

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

Ambient Macroinvertebrate Invertebrate 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, 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, habitat alteration, and nonpoint source pollution. Because of these limitations, the 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). The Bureau of Freshwater and Biological Monitoring (BFBM) in the Division of Water Monitoring and Standards at NJDEP administers the AMNET and FIBI programs.

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, or immobile. 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 is 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.

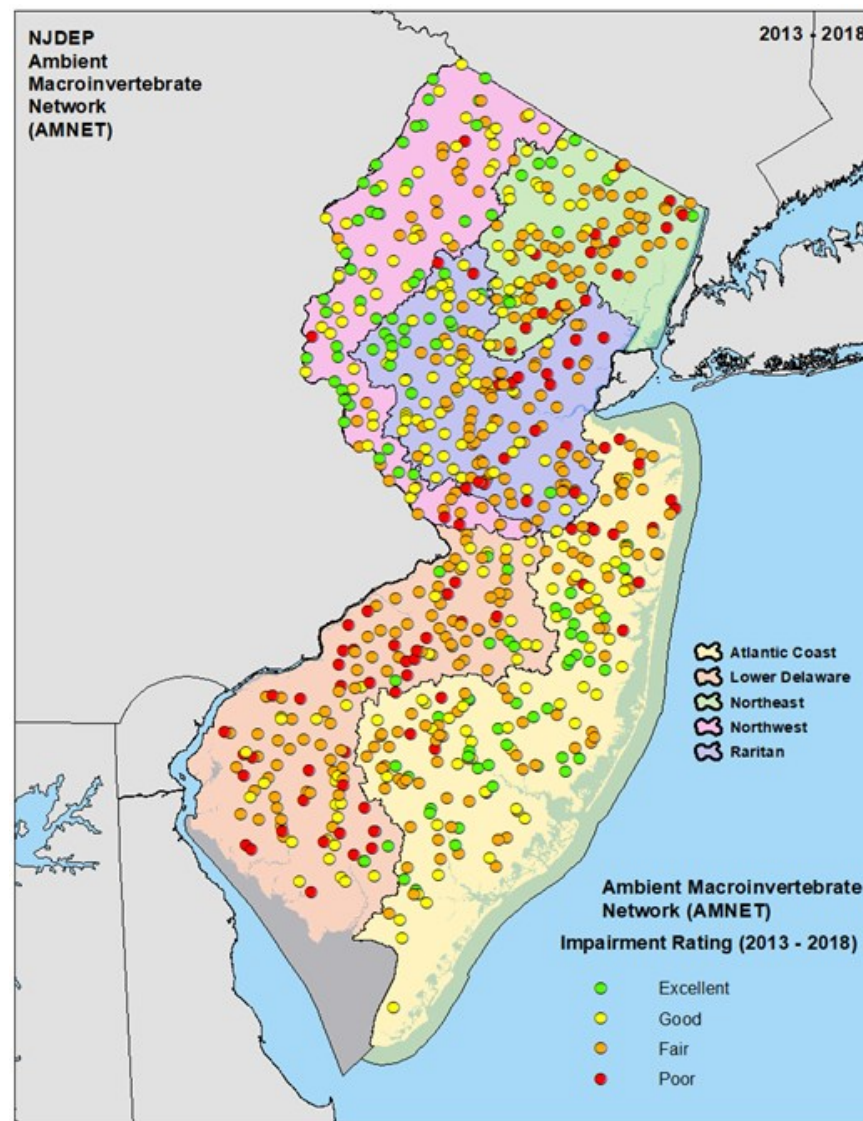


Figure 1. AMNET sampling locations and impairment ratings.

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. 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.

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, Northwest (Upper Delaware) and Northeast regions). Stations are sampled once every five years in each region on a rotating basis. To date, five 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 Gradient Macroinvertebrate Index (HGMI)¹ for use above the fall line, and the Pinelands Macroinvertebrate Index (PMI)² for use in and surrounding the ecologically-unique Pinelands National Reserve of southern New Jersey (Figure 2). A third index, previously developed by a multi-state workgroup to assess streams in the Coastal Plain ecoregion, was employed for non-Pinelands streams below the geological fall line. This index, known as the Coastal Plain Macroinvertebrate Index (CPMI),³ along with the HGMI and PMI, provides a four-tiered assessment framework - Excellent, Good, Fair, and Poor- and allows the DEP to perform benthic macroinvertebrate monitoring at non-tidal freshwater rivers and streams throughout the state. The New Jersey Integrated Water Quality Monitoring and Assessment Report (Integrated Report) considers Excellent and Good as supporting aquatic life use, Fair and Poor as not supporting aquatic life use. These new indices are not applicable to tidal streams. Therefore, stations located on tidal portions of streams were omitted from subsequent analyses.

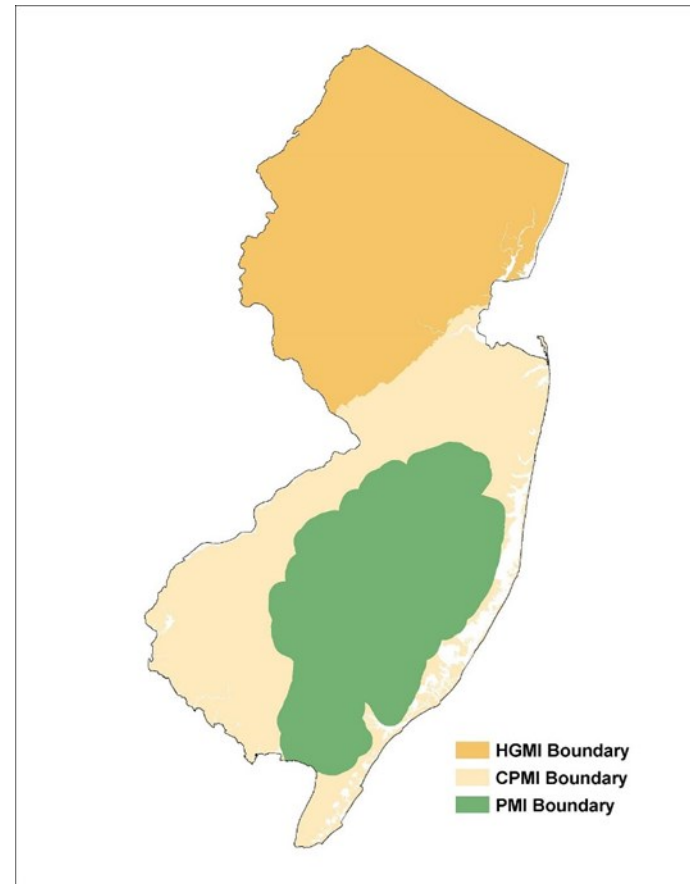


Figure 2. Geographic boundaries of each macroinvertebrate index region.

With the development of the new indices, all previous data were re-assessed using the appropriate new index - HGMI, CPMI, or PMI. Therefore, all five rounds of assessments presented in Figure 3 below use the index appropriate for the geographical area of the site. The comparisons below are only for common sites sampled in all five rounds. The statewide results showed that since Round 1 beginning in 1989, through Round 5 ending in 2018, 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 12.6% in Round 5. With the decline in sites rated as “Poor”, there has been a continual increase in sites rated as “Fair” from Round 1 to Round 5, going from 33.2% to 43.9% in Round 5.

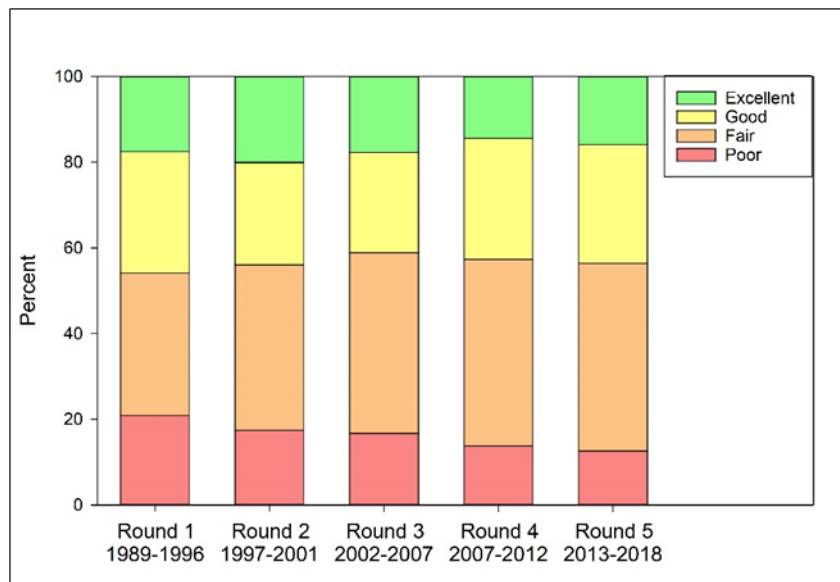


Figure 3. AMNET assessments for five rounds of sampling (1989 to 2018).

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. Figure 3 shows the statewide assessment results. Individual site assessment results can be found at: <https://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 reduction in the percentage of sites rated as “Poor”, and an increase in the percentage of sites rated as “Fair”. Some of the increase in the “Fair” category can be attributed to the decline in the “Poor” category. There has also been an overall reduction in the percentage of sites rated as “Excellent.” The percentage of sites rated as “Good” dropped in the late 1990s and early 2000s then rebounded to its original range.

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 causes of the impairment, or whether it is due to 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-specific 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.⁴

Currently, benthic macroinvertebrate sampling for the 6th round of AMNET is underway. Statewide sampling is scheduled to be completed for this round in 2022.

Fish Index of Biotic Integrity (FIBI) 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 impairments. 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 and other aquatic assemblages or communities such as species type and number and trophic structure.

The FIBI program is divided into three different indices based on physiographic province and watershed size. Presently, DEP utilizes a southern index of biotic

integrity (SIBI) which is not applied to waters in the Pinelands Region, a northern index of biotic integrity (NIBI), and a headwaters index of biotic integrity (HIBI) which uses fish, amphibians, and crayfish. Each index is designed to accurately describe the health of the resident fish/amphibian/crayfish population and is comprised of varying metrics, due to differences in regional populations throughout NJ. Each site sampled is 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 IBI 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 the sampling efforts. The data provided by the IBI Programs 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 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 is used in the Integrated Report and in part to determine a waterbody's potential for upgrade to a Category One antidegradation classification based on exceptional ecological significance.

Presently, fish IBI monitoring has a combined 302 site network consisting of sites located in the Highlands, Piedmont, Ridge and Valley, and Inner Coastal Plain physiographic provinces of New Jersey. The monitoring sites are designated by index in Figure 4. BFBM has not developed a fish index for the Pinelands region or Outer Coastal Plain.

The monitoring network consists of fixed, probabilistic, and sentinel sites. The data from fixed sites is used to assess long-term trends, while probabilistic sites are important for assessing overall aquatic life use in the waters of the state. Probabilistic sites were selected using EPA probabilistic site selection methodology.⁵ Sentinel sites are considered high quality waterbodies located in fully or partially protected watersheds, which are sampled on a routine basis to evaluate changes to fish assemblages due to environmental changes such as climate change.

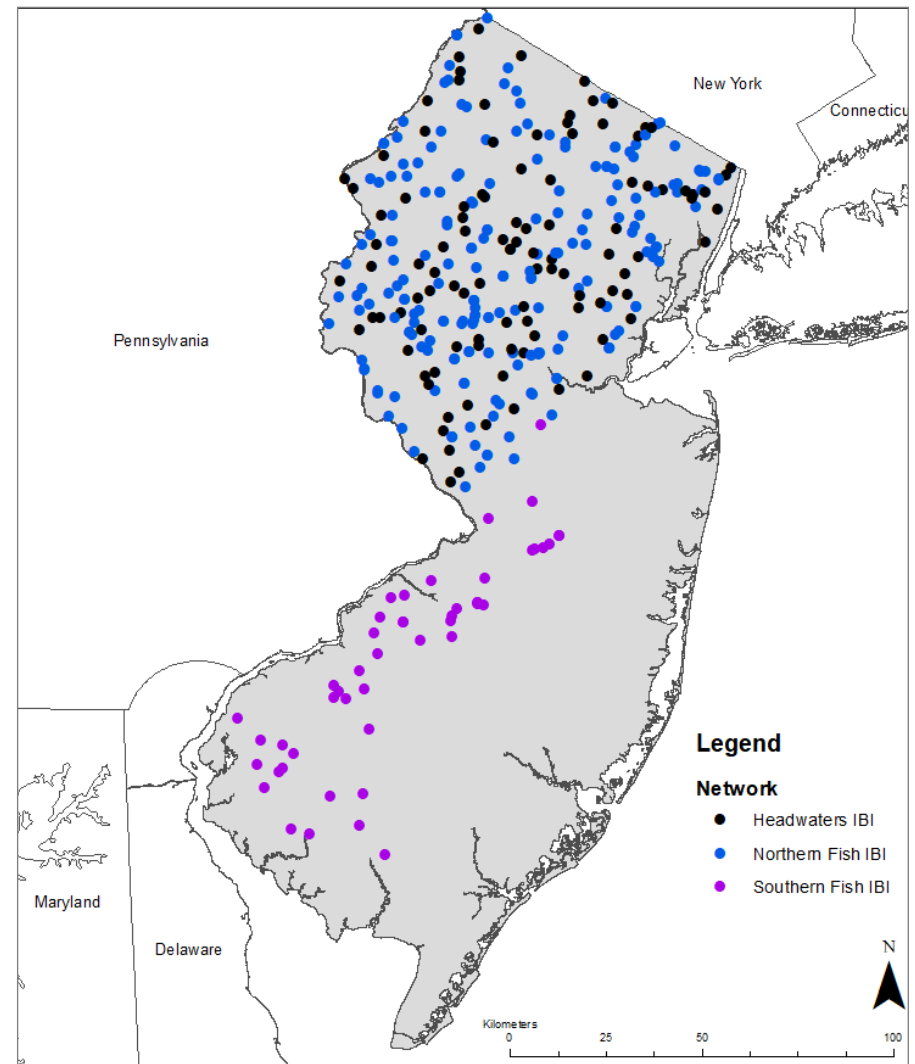


Figure 4. Fish Index of Biotic Integrity and Headwaters IBI network.

Status and Trends—Northern Fish IBI

Northern IBI monitoring takes place in medium to large wadeable 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.

The 2019 season marked the end of the fourth round of sampling for the Northern IBI, in which the Department returned to many of the 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.⁶ This recalibration resulted in modifications in scoring criteria and metrics. As such, all data from previous rounds has been rescored using the new metrics to insure a direct comparison of results. Figure 5 shows the results for the same sites from rounds one, two, three, and four. Overall, results were varied with the number of “excellent” sites declining since Round 1 and the number of “good” sites increasing, especially in Round 4. The number of “very poor” sites were relatively constant among the four rounds, while the number of “poor” sites declined slightly in Round 4.

Between the first (2000-2004), second (2005-2009), third (2010-2014), and fourth (2015-2019) rounds of Northern IBI monitoring for common sites sampled, the scores for 17.5% of sites evaluated exhibited a positive change in rating, whereas 22.5% exhibited a negative rating change, 25% exhibited no change in rating, and 35% exhibited no clear trend. On the whole, these changes appear to indicate a slight negative trend. Looking at the results in more detail further emphasizes this declining trend for those sites considered higher quality during the earlier rounds of monitoring. Of those sites which are listed as Category One waters, 63% exhibited variable or declining results over the next rounds, while just 14% showed a positive change. In addition, 62% of the sites listed as trout production streams exhibited variable or declining results over time. Of the sites considered healthy (“excellent” and “good”) in Round 1, almost 40% declined at least one rating category in Round 4.

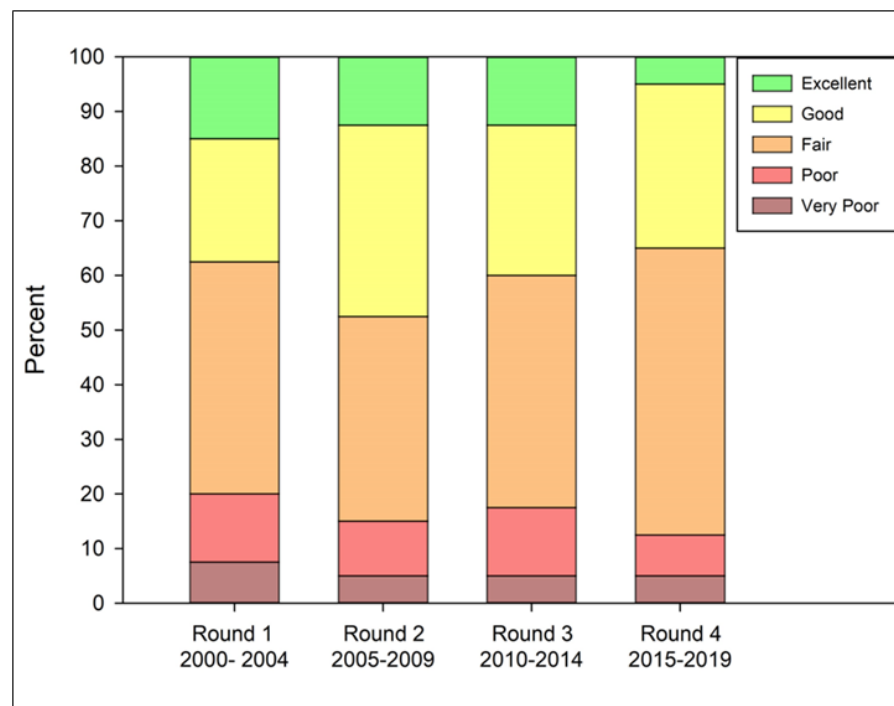


Figure 5. Northern Fish IBI results by round of sampling.

Status and Trends—Southern Fish IBI

The BFBM began collecting data in 2007 to finalize and validate metrics for the Southern Fish IBI. 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 area, and requires a drainage basin greater than 2 mi² (5.2 km²).

The trend analysis uses data collected in the final validation (2005-2009) of the Southern IBI with the same sites sampled in Round 3 (2015-2019). In 2012, fixed site monitoring shifted to a regional approach in which a different water region of the state would be sampled each year. This shift resulted in only a

limited number of sites being sampled in Round 2 (2010-2014) and as a result these data were not included in the trends analysis.

Overall, results indicate a decline in ratings for those sites at the upper end of the scoring scale, as the number of “excellent” and “good” sites decreased, while the number of “fair” sites increased significantly over time (Figure 6). A positive trend was observed at the lower end of the scoring scale since the percentage of sites considered impaired for aquatic life use (“poor” and “very poor”) declined from a total of 15% in Round 1 to just 8% in Round 3. In general, these results indicate many of the healthy streams are declining and many of the degraded streams are improving.

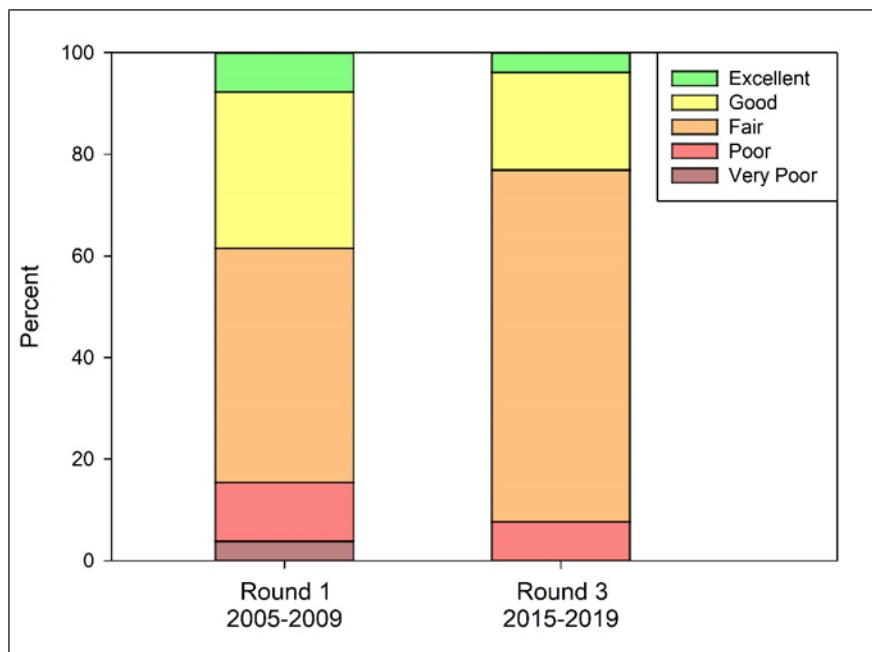


Figure 6. Southern Fish IBI results by round of sampling.

Between the first (2005-2009) and third (2015-2019) rounds of Southern IBI monitoring for common sites sampled, 19.2% of sites exhibited a positive change, 26.9% exhibited a negative change, and 53.8% exhibited no change in impairment

rating. On the whole, fixed site trends would seem to indicate relatively consistent results over time. Further analysis, however, indicates that many sites at the lower or middle ranges of the scoring scale have improved, while those stations at the upper end of the scoring scale in the first round have been declining.

Status and Trends—Headwaters Fish IBI

In 2013, the Headwaters Index of Biotic Integrity (HIBI) was developed 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 headwaters IBI is a multi-metric index that 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 that occupy critical niches, 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 provided BFBM biologists with the opportunity to monitor all Wadeable streams north of the geological fall-line via IBI metrics to accurately assess ecosystem health.

The Headwaters IBI program is in its second round of monitoring, which is expected to conclude in 2021. A total of 118 sites have been sampled since its inception in 2013. Eighteen of those sites have been surveyed at least twice throughout the seven years of monitoring and were used to compare results between the two rounds of monitoring; Round 1 (2013-2016) and Round 2 (2017-2019) (Figure 7). In general, higher quality streams (“excellent” and “good”) have remained stable while degraded sites (“very poor” and “poor”) have seen slight improvements. A total of 4 sites (22.2%) saw positive changes in their IBI rating, 11 sites (61.1%) remained the same IBI rating, and 3 sites (16.7%) had a negative rating change in Round 2.

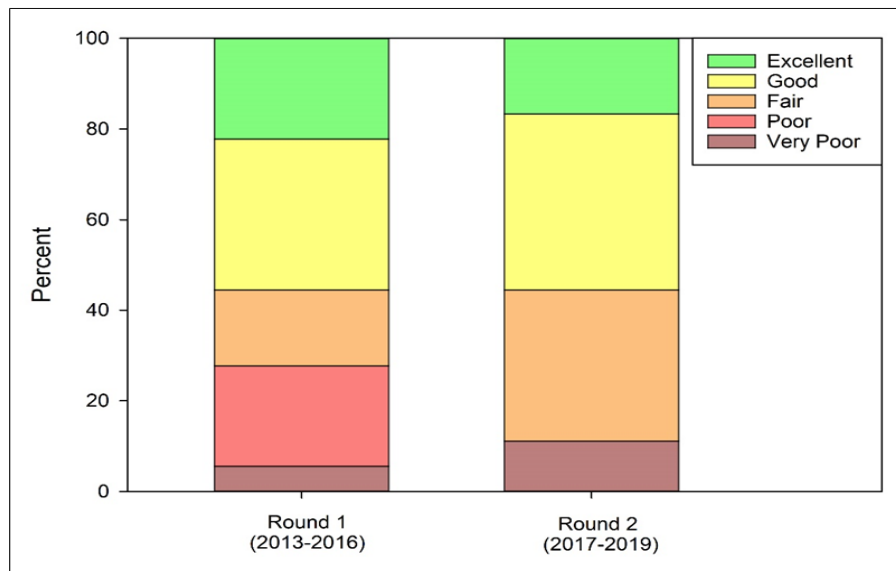


Figure 7. Headwaters IBI results by round of sampling.

Outlook and Implications

In the Northern Fish IBI, the number of “good” sites has increased in Round 4 (2015-2019), while the number of “excellent” sites declined. Overall, the number of sites considered impaired for aquatic life use (“poor” and “very poor”) has declined since the earliest round. Data from Round 4 (2015-2019) exhibited the biggest gap between the number of impaired sites (12.5%) and non-impaired sites (87.5%). In general, sites in the higher rating categories have been declining, while those sites in the lower rating categories have been improving.

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. Recent 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.

Among those sites exhibiting fluctuating scores and ratings over the four rounds of monitoring, metrics associated with the lithophilic species (associated with a stony substrate) and rheophilic species (species that prefer fast-moving waters) generally displayed the greatest variability for the Northern IBI. These metrics generally indicate changes in stream flow and substrate, typically a result of stream channelization and increased sediment loading.

Over the four rounds of sampling in the Northern IBI, at Category One sites there has been a decline in the average scores for rheophilic species (72.8 in Round 1 to 56.6 in Round 4) and lithophilic species (62.0 in Round 1 to 55.9 in Round 4). At trout production sites, there has been a decline in the average scores for rheophilic species (79.2 in Round 1 to 62.2 in Round 4) and the average habitat ratings (158.6 in Round 1 to 150.7 in Round 4). The percent abundance of wild trout at trout production streams has declined at most network sites, with the lowest percentage of wild trout occurring in Round 4 for 66% of the trout production streams. In Round 4, there was no documented wild trout reproduction at 38% of trout production sites.

There has been an overall decline in Southern IBI scores for sites in the upper end of the scoring scale. In addition, the average scores for intolerant species exhibited a sharp decline (58.1 in Round 1 to 42.2 in Round 3). The average scores for percent insectivores also declined sharply (58.9 in Round 1 to 46.2 in Round 3). Sentinel sites have seen a similar decline, indicating the potential for broader environmental impacts in this region. Analysis of the healthy (“excellent” and “good”) sites from Round 1 indicates 70% of those sites have declining scores over time, with 60% of those sites dropping in rating (i.e. “excellent” → “good”; “good” → “fair”).

In the Headwaters IBI, there has been overall improvement in the “fair” and “good” sites along with some decline among the “excellent” sites. The percentage of impaired (“poor and “very poor”) HIBI sites declined in Round 2 (11.1%) compared to Round 1 (28%). The average scores for brook trout density decreased from 30.6 in Round 1 to 19.3 in Round 2. Analysis of the healthy (“excellent” and “good”) sites from Round 1 indicates 50% of those sites have

declined in score in Round 2, while 11% of those sites have dropped in rating (i.e. “excellent” → “good”; “good” → “fair”).

In the most recent round of monitoring there were some consistent trends among the three IBIs. Across the state, there was a reduction in the number of sites classified as “excellent” and impaired (“poor” and “very poor”), while the number of sites classified as “fair” has increased. The results for the latest round of monitoring for the Northern and Southern IBIs indicate that most sites are rated “fair”, while most sites monitored for the Headwaters IBI are rated “good”. The Bureau of Freshwater and Biological Monitoring will continue monitoring streams in NJ to update the scores and ratings, thus providing a valuable tool for NJDEP to assess the long-term health of its rivers and streams using fish assemblages.

More Information

Data and reports of the Fish and Headwaters IBI can be obtained by visiting <https://www.state.nj.us/dep/wms/bfbm/> or by calling (609) 292-0427.

Northern Fish IBI data can be found at <https://www.nj.gov/dep/wms/bfbm/ibimainsummarypage.htm>.

Southern Fish IBI data can be found at <https://www.nj.gov/dep/wms/bfbm/ibisibidatapage.htm>.

Headwaters IBI data can be found at <https://www.nj.gov/dep/wms/bfbm/ibihidatapage.html>.

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