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Density and ecological aspect of endangered limpet *Patella ferruginea* in the western Algerian coast: Implications for the Conservation

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ABSTRACT

The endemic limpet *Patella ferruginea* is the most endangered invertebrate in the Mediterranean Sea. The study of this species, as a species in danger of extinction, was carried out to provide a detailed map of the distribution of *P. ferruginea* and implication for preservation as well as its morphological types. A total of 1262 specimens of *P. ferruginea* were found in two areas of the Algerian western coast: one continental (Cap Falcon) and the other insular (Habibas Islands). The mean size of *P. ferruginea* on the Habibas Islands (61.2 mm) was significantly ($p < 0.001$) greater than that on Cap Falcon (39.5 mm). The best Size–frequency distribution of this species was observed in Habibas Islands, with the largest specimen measured 137 mm. *P. ferruginea* in Algeria showed the highest mean density ever reported (1.5 individual/m). The population structure was characterized by high numbers of females. Area accessibility had greatly impacted the occurrence of this species. Two different morphological types of *P. ferruginea* has been recorded in the studied areas where the results demonstrated the dominance of the Lamarcki form, while the Rouxi form was confined to exposed sites.

INTRODUCTION

The location of Algeria as the central country of the Al Maghreb Al-Arabi and its long coastline (1280 km), make it encompasses a wide range of habitats. Algeria gives a lot of attention to the current state of conservation and potential future risks of space exploitation. Generally, many marine species have declined dramatically, and/or disappeared from part of their geographical area (Boutiba, 1997).

Patella ferruginea (Gmelin, 1791) is an intertidal species endemic of the Mediterranean Sea, listed as the most endangered marine invertebrate on western Mediterranean rocky shores (Ramos, 1998; Espinosa, 2009). However, under serious risk of extinction (Laborel-Deguen and Laborel, 1991; Templado and Moreno, 1997), its presence is reduced to few coastal areas in the western basin (Cretella et *al*., 1994; Paracuellos et *al*., 2003; Guerra- García et *al*., 2004; Espinosa and Ozawa, 2006; Espinosa et *al*., 2007). This species generally occurs in the high mesolittoral, but can also be found in the supralittoral (Paracuellos *et al*., 2003; Guerra-García *et al*., 2004; Casu *et al*., 2006). In addition, *P. ferruginea* lives on rocky shores exposed to mid-high hydrodynamics with high oxygen concentrations and low pollution levels (Coppa *et al*., 2012).

It is a protandrous species (Espinosa *et al*., 2008), achieving sexual maturity as a male between the second and the third year at a shell length of 25-30 mm and changing to female when it exceeds 40 mm (Guerra-García *et al*., 2004), and at about 60 mm (Espinosa *et al*. 2006).

Nowadays, populations of *P. ferruginea* can be observed along the coasts of Morocco, Algeria, Tunisia, Spain, Corsica, Sardinia, Pantelleria, the Strait of Sicily and Tuscan Archipelago, although the populations in Sardinia and Corsica are in clear decline (Guerra-García *et al*., 2004; Espinosa *et al*., 2009b). Although the coastal biodiversity of Algeria is still poorly known, the coast of Algeria remains a key element in the conservation of marine and coastal biodiversity of the Mediterranean basin (Grimes *et al*, 2004). The Western Algerian Islands (Rachgoun, Habibas and Plane) are sites of high ecological value where a number of endemic and endangered Mediterranean marine species living there (Bachet *et al*., 2007; Espinosa *et al*., 2009b). Important populations of the endangered mollusc *P. ferruginea* have been recorded on Rachgoun (Frenkiel, 1975) and Habibas Islands (Boumaza and Semroud, 2001; Espinosa *et al*., 2009).

This study was carried out in two different areas; the MPA Habibas islands and Cape Falcon, between 2007 and 2010, where no information on the status of *P. ferruginea* was available in Cape Falcon. So, the aim of this work was to gather information regarding the population structure and distribution of *P. ferruginea* and to investigate the effects of the area accessibility, exposure and slope of the coast on its occurrence as a tool for the effective management and conservation of this species.

MATERIALS AND METHODS

Study area:

To study the presence and density of *P. ferruginea*, two distinct coastal areas were chosen, the first one is a continental site (Cape Falcon) and the other is island (Habibas Islands) that located on the West coast of Algeria (Fig. 1).

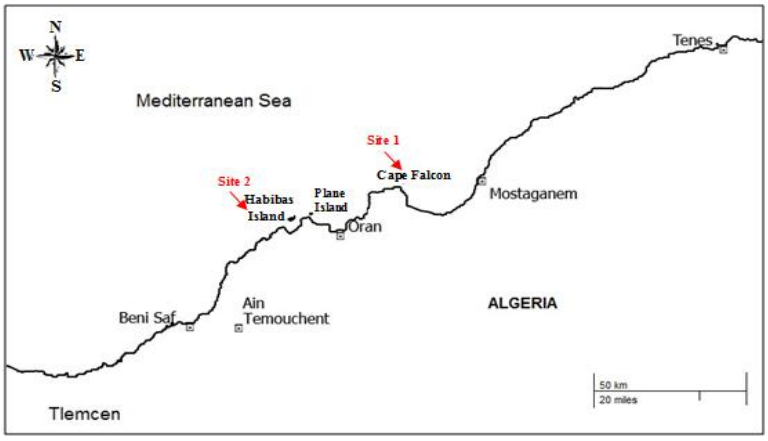

Fig. 1: Map of the study sites showing the location of Habibas Islands and Cape Falcon.

The coasts of Cape Falcon are composed of natural rocky shores and beaches, and the rocky sites encouraged the diversification of the biotopes. Therefore, it has the capacity to gather an astonishing diversity of the populations. Also, the strong currents and the variations in its beaches and sheltered places as well as the topographic particularities explain the diversity of the biotopes in this area.

Habibas islands, which declared Marine Protected Area (MPA) in 2003 by the Algerian Government (decree nº 03.147, 29 March), covers a surface about 26.84 km. These islands are under the influence of the Atlantic waters from the Alborán Sea (Robinson *et al*., 2001) and they are located at the southern end of the Almería-Oran oceanographic front (Templado *et al*., 2006).

Sampling methods

The monitoring was undertaken during 2007 and 2010, the first survey was done between February and May 2007 to map the specimens distribution, continuing to the second survey in April 2010. The geo-referenced meso-littoral strip of rocky was systematically examined that could potentially find *P. ferruginea* individuals. Additionally, the coast of each sector was examined by using 10 m transects, with the help of a metric tape. For each observed specimen the length (mm), width (mm) and the height (mm) were measured to the nearest 0.1 mm using a caliper (Laborel-Deguen and Laborel, 1985; Guerra-García *et al*., 2004; Espinosa, 2009; Rivera-Ingraham, 2010).

Small individuals were excluded from the analyses, because the external morphological characters of the shell still do not show clearly the specific characters of this species (Guallart *et al*., 2006; Casu *et al*., 2010), or the possibly belonging to either limpet. However, the biometric data (length, width and height) were used to describe the structure of the population and to identify the presence and the abundance of the two morphotypes described for *P. ferruginea* (Espinosa and Ozawa, 2006).

Statistical analyses

The distinction between the two morphotypes of *Patella ferruginea*, the rouxi form and lamarcki form, was done by testing the interrelationship and by simple regression using ORIGIN software (Microcol TM ORIGIN version 6), for the population parameters (density of individuals per size class, maximum shell size, adult density and total density).

Univariate analyses were carried out using the statistical package SPSS 10.0, and nonparametric tests were applied using STATISTICA 8® software. Multivariate analyses were also conducted to compare size distributions among populations, as has been satisfactorily (Sagarin *et al*., 2007; Espinosa, 2009). The Analysis of Variance (ANOVA) was used for statistical analysis, Newman-Keuls test was used for post hoc comparisons.

RESULTS

A total of 1262 specimens of *P. ferruginea* were recorded in the two chosen areas along the Algerian western coast, the continental area (Cape Falcon) and the insular one (Habibas Islands). A total of 578 specimens of *P. ferruginea* were recorded during the first sampling between February and May 2007 (195 specimens in Habibas Islands and 383specimens in Cape Falcon), compared to 684 specimens during the second sampling in April 2010 (455 in Habibas Islands and 229 specimens in Cape Falcon).

Cape Falcon area

In 2007 an average of 1.39 individual/m per linear transect was recorded in 28 transects each composed of 10 m, the maximum density observed between 40-50 mm, Length ranged between 8 and 68 mm (Fig. 2). A total of 295 individuals larger than 30 mm and 88 specimens smaller than 30 mm were counted and measured, the

mature specimens (>30 mm) dominated in the population constituting about 77% of the specimens recorded in those sectors where comprehensive surveys were carried.

In 2010, the length ranged between 8 and 69 mm and the distribution was unimodal, with a maximum between 40 and 50 mm (Fig. 2). Up to 173 individuals larger than 30 mm and 56 specimens smaller than 30 mm were measured, and the mature specimens (>30 mm) were dominated in the population forming about 75.5% of the specimens recorded.

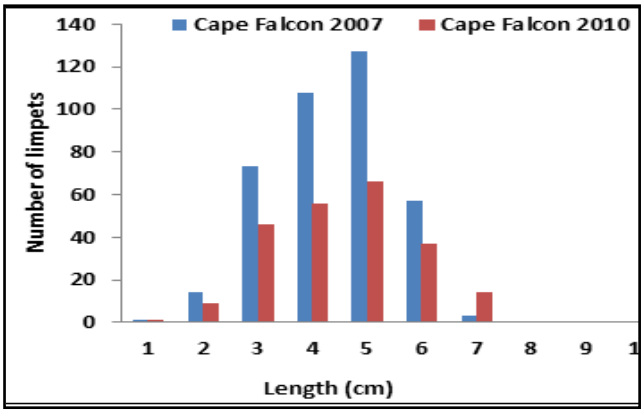

Fig. 2: Size frequencies of *Patella ferruginea* in Cape Falcon between 2007 and 2010.

Considering the accessibility of the strips of littoral, significantly differences were observed in the density of the limpets based on the degree of access. Fig. 3 shows how the general distribution of *P. ferruginea* in Cape Falcon is. From the figure, it is clear that there is an extreme variability within sectors on this site, although the North sector showed the greatest densities of this species, the east one showed an absence of this species. Also, the area accessibility was impacted the size range of the species where limpets located in sector of less accessible by land were bigger in size than those found in more accessible zones.

Fig. 3: Distribution of *P. ferruginea* in Cape Falcon, the red color indicates the locality where was recorded, and green where was absent.

The shell height/length ratio was used to distinguish the two morphotypes (Espinosa and Ozawa, 2006). In 2007, the Lamarcki form (N=299) was outnumber the Rouxi form (N=88); the same finding was observed in 2010, the Lamarki form was significantly more abundant where Lamarcki form counted 177 individuals and Rouxi form counted 52 ones. Furthermore, the different biometrical measures were compared between the two forms where the linear relations confirmed a great percentage of variance (Fig. 4).

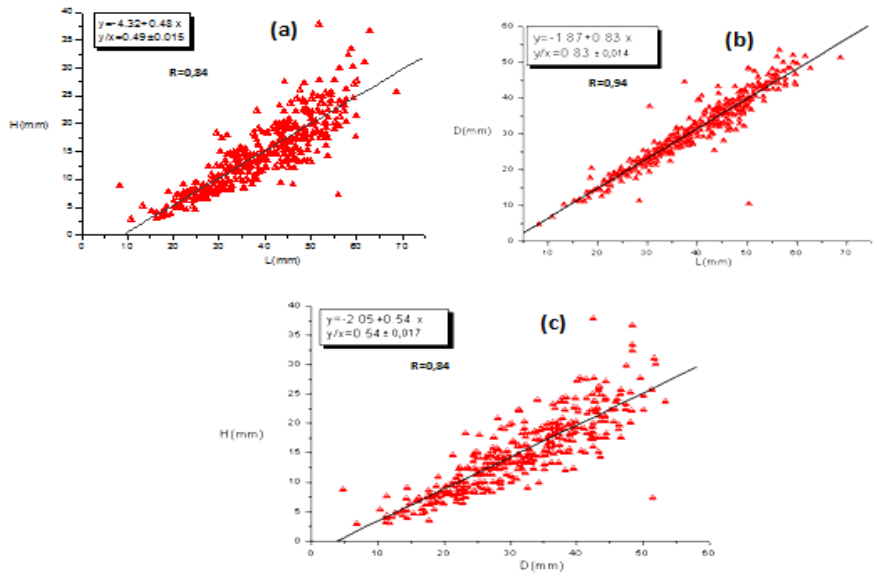

Fig. 4: Statistical relationships between: height (H)-length (L) **(a),** width (D)-length (L) **(b)** and H-D **(c)** of *Patella ferruginea* in the Cape Falcon during 2007 (y/x=average value ± SD).

The analysis of the difference between the two morphotypes of *P. ferruginea* based on the variability in the shell shape, revealed that there is a strong difference in number where the number of Rouxi type was very low in relation to Lamarcki type numbers. Also, ANOVA confirmed the dominance of Lamarcki type (Fig. 5).

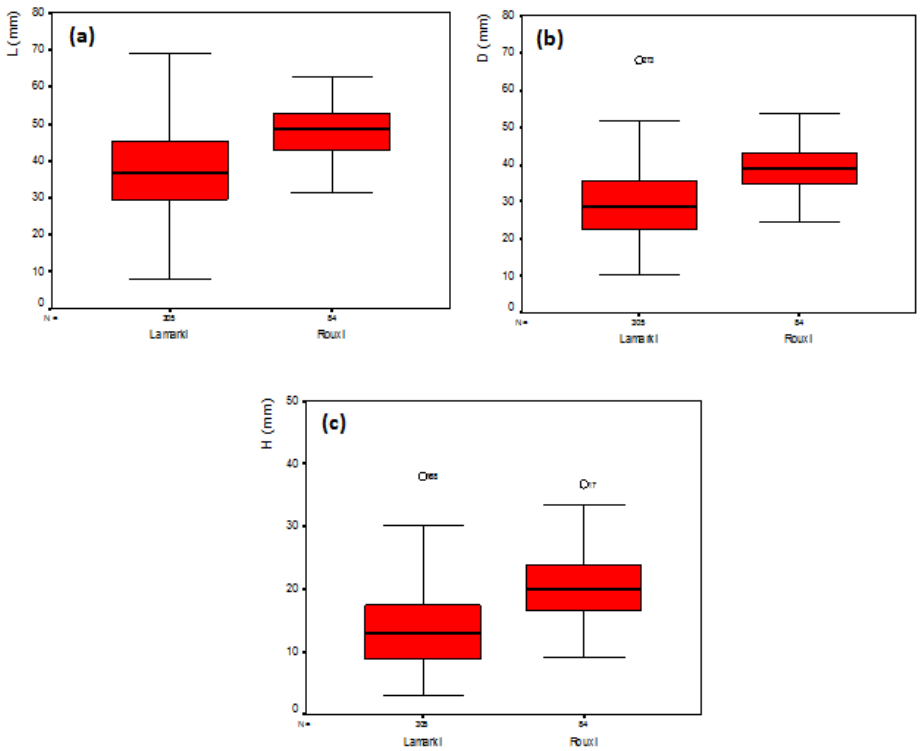

Fig. 5: Box-and-whisker plots of *Patella ferruginea* shell length between the different parameters of the two populations: (a): length; (b): width; (c): height.

Moreover, the regression analysis between the height and length could be distinguish the two forms Lamarcki and Rouxi (Fig. 6). Post-hoc comparison

(Newman-Keuls test) highlighted a significantly lower (P<0.001) variance value of the different parameters of the two morphotypes.

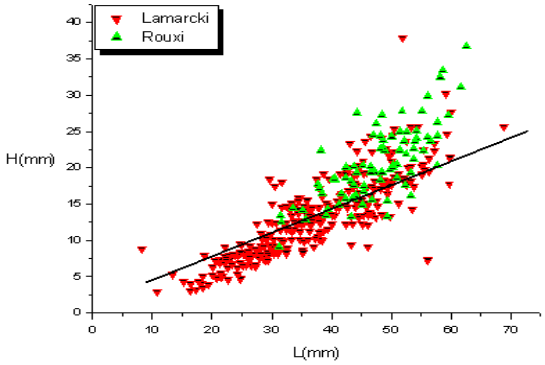

Fig. 6: Relationship between height (H) and length (L) of *Patella ferruginea* to distinguish the Lamarki and the Rouxi morphotypes (P<0.001).

Habibas islands area

A total of 650 individuals of *P. ferruginea* were recorded and measured. The distribution of the limpets was not homogenous; the greater part of the population was concentrated in Eastern part (Fig. 7). In 2007, 195 individuals were recorded with density equal to 1.5 ind/m per linear transect that registered in 13 transects each composed of 10 m, the maximum density observed between 70-80 mm, with the highest maximum shell size value of 137 mm (Fig. 8).

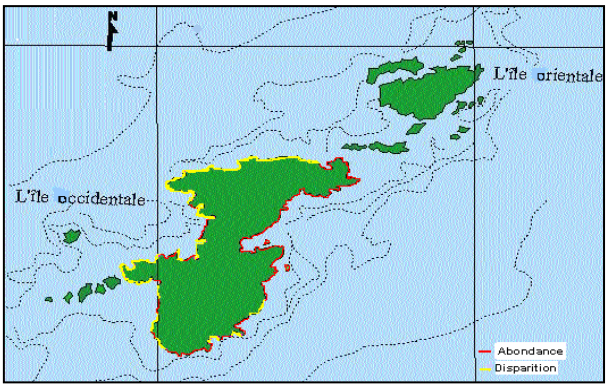

Fig. 7: Distribution of *P. ferruginea* in Habibas islands, the red color indicates a locality where was recorded, and yellow where was absent.

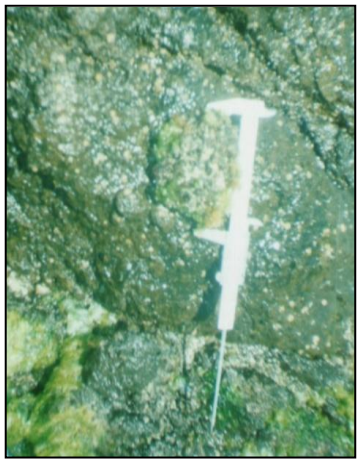

Fig. 8: Specimen of *Patella ferruginea* with the highest maximum shell size value 137 mm found on the Habibas Islands during 2007.

The analysis of the length frequency distribution indicates a wide range of lengths where it ranged between 17 and 137 mm and distribution was unimodal (Fig. 9). Up to 192 individuals were larger than 30 mm and 3 specimens were smaller than 30 mm, where the mature specimens (>30 mm) were dominated in the population forming about 98.5% of the specimens recorded. In 2010, length was ranged between 11 and 121 mm and the distribution was unimodal, with a maximum between 60 and 80 mm (Fig. 9).

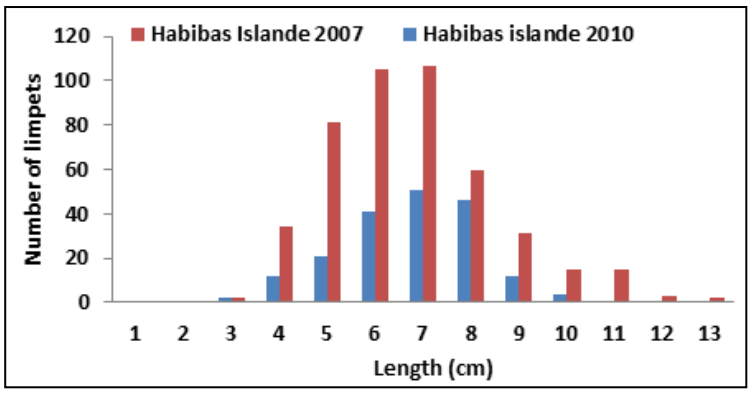

Fig. 9: Size frequencies of *Patella ferruginea* in Habibas islands during 2007 and 2010.

By distinguishing between the two morphotypes used the shell height/length ratio, the Lamarcki form was significantly more abundant. In 2007, Lamarcki form counted 109 specimens and the Rouxi form counted only 86 ones, while in 2010, Rouxi form counted 135 and Lamarcki form counted 302. As reported in Cape Falcon, the different biometrical measures were compared between each other and the linear relations explained a great percentage of variance (Fig. 10).

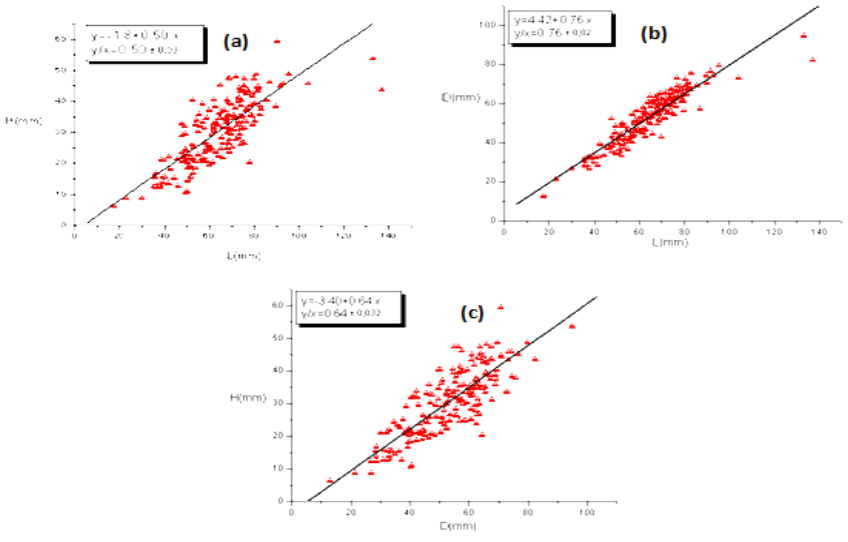

Fig. 10: Statistical relationships between: height (H)- length (L) **(a),** width (D)- length (L) **(b)** and H-D **(c)** of *Patella ferruginea* in Habibas Islands during 2007 (y/x=Average value ± SD).

Also, the presence of the two morphotypes appears strong unbalanced where the number of Rouxi was very low in relation to Lamarcki. The ANOVA results showed significant differences between the Rouxi and Lamarcki form (Fig. 11).

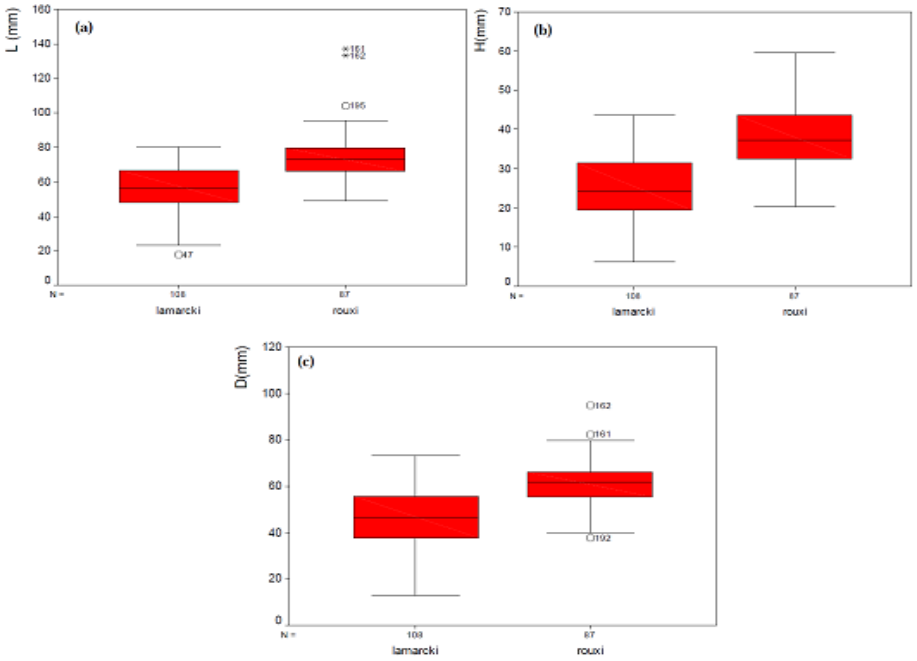

Fig. 11: Box-and-whisker plots of *Patella ferruginea* shell length between the different parameters of the two populations: (a): length; (b): width; (c): height.

Additionally, to confirm the significant differences between the two populations (P<0.001, Newman-Keuls test), the height and length relationship was estimated (Fig. 12).

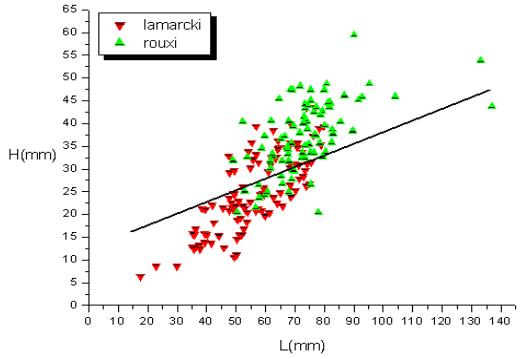

Fig. 12: Relationship between height (H) and length (L) of *Patella ferruginea* to distinguish the Lamarki and the Rouxi morphotypes (P<0.001).

DISCUSSION

This study was conducted to better understand the distribution of the *Patella ferruginea* population in Algeria, as well as the densities of the most favourable areas. This study confirms the highly distribution of population of *P. ferruginea* in the western Algerian coast, especially in Habibas Islands, with average density (1.5 ind/m), but in the Cape Falcon site the density was moderate. However, the comparisons of values of density of this endangered limpet between localities have recently been discussed in detail by Espinosa (2009). In other littoral zones the average density of this limpet is much lower, in Zembra Island, was 0.85 ind/m and 0.73 adults/m (Tlig-Zouari *et al*., 2010), in the Penisola del Sinis–Isola di Mal di Ventre Marine Protected Area in Sardinia, it was 0.024 specimens/m (Coppa *et al*.,

2012) and in the Penon de Vélez de la Gomera was 0.13 adults/m (Orozco *et al*., 2013).

Our results demonstrated that in Cape Falcon site, the level of accessibility of the coast is a major factor affecting the occurrence of *P. ferruginea*. However, we consider the local protection for eastern sector for Cape Falcon inhabited by a small military garrison, who aware well the distribution of population in this site.

Population size structures are an important indicator of the population status and can be used comparatively across sites and through time to identify the key factors controlling population dynamics (Espinosa *et al*., 2009). In addition, it has been used to track losses of large individuals from populations which are often the target of exploitation by humans (Rochet and Trenkel, 2003), as happened with limpets, which are collected as food or as fishing bait because of their large muscular foot (Pombo and Escofet, 1996).

The human exploitation, and the consequent loss of large-sized females, is the main cause of the vulnerability of the populations, especially in protandrous species (Hawkins *et al*., 2000). The first deduction that shows the existence of a rarefaction of the large sized individuals in the studied sites is bound presumably to human collection during the summer season, the period during which the human pressure is impressive. The presence of *Patella ferruginea* in the Habibas Islands was reported by Boumaza and Semroud (2001), Larbi Doukara *et al.* (2007; 2008) and Espinosa (2009).

The population of *P. ferruginea* in the studied areas shows a well-structured size/age distribution, with a wide range of sizes from adults to large individuals. Noteworthy is the high number of adults found, 98.46% of the specimens observed were >30 mm. It could be related to the high inter-annual variability found in the recruitment of this species in other localities of Mediterranean.

For the second deduction, one can say that a rarefaction of the young individuals exists, is due to the natural predation, where we observed that there is an overpopulation of the seagull (*Larus cachinnans*) and rats (*Rattus rattus*) in the western island, which considered as the main two predators of *P. ferruginea*. According to the present observations, nearly the majority of the individuals living on the studied sites were probably adults, where the distribution of the sizes showed two peaks between two classes of sizes, the first (70-80 mm) and the other of (50-60 mm). These data indicate the existence of a mixture of females and the reproductive males which permits the fertilization (Templado, 2001; Paracuellos *et al.*, 2003).

The variability of the shell shape has led to the subdivision of *P. ferruginea* into two morphotypes: the Lamarki form, with rare large ribs and a flattened shell, and the Rouxi form which has more numerous thin ribs on a conical shell (Coppa *et al*., 2012). However, this two forms are different ecotypes rather than different species or subspecies, with significant differences in their height (H)/length (L) ratio (H/L Lamarcki <0.37; H/L Rouxi> 0.37) (Espinosa and Ozawa, 2006). Our results provided the first evidence of a spatial separation between the two morphotypes of *P. ferruginea*, with higher distribution of the Lamarcki form than that of the Rouxi form. According to the results of Espinosa and Ozawa (2006), The H/L ratio observed, according to the Newman-Keuls test, was significantly higher in the Rouxi form than that in the Lamarcki form showing clear morphological shell differences between the two phenotypes.

Our direct observations indicate that the population is in evolutionary regression on the site of Cape Falcon, because of the rarefaction of the species of big

sizes, and also those of small sizes. In the same time, the number was very weak in the zones of easy accessibility to the coast.

The inshore marine ecosystem of the Cape Falcon remains conserved naturally in relation to the other inshore sectors of the Algerian western coastline in spite of the human threats that exist. It is therefore preferable to take immediately action to protect this species and the whole site before the populations reach a degree at which they couldn't able to rebuild their communities. In respect to the insular site of the Habibas Islands, the wealth and the high density may be due to the introduced populations of *patellid* limpet from the different inshore regions of the Mediterranean countries. Also, the gotten data show that this insular sector shelters specimens of big sizes with parameters exceed all recorded sizes before (length = 137 mm; width =82.3 mm; height = 43.7 mm).

The prospecting of the Algerian western coastline gave encouraging and comforting strong results, since the species *Patella ferruginea* is present in many inshore sites and in a good state as well as in the big inshore urban agglomerations (Kristel, Maddagh, Sassel, Ghazaouet).

The conclusion of this survey is that the human predation and behavior are the main reason of the reduction of this endangered marine mollusk and some urgent actions should be implemented.

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