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Richness of land snail species under isolated stones in a karst area on Öland, Sweden

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Species richness of land snails living under isolated stones on an exposed rock surface on the Baltic island of Öland, Sweden, was examined in relation to stone size, microhabitat diversity and isolation. Twelve species were collected under 65 stones of different size. A further five species were found in the surrounding grassland. Surface area of the stone was the most important variable for snail species richness explaining 68.3% of its variation. Microhabitat diversity accounted for further 4.8% of the variation and distance to the nearest stone for 1.9%.

Key words: Gastropoda, Pulmonata, ecology, species richness, island biogeography, Sweden.

INTRODUCTION

The relationship between the number of species found in an area and the size of that area is one of the best documented phenomena in community ecology (MacArthur & Wilson, 1967; Simberloff, 1974; Connor & McCoy, 1979; McGuinness, 1984). In the present study I investigated the distribution of land snail species living under stones of different size on an exposed bedrock in a karst area on the island of Öland, Sweden. On exposed bedrock land snails mainly occur in vegetation patches, in crevices, and under stones. The activity of the snails is restricted to periods of high air humidity and rain, which they utilize for grazing lichen and moss (Schmid, 1929; Neuckel, 1981). Regarding the distances covered during activity, an isolated stone may be considered an island for small-sized snails. Here I have considered snail species richness in relation to stone size, microhabitat diversity and isolation.

STUDY AREA

The study was conducted in a karst area on the southern part of the Baltic island of Öland, Sweden (56°30′N 16°30′E). The area investigated is an approximately 100 × 120 m bare limestone rock surface in the heath-like grassland Stora Alvaret. In this exposed rock area phanerogams occur only in and along fissures where soil accumulates and where microclimatic conditions differ from the surrounding bedrock (Rosén, 1982). The vegetation on the rock surface consists of xerophilous lichens and mosses. The grassland, which surrounds the investigated area, contains a few marshy patches and is heavily grazed by sheep in late summer and autumn. Climate, geomorphology and vegetation of Stora Alvaret are comprehensively described by Rosén (1982).

By weathering, stone plates crumble. Such stone plates, hereafter referred to as stones, range in thickness from 1 to 50 cm and in lower surface area from a few square centimetres to several square metres. These stones are randomly distributed within the investigation area. They are covered by calcareous lichens; accumulated soil and mosses can be found under and around the stones.

METHODS

Sampling was performed in June 1986. A total of 73 stones with a size range from 6 to 3028 cm^2 were used (the size of a stone plate is expressed as the surface area of its lower side). All snails observed under the stones were collected and identified following Kerney & Cameron (1979). In order to estimate the number of snail species in the surrounding grassland, snails were hand-collected for one hour at each of six places, paying particular attention to rocks and stones. Small amounts of soil were searched for snails under a binocular microscope.

To evaluate possible isolation effects, the following distances were measured for each stone: distance to the nearest crevice (mean 96.0 cm; range 0-520 cm), to the nearest moss patch (4.6 cm; 0-90 cm), to the nearest grass patch (75.8 cm; 0-298 cm), to the nearest grass patch > 1 m^2 (230.7 cm; 22-750 cm), and to the nearest stone (80.7 cm; 0-1500 cm). As a measure of microhabitat diversity the number of different substrate types occurring on and under a stone was counted: bare rock, lichen, accumulated soil, and moss.

Species collected under stones	% occurrence
Chondrina clienta (Westerlund, 1883)	87.7
Pupilla muscorum (L., 1758)	72.3
Clausilia bidentata (Ström, 1765)	33.8
Vallonia pulchella (Müller, 1774)	29.2
Vitrina pellucida (Müller, 1774)	20.0
Vallonia costata (Müller, 1774)	13.8
Vertigo pygmaea (Draparnaud, 1801)	12.3
Punctum pygmaeum (Draparnaud, 1801)	9.2
Euomphalia strigella (Draparnaud, 1801)	9.2
Truncatellina cylindrica (Férussac, 1807)	7.7
Vitrea contracta (Westerlund, 1871)	4.6
Cochlicopa lubricella (Porro, 1838)	4.6
Species only found in the surrounding grassland	
Catinella arenaria (Bouchard-Chantereaux, 1837)	
Oxyloma pfeifferi (Rossmässler, 1835)	
Balea perversa (L., 1758)	
Helicigona lapicida (L., 1758)	
Deroceras sp. (juvenile)	

Table 1. Frequency of snail species collected under isolated stones on an exposed bedrock on Öland, Sweden, and species only found in the surrounding grassland.

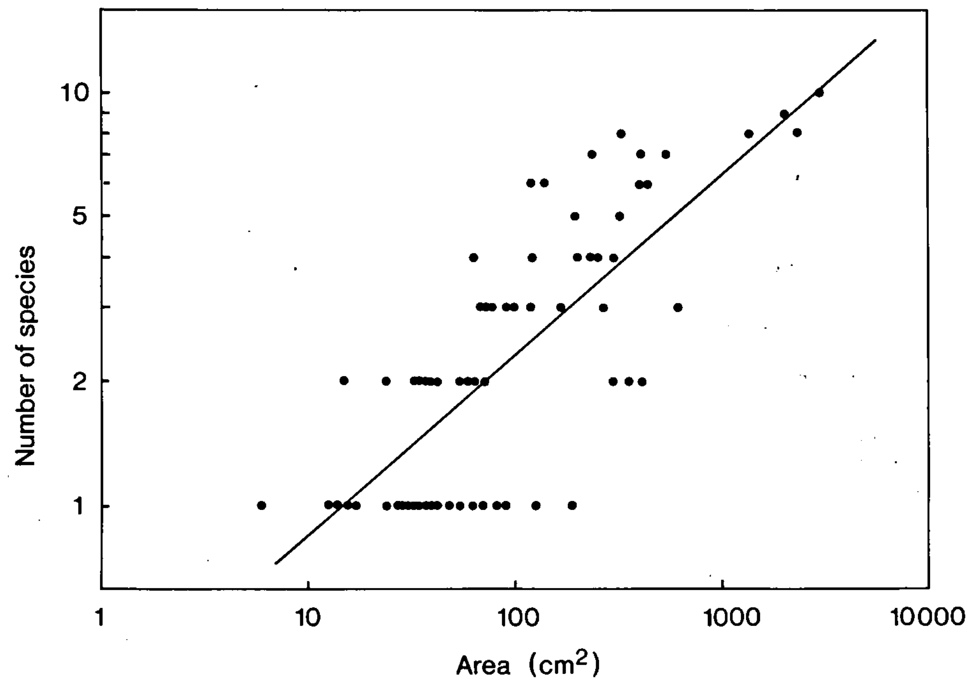

Fig. 1. Species-area relationship for land snails under stones on an exposed bedrock on Öland, Sweden. The abscissa represents the lower surface area of the stones.

RESULTS

A total of 12 snail species was found under 65 stones sampled (table 1), while under eight stones no snails could be found. Stones without snails were significantly smaller than those with snails (Mann-Whitney *U*-test, $P < 0.001$). The number of snail species increased with increasing stone size (fig. 1), indicating a significant species-area relationship (log(number of species) = 0.439log(stone size)-0.511, $r^2 = 0.606$, $N = 65$, $P < 0.001$). In a multiple regression analysis, stone size explained 68.3% of the observed variation in species number, habitat diversity accounted for 4.8% and distance to the nearest stone for 1.9%. The remaining variables did not appear to influence snail species richness under isolated stones.

Seventeen snail species were recorded in the surrounding grassland, including all species found under stones (table 1). The frequency of the different snail species collected under stones is given in table 1. Three groups of species can be broadly discriminated. First, the two (in the area of Stora Alvaret) widespread and pioneering species *Chondrina clienta* and *Pupilla muscorum*, both occurring under almost all stones and also being the exclusive inhabitants of the smallest stones. Second, a group of relatively common species (*Clausilia bidentata, Vallonia pulchella*, and *Vitrina pellucida*) and, third, the rare species, occurring only under large stones with accumulated soil and mosses.

DISCUSSION

This study demonstrates that species richness of land snails living under stones is mainly determined by the size of the stone, resulting in a highly significant species-area relationship. In addition to stone size, microhabitat diversity was found to influence species richness. Thus, for stones of equal size, those with a higher microhabitat diversity have a richer snail fauna. Microhabitat diversity increases with progressive succession (cf. Rosén, 1982). Correspondingly, snail species richness is also related to the successional stage of the vegetation on or around the stone. Furthermore, snail species richness is influenced by the degree of isolation of the stone.

An isolated stone in a land snail's perspective may be an island. Ten out of the 12 species found under stones are smaller than 6 mm (adult shell size), and some of them even smaller than 3 mm. The distances covered by such minute snails seldom exceed 50 cm during one activity period (Baur, unpublished data). Consequently, they may spend their whole life on and under one particular stone (= island).

All species found under stones may be able to survive and reproduce in the microhabitats available under stones (lichen, moss and some soil). Indeed, under most stones the species were represented by several individuals from different age classes. Moreover, some of these snail species are particularly adapted to rocky habitats. They have specialized radulae to graze lichen and algae from rock-faces (e.g. *Chondrina clienta*, *Clausilia bidentata*, see Gittenberger, 1973, and Breure & Gittenberger, 1982), they are ovoviviparous (e.g. *Pupilla muscorum*, see Steenberg, 1925) and self-fertilizing (e.g. *Vallonia pulchella*, *Punctum pygmaeum*, see Whitney, 1938, and Baur, 1987), and show a high temperature tolerance (cf. Neuckel, 1981).

The species composition of the snail fauna under a stone may be determined in part by the species that live in its vicinity. In addition, survival and reproductive success of a colonizing snail appear to depend on the presence of a suitable (micro-)habitat under the stone (cf. Baur & Bengtsson, 1987). Furthermore, the snail's dispersal ability, the degree of plasticity, the presence or absence of predators and/or of potential competitors are also likely to influence colonization success. Stochastic extinctions of local snail populations (single stones) may be common. However, the probability of extinction of a species throughout the whole karst area may be extremely small.

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