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A COMPARISON OF DIVERSITY INDICES

Seven different indices for describing the species diversity of benthic invertebrates have been devised by various scientists. Four of these are used by southern California dischargers to meet their monitoring requirements. As the dischargers are all not required to use the same index, and because it does not make much sense to have neighboring areas reporting by different methods, we have attempted to compare these indices and comment on their value.

Diversity is a measure of community structure, which can be defined as (1) the number of different kinds (species) of animals that occur in an area or sample, (2) the number of individual organisms that are present, and (3) the distribution of these organisms among the different species. Various indices put different weights on the importance of these components because they were originally developed to examine widely differing concepts, some of which do not apply directly to the problems of this area.

Every coastal area has a characteristic range of diversity that is influenced by hydrography, exposure, and—in these latitudes—rhythmic seasonality. Our problem is to detect signs of change caused by man against the background of natural change.

METHODS

The biological and physical/chemical data used in this study are the same as that described in the preceding article, "Numerical Analysis of Benthic Communities," except that the data from all 40 sampling stations on the Palos Verdes shelf were used, and all species were considered.

Two procedures for comparing the indices were used. First, the characteristics of seven indices were determined from a review of the literature and the author's personal experience. Then the relationships of the indices to the environmental (physical/chemical) factors were determined by statistical (regression) techniques.

RESULTS

The seven indices listed in Table 1 have been divided into three groups according to the emphasis each places on the structural components of the community (indices currently in use are indicated by an asterisk).

The diversity values calculated for each of the indices on the 40 Palos Verdes samples are compared in Table 2, which is a matrix of correlation coefficients. Coefficients of less than 0.800 are not considered to be of much ecological value in the present context. The coefficients between indices within the same group are very high. Coefficients between the indices of Groups I and III are quite low, as would be expected, and the moderately high coefficients between these indices and those in Group II show the relative contributions of the species and evenness components of diversity to the Group II indices.

To determine if the indices were correlated to the same or different sets of environmental parameters, a linear stepwise regression technique was used. The results are shown on Table 3, where the environmental parameters are arranged according to their importance in explaining the variability in the diversity indices.

Depth is seen to be the most important parameter for the Group I indices, followed by ORC (outfall-related chemicals; these are total mercury, total DDT, and percent organic nitrogen) and sulfides or sediment coarseness (DSC). These parameters account for over 82 percent of the variability in these indices.

In Group II, the ORC are most important, and depth is of secondary importance. Together, these parameters explain more than 62 percent of the variability in these indices.

The environmental parameters associated with Group III indices vary between ORC and sediment coarseness (percent sand). More important, however, is that these parameters explain only 22 to 32 percent of the variability in the indices; the unexplained variance is probably due to unknown biological factors, such as competition, predation, or bio-mass, or possibly unmeasured environmental parameters.

As a result of this study, we have concluded that the different types of diversity indices were designed to mea-sure different ecological qualities, and that each of these qualities provides useful but different information on the status of the biological community. Therefore, we recommend the following procedures in analyzing biological data in a pollution study:

- Either of the Group II indices should be used. These indices incorporate all three components of community structure and appear to be more responsive to outfall-related factors. The Brillouin Index is slightly favored, because it is not encumbered by unresolved assumptions.
- The total number of species and individuals counted from a sample should always be reported. Neither is an actual index of diversity, but each provides a valuable description of the sample.
- A measure of the evenness or dominance component of diversity (one of the Group III indices) may also be useful.
- Indices that are excessively sensitive to change in sample size, gear, or handling procedures, e.g., Gleason's Index, should be avoided. Although these indices may perform well within a given survey, the results cannot be meaningfully compared with those from other surveys where different techniques were used.
- Diversity indices are generally good indicators of change in community structure, but they should not be used to evaluate the quality or the cause of the change. Such evaluations should be based on collaborative data.

At the suggestion of Prof. John Isaacs, we eliminated the influence of depth from the preceeding stepwise regression analyses by examining samples from the 60-m (most effected) and 300-m (least effected) depth contours separately. A large proportion of the variability (about 84 percent) in the Group I (species) indices was explained at 60 m than for the others indices; approximately 91 percent of the variability in the Group III (evenness) indices was explained at 300 m. At both depths, the amount of variability explained for the Group II indices was intermediate to that of the other groups, the regression equations were significant, and ORC parameters were most important. This latter result supports the previous recommendation for the general use of Group II indices (Brillouin's or Shannon's Index) in pollution studies.

This report is a summary of part of a study supported by the Environmental Protection Agency.

Table 1. Features of seven diversity indices. The indices currently in use are indicated with an asterick.

GROUP I

Emphasis is on the number of species.

- Species Richness Index, S_R*

Advantages	A count of the number of species in a sample; a good descriptive measure of variety.
Disadvantage	Varies greatly with changes in sample size, gear, handling procedures.

- Gleason's (Margalef) Index, D*

Advantage	Simple to calculate (similar to S_R when sample is large).
Disadvantage	Behaves erratically (similar to S_R).

GROUP II

Emphasis is on both the number of species and the distribution of individuals among the species (evenness).

- Brillouin's Index, H

Advantages	Measures diversity in a fully counted sample and is not an estimate of an unknown universe; not greatly affected by sample size.
Disadvantage	Complex to calculate; contributions of components not easily interpreted.

- Shannon's (Margalef) Index, H'*

Advantages	Results similar to H, but easier to calculate; not greatly affected by changes in sample size.
Disadvantages	Biased because knowledge of all species in a much larger area is assumed (especially biased when sample is small); not easily interpreted.

GROUP III

Emphasis is on evenness or dominance component.

- Simpson's Index, SI*

Advantage	A measure of dominance.
Disadvantage	Neglects all but the most abundant species.

- Shannon's Index (Scaled), H'(s)

Advantages	Same as H' but designed to eliminate the influence of the number of species; compatible with H' (a similar index, H(s), exists for H).
Disadvantages	Same as H'; both H'(s) and H(s) are difficult to calculate.

- Standard Deviation (Scaled), SD(s)

Advantages	Based on most widely used statistical measure of dispersion, the standard deviation; designed to eliminate the influence of the number of species; sensitive to most abundant and rarest species.
Disadvantages	Not long in use; more complex to calculate.

Table 2. Correlation coefficients of seven diversity indices. Values less than 0.800 are not considered to be of ecological value in this study.

	Group I		Group II		Group III		
Index	S_R	D	H	H′	SI	SD(s)	H′(s)
Group I (Species)							
Species richness, S_R	1.000	0.978	0.689	0.662	0.404	0.380	0.320
Gleason's, D		1.000	0.787	0.772	0.518	0.518	0.440
Group II (Species and Evenness)							
Brillouin's, H			1.000	0.997	0.916	0.889	0.889
Shannon's, H′				1.000	0.917	0.881	0.895
Group III (Evenness)							
Simpson's, SI					1.000	0.978	0.965
Std. Dev. (scaled), SD(s)						1.000	0.961
Shannon's (scaled), H′(s)							1.000

Table 3. Summary of stepwise regression analyses showing the environmental parameters significantly related to each index, and the amount of variability accounted for in each index.

	Environmental Parameters*			Variability Accounted For, R_2
Index	First	Second	Third	(%)
Group I (Species)				
Gleason's, D	depth	ORC	sulfide	82.5
Species richness, S_R	depth	sulfide	DSC	82.2
Group II (Species and Evenness)				
Brillouin's, H	ORC	depth		63.0
Shannon's, H′	ORC	depth		62.0
Group III (Evenness)				
Shannon's (scaled), H′(s)	ORC	depth		32.8
Simpson's, SI	% sand			26.2
Std. Dev. (scaled), SD(s)	% sand			22.0

*ORC = outfall-related chemicals (total mercury, total DDT, and percent organic nitrogen). DSC and % sand represent different aspects of sediment coarseness.