmonid fishes and their habitats*” American Fisheries Society, Special Publication 19.
22. Miller, D.L., P.M. Leonard, R.M. Hughes, J.R. Karr, P.B. Moyle, L.H. Schrader, B.A. Thompson, R.A.Daniels, K.D. Fausch, G.A. Fitzhugh, J.R. Gammon, D.B. Halliwell, P.L. Angermeier, and D.O. Orth. 1988. “*Regional applications of an index of biotic integrity for use in water resource management”* Fisheries 13:3-11.
23. Newcombe, C.P. and J.O.T. Jensen. (1996 Nov). “*Channel suspended sediment and fisheries: A synthesis for quantitative assessment of fish and impact.”* North American Journal of Fisheries Management., Vol.16, no. 4, 693- 727.
24. Ohio Environmental Protection Agency. 1987. “*Biological criteria for the protection of aquatic life: Vol. II. Users Manual for biological field assessment of Ohio surface waters*” Ohio EPA, Division of Water Quality Monitoring and Ass't, Surface Water Section, Columbus, OH.
25. Page, L.M., and B.M. Burr. 1991. “*Peterson Field Guides, Freshwater Fishes*” Houghton Mifflin Company, New York.
26. Peters, J.C. 1967. “*Effects on a trout stream of sediment from agricultural practices*” Journal of Wildlife Management. 31:805-812.
27. Plafkin, J. L., M.T. Barbour, K.D. Porter, S.K. Gross and R.M. Hughes. 1989. “*Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish*” U.S. EPA. EPA/444/4-89-001.
28. Smith, C.L. 1985. “*The inland fishes of New York State*” N.Y. State Department of Environmental Conservation, Albany, N.Y.
29. Steedman, R.J. 1988. “*Modification and assessment of an index of biotic integrity to qualify stream quality in southern Ontario”* Canadian Journal of Fisheries and Aquatic Sciences 45:492-501.
30. Stiles, E. W. 1978, “*Vertebrates of New Jersey*” Somerset, New Jersey
31. Warren, M. L., Jr. and B.M. Burr. 1994. “*Status of freshwater fishes of the US: Overview of an imperiled fauna*” Fisheries 19(1):6-18.
32. Wang, L. and J. Lyons. 2003. “*Fish and benthic macroinvertebrate assemblages as indicators of stream degradation in urbanizing watersheds*.” pp 227-249, In T. P. Simon (editor), “*Biological Response Signatures: Indicator Patterns Using Aquatic Communities*.” CRC Press, Boca Raton, FL.
33. Wang, L. J. Lyons, and P. Kanehl 2001. “*Impacts of urbanization on stream habitat and fish across multiple spatial scales.”* Environmental Management. 28(2): 255-266
34. Wang, L. J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons 2000. “*Watershed urbanization and changes in fish communities in southeastern Wisconsin streams.”* Journal of the American Water Resources Association. 36:5(1173-1187).
35. Werner, R.G. 1980. “*Freshwater Fishes of New York State: A Field Guide*” Syracuse University Press, New York.

APPENDIX 1

Revised List of New Jersey Freshwater Fishes

December 2000

	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	--	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*)	I	--	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*)	O	--	E
Grass Carp (*Ctenopharyngodon idella*)	H	--	E
Satinfin Shiner (*Cyprinella analostana*)	I	--	N
Spotfin Shiner (*C. spiloptera*)	I	--	N
Common Carp (*Cyprinus carpio*)	O	--	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

APPENDIX 1

	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
Catostomidae:			
White Sucker (*Catostomus commersoni*)	BI	--	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*)	BI	--	NN
Yellow Bullhead (*A. natalis*)	BI	--	N
Brown Bullhead (*A. nebulosus*)	BI	--	N
Channel Catfish (*Ictalurus punctatus*)	I/P	--	NN
Tadpole Madtom (*Noturus gyrinus*)	BI	--	N
Margined Madtom (*N. insignis*)	BI	IS	N
Aphredoderidae:			
Pirate Perch (*Aphredoderus sayanus*)	I	--	N
Cyprinodontidae:			
Banded Killifish (*Fundulus diaphanus*)	I	--	N
Mummichog (*F. heteroclitus*)	I	--	N
Poeciliidae:			
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	--	NN
Blackbanded Sunfish (*Enneacanthus chaetodon*)	I	--	N
Bluespotted Sunfish (*E. gloriosus*)	I	--	N
Banded Sunfish (*E. obesus*)	I	--	N
Redbreasted Sunfish (*Lepomis auritus*)	I	--	N
Green Sunfish (*L. cyanellus*)	I	--	NN

APPENDIX 1

	Trophic Guild	Tolerance	Historical Presence
Pumpkinseed (*L. gibbosus*)	I	--	N
Bluegill (*L. macrochirus*)	I	--	NN
Smallmouth Bass (*Micropterus dolomieu*)	I/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*)	I/P	--	N
Shield Darter (*Percina peltata*)	BI	IS	N
Walleye (*Stizostedion vitreum*)	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		

APPENDIX 2

IBI For Northern New Jersey

(Metrics and Scoring Criteria)
as of 05/03/2000

	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 individuals as white suckers	<10%	10-30%	>30%
TROPHIC COMPOSITION:			
6) Proportion of individuals as generalists (carp, creek chub, goldfish, fathead minnow, green sunfish, banded killifish)	<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, white suckers and other 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, whites suckers and other tolerant species); older age classes of trout and/or top carnivores may be rare.
10-28 Poor	Low species richness, dominated by generalists, white suckers or other 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.

APPENDIX 2

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

Benthic Insectivores (Metric 2) – Sturgeon, Cutlips Minnow, Dace, Suckers, Bullheads, Madtoms, Darters and Sculpins

Trout* and Sunfish (Metric 3, 8) – All species in the families Salmonidae and Centrarchidae

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

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

Piscivores (Metric 8)[+]

* 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.

[+]The current form of the New Jersey IBI (Kurtenbach 1994) requires the classification of fish species into trophic categories prior to scoring metric #8. However, many fish species fall into multiple categories as a function of size and life stage. Consequently, the bureau has used available literature (Turner and Kraatz, 1921; Keast and Webb, 1966; Goldstein, 1993), stomach content analysis (Bremer-Faust, 2001; Margolis, unpublished data) and best professional judgement to designate trophic guilds for these species for the 2002 IBI. These designations, which only affect Metric #8, are as follows:

Green Sunfish	Insectivorous
Rock Bass	Insectivorous
Smallmouth Bass	> 90 mm - Piscivorous
Largemouth Bass	> 90 mm - Piscivorous
Yellow Perch	>150 mm - Piscivorous

Literature Cited

Bremer-Faust, C.M. 2001. *Piscivory in green sunfish (Lepomis cyanellus): A comparison of methods of analysis.* George H. Cook Honors Thesis, Cook College, Rutgers University. 49 pp.

Goldstein, R.M. 1993. *Size selection of prey by young largemouth bass.* Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies. 47:596-604.

Karr, J. R., K.D. Fausch, P.L. Angermeier, P. R. Yant, and I.S. Schlosser. 1986. "*Assessing biological integrity in running waters: a method and its rationale*" Illinois Natural History Survey, Champaigne, IL, Special Publication 5.

Keast, A. and D. Webb. 1966. *Mouth and body form relative to feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario.* J. Fish. Res. Bd. Canada. 23(12):1845-1874.

Kurtenbach, J.P. 1994. *Index of biotic integrity study of northern New Jersey drainages.* U.S. EPA, Region 2, Division of Environmental Science and Assessment, Edison, NJ.

Turner, C.L. and W.C. Kraatz. 1921. *Food of young large-mouth black bass in some Ohio waters.* Trans. Am. Fish. Soc. 50:372-380.

APPENDIX 3

IBI AND HABITAT SCORING SHEETS/GRAPHS

LABEL **IBI SCORING SHEET**

Scorer 1	
Date	
Scorer 2	
Date	

Excellent Good Fair Poor

Excellent Good Fair Poor

	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 Individuals as White Suckers		
Proportion of Individuals as Generalists (carp, creek chub, banded killifish, goldfish, fathead minnow, green sunfish)		
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		

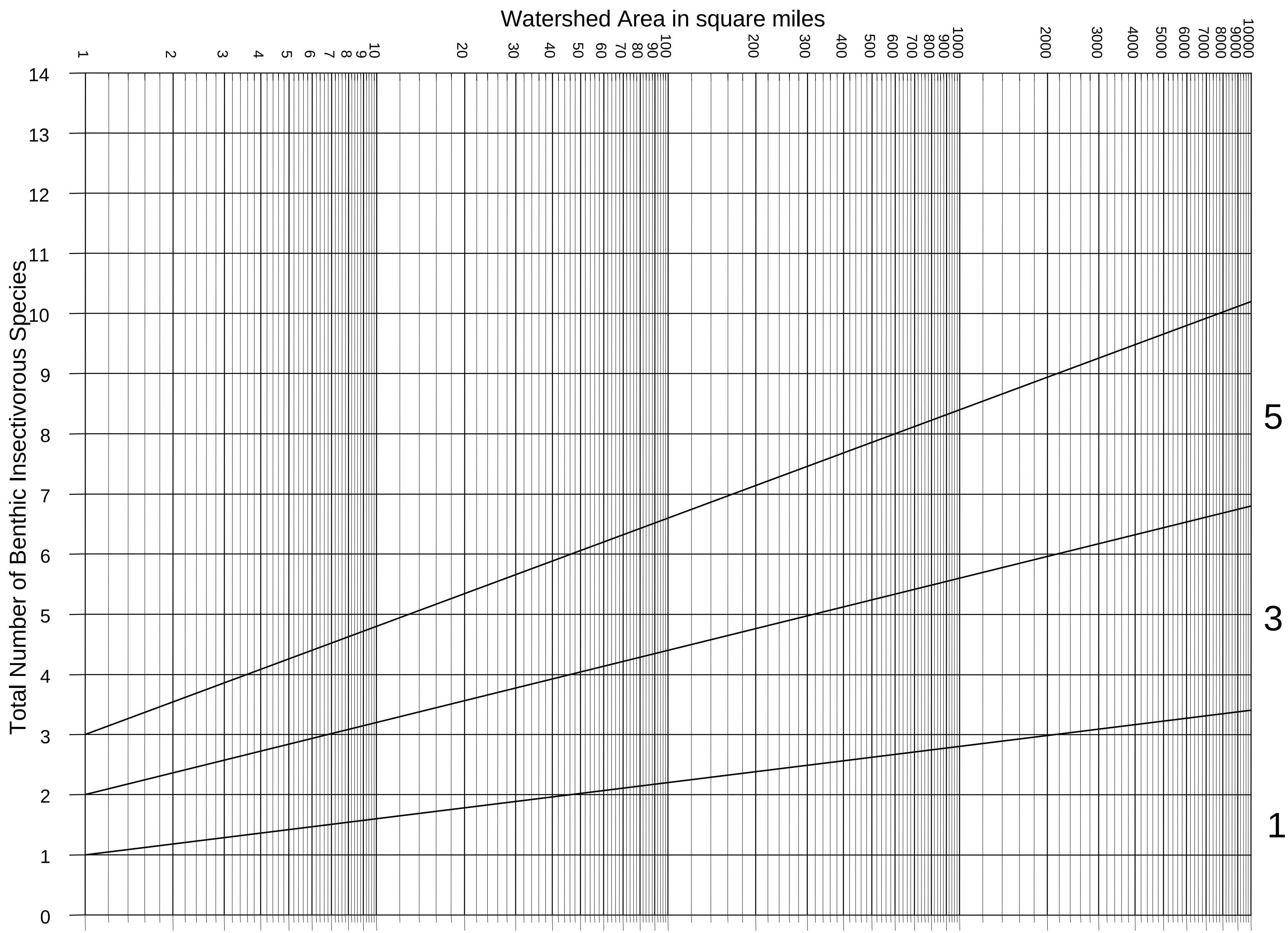
*whichever gives better score

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

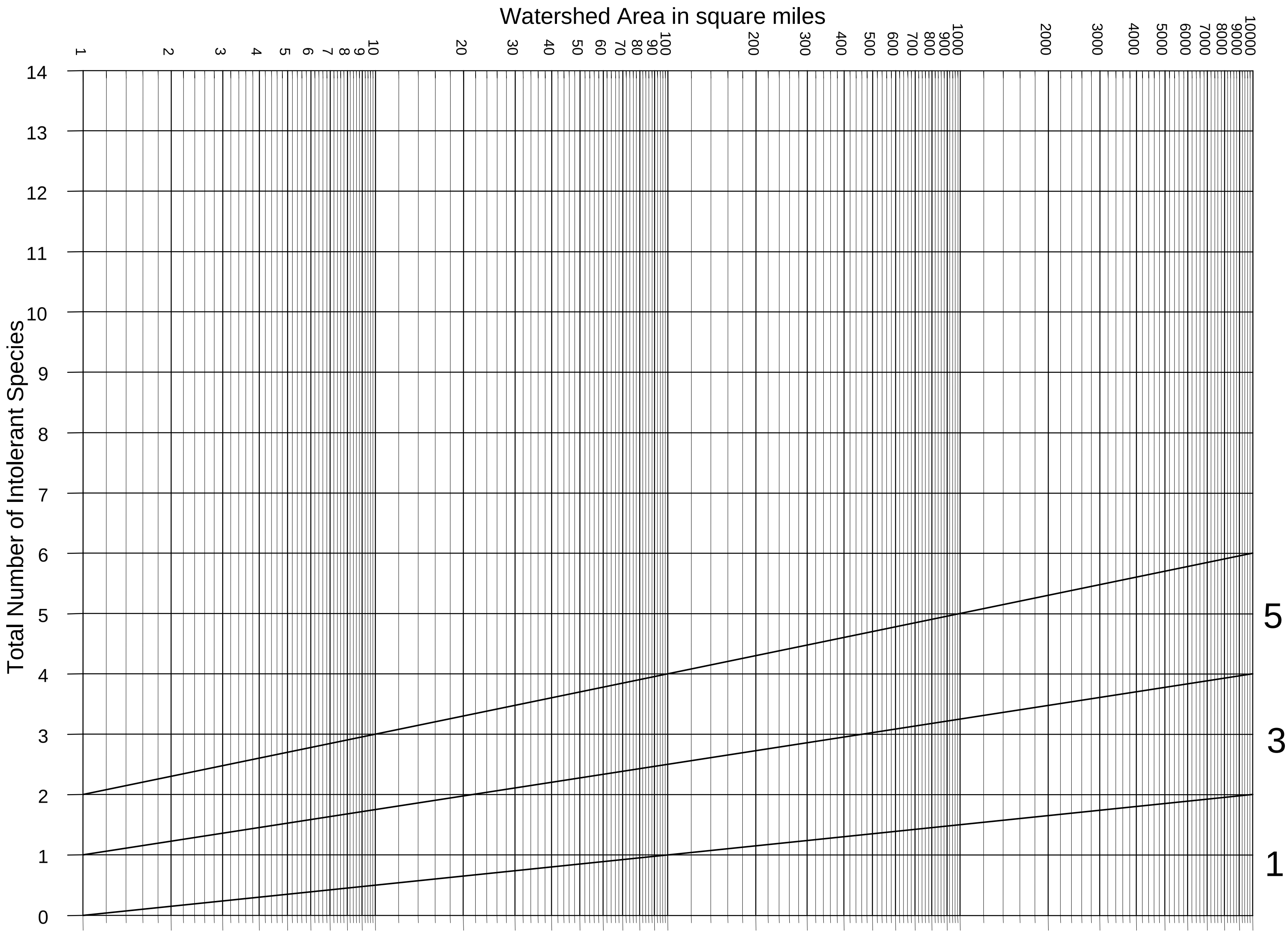
HABITAT SCORE

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

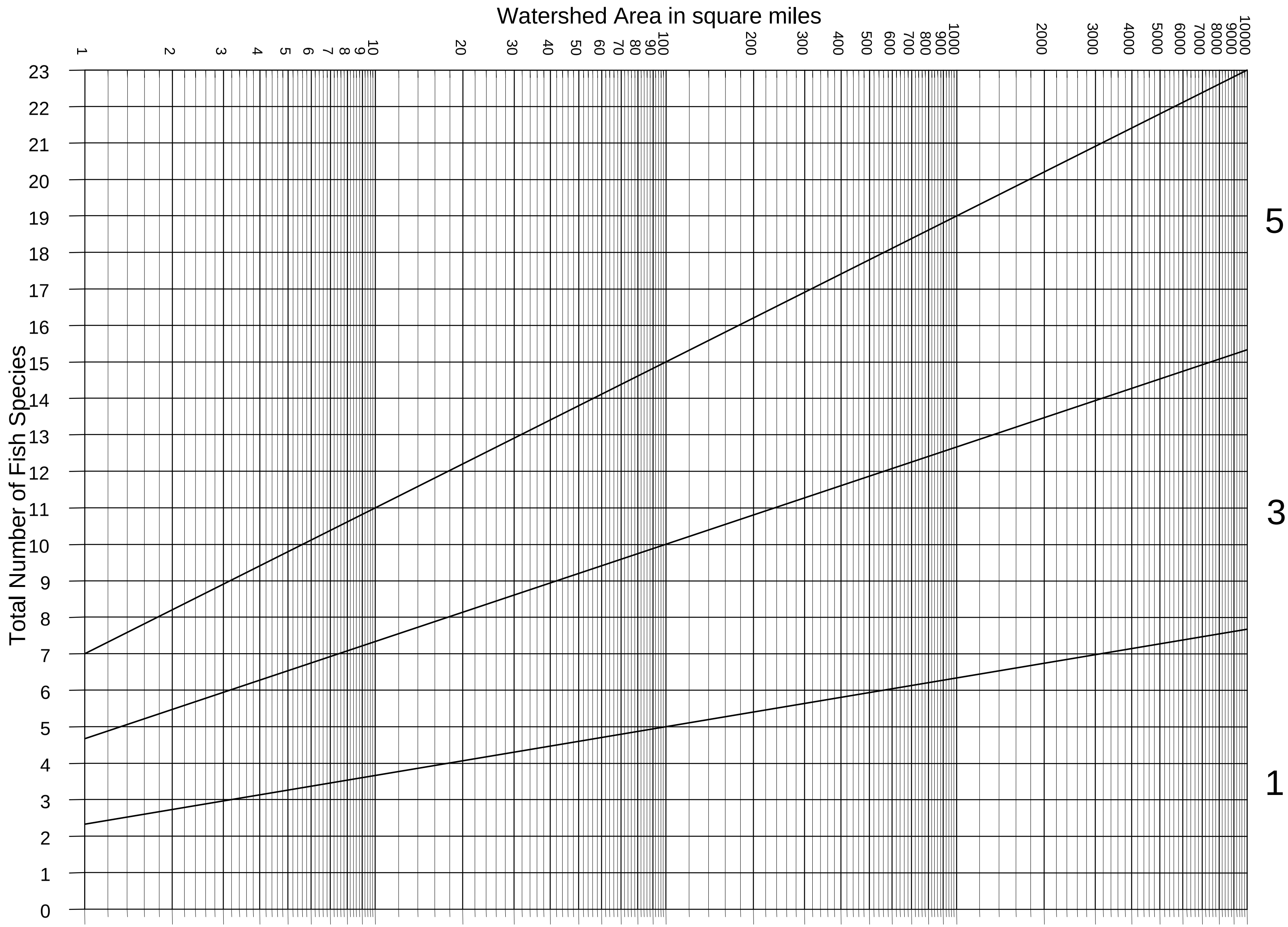
Total number of benthic insectivorous fish species versus watershed area for New Jersey ecoregion reference sites



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



Total number of 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