

Macroinvertebrate MMI

Multimetric indexes (MMI) allow multiple biological measurements, or metrics, to be combined into a single, unitless index value. Metrics are attributes of the biological assemblage, which can be quantified as a response to human and natural alteration or stress of the environment. MMIs are calibrated using reference conditions and are created to exhibit a site's correlation to these conditions based on multiple categories (metrics). By incorporating metrics such as richness, composition, functional feeding group, and pollutant tolerance for benthic macroinvertebrate communities, MMIs can accurately indicate macroinvertebrate community health and aide in stream condition determination statewide. Tetra Tech, Inc. developed Colorado's initial Macroinvertebrate MMI as part of a 319 grant project.

Candidate metrics were drawn from five categories: richness, composition, pollution tolerance, functional feeding group (trophic), and habit (locomotion). Selection was based on discrimination efficiency (DE), low variability, ecological meaningfulness, contribution of representative and unique information, and sufficient range of values.

Table 1—Macroinvertebrate MMI Metrics

Bioregion	Metric	Category
Plains	Percent Chironomidae	Composition
	EPT Taxa	Richness
	Hilsenhoff Biotic Index	Tolerance
	Percent Burrowers	Habit
	Percent Predators	Trophic
Xeric	Percent Coleoptera	Composition
	Diptera Taxa	Richness
	Percent dominant taxon	Tolerance
	Percent Climbers	Habit
Mountains	Predator Taxa	Trophic
	Percent Oligochaete	Composition
	Total Taxa	Richness
	Percent Climbers	Habit
	Percent Trichoptera which are Hydropsychidae	Tolerance

In this case, discrimination efficiency is the capacity of biological indicators to detect stressed conditions. Box plots of inter-quartile ranges of reference and stressed sites display the indicator's ability to discriminate between reference and stressed conditions. If the boxes do not overlap, the DE is said to be 75% or greater. The metrics with higher DE values were preferred, and those less than 25% were excluded from the index. The Coefficient of Variability ($CV = \text{Standard Deviation} / \text{Mean}$) was calculated for each reference site and, although no numeric threshold was set, lower CV values were preferred. Metrics selected were also indicative of expected responses of assemblages to change. The largest number of non-redundant metrics was used to encompass as many indicators of stress as possible.

Macroinvertebrate O/E Model

RIVPACS (River Invertebrate Prediction and Classification System) (Moss et al. 1987, Wright 1995) assessments determine biological condition or quality by estimating the taxonomic completeness of a standard sample. Taxonomic completeness is a fundamental aspect of biological integrity and is defined here as the proportion of taxa that occur versus those that are expected in a single sample. The O/E model describes which taxon are predicted to naturally occur at a site (E, expected) versus which taxon were actually collected by sampling the site (O, observed), where E is the sum of the probabilities of capture for each taxa. Individual probabilities of capture are derived from regionally classified reference sites, which are grouped by taxonomic similarity.

The O/E model output is a number from 1 (O=E) to 0 (O<E), where a departure from 1 indicates the presence, as well as the degree, of biological impairment. Developmental steps of O/E models are:

1. Select reference sites representing natural environmental gradients
2. Classify sites based on taxonomic similarity (predictor variables) by pair-wise similarities (dendrogram)
3. Calculate (Tally) each taxonomic occurrence frequency for each reference site class
4. Develop a discriminate model based on taxonomic distribution variables to predict probabilities of new sites' reference class designation
5. Estimate taxonomic probability of capture as the frequency of occurrence among classes weighted by site classification probability
6. Estimate E as the sum of the probabilities of capture
7. Assess model performance by comparing the O with E and calculating the precision of O/E estimates

Ninety-seven reference (least-disturbed) sites were used for the development of the O/E model for Colorado. These sites contained 173 OTU's, eighty of which occurred in five or more samples and were used to biologically classify sites for the model. Sites were well-distributed geographically throughout the state with the exception of a cluster along the western base of the southern Rocky Mountains. These sites were selected as adequate representation of natural conditions due to low chemical contamination, low flow alteration, and natural riparian and habitat conditions. Sites were then classified based on their taxonomic similarities.

Sites were divided into as many classes as were feasible in order to maximize similarity, with the requirement that each class contain no fewer than five sites. Classification of sites allowed for the estimation of frequencies of taxon occurrence in each site class and the development of a discriminate function model from taxonomic predictor variables that allowed the prediction of reference site classification probability for new sites. John Van Sickle's (USEPA) all subsets software was utilized to evaluate 32,767 discriminate models in order to determine which metric combination maximized precision and minimized bias for each predictor variable.

Performance measures were based on internal validation and included the mean, standard deviation, and root mean square error of O/E. Predictor variables that could be influenced by humans were eliminated, and only map-derived variables were utilized to illustrate the influence of local factors on spatial and temporal distribution of the biota. The final three predictor variables were: longitude (decimal degrees), mean annual air temperature ($^{\circ}\text{C} \times 10$), and log watershed area (km^2). A strong relationship between temperature and biotic classes implies that thermal variation across Colorado is the single most important factor affecting the distribution of stream taxa. (Tetra Tech, Inc. 2005)

Table 2—O/E Model Predictor Variables

Predictor Variables
Longitude (Decimal Degrees)
Mean annual air temperature ($^{\circ}\text{C} \times 10$)
log watershed area (km^2)

O/E score calculations are based on a probability of capture threshold of >0.5 . Ideally, the greatest number of taxa are used to develop a model, but this threshold is used as it minimizes predictive error based on the presence of rare taxa. It should be noted that utilizing this capture threshold decreases taxonomic resolution and may mask specific species' sensitivity to stress.