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Does diet in lacertid lizards reflect prey availability? Evidence for selective predation in the Aeolian wall lizard, *Podarcis raffonei* (Mertens, 1952) (Reptilia, Lacertidae)

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ABSTRACT In this paper the invertebrate fauna occurring on Scoglio Faraglione, a tiny Aeolian island (Aeolian Archipelago, NE Sicily) inhabited by a population of the critically endangered lacertid lizard *Podarcis raffonei* (Mertens, 1952), was censused at different seasons and the resulting data were then compared with data obtained analysing prey composition and prey abundance in the diet of the lizards occurring on the same islet. The diet of *Podarcis raffonei* was mainly based on insects and other arthropods. The results indicate that diet composition is not directly influenced by prey availability and temporal prey abundance, and that there is strong evidence indicating selective predation. Lizards prey upon a number of arthropod categories fewer than that recorded in field. Some invertebrate taxa (e.g. Diptera and Gastropoda) are really less attractive for lizards and are rarely preyed or not preyed at all despite their spatial and/or temporal abundance. This suggests that *Podarcis raffonei* is able to operate a hierarchical choice within the range of prey items constituting its prey spectrum, probably through the ability to discriminate between prey chemicals or visually oriented predation.

KEY WORDS *Podarcis raffonei;* Lacertidae; predator selectivity; prey availability; feeding behavior; Aeolian Islands.

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INTRODUCTION

Most lacertid lizards of the Mediterranean area are known to be active foragers and generalist predators (see e.g. *Podarcis siculus*: Kabisch & Engelmann, 1969; Pérez-Mellado & Corti, 1993). They prey on a wide variety of invertebrates, mainly on arthropods (e.g. Arachnidae, Insects larvae, Diptera, Coleoptera, Heteroptera, Hymenoptera, Orthoptera, Gastropoda) (see e.g. Capula et al., 1993; Rugiero, 1994; Corti & Lo Cascio, 2002; Bonacci et al., 2008; Corti et al., 2011), while occasionally small vertebrates and vegetal matter can be also eaten (Sorci, 1990; Sicilia et al., 2001; Capula & Aloise, in press). The feeding behavior of some lacertid lizards seems to be opportunistic, as indicated by the consumption of different preys in different habitats and/or geographic areas by the same species. However, few data are available on predator selectivity and prey choice as well as prey availability in the field (see e.g. Heulin, 1986; Domínguez & Salvador, 1990; Maragou et al., 1996; Adamopoulou & Legakis, 2002; Pérez-Mellado et al., 2003; Bonacci et al., 2008). Hence special attention should be devoted to study selective predation and how diets of lacertid lizards relate to changes in the abundance of their prey, especially in micro-insular habitats, which are generally affected by extreme poorness of trophic resources and where lizards are usually assumed to be adapted to exploit the widest range of preys, alternatively adopting opportunistic or generalist feeding strategies (Pérez-Mellado & Corti, 1993; Carretero, 2004; Luiselli, 2008).

Podarcis raffonei (Mertens, 1952) is a lacertid lizard endemic to the Aeolian Archipelago (NE Sicily), where it occurs with four relict populations on three tiny islets

(Strombolicchio, Scoglio Faraglione, La Canna) and on a very small area of Vulcano Island (Lo Cascio, 2010; Capula & Lo Cascio, 2011). The conservation status of this species has recently received attention because it is likely threatened with extinction (Capula et al., 2002; Capula, 2006; Lo Cascio, 2010; Capula & Lo Cascio, 2011). As most of Mediterranean island lacertid lizards (see e.g. Pérez-Mellado & Corti, 1993; Van Damme, 1999), the diet of the Aeolian wall lizard is known to be based mainly on insects and other arthropods, but also includes variable percentages of vegetal matter (Luiselli et al., 2004; Lo Cascio, 2006; Capula & Lo Cascio, 2011). However, no data are available concerning prey choice and prey availability for the species.

The main aim of this study was to explore whether *P. raffonei* selects preys in accordance with their availability in the environment. To test this, the invertebrate fauna occurring on Scoglio Faraglione, which is an Aeolian tiny islet inhabited by *P. raffonei*, was censused at different seasons, and the resulting data were then compared with data obtained analysing prey composition and prey abundance in the diet of the lizards occurring on the same islet.

MATERIALS AND METHODS

Study area

Scoglio Faraglione (38°34'77" N – 14°48'08" E of Greenwich) is an uninhabited tiny islet of the Aeolian Archipelago. It lies in the Pollara Bay, 300 m off the western coast of Salina Island. The surface is 5,765 m^2 and the maximum altitude is 33 m a.s.l. The islet is composed by basaltic lavas, and was definitively isolated from the main island about 15,000-10,000 years ago, due to erosive processes, changes in eustatic sea level which occurred after the Last Glacial Maximum, and catastrophic eruption of the Pollara crater (13,000 yrs B.P.), which involved most part of the western slope of Salina Island and destroyed its original extension (Calanchi et al., 2007). Average annual rainfall (on the main island) is about 600 mm, with a peak in December and a minimum in July; average temperatures range from 13.3 °C (January) to 29.8 °C (August). The top of the Scoglio Faraglione islet is covered by dense shrub vegetation, which is characterized by the occurrence of *Senecio cineraria* ssp. *bicolor*, *Dianthus rupicola* ssp. *aeolicus*, and *Lotus cytisoides*, while the rocky slopes of the basal belt harbour halo-chasmophytic plant communities dominated by *Limonium minutiflorum* and *Inula crithmoides*. Apart from the lizards, the only vertebrates that inhabit the islet are the Moorish gecko, *Tarentola mauritanica*, a small colony of Yellow-legged gull, *Larus michahellis*, and few pairs of other seabird species. As to the invertebrate fauna of Scoglio Faraglione, a non-exhaustive list is given by Lo Cascio & Navarra (2003).

Study lizards

The population of *Podarcis raffonei* occurring on Scoglio Faraglione islet is characterized by medium-sized lizards with brownish dorsal coloration and ventral parts pearl-grey; it is referred to the ssp. *alvearioi* and is morphologically relatively differentiated from the populations of the same subspecies occurring on La Canna islet and Vulcano Island (Capula et al., 2009). Lizards are observed especially on the top of the islet, and are active mainly from March to November; however, occasional activity may be recorded also in sunny days during Winter. The activity pattern is unimodal in Spring and Autumn, and bimodal in Summer (Lo Cascio, 2006). The density of lizards ranges from 0.18 to 0.37 individuals/m^2, and the estimated population size is about 300 individuals (Lo Cascio, 2006; Capula & Lo Cascio, 2011).

Sampling and taxonomic identification

Field sampling was carried out during three visits in May, July, and October 2005. For the invertebrates, two sampling areas per session were selected on the top of the islet; each was 1 x 1 m sized. A better procedure would have required to seal completely the sample-area, using a biocenometer of 1 m^3 (see Pérez-Mellado et al., 2003), in order to collect all the animals occurring on soil, on vegetation and aerial parts inside the box. However, taking into account the fragility of the studied ecosystem, the peculiar vegetation pattern, and the morphology of the islet, a different methodological protocol was adopted, following some of the proposals summarized by Disney (1986) and Ausden (1996). Into each sampling area invertebrates were collected i) by direct searching on substrate, under stones and on plants, using a pooter; ii) taking samples of soil and plant debris up to 10-15 cm depth, which were then examined and hand sorted in laboratory; iii) by sweep netting and beating on foliage; also, a plastic yellow Moericke trap (40 cm of diameter, filled by water and detergent to decrease the surface tension) was placed at the same level of the higher layer of vegetation for 5-6 hours, corresponding to the timeframe of lizards' activity. All the collected specimens were preserved in alcohol, except for Coleoptera, which were stored as dry material in the collection of one of the authors (PLC) and used for further studies. The taxonomic identification of the invertebrate fauna samples collected was performed comparing material preserved in the entomological collections of the Zoological Museum of Florence "La Specola". In the present analysis, the representatives of the invertebrate fauna were identified to OTUs (Operative Taxonomic Units: see Sneath & Sokal, 1973; Carretero, 2004), approximated to class/order level; the identification to OTUs at the family level was only performed for Coleoptera Melyridae and Hymenoptera Formicidae, because of the importance of these taxa in the diet of the local population of *P. raffonei* (Lo Cascio, 2006). The following abbreviations were used to indicate the OTUs in the text and figures: ACA, Acarina; ARA, Araneae; ART, unidentified Arthropoda; CHI, Chilopoda; CLB, Collembola; COL, Coleoptera; DPL, Diplopoda; DPT, Diptera; FOR, Hymenoptera Formicidae; GAS, Gastropoda; HET, Heteroptera; HOM, Homoptera; HYM, Hymenoptera; ISO, Crustacea Isopoda; LAR, insect larvae; LEP, Lepidoptera; MEL, Coleoptera Melyridae; NEM, Nematoda; NEU, Neuroptera; ODO, Odonata; PSE, Pseudoscorpiones.

Invertebrate fauna biomass was assessed using the following protocol: to each OTU was assigned a value (ranging from 0 to 10) which was estimated on the basis of its average size. For instance, the coleopterans occurring on the islet include about ten species, whose length ranges from 4 to 15 mm; the average size calculated for that taxon was 5.5. The value assigned to each OTU was then multiplied with the total number of specimens collected in the field for each OTU. The diet of lizards (adult individuals only; snout-vent length (SVL) ≥ 40 mm) was studied on the basis of faecal pellets analysis. Faecal pellets were obtained from individuals captured in the field; after faecal pellets collecting, lizards were released in the site of capture (see Lo Cascio, 2006). Faecal contents were examined in the laboratory under stereoscope (10-40 X); item counting was based on the analysis of cephalic capsulae, wings, and legs, following the minimum numbers criterion by sample. The invertebrate remains were identified to OTUs at class/order/family level, as above mentioned.

Statistical analysis

The diversity of prey item OTUs and invertebrate fauna OTUs collected in the field was calculated using Shannon Index (Shannon, 1948; see also Chao & Shen, 2003). Statistical analyses were performed using SPSS© version 11.5 for Windows PC package, with alpha set at 5% and all test being two tailed.

RESULTS

The diet of lizards was composed mainly by arthropods, although plant matter was also recorded. A total number of 95 remains of arthropod preys were obtained from 34 faecal pellets of lizards at the study area. The composition and abundance of prey items and their temporal variations are summarized in Table 1. The identifiable preys (i.p.) were 2.94 ± 1.87 per faecal pellet; the i.p. number differed significantly among seasons (May: 4.18 ± 2.08; July: 2.75 ± 1.98; October: 1.92 ± 0.90; $F_{2,28}$ = 5.22, P = 0.01). The prey spectrum also varied in a statistically significant way among seasons (χ^2 = 47.59, df = 26, P = 0.006), and the diet of lizards was more diversified in October (H_s = 2.146) and May (H_s = 2.058) than in July (H_s = 1.898); however, in the latter comparison prey diversity was estimated analysing total amount of consumed preys only, without considering their seasonal variation. Overall, N = 696 invertebrates belonging to 21 different OTUs were collected into the sampling areas (see Fig. 1). Sixty seven percent of the OTUs collected in the sampling areas (14 out of 21) were found as prey items of lizards (see Table 1). Formicidae (FOR), Coleoptera (COL+MEL), Hymenoptera (HYM) and Diplopoda (DPL) accounted for the great part of the dietary spectrum. FOR, HYM, ART and HET were found in the diet of lizards from May to October, while DPL were found in July and October, and COL+MEL in May and July only. The other preyed OTUs (ARA, DPT, GAS, HOM, ISO, LAR, PSE) occurred with low frequency in the diet of lizards. The following OTUs were never found as prey items: ACA, CLB, CHI, LEP, NEM, NEU, ODO. Among the highly preyed taxa, Coleptera and Heteroptera were represented in the diet with a percentage higher than that observed in the field (COL, diet: 12.6%, field: 7.8%; HET, diet: 4.2%, field: 1.8%). Hymenoptera were represented in the diet with a percentage (11.6%) close to that observed in the field (13.4%), and Formicidae occurred with relatively high frequency in the diet of lizards regardless of the season. Some taxa were represented in the diet with low or very low frequency despite their spatial/temporal abundance in the field. This is the case of Diptera, which constitute the 4.2% of the diet although representing the 19.5% of the invertebrate biomass on the islet, and Gastropoda, which constitute the 1% of the diet only although being the 5.1% of the invertebrate biomass at the study area. Moreover, some invertebrates which are widespread and abundant in the field, such as e.g. Acarina and Collembola, were not present at all in the diet of lizards.

To test any relationship between the biomass of both prey items really hunted by lizards and potential prey items occurring in the field, the estimated biomass of the OTUs constituting the prey spectrum of lizards was compared with that of the OTUs sampled in the field. The comparison shows that the two groups are significantly different to each other ($\chi^2 = 34.20$, df = 13, $P = 0.001$), thus suggesting little or no relationship. The estimation of the Shannon index gives similar values for both groups (hunted prey items: $H_s = 2.265$; potential prey items: $H_s = 2.269$), indicating a relatively high amount of diversity within each group.

Taxon	May	July	October
Araneae	10	-	6
Arthropoda (unidentified)	2	14	14
Coleoptera s.l.	19	5	-
Coleoptera Melyridae	28	5	-
Diptera	4	-	8
Diplopoda	-	23	22
Gastropoda	2	-	-
Heteroptera	2	10	6
Homoptera	2	5	-
Hymenoptera s.l.	6	24	6
Hymenoptera Formicidae	19	14	23
Insect larvae	2	-	5
Isopoda	4	-	5
Pseudoscorpiones	-	-	5

Table 1. Diet composition (in %) of *Podarcis raffonei* at Scoglio Faraglione Islet during 2005.

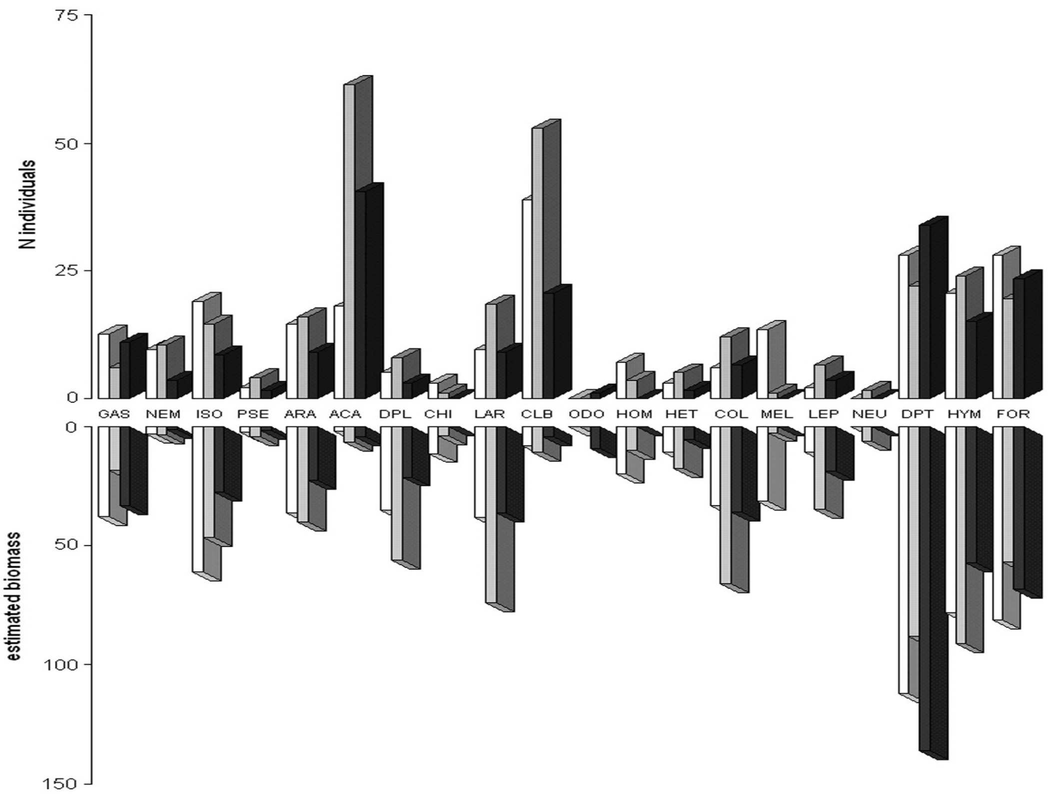

Figure 1. Frequency and estimated biomass of invertebrate fauna at the sampling areas during May (white histograms), July (grey) and October (black). Above: number of specimens collected in the field; below: estimated biomass of OTUs (see Material and methods for explanations).

DISCUSSION

This study shows that in *P. raffonei* diet compositon is not directly influenced by prey availability and temporal prey abundance, and that there is strong evidence indicating selective predation. These results suggest the occurrence of a food preference strategy similar to that observed in some lacertid lizard species (see e.g. Heulin, 1986; Domínguez & Salvador, 1990; Maragou et al., 1996; Adamopoulou & Legakis, 2002). Although caution should be exercised when inferring diet composition by faecal pellets analysis, as this methodology probably under-estimates the number of prey items and results depend on the number of samples collected and the subjectivity and taxonomic knowledge of the investigator, our data indicate that some OTUs are really less attractive for lizards and are rarely preyed or not preyed at all despite their spatial and/or temporal abundance, probably because of prey chemicals or visual discrimination by lizards among possible prey items. This is the case of Diptera and Gastropoda, which were clearly neglected or rarely preyed by lizards, regardless of their abundance in the field, and Acarina and Collembola, which were never preyed by lizards, possibly because of the very small size (often less than 1 mm) of these arthropods, which cannot be considered as suitable preys for a medium-sized predator such as *Podarcis raffonei* (adult SVL of lizards ranging from ca. 40 to 80 mm).

Based on our results, it can be inferred that the Aeolian wall lizard is able to operate a hierarchical choice within the range of prey items constituting its prey spectrum, probably through (i) the ability to discriminate between prey chemicals, or (ii) visually oriented predation. For instance, among the 14 OTUs usually preyed by the Aeolian wall lizard, Coleptera, Heteroptera, Hymenoptera s.l. and Hymenoptera Formicidae can be clearly considered as preferred prey items by the species. In the case of Formicidae, it must be noted that myrmecophagy is a well-known feeding preference habit in island lizard populations (Pérez-Mellado & Corti, 1993; Adamopoulou et al., 1999; Carretero, 2004; Bombi et al., 2005; Lo Cascio & Pasta, 2006; Carretero et al., 2010). Diplopoda, which are known to produce a wide array of chemical defenses (see e.g. Blum & Porter Woodring, 1962; Duffey et al., 1977; Eisner et al., 1978; Kuwahara et al., 2002), apparently should not be considered as appetible preys by lizards. However, these arthropods can be found in the diet of Aeolian wall lizards from July to October with relatively high frequencies (see Table 1), and are completely missing as prey items in the periods of higher availability of most "appetible" preys, such as e.g. Coleoptera Melyridae, which not by chance are highly represented in the diet (and in the field) during Spring.

The analysis of the dietary spectrum of *Podarcis raffonei* clearly indicates that the species – differently from several *Podarcis* lizards occurring on western Mediterranean islands (Pérez-Mellado & Traverset, 1999; Van Damme, 1999) – consumes a low amount of plant matter (see also Luiselli et al., 2004; Lo Cascio, 2006) and can be considered as an opportunistic and mainly insectivorous predator. Although our results allow to hypothesize the occurrence of both visual and chemical discrimination of preys by the Aeolian wall lizard, at present we cannot say anything about the behavioral responses to the different kinds of prey and the chemicals involved in prey discrimination by *P. raffonei*. Further studies should thus be needed to investigate on the ability of the species to discriminate repellent chemicals and/or warning odours produced by several kinds of prey, and the senses that mediate this ability.

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