http://www.epa.gov/bioiweb1/html/ibi_metrics.html
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Biological Indicators of Watershed Health

Metrics and the Index of Biotic Integrity

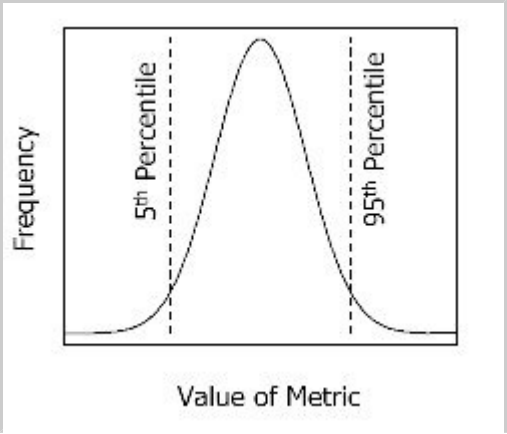
Selecting Metrics

The IBI has made great advances, especially in the selection and testing of metrics and indices. Before an index can be built and tested, the metrics need to be carefully selected. Most approaches today start from a list of dozens of potential metrics (see Table at the bottom of this page) and then use a systematic process to eliminate those metrics that do not meet certain criteria such as:

- **the effective range of response** -metrics with a limited range of values, such as 0 or 1, or 0, 1, 2, will not contribute useful information to the IBI
- **the repeatability of measurements** (signal to noise) - an effective metric should exhibit higher between site variance than within site variance so higher signal to noise is better
- **relationship to watershed area** - if the metrics correlate with watershed area, then those metrics need to be normalized to minimze the effect of natural variability
- **metrics that provided redundant information** - only one selected for further testing
- **the discriminatory ability of the metrics** - metrics should respond predictably to a disturbance gradient (see the Biological Condition Gradient figures below)

One example of an approach used in the Mid-Atlantic Highlands Streams Assessment and is documented in the MAHA Technical Support Document and further discussed in Developing Biological Indicators:Lessons Learned in Mid-Atlantic Streams. Also see Biological Monitoring and Assessment: Using Multimetric Indexes Effectively (155 pp, 10.7MBAbout PDF)

Standardizing Metrics (Scoring/Normalizing)



Once the metrics are selected, they need to all be on the same scale whether it is the original IBI approach of 1,3,5 or a scale from 1-100.. For example, the potential range of values can be quite different, especially if metrics representing a number of taxa and the percentage of taxa are used. Scoring, or normalizing, the metrics have been done using many different approaches, but they all are attempting to accomplish the same result.

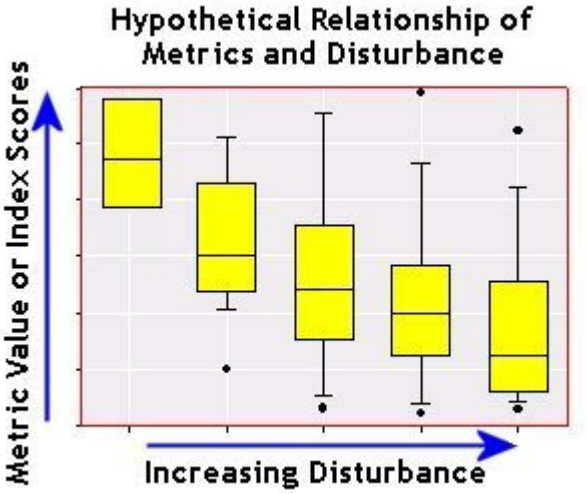
One approach standardized each metric to a 100-point scale where 0 represented the worst condition observed, and 100 the best. A score corresponded to its rank between the 5th and 95th percentiles in the distribution of all data collected (not just the reference sites). Extreme values below the 5th percentile or greater than the 95th percentile were assigned 0 or 100, respectively (see Figure). This practice eliminates the influence of outliers and reduces the effect that different datasets in the future will have on setting the SCI scores.

Disturbance Gradient

One the metrics are scored, or normalized, they can be combined into a new index. The new IBI is then subjected to testing to ensure that the index can consistently and predicatbly respond to a disturbance gradient (see the figure to the right). For more information on disturbance gradients, see the Biological Condition Gradient discussion).

Learn more about metric and index testing from the report "Developing Biological Indicators: Lessons Learned from Mid-Atlantic Streams".

Figure 1.



IBI Metrics Used - 1995

List of Original index of Biotic Integrity Metrics (in bold) Proposed by Karr (1981) for Streams in the Central United States, Followed by Modifications Proposed by Subsequent Authors for Streams in Other Regions or for Different Streams and River Types

Species Richness and Composition Metrics

A. Total Number of Fish Species (1-7, 11, 13-15, 18, 19, 22)

1. Number of native fish species (8-10, 12, 16, 17, 20, 22)
2. Number of fish species, excluding Salmonidae (13)
3. Number of amphibian species (3, 13)

B. Number of Catostomidae Species (1, 4-6, 8, 9, 12, 15, 17, 19, 20)

1. Percent of individuals that are Catostomidae (9)
2. Percent of individuals that are round-bodied Catostomidae: Cycleptus, Hypentelium, Minytrema, and Moxostoma (9, 17, 19)
3. Number of Catostomidae and Ictaluridae species (10)
4. Number of Catostomidae and Cyprinidae species (17)
5. Number of benthic insectivorous species (7, 11, 17, 22)
6. Number of laterally compressed minnow species (21)
7. Number of minnow species (4, 6, 9, 14, 15, 17, 22)

8. This metric deleted from IBI (2, 3, 13, 14)

C. Number of Darter Species (Percidae genera: Crystallaria, Etheostoma, Percina, Ammocrypta) (1, 2, 4, 5, 8, 9, 12, 15-17, 19, 22)

1. Number of darter and Cottidae species (9, 10)
2. Number of darter, Cottidae, and Noturus (Ictaluridae) species (15, 16, 19)
3. Number of darter, Cottidae, and round-bodied Catostomidae species (17)
4. Number of Cottidae species (6, 13)
5. Abundance of Cottidae individuals (3)
6. Number of benthic species (11, 18)
7. Percent of individuals that are native benthic species (11)(same as #2)
8. Number of benthic insectivorous species (7)
9. Number of darter species, excluding "tolerant darter species" (headwater sites) (21)
10. Percent cyprinids with subterminal mouths (22) K. This metric deleted from IBI (14)

D. Number of Sunfish Species (Centrarchidae excluding Micropterus)(1, 4, 5, 14-17, 20)

1. Number of native sunfish species (9, 12)
2. Number of sunfish and Salmonidae species (10)
3. Number of sunfish species and Perca flavescens (Percidae) (16)
4. Number of headwater (restricted to small streams) species (9, 15, 22)
5. Number of water column (non-benthic) species (7, 17, 18)
6. Number of water column cyprinid species (17)
7. Number of sunfish species including Micropterus (19, 22)
8. This metric deleted from IBI (11)

Indicator Species Metrics

E. Number of Intolerant or Sensitive Species (1-4, 6-8, 10-12, 14, 15, 17-20, 22)

1. Number of Salmonidae species (3,15)
2. Percent of individuals that are Salmonidae (11)
3. Juvenile Salmonidae presence or abundance (3, 18)
4. Large (>1 5-20 cm) or adult Salmonidae presence or abundance (3, 6, 18)
5. Abundance or biomass of all sizes of Salmonidae (3, 13)
6. Mean length or weight of Salmonidae (13)
7. Percent of individuals that are anadromous Oncorhynchus mykiss (Salmonidae) older than age 1 (3)
8. Presence of Salvelinus fontinalis (Salmonidae) (10)
9. Presence of juvenile or large Esox lucius (Esocidae) (18)
10. Number of Large River (restricted to great rivers) species (19, 22)
11. Percent of species that are native species (3)
12. Percent of individuals that are native species (3)
13. This metric deleted from IBI (2, 14)

F. Percent of Individuals that Are Lepomis cyanellus (Centrarchidae) (1, 17)

1. Percent of individuals that are Lepomis megalotis (Centrarchidae) (5)
2. Percent of individuals that are Cyprinus carpio (Cyprinidae) (6)
3. Percent of individuals that are Semotilus atromaculatus (Cyprinidae)(2)
4. Percent of individuals that are Rutilus rutilus (Cyprinidae) (18)
5. Percent of individuals that are Rhinichthys species (Cyprinidae) (10)
6. Percent of individuals that are Catostomus commersoni (Catostomidae) (4, 7, 11)
7. Percent of individuals that are tolerant species (8, 9, 12, 14-17, 19, 22)
8. Percent of individuals that are "pioneering" species (9, 15, 22)

9. Percent of individuals that are introduced species (4, 6, 12, 14)
10. Number of introduced species (12, 13)
11. Evenness (22)
12. This metric deleted from IBI (3)

Trophic Function Metrics

G. Percent of Individuals that Are Omnivores (1-4, 6-8, 10, 12, 14-20, 22)

1. Percent of individuals that are omnivorous Cyprinidae species (10)
2. Percent of individuals that are Luxilus cornutus or Cyprinella spiloptera (Cyprinidae), facultative omnivores (9)
3. Percent of individuals that are generalized feeders that eat a wide range of animal material but limited plant material (2, 9, 11)
4. Percent biomass of omnivores (22)
5. This metric deleted from IBI (3, 13)

H. Percent of Individuals that Are Insectivorous Cyprinidae (1, 17)

1. Percent of individuals that are insectivores/invertivores (5-7, 9, 12, 14-19)
2. Percent of individuals that are specialized insectivores (2, 4, 20)
3. Percent of individuals that are specialized insectivorous minnows and darters (8)
4. Percent biomass of insectivorous cyprinids (22)
5. This metric deleted from IBI (3, 10, 13)

I. Percent of Individuals that Are Top Carnivores or Piscivores (1, 5, 7-9, 11, 12, 15-20)

1. Percent of individuals that are large (> 20 cm) piscivores (10)
2. Percent biomass of top carnivores (22)
3. This metric deleted from IBI (2-4, 6, 13-15)

Reproductive Function Metrics

J. Percent of Individuals that Are Hybrids (1, 7, 8, 13)

1. Percent of individuals that are simple lithophilous species: spawn on gravel, no nest, no parental care (9, 15-17, 19, 20, 22)
2. Percent of individuals that are gravel spawners (18)
3. Ratio of broadcast spawning to nest building cyprinids (22)
4. This metric deleted from IBI (2-6, 10-12, 14)

Abundance and Condition Metrics

K. Abundance or Catch per Effort of Fish (1 -8, 10-11, 14-15, 18, 19, 22)

1. Catch per effort of fish, excluding tolerant species (9, 16, 20)
2. Biomass of fish (6, 13, 22)
3. Biomass of amphibians (13)
4. Density of macroinvertebrates (13)
5. This metric deleted from IBI (17)

L. Percent of Individuals that are Diseased, Deformed, or Have Eroded Fins, Lesions, or Tumors (1-7, 9, 11, 12, 14-16, 18, 19, 20, 22)

11. Percent of individuals with heavy infestation of cysts of the parasite Neascus (10)
12. This metric deleted from the IBI (13, 17)

Note: The numbers in parentheses correspond to the following references.**

1. Karr (1981); Fausch et al. (1984); Karr et al. (1985a,b); Karr et al. (1986); Angermeier and Karr (1986); Berkman et al. (1986); Karr et al. (1987); Hite and Bertrand (1989); Angermeier and Schlosser (1988); Hite et al. (1992); Osborne et al. (1992).
2. Leonard and Orth (1986).
3. Moyle et al. (1986).
4. Schrader (1986).
5. Foster (1987).
6. Hughes and Gammon (1987).
7. Miller et al. (1988).
8. Saylor and Scott (1987); Saylor et al. (1988); Saylor and Ahlstedt (1990).
9. Ohio EPA (1987a,b).
10. Steedman (1988).
11. Langdon (1989).
12. Crumby et al. (1990).
13. Fisher (1990).
14. Bramblet and Fausch (1991).
15. Simon (1991).
16. Lyons (1992).
17. Hoefs and Boyle (1992).
18. Oberdorff and Hughes (1992).
19. Simon (1992).
20. Bailey et al. (1993).
21. Gatz and Harig (1993).
22. Goldstein et al. (1994).

(adapted from Simon EXIT Disclaimer and Lyons "Application of the Index of Biotic Integrity to Evaluate Water Resource Integrity in Freshwater Ecosystems," Chapter 16, in Davis and Simon EXIT Disclaimer. 1995. Biological Assessment and Criteria - Tools for Water Resource Planning and Decision Making.)

- ** Angermeier, P. L. and J. R. Karr. 1984. Relationships between woody debris and fish habitat in a small warmwater stream. Transactions of the American Fisheries Society 113: 716-726.
- Angermeier, P. L. and J. R. Karr. 1986. Applying an index of biotic integrity based on stream-fish communities: considerations in sampling and interpretation. North American Journal of Fisheries Management 6: 418-429.
- Angermeier, P. L. and I. J. Schlosser. 1987. Assessing biotic integrity of the fish community in a small Illinois stream. North American Journal of Fisheries Management 7: 331-338.
- Bailey, P. A., J. W. Enblom, S. R. Hanson, P. A. Renard and K. Schmidt. 1993. A fish community analysis of the Minnesota River basin. Minnesota Pollution Control Agency, St. Paul, Minnesota.
- Bramblett, R. G. and K. D. Fausch. 1991. Variable fish communities and the Index of Biotic Integrity in a western Great Plains river. Transactions of the American Fisheries Society 120: 752-769.
- Crumby, W. D., M. A. Webb, F. J. Bulow and H. J. Cathey. 1990. Changes in the biotic integrity of a river in north-central Tennessee. Transactions of the American Fisheries Society 119: 885-893.
- Fausch, D.O., J.R. Karr and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Transactions of the American Fisheries Society 113: 39 55.
- Fisher, T. R. 1989. Application and Testing of Indices of Biotic Integrity in Northern and Central Idaho Headwater Streams. Master of Science Thesis, University of Idaho, Moscow.
- Goldstein, R. M., T. P. Simon, P. A. Bailey, M. Ell, K. Schmidt and J. W. Emblom. 1994. Proposed metrics for the index of biotic integrity for the streams of the Red River of the North basin. Transactions of the North Dakota Academy of Science (in press).
- Hite, R. 1988. Overview of stream quality assessments and stream classification in Illinois. Pages 98-120 in T. P. Simon, L. L. Holst and L. J. Shepard (editors). Proceedings of the First National Workshop on Biological Criteria, Lincolnwood, Illinois. EPA 905-9-89-003. U. S. Environmental Protection Agency, Region 5, Chicago, Illinois.
- Hite, R. L. and B. A. Bertrand. 1989. Biological Stream Characterization (BSC): A Biological Assessment of Illinois Stream Quality. IEPA/WPC/89-275. Illinois Environmental Protection Agency, Illinois State Water Plan

Task Force, Special Report Number 13, Springfield, Illinois.
- Hoefs, N. J., and T. P. Boyle. 1992. Contribution of fish community metrics to the index of biotic integrity in two Ozark rivers. Pages 283-303 in D. H. McKenzie, D. E. Hyatt, and V. J. McDonald (editors). Ecological Indicators, Volume 1. Elsevier Applied Science, New York.
- Hughes, R.M. and J.R. Gammon. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Transactions of the American Fisheries Society 116: 196-209.
- Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries (Bethesda) 6: 21-27.
- Karr, J. R., R. C. Heidinger and E. H. Helmer. 1985a. Sensitivity of the index of biotic integrity to changes in chlorine and ammonia levels from wastewater treatment facilities. Journal of the Water Pollution Control Federation 57: 912-915.
- Karr, J. R., L. A. Toth and D. R. Dudley. 1985b. Fish communities of midwestern rivers: a history of degradation. BioScience 35: 90-95.
- Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant and I. J. Schlosser. 1986. Assessment of Biological Integrity in Running Waters: A Method and its Rationale. Illinois Natural History Survey Special Publication 5, Champaign, Illinois.
- Karr, J. R., P. R. Yant, K. D. Fausch and I. J. Schlosser. 1987. Spatial and temporal variability of the Index of Biotic Integrity in three midwestern streams. Transactions of the American Fisheries Society 116: 1-11.
- Langdon, R. 1989. The development of fish population-based biocriteria in Vermont. Pages 12-25 in T. P. Simon, L. L. Holst, and L. J. Shepard (editors). EPA 905-9-89-003. Proceedings of the First National Workshop on Biological Criteria. U.S. Environmental Protection Agency, Region 5, Environmental Sciences Division, Chicago, Illinois.
- Leonard, P. M. and D. J. Orth. 1986. Application and testing of an index of biotic integrity in small, coolwater streams. Transactions of the American Fisheries Society 115: 401-414.
- Lyons, J. 1992. Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin. General Technical Report NC-149. North Central Forest Experiment Station, U.S. Department of Agriculture, St. Paul, Minnesota.
- Miller, D. L., P. M. Leonard, R. M. Hughes, J. R. Karr, P. B. Moyle, L. H. Schrader, B. A. Thompson, R. A. Daniel, K. D. Fausch, G. A. Fitzhugh, J. R. Gammon, D. B. Halliwell, P. L. Angermeier and D. J. Orth. 1988. Regional applications of an Index of Biotic Integrity for use in water resource management. Fisheries 13: 12-20.
- Moyle, P. B., L. R. Brown and B. Herbold. 1986. Final Report on Development and Preliminary Tests of Indices of Biotic Integrity for California. Final Project Report submitted to the U.S. Environmental Protection Agency, Corvallis, Oregon.
- Oberdorff, T. and R. M. Hughes. 1992. Modification of an Index of Biotic Integrity based on fish assemblages to characterize rivers of the Seine-Normandie basin, France. Hydrobiologia 228: 117-130.
- Ohio Environmental Protection Agency (Ohio EPA). 1987. Biological Criteria for the Protection of Aquatic Life: Volumes I-III. Volume I. The role of biological data in water quality assessment. Volume II: Users manual for biological field assessment of Ohio surface waters. Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Ohio EPA, Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio (updated 1988,1989).
- Osborne, L. L., S. L. Kohler, P. B. Bayley, D. M. Day, W. A. Bertrand, M. J. Wiley and R. Sauer. 1992. Influence of stream location in a drainage network on the Index of Biotic Integrity. Transactions of the American Fisheries Society 121: 635-643.
- Saylor, C. F. and E. M. Scott, Jr. 1987. Application of the Index of Biotic Integrity to Existing Tennessee Valley Authority Data. TVA/ONRED/AWR 87/32. Tennessee Valley Authority, Office of Natural Resources and Economic Development, Water Resources, Aquatic Biology Department Publication, Norris, Tennessee.
- Saylor, C. F., D. M. Hill, S. A. Ahlstedt and A. M. Brown. 1988. Middle Fork Holston River Watershed Biological Assessment, Summers of 1986 and 1987. TVA/ONRED/AWR 88/25. Tennessee Valley Authority, Office of Natural Resources and Economic Development, Division of Air and Water Resources, Norris, Tennessee.
- Saylor, C. F. and S. A. Ahlstedt. 1990. Application of Index of Biotic Integrity (IBI) to Fixed Station Water Quality Monitoring Sites. Tennessee Valley Authority, Water Resources, Aquatic Biology Department Publication, Norris, Tennessee.
- Schrader, L. H. 1986. Testing the Index of Biotic Integrity in the South Platte River basin of the Northeastern Colorado. Master of Science Thesis, Colorado State University, Fort Collins, Colorado.
- Simon, T. P. 1991. Development of Ecoregion Expectations for the Index of Biotic Integrity. I. Central Corn Belt Plain. EPA 905-9-91-025. U.S. Environmental Protection Agency, Region 5, Chicago, Illinois.
- Simon, T. P. 1992. Development of Biological Criteria for Large Rivers with an Emphasis on an Assessment of the White River Drainage, Indiana. EPA 905-R-92-026. U.S. Environmental Protection Agency, Region 5, Chicago, Illinois.
- Steedman, R.J. 1988. Modification and assessment of an index of biotic integrity to quantify stream quality in southern Ontario. Canadian Journal of Fisheries and Aquatic Sciences 45: 492-501.