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COMPARING SPATIAL RARITY BETWEEN LONG DISTANCE MIGRANT AND SEDENTARY BIRD SPECIES USING ATLAS DATA AND DIVERSITY/DOMINANCE DIAGRAMS

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ATLAS
FREQUENCY OF OCCURRENCE
PHENOLOGY
LONG DISTANCE MIGRANTS
SEDENTARY BIRDS
DIVERSITY
DOMINANCE DIAGRAMS
APENNINES
ITALY

ABSTRACT. – Analyses using the spatial frequency of species occurrences, as obtained by faunal atlases, allows us to obtain information on assembly rules of local bird assemblages. Here, diversity/dominance diagrams have been used to relate the structural differences in two phenology-based assemblages (i.e. sedentary species and long distance migrants) obtained by an occurrence data set throughout a local breeding bird atlas in an Apennine nature reserve of Central Italy. Among the 58 breeding bird species sampled, 28 % were long distance migrants. On the average, long distance migrants were spatially rarer when compared to sedentary species. In diversity/dominance diagrams, sedentary species show a trend similar to that obtained by the entire community (broken-stick pattern), while long distance migrants have a curve with slope tending to fit geometrically. Geometric species models show steep plots and are typical of assemblages with high relative dominance, low evenness and few species (in our case, the long distance migrants). Moving from geometric series towards a broken-stick model, the assemblages tend to be even more species rich (in our case, the sedentary species). In a Palearctic bird community, long distance migrants are generally rarer in abundance and spatial distribution when compared to sedentary species. A different phenology may imply differences in species evolution, history and ecology with consequences for abundance, distribution and rarity patterns. In our study area, patterns of spatial occurrences evidenced by diversity/dominance curves may be due to the influence of long-term history, short-term competition and local disturbances that differentiated the two phenologic sub-assemblages.

INTRODUCTION

Biological atlases provide an explicit representation of plant and animal species distributions in near-equal-area grid cells on maps (Sutherland 2006). Among the various taxa, birds have been well-studied in the last thirty years in several regions of Europe with atlases compiled at different scales (from continental to local) (Sharrock 1976, Lack 1986, Gibbons *et al.* 1993, Bibby *et al.* 2000). When developed for large areas, these atlases have been achieved using a large number of volunteers with different expertise. Nevertheless, this approach may induce a bias due to a lack in standardization of research effort (Sutherland 2006). At local scales (i.e. on a grid map of 100-1000 km²), it is possible to reduce this bias and inaccuracy by limiting the number of researchers and standardizing the sampling protocols (e.g. at level of sample cells; Donald & Fuller 1998, Sutherland 2006).

Local atlases may represent a useful tool for site management strategies. Indeed, the smaller and finer the grain of atlas grid, the more detailed data will be attributed to the grid cells, facilitating the definition of site-specific conservation measures (e.g. nature reserve selection, restoration projects; Araùjo & Williams 2000, Pressey 2004, Araùjo *et al.* 2005). Moreover, when correlating atlas data with vegetation types and land use heterogeneity it is pos-

sible to obtain information on local ecology of single species, useful to develop predictive models (e.g. Osborne & Tigar 1992). Further analyses, using the spatial frequency of species occurrences, allow us to obtain information on the role of single species in local bird assemblages (e.g. if spatially dominant, common or rare) and on assembly rules (e.g. if competition-based, casual or disturbance-based; Gotelli *et al.* 1997), with implications on the relationships between habitat heterogeneity, richness and taxonomic diversity (Wiens 1989, Pacini *et al.* 2009).

The number of sampling units (i.e. cells) in an atlas in which a species occurs (occurrence or incidence) is a common indirect method to estimate abundance (Magurran 2004). Occurrence data are extremely useful in diversity measurements allowing us to determine if a species is locally distributed or widespread in a study area. In this sense, occurrence data may be useful to assess the level of spatial (geographic) rarity of a species, i.e. a type of rarity (see for further details on several forms of numerical, ecological, geographic rarity: May 1975, Rabinowitz 1981, Kunin & Gaston 1993, Gaston 1994, Williams *et al.* 1996, Gaston & Blackburn 2000). Therefore, in this work we refer to spatial (geographic) rarity as a species-specific attribute that depends on their spatial occurrence in an atlas grid.

The diversity/dominance (DD) diagrams in much of the ecological literature are used to relate the structural differences in species assemblages (Whittaker 1960, Ghazoul 2002). Indeed, the profile, trend, and shape of the diagram lines may convey information on possible anthropogenic or natural stresses occurring in the assemblages or others structural dissimilarities (Magurran 2004). The data, in these diagrams, are arranged in species rank/frequency comparisons where all the species in a sample are ranked from the most to the least relatively abundant (e.g. Battisti *et al.* 2008). DD diagrams may be compiled also from occurrence data with species frequencies from presence/absence data instead of individual abundance. The concept of niche size and niche occupancy in occurrence data should be interpreted in spatial sense (see Battisti *et al.* 2009).

The patterns of species richness and their relative abundance or occurrence in DD diagrams are clearly displayed. Moreover these plots highlight differences in evenness amongst assemblages (Smith & Wilson 1996). Curves in DD diagrams have been obtained from abundance/occurrence data mainly by taxonomically- or ecologically-characterized groups, while data analyses carried out on phenology-characterized assemblages are lacking. In this study, we obtained an occurrence data set throughout a local breeding bird atlas in an Apennine nature reserve of Central Italy. We analyzed this data-set: i) to rank the species occurrences following an increasing gradient of spatial rarity; ii) to assess the differences in this gradient comparing two sub-assemblages of species phenology-based (sedentary *vs.* long distance migrants in Italy following Meschini & Frugis 1993) using a DD approach.

MATERIALS AND METHODS

Study area: The Monte Catillo nature reserve (1,340 ha) represents a protected area including a calcareous hilly sector near Tivoli (Rome) marking the boundary between the Campagna Romana and Apennines (Central Italy). The entire reserve develops an altitudinal range comprised between 170 and 612 m above sea level. Phytoclimatically the area is mainly placed within the temperate region of transition (mesaxeric region, ipomesaxeric region) with a prevailing vegetation represented by the series of *Quercion-pubescenti-petraea*, *Ostryon-Carpinion orientalis*, *Laburno-Ostryon* and *Ostryon-Carpinion orientalis* (Blasi 1994) and to a lesser extent *Fraxino orni-Quercetum ilicis* Horvatic (1956) 1958. Landscape mosaic is highly heterogeneous including several phytocoenoses (i.e. plant communities), including: i) patchy sub-Mediterranean xerophilous scrub (balcanic shibljak with *Styrax officinalis*, *Pistacio terebinthi-Paliuretum spinachristi* Blasi & Di Pietro 2001, ii) garrigue and pseudo-steppe with grasses and annuals with *Ampelodesmos mauritanica* (*Elaseolino asclepii-Ampelodesmetum maritanici* Filesi, Blasi, Di Marzio 1996), iii) hornbeam woodlands (*Ostryo-Carpinion*

orientalis Horvat 1954), iv) termophilous sub-Mediterranean deciduous *Quercus cerris* woods (*Echinopo siculi-Quercetum frainetto* Blasi et Paura 1993), v) heathlands with *Erica arborea* and localized *Quercus suber* wood fragments (*Cytiso villosi-Quercetum suberis* Testi, Lucattini 1994), vi) xerophilous woods with *Cercis siliquastrum*, *Acer monspessulanum*, *Pistacia terebinthus*, vii) a river (Fiume Aniene) with *Phragmites* reed beds along the banks (further details in Guidi 2007).

Protocol: We carried out a local breeding bird atlas juxtaposing a grid with 74 500 x 500 m-wide cells as sample units (hereafter, SU) on the entire Monte Catillo nature reserve (and immediately surrounding sectors). This grid was obtained subdividing the UTM 1 x 1 km grid of the Technical Regional Map (scale 1:10,000; Regione Lazio 1990).

In the 2009 breeding period (from March 13th to July 2nd) we carried out a non-linear random transect in each SU in a way that represents their entire internal heterogeneity. Each transect was 20 minutes-timed and was repeated twice (i.e. two sessions) during the breeding period. A first session was carried out from March to April and a second session from May to July for a total of 148 20'-sessions (74 SU per 2).

We obtained direct (sightings) and indirect (song, nests, tracks) data on bird occurrences during each sampling in each transect. We considered a species "occurs" in a SU if at least one direct or indirect record of this species was sampled at least in one session. Then, we cumulated the occurrence data of the two sessions for each SU. We did not obtain data at quantitative level (e.g. species abundance as number of individuals) for each bird species in the whole SU.

The positive correlation between abundance and range size has often been observed (Bock & Ricklefs 1983, Blackburn *et al.* 1997). Therefore, we assumed the occurrence values as an indirect measure of spatially-explicated abundance.

Data analysis: For each species, we obtained: i) the number of occupied SUs (i.e. number of SU where a species occurs, cumulating direct and indirect records of the two sessions: Ns); ii) the grid frequency of cumulative occurrences (the ratio between Ns and total number of SUs = 74; G). This last parameter allows to rank the local spatial rarity among the species (from the more widely distributed to the more localized species) with no implication in their spatial pattern (e.g. if aggregated, random or regular). Then, the G values were log-transformed evidencing a commonness-rarity gradient in local spatial distribution with a semi log-transformed DD (or species/rank) diagram (Whittaker 1970). Each species has a rank, which is plotted on the X-axis, and a frequency on the Y-axis. The frequency of the most abundant species is plotted first, then the next most common ones (Magurran 2004). There are three main species/abundance patterns that are explicit in DD diagrams: they are the broken-stick, the log-normal and the geometric patterns, each one implying a specific structure and driving forces (e.g. stresses) in the assemblage studied (Whittaker 1970, Krebs 1995).

We separated the data for two phenology-based sub-assemblages of species: sedentary and long distance migrant species

Table I. – Check-list of sampled species in local atlas of Monte Catillo nature reserve. Number of occupied cells (Ns) and grid-percent-age occurrence (G) are reported. M: long distance migrant species; S: sedentary species.

Species	Ns	G	Species	Ns	G
<i>Turdus merula</i> (S)	68	0.92	<i>Dendrocopos major</i> (S)	10	0.14
<i>Sylvia atricapilla</i> (S)	68	0.92	<i>Carduelis cannabina</i> (S)	10	0.14
<i>Cyanistes caeruleus</i> (S)	63	0.85	<i>Streptopelia turtur</i> (M)	10	0.14
<i>Corvus cornix</i> (S)	62	0.84	<i>Motacilla alba</i> (S)	9	0.12
<i>Fringilla coelebs</i> (S)	55	0.74	<i>Falco tinnunculus</i> (S)	8	0.11
<i>Parus major</i> (S)	51	0.69	<i>Oriolus oriolus</i> (M)	8	0.11
<i>Sylvia melanocephala</i> (S)	50	0.68	<i>Cettia cetti</i> (S)	6	0.08
<i>Erithacus rubecula</i> (S)	47	0.64	<i>Muscicapa striata</i> (M)	5	0.07
<i>Picus viridis</i> (S)	42	0.57	<i>Buteo buteo</i> (S)	5	0.07
<i>Emberiza cirrus</i> (S)	38	0.51	<i>Upupa epops</i> (M)	5	0.07
<i>Troglodytes troglodytes</i> (S)	37	0.50	<i>Anas platyrhynchos</i> (S)	4	0.05
<i>Colomba palumbus</i> (S)	35	0.47	<i>Pica pica</i> (S)	4	0.05
<i>Serinus serinus</i> (S)	31	0.42	<i>Sturnus vulgaris</i> (S)	4	0.05
<i>Luscinia megarhynchos</i> (M)	30	0.41	<i>Gallinula chloropus</i> (S)	3	0.04
<i>Garrulus glandarius</i> (S)	29	0.39	<i>Phylloscopus sibilatrix</i> (M)	3	0.04
<i>Passer domesticus</i> (S)	27	0.36	<i>Monticola solitarius</i> (S)	3	0.04
<i>Certhia brachydactyla</i> (S)	26	0.35	<i>Saxicola torquatus</i> (S)	3	0.04
<i>Carduelis chloris</i> (S)	22	0.30	<i>Jynx torquilla</i> (M)	3	0.04
<i>Aegithalos caudatus</i> (S)	20	0.27	<i>Fulica atra</i> (S)	2	0.03
<i>Carduelis carduelis</i> (S)	20	0.27	<i>Passer montanus</i> (S)	2	0.03
<i>Hirundo rustica</i> (M)	16	0.22	<i>Corvus monedula</i> (S)	2	0.03
<i>Apus apus</i> (M)	16	0.22	<i>Hippolais polyglotta</i> (M)	1	0.01
<i>Sitta europaea</i> (S)	15	0.20	<i>Acrocephalus scirpaceus</i> (M)	1	0.01
<i>Columba livia dom.</i> (S)	13	0.18	<i>Periparus ater</i> (S)	1	0.01
<i>Phylloscopus collybita</i> (S)	12	0.16	<i>Phoenicurus ochruros</i> (S)	1	0.01
<i>Sylvia cantillans</i> (M)	12	0.16	<i>Falco peregrinus</i> (S)	1	0.01
<i>Delichon urbicum</i> (M)	12	0.16	<i>Falco subbuteo</i> (M)	1	0.01
<i>Cuculus canorus</i> (M)	12	0.16	<i>Phylloscopus bonelli</i> (M)	1	0.01
<i>Regulus ignicapillus</i> (S)	11	0.15	<i>Tachybaptus ruficollis</i> (S)	1	0.01

(local phenology from Boano *et al.* 1995). Inside these two sub-sets, we performed two DD diagrams ranking the log-transformed G values of species (Magurran 2004). G values of each species were grouped in cumulative occurrence classes to assess the proportion of spatially rare species (i.e. with Ns < 20 %, as conventional threshold). Each class ranged of 10% (0-10 %, > 10-20 % and so on), obtaining the relative percentage values for each sub-assembly.

We performed: i) a χ^2 test to compare the percentage of records belonging to the two phenology-based assemblages; ii) Mann-Whitney U test to compare the median Ns values between sedentary and long distance migrant species. Tests were two-tailed and statistical significance was set at alpha 5 %, using SPSS version 13.0 (SPSS Inc. 2003).

We followed AERC-TAC (2003) for birds; Pignatti (1982) for higher plants. Vegetation is described in Guidi (2007), further data and syntaxa in Provincia di Roma (2007, Fanelli, Bianco eds).

RESULTS

We obtained 1057 records of cumulative occurrences belonging to 58 breeding bird species (Table I). Among them, 16 species (about 28 %) and 136 records (about 13 %) belonged to long distance migrant species.

A wide set of thirty-six species showed the lowest G values (spatially rare species with G values < 20 %; Table I). The DD diagram with G values for all the species is shown in Fig. 1.

The four spatially commonest species (> 80 % in G values) were all sedentaries (*Turdus merula*, *Sylvia atricapilla*, *Cyanistes caeruleus*, *Corvus cornix*).

The percentage of records belonging to long distance migrant species was significantly lower when compared to relative percentage of sedentary species ($\chi^2 = 387.9$, $p < 0.01$). On the average, long distance migrants tend

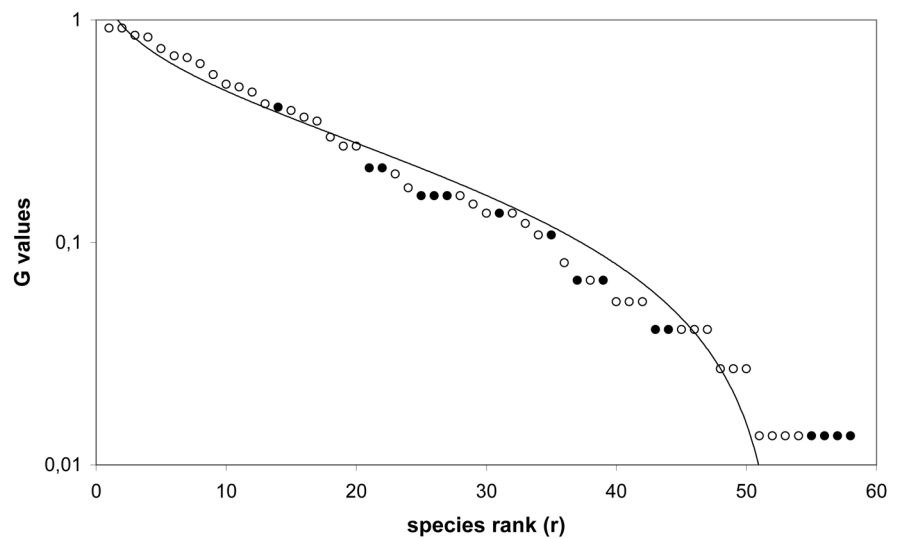


Fig. 1. – Species/rank diagram for G values. Black circles: long distance migrant species; white circles: sedentary species (Line equation: $G = -0.29\ln(r) + 1.14$; $R^2 = 0.97$).

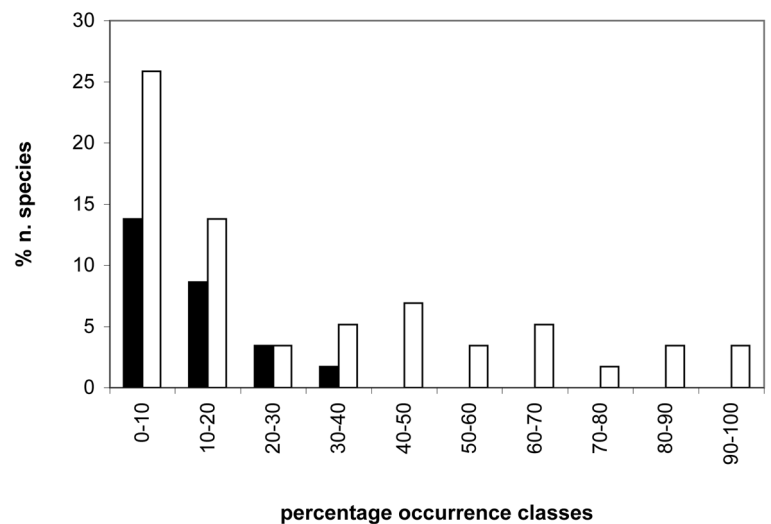


Fig. 2. – Percentage of species (on the total number; $n = 58$) for classes of occurrence. Black: long distance migrants; white: sedentary species.

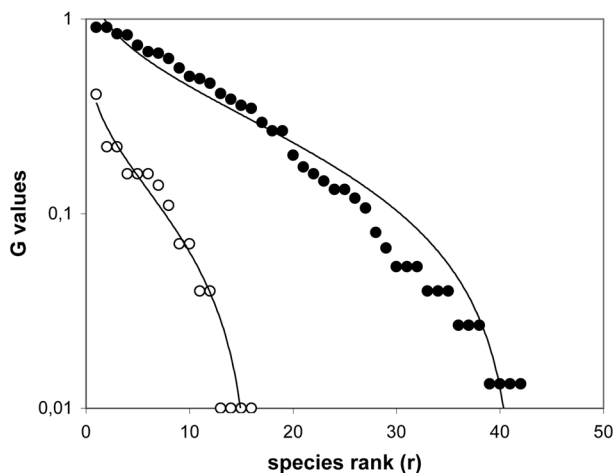


Fig. 3. – Species/rank diagram for G values. In white, the long distance migrant species (Line equation: $G = -0.13\ln(r) + 0.36$; $R^2 = 0.95$); in black, the sedentary species (Line equation: $G = -0.32\ln(r) + 1.19$; $R^2 = 0.95$).

to be spatially rarer when compared to sedentary species (mean Ns: long distance migrants: $8.5 \text{ SU} \pm 7.85$; sedentary species: $21.93 \text{ SU} \pm 21.33$; $Z_{\text{subT}} = 1.979$; $p = 0.048$; U Mann-Whitney test).

The percentage occurrence classes are skewed toward left (high proportion of spatially rare species, with G values $< 20\%$). Species with G values $> 40\%$ are all sedentaries (Fig. 2).

We obtained two curves with different slope (more abrupt in long distance migrants; Fig. 3) in the two phenology-based sub-sets of species.

DISCUSSION

Our space-related breeding bird community shows more rare (localized) species than widely distributed ones. Many rare and few common species is a well known model in rich bird communities (Magurran 2004).

Long distance migrants, on the average, showed a less rich assemblage with more spatially rare species between phenological sub-assemblages. On the contrary, sedentary species include the more widely distributed ones. In a Palearctic bird community, long distance migrants are generally more rare in individuals (abundance) and in spatial distribution when compared to sedentary species (Alerstam 1990). A different phenology may imply different strategies in space and resource use. Moreover, this implies different relationships with the environmental productivity with consequences at the level of their abundance, distribution and rarity patterns (Alerstam 1990, Cuadrado 1997, Blondel & Aronson 1999, Mönkkönen *et al.* 2006, Brown & Long 2007, Brown & Sherry 2008).

In our DD diagrams, sedentary species show a trend similar to the one obtained by the entire community (broken-stick pattern; MacArthur 1957), while long distance migrants shape a curve with a slope tending to fit geometrically. Sedentary species represent almost $\frac{3}{4}$ of the species and thus could be expected to determine the curve for the whole species set.

The shape of curves in DD plots is used to infer which species abundance or species occurrence model best describes the data (Wiens 1989, Magurran 2004). Among the three main typical species/abundance (or occurrence) models (i.e. broken-stick, log-normal and geometric; Whittaker 1970, Krebs 1995), the geometric model shows steep plots and is typical of assemblages with high relative dominance, low evenness and few species (in our case, the long distance migrants). Moving from geometric model toward broken-stick model, the assemblages tend to be more species rich (in our case, the sedentary species) and with higher evenness. Marked differences in slope and shape of the curves evidence differences in species/abundance (or occurrence) patterns.

Some authors attributed the changes in shape of the curves in DD diagrams to different factors and processes. For example, distributional patterns of abundance and occurrence have been used as evidence of community-level based processes as competition (Róv 1975, Wiens 1989). Indeed, a set of species might divide their niches randomly among themselves, so that they occupy overlapping niches. If abundance is proportional to niche size, the distribution of species abundance will show a higher evenness, with little numerical dominance by one or a few species (broken-stick model; MacArthur 1957). Nevertheless, many other factors may act to determine the patterns of occurrence, abundance and rarity and consequently the slope of curves in DD diagrams. In particular, the intrinsic biology and ecology of species, the history and events at different temporal and spatial scales (anthropogenic and natural disturbances, climate changes; e.g. Pickett & White 1985) may affect DD patterns (Wiens 1989). Therefore, the patterns of spatial occurrences as revealed by DD curves may be due to both the extrinsic and intrinsic factors affecting assemblages (e.g. natural

and/or human-induced disturbances, competition; Ugland & Gray 1982, Pickett & White 1985). In Mediterranean regions, the historical events contributed to differentiate the patterns of occurrence and rarity between sedentary and long distance migrant species at a wider temporal and spatial scale (Blondel & Aronson 1999). Probably, a short-term scale competition among species with different phenology could further intervene to shape the different pattern obtained (see Wiens 1989).

DD approaches have never been applied to phenology-based assemblages both in absolute or in comparative way (e.g. Battisti *et al.* 2009). In this sense, further research is necessary to verify the universality or specificity of these patterns also in other contexts (e.g. non-Mediterranean).

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