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Mean range size of the species, bird richness and ecogeographical factors: data from italian peninsula and islands[1]

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Abstract - Islands are, generally, inhabited by widespread and generalist bird species. This phenomenon, well known in literature and here extended to a peninsular gradient, is confirmed in Italy for breeding landbirds, and for the sedentary ones, elaborating data of the Atlases.
The mean range size values of the species are higher in all the studied islands compared to the mainland. The lesser the island area the higher is the mean range size of the species found. Stenotopic species, rare and localised, are present with lower frequency in small islands, the contrary occurs for widespread species. Along the Italian peninsula a high inverse correlation between mean range of distribution of the species and a number of variables of the latitudinal transects (number of species, highest altitude, area, latitude) has been found.
This may be explained, mainly, by the different orophysiographical and environmental availability which affect, at the same time, the bird richness and, in particular, the distribution of the rare and localised species.

Introduction

The classic theory of island biogeography (Mac Arthur and Wilson 1967) does not deal with species-specific differences in the colonization process of isolated areas. Indeed, the colonization may be also a function of the vagility, of the ecological valence (*e.g.*, the ability to establish; Carlquist 1974) and of the diffusion and abundance of the species on the mainland (for a review on the mediterranean area see Blondel 1985, 1991; Covas and Blondel 1998). Consequently, isolated communities are not a casual sample of mainland species: generalist (euryecious) and widespread (eurytopic) species, more adapted to colonize, are present with higher proportion on the islands, whilst localised (stenotopic) and specialist (stenoecious) ones are under-represented (Lack 1976, Safriel and Ritte 1980, Brown 1984, Futuyma 1984).
Widespread (eurytopic) species have a wide geographical distribution, are present in a large number of environments and have a broad ecological range of tolerance. We refer to the complex of such species as "eurytopic", according to a consolited literature (Mac Fayden 1957, Udvardy 1969, Margalef 1977, Lincoln *et al.* 1982, Parson 1982, Fasola 1985). These species are, generally, the most abundant (positive correlation between geographical range and local abundance; see, *e.g.*, Bock and Ricklefs 1983, Sutherland and Baillie 1995, Lawton 1996, Newton 1997).
Generalist (euryecious) species, characterized by a great dispersal capacity, are often widespread and seem to be more successfull island colonists (Allee and Schmidt 1951, Sacchi and Testard 1971, Carlquist 1974).
Environmental tolerance and interspecific effects are the main factors argued to set range size of the species (Gaston *et al.* 1998a).
Extending the analysis on the peninsular pattern, in Italy is well known a local latitudinal richness gradient (decrease towards South; *e.g.* Massa 1982), opposite to global trend (see discussion). Orogeographical, hystorical-climatic and environmental *s.l.* factors seem to be the main local causes of this tendency.
Linked to species richness, a global decrease of mean range size of the species towards South exists, at least in some groups, like birds (Rapoport's rule; Stevens 1989). Studies of relationship between range size and latitude were carried out by several authors (for a review, see Gaston *et al.* 1998a).
The aim of this study is to relate the mean range size of the breeding landbirds to a number of eco-

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geographical variables in islands as well as in the peninsula.
For islands we tested the hypothesis that the proportion of widespread species increase with the insularity degree; for the Italian peninsula we related the ecogeographical variables and richness of each latitudinal transect to the mean range size of the species, testing the aforementioned hypothesis for Italy.

Methods

The study was carried out on the Italian peninsula, Sicily, Sardinia and 23 small circumpeninsular and circumsicilian islands (South to North: Lampedusa, Linosa, Pantelleria, Favignana, Marettimo, Levanzo, Vulcano, Lipari, Alicudi, Filicudi, Salina, Panarea, Ustica, Stromboli, Capri, Ischia, Ponza, Giannutri, Montecristo, Giglio, Elba, Capraia, Gorgona).
For each small island, highest altitude (m a.s.l.), area (km^2) and distance from mainland (km) have been calculated from literature.
Italian islands have been divided in categories of altitude (0-300 m a.s.l., 301-600, 601-900, >900), area (0-10 km^2, 11-100 km^2, Elba, Sicily, Sardinia) and of distance from mainland (for small islands only: 0 to 10 km, 11 to 20, 21 to 40, 41 to 80, 81 to 160, > 161; for circumsicilian island distance from Sicily has been considered; for Lampedusa distance from Tunisia: see Massa and Di Palma 1988).
The peninsula has been divided, from North to South in transects (1 to 27; fig. 1), each corresponding to a group of IGMI maps 1:100000 with the same latitude.
For each island, insular category and peninsular transect we have calculated the total number of breeding landbird species (Columbiformes to Passeriformes; Vaurie 1959 and 1965 in Massa 1982: data from Meschini and Frugis 1993).
Values of territorial coverage on national scale (a geographic amplitude value, in %: "range size"), quoted for each species in Italian Breeding Bird Atlas (Meschini and Frugis 1993), were utilized for subsequent processing data.
The following matrices were built: landbird species/peninsular transects (146x27) and species/islands. Values of range size of each present species were indicated for each transect and island and then the average, among all the present species in each transect and island, respectively, was calculated ("mean range size").
Same procedure was applied to the sedentary landbirds (for all the islands and for the whole peninsula also the total number of species has been calculated; data from Meschini and Frugis 1993, Boano *et al.* 1995, Massa 1985; for phenological classification between sedentary and migrant species: Brichetti and Massa 1984, utilizing the more characteristic category on the whole national territory).
Mean value has been correlated, for each island, to the highest altitude (in m a.s.l.), area (km^2), distance from mainland (km) and number of species (Spearman test) and compared with insular categories of altitude, surface amplitude and distance from mainland.
For each peninsular transect a correlation has been calculated with the highest altitude (in m a.s.l.), area (expressed as $\log_{10} km^2$, approximated to the IGMI map 1:100000), latitude North and number of species (Spearman test).
Nevertheless, there are some limitation in the methodology.
These are cumulative data obtained, in a number of years, from Atlases, hence they might give an overestimation of the richness (Diamond and May 1977, Minelli 1990) and of the range size (Gaston 1996; ranges of more rare species may lead an over-estimation: Gaston *et al.* 1998b). Moreover, in Italy, some species show "mixed" phenology (Brichetti 1995) and sedentary criteria are not always clear on the islands (Massa 1987). The values of distribution of the species (range size, in %) are limited to the Italian breeding ranges (not to overall range of the species: see Gaston *et al.* 1998b) and are relative to Atlas scale (patterns of range size may be scale dependent: see Gaston 1996 for a review on the methods and limitations). Moreover, the anthropic-historic action must not be underestimated because it certainly had an important role in the modification of range size of the species (Gaston *et al.* 1998a). For these reasons our data must be considered indicative.

Results

Islands

Although no significant correlation has been found between each variable (highest altitude, area, distance from mainland, number of landbird species) and mean range of the species on each small island (Spearman test), trends can be observed when grouping the islands in categories of area (see Methods).
The smallest islands show, on average, the highest values of mean range size (fig. 2).
Rare and localised species are present with lower proportion in the small islands, the contrary happens for widespread species (fig. 3 a,b). Highly widespread species (the largest range size class: >80 % of the Italian territory) are the mode in small islands (<100 km^2), Elba and Sardinia. Increasing the island area, these species decrease in proportion but not in number. Differences

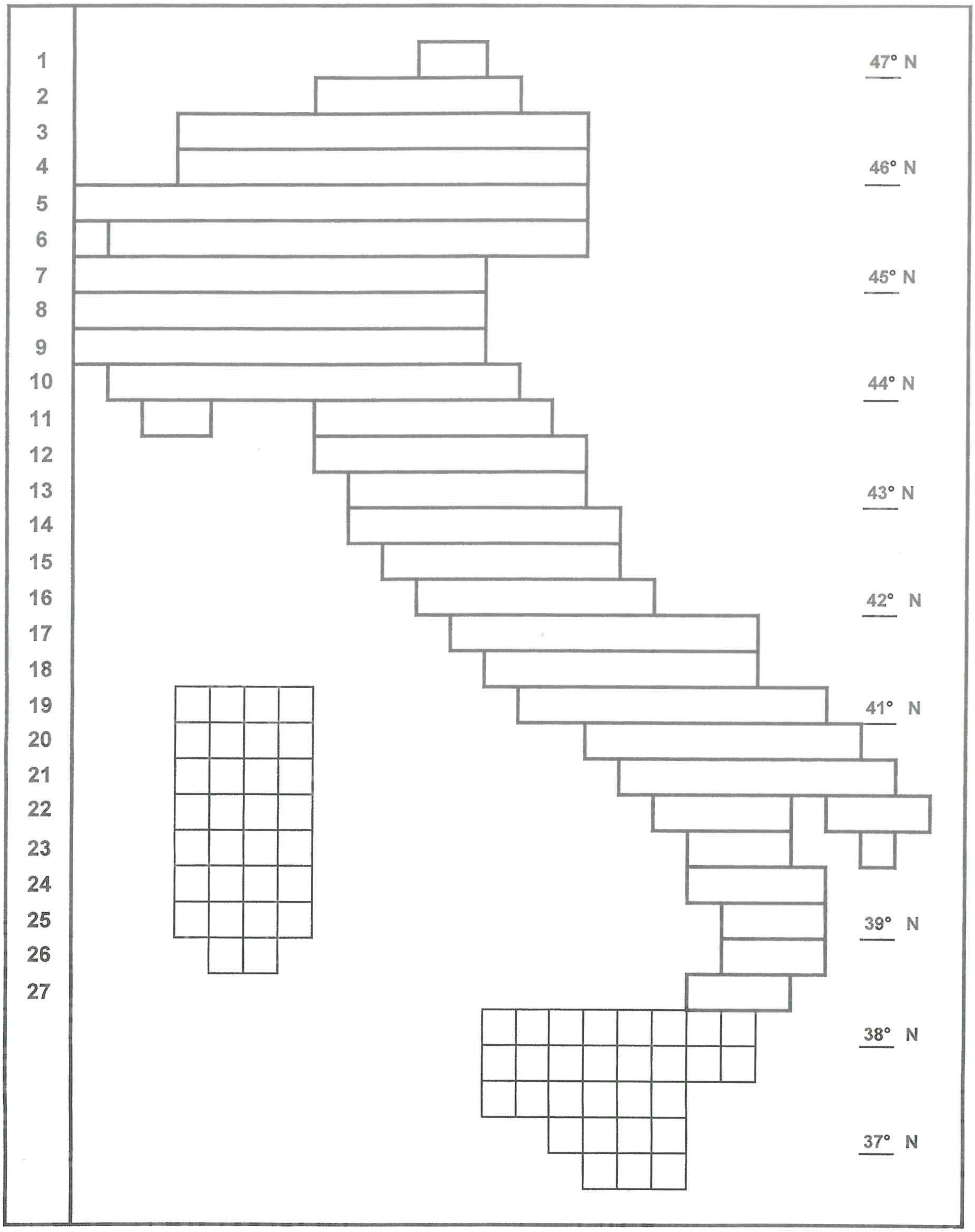

Fig. 1. 1:100000 I.G.M.I. geographic grid of Italy. 1 to 27 : latitudinal transects (bold line).

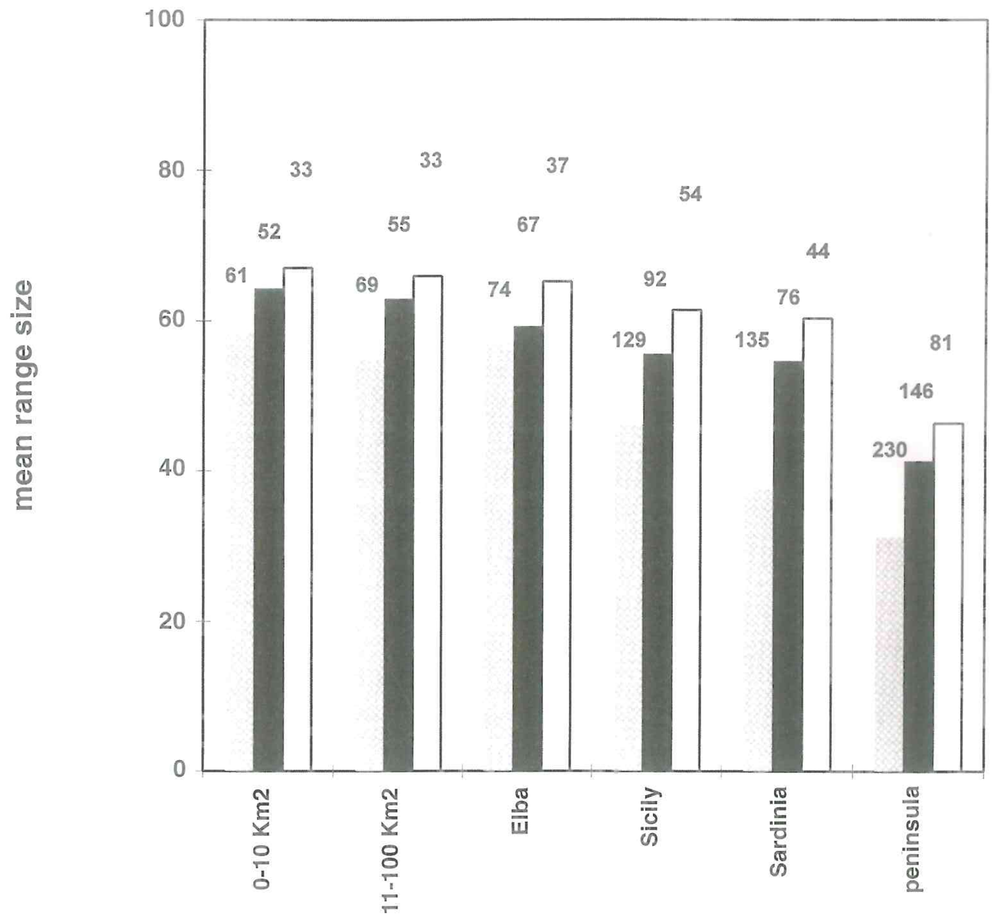

Fig. 2. Categories of island area and peninsula - mean range of distribution. Grey: total number of species; black: landbird species; white: sedentary landbird species. Introduced species excluded. "Secret species" (species whose localisation has not been published in Italian Breeding Bird Atlas for conservational purpose: Meschini and Frugis 1993): data from Boano et al. 1995, Massa 1985, Snow and Perrins 1998. Area < 10 km^2 : Alicudi, Capri, Filicudi, Giannutri, Gorgona, Levanzo, Linosa, Montecristo, Panarea, Ponza, Ustica (min-max values: all the species: 0,74-98,08; landbirds: 9,67-98,08; sedentary landbirds: 11,37-98,08); 11 to 100 km^2: Capraia, Favignana, Giglio, Ischia, Lampedusa, Lipari, Marettimo, Pantelleria, Salina, Stromboli, Vulcano (0,74-98,08; 8,93-98,08; 8,93-98,08); Elba (1,7-98,08; 1,7-98,08; 8,93-98,08); Sicily (0,96-98,08; 2,87-98,08; 7,97-98,08); Sardinia (0,32-98,08; 1,17-98,08; 7,97-98,08); peninsula (0,11-98,08; 0,21-98,08; 0,64-98,08). Numbers are n. of species for each category.

among categories of range size are significant for small islands and peninsula (χ_4^2 test; see text fig. 3a).
The sedentary landbirds, more diffused in average, have a similar trend.
In landbird no evident trend is observable when mean range of distribution is compared with distance from mainland. Nevertheless, considering the total number of species, mean range values decrease with distance (for the higher proportion of the more rare and localised marine species) (fig. 4).
No trend exists with altitudinal categories of the islands.

Peninsula

For each transect the mean range of distribution of the species was inversely correlated to all variables:

– number of species (fig.5): a higher number of rare and localised species are present in the richer transect (generally, with more habitat diversity);
– highest altitude (fig.6): a higher altitude may correspond, generally, to a higher environmental diversity (with higher richness and higher possibility for specialist and localised species: correlation highest altitude-landbird richness: r_s=.78; P<.001);
– area (fig. 7): there is a direct correlation between highest altitude and area of the transect in the Italian orogeographic pattern (r_s=.45; P<.05), that may explain, indirectly, the observed correlation between area and mean range of the species. Area *per se* can give a contribution to this correlation (e.g., larger area, more environmental diversity and richness, more

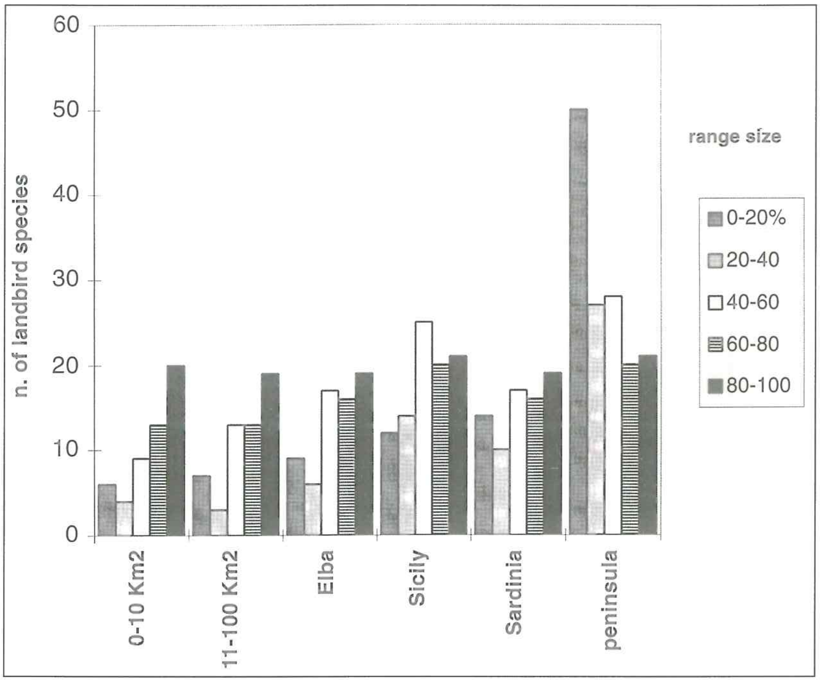

Fig. 3a. Number of landbird species for each range size and insular categories of area (and peninsula). Legend: categories of range size (% of presence of the species on the italian territory: 0-20 % localised species; 80-100 % widespread species). $\chi_4{}^2$ test (for each category): area<10 km^2: $\chi_4{}^2 = 15.5$ P<.01; 11 to 100 km^2: $\chi_4{}^2 = 13.81$ P<.01; Elba: $\chi_4{}^2 = 9.34$ P n.s; Sicily: $\chi_4{}^2 = 6.15$ P n.s.; Sardinia: $\chi_4{}^2 = 3.08$ P n.s.; peninsula: $\chi_4{}^2 = 20.23$ P<<.01.

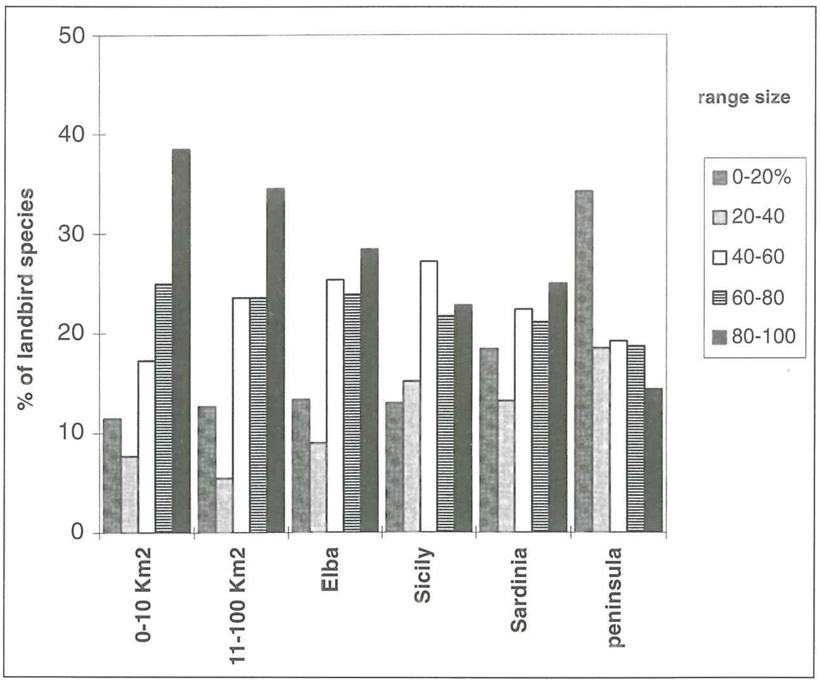

Fig. 3b. Relative frequency (in % on the total of each category). Legend: categories of range size (% of presence of the species on the italian territory: 0-20 % localised species; 80-100 % widespread species).

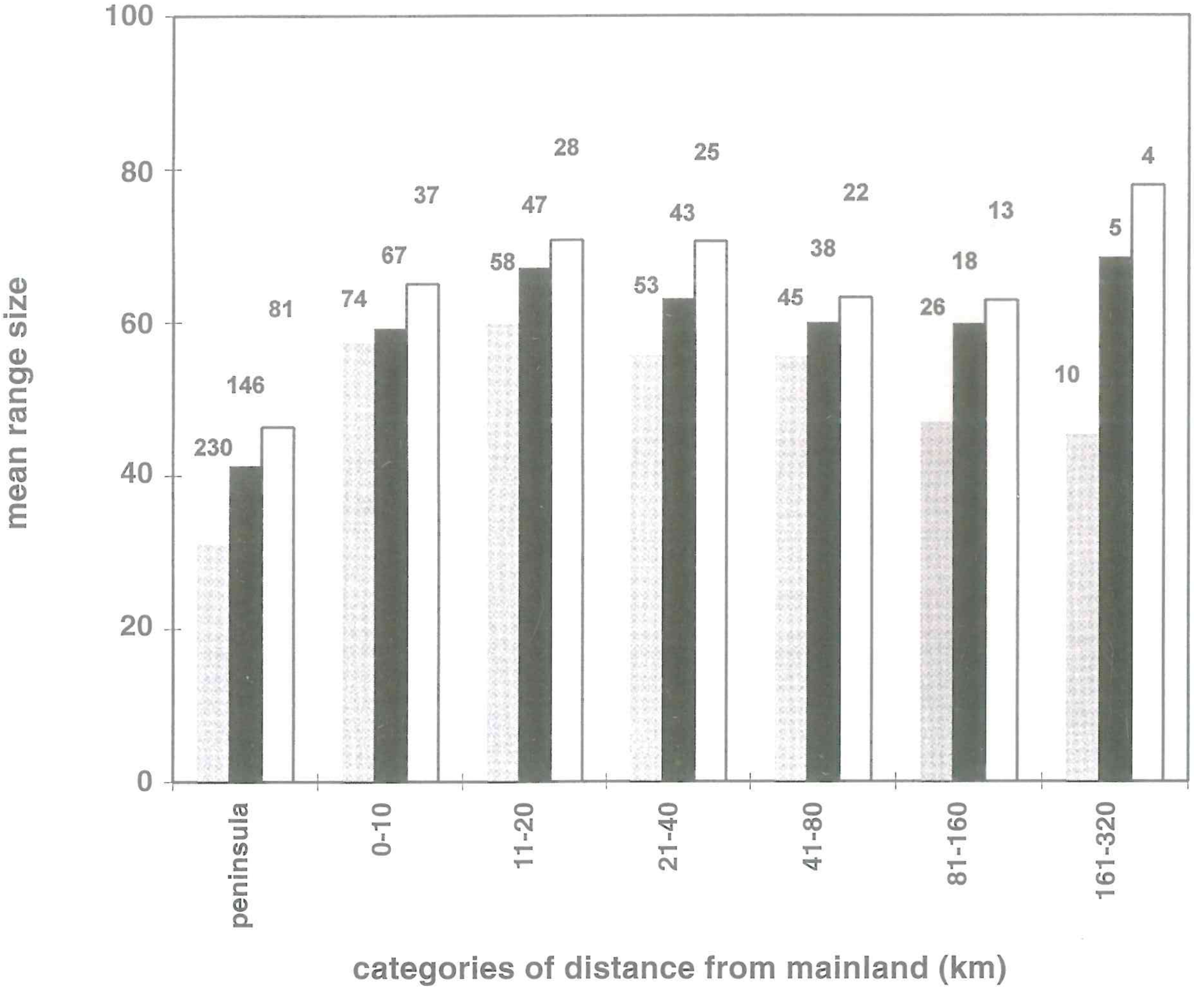

Fig. 4. Categories of distance from mainland (in km) - mean range of distribution (%). Grey: total number of species; black: landbird species; white: sedentary landbird species.Introduced species excluded. "Secret species": see text fig. 2. Distance <10 km: Ischia, Capri, Elba (min-max values: all the species: 1,7-98,08; landbirds:1,7-98,08; sedentary landbirds: 8,93-98,08); 11 to 20: Favignana, Giannutri, Giglio, Levanzo, Vulcano (0,74-98,08; 9,67-98,08; 17,74-98,08); 21 to 40: Gorgona, Lipari, Marettimo, Ponza, Salina (0,74-98,08; 9,67-98,08; 12-98,08); 41 to 80: Alicudi, Capraia, Filicudi, Montecristo, Panarea, Stromboli, Ustica (3,5-98,08; 8,93-98,08; 8,93-98,08); 81 to 160: Pantelleria, Lampedusa (considered distance from Tunisia)(0,74-98,08; 8,93-98,08; 8,93-98,08); >161 km: Linosa (1,27-89,47; 30,92-89,47; 63,65-89,47). Numbers are n. of species for each category.

possibility for rare and localised species: correlation transect area - landbird richness: r_s=.73; P<.001);

– latitude (fig. 8): this correlation may depend, partly, on the above three factors. In fact, in the Italian peninsula highest altitude, area and number of landbirds of the transect decrease with the latitude (r_s=.75, P<.001; r_s=.52, P<.01; r_s=.76 P<.001, respectively).

The sedentary landbirds are, on average, more diffused compared to whole landbirds and have a similar trend (like in islands).

Utilizing the median values, all patterns shows similar trends.

Discussion

Islands

Our results support the concept that the range size of the species may be a variable linked to the insular bird richness.

Insular avifauna is composed, on average, by a higher proportion of widespread landbird species compared to the mainland.

On small islands a high values of the mean range of the species was observed, due to the high frequency of

Tab. I. N. of the transect, Latitude North, highest altitude, area ($\log_{10}$ km^2), n. of landbird species, mean range size (in %), min-max values (in %), n. of sedentary landbird species, mean range size (in %), min-max values (in %).

N	LAT N	highest altitude	area	landbirds	mean range size	min-max values	sedentary landbirds	mean range size	min-max values
1	47°10'	3738	3,51	104	47,46	2,87-98,08	73	46,73	2,87-98,08
2	46°50'	3905	3,98	117	46,90	0,21-98,08	79	48,08	2,87-98,08
3	46°30'	4049	4,28	123	46,48	2,02-98,08	80	48,36	2,87-98,08
4	46°10'	4810	4,28	131	45,07	2,02-98,08	85	46,94	2,87-98,08
5	45°50'	4061	4,38	131	45,12	2,02-98,08	84	47,45	4,14-98,08
6	45°30'	3676	4,35	130	45,20	0,21-98,08	85	46,82	2,87-98,08
7	45°10'	3303	4,28	130	44,84	1,70-98,08	83	47,23	2,87-98,08
8	44°50'	3841	4,28	129	45,50	1,70-98,08	83	47,83	2,87-98,08
9	44°30'	3297	4,28	114	49,70	1,17-98,08	71	53,37	4,14-98,08
10	44°10'	1654	4,28	110	50,81	2,87-98,08	69	54,58	2,87-98,08
11	43°50'	1701	4,05	110	50,91	1,17-98,08	69	54,57	2,87-98,08
12	43°30'	1576	4,11	104	52,54	1,17-98,08	67	55,51	2,34-98,08
13	43°10'	2478	4,05	115	49,30	1,17-98,08	72	52,76	2,87-98,08
14	42°50'	2912	4,11	122	47,13	1,17-98,08	76	50,54	2,34-98,08
15	42°30'	2795	4,05	121	47,86	1,17-98,08	77	50,60	2,34-98,08
16	42°10'	2283	4,05	121	47,64	0,64-98,08	78	49,92	0,64-98,08
17	41°50'	2050	4,16	115	49,62	2,87-98,08	74	51,98	2,87-98,08
18	41°30'	1533	4,11	101	53,19	1,17-98,08	62	58,51	4,36-98,08
19	41°10'	1899	4,16	106	52,25	2,34-98,08	67	55,89	2,34-98,08
20	40°50'	1836	4,16	109	51,15	1,17-98,08	69	54,58	2,34-98,08
21	40°30'	2005	4,16	108	51,05	2,34-98,08	69	53,89	2,34-98,08
22	40°10'	2267	4,05	79	59,64	9,67-98,08	53	62,68	11,15-98,08
23	39°50'	1785	3,81	91	55,92	2,34-98,08	58	59,28	2,34-98,08
24	39°30'	1928	3,81	95	55,61	5,21-98,08	61	58,91	10,41-98,08
25	39°10'	1013	3,68	79	60,27	10,41-98,08	52	63,92	10,41-98,08
26	38°50'	1423	3,68	67	64,51	10,62-98,08	49	65,90	11,15-98,08
27	38°30'	1956	3,68	76	61,12	6,06-98,08	52	62,91	10,41-98,08

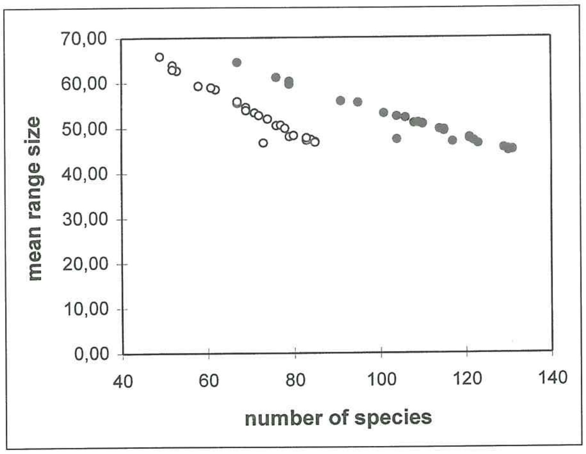

Fig. 5. Number of species of the transect - mean range of distribution (%) diagram (italian peninsula). • = landbirds ($P<.001$; r_s= -.95); ○ = sedentary landbirds ($P<.001$; r_s=.-95).

widespread (eurytopic and euryecious) species. This may be explained by ecological reasons (low habitat availability, absence of suitable resources, etc.) and by dispersal factors, affecting also the richness (*e.g.*: Power 1971; Reed 1985).

The largest islands show the presence of many more species and, among them, of more strictly distributed ones, compared to smaller islands, probably due to the higher diversity of habitats (Blondel 1985, Massa 1987): this decreases, in largest islands, the mean range values.

Locally distributed landbird species (stenotopic and

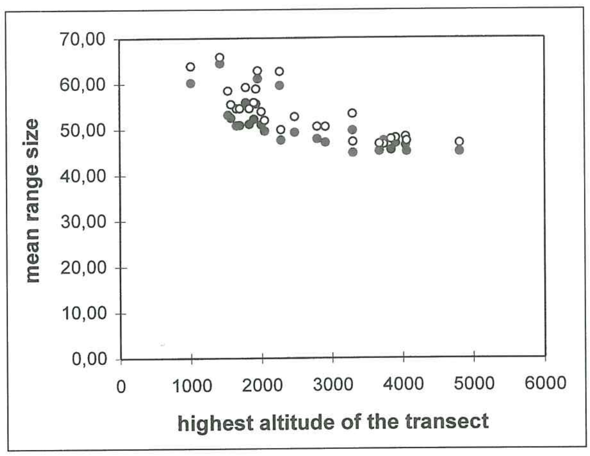

Fig. 6. Highest altitude of the transect (m a. s. l.) - mean range of distribution (%) diagram (italian peninsula). • = landbirds ($P<.001$; r_s= -.86); ○ = sedentary landbirds ($P<.001$; r_s= -.84).

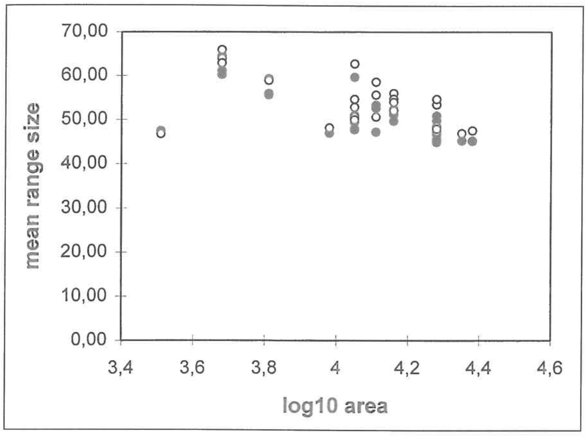

Fig. 7. Area of the transect (in $\log_{10}$ km^2, approximated to the IGMI map 1:100000) - mean range of distribution (%) diagram (italian peninsula). • = landbirds (P<.01; r_s= -.63); ∘ = sedentary landbirds (P<.01; r_s= -.51).

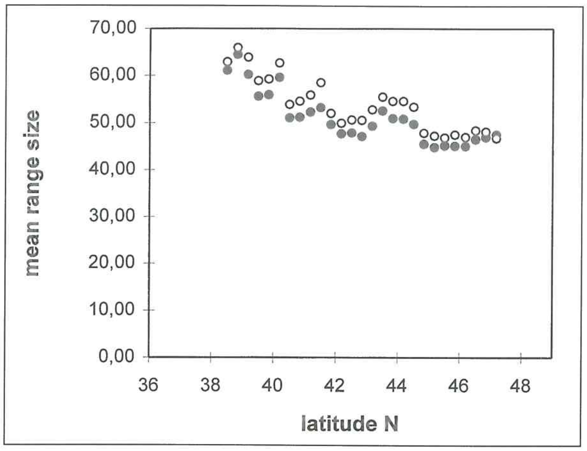

Fig. 8. Latitude North - mean range of distribution (%) diagram (italian peninsula). • = landbirds (P<.001; r_s= -.87); ∘ = sedentary landbirds (P<.001; r_s= -.89).

stenoecious) have, in general, less probability to find their habitat on the islands; moreover, the sea may be a barrier for the less vagile (and more rare and localised) landbirds (for ethological reasons as well; Diamond 1981).

This agrees, for Italy, with the results of Massa and Schenk (1983) and Catalisano and Massa (1986). Massa and Di Palma (1988) have pointed out that landbird species of new colonization in circum-sicilian islands are in expansion in Sicily.

Our data confirm Lebreton and Ledant (1980) results for the large mediterranean islands, utilizing the similar "Index of Geographic Amplitude"; Covas and Blondel (1998) showed that the only significant differences in species-specific attributes between mainland and island are a larger geographic amplitude of species present on islands (see also Blondel 1985). Jarvinen and Ranta (1987) observed that most of the absent species on the Northern Baltic islands are rare on the mainland. Lack (1976) observed that most of the breeding landbirds in Ireland are widespread in Great Britain (see also Martin 1983 for a Finnish archipelago). Adler (1994), studying tropical Indian avifauna, pointed out that only the widespread and species-rich families have been able to colonize the most remote archipelagos.

Peninsula

Decrease southward of mean range of the distribution found in peninsular transect could be explained, generally, by ecogeographical factors that influence also the richness.

Along the peninsula mean range of the species is highly correlated with the number of landbird species, higher altitude, area and latitude of the transect.

In the Italian context, area, altitude and latitude are strictly correlated to each other (see results) and affect the number of species (see below). The values of the mean range size of the species reflect this trend.

Transects with more extended area and more elevation have, generally (at least in peninsular Italy), a higher habitat diversity and richness (with more rare and localised species which decrease mean range size).

Considering the latitude, the decrease, towards South, of peninsula breadth and altitude, and, consequently the decrease of habitat diversity, may explain, partially, the avifaunistic impoverishment.

In Italy a faunistic richness gradient along the latitude is well known (Massa 1982, Battisti and Contoli 1997), also on ecological grounds (*e.g.*, in micromammals: latitudinal gradient of ecological parameters; Contoli 1991, Contoli *et al.* 1985, Battisti *et al.* 1997). This richness gradient may affect the mean range size of the species.

Northern transects, have a lower value of mean range size (more area, more habitat diversity, more richness and higher proportion of stenotopic species). In Italy, more than half of the localised landbird species (range size < 20 % of the territory: N=49) are typical of wetlands and/or alpine habitats (N=27), which are more frequent northward. This reduces the mean value of range size in northern areas.

High correlation between number of species and mean range size can be also explained by frequency distribution of the species in range size classes, highly asymmetric, if untrasformed (see Rapoport 1982, Anderson 1985, Gaston 1996, Gaston *et al.* 1998b). In peninsular Italy, there are more localised (stenotopic) than widespread (eurytopic) landbird species (fig. 3a: peninsula). Consequently, transects with more species may have, generally, more rare and localised ones (and lower mean range values). Lebreton and Ledant (1980) showed high relationship between number of species and "Index of Geographic Amplitude" in the Mediterranean area.

Data relative to a specific parameter, such as mean range of distribution, can be inserted, indirectly, in the general debate on the "peninsula effect" (Simpson 1964; for a review see, *e.g.*, Brown and Opler 1990, Tackaberry and Kellman 1996).

On a global scale, Stevens (1989) observed that the mean range of the species is directly related to the latitude (Rapoport's rule; Rapoport 1982), although some exceptions are known (Gaston *et al.* 1998a) and one single explanation is adequate to explaine this rule (Gaston *et al.* 1998a). Species of low latitudes have, generally, a range size more restricted, are more sedentary and specialist and have lower dispersal ability than those of higher latitudes (Diamond 1973, Abbott and Grant 1976; smaller range size allow more species to "pack-in": Stevens 1989 in Blackburn *et al.* 1997).

Our results do not support this trend. This apparent contrast with the Rapoport's rule is probably a local feature linked to peninsular ecobiogeography and to the low latitudinal range analysed.

The latitudinal richness gradient observed in peninsular Italy (decrease towards South, see above), for local complex causes (oro- and ecobiogeography, hystory, climate, isolation, etc.), is in countertendency compared to latitudinal trend on global scale (increase of the richness towards tropics: *e.g.*, Fischer 1959, Cook 1969, Blackburn and Gaston 1996, etc.). This anomalous pattern is linked with latitudinal range size gradient (decrease of mean range size towards tropics; Stevens 1989), opposite to general trend in Italy (increase towards South; this work). Conseguently, these data are in addition to general debate on the range-size and richness patterns and underline the biogeographic peculiarity of the Italian peninsula, compared with the latitudinal trends on different scale.

Although these analyses may be affected by some limitations and, consequently, these data are preliminary and indicative, it is important point out that the elaboration of Atlas' data, may give useful ecobiogeographic suggestions.

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