动物学报 53(1):179 - 183,2007
Acta Zoologica Sinica

Preliminary observations on activity rhythms and foraging behaviour in the endangered limpet *Patella ferruginea* *

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濒危帽贝铁锈笠螺的活动节律和采食行为的初步观察 *

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摘 要 铁锈笠螺是地中海最濒危的海洋无脊椎动物,对其生物学知之甚少,缺少对其活动节律和采食行为的了解。使用环氧树脂 Eporai 1127© 原位标记了 20 个不同外壳长度的个体,并在每个外壳上标有不同的数字,作者在白昼或黑夜的高潮和低潮期收集了有关数据。可能由于云斑厚纹蟹(*Pachygrapsus marmoratus*)的捕食影响,铁锈笠螺白天的活动和运动多于夜间,但铁锈笠螺采食行为似乎仅限于高潮期。此外,汹涌的海面条件 诱导了铁锈笠螺的活动和运动[动物学报 53(1):179 - 183,2007]。

关键词 濒危帽贝 铁锈笠螺 活动 环境因子

Keywords Endangered limpet, *Patella ferruginea*, Activity, Environmental factors

Within limpets, a wide variety of foraging patterns exists in relation to external factors, such as tidal cycles and day/night cycles, and other less predictable factors, such as wave action and rainfall (see reviews by Branch, 1981; Hawkins and Hartnoll, 1983).

Patterns of foraging activity in limpets have been classified into three main groups based on their relation to tidal and day/night cycles (see Branch, 1981). However, Hawkins and Hartnoll (1983) have since emphasized that rigid classification is impossible due to the labile nature of these patterns. The most common activity pattern described in herbivorous intertidal marine molluscs is to be active while submerged (Gray and Hodgson, 1998). Although there are many works on the activity patterns of pulmonate limpets (Branch and Cherry, 1985; López-Gappa et al., 1996; Gray and Hodgson 1997, 1998; Ocaña and Emson, 1999) and prosobranch limpets (Hartnoll and Wright, 1977; Hawkins and Hartnoll, 1982; Little and Stirling, 1985; Little et al., 1988, 1990; Della Santina and Chelazzi, 1991; Della Santina et al., 1994, 1995; Gray and Naylor, 1996; Gray and Hodgson, 1998, Santini et al., 2004), there is a lack of knowledge about the activity rhythm and foraging behaviour of the endangered limpet *Patella ferruginea* Gmelin, 1791. Little is known about the biology of this species (Guerra-García et al., 2004), in spite of being the most endangered marine invertebrate in the Mediterranean (Laborel-Deguen and Laborel, 1991a; BOE, 1999), included in the list of the European Council Directive 92/43/EEC on the conservation of Natural Habitats and of Wild Fauna and Flora, 1992 (Ramos, 1998). Furthermore, it is

Received 28 Apr. 2006; revised 19 Sep. 2006

* The present research was funded by *Autoridad Portuaria de Ceuta* and a PhD grant FPU AP-3556-2001 (to F. Espinosa) from the Ministry of Education and Culture of Spain

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presently, under serious risk of extinction (Laborel-Deguen and Laborel, 1991a; Templado and Moreno, 1997; Templado et al., 2004; Espinosa et al., 2005; Espinosa, 2006; Espinosa and Ozawa, 2006; Espinosa et al. 2006, in press). Except for the qualitative observations made by Biagi and Poli (1986) and Laborel-Deguen and Laborel (1991b), no quantitative studies have been carried out on the activity and foraging behaviour of the homing species *Patella ferruginea* before the present study.

1 Material and methods

Observations were made inside of the harbour of Ceuta, located in Northern Africa (35°53′20″N/5°18′30″W). This site consisted of an artificial breakwater being composed of dolomite boulders, which experienced equal semi-diurnal tides. Other limpet species present are *Patella rustica*, *P. caerulea*, *P. ulyssiponensis*, *Cymbula safiana* and *Siphonaria pectinata* (Espinosa et al., 2006). Measurements were carried out on 20 labelled specimens of different shell lengths (following López-Gappa et al., 1996; Gray and Hodgson, 1998) marked *in situ* individually using the epoxy resin Eporai 1127© with a specific number for each one. The observations were conducted at high and low spring tide peaks, either day or night both in calm (10 – 11 March 2004) and rough sea (15 – 16 March 2004) periods. The activity of the individuals was recorded assigning a value of 0 (no activity) and 1 (activity), whereas the distance was measured to the nearest mm using a tape measure to follow the rock profile from the center of the home scar (clearly visible as a white zone with the profile of the shell, see Laborel-Deguen and Laborel, 1991b) until the border of the shell where the individual was located at the time of sampling.

Environmental variables were obtained from the buoy network data of "Puertos del Estado" (Ministry of Public Works of Spain) for sea wave heights (one measurement per hour) and "Instituto Nacional de Meteorología" (Ministry of Environment of Spain) for air speed (measurements made at 00 h, 07 h, 13 h, 18 h) at the study site during the days of sampling program. Data were analysed using the Kruskal-Wallis test to compare means, after verifying that hypothesis of normality (Shapiro-Wilk test) was not passed. Statistical analyses were conducted using BMDP program (Dixon, 1983).

2 Results

Wave heights and air speed during the present study are given in Table 1. Different environmental conditions clearly appeared between calm and rough seawater conditions, taking into account the statistical differences observed, with faster air speeds and, consequently, higher wave heights in rough periods than in calm conditions. Therefore, these two periods would be representative of different environmental conditions.

Table 1 Physical parameters (Mean ± *SD*) during calm and rough periods

	Wave height (m) $n = 48$	Air speed (km/h) $n = 8$
Calm (10 – 11 March)	0.67 ± 0.2	10.62 ± 4.4
Rough (15 – 16 March)	1.46 ± 0.35	16.62 ± 2.38
K	– 13.17***	– 3.38**

Value of the Kruskal-Wallis test, *** $P < 0.001$, ** $P < 0.01$.

All limpets remained inactive during low tides, irrespective of calm or rough conditions of the sea and day/night cycle. Foraging behaviour was limited to high tides, both diurnal and nocturnal (Fig.1, 2). Nevertheless, a different level of activity and movement can be observed between day and night, so more individuals were active and covered longer distances during daytime than at night tides (Fig.1, 2), this pattern being more noticeable during rough periods, where statistical differences can be detected due to the greater activity exhibited. In this sense, significant statistical differences using the Kruskal-Wallis test were recorded between calm and rough periods at diurnal hightides in activity ($P < 0.01$) and movement ($P < 0.01$) with a mean trip length of 0.77 cm (± 0.38 standard error of the mean) during calm periods and 6.4 cm (± 1.82 standard error of the mean) during rough periods. On the other hand, during nocturnal hightides there were no significant differences between calm and rough periods, probably due to the lower activity in general than at diurnal tides, although higher values of trip length can be observed during rough periods (mean of 1.57 cm ± 1.57 standard error of the mean) than during calm periods (mean of 0.65 cm ± 0.64 standard error of the mean).

3 Discussion

Foraging behaviour in *Patella ferruginea* appears to be restricted to high tides, whereas during low tides the individuals are completely inactive, in agreement with the Branch's (1981) report on activity of limpets. This pattern is shared by the sympatric limpet *P. caerulea* (Santini and Chelazzi, 1995), which inhabits the same area from the mid to upper intertidal zone (Espinosa et al., 2006). Physical factors and predation are probably the most important constraints on activity of limpets (see Branch and Barkai, 1988). Predation by crabs has been extensively documented in limpets (Chapin, 1968; Little, 1989; Cannicci et al., 2002; Santini et al., 2004), and these predators are usually more active during nocturnal periods (Wells, 1980; Little, 1989). The crab *Pachygrapsus marmoratus* is very abundant in Mediterranean and Atlantic areas (Cannicci et al., 1999) as well as in Ceuta harbour (pers. obs.), and this species is an important predator of limpets (Cannicci et

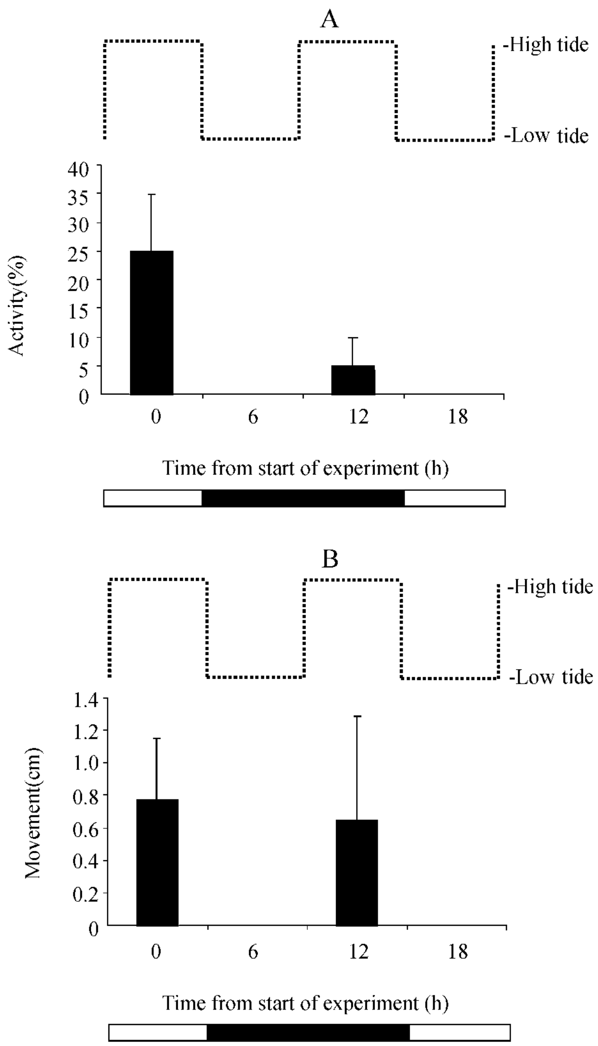

Fig.1　Pattern of foraging behaviour in *Patella ferruginea* population at Ceuta harbour during calm water

Immersion-emersion curve (dotted line) and day/night cycles (white bars day, black bars night) are indicated. Value of the Kruskal-Wallis test statistic (K) and level of significance (P) between day and night foraging behaviour are referred. A. Mean percentage of active limpets (± standard error of the mean) during a 24 h period. $K = 1.79$, $P = 0.08$. B. Trip lengths (± standard error of the mean) during a 24 h period. $K = 0.16$, $P = 0.86$.

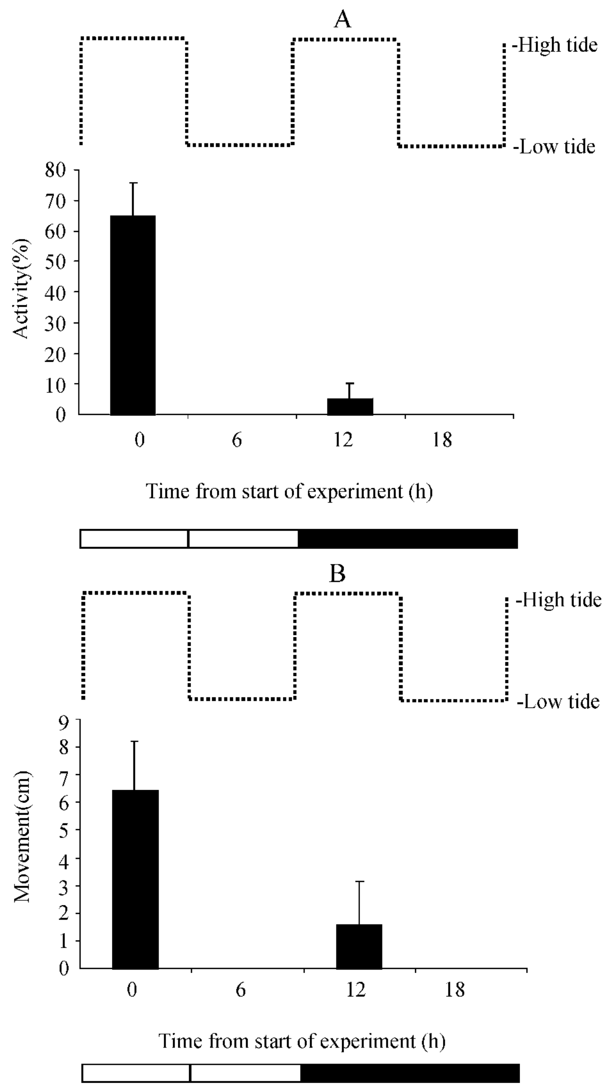

Fig.2　Pattern of foraging behaviour in *Patella ferruginea* population at Ceuta harbour during rough water

Immersion-emersion curve (dotted line) and day/night cycles (white bars day, black bars night) are indicated. Value of the Kruskal-Wallis test statistic (K) and level of significance (P) between day and night foraging behaviour are referred. A Mean percentage of active limpets (± standard error of the mean) during a 24 h period. $K = 4.98$, $P < 0.001$. B Length of the trips (± standard error of the mean) during a 24 h period. $K = 1.99$, $P < 0.05$.

al., 2002), capable of crushing small *P. ferruginea* shells (pers. obs.). Thus, the more plausible explanation for the differences between diurnal and nocturnal cycles of activity in *P. ferruginea* at Ceuta harbour could be determined by the higher predation pressure of *P. marmoratus* during night than at daytime.

An additional factor to consider in this study is the dimensions of the individuals studied, since an inverse relationship between activity and shell length has been described in *P. vulgata* by Williams and Morrit (1991) and Della Santina et al. (1994). Moreover, during the present study the only three individuals that did not show any activity measured: 2.2, 3.6 and 3.8 cm [taking into account that the maximum size in *P. ferruginea* exceeds 10 cm (Templado, 2001; Espinosa, 2006)]. Their reduced activity was probably due to predation risk.

Finally, moderate wave action has been pointed out as an inductor of activity in limpets (Laborel-Deguen and Laborel, 1991b; Santini and Chelazzi, 1995). In this sense, Laborel-Deguen and Laborel (1991b) have proposed that movement in *P. ferruginea* would be favoured by rough seas, although these authors could not establish a direct relationship between increased wave action and movement in *P. ferruginea*. The preliminary results of the present study indicate that rough periods enhance activity and movement in this species, as is supported by several additional field observations. Biagi and Poli (1986) indicated that *P. ferruginea* could remain several days without any activity, and this was observed for some individuals during the present work. Calm periods cause an increase of physical stress due to dehydration, especially during the summer months (Santini et al., 2004), while moderate wave action would increase the splash and, therefore, the substrate would remain wet allowing a greater activity of *P. ferruginea*. However, it would be of great interest to investigate whether if *P. ferruginea* varies its activity related to spring and neap tides or other seasonal factors. Further studies are required in order to examine the biological rhythms of this endangered species.

Acknowledgements Our gratitude to staff of Parque del Mediterráneo from Ceuta for their collaboration.

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