BREEDING AND WINTERING BIRD ASSEMBLAGES IN A MEDITERRANEAN WETLAND: A COMPARISON USING A DIVERSITY/DOMINANCE APPROACH

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SPECIES RICHNESS
DIVERSITY
EVENNESS
HABITAT HETEROGENEITY
WHITTAKER PLOTS
K-DOMINANCE PLOTS

ABSTRACT. – We studied the structure of breeding and wintering bird assemblages in a Mediterranean wetland of Central Italy with the aim of evaluating seasonal structural changes and the role of habitat heterogeneity on the avian community. The wintering assemblage showed higher values of species richness, diversity and evenness. The seasonal differences were represented through a diversity/dominance approach (species rank/relative occurrence diagram or Whittaker plots), and the curve obtained for winter showed a significantly shallower slope if compared with that for the breeding season (Kolmogorov-Smirnov test). K-dominance plots also revealed a different shape in the accumulation curve of the relative occurrence values between wintering and breeding season. Whittaker's β-diversity was higher in winter. In Mediterranean wetlands, intrinsic constraints (e.g. phenology and ecology of the species) seem to be crucial in determining the community structure and the shape of diversity/dominance curves. In winter, many species are vagrant and sparsely distributed, and belong to species-rich taxonomic groups (e.g., waders, ducks), while in the breeding season most of species are common and more uniformly spread. Extrinsic constraints also affect bird assemblages in winter: the presence of water induces an increase of habitat heterogeneity, expressed by the β-diversity index. These habitat changes induce an increase of occurrence values, species richness, diversity and evenness. The shape of the seasonal curves in Whittaker plots followed the MacArthur broken-stick model.

INTRODUCTION

A large number of bird species uses wetlands as suitable habitats for feeding, breeding, roosting, wintering and stopover points (e.g., Pöysä 1983, Gibbs 2000, BirdLife International 2004). In the Mediterranean region, wetlands show high habitat heterogeneity at local scale, mainly as a consequence of human-induced disturbances (Hobbs & Huenneke 1992, Celada & Bogliani 1993, Graveland 1998, Austin 2002, Connor & Gabor 2006, Paracuellos 2006). Consequently, wetlands appear as a patchy "disturbance mosaic", with a high dynamics in time and space (Nichols *et al*. 1998, Paracuellos 2006). Seasonal changes in water availability and the phenological differences of species induce a high turnover rate in breeding and wintering bird assemblages (Paracuellos 2006). Therefore, the analysis of variables, such as species richness, evenness or diversity, and of relative species turnover, is a goal of ecological and conservation concern, especially in small sized and isolated Mediterranean wetlands (Leibowitz 2003).

In order to depict changes in community structure, ecologists often calculate the frequency distribution of the species through a diversity/dominance approach, thus placing data in species rank/abundance or rank/occurrence diagrams (Whittaker plots) (Magurran 2004). The trend and shape of the diagram line contain information on the community structure, highlighting atypical conditions as, e.g., anthropogenic or natural stresses (Ganis 1991, Krebs 1999, Fattorini 2005). In disturbed and heterogeneous ecosystems, three major patterns can emerge from Whittaker plots: (1) a small group of dominant species; (2) several species occurring with an intermediate frequency; and (3) many rare species (see the 'broken-stick' model by MacArthur 1957). When a stress induced by an anthropogenic disturbance occurs, indeed, the shape and slope of diversity/dominance curve change in response to a disruption in the relative abundance, richness and evenness of the species (Tokeshi 1993, Magurran 2004). In particular, curves with lower slope indicate higher evenness and diversity if compared with curves with lower slope (Magurran 2004).

The diversity/dominance approach by means of Whittaker and k-dominance plots was used to describe changes in community structure due to different disturbance regimes in time and in space (Magurran 2004). Diversity/dominance curves have been widely applied, e.g. on tree communities at different altitude (Whittaker 1960), in fish communities occurring in streams for different pollution levels (Harrel *et al*. 1967), in plant communities affected by continuous application of nitrogen fertilizer (Tokeshi 1993), in butterflies from logged forests (Ghazoul 2002), in wetland bird communities affected by water stress (Preston 1960, Battisti *et al*. 2006). Nevertheless, seasonal comparisons among bird assemblages through this approach are still lacking.

The aims of this study are: (1) to evaluate the structural changes in seasonal bird assemblages during breeding and wintering periods in a Mediterranean wetland of Central Italy; (2) to assess the role to habitat heterogeneity in a protected area.

MATERIALS AND METHODS

Study area: The study area embraces the “Torre Flavia” wetland (Central Italy; 41°58’N; 12°03’E), a protected area (40 ha) on the Tyrrhenian coast (Special Area of Protection according to the EU Directive 79/409). From a bioclimatic point of view, the area can be classified in the meso-Mediterranean xeric region (Tomaselli *et al*. 1973, Blasi & Michetti 2005). The study area is the remnant of a larger wetland, partially drained and transformed in the last fifty years, where water is mainly of rainfall and sea storm origin. Flow from surrounding areas is very scarce (Battisti 2006).

At a landscape scale, the study area can be considered as a fine-grained disturbance mosaic (Hobbs & Huenneke 1992) within a human transformed land use matrix (see Forman 1995, Nichols *et al*. 1998). Land use/cover types show various disturbance degrees, both natural and anthropogenic (pastures and scattered orchards). This remnant wetland shows a specific, semi-natural patchiness, composed of reed beds (*Phragmites australis* dominated), water basins like ponds and channels (used for fish farming of mullets: *Mugil cephalus, Liza ramada, L. saliens*), rush flooded meadows (*Juncus* sp. and *Carex* sp.), and coastal dunes (Guidi 2006, Provincia di Roma 2007). The surrounding matrix, adjacent to human settlements, is occupied by a mosaic of cultivated and uncultivated lands, including a seasonally flooded pasture moderately grazed by horses. The water depth in channels varies with seasons: from October to March the flood level reaches a depth of about 120-140 cm, while from April to September the level is minimum and the rush bed is reduced to muddy soil (Battisti & Sorace 2005).

Protocol: The bird community was sampled by the point count method (Blondel 1975, Bibby & Burgess 1992). We refer to species assemblages, as taxonomically related assortments of species seasonally occurring in the study area (Fauth *et al*. 1996). The study area was divided into a grid of 67 squared cells (100 x 100 m). Sampling sites (hereafter, point counts) were situated in the centre of each cell. The terrestrial coordinates of each point count were obtained by MGE Coordinate System Operation (MCSO) (Intergraph 1995).

Each point count was sampled in the early hours of the morning (7:00-11:00 a.m.) with sessions of 5 minutes each, always by the same observer (R.M.). We recorded the occurrence of each bird species seen or heard within 50 m from the point count. We reported only the occurrence data of the species (*i.e*., the recorded presence of a species in a point count), not the abundance (*i.e*., number of individuals). Therefore, we obtained a set of occurrence data for each species (*i.e*., species occurrence), for each season (period) and each point count.

We carried out the samplings in two sessions for each study period: two sessions during the breeding season (I: 1-28th April 2005; II: 1st May-10th June 2005) and two sessions during the wintering season (I: 15th November 2005-30th January 2006; II: 15th February 2006-15th March 2006). The whole sampling effort was 1340 minutes.

Samples were taken under favorable environmental conditions, avoiding extreme rain and strong wind; moreover, we performed a randomly ordered sampling, reducing the chances of double counting (see Bibby & Burgess 1992).

Variables for bird assemblages and data analysis:

For each season, we calculated the following variables related to bird assemblage:

- total number of species occurrence values (n) and mean number of species occurrence values (n_m) recorded from each point count;
- total species richness (S), i.e. total number of species sampled;
- mean species richness (S_m), i.e. ratio between total species richness and number of point counts; this variable normalizes the number of recorded species in respect to the number of point counts;
- Margalef richness index (D_{Mg}) as

$$D = (S-1)/\log n$$

where S is the number of species recorded and n is the number of species occurrence in the seasonal samples (Clifford & Stephenson 1975, Magurran 2004); this parameter normalizes the number of sampled species in respect to sample size (i.e. number of occurrence values, n);

- Shannon diversity index (H’; Shannon & Weaver 1949) as

$$H' = -\Sigma fr_i \ln(fr_i)$$

with fr_i = frequency of ith species (i.e., ratio occurrence of ith species/total number of occurrence values);

- Whittaker’s β-diversity index (Whittaker 1960) as

$$\beta_W = S / S_m$$

where S is the total number of species recorded in each season (i.e. a measure of γ-diversity) and S_m is the mean species richness (i.e., a measure of average α-diversity); this index, measuring the turnover of species among point counts, is an indirect expression of habitat heterogeneity (Magurran 2004);

- evenness index (Lloyd & Ghelardi 1964), as:

$$J = H'/H'_{max}$$

where H'_{max} = ln S (where S is the total number of species recorded in each season: Pielou 1966) and H’ is the Shannon diversity index.

In order to depict the structural changes of a community, we represented the frequency distribution of the species through a diversity/dominance approach, which consisted in plotting the data to obtain a rank/abundance diagram (following a individual-based approach) or a rank/relative occurrence diagram (following a sample-based approach: Magurran 2004). Therefore, a diversity/dominance analysis was carried out by rank/occurrence diagrams (Whittaker plots; Whittaker 1965, Ganis 1991, Krebs 1999), using the occurrence dataset of species for the two periods (wintering and breeding). In the rank/occurrence diagrams, all species were ranked from the most occurring to the least occurring ("rare") the species in the sample. Therefore, we named "rare" species with a low relative frequency of occurrence in our samples.

Each species has its rank (plotted on the horizontal axis), determined by the value of its relative occurrence (plotted on the vertical axis). The relative occurrence is the ratio (log-transformed) between the number of occurrence values of each species in all point counts / total number of occurrence values of all species (Magurran 2004). The value of the most occurring species is plotted first (on the left of the diagram), then follows the next ranked species, and so on (Whittaker 1965, Magurran 1988).

For each season, we performed a k-dominance plot (Lambshead *et al.* 1983, Platt *et al.* 1984), whose diagram shows the percentage of the cumulative occurrence (y axis) in relation to the log-transformed species rank (x axis). With this plotting method, the more elevated the curve, the less diverse is the assemblage (Magurran 2004).

In order to evaluate the differences between the frequency distribution diagram in the two seasons (Whittaker plots), we performed a Kolmogorov-Smirnov test (according to Magurran 2004), with alpha set at 0.01. For statistical analyses, SPSS 13.0 Software for Windows (SPCC Inc 2004) was used.

RESULTS

The wintering bird assemblage showed higher values for all the variables investigated (total number of occurrence values, total and normalized species richness, diversity index and evenness, β-diversity) (Table I). This difference between the two seasons were also depicted by the rank / relative occurrence diagram (Whittaker plot), where the curve obtained for wintering season showed a steeper slope compared to the breeding season (Fig. 1). Differences among frequency distributions between wintering and breeding curves in Whittaker plots were significant ($z = 1.901$; $P < 0.01$). K-dominance plots evidenced a different shape in the accumulation curve of the relative occurrence values between wintering and breeding season (Fig. 2).

DISCUSSION

The wintering assemblage of birds showed higher values for richness (even after normalization for the number of occurrence values), evenness and diversity, than the breeding community. Some quantitative differences emerged from the diversity/dominance diagram on species occurrence values, where the curve with a shallower slope evidenced an increasing even assemblage (Magurran 2004). In winter, the high values of total species richness, with many "rare" species, induced an increase of evenness in the assemblage.

Table I. – Structural parameters of the breeding and wintering assemblages. *n*: total number of occurrence values. n_m: mean number of occurrence values / survey units (N = 67); *S*: total species richness; S_m: mean species richness; D_{Mg}: Margalef's richness index; *H'*, Shannon diversity index; *β*, Whittaker's β index; *J*, evenness index.

Parameter		Breeding	Wintering
Species occurrence	n	287	365
	n_m	4.28	5.45
Species richness	S	23	40
	S_m	4.49	5.69
	D_{Mg}	3.89	6.61
Diversity	H'	2.73	3.35
	β	5.12	7.03
Evenness	J	0.87	0.91

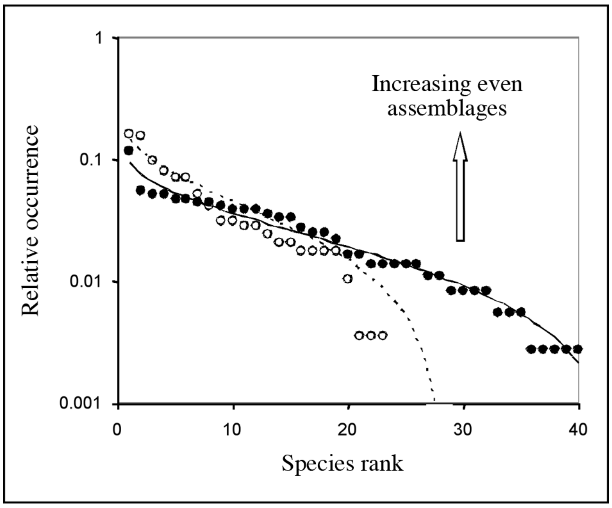

Fig. 1. – Species rank / relative occurrence diagram (log-transformed) for breeding (white circles) and wintering (black circles) bird assemblages in the Mediterranean wetland studied.

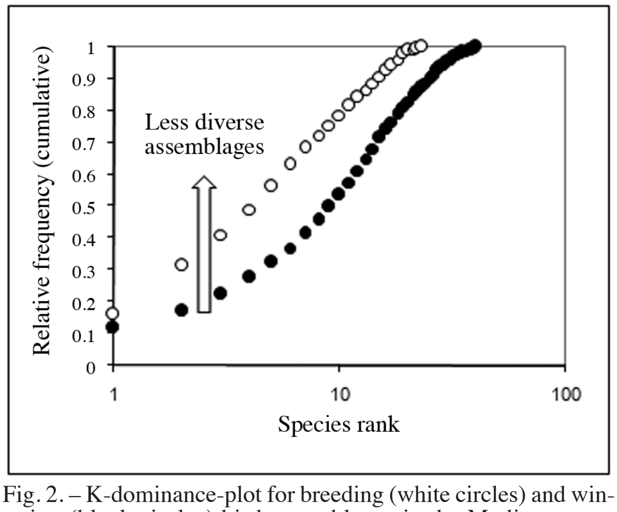

Fig. 2. – K-dominance-plot for breeding (white circles) and wintering (black circles) bird assemblages in the Mediterranean wetland studied.

Species-specific intrinsic constraints, as phenology and ecology of the wintering and breeding species, may be crucial in determining differences in the seasonal community structure and consequently in the shape of diversity/dominance curves. In winter many species of waterfowl (Anseriformes) and waders (Charadriformes) are vagrant and follow a scattered distribution pattern throughout Mediterranean wetlands; on the contrary, during the breeding period there are less vagrant species and more territorial ones, usually common and more uniformly spread (BirdLife International 2004).

An extrinsic constraint is represented by the spatial habitat heterogeneity (sensu Tews *et al*. 2004). The latter is higher in winter if compared with the breeding period. Indeed, a lot of temporary water bodies, such as ponds and channels, appear in the study area in winter and form a complex patchiness that increases habitat diversity. A variety of food resource becomes available in these conditions and increases niche availability, e.g., different levels in water ponds ensure high species richness in ducks (Nillson 1972, Pöysä 1983) and muddy patches are a suitable habitat for many species of waders (Cramp & Simmons 1977, Cramp & Simmons 1980). Therefore, these factors induce an increase of species richness, evenness and diversity (Wiens 1976, Wiens 1989). In winter, the best predictors of species richness in Mediterranean wetlands are the spatial pattern, shape, size, edge-length and isolation of water-related microhabitat, while the vegetation types play a secondary role (Paracuellos 2006). In winter, the complex mosaic built by water ponds and reed beds induce a spatial heterogeneity suitable to many species of either passerine birds (mainly warblers, buntings and sparrows), and water-related non passerine birds (mainly gulls, herons, ducks and rails) (Bàldi & Kisbenedek 2000).

Whittaker's β-diversity index is an indirect measure of habitat heterogeneity expressed by bird assemblages as indicators (Whittaker 1960, Magurran 2004). In this sense, the increase of β-diversity values in winter could be related to an increase of the habitat heterogeneity perceived by birds during this season.

The shape of both seasonal curves in Whittaker plot for the study area is typical of communities that follow the 'broken-stick' model proposed by MacArthur (1957, see May 1975, Ganis 1991, Magurran 2004). The broken-stick model highlights the subdivision of niche space within an assemblage. According to the model, the relative abundance of the species is considered as a surrogate of niche size. The 'broken-stick' obtained in the Whittaker plot from our occurrence data better evidenced the subdivision of niche space among bird species. In this study, the number of occurrences of a species in a sampling session (i.e., in the set of point counts) expresses this spatial distribution at local scale, while the frequency of occurrence expresses the ratio between the number of species-specific occurrence values and the total number of occurrence values. Therefore, "rare" birds are species with a low relative frequency of occurrence (less than 0.01, see Appendix 1 for species names): the "rareness" of a species is referred to a limited local spatial distribution (i.e. a low number of point counts with the sampled presence), normalized to the sample (total no. of occurrence values); and vice versa, the "commonness". In terms of occurrence, "rareness" and "commonness" are referred to the spatial distribution of individuals and species and to the subdivision of spatial niche as evidenced by MacArthur 'broken-stick' model.

Rareness/commonness concepts, through this approach from occurrence data, enlightened the role of ecological constraints inducing seasonal changes in the spatial distribution of the species.

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Appendix I. – Frequency of occurrence (fr_i) for each species in breeding (n = 287) and wintering (n = 365) season, in decreasing order.

breeding season		wintering season	
Species	fr_i	species	fr_i
Cisticola jundicis	0.160	*Anthus pratensis*	0.118
Passer italiae	0.153	*Passer italiae*	0.055
Turdus merula	0.098	*Corvus corone*	0.052
Cettia cetti	0.080	*Motacilla alba*	0.052
Corvus corone	0.070	*Gallinago gallinago*	0.047
Sturnus vulgaris	0.070	*Erithacus rubecula*	0.047
Motacilla alba	0.004	*Larus ridibundus*	0.044
Galerida cristata	0.052	*Saxicola torquata*	0.044
Saxicola torquata	0.028	*Cisticola jundicis*	0.041
Miliaria calandra	0.042	*Turdus merula*	0.038
Anas platyrhynchos	0.031	*Galerida cristata*	0.038
Carduelis carduelis	0.031	*Emberiza schoeniclus*	0.038
Serinus serinus	0.028	*Phoenicurus ochruros*	0.036
Gallinula chloropus	0.024	*Anas platyrhynchos*	0.033
Fulica atra	0.021	*Columba livia* forma *domestica*	0.033
Acrocephalus scirpaceus	0.021	*Cettia cetti*	0.027
Carduelis chloris	0.017	*Sturnus vulgaris*	0.025
Remiz pendulinus	0.017	*Carduelis carduelis*	0.025
Alauda arvensis	0.017	*Gallinula chloropus*	0.022
Sylvia melanocephala	0.017	*Pica pica*	0.016
Passer montanus	0.011	*Rallus aquaticus*	0.016
Falco tinnunculus	0.004	*Acrocephalus scirpaceus*	0.014
Acrocephalus arundinaceus	0.004	*Remiz pendulinus*	0.014
		Circus aeruginosus	0.014
		Charadrius hiaticula	0.014
		Passer montanus	0.014
		Phalacrocorax carbo	0.011
		Anas crecca	0.011
		Carduelis chloris	0.008
		Streptopelia decaocto	0.008
		Pluvialis squatarola	0.008
		Vanellus vanellus	0.008
		Ixobrychus minutus	0.005
		Casmerodius albus	0.005
		Anas penelope	0.005
		Serinus serinus	0.003
		Tachybaptus ruficollis	0.003
		Ardea cinerea	0.003
		Anas clypeata	0.003
		Alcedo atthis	0.003