HABITAT STRUCTURE EFFECTS ON THE DISTRIBUTION AND ABUNDANCE OF THE RARE SNAIL *VERTIGO MOULINSIANA* (DUPUY, 1849)

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Abstract Vertigo moulinsiana *is a rare, small, land snail species, living in wet areas with high pH and calcium content. This paper presents the results of analysis of microclimatic and microhabitat variables, and their effect on the occurrence and abundance of this species. The research was carried out at one of the few sites for the species in Poland: in wetlands located in the valley of the Nida river.* Vertigo moulinsiana *in the studied area selects microhabitats with a high level of groundwater, covered with vegetation of reed mannagrass: "carex and glyceria" and "glyceria", and a thick layer of litter. The vegetation type significantly depends on the groundwater level and significantly affects the soil content of organic matter and the vegetation height.*

Key words Vertigo moulinsiana, *Desmoulin's whorl snail, distribution and abundance, microhabitat, microclimate, habitat structure, Polish wetlands*

Introduction

The small snail *Vertigo moulinsiana* (2.7mm high and 1.6mm wide) has been recognized as a vulnerable species throughout Europe (IUCN, 2013) and listed in Appendix II of the Habitats Directive (Directive, 1992). The species biology and ecology has been described in a number of studies in Poland (Killeen, 2003; Lipińska, Gołąb & Ćmiel, 2011; Myzyk, 2005; 2011; Pokryszko, 1987; 1990; 2003) but its microhabitat distribution has not been studied before. It is known that the snail occurs in open wetlands with high levels of calcium in water and soil (Killeen, 2003; Pokryszko, 2004; Zając, 2004; Lipińska, 2010; Lipińska, Książkiewicz, Zając & Barga-Więcławska, 2012). Literature data suggest that the main factor responsible for the occurrence of this species is an appropriate groundwater level (Killeen, 2003; McInnes & Tattersfield, 2003). So far it has not been possible to answer the question why there are many habitats suitable for *Vertigo moulinsiana* but where this species does not occur. The issue of the species' habitat microstructure has not yet been addressed in the literature, whereas the role of microhabitats and their effect on the distribution of small snail species has been already recognized (Olabarria *et al*., 2002; Kuczyńska & Moorkens, 2010).

This paper presents the results of research on variables of the microhabitat of *Vertigo moulinsiana* and their impact on the occurrence and abundance of this species. The aim of the study was to analyse the pattern of the distribution along gradients of environmental variables in order to find the habitat preferences of the snail.

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Materials and Methods

The study was conducted at one of the south-eastern sites of *Vertigo moulinsiana* in Poland, over a 6.1 ha area, situated in the so-called Inland Delta of the Nida River (50°34'30" N, 20°31'27" E). The study area is covered by a dense network of open wetland areas, meadows and old river-beds (details in Lipińska *et al*. 2011).

In July 2011, two transects (A and B) were laid out, each 50m long (Figs 1 and 2). The following parameters were measured at 1m intervals:

– the number of *Vertigo moulinsiana* individuals (searched on 25×25cm plots of vegetation with all plants examined within),
– plants on which snails occurred (identified to the genus level),
– groundwater level (stagnant water depth related to the ground level: modulo (g–d), where g-ground level (0) and d-water level depth),
– vegetation type (categorized according to the distinguished four land cover types): "carex" (area overgrown mostly with *Carex elata*), "carex and glyceria" (area overgrown mostly with *Carex elata* and *Glyceria maxima*), "glyceria" (area overgrown mostly with *Glyceria maxima*) and "meadow" (Lipińska *et al*. 2011),

– vegetation canopy height,
– thickness of litter
– light intensity (lx; Digital Lux Meter Nicety Lx 802), the amount of UV radiation (10-degree scale, the Oregon Scientific Baby Comfort weather station), temperature (°C) and relative air humidity (%RH; Precision Hygro-Thermometer CEM DT-3321) measured under the vegetation canopy

Measurements of temperature and relative air humidity were performed along transect A, while measurements of litter thickness along transect B. Measurements were carried out only once, between 9 and 12 a.m. on the 21st of July 2011. It was sunny with cloudless sky, and no wind.

To determine the organic matter content, 15 soil samples were collected from each of the three types of the microhabitat ("carex", "glyceria", "carex and glyceria"). The method of loss on ignition (LOI) analysis was applied to the samples (Heiri, Lotter & Lemcke, 2001).

Statistical analysis was performed using the software Statistica 10.1.

Results

The number of *Vertigo moulinsiana* snails in relation to microhabitat parameters is presented in Fig. 1. Fig. 2 shows the graphical presentation of preformed statistical analyses. Results of those analyses are presented in Table 1.

The largest numbers of snails were found in the "carex and glyceria" vegetation type, followed by "glyceria" and "carex", while the smallest number in "meadow". The abundance of snails significantly increases with a groundwater level rise and an increase in the litter thickness. The effect of the height of the vegetation on the number of snails is not statistically significant. The average number of *Vertigo moulinsiana* individuals occurring on a sedge plant *Carex sp.* (N_{mean}=0.7) is significantly different from the average number of snails occurring on reed mannagrass *Glyceria maxima* (N_{mean}=3). Differences in the number of snails between transects A and B are statistically significant.

The vegetation type significantly depends on the groundwater level. "Carex and glyceria" and "glyceria" vegetation types occurred in places of a significantly higher groundwater level compared to "carex" and "meadow" vegetation types. Vegetation types significantly affect the

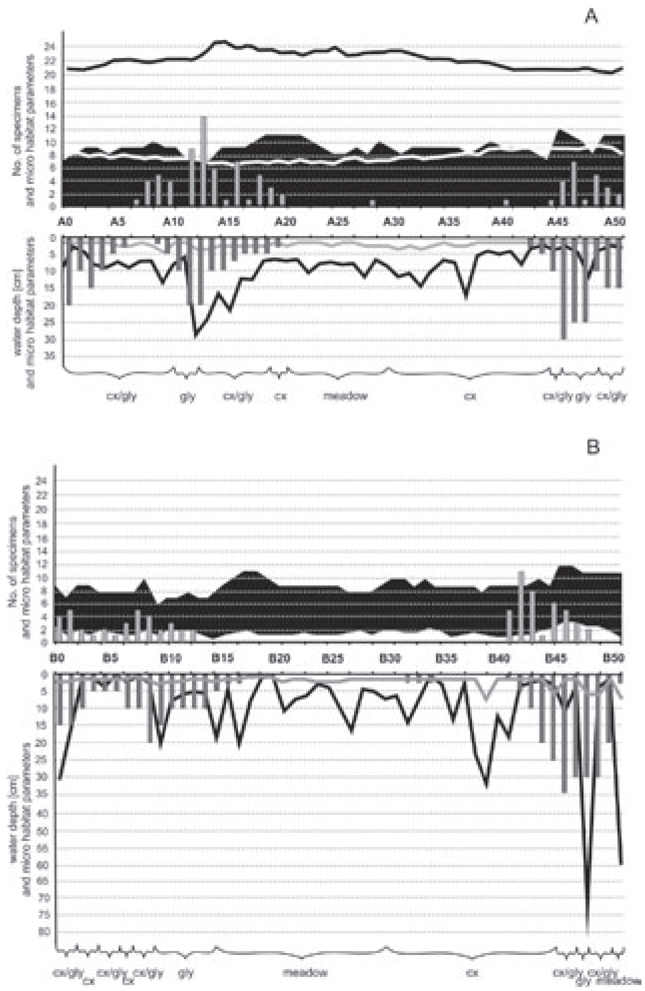

Figure 1 The number of *Vertigo moulinsiana* snails along transects in relation to microhabitat parameters. (A) Transect A – the upper graph: grey bars – the number of specimens, black surface chart – vegetation canopy height [cm] (values divided by 10), black solid line – the average air temperature [°C], white solid line – average relative air humidity [%RH] (values divided by 10); the lower graph: grey bars – stagnant water depth [cm], black solid line – light intensity [lx] (values divided by 1000), grey solid line – the amount of UV radiation [10-degree scale]. Brackets at the bottom of the graph indicate the occurrence limits of the vegetation types: cx-"carex", gly-"glyceria", cx/gly-"carex and glyceria" and "meadow". (B) Transect B – the upper graph: grey bars – the number of specimens, black surface chart – vegetation canopy height [cm] (values divided by 10), white surface chart – thickness of litter [cm]; lower graph: grey bars – stagnant water depth [cm], black solid line – light intensity [lx] (values divided by 1000), grey solid line – the amount of UV radiation [10-degree scale]. Brackets at the bottom of the graph indicate the occurrence limits of the vegetation types: cx-"carex", gly-"glyceria", cx/gly-"carex and glyceria" and "meadow".

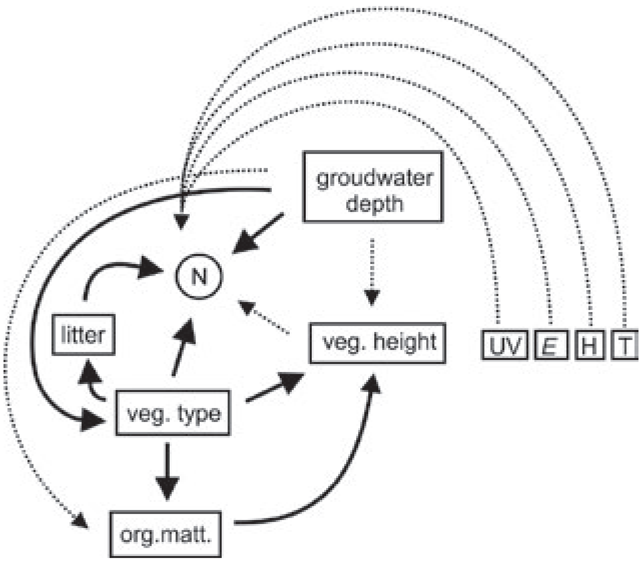

Figure 2 Graphical presentation of statistical analyses: N – the number of *Vertigo moulinsiana* snails, occur. height – the height of snails' occurrence, T – temperature, H – relative air humidity, *E* – light intensity, UV – the amount of UV radiation, groundwater depth – groundwater level, veg. height – vegetation height, litter – thickness of litter, veg. type – vegetation type, org. matt. – organic matter content; arrows with solid lines – statistically significant influence, arrows with dotted lines – no statistical significance

height of plants. The effect of the groundwater level on the height of plants is not significant.

The thickness of litter differs significantly between the vegetation types; the thickest layer of litter occurred in the "carex and glyceria" vegetation type. The analysis of the organic matter content in the soil revealed that the vegetation type defined as "glyceria" is characterized by a significantly higher content of organic matter compared to the two other vegetation types: "carex" and "carex and glyceria".

Values of weather parameters are presented in Table 2. The air temperature, relative air humidity, light intensity and the amount of UV radiation had no significant effect on the number of snails.

DISCUSSION

It has been found that *Vertigo moulinsiana* in the studied area selects microhabitats with a high groundwater level (Figs 1–2), covered with vegetation of reed mannagrass: "carex and glyceria" and "glyceria" (Figs 1–2) and a thick layer of litter (Figs 1–2). Canopy height and microclimate parameters have insignificant influence on the number of snails (Tab. 2, Fig 2).

The significant influence of the groundwater level on the distribution and abundance of the snail found in our study is confirmed in the literature. The groundwater level is the most significant factor determining the occurrence of this species in a given area (Seddon, 1996; Hornung, Majaros, Fehér & Varga, 2003; McInnes & Tattersfield, 2003; Killeen, 2003; Lipińska *et al*., 2011; Książkiewicz, 2013).

Table 1 Summary of statistical analyses

Response	Factors	test	Statistic	p
	Groundwater level	Poisson regression	W=156.09	<0.0001
	Litter thickness	Poisson regression	W=22.67	<0.0001
	Plants height	Poisson regression	W=1.96	0.1612
	Transect	GLZ Log Poisson	W=11.18	0.0008
Number of snails	Vegetation type	GLZ Log Poisson	W=66.75	<0.0001
	Air temperature	Poisson regression	W=2.98	0.084
	Relative air humidity	Poisson regression	W=0.01	0.0947
	Light intensity	GLZ Log Poisson	W=2.20	0.1378
	UV radiation	GLZ Log Poisson	W=0.95	0.3306
	Vegetation type (*Carex sp. vs Glyceria maxima)*	t-test	t=–4.58	<0.0001
Groundwater level	Vegetation type	One-Way ANOVA	F=25.47	<0.0001
Plants height	Vegetation type	One-Way ANOVA	F=3.46	0.0196
	Groundwater level	Linear regression	b=0.16	0.089
Litter thickness	Vegetation type	One-Way ANOVA	F=4.82	0.0053
Organic matter content	Vegetation type	One-Way ANOVA	F=12.56	<0.0001

Table 2 Values of weather parameters: T – air temperature [°C], H – relative air humidity [%RH], *E* – light intensity [lx], UV – the amount of UV radiation [10-degree scale], m – mean, SD – standard deviation, med – median, Min – minimum value, Max – maximum value

parameter	m	SD	med	Min	Max
T	22.4	1.28	22.4	20.3	24.8
H	81.2	8.5	81	66	96
E	9456	9472	6800	1370	72300
UV	1.56	1.3	1	0	9

The relationship between *Vertigo moulinsiana* and the reed-mannagrass vegetation type has already been described in our previous paper (Lipinska *et al.*, 2011). It is known that *Vertigo moulinsiana* occurs on reed mannagrass frequently and abundantly (Jankowski, 1939; Książkiewicz 2013; Hornung *et al.*, 2003; Killeen, 2003; Killeen & Moorkens, 2003; Myzyk, 2004; Pilāte, 2004; Moorkens & Killeen, 2011). In Europe, the species has been observed on many different plant species, depending on the geographic location of a given site (detailed description in Lipinska *et al.*, 2011). Different habitat types occupied by the same species in different parts of the species range may indicate the importance of abiotic factors in its distribution.

As it appears from our research, a large amount of litter deposited in the vegetation types preferred by *Vertigo moulinsiana* is of great importance for the species. It is known that the relationship between different snail and plant species may result from specific properties of the litter, in the formation of which the latter take an active part (Nekola, 2003). This is consistent with the results of our analyses, which show that the amount of litter is significantly different between the vegetation types, and the largest amounts of litter occur in the "carex and glyceria" vegetation type, i.e. a habitat where the largest numbers of *Vertigo moulinsiana* specimens were recorded.

A significantly higher content of organic matter in "glyceria" compared to "carex and glyceria" and "carex" found in our study indicates a higher increase in the biomass in this vegetation type. Trophic conditions significantly affect the distribution of *V. moulinisina* (Książkiewicz, 2013). The optimum for the species, according to the scale of Zarzycki, Trzcińska-Tacik, Różański, Szeląg, Wołek & Korzeniak (2002), oscillates around the value of 4, characteristic of plants such as *Glyceria*, *Sparganium* spp. or *Phragmites australis*. According to Książkiewicz (2013), soil richness may not directly affect *Vertigo moulinsiana* due to the species biology (its frequent dwelling on plants), it determines the vegetation type covering this type of soil.

Interestingly the atmospheric factors do not have a significant effect on the abundance and distribution of *Vertigo moulinsiana*. As it appears from the analyses, temperature and relative air humidity prevailing under a vegetation canopy remain relatively stable. Differences observed within the light intensity and the amount of UV radiation, do not depend on the vegetation type (Figs 1–2). So far, there has been no evidence on the significant effect of microclimatic factors on the number of snails from the genus *Vertigo* (Kuczyńska & Moorkens, 2010). Probably the microclimate develops at a larger spatial scale and affects habitats rather than microhabitats.

Although it is generally believed that the habitats of snails from the genus *Vertigo* are waterlogged areas with a limestone substrate, a microhabitat of these tiny snails may cover a small space of a few square centimetres (Kuczyńska & Moorkens, 2010). The groundwater level is of major importance, both for the habitat properties, and the distribution and abundance of the studied species. It reflects the topography and shapes the proper conditions for the development of vegetation types. Vegetation types determine the height of plants, the amount of litter and organic matter in the soil. Microclimate is a result of all these factors and local atmospheric conditions characteristic of a given area. Micrometeorological conditions are relatively homogeneous across the area, and variability of these parameters is determined more by a habitat on a macro-scale, rather than microhabitat parameters (Table 2; Fig. 1).

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