Freshwater Ecological Health: Stream Biomonitoring- Ambient Macroinvertebrate Network (AMNET) and Fish Index of Biotic Integrity Network (FIBI)

Ambient Macroinvertebrate Network (AMNET)

Background

The federal Clean Water Act requires New Jersey to determine every two years whether the State’s waters meet the objectives of the Act, to attain state water-quality standards and provide for the protection and propagation of balanced populations of fish, shellfish and wildlife. Furthermore, the state is required to assess and report on the extent to which pollution-control programs have improved water quality.

Discrete chemical monitoring of conditions at the time of sampling may fail to detect acute pollution events, such as runoff from heavy rain; non-chemical pollution, such as habitat alteration; and nonpoint source pollution.

Because of these limitations, DEP supplements its chemical monitoring with biological monitoring. In 1989, the DEP began a statewide Ambient Macroinvertebrate Network (AMNET) to collect and assess benthic macroinvertebrate populations (insects, worms, mollusks, and other indicator species) in the state’s freshwater streams (Figure 1). Biological communities reflect the overall ecological integrity of a river or stream, and integrate the effects of different stressors, providing a broad measure of their aggregate impact. Benthic macroinvertebrates are good indicators of localized conditions because they are relatively sessile. Therefore, the composition of a stream benthic macroinvertebrate community can be used to assess the effects of both short-term and long-term variations in water quality, as well as habitat quality. The primary goal of AMNET is to provide a long-term, cost-efficient means of gauging the quality of surface waters and watershed areas throughout the state. The data generated by AMNET are used in the DEP’s preparation of the biennial “Integrated Water Quality Monitoring and Assessment Report (includes 305(b) Report and 303(d) List). The information is also used to help determine the waterbodies that should be given Category One protection based on “exceptional ecological significance.” The Category One designation provides special protections for high-quality waters to protect against degradation.

The USEPA recommends multiple assemblages be used in freshwater biomonitoring programs, which could include benthic macroinvertebrates, fish, and algae. Therefore, in 2000, fish were added to the state’s biomonitoring program to augment and enhance the established benthic macroinvertebrate monitoring network. Fish are good indicators of long-term effects and broad habitat conditions because they are relatively long-lived and mobile. A fish index of biotic integrity (FIBI) was developed to measure the health of a stream based on multiple attributes of the resident fish community such as species type and number, and the presence of disease or deformities. Work on an index for a third freshwater assemblage, algae using periphytic diatoms, is in development. Algae, as primary producers, are very responsive to nutrients and can be a valuable tool in assessing nutrient impairments in freshwater rivers and streams.
**Status and Trends—AMNET**

The network consists of over 760 non-tidal stations distributed equally throughout the state’s five water regions (Atlantic, Raritan, Lower Delaware, Upper Delaware and Northeast regions). Stations are sampled once every five years in each region on a rotating basis. To date, four statewide rounds of sampling have been completed. Initially, a single multi-metric index called the New Jersey Impairment Score (NJIS) was used to assess streams throughout the state. The Department recognized the limitations of the NJIS when applied statewide. With the diversity of ecological habitats in New Jersey multiple statistical methods were necessary for the interpretation of the raw benthic macroinvertebrate data into a meaningful environmental indicator. Accordingly, the Department worked with USEPA- Region 2 to develop and calibrate two new indices for New Jersey- the High Freshwater Ecological Health: Stream Biomonitoring- Ambient Macroinvertebrate Network (AMNET) and Fish Index of Biotic Integrity Network (FIBI).

With the development of the new indices, all previous data were re-assessed using the appropriate new index- HGMi, CPMI, or PMI. Therefore, all four rounds of assessments presented below use the index appropriate for the geographical area of the site. The comparisons below are only for common sites sampled in all four rounds. The statewide results showed that since Round 1 beginning in 1989, through Round 4 ending in 2012, the percentage of sites statewide rated as “Excellent” was highest with Round 2 at 20.1% and the lowest in Round 4 with 14.4%. Over the same period, the percentage of sites rated as “Poor” has declined from 20.9% in Round 1 to 14.0% in Round 4. With the decline in sites rated as “Poor”, there has been a continual increase in sites rated as “Fair” from Round 1 to Round 4, going from 33.2% to 43.7% in Round 4 (Figure 3).

The first two rounds included year-round sampling, and therefore, included assessments made with samples collected outside the currently accepted sampling window. When comparing results for sites sampled during the winter with the same site sampled in subsequent rounds within the April through November index period, there was no significant change in results. Also, sites now considered to be tidally-influenced, which may have been included in previously reported results for Rounds 1 and 2, have been removed, since the indices are not applicable to these areas. Table 1 and Figure 3 show the statewide assessment results. Individual site results vary from stable to improving or declining. Individual site assessment results can be found at: http://www.state.nj.us/dep/wms/bfbm/amnet.html.
Outlook and Implications

Since the inception of this statewide network in 1989, there has been an overall decline in the percentage of sites rated as “Poor”, and an increase in the percentage of sites rated as “Fair”. While some of the increase in the “Fair” category can be attributed to the decline in the “Poor” category, changes in both the “Excellent” and “Good” categories, may also be reflected.

Biological assessments are important for indicating the overall ecological health of our waters and the extent of impairments. However, biological assessments do not identify the cause or causes of the impairment, or whether it is a chemical stressor or physical habitat alteration, such as sedimentation. Further investigation with additional data, including chemical and biological sampling, is necessary to determine why a site's biological assessment has declined or improved, and if these changes are related to water quality, habitat quality, or to flow-related episodic events such as droughts and floods. Most stressors impacting instream biological communities are directly related to the land use of the watershed. It is clear that increasing urbanization and consequent decreasing area of forested land greatly affect the biotic integrity of benthic communities (USGS, 1998).

Currently, benthic macroinvertebrate sampling for the 5th round of AMNET is underway. Statewide sampling is scheduled to be completed for this round in 2018.

Fish Index of Biotic Integrity Network

Background

As discussed above, monitoring of benthic macroinvertebrate populations is widely practiced in New Jersey. However, these species generally are reflective of short-term and local impairment. To assess environmental conditions on a larger scale, the Department established a Fish Index of Biotic Integrity (FIBI) to monitor New Jersey’s streams in 2000. A FIBI measures the health of a stream based on multiple attributes of the resident fish assemblage or community such as species type and number and trophic structure. Each site sampled is then scored based on its deviation from reference conditions (i.e., what would be found in an un-impacted stream) and classified as “very poor”, “poor”, “fair”, “good” or “excellent”. In addition, habitat is evaluated at each site and classified as “poor”, “marginal”, “suboptimal” or “optimal”.

Primary objectives of the fish collections are to obtain samples with representative species and abundances, at a reasonable level of effort. Using similar stream lengths, collection methods and habitat types standardizes sampling efforts.

Status and Trends—FIBI

The FIBI program is divided into 3 different indices based on physiographic province and watershed size. Presently the Bureau has two fish-based monitoring programs, 1) a southern index of biotic integrity (SIBI) and 2) a northern index of biotic integrity (NIBI). Each Index is designed to accurately

<table>
<thead>
<tr>
<th>Round</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 1 (1989-96)</td>
<td>17.5%</td>
<td>28.3%</td>
<td>33.2%</td>
<td>20.9%</td>
</tr>
<tr>
<td>Round 2 (1997-01)</td>
<td>20.1%</td>
<td>23.9%</td>
<td>38.7%</td>
<td>17.4%</td>
</tr>
<tr>
<td>Round 3 (2002-07)</td>
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<td>23.5%</td>
<td>42.2%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Round 4 (2007-12)</td>
<td>14.4%</td>
<td>27.9%</td>
<td>43.7%</td>
<td>14.0%</td>
</tr>
</tbody>
</table>

Table 1: Assessment Results
describe the health of the resident fish population and is comprised of varying metrics, due to differences in regional fish populations throughout NJ. Southern IBI monitoring takes place in streams located in southern New Jersey, south of the geologic fall-line, within the inner coastal plain but excluding the pinelands boundary, and requires a drainage basin greater than 2 mi² (5.2 km²). Northern IBI monitoring takes place in medium to large high gradient streams and rivers located in northern New Jersey, north of the geologic fall-line including the following physiographic provinces: Piedmont, Highlands and Ridge and Valley, and requires a drainage basin greater than 4 mi² (10.4 km²), typically Strahler stream orders 4 and 5.

Additionally, in 2013, another program called the headwaters index of biotic integrity (HIBI) was designed to complement the existing fish IBI programs to assess stream condition, water quality and habitat in high gradient headwater streams (typically Strahler stream orders 1-3) north of the geological fall-line with drainages less than 4 mi² (10.4 km²). The headwater IBI is also a multi-metric index, however, it utilizes the biological assemblage (fish, crayfish, and amphibians), rather than just fish, present within and along a stream to assess the overall condition of the headwater stream. The entire biological assemblage is utilized because small order streams often have naturally low fish species richness and cannot be accurately assessed with a solely fish based IBI. Therefore, other biota such as crayfish, frogs, and salamanders occupy critical niches and can be used to supplement the development of a biotic index. The creation of the HIBI program, along with the existing fish IBI programs has allowed biologists at BFBM the potential to monitor all wadeable streams north of the geological fall-line via IBI metrics to accurately assess ecosystem health.

The data provided by the IBI program is an important component of the DEP's suite of environmental indicators and helps measure water-quality use attainment and the DEP's success in attaining the Clean Water Act goal of “fishable” waters. IBI data also will 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 are used in part to determine a waterbody’s potential for upgrade to a Category One antidegradation classification based on exceptional ecological significance.

The Bureau of Freshwater and Biological Monitoring currently has a 220 station IBI monitoring network in New Jersey (See Figure 4). The monitoring network consists of fixed, probabilistic, and sentinel sites. Fixed stations will be visited once every five years as part of the Department’s ambient monitoring efforts. Since Southern IBI and Headwaters IBI monitoring was recently initiated by the Department, there are insufficient data to assess trends; therefore, the following results represent only Northern IBI data.
The 2014 season marked the end of the third round of sampling for the Northern IBI, in which the Department returned to those network sites originally sampled in Round 1 (2000-2004). In an effort to ensure sensitivity to anthropogenic stressors, the Northern Fish IBI was recently revised. This recalibration resulted in modifications in scoring criteria and metrics. As such, all data from previous rounds have been rescored using the new metrics to ensure a direct comparison of results. The following trends compare results for the same 62 sites from rounds one, two, and three (Figure 5). Overall, results were varied with the number of “excellent” sites declining slightly since Round 1 and the number of “fair” sites increasing since Round 1. The number of “good” and “poor” sites was relatively constant among the three rounds.

A comparison of Northern IBI scores for the same 62 sites among rounds indicates no significant difference in the distribution of scores (Kruskal-Wallis test; p=0.998; Figure 6). The distribution of overall scores for Rounds 1 and 3 were similar, while scores in Round 2 tended to be centered around the “fair” range.

Between the first (2000-2004), second (2005-2009), and third (2010-2014) rounds of Northern IBI monitoring for the 62 common sites sampled, 18% exhibited a positive change, 21% exhibited a negative change, 42% exhibited no change in impairment rating, and 19% exhibited variable results. On the whole, these trends would seem to indicate a “status-quo”, with a slight negative trend. Almost as many stations are showing an improvement as are exhibiting degradation over this 15-year time period. However, both the negative and positive trends are marginal ones reflecting shifts in impairment to an adjoining category; for example, from a “Poor” rating to a “Fair” rating or the reverse.

Data can be found at [http://www.nj.gov/dep/wms//bfbm/fishibi.html](http://www.nj.gov/dep/wms//bfbm/fishibi.html).
Outlook and Implications

The number of “fair” sites has increased slightly since Round 1 (2000-2004), but in general results have remained relatively static since sampling was initiated in 2000. Overall, the number of sites considered impaired for aquatic life use (“poor” and “very poor”) has declined since the earliest round. Data from Round 2 (2005-2009) exhibited the biggest gap between the number of impaired sites (20.9%) and non-impaired sites (79%).

Northern fish IBI metrics are broken into ecological classes which can help identify potential stressors to fish. These 8 fish metrics are broken into the following categories: stream flow, thermal preference, trophic designation, tolerance, reproduction, species composition, and habitat. Round 3 data indicate fish biotic integrity is highly sensitive to anthropogenic stressors including impervious cover, siltation, and increased run-off from storm water outfalls. These stressors impact reproduction of clean substrate spawning fish (lithophilic), survival of sensitive species, feeding ability of species with specialized diets and feeding strategies, and the overall composition and richness of the resident fish community. These data conclude the following:

1. Northern Fish IBI data indicates a significant decline in fish biotic integrity with increasing urban land use (Pearson Correlation; r = -0.75; p<0.001)

2. Percent richness of lithophilic spawning fish are negatively correlated with increasing impervious cover (Pearson Correlation; r = -0.64; p<0.001) and are positively correlated with percent forest land use land cover (Pearson Correlation; r = 0.60; p < 0.001)

3. Percent richness of generalist fish are positively correlated with increasing human population density (Pearson Correlation; r = 0.69; p<0.001)

More Information

Data and reports of the FIBI can be obtained by visiting www.state.nj.us/dep/wms/bfbm or by calling (609) 292-0427.

References


USGS, 1998. Relation of benthic macroinvertebrate community impairment to basin characteristics in New Jersey Streams. Fact Sheet FS-057-98, USGS, West Trenton, NJ.