ME DEP Aquatic Life Decision Models and Sample Variables

ME DEP's aquatic life decision models are four statistical models that use 30 variables of the macroinvertebrate community to determine the strength of association of a sample community to Maine's water quality classes. Each of the four linear discriminant models uses different variables, providing independent estimates of class membership. Association values are computed for each classification using one four-way model and three two-way models. The protocol is outlined in the ME DEP methods manual (Davies and Tsomides 2002).

First Stage Model and Variables

The first stage model acts as a screen, and gives the strength of association of the sample to each of the different water quality classes. This model provides four initial probabilities that a given site attains one of three classes (A, B, or C) or is in nonattainment (NA) of the minimum criteria for any class. These probabilities have a possible range from 0.0 to 1.0 and are used, after transformation, as variables in each of the three subsequent second stage or final decision models. See section below on second stage models.

The variables used in the first stage model are variables important to the evaluation of all classes. Of the nine variables used in the first modeling stage, 5 measure abundance, 2 measure richness, and 2 variables are biotic indices involving tolerance to pollution and abundance. The **first stage model** uses the following nine variables:

1. **Total Mean Abundance –** Total mean abundance (the mean number of individuals in a sample, usually based on 3 replicates) is a basic measure of community structure and is a strong predictor of both Class A and nonattainment. Total abundance values for the water quality classes appear to follow a curve shaped like Odum et al. (1979) subsidy-stress gradient. Values for Class A are relatively low, due to low nutrients in natural Maine waters. Values for Class B and C communities tend to be high, indicating increased resources that might be available in a waterbody with increased loadings of materials from human alterations. Abundance values in nonattainment waters tend to be low, but can also be highly variable.

2. **Generic Richness –** Richness (total number of taxa in a sample) is a good measure of water quality impact, declining as water quality declines. Low richness is a good predictor of nonattainment. Like abundance, richness follows the generalized subsidy-stress curve.

3. **Plecoptera Mean Abundance –** Plecoptera, or stoneflies, are very intolerant of even mild levels of pollution. Abundance is highest for Class A and declines with the classes to be nearly absent from nonattainment class. The Maine water quality classification requires that Class A and B waters support all indigenous species, so it is expected that Plecoptera numbers will be maintained in those classes. Stoneflies function as predators and shredders.

4. **Ephemeroptera Mean Abundance –** Ephemeroptera, or mayflies, are intolerant of many pollutants, so abundances are distinctly lower for nonattainment samples than the

other classes. Mayflies function as scrapers and collectors. Together with the stoneflies, these two groups represent highly sensitive orders which fulfill the major functional feeding roles in the community. These orders are important components of a Class A or B community.

5. **Shannon-Wiener Generic Diversity** (Shannon and Weaver 1963.) **–** Diversity is composed of a richness factor and an eveness factor.   Richness distributes between the classes along a subsidy-stress curve. Diversity shows a decline in value from Class A to the nonattainment class as certain pollution-tolerant taxa gain advantages, due to increasing pollution load or other activities. As both diversity and richness decline, the stability of most natural communities usually declines.

6. **Hilsenhoff Biotic Index** (Hilsenhoff 1987.) **–** The biotic index provides a measure of the general tolerance level of the sample community toward organic (nutrient) enrichment. The index increases in value from Class A to the nonattainment class, indicating that increases in abundance may be attributable to increases among the tolerant taxa (a change allowed in Class B or C), or that there may be a decline in the taxa pool of intolerant organisms (a change allowed in Class C).

7. **Relative Chironomidae Abundance –** Chironomidae, a Family of Flies in the Order Diptera that includes Non-biting Midges and Midges, consist of a great number of taxa with wide-ranging tolerances and adaptations. Many tend to increase with increasing pollution load, probably as a response to reduced competition and predation, and to increased organic matter supply. Many have very short generation times and are thus capable of quickly colonizing areas where these conditions exist. The taxa which cause these increases are the collector types adapted to feeding on fine organic mater; some are primarily predators. These genera have been observed to increase in relative abundance presumably because of tolerance to reduced water quality, particularly the presence of some toxic substances, and the availability of other pollution tolerant prey.

8. **Relative Diptera Richness –** Many Diptera, or True Flies, are pollution tolerant organisms. Relative Diptera richness increases from Class A to the nonattainment class. Increases in Diptera, particularly the Chironomidae, have been observed with increasing pollution and sedimentation and loss of Ephemeroptera, Plecoptera and Trichoptera.

9. ***Hydropsyche* Mean Abundance –** The genus *Hydropsyche*, one of the common net-spinning Caddisflies, provides some added discrimination to the model. Higher values for *Hydropsyche* abundance are found for Class B and are nearly absent from nonattainment samples. *Hydropsyche* is a filter-feeder and prospers under conditions of mild enrichment of suspended organic particles, conditions that might naturally be found below a lake outlet or might be found in Class B waters below a treatment plant outfall or in the presence of nutrient enrichment from nonpoint source pollution activities (e.g. agriculture). Relative to other genera of the Hydropsychidae family, *Hydropsyche* is usually less tolerant of low dissolved oxygen or toxic substances.

Stage 2 Models and Variables
The final decision models (the three, two-way models) are designed to distinguish between a given class and any higher classes as one group and any lower classes as another group (e.g. Classes A+B+C vs NA; Classes A+B vs Class C+NA; Class A vs Classes B+C+NA). The equations for the final decision models use the predictor variables relevant to the class being tested. The process of determining attainment class using association values is outlined in Appendix F of the ME DEP methods manual (Davies and Tsomides 2002). Application of the three second stage models or two-group tests is hierarchical:

"C or better" model: The first second stage model determines the probability that an unknown sample belongs in the cluster of samples A+B+C versus the probability that it belongs in the cluster of non-attainment of Class C samples. This is referred to as the "C or better" model which determines if the sample is at least a Class C, using the following variables:

10. **Probability (A+B+C)** from First Stage Model

11. ***Cheumatopsyche* Mean Abundance** - The abundance of *Cheumatopsyche*, one of the common net-spinning Caddisflies, generally increases with declining water quality and is usually the last of the Ephemeriptera-Plecoptera-Trichoptera genera found in abundance as water quality declines because *Cheumatopsyche* are generally found to be the most pollution tolerant genera within the family Hydropsychidae, among the order Trichopera.

12. **EPT – Diptera Richness Ratio –** (uses all Diptera rather than just the Chironomidae.) The Ephemeroptera-Plecoptera-Trichoptera are usually poorly represented in communities where water quality is poor. These orders provide considerable functional variety to aquatic communities, and when severely depleted, or replaced by Diptera, signal dysfunction of the community. Maine data show distinct separation of values for this variable between Class A, B, and C communities and the nonattainment communities.

13. **Relative Oligochaeta Abundance –** Proliferation of Oligochaeta, Aquatic Worms, has long been recognized as an indication of polluted waters, since many taxa are highly tolerant of low oxygen conditions and certain toxic substances, feed on fine organic particles and can colonize quickly in the absence of predators. Communities dominated by Oligochaeta are found when pollution loads are excessive. These organisms are usually the last to be eliminated by pollutant overloading and as the relative abundance of Oligochaeta increases, community structure and function are usually diminished.

"B or better" model: The second two-way model is the "B or better" model which determines if the unknown sample attains at least Class B standards. It discriminates between the cluster of A+B samples and the cluster of C+non-attainment of Class C samples. Family functional groups are important in this second two-way model. Changes in functional feeding group composition indicate the energy pathways through the aquatic ecosystem have been significantly altered. The major functional groups in the Maine data are: collector-filterer, collector-gatherer, piercer, predator, scraper, and shredder. The "B or better" model uses the following variables:

14. **Probability (A+B)** from First Stage Model

15. **Perlidae Mean Abundance** (Family functional Group) - Greater abundance of this family functional group is expected to occur in higher quality waters. This family of Stoneflies are large predators and usually occur in waters of good quality. Generation time for some of these taxa is greater than one year; therefore populations will persist only where water quality is consistently good for long periods of time.

16. **Tanypodinae Mean Abundance** (Family functional Group) - This subfamily functional group is usually found in greater abundance in waters of lower quality. This Chironomidae subfamily is also a predator group, but these organisms are small in comparison to the Perlidae, and feed on small Oligochaeta and other Chironomidae which can also tolerate lower water quality.

17. **Chironomini Mean Abundance** (Family Functional Group) - Greater abundance of this Chironomidae subfamily group indicates increased availability of organic matter. Many taxa in this group are known to tolerate lower water quality. These organisms are collector-gatherers favoring fine, settled organic particles. Many of these taxa are multivoltine, capable of quickly colonizing favorable habitats and recolonizing after disturbances.

18. **Relative Ephemeroptera Abundance** - The Ephemeroptera, or Mayflies, are generally an intolerant order and tend to be indicators of good to excellent water quality. While total Ephemeroptera abundance was used as a discriminating variable in the second stage discriminant model to separate the four classes, relative abundance is used to separate these two groups, particularly between the B and C class waters. While Ehemeroptera abundance may not decline appreciably in Class C waters, there is an expectation for other non-Ephemeroptera taxa to increase.

19. **EPT Generic Richness –** EPT richness has been a common measure to identify waters of good quality. Of the three orders, Ephemeroptera and Plecoptera are considered the more intolerant. Many of the Tricholptera are also intolerant of low water quality. Collectively, these orders have a wide array of functional characteristics (feeding strategies and preferred resources, reproductive and life cycle strategies, habitat preferences). Higher values for EPT richness are indicative of a structurally and functionally diverse community. As EPT richness diminishes, it is presumed that this functional diversity also declines.

20. Variable Reserved -

21. **Sum of Mean Abundances of: *Dicrotendipes, Micropsectra, Parachironomus* and *Helobdella*** - The sum of the abundance of four indicator taxa (three Chironomidae genera and one leech genera) is also used. All four are detritivores and generally occur in abundance only when water quality is diminished. A high abundance of this group is indicative of conditions of Class C or nonattainment.

“Class A” model: Class A is the highest quality water and is expected to be supportive of natural populations with the expectation that the community include many pollutant-intolerant organisms. The Class A decision model relies on the probability score from the second stage linear discriminant function and many indicator taxa to ascertain Class A quality. The third two-way model is the “Class A” model and discriminates Class A samples from the cluster of samples in Classes B+C+Non-attainment of Class C using the following variables:

22. **Probability of Class A** from First Stage Model

23. **Relative Plecoptera Richness –** Plecoptera are well known as an intolerant Order, showing great intolerance to a variety of pollutants. Their reproductive strategies render them slow to re-colonize areas where they have been eliminated. Water quality therefore needs to be consistently good for the Plecoptera to be present. Relative richness of Plecoptera is expected to be greatest in the highest quality waters.

24. Variable Reserved

25. **Sum of Mean Abundance of Cheumatopsyche, Cricotopus, Tanytarsus, and Ablabesmyia** - These four taxa (a net-spinning Caddisfly and three Chironomidae genera) are considered pollution-tolerant and are not expected to occur in abundance in Class A waters. All four taxa occur most commonly in lower quality waters, and may replace functions of less tolerant organisms when those populations decline.

26. **Sum of Mean Abundances of Acroneuria and Stenonema** - *Acroneuria* (a Stonefly genera of the Perlidae Family) and *Stenonema* (a Mayfly genera) are two of the most common and abundant taxa in their respective orders and indicators of good water quality. The sum of their abundance provides a good discriminating variable.

27. Variable Reserved

28. **Ratio of EP Generic Richness** - EPT richness is a good discriminating variable to identify Class A and B waters, but of this group, the Ephemeroptera and Plecoptera were usually the less tolerant taxa of the three orders. EP richness is thus used as a variable for Class A waters.

29. Variable Reserved

30. **Ratio of Class A Indicator Taxa –** The number of Class A indicators divided by 7 (which is the total number possible). Seven indicator taxa were identified for Class A communities. Class A indicator taxa were present in 100% of Class A communities, <26% of Class B communities, <16% of Class C communities, and <1% of nonattainment communities. Class A indicator taxa were rarely found to be dominant taxa except in Class A communities. Values of zero for this variable (# of Class A indicator taxa among 5 most dominant taxa) were found in sample communities which were not determined to support Class A conditions. Class A communities had one or

more indicator taxa among the five most dominant taxa for 54% of the samples. The Class A indicators are: *Brachycentrus* (Trichoptera: Brachycentridae), *Serratella* (Ephemeroptera: Ephemerellidae), *Leucrocuta* (Ephemeroptera: Heptageniidae), *Glossosoma* (Trichoptera: Glossosomatidae), *Paragnetina* (Plecoptera: Perlidae), *Eurylophella* (Ephemeroptera: Ephemerellidae), and *Psilotreta* (Trichoptera: Odontoceridae)