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A Comparative Study of Different Biological Indices Sensitivity: A Case Study of Macroinvertebrates of Gomishan Wetland, Iran

F. Shirood Mirzaie, R. Ghorbani and S. Montajami

Faculty of Fisheries,
Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

Abstract: Biological indices are numerous but the choice of the best and the most sensitive index to calculate is difficult. Three divisions of biological indices (richness, evenness and dominant) and their classification and sensitivity of them were investigated in this study using macroinvertebrate communities sampled in Gomishan Wetland. Calculating a lot of indices for ecological estimations is difficult and needs a long time. A simple and quick way has been suggested in this study to choose the best index in each division. This way, which depends on the kind of data analysis, index properties wanted by users and the study ecosystem, is drawing the graphs of indices in each division and the investigation of their trends. The index with the most gradient is the best and the most sensitive index for that concept of ecological estimations. The proposed way does not need statistical analyses and can introduce the best indices for ecological investigations.

Key words: Biological Indices · Sensitivity of Indices · Macroinvertebrates · Gomishan Wetland

INTRODUCTION

Ecosystem evaluation is one of the most important concepts in ecology. It can be obtained in different ways which one of them is biological indices. Many biological indices have been introduced to estimate the evenness, richness and dominance of various biological communities in ecosystems. Biological indicators are utilized in monitoring programs which can provide determine anthropogenic effects on aquatic ecosystems [1] Sometimes, several indices are utilized for ecosystem evaluation and sometimes, a comprehensive index is used for the large numbers of data. But it is better to find the most sensitive and the most accurate index for ecosystem evaluation with paying attention to the purpose of evaluation. The choice of the best index becomes more difficult with the large numbers of biological indices [2].

Although a single index cannot describe the whole aspects of community structure, but biological indices are used in many conditions and can make easier the ecological interpretation of data sets. Biological indices are a useful way to summarize data even for the people with little biological information and expertise [3].

Resh and Mcelravy [4] expressed that about 40% of researches utilize biological indices for freshwater lotic and lentic studies.

Some authors believe that using a single index for ecological estimations often causes erroneous conclusions [e.g. 5] but sometimes quick scrutiny for ecological estimation are necessary. The aim of this study is to propose a simple and quick way to specify the appropriate index for ecosystem evaluation in three divisions of evenness, richness and dominance of biological communities.

MATERIALS AND METHODS

Study Area: Gomishan Wetland, with summer-wet hydroperiods [6], is a coastal and permanent wetland [7] which has located between 37° 9′ to 37° 20′ in longitude and 53° 54′ to 53° 58′ in latitude, in the southeast of Caspian Sea. The eastern border of this wetland is subjected to change due to fluctuations of Caspian Sea water level [8].

Field Sampling and Laboratory Processing: In this study, the sampling was carried out in two seasons: spring and summer. In each season, 48 samples of macroinvertebrates were collected from four stations: Shrimp Breeding Station (1), Gomishan Coast (2), Drainage (3) and Bandar-e-Torkaman Coast (4) (Fig. 1). The samples of macroinvertebrates were collected by Ekman Grab

Corresponding Author: F. Shirood Mirzaie, Faculty of fisherish, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Table 1: The calculated indices and their formulas in this study

Index	Formula	Explanation
Margalef's Diversity Index	$R_i = S - 1/Ln(N)$	S: the total number of species N: the total density of species
Menhinick's Index	$D_{Me} = \frac{S}{\sqrt{N}}$	S: the total number of identified groups N: the total number of counted individuals
Simpson's Measure of Evenness	$V' = \frac{D}{D_{max}}$	D: the species diversity index D_{max}: the maximum amount of the species diversity index
Pielou Evenness Index	$J' = \frac{H'}{H'_{max}} = \frac{H'}{LnS}$	H': the amount of Shannon_Wiener Index H'_{max}: the maximum amount of Shannon_Wiener Index S: the number of taxon in samples
Simpson's Index	$D = \sum_{i=1}^{n} P_i^2$	P_i: the ratio of the species i
Berger-Parker Index	$D = n_{max} / N$	n_{max}: the maximum number of identified species N: the total number of individuals
Shannon-Wiener Index	$H' = -\sum_{i=1}^{n} P_i \log 2 P_i$	n: the total number of species P_i: the ratio of the species i

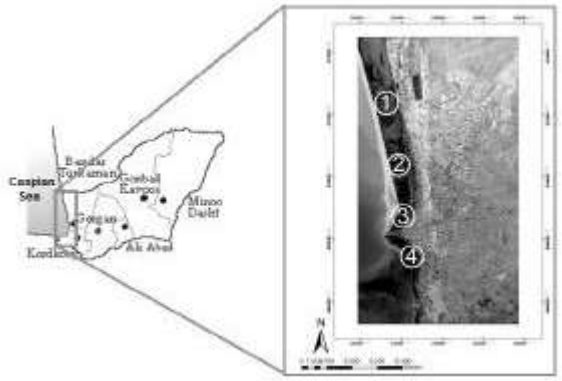

Fig. 1: The study area of Gomishan Wetland and sampling locations

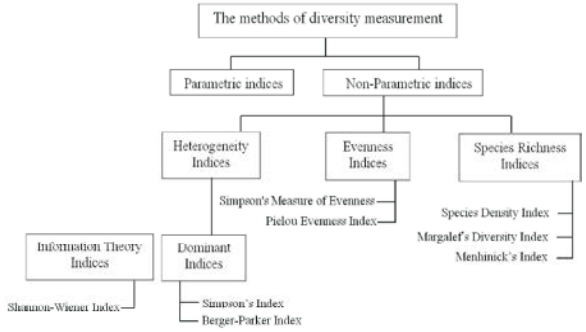

Fig. 2: The classification of biological indices performed by Ejtehadi *et al*. [2] and the calculated indices in this study

(sampling surface area: 225 cm^2), sieved alive over a 60 µm mesh-sized sieve, fixed in 4% formalin and transported to the laboratory for counting and identification. The macroinvertebrates were identified by the Atlas of Caspian Sea Invertebrates [9] and counted.

Biological Indices: Ejtehadi *et al*. [2] stated that there are two main groups of indices to estimate the diversity: parametric and non-parametric indices. The classification of biological indices which has been performed by Ejtehadi *et al*. [2] and the calculated indices in this study have been shown in Fig. 2.

Species Richness Indices: This index is based on the total number of species and individuals in the sample. If it is possible to distinguish all the species in the sample successfully, these types of indices would be an appropriate method for estimating of richness [2].

Heterogeneity Indices: These indices are based on the relative abundance of species and called Heterogeneity Indices because they can measure richness and evenness, together. The Dominant Indices are sensitive on the species which have the maximum density in the study area. Information Theory Indices can give a collection of information which can be useful for biological estimating of ecosystems [2].

Evenness Indices: There are many Evenness Indices but the usual method of evenness estimating is the amount of Heterogeneity index ? maximum amount of Heterogeneity index.

According to Fig. 2, seven indices have been calculated in this study and shown with their formulas in Table 1.

Data Analysis: For calculating indices and statistical analysis, Excel (2010) and SPSS (16) were used and the amount of indices in different stations were analyzed with one-way ANOVA □ Duncan ($p<0.05$).

RESULT

Identifying and Counting of Macroinvertebrates: Altogether, 163922 individuals of macroinvertebrates were counted at the sampling stations of Gomishan Wetland during spring and summer which belong to 3 phyla, 6 classes, 7 orders and 10 families (Table 2).

Biological Indices: According to Table 3, similar indices which had been classified in one group (such as Simpson's Index and Berger-Parker Index), were different from each other in the stations. Therefore, more investigations are necessary to choose the best index from each group of biological indices. For example, it should be determined that which index is the best for evenness investigations; Simpson's Measure of Evenness or Pielou Evenness Index?

It is obvious that all of indices are valuable to determine the each concept of richness, evenness and diversity, but the sensitivity of each index is different from other similar indices and depends on the studied ecosystem and the aim of studying [5]. Therefore, the similar indices were compared in this study to determine the most sensitive and the most comprehensive index.

In this study, Margalef's Diversity Index and Menhinick's Index were calculated as representatives of Species Richness Indices. According to Fig. 3, the gradients of the graphs have changed similarly and their sensitivities are the same in the Gomishan Wetland. Therefore, both of them have similar sensitivity to richness estimations of study area.

From Evenness Indices, two indices were calculated: Pielou Evenness Index and Simpson's Measure of Evenness. According to Fig. 4, the changing procedure of the graphs is opposite of each other because of their formula. But their procedure can be compared in a reverse way. Pielou Evenness Index has more gradient in its graph

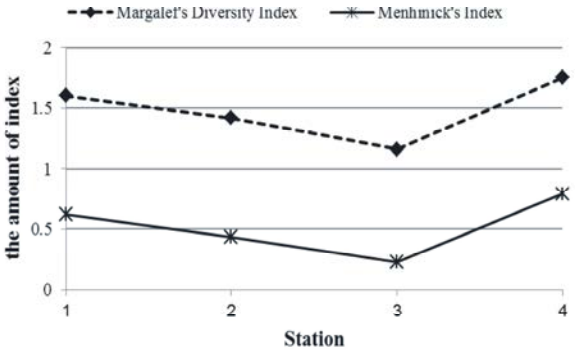

Fig. 3: The comparisons of the trends of Species Richness Indices among different stations of Gomishan Wetland

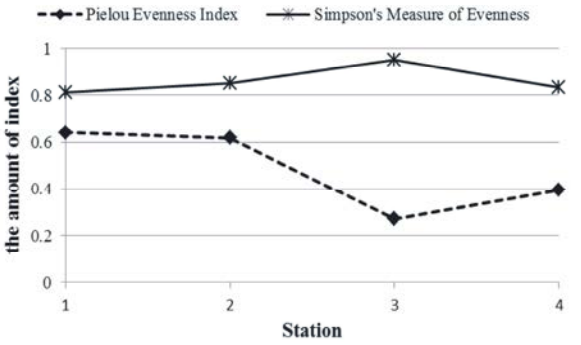

Fig. 4: The comparisons of the trends of Evenness Indices among different stations of Gomishan Wetland

Fig. 5: The comparisons of the trends of Heterogeneity Indices among different stations of Gomishan Wetland

in comparing to Simpson's Measure of Evenness and seems more sensitive and precision for evenness investigations of Gomishan Wetland.

Among the Heterogeneity indices, Berger-Parker Index, Simpson's Index and Shannon-Wiener Index had been calculated and their graphs have been shown in Fig. 5. Shannon-Wiener Index has an opposite procedure

Table 2: Identified macroinvertebrates in Gomishan Wetland

Phylum	Class	Order	Family
Mollusca	Bivalvia	Gastrotriteia	Scrobiculariidae
		Mytiloida	Mytilidae
		Veneroida	Cardiidae
	Gastropoda	Taenioglossa	Pyrgulidae
Arthropoda	Insecta	Diptera	Chironomidae
	Malacostraca	Amphipoda	Gammaridae
	Maxillopoda	Sessilia	Balanidae
Annelida	Polychaeta	Canalipalpata	Ampharetidae
		Aciculata	Nereidae
	Oligochaeta	Oligochaeta	Tubificidae

Table 3: The average amount of indices and their statistical comparisons in different stations

	Station			
Index	Shrimp Breeding Station	Gomishan Coast	Drainage	Bandar-e-Torkaman Coast
Species Density Index	19819^{b}	37388^{b}	231219^{a}	15136^{b}
Margalef's Diversity Index	1.601^{a}	1.419^{b}	1.158^{c}	1.751^{a}
Menhinick's Index	0.295^{b}	0.209^{c}	0.092^{d}	0.335^{a}
Simpson's Measure of Evenness	0.814^{b}	0.85^{b}	0.952^{a}	0.834^{b}
Pielou Evenness Index	0.834^{a}	0.764^{a}	0.759^{b}	0.56^{b}
Simpson's Index	0.664^{b}	0.672^{b}	0.894^{a}	0.696^{b}
Berger-Parker Index	0.755^{b}	0.775^{b}	0.944^{a}	0.8^{b}
Shannon-Wiener Index	0.642^{a}	0.62^{a}	0.27^{b}	0.56^{a}

Means with the same superscript letters in the same column are not significantly different ($P<0.05$)

in comparison to other indices because of its formula. The maximum gradient belongs to Shannon-Wiener Index and it states that this index is more suitable than the other indices in heterogeneity indices group.

DISCUSSION

Indices summarizing community structure are utilized to evaluate species interaction, fundamental community ecology, environmental stress and biogeographical factors. An acceptable measure of diversity should be reasonably simple to compute and understand, have some appropriate foundation in terms of a biological theory, statistics or mathematics, be influenced by both the number of species and the degree of uniformity or evenness of their frequency distribution, have intuitively reasonable interpretation and possess desirable properties [10].

Lack of knowledge about the properties of the various indices has been suggested as a limitation to their ecological usefulness [11]. Many indices have been proposed for measuring species evenness in ecological communities, but there is no consensus on which is the best [12].

Evenness indices can be calculated as relative diversity indices [13] or normalizations of diversity indices [14]. Diversity is the other mostly used concept, focusing on the fact that the relationship between diversity and disturbances can be seen as a decrease in the diversity when the disturbances increase [15]. But there is no single way to measure evenness [5, 11, 12], richness or diversity of an ecosystem but calculating biological indices can be a good way to ecological estimations.

Beisel *et al*. [5] believe that evenness indices must be interpreted with both richness and diversity indices. By this way, data interpretation can perhaps facilitate.

Boyle *et al.* [10] used sixteen indices to assess the status of aquatic communities in water quality studies and it was evaluated by using computer simulation techniques to determine specific index responses. Finally, the behavior of the indices was analyzed graphically and differential response due to initial community structure and type of community change was documented.

It is obvious that the biological indices should be chosen considering the kind of data and the aim of study. The kind of data is very effective on the selection of biological indices. For example, in the study of zooplankton community, the indices have been chosen

with a high sensitivity to changes in abundance of dominant taxa [5]. Therefore, dominant indices are more appropriate in these researches. But the large numbers of indices exist to measure the same features and all biological indices do not show the same sensitivity. The aim of study and ecological frameworks determine that which index should be calculated according to its sensitivity to changes in taxa's frequency. The best way which is quick and accurate for biological investigations by different indices is to investigate the graphs of similar indices which evaluate the same properties of biological communities and investigate the procedure of them. The index with maximum gradient in its graph is the most sensitive and the best index for that kind of ecological evaluation.

Like other methods of biological investigations, the proposed method in this study has defects. In this method, it is better to calculate more indices. When the comparisons are performed between a lot of indices, the result is more accurate and scrutiny. But finding and calculating several numbers of biological indices is difficult. Indeed, it is suggested to calculate some prevalent indices from each division of biological investigations and compare them by their graphs. The suggested method can be a fast, easy and accurate way to select the best index in biological investigations.

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