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Documenting and Comparing Plant Species Diversity by Using Numerical and Parametric Methods in Khaje Kalat, NE Iran

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Abstract: The aim was to examine and document several aspects of numerical diversity such as species richness, species diversity and evenness and to compare diversity in different slope aspects of the area by using numerical and parametric methods. About 193 quadrats of 4 m^2 were located according to the nature of vegetation. Species composition and their abundance were recorded in a two-year period (2005 to 2006). The result of field investigation was collecting and identifying of the total 225 plant species belonging to 154 genera and 37 families. The abundance data were subjected to analyses by specific diversity packages to characterize and obtain numerical indices (Shannon, Simpson, Brillouin, McIntosh, etc.,) and parametric families of species diversity. Numerical indices were calculated and documented for monitoring purposes. The results of diversity in main slope aspects (N, S, E, W) showed higher species richness and species diversity indices in the north aspect than in the others but it was not true with evenness indices. About 30 species such as *Acanthophyllum glandulosum*, *Acroptilon repens*, *Alcea tiliacea*, *Bromus sericeous*, *Astragalus turbinatus*, *Centaurea balsamita* etc., were detected exclusively in the north aspect. This can be important in reducing the evenness. Diversity comparing by using rank-abundance plot as well as diversity ordering of Hill, Renyi and Patil and Taillie confirmed high species diversity in the north yet the result of ANOVA showed no significant differences in the four aspects. The result of diversity based on the models revealed that the whole area, the south and the west aspects follow lognormal distribution, north aspect follows logarithmic whereas the east follows both lognormal and logarithmic distribution. In other word, a shift from being lognormal to logarithmic model was observed in the east aspect.

Key words: Species diversity, numerical indices, parametric methods, Khaje-Kalat, Iran

INTRODUCTION

There are different definitions for the word Biological Diversity or Biodiversity (Gaston, 1997). The Convention on Biological Diversity define it as variability among living organisms from all sources including, *inter alia*, terrestrial and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Johnson, 1993). Study of biodiversity has been widely improved to have successful management and logical exploitation of natural resources. Species diversity was the best known subject because it was usually the easiest to measure in the field (Smith, 1996). A combination of the number of species in the community (species richness) and their relative abundance (species evenness) defines species diversity (Molles, 1999). Species evenness (E) is a measure of the degree to which all species share dominance in an area (Rentch *et al*., 2005) and its dependence to species richness has been assessed by Gosselin (2006). Changes of species number, species composition as well as the relative abundance and dominance of the species have been especially useful as indicator variables in monitoring programs to assess the environmental quality. Several aspects of diversity such as species richness, species diversity, evenness, diversity and related models, diversity based on the rank/abundance plots as well as methods of diversity ordering can be considered in species diversity investigations. These include broad comparisons of community diversity (Auclair and Goff, 1971; Glenn-Lewin, 1977; Peet, 1978), experimental studies of the effect of individual environmental factors such as grazing and fire (Colins and Barber, 1985;

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Keeley *et al*., 2005) as well as theoretical and experimental studies of disturbance (Peet *et al*., 1983; Huston, 1979). There is a long history of these studies ranging from the classical description of vegetation towards the more sophisticated relationship to the diversity (Huston, 1979) and the stability (Noy-Meir *et al*., 1989; May, 1977). In parallel, some ecological hypotheses such as intermediate disturbance hypothesis was proposed by Connel (1978) that stress the highest diversity is maintained at the intermediate levels of disturbance. It is well documented that under extreme environmental conditions, the diversity of communities decreases (Fowler and Mooney, 1990; Dumont *et al*., 1990; Rabatin and Stinner, 1989). As Magurran (1988) stated, species diversity measures can be divided into three main categories. The first are the species richness indices. These indices are essentially a measure of the number of species in a defined sampling unit. The number of species is the most frequently used and easily understood measure of biological diversity (Purvis and Hector, 2000) and a general sign of ecosystem stress is a reduction in variety of organisms inhabiting a given area. In the current atmosphere of human transformation of earth's ecosystems, it is increasingly important to understand the relationship between biodiversity and ecosystem functioning (Loreau *et al*., 2001; Thompson *et al*., 2005). Although the species richness indices give an instant comprehensive measure of communities, but an important aspect of the numerical structure of communities is completely ignored when the composition of the community is described simply in terms of the number of species present. It misses the information that some species are rare and others common. Therefore, it seems to be important to couple the richness indices with the second group of indices which are based on the proportional abundances of species that consider both abundance (or biomass) parameters and species richness. A special method for the comparison of communities have been developed (Patil and Taillie, 1979). It is well-known that different indices may inconsistently rank a given pair of communities (Hurlbert, 1971) i.e., two communities are ranked in the opposite sense by the Shannon (H) and Simpson (D) indices. There are many reasons for this miss-ordering. Patil and Taillie (1979) emphasized that such inconsistencies are inevitable whenever one attempts to reduce a multidimensional concept like a community to a single number. A more straightforward illumination of the problem is related to the different sensitivities of diversity indices. A possible solution is to use parametric families of diversity indices instead of a numerical-valued diversity index. When we use a one-parameter family {$D\alpha$: (α real} of diversity indices the family may be portrayed graphically by plotting diversities (D) against the scale parameter. This curve is frequently mentioned as the diversity profile of the community (Patil and Taillie, 1979, 1982). Using diversity profiles we can define the diversity ordering of communities (Tóthmérész, 1993). Thirdly, there are species abundance models which describe the distribution of the species abundances. The species abundance models range from those which represent situations where there is high evenness to those which characterize cases where the abundances of species are very unequal. The diversity of a community may therefore be described by referring to the models which provides the closest fit to the observed pattern of the species abundance. Although species abundance data will frequently be described by one or more of a family of distributions (Pielou, 1975), diversity is usually examined in relation to the four main models (May, 1975). These are the geometric series, where a few species are dominant with the remainder fairly uncommon, the logarithmic series and the log normal where species of intermediate abundance become more common and indicate large, mature and varied natural communities and finally McArthur's broken stick model where species are as equally abundant as ever observed in the real world. Therefore a study was carried out on vegetation of Khaje-Kalat in the North-East of Iran to examine and document several aspects of numerical diversity such as species richness, species diversity and evenness and to compare diversity of the area by using numerical and parametric methods.

MATERIALS AND METHODS

This research was carried out on vegetation of Khaje-Kalat in the North-East of Iran, located in geographical position of 36°35′ N and 60°30′ E with the mean annual precipitation and temperature of about 255 mm and 18°C, respectively. Soil is classified in the orders of Entisols and Aridisols. The climate, based on De Martonne, is classified as dry. The dominant species is *Pistacia vera* with some understory species such as *Artemisia diffusa*, *Poa bolbusa*, *Amygdalus spinosissima*, *Ferula yommosa*, *Bunium persicum*, *Ephedra foliat*, *Zygophyllum atripelicoides*, etc. About 193 quadrats of 4 m^2 were located according to the nature of vegetation. Species composition and their abundance as well as some environmental variables such as slope aspects were recorded in each quadrat in a two-year period from 2005 to 2006. Geographical positions of the quadrats were obtained by using GPS.

The abundance data were used in the analyses. Several aspects of diversity including species richness, species diversity and evenness (equitability) as well as diversity profiles and species abundance models (geometric-series, logarithmic-series, log-normal and broken-stick model) related to the whole area and different slope aspects were considered. Diversity was also considered based on the families of diversity parameter including those of Patil and Taillie, Hill and Rényi.

RESULTS AND DISCUSSION

The result of field investigation was collecting and identifying of the total 225 plant species belonging to 154 genera and 37 families. Species richness of the whole area based on Menhinick and Margalef indices were 1.43 and 14.56, respectively. Number of species in the north, south, east and west slope aspects were 95, 52, 41 and 58, respectively and species richness indices were high in the north than the other aspects (Table 1). Since the area is dry, higher species richness may be related to high moisture and low temperature in the north aspect. Badano *et al.* (2005) studied influences of slope aspect on plant association patterns in the Mediterranean matorral of central Chile. Part of their results revealed that observed species richness in both xeric (equatorial-facing) slopes was lower than on mesic (polar-facing) slopes. Species richness, while giving a valuable insight into species diversity, can mask shifts in dominance/evenness relations. It would therefore appear important to couple an estimate of species richness with a measure of either dominance or evenness wherever possible. Table 2 shows diversity indices that take both abundances and species richness into consideration. The results of diversity and evenness indices for the whole area may be documented for monitoring spatial and temporal changes of plant species diversity. Since the evenness index is varied from 0 to 1, it shows the high evenness for the study area. Comparison of diversity in the four aspects revealed that most of indices in the north-facing slopes were higher than on the others but it was not the case for the evenness. About 30 species such as *Acanthophyllum glandulosum*, *Acroptilon repens*, *Alcea tiliacea*, *Bromus sericeous*, *Astragalus* (*Alopecuroidei*) *turbinatus*, *Astragalus* (*Hispiduli*) *bakaliensis*, *Bupleurum exaltatum*, *Caccinia macranther*, *Centaurea balsamita*, *Centaurea behen*, *Cephalorrhizum turcomanicum*, *Chrosophora hierosolymitana*, *Consolida rogulosa*, *Convolvolus arvensis*, *Cruscianella gilanica*, *Cuminum setifolium*, *Cymatocarpus pillosissimus* etc., were exclusively detected in the north aspect. This can be important in increasing species richness and decreasing the evenness. Dsepite the fact, ANOVA showed no significant differences in diversity of

Table 1: Species richness of the main four aspects in the study area

	Species richness			
Study area	No. of species	Rarefaction	Margalef	Menhinick
North (N)	95	69.42	11.40	1.54
South (S)	52	46.53	6.90	1.34
East (E)	41	36.39	5.80	1.34
West (W)	58	49.24	7.30	1.19

Table 2: Values calculated based on different indices of diversity and Pielou index of evenness for the study area and the main four aspects

	Diversity					
Study area	Shannon	Brillouin	Simpson	McIntosh	Berger-parker	Evenness pielou
Diversity	3.44	3.40	0.93	0.74	0.91	0.70
North (N)	3.38	3.33	0.93	0.75	0.19	0.74
South (S)	2.99	2.92	0.92	0.74	0.15	0.75
East (E)	2.84	2.76	0.89	0.70	0.24	0.76
West (W)	2.94	2.89	0.90	0.71	0.20	0.72

the four aspects. The valley forests at Songgyesa-Motbong-Wolhatan area in Deogyusan National Park, Korea Republic, were studied by InHyeop and YunHo (2004) to investigate forest structure in relation to aspect and altitude of the slope. They concluded that the species diversity of the north- and south-facing slope was 1.362 and 1.242, respectively. Huebner *et al.* (1995) investigated environmental factors affecting understory diversity in second-growth deciduous forests and concluded that Mesic sites were more diverse in common understory species than xeric sites but had lower total cover and different species.

In order to get a more clear-cut notion of the species abundance distribution of the sites, fitting of different distribution models were checked. According to the mentioned rank abundance models and goodness of fit test, the study area, the south and the west aspects follow lognormal distribution, north aspect follows logarithmic whereas the east follows both lognormal and logarithmic distribution. In other word, a shift from being lognormal to logarithmic model was observed in the east aspect. Geometric model is clearly typical for extreme environments with high species dominance where one environmental factor, either stress or a disturbance factor dominates and the log-normal distribution would refer to species-rich situation (Magurran, 1988). It should be considered that from the large number of diversity statistic and measurement methods available, it may be difficult to select the most appropriate method of diversity measuring. To be really useful, indices must be capable of detecting subtle differences between sites. In other word, they must discriminate between samples that are not unduly different. This attribute and other characteristics such as their sensivities to sample size, their capabilities

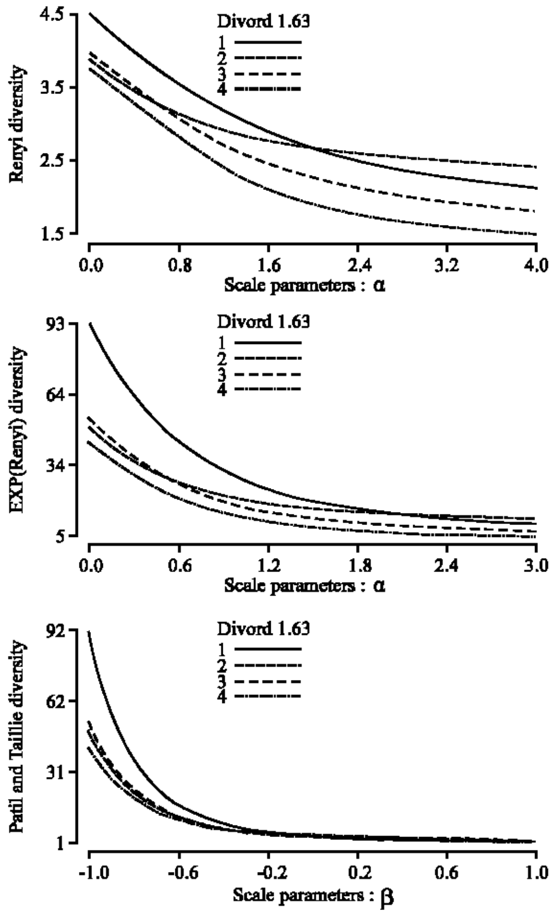

Fig. 1: Diversity ordering of the four main aspects (1: N, 2: S, 3: E and 4: W) based on Renyi, Exp (Renyi) or Hill and Patil and Taillie's diversity

to measure richness, evenness or dominance, simplicity or complexity to calculation were considered in this investigation. Based on the results, there were no significant differences between the indices in the slope aspects. Species abundance models could be useful to detect the ecological condition of the site. As May (1975) pointed out the species abundance models range from those which represent the situations where there is high evenness to those which characterize cases where the abundances of species are very unequal. The first situation exists where several environmental factors determines the ecology of the area. Results of fitting the models showed that the south, east and west-face slopes as well as the whole area were fitted to lognormal and the north-face slope to logarithmic model. So it can be concluded that good ecological condition is dominated in the study area. This is very important for making decision on site management and conservation of the area.

Diversity of the sites were also compared by using diversity profiles (Patil and Taillie, 1979; Tóthmérész, 1993). Figure 1 shows the results of diversity ordering for the four main aspects. As in the figure, they have well ordered based on Patil and Taillie's diversity, but in the case of Hill's and Rényi's diversities, the north, south and east aspects are not comparable. However it is obvious that the diversity profile of the north lie above the diversity profile of the others. So, Diversity in the north aspect is higher than on the others but it is not statistically significant. So, study of plant biodiversity is widely accomplished in order to have a successful management, conservation and logical exploitation of the natural resources. The study area, with a dry climate, is influenced by grazing of domestic animals. Therefore, some authors have suggested that the integrated effect of abiotic stress and biotic interactions is the main force driving community diversity (Callaway, 1995; Bruno *et al*., 2003). Species richness, diversity and evenness indices calculated for the area is of central importance to document and characterize the present condition and to compare the spatial and temporal changes of vegetation in the future.

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