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XANTHORIA PARIETINA AS A FOOD RESOURCE AND SHELTER FOR THE LAND SNAIL *BALEA PERVERSA*

Lichens may provide arthropods and gastropods with either food or refuge or both (Peake & James 1967; Gerson 1973). A variety of species of oribatid mites, beetles, and Lepidopteran larvae live in and feed on lichens (Gerson & Seaward 1977; Seyd & Seaward 1984; Søchting & Gjelstrup 1985). However, relatively little is known about lichen-gastropod associations (Coker 1967; Peake & James 1967; Fröberg *et al.* 1993). In this note we present the results of field observations and laboratory experiments showing that *Xanthoria parietina* serves as food as well as shelter for the land snail *Balea perversa* (L.).

Field observations were made on limestone walls in the Great Alvar grassland on the Baltic island of Öland, south-eastern Sweden (56°34′N, 16°27′E) in 1994 and 1995. After heavy rain hundreds of individuals of the land snail *B. perversa* were observed moving over these walls (Baur *et al.* 1994), the majority grazing on *Aspicilia calcarea* (the dominent lichen species), but some individuals also feeding on *Tephromela atra*, *Xanthoria parietina* and *Physcia adscendens*. Detailed examination indicated that grazing damage occurred in 33 (63·5%) of the 52 lichen species recorded on 12 stone walls (Baur *et al.* 1995). *Balea perversa* has a narrowly conical shell, which in adults is 7–10 mm high. On these limestone walls it co-exists with another lichen-feeding land snail, *Chondrina clienta* (Westerlund) (Baur & Baur 1990).

We observed that juvenile and adult individuals of *B. perversa* are found under thalli of *X. parietina*. To examine how frequently the snails use this lichen as shelter, 50 specimens of *X. parietina* were examined for the presence of *B. perversa* on each of three limestone walls: (1) 500 m S of the Ecological Research Station, Ölands Skogsby; (2) 1 km N of Frösslunda, and (3) 1 km N of Södra Baspunkten. The localities were situated at least 8 km apart. For each

TABLE 1. *Number of marked and unmarked* Balea perversa *that were recorded under the thalli of selected individuals of* Xanthoria parietina *after different periods of time*

Period	Number of days	Number of lichens	Number of snails marked at the beginning of the period	Number of snails found at the end of the period	Number (%) of marked snails recovered
15 October 1994–31 March 1995	168	6	38	36	12 (31·6)
4 April–8 August 1995	127	6	15	8	6 (40·0)
8 August–12 October 1995	66	4	16	17	8 (50·0)

lichen specimen we recorded the following variables: presence/absence of *B. perversa* resting under the lichen thalli, size of the lichen (area covered in cm^2), distance to the nearest neighbouring *X. parietina* (in cm), height and breadth of the stone wall (in cm), and distance to the nearest aggregation of resting *B. perversa* (in cm).

At site 1, one or more individuals of *B. perversa* were found under 50% of the *X. parietina* specimens examined. The corresponding figures for sites 2 and 3 were 36% and 42%, respectively. *Balea perversa* occurred preferentially under lichen thalli exhibiting irregularities such as ridges or folds. Overall, *X. parietina* thalli that served as shelter for snails were larger (50 ± 74 cm^2; mean cover $\pm$ 1 S.D.; n=64) than thalli without snails (24 ± 28 cm^2; n=86; Mann-Whitney U-test, P=0·003). Individuals of *X. parietina* with resting snails were situated closer to *B. perversa* aggregations between stones of the walls than lichen thalli without snails (15 ± 8 cm, n=64 vs. 26 ± 32 cm, n=86; Mann-Whitney U-test, P=0·002). The presence of resting snails under *X. parietina* was neither affected by the height (88 ± 20 cm; grand mean $\pm$ 1 S.D.) nor by the breadth of the limestone walls (46 ± 10 cm; Mann-Whitney U-test, in both cases, P>0·1). Finally, the distance to the nearest neighbouring *X. parietina* did not differ between lichens with and without snails (35 ± 89 cm; Mann-Whitney U-test, P>0·1).

To examine whether the number of snails resting under a lichen thallus is related to the size of this lichen (area covered), we removed the thalli of 21 *X. parietina* and counted the number of juvenile and adult *B. perversa*. The size of *X. parietina* averaged 59 ± 51 cm^2 (range 3–198 cm^2). The number of resting snails found under the thalli of *X. parietina* averaged 6·0 (3·5 juveniles and 2·5 adults) with a range from 1 to 17. However, the number of snails resting under a thallus was not correlated with the size of the lichen (r=0·10, n=21, P=0·67).

To investigate whether individuals of *B. perversa* hide repeatedly under the same lichen thallus, on three occasions all snails found under four to six lichens were marked on their shells with a spot of car lacquer and released immediately under the lichen where they were found (Table 1). The individual lichen thalli were more than 10 m apart from each other. The total number of snails recorded under the lichen thalli after 2, 4 and 6 months, respectively, were similar to those marked at the beginning of the periods (Table 1). The percentage of marked snails recovered under the original lichen thallus ranged from 31·6 to 50·0% (Table 1). This variation may partly be due to the different lengths of the periods. The results indicate that there is some turnover in the composition of snail populations resting under a particular thallus, and that some snails repeatedly return to the same place of shelter after a period of feeding activity (i.e. they show a kind of homing behaviour).

In order to graze on the surrounding lichens, juvenile *B. perversa* (individuals with a shell height of 1·5–3 mm) beneath *X. parietina* have to move—in relation to their size—considerable distances to leave their shelter. As an alternative behaviour, however, the snails might feed directly on the thallus under which they are resting.

To examine whether *X. parietina* provides all essential elements and nutrients necessary for snail growth, 14 juvenile *B. perversa* were fed exclusively on an *X. parietina* diet until they reached sexual maturity. The juvenile snails were obtained from parents maintained on an *X. parietina* diet (i.e. the juveniles had never encountered any other food). Juveniles were kept in two groups in transparent plastic dishes (6·5 cm in diameter, 2 cm in height) with the bases lined with paper towelling on which a piece of *X. parietina* approximately 3 cm in diameter was placed. Pieces of *X. parietina* were obtained from a limestone wall. To stimulate snail activity, the piece of lichen and paper towel were moistened and the dish covered with an acetate film; after 12 h, the waterproof cover was exchanged for a paper towel to dry out the dish. This procedure was carried out repeatedly at 48-h intervals, resulting in a rhythm of alternating 12 h activity and 36 h resting. The piece of lichen was replaced every 20 days. Snails grew rapidly when fed exclusively on *X. parietina* and after 6 months all of them had reached adulthood, as indicated by the formation of a thickened lip at the shell aperture (mean shell height: 8·7 mm; range: 8·4–8·9 mm; $n=14$).

To examine whether *X. parietina* provides the nutrients and trace elements necessary for snail reproduction, the 14 sexually mature *B. perversa* were kept singly in plastic dishes and fed on an *X. parietina* diet for 100 days as described above (*B. perversa* reproduces predominantly by self-fertilization; Baur 1990). The food was replaced every 20 days. At the same time the young produced by each snail were counted and removed. All 14 snails survived the experimental period of 100 days. Thirteen of them began to reproduce within 40 days; one snail did not reproduce at all during the experiment. The snails produced on average $10{\cdot}5 \pm 3{\cdot}6$ young within 100 days. When the snail that did not reproduce was omitted, the remaining 13 snails produced $11{\cdot}3 \pm 2{\cdot}4$ young. This indicates that *X. parietina* may provide all essential nutrients and enough calcium carbonate to build up the embryonic shell and thus to secure the gastropod life cycle.

The present study shows that *X. parietina* can provide a land snail with both shelter and food. In general, snails resting under the thalli of *X. parietina* may reach abundant food resources more rapidly than snails resting in fissures between layers of stones, since most lichens are situated on the top layer of the stone walls. This may be an advantage especially for juvenile snails. However, snails resting under the thalli of foliose lichens may be exposed to more pronounced fluctuations of the environment conditions (e.g. temperature, moisture) than snails resting in fissures.

We recorded high levels of grazing damage in both *X. parietina* and *A. calcarea*; in the latter lichen the level of grazing was correlated with the local population density of *B. perversa* (Baur *et al.* 1995). *Xanthoria parietina* produces parietin, which has many potential roles in lichens including as a defence agent against generalist herbivores and thus might be toxic or at least unpalatable (Lawrey 1983, 1984). The results of our laboratory experiments showed that *B. perversa* can grow and reproduce when kept on an *X. parietina* diet. *Balea perversa* feeding on *X. parietina* absorbs parietin (Hesbacher *et al.* 1995). Parietin is also transferred from the mother to the eggs in the reproductive tract of the snails. However, it is not known whether parietin affects the growth rate and reproduction of *B. perversa*, although the reproductive rate (10·5 young within 100 days) was rather high compared with that of *B. perversa* fed on a cyanobacterial diet (6·9 young within 100 days; Baur & Baur 1992). Experiments in which juvenile and adult *B. perversa* are fed on different lichen diets are needed.

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