BIRD ASSEMBLAGES IN A STRUCTURALLY SIMPLIFIED MEDITERRANEAN SANDY BEACH: AN ANALYSIS AT SPATIAL AND TEMPORAL LEVEL

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RÉSUMÉ. — *Assemblages d'oiseaux sur une plage sableuse méditerranéenne structuralement simplifiée: analyse spatio-temporelle*. — Les études des patterns de richesse et d'abondance spécifique sur les côtes sableuses sont quasi négligées. Une meilleure connaissance de la structure des assemblages d'oiseaux pourrait permettre le développement de stratégies de conservation appropriées dans ces écosystèmes-clés. Dans la présente étude, nous nous proposons de tester l'hypothèse qu'un écosystème aussi morcelé et structuralement aussi simplifié qu'une plage sableuse méditerranéenne pourrait abriter des assemblages d'oiseaux hautement variables dans le temps et dans l'espace et relativement pauvres en richesse et abondance, dont la structure serait donc affecté par le hasard. En 2007 un transect a été établi le long d'une plage sableuse afin d'analyser les données temporelles (six périodes de deux mois) et spatiales (trois types d'habitats longitudinaux) au niveau d'une espèce ou d'un assemblage. Nous avons observé un total de 25 espèces. Les assemblages d'oiseaux ont montré une hétérogénéité taxinomique, phénologique et écologique. La plage hébergeait l'assemblage le plus riche en fin d'automne-hiver, le plus pauvre en été-automne. Les valeurs moyennes de la richesse spécifique se sont avérées significativement différentes selon la période de deux mois. Les plages représentent des écosystèmes morcelés avec des disponibilités en ressources différentes dans le temps et dans l'espace. La présence de végétation et des ressources trophiques associées permet vraisemblablement une grande variation de la disponibilité des ressources qui détermine un fort renouvellement des diverses espèces le long de la niche spatio-temporelle. Enfin, nous avons observé une relation inverse entre la présence humaine et la richesse spécifique.

SUMMARY. — Studies on the bird richness and abundance patterning in sandy coastal areas are almost neglected. A better knowledge of bird assemblage structure could permit the developing of appropriate conservation strategies in these key ecosystems. In this study, we aimed to test the hypothesis that a patchy and structurally oversimplified ecosystem, as a Mediterranean sandy beach, may host bird assemblages highly variable in space and time and relatively poor in richness and abundance, whose structure should be therefore affected by chance. In 2007 a transect laid along a sandy beach was carried out, allowing to analyse the data temporally (six 2-month periods) and spatially (three longitudinal habitat types), either at single species or assemblage level. We observed a total of 25 bird species. Bird assemblages showed a taxonomical, phenological and ecological heterogeneity. In late autumn-winter the beach hosted the richest assemblage, in summer-autumn the lowest. Differences in mean values among 2-month periods were significant for species richness. Beaches represent patchy ecosystems with a different availability of resources in space and time. The presence of vegetation and linked trophic resources presumably permits the occurrence of a large variation in resource availability that determines a high turnover for different species along the temporal and spatial niche. Finally, we observed an inverse relationship between human presence and species richness.

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Sandy beaches are transitional ecosystems linking marine and terrestrial systems in the coastal zone (Komar, 1998). They provide nesting, foraging and stop-over areas for many species of vertebrates and invertebrates and harbour unique biological assemblages (McLachlan & Brown, 2006).

In these structurally simplified ecosystems, birds occur with specific patterns of abundance and richness reflecting the peculiar regime of resources, heterogeneous in space and dynamics in time (Wiens, 1989). Nevertheless, studies on time fluctuations around yearly cycles are very scarce or limited to species and assemblages of conservation concern or to responses to human-induced threats (e.g., Williams *et al.*, 2004).

Sandy beaches are commonly exploited by humans for recreational purposes (i.e., walking, taking bath, sunbathing, water sports, etc). The usual presence of humans in such areas contributes in determining bird assemblage and structure constituting a form of disturbance. In response to such a disturbance, birds usually fly away doing short flights that are energetically costly particularly for small birds, and overall this may cause shorebirds to be unsuccessful in gaining necessary fat reserves, with consequent low survival rates (Nudds & Bryant, 2000). The resulting disturbance from humans constitutes a detriment for shorebirds because disturbance may reduce foraging efficiency and opportunities for rest (Burger & Gochfield, 1993; Giese,1999). If chronic, the cumulative disturbance could reduce the reproduction and survivorship of bird species linked to beach areas.

The knowledge of the patterns of bird richness and abundance in sandy coastal areas could permit to better evaluate the role of these neglected and often highly disturbed ecosystems and developing appropriate conservation strategies either site-based (i.e., focused on the whole of the ecosystem) or target-based (i.e., on specific target species or assemblages) (Schlacher *et al.*, 2006). Moreover, these ecosystems are vey peculiar with an oversimplification of their structure and a strong seasonality.

Our aims in this paper are to determine: (1) the species composition and diversity of the bird assemblages exploiting the study area along temporal and spatial dimensions; (2) the effects of the human use of the study site on bird composition and richness. We expected that, if there is any, (a) the temporal variation in bird assemblage diversity should be affected by both phenological and species-specific tolerance to human disturbance, and (b) the qualitative and quantitative differences of bird assemblages among habitats reflect their heterogeneity in resource availability (i.e. nest sites, rest sites, food) characterizing each single habitat.

METHODS

Study area

The study area was a sandy beach situated along the Tyrrhenian coast of Central Italy (Latium; Municipalities of Cerveteri and Ladispoli; 41°58’ N; 12°03’ E). This beach is included in the “Palude di Torre Flavia” natural Monument, a small protected coastal Mediterranean wetland (40 ha-wide; Special Area of Conservation, according to the EC Directive on the Conservation of Wild Bird 79/409/EEC) which is a relict of a larger wetland drained and transformed by land reclamation in the last century (Battisti, 2006; Battisti *et al.*, 2006).

The sector of sandy beach surveyed for this study was approximately 1000 m-long and showed a specific, semi-natural patchiness with a seashore area, an intermediate sandy zone and an inner dune area. At landscape scale, this area showed characteristics of a remnant fragment of sandy beach embedded in an agricultural and urbanized matrix. Among the most significant disturbance factors and processes affecting this sandy beach, coastal erosion has a prevailing role, with irreversible destruction of geo-forms supporting plant communities (Acosta & Izzi, 2006). On the beach, trampling, motor vehicle transit and others recreational activities resulted the main human-induced threats promoting local floristic and structural vegetation changes (Battisti *et al.,* 2008). Climate of the study area is xeric-meso-Mediterranean (Tomaselli *et al.,* 1973; Blasi & Michetti, 2005).

Protocol

Data were obtained by carrying out a line transect method (Bibby *et al.*, 2000). A transect 1000 m in length and approximately 30 m wide was covered along the Torre Flavia sandy beach in a parallel way in respect to the coastline. Along the beach, we selected three longitudinal habitat types (hereafter, LHTs), from the seashore to the inner sides:

(1) a seashore area (SEA), where the waves break on the sand;

(2) an intermediate sandy zone (SAN) with natural and anthropogenic debris (molluscan shells, seaweeds, pebbles, woods and others natural sediments, human garbages);

(3) an inner embryonic shifting dunes (DUN) and annual vegetation of drift lines (with dominance of *Agropyrum junceum*, *Sporobolus pungens*, *Euphorbia peplis*, *Otanthus maritimus*, *Medicago marina*, *Anthemis maritima*, *Eryngium maritimum*, *Pancratium maritimum*), corresponding to 1210 and 2110 EC habitat types (92/43 "Habitat" Directive) (Guidi, 2006). Each longitudinal zone was approximately 10 m wide.

Around a yearly cycle, an observer (CB) walked along the transect three times per months from 10 January to 29 December 2007, in the morning, within an hour after the dawn, for a total of 36 visits and 1200 minutes of total sampling. All bird individuals were recorded by direct observation. We carried out our sampling at assemblage level in the dawn because a large part of birds is more active in early morning (e.g., for singing and foraging activities, migration, etc.; Bibby *et al.*, 2000). The observer walked along the transect, lying parallel of the sea-shore, looking for birds on his own left and right. We assigned the values 1 at each individual record (Bibby *et al.*, 2000). When occurring, the vegetation along the transect was lower than 30 cm and we assumed that detection probability was uniform for all the bird individuals occurring in the area (Boulinier *et al.,* 1998). Flying birds were not considered in our analyses. We did not sample species with crepuscular and nocturnal activity.

Line transect as a study method was selected because the mapping method (Bibby *et al.,* 2000) is more time consuming and suitable for more structured ecosystems and for territorial birds, while point counts (e.g., E.F.P.; Blondel *et al.*, 1970) do not permit to acquire a significant number of data in small linear fragments such as this sandy beach fragment (see also Sutherland, 2006).

During each survey the number of person beach dwellers was noted regardless of their level of internal distribution (whether individual or group). Since the study was carried out at dawn we never noticed large group of people aggregates, therefore in this study we considered negligible the level of grouping of users. Due to the time at which the samples were conducted, the overall disturb estimate (N persons * Km^{-1}) was certainly undervalued because human peak activity in the study area concentrates in the central hours of the day (touristic frequentation for bathing; Battisti, 2006 and pers. obs.).

Data analysis

In 2007, data obtained in each visit were elaborated in 6 2-month periods either at single species or assemblage level (sensu Fauth *et al.*, 1996). We calculated the following assemblage parameters:

— species frequency for each species (number of species record/total records in the assemblages), in each LHT (for the whole of yearly cycle) and for each 2-month period (for the whole of LHTs);

— species richness (S) and mean species richness (Sm), as the number of species checked in each 2-month period;

— normalized species richness, utilizing the Margalef index as Dm = (S-1)/log N where S is the number of species sampled and N, the number of sampled individuals (Magurran, 2004);

— PIE Hurlbert´s (1971) index as the probability of an interspecific encounter (i.e., the probability that two randomly sampled individuals from the same assemblage represent two different species) $PIE = [(N)/(N-1)]*[1-\Sigma pi^2]$

We elaborated data for each LHT and for each 2-month period. Taxonomic nomenclature follows the recent AERC TAC (2003).

Statistical analysis

Each individual bird was taken as a sampling unit. Given that these data did not follow a normal distribution, differences in terms of Sm among 2-month periods and LHTs were tested with the Kruskal-Wallis test.

In order to explore whether the species diversity (measured as the richness and the probability of an interspecific encounter – PIE index – Hurlbert, 1971) significantly varied among periods and LHTs, we randomized the observed matrices 10 000 times with a full Monte Carlo procedure using Ecosim (version 7.0). We controlled for biases in abundance differences among samples rarefying our samples (periods and LHTs) down to a common abundance level (N individuals), randomly sampling individuals, and then we compared species richness (Sanders, 1968). We performed a nestedness analysis in order to explore species diversity variation among periods and LHTs using NODF software (Almeida-Neto & Ulrich, 2010). We used presence-absence matrices and generated 10 000 randomized matrices using the fixed-fixed model algorithm (fixed rows and fixed columns; Gotelli, 2000). Statistical inference is done from a null model approach comparing observed versus expected (i.e. simulated) nestedness scores. This method makes it possible to quantify independently (1) whether depauperate assemblages constitute subsets of progressively richer assemblages and (2) whether less frequent species are found in subsets of the sites where the most widespread occur (Ulrich *et al.,* 2009).

We correlated bird presence to disturbance (Nperson * Km^{-1}) by means of Spearman Rank Correlation test. Significance levels were set at $p < 0.05$ and $p < 0.01$. We used statistical package SPSS 13.0 for Windows.

RESULTS

A total of 377 individuals belonging to 25 bird species were observed along the yearly cycle (Tab. I); among them, 266 individuals (70.6 %) and 9 species were sampled in the intermediate SAN zone; 84 (22.3 %) and 13 species in the inner DUN zone, and 27 (7.2 %) and 17 species in the SEA zone (Tab. II).

TABLE I

Species frequency in each 2-month period inside the Mediterranean sandy beach. I: January-February, II: March-April, III: May-June, IV: July-August, V: September-October, VI: November-December. Total records (both for species and 2-month period, n), species richness (S) and Margalef index (Dm) are reported

	2-month periods						
Species	I	II	III	IV	V	VI	n
Ardea cinerea	0	0.018	0	0	0	0	1
Anser anser	0.029	0	0	0	0	0	1
Anas platyrhynchos	0.059	0	0	0	0	0	2
Charadrius dubius	0	0.125	0.114	0	0	0	11
Charadrius alexandrinus	0.029	0.018	0.029	0	0	0.081	6
Pluvialis squatarola	0	0	0	0	0	0.027	1
Actitis hypoleucos	0	0	0	0.147	0	0	5
Chroicocephalus ridibundus	0.088	0	0	0.029	0.890	0.135	170
Larus michaellis	0	0	0.029	0.206	0.006	0	9
Galerida cristata	0	0.089	0.114	0	0	0.027	10
Anthus pratensis	0.118	0.446	0	0	0.006	0.189	37
Motacilla flava	0	0.036	0	0	0	0	2
Motacilla alba	0.235	0.125	0.114	0.088	0.033	0.189	35
Erithacus rubecula	0.059	0	0	0	0	0.027	3
Saxicola torquatus	0.029	0.054	0	0	0.033	0.027	11
Oenanthe oenanthe	0	0	0	0	0.006	0	1
Cisticola juncidis	0	0.018	0.029	0	0.006	0.027	4
Phylloscopus collybita	0	0	0	0	0	0.108	4
Pica pica	0	0	0.029	0	0	0	1
Corvus cornix	0.235	0.054	0.057	0.353	0.022	0	29
Passer domesticus	0	0	0.457	0.176	0	0	22
Fringilla coelebs	0.029	0	0.000	0	0	0	1
Carduelis cannabina	0	0	0.000	0	0	0.162	6
Carduelis chloris	0.029	0	0.029	0	0	0	2
Emberiza schoeniclus	0.059	0.018	0	0	0	0	3
Total	34	56	35	34	181	37	377
S	12	11	10	6	8	11	
Dm	7.18	5.72	5.83	3.26	3.1	6.38	

At the level of single species, *Chroicocephalus ridibundus, Corvus cornix* and *Passer domesticus* were sampled prevalently in the intermediate SAN zone, while a large set of granivorous and insectivorous Passeriformes (e.g., Fringillidae) occurred only in the inner DUN zone. Several water-obligated species (e.g., *Ardea cinerea, Anser anser, Pluvialis squatarola*) occurred occasionally only in the SEA zone (Tab. II).

At the assemblage level, along the yearly cycle, DUN hosted the richest assemblage (highest score for normalized species richness), SAN the lowest score in normalized species richness (Tab. II). A rarefaction test confirmed that SAN was characterized by the lowest cumulate richness and PIE values.

TABLE II

Species frequency in each longitudinal habitat types (LHTs) inside the Mediterranean sandy beach SEA: seashore area; SAN: intermediate sandy zone; DUN: inner embryonic shifting dunes

	LHTs		
Species	SEA	SAN	DUN
Ardea cinerea	0.037	0	0
Anser anser	0.037	0	0
Anas platyrhynchos	0	0.004	0.012
Charadrius dubius	0.037	0.023	0.048
Charadrius alexandrinus	0.111	0.008	0.012
Pluvialis squatarola	0.037	0	0
Actitis hypoleucos	0.185	0	0
Chroicocephalus ridibundus	0.185	0.620	0
Larus michaellis	0.259	0.008	0
Galerida cristata	0	0	0.107
Anthus pratensis	0	0.060	0.250
Motacilla flava	0	0	0.024
Motacilla alba	0.111	0.083	0.119
Erithacus rubecula	0	0	0.036
Saxicola torquatus	0	0.008	0.107
Oenanthe oenanthe	0	0	0
Cisticola juncidis	0	0	0.048
Phylloscopus collybita	0	0	0.048
Pica pica	0	0	0
Corvus cornix	0	0.102	0.024
Passer domesticus	0	0.075	0.024
Fringilla coelebs	0	0	0.012
Carduelis cannabina	0	0	0.071
Carduelis chloris	0	0	0.024
Emberiza schoeniclus	0	0	0.036
Total abundance	27	266	84
Total n. of species	9	13	17
Dm	5.59	4.95	8.31

Differences in Sm values among 2-month periods were significant (H = 8.655; p = 0.044; 5 df; Kruskal Wallis test). Data separated for the three LHTs showed a significant difference among 2-month periods for Sm only for the DUN zone (H = 10.507; p = 0.019; Kruskal-Wallis test test, 5 d.f.; Tab. III).

A rarefaction test revealed that both the species richness and PIE index non-randomly varied among the temporal (2-month periods; Tab. IV). As concerns LHT, DUN presented the highest value of species richness and SEA the lowest. The variation of the PIE index along the spatial niche was due to chance (LHTs; Tab. V). The period January-February showed the highest species richness, whereas May-June, July-August, and September-October the lowest. PIE index was significantly higher in January-February and November-December than in the other periods.

TABLE III

*Mean values (and standard deviation, s.d.) of species richness (S) for 2-month periods in each longitudinal habitat type (TOT: total area; SEA: seashore area; SAN: intermediate sandy zone; DUN: inner embryonic shifting dunes) (** = p < 0.01, * = p < 0.05)*

			TOT		SEA		SAN		DUN	
						S				
period	H	P	mean	(s.d.)	mean	(s.d.)	mean	(s.d.)	mean	(s.d.)
Jan-Feb	6.975	0.031*	4.17	(1.94)	0.33	(0.52)	1.83	(0.98)	2.00	(1.67)
Mar-Apr	4.073	0.131	3.83	(2.71)	0.33	(0.52)	1.50	(1.76)	2.00	(1.67)
May-Jun	12.174	0.002**	3.50	(1.05)	0	-	2.17	(0.75)	1.33	(0.82)
Jul-Aug	6.989	0.030*	1.83	(0.41)	0.33	(0.82)	1.33	(0.82)	0.17	(0.41)
Sep-Oct	5.306	0.070	2.67	(1.97)	0.17	(0.41)	1.33	(1.21)	1.17	(0.98)
Nov-Dec	3.880	0.144	3.5	(0.84)	1.00	(1.55)	0.50	(0.55)	2.00	(1.26)

TABLE IV

Rarefaction analysis performed on temporal niche. 2-month periods Sep-Oct was set as common abundance level (n = 31). S: species richness; PIE: probability of an interspecific encounter (Hurlbert, 1971); 95% C.L.: confidential limits at 95% (note that there are not C.L. for the categories with the lowest individual number used as the common abundance level in the rarefaction procedure)

Period		Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
S	Mean	11.54	8.83	9.41	5.91	8	10.18
	95% C.L.	10-12	7-11	8-10	5-6	-	8-11
PIE	Mean	0.88	0.77	0.77	0.79	0.8	0.89
	95% C.L.	0.86-0.90	0.67-0.84	0.71-0.82	0.77-0.82		0.87-0.90

TABLE V

Rarefaction analysis performed on spatial niche. Longitudinal habitat types (LHTs) SEA: seashore area; SAN: intermediate sandy zone; DUN: inner embryonic shifting dunes. SEA was set as common abundance level (n = 27). S: species richness; PIE: probability of an interspecific encounter (Hurlbert, 1971)

LHT		SEA	SAN	DUN
S	Mean	9	7.9	11.75
	95% C.L.		6-10	9-14
PIE	Mean	0.87	0.85	0.89
	95% C.L.		0.79-0.89	0.83-0.94

Nestedness analysis revealed no nested pattern bird assemblages among periods. Birds species richness showed a significant correlation to human presence (N = 36; r = -0.417; p = 0.011; Spearman Rank Correlation) (Fig. 1).

The 2-month period January-February showed the highest species richness, whereas May-June, July-August and September-October presented the lowest values of richness and PIE index. PIE index was significantly higher in January-February and November-December than in the other periods. Beach represents a site of stop-over for many species in winter period, hence our observations should be considered with this point taken into account.

Furthermore, disturbance by human frequentation may affect species richness in sandy beach (Brown & McLachlan, 2002), as verified in our study area (human presence *per se* and as source mechanism of trampling; Battisti *et al*., 2008). While data on this topic at species level are widely available (e.g., Yorio & Boersma, 1992; Burger & Gochfield, 1993), there is a lack of information for Mediterranean area and at assemblage level.

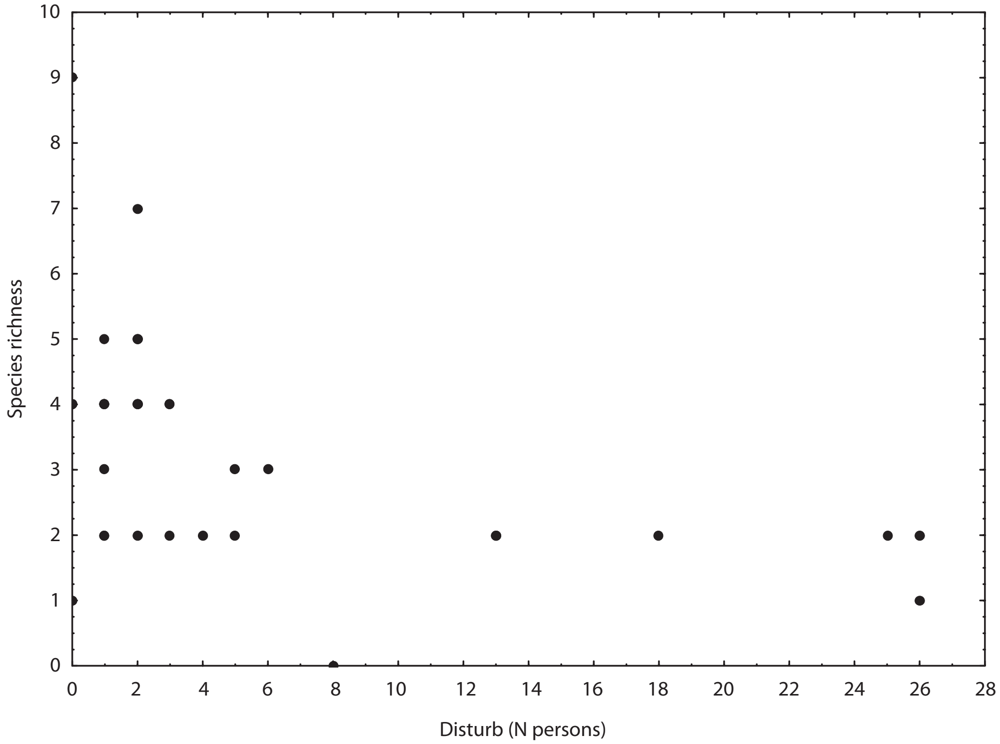

Figure 1. — Relationship between disturbance (disturb) and species richness in "Torre Flavia" wetland bird assemblages.

For their structural simplification and seasonality, beaches may represent an interesting habitat model to study the spatial and temporal niche of avian species. Moreover, the low number of individuals and species may facilitate the use of the rarefaction approach to test whether the differences in space and time may be due to chance.

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