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Trophic niche and feeding biology of the Italian wall lizard, *Podarcis siculus campestris* (De Betta, 1857) along western Mediterranean coast

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Abstract. Trophic niche of the Italian wall lizard was studied at three different sites in Tuscany (central northern Italy), two along the Mediterranean sea, one inland. Fecal pellet analysis was carried out on 71 pellets (37 of male and 34 of female adult lizards), accounting on the whole for 184 prey items. Coleoptera, Hymenoptera (ants), Araneae and Gastropoda were the most represented taxa (numerical abundance of ca 22, 7, 7, 6% respectively). We found Brillouin diversity index similar in females and in males, with a marked overlap between sexes, but differences in niche overlapping among localities. Diet spectrum was quite different with that found in other central Italy localities, in the Tuscan Archipelago, or in areas where *P. siculus* has recently introduced. Our study confirms the opportunistic pattern and adaptability of this lizard species, and increases the range of sampled localities within the species' range.

Keywords. Italian wall lizard, *Podarcis siculus,* diet, feeding ecology, western Tuscany, Italy.

The Italian wall lizard, *Podarcis siculus*, is very spread in Italy and Dalmatia (Corti et al., 2011), assessed by IUCN as near threatened (Crnobrnja-Isailovic et al., 2008), and protected by European, regional and local laws. Despite well known for distributive and faunistical data set (Henle and Klaver, 1986; Corti, 2006; Vanni and Nistri, 2006; Corti et al., 2011) it is a relatively less studied species (Herrel et al., 2008; Biaggini et al., 2009).

Feeding ecology is relatively much more studied. Diet ranges from insects, spiders to small terrestrial crustaceans (see Henle and Klaver, 1986 and literature therein). On average, variability in feeding ecology has been found as habitat dependent on geographical position and ecological conditions (e.g., continental vs insular; Pérez-Mellado and Corti, 1993) or according to season and to local prey fauna composition (Rugiero, 1994). When Arthropod preys are scarce, *P. siculus* may integrate its diet with small molluscs, plant matters (plants, seeds, fruit; Pérez-Mellado and Corti, 1993). Exceptionally, large individuals may prey upon conspecifics, mainly hatchlings (Rugiero, 1994; Grano et al., 2011), but also to other lizard species or small mammals (Capula and Aloise, 2011).

Variability of feeding ecology of *Podarcis siculus* has been tested on some localities (Ouboter, 1981; Sorci, 1990; Capula et al., 1993; Perez-Mellado and Corti, 1993; Rugiero, 1994; Bombi and Bologna, 2002; Salvador, 2006; Herrel et al., 2008). Recently, Herrel et al. (2008) found that an introduced population in a small island of the Dalmatian coast, with different habitat structure and scarcity of prey taxa, rapidly evolved, modifying the alimentary tract with the formation of intestinal caeca (as in typically herbivory reptiles) and adapting body structure (fore and hind limbs ratio on snout to vent length) to the new habitat. Due to the species' wide distribution, it is worth-studying diet variability in many different contexts (see Perez-Mellado and Corti, 1993). In this paper we are aimed at testing i) variability in trophic niche of *P. siculus* along multiple sites and ii) comparing differences in diet, if any, with the other known studied Italian populations.

Sampling localities were in western and central Northern Tuscany. We sampled lizards in March-June 2009 in Lucca (Viareggio-Lecciona, 43°50'47"N, 10°14'52"E), and in Pisa (San Rossore, within the Region-

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al natural “Parco di Migliarino San Rossore Massaciuccoli”, 43°43’11”N, 10°16’41”E) province. We sampled in March-June 2008 and 2009 in Pistoia (Lamporecchio and Casalbosco, 43°56’29”N, 10°59’52”E) province. Sampling areas in Lucca and Pisa provinces represented coastal samples, while the Pistoia area represented a continental area. In Lucca and Pisa sites, *P. siculus* was the unique lizard present; in Pistoia sites, *P. muralis* and *L. viridis* were also present.

Fecal pellets were collected at lizard capture. After measurement (snout to vent length, body mass), the animal was then released at the capture point. We collected 71 pellets (37 of male and 34 of female adult lizards): 14 from Lucca, 32 from Pisa and 25 from Pistoia. Each sample was analyzed under stereomicroscope, determining prey composition at the lowest taxonomical rank as possible (Order), with assistance of a specialist of main taxa (see Acknowledgments).

Data obtained from fecal pellet analysis were used to describe the trophic niche width (diversity niche index and niche overlap). As Shannon-Wiener H’ index assumes random sampling, which is quite doubtful since diet selection has been reported for different lacertids (see Carretero, 2004 and references therein), we preferred to measure the species diversity using Brillouin index, suitable for non-random samples, and Simpson diversity indices. Brillouin index considers the total number of species and the frequency with which individuals are distributed within a species. High Brillouin index values underline an increase of specific diversity in the considered community. Simpson’s high index values (as reciprocal) indicate an higher width in resources use (e.g., many resources are used with high frequency). Both indices were used to compare our data with other data set and references.

Trophic niche overlapping of males and females, and among areas (sampled sub-groups of the coastal vs continental areas) was calculated with Morisita’s overlap indices. We tested the overlapping degree or the exclusion degree in prey types by males and females and overlapping or exclusion between sexes of the considered areas.

To calculate width and overlapping values, we used the free source software Bio-DAP (Thomas, 2000). Bio-DAP calculates diversity indices that correspond to those shown by Magurran (1988). Analyses were not performed on the unidentified groups (see Results). Parametric and non parametric analyses were performed with SPSS 13.0, two tailed with α at 0.05.

On average, in *Podarcis siculus* pellets, we found 17 different groups, accounting for 277 items: Coleoptera, Orthoptera, Hymenoptera, Hemiptera, Blattoidea, Dermaptera, Diptera, Aracnida (Aranaea), Anellida, Gastropoda, Reptilia, insect wings (thereafter Insects), furs, plant matters, sand, unidentified Arthropoda, unidentified matters (Table 1). Within Coleoptera, the identified families are Aphodiidae (*Brindalus porcicollis*), Curculionidae, Carabidae, Chrysomelidae, Tenebrionidae, Cerambycidae, Staphylinidae (Carabidae and Curculionidae more abundant). Among Hymenoptera, only the family Formicidae.

Brillouin diversity index was 1.80 and 1.95 respectively for males and females, and niche overlap was 0.952 (CmH, similarity Morisita-Horn, Bio-DAP). These indices underlined a strong similarity and a marked overlap, respectively, in the trophic spectrum between sexes (Table 2). More in depth, the trophic niche as resulting from Simpson’s index on 15 suitable categories was 0.181 for males and 0.138 for females, and reciprocal was 5.513 and 7.225 respectively. Considering sampled matters divided per sex, we did not find any significant difference (nine prey categories with $n > 5$, and sex, with a $\chi 2 = 8.141$, 8 df, NS), suggesting the absence of any sexual preference in diet in these populations of the Italian wall lizards.

For the observed similarity of diet of the two sexes, we merged all sampled data, dividing them among the three main sites (Table 3): Lucca, Pisa and Pistoia ($n = 47$, 120 and 88 respectively). We firstly tested data normality in sampling effort (normality test, $Z = 1.11$, $P = 0.17$, NS), and any difference in prey and items distribution, finding slight differences only for Lucca-Pisa (ANOVA, $F = 2.845$, $P = 0.078$, 2 df, LSD post-hoc test P =

Table 1. Frequency of predated categories on the total sample of *Podarcis siculus.*

Category	n	%
Coleoptera	61	22.022
Orthoptera	11	3.972
Hymenoptera	22	7.942
Hemiptera	5	1.805
Blaptoidea	1	0.361
Dermaptera	1	0.361
Diptera	1	0.361
Insects	21	7.581
Araneae	19	6.859
Anellida	1	0.361
Gastropoda	17	6.138
Reptilia	3	1.083
Hairs	11	3.971
Vegetals	1	0.361
Sand	9	3.249
unidentified Arthropoda	36	12.996
Unidentified material	57	20.577
Total	277	100

Table 2. Diversity and similarity indices in *P. siculus* samples (Roman numbers denote a diversity rank; I = higher).

	Males	Females	Lucca	Pisa	Pistoia
Brillouin HB	1.80	1.95	1.66	1.74	1.91
	II	I	III	II	I
Simpson's	0.181	0.138	0.150	0.187	0.140
1/Simpson's	5.513	7.225	6.679	5.359	7.141
	II	I	II	III	I
Morisita-Horn	0.952		Lucca vs Pisa II		0.922
				Pisa vs Pistoia I	0.942
			Lucca vs Pistoia III		0.903

Table 3. Frequency of predated categories by *Podarcis siculus* in three Tuscany sites.

Category	Lucca	%	Pisa	%	Pistoia	%
Coleoptera	11	32.354	29	37.665	21	28.767
Othoptera	2	5.882	4	5.196	5	6.849
Hymenoptera	1	2.941	9	11.688	12	16.438
Hemiptera	2	5.882	0	0.0	3	4.109
Blaptoidea	0	0	0	0.0	1	1.369
Dermaptera	0	0	1	1.298	0	0.0
Diptera	0	0	0	0.0	1	1.369
Insects	6	17.647	6	7.785	9	12.328
Araneae	3	8.824	8	10.390	8	10.958
Anellida	0	0	0	0.0	1	1.369
Gastropoda	4	11.764	9	11.690	4	5.479
Reptilia	1	2.941	2	2.598	0	0.0
Hairs	1	2.941	6	7.794	4	5.479
Vegetals	0	0	0	0.0	1	1.369
Sand	3	8.824	3	3.896	3	4.109
Total	34	100	77	100	73	100

0.026). We then excluded from the analysis also the "unidentified material" and "unidentified Arthopods": at this stage, after removal unsuitable matters, ANOVA analysis on distribution of consumed taxa was not significant (F = 2.13, P = 0.144, 2 df, with not significant post-hoc tests). Being no significant differences in sample size among localities, we considered the examined sample well balanced on the whole.

The trophic niche of the whole sample (Simpson index on 15 categories), was 0.163, and reciprocal (1/Simpson's index), was 6.151, showing a marked diversity niche, indicating euriphagy. Simpson's index, on 15 usable categories among the three localities was 0.150 for Lucca, 0.187 for Pisa and 0.140 for Pistoia; reciprocal (1/Simpson index), was 6.679, 5.359 and 7.141 for Lucca, Pisa and Pistoia respectively. Brillouin index was 1.66, 1.74 and 1.91 for Lucca, Pisa and Pistoia, respectively, indicating a strong similarity among samples.

Diet of *Podarcis siculus campestris* is characterized by a wide range of invertebrates, mainly Insects and Arthropods. It is worth noting that a great part of the examined sample is composed by parts and small pieces of Arthopodes *sensu lato,* even if Arachnida and Gastropoda are furthermore relevant in term of sample size. The reptile items were lizard tail scales and mammal item were small micro-mammal hairs (insectivore or rodent, items too digested to make firm determination). Our data set shows the actually variable diet spectrum of the Italian wall lizard.

Comparatively with previously published papers, there are slight, but worth mentioning different results: in central Italy (Latium, in a coastal, sandy habitat not far from Rome) Isopoda represented fairly 50% of the detected preys (Rugiero, 1994). Lepidoptera, Coleoptera, Araneida and Gasteropoda are other well represented taxa. Also a juvenile was preyed upon a large male. Thus, Arthropods represent about 90% of the total preys taxa. This is not surprising at all. Arthropods are the larger group of invertebrates living in almost of terrestrial habitats.

Opportunistic cannibalism and predation upon other reptiles and vertebrates was furthermore recorded in this and in other small lizards (Rugiero, 1994; Capula and Aloise, 2011; Grano et al., 2011). Bombi and Bologna (2002), in another locality in Latium, showed that *Podarcis siculus* diet differed quite markedly with respect to the sympatric *P. muralis*: *P. siculus* population seems more euriphagous than *P. muralis*, that shows a diet basically based on Formicidae. In the wider and more comprehensive paper of Perèz-Mellado and Corti (1993; cumulative data set from the six islands of the Tuscan Archipelago), *P. siculus* mainly fed on Diptera, and with minor occurrence on Coleoptera and Hymenoptera (Formicidae). From the same study, it is worth mentioning that *P. lilfordi* showed a seasonal shift in prey consumption, with Coleopterans in spring and Isopoda-Formicidae in summer. In Menorca Island, *P. siculus* fed mainly on spiders (23.8%), Coleopterans (21.42%), and Isopoda (11.9%), and with lower frequency on other invertebrate taxa (Salvador, 2006). While variation in diet composition was not significant in *P. siculus* between Menorca and the Tuscan Archipelago, in this archipelago, interspecific differences were on the contrary significant (Pérez-Mellado and Corti, 1993). The *Podarcis* lizards that consumed a high proportion of plant matters in their diet, also showed high frequency of aggregated preys, mainly ants. In the Balearic islands, *P. lilfordi* and *P. pityusensis,* were strictly stenophagous (Homoptera, some Coleopteran families, but especially ants), independently of their phylogenetic relationships (as discussed in Carretero, 2004). It has then supposed that myrmecophagy, widely shared among insular populations, is a very good strategy in arid environments or during prolonged drought. Several studies suggest that *Podarcis* species have an active role in pollen load and transport (Pérez-Mellado et al., 2000a); in addition, herbivory in *Podarcis* is more adaptive than random and that coevolution between lizards and plants is a matter of fact (see Castilla, 1999; Pérez-Mellado et al., 2000a, b; Riera et al., 2002; Espinoza et al., 2004; Rodríguez-Pérez et al., 2005), despite this phenomenon is not strictly the case for *P. siculus* (but see Herrel et al., 2008; Vervust et al., 2010). In the Tuscan Archipelago drought during mid-end summer is less pronounced than on the main land and, therefore, we can find more flowering plants, associated insects and arthropods taxa than on the continent (Pérez-Mellado and Corti, 1993). In non sympatric Greek *Podarcis* populations (*Podarcis milensis, P. gaigeae* and *P. erhardii*) of the Aegean Archipelago, it has been noted that the preys aggregated to plant matters were usually related to a different food source (nectar) (Adamopoulou et al., 1999).

Interestingly, comparing the niche indices of continental, insular, native and not native populations [Hierarchical Cluster analysis to 1/H Simpson's Index, recalculated from the percent expressed raw data in Peréz-Mellado and Corti (1993), Rugiero (1994), Bombi and Bologna (2002), and Burke and Mercurio (2002)], we wish to underline that our *Podarcis siculus campestris* had a trophic niche i) quite similar to that found by Peréz-Mellado and Corti (1993), ii) relatively distant from that found by Rugiero (1994) and by Bombi and Bologna (2002), and iii) much different from results obtained in the Long Island population (Burke and Mercurio, 2002) (Fig. 1).

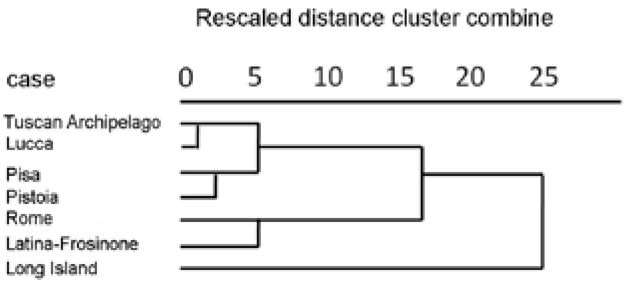

Fig. 1. Dendrogram (average linkage algorithm) of Hierarchical Cluster Analysis on *Podarcis siculus* 1/H Simpsons's diversity index.

Specifically it is also worth mentioning that the predation on mammals, or the scavenging on (see Capula and Aloise, 2011) is not so uncommon, likely being a pattern with a low occurrence. Furthermore, cannibalism (in our sample, remains of caudal scales, nails and fingers make predation an evident matter) has been usually reported as male peculiarity (Grano et al., 2011), while in our sample the pattern was recorded in females only, and limited to the coastal area. Any conclusion on directional cannibalism is however preliminary, due to the very small sample size. Euriphagy and marked opportunistic behaviour is widely reported in all cases studied to date in *Podarcis siculus* spp. We therefore underline that future research will consider more comprehensive data set on multiple sites, at least during two to three consecutive years (on average a population life span, Zuffi et al., unpublished), and with analysis on prey energetics/lizard metabolic demands.

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