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Plant indicator values as a tool for land mollusc autecology assessment

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ABSTRACT

The aim of this paper was to utilize Ellenberg's plant indicator system for assessing mollusc autecology and to highlight possibilities and advantages of that approach in the case of fen mollusc communities. Molluscs and plants from 137 fen sites in the Western Carpathian Mountains were recorded quantitatively from homogeneous areas of 16 m^2. Water conductivity and pH were measured in the field. Values of Ellenberg's ''light, temperature, continentality, moisture, soil reaction, and nutrients'' were estimated for each site. The whole data set was processed using ordinations (PCA, DCA, and CCA) and generalized additive models (GAMs). We observed a strong correlation between water pH and Ellenberg soil reaction estimated by plant indicator values ($r = 0.72$, $P < 0.001$). Ellenberg soil reaction was found to be the best predictor of mollusc species composition, which expressed the main mineral-richness gradient. We found the existence of a second important gradient, the gradient of ''light'', expressing site and canopy openness. A tight correspondence between the results of species response curve modelling based on water conductivity and Ellenberg soil reaction confirmed that ''soil reaction'' does not express merely pH, but rather the total amount of calcium. We conclude that the Ellenberg's indicator system can be used to study the ecology of land molluscs, an important group of invertebrates in bioindication and nature conservation. Our data and approach could help design appropriate conservation management regimes for threatened snail species. We propose that our approach will be useful also in ecological studies of other animal groups.

1. Introduction

One of the main goals of community ecology is to explain patterns of species composition and distributions. Several variables are responsible for these patterns and different species' ecological requirements play an important role, especially at smaller scales. The understanding of individual species ecology is important not only for the understanding of their within-the-range distribution but also for the prediction of species occurrences, and in the case of threatened species, for appropriate conservation scenarios and managements.

Land molluscs, especially snails, are an ecologically extraordinary group of animals due to the strong dependence on calcium as a major macronutrient constituent of their

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body (Dallinger et al., 2001). Molluscs need calcium for the growth of their shells (Wäreborn, 1970) and lack of calcium may also restrict their reproduction (Wäreborn, 1979). This relationship has been well studied on a community level and numerous authors have found a close relationship between the calcium content and the number of mollusc species and/or individuals (tens of papers, e.g. Wäreborn, 1970; Waldén, 1981; Pokryszko, 1993; Horsák and Hájek, 2003; Hylander et al., 2005). Unfortunately, the knowledge about individual species responses to single ecological factors is still lacking, except for calcium (Horsák, 2006) and our knowledge consists of fragmented data (despite many published papers, as cited above) or they concern only a few species (e.g. von Proschwitz, 1993; Speight et al., 2003; Horsák and Hájek, 2005). The second important environmental factor for land snails is soil moisture, however, fewer studies deal with this topic and most of them are without direct measurements (e.g. Wäreborn, 1969; Getz and Uetz, 1994; Martin and Sommer, 2004a,b). Unfortunately, little work has been done on the influence of other physical features of the habitat (e.g. Hermida et al., 1995; Barker and Mayhill, 1999; Nekola and Smith, 1999). Thus, we have a good understanding of land snail patterns in relation to gradients of calcium, but our knowledge of other aspects of their ecology is rudimentary.

There are probably two good reasons why the research on calcium has been dominant: (a) generally, the calcium content is the main control of snail community composition and structure, often significantly overtopping other environmental variables; and (b) it is an easily measurable factor, sometimes approximated by soil or litter pH, and it is also relatively temporary stable. Other environmental variables, in comparison, are not as easily measured. There are other difficulties, also, such as seasonal variation of environmental variables, which necessitate multiple repeated measurements, or technical problems associated with measurement of variable factors such as light, temperature, available nutrients or water regime on a large number of sites, especially if sites are far apart. Cost is also a factor. Therefore, inexpensive, flexible, and indirect methods of measuring these factors would be valuable. One potential approach is to use so-called plant indicator values to meet these requirements. In Central Europe, the ecological profiles of vascular plants are well known due to a long tradition of plant ecology, and due to the existence of large databases of species co-occurrences. Plant indicator systems can provide information about environmental factors quickly and easily on the basis of vegetation composition (Thomson et al., 1993; Ewald, 2003a). A recent and comprehensive system – Ellenberg's indicator values (Ellenberg et al., 1992) – provides tabular data about habitat requirements of nearly all Central European vascular plant species. By calculating the mean Ellenberg value of all plants recorded in a study site/plot we can obtain the position of a site/plot along particular ecological gradients. For these reasons the Ellenberg's system has enjoyed widespread application in plant ecology studies in Europe (e.g. Hill and Carey, 1997; Chytrý et al., 2003; Diekmann, 2003; and many others). The use of such plant indicator value systems in the study of animal autecology is in its infancy, but there have been some studies, e.g. butterflies (Oostermeijer and van Swaay, 1998; Konvička et al., 2003).

The aim of this study is to utilize the information contained in Ellenberg IVs in order to obtain new knowledge about the ecology of land molluscs, especially those inhabiting fens. We had five primary objectives: (1) to examine the possibility of using plant IVs for assessing autecology of molluscs inhabiting fens, (2) to test the validity of that approach on the basis of concordances between measured water pH and values obtained indirectly from plant IVs, (3) to study the interactions between other variables (light, temperature, continentality, moisture, soil reaction, and nutrients) and to highlight the main ecological gradients with respect to mollusc communities, (4) to explore which variable is the best predictor of mollusc community composition, and (5) to highlight possible utilization of plant indicator systems in studies of animal ecology.

2. Materials and methods

2.1. Study area and study sites

The study of 137 spring fen sites was carried out in the Western Carpathian Mountains of Central and Eastern Europe. The overall extent of study area was 12 000 km^2 (Fig. 1). The study area consists of two principal regions differing in their geology and historical development. The first one – the western region – includes the borderland between the Czech Republic and Slovakia and the Orava region in northern Slovakia. It is composed of flysch – a bedrock with sandstone and claystone alternating in each geological stratum (bed). The beds differ from each other both in chemistry and proportion of sandstone and claystone. The second one – the eastern region – is the northwestern part of the Inner Western Carpathians, which typically contains cores of Palaeozoic and crystalline schists overlaid by Mesozoic shale–sandstone and carbonate lithofacies (limestone and dolomite). The chemical composition of groundwater reflects the rock chemistry (Rapant et al., 1996). The overall chemical composition and climatic features do not differ between the regions (Hájek and Hekera, 2005; Hájek et al., 2005). The study sites were treeless sloping spring fens, which covered the entire variability of fens along the mineral poor–rich gradient (Malmer, 1986; Hájek et al., 2006). The six following vegetation types represent the most common fen habitats (arranged from mineral-richest to mineral-poorest): (1) Inner-Carpathian travertine swards (*Glauco-Trichophoretum pumili* association), (2) extremely mineral-rich tufa-forming fens (*Carici flavae-Cratoneuretum* ass.), (3) Inner-Carpathian calcareous peat-forming fens (*Caricetum davallianae* ass.), (4) Outer-Carpathian extremely rich peat-forming fens (*Valeriano simplicifoliae-Caricetum flavae* ass.), (5) moderately calcium-rich *Sphagnum*-fens (*Sphagno warnstorfii-Tomenthypnion* alliance), and (6) poor acid *Sphagnum*-fens (*Sphagno recurvi-Caricion canescentis* all.). For species composition of the above-mentioned vegetation types see Valachovič (2001) and Hájek et al. (2005).

2.2. Field sampling and data collection

Field work was conducted from 2000 to 2004. In each site, one sample of 12 l volume comprising the upper soil layer