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# Diversity and Habitat Preferences in Lizard Assemblages (Reptilia: Sauria) from Model Territories in Western Bulgaria

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**Abstract:** The spatial niches and habitat preferences of six sympatric lizard species were studied in two model territories in western Bulgaria. The highest level of species diversity (based on two indices, Simpson and Shannon) was reported in the ecotone between oak forests and meadows. The spatial niche breadth was wider in the wall lizard *Podarcis muralis* and the eastern green lizard *Lacerta viridis,* while other species showed more restricted preferences to a particular habitat type. To our knowledge, this is the first purposeful research on the habitat preferences of lizard species of the Balkans, based on quantitative data. The results in the present work could be used in further and more detailed analyses.

**Key words**: *Lacerta*, *Podarcis*, *Darevskia*, *Ablepharus*, *Anguis*, Balkan Peninsula, spatial niche.

## Introduction

Lizards are an important and characteristic part of the European reptile communities; they are suitable model species for ecological and community biological studies due to their diversity and presence in a great number (Amaral et al. 2012, Mayer & Beyerlein 1999, Menke 2003, Orriols 2011). Interspecific competition is one of the main biotic factors shaping the species distribution and habitat occupancy (Case & Bolger 1991, Edwards & Lailvaux 2013, Langkilde & Shine 2007). Species that coexist in the same habitat avoid competition in different ways. For example, to reduce the interspecific competition and facilitate coexistence, lizards may partition one or more of three main niche axes: temporal, spatial and trophic (Pianka 1986). Considerable evidence based on research on habitat selection suggests that the majority of lizard communities partition the spatial (habitat or microhabitat) niche axis to avoid competition (e.g. Díaz et al. 2006, du Plessis & Mouton 2011, Garden et al. 2007, Heltai et al. 2015, Korsós 1984, Maura et al. 2011, Pianka 1973, 1986). The habitat features by which European lizards differ could be divided into two main classes: structural and climatic. Structural features include type of substrate (e.g. rock, stones, screes, soil), type of vegetation (open space, presence or absence of shrubs and trees) and available refuges; climatic features include humidity, temperature and shadiness of the microhabitat (Arnold 1987). Furthermore, as ectotherms, lizards have to choose suitable thermal microhabitats (Sagonas et al. 2017, Žagar et al. 2015). This often defines behaviours in which microhabitat features might be changed throughout the day and season (Ortega & Perrez-Mellado 2016).

Sympatric occurrence of more than five lizard species is very rare in Europe. It has been mostly mentioned of lizards of the family Lacertidae, for example sympatry of seven lacertid species was described near Gacko in Bosnia and Herzegovina (Arnold 1987) and in the Arcadian Highlands on the

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Peloponnese, Greece (Mayer & Beyerlein 1999). For Bulgaria, Tzankov (2004) described sympatry of six lacertids in the Eastern Rhodope Mountains. In Europe, only few skinks are present, mainly in the Mediterranean Region (see Speybroeck et al. 2016) and the snake-eyed skink (the only representative of the family Scincidae in Bulgaria) co-occurs in many lacertid habitats (Kovács & Kiss 2016). The slow worms (*Anguis* spp.) are present in a wide variety of habitats across Europe, where they co-exist with other lizard species (Canova & Marchesi 2007, Capizzi et al. 1998, Ceirans 2004).

In Bulgaria, 14 lizard species occur, nine belonging to the family Lacertidae (Stojanov et al. 2011). Despite the high species diversity reported in Bulgaria, habitat preferences of lizards are still understudied. Therefore, the main aim of this study was to explore the habitat preferences of six co-existing lizard species from two different locations in Bulgaria. Thus, we formulated the following research questions: (1) which habitats harbour the highest lizard diversity; (2) what was the spatial niche width for each species (3) which species show similar habitat preferences; (4) which are the most suitable habitats for each species; (5) are there any differences in habitat preferences between sex and age within different species.

# Materials and Methods

### Study area and habitat types

We chose two sites in western Bulgaria, about 140 km apart (Fig. 1), as model territories for conduction of the study. Based on our preliminary observations, these territories had similar and relatively high lizard diversity. The first site (called S1 from now on) was situated at the east coast of the Ogosta Reservoir, south of the city of Montana (N 43.3739º, E 23.2086º, 180–240 m a.s.l.). The second site (S2) was situated in the Dalbochitsa River's valley near Gabrovitsa Village (N 42.2602º, E 23.9208º, 430–570 m a.s.l.). S1 represents an anthropogenically-impacted area with fragmented habitats, while S2 represents natural woodland, covered by different types of deciduous forests.

Based on land cover (vegetation, substrate, microrelief, etc.) and dominant species/characteristics, 13 habitat types were defined: (1) Oak forest (FOO) – predominantly occupied by *Quercus robur* L. (present both in S1 and S2, but with the smallest canopy among the other forest types in S2); (2) Beech forest (FOB) – mainly *Fagus sylvatica* L. (in S2 only); (3) Mixed broadleaved forest (FOM) – mixed broadleaved tree species with no dominant species (in S2 only); (4) Coniferous forest (FOC) – a monoculture of *Pinus nigra* Arnold. (in S1 only); (5) Ecotone (ECO) – the only defined type of ecotone is the border area (about 20 m wide) between forests (any type) and meadows, often containing a large number of shrubs and single trees (both in S1 and S2); (6) Meadows (MEA) – composed of herbaceous vegetation with single shrubs and single stones (both in S1 and S2); (7) River bed (RIB) – a territory along the stream (can be associated to the term fluvial terrace), covered by large stones, herbaceous vegetation and small shrubs (in S2 only); (8) Road (ROA) – dirt roads, including their marginal areas, occupied by shrubs, separate trees, building ruins, etc. (in S1 only); (9) Sandy shore (SSA) – a sandy strip along the shore of the reservoir, covered by low herbaceous vegetation and small amount of stones (in S1 only); (10) Stony shore (SST) – a stony strip along the shore of the reservoir with scarce, mostly herbaceous vegetation (in S1 only); (11) Scree (SCR) – steep screes with sparse vegetation (in S2 only); (12) Rock (ROC) – large rocks almost without vegetation (in S2 only); (13) Private estates (PES) – territories, occupied by separate buildings, yards, small plantations, etc. (in S1 only) – no field work was done in these territories, because they were fenced out. The spatial distribution of the aforementioned habitats is visualised in Fig. 1. The borders of the habitats were manually outlined on an orthophoto layer from 2011 (available on-line at http://gis.mrrb.government.bg/) using ArcGIS 10.1, after field verification.

### Field observations

The field observations were carried out from May to September in 2013, 2014 and 2016 for S1, and in 2017 and 2018 for S2. The total number of visits (one per day) was 28 in S1 and 25 in S2. During each visit we followed nearly the same routes, predefined in order to pass through each type of habitat in the respective model territory. The predefined route length was ca. 4.2 km for S1 and ca. 4.4 km for S2; in spite of that, the real route length varied of about ± 0.5 km and the deviation left/right varied of about ± 0.05 km). Individual's locations were recorded using a hand-held GPS receiver Garmin eTrex 30 (accuracy ±10 m; Olathe, Kansas). For each captured or observed lizard we recorded (besides species) the habitat type and, when it was possible, the age class and sex of the individual (in adults only). We determined the sex in lacertids based on the distinguished pattern and coloration, and the general appearance (larger head in males vs. slender head and larger trunk in females, see Cox et al. 2003 and the references there). For *A. kitaibelii* and *Anguis fragilis* complex sex determination was done after close inspection only in lizards, which were caught and handled.

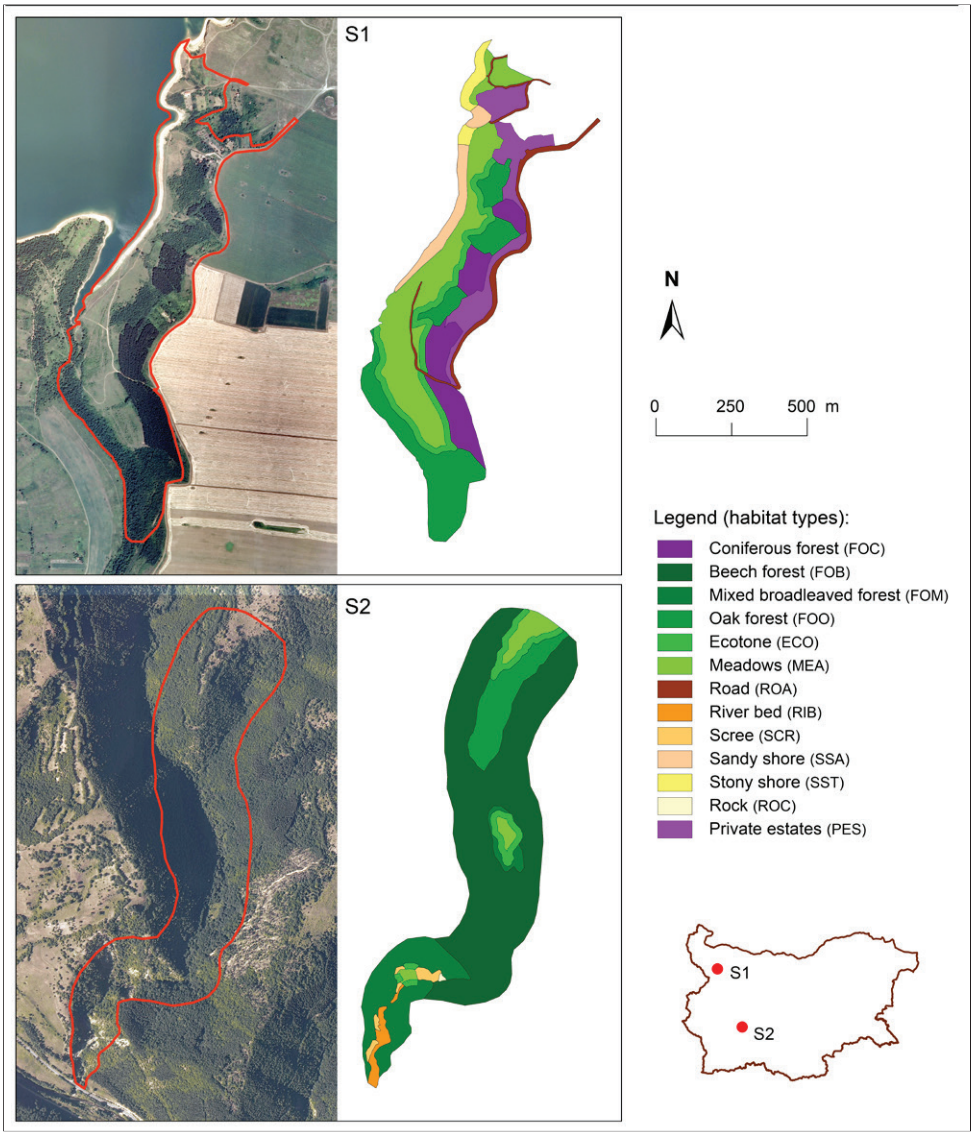

**Fig. 1.** Outlines of the study sites (on aerial photographs), spatial distribution of the habitat types and position of the sites on the territory of Bulgaria.

## Taxonomical framework

The used scientific names of species are in accordance with Stojanov et al. (2011), except the following: (1) for *Darevskia praticola*, we used the extension "*sensu lato*" (s.l.) because the Balkan population most probably represents a separate taxon with species rank (see Freitas et al. 2016, Saberi-Pirooz et al. 2018); (2) for the genus *Anguis*, we used the extension "*A. fragilis* complex" because, in Bulgaria the contact zone between *A. colchica* and *A. fragilis* still has not been precisely determined (Gvoždík et al. 2010) and no genotyping was done in the present research.

## Statistics

All statistical operations were based on a frequency matrix (number of recorded specimens per habitat type, without any other manipulations). For describing the lizard diversity per habitat and the breadth of the spatial niches, two diversity indices were used: the Shannon's index, which gives higher weight to rare species, and the Simpson's index, which gives higher weight to abundant species (see Krebs 1999). The permutation test was used to determine differences between sexes and between age classes. As a measure for similarity, the Morisita index was chosen as the most robust and independent of sample size, when the number of individuals was used (see Wolda 1981). A cluster analysis (by the commonly used UPGMA algorithm) was done on the base of the calculated values of the Morisita index. A correspondence analysis was based on the frequency table. Statistical analyses were done using PAST 3.21 (Hammer et al. 2001) and Statistica 10.0 (StatSoft Inc. 2011).

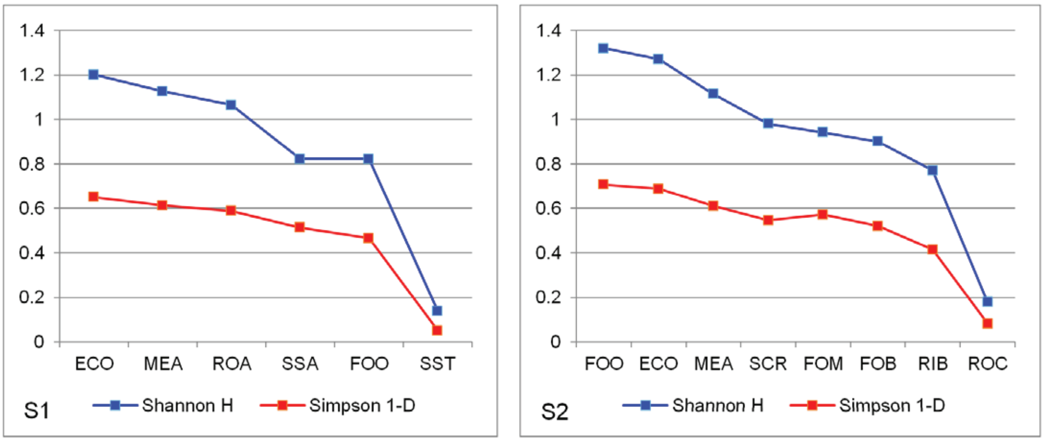

**Fig. 2.** Values (in descending order) of the diversity indices per habitats (for abbreviations see Material and Methods).

# Results

A total of 2026 individual locations of six lizard species were recorded. The registered species belong to three families with the following species: Anguidae – *Anguis fragilis* complex; Lacertidae – *Darevskia praticola* s.l., *Lacerta viridis* (Laurenti, 1768), *Podarcis muralis* (Laurenti, 1768) and *Podarcis tauricus* (Pallas, 1814); Scincidae – *Ablepharus kitaibelii* (Bibron & Bory de Saint-Vincent, 1833). Five species were found in both S1 and S2, while *P. tauricus* was registered in S1 only. Given the known distribution of the lizards in Bulgaria, in both studied sites the presence of other species was not likely (see Stojanov et al. 2011).The distribution of the recorded individuals per species and habitats, as well as the calculated diversity indices, are given in Appendix 1.

## Lizard diversity by habitat types

The number of observed species per habitat varied between two and six (see Appendix 1). The maximal number of species (all of them) for S1 was found in one habitat (MEA) and in S2 – in three of the habitats (FOO and FOB and RIB).

According to both indices (Fig. 2), it appeared that the combined lizard diversity was the highest in the ECO, FOO, MEA and ROA. The lowest values were found for SST and ROC. In addition, S1 included one more habitat: FOC, representing non-natural plantations of black pine (see Fig. 1). This habitat was studied equally with the other habitats but no lizards were found there; the only exception was a female of *P. muralis*. It was found in the FOC but 7–8 m from the border with the MEA and thus was assigned to the ECO. Other studies also confirmed avoidance of non-natural woodlands by lacertids (see Amo et al 2007 and Sacchi et al. 2011).

The highest level of similarity based on the cluster analysis (Fig. 3) was found between MEA and ECO (at both sites), as well as between SCR and RIB (in S1). At the lowest values of similarity, three main clusters of habitats were observed. One included the habitats with the lowest herbaceous cover (SSA and SST in S1, and ROC, SCR and RIB in S2), the other – those with the highest vegetation cover (FOO, as the only forest type in S1, and FOB and FOM in S2) and the third – those with medium vegetation cover (ECO and MEA at both sites, and ROA or FOO in S1 and S2, respectively). Comparing the values of diversity (Fig. 2), on both investigated territories the first three habitats with the highest diversity formed separate clusters (namely those, formed by the habitats with medium vegetation cover).

## Habitat preferences and spatial niche partitioning

Species were distributed unequally amongst habitat types (Fig. 4). *Ablepharus kitaibelii* was found in seven habitat types, with the highest number of records in MEA for S1 (66% of all records) and in FOO (56%) for S2. *Darevskia praticola* s. l. (found in eight habitat types) was most abundant in FOO (83% and 49% for S1 and S2, respectively). *Lacerta viridis* was established in all habitats on both territories (except FOC, see above) with the most records in MEA (43%) for S1 and in FOO (34%) for S2. *Podarcis muralis* was also established in all habitat types (except FOC) with the highest presence in SST (64%) for S1 and in SCR (30%) for S2. *Podarcis tauricus* was established in four habitat types (in S1 only) but most of all in SSA (70%). *Anguis fragilis* complex was found in five habitat types but with single individuals and thus was not further analysed. That does not reflect the true abundance of the species, as it is amongst the most secretive lizards in

Bulgaria, the observations of which are mostly opportunistic (unless a targeted survey is carried out, e.g. one with setting coverboards, etc.).

The breadth of the spatial niche was widest in *P. muralis* and *L. viridis* (Fig. 5). The similarity (interpreted here as spatial niche overlap; Table 1) in S1 was the highest between *L. viridis* and *A. kitaibelii* and in S2 – between the two generalist species *L. viridis* and *P. muralis*. Comparing the two sites, the niche breadth as well as the degree of niche overlap were higher in S2. That could be a result of the differences between the territories in the land cover (see Fig. 1). In S1 the number of the habitats was lower (if we exclude FOC and PES, as was mentioned above) and the proportion (as whole territory coverage) between the forest and open habitats was almost equal. On the other hand, in S2 besides the higher number of habitat types, the proportion between forests and open habitats was different (forests covered bigger area than open areas).

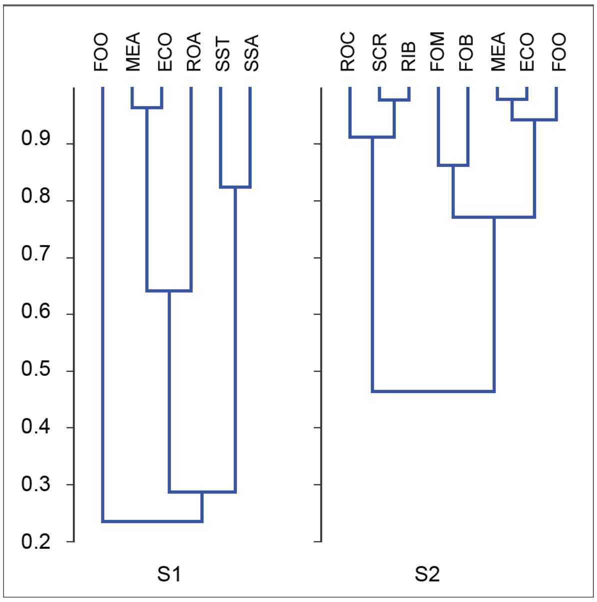

**Fig. 3.** Similarity between the habitats, based on the Morisita index (separately for S1 and S2; for abbreviations see Material and Methods).

Correspondence analyses (Fig. 6) showed similar relationships between species and habitats, as was obtained by the diversity/similarity indices. For both S1 and S2, the first two axes together explained more than 80% from the total dispersion, which gave a reason for a more detailed interpretation.

For S1, the first axis divided *P. muralis* and *P. tauricus* from the other species, while the second axis clearly discriminated *D. praticola* s. l. In regard to habitats, SST and SSA could be associated with *P. muralis* and *P. tauricus*, respectively, ECO and MEA with *L. viridis* and *A. kitaibelii* and FOO with *D. praticola* s. l. The ordination of the habitats by the axis corresponded well to the clustering (Fig. 3).

In S2, the first axis itself explained much larger part of the total. Considering the sign of the values on this axis, *P. muralis* and *L. viridis* divided from *D. praticola* s. l. and *A. kitaibelii*. In the ordination of the habitats a well-expressed congruence to the clustering could be seen (as for S1). With higher absolute values on the first axis and lower on the second were habitats with sparse vegetation (negative

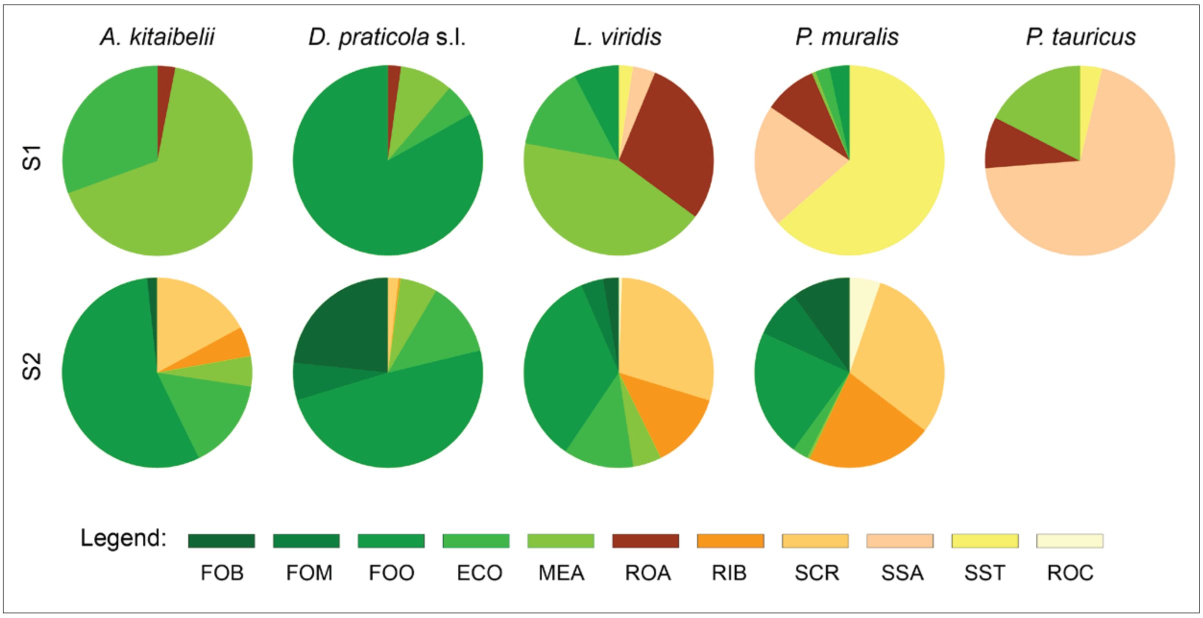

**Fig. 4.** Proportions of individuals per habitat type (as a percentage from the total number of specimens in S1 and S2; for abbreviations see Material and Methods).

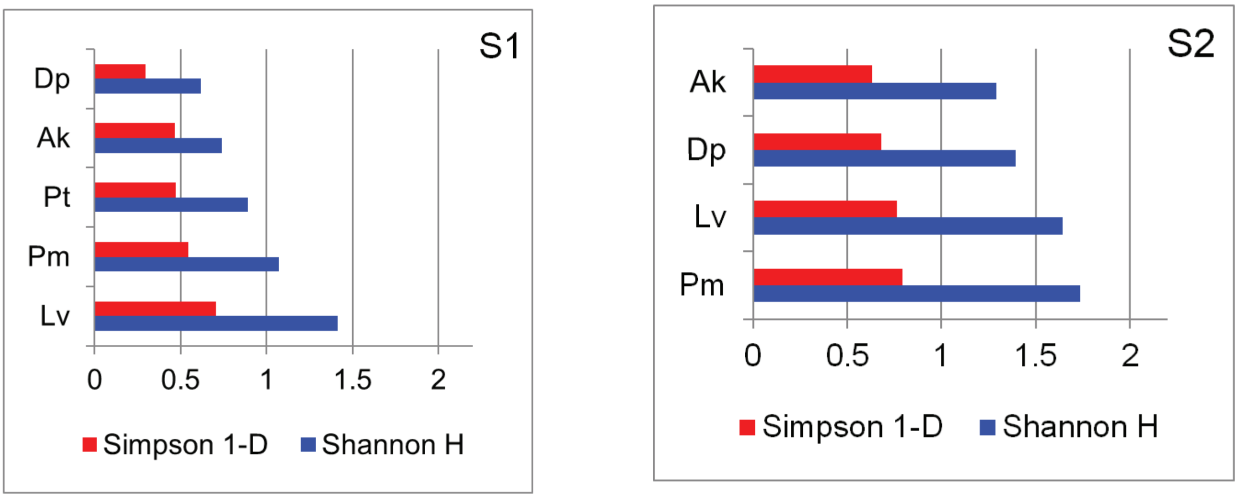

**Fig. 5.** Values of the diversity indices per species (separately for S1 and S2). Legend: Ak – *A. kitaibelii*, Dp – *D. praticola* s. l., Pm – *P. muralis*, Pt – *P. tauricus*, Lv – *L. viridis*.

**Table 1.** Similarity between species based on the Morisita Index (separately for S1 and S2).

| S1 | | | | |
|---|---|---|---|---|
| | *L. viridis* | *D. praticola* s.l. | *P. muralis* | *P. tauricus* |
| *A. kitaibelii* | 0.812 | 0.125 | 0.029 | 0.223 |
| *L. viridis* | | 0.234 | 0.155 | 0.310 |
| *D. praticola* s.l. | | | 0.056 | 0.029 |
| *P. muralis* | | | | 0.364 |
| **S2** | | | | |
| | *L. viridis* | *D. praticola* s.l. | *P. muralis* | |
| *A. kitaibelii* | 0.884 | 0.881 | 0.663 | |
| *L. viridis* | | 0.718 | 0.904 | |
| *D. praticola* s.l. | | | 0.554 | |

values) and those with medium vegetation and FOO (positive values). With higher values on the second axis were FOB and FOM. *Podarcis muralis* could be linked to the habitats with sparse vegetation (as in S1), *D. praticola* s. l. and *A. kitaibelii* – to the habitats with medium vegetation cover and FOO and *L. viridis* could not be linked with any specific habitat or group of habitats but the second axis separated it from the habitats with higher vegetation cover.

### Age and sex dimorphism in the habitat choice

Statistically significant differences in habitat preference between adults and immatures (juveniles and subadults combined) were established for two species (Table 2, Appendix 2). In S1, the difference was statistically significant for *A. kitaibelii* (both diversity indices) as well as in *P. muralis* (only for Shannon index). For *A. kitaibelii* (for S1), most of the adults were recorded in MEA (open, but well-vegetated habitat, which could provide hiding places), while most of the immatures were in ECO (a habitat with deep leaf coverage). These data support previous findings for *A. kitaibelli* (see Kovács & Kiss 2016). In S2, significant difference between adults and non-adults was observed only for *P. muralis*. For *P. muralis* (both for S1 and S2), immatures could be found in most open areas with scarce vegetation.

Differences between sexes (in adults) in habitat preferences were very low (Table 3, Appendix 3). In S1, no statistically significant difference was found between sexes in any species. In S2, significant difference was observed only in *D. praticola* s. l. (in both indices): the level of evenness in abundance per habitat was higher in males, while in females, the number of individuals in FOO was much higher than in the other habitats.

## Discussion

### Lizard diversity by habitat types

The occurrence of all species in MEA could be explained with the intermediate position of this habitat among the others. Furthermore, its open character and low vegetation density provide an opportunity and easy access for sunbathing. ECO combines the characteristics of the open habitats (but with diverse vegetation) and provide more opportunities for effective thermoregulations as shadiness and hiding places. In spite of its limited width, often ECO is the most preferred habitat (Menke 2003, Sacchi et al. 2011). Road edges are considered preferred habi-

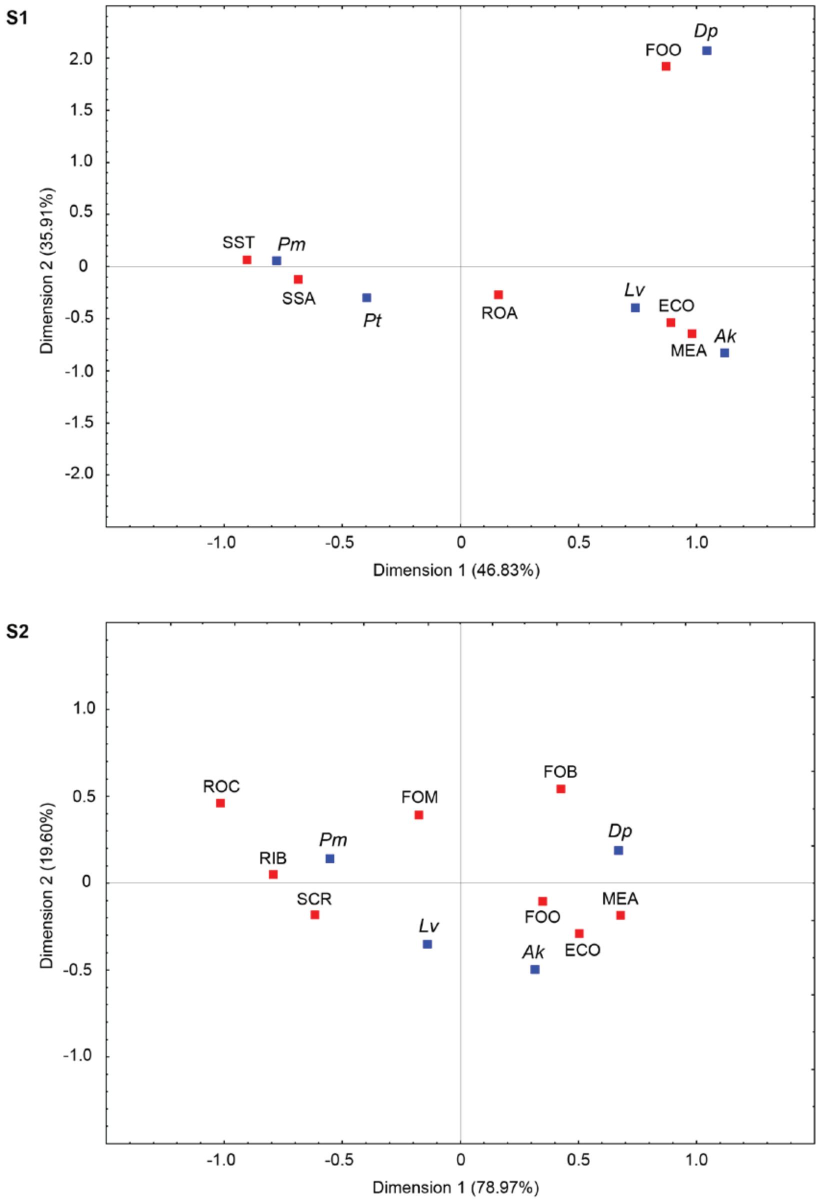

**Fig. 6.** The species ordinance and habitat in the space defined by the first two dimensions through correspondent analysis (separately for S1 and S2; for abbreviations see above).

tat for many lizard species (Delgado Garcia et al. 2007, Spellerberg 1998) and the significance of the roads in fragmented landscape (Meek 2014) is considerable as places for sunbathing or foraging. Overall, our results confirm the significance of the vegetation coverage for lizard diversity.

## Habitat preferences and spatial niche partitioning

Our results showed that *L. viridis* and *P. muralis* were the species with the widest spatial niche. *Lacerta viridis*, probably because of its larger size and population density (which could lead to intraspecific competition and occupation to suboptimal habitats), was found in all of the habitats (except FOC), but was most frequent in open areas, covered with shrubs and trees, like MEA with high presence of shrubs. Previous research also supports the preference to open areas with trees and shrubs, ecotones and bushy edge zones not only for *L. viridis* (Heltai et al. 2015, Korsós 1982, Spellerberg 1998) but also for other *Lacerta* spp. (Mazzotti 1999, Sacchi et al. 2011). The role of shrubs and opulent vegetation is significant as they provide suitable hiding places, especially for the juveniles. In S2, the most preferred habitat was FOO. However, the restricted area of MEA and other open areas at this site have to be considered (Fig. 1), which could explain the preference of *L. viridis* to FOO as most open among the other forest types.

**Table 2.** Values of the diversity indices per age classes and statistical significance of the differences (based on a permutation importance test; ** – significant at $p < 0.05$, * – significant at $p < 0.01$)

| Site | Species | Index | Adults | Imma-tures | Perm. *p* |
|---|---|---|---|---|---|
| **S1** | A. kitaibelii | Shannon H | 0.474 | 0.898 | 0.001** |
| | | Simpson 1-D | 0.298 | 0.561 | 0.002** |
| | *D. praticola* s.l. | Shannon H | 0.474 | 0.670 | 0.465 |
| | | Simpson 1-D | 0.212 | 0.363 | 0.279 |
| | *L. viridis* | Shannon H | 1.475 | 1.301 | 0.138 |
| | | Simpson 1-D | 0.730 | 0.670 | 0.106 |
| | *P. muralis* | Shannon H | 1.177 | 0.962 | 0.040* |
| | | Simpson 1-D | 0.585 | 0.517 | 0.195 |
| | *P. tauricus* | Shannon H | 0.862 | 0.600 | 0.478 |
| | | Simpson 1-D | 0.446 | 0.314 | 0.555 |
| **S2** | *A. kitaibelii* | Shannon H | 1.338 | 0.974 | 0.192 |
| | | Simpson 1-D | 0.649 | 0.512 | 0.255 |
| | *D. praticola* s.l. | Shannon H | 1.345 | 1.340 | 0.969 |
| | | Simpson 1-D | 0.665 | 0.662 | 0.950 |
| | *L. viridis* | Shannon H | 1.607 | 1.498 | 0.395 |
| | | Simpson 1-D | 0.750 | 0.709 | 0.260 |
| | *P. muralis* | Shannon H | 1.743 | 1.631 | 0.139 |
| | | Simpson 1-D | 0.804 | 0.744 | 0.003** |

**Table 3.** Values of the diversity indices per sexes and statistical significance of the differences (based on a permutation importance test; ** – significant at $p < 0.05$, * – significant at $p < 0.01$)

| Site | Species | Index | Males | Fe-males | Perm. *p* |
|---|---|---|---|---|---|
| **S1** | *A. kitaibelii* | Shannon H | 0.483 | 0.466 | 1.000 |
| | | Simpson 1-D | 0.305 | 0.291 | 1.000 |
| | *D. praticola* s.l. | Shannon H | 0.598 | 0.199 | 0.239 |
| | | Simpson 1-D | 0.279 | 0.095 | 0.285 |
| | *L. viridis* | Shannon H | 1.500 | 1.449 | 0.774 |
| | | Simpson 1-D | 0.738 | 0.722 | 0.781 |
| | *P. muralis* | Shannon H | 1.247 | 1.038 | 0.097 |
| | | Simpson 1-D | 0.615 | 0.535 | 0.200 |
| | *P. tauricus* | Shannon H | 0.774 | 0.955 | 0.558 |
| | | Simpson 1-D | 0.388 | 0.508 | 0.422 |
| **S2** | *A. kitaibelii* | Shannon H | 1.084 | 1.397 | 0.224 |
| | | Simpson 1-D | 0.583 | 0.673 | 0.425 |
| | *D. praticola* s.l. | Shannon H | 1.472 | 1.198 | 0.018* |
| | | Simpson 1-D | 0.732 | 0.586 | 0.006** |
| | *L. viridis* | Shannon H | 1.617 | 1.510 | 0.558 |
| | | Simpson 1-D | 0.736 | 0.742 | 0.932 |
| | *P. muralis* | Shannon H | 1.715 | 1.765 | 0.457 |
| | | Simpson 1-D | 0.798 | 0.810 | 0.486 |

The species of *Podarcis* showed higher preferences to the most open habitats. *Podarcis muralis*, as a saxicolous species, prefers rocky habitats, such as stones and walls (ARNOLD 1987, *Žagar* 2016). We recorded the species mainly from the stony shore (SST) in S1 and in all saxicolous habitats in S2. *Podarcis tauricus* is a typical ground-dwelling lizard, restricted to sunny areas with low vegetation (IOANNIDIS & BOUSBOURAS 1997) and preferred SSA. According to CHONDROPOULOS & LYKAKIS (1983), *P. tauricus* s. l. typically seeks cover in the herb layer (or in burrows in the substrate). The highest number of individuals found on the sandy shore could be explained by the increased opportunity for sunbathing there and the openness facilitating prey finding (ADAMOPOULOU & LEGAKIS 2002). KIM et al. (2012) assumed that the smaller size of the home range of the ecologically similar species, the steppe-runner *Eremias arguta* (Pallas, 1773), which inhabits small grass sand dunes, might be connected with the sufficiently large importance of the habitat for satisfying the lizards' ecological requirements for foraging, mating and cover.

*Darevskia praticola* s. l. was the species with the most limited spatial niche in S1, being confined mainly to FOO (the only forest type there). Its activity drastically declined in the hottest and dry months. This species prefers humid habitats (STRIJBOSCH et al. 1989, COVACIU-MARCOV et al. 2009a, b, ĆOROVIĆ et al. 2018) and in S1 was most abundant near the humid gully in the forest. *Podarcis muralis* also was found in FOO, but in contrast to *D. praticola* s. l., it preferred the sunny and dry forest parts. In S2, where the number of forest types was larger (than in S1) and they occupied much larger area than the open habitats, *D. praticola* s. l. displayed preference to FOO, but was also found in other deciduous forests, which corresponds well to literature data (e.g. ARNOLD & OVENDEN 2002; STOJANOV et al. 2011).

*Ablepharus kitaibelii* showed great similarity in habitat use with *L. viridis* (a similar coexistence was established also by HERCZEG et al. 2007), being most common in MEA with shrubs and in ECO between the grasslands and the broad-leaved forest. Numerous researches demonstrate the attachment of *A. kitaibelii* to grasslands with tussock-forming grass and places with leaf litter (the forest border), where animals can easily escape from predators (see KOVÁCS & KISS 2016).

## Age and sex dimorphism in the habitat choice

The habitat preference could be driven by morphological differences between adults and non-adults, which could affect whole-body performance and especially locomotor performance (KALIONTZOPOULOU et al. 2010). On the other hand, it could be interpreted as a social interaction. Adults occupy the most favourable habitats, forcing juveniles to choose the less favourable ones, in order to avoid competition or direct risk of predation (cannibalism in *P. muralis* was reported by Žagar & Carretero 2012 and Simović & Marković 2013). Habitats that are more open could increase susceptibility to predators such as snakes or birds, wherein screes could provide good refuge opportunities (Vanhooydonck & Van Damme 2003).

The difference between sexes could be interpreted as an avoidance of intraspecific competition in general, but it also could be related to nesting behaviour, i.e. females could have a narrow home range (Angilletta et al. 2009) and could be more attached to sunny patches, presented mainly in FOO (in an area generally dominated by forests as S2).

# Conclusion

Lizard diversity in the mountain foothills of western Bulgaria was the highest in the territories with medium vegetation coverage (meadows with shrubs, ecotones, open oak forests, etc.). Lizards avoid non-natural pine plantations, a fact once again proving the detrimental effect of the afforestation with non-native tree species on the herpetofauna. Among the studied species, *Lacerta viridis* and *Podarcis muralis* had the highest spatial niche breadth, so they can be defined as opportunists. Age dimorphism (adults vs. immatures) in habitat preferences was well expressed only in *Ablepharus kitaibelii* and *Podarcis muralis*. It seems that in most species (except *Darevskia praticola* s. l.), there was no distinction between sexes in habitat choice. Overall, to clarify ontogenetic and sexual differences in habitat preferences, further and more detailed research is need.

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**Appendix 1.** Number of observed specimens per habitat (all specimens, including those for which age and sex were not determined) and values of diversity indices (for abbreviations see Material and Methods).

| **S1** | **FOO** | **ECO** | **ROA** | **MEA** | **SSA** | **SST** | **Sum total** | **Shannon H** | **Simpson 1-D** |
|---|---|---|---|---|---|---|---|---|---|
| ***A. fragilis* complex** | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 0.69 | 0.5 |
| *A. kitaibelii* | 0 | 40 | 4 | 87 | 0 | 0 | 131 | 0.74 | 0.46 |
| ***D. praticola* s.l.** | 74 | 5 | 2 | 8 | 0 | 0 | 89 | 0.62 | 0.3 |
| *L. viridis* | 16 | 30 | 60 | 89 | 8 | 5 | 208 | 1.41 | 0.7 |
| *P. muralis* | 16 | 11 | 42 | 3 | 97 | 294 | 463 | 1.07 | 0.54 |
| *P. tauricus* | 0 | 0 | 7 | 14 | 56 | 3 | 80 | 0.89 | 0.47 |
| Sum total | 106 | 87 | 115 | 202 | 161 | 302 | 973 | | |
| Shannon H | 0.82 | 1.2 | 1.07 | 1.13 | 0.82 | 0.14 | | | |
| Simpson 1-D | 0.47 | 0.65 | 0.59 | 0.61 | 0.51 | 0.05 | | | |

| **S2** | **FOO** | **FOB** | **FOM** | **ECO** | **RIB** | **MEA** | **SCR** | **ROC** | **Sum total** | **Shannon H** | **Simpson 1-D** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***A. fragilis* complex** | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 1.1 | 0.67 |
| *A. kitaibelii* | 65 | 2 | 0 | 18 | 6 | 6 | 20 | 0 | 117 | 1.29 | 0.63 |
| ***D. praticola* s.l.** | 162 | 77 | 21 | 42 | 1 | 21 | 6 | 0 | 330 | 1.39 | 0.68 |
| *L. viridis* | 63 | 5 | 7 | 22 | 24 | 9 | 54 | 1 | 185 | 1.64 | 0.76 |
| *P. muralis* | 91 | 42 | 34 | 11 | 90 | 2 | 126 | 22 | 418 | 1.74 | 0.8 |
| Sum total | 382 | 127 | 62 | 93 | 122 | 38 | 206 | 23 | 1053 | | |
| Shannon H | 1.32 | 0.9 | 0.94 | 1.27 | 0.77 | 1.12 | 0.98 | 0.18 | | | |
| Simpson 1-D | 0.71 | 0.52 | 0.57 | 0.69 | 0.41 | 0.61 | 0.55 | 0.08 | | | |

**Appendix 2.** Division of the observed specimens per habitat (for abbreviations see Material and Methods) by age class (as percentage from the total number).

| **S1** | **Habitat** | **Adults** | **Immatures** |
|---|---|---|---|
| ***A. kitaibelii***<br>n (ad.) = 33<br>n (imm.) = 28 | MEA | 81.82 | 42.86 |
| | ECO | 18.18 | 50.00 |
| | ROA | - | 7.14 |
| ***D. praticola* s.l.**<br>n (ad.) = 52<br>n (imm.) = 23 | MEA | 3.85 | 13.04 |
| | ECO | 5.77 | 8.70 |
| | FOO | 88.46 | 78.26 |
| | ROA | 1.92 | - |
| ***L. viridis***<br>n (ad.) = 77<br>n (imm.) = 75 | SSA | 3.90 | 2.67 |
| | SST | 2.60 | 1.33 |
| | MEA | 28.57 | 48.00 |
| | ECO | 11.69 | 21.33 |
| | FOO | 14.29 | 4.00 |
| | ROA | 38.96 | 22.67 |
| ***P. muralis***<br>n (ad.) = 234<br>n (imm.) = 123 | SSA | 18.38 | 22.76 |
| | SST | 60.26 | 65.04 |
| | MEA | 0.85 | - |
| | ECO | 2.99 | 2.44 |
| | FOO | 5.56 | 0.81 |
| | ROA | 11.97 | 8.94 |
| ***P. tauricus***<br>n (ad.) = 47<br>n (imm.) = 11 | SSA | 72.34 | 81.82 |
| | SST | 4.26 | - |
| | MEA | 14.89 | 9.09 |
| | ROA | 8.51 | 9.09 |

| **S2** | **Habitat** | **Adults** | **Immatures** |
|---|---|---|---|
| ***A. kitaibelii***<br>n (ad.) = 57<br>n (imm.) = 18 | RIB | 8.77 | - |
| | SCR | 14.04 | 16.67 |
| | MEA | 5.26 | 5.56 |
| | ECO | 15.79 | 11.11 |
| | FOO | 54.39 | 66.67 |
| | FOB | 1.75 | - |
| ***D. praticola* s.l.**<br>n (ad.) = 209<br>n (imm.) = 96 | RIB | - | 1.04 |
| | SCR | 0.96 | 3.13 |
| | MEA | 6.22 | 4.17 |
| | ECO | 16.27 | 5.21 |
| | FOM | 6.70 | 6.25 |
| | FOO | 51.67 | 45.83 |
| | FOB | 18.18 | 34.38 |
| ***L. viridis***<br>n (ad.) = 82<br>n (imm.) = 83 | RIB | 12.20 | 13.25 |
| | SCR | 40.24 | 19.28 |
| | MEA | 2.44 | 7.23 |
| | ECO | 10.98 | 9.64 |
| | FOM | 7.32 | - |
| | FOO | 23.17 | 46.99 |
| | FOB | 3.66 | 2.41 |
| | ROC | - | 1.20 |

**Appendix 2.** Continuation.

| **S2** | **Habitat** | **Adults** | **Immatures** |
|---|---|---|---|
| ***P. muralis***<br>n (ad.) = 284<br>n (imm.) = 114 | RIB | 21.48 | 21.93 |
| | SCR | 24.30 | 42.11 |
| | MEA | - | 1.75 |
| | ECO | 2.11 | 3.51 |
| | FOM | 9.86 | 5.26 |
| | FOO | 25.70 | 11.40 |
| | FOB | 9.86 | 11.40 |
| | ROC | 6.69 | 2.63 |

**Appendix 3.** Division of the observed specimens per habitat (for abbreviations see Material and Methods) by sex (as percentage from the total number).

| **S1** | **Habitat** | **Males** | **Females** |
|---|---|---|---|
| ***A. kitaibelii***<br>n (m.) = 16<br>n (f.) = 17 | MEA | 81.25 | 82.35 |
| | ECO | 18.75 | 17.65 |
| | ROA | - | - |
| ***D. praticola* s.l.**<br>n (m.) = 32<br>n (f.) = 20 | MEA | 6.25 | - |
| | ECO | 6.25 | 5.00 |
| | FOO | 84.38 | 95.00 |
| | ROA | 3.13 | - |
| ***L. viridis***<br>n (m.) = 30<br>n (f.) = 47 | SSA | 3.33 | 4.26 |
| | SST | 3.33 | 2.13 |
| | MEA | 23.33 | 31.91 |
| | ECO | 13.33 | 10.64 |
| | FOO | 16.67 | 12.77 |
| | ROA | 40.00 | 38.30 |
| ***P. muralis***<br>n (m.) = 139<br>n (f.) = 95 | SSA | 17.99 | 18.95 |
| | SST | 57.55 | 64.21 |
| | MEA | 0.72 | 1.05 |
| | ECO | 4.32 | 1.05 |
| | FOO | 7.91 | 2.11 |
| | ROA | 11.51 | 12.63 |
| ***P. tauricus***<br>n (m.) = 26<br>n (f.) = 21 | SSA | 76.92 | 66.67 |
| | SST | 3.85 | 4.76 |
| | MEA | 11.54 | 19.05 |
| | ROA | 7.69 | 9.52 |

| **S2** | **Habitat** | **Males** | **Females** |
|---|---|---|---|
| ***A. kitaibelii***<br>n (m.) = 22<br>n (f.) = 35 | RIB | 9.09 | 8.57 |
| | SCR | 22.73 | 8.57 |
| | MEA | - | 8.57 |
| | ECO | 9.09 | 20.00 |
| | FOO | 59.09 | 51.43 |
| | FOB | - | 2.86 |
| ***D. praticola* s.l.**<br>n (m.) = 92<br>n (f.) = 117 | RIB | - | - |
| | SCR | 1.09 | 0.85 |
| | MEA | 6.52 | 5.98 |
| | ECO | 17.39 | 15.38 |
| | FOM | 9.78 | 4.27 |
| | FOO | 40.22 | 60.68 |
| | FOB | 25.00 | 12.82 |
| ***L. viridis***<br>n (m.) = 40<br>n (f.) = 42 | RIB | 15.00 | 9.52 |
| | SCR | 45.00 | 35.71 |
| | MEA | 5.00 | - |
| | ECO | 7.50 | 14.29 |
| | FOM | 7.50 | 7.14 |
| | FOO | 15.00 | 30.95 |
| | FOB | 5.00 | 2.38 |
| | ROC | - | - |
| ***P. muralis***<br>n (m.) = 164<br>n (f.) = 120 | RIB | 20.73 | 22.50 |
| | SCR | 25.00 | 23.33 |
| | MEA | - | - |
| | ECO | 1.83 | 2.50 |
| | FOM | 9.15 | 10.83 |
| | FOO | 26.83 | 24.17 |
| | FOB | 11.59 | 7.50 |
| | ROC | 4.88 | 9.17 |