

The efficiency of indices of richness, evenness and biodiversity in the investigation of species diversity changes (case study: migratory water birds of Parishan international wetland, Fars province, Iran)

Abstract

The species diversity in a region is investigated by the indices (species richness, evenness and biodiversity) and their common methods of measurement (evenness index: Simpson, Camargo and Smith & Wilson; biodiversity index: Shannon-Wiener, Brillouin and Simpson). It is important to know the suitable index and its measurement method to study species diversity. To analyze the efficiency of the indices and their methods and the relationship between them in this research, the migratory aquatic birds in Parishan wetland was studied as biodiversity is better understood for birds than for any other organisms. Results showed that species richness alone cannot be utilized to estimate the species diversity of the study area. On the other hand, there are dissimilarities between the trends of evenness and biodiversity indices. In order to measure evenness index, there was no difference between Simpson and Camargo methods and their correlation was significantly high but Smith & Wilson was unequal to them. In biodiversity index, there also was no difference between Shannon-Wiener and Brillouin methods with significantly high correlation but Simpson was unlike them. This research showed that the application of indices of species diversity and their methods of measurement should be employed due to the purpose of experiment.

Keywords: Richness index, evenness index, biodiversity index, parishan wetland, correlation

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Introduction

Wetlands are among the world's most productive environments and one of their best known functions is to provide a habitat for migratory aquatic birds.¹⁻³ Wetlands are important habitats that these birds use them for wintering, resting, shelter, and they are also used as a source of drinking water, feeding, and social interactions. On the other hand, wetlands are strongly influenced by human impacts, because they are located where people live, such as nutrient-rich soils for agriculture and silviculture. Human activities can degrade or even destroy wetland habitats, and the health and livelihood of migratory aquatic birds are put at risk.⁴⁻⁶ Despite the increase in wetland conservation efforts over the past three decades,^{1,7} substantial losses of wetlands continue. It is not surprising then that many waterbird populations in different parts of the world remain in long-term and considerable decline, since wetland loss and degradation continue to be the main cause for these population changes, probably now being exacerbated by severe and prolonged droughts and other impacts of climate change. All these circumstances determine habitat selection by migrant birds and habitat loss hence is the major threat to them and habitat protection is the most important means of conserving their biodiversity. In Zagros landscapes located in the western Iran, wetlands, as in other dry lands, represent a broad variety of natural resources with environmental, social, and scientific values and play an important role in the maintenance of biological diversity. Despite their great intrinsic values, these ecosystems are suffering a severe pressure caused by human demands for water, agricultural production and habitation leading to the disappearance of many of them.

Migratory waterbirds depend on suitable wetlands and migration success depends on intact migratory routes with the availability of certain key food resources and resting opportunities at these sites. We believe that they are susceptible to changes happened to wetlands and it might affect their habitat preferences for wintering.^{8,9} Being more vulnerable to environmental changes, migratory waterfowls can be a robust bioindicator of wetlands status. These biodiversity indicators are quantifiable environmental factors¹⁰ that can show how the circumstances vary and help assess the suitable environment for migrating birds induced by human impacts. Responses of migrant waterbirds to the characteristics of natural wetlands influence their richness and diversity. We therefore suggested long-term monitoring of their biodiversity to discover how internationally concerned wetlands have been degraded and what are the consequences of this degradation on migratory birds. One basic approach to quantify biodiversity is to apply the predefined measures i.e. richness, evenness and diversity.¹¹⁻¹⁴ Estimating these indices, there are some common methods i.e. Simpson, Camargo and Smith & Wilson in evenness and Shannon-Wiener, Brillouin and Simpson in biodiversity.^{3,14,15} It is believed that each one of the mentioned criteria may provide meaningful understanding of the wetland's biodiversity changes. The integration of biodiversity monitoring is an essential step in the assessment of the wetland's conditions.

There are some investigations that have studied birds biodiversity.^{3,4,8,16-18} The diversity of aquatic birds was also performed in some wetlands in Iran.¹⁹⁻²³ The most suitable index and method of biodiversity evaluation is not mentioned in these researches. Also the results of different indices and their methods of measurement

have not been discussed about waterbirds diversity. The objectives of present research are: 1) to introduce the biodiversity of migrating aquatic birds as a robust bioindicator of wetlands degradation, 2) to validate the efficiency of common biodiversity indices in migratory waterbirds, 3) to compare the results of diversity indices and their methods to choose the suitable one.

Materials and methods

Study area

Parishan International wetland (PIW), an Iranian Ramsar Site in Fars Province, is one of the two demonstration sites for the UNDP/GEF Conservation of Iranian Wetlands Project. It lies to the east of Kazeroun City (51° 47' N and 29° 30' E) and is part of the Arjan Parishan Protected Area and is recognized by UNESCO as a Biosphere Reserve. The wetland is designated, since 1976, as a Ramsar site and a UNESCO Biosphere Reserve. The surface area of this wetland changes from 2500 to 5200 ha depending on hydrologic conditions.^{24,25}

Bird surveys

It was necessary to count the migratory waterbirds of PIW in each year. This has been performed by Environment Preservation Organization (EPO) during 5 January till 5 February of each year using standardizing survey methodology for wetlands. The 21-year (1989-2009) census of migrating birds was applied in this research.

Data analysis

The diversity indices i.e. richness, evenness and biodiversity were evaluated for waterbirds diversity applying the most common methods of their estimation mentioned in previous studies.^{18,26}

Richness

Species richness (or the number of species) is currently the most widely used diversity measure. Different methods were suggested by many investigators to measure this index and the number of species (n) as the species richness (s) is the most common method among others.^{3,27}

Evenness

Species evenness (or relative species abundance) in a community is another factor that affects diversity. One of the most frequent methods of evenness measurement is Simpson.¹⁵ Simpson's evenness index is defined as:

$$E_{1/D} = \frac{1/D}{n}$$

where D is Simpson's biodiversity index and n is the number of species. The second general method is Camargo suggested by Camargo (1993). As is the case for Simpson, this method is less sensitive to rare species. Camargo's evenness index is calculated by:

$$\dot{E} = 1 - \frac{\sum_{n_1=1}^n \sum_{n_2=n_1+1}^n |p_{n_1} - p_{n_2}|}{n}$$

where P_n is species frequency and n is the number of species. Smith & Wilson (1996) suggested a new method that is based on species frequency. This method is sensitive to rare and dominant species of

the community. It is measured through the equation:

$$E_{var} = 1 - 2/\pi \arctan \left[\frac{\sum_{n_1=1}^n \left(\ln(x_{n_1}) - \frac{\sum_{n_2=1}^n (\ln(x_{n_2}))}{n} \right)^2}{n} \right]$$

where n_1 is the number of individuals of the first species, n_2 is the number of individuals of the second species and n is the number of all individuals in all species.

Biodiversity

Biodiversity is a combination of richness and evenness. Simpson is the most popular and frequently used biodiversity index.^{28,29} It defines the probability that two equal individuals, selected randomly, belong to different species. This method is measured by:

$$D = 1 - \sum_{i=1}^n p_i^2$$

where n is the number of species and p_i is the relative frequency of each species. The other common method of biodiversity measurement is Shannon-Wiener. It estimates the average uncertainty in predicting which species each randomly selected individual belongs to. The following equation is applied:

$$H' = \sum_{i=1}^n p_i \ln p_i$$

where n is the number of species and p_i is the relative frequency of each species. The third method of biodiversity estimation is Brillouin. It is similar to Shannon-Wiener and is applied when random selection of samples is doubtful and is defined as:

$$HB = 1/n \ln n! / n_1! n_2! \dots$$

where n_1 is the number of individuals of the first species, n_2 is the number of individuals of second species and n is the number of all individuals in all species.

Correlation tests

The correlation between these measures was studied by Pearson correlation test. It is then possible to figure out how the indices and methods are related. The statistically significance of the correlation coefficient was evaluated by t-test (one-tailed).^{3,8}

Results

There were 91 species in PIW during the study period (1989-2009). The highest and the lowest amounts were observed in 1989 (39,806 birds) and 2009 (200 birds), respectively that showed a decreasing trend (Figure 1). The richness index was at its highest rate in 1994 (57) and the lowest one was observed in 2009 (10) (Figure 2). The results showed that there was no high correlation between richness and biodiversity although it was statistically significant (Table 1). The evenness index of aquatic birds in PIW was the highest in 2009 (0.424) applying Simpson and Camargo but Smith & Wilson showed that it was the highest in 1999 (0.296) (Fig. 3). The correlation was also significantly high between Simpson and Camargo (0.958) but it was not the case for Smith & Wilson (Table 1). Comparing the Shannon-Wiener index of biodiversity and the Simpson index of evenness showed contradictory results in the study area (1996-97 and 2008-09) (Figure 3) (Figure 4).

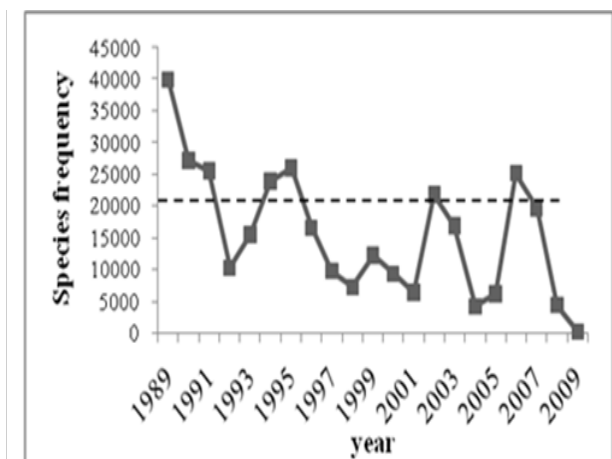


Figure 1 The species frequency of aquatic birds in PIW from 1989 to 2009.

Discussion and conclusion

The richness index was at its highest rate in 1994 (57) and the lowest one was observed in 2009 (10) (Figure 2). The results showed that there was no high correlation between richness and biodiversity although it was statistically significant (Table 1). On the other hand, the trend of richness was opposite of the biodiversity in some years (e.g. 1989-90 and 2005-06). These conflicts were also observed in species frequency and evenness. This relationship was obtained by Alvarez & Fors.¹⁷ It is concluded that richness index alone is not suitable enough to investigate the biodiversity of waterbirds in the study area.

The evenness index of aquatic birds in PIW was the highest in 2009 (0.424) applying Simpson and Camargo but Smith & Wilson showed that it was the highest in 1999 (0.296) (Figure 3). The correlation was also significantly high between Simpson and Camargo (0.958) but it was not the case for Smith & Wilson (Table 1). So there is no difference between Simpson and Camargo indices of evenness. This result is different from Golshahi et al.²³ because of the opposite trend between these two methods in his investigation. The changes of evenness and biodiversity were not the same in the migrating birds of PIW. Comparing the Shannon-Wiener index of biodiversity and the Simpson index of evenness showed contradictory results in the study area (1996-97 and 2008-09) (Figure 3) (Figure 4). Although Hvenegaard¹¹ deduced that the mentioned indices have the same style in his research. The results proved that different indices of evenness cannot alone be applied to measure the species diversity of migratory aquatic birds. It is suggested to utilize Simpson or Camargo measures if it is necessary to estimate the evenness index.

Beside richness and evenness, the biodiversity of birds is calculated in some researches. Our analyses showed that unlike Simpson index of biodiversity, Shannon-Wiener and Brillouin methods were completely the same (Figure 4). The similar outcomes were accomplished by correlation tests either (0.999 correlation coefficient between Shannon-Wiener and Brillouin) (Table 1). This relationship was also shown by Behroozi Rad et al.²⁰ and Nabavi et al.²¹

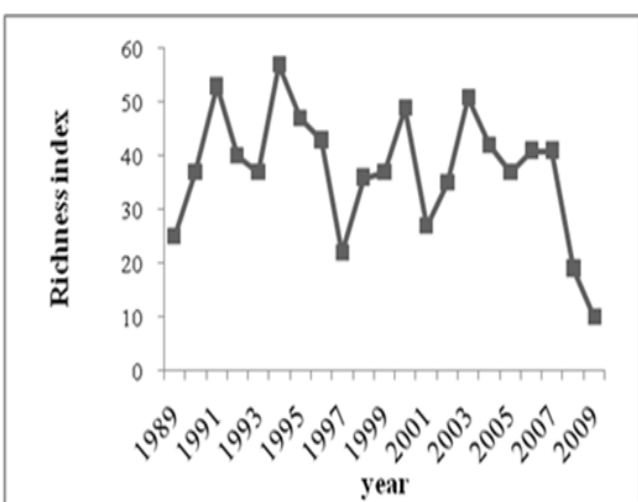


Figure 2 The richness index of aquatic birds in PIW.

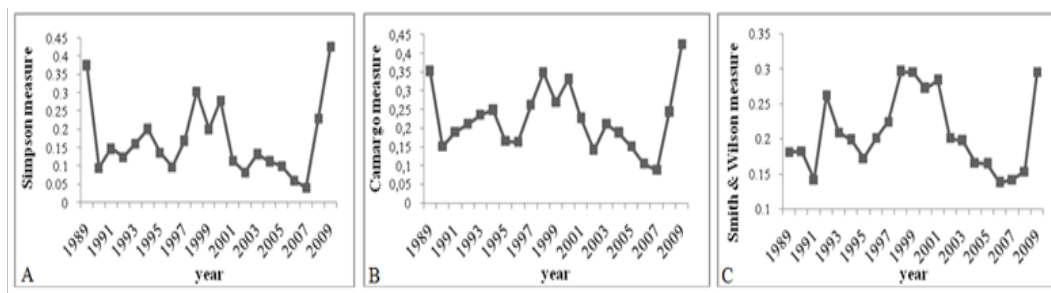


Figure 3 The evenness index of aquatic birds in PIW applying three methods of A) Simpson, B) Camargo and C) Smith & Wilson

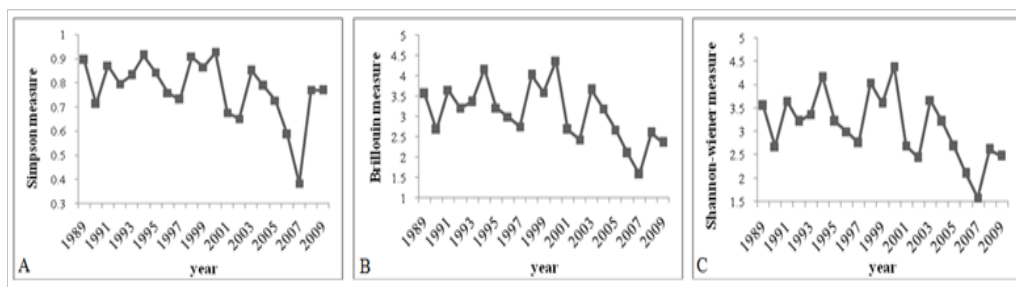


Figure 4 The biodiversity index of aquatic birds in PIW applying three methods of A) Simpson, B) Brillouin and C) Shannon-Wiener.

Table 1 Pearson correlation test between different indices and their methods

Indices and methods	Richness	Evenness			Biodiversity		
		Simpson	Camargo	Smith & Wilson	Simpson	Shannon-wiener	Brillouin
Richness	1	-0.461*	-0.447*	-0.295	0.206	0.457*	0.472*
Evenness	Simpson	-0.461*	1	0.958*	0.582*	0.436*	0.414*
	Camargo	-0.447*	0.958**	1	0.631**	0.517**	0.495*
	Smith & Wilson	-0.295	0.504**	0.684**	1	0.368	0.352
Biodiversity	Simpson	0.206	0.582**	0.631**	1	0.924**	0.918**
	Shannon-Wiener	0.457*	0.436*	0.517**	0.369*	1	0.999**
	Brillouin	0.472*	0.414*	0.495*	0.352	0.918**	1

Overall, the indices of species diversity (richness, evenness and biodiversity) and their measures should be applied due to the aims of each research. It is necessary to know that the species richness is biased toward rare species while the species evenness is biased toward dominant species. The negative correlation between them in this study proves this relationship. Due to the results, it is recommended to apply a combination of richness, evenness and biodiversity to investigate the species diversity of migrating waterbirds. The results of these indices are not completely the same all the time and it should be taken into consideration while interpreting the species diversity. According to this study, Simpson (or Camargo) index of evenness and Shannon-Wiener (or Brillouin) index of biodiversity are suggested for future researches on aquatic birds. Finally, the decreasing trend of the species frequency (Figure 1), the richness (Figure 2) and the biodiversity (Figure 4) of migratory birds denotes the degradation of PIW along the 21-year period. It is concluded that long-term monitoring of the biodiversity of migrating aquatic birds is a robust bioindicator of wetlands degradation.

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None.

Conflict of interest

Authors declare there is no conflict of interest.

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