IBI Study

New Jersey

Passaic, Wallkill, Delaware and

Raritan Drainages

summer (1990-1993)

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Executive Summary

Under the Clean Water Act, states are required to measure status and trends of surface water quality and determine the extent to which waterbodies support balanced biological communities. To date, this has been accomplished through monitoring'programs designed to routinely monitor waterbodies for various chemical, physical and biological parameters. Fish have a long history of use as biological indicators of water quality. For example, the re-establishment of fish populations in waterbodies from which they were once absent, has been used to demonstrate the successfulness of various pollution abatement programs. In addition, to determine the extent and magnitude of chemical contamination in the environment, fish are routinely collected and their tissue analyzed for chemical contaminants. More recently, with the development of the Index of Biotic Integrity (IBI), the use of fish communities is gaining support for assessing environmental quality. The IBI utilizes various ecological attributes of fish communities (i.e., species richness, trophic composition, abundance, fish condition) to assess environmental quality of streams and rivers.

This document reports the findings of a study conducted to evaluate the application and use of the IBI in New Jersey, including several recommendations regarding the use of the IBI as a water monitoring assessment tool.

Fish samplings were conducted over a four summer period (1990 - 1993), at 122 stream sites located in the Passaic, Wallkill, Delaware and Raritan drainages. Stream drainages ranged in size from approximately 5 to 350 square miles. Chemical and benthic macroinvertebrate data were obtained at 30 and 63 sites, respectively, and used to examine their relationship with the IBI.

Study findings suggests the IBI may be limited to screening sites for the detection of seriously degraded conditions., Strong relationships between IBI data and both chemical and benthic macroinvertebrate data were not apparent. Several trends were evident suggesting that some biometrics comprising the IBI may contribute little information to the overall IBI. Like most monitoring tools, it is not recommended the IBI be used to replace information obtained by other monitoring tools, but rather to enhance existing information.

Backqround

New Jersey like other states, is required to measure status and trends of surface water quality and determine the extent to which waterbodies. support balanced biological communities (Section 305(b) of the Clean Water Act). To accomplish this, the New Jersey Department of Environmental Protection and Energy routinely monitors waterbodies for various chemical, physical and biological parameters. In practice, measurements of these parameters should enable states to determine whether they are meeting the goals of the Clean Water Act. Objectives stated in Section 101 of the Clean Water Act are "to restore and maintain the chemical, physical and biological integrity of the Nation's waters". At the present time, numerous assessment tools are being utilized or proposed for the routine monitoring of surface water quality. Unfortunately, there is substantial controversy regarding the present ability of monitoring programs to document water quality improvements or declines on a regional and national scale. In response to this concern, a number of recommendations have been made to enhance surface water monitoring, including the application and development of'promising biological techniques (U.S. EPA 1987). As an outgrowth of these recommendations and a renewed interest in biological assessments, Environmental Services Division personnel examined the potential application of two newly proposed bioassessment tools: rapid bioassessment protocols (RBP's) and the index of biological integrity (IBI). This report describes our assessment and application of the IBI in northern New Jersey streams. To date, a rigorous analysis of the relationship of the IBI to environmental quality in New Jersey streams has not occurred.

Develonment and Descriotion of the IBI

The IBI developed by Karr et al. (1986), utilizes various ecological attributes of stream fish communities to assess habitat and water quality. Karr and Dudley (1981) defined biotic integrity as "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region". The original IBI was developed for use on small wadable streams located in Illinois and Indiana. More recently, a number of modifications and regional applications of the IBI have occurred (Leonard and Orth 1986; Hughes and Gammon 1987; Miller et al. 1988; Steedman 1988; Lyons 1992). Regional modifications were necessary to account for regional differences in fish distribution and community structure.

The New Jersey version of the IBI described here consists of ten biometrics:

Species Richness and Composition

1. Total number of fish species (excluding trout)
2. Number and identity of benthic insectivorous species
3. Number and identity of trout (non-stocked) and/or sunfish species
4. Number and identity of intolerant species
5. Proportion of individuals as white suckers

Trophic Composition

6. Proportion of individuals as omnivores
7. Proportion of individuals as insectivorous cyprinids
8. Proportion of individuals as non-stocked trout or proportion of individuals as piscivores

Fish Abundance and Condition

9. Number of individuals in the sample
10. Proportion of individuals with disease or anomalies

Consistent with Karr et al. (1986), a theoretical framework utilizing several biological metrics is used to assess a fish communities richness, trophic composition, abundance and condition as compared to fish communities found in regional reference streams. Six of Karr's (1986) original twelve metrics: total number of fish species, number and identity of intolerant species, proportion of individuals as omnivores, proportion of individuals as insectivorous cyprinids, number of individuals in sample and proportion of individuals with disease, tumors, fin damage, and skeletal anomalies, were retained for the modified version. Two metrics, number and identity of benthic insectivorous species and proportion of individuals as white suckers (<u>Catostomus commersoni</u>) were taken from (Miller et al. 1988). The trophic composition metric, proportion of individuals as trout or proportion of individuals as piscivores, was developed for use in Vermont (Langdon 1992). Unlike the Vermont IBI, the New Jersey version was modified not to include stocked trout. Abundances of stocked trout in streams often depend on fish angling pressure and numbers of fish stocked, and may not be directly related to environmental quality.

In high quality streams, fish communities have structural and functional characteristics similar to communities found in ecoregion reference streams. Ecoregion reference sites as defined here, are unimpaired (minimal impact) streams in areas of relatively homogeneous ecological systems. In order to calculate the IBI and make an accurate assessment of environmental conditions, a thorough understanding of species richness, composition and condition of a healthy fish community is necessary. When the fish community observed at a site is similar to the expected (based on ecoregional references), environmental degradation is unlikely. Conversely, when the fish community observed deviates from the expected, environmental degradation can be inferred. In streams exhibiting good water quality, fish' communities are represented by high total species, benthic insectivorous species and intolerant species richnesses. Intolerant species are those fish which are most sensitive to water pollution and habitat alteration. High quality streams are also characterized by balanced trophic composition representing species with specialized and generalized foraging behaviors. Further, fish populations are abundant and individual fish are in healthy condition. When stream degradation occurs, total species richness, intolerant species richness and species richnesses of other taxonomic groups decline. The fish community shifts toward species with more generalized feeding'habits. Omnivores often dominate, while insectivorous cyprinids and top carnivores become less numerous. When water quality is severely degraded, fish population abundances are low and incidences of disease and anomalies are often prevalent.

Field Collection

Primary objectives of the fish collection 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, sampling times and habitat types.

Stream segments selected for sampling must have at a minimum, *one* riffle, run and pool sequence to be considered representative. Approximately equal proportions of these habitats are sampled among sites being compared. Channelized streams may be an obvious exception, as are streams located in central and southern New Jersey, were low gradient precludes typical riffle habitat. In low gradient streams, the sampling requires that stream lenghts encompass major habitat types such as pools, runs, bends and log jams. Determining stream lengths necessary for adequate sampling is based on stream size (Table 1). Streams with drainage areas less than 5 square miles are excluded from IBI scoring because of naturally occuring 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 bridge crossings, dams and mouths of tributaries should be avoided, unless the intent of the study is to determine the influence these habitats have on the fish community. Most often, sampling atypical habitats results in the collection of fish species not represented in typical stream reaches. Sampling intermittent streams should also be avoided. These streams require the development of a separate set of IBI scoring criteria.

Table 1. 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	200-150 m	150 m
Electrofishing Gear:	12' boat	Longline(400')and streambank generator pulsator unit	Backpack shocker
Power Source:	5000 watt generator	2500 watt generator	12 volt battery

Fish are sampled using electrofishing gear with pulsed direct current output. Direct current is safer, more effective in turbid water and less harmful to the fish. In low conductivity waters (less than 75 umhos/cm), alternating current should be used. Selection of appropriate electrofishing gear is dependent on stream size (Table 1). A typical sampling crew consists of three to four people depending on the gear being utilized. A minimum of two people is required for netting the stunned fish. Electrofishing is conducted by working slowly upstream and placing the electrodes in all available fish holding habitat. Stunned fish should be netted at and below the electrodes as they drift downstream. Long handled nets with sufficient frame width and depth having a 3/16" mesh size are utilized. Netters should attempt to capture fish representing all size classes. To maximize fish capture efficiency, all sampling crew members must wear polarized sunglasses to reduce sun glare.

All fish captured are placed in water filled styrafoam coolers located along the streambank. Coolers should be within at least 20 meters of each other. To reduce fish mortality, coolers must contain sufficient water and never be placed in direct sunlight.

Sampling time generally requires two hours per station. This includes the measurement of routine chemical and physical parameters. Sampling is conducted in the daytime, June through early October, during normal or low flows, and never under atypical conditions such as high flows or excessive turbidity caused by significant precipitation. Fish collections made in the summer and early fall are easier, safer and less likely to disturb spawning fish.

Samnle Processinq

Fish are identified to the species level, counted, examined for disease and anomalies, released and recorded on fish data sheets in the field (Appendix 1). Only fish greater than 20 mm in length are counted. All fish must be identified accurately to species. Reference specimens for difficult to identify individuals are placed in jars containing 10 percent fomaldehyde and later confirmed at the laboratory using regional taxonomic keys (Stiles 1978: Werner 1980; Smith 1985). Under certain circumstances, the capture of fish using electrofishing gear may result in some fish receiving electrode scares or apparent backbone deformities. These fish must be excluded from the assessment of disease and anomalies. All fish should be handled gently during counting and released immediately to reduce mortality which may result from handling stress.

Measurement of Phvsical and Chemical Parameters

Physical and chemical measurements of existing stream conditions are recorded on physical characterization/water quality field data sheets (Appendix 2) (Plafkin et. al. 1989). Additional notes on the absence or presence of aquatic macrophyte, algae, benthic macroinvertebrate species and other pertinent information should be recorded. In addition, when impairment is observed, an impairment assessment sheet (Appendix 3) (Plafkin et. al. 1989) is completed.

Habitat Assessment

Habitat assessments are conducted at every sampling site and all information is recorded on field data sheets (Appendix 4). Habitat *assessments* provide useful information on probable causes of impairment to instream biota, when water quality parameters do not indicate any limitations. The habitat assessment consists of an evaluation of the following physical features: substrate, channel morphology and streamside cover. Each of these groups is scored and summed to produce a total score which is assigned a habitat quality category: excellent, good, fair or poor.

Usina and Internretina the IBI

Once fish from sample,collections have been identified, counted, examined for disease and anomalies, and recorded, several biometrics are applied to evaluate biological integrity. Fish community analysis is accomplished using a regional modification of the original IBI (Karr et. al. 1986). The modified IBI (New Jersey version) uses the following ten biometrics: 1) total number of fish species, 2) number and identity of benthic insectivorous species, 3) number and identity of trout and/or sunfish species, 4) number and identity of intolerant species, 5) proportion of individuals as white suckers, 6) proportion of individuals as omnivores, 7) proportion of individuals as insectivorous cyprinids, 8) proportion of individuals as non-stocked trout or proportion of individuals as piscivores, 9) number of individuals in the sample and 10) proportion of individuals with disease or anomalies.

Four biometrics require the use of Maximum Species Richness (MSR) lines. MSR lines relate species richness to stream size and environmental quality. For any given stream, 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, poor quality stream. MSR lines (Figures l-4) were developed to show the relationship between species richness and waterbody size in New Jersey. Historical fisheries data (unpublished New Jersey Division of Fish and Game) collected at 126 stream sites located in the Delaware, Passaic and Raritan drainages were used to plot this relationship. The fish collection methods and the stream lengths sampled in the historical study were similar to ours (Table 1).

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Using the procedure described in (Karr et al. 1986), MSR lines for each richness metric were drawn with slopes fit by eye to include 95% of the data points. 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 total species richness (Figure l), 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 an expected condition.

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. 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 sires found in New Jersey, with the exception of large rivers.

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 sites. Scores for the individual biometrics at each sampling location are summed to produce a total score which is then assigned a condition category (Appendix 5). The maximum possible IBI score is 50, representing excellent biological integrity. A score of less than 18 indicates a stream has very poor biological integrity. 10 is the lowest score a site can receive. Trophic guilds, pollution tolerances and origins (exotic or introduced) for each fish species used in calculating the IBI (Appendix 6) 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). A description of each biological metric used to measure biological integrity is presented below.

Species Richness and Composition

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 that are least tolerant of environmental change are the first to become absent when water quality degradation increases.

2. Number and identity .of benthic insectivorous species:

Many 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). 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. Their sessile mode of life, make them particularly susceptible to toxicant effects.

3. Number and identity of trout and/or sunfish species:

Sunfish.species numbers decline with pool habitat degradation and loss **of** instream cover (Gammon et al. 1981; Angermeier 198~3). In coldwater streams where sunfish are 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 (Boussu 1954; Bowlby and Roff 1986).

4. Number and identity of intolerant species:

This metric provides a measure of the fish species most sensitive to environmental degradation. The absence of some fish species occurs when only subtle enviromental changes are caused by chemical or physical perturbations. Fish species classified 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:

White suckers are a common fish species 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

6. Proportion of individuals as omnivores:

This metric provides information on the dynamics of a stream ecosystem. Often a shift in feeding behavior from specialized to generalized occurs when water quality becomes degraded. For example, excessive nutrient enrichment may result in the proliferation of algae, thus providing an additional food source available for exploitation by fish species with flexible feeding strategies.

7: **Proportion of individuals as insectivorous cyprinids:**

Cyprinids are the dominant insectivorous group found in northern New Jersey streams and in general, insectivores are the dominant trophic guild found in lotic systems. A shift from insectivores to omnivores often indicates poor conditions associated with water quality and/or physical habitat degradation. Similar to the benthic insectivore metric, insectivorous cyprinids may indirectly measure the effects of toxicity.

8.. Proportion of individuals as non-stocked trout or proportion of individuals as piscivores:

Streams with slight or moderate water quality impairment generally contain several top predator fish species. In coldwater streams were true piscivcres are absent, adult trout may be used to replace piscivores.

Fish Abundance and Condition

9. Number of individuals in the sample:

This metric measures the relative abundance of fish captured in a specified area or stream length and is used to distinguish streams with severe water quality impairment. Severe toxicity and oxygen depletion are examples of perturbations often responsible for extremely low fish abundances.

10. Proportion of individuals with disease or anomalies:

This metric provides a relative measure of the condition of individual fish. Similar to metric nine, this fish condition metric is especially useful for distinguishing streams with serious water quality impacts. This metric often detects impacts occurring below subacute chemical discharges or areas highly contaminated by chemicals.

Testing and Application of the IBI in Northern New Jersey Streams

Methods

Electrofishing surveys were conducted over a four summer period (1990 - 1993), at 122 stream sites located in the Passaic, Wallkill, Delaware and Raritan drainages (Appendix 7). All sampling was performed in the summer and early fall. Stream drainages ranged in sire from approximately 5 to 350 square miles and were determined using information obtained from the United States Geological Survey (Velnich 1982 and unpublished data). Routine chemical and physical parameters (Appendix 2), including the assessment of habitat, were measured in conjunction with fish collections at each site. Data collected from 30 sites (Table 2)

Table 2. IBI and water quality data for stream sites sampled during 1990-1993.

RIVER	DRAINAGE	WQI[1] SCORE	IBI[2] SCORE
Assunpink Creek	Delaware	72	40
Bedens Brook	Raritan	42	46
Big Flat Brook	Delaware	19	48
Black Creek	Wallkill	51	36
Crosswicks Creek	Delaware	37	42
Doctors Creek	Delaware	45	40
Elizabeth River	Passaic	82	24
Lamington River	Raritan	58	38
Lamington River	Raritan	22	40
Lamington River	Raritan	30	42
Millstone River	Raritan	25	38
Millstone River	Raritan	32	30
Millstone River	Raritan	43	36
Musconetcong River	Delaware	39	38
Neshanic River	Raritan	85	42
Passaic River	Passaic	80	40
Passaic River	Passaic	57	38
Paulins Kill	Delaware	58	44
Paulins Kill	Delaware	32	42
Pequannock river	Passaic	26	38
Rahway River	Passaic	72	38
Ramapo River	Passaic	42	32
Rockaway River	Passaic	86	36
Saddle River	Passaic	83	40
South Branch Raritan River	Raritan	35	44
Spruce Run Creek	Raritan	37	42
Wallkill River	Wallkill	26	40
Wanaque River	Passaic	4	34
Whippany River	Passaic	94	36
Wickecheoke Creek	Delaware	51	40

1 On a scale of 0 (excellent) to 100 (very poor). WQI scores of the worst three months average were taken from the 1990 New Jersey 305(b) report.

2 On a scale of 10 (very poor) to 50 (excellent)

were evaluated to determine the relationship between the IBI and a water quality index (WQI). The WQI is a numeric value, ranging from 0 (best) to 100 (worst), used to reflect the composite influence of eight constituents (temperature, oxygen, pH bacteria, nutrients, solids, ammonia and metals) considered most important'in determining water quality. Statistical analysis of the data set was performed using a correlation coefficient statistic. In addition, at 63 sites where IBI data and benthic macroinvertebrate data were collected (Table 3), the data were compared to examine the relationship between the two measures.

Studv Area

Streams selected for sampling were located near or north of the fall line that runs from approximately Trenton to Raritan Bay. This area is divided disproportionately into four ecoregions: Northern Piedmont, North Central Appalachians, Northeastern Highlands and Northeastern Coastal Zone (Omernik 1987). The Peidmont ecoregion comprises the largest percent area. All watersheds have varied land uses consisting of agriculture, forest, suburban development and urbanization. Watersheds heavily influenced by urbanization are located in the Trenton area and northeastern New Jersey. The extreme northwestern and northern portions of the state are predominantly forested. The remaining areas have a mixture of forest, agriculture and residential development.

Results and Discussion

Assessing the IBI as an Indicator of Stream Quality

In our study, stream health as measured by the IBI was not strongly related to an independent measure of'water quality, based on WQI scores. Statistical analyses using Spearman Rank Correlation Coefficient measured a weak correlation (Spearmans r =- 0.1677). Correlation with the WQI is negative because WQI scores decrease as water quality increases. This relationship. implies the IBI may not be a sensitive indicator of overall water quality.

A relationship appeared to exist between IBI and RBP scores for streams with degraded, environmental conditions. 18 sites assessed as poor, fair and fair-good using the IBI were assessed as moderately or severely impacted using RBP's. Relationships between the IBI and RBP were unclear at the other end of the water quality scale. At 45 sites environmental conditions measured by the IBI were good, good-excellent and excellent. Concomitant assessments using RBP's determined that 31 sites (69%) and 14 sites (31%) were non-impacted and moderately impacted, respectively. At 31 percent of the sites, assessments of benthic macroinvertebrates appeared to provide a more sensitive indicator of environmental quality.

RBP Rapid Bioassessment Protocol

Table 3. IBI and rapid bioassessment protocol data for stream sites sampled during 1933-1993.

RIVER	DRAINAGE	CONDITION CATEGORY IBI	RBP [1]
Assunpink Creak	Delaware	Good	MI
Big Flatbrook	Delaware	Good to Excellent	NI
Big Flatbrook	Delaware	Good	NI
Big Flatbrook	Delaware	Good to Excellent	NI
Big Flatbrook	Delaware	Good to Excellent	NI
Big Flatbrook	Delaware	Good to Excellent	NI
Bound Brook	Raritan	Fair	MI
Bound Brook	Raritan	Poor	MI
Bound Brook	Raritan	Poor to Fair	SI
Capoolong Creek	Raritan	Good	MI
Crosswicks Creek	Delaware	Good	MI
Doctors Creek	Delaware	Fair to Good	MI
Doctors Creek	Delaware	Good	NI
Drakes Brook	Raritan	Excellent	NI
Furnace Brook	Delaware	Poor	MI
Furnace Brook	Delaware	Good	NI
Green Brook	Raritan	Good to Excellent	NI
Green Brook	Raritan	Good	MI
Hakihokake Creek	Delaware	Good to Excellent	NI
Hakihokake Creek	Delaware	Good	NI
Harihokake Creek	Delaware	Excellent	NI
Lamington River	Raritan	Good	NI
Lamington River	Raritan	Good	NI
Lockatong Creek	Delaware	Good	NI
Middle Brook	Raritan	Good	MI
Millstone River	Raritan	Fair to Good	MI
Millstone River	Raritan	Good	MI
Musconetcong River	Delaware	Good	MI
Nishisakawick Creek	Delaware	Excellent	NI
North Branch Raritan River	Raritan	Good	MI
North Branch Raritan River	Raritan	Good	MI
North Branch Rockaway Creek	Raritan	Fair to Good	MI
Passaic River	Passaic	Fair	MI
Passaic River	Passaic	Good	NI
Passaic River	Passaic	Good to Excellent	NI
Paulins Kill River	Delaware	Good to Excellent	MI
Peapack Brook	Raritan	Good	NI
Peckmans River	Passaic	Poor	MI
Pequannock River	Passaic	Fair	MI
Pequannock River	Passaic	Good	MI
Pequest River	Delaware	Fair	MI
Pchatcong Creek	Delaware	Good to Excellent	NI
Pompton River	Passaic	Fair	SI
Pompton River	Passaic	Fair	SI
Ramapo River	Passaic	Fair	MI
Rockaway River	Passaic	Good	NI
Rockaway River	Passaic	Good	MI
Rockaway River	Passaic	Fair to Good	MI
South Branch Raritan River	Raritan	Good to Excellent	NI
South Branch Raritan River	Raritan	Good	MI
South Branch Raritan River	Raritan	Good to Excellent	NI
South Branch Raritan River	Raritan	Fair to Good	MI
South Branch Raritan River	Raritan	Good	MI
Spruce Run Creek	Raritan	Good	NI
Stony Brook	Raritan	Good to Excellent	NI
Van Campens Brook	Delaware	Excellent	NI
Wallkill River	Wallkill	Good	NI
Wanaque River	Passaic	Good	NI
Wanaque River	Passaic	Fair	SI
Whippany river	Passaic	Good	NI
Whippany River	Passaic	Fair to Good	MI
Whippany River	Passaic	Good to Excellent	NI
Wickecheoke Creek	Delaware	Good	NI

[1] Rapid bioassessment protocol condition categories (NI = non-impacted, MI = moderately impacted, SI = severly impacted)

Our testing of the New Jersey version of the IBI, suggests the * IBI may be limited to screening sites for the detection of seriously degraded conditions. Fish community and benthic macroinvertebrate assessments are both effective in distinquisinq sites that have degraded water quality. Based on the poor relationship between IBI and WQI scores, the present version of the IBI is not recommended as an assessment tool for measuring subtle changes in environmental quality. Further, caution must be exercised when solely using the IBI to evaluate stream health. In our study, several site assessments concluded healhty stream conditions using the IBI. In contrast, benthic macroinvertebrate assessments conducted at the same sites suggested moderate impairment.

Assessment of the Metrics:

After applying the New Jersey version of the IBI on 122 stream sites, certain trends were evident regarding each metric's contribution of useful information to the IBI. Inferences drawn here are based on field observations and the review of IBI data, and should not be construed as conclusions supported by rigorous statistical testing and analyses.

Two of the species richness and composition metrics may require additional refinements or adjustments. The number and identity of trout and/or sunfish species metric appears to have limitations when applied to small coolwater and warmwater streams. Sunfish species richness in New Jersey streams is generally poor. Even for larger streams, the maximum number of sunfish species typically captured in our survey was only five species (not excluding Micropterus sp.) Unlike Karr et al. (1986), black basses (Microuterus sp.) were included in the metric, in order to inflate already low centrachid family richness. Our findings concur with other studies that have evaluated regional applications of the IBI. Maintaining the theoretical rationale of the original metric, Miller et al. (1988) replaced the sunfish richness metric with a water column species richness metric. The authors felt it was not possible to use a sunfish richness metric because drainages located in the northeast were typically depauperate of native sunfish species.

Use of the metric on number and identity of intolerant species was problematic. Information on tolerances of individual fish species to environmental perturbations is incomplete and somewhat subjective, especially for freshwater fish found in New Jersey. Karr et al. (1986)' recommended for the purposes of the IBI, assignment of the intolerant class be restricted to 5 to 10% of the total species known to be sensitive to major environmental disturbances (e.g. nutrient enrichment, channelization). In order to meet this requirement, intolerant species assignments developed for other northeastern drainages were used (Miller et al. 1988). Several species, redfin pickerel (Esox americanus) and creek chubsucker (Erimyzon oblongus), although classified as intolerant, were common throughout a range of water quality conditions in our study, and would not appear to represent pollution sensitive species. This discrepency may be explained in part by zoogeographic fish distributions. Redfin pickerel, creek chubsucker and several other fish species originated from the Mid-Atlantic refugia (Hocutt et al. 1986) and are at northern limits of their distribution in the northeast. These species may be rare in the northeast, but not necessarily intolerant of poor environmental conditions. Limited distributions of these species may have been used to falsely infer intolerance. As a result, the intolerant species metric did not contribute significantly to the overall IBI.

Use of the trophic composition metrics, proportion of individuals as omnivores and piscivores, did not contribute significant information to the IBI. Omnivorous fish species are depauperate in New Jersey. Golden shiners (Notemioonus crvsoleucas) are the only native omnivore present in New Jersey, and are generally restricted to lakes and large streams, thus limiting their use in small and intermediate streams. Common carp (Cyprinus carpio), an introduced omnivore with a known tolerance to pollution are commonly found in New Jersey. Most streams in northern New Jersey are typically characterized by having moderate gradients. Common carp, however, do not prefer stream habitats that have significant gradient. Consequently, the 'use of carp in the omnivore metric is limited to use on low gradient streams.

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Piscivorous fish species are depauperate in New Jersey streams. Chain pickerel (Esox niger), redfin pickerel and the american eel (Anquilla rostrata) are among the only native predatory species. Introduced species such as smallmouth bass (Micropterus dolomieiu) and largemouth bass (Microaterus salmoides) have well established populations and do inflate the richness of total piscivorous species. With the exception of american eels, piscivorous fish abundances were low at most of our collection sites, and probably reflect the depauperate nature of freshwater streams in New Jersey. American eels on the other hand, were abundant in most of the fish collections. The ubiquity of american eels in streams having a wide range of water quality and habitat conditions, limits their use as an indicator of aquatic health. Overall, the metric, using proportion of individuals as piscivores, appeared to contribute insignificantly to the IBI.

Fish abundance as measured by the number of individuals in the sample generally contributes to the IBI scoring. However, when fish capture abundances are very low, IBI scoring may be biased and not representative of the environmental conditions at a site. When abundances are low, the presence and absence of a few individuals can significantly influence metric scores. Lyons (1992) recommended for samples with fewer than 50 fish, an IBI not be calculated, and instead a correction factor be used that subtracts 10 points from the total IBI score. Low fish capture rates alone should provide sufficient evidence of poor biological integrity.

Conclusions

The New Jersey version of the IBI described here should be limited to use only as a screening tool for the detection of seriously impaired water quality. Future analysis of our data with replacement metrics for those metrics that were determined to contribute little information, may improve the overall ability of the IBI to detect a broad range of environmental conditions. Like most monitoring tools, the IBI should not be used to replace information obtained by othermonitoring tools, but rather to enhance existing information.

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APPENDIX 1

FISH DATA SHEET

Waterbody Name ____________________ Location ____________________

County ____________________ state ____________

Station Number ____________________ Investigators ____________________

Date ____________ Time ________ Affiliation ____________________

Sampling Distance ______ Sampling Time ______ Gear Used ____________________

Number of Species ______ Comments ______________________________

Species	Number	Number of Anomalies

APPENDIX 2

ATTACHMENT III-1
PHYSICAL CHARACTERIZATION/WATER QUALITY
FIELD DATA SHEET

Waterbody Name ____________ Location ____________
Reach/Milepoint ____________ Latitude/Longitude ____________
County ____________ State ____________ Aquatic Ecoregion ____________

Station Number ____________ Investigators ____________
Date ____________ Time ____________ Affiliation ____________
Hydrologic Unit Code ____________ Form Completed By ____________
Reason for Survey ____________

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/WATER

Predominant Surrounding Land Use:

Forest Field/Pasture Agricultural Residential Commercial Industrial Other ____________

Estimated Stream Width ____ m Estimated Stream Depth: Riffle ____ m Run ____ m Pool ____ m

High Water Mark ____ m Velocity ____ Dam Present: Yes ___ No ___ Channelized: Yes ___ No ___

Canopy Cover: Open Partly Open Partly Shaded Shaded

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal Sewage Petroleum Chemical Anaerobic None Other ____________

Sediment Oils: Absent Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber Sand Relict Shells Other ____________

Are the undersides of stones which are not deeply embedded black? Yes No

Inorganic Substrate Components			Organic Substrate Components		
Substrate Type	Diameter	Percent Composition in Sampling Area	Substrate Type	Characteristic	Percent Composition in Sampling Area
Bedrock			Detritus	Sticks, Wood,	
Boulder	>256-mm (10 in.)			Coarse Plant	
Cobble	64-256-mm (2.5-10 in.)			Materials (CPOM)	
Gravel	2-64-mm (0.1-2.5 in.)		Muck-Mud	Black, Very Fine	
Sand	0.06-2.00-mm (gritty)			Organic (FPOM)	
Silt	.004-.06-mm		Marl	Grey, Shell	
Clay	<.004-mm (slick)			Fragments	

WATER QUALITY

Temperature ____ C Dissolved Oxygen ____ pH ____ Conductivity ____ Other ____________

Instrument(s) Used ____________

Stream Type: Coldwater Warmwater

Water Odors: Normal Sewage Petroleum Chemical None Other ____________

Water Surface Oils: Slick Sheen Globs Flecks None

Turbidity: Clear Slightly Turbid Turbid Opaque Water Color ____________

WEATHER CONDITIONS

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH

APPENDIX 3

ATTACHMENT II-4

IMPAIRMENT ASSESSKENT SHEET

Vaterbody Name ______________ Location ______________

Reach/Milepoint ______________ Latitude/longitude ______________

County __________ state ______ Aquatic Ecoregion ______________

Station Number ______________ Investigators ______________

Date __________ Time ______ Affiliation ______________

Hydrologic Unit Code ______________ Form Completed By ______________

Reason for survey ______________

1. Detection of impairment: Impairment detected (Complete items 2-6) No impairment detected (Stop here)

2. Biological impairment indicator:

Benthic macroinvertebrates
- _ absence of EPT taxa
- ____ dominance of tolerant groups
- ____ lov benthic abundance
- ____ lov taxa richness
- ____ other

Other aquatic communities
- ____ Periphyton
  - ____ filamentous
  - ____ other
- ____ Macrophytes
- ____ Slimes
- ____ Fish

3. Brief description of problem: ______________

Year and date of previous surveys: ______________

Survey data available in: ______________

ACause: (indicate major cause) organic enrichment toxicants flov

habitat limitations other ______

5. Estimated area1 extent of problem (m^2) and length of stream reach affected (m), where applicable: ______________

6. Suspected source(s) of problem:

- ____ point source discbarge (name, type of facility, location)
- ____ construction site runoff
- ____ combined sever outfall
- ____ animal feedlot
- ____ agricultural runoff
- ____ urban runoff
- ____ ground vater
- ____ other
- ____ unknown

Briefly explain:

APPENDIX 4.1

HABITAT ASSESSMENT FIELD SHEET •

Category/Parameter	Condition: Excellent	Good	Fair	Poor
PRIMARY--SUBSTRATE AND INSTREAM COVER				
1. bottom substrate and available cover	1640	11-15	6-10	0-5
2. embeddedness	16-20	11-15	6-10	O-S
3. flow/velocity	16-20	11-15	6-10	O-S
SECONDARY--CHANNEL MORPHOLOGY				
4. channel ● ltcrrtion	12-1s	E-11	4-7	o-3
5. bottom scouring and deposition	12-1s	8-11	4-7	O-3
6. pool/riffle, run/bend ratio	12-1s	. 8-11	4-7	o-3
TERTIARY--RIPARIAN AND SANK STRUCTURE				
7. bank stability	9-10	6-8	3-S	o-2
8. bank vegetation	9-10	6-8	3-S	O-2
9. streamside cover	9-10	6-8	3-S	o-2
	___	___	___	___
Total Score				

Condition:

Excellent	111 - 135
Good	75 - 102
Pair	39 - 66
Poor	0 - 30

• Taken from Plrfkin cc. al. 1988.

APPENDIX 4.2

HABITAT ASSESSMENT - COASTAL PLAIN REGION

Habitat Parameters	Condition			
GENERAL CHARACTERISTICS	**Excellent**	**Good**	**Fair**	**Poor**
1. Channel modification	12-15	8-11	4-7 ·	0-3
INSTREAM MEASUREMENTS				
2. Instream habitat	16-20	11-15	6-10	0-5
3. Pool variety	12-15	8-11	4-7	0-3
STREAMBANK MEASUREMENTS				
4. Bank stability	12-15	8-11	4-7	0-3
5. Bank vegetative type				
left edge water	9-10	6-8	3-5	0-2
right edge water	9-10	6-8	3-5	0-2
RIPARIAN ZONE MEASUREMENTS				
6. Shading	9-10	6-8	3-5	0-2
7. Riparian vegetative:				
left bank	4-5	3	2	0-1
rightbank	4-5	3	2	0-1

column totals: ____

Score: ______

Condition:

Excellent	88 - 105
Good	59 - 80
Fair	30 - 51
Poor	0 - 22

APPENDIX 5

Proposed IBI for Northern New Jersey
(metrics and scoring criteria)

	Scoring Criteria 5	3	1
Species Richness and Composition:			
1. Total number of fish species (excluding trout)	Varies with stream size		
2. Number and identity of benthic insectivorous species	Varies with stream size		
3. Number and identity of trout (non-stocked) 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 omnivores	<20%	21-45%	>45%
7. Proportion of individuals es insectivorous cyprinids	>45%	20-45%	<20%
8. Proportion of individuals as non-stocked trout	>10%	3-10%	<3%
or			
Proportion of individuals as piscivores	>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 or anomalies	<2%	2-5%	>5%

Condition Categories:

excellent	50-47
good to excellent	46-43
good	42-38
fair to good	37-35
fair	34-30
poor to fair	29-27
poor	26-21
very poor to poor	20-18
very poor	<18

APPENDIX 6

Freshwater Fishes of New Jersey

	Trophic Guild	Tolerance	Historical Presence
Petromyzontidae:			
American Brook Lamprey (Lampetra appendix)	F	-	N
Sea Lamprey (Petromyzon marinus)	P	-	N
Acipenseridae:			
Atlantic Sturgeon (Acipenser oxyrhynchus)	BI	-	N
Shortnose Sturgeon (A. brevirostrum)	BI	-	N
Lepidosoteidae:			
Longnose Gar (Lepisosteus osseus)	P	-	N
Amiidae:			
Bowfin (Amia calva)	P	-	E
Anguillidae:			
American Eel (Anguilla rostrata)	P	-	N
Clupeidae:			
Blueback Herring (Alosa aestivalis)	PL	-	N
Hickory Shad (A. mediocris)	I/P	-	N
Alewife (A. psendoharengus)	PL	-	N
American Shad (A. sapidissima)	PL	-	N
Gizzard Shad (Drosoma cepedianum)	O	-	N
Salmonidae:			
Rainbow Trout (Oncorhynchus mykiss)	I/P	-	E
Brown Trout (Salmo trutta)	I/P	-	E
Brook Trout (Salvelinus fontinalis)	I/P	IS	N
Lake Trout (S. namaycush)	P		E
Osmeridae:			
Rainbow Smelt (Osmerus mordax)	I		N
Umbridae:			
Eastern *Mudminnow* (Umbra pygmaea)	I	-	N

Esocidae:			
Redfin Pickerel (Esox americanus)	P	IS	N
Northern Pike (E. lucius)	P		E
Chain Pickerel (E. niger)	P	IS	N
Muskellunge (E. masguinongy)	P		E
Cyprinidae:			
Goldfish (Carassius auratus)	O		E
Carp (Cyprinus carpio)	O		E
Culips Minnow (Exoglossum maxillingua)	BI	IS	N
Eastern Silvery Minnow (Hybognathus regius)	H	IS	N
Golden Shiner (Notemigonus crysoleucas)	O		N
Comely Shiner (Notropis amoenus)	I		N
Satinfin Shiner (cyprinella analostana)	I		N
Bridle Shiner (Notropis bifrenatus)	I		N
Ironcolor Shiner (N. chalybaeus)	I		N
Common Shiner (Luxilis cornutus)	I		N
Spottail Shiner (Notropis hudsonius)	I		N
Shallowtail Shiner (N. Procne)	-		N
Spotfin Shiner (Cyprinella spiloptera)	I		N
Fathead Minnow (Pimephales promelas)	O		E
Bluntnose Minnow (P. notatus)	O		N
Blacknose Dace (Rhinichtys 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
Longnose Sucker			

(C. catostomus)	BI		N
Creek Chubsucker			
(Erimyzon oblongus)	BI	IS	N
Northern Hog Sucker			
(Hypentelium nigricans)	BI	IS	N
Ictaluridae:			
White Catfish			
(Ameiurus catus)	I/P		N
Black Bullhead			
(A. melas)	BI		E
Yellow Bullhead			
(A. natalis)	BI		N
Brown Bullhead			
(A. nebulosus)	BI		N
Channel Catfish			
(Ictalurus punctatus)	I/P		E
Tadpole Madtom			
(Noturus gyrinus)	BI	IS	N
Margined Madtom			
(N. insignis)	BI	IS	N
Aphredoderidae:			
pirate perch			
(Aphredoderus sayanus)	I		N
Cyprinodontidae:			
Banded Killifish			
(Fundulus diaphanus)	I		N
Poeciliidae:			
Mosguitofish			
(Gambusia holbrooki)	I		E
Gasterosteidae:			
Fourspine Stickleback			
(Apeltes guadracus)	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	IS	E
Blackbanded Sunfish			
(Enneacanthus chaetodon)	I		N
Bluespotted Sunfish			
(E. gloriosus)	I		N
Banded Sunfish			
(E. obesus)	I	IS	N

Green Sunfish (Lepomis cyanellus)	I/P	-	E
Pumpkinseed (L. gibbosus)	I	-	N
Bluegill (L. macrochirus)	I	-	E
Redbreasted Sunfish (L. auritus)	I	-	N
Smallmouth Bass (Micropterus dolomieui)	I/P	-	E
Largemouth Bass (M. salmoides)	P	-	E
White Crappie (Pomoxis annularis)	I/P	-	E
Black Crappie (Pomoxis nigromaculatus)	I/P	-	E
Percidae:			
Swamp Darter (Etheostoma fusiforme)	BI	IS	N
Tessellated Darter (E. olmstedi)	BI		N
Yellow Perch (Perca flavescens)	I/P		N
Logperch (Percina caprodes)	BI		N
Shield Darter (P. peltata)	BI		N
Walleye (Stizostedion vitreum)	P		E
Cottidae:			
Slimy Sculpin (Cottus cognatus)	BI	IS	N

Abbreviations:

BI - Benthic Insectivore or Invertivore
E - Exotic
F - Filter Feeder
H - Herbivore
I - Insectivore
IS - Intolerant Species
N - Native
0 - Omnivore
P - Piscivore
PL - Planktivore

APPENDIX 7

WATERBODY	DATE	LOCATION	CONDITION
Alexauken Creek	18-Aug-93	Us Route 29 (S1)	Good to Excellent
Ambrose Brook	18-Oct-90	Ambrose-Doty's Park (Off Centennial Ave.) (SC)	Good
Assunpink Creek	OQ-Jon-93	Off Assunpink Ave. (S1)	Good
Bear Creek	IO-Ccl-91	Upstream of Bear Creek Rd. (SC1)	Good
Bear Creek	10-Oct-91	Downstream of Shades of Death Rd. (SC2)	Good
Beaver Brook	2-Oct-91	Old Beach Glen Rd. (Sl)	Good
Beaver Brook	13-Aug-91	Downstream of Lake Just It Rd. (SB)	Good to Excellent
Bedens Brook	08-Aug-91	Off River Road Downstream of Pike Run con. (SB2)	Good
Bedens Brook	08-Aug-91	Downstream of Co. Hwy 601 (Great Road) (SB1)	Excellent
Big Flat Brook	26-July-91	(downstream)	Good to Excellent
Big Flat Brook	26-July-91	(upstream)	Good to Excellent
Big Flat Brook	05-Jul-91	Off Flatbrook Road (S1)	Good to Excellent
Big Flat Brook	IO-Jul-91	Upstream of Hwy 521 (S2)	Good
Big Flat Brook	IO-Jul-91	Hwy 615 and Brook Road (S3)	Good to Excellent
Black Creek	06-Aug-93	Ds Hwy. 644 (Sl)	Fair to Good
Black River	23-Jul-93	Us. Righter Rd. (Sl)	Good
Blair Creek	14-Aug-91	Upstream unpaved bridge off Co. Hwy 602 (SB)	Good to Excellent
Bound Brook	22-Jul-91	Adjacent to RR Ds of Lakeview Ave. (SB)	Poor
Bound Brook	17-Jun-92	Downstream of Lakeview Ave. (Sl)	Fair to Poor
Bound Brook	17-Jun-92	Downstream of Prospect Ave. (S2)	Fair
Canoe Brook	21-Jul-92	Upstream of Hobart Rd. (Sl)	Fair
Capoolong Creek	1 -Aug-90	Upstream of White Bridge Rd. (Sl)	Good
Capoolong Creek	26-Sep-90	Upstream of Lower Landsdown Road above R.R. (SF)	Good
Clove Brook	04-Sep-91	Downstream of Discharge (SB2)	Good to Excellent
Clove Brook	04-Sep-91	Upstream of Discharge (SB1)	Good to Excellent
Crooked Brook	02-Oct-91	Downstream of Horseneck Rd. (SC)	Fair to Good
Crosswicks Creek	12-Jul-93	Ds Province Line Rd. (S1)	Good
Cuckles Brook	11-Jun-93	Us MUA Discharge (sl)	Poor
Dead River	22-Aug-91	1/2 way between Allen Rd. and Hwy 512 (SB1)	Good to Excellent
De” Brook	16-Oct-91	Upstream of Cooper Rd. (SB)	Good
Doctors Creek	07-Oct-91	Upstream from Crosswicks Hamilton Square Rd. (SA2)	Fair to Good
Doctors Creek	07-Oct-91	Upstream of Co. Hwy 524 (SA1)	Good
Drakes Brook	13-Aug-90	Adjacent to West Morris High School (SG)	Excellent
Elizabeth River	18-Jun-92	Upstream of U.S. Hwy 76 (Sl)	Poor
Elizabeth River	18-Jun-92	Downstream of Union Ave. (S2)	Poor
Elizabeth River	05-Aug-92	Off Conant Street, downstream of Salem Rd. (S3)	Poor
Furnace Brook	23-Aug-90	Upstream Pequest Rd. Downstream of RR grade	Poor
Furnace Brook	23-Aug-90	Downstream of Hwy 31 (SD1)	Good
Goffles Brook	10-Aug-93	Ds N.Hadeon Rd. (S1)	Poor to Fair
Green Brook	15-Jul-91	Green Brook Park Us of Stony Brook (SA2)	Good to Excellent
Green Brook	15-Jul-91	Off New Providence Rd Ds of Blue Brook (SA1)	Good
Hakihokake Creek	OQ-Aug-93	Milford Park (Sl)	Good
Hakihokake Creek	08-Sep-92	Downstream of Water Street (Sl)	Good to Excellent
Harihokake Creek	15-Jul-93	Us Hwy 619 (S1)	Excellent
Harrisons Brook	01-Aug-91	Downstream of Hwy 512 & Us of the Dead River (SC1)	Good
Hohokus Creek	17-Oct-90	Downstream of Wykoff Rd. (SF1)	Fair
Holland Brook	16-Jul-91	Upstream of Hwy 202 (SB)	Good
Lamington River	08-Oct-92	Gff McCans Mill Rd. (Ds. Potterstown STP) (S1)	Good
Lamington River	17-Jun-93	Off Hwy. 620 (Ds) (S2)	Good
Little Flat Brook	04-Aug-92	Upstream of Ennis Rd. (Sl)	Good
Lockatong Creek	23-Jul-91	Upstream of Co. Hwy 519 (SC)	Good
Lopatcong Creek	03-Aug-93	Ds P-burg STP (Sl)	Poor
Meadow Brook	16-Aug-93	Us. Highland Ave. (S1)	Good
Middle Brook	13-Jul-93	Ds Thompson Rd. (Sl)	Good
Millstone River	26-Jul-93	Off Millstone Rd. (Sl)	Fair
Millstone River	30-Jun-93	Us Causeway Rd. (S2)	Fair to good
Millstone River	06-Oct-92	Off River Rd. at Stony Brook STP (Sl)	Good
Molly Ann Brook	IO-Aug-93	Us Preakness Rd. (Sl)	Fair
Musconetcong River	24-Jul-91	Hackettstown behind K-Mart (SE)	Good
Musquapsink Creek	II-Jul-92	Off Meyer Place, off Sand Rd. (Sl)	Fair
Neshanic River	03-Jun-93	Off Black Point Rd. (Sl)	Good

Neshanic River	03-Jun-93	Cff Kuhl's Rd. (S2)	Good
Nishisakawick Creek	oe-Sap-92	Upstream of Kingwood Ave. (S1)	Excellent
N.B. Raritan River	14-Aug-90	Downstream of Hwy 202 (SA)	Good
N.B. Rockaway Creak	14-Aug-91	Off Rockaway Road (SD)	Good
N.B. Rockaway Creek	31 -July-90	Off Rockaway Rd. (SI)	Fair to Good
Papakating Creek	05-Aug-93	Us Plains Rd. (SI)	Good
Pascack Creek	22-Jul-92	CM Brookside Ave. (SI)	Fair to Poor
Passaic River	15-Jun-93	Off Popular Drive (SI)	Good
Passaic River	15-Jun-93	Off Thackery Rd. (S2)	Good
Passaic River	21 -Aug-90	Upstream of Hwy 202 (SA1)	Good to Excellent
Passaic River	06-Aug-91	Downstream of Summit Ave.(SA3)	Fair
Passaic River	06-Aug-91	Downstream of Stanley Road below USGS st. (SA2)	Good
Paulinskill River	Ol-Jul-93	Off Hwy. 94 (S2)	Good
Paulinskill River	01 -Jul-93	Ds Smith Hill Rd. (S1)	Good to Excellent
Peapack Brook	13-Aug-90	Off Hwy 206 Ds of RR crossing (SB)	Good
Peckmans River	22-Jun-92	Downstream of Pompton Ave. (S1)	Poor
Pequannock River	17-Jul-90	Off Garde" Rd. (SG2)	Fair
Pequannock River	20-Sep-90	Off Rt. 23 adjacent to Silas Co. Park (SG1)	Good
Pequest River	30-Jul-91	Off Cemetery Rd. (SA)	Fair
Peters Brook	I I -Ju"-93	Ds Hwy 612 (S1)	Fair to Good
Pike Run	09-Oct-91	Downstream of the Mill Pond Dam and Road (SA)	Excellent
Pohatcong Creek	09-Jul-93	Ds Tunnel Hill Rd. (S1)	Good to Excellent
Pompton River	16-Jun-93	Off Riverside Drive (S1)	Fair
Pompton River	16-Jun-93	Off N. Pequannock Ave. (S2)	Fair
Preakness Brook	03-Aug-92	Downstream of Ratzer Rd. (S1)	Good
Rahway River	5-Aug-92	Off Washington Ave. (SI)	Good
Rahway River	16-Jun-92	Downstream of Millburn Ave. (S2)	Fair
Rahway River (Trib)	16-Jun-92	Downstream of Meisel Ave. (S1)	Fair to Good
Ramapo River	OS-Aug-92	Off Hwy 202 on Ramapo Valley Reservation (S1)	Fair
Rockaway River	16-Jul-90	Downstream Berkshire Rd Bridge off Taylor Rd (SA1)	Good
Rockaway River	16-Jul-90	Off Berkshire Rd. (SA2)	Good
Rockaway River	07-Aug-92	Off RIver Rd. adjacent to Knoll Golf Course (S1)	Fair to Good
Royce Brook	OQ-Ccl-91	Upstream of Hamilton Road (SC)	Good
Saddle River	25-Jun-92	Saddle River Park off Dunkerhook Rd. (S1)	Good
Saddle River	17-Oct-90	Upstream of Lake Rd. (SE1)	Good
Spruce Run Creek	18-Jul-91	Off Hwy 31 Downstream of Rock Run Confluence (SE)	Good
Stony Brook	29-Sep-92	Off Stony Brook Rd.. Downstream of Mine Rd. (S1)	Good to Excellent
Stony Brook	20-Jul-93	Us Green Brook (SI)	Good
S.B. Raritan River	07-Jul-93	Off 513/US GrayRock Rd. (SI)	Good to Excellent
S.B. Raritan River	18-Jul-91	Downstream of River Road (SA3)	Fair to Good
S.B. Raritan River	27-Sep-90	Upstream of River Road (SA2)	Good
S.B. Raritan River	27-Jul-90	Upstream *of* River Road (SA2)	*Good*
S.B. Raritan River	04-Oct-91	Downstream of Flanders-Drakestown Road (SA1)	Good to Excellent
S.B. Raritan River	8-Oct-91	Tarn Site (downstream)	Good
S.B. Raritan River	8-Oct-91	Tarn Site (upstream)	Fair to Good
S.B. Rockaway Creek	16-Jul-91	Upstream of Mountain Road (SC)	Fair to Good
Third River	20-Jul-92	Off Park Rd., upstream of Chestnut Rd. (S1)	Fair to Good
Troy Brook	03-Aug-92	Upstream of South Beverwyck Rd. (S1)	Good
VanCampens Brook	15-Oct-91	Ds of 1st wooden bridge of Old Mine Rd. (SF)	Excellent
Wallkill River	05-Sep-91	Downstream of Hwy 33 (SA)	Fair
Wallkill River	05-Sep-91	Upstream of Hwy 565 (SA2)	Good
Wallkill River	14-Aug-90	Sparta Township Park	Good
Wanaque River	02-Aug-91	Off East Shore Rd. (SD1)	Good
Wanaque River	15-Oct-92	Off Highland Ave. Us of Wanaque Val WSA (SI)	Fair
Whippany River	31-Jul-91	Between Cedar Knolls and US 267 bridges (SA1)	Fair to Good
Whippany River	22-Aug-90	Cff Rt. 24 Mendham, East of Tingley Rd.	Good to Excellent
Whippany River	31 -Jul-91	Downstream Whippany Rd. (SA2)	Good
Wickecheoke Creek	23-Jul-91	Off Lower Creek Rd. (SD)	Good
W.B. Papakating Creek	*05-Aug-93*	US Hwy 565 (S1)	*Good*