3 The development of numerical water quality criteria using a regional database

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Indicator taxa can be important components in the numerical evaluation of the biological integrity of surface waters. A regional database collected by the Maine Department of Environmental Protection, USA, (MEDEP) was analyzed by establishing tolerance values (0 to 9) based upon the percentage of organisms found in Maine's a priori *water quality classification program. The organisms demonstrating the greatest intolerance to water quality degradation (tolerance ratings of 0 and 1) were designated as indicator taxa. Similar tolerance ratings were previously assigned by Hilsenhoff for many of the same genera. Ratings for* Ephemerella, *however, varied greatly between the two systems. Results of this technique demonstrate that Ephemeroptera follow both the Trichoptera and Plecoptera in order of importance for water quality determinations.*

Introduction

Biological assessments of stream macroinvertebrate communities can provide useful information about the quality of surface waters. The resident biota in a stream can act as continual monitors of the effects of episodic events, toxic nonpoint-source pollution, cumulative pollution or other impacts that might be undetected by physical or chemical monitoring (USEPA 1990).

In its guidance document for surface waters, the EPA directed individual states to develop narrative water quality criteria based on biological standards. In anticipation of establishing biological water quality standards for the State of Maine, the Maine Department of Environmental Protection (MEDEP) initiated a standardized collection technique for benthic macroinvertebrates in 1983. Cylindrical wire baskets (15 cm dia., 25 cm length) were filled with stones (1.5 to 5.0 cm) and placed in wadable streams and rivers. Three rock baskets were placed at each sample site. The rock baskets were left in place for at least 30 days to allow

colonization and were then retrieved with an aquatic net to avoid the loss of organisms.

A range of stream orders was chosen, and within those both unpolluted and polluted sites were sampled. The sampling period for each year was from late July through September. This program was carried out for seven years with a resulting database of benthic communities from 146 sites. Collected organisms were identified to the lowest practicable taxon. For evaluation purposes, however, all organisms were grouped to genus.

To place the benthic community into one of three narrative water quality standards, MEDEP personnel independently evaluated each site using best professional judgement and a combination of community analysis metrics chosen by each biologist. The narrative aquatic life standards that have been adopted for the State of Maine are:

Class A: Natural habitat for aquatic life; aquatic life shall be as naturally occurs (highest water quality)

Class B: Unimpaired habitat for aquatic life; discharges shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community (good water quality)

Class C: Habitat for aquatic life; discharges may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community (low water quality)

A fourth category, non-attainment (NA), includes those sites in which the structure or function of the community has not been maintained (MEDEP 1987). A consensus determination for each site was reached, and each site was placed in a narrative water quality standard. The resulting data base is comprised of 43 A sites, 51 B sites, 25 C sites and 27 NA sites, for a total of 146 sites.

MEDEP evaluated the entire database for the purpose of developing a series of objective community composition parameters that would discriminate between the different water quality standards. The authors became involved in this process as part of a technical review group that MEDEP formed to aid in the biological classification of water quality. This paper represents a technique developed by the authors to assist in water quality evaluations. This technique uses a rating system derived solely from the Maine database to establish a number of taxa which could serve as indicators of good water quality.

Table 1. Decision criteria for Tolerance Rating Assignment.

Tolerance Rating	Criteria
0	>75% in A; <5% in C; <1% in NA
1	<75% but >50% in A; <5% in C; <1% in NA
2	Dominant in A, >5% in C or NA
3	>75% in B; <2% in NA
4	<75% but >50% in B; <5% in NA
5	Dominant in B (<50%)
6	>75% in C
7	<75% but >50% in C
8	Dominant in C (<50%)
9	Dominant in NA

Materials and Methods

The database was analyzed to determine the total number of organisms collected within each taxon, the percentage of sites from which an individual taxon was collected and the percentage of organisms within a certain taxon collected in each water quality classification.

A tolerance rating (0 to 9) was assigned to each taxon using both the percentage of organisms collected from a certain water classification category and the absence of the taxon in other water classification categories. For example, if greater than 75 per cent of all the organisms within a taxon were collected in Class A water quality sites and less than 5 per cent and 1 per cent of the organisms were collected in the Class C and NA categories respectively, the taxon was assigned a tolerance rating (T.R.) of 0. A T.R. of 1 was assigned to taxa that were less dominant in Class A (less than 75 per cent but greater than 50 per cent) but still met the threshold criteria of less than 5 per cent in Class C and less than 1 per cent in NA. The different criteria for tolerance ratings 0 to 9 are listed in Table 1.

Table 2. Representative taxa from the Maine Department of Environmental Protection database.

Taxon	Occurrence (% of Sites)	% of Organisms by Class				Tolerance Rating
		A	B	C	NA	
Coleoptera						
Promoresia	25	12	86	2	0	3
Diptera						
Chironomus	16	1	3	34	62	9
Rheotanytarsus	69	8	34	51	7	7
Ephemeroptera						
Baetis	61	25	66	9	<1	4
Ephemerella	17	18	38	44	<1	8
Isonychia	34	38	58	3	1	4
Leucrocuta	18	85	11	4	0	0
Paraleptophlebia	34	29	30	11	30	ND *
Serratella	20	89	9	2	<1	0
Plecoptera						
Paragnetina	15	60	26	13	1	2
Trichoptera						
Glossosoma	16	72	28	0	0	1
Psilotreta	11	95	5	0	0	0

* No Determination

Indicator taxa were designated as those taxa assigned a T.R. of 0 or 1. If indicator taxa are to be useful for the interpretation of water quality, they should occur regularly in stream communities with good water quality but should not be equally represented across the water quality classes. We therefore separated all indicator taxa into two groups. "Primary indicators" are the taxa recovered in greater than 5 per cent of all sample sites, whereas "secondary indicators" are those found in 5 per cent or less of the sample sites. For the purpose of this paper, only primary indicators are discussed.

Results

Tolerance ratings derived using this system are provided in Table 2 for 12 representative genera from several different insect orders.

More than 75 per cent of all the *Serratella, Leucrocuta* and *Psilotreta* were collected in the Class A water quality sites; less than 5 per cent of each were collected in the C water quality sites and less than 1 per cent were collected in the non-attainment (NA) category. Therefore, a T.R. of 0 was assigned to these taxa. *Glossosoma* was also predominately collected in the Class A sites and it was not collected in either the Class C or NA categories. Because it did not meet the 75 per cent Class A criterion, however, it was assigned a T.R. of 1. Similarly, *Paragnetina* was most abundant in Class A sites, but greater than 5 per cent were collected in Class C sites so the T.R. assigned to this taxa was 2. *Paraleptophlebia* could not be assigned a tolerance rating because no trend was observed.

Primary indicator taxa were selected using the tolerance-rating criteria and the greater-than-5 per cent rule (Table 3). All 11 primary indicator taxa were genera within the orders Ephemeroptera, Plecoptera or Trichoptera. Hilsenhoff's (1987) rating system for these taxa is also included in Table 3.

Discussion

Presently, the primary database consists of 99 taxa collected in 5 per cent or more of the sample sites. The 11 primary indicator taxa represent 11.1 per cent of the total number of taxa collected. Two of the 11 primary indicator taxa were Ephemeroptera, constituting only 11 per cent of the mayfly genera in the primary database. In comparison, the five Trichoptera indicators constitute 25 per cent of the caddisfly genera in the primary database; the four genera of Plecoptera constitute 57 per cent of the stonefly genera. Of the taxa generally considered to be important for the assessment of water quality (Ephemeroptera, Plecoptera and Trichoptera), Ephemeroptera appear to be the least represented as indicator taxa using the primary database.

Table 3. List of primary indicator taxa derived from the Maine Department of Environmental Protection database.

Indicator Taxa	Occurrence (% of Sites)	Taxonomic Rating	Hilsenhoff Rating
Ephemeroptera			
Serratella	20	0	2
Leucrocuta	18	0	1
Plecoptera			
Isoperla	6	0	2
Leuctra	6	0	0
Pteronarcys	7	1	0
Taeniopteryx	9	1	1
Trichoptera			
Brachycentrus	34	0	1
Glossosoma	16	1	0
Helicopsyche	11	0	3
Micrasema	9	1	2
Psilotreta	11	0	0

Hilsenhoff (1977) introduced a system of tolerance ratings and modified his techniques in later publications (Hilsenhoff 1982, 1987). In the development of these criteria, he acknowledged the biases that the method and season of collection may introduce and suggested that correction factors may be needed to compensate for these differences.

Hilsenhoff assigned ratings between 0-2 for species within the genus *Ephemerella*, indicating that this genus is intolerant of organic pollution. Conversely, *Ephemerella* was characterized as a more tolerant species by the Maine database,

with a T.R. of 8. Several possible reasons exist for this discrepancy. A majority of *Ephemerella* species are not readily collectable in late summer in Maine (S.K. Burian, Southern Connecticut State University, personal communication), which would account for the low total number of this genus collected since 1983. Because the percentages appearing in the different water quality classifications are based upon the total number of organisms collected, only a few sites with an *Ephemerella* dominance would be necessary to skew the distribution. This does not detract from the validity of the system, however, as the collection season and procedure are standardized for the State of Maine. A comparison of Hilsenhoff ratings and T.R. values for the primary indicator taxa demonstrates that the values derived from each system are similar (Table 3).

Paraleptophlebia is included to demonstrate that not all taxa were assigned tolerance ratings. Table 2 demonstrates that *Paraleptophlebia* were essentially equally distributed between the Class A, B and NA categories. Because no trend was observed, no rating was assigned.

Because the identification of indicator taxa is dependent upon their occurrence in a minimum threshold of sites, it is expected that the number of primary indicators will change over time. These changes would depend on the focus of sample collection. If the focus of collection is on sites with good water quality (Class A and B), a number of secondary indicators may meet the 5 per cent or greater site occurrence criterion.

Decreases in the number of indicator taxa can be expected if there is a focus on site collections in the Class C and/or NA categories. This would likely decrease the overall percentage of sites in which organisms such as *Leuctra* and *Isoperla*, for example, would be found and thus move these two genera into the secondary indicator category.

Provided that the database is periodically updated, the number of indicator taxa used to evaluate water quality is regulated through the feedback loop of data collection, establishment of tolerance ratings and designation of indicator taxa. By using the criteria in Table 1, a T.R. can be derived for almost all taxa that occur preferentially in a water quality class. While the described procedure for designating indicator taxa uses a statewide database, the same procedure could be used with a geographical area such as an ecoregion or watershed.