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The survey of macrophytes diversity in wetland zone of Boujagh National Park, Guilan, Iran

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ABSTRACT The aim of this study was to identify the ecological species groups and investigate the diversity among them. The research area comprises a wetland system of Boujagh National Park, in Northern of Guilan Province, Iran. Vegetation sampling was carried out by 44 sample plots placed within the different zones in a stratified random manner. In each sampled plot, the cover percentage value of each species was estimated using Bran-Blanquet scales. Vegetation was classified using Two-Way Indicator Species Analysis (TWINSPAN). Classification of plots showed four vegetation groups: "*Ceratophyllum demersum-Nelumbo nucifera*, *Juncus acutus-Rubus sanctus*, *Mentha aquatica-Phragmites australis*, *Hydrocotyle vulgaris-Phragmites australis*". Plant diversity in these vegetation groups has been evaluated.The comparison of diversity indices among groups was performed with ANOVA test. Results of analysis of variance in species diversity indices showed significant differences among the groups in terms of some biodiversity indices. The survey of variation in the groups showed that group 3 had the highest value and group1 had the lowest in Fisher's diversity indices and Menhinink's and Margalef's richness indices, respectively. In Sheldon's evenness index group1 had the highest and group 2 had the lowest measure. Finally, the overall survey of indices showed that despite the high richness and diversity in groups 3 and 2, evenness of these groups was less than group 1 showing the lowest richness and diversity.

KEY WORDS Boujagh National Park; macrophytes; Caspian Sea; Iran.

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INTRODUCTION

Wetland macrophytes are defined as aquatic emergent, submergent or floating plants growing in or near water (USEPA, 1998). There are however some noted shortcomings of using macrophytes as biological indicators. These include the potential delay in response time for perennial vegetation, difficulty in identifying taxa to the species level in certain seasons and for some genera, different herbivory patterns and varied pest-management practices (Cronk & Fennessy, 2001). Despite these limitations, macrophytes have provided strong signals of anthropogenic influence (USEPA, 2003). Know-ledge of the plant communities enables us to forecast the likely changes in floristic composition after changes of site factors (Grevilliot & Muller, 2002). Description of patterns in species assemblages and diversity is an essential step before generating hypotheses in functional ecology (Jonsson & Moen, 1998).

Vegetation studies on Water and surrounding

area in wetland habitats along the southern Caspian shore have been done by Asri & Aftekhari (2002), Riazi (1996), Ghahreman & Attar (2003), Shokri et al. (2004), Asri & Moradi (2006), Jalili et al. (2009), Zahed et al. (2013) and Naqinezhad & Hosseinzadeh (2014).

Boujagh National Park (BNP) is the first founded land-marine National Park and one of nineteen National Parks in Iran located in Caspian coastline (Naqinezhad et al., 2006). BNP is a very important ecosystem complex because of the fact that this area serves as a very valuable resting, nesting and wintering place for a wide variety of waterfowls particularly Siberian Crane, an endangered migratory bird (Naqinezhad, 2012). Some studies were conducted on the Flora and identification of species groups of this national park. The floristic study of this unique ecosystem was investigated for the first time by Naqinezhad et al. (2006). They identified 248 vascular plants and 10 bryophytes out of which six taxa are endemic for the flora of Iran. Naqinezhad (2012) recognized nine vegetation types in the area based with physiognomic-ecologic approach. This study was carried out to identify ecological species groups of the wetland zone of Boujagh National Park by phytosociological analysis of existing vegetation and inventory plant species diversity in this part of BNP.

MATERIAL AND METHODS

Study area

Boujagh National Park is located on the coast of Caspian Sea. This national park is located in Guilan Province, about 2 km away from north of Kiashahr city, and 35 km from northwest of Rasht city. It is 21 m below sea level and has an area of 3177 ha. Its geographical coordinates are 49°51′40″-49°59′50″E and 37°25′00″- 37°28′50″N. Boujagh and Kiashahr Lagoons are located within this national park (Reihanian et al., 2012; Naqinezhad, 2012).

Sampling methods

Vegetation surveys were conducted within the period 2013–2014. A total of 44 sample plots (2 m x 2 m) were placed within the different zones in a stratified random manner. In each sampled plot, the cover percentage value of each species was estimated using Braun-Blanquet scale (Braun-Blaunquet, 1964; Mueller-Dombois & Ellenberg, 1974).

Data analysis

Vegetation analysis method

The phytosociological data were collected during 2014–2015 using the cover-abundance scales. A divisive classification of 44 items was carried out, using the modified TWINSPAN embedded in a JUICE program (Tichý, 2002). Pseudospecies cut levels were set to seven and the values of cut levels to 1, 2, 3, 4, 5, 6, 7. Five items were selected as a minimum group size for division. The fidelity of species to clusters and diagnostic species for particular vegetation units were calculated with the help of presence/absence data using the phi-coefficient. Threshold value of phi = 0.25 was selected (Tichý & Chytrý, 2006).

Measuring plant diversity

To quantify the diversity of the plant species, The Shannon-Wiener diversity index (H'), Simpson diversity index (1-D), Fisher's alpha-a diversity index(a), Menhinink richness index (DMn), Margalef richness index (DMg) and Sheldon eveness index (Buzas & Gibson eveness index) (E3) were used (Kent & Cocker, 1992; Harper, 1999). The formulas are shown in Table 1.

Comparison of plant diversity

Normality of the data distribution was checked by Kolmogorov Smirnov test, and Levene's test was used to examine the equality of the variances. One-way analysis (ANOVA) of variance was used to compare groups with normal distribution data. Duncan test was used to test for significant differences in the species richness, diversity and evenness indices among the groups. This analysis was conducted using SPSS 16.0.

RESULTS

Modified TWINSPAN analysis was based on

44 plots from coastal area of Boujagh National Park. Four distinct groups of species were identified (Fig. 1).

Details of each group are as follows:

Group I (*Ceratophyllum demersum-Nelumbo nucifera*). This plant group shows13 plots situated in the middle of Boujagh and Kiashahr Lagoons, in the deepest areas. *Ceratophyllum demersum* L. and *Nelumbo nucifera* Gaertn. are dominant species. This group was seen in Boujagh Lagoon with *Nelumbo nucifera* Gaertn. but this species was not seen in Kiashahr Lagoon. Most important indicator species include *Myriophyllum spicatum* L., *Potamogeton crispus* L., *Potamogeton pectinatus*, *Potamogeton pusillus* L., *Stuckenia pectinata* (L.) Böerner, and *Zannichellia palustris* L.

Group II (*Juncus acutus-Rubus sanctus*). This group with 8 plots grows in wet marginal area of the lagoons where soil consists of sand and clay. This group includes a narrow strip on the eastern and western parts of Kiashahr Lagoon and northern and southern parts of Boujagh Lagoon. *Juncus acutus* L., *Rubus sanctus* Schreb., *Equisetum ramosissimum* Desf. and *Geraniumn molle* L. are diagnostic species.

Group III (*Mentha aquatica-Phragmites australis*). This group shows 6 plots situated in the marginal area of lagoons where soil is wet and swampy. *Phragmites australis* (Cav.) Trin. ex Steud. can be found in a narrow strip around the lagoons. It is an invasive-helophyte species and reduces frequency of hydrophyte in open water. Also *Mentha aquatica* L. is an indicator species that can be seen in the most wet area particularly East of Kiashahr Lagoon and South of Boujagh Lagoon.

Group IV (*Hydrocotyle vulgaris-Phragmites australis*). This group including 17 plots is situated in the wet marginal (northeastern and eastern) area of Kiashahr lagoon. This group makes a border between marginal and open water. *Hydrocotyle vulgaris* L., *Phragmites australis*, *Poa annua* L., and *Sambucus ebulus L.* are diagnostic species.

Diversity index	Richness index	Eveness index
$H' = -\sum_{i=1}^{s} Pi \ln Pi = -\sum_{i=1}^{s} (Pi)(\log pi)$ $1 - D = \sum_{i=1}^{s} P_i^2 \qquad Pi = \frac{ni}{N}$ $S = a^* \ln(1 + n/a)$	$D_{Mg} = \frac{S-1}{\ln N}$ $D_{Mn} = \frac{S}{\sqrt{n}}$	$E_3 = \frac{e^H}{S}$

Table 1. Richness, diversity and evenness indices used in this study. Pi = relative frequency of ith species, S = number of species(taxa), n is number of individuals, N = Total individual of species

Species diversity among groups

First of all, based on Kolmogorov-Smirnov test it was confirmed that data were normally distributed. For analyzing the diversity among the groups, one-way Analysis of variance (ANOVA) was used. ANOVA results of diversity indices among groups and mean and standard error of diversity indices are listed in Table 2. ANOVA showed that there were significant differences among groups in terms of Sheldon's evenness index and Menhinink 's richness index ($P<0.05$).

Duncan's test of groups is showed in figures 2-5. Figure 2 shows the changes of Fisher diversity indices; group 3 and group 1 show the maximum and minimum values, respectively. No significant difference was observed between groups 2 and 4.

Figures 3 and 4 show the changes of Menhinink and Margalef's richness indices among ecological groups. Group 1 had the lowest value, whereas the highest value was showed by Group 3. These measurements indicated that there is not significant difference between groups 2 and 3 for both Menhinink and Margalef indexes.

Figure 5 shows the changes of sheldon's evenness index among ecological groups. The highest value of sheldon's evenness index was in group 1. While group 2 had the lowest value. Fort his index there was not significant difference between groups 3 and 4. Finally, the overall survey of indices showed that, despite the high richness and diversity in groups 3 and 2, evenness of these groups was lower than in group 1, which had the lowest richness and diversity.

DISCUSSION

This study, for the first time, introduced ecological species groups in wetland zone of Boujagh

Diversity index		F	P	Mean square	df	Mean and standard error
Diversity index	Shanon diversity index	0.828	0.48	0.188	3	1.440 ±0.071
	Simpson diversity index	0.210	0.88	0.006	3	0.677 ±0.024
	Fisher's diversity index	2.227	010	3.867	3	2.022 ±0.209
Richness index	Menhinink 's richness index	2.730	0.05*	0.265	3	0.644 ±0.049
	Margalef richness index	7.2.617	0.06	1.800	3	1.485 ±0.131
Evenness index	Sheldon's evenness index	3.856	0.01*	0.087	3	0.563 ±0.024

Table 2. ANOVA results of diversity indices among groups and mean and standard error of diversity indices.

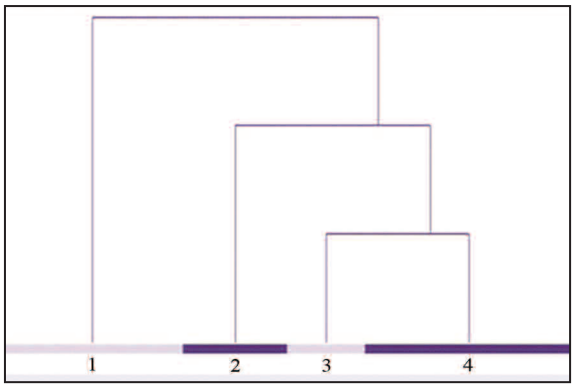

Figure 1. The cluster analysis to classify samples by Modified TWINSPANS.

National Park (BNP) assessed by floristic method and multivariate analysis. Modified TWINSPAN analysis identified four species groups.

The vegetation groups in the Caspian Sea coastal wetlands were analyzed by different methods such as physiognomic, Braun-Blanquet and multivariate methods which led to the identification of the following groups, communities and types: *Juncus*, *Rubus*, Sand dune, Halophyte, Hydrophyte (Shokri et al., 2004); *Juncus acutus* L., *Ruppia maritima* L., *Typha latifolia-Phragmites australis*, *Schoenoplectus litoralis* (Schrad.) Palla, *Nelumbium caspicum* Fisch. ex DC., *Ceratophyllum demersum-Myriophyllum spicatum* (Naqinezhad, 2012), *Potamogeton pectinatus*, *Ceratophylletum demersum-Azolla filiculoides*, *Nymphaea alba*, *Nelumbo nucifera* Gaertn., *Phragmites australis*, *Hydrocotyle ranunculoides* L.f., *Typha latifolia* L., *Cladium mariscus* (L.) Pohl., *Sparganium neglectum* Beeby, *Cyperus transitorius* Kük., *Paspalum distichum* L., *Cerastium dichotomum* L. (Asri & Moradi, 2006); *Lemno minoris-Azolletum filiculoidis*, *Lemno minoris-Spirodeletum polyrrhizae*, *Lemnetum minori-trisulcae*, *Salvinietum natantis*, *Hydrocharitetum morsus-ranae*, *Utricularietum australis*, *Trapo-Potametum crispi*, *Trapo-Potametum pectinati*, *Potametum pectinati*, *Ceratophylletum demersi*, *Hydrilletum verticillatae*, *Myriophylletum verticillati*, *Nelumbietum nucifei*, *Batrachietum trichophylli*, *Marsileo-Callirichetum brutiae*, *Potametum nodosi*, *Phragmitetum australis*, *Schoenoplectetum lacustris*, *Hydrocotyletum ranunculoidis*, *Iridetum pseudacori*, *Typhetum latifoliae*, *Sparganietum neglecti*, *Nasturietum officinalis*, *Paspaletum distichi*, *Rorippetum islandicae*, *Cyperetum serotini*, *Alismo-Sagittarietum sagittifoliae*, *Caricetum ripariae*, *Juncetum effusi*, *Cyperetum longi*, *Bidentetum cernuae*, *Bidento tripartitae-Polygonetum hydropiperis* (Asri & Eftekhari, 2002).

Comparing our research to other studies showed that groups of *Mentha aquatica-Phragmites australis* and *Hydrocotyle vulgaris-Phragmites australis* are new groups in wetland of southern Caspian Sea.

Naqinezhad et al. (2013) in survay of biomass in Babol wetlands (cosatal wetlands of southern Caspian Sea) mentioned that *Ceratophyllum demersum* and *Nelumbium nuciferum* can be rarely obseved together, mainly because they grow at different depths. The co-existence of the two species in the Boujagh wetland conflicts with the above results. In this case, the overlap of depth ranges of the two groups of floating (10–140 cm) and submerged plants (40–160 cm) (Jalili et al., 2009) justifies their co-existence in the same group.

ANOVA results indicated that group1 (*Ceratophyllum demersum-Nelumbo nucifera*) showed less diversity and richness but more evenness than others groups. The survey of geographical location of these groups showed group 1is located in a deep area, whereas other groups are on the sidelines or shallow area. Low diversity and richness of this group, compared to other groups, could be due to the reduction of the area of the deep section and the increase of the other areas (sidelines and shallow area); also euhydrophytic plants have less diversity than terrestrial and marginal ones because of more uniformity in aquatic ecosystems. In fact, as already reported (Seabloom et al., 1998), depth gradients can show floristic differences in wetlands.

Groups 2 and 3 had more diversity and richness than group 4. Evaluation of functional types of species in each of these groups showed groups 2 and 3 consist of emergent indicator species while groups 4 included emergent and floating species. In particular, marginal groups, i.e. those settled at lower depth, with low humidity and faraway from the center of the lagoon, showedmore richness and diversity.

Boujagh National Park is the first land-marine national park and one of 19 National Parks in Iran as well as the first one in Guilan Province. Habitat variation in the study area makes it possible to provide diversity of plant taxa as well as the development of ecologically specialized plant communities (Naqinezhad et al., 2006). On the other hand, this unique ecosystem does not show suitable environmental conditions. The main reasons for the destruction of this wetland ecosystem include: pollution of agricultural land, urban and rural settlements, agricultural land and industries, implementation of development projects and infrastructure such as roads, power transmission lines, port development of fisheries to Commercial port, creating fish ponds, illegal hunting, waste accumulation on the eastern part of the wetland, presence of non-native *Azolla* species, harvesting of wetland

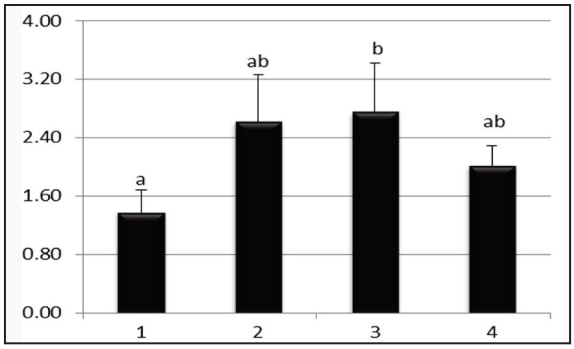

Figure 2. Changes in Fisher's diversity index among ecological groups.

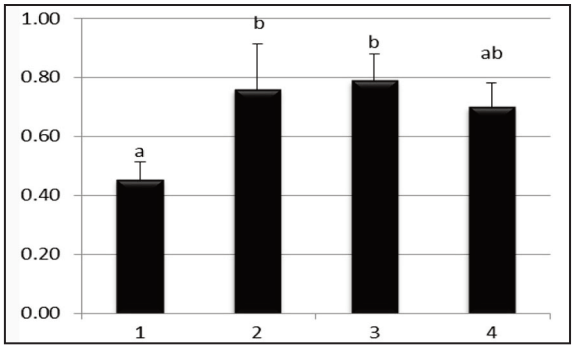

Figure 4. Changes in Margalef 's richness index among ecological groups.

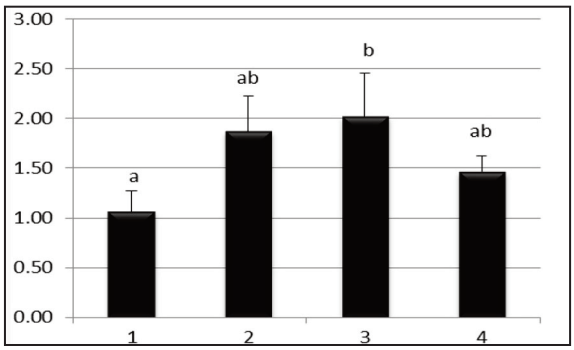

Figure 3. Changes in Menhinink 's richness index among ecological groups.

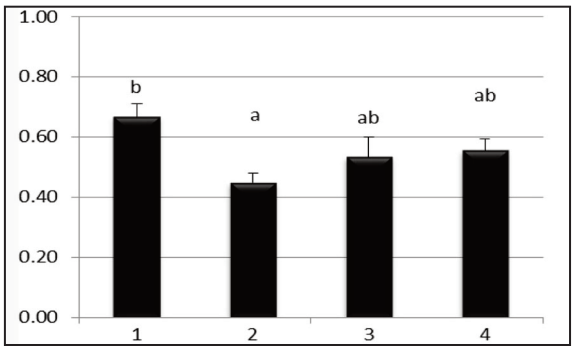

Figure 5. Changes in in sheldon's evennes index among ecological groups.

margins and widespread and uncontrolled presence of tourists. Comprehensive management plans within the framework of the ecosystem can be of some help inconservation and protection of species diversity in this park.

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