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A contribution to the knowledge of the trophic spectrum of three lacertid lizards from Bulgaria

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Article info:
Received: 29 October 2012
Accepted: 29 March 2013

ABSTRACT

A study on the trophic spectrum of three species of lacertid lizards (*Lacerta agilis*, *Lacerta trilineata* and *Podarcis muralis*) was carried out, based on 20 specimens collected in the period 1967-1973 in various localities in Bulgaria. The analyzed data showed that the insects (Insecta) are the most numerous and the most frequently met among the alimentary components of the total amount of food of the studied stomachs (except for *Lacerta agilis*, where spiders are slightly predominating). The non-insect components consisted spiders and isopods. The largest niche breadth was recorded in *Lacerta trilineata* (8.25), followed by *Podarcis muralis* (5.20) and *Lacerta agilis* (3.44). The niche overlap between the three species (pair-wise comparison) showed medium values and in our opinion there should not be any serious competition for food resources at the places with sympatric distribution.

Key words: trophic spectrum, niche breadth, niche overlap, *Lacerta trilineata*, *Lacerta agilis*, *Podarcis muralis*, Bulgaria

Introduction

The lizard family Lacertidae is presented with nine species in Bulgaria (Beshkov & Nanev, 2002). So far, six species are studied regarding their trophic spectrum – *Lacerta viridis*, *Lacerta trilineata*, *Lacerta agilis*, *Podarcis muralis*, *Podarcis tauricus* and *Zootoca vivipara* (Peters, 1963; Angelov et al., 1966; Kabisch & Engelmann 1969, 1970; Angelov et al., 1972a, 1972b, 1972c; Donev, 1984a, 1984b; Tomov, 1990; Mitov, 1995; Donev et al., 2005), but information about some species is very scarce. The feeding ecology and behavior is important aspect of the ecological studies and currently there is still a big gap of knowledge concerning the Bulgarian lizards.

The aim of the current study was to obtain rich qualitative and quantitative data about the trophic spectrum of three lizards from the Lacertidae family (*Lacerta agilis*, *Lacerta trilineata* and *Podarcis muralis*).

Materials and Methods

During the current study we analyzed the stomach contents of 20 specimens, belonging to the following species: *Lacerta agilis* (8 spec.), *Lacerta trilineata* (5 spec.) and *Podarcis muralis* (7 spec.). The material was collected in the period April-September 1967-1973 and kept in the zoological collection of Department of Zoology, Faculty of Biology at the Plovdiv University. The stomach contents were preserved in 70% alcohol and were analyzed in laboratory by means of binocular microscope. The prey taxa were identified to the lowest possible taxon, based on its degree of composition. The systematic of the identified invertebrate taxa follows "Fauna Europaea" (Fauna Europaea Web Service 2012). The collection data are presented in Table 1.

Sampling adequacy was determined using Lehner`s formula (Lehner, 1996):

$$Q = 1 - \frac{N_1}{I},$$

rising from 0 to 1, where N_1 is the number of the food components occurring only once, and I is the total number of the food components.

The diversity of the diet (niche breadth) was calculated for each species, using the reciprocal value of the Simpson's diversity index (Pianka, 1973; Begon et al., 1986):

$$S = \frac{1}{\sum p_i^2},$$

where: S – trophic niche breadth; P_i – proportion of food component i.

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Table 1. *Collection data of the used material.*

Species	Number of stomachs	Location	UTM	Date
Lacerta agilis	1	Area of "Zdravets" Hut (Rhodopes Mts.)	LG05	16.5.1969
Lacerta agilis	1	Area of "Zdravets" Hut (Rhodopes Mts.)	LG05	17.5.1969
Lacerta agilis	1	Area of "Iglika" Hut (Vitosha Mt.)	FN81	26.6.1969
Lacerta agilis	1	Ognyanovo Village (Sofia District)	GN22	27.5.2971
Lacerta agilis	4	Area of "Smolyanski ezera" Hut (Pamporovo, Rhodopes Mts.)	LG01	20.7.1973
Lacerta trilineata	1	Plovdiv	LG16	05.4.1967
Lacerta trilineata	3	Komatevo, Plovdiv	LG16	17.7.1969
Lacerta trilineata	1	Septemvri Town (Pazardzhik District)	KG67	03.9.1973
Podarcis muralis	5	Asenovgrad Town (Plovdiv District)	LG25	18.4.1973
Podarcis muralis	1	Asenovgrad Town (Plovdiv District)	LG25	11.5.1963
Podarcis muralis	1	Asenovgrad Town (Plovdiv District)	LG25	14.5. 1963

To determine the level of the food specialization of each species we used the index of dominance of Berger-Parker (*d*), calculated by the following formula (Magurran, 1988):

$$d = \frac{n_i \max}{N},$$

where: N – the number of all recorded food components (taxa); $n_i$max – the number of the specimens form taxon i (the most numerous taxon in the diet). The Berger-Parker index (d) varies between 1/N and 1. A value closer to 1 means a higher specialization in the choice of food; a value closer to 1/N is typical for a species that is a general feeder (polyphage).

The food niche overlap was calculated by Pianka`s adaptation of Mac Arthur and Levin's formula (Pianka, 1973):

$$O_{j,k} = \frac{\sum P_{ij}.P_{ik}}{\sqrt{\sum P_{ij}^{\,2} \cdot \sum P_{ik}^{\,2}}},$$

where j and k refer to the two species under comparison, O – niche overlap, P_i – proportion of food component i.

The results were statistically processed using descriptive statistics and *t*-test for independent samples, to compare the numeric proportion all prey taxa between species in order to detect differences in the use of food resources. Because the data did not have normal distribution it was normalized using the arcsine transformation (Fowler et al., 1998).

For the statistical processing of the data we used the software package "Statistica 7.0" (StatSoft Inc., 2004). For the calculations of Simpson's diversity index and the Berger-Parker index we used the computer software "BioDiversityPro" (McAleece et al., 1997) and for the calculation of the niche overlap we used the computer program "EcoSim 7.0" (Gotelli & Entsminger, 2001).

Results and Discussion

In the analyzed stomach contents of total 20 stomachs were obtained 52 prey items, divided in 13 prey categories (Table 2). The average number of prey items per stomach for the studied lizard species is as follows: *Lacerta agilis* - 3.25 (SD=1.58); *Lacerta trilineata* - 2.40 (SD=3.04); *Podarcis muralis* - 1.86 (SD=2.04) (Figure.1). According to our results the sand lizard shows the highest feeding activity. Since the stomachs are collected in different time (seasons), an analysis on seasonal dynamics of the trophic spectrum cannot be done. Table 3 presents the qualitative and quantitive proportion of the trophic spectrum of the three studied lizard species. The insects are the predominating prey in all three species, except for the sand lizard, where the spiders are predominating.

For *Lacerta agilis* the insects take about 44.45% from the diet, for *Lacerta trilineata* – 91.67% and for *Podarcis muralis* – 92.31%. For *L. agilis* we did not record any empty stomachs and the most important prey category was Araneae (51.85%), followed by Hemiptera (14.82%) and Coleoptera (14.81%).The Berger-Parker index showed a medium value - 0.52, which may indicate a slight preference toward the spiders, but with such low amount of studied stomachs (8) that statement cannot be confirmed for sure (Table 3).

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Table 2. *Descriptive statistics of the diet of the three studied lizard species.*

Species	Number of stomachs	Number of prey categories	Number of prey items	Mean	Standard Deviation (SD)	Standard Error (SE)
Lacerta agilis	8	13	27	2.08	3.82	1.06
Lacerta trilineata	5		12	0.92	1.19	0.33
Podarcis muralis	7		13	1.00	1.58	0.44

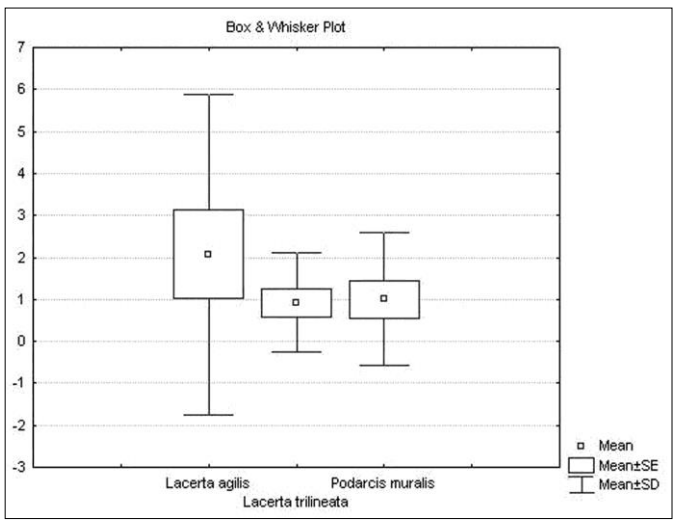

Figure1. *Box & Whiskers plots of the diet of the three studied lizard species.*

The trophic niche breadth is considered relatively low (3.44). Both studies of Angelov et al. (1966, 1972c), based on 12 examined stomachs from *Lacerta agilis*, reported that the most important prey are insects. Angelov et al. (1966) reported that the most numerous taxon is Coleoptera (50%), followed by Aranei (32.7%) and Lepidoptera-larvae (13.5%), and according to Angelov et al., 1972c the predominating prey is Orthoptera (44.12%), followed by Hymenoptera (14.71%) and Araneae (8.82%). The trophic niche breadth calculated from their results is accordingly 2.75 and 5.24, which is close to our results. There is another study on the trophic spectrum of the sand lizard in Bulgaria, conducted by Donev et al., 2005, based only on two specimens and according to their results the predominating prey taxa is Coleoptera (40%). Depending on the habitat and the season, the predominating prey type may vary, but in our opinion the sand lizard should be considered as a polyphage, with slight preference towards spiders and beetles and with low to moderate trophic niche breadth.

For *Lacerta trilineata* we recorded two empty stomachs. The predominating food type were insects, where the most numerous taxon was Coleoptera (50%), especially the Carabidae and Dermestidae families, followed by Lepidoptera (larvae) (33.34%), flies (Diptera, Muscidae) and spiders (Araneae) – 8.33% each. The Berger-Parker index showed a low value (0.33) and the trophic niche breadth is moderate (8.25) (Table 3). There are only two other studies conducted on the trophic spectrum of *Lacerta trilineata* in Bulgaria so far (Peters, 1963; Angelov et al., 1966). The first author examines 62 specimens from the area of Slanchev bruag Resort and reported that the predominated prey are the ants (Hymenoptera, Formicidae – 40.4%), followed by Coleoptera + larvae (21.6%) and Diptera, Muscidae (8.8 %). Angelov et al. (1966) examined 9 specimens from South Bulgaria and reported that the most important food type in the diet of the Balkan Green lizard again are the ants (Hymenoptera, Formicidae – 43.5%), followed by Coleoptera (28.3%) and Hemiptera (15.1%). The trophic niche breadth calculated from their results is accordingly 4.34 and 4.52. Our results differ from the previous two studies, conducted on the diet of this species, but according to Peters (1963) the presence of the ants in the diet of the Balkan Green lizard may vary depending on the habitat and the season. The fact that we did not record any ants in our samples may be partially explain this statement and another reason could be the small sample size.

In conclusion, in our opinion *Lacerta trilineata* should be considered as a general feeder (polyphage) with slight reference towards ants and beetles. The beetles and ants are basic food most probably due to the abundance of this preys and the wide range of habitats where they can be found (Mollov, 2008).

For *Podarcis muralis* we recorded two empty stomachs.

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Table 3. *Qualitative and quantitative contents of the diet of the three studied species of lizards.*

Prey taxa	*Lacerta agilis*				*Lacerta trilineata*				*Podarcis muralis*			
	s	**%**	**n**	**%**	**s**	**%**	**n**	**%**	**s**	**%**	**n**	**%**
Isopoda, Oniscidae	1	12.50	1	3.70	—	—	—	—	—	—	—	—
Arachnida, Araneae	6	75.00	14	51.85	1	20.00	1	8.33	1	14.28	1	7.69
Insecta												
Hemiptera	3	37.50	4	14.82	—	—	—	—	—	—	—	—
Diptera – undet.	2	25.00	2	7.41	—	—	—	—	—	—	—	—
Muscidae	—	—	—	—	1	20.00	1	8.33	—	—	—	—
Diptera (larvae)	—	—	—	—	—	—	—	—	1	14.28	5	38.47
Coleoptera – undet.	2	25.00	3	11.11	—	—	—	—	—	—	—	—
Curculionidae	—	—	—	—	—	—	—	—	3	43.86	3	23.08
Carabidae	—	—	—	—	1	20.00	2	16.67	2	28.57	2	15.38
Elateridae	1	12.50	1	3.70	1	20.00	1	8.33	—	—	—	—
Dermestidae	—	—	—	—	1	20.00	2	16.67	—	—	—	—
Coleoptera (larvae)	—	—	—	—	1	20.00	1	8.33	—	—	—	—
Lepidoptera (larvae)	2	25.00	2	7.41	1	20.00	4	33.34	1	14.28	2	15.38
Lehner's index	**0.926**				**0.667**				**0.923**			
Berger-Parker index	**0.518**				**0.333**				**0.384**			
Niche breadth (1/Simpson)	**3.441**				**8.250**				**5.200**			

Legend: s – number of stomachs; n – number of food components.

The predominating food type were insects, where the most numerous taxa were Coleoptera and Diptera-larvae (about 38.47% each), followed by Lepidoptera (larvae) (15.38%) and Aranei (7.69%). The Berger-Parker index showed a low value (0.38) and the trophic niche breadth is moderate (5.20) (Table 3). So far, the trophic spectrum of the common wall lizard in Bulgaria is studied by Angelov et al. (1966), Kabisch & Engelmann (1969), Angelov et al. (1972b), Tomov (1990). According to Angelov et al. (1966), the predominated food type is Hymenoptera (23.4%), followed by Coleoptera (20.4%) and Araneae (17.0%), based on 51 examined specimens. The trophic niche breadth calculated from their results is 6.74. Kabisch & Engelmann (1969) examined 44 specimens from two different habitats from Balchik and Varna. They registered that the predominating food type in the first habitat is Diptera (52.0%), followed by Lepidoptera (22.0%) and Coleoptera (8.0%), and in the second habitat – Amphipoda (41.3%), followed by Diptera (15.8%) and Hymenoptera (13.8%). The authors however did not separate the imago from the larvae as food categories, which makes it more difficult to compare our results with theirs. Redford & Dorea (1984) claimed that adult insects do not vary much as nutrition content, but still it is considered that the larvae and pupae elements of homometabolic insects are rich in lipids and thus, more nutritive (Brooks et al., 1996). According to Angelov et al. (1972b), based on 48 specimens, the predominated food is Coleoptera (35.35%), followed by Aranea (17.17%) and Lepidoptera-larvae (14.14%). The trophic niche breadth calculated from their results is 5.70. According to Tomov (1990), based on 202 specimens reported, the predominated food type is Hymenoptera, Formicidae (25.26%), followed by Orthoptera (22.59%) and Coleoptera (15.81%). The trophic niche breadth calculated from his results is 6.67.

The registered high percentage of larvae of Diptera in our study is more like an exception, since they were recorded in only one stomach. Having in mind that most of the larvae of Diptera are aquatic organisms, this one specimen must have caught them near a spring or creek with extremely low water level. Similarly to the other two species, the diet of *Podarcis muralis* may vary depending on the habitat and the season, but in our opinion it should be considered a polyphage with slight preference to Coleoptera and Hymenoptera (especially Formicidae). The trophic niche breadth varies from 5.20 (current study) to 6.74 is considered as moderate.

The results from our study, as well as the previous studies conducted by other authors, revealed that the predominated food in all three species is insects. The trophic niche breadth of all three species is low to moderate. The *t*-test for independent samples showed no statistically significant differences between the trophic spectrum of the three lizards (Table 4), but according to Pianka's niche overlap index we calculated that the niche overlap between *Lacerta agilis* and *Lacerta trilineata* is 53.66%. Between *Lacerta agilis* and

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Podarcis muralis it is 54.70% and between *Lacerta trilineata* and *Podarcis muralis* it is 63.49%.

Table 4. *Comparison of the trophic spectrum of the three studied lizard species (t-test for independent samples).*

Species	t-value	p
Lacerta agilis vs. Lacerta trilineata	-0.1996	0.8435
Lacerta agilis vs. Podarcis muralis	0.7649	0.4518
Lacerta trilineata vs. Podarcis muralis	0.9676	0.3429

In our opinion there should not be any considerable competition for food resources among these species at the places with sympatric distribution, because each one of them tends to show a slight preference to a specific taxon or taxa depending on the habitat or season.

Conclusions

During our study we analysed the contents of total 20 stomachs and identified 52 prey items, divided in 13 prey categories. The average number of prey items per stomach for the studied lizard species is as follows: *Lacerta agilis* - 3.25 (SD=1.58); *Lacerta trilineata* - 2.40 (SD=3.04); *Podarcis muralis* - 1.86 (SD=2.04).

For *Lacerta agilis* the most important prey category was Aranea(51.85%), followed by Hemiptera (14.82%) and Coleoptera (14.81%). For *Lacerta trilineata* the predominating food type were insects, where the most numerous taxon was Coleoptera (50.00%), especially the Carabidae and Dermestidae families, followed by Lepidoptera (larvae) (33.34%), flies (Diptera, Muscidae) and spiders (Araneae) – 8.33% each. For *Podarcis muralis* the most numerous taxa in the diet were Coleoptera and Diptera-larvae (about 38.47% each), followed by Lepidoptera (larvae) (15.38%) and Araneae (7.69%).

The Berger-Parker index showed a low value for all three species, although a slight preference to a certain taxon or taxa depending on the habitat or season may be observed.

The calculated trophic niche breadth for the three studies lizard species is as follows: *Lacerta agilis* - 3.44; *Lacerta trilineata* - 8.25; *Podarcis muralis* - 5.20. The trophic niche overlap between the three species is moderate and in our opinion there should not be any considerable competition for food resources among these species at the places with sympatric distribution.

Acknowledgement

The authors would like to thank Assoc. Prof. Dr. Vasil Tomov and Assist. Prof. Dr. Petar Boyadzhiev for the given data about the trophic spectrum of the lizard species used in the current study.

References

Angelov P, Gruev B, Tomov V. 1972a. Studies on the food of the Green Lizard *Lacerta viridis* Laur. in Bulgaria. Travaux Scientifiques des Universite d'Plovdiv - Biologie, 10(1): 155-161. (In Bulgarian).

Angelov P, Gruev B, Tomov V. 1972c. Untersuchungen über die Nahrung von *Lacerta agilis* L. und *Lacerta taurica* Pall. Aus dem Rhodopi-Gebirge. Natura, V(1): 121-122. (In Bulgarian).

Angelov P, Tomov V, Gruev B. 1972b. Studies on the food of*Lacerta muralis* Laur in Bulgaria. Travaux Scientifiques des Universite d'Plovdiv - Biologie, 10(2): 147-150. (In Bulgarian).

Angelov P, Tomov V, Gruev B. 1966. A study on the diet of some lizards in Bulgaria. Scientific studies of the Superior Pedagogical Institute – Plovdiv, Biology, 4(3): 99-105. (In Bulgarian).

Begon M, Harper J, Townsend C. 1986. Ecology – individuals, populations and communites. - Oxford, London, Edinburgh, Boston, Palo Alto, Melbourne. Blackwell Scientific Publications, p. 876

Beshkov V, Nanev K. 2002. The amphibians and reptiles in Bulgaria. - Sofia-Moscow, Pensoft, p. 120 (In Bulgarian).

Brooks J, Calver C, Dickman R, Meathrel E, Bradley S. 1996. Does intraspecific variation in the energy value of a prey species to its predators matter in studies of ecological energetics? A case study using insectivorous vertebrates. Ecoscience, 3(3): 247-251.

Donev A. 1984a. Studies on the food of the Balkan Wall lizard (*Lacerta taurica* Pall.). Travaux Scientifiques des Universite d'Plovdiv - Biologie, 22(1): 45-50. (In Bulgarian).

Donev A. 1984b. Studies on the food of the Green lizard *Lacerta viridis* Laur. Travaux Scientifiques des Universite d'Plovdiv - Biologie, 22(2): 121-126. (In Bulgarian).

Donev A, Mollov I, Kechev M. 2005. A contribution to knowledge of the trophic spectrum of three species of lacertid lizards from South Bulgaria. Scientific Studies of the University of Plovdiv - Biology, Animalia, 41: 109-114. (In Bulgarian).

Fauna Europaea Web Service. 2012. Fauna Europaea ver. 2.4. Available at: http://www.faunaeur.org.

Fowler J, Cohen L, Jarvis P. 1998. Practical statistics for field biology. - Chichester: John Wiley & Sons, p. 259

Gotelli N, Entsminger G. 2001. EcoSim: Null Models Software for Ecology, Version 7.0. Computer software. Acquired Intelligence Inc. & Kesey-Bear. Available at: http://homepages.together.net/~gentsmin/ecosim.htm

Kabisch K, Engelmann W. 1969. Zur Nahrung von *Lacerta muralis* (Laurenti) in Ostbulgarien. Zoologische Abhandlung Berlinen Museum, Tierkunde. Dresden, 30(4): 89-92.

Kabisch K, Engelmann W. 1970. Zur Ernahrung von *Lacerta taurica* in Ostbulgarien.Salamandra, 8(3-4): 104-107.

RESEARCH ARTICLE

Lehner P. 1996. Handbook of ethological methods. - Cambridge University Press, Cambridge, p. 672.

Magurran A. 1988. Ecological diversity and its measurement. - Princeton University Press, Princeton, N. J., p. 179.

McAleece N, Lambshead P, Paterson G, Gage J. 1997. BioDiversity Professional London (UK), Oban (Scotland). The Natural History Museum, The Scottish Association for Marine Sciences.Software, Available at: http://www.sams.ac.uk/research/software.

Mitov P. 1995. Opiliones (Arachnida) as a component of the food stuffs of some animals. Annuaire de l'Universite de Sofia "St. Kliment Ohridski", Faculte de Biologie, Livre 1 – Zoologie, Tome 86-87: 67-74.

Mollov I. 2008. Sex based differences in the trophic niche of *Pelophylax ridibundus* (Pallas, 1771) (Amphibia: Anura) from Bulgaria. Acta Zoologica Bulgarica, 60(3): 277-284.

Peters G. 1963. Studien zur Taxonomie, Verbraitung und Okologie der Smaragdeidechsen. II. Okologische Notizen uber einige ostbulgarische Populationen von Lacerta trilineata. Mittelungen aus dem Zoologischen Museum in Berlin, 39: 203-222.

Pianka E. 1973. The structure of lizard communities. Annual Review of Ecology and Systematics, 4: 53-74.

Redford K, Dorea J. 1984. The nutritional value of invertebrates with emphasis on ants and termites as food for mammals. Journal of Zoology, 203: 385-395.

StatSoft Inc. 2004. STATISTICA (data analysis software system), version 7. Available at: www.statsoft.com.

Tomov V. 1990. Studies on the food *Lacerta muralis* Laur. Travaux Scientifiques des Universite d'Plovdiv - Biologie, 28(6): 131-137. (In Bulgarian).