Environmental and overwintering conditions of *Pellenes* spp. (Araneae: Salticidae)

Kristina Stempakova, Vladimir Hula
Department of Zoology, Fisheries, Hydrobiology and Apiculture
Mendel University in Brno
Zemedelska 1, 613 00 Brno
CZECH REPUBLIC

xstempak@mendelu.cz

Abstract: The research consisted of two parts. In the first part, the influence of the microclimate of hibernating hiding place (shade of shells) on the gregarious hibernation was solved and thus possible explanation of the formation of unusual social behaviour in these predatory species. In the second part, the presence/absence of spider species of interest – *Pellenes tripunctatus* (Walckenaer, 1802) and *P. nigrociliatus* (Simon, 1875) were observed at localities without calcareous bedrock, respectively without natural presence of gastropods by using scattered empty shells. The results showed that *P. nigrociliatus* also occurs at localities with acidic bedrock (27.59% occupancy of shells). It is interesting that individuals overwintered in larger shells of *Caucasotachea vindobonensis* (Férussac, 1821) despite the more frequent overwintering and affinity to the shell of *Xerolenta obvia* (Menke, 1828), what is mentioned in previous works. Up to 59.38% of individuals chose a larger shell. It has not been confirmed that the microclimate of shells affects group wintering. The white shells were the most inhabited (25.74%), but mainly by one individual, the brown shells were the least inhabited (17.61%). Regarding to gregarious hibernation, uncoloured shells were the most inhabited (20.65%). The highest number in the group of overwintering individuals was six individuals of *P. tripunctatus*.

Key Words: spiders, shells, environment, hibernation, behaviour

INTRODUCTION

Pellenes tripunctatus (Walckenaer, 1802) and *Pellenes nigrociliatus* (Simon, 1875) of the family Salticidae are typical thermophilic species with Eurasian distribution (Żabka 1997). In the Czech Republic, they belong to scarce species occurring at natural steppe and steppe-like habitats and secondary habitats such as various post-industrial sites. Despite a similar distribution area, environmental conditions such as vegetation cover density and stony substrate differ between these species. Spiders of species *P. tripunctatus* prefer more pronounced vegetation cover. In the southern parts of the country, it even inhabits meadows and pastures. Spiders of species *P. nigrociliatus* favour areas with low vegetation. It can be found on rocky steppes or sandbars (Kůrka et al. 2014). In addition, there was recorded a high abundance of these spider species on localities with empty shells of terrestrial gastropods (50–80% of occupancy in the shells). These are particularly steppe areas on calcareous bedrock, guaranteeing a high number of gastropods (Horn 1980, Bauchhenss 1995, Szinetár et al. 1998, Moreno-Rueda et al. 2008). Most of the life processes of these spiders are closely bound to the presence of the empty shells. These two spider species use empty shells not only for hibernation but also for mating, oviposition and taking care of offspring (Mikulska 1961, Horn 1980). In addition, preferred shells of certain species of gastropods have been detected. The most well-known is the affinity of *P. nigrociliatus* to the shell of *Xerolenta obvia* (Menke, 1828), which is described by Mikulska (1961) and Horn (1980). Species of *P. tripunctatus* prefers shells of the larger gastropod – *Caucasotachea vindobonensis* (Férussac, 1821), as described Niedobová et al. (2013) in their work. In this case, however, the affinity is not as pronounced and there are also records in shells of the genus *Zebrina* sp. and *Xerolenta* sp. (Bauchhenss 1995). At present, the abundance of these species is well known in the steppe landscape with calcareous bedrock. But are habitats on acidic bedrock (with similar natural conditions) suitable habitats for the life of these species? To what extent does the abundance of these species relate to the abundance of empty shells in the habitat and the strong affinity to these shells?

In addition, there was found group hibernation in one shell in the case of *P. tripunctatus* and *P. nigrociliatus*. It is more significant in species of *P. tripunctatus* (Štempáková 2016 and personal observation). Most spiders are solitary and cannibalism is widespread among them, as is the case with the Salticidae family (Buskirsk 1981, Herberstein 2011). Despite this, in some cases certain groups are formed where natural aggressiveness is suppressed and mutual tolerance developed (Bilde and Lubin 2001). Before the formation of a certain aggregation, communication takes place, whether by means of chemical, sound or tactile signals. In addition, the Salticidae family use excellent eyesight (Krafft and Cookson 2012, Herberstein 2011). Also important in this case is the spider web, which plays a key role in spider sociality and explains the phenomena of group cohesion and cooperation (Krafft and Cookson 2012). For example, jumping spiders of *Phidippus audax* (Hentz, 1845) occasionally aggregate in dense cocoons below the bark. Temporary aggregations have also been reported for *Paraphidippus marginatus* (Hentz, 1845) or *Marpissa undata* (C. L. Koch, 1846). In the summer, cocoons were seen under the blades of grass in the case of *Marpissa radiata* (Grube, 1859) or *Sitticus littoralis* (Hahn, 1832), which also clustered with other species (Buskirsk 1981).

The shell of *C. vindobonensis*, which *P. tripunctatus* most often uses in our conditions, shows a distinct polymorphism. This is to some extent influenced by the habitat type and is shown externally by the tint of the shell, the tint of the band on the shell, the thickness of the bands, etc. Darker shells and shells with more marked bands absorb more heat from the sun (Ożgo and Komorowska 2009). Thus, the microclimate of shell could play an important role in spiders grouping within the gregarious wintering. Are darker shells inhabited more pronounced? And are they more often inhabited by a group of spiders or by the individual? So, is the microclimate inside the empty shell crucial to its selection and explains the group wintering?

MATERIAL AND METHODS

The methodology describes two parts of the research. The first part is focused on an experiment describing the effect of the microclimate inside the shell (shade of shells) on the spider hibernation. The second part describes the detection of the presence of spider species of interest in habitats with acidic bedrock.

Influence of shells microclimate on spider hibernation

The research was carried out at two steppe habitats with calcareous bedrock. The location of the habitats is shown in Figure 1. Empty shells of *C. vindobonensis* were scattered in number of 1050 shells in June 2017. At both localities, the rectangular areas (9 m x 3 m) were divided into three square sections. Specifically, at the locality of Malhotky, 8 areas were designed with 600 shells, and at the locality of Kamenný vrch, 6 areas were designed with 450 shells. Each square contained 25 shells in a different shade. For better results by emphasizing a more significant microclimate inside, the shells were painted in brown and white. The original shells that occurred on the localities were removed. In order to maximize the possibility of inhabit by spiders, the shells were left for two years at localities. Upon arrival, the shells were individually collected with locality designation, number of square and serial number. After collecting, the evaluation was based on the inhabitancy of the shells (in this case mainly *P. tripunctatus*), species diversity and which shells were preferred for gregarious hibernation.

Influence of natural conditions on the presence of species of interest and affinity to shells

The research was carried out at five localities with natural conditions (low and sparse vegetation, presence of stony substrate, moss, etc.) close to the species of interest (*P. tripunctatus*, *P. nigrociliatus*), but without the calcareous bedrock, respectively without the natural presence of gastropods – *C. vindobonensis* and *X. obvia*. The location of the habitats is shown in Figure 2. A total of 500 empty shells were scattered in July 2017. An area (10 m x 10 m) was designated at each locality. In number of 50 shells of *C. vindobonensis* and 50 shells of *X. obvia* were designed for each demarcated square. The shells were also collected after two years. The evaluation consisted in detection the presence/absence of the two spider species of interest and in confirming the strength of the affinity to the shells of the gastropods.

Figure 1 The location of the habitats – NR Kamenný vrch u Kurdějova (1) and NNM Malhotky (2)

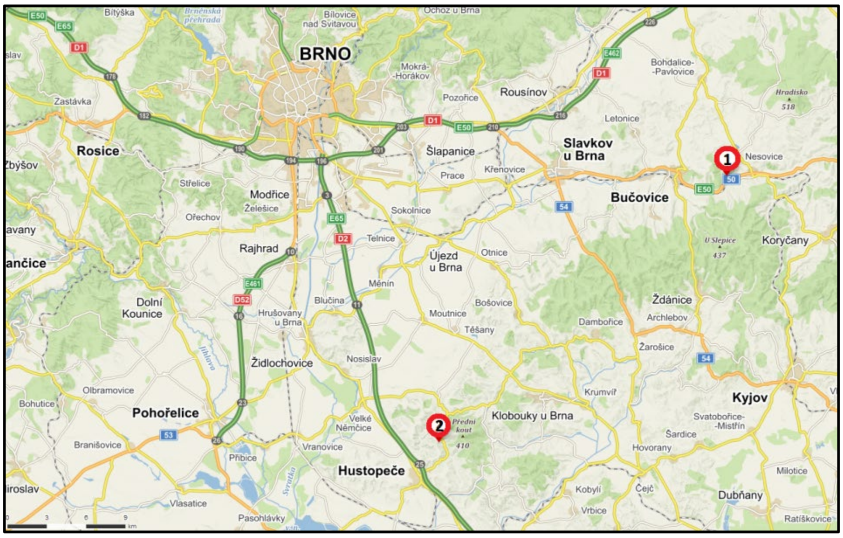
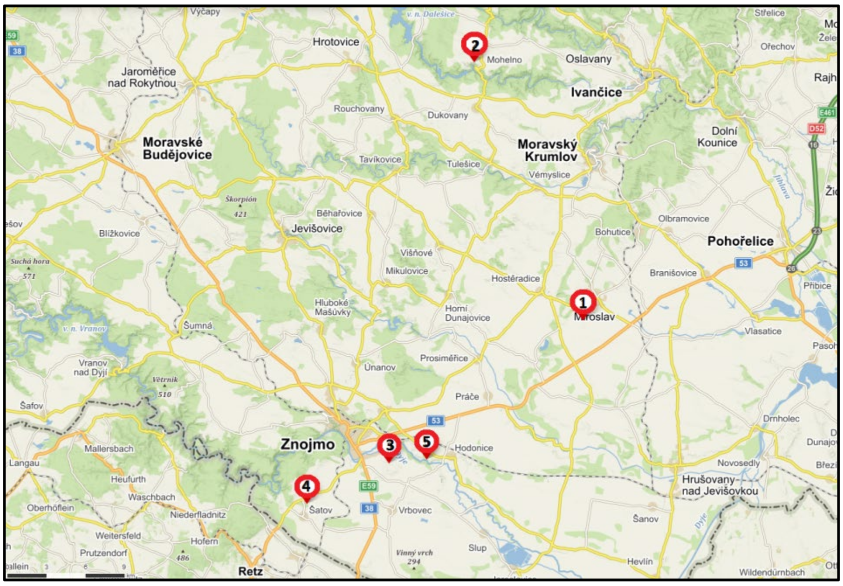


Figure 2 The location of the habitats – NNM Miroslavské kopce (1), NNR Mohelenská hadcová step (2), NM Načeratický kopec (3), NM Skalky u Havraníků (4), NM Tasovické svahy (5)



RESULTS AND DISCUSSION

Influence of shells microclimate on spider hibernation (only *P. tripunctatus*)

In the first part of the research, in winter 2019 altogether 672 shells (426 shells at Malhotky, 246 shells at Kamenný vrch) were collected. Thus, 64% of the 1050 shells were obtained. The smallest amount was represented by brown shells (159 shells), which were more difficult to identify in the country, especially on the experimental squares at the Kamenný vrch, where higher vegetation was left within the management (mosaic mowing). Regarding to spiders, 146 individuals of *P. tripunctatus* were obtained from these shells. The total occupancy (also in the case of group hibernation) is 21.73%. The numbers of collected shells and their occupancy are described in Table 1. The brown shells were inhabited the least. This low occupancy can be caused by the high temperature inside the shell absorbed by the dark surface. This can cause undesirable interruption of hibernation. Interestingly, the white shells were the most inhabited, mainly by individual occupancy (Total – 25.74%, Kamenný vrch – up to 31.04%). It was assumed that white shells would most often be inhabited by a larger number of individuals to provide a higher temperature inside the shell. In the case of group wintering in shells, this could be a sub sociality in which sub social species live in colonies only for a period of time benefiting from this coexistence (Yip and Rayor 2014, Herberstein 2011). Thus, one advantage could be the higher number of aggregating individuals and the associated social thermoregulation, well known in social insects (Jones and Oldroyd 2006). Gregarious hibernation was most observed in uncoloured shells (see Table 2). Up to six hibernating individuals were found in one uncoloured shell at Malhotky. This is certainly interesting information when natural predators reaching the size of 5–7 mm can tolerate to each other and can hibernate together in relatively small shells with a diameter of about 20 mm (Kůrka et al. 2014, Welter-Schultes 2012). From the achieved results, however, it cannot be unambiguously determined that the microclimate of shells plays a role in its inhabitation. It is necessary to carry out several other experiments to confirm or refute the hypothesis. The formation of these groups is thus caused by another factor, which may be just communication, some form of agreement and the learning of socialization, which is mentioned in some of the few works of jumping spiders (Liedtke and Schneider 2017).

Table 1 The numbers of collected shells and their occupancy (red font - a case of group wintering in which shells were inhabited by more than one individual)

Locality	Brown shells			White shells			Uncoloured shells			Total		
	Number of collected shells	Number of occupied shells	Number of spiders in shells	Number of collected shells	Number of occupied shells	Number of spiders in shells	Number of collected shells	Number of occupied shells	Number of spiders in shells	Number of collected shells	Number of occupied shells	Number of spiders in shells
Malhotky	102	12	13	150	31	34	174	26	39	426	69	86
Kamenný vrch	57	12	15	87	26	27	102	16	18	246	54	60
All shells	159			237			276			**672**		
All spiders	28			61			57			**146**		

Table 2 Gregarious hibernation in species of P. tripunctatus

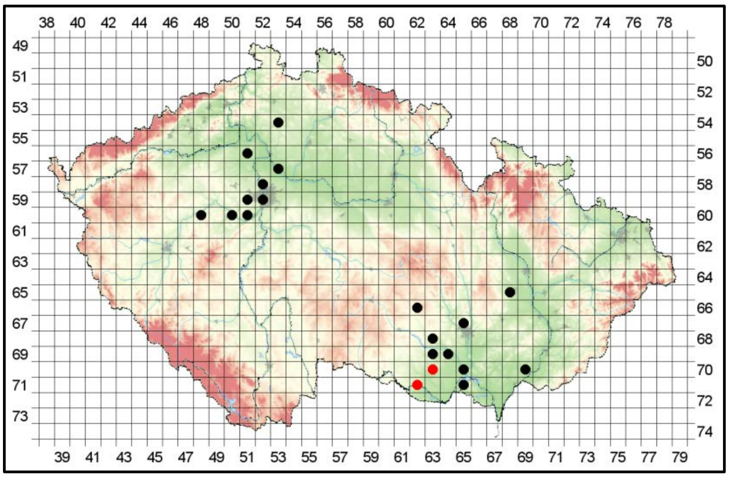
Locality	Shell	Number of individuals
Malhotky	uncoloured	6
Malhotky	uncoloured	4
Malhotky	uncoloured	4
Malhotky	white	3
Malhotky	uncoloured	2
Malhotky	uncoloured	2
Malhotky	white	2
Malhotky	brown	2
		25
Kamenný vrch u K.	brown	3
Kamenný vrch u K.	uncoloured	3
Kamenný vrch u K.	brown	2
Kamenný vrch u K.	white	2
		10

Influence of natural conditions on the presence of species of interest and affinity to shells

In the second part of the research, which also took place in the winter of 2019, the collection of shells was carried out at localities without calcareous bedrock and therefore without the natural presence of gastropods of interest. Unfortunately, only 116 shells were collected, representing 23.20%. No shells were recorded at Tasovické svahy. The reason was the passage of heavy mechanization, probably within certain management. The locality of Načeratický kopec brought a similar result.

A total of 56 shells of *C. vindobonensis* and 60 shells of *X. obvia* were collected. Of the total number, 32 were found inhabited by *P. nigrociliatus*. Spiders of *P. tripunctatus* were not found. In spite of the small amount of material obtained, new records of *P. nigrociliatus* species were identified, which complement the before discovered records mainly in southern Moravia and in the wider surroundings of Prague (Buchar and Růžička 2002). New information about the occurrence of the species is shown in Figure 3. An interesting discovery is the more frequent presence of this species in the shell of *C. vindobonensis* (up to 59.38%) despite the already mentioned strong affinity to the shell of the *X. obvia* (Mikulska 1961, Horn 1980). It was assumed that individuals would choose a smaller shell of *X. obvia* also in terms of a possibly more favourable size ratio. Consequently, there is no affinity to the shell in this case and the choice of shell kind is probably random.

Figure 3 The occurrence of species Pellenes nigrociliatus in the Czech republic. The black dots represent older records. The red dots show new records of P. nigrociliatus.



Other spider species found in the research

Another nine species of spiders were found from both parts of the research. The Malhotky locality with 6 species was the most interesting, of which 59.58% were *Euryopis quinqueguttata* (Thorell, 1875) classified as EN. Among others, five records of the species *Attulus penicillatus* (Simon, 1875), which is also in the EN category, can be mentioned. It was found at localities Malhotky and Miroslavské kopce. It is worth mentioning the species *Haplodrassus kulczynskii* (Lohmander, 1942) from the category VU (Řezáč et al. 2015) found on the locality Kamenný vrch.

CONCLUSION

The results brought information regarding to new records of *P. nigrociliatus* also at localities without calcareous bedrock and natural occurrence of empty gastropods, to which the living conditions of this species of spider are strongly linked. In addition, overwintering has been found to occur in a larger species of shell – *C. vindobonensis* rather than a predicted smaller species – *X. obvia* despite its availability. Thus, if both species of gastropods are present, *P. nigrociliatus* is likely to use both sources. In the group hibernation of *P. tripunctatus* species in one shell, the microclimate of the shell is probably not the cause of clustering of individuals and the associated social thermoregulation. White shells were mostly occupied by one spider. Group wintering was most common in uncoloured shells. Six individuals were the highest quantity found in one shell. Thus, the unusual gregarious hibernation in one shell of these otherwise predatory species causes a different factor than the shade of the shell providing a certain microclimate.

ACKNOWLEDGEMENTS

The research was financially supported by IGA MENDELU grant no. AF-IGA-2018-tym004.

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