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Rapid field assessment of organic pollution with a family-level biotic index

WILLIAM L. HILSENHOFF

Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706 USA

Abstract. Tolerance values for families of arthropods are presented to enable calculation of a family-level biotic index (FBI) in the field. In six streams differing in substrates and degree of organic pollution, an average of 23 min, 35 s was needed to assess the condition of a stream in the field using the FBI; this period was at least an hour less than is normally required to evaluate a stream with the generic- and species-level biotic index (BI). Comparison of the FBI and BI of replicated samples from these six streams and from 120 random samples from other Wisconsin streams showed that some accuracy is lost by using the FBI, with the FBI usually indicating greater pollution than the BI in unpolluted or slightly polluted streams and less pollution in polluted streams. The purpose of the FBI is to provide a rapid, but less critical, evaluation of streams in the field by biologists who can recognize arthropod families by sight. It is not intended as a substitute for the BI.

Key words: biotic index, stream, arthropods, insects, organic pollution, rapid assessment, biological monitoring, field evaluation.

A special symposium on rapid biological assessment at the 1986 meeting of the North American Benthological Society stressed the need for rapid field-based assessment approaches. It was recognized that in order to save time, a degree of accuracy would be sacrificed. Consequently, I adapted the biotic index (BI) of organic pollution (Hilsenhoff 1987) for rapid evaluation by providing tolerance values for families (Appendix 1) to allow a family-level biotic index (FBI) to be calculated in the field. The FBI is an average of tolerance values of all arthropod families in a sample. It is not intended as a replacement for the BI and can be effectively used in the field only by biologists who are familiar enough with arthropods to be able to identify families without using keys.

Methods

Using the same method and more than 2000 stream samples from throughout Wisconsin that were used to revise tolerance values for species and genera (Hilsenhoff 1987), family-level tolerance values were established by comparing occurrence of each family with the average BI of streams in which they occurred in the greatest numbers. Thus, family-level tolerance values tend to be a weighted average of tolerance values of species and genera within each family based on their relative abundance in Wisconsin.

The BI and FBI were compared for spring and fall samples from 10 randomly selected streams from each of the six Department of Natural Resources regions in Wisconsin using data from collections made in 1980. Also compared were six streams in southern Wisconsin that had varying degrees and sources of organic pollution. These streams had been sampled at 2-wk intervals in 1984 and 1985 to develop a seasonal correction factor for the BI (Hilsenhoff 1988). All are second- or third-order streams; Otter Creek and Trout Creek are unpolluted, whereas the Sugar River, Narrows Creek, the West Branch of the Pecatonica River, and Badfish Creek all receive organic pollution from pasturing of cattle and hogs, or from sewage effluent (Hilsenhoff 1988). The FBI and BI were compared by *t*-tests using data from three riffle samples collected from each of these six streams in mid-April, late-June, early-September, and mid-November. Standard deviations of all replicates from their means were calculated for each year and for all samples. Standard collecting and processing procedures for the BI were used for all samples (Hilsenhoff 1987).

On 10 October 1986, these same six streams were sampled and an FBI was calculated in the field based on family identifications made there. Samples from riffles were collected with a D-frame net, picked, sorted, identified, and an FBI calculated according to procedures outlined below. Time required for each procedure was recorded. Preserved arthropods were returned

TABLE 1. Comparison of the family-level biotic index (FBI) with the biotic index (BI) of spring and fall samples from 60 Wisconsin streams in 1980.

BI Range	Water Quality[a]	Number of Samples	FBI in relation to BI[b]	
			Range	Ave.
0.00-3.50	Excellent	29	−0.26 to +1.41	+0.27
3.51-4.50	Very good	27	−0.64 to +0.75	−0.03
4.51-5.50	Good	23	−1.05 to +0.69	−0.46
5.51-6.50	Fair	26	−1.42 to +1.17	−0.52
6.51-7.50	Fairly poor	11	−1.27 to +0.09	−0.53
7.51-8.50	Poor	4	−1.63 to −0.59	−1.18
8.50-10.00	Very poor	0		

[a] From Hilsenhoff (1987).
[b] "+" indicates the FBI was greater than the BI, "−" that it was less.

to the laboratory where identifications were verified and species were identified to enable calculation of the BI for comparison with the FBI.

Procedure for evaluating streams with the family-level biotic index

1. Using an aquatic net, samples are collected from a riffle area or shallow run where the current is greater than 0.30 m/s (1.0 ft/s) and the substrate is composed of gravel, pebbles, and (or) small rocks. Collection of arthropods is best accomplished by placing the net against the stream bottom and disturbing the substrate immediately upstream from the net. Snags of debris may be sampled if no riffle or run is present.
2. Sampling continues until somewhat in excess of 100 arthropods are collected, but no more than 200 because large numbers may bias picking of the sample.
3. The contents of the net are placed in a shallow white pan with a small amount of water.
4. About eight small white dishes containing 70% ethanol are arranged to receive arthropods picked from the pan, each dish holding an order or common family.
5. Arthropods clinging to the net are placed in the appropriate dish. No more than 20 arthropods should be removed from the net to avoid bias in the sample.
6. One hundred arthropods are removed from the pan and net, excluding Hemiptera and Coleoptera (except Dryopoidea) and individuals that are too small to be identified to family.
7. The number of arthropods in each family is recorded, using a hand lens for identification if needed.
8. An FBI is calculated by multiplying the number in each family by the tolerance value for that family (Appendix 1), summing the products, and dividing by the total arthropods in the sample (100).

Results and Discussion

Comparison of the BI and FBI of spring and fall samples from 60 Wisconsin streams shows that the FBI usually indicates greater pollution of clean streams by overestimating BI values

TABLE 2. Evaluation of water quality using the family-level biotic index.

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

TABLE 3. Comparison of differences (*t*-test) between means of the biotic index (BI) and the family-level biotic index (FBI) of three replicate samples from six streams in mid-April, late-June, early-September, and mid-November in 1984 and 1985. (SD = standard deviation from the mean of replicated samples.)

Stream	Year	Mean			SD	
		BI	FBI	t^a	BI	FBI
Trout Creek	1984	2.23	2.52	4.41**	0.45	0.54
	1985	2.61	3.18	4.84**	0.35	0.39
Otter Creek	1984	2.43	2.77	4.65**	0.22	0.30
	1985	2.62	3.27	4.90**	0.27	0.37
Sugar River	1984	5.49	5.13	7.28**	0.28	0.33
	1985	5.44	4.83	8.73**	0.23	0.28
West Branch of the	1984	6.31	6.31	0.06	0.19	0.21
Pecatonica River	1985	5.81	5.76	0.34	0.20	0.23
Narrows Creek	1984	6.68	6.15	6.67**	0.20	0.34
	1985	6.36	5.83	10.76**	0.18	0.20
Badfish Creek	1984	7.05	6.71	2.20*	0.17	0.30
	1985	6.77	6.24	6.08**	0.15	0.36
All samples					0.24	0.32

[a] * $p = 0.05$; ** $p = 0.01$.

and usually indicates less pollution in polluted streams by underestimating BI values (Table 1). In 42% of the samples the FBI differed from the BI by 0.50 or more and in 14% of the samples it differed by more than 1.00. Based on a comparison of the BI and FBI of these samples and comparisons provided by S. Szczyto (University of Wisconsin–Stevens Point, personal communication), Table 2 is provided as a guide to evaluation of water quality with the FBI.

A similar pattern was found in the six streams in southern Wisconsin that were sampled over a 2-yr period. In all streams, except the West Branch of the Pecatonica River, differences between the FBI and the BI were significant in both years (Table 3). In unpolluted streams the FBI was higher than the BI, suggesting lower water quality, and in polluted streams it was lower, suggesting higher water quality. These results occurred because the more intolerant genera and species in each family predominate in clean streams, whereas the more tolerant genera and species predominate in polluted streams. The standard deviation was greater in the FBI than in the BI in all samples (Table 3), showing that the FBI is less accurate than the BI.

For samples collected on 10 October 1986, an average of 23 min, 35 s (range 16 min, 2 s to 32 min, 28 s) was required to sample, sort, and calculate an FBI in the field, compared with at least 85 min to calculate a BI (Hilsenhoff 1982), a saving of more than an hour. An average of 7 min, 29 s was required to collect a sample, 11 min, 23 s to pick and sort it, 3 min, 13 s to identify families and count specimens, and 1 min, 31 s to calculate the FBI. Examination of samples in the laboratory revealed only one misidentification; two small Leptophlebiidae nymphs had been identified as Baetidae. Field identification at the family level did not present a problem, but a hand lens was helpful in distinguishing some families.

The BI, field FBI, and laboratory FBI of the October samples are compared in Table 4. Lower values for the FBI in Table 4 than in Table 3 reflect seasonal changes and continued recovery of the polluted streams. Samples evaluated with the FBI have values that tend to be closer

TABLE 4. Comparison of the biotic index (BI) of samples collected 10 October 1986 with a family-level biotic index (FBI) calculated in the field and in the laboratory.

Stream	BI	FBI	
		Field	Lab.
Otter Creek	1.37	1.91	1.92
Trout Creek	2.59	2.70	2.71
Sugar River	4.57	4.06	4.04
W. Br. Pecatonica R.	5.22	4.83	4.83
Badfish Creek	5.88	5.19	5.03
Narrows Creek	6.11	4.90	4.98

to 4.0 than those of the BI, and all levels of pollution will be underestimated. This is mostly because three very common families, Baetidae, Heptageniidae, and Hydropsychidae, all have a tolerance value of 4, whereas species within these families have a wide range of tolerance values. An excellent example is Narrows Creek (Table 4), a stream polluted by pasturing of cattle. Here, the FBI greatly underestimated the degree of pollution because tolerance values for Baetidae and Heptageniidae are both 4 whereas the dominant species from these families were 36 *Baetis intercalaris* (tolerance value 6) and 9 *Stenacron interpunctatum* (tolerance value 7). In contrast, the dominant baetid in unpolluted Trout Creek was *Baetis vagans* (tolerance value 2) and the dominant heptageniid in unpolluted Otter Creek was *Stenonema vicarium* (tolerance value 2). In streams with severe organic pollution the FBI will usually be much lower than the BI because *Chironomus* and *Glyptotendipes*, which both have a tolerance value of 10 and dominate the arthropod fauna of severely polluted streams, have a family tolerance value of only 8.

Use of the FBI is advantageous for evaluating the general status of organic pollution in streams within a watershed for the purpose of deciding which streams or which watersheds should be studied further. If each family is saved in a separate vial after it is counted in the field, a BI can always be calculated after species identifications have been made in the laboratory. The FBI is intended only for use as a rapid field procedure. It should not be substituted for the BI; it is less accurate and can more frequently lead to erroneous conclusions about water quality.

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APPENDIX 1. Tolerance values for families of stream arthropods in the western Great Lakes region.

PLECOPTERA—Capniidae 1, Chloroperlidae 1, Leuctridae 0, Nemouridae 2, Perlidae 1, Perlodidae 2, Pteronarcyidae 0, Taeniopterygidae 2

EPHEMEROPTERA—Baetidae 4, Baetiscidae 3, Caenidae 7, Ephemerellidae 1, Ephemeridae 4, Heptageniidae 4, Leptophlebiidae 2, Metretopodidae 2, Oligoneuriidae 2, Polymitarcyidae 2, Potomanthidae 4, Siphlonuridae 7, Tricorythidae 4

ODONATA—Aeshnidae 3, Calopterygidae 5, Coenagrionidae 9, Cordulegastridae 3, Corduliidae 5, Gomphidae 1, Lestidae 9, Libellulidae 9, Macromiidae 3

TRICHOPTERA—Brachycentridae 1, Glossosomatidae 0, Helicopsychidae 3, Hydropsychidae 4, Hydroptilidae 4, Lepidostomatidae 1, Leptoceridae 4, Limnephilidae 4, Molannidae 6, Odontoceridae 0, Philopotamidae 3, Phryganeidae 4, Polycentropodidae 6, Psychomyiidae 2, Rhyacophilidae 0, Sericostomatidae 3

MEGALOPTERA—Corydalidae 0, Sialidae 4

LEPIDOPTERA—Pyralidae 5

COLEOPTERA—Dryopidae 5, Elmidae 4, Psephenidae 4

DIPTERA—Athericidae 2, Blephariceridae 0, Ceratopogonidae 6, Blood-red Chironomidae (Chironomini) 8, other (including pink) Chironomidae 6, Dolochopodidae 4, Empididae 6, Ephydridae 6, Psychodidae 10, Simuliidae 6, Muscidae 6, Syrphidae 10, Tabanidae 6, Tipulidae 3

AMPHIPODA—Gammaridae 4, Talitridae 8

ISOPODA—Asellidae 8