ELSEVIER

Journal of Arid Environments 67 (2006) 336–342

Journal of Arid Environments

www.elsevier.com/locate/jnlabr/yjare

Short communication

Habitat use by the arid-dwelling land snail *Iberus g. gualtieranus*

G. Moreno-Rueda*

Departamento de Biología Animal y Ecología, Facultad de Ciencias, Universidad de Granada. E-18071, Granada, Spain

Received 14 September 2005; received in revised form 25 November 2005; accepted 21 February 2006
Available online 11 April 2006

Abstract

Iberus gualtieranus gualtieranus is an arid-dwelling land snail that needs to use karstic fissures as refuge in order to survive in arid environments. Karstic fissures are primarily on vertical rocky walls. Because displacement is costly to terrestrial gastropods, it is predictable that this snail will move on vertical substrates near its refuges. However, this species eats primarily phanerogam plants, which are placed on bare soil in horizontal surfaces. Thus, it is also predictable that this snail will move on horizontal substrates far of its refuges. In the present study, this contradiction is examined. Results show that this snail moves far of its refuges to forage on horizontal substrates, while is sheltered in fissures on vertical and rocky surfaces. This suggests that the need of a refuge for survive imposes on this species a habitat use based in the alternation of two microhabitats: vertical and rocky substratum when inactive, and horizontal and bare soil when active.

Keywords: Foraging; Microhabitat; Refuge selection; Shell morphology

1. Introduction

All organisms need a set of resources to live and reproduce (Margalef, 1995; Pianka, 2000), and mobile organisms, such as most of animals, may travel searching for those resources they need. Animals will determine their habitat in that zone where they find the resources that they need (Pulliam, 2000), and they should become adapted to optimize the

*Tel.: +34 958 24 30 82.
E-mail address: gmr@ugr.es.

0140-1963/$ - see front matter
doi:10.1016/j.jaridenv.2006.02.008

use of those resources (Darwin, 1859; Pianka, 2000). Therefore, animals should use their habitats in a way that enables them to attain the resources they need.

An essential resource for terrestrial gastropods is protective refuges against dehydration (a conspicuous danger for snails and slugs, Prior, 1985; Cook, 2001; Luchtel and Deyrup-Olsen, 2001) and predation (Yanes et al., 1991). Other essential resource, obviously, is food. Movement from refuges to food items may be very costly for snails, because movement by crawling is energetically expensive (Denny, 1980), and foraging snails are exposed to dehydration and predation. Therefore, it would be predictable that snails should forage near of their refuges, or must seek shelter near of their foraging zones. For example, *Euchondrus* ssp. shelters itself under stones and feeds on endolithic lichens on the same stones (Shachak et al., 1987). Similarly, *Helix aspersa* finds refuge and food in the stems of nettle (*Urtica dioica*) (Iglesias et al., 1996). These types of behaviours in land snails presumably save energy and lower the costs and dangers of displacement.

In the present work, I examine the habitat use during the exploitation of different resources (food and refuge) in the land snail *Iberus gualtieranus gualtieranus. Iberus gualtieranus* is a helicid endemic to the Iberian Peninsula adapted to Mediterranean ecosystems, with the subspecies *Iberus g. gualtieranus* especially adapted to arid or semi-arid environments in karstic mountains of southeastern Spain (Alonso et al., 1985). Land snails are very susceptible to dehydration (Prior, 1985; Luchtel and Deyrup-Olsen, 2001), a problem accentuated in arid environments. Presumably, to dwell in such environments, *Iberus g. gualtieranus* needs to use a protective refuge against dehydration: the karstic fissures (Moreno-Rueda, 2002). In fact, to use these refuges, in this snail has evolved a flattened shell, because individuals with more flattened shells have easier access to fissures (de Bartolomé, 1982; López-Alcántara et al., 1983, 1985). Considering that the use of fissures is vital for the survival of this snail, this snail should be spatially associated with the location of protective fissures. Karstic fissures are associated primarily on vertical and rocky surfaces, where this snail should be found. Fissures also may protect snails of predation. On the other hand, the diet of this snail is principally composed by phanerogam plants (Moreno-Rueda and Díaz-Fernández, 2003), and most of vegetation on rocks are lichens and moss, phanerogam plants being associated with non-rocky soil on horizontal substrates. On the basis of this information, it is predictable that a conflict may have arisen in the habitat use of this land snail because of the different spatial location of the two types of resources that it needs. In the present study, I investigate if this land snail moves from its refuges on karstic rocks (vertical surfaces) to its food on non-rocky soil (horizontal surfaces). For this, I monitored microhabitat use in a population of *Iberus g. gualtieranus* when the snails were inactive (sheltered) and when they were active (foraging).

2. Methods

This study was performed on a south-facing slope 500 m^2 from Sierra Elvira (SE, Spain). Sierra Elvira is a karstic mountain with scarce vegetation, principally grasses and small bushes of *Rosmarinus officinalis*, *Stipa tenacissima* and *Genista sp.* The climate is defined as accentuated mesomediterranean (UNESCO, 1963), with 5 months of drought during the year (Alonso et al., 1985). *Iberus g. gualtieranus* is active only during autumn and winter (Moreno-Rueda, submitted). For this reason, I included in this study only data collected from October 2000 to March 2001. Samples were taken at different hours, both day and night. When a specimen was found, I recorded whether it was active or inactive. I considered individuals as inactive when their soft bodies were secluded inside the shell with an epyphragm closing the entrance. Adult individuals were identified by their umbilicus, which is closed by a fringe of the peristome (Fechter and Falkner, 1993). Immature individuals had a shell size similar to that in adults. Very small individuals were not considered.

I recorded the microhabitat where individuals were found, as well as whether the individuals were sheltered inside fissures or unsheltered. The inclination of substrate in which individuals were found was recorded as 0–30°, 31–60°, 61–90° and >90°. The availability of different inclinations (0–30°, 31–60° and 61–90°; >90° was not possible) was estimated from 200 points randomly assigned in the study area. This allowed me to compare the inclinations used with those available to snails. I also noted whether individuals were found on bare soil, on a rock or on a plant. To determine whether individuals preferred bare soil or rock, the availability of both types was estimated from 250 points randomly assigned in the study area.

Some data were missing for some individuals and sample size may vary. Data are shown as percentages, number of observations or mean ± standard deviation. Non-parametric statistics were used according to Siegel and Castellan (1988). All tests performed were two-tailed.

3. Results

Most of active individuals were unsheltered (35 of 56), whereas most of inactive individuals were sheltered in fissures (86 of 110 individuals). Differences were significant (Fisher exact test, $P<0.001$). Active individuals were found primarily during the day (64 of 70), while inactive individuals were found during the night (105 of 143 individuals) (Fisher exact test, $P<0.001$).

The slope of substrate where individuals were found did not significantly differ between adult and immature individuals ($\chi^2_3 = 5.19, P = 0.16$), and the two age categories were pooled. Active individuals were found primarily on horizontal substrates, while inactive individuals were found mainly on vertical substrates (Fig. 1a; $\chi^2_3 = 34.58, P<0.001$). I compared the distribution of the three first categories of slopes with the distribution expected by chance, according to the availability in the study area. For inactive individuals, the slope selected differed significantly from the chance ($\chi^2_2 = 124.39, P<0.001$; Fig. 1b), but this was not so for the slope of active individuals ($\chi^2_2 = 3.23, P = 0.20$; Fig. 1b). Thus, inactive individuals were found on vertical substrates more than expected by chance. In contrast, active individuals seemed move on substrates according to its availability in the study area.

The frequency with which adult and immature individuals used the different types of substrate was not significantly different ($\chi^2_2 = 0.60, P = 0.74$). For inactive individuals, 86.7% ($n = 143$) were found on rocky substrate. Active individuals also appeared preferentially on rocky substrate (65.2%, $n = 69$), but the frequency was significantly lower ($\chi^2_2 = 17.12, P<0.001$; Fig. 2a). Inactive individuals selected rocky soil more frequently that expected by chance ($\chi^2_1 = 45.04, P<0.001$), while active individuals were found on rocky soil or bare soil with a frequency not significantly different from that expected by chance ($\chi^2_1 = 2.13, P = 0.09$; Fig. 2b). Therefore, inactive individuals were associated with rocky soil.

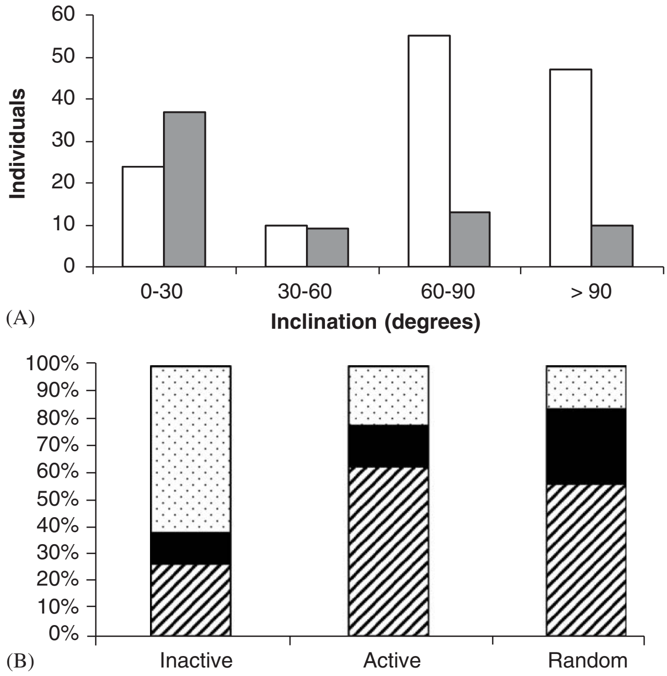

Fig. 1. (A) Number of active (grey) and inactive (white) individuals on different slopes. (B) Percentage of individuals on slopes of 0–30° (hatched), 31–60° (black) and 61–90° (dotted), according to their condition (actives or inactive), in comparison with the proportion of random points with those slopes.

4. Discussion

Results show that *Iberus g. gualtieranus*, when inactive, sheltered itself in karstic fissures on vertical and rocky surface, but moved outside this microhabitat when active, foraging on horizontal substrates, in rocky or open soil, according to their frequency in the area. Data from adult and immature individuals did not differ, suggesting that activities associated with reproduction did not affect the results. Why this land snail uses different microhabitats when active and inactive is presumably related with the different location of the resources it needs, with karstic fissures on vertical rocks, and phanerogam plants on horizontal soil.

This situation might be avoided if this land snail attains adequate refuges near of its food items. However, this seems improbable. This land snail is very dependent of karstic fissures as refuge to survive (Moreno-Rueda, submitted). Even, the morphology of its shell has evolved in order to improve the access to fissures (López-Alcántara et al., 1983, 1985). Probably, near the microhabitats where phanerogam plants are, there are not adequate refuges for the survival of this snail, and this provokes that this snail displaces vertical substrates where fissures are.

On the other hand, if this snail attains the food it needs near the fissures, a change of microhabitat would not be necessary. The diet of *Iberus g. gualtieranus* includes moss and lichens (Moreno-Rueda and Díaz-Fernández, 2003), but it is possible that this food items

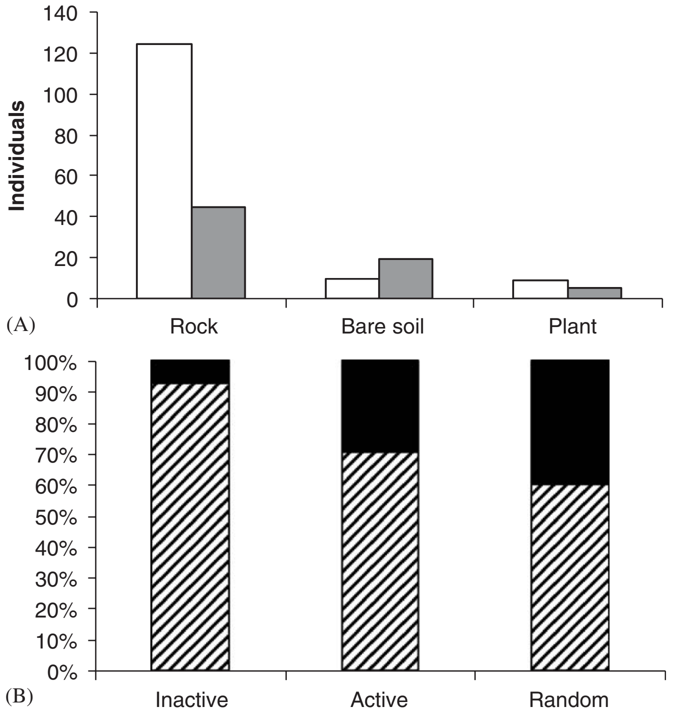

Fig. 2. (A) Number of active (grey) and inactive (white) individuals on different types of substrate (rocky, bare soil or plant). (B) Percentage of active and inactive individuals on rocky (hatched) on bare soil (black), in comparison with the availability of the two substrates in the study zone.

do not satisfy all requirements of this snail. This would do that this land snail cannot successfully forage near its refuges.

Alternatively, it is possible that the flattened shell morphology of this land snail hinders the foraging movement on vertical substrates for this snail, and this obliges it to forage on horizontal substrates. Snails with flattened shells are found primarily on horizontal substrates (Cain and Cowie, 1978; Cameron, 1978). This, probably, is because snails with flattened shells save energy when crawling on horizontal substrates, whereas it is very expensive for these snails to crawl on vertical substrates (Cain, 1977). If this is correct, the flattened form of *Iberus g. gualtieranus* (evolved to use karstic fissures as refuges) would have limited the capacity of displacement on vertical substrates for this snail. For this reason, this subspecies should migrate daily from vertical substrates, where it is sheltered, to horizontal substrates to forage.

These results may have importance in the conservation of this land snail. *Iberus g. gualtieranus* is an endangered land snail (Arrébola, 2002), and the destruction of its habitat by quarries is its principal threat (Moreno-Rueda and Ruiz-Avilés, 2005). Habitat restoration may help in the protection of this land snail. Such restoration should generate a heterogeneous habitat with rocky soil with fissures and horizontal soil with plants.

In conclusion, *Iberus g. gualtieranus* use two different microhabitats: vertical rocky substrates when inactive, in order to shelter itself in karstic fissures, and horizontal soil when active, in order to forage for phanerogam plants. This habitat use seems imposed by the necessity of protective refuges, as a consequence of the arid environment where the snail dwells. This result suggests that habitat use is probably more constrained in arid-dwelling land snails, because they need shelters that are more protective.

Acknowledgements

Amelia Ocaña and Adela González Mejías provided logistic support, David F. Díaz Fernández assisted in the field work. Comments by José Antonio Hódar and anonymous referees greatly improved the manuscript. David Nesbitt improved the English.

References

Alonso, M.R., López-Alcántara, A., Rivas, P., Ibáñez, M., 1985. A biogeographic study of *Iberus gualtierianus* (L.) (Pulmonata: Helicidae). Soosiana 13, 1–10.

Arrébola, J.R., 2002. Caracoles terrestres de Andalucía. Consejería de Medio Ambiente, Cádiz.

de Bartolomé, J.F.M., 1982. Comments on some mediterranean rockdwelling helicids. Journal of Conchology 31, 1–6.

Cain, A.J., 1977. Variation in the spire index of some coiled gastropod shells, and its evolutionary significance. Philosophical Transactions of the Royal Society of London B 277, 377–428.

Cain, A.J., Cowie, R.H., 1978. Activity of different species of land-snail on surfaces of different inclinations. Journal of Conchology 29, 267–272.

Cameron, R.A.D., 1978. Differences in the sites of activity of coexisting species of land mollusc. Journal of Conchology 29, 273–278.

Cook, A., 2001. Behavioural ecology: On doing the right thing, in the right place at the right time. In: Barker, G.M. (Ed.), The Biology of Terrestrial Molluscs. CAB International, Wallingford, pp. 447–487.

Darwin, C., 1859. The Origins of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life. John Murray, London.

Denny, M., 1980. Locomotion: the cost of Gastropod crawling. Science 208, 1288–1290.

Fechter, R., Falkner, G., 1993. Moluscos. Blume, Barcelona.

Iglesias, J., Castillejo, J., Garrido, C., 1996. Asociación de *Helix aspersa* (Gastropoda, Pulmonata) con *Urtica dioica* en el medio natural. Iberus 14, 57–65.

López-Alcántara, A., Rivas, P., Alonso, M.R., Ibáñez, M., 1983. Origen de *Iberus gualtierianus*. Modelo evolutivo. Haliotis 13, 145–154.

López-Alcántara, A., Rivas, P., Alonso, M.R., Ibáñez, M., 1985. Variabilidad de *Iberus gualtierianus* (Linneo, 1758) (Pulmonata, Helicidae). Iberus 5, 83–112.

Luchtel, D.L., Deyrup-Olsen, I., 2001. Body wall: form and function. In: Barker, G.M. (Ed.), The Biology of Terrestrial Molluscs. CAB International, Wallingford, pp. 147–178.

Margalef, R., 1995. Ecología. Omega, Barcelona.

Moreno-Rueda, G., 2002. Selección de hábitat por *Iberus gualtierianus*, *Rumina decollata* y *Sphincterochila candidissima* (Gastropoda: Pulmonata) en una sierra del sureste español. Iberus 20, 55–62.

Moreno-Rueda, G., Díaz-Fernández, D.F., 2003. Notas sobre la alimentación de *Iberus gualtierianus gualtierianus* (Linnaeus, 1758) (Gastropoda: Helicidae). Acta Granatense 2, 89–92.

Moreno-Rueda, G., Ruiz-Avilés, F.A., 2005. Impacto de las canteras en el monte granadino de Sierra Elvira. Quercus 233, 4.

Pianka, E.R., 2000. Evolutionary Ecology, sixth ed. Benjamin/Cummings, San Francisco.

Prior, D.J., 1985. Water-regulatory behaviour in terrestrial gastropods. Biological Reviews 60, 403–424.

Pulliam, H.R., 2000. On the relationship between niche and distribution. Ecology Letters 3, 349–361.

Shachak, M., Jones, C.G., Granot, Y., 1987. Hervibory in rocks and the weathering of a desert. Science 236, 1098–1099.

Siegel, S., Castellan Jr., N.J., 1988. Non-parametric Statistics for the Behavioral Sciences, second ed. McGraw-Hill, Singapore.

UNESCO, 1963. Recherches sur la zone aride. Etude écologique de la zone méditerraéenne. Carte bioclimatique de la zone méditerranéenne. Notice explicative. UNESCO, Paris.

Yanes, M., Suárez, F., Manrique, J., 1991. La cogujada montesina, *Galerida theklae*, como depredador del caracol *Otala lactea*: comportamiento alimenticio y selección de presa. Ardeola 38, 297–303.