BIHAREAN BIOLOGIST 18 (1): 51 – 56
Article No.: e241301

http://biozoojournals.ro/bihbiol/index.html

Some insights into the diet of the Balkan wall lizard *Podarcis tauricus* (Pallas, 1814) in northwestern Bulgaria

Emiliya VACHEVA * and Borislav NAUMOV

Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Street, 1113 Sofia, Bulgaria
* Corresponding author: E. Vacheva, E-mail: emilia.vacheva@gmail.com

Received: 22 February 2024 / Accepted: 21 March 2024 / Available online: June 2024 / Printed: June 2024

Abstract. The Balkan wall lizard (*Podarcis tauricus*) is a small-sized ground-dwelling species distributed in southeastern Europe and northwestern Anatolia. Although some insights into its diet and food preferences were published, there is still a lack of knowledge of its feeding ecology in parts of its range, especially in Bulgaria. Our results showed that the trophic spectrum of *P. tauricus* in NW Bulgaria consists of insects and arachnids. At a lower taxonomic level, two orders - Hymenoptera (incl. Formicidae) (24.63%) and Heteroptera (23.19%) have almost equal participation and together represent nearly 50% of the diet, while among other groups, only Orthoptera (13.04%) and Araneae (11.59%) have a significant presence.

Keywords: Balkan Peninsula, Lacertidae, trophic spectrum, food preferences, physical characteristics of the prey.

Introduction

Diet is a fundamental aspect of a species' ecological niche and plays an essential role in animal biology and ecology as well as intra- and interspecific relations (Huey & Pianka 1981).

The Balkan wall lizard (*Podarcis tauricus* Pallas, 1814) is a small-sized (reaching up to ca. 80 mm body length) ground-dwelling heliothermic species (see Kabisch 1986 and references therein). It is distributed mainly in the central, southern, and eastern parts of the Balkan Peninsula. Still, in the northwest, it penetrates the western parts of the Pannonian Plain (with geographically isolated populations in Hungary and north-western Romania), in the northeast – to the Crimean Peninsula, and in the southeast – to the extreme northwestern parts of Asia Minor (Sillero et al. 2014, Psonis et al. 2017, Rehak et al. 2022). In Bulgaria, it mainly inhabits lowlands and low-mountain areas up to 500 m above sea level, occupying a wide range of open habitats, often with low vegetation and sandy soil (Stojanov et al. 2011, Vacheva et al. 2020). The Balkan wall lizard is an insectivorous species, and some insights into its diet and food preferences were published by Szczerbak (1966), Cruce (1972), and Gyovai (1984). Specifically for Bulgaria, the diet of *P. tauricus* was investigated by Angelov et al. (1966), Kabisch & Engelmann (1970), Angelov et al. (1972), and Mollov et al. (2012), Mollov & Boyadzhiev (2021) but these researches concern only the southeastern part of the species' national range, while there are no data for the northern part. The present study aims to contribute to a better understanding of the trophic ecology of *P. tauricus*, providing data on its diet in northwestern Bulgaria.

Material and methods

The study site is located on the eastern shore of the Ogosta Reservoir, 3.5 km from the town of Montana (N43.3739º, E23.2086º, 180–250 m a.s.l.) and includes different types of land cover (see

Vacheva et al. 2020). The highest number of individuals was found on the sandy shore, followed by meadows. The sandy shore was characterized by a higher coverage of low and sparse grass vegetation, due to the periodic flooding by the dam's waters, while the presence of stones was low (10 % and less). The meadows were composed of higher grasses (predominantly Poaceae) and shrubs, mainly common hawthorn (*Crataegus monogyna*), blackthorn (*Prunus spinosa*), dog rose (*Rosa canina*), and also low trees, such as cherry plum (*Prunus cerasifera*), black locust (*Robinia pseudoacacia*) and others. The lizards were captured opportunistically by hand on sunny days in May, July, September 2013, and May 2014. Upon capture, snout-vent length (SVL) was measured using a transparent ruler, and age group and sex were determined based on animal size and body coloration. Two age categories were distinguished: subadults (without sex determination) (SVL < 47 mm) and adults (SVL ≥ 47 mm) (Tzankov 2007, Ljubisavljević et al. 2010).

The trophic spectrum was based on an analysis of the food remnants in the fecal samples of the captured lizards. For this purpose, the captured animals were kept individually in small plastic containers for 1–2 days. Fecal samples were placed in 2 ml Eppendorf tubes with 95% ethyl alcohol and examined afterward. After collecting fecal samples, the lizards were released at the exact place of their capture. The fecal samples were observed under a stereomicroscope (magnification 10–40×). In most cases, the food remnants were determined to order level. All remnants of invertebrates were united in the so-called "operational taxonomic units" (abbr. OTU) (Carretero 2004) because the defined taxa were not of equivalent rank. The prey items were categorized according to their evasiveness (sedentary, intermediate, and evasive, abbreviated respectively as E1, E2, and E3) and hardness (soft, intermediate, and hard, abbreviated respectively as H1, H2, and H3) in accordance with Verwaijen et al. (2002) and Vanhooydonck et al. (2007). Such an approach is widely used in the study of the food spectrum of lizards, but specifically for Bulgaria, the research based on this approach is still very few (see Vacheva & Naumov 2020, 2022).

The correlation between the abundance and the frequency of occurrence of OTUs in the fecal samples was derived using Spearman's rank correlation coefficient (Rho). Comparison between sexes was done in two ways: 1) ordering according to taxonomic diversity of diet via Rényi's index family (diversity profiles) (see Tóthmérész 1995); 2) testing for a difference based on the frequency of occurrence of the separate categories of evasiveness and hardness (using Chi-square test). Statistical procedures were performed using PAST 4.07 (Hammer et al. 2001).

Results

Nineteen fecal samples from *P. tauricus* were collected (10 from adult males, 7 from adult females, and 2 from subadult individuals). The specified chitinized remains could be assigned to 69 separate invertebrate prey items. The average number of remains found in the samples was 2.53 (2.8 in males and 2.4 in females), and the maximum was 6. Invertebrates' remains can be considered 11 OTUs (Appendix 1). The most abundant OTUs were Heteroptera, Orthoptera, and Hymenoptera (except ants), and the most common were Heteroptera, Orthoptera, and Araneae (Fig. 1). The correlation between the abundance and the frequency of OTUs in the fecal samples was positive and statistically significant (Rho = 0.970, $p < 0.001$). In terms of evasiveness, predominant were the OTUs with intermediate mobility (E2), and in terms of hardness, the participation of soft-bodied (H1) and highly chitinized (H3) OTUs was almost equal at the expense of the intermediate category (Fig. 2).

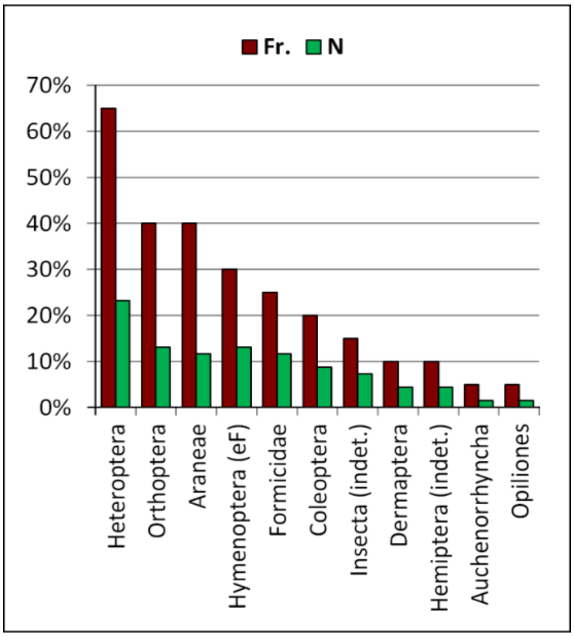

Figure 1. Percentage participation of the OTUs in the faecal samples of *P. tauricus* (Fr. = frequency of occurrence; N = number of individuals).

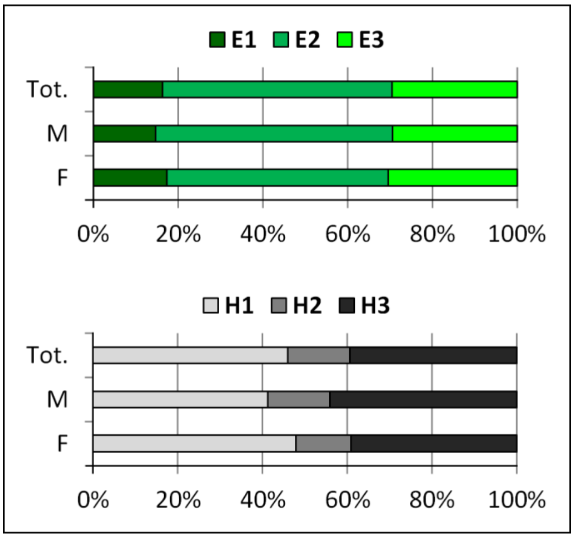

Figure 2. Percentage participation of the categories of evasiveness (E1, E2, and E3) and hardness (H1, H2, and H3) according to the number of categorized invertebrates in the faecal samples of *P. tauricus* (Tot. = the entire sample; M = males; F = females).

The comparison of the samples from males and females showed that 9 out of the 11 OTUs were present in both sexes. It was not possible to identify a difference in the diversity of the diet based on sex because the Rényi's profiles intersect (Fig. 3). Regarding the abundance of victims per category of evasiveness and hardness, no difference was observed (Fig. 2), in terms of frequency, the Chi-square test showed no significant difference between sexes neither in terms of evasiveness ($\chi^2 = 3.835$; df = 2; p = 0.147) nor in terms of hardness ($\chi^2 = 1.685$; df = 2; p = 0.431).

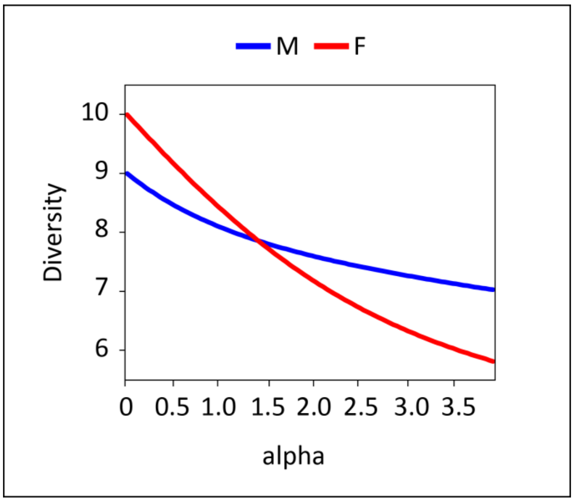

Figure 3. Diversity profiles of the diet in males (M) and females (F) *P. tauricus* according to the abundance of OTUs in the faecal samples.

Discussion

Our results showed that the trophic spectrum of *P. tauricus* in the study area consists of insects and (to a much lesser extent) of arachnids. The same (at the class level) was registered by Angelov et al. (1966, 1972), Mollov et al. (2012), and Mollov & Boyadzhiev (2021) based on research in southern Bulgaria. We did not detect the presence of other classes/phyla of invertebrates in the fecal samples. Still, other studies indicate that centipedes, crustaceans, and mollusks are also involved (albeit to a lesser extent) in the food spectrum of the species (e.g., Szczerbak 1966, Kabisch & Engelmann 1970, Cruce 1972, Mollov et al. 2012).

At a lower taxonomic level, our results showed that Hymenoptera (incl. Formicidae) and Heteroptera have almost equal participation (24.63% and 23.19% respectively) and together represent nearly 50% of the diet by number of items, while among other groups, only Orthoptera (13.04%) and Araneae (11.59%) have a significant presence. Other studies have shown a different quantitative distribution of arthropods in the food spectrum of *P. tauricus*. Based on data from the central part of southern Bulgaria, Angelov et al. (1966) found the greatest abundance of Coleoptera and Aranea (both 37%) and a complete absence of Hymenoptera; Mollov et al. (2012), also based on data from the central part of southern Bulgaria, found the highest abundance of Orthoptera (44.62%), followed by Coleoptera (18.46%) and Hemiptera (7.18%). Kabisch & Engelmann (1970) established a predominance of Heteroptera (32.7%), Coleoptera (17.2%), Hymenoptera (mostly ants) (14.1%), and Araneae (11%) (based on data from the Black Sea coast, SE Bulgaria). Similar results were reported from south Bulgaria by Mollov & Boyadzhiev (2021) - Coleoptera and Lepidoptera (larvae) (23.53%) and Araneae (23.53%). For SW Romania, Araneae (21.4%) have the largest share of the food spectrum of the species, followed by Coleoptera (20.4%) (Cruce 1972). Only Szczerbak (1966), based on research in Crimea, found the largest share of Hymenoptera, as it is in our case. The ants, which were usually given separately from other Hymenoptera in a number of publications on the lizards' diet, were present in a relatively large quantity in our sample. In the food of *P. tauricus*, the noticeable presence of ants was documented also by Szczerbak (1966), Kabisch & Engelmann (1970), and Mollov et al. (2012). Feeding on ants is considered energetically disadvantageous, but the advantages of myrmecophagy are expressed in the spatial distribution of ants and their clustering, which reduces the energy needed to find them (Huey & Pianka 1981). For two taxa (Dermaptera and Opiliones) registered by us in the fecal samples, there has been no evidence of their presence in the food of *P. tauricus* so far (at least to our knowledge).

Regarding the physical characteristics of the prey (evasiveness and hardness), our results can hardly be compared with other data since the diet of *P. tauricus* does not seem to have been analyzed in this way until now. Specifically for Bulgaria, similar analyses were made for two other lacertids (*Zootoca vivipara* and *Darevskia praticola* sensu lato; see Vacheva & Naumov 2020, 2022), and in terms of evasiveness, slow-moving prey (E1) predominated for both species, while in *P. tauricus*, according to our data, prey with a medium degree of mobility (E2) predominates. In terms of hardness, prey with a high degree of hardness (H3) predominated in *Z. vivipara* and prey with a low degree of hardness (H1) in D. praticola s.l., while for this population of *P. tauricus*, the participation of H1 and H3 was almost equal. Substantial differences between sexes regarding the food sources used were not established (neither in the taxonomic aspect, nor in the evasiveness and hardness categories), but this could be possibly because of the lowest number of samples. In the accessible literature on the trophic biology of *P. tauricus*, the question of potential differences between males and females is not considered.

In conclusion, the results presented here add to our knowledge of the trophic spectrum of *P. tauricus*. Potential sex- and age-related differences in food preferences remain unclear, so further research is needed.

Acknowledgments

We thank Yurii Kornilev for the valuable suggestions and the language improvement. This study was partly supported by the Bulgarian Ministry of Education and Science under the National Research Programme "Young scientists and postdoctoral students-2." The handling of animals was in accordance with Ministry of Environment and Water permits № 520/23.04.2013.

References

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].

Angelov, P., Gruev, B., Tomov, V. (1972): Untersuchungen uber die Nahrung von *Lacerta agilis* L. und *Lacerta taurica* Pall. Aus dem Rhodopi-Gebirge. Natura 5 (1): 121-122. [In Bulgarian].

Carretero, M.A. (2004): From set menu to a la carte. Linking issues in trophic ecology of Mediterranean lizards. Italian Journal of Zoology 71: 121-133.

Cruce, M. (1972): Variatia sezoniera a hranei la sopirla de iarba (*Lacerta taurica taurica* Pallas). Studii şi Cercetąri Biologie, Seria Zoologie 24(2): 178-188. [in Romanian].

Gyovai, F. (1984): Synbiological study of the lizard populations of sandy grasslands. Acta Biologica Szegediensis 30: 159-174.

Hammer, Ø., Harper, D.A.T., Ryan, P.D. (2001): PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 1-9.

Huey, R.B., Pianka, E.R. (1981): Ecological consequences of foraging mode. Ecology 62(4): 991-999.

Kabisch, K. (1986): *Podarcìs taurica* (Pallas, 1814) Taurische Eidechse. pp. 343-362. In: Böhme, W. (eds.), Handbuch der Reptilien und Amphibien Europas. Band 2/II. Echsen (Sauria) III. (Lacertidae III: *Podarcis*). Aula-Verlag.

Kabisch, K., Engelmann, W.-E. (1970): Zur Ernährung von *Lacerta taurica* in Ostbulgarien. Salamandra 6 (3/4): 104-107.

Ljubisavljević, K., Džukić, G., Kalezić, M.L. (2010): Female reproductive characteristics of the Balkan wall lizard (*Podarcis taurica*) in the northwestern periphery of its range. Central European Journal of Biology 5 (3): 391-395.

Mollov, I., Boyadzhiev, P. (2021): Another contribution to the knowledge of the trophic spectrum of few lacertid lizards (Reptilia, Squamata, Lacertidae) from Southern Bulgaria. ZooNotes 190: 1-4.

Mollov, I., Boyadzhiev, P., Donev, A. (2012): Trophic niche breadth and niche overlap between two lacertid lizards (Reptilia: Lacertidae) from South Bulgaria. Acta Zoologica Bulgarica Suppl. 4: 129-136.

Psonis, N., Antoniou, A., Kukushkin, O., Jablonski, D., Petrov, B., Crnobrnja-Isailovic, J., Sotiropoulos, K., Gherghel, I., Lymberakis, P., Poulakakis, N. (2017): Hidden diversity in the *Podarcis tauricus* (Sauria, Lacertidae) species subgroup in the light of multilocus phylogeny and species delimitation. Molecular Phylogenetics and Evolution 106: 6-17.

Rehak, I., Fischer, D., Kratochvil, L., Rovatsos, M. (2022): Origin and haplotype diversity of the northernmost population of *Podarcis tauricus* (Squamata, Lacertidae): Do lizards respond to climate change and go north? Biodiversity Data Journal 10: e82156.

Sillero, N., Campos, J., Bonardi, A., Corti, C., Creemers, R., Crochet, P.-A., Crnobrnja-Isailović, J., Denoël, M., Ficetola, G.F., Gonçalves, J., Kuzmin, S., Lymberakis, P., de Pous, P., Rodríguez, A., Sindaco, R., Speybroeck, J., Toxopeus, B., Vieites, D., Vences, M. (2014): Updated distribution and biogeography of amphibians and reptiles of Europe. Amphibia-Reptilia 35: 1-31.

Stojanov, A., Tzankov, N., Naumov, B. (2011): Die Amphibien und Reptilien Bulgariens. Frankfurt am Main, Germany, Chimaira.

Szczerbak, N. (1966): Amphibians and reptiles of Crimea (Herpetologia Taurica). Naukova Dumka, Kiev. [In Russian].

Tóthmérész, B. (1995): Comparison of different methods for diversity ordering. Journal of Vegetation Science 6: 283-290.

Tzankov, N. (2007): Study on the external morphology, intraspecific differentiation sexual dimorphism and taxonomy of the lizards from Lacertidae family in Bulgaria. PhD thesis, Faculty of Biology, Sofia University "St. Kliment Ohridski", 4. [In Bulgarian].

Vacheva, E., Naumov, B. (2020): Diet of the Viviparous lizard *Zootoca vivipara* (Lichtenstein, 1823) (Reptilia: Lacertidae) from its southern range. North-Western Journal of Zoology 16 (2): 178-190.

Vacheva, E., Naumov, B. (2022): A contribution to the knowledge on the diet and food preferences of *Darevskia praticola* (Reptilia: Lacertidae). Acta Herpetologica 17 (1): 27-36.

Vacheva, E.D., Naumov, B.Y., Tzankov, N.D. (2020): Diversity and habitat preferences in lizard assemblages (Reptilia: Sauria) from model territories in Western Bulgaria. Acta Zoologica Bulgarica 72 (3): 385-396.

Vanhooydonck, B., Herrel, A., Van Damme, R. (2007): Interactions between habitat use, behaviour and the trophic niche of lacertid lizards. pp. 427-449. In: Reilly, S.M., McBrayer, L.D., Miles, D.B. (eds.), Lizards ecology: The evolutionary consequences of foraging mode. Cambridge University Press.

Verwaijen, D., Van Damme, R., Herrel, A. (2002): Relationships between head size, bite force, prey handling efficiency and diet in two sympatric lacertid lizards. Functional Ecology 16: 842-850.

+ Appendix 1

Appendix 1. Distribution of the material from the fecal samples of *Podarcis tauricus* per OTU [E = evasiveness (E1, E2, and E3 refer to sedentary, intermediate, and evasive, respectively); H = hardness (H1, H2, and H3 refer to soft, intermediate, and hard, respectively)]; N = number of identified individual remnants; Fr: = number of the faecal samples in which the OTU occurs.

Class	**OTU [E; H]**	**Total (n = 19)**		**Males (n = 10)**		**Females (n = 7)**		**Subadults (n = 2)**	
		N	Fr.	N	Fr.	N	Fr.	N	Fr.
Arachnida	Araneae [E1; H1]	8	8	5	5	2	2	1	1
Arachnida	Opiliones [E1; H1]	1	1	0	0	1	1	0	0
Insecta	Heteroptera [E2; H1]	16	13	8	7	6	4	2	2
Insecta	Orthoptera [E3; H2]	9	8	5	5	3	2	1	1
Insecta	Hymenoptera (eF)* [E3; H3]	9	6	5	4	4	2	0	0
Insecta	Formicidae [E2; H3]	8	5	6	3	2	2	0	0
Insecta	Coleoptera [E2; H3]	6	4	4	2	2	2	0	0
Insecta	Dermaptera [E2; H1]	3	2	1	1	2	1	0	0
Insecta	Hemiptera (indet.) [n/a]	3	2	2	1	1	1	0	0
Insecta	Auchenorrhyncha [E1; H3]	1	1	0	0	1	1	0	0
Insecta	Insecta (indet.) [n/a]	5	3	5	3	0	0	0	0

* eF = except Formicidae