

Land snail assemblage patterns along motorways in relation to environmental variables

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Motorways are one of the widespread and frequently discussed landscape features, especially in Central Europe. We established three transects along the three main motorways in southeastern, southwestern, and northern directions from Prague (D1, D5, R10). These transects covered major environmental gradients of geographical position, altitude, succession, and vegetation cover. Altogether 44 land snail species (more than 26 % of the Czech Republic's land snail fauna) were found at the 45 sites on the verges along 225 km of motorways. Surprisingly 21 % of species were such included in the Red List of the Czech Republic's molluscs, and the endangered species *Daudebardia brevipes* was even present by a very abundant population. We expected the motorways to be of importance as man-made linear structure for the spreading of invasive and synanthropic species, but only one such species has been found - *Monacha cartusiana*. Our hypothesis about assemblages made up of invasive or synanthropic species was not verified. The most important factors were: geographical position, altitude, vegetation cover (especially presence / absence of shrubs), and succession stage explained by the age of motorway construction. We distinguished three main groups of land snails: species of open stands, and two groups of woodland species. The representation of open country species and ubiquitous species in the land snail assemblages of motorway verges is higher than in the fauna of the Czech Republic as a whole. The occurrence of sensitive species increased in stands covered by natural vegetation contrary to the outplanting.

Keywords: Land snails, motorways, biocorridors.

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Introduction

Roads are a widespread and increasing feature of most landscapes. Motorways are one of the most discussed modifications of landscapes, especially in Central Europe, where the existing network of motorways is still being expanded. Spellenberg (1998) and Trombulak and Frissell (2000) reviewed literature concerning ecological effects of roads. They considered roads as dispersal lines for invasive and stress-tolerant species. We tested the role of motorway biocorridors for land snail assemblages. The main questions were:

1. Are land snail assemblages of motorway verges uniform with the dominance of invasive or synanthropic species?
2. Are there important differences among land snail assemblages in different geographical areas?
3. Are motorway verges important corridors for the open country species and/or woodland species?
4. Are land snail assemblages on older motorway verges more stable? Does the species diversity depend on succession stages?

5. Are there any other habitat factors influencing land snail assemblages, such as altitude, microrelief or vegetation cover?

Methods

Localities

Three transects were studied along the three main motorways in the southeastern, southwestern, and northern directions from Prague (D1, D5, R10). These transects covered major environmental factors in gradients of geographical position, altitude, succession, and vegetation cover.

Material was collected using standard litter samples (e.g. Ložek, 1956). The samples of litter and topsoil layer were collected from one square of 10 m x 10 m in each site for a total volume of ca. 3 litres. The samples were dried, washed, and the organic material sorted, after repeated drying, to separate size categories. Land snails were then picked by sorting under a binocular microscope.

Environmental variables

The following environmental variables were used: (1) altitude (range 195-510 m a.s.l.), (2) insolation represented by heat index sensu Geiger (1966) (\cos [orientation - 202.5°] x tg [slope]), (3) geographical position (latitude, longitude), (4) vegetation cover represented by tree (E3), shrub (E2), and herb (E1) layers, a special layer was determined for brambles (ER), (5) age of motorway. Categorical (indicator, so-called "dummy") variables were as covariates: (6) motorway (D1, D5, R10), and (7) direction from Prague (L).

Numerical analyses

To describe interrelations between land snails and studied environmental factors such as altitude, geographical position, stand cover, age and insolation of habitats, a multivariate analysis was used (Jongman et al., 1987; Legendre and Legendre, 1998). Both unconstrained and constrained ordinations were additionally computed in Canoco for Windows v. 4.5 (Ter Braak and Šmilauer, 2002). The interspecific correlations were computed by Principal Component Analysis (PCA). Subsequently, the positions of highways were projected as passive indicator variables. The relationships between the species and the environmental variables were studied by direct gradient analysis (constrained ordination, see Lepš and Šmilauer, 2003) and the statistical significance of the species-environment relation was tested using the Monte Carlo permutation test (MCPT) in Canonical Correspondence Analysis (CCA). We selected a method with unimodal species response to environment due to the result of analysis of ecological gradient length in Detrended Correspondence Analysis (DCA: weighted-averaging method with detrending; the beta diversity in community composition as measured as the length of the largest gradient was 5.055; for an explanation see Lepš and Šmilauer, 2003: 51.). The species abundance data were log-transformed. For further CCA analyses the centering by species and biplot scaling were selected, and the standardization by species was selected due to the species differences in quantity. Eigenvalues (λ) measure explanatory power of axes and they express their relative importance (Lepš and Šmilauer, 2003). The explanatory effects of environmental variables were evaluated in MCPT by the stepwise procedure that selects variables with the best fit of species data. The MCPT procedure tests the significance of regression (F-statistics and probability of Type I error) under the null hypothesis of independence of species data on the environmental variables. The number of permutations was arbitrarily assigned to 4999. This test evaluated the power of particular environmental variables (Table 1). The significantly important environmental variables were visualized by the ordination biplots in Cano Draw v. 4.12 (Fig. 1) (Ter Braak and Šmilauer, 2002).

Results

Fauna

Samples from 45 sites along 225 km of motorway verges yielded 44 land snail species (more than 26 % of the Czech Republic's land snail fauna). The most abundant ecological groups were: open country species *Vallonia pulchella* (35 sites, 990 specimens) and *V. costata* (15 sites, 304 specimens), species typical for initial stages of succession (*Perpolita hammonis*, *Vitrina pellucida*, and *Cochlicopa lubrica*), and the "snail weeds" (*Trichia hispida* and *Cepaea hortensis*). Surprisingly, 21 % of the recorded species are given in the Red List of the Czech Republic's mollusks, and the endangered species *Daudebardia brevipes* was even present by a very abundant population. No slug species was found.

The effect of environmental variables on the variability of species composition

We distinguished three main groups of land snails: (i) *Pupilla muscorum*, *Xerolenta obvia*, *Chondrula tridens*, *Valonia costata*, *V. pulchella*, *Truncatellina cylindrica* – species typical for open stands; (ii) *Arianta arbustorum*, *Vertigo pusilla*, *Columella edentula*, *Daudebardia brevipes*, *Semilimax semilimax*, *Discus rotundatus*, *Aegopinella pura*, *A. minor*, *Plicuteria lubomirskii* - typical for woodlands and shrubs of later succession stages (increasing age) with high cover of brambles (Er); and (iii) *Cochlodina laminata*, *Clausilia pumila*, *Carychium tridentatum*, *Vertigo angustior* – also woodlands snails, but exclusively collected at one site adjacent to the motorway D5.

The variability of species composition was significantly affected by the geographical situation (D1), succession stage (Age), and vegetation cover (E1, Er) (Fig. 1).

Discussion

1. We expected the studied motorways to present man-made linear structures important for the spreading of invasive species (for example Lill et al., 1997), but only a single one has been collected, that is *Monacha cartusiana*. No synantropic species was found. Hence the hypothesis suggesting prevalence of uniform assemblages of invasive or synantropic species was not verified.

2. Every single motorway verge had a unique land snail assemblage different from those of the other sites studied, depending on altitude, vegetation cover, and history.

3. The representation of open country species and ubiquitous species in the land snail assemblages of motorway verges is higher than in the fauna of the Czech Republic as a whole (Juříčková et al., 2001). Woodland species occurred more frequently at sites

Table 1. Permutation test of selected/significant environmental variables (restricted model, variance explained by all variables = 2.39, no. of permutations 4999).

Variable	fit	F	p-value	expl_env var %	expl_spec
brambles (ER)	0.336	3.063	0.0188	14.1	6.6
motorway number D1	0.256	2.405	0.0002	10.7	5.1
herbs (E1)	0.195	1.87	0.0036	8.2	3.9
km from Prague	0.178	1.739	0.0088	7.4	3.5
inclination (tg(Incl))	0.177	1.763	0.0400	7.4	3.5
age of motorway (age)	0.177	1.805	0.0080	7.4	3.5
geographical position (L)	0.178	1.848	0.0028	7.4	3.5
North	0.147	1.551	0.0410	6.1	2.9
				68.8	32.5

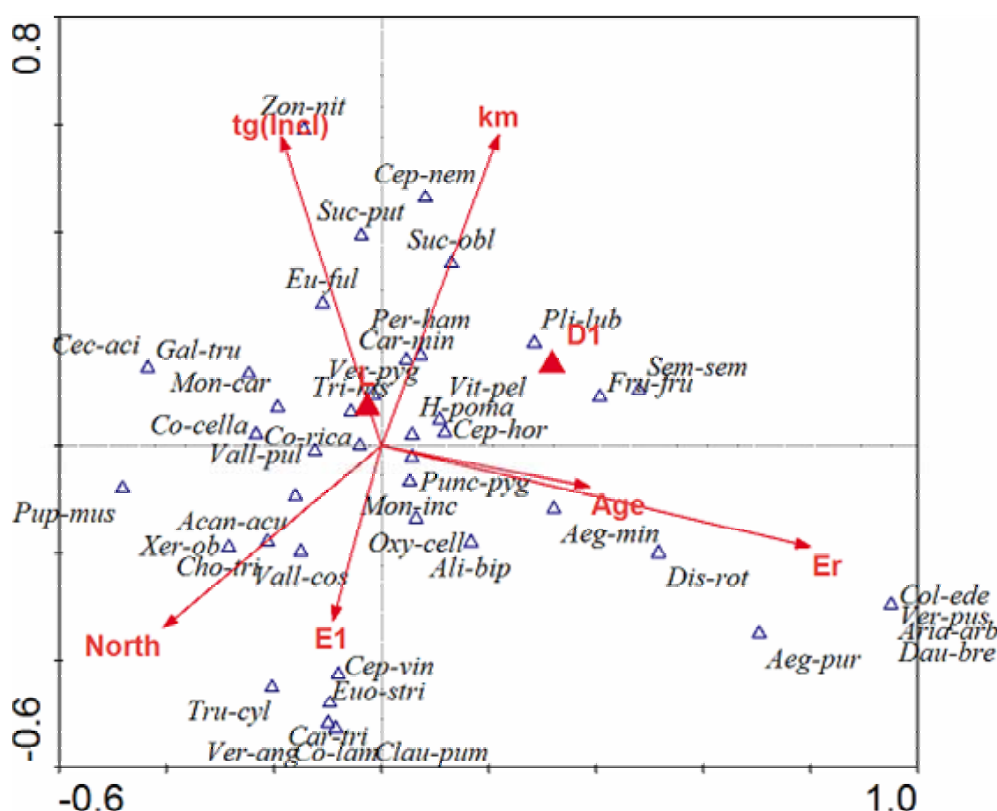


Fig. 1. Species-environment CCA biplot diagram of the first ($\lambda_x = 0.41$) and second ($\lambda_y = 0.31$) ordinal axes of the significant model. Explanations: arrows are significant environmental factors; tg(Incl) – inclination of motorway verges; km – km from Prague; D1 – motorway D1; Age – number of years since the construction of the corresponding part of motorway; Er – brambles; E1 herb layer; North – orientation.

with shrubs. The reason why brambles were important for the occurrence of the woodland species is still unclear (maybe higher humidity under *Rubus* shrubs?).

4. The strong effect of the age of the motorway (succession stage) is connected with the shrub layer. The occurrence of sensitive species increased in stands covered by natural vegetation contrary to the outplanting.

5. The variability in species composition was also highly affected by the distance from Prague (km), which acted as a substitute variable for altitude, because

Prague is surrounded by midlands. Altitude together with inclination (tg (incl)), may be considered as a proxy variable of humidity, as indicated by the position of the hygrophilous snails *Zonitoides nitidus* and *Succinea putris* (Fig. 1).

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