Folia Zool. – 62 (4): 264–268 (2013)

Feeding habits of the sand lizard, *Lacerta agilis*, from North-Western Italian Alps

Federico CROVETTO and Sebastiano SALVIDIO

Dipartimento di Scienze della Terra, dell'Ambiente e della Vita (DISTAV), Corso Europa 26, I-16132 Genova, Italy; e-mail: salvidio@dipteris.unige.it

Received 17 June 2013; Accepted 9 October 2013

Abstract. The dietary habits of a population of the sand lizard *Lacerta agilis* were studied in the Alpine valley Stura di Demonte, North-western Italy. The faecal contents of 33 adults (16 females and 17 males) and 8 juveniles were analysed. There were negligible sexual differences in terms of trophic diversity and of the overall diet based on taxonomic prey categories. Juveniles had a lower prey diversity value in comparison with females but not with males. There was a positive relationship between the total number of prey items found in individual faecal contents and lizard body size, and this result may explain the more diverse diet of adults in comparison to juveniles. When the adult trophic strategy was analysed by means of the relativized electivity index, that takes into account prey availability, it was observed that the main taxonomic prey groups were eaten according to their proportion in the environment, with the only exception of ants (Formicidae) that were highly avoided by lizards.

Key words: trophic ecology, electivity index, Italy, diet, prey availability, ant avoidance

Introduction

The sand lizard, *Lacerta agilis* Linnaeus, 1758, is a Euro-Siberian reptile found in large parts of Northern and Central Europe and in Asia, where it reaches North-Western China and South-Western Mongolia (Sindaco & Jeremčenko 2008). This species is characterized by an adult sexual size dimorphism, females being larger than males (Bischoff 1984, Gvoždík & Boukal 1998, Venchi & Sindaco 2011). Sexes differ also in their overall colouration, with females usually completely brownish or grey with dark bands and white spots on their back and males with a prevalent greenish colouration on theirs sides and neck (Bischoff 1984, Pérez-Mellado 1998).

Sand lizards are considered generalist and opportunistic foragers (e.g. Strijbosch 1986), that typically behave as ambush predators of ground-dwelling invertebrates (Nemes 2002). The food habits of different sand lizard populations have been described in different countries, such as Russia (Yablokov 1976 in Bischoff 1984), Netherlands (Strijbosch 1986), Hungary (Korsós 1984) and Czech Republic (Gvoždík & Boukal 1998). However, no data are available on the diet and the trophic behaviour of populations at the peripheral boundary of the species distribution area. Therefore, the aim of this study was to analyse the trophic ecology and the prey selection behaviour of an isolate population living at high elevation in the North-western Italian Alps, at the peripheral boundary of the species distribution area. These populations are characterised by short life-span and low population densities (Guarino et al. 2010, Crovetto unpublished data), therefore bearing national conservation concern (Guarino et al. 2010). Dietary habits were studied in adults and juveniles by the analysis of prey items found in faecal contents, while prey selection of adult lizards was investigated by comparing their realised diet with available prey items sampled in their habitat by two different methods.

Material and Methods

The study area is located along a river terrace, near Bersezio at about 1650 m a.s.l., in the Municipality of Argentera (Province of Cuneo, Piedmont administrative Region). The prevalent vegetation is composed by riparian shrubs *Salix eleagnos* and *Salix purpurea* interspersed with trees such as *Larix decidua*, *Betula alba* and *Salix alba* and also with grassland vegetation. At this site, the lizard population was relatively localized and isolated and all captures occurred within an area of about 4 ha. The only other lizard species present at the study site is the wall lizard *Podarcis muralis*, rarely observed in the marginal study zone along the river banks.

Lizards were captured from May to August in 2011 and 2012, by hand or by means of a noose. Sex was determined by the examination of the secondary sexual characters (e.g. overall colouration, larger head and more developed femoral pores in males and developing eggs in females, Bischoff 1984). Lizards were measured from the snout to the posterior end of the vent (SVL) to the nearest mm and those with SVL < 50 mm were considered juveniles (Guarino et al. 2010). All individuals were marked by clipping a single hind-limb toe, that was preserved in 70 % ethyl alcohol for further skeletochronological analysis. Lizards were kept individually in plastic boxes until faeces were obtained. During this study, 48 different individuals were captured, but faecal samples were obtained only from 41 lizards. All individuals were set free at their original site, usually within 24 h from capture. Recaptured individuals were not used in the dietary study to avoid pseudoreplications.

Food availability was sampled in July 2011 by two different methods: three 0.5 l pitfall traps were buried into the soil and left active for one week to capture terrestrial invertebrates, while sweep-netting (20 sweeps along a transect long about 100 m) was used to collect flying and floral insects (Southwood & Henderson 2000). Potential prey constituted a reference collection that aided in the identification of prey remains found in lizards' faeces and also to calculate electivity indexes (see below). The use of each taxonomic prey category was expressed as a percentage of the total number of prey items and also as frequency of occurrence (FO, the number of individual faeces containing that prey). In addition, taxonomic prey diversity of lizard samples was evaluated by mean of Simpson's index (D), that ranges from 0 to +1 (Magurran & McGill 2011). Analysis of similarity (ANOSIM, Clarke 1993) based on Bray-Curtis distance measures was used to compare the diets between years and among samples. Feeding selectivity of adult lizards was estimated in relation to prey abundance in the environment by means of the relativized electivity index (E*), that measures the utilisation of food categories in relation to their availability in the environment (Vanderploeg & Scavia 1979):

$E^* = [w_i - (1 - n)/ w_i + (1 - n)]$

where n = number of prey categories and $w_i = (r_i/p_i)/(\sum r_i/p_i)$, ri and pi being the proportional abundance of the i prey category in the predator diet and in the environment, respectively. This index varies between +1 (positive selection of prey) to –1 (complete avoidance) and when E* = 0, then the predator consumes its prey in the exact proportion as its found in the environment (Vanderploeg & Scavia 1979). The threshold electivity value for each prey category with more than four trapped individuals, was calculated as the 5th percentile of the absolute values of E* (Ramos-Jiliberto et al. 2011). The distribution of prey items among juvenile, male and female samples was tested by Kruskal-Wallis non-parametric ANOVA, while a generalized linear model with Poisson distribution was used to regress the total number of ingested prey on individual SVL. All statistical tests were performed with Past software version 2.17 (Hammer et al. 2001).

Results

During this study, the faecal contents from 41 sand lizards were obtained: 25 in 2011 (9 males, 11 females and 4 juveniles) and 17 in 2012 (8 males, 5 females and 4 juveniles). Although females had on average a longer SVL (mean SVL = 68.7, SD = 9.4 mm) than males (mean SVL = 64.2, SD = 8.1 mm) the two samples did not show significant differences (t = 1.45, DF = 29, P = 0.16, Levenes's test for equal variances, P = 0.92).

Overall, 16 taxonomic prey categories were identified in the faecal contents, in addition to indeterminate insects, shed skin, plant remains and inorganic material (Table 1). The most common prey taxa, according to the FO, where adult flies, adult beetles, larval butterflies and crickets, both for males and females, while all juvenile faecal contents contained spiders (Table 1). The mean number of prey items per individual was 4.5, SD = 3.2 in juveniles, 5.6, SD = 3.8 in males and 7.3, SD = 4.5 in females (Table 1), these differences being statistically significant only between females and juveniles (Kruskal-Wallis

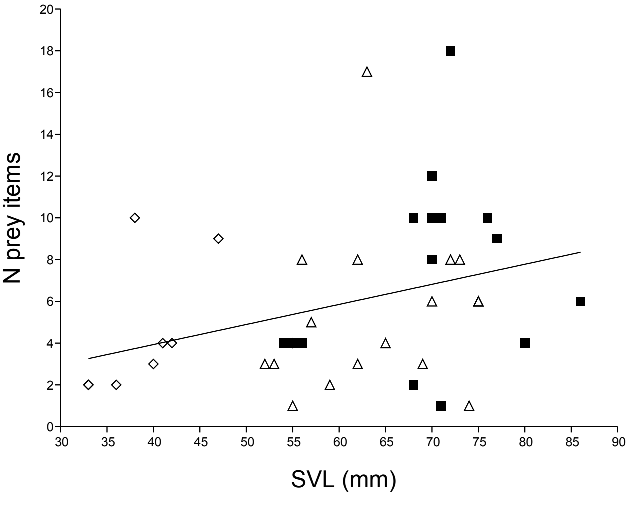

Fig. 1. Scatterplot showing the relationship between number of prey items and body size (SVL) in *Lacerta agilis* from the Italian Alps. Data were fitted with GLM regression for Poisson-distributed data. Filled square = adult females, open triangles = adult males, open diamonds = juveniles.

Table 1. Numbers (N), percentages (%) and frequency of occurrence (FO) of prey taxa in *Lacerta agilis* from North-Western Alps in Italy.

Prey taxa	Males (n = 17)		Females (n = 16)		Juveniles (n = 8)	
	N (%)		FO		N (%)	
Araneida	22 (24)	25	3 (3)	12	10 (28)	100
Diptera (adults)	16 (17)	53	26 (22)	75	8 (22)	75
Diptera (larvae)	1 (1)	6	-	19	2 (6)	25
Coleoptera (adults)	10 (11)	47	16 (14)	62	8 (22)	63
Phalangida	8 (9)	29	3 (3)	25	2 (6)	12
Gastropoda	3 (3)	12	3 (3)	25	2 (6)	25
Coleoptera (larvae)	3 (3)	12	4 (3)	19	-	-
Lepidoptera (larvae)	10 (11)	41	11 (9)	50	1 (3)	12
Orthoptera	13 (14)	53	15 (13)	75	-	-
Dermaptera	-	-	9 (8)	25	-	-
Hymenoptera Formicidae	-	-	4 (3)	25	-	-
Hymenoptera other families	1 (1)	6	7 (6)	25	-	-
Lepidoptera (adults)	-	-	2 (2)	12	-	-
Ephemeroptera	-	-	2 (2)	6	-	-
Homoptera	-	-	2 (2)	6	-	-
Heteroptera	-	-	1 (1)	6	-	-
Hexapoda undetermined	6 (7)	18	8 (7)	44	3 (8)	12
Total prey items	96		116		36	
Total prey categories	11		16		8	
Other material						
Plant remains	5		3		3	
Shed skin	-		1		0	
Inorganic detritus	-		1		0	

Table 2. Relativized electivity index (E*) according to Vanderploeg & Scavia (1979) for main prey categories in adult *Lacerta agilis* faecal contents 2011 (n = 20). D = lizard diet, PA = prey availability in the environment, value in bold is statistically significant at *P* < 0.05.

Taxa	PA	D	% PA	% D	E*
Coleoptera adult	12	26	12.63	15.95	–0.18
Formicidae	44	4	46.32	2.45	**–0.94**
Dermaptera	2	9	2.1	5.52	0.18
Coleoptera larvae	6	7	6.32	4.29	–0.45
Orthoptera acrididae	12	28	12.63	17.18	–0.14
Lepidoptera larvae	6	21	6.32	12.88	0.06
Diptera adult	5	42	5.26	25.77	0.46

non-parametric ANOVA with Bonferroni correction: males *vs.* females, P = 0.267; males *vs.* juveniles, P = 0.139; females *vs.* juveniles, P = 0.003).

In trophic Simpson's diversity assessment and multivariate analysis, samples from 2011 and 2012 were pooled according to sex and age. Simpson diversity values were similar between females (D = 0.89) and males (D = 0.86, permutation test P = 0.094) and between males and juveniles (D = 0.81, P = 0.128), but there was a significant difference between juveniles and females (P = 0.031). When the overall diet of males, females and juveniles was compared by means of ANOSIM, a significant difference was observed (overall R = 0.131, P = 0.006). Males and females had similar diets (pairwise comparison with Bonferroni correction, P = 0.433), while juveniles differed from both males and females (pairwise comparison with Bonferroni correction, males-juveniles P = 0.033 and females-juveniles P = 0.009). In 2011, the lizards feeding selectivity was analysed for the pooled adult sample (n = 20), by comparing the realised diet with the available prey items captured in the environment (Table 2). With the exception of ants (Formicidae, E* = –0.94) that were highly discarded, adult sand lizards seemed to capture their main prey categories according to their availability in the environment, with electivity index values ranging between –0.45 and 0.46 (Table 2).

When the total number of prey items found in individual faecal contents was regressed against lizard SVL (Fig. 1), a significant positive relationship was observed (GLM regression analysis: slope = 0.09, SE = 0.03, G = 10.67, P = 0.001), indicating that there was a clear ontogenetic increase in the number of prey eaten by the sand lizards.

Discussion

This study provides the first data on the sand lizard dietary habits and on some aspects of its food selectivity, in the Alpine region. There are some limitations in the present study, mainly because of the method used to obtain the dietary data. In fact, although the analysis of faecal contents is considered adequate in lizard dietary studies by some authors (e.g. Angelici et al. 1997, Pérez-Mellado et al. 2011), others ecologists argue that soft-bodied invertebrates (i.e. those lacking heavy chitinized exoskeletons) may be under-represented in lizard faeces, because of their complete degradation during digestion (Carretero 2004, Pincheira-Donoso 2008). Thus, faecal analysis may result in loss of information concerning small and soft-bodied prey items in comparison to large and chitinized invertebrates, as experimentally demonstrated by Pincheira-Donoso (2008) in captive lizards. Moreover, it was not possible to estimate the overall size or volume of prey categories found in faecal contents. For these reasons the dietary analysis was limited to the proportion and frequency of occurrence of prey taxa. In any case, the analysis of faecal contents was preferred to stomach flushing techniques to prevent possible negative impacts, such as reduced individual survival on the study individuals (Carretero 2004, Luiselli et al. 2011). The findings from this study confirm previous results obtained in *L. agilis*, and in particular that males and females have similar food habits, at least when prey taxa categories are considered (e.g. Gvoždík & Boukal 1998). Literature data on juvenile trophic habits are lacking and our sample was too small to allow definitive conclusions but it seems that, at least in the study population, there was a clear ontogenetic increase in the total number of prey items ingested by lizards (see Fig. 1). Further studies should investigate if changes in mean prey size follow the same ontogenetic trend as could be expected by the present evidence.

The analysis of electivity indexes gave also interesting and original insights on the trophic behaviour of adult sand lizards. Indeed, without some estimation of the availability of food categories found in the environment, every consideration about the lizard realised trophic niche seems rather subjective and usually generate merely descriptive statistics. Moreover, without the estimation of potential prey taxa, the comparison of the possible trophic strategies (i.e. generalist *vs.* specialist) among populations living in different climates, geographic areas and habitat types seems not supported by objective data. For example, several studies on *L. agilis* populations from different geographic areas reported absence or low frequencies of ants as prey in the sand lizard diet (e.g. Strijbosch 1986, Gvoždík & Boukal 1998). The present study gave similar indications, but suggested an ecological explanation. In fact, ants were very abundant in pitfall traps, suggesting the lizards actively avoided this prey type (Table 2), possibly recognizing the ants by tongue chemosensory sampling (Nemes 2002). Indeed, the use of tongue flicking has been reported in many lizards belonging to the family Lacertidae (Cooper 1990), in which avoidance of ants may be present (Carretero 2004). These findings are not due to a selective digestions of ants by the lizards, because ants are among the most chitinized invertebrates and are easily recognised even if their remains are highly fragmented. Conversely, ants accumulate in the faeces becoming in some cases a dominant prey category, in relation to other more digestible invertebrates (e.g. Crovetto et al. 2012). Apart from ants, the analysis of electivity indexes did not suggest any kind of positive selection of other prey types and all the available prey categories were eaten in similar proportions as they were encountered in the environment. However, further studies on sand lizard trophic behaviour should focus also on prey-specific body size, or even on prey-specific behaviour and ecology.

Acknowledgements

Capture permits were obtained from the Italian Ministry of Environment (PNM-2011-0017858). We are grateful to two anonymous reviewers for their useful comments.

Literature

Angelici F.M., Luiselli L. & Ruggiero L. 1997: Food habits of the green lizard, *Lacerta bilineata*, in Central Italy and a reliability test of faecal pellet analysis. *Ital. J. Zool. 64: 267–272.*

Bischoff W. 1984: *Lacerta agilis* Linnaeus 1758 – Zauneidechse. In: Böhme W. (ed.), Handbuch der Reptilien und Amphibien Europas. Band 2/1(2). *Aula-Verlag, Wiesbaden: 23–68.*

Carretero M.A. 2004: From set menu to *a la carte*. Linking issues in trophic ecology of Mediterranean lizards. *Ital. J. Zool. 74 (Suppl. 2): 121–133.*

Clarke K.R. 1993: Non-parametric multivariate analysis of changes in community structure. *Aust. J. Ecol. 18: 117–143.*

Cooper W.E., Jr. 1990: Prey odor detection by teiid and lacertid lizards and the relationship of prey odor detection to foraging mode in lizard families. *Copeia 1990: 237–242.*

Crovetto F., Romano A. & Salvidio S. 2012: A comparison of two non-lethal methods for dietary studies in terrestrial salamanders. *Wildlife Res. 39: 266–270.*

Gvoždík L. & Boukal M. 1998: Sexual dimorphism and intersexual niche overlap in the sand lizard *Lacerta agilis* (Squamata: Lacertidae). *Folia Zool. 47: 189–195.*

Guarino F.M., Di Già I. & Sindaco R. 2010: Age and growth of the sand lizard (*Lacerta agilis*) from a high Alpine population of north-western Italy. *Acta Herpetol. 5: 23–29.*

Hammer Ø., Harper D.A.T. & Ryan P.D. 2001: PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica 4: 1–9.*

Korsós Z. 1984: Comparative niche analysis of two sympatric lizard species (*Lacerta viridis* and *Lacerta agilis*). *Vert. Hung. 22 : 5–14.*

Luiselli L., Akani G.C., Ebere N. & Pérez-Mellado V. 2011: Stomach flushing affects survival/emigration in wild lizards: a study case with rainbow lizards (*Agama agama*) in Nigeria. *Amphibia-Reptilia 32: 253–260.*

Magurran A.E. & McGill B. 2011: Biological diversity – frontiers in measurement and assessment. *Oxford University Press, Oxford.*

Nemes S. 2002: Foraging mode of the sand lizard, *Lacerta agilis*, at the beginning of its yearly activity period. *Russian J. Herpetol. 9: 57–62.*

Pérez-Mellado V. 1998: *Lacerta agilis* Linnaeus, 1758. In: Salvador A. (ed.), Reptiles. Fauna Ibérica, 10. *Museo Nacional de Ciencias Naturales, Madrid: 182–191.*

Pérez-Mellado V., Pérez-Cembranos A., Garrido M., Luiselli L. & Corti C. 2011: Using faecal samples in lizard dietary studies. *Amphibia-Reptilia 32: 1–7.*

Pincheira-Donoso D. 2008: Testing the accuracy of fecal-based analyses in studies of trophic ecology in lizards. *Copeia 2008: 322–325.*

Ramos-Jiliberto R., Valdovinos F.S., Arias J., Alcaraz C. & García-Berthou E. 2011: A network-based approach to the analysis of ontogenetic diet shifts: an example with an endangered, small-sized fish. *Ecol. Compl. 8: 123–129.*

Sindaco R. & Jeremčenko V.K. 2008: The reptiles of the Western Paleartic, 1. Annotated checklist and distributional atlas of the turtles, crocodiles, amphisbaenians and lizards of Europe, North Africa, Middle East and Central Asia. *Edizioni Belvedere, Latina.*

Southwood T.R.E & Henderson P.A. 2000: Ecological Methods. 3rd Edition. *Blackwell Science Ltd. Malden.*

Strijbosch H. 1986: Niche segregation in sympatric *Lacerta agilis* and *L. vivipara*. In: Rocek Z. (ed.), Studies in Herpetology. *Proceedings of the 3rd Ordinary General Meeting of the Societas Europaea Herpetologica*, *Charles University, Praha: 449–454.*

Vanderploeg H.A. & Scavia D. 1979: Two electivity indices for feeding with special reference to zooplankton grazing. *J. Fish. Board Can. 36: 362–365.*

Venchi A. & Sindaco R. 2011: *Lacerta agilis* Linnaeus 1758. In. Corti C., Capula M., Luiselli L., Razzetti E. & Sindaco R. (eds.), Fauna d'Italia – XLV Reptilia. *Calderini Edizioni, Bologna: 357–361.*