

Conservational status and demographic characteristics of *Patella ferruginea* Gmelin, 1791 (Mollusca, Gastropoda) on the Alboran Island (Western Mediterranean)

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Paracuellos, M., Nevado, J. C., Moreno, D., Giménez, A. & Alesina, J. J., 2003. Conservational status and demographic characteristics of *Patella ferruginea* Gmelin, 1791 (Mollusca, Gastropoda) on the Alboran Island (Western Mediterranean). *Animal Biodiversity and Conservation*, 26.2: 29–37.

Abstract

Conservational status and demographic characteristics of Patella ferruginea Gmelin, 1791 (Mollusca, Gastropoda) on the Alboran Island (Western Mediterranean).— Due to the high risk of the global extinction in which *Patella ferruginea* Gmelin, 1791 is found, it is considered of great interest to describe and quantify its demographic characteristics in those sites where it still persists, as well as to evaluate the reasons which have led this limpet to be one of the most threatened marine species in the Mediterranean Sea. Over the study period (2000–2002), systematic census were made on the perimeter of the Alboran Island (Alboran Sea, westernmost area of the Mediterranean Sea) with the object to quantify the abundance of the species in the locality, as well as their external biometry and spatial distribution. As a result, the presence of a probable reproductive population of *P. ferruginea* was found on the island. The negative effect provoked by the continuous presence of man was proved, prejudicing the population in those zones which were more accessible for their harvesting. For this reason, it is necessary to regulate the use of the natural resources of the island to favour the conservation and spontaneous recolonisation of the zone by *P. ferruginea*.

Key words: *Patella ferruginea*, Alboran Island, Population, Conservation, Human influence, Western Mediterranean.

Resumen

Estado de conservación y características demográficas de Patella ferruginea Gmelin, 1791 (Mollusca, Gastropoda) en la Isla de Alborán (Mediterráneo occidental).— Dado el peligro de extinción global en el que actualmente se encuentra *Patella ferruginea* Gmelin, 1791, se considera de gran interés describir y cuantificar las características poblacionales de la especie en aquellas localidades donde aún persiste, así como evaluar las razones que han llevado a considerar a esta lapa como una de las especies marinas más amenazadas de extinción del Mediterráneo. Durante el período de estudio (2000–2002) fueron realizados muestreos sistemáticos en el perímetro de la Isla de Alborán (Mar de Alborán, extremo occidental del Mediterráneo) con objeto de cuantificar la abundancia de la especie en la localidad, así como su biometría externa y distribución espacial. Como resultado, se ha constatado la presencia en la isla de una población de *P. ferruginea* probablemente reproductora. Se ha comprobado el efecto negativo provocado por la continua presencia humana en la isla, perjudicando a la población en aquellas zonas más accesibles para la recolección de ejemplares. Es por ello que se considera necesario regular el uso de los recursos naturales en la isla con objeto de favorecer la conservación y recolonización espontánea de la localidad por *P. ferruginea*.

Palabras clave: *Patella ferruginea*, Isla de Alborán, Población, Conservación, Influencia humana, Mediterráneo occidental.

(Received: 26 III 03; Final acceptance: 26 V 03)

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Introduction

Patella ferruginea Gmelin, 1791 is an endemic species of the Western Mediterranean Sea. Although its distribution in this basin was widespread during the Pleistocene, in prehistorical and historical times has entered obvious regression owing to human predation and it is now considered in high risk of extinction (IMPERATORI, 1968; TEMPLADO, 2001). Given this situation, the species has been catalogued in Annex II of the Convention Relative to the Conservation of the Wildlife and Natural Environment in Europe (Bern Convention, European Council, 19 September 1979; Royal Decree of 13 May 1986; BOE, 235, 1 October 1986) as a strictly protected species, in Annex II of the Barcelona Convention (Monaco, 24 November 1996) as "endangered or threatened", in Annex IV of the Directive 97/62/CE of the Council (Habitat Directive, of 27 October; DOCE, L 305, 8 November 1997) as communitarian interest requiring strict protection, as well as in the National Catalogue of Threatened Species (Order of 9 June 1999; BOE, 148, 22 June 1999) as "in risk of extinction". One factor which likely accounts for the decline of the species is that the limpet usually lives on rocky substrates above sea level (upper mesolittoral) and is therefore easily detectable by man. As it reaches a considerable size when adult, it is well appreciated for human consumption and decoration. Other causes which may have influenced its present scarcity and decline could be the progressive deterioration of the coastal strip where the species inhabits, the low fecundity of individuals and their scarce dispersal ability (LABOREL-DEGUEN & LABOREL, 1991a, 1991b; TEMPLADO, 2001). Therefore, it is considered of great interest to describe and quantify its population structure in those areas where it still persists, as well as to evaluate the reasons that have made this limpet one of the marine species at highest risk of extinction in the Mediterranean Sea (PORCHEDDU & MILELLA, 1991; TEMPLADO, 1998). However, although various authors have analysed diverse aspects of the distribution and biology of *P. ferruginea* (CURINI-GALLETTI, 1979; GRANDFILS, 1982; BIAGI & POLI, 1986; BOUDOURESQUE & LABOREL-DEGUEN, 1986; LABOREL-DEGUEN & LABOREL, 1990, 1991a, 1991c; PORCHEDDU & MILELLA, 1991; MORENO, 1992; LABOREL-DEGUEN et al., 1993; CRETILLA et al., 1994; APARICI-SEGUER et al., 1995), few studies to date have quantified the repercussions of the human factor as the cause of its spatial distribution and regression of the populations (however see, LABOREL-DEGUEN & LABOREL, 1991b).

The presence of *P. ferruginea* on the Alboran Island is described in various studies (i. e., GARCÍA RASO & SALAS, 1984; YUS & CABO, 1986; RUBIO, 2001). However, although some papers indicate the species is abundant in the area (SALAS & LUQUE, 1986), TEMPLADO (2001) observed a very low number of individuals (28 in 1996 and 13 in

1998) during the last census ("Fauna IV" and "Alboran 98", respectively). This author emphasised the possibility that in those years the population was not viable as reproductive, due to the low number of specimens detected and the fact that they were some distance away from each other, making fecundation difficult.

In this study, the current diverse aspects related to *P. ferruginea* on the Alboran Island are described, paying special attention to its demographic characteristics, external biometry, spatial distribution and repercussion of the human factor on its presence and development.

Materials and methods

Study area

The Alboran Island (Almería; 35° 56' N, 3° 02' W) is situated in the centre of the Alboran Sea (westernmost area of the Mediterranean Sea), 46.5 miles from the Iberian coast and 30 from the Maghreb coast. It is a small remote promontory of 7.1 ha in size, 605 m in length, 265 m wide, with a maximum height of 14 m and a perimeter of about 2000 m of shoreline (fig. 1).

The lithological nature of the area is essentially volcanic, mainly made up of an andesite tufa substrate (HERNÁNDEZ-PACHECO & IBARROLA, 1970). Its surface is flat, with a contour of vertical cliffs or steep slopes 8–12 m in height along most of its perimeter (except for two small beaches / landing places). At the base of the border of the island, where the action of waves occurs, there is a horizontal platform which is uncovered at low tide, forming a surrounding stretch of 15–20 m in average width. Apart from the main island, there are some small inlets close to its shores, for example the Nube inlet or the inlet near to the Cuevas Viejas (fig. 1). Therefore, with the exception of the existent beaches, the rest of the contour is favourable for the colonisation of *P. ferruginea*.

Mankind has been present on the island throughout history, but mainly since the construction of a lighthouse and associated buildings in the 19th century (ARCHDUKE LUIS SALVADOR, 1898; RUBIO, 2001). Since 1997, a permanent military garrison composed of a normal complement of 12 members exists. In relation to man's uses in the locality, an Integral Reserve within a Natural Reserve has been declared since 1997 on the surroundings of the island, this including therefore the interior limits inhabited by *P. ferruginea*. Therefore and since its protection, it is expressly forbidden to collect or fish the flora and fauna in this area (Order of 31 July 1997; BOE, 204, 26 August 1997; GUIRADO et al., 1999). At present, the global protection of the total area in and around the Alboran Island as a "Paraje Natural" and the official approval of the Development Plan of the Natural Resources of the Alboran Island are underway, both measures which should help to

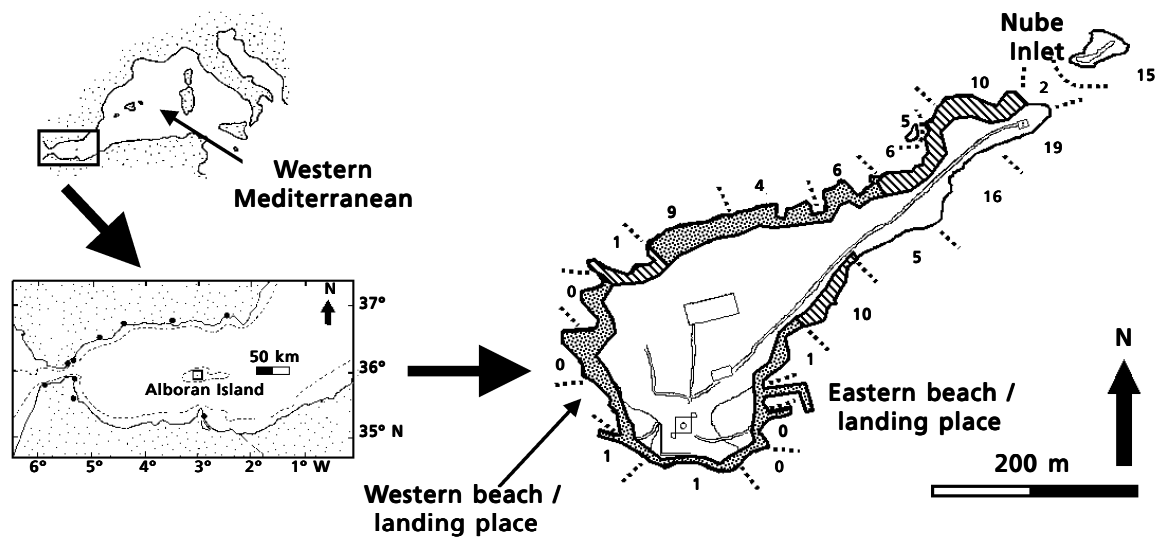


Fig. 1. The Alboran Island and its geographical location. Dotted lines delimit the distinct stretches of shore taken into account, showing the numbers of specimens of *Patella ferruginea* found at each in July 2002. Accessibility by land to each of the stretches is also shown: Dotted. High accessibility; Striped. Medium accessibility; In white. Null accessibility (see Field methods).

Fig. 1. La isla de Alborán y su ubicación geográfica. Mediante líneas discontinuas se delimitan los distintos tramos de orilla considerados, mostrando para cada uno de ellos el número de ejemplares de *Patella ferruginea* encontrados durante julio de 2002. También se señala la accesibilidad por tierra a cada tramo: Punteado. Accesibilidad alta; Rayado. Accesibilidad media; En blanco. Accesibilidad nula (ver Field methods).

guarantee the future conservation of the species and its habitat on the island (Agreement of 20 December 1998, of the Council of the Government of the Junta de Andalucía; PINILLA, 2001; DIRECCIÓN GENERAL DE PLANIFICACIÓN, 2002).

Field methods

The monitoring was undertaken from 2000 to 2002. A first survey was made in June 2000 to estimate and map the specimens, continuing with total and supplementary census in October 2001 and in July 2002 for the definitive collection of data. The samplings were always carried out during the day, taking advantage of the optimal environmental conditions (calm day at low tide).

In order to quantify the population and distribution of the species on Alboran, systematic census of the individuals was carried out around the entire island. The shoreline of the island and its inlets were divided into transects, and the mesolittoral level of the peripheral platform, and the close zones of the supra and infralittoral levels were surveyed. All transects were covered by 1–3 people, using a boat along the stretches where accessibility was difficult or impracticable. The following data were taken *in situ* on each of the observed individuals: 1. Location (using car-

tography); 2. Length (widest diameter of the shell); 3. Width (narrowest diameter of the shell); 4. Height (elevation of the shell from the base to the apex) (also see GRANDFILS, 1982; PORCHEDDU & MILELLA, 1991; APARICI-SEGUER et al., 1995). The shells were measured with a vernier calliper, with a precision to a 0.1 mm. Full length digital photographs of all individuals located were taken.

Taking into account the historical presence of man on Alboran, accessibility to the potentially habitable zones for the species was evaluated, in order to analyse the pressure provoked by collection for human consumption on the population and distribution of *P. ferruginea* on the island. The more accessible intervals of shoreline for man were expected to be more exposed to exploitation, presenting a fewer and smaller specimens (less appreciated) than in less accessible zones with a hypothetical higher number of specimens and larger sizes (more appreciated), taking into account the specimen's length as a standard measure (see as well, LABOREL-DEGUEN & LABOREL, 1991b). To quantify the level of accessibility to shoreline, the perimeter was divided into 20 strips of similar extension according to the map. Depending on the cartography and estimates in the area, two variables directly associated to the human capability of access to the areas were taken

into account. On one hand, accessibility by land to each sectors was defined: i. Highly accessible strips of the shore zones which could be reached on foot from the interior of the island along their entire length; ii. Semi-accessible strips, which could be reached on foot from the interior of the island only partly; iii. Non-accessible strips, which were not accessible on foot from the interior of the island. On the other hand, the degree of access by sea to the different sectors was estimated, taking into account the distance by swimming or by boat from the nearest beach / landing place to the midpoint of the established sectors (the farther from the beaches / landing places, the more effort needed to collect and the less accessibility degree by sea).

The Analysis of Variance (ANOVA, applying the Duncan Test post hoc) as well as the Simple and Multiple Regression Analysis were used for statistical analysis (SOKAL & ROHLF, 1994). When needed and according to the nature of the data, certain variables were used after their trigonometrical transformation.

Results

A total of 80 specimens of *P. ferruginea* were located on the Alboran Island during the first sampling in June 2000, as compared to 92 and 111 during the later systematic census in October 2001 and July 2002 respectively. The number of individuals found in each stretch of shore is shown in figure 1, and one of the specimens measured can be seen in figure 2. Length ranged between 21 and 96 mm and distribution was bimodal, with a maximum between 30 and 40 mm and another, of a bigger magnitude, between 70 and 80 (fig. 3A). The width of the individuals varied between 15 and 80 mm, the bimodal distribution being less apparent, with the greatest number between 60 and 70 (fig. 3B). The height of the shells varied between 7 and 50 mm, the highest number being between 30 and 40 (fig. 3C). When the different biometrical measures were compared between them adjustments to the lineal relations explained a great percentage of variance with high regression coefficients (fig. 4).

The average density of the specimens encountered was 0.06 individuals/m over the entire rocky shoreline. The distribution of the limpets was not homogeneous throughout the total perimeter of the island; being the greatest part of the population concentrated in the northeastern sector (fig. 1). Considering accessibility by land to the delimited strips of littoral, significative differences were observed in the density of the limpets according to the degree of access; having the areas more easily reached from the interior of the island fewer specimens / m of shore than the less accessible areas (fig. 5A), principally due to the existing contrasts between the intervals with high and

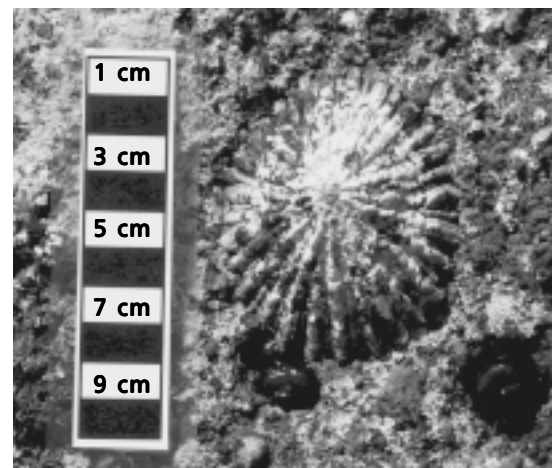


Fig. 2. Specimen of *Patella ferruginea* found on the Alboran Island in July 2002.

Fig. 2. Especimen de *Patella ferruginea* encontrado en la Isla de Alborán durante julio de 2002.

null accessibility ($P = 0.004$). Although limpets located in areas which were more inaccessible by land were in many cases bigger in size than those found in more accessible zones, there were no significative differences in the length of their shells (fig. 5B). When relating the distance by sea from the nearest beach / landing place to each of the strips with its average number of limpets / m of shore and with the average size of the encountered individuals, a direct and significative relationship could be observed between the variables. Stretches farther from the beaches or landing places usually had specimens of a higher density and a bigger size than closer ones (fig. 6). However, the maximum percentage of variance was explained when relating both variables of accessibility jointly, by land and sea, with the number of limpets / m of shore in each strip:

$$D = 0.07 - 0.04 \arcsine(\sqrt{x}) + z \\ (r^2 = 0.53, F_{2,17} = 9.63, P = 0.002, N = 20)$$

and with their average size in each strip:

$$S = 65.30 - 1.96 \arcsine(\sqrt{x}) + 0.03z \\ (r^2 = 0.51, F_{2,13} = 6.80, P = 0.009, N = 16)$$

where D represents the number of limpets / m of shore, S the average size of limpets, x the proportion of length of accessible strip by land according to the continuous values from 0 (totally inaccessible strips) to 1 (totally accessible strips), and z the distance to the nearest beach / landing place.

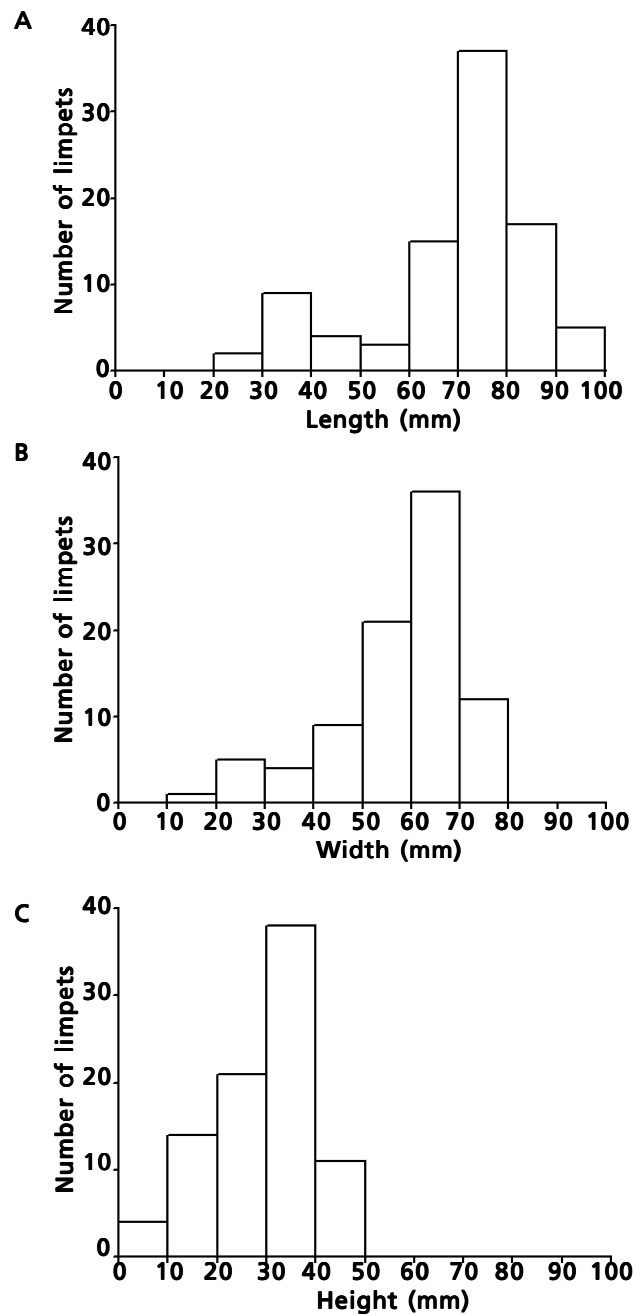


Fig. 3. Frequency of distribution found for the length (A), the width (B) and the height (C) of the shells of *Patella ferruginea* in the population of the Alboran Island during October 2001.

Fig. 3. Frecuencia de distribución encontrada para la longitud (A), la anchura (B) y la altura (C) de la concha de Patella ferruginea en la población de la isla de Alborán durante octubre de 2001.

Discussion

Results regarding the number of specimens of the population of *P. ferruginea* on the Alboran Island surpassed the number cited by TEMPLADO (2001) over eight-fold. Data provided by this

author show a very scarce population of species during 1996 and 1998, disperse and composed mainly of females (large specimens), aspects which probably made it non-reproductive. However, the characteristics of the population found during the present study (2000–2002) suggest it was po-

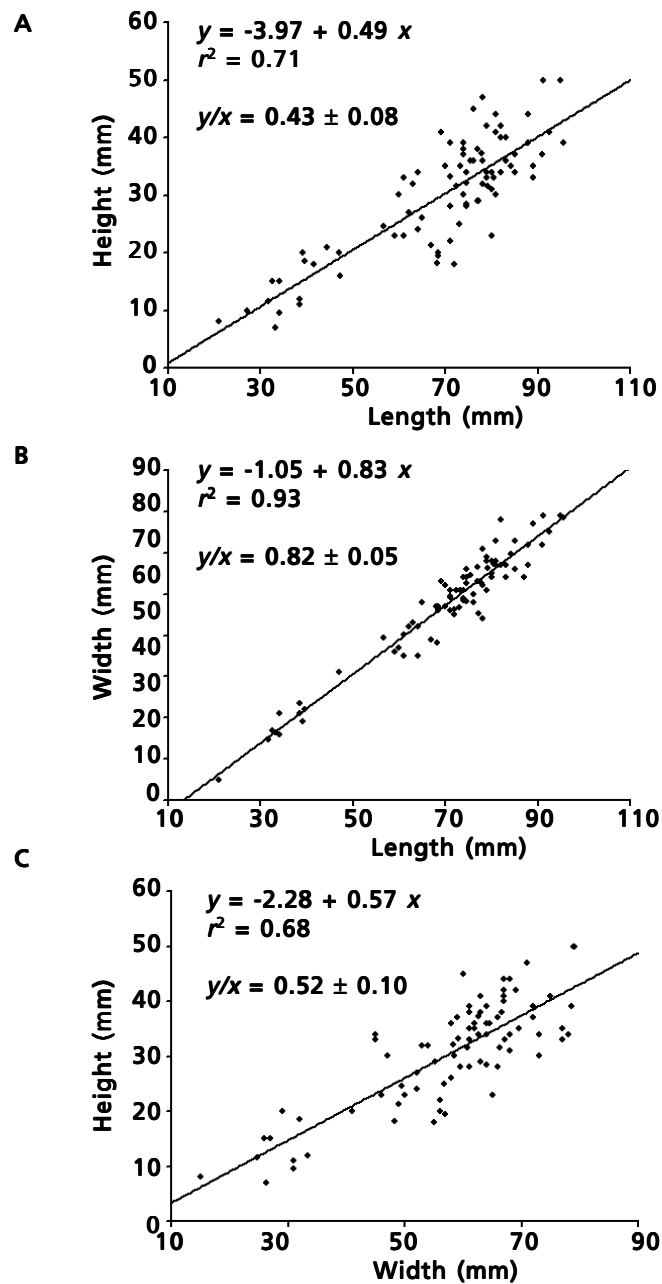


Fig. 4. Statistical relationships (Simple Regression Analysis) between: height vs. length (A), width vs. length (B) and height vs. width (C) of shells of *Patella ferruginea* on the Alboran Island during October 2001. Average value \pm SD is also expressed for each relationship (y/x).

Fig. 4. Relaciones estadísticas (Análisis de Regresión Lineal Simple) entre altura vs. longitud (A), anchura vs. longitud (B) y altura vs. anchura (C) de *Patella ferruginea* en la isla de Alborán durante octubre de 2001. También se expresa para cada relación (y/x) su valor medio \pm DE

tentially fertile. This could possibly be due to the relative high number of individuals present, with the greatest numbers found in a reduced sector of shore (more than 90 % of specimens were observed in a sector of about 1000 m), permitting

the external fertilisation of the eggs. According to the measures obtained (some of the biggest observed for the species), nearly all the located individuals were possibly adults (GRANDFILS, 1982; LABOREL-DEGUEN & LABOREL, 1991a; TEMPLADO,

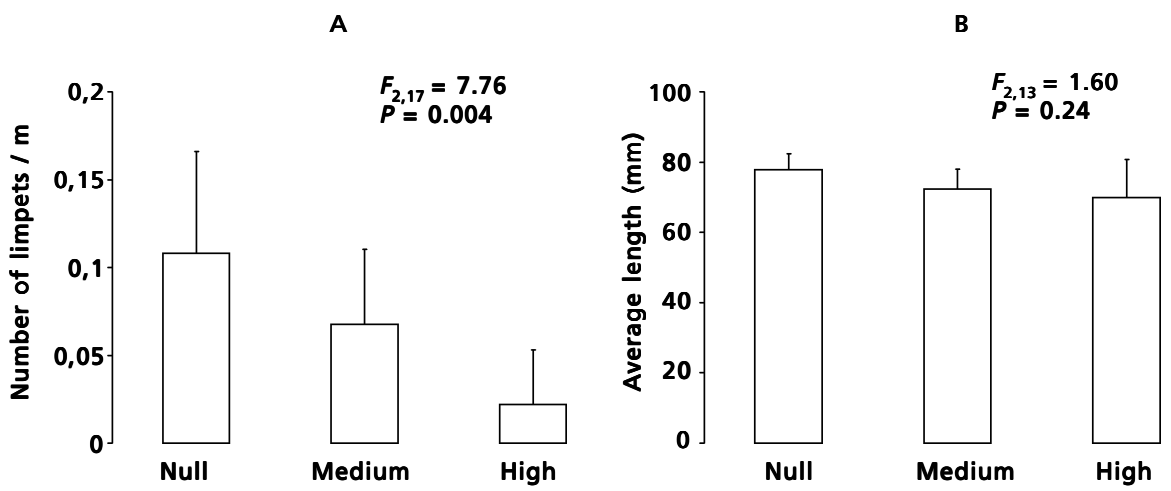


Fig. 5. Statistical differences (ANOVA) of the density (average number of limpets / m of shore ± SD) (A) and the size (average length of limpets ± SD) (B) of *Patella ferruginea* according to the degree of accessibility by land to the different delimited stretches on the Alboran Island during July 2002.

Fig. 5. Diferencias estadísticas (ANOVA) de la densidad (nº medio de lapas / m de orilla ± DE) (A) y el tamaño (longitud media de las lapas ± DE) (B) de Patella ferruginea según el grado de accesibilidad por tierra a los diferentes tramos delimitados en la isla de Alborán durante julio de 2002.

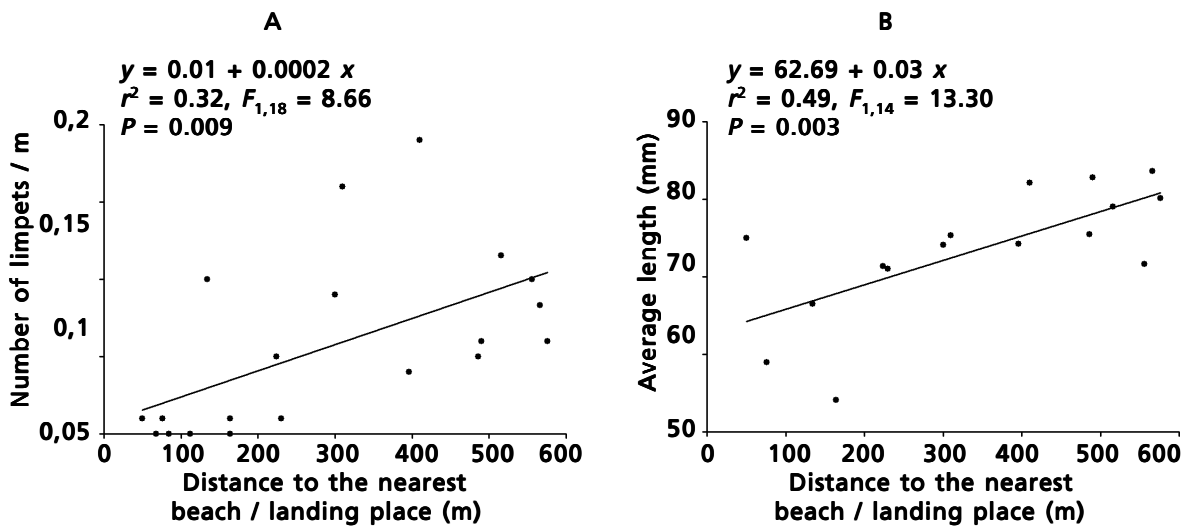


Fig. 6. Statistical relationships (Simple Regression Analysis) between the density (number of limpets / m of shore) (A) as well as the size (average length of limpets) (B) of *Patella ferruginea* in the different stretches delimited on the Alboran Island and accessibility to these areas by sea to the same (distance by sea from the nearest beach / landing place) during July 2002.

Fig. 6. Relaciones estadísticas (Análisis de Regresión Lineal Simple) entre la densidad (nº de lapas / m de orilla) (A) así como el tamaño (longitud media de las lapas) (B) de Patella ferruginea en los diferentes tramos delimitados de la isla de Alborán y la accesibilidad por mar a los mismos (distancia por mar desde la playa / embarcadero más cercana) durante julio de 2002.

2001). The distribution of sizes, with a maximum of specimens with a length between 70–80 mm and another between 30–40, could have indicated the mixed presence of adult females (bigger and around the former maximum) along with the reproductive males (smaller and around the latter maximum), also allowing cross fertilisation (see TEMPLADO, 2001). However, recruitment of new specimens of this population of the limpet should be investigated in the near future to evaluate its conservational status on the island over the following years.

The height vs. length ratio of the shell on Alboran Island was high when compared with those given for other populations in the Mediterranean (see data of GRANDFILS, 1982; PORCHEDDU & MILELLA, 1991). The conical profile of the shells in the study locality could be related to the level inhabited by the species with respect to the sea level. Limpets living in the higher parts of the mesolittoral normally required a greater hydric reserve and, therefore, presented higher shells (with a higher internal volume) than those others located in the lower part of the mesolittoral and exposed to greater hydrodynamism, with flatter shells (GRANDFILS, 1982; TEMPLADO, 2001). Although the level where individuals were found was not evaluated in this study, the proportionally high shells of specimens of Alboran probably indicated limpet location at a certain height with respect to the sea level, as on the Chafarinas Islands (GRANDFILS, 1982).

It could be deduced that the distribution and range sizes of *P. ferruginea* on the island during the study period was very affected by the human accessibility to its habitat, thus verifying the initial hypotheses and in spite of the fact that the species is still frequent in the locality. Accordingly, zones which were more accessible on foot from the interior and closer to usual swimming places or landing areas, presented lower populations of *Patella ferruginea* than hard-to-reach zones by land or sea, where the main surviving population was concentrated and, in many cases, composed of older individuals. Consequently, continued human presence on the island appears to lead to a probable decline of the limpet in some of its zones from harvesting, confirmed by the presence of shell remains of the species in rubbish tips in the island (pers. obs.). Another finding supporting the negative effect provoked by man on the species is related to the possible increase and recovery of its population in recent years, coinciding with the definitive installation of the military garrison and the declaration of the Integral Reserve on the island, as dissuasive factors of despoliation on the littoral perimeter of Alboran (on comparison of data on numbers of individuals from TEMPLADO, 2001 and present study). This confirms the need to regulate anthropic uses in the island, as it appears in the Development Plan of the Natural Resources of the Alboran Island

awaiting approval, with the object to favour the conservation and the future spontaneous recolonisation of *P. ferruginea* on the entire littoral perimeter of the island.

Acknowledgments

We would like to thank Juan García and Antonio Rodríguez, the crew of the AMA VII (Junta de Andalucía), without whose ever available collaboration and help access to the island and the sampling of the limpets would not have been feasible. The authors also wish to thank José Templado (Museo Nacional de Ciencias Naturales, Madrid) for his comments as referee, José Carlos García-Gómez (Sevilla University) for contributing information and Philip Kramer for the translation to English.

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