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Diversity of small mammal communities of the Tuscan Archipelago: testing the effects of island size, distance from mainland and human density

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Abstract. Barn owl pellets were analyzed for comparing the small mammal fauna among three islands of Tuscan archipelago, Italy. Rarefaction analyses and diversity analyses were used on barn owl pellet samples at a total of 18 sites. *Apodemus sylvaticus* appeared the most abundant species in Elba and Capraia, and *Mus musculus* in Pianosa. Diversity profiles showed that Pianosa and Elba were very similar in terms of dominance and evenness profiles, whereas Capraia had higher dominance and lower evenness. Using our original data and literature review, we found that 5 species are found in Pianosa, 1 in Giannutri, 0 in Montecristo, 5 in Giglio, 7 in Elba, 6 in Capraia, and 1 in Gorgona. There was no effect of island area, human population size, or linear distance from mainland on species richness.

Key words: mammals, faunal composition, Mediterranean, owl pellets, Italy

Introduction

The knowledge of the small mammals of the Tuscan Archipelago (Tyrrhenian Sea, central Italy) is still fragmentary and anyway not available for all islands. Comparatively, the bulk of information comes from the island of Elba, such as Üttendörfer (1952) on the diets of the Griffon vulture and little owl, Vesmanis & Hutterer (1980), Vesmanis & Vesmanis (1980), and Contoli et al. (1988) on the diets of nocturnal bird of prey, up to Szpunar et al. (2008) on the same subject. For the other islands, only sporadic data are available, for a summary of sightings, see Angelici et al. (2009). The aim of this paper is to provide an updated overview of the knowledge of small mammals (Soricomorpha and Rodentia) in the islands of the Tuscan Archipelago (for two of these islands, i.e. Pianosa and Capraia, there were no data on mammals species before this study), and to use barn owl pellets for comparisons of the small mammal fauna among the islands of Tuscan Archipelago. More explicitly, we test whether there was any effect of (1) island size, (2) its distance from mainland, and (3) human population size, on species richness and diversity indices. These factors are certainly important in the light of (i) island biogeography theory (factors (1) and (2); see McArthur & Wilson 1963), and in the light of the deep human intervention that has characterized the islands of the Tuscan Archipelago, and the Mediterranean islands in general, since centuries (factor (3); see Masseti 2009a, b).

Material and Methods

The field study was carried out in three islands of the Tuscan Archipelago, that is a chain of islands between the Ligurian Sea and Tyrrhenian Sea, west of Tuscany, Italy (Fig. 1). The archipelago contains the islands of Gorgona, Capraia, Elba (the largest island of the group), Pianosa, Montecristo, Giglio, and Giannutri. All of these islands are protected as part of the Tuscan Archipelago National Park. Our field data were collected at several roosts of Elba, Capraia, and Pianosa, whereas surveys at Giglio did not provide

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any data because no barn owl roost was detected. More specifically, barn owl pellets were collected at one site of Pianosa, one site of Capraia and three sites of Elba islands during multiple samples (data collected by one of us, RP) (see Table 1).

Fig. 1. Map of the Tuscan Archipelago.

For the analysis of the pellets, we used the dry method: pellets were opened along the lines of fracture and skulls (or their fragments) and jaws were taken. The determination of the bone material was carried out through observation of the material to the stereo-binocular microscope, using the keys proposed by Chaline et al. (1974), Toschi (1965) and Amori et al. (2008).

For each species of small mammals, separate counts were taken for right and left maxillary and mandibular hemiarchs. For enumeration of each species, we considered only the largest group (or mandibles or jaws), and we used as the final value the highest number between the two sides.

In order to make a comprehensive checklist of small mammal composition for each island, we complemented the original data surveys with available literature.

We used rarefaction analysis to compare all diversity indices to the same number of individuals sampled, and based on this analysis, it was clear that a plateau phase was reached as for the whole archipelago, despite the samples of the various single sites were not equally reliable (Fig. 2A, B). The following indices of prey species diversity were calculated: 1) species richness (Taxa S), that is the total number of taxa recorded during either the wet or the dry season; 2) evenness, calculated by Pielou formula; 3) Simpson index; 4) Shannon index; and 5) Chao 1 bias corrected index,

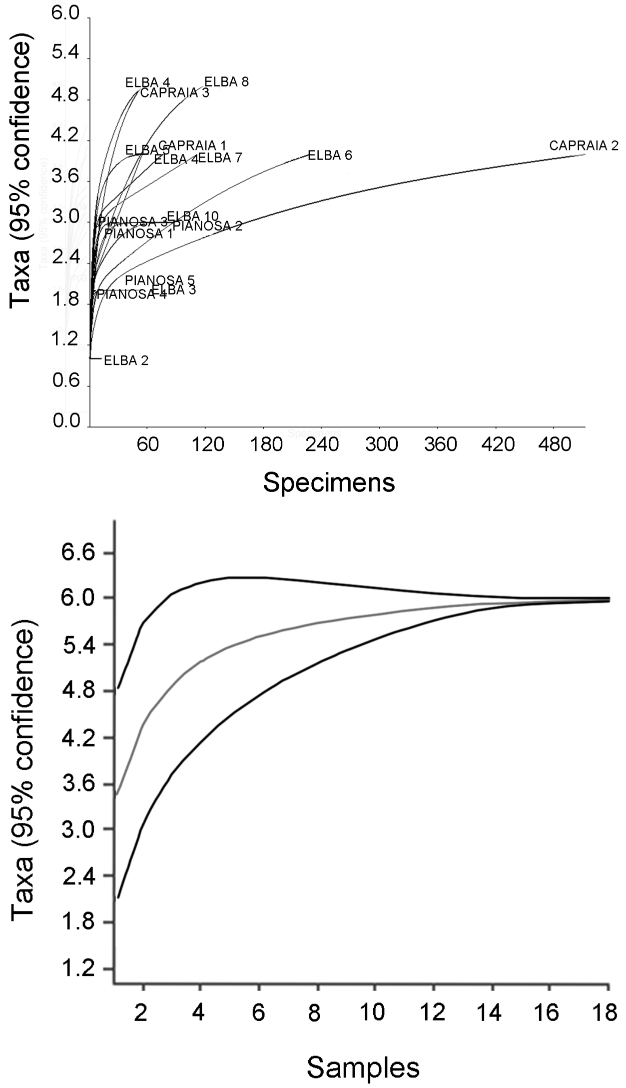

Fig. 2. Rarefaction curve comparing individuals samples at the various sites (upper), and overall (lower).

and 6) Dominance index (see Magurran 1988 for the formulas). Statistical differences among islands in terms of diversity indices were calculated using bootstrapping procedures. More precisely, upper and lower confidence limits of the estimates for the above-mentioned indices were calculated by 10000 bootstraps, with all random samples being produced with the same total number of individuals as in each original sample. The random samples were taken from the total, pooled data set (i.e. with dry and wet season counts cumulated). For each individual in the random sample, the taxon was chosen with probabilities according to the original abundances calculated on the pooled data set. A 95 % confidence interval was then calculated. Comparisons between frequencies of occurrence of the various prey species from original field surveys and literature were made by contingency

Table 1. Synoptic table summarizing the original data collected in the present study.

Island	Precise locality of owl roosts	Dates	*S. etruscus*	*C. suaveolens*	*G. glis*	*A. sylvaticus*	*M. musculus*	*R. rattus*
PIANOSA	Cheese factory	11/07/2013	9				18	4
PIANOSA	Cheese factory	27/04/2013	8				63	18
PIANOSA	Prison (lateral building)	18/10/2013				2	1	3
PIANOSA	Prison (Judge's palace)	18/10/2013				1		2
PIANOSA	Prison (gymnasium)	17/10/2013					8	2
Total			17	0	0	3	90	29
ELBA	La Zanca	28/04/2013				3		4
ELBA	Marciana	28/04/2013				13		
ELBA	Mortigliano	27/04/2013				32		20
ELBA	Mortigliano	08/07/2013	1	2		40	3	9
ELBA	Rio nell'Elba	09/07/2013		1		34	23	18
ELBA	Poggio cemetery	09/07/2013		2	1	180		46
ELBA	Mulinaccio	08/07/2013		1		53	15	43
ELBA	Calcinaio S. Stefano	12/12/2013	1	3		55	2	57
ELBA	Cala Seregola (mines area)	12/12/2013		3		48		31
ELBA	Cala Seregola (mines area)	Sept. 2013	1	1		31		22
Total			3	13	1	489	43	250
CAPRAIA	Abandoned Penal Settlement	04/12/2013		3		32	14	14
CAPRAIA	Cemetery	19/11/2013		3	1	458		51
CAPRAIA	Abandoned Penal Settlement	04/12/2013	2	2		25	12	22
Total			2	8	1	515	26	87

table χ^2 test. A General Linear Model (GLM) was designed to assess the effects of island area (km^2), human population size (number of inhabitants as in 2012), and linear distance from the mainland (km) on the species richness per island. The intercept term was included in the model. The GLM was designed assuming that the overall sample was accurate (as showed by the curve plateau in Fig. 2B).

All statistical analyses, including rarefaction analyses, were performed with a PAST statistical software, apart GLM which was performed wit PASW 18.0 statistical software. In all cases, tests being two-tailed and alpha set at 5 %.

Results

Original barn owl pellet data

The synoptic survey of collected data is given in Table 1. The relative percent frequency of individual species across surveyed islands is given in Fig. 3. The frequencies of occurrence of the various species differed significantly across islands (χ^2 = 132.1, P < 0.005). *Apodemus sylvaticus* was by far the most abundant species in Elba and Capraia, whereas *Mus musculus* dominated the sample in Pianosa (Fig. 3). A dendrogram analysis revealed that three clusters of species are found (Fig. 4). Diversity profiles showed that Pianosa and Elba were very similar in terms of dominance and evenness confidence intervals profiles, whereas Capraia, despite having the same species richness as Elba, showed a significantly higher dominance (P < 0.05) and a significantly lower

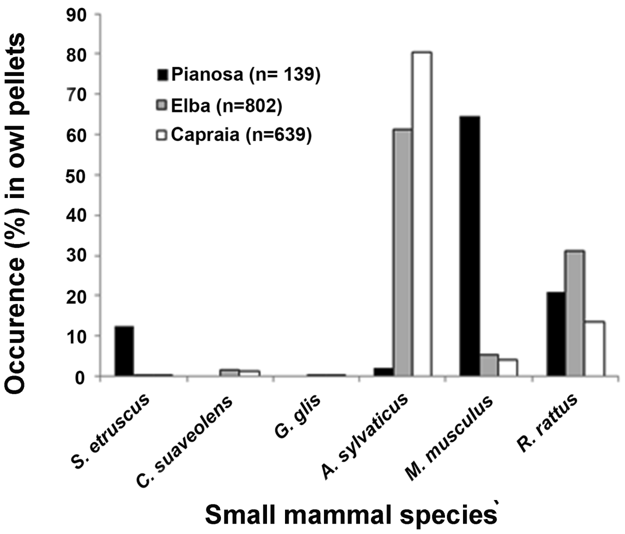

Fig. 3. Frequency of occurrence (%) of small mammal remains in barn owl pellets in the Tuscan Archipelago.

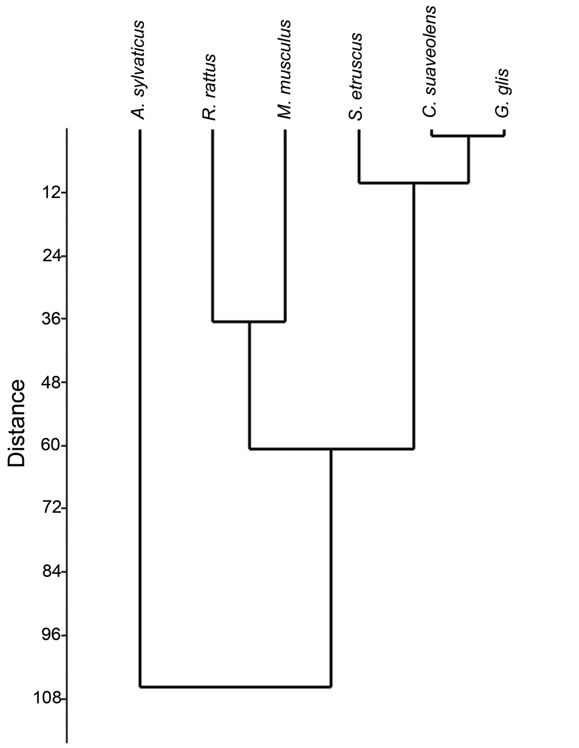

Fig. 4. Dendrogram (Ward's method with Euclidean distances) showing the dissimilarities among small mammal species in terms of their relative frequency of occurrence across islands.

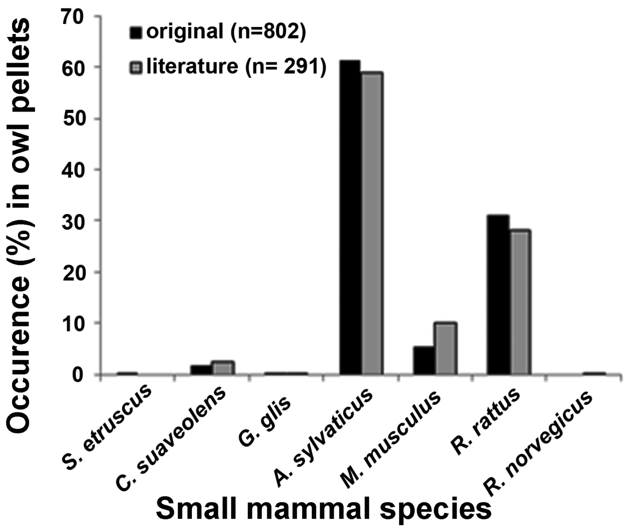

Fig. 5. Comparative frequency of occurrence of small mammal items in barn owl pellets at Elba, based on original data and Contoli et al. (1988).

evenness ($P < 0.01$) when comparing the estimates (Table 2).

Comparisons between original and published datasets

A quantitative comparison between our original data and literature data can be done only for Elba, using

Table 2. Diversity indices (including upper and lower 95 % confidence intervals) for the three studied islands, based on the frequency of occurrences of the small mammal species in the barn owl pellets.

	Pianosa			Elba			Capraia		
	estimate	lower	upper	estimate	lower	upper	estimate	lower	upper
Taxa_S	4	4	5	6	4	7	6	4	7
Dominance_D	0.4775	0.3062	0.4164	0.4763	0.3046	0.4118	0.6684	0.306	0.4109
Simpson_1-D	0.5225	0.5832	0.6934	0.5237	0.5868	0.6952	0.3316	0.5883	0.6936
Shannon_H	0.95	1.041	1.29	0.9162	1.038	1.293	0.6632	1.041	1.297
Evenness_e^H/S	0.6465	0.6014	0.8633	0.4166	0.6044	0.8643	0.3235	0.6018	0.8636
Chao-1	4	4	5	6	4	5	6	4	6

Table 3. Results of the General Linear Model on the effects of human population size, island size (km^2), and distance (km) from the mainland on the species richness of small mammals in the various island of the Tuscan Archipelago. Species richness was the dependent variable.

Source	Type III Sum of Squares	df	Mean Square	F	P
Corrected Model	23.469[a]	3	7.823	1.350	0.406
Intercept	13.493	1	13.493	2.328	0.224
Human population	9.312	1	9.312	1.607	0.294
Distance from mainland	7.474	1	7.474	1.290	0.339
Island area (km^2)	10.201	1	10.201	1.760	0.277
Error	17.388	3	5.796		
Total	161.000	7			
Corrected Total	40.857	6			

[a] $R^2 = 0.574$ (Adjusted $R^2 = 0.149$).

Contoli et al. (1988). Overall, the relative frequencies of occurrence of the various species did not differ significantly between Contoli et al. (1988) and our samples ($\chi^2 = 2.54$, df = 6, P = 0.864). Nonetheless, one species was recorded only in our samples (*S. etruscus*) and one only in Contoli et al. (1988) samples (*R. norvegicus*) (Fig. 5).

Comparisons of faunistic assemblages across islands
Updated information on the presence/absence of small mammals in all islands of the archipelago revealed that five species are found in Pianosa (i.e. *S. etruscus*, *A. sylvaticus*, *R. rattus*, *R. norvegicus*, *M. musculus*), one in Giannutri (*R. rattus*), no in Montecristo (after the recent eradication of *R. rattus*, finished in 2012), five in Giglio (*C. suaveolens*, *A. sylvaticus*, *R. rattus*, *R. norvegicus*, *M. musculus*), seven in Elba (*C. suaveolens*, *S. etruscus*, *G. glis*, *A. sylvaticus*, *R. rattus*, *R. norvegicus*, *M. musculus*), six in Capraia (*S. etruscus*, *C. suaveolens*, *G. glis*, *A. sylvaticus*, *R. rattus*, *M. musculus*), and one in Gorgona (*R. rattus*). A GLM design showed that there was no effect of either island area, human population size, or linear distance from the coast on the species richness per island (Table 3).

Discussion

Our study provided quantitative information on the small mammal communities of three islands of the Tuscan Archipelago, whereas it was not possible to obtain original data for the islands Gorgona, Giannutri and Giglio. It is suggested that it would be appropriate to carry out additional well-focused field research in Giglio because of its relatively large surface (24 km^2). A surprising result of our own field research was in that Capraia, despite its small size (19 km^2), showed a community of small mammals (six species) similar to that of Elba (224 km^2, seven species). Equally surprising was the discovery of dormouse (*Glis glis*) among the prey of barn owl in Capraia. We suggest that both the above-mentioned findings deserve further confirmation through direct field sightings on the local presence of these species (and particularly *G. glis*). Only dormouse specimen found in the present study may have been preyed upon by a barn owl in Elba island or in Corsica (respectively located at 33 and 27 km distance from Capraia), the same being true of course also for some of the other species. Indeed, it has been demonstrated that the barn owl can make long distance to go to catch prey (Bunn et al. 1982, Guerra et al. 2014), and the distances between the islands of the Tuscan Archipelago (range 13-75 km) are possibly compatible with this hypothesis. Accidental (passive) human introduction can be also another explanation for our record of *G. glis* from Capraia. In addition, the high dominance of commensal species (*Mus musculus* and *Rattus rattus*, overall accounting for 86 % of the total sample) could be explained by the fact that these samples were collected around a cheese factory. However, the small size of the island might mean that all owls in this island may have access to every habitat present in the island.
Interestingly, dominance index was very high in Capraia, which also showed a low evenness of barn owl dietary niche as compared to the other studied islands. It is likely that the high dominance index value for Capraia depended on the fact that the small mammal community is characterized by a preponderance of *Apodemus sylvaticus* in the maquis habitats of this island. Unfortunately, however, no field trapping surveys of small mammals are available to date to confirm this hypothesis.
The non-effects on species richness of island area, human population size, and linear distance from mainland could be explained by the history of human colonization and agricultural practices of the various islands (Sarà 1998). Therefore, the eventual biological effects predictable on the basis of island colonization theories (e.g. McArthur & Wilson 1963, Simberloff 1976, Ricklefs 1982) could not be confirmed in the case under study. Interestingly, previous studies on birds (Massa 1985), amphibians and reptiles (Massa & Di Palma 1988, Parlanti et al. 1988), and mammals (Sarà 1998) also showed that MacArthur & Wilson's (1963) theory fails in continental islands in terms of species-area relationships. Alternatively, it is also possible that the observed insular patterns were shaped by the hypothesis of Sarà & Morand (2002), who suggested that mammals with a high density compared to the density/mass relationship are the best invaders and/or probably have less chance of going extinct on small islands when population size is small.

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