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Importance of soil exchangeable cations and aluminium content on land snail distribution

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Abstract

The influence of soil exchangeable cations and aluminium content on the distribution of various terrestrial gastropods was investigated. Calcium was the most important factor, though aluminium and magnesium content also had some effect. Potassium and sodium had no significant influence on distribution. The species most sensitive to the factors analysed were *Cochlicopa lubrica*, *Vertigo pygmaea* and *Carychium tridentatum*. © 1998 Elsevier Science B.V.

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1. Introduction

The influence of edaphic factors on the distribution of terrestrial gastropods is well documented, but there is considerable controversy as to which factors are important (Wäreborn, 1982; Radea and Mylonas, 1992; Outeiro et al., 1993; Hermida et al., 1995). This controversy is attributable to a lack of quantitative studies, and to poor understanding of the ranges of tolerance and optima of particular species.

In the work reported here, we carried out a quantitative study of relationships between the distribution of terrestrial gastropods and two key soil properties (exchangeable cation content and aluminium content). Samples were collected over a large area, and the data were analysed by ecological profile analysis (Daget and Godron, 1982).

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2. Material and methods

The study area comprised western Galicia (i.e. A Coruña and Pontevedra Provinces) in northwest Spain. For sampling, the area was divided into a grid of 10×10 km squares. Within each of the 166 squares, three quantitative samples of surface soil (0.5 m^2 to a depth of about 5 cm) were collected, from meadow, riverside and woodland habitats, giving a total of 498 samples. Each sample was wet-sieved and examined under a magnifying glass for detection of live gastropods. Additional soil samples were collected for determination of exchangeable cation contents (Na^+, K^+, Ca^{2+} and Mg^{2+}) and aluminium content.

Ecological profile analysis, which has previously been applied to malacological studies by André (1975); Outeiro et al. (1989, 1993); Ondina et al. (1995), was used to study the relationships between soil factors and snail species. The factors were

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Table 1
Class intervals for each factor (units: meq/100 g)

Factor	LC1	LC2	LC3	LC4	LC5	LC6	NC1	NC2	NC3	NC4	NC5	NC6
Sodium	0.00–0.007	0.08–0.12	0.13–0.20	0.21–0.37	0.38–0.67	0.68–4.0	82	80	96	77	80	83
Potassium	0.05–0.15	0.16–0.21	0.22–0.28	0.29–0.35	0.36–0.49	0.50–2.0	80	89	90	67	92	80
Calcium	0.11–0.62	0.63–1.18	1.19–1.92	1.93–3.00	3.01–5.33	5.34–26.0	82	84	83	83	83	83
Magnesium	0.04–0.034	0.35–0.57	0.58–0.81	0.82–1.21	1.22–2.21	2.22–12.0	81	85	83	81	86	82
Aluminium	0.00–0.08	0.09–0.61	0.62–1.08	1.09–1.91	1.92–3.41	3.42–11.0	81	86	81	84	84	82

LC1. . .LC6 represent the class intervals (low and hight limit of each class) for each edaphic factor considered, as defined for ecological profile analysis.
NC1. . .NC6 are the numbers of samples within each class.

exchangeable cation and aluminium contents, with class intervals as indicated in Table 1. Corrected frequencies (C(K)) were calculated for the different snail species as follows:

$$C(K) = \frac{U(K)/R(K)}{U(E)/NR}$$

where U(K)=occurrences of species E in factor class K, U(E)=total number of occurrences of species E, R(K)=number of samples for factor class K and N(R)=total number of samples. Chi^2 tests were carried out to determine whether the observed profile distributions in relation to factors deviated significantly from uniformity. The degree of departure of C(K) values from 1 indicates the level of response to given soil factor classes, and the statistical significance of such departures was evaluated by means of 2×2 contingency tables.

In order to obtain an estimate of the degree of information provided by the factors in relation to the species as a group, the entropy factor was expressed in terms of the mean of the joint species-factor information. The factors with greatest mutual species-factor information values are the ‘effective’ ones (Daget and Godron, 1982).

3. Results

A total of 47 species was detected. In what follows, we consider only those species detected in at least 10% of samples from at least one habitat type (meadow, riverside or woodland), namely *Acanthinula aculeata* (O.F. Müller), *Aegopinella nitidula* (Draparnaud), *Columella aspera* (Waldén), *Cochlicopa lubrica* (O.F. Müller), *Carychium tridentatum* (Risso), *Discus rotundatus* (O.F. Müller), *Euconulus fulvus* (O.F. Müller), *Nesovitrea hammonis* (Ström), *Oxychilus alliarius* (Miller), *Ponentina subvirescens* (Bellamy), *Punctum pygmaeum* (Draparnaud), *Vitrea contracta* (Westerlund), *Vertigo pygmaea* (Draparnaud) and *Zonitoides excavatus* (Alder).

The plot of factor entropies against mean joint species-factor information (Fig. 1) indicates that the most efficient factor for predicting presence/absence of the species considered is calcium. Corrected frequency profiles for those species whose distributions with respect to at least one of the factors considered were significantly non-uniform are shown in Fig. 2. The frequencies of *C. lubrica*, *C. tridentatum*, *V. pygmaea* and *D. rotundatus* increased with increasing calcium and magnesium levels, and decreased with

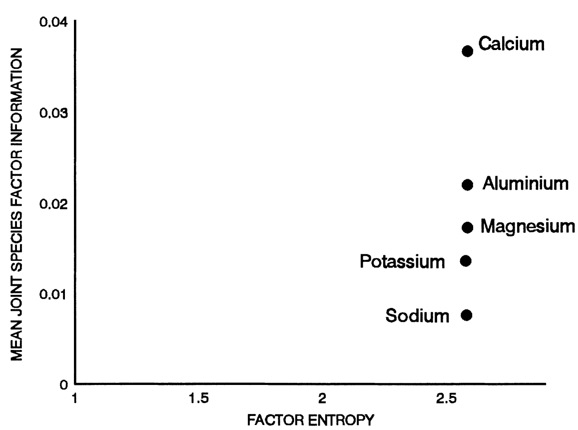

Fig. 1. Plot of mean joint species-factor information against factor entropy.

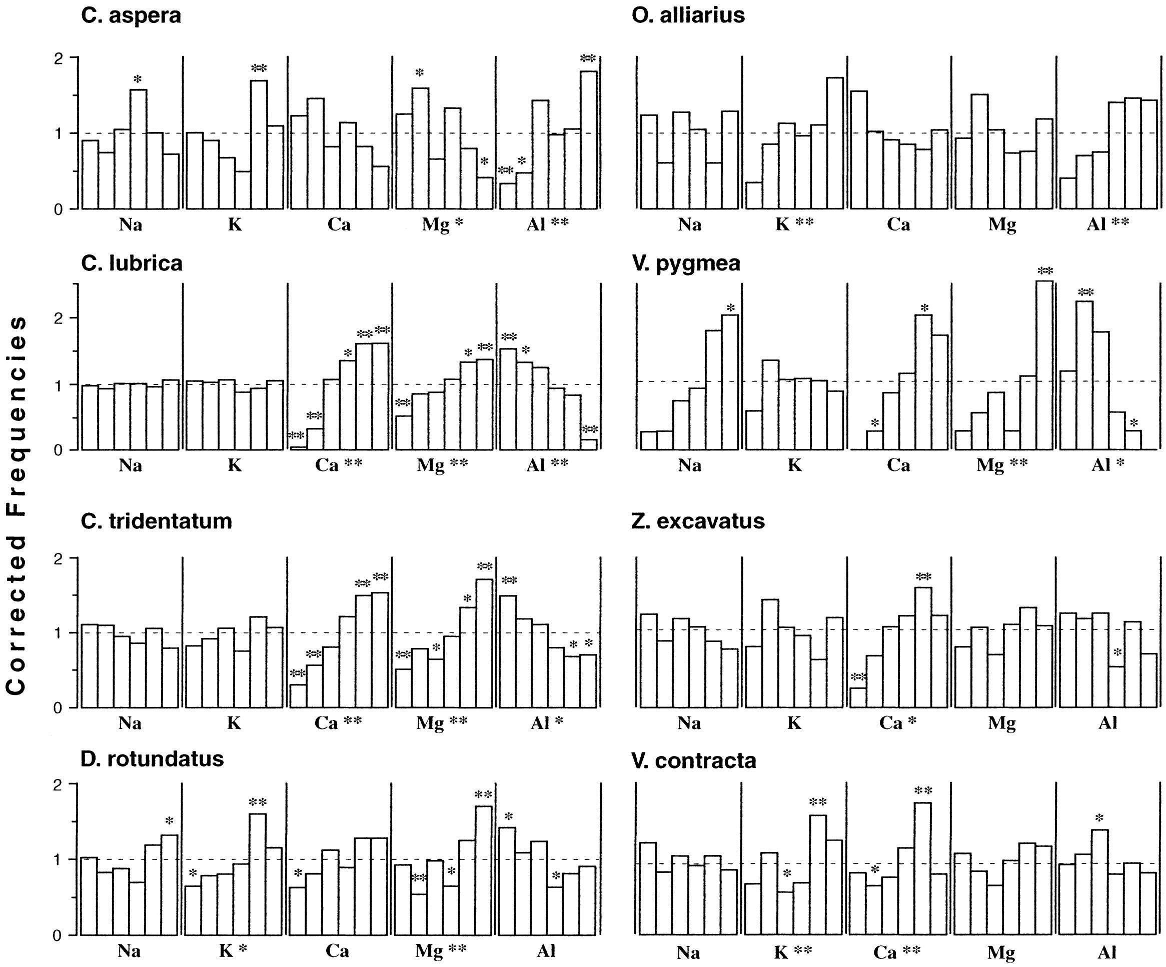

Fig. 2. Ecological profiles with respect to the soil factors Na^+, K^+, Ca^{2+}, Mg^{2+} and Al, for those species which showed significantly non-uniform distributions with respect to at least one factor. Corrected species frequency values are given for six classes per factor (see Table 1 for class intervals). Asterisks on factors indicate significantly non-uniform distribution with respect to those factors; asterisks on histograms indicate significant departures from uniformity in relation to particular soil factor classes (*=p<0.05, **=p<0.01). Profile values of 1 indicate uniform distribution; values greater than 1 indicate preference.

increasing aluminium levels. By contrast, *C. aspera* and *O. alliarius* appear to prefer soils with low calcium/magnesium and high aluminium contents. *Z. excavatus* showed a preference for medium-high calcium levels. Sodium and potassium (Fig. 1) appear to be of little importance for determining distributions: none of the species considered (Fig. 2) showed a non-uniform distribution with respect to sodium, and only *D. rotundatus*, *O. alliarius* and *V. contracta* showed significant affinity for soils with high potassium values.

4. Discussion

The present results are in broad accordance with those of previous studies. The preference shown by *C. lubrica*, *C. tridentatum* and *V. pygmaea* for high-calcium/magnesium soils has been noted by Outeiro (1988); Cameron et al. (1980). Recently, Wäreborn (1992) cited *C. lubrica* as one of the species most strongly affected by soil acidification due to cation leaching, and suggested that its abundance is a function of base saturation. Hermida et al. (1995) have likewise reported that this species shows a preference for soils with low aluminium levels. Similarly, *C. aspera* has previously been reported to be a species characteristic of oligotrophic sites, in association with calcifuges (Paul, 1975). *O. alliarius* has been reported by various authors to be capable of colonizing a wide variety of habitats, independently of soil type (Bishop, 1977), though Riballo (1990) reported a preference for high-aluminium soils. As regards potassium, Outeiro (1988); Riballo (1990) found a positive relationship between the level of this cation and the frequency of *V. contracta*. As in the present study, however, these authors concluded that soil potassium level has relatively little influence on the distribution of terrestrial gastropods. Finally, it is worth pointing out that there is little information available on the distribution of *Z. excavatus* with respect to soil calcium levels, although it has been reported to be a calcifuge species. Our results suggest that the optimum calcium level for this species is between 3.05 and 5.33 meq per 100 g (Fig. 2 and Table 1).

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