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Density and distribution of *Patella ferruginea* in a Marine Protected Area (western Sardinia, Italy): Constraint analysis for population conservation

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Abstract

The endemic limpet *Patella ferruginea* is the most endangered invertebrate in the Mediterranean Sea. Our study examined a population of *P. ferruginea* in the Marine Protected Area of "Penisola del Sinis - Isola di Mal di Ventre" (western Sardinia, Italy). During the summer 2009, we carried out a systematic census of *P. ferruginea* along a 8114 m georeferenced perimeter of coast in the "no take-no entry area" to assess its density, spatial distribution, and morphometric characteristics. Our aim was to provide a detailed map of the distribution of *P. ferruginea* and to investigate the effects of accessibility, wave exposure and slope of the coast on its occurrence. *Patella ferruginea* showed the lowest mean density ever reported (0.02 ind/m) and a unimodal population structure characterised by fewer females and juveniles. Accessibility had a major negative effect on the occurrence of *P. ferruginea*. Exposure was also an important factor in influencing its density, size composition and specimen position within the mesolittoral, while the slope had little influence. Morphometric analysis showed the dominance of the Rouxi form, while the Lamarcki form was confined to exposed sites. Our results demonstrate a highly endangered population of *P. ferruginea* and suggest that human pressure represents the main risk factor.

Keywords: *Patella ferruginea,* Marine Protected Area, Sardinia, Human influence, Endangered species, GIS applications.

Introduction

Patella ferruginea Gmelin, 1791 is an endemic limpet of the Mediterranean Sea, listed in the European Council Directive 92/43/EEC as the most endangered marine invertebrate on western Mediterranean rocky shores (Ramos, 1998; Espinosa, 2009). 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), often associated with the lichen *Verrucaria symbalana* Nyl., 1873 (Doneddu & Manunza, 1992), and in the low mesolittoral (Casu *et al*., 2004). Usually *P. ferruginea* lives on rocky shores exposed to mid-high hydrodynamics with high oxygen concentrations and low pollution levels. However, high densities have also been reported to occur in sheltered areas (Guerra-García *et al*., 2004 and literature therein). According to the literature, the mean density of *P. ferruginea* populations ranges between 0.06 (Paracuellos *et al*., 2003) and 6.86 (Espinosa *et al*., 2009a) individuals per linear meter (ind/m), with peaks up to 15 ind/m and exceptionally >50 ind/m under optimal conditions (MMAMRM, 2008).

The variability of the shell shape has led to the subdivision of *P. ferruginea* into two morphotypes (Payraudeau, 1826): the Lamarki form, with rare and large ribs and a flattened shell, and the Rouxi form, having more numerous and thin ribs on a conical shell. Espinosa & Ozawa (2006) demonstrated that the 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). The most supported hypothesis to explain these differences relates to the position of the limpet on the shore and, consequently, to factors such as desiccation stress and water turbulence. Limpets located in the high mesolittoral normally require a greater water reserve and, therefore, have a higher internal volume (conic shell) than those colonizing the low mesolittoral, which are more exposed to hydrodynamics and have a flatter profile (Paracuellos *et al*., 2003 and literature therein). It is also known that the space colonization on the shore is species-determined and the grazing area of individuals can change according to hydrodynamics (e.g. Hawkins *et al*., 2000 and literature therein). However, different spatial patterns of the two forms of *P. ferruginea* have not yet been demonstrated.

The main predators of *P. ferruginea* are crabs (e.g. *Pachygrapsus marmoratus* Fabricius, 1787, *Carcinus mediterraneus* Czerniavsky, 1884, *Eriphia verrucosa* Forskal, 1775), gastropods (e.g. *Stramonita haemastoma* Linnaeus, 1758, *Lunatia poliana* Della Chiaje, 1826) and, occasionally, birds (Laborel-Deguen & Laborel, 1991a; Espinosa *et al*., 2007a; Espinosa *et al*., 2008a; Espinosa, 2009; Tlig-Zouari *et al*., 2010). *Patella ferruginea* is a long-lived species; its lifespan is estimated to range between 8 and 35 years, depending on environmental conditions (Espinosa *et al*., 2008b). *Patella ferruginea* has a short larval stage which lasts a maximum of 10 days, and very slow growth and reproduction rates (Laborel-Deguen & Laborel, 1991b; Guerra-García *et al*., 2004). It is a protandrous species (Espinosa *et al*., 2008c), 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). However, Espinosa *et al*. (2006) suggest that most of the females are at least 60 mm. The maturation of the gonads begins in September and therefore the reproductive season occurs in autumn (MMAMRM, 2008). Settlement is positively influenced by chemical cues of adult conspecifics (Rivera-Ingraham *et al*., 2011).

Originally, *P. ferruginea* was distributed through the whole western Mediterranean, but currently 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 & Ozawa, 2006; Espinosa *et al*., 2007a). This is thought to be mainly caused by human collection and anthropogenic impact on coastal ecosystems (Paracuellos *et al*., 2003; 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 and literature therein; Espinosa *et al*., 2009b). Due to the contraction of the geographic range and population of *P. ferruginea*, this species is now considered the most threatened with extinction in the Mediterranean Sea (Guerra-García *et al*., 2004; Espinosa, 2009) and, hence, protected by the European laws (Ann. II of Bern and Barcelona Conventions, Ann. IV of Habitat Directive). In spite of this, literature on the ecology and distribution of *P. ferruginea* is scarce and limited to a few areas.

In Sardinia, western Mediterranean, genetic population studies demonstrated the presence of *P. ferruginea* populations in three Marine Protected Areas (MPAs), including "Tavolara - Punta Coda Cavallo", "Asinara" and "Penisola del Sinis - Isola di Mal di Ventre" (Casu *et al*., 2004; Casu *et al*., 2006; Lai *et al*., 2009). Casu *et al.* (2004) and Lai *et al*. (2009) highlighted a remarkable genetic homogeneity among the "Asinara" samples, suggesting little genetic divergence at the small spatial scale. A comparison of the Sinis and "Asinara" populations confirmed a very low rate of gene flow (Casu *et al*., 2006). Such poor connectivity between MPAs could be due to the overexploitation of the species in the surrounding unprotected areas which are easily accessible by humans (Lai *et al*., 2009). Anthropogenic pressure affecting *P. ferruginea* populations was also demonstrated by Doneddu & Manunza (1992) in Chiscinagghiu Bay (north Sardinia), Cristo *et al*. (2007) and Cristo & Caronni (2008) in Capo Ceraso Bay (Olbia, north east Sardina). Other Sardinian sites where *P. ferruginea* has been reported in include the Maddalena archipelago and the harbour of Arbatax (Doneddu & Manunza, 1992). Overall, the spatial distribution, abundance and status of *P. ferruginea* along the Sardinian coast remain largely unknown. This makes it difficult to plan and implement management strategies for the conservation of the species at local level.

This study was carried out in the MPA of "Penisola del Sinis - Isola di Mal di Ventre" (western Sardinia, Italy) where no information on the status of *P. ferruginea* was available. We aimed to gather basic information regarding the population structure and distribution of *P. ferruginea* and to investigate the effects of 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

This study was carried out in the MPA of "Penisola del Sinis - Isola di Mal di Ventre", on the western coast of Sardinia (Fig. 1). This MPA, established in 1997 by National Decree of the Environment Ministry, covers a surface of about 25000 ha and includes 30 km of coast. It consists of two "no take-no entry areas" (defined as "Zones A" by Italian law) which cover 1.5% of the total surface, two areas of "high protection" (Zones B), which cover 4% of the total surface, and a wide buffer area of "partial protection" (Zone C). Although restrictions on human uses are generally higher in Zone B than in Zone C (Claudet *et al*., 2006), in the Sinis MPA differences between the two categories are very limited. Indeed, the actual level of enforcement and the respect for the rules in the studied MPA are low, as demonstrated by Guidetti *et al*. (2008), who used fish assemblage as indicator of the MPA effectiveness.

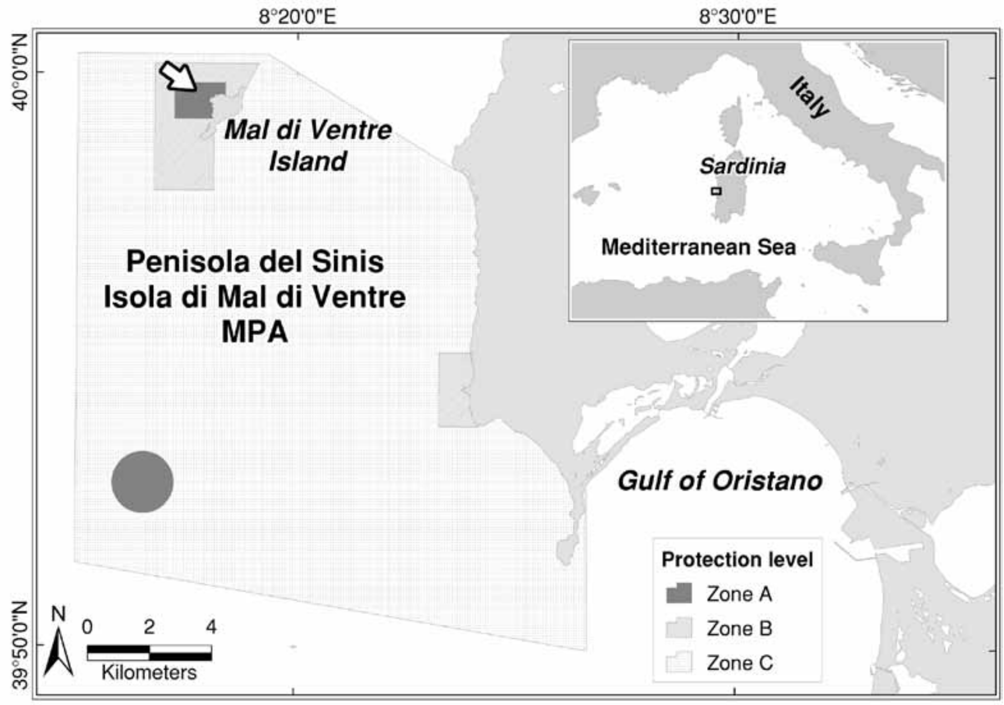

Fig. 1: Location of the Marine Protected Area (MPA) of "Penisola del Sinis - Isola di Mal di Ventre" (western Sardinia, Italy), and the study area in the northwestern sector of the Mal di Ventre Island (Zone A; white arrow).

Our research was conducted on the western side of the Mal di Ventre Island where a population of *Patella ferruginea* has been recently reported (Casu *et al*., 2006). Mal di Ventre is a granitic island 5 nautical miles away from the Sardinian coast, with a surface area smaller than 1 km^2. The western side of the island, exposed to the prevailing wind (Mistral), is jagged with a lot of emerging rocks that constitutes a risk for landing and some high cliffs that prevent coastal access by land. In contrast, the eastern side of the island is flat and characterised by numerous small beaches.

In order to estimate as precisely as possible the size of the population of *P. ferruginea* we chose to perform a systematic census of the study area that includes the whole Zone A of Mal di Ventre Island and a little portion of Zone B (<15% of the total) near to the limits of the "no take-no entry area" (Fig. 1). Field observations were carried out between July and September 2009 by a team of 2−3 snorkelers in order to optimise the detectability of individuals.

Perimeters analysis

The perimeter of the coastline was estimated using aerial high-resolution georeferenced photos and GIS application *ESRI Arcgis 9.2*®. This allowed us to subdivide the perimeter of the analyzed coastline according to the following factors: accessibility, exposure (i.e. exposed and sheltered surfaces with respect to the prevailing north-west Mistral wind, 225°−44° and 45°−224°, respectively) and slope (vertical substrate or not). Three levels were considered to assess the degree of accessibility of the coast as suggested by Paracuellos *et al*. (2003): (i) easily accessible - strips easily reachable by land and sea; (ii) semi accessible - sectors reachable only partially and with difficulty by land and sea; (iii) hardly accessible - isolated rocks or cliffs hardly reachable by swimming from the coast or by boat due to the presence of dangerous rocky outcrops.

Patella ferruginea population analysis

The georeferenced mesolittoral strip was systematically examined for the presence of *P. ferruginea* (Fig. 1). For each observed specimen the following variables were considered: geographical coordinates, length (mm), width (mm), height (mm), distance from the lowest tide level (cm), accessibility, exposure and slope of the coast. Specimens smaller than 10 mm were excluded from the analyses because the external morphological characters of the shell still do not show clearly the specific features of this species (i.e. corrugated edge and marked ribs) (Casu *et al*., 2010). However, their number was limited (about ten) possibly belonging to either *P. ferruginea* or the co-occurring *Patella rustica* Linnaeus, 1758, *Patella ulyssiponensis* Gmelin, 1791 and *Patella caerulea* Linnaeus, 1758. The length and width of each individual were measured to the nearest 0.1 mm using a calliper. The height was also measured using a modified calliper without removing the specimens from the substrate,

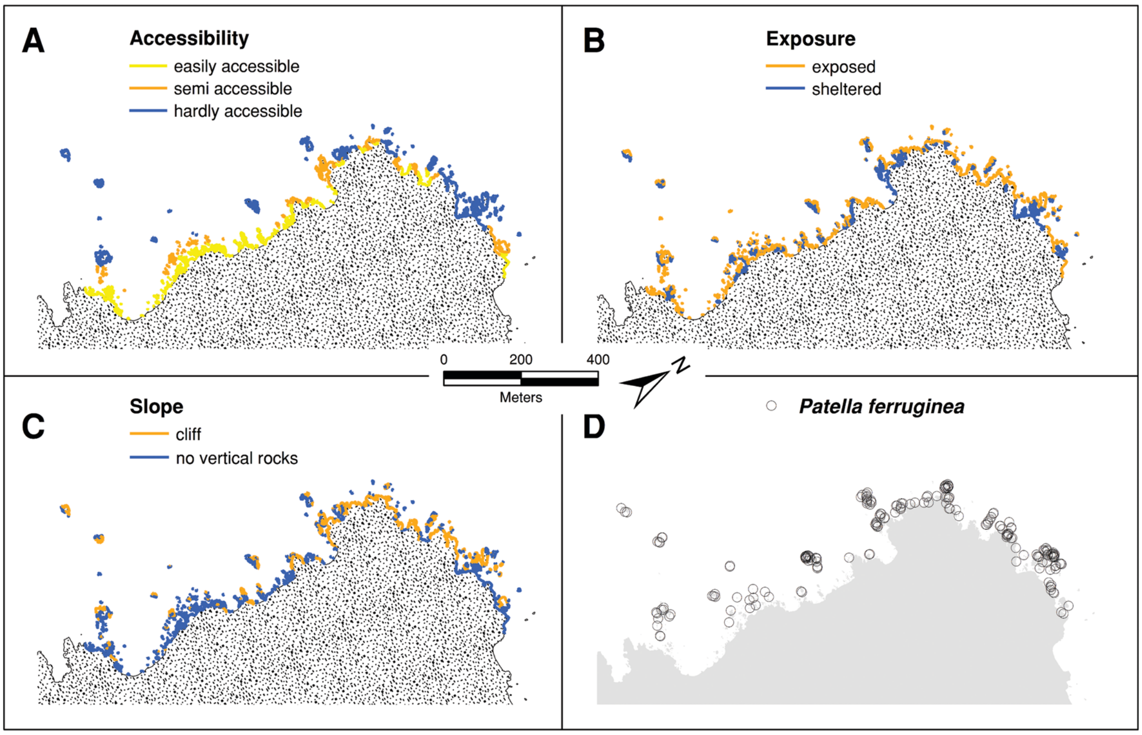

Fig. 2: Analyzed perimeter of the Mal di Ventre Island classified in relation to the accessibility (A), exposure (B) and slope (C) of the coast, and the georeferenced distribution *Patella ferruginea* individuals (D).

thereby minimizing stress. Biometric data (i.e. 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 & Ozawa, 2006).

In order to compare the "size" and/or the "height from minimum tide level" in relation to "accessibility", "exposure", "slope" of the coast and "morphotype", non-parametric tests were applied using STATISTICA 8® software. If the considered factors had more than two levels (e.g. accessibility) a Kruskal-Wallis test was performed; otherwise a Mann-Whitney U test or Kolmogorov-Smirnov test was used. For the slope estimation, a subdivision in sectors was considered: vertical (90°−60°), inclined

Table 1. Classification of the coast in relation to its accessibility, exposure and slope.

Accessibility	Exposure	Slope	Length (m)
1. Easily accessible (3140 m; 39%)	a. Exposed	i. Cliff	402 (5%)
		ii. No vertical rocks	1618 (20%)
	b. Sheltered	i. Cliff	180 (2%)
		ii. No vertical rocks	940 (12%)
2. Semi accessible (1863 m; 23%)	a. Exposed	i. Cliff	504 (6%)
		ii. No vertical rocks	596 (7%)
	b. Sheltered	i. Cliff	379 (5%)
		ii. No vertical rocks	384 (5%)
3. Hardly accessible (3111 m; 38%)	a. Exposed	i. Cliff	912 (11%)
		ii. No vertical rocks	742 (9%)
	b. Sheltered	i. Cliff	650 (8%)
		ii. No vertical rocks	807 (10%)
Total perimeter monitored 8114 m			

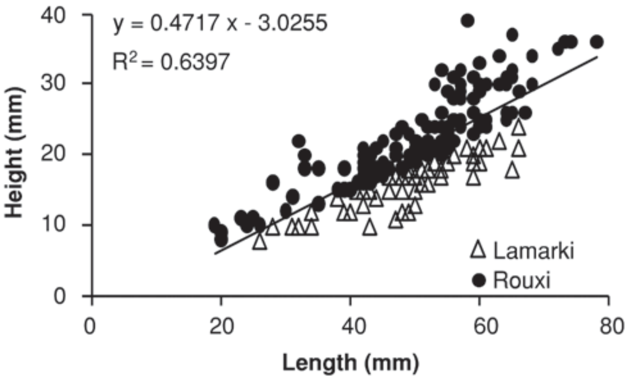

Fig. 3: Relationship between height *vs.* length of *Patella ferruginea* (P<0.001). The height (H)/length (L) ratio was used to distinguish the Lamarki (H/L<0.37) and the Rouxi (H/L>0.37) morphotypes.

(60°−30°), horizontal (30°−0°), negative (-30°−0°). With the aim to unravel whether *P. ferruginea* density changes in relation to the accessibility, exposure and slope of the coast a chi-square test was assessed. Only for the latter analysis (slope) a reduction into 2 levels (vertical cliff or other) was applied, due the impossibility of distinguishing the various degrees of coastal slope using aerial photos. A chi-square test was applied to assess whether the morphotype distribution depends on the exposure of the coast. Additionally, the occurrence of a preferred exposure in relation to quadrants [(NE (1°−90°), SE (91°−180°), SW (181°−270°), NW (271°−360°)] was tested for the individuals found on isolated rocks. The sample distribution was compared to a uniform distribution by means of a chi-square test.

Results

Study area features

The total perimeter of the monitored coast was 8114 m (Table 1). "Easily accessible" and "Hardly accessible" shore was predominant, accounting for 39% and 38% of the total coast, respectively (Table 1; Fig. 2a). More than half of the coast (4774 m) was exposed to the Mistral wind, while more than one third was represented by cliff (Table 1, Fig. 2b,c).

Patella ferruginea population

A total of 196 individuals of *P. ferruginea* was found in the study area, corresponding to a mean density of 0.02 ind/m (Fig. 2d). The shell height/length ratio, used to distinguish the two morphotypes (Espinosa & Ozawa, 2006), highlighted the prevalence of the Rouxi form (N=133) over the Lamarcki form (N=63) (Fig. 3). The Mann-Whitney U test did not show significant spatial differences between the two morphotypes (U=4026; P=0.659), with an average position within the mesolittoral of 8.7 cm ± 0.5 above the lowest tidal level. However, the Lamarki form was significantly more abundant in the exposed sites (χ^2=4.13; P=0.04); in contrast with the Rouxi form which showed a homogeneous distribution according to hydrodynamics (χ^2=0.24; P=0.62).

The population structure showed a unimodal distribution with a peak of individuals of 50−59 mm length and a maximum length of 78 mm (Fig. 4). The relatively small portion of individuals <30 mm and the lack of large-sized specimens (>80 mm, mainly females) was an indication of a threatened population (Fig. 4). The comparison of frequency distributions with healthier populations (e.g. Habibas, Algeria; Fig. 4) confirmed significant differences between the two populations (P<0.001, Kolmogorov-Smirnov test). The mean size of the three levels of accessibility did not differ significantly (H=0.445, P=0.8), while the respective variance values did (median-based Levene test, P<0.0001). Post-hoc comparison (Tukey test) highlighted a significantly lower (P<0.001) variance value of the easily accessible sites compared to the semi-accessible and hardly accessible sites. This was due to the absence of both juveniles (<20 mm) and large adults (>70 mm), which instead were commonly found on the semi-accessible and hardly accessible coast (Fig. 5).

The density was largely dependent on the level of accessibility of the coast, with 148 specimens found

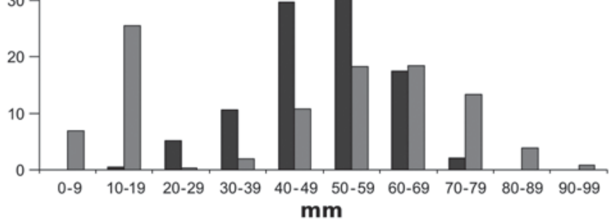

Fig. 4: Size-class frequency of *Patella ferruginea* population in the Mal di Ventre Island (present study, black columns) and Habibas, Algeria (Espinosa, 2009; grey columns).

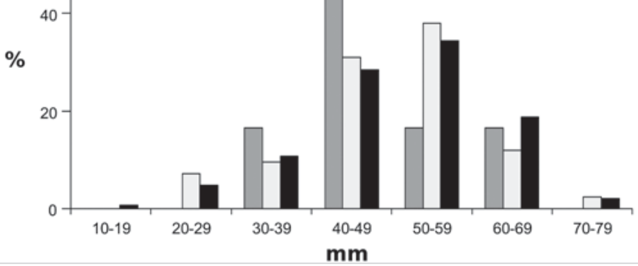

Fig. 5: Size-class distribution of *Patella ferruginea* in relation to the accessibility of the coast.

Table 2. Result of chi-square test (Obs, observed frequencies; Exp, expected frequencies) to test the density of *Patella ferruginea* in relation to the accessibility, exposure and slope of the coast.

		Cliff		No vertical rocks	
Accessibility	**Exposure**	Obs	Exp	Obs	Exp
1. Easily accessible χ^2=64.63 df=3 P<0.00001	a. Exposed	2.00	9.72	2.00	39.09
	b. Sheltered	1.00	4.33	1.00	22.69
2. Semi accessible χ^2=4.54 df=3 P<0.2088	a. Exposed	13.00	12.18	15.00	14.39
	b. Sheltered	3.00	9.16	11.00	9.27
3. Hardly accessible χ^2=87.90 df=3 P<0.00001	a. Exposed	45.00	22.02	48.00	17.93
	b. Sheltered	20.00	15.71	35.00	19.50

along the hardly accessible perimeter (0.05 ind/m), 42 on semi-accessible sites (0.02 ind/m) and only 6 individuals in the easily reachable sites (0.002 ind/m) (Table 2). The chi-square test confirmed that the density of *P. ferruginea* was significantly higher in the hardly accessible sites (Table 2). Within these sites, this analysis also highlighted a homogeneous occurrence of individuals in relation to the slope and a significantly higher density along the exposed coast (south-west to north-east: 225°−44°). The analysis of *P. ferruginea* distribution in relation to directional quadrant discarded the hypothesis of a random distribution (χ^2=20.13, P<0.0002). In particular, 40% of the individuals found on isolated rocks (N=173) were grouped on the coast oriented towards the fourth quadrant (Mistral wind direction). These results demonstrated a preference of *P. ferruginea* for sites with the highest level of hydrodynamics. Furthermore, the results of the Mann-Whitney U test showed that specimens in the exposed sites were significantly larger than those in the sheltered sites (U=3433.5; P=0.0102; N_1=126, N_2=70; Fig. 6), also occupying a significantly lower position within the mesolittoral (U=3282; P=0.0029; N_1=126, N_2=70; Fig. 7). Finally, no significant effect of inclination (vertical: N=106; inclined: N=72; horizontal: N=9; negative: N=9) was found in relation to the shell size (H=1315, P=0.7256), nor to the position of specimens within the mesolittoral (H=601; P=0.2035).

Discussion

The population of *Patella ferruginea* in the Mal di Ventre Island showed the lowest average density (0.02 ind/m) ever reported for this species. In particular, it was three times lower than that found on the Alboran Islands similarly affected by human collection (Paracuellos *et al*., 2003). This study thus confirms the highly endangered status of *P. ferruginea* on Sardinian rocky shores where it is reported to be at serious risk of extinction (Guerra-García *et al*., 2004 and literature therein; Espinosa *et al*., 2009b). Our results demonstrated that the level of accessibility of the coast still plays a major role in determining the occurrence of *P. ferruginea* (e.g. Paracuellos *et al*., 2003; Guerra-García *et al*., 2004; Espinosa *et al*., 2009a), even though within the "no take-no entry zone", with a density of 0.05 and 0.002 ind/m in the hardly and easily accessible sites, respectively. Indirect evidence of how Zone A is disregarded comes from our recurrent observations of leisure boats and/or snorkelers in the latter sites, in spite of access to Zone A being banned except for research or surveillance purposes. In fact, the importance of no take areas for the conservation of the marine ecosystem is increasingly emphasized worldwide (e.g. Manríquez & Castilla, 2001; Claudet *et al*., 2008; Chittaro *et al*., 2009). However, we consider the local protection measures for Zone A to be ineffective, and assume that illegal catches constitute the main constraint for the population success in Mal di Ventre Island.

The size distribution of *P. ferruginea*, with fewer individuals >70 mm, was a further indication of human exploitation, as larger individuals constitute the main target of illegal catches (Sagarin *et al*., 2007; Espinosa, 2009). For instance, Espinosa *et al*. (2009a) on the Strait of Gibraltar reported individuals >100 mm in protected ('under custody') military areas, not found in adjacent 'without custody' areas. The human exploitation, and the consequent loss of larger-sized females, is the main cause of the vulnerability of the populations, especially in protandrous species (Hawkins *et al*., 2000). The evidence of a tight link between size and reproductive output of *P. ferruginea* was demonstrated by Espinosa *et al*. (2006). They showed that an 8-cm female spawns a number of oocytes ten time greater than an individual of 6 cm in length. Moreover, the decreased population density further reduces the success of external fertilization and recruitment as a consequence of a higher dispersal of individuals (Hawkins *et al*., 2000 and literature therein). In our study area, such a population structure profile, with few individuals <30 mm and >70 mm, most apparent in the easily accessible sites, confirmed that *P. ferruginea* is threatened. Thus, effective enforcement of Zone A has to

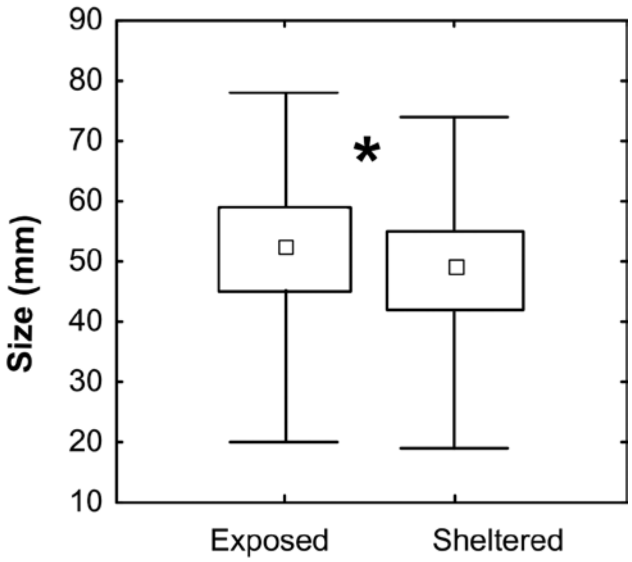

Fig. 6: Box-and-whisker plots of *Patella ferruginea* shell length in exposed (225°−44°) and sheltered (45°−224°) sites. Boxes are inter-quartile ranges; open squares within boxes are medians; whisker endpoints are high/low extremes. *, *P*<0.05.

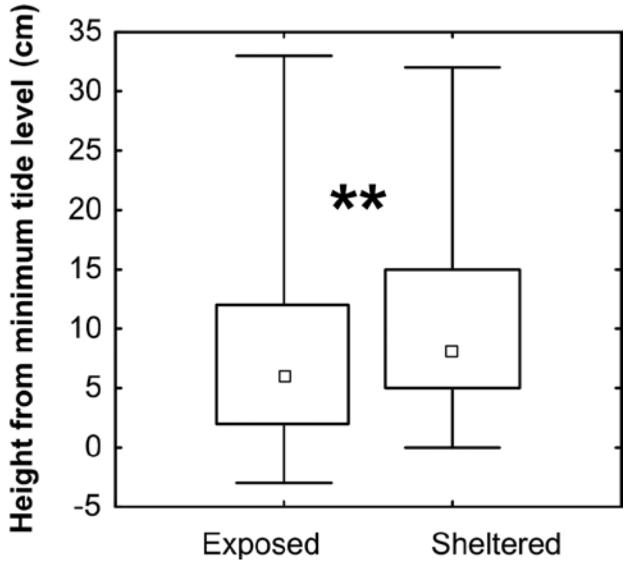

Fig. 7: Box-and-whisker plots of *Patella ferruginea* height from the minimum tidal level in exposed (225°−44°) and sheltered (45°−224°) sites. Boxes are inter-quartile ranges; open squares within boxes are medians; whisker endpoints are high/low extremes. **, *P*<0.01.

be pursued in order to increase the mean size and hence the reproductive effort and viability of this population.

In our study area, the exposure of the coast to wave actions was also an important factor influencing the distribution of *P. ferruginea*, as previously found in studies focusing on the effect of hydrodynamics on limpets in the intertidal zone (e.g. Denny, 2000; Denny & Blanchette, 2000; Denny *et al*., 2003). Density was significantly higher on the coast most exposed to the prevailing north-western Mistral wind, and thus with greater wave action. Other studies suggested that *P. ferruginea* is usually associated with rocky shores exposed to wave action (Porcheddu & Milella, 1991; Doneddu & Manunza, 1992; Tlig-Zouari *et al*. 2010). In contrast, Guerra-García *et al*. (2004) showed that high densities occur also in sheltered areas with little water exchange. Our results suggest that strong wave motion, in addition to possibly promoting the success of the population due to an increased grazing surface (Espinosa *et al*., 2007b), makes the same (most exposed) sites the least accessible to human exploitation. This can also partly explain the higher density of larger individuals in the exposed sites (Fig. 6), while the lower position of *P. ferruginea* within the mesolittoral (Fig. 7) may be related to a different temporal and spatial use of the grazing area. However in order to explain the distribution of *P. ferruginea* according to hydrodynamics, experimental studies are needed in order to evaluate the possible additive or synergistic effects of other abiotic and biotic factors (e.g. insulation, abundance and distribution of predators and competitors, variability in algal assemblage) affecting these patterns.

Our results provided the first evidence of a spatial separation between the two morphotypes of *P. ferruginea* within the mesolittoral. In particular, while the distribution of the Rouxi form was unrelated to the exposure of the coast, the Lamarki form was significantly confined to the exposed sites. This corroborates an earlier hypothesis of a higher adaptability of the Rouxi form due to a larger internal volume which allows longer periods of respiratory autonomy (Paracuellos *et al*., 2003 and literature therein). We infer that this can also be a reason for the greater success of the Rouxi form (N=133) over the Lamarki form (N=63) in our study area.

Finally, contrary to previous studies, we did not find any differences on *P. ferruginea* distribution according to the slope of the substrate. For instance, along the Spanish coast *P. ferruginea* generally colonizes inclined substrates with a lower preference for vertical cliff (MMAMRM, 2008), while Doneddu & Manunza (1992) recorded a higher colonization of *P. ferruginea* on horizontal substrates. These heterogeneous results suggest that the choice of a particular slope by *P. ferruginea* may be site-specific, i.e. related to the local characteristics. However, the extension of the surveyed area (>8 km) did not allow us to associate the main observed slopes with the respective surface, nor previous studies on *P. ferruginea* did. A specific study aimed at clarifying this aspect is necessary.

Overall, the results of this study highlighted the limited effectiveness of Zone A against human pressure. However, they also provided useful information on the distribution of *P. ferruginea* as the basis for its protection and conservation in the MPA of "Penisola del Sinis-Isola di Mal di Ventre". We infer that the low frequency and the high predictability of local surveillance, as well as the modest fines provided by the Italian legislation to transgressors, are major drawbacks limiting the effectiveness of this MPA as a flagship tool of marine conservation (e.g. Agardy, 1994; Allison *et al*., 1998; Branch & Odendaal, 2003; Mora *et al*., 2006; Chittaro *et al*., 2009, Espinoza-Tenorio *et al*., 2010 and literature therein). In addition, according to the Italian legislation, the application of sanctions to transgressors (e.g. people catching protected species within Zone A) is sole responsibility of national enforcement bodies, with little power given to the local staff or collaborators of the MPA. Nowadays the lack of an effective and direct surveillance of MPAs is considered one of their greater handicaps (e.g. Rodríguez-Martínez 2008; Guidetti *et al*., 2008; García-Gómez *et al*., 2010). A partial solution to these problems would be a stricter control of the MPA, including the presence of national enforcement bodies during the patrol activities of the MPA staff as proposed by Rodríguez-Martínez (2008), or the use of a video surveillance system as suggested by Espinosa *et al*. (2009a). In fact, experience has demonstrated that the main causes that lead to the failure of a MPA can be ascribed to socioeconomic factors such as the low participation of local communities (Rodríguez-Martínez, 2008; Ferse *et al*., 2010). Studies performed in several countries demonstrated that the majority of the local users perceive themselves as the recipients of rules against their interests, thus negating any possible benefits (Ferse *et al*., 2010). This also implies that the time needed to benefit from any conservation measures may exceed the time that the local communities are willing to wait for concrete results (Ferse *et al*., 2010 and literature therein).

We may conclude that, due to the general regression of the geographic distribution of *P. ferruginea* (e.g. Ramos, 1998; Guerra-García *et al*., 2004; Espinosa, 2009), the protection of the hot spots of this species should be considered a priority. In fact, MPAs should play a fundamental role as a refuge area for the remaining populations (Espinosa *et al*., 2009a,b; Martins *et al*., 2010; Van Hoey *et al*., 2010). In order to prevent the extinction of *P. ferruginea* in Sardinia it will be important to combine the knowledge and experience of all stakeholders, as the Spanish experience has shown (MMAMRM, 2008). Only when conservation strategies are created with the participation of the local community and based on a solid understanding of the causes of populations decline, can the extinction of the species be prevented.

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