POPULATIONAL STATUS OF THE ENDANGERED MOLLUSC PATELLA FERRUGINEA (GASTROPODA: PATELLIDAE) IN ALGERIAN ISLANDS

Petites îles de Méditerranée 07

April 08

Par : **Free Espinosa**, Universidad de Sevilla

INTRODUCTION

The Western Algerian islands (Rachgoun, Habibas and Plane) are sites of high ecological value taking into account the number of endemic and endangered marine species from Mediterranean that are living there (BACHET et al., 2007). In this sense, important populations of the endangered mollusc Patella ferruginea have been recorded in Rachgoun (FRENKIEL, 1975) and Habibas islands (BOUMAZA and SEMROUD, 2001).

Patella ferruginea, endemic to the Mediterranean, is the most endangered marine macroinvertebrate in the Western Mediterranean rocky shores under 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), and it is, presently, under serious risk of extinction (LABOREL-DEGUEN and LABOREL, 1991; TEMPLADO and MORENO, 1997). This is a long-lived species (K-strategist), protandrous hermaphrodite (from 20-30 mm achieves sexual maturation as male and then change to female around 60 mm) that requires clean waters and medium-strong wave action (ESPINOSA, 2006). The study of the population status of the species dealing with involved pressure factors is basic for a best management and conservation measures.

Population size structures (in the sense of distribution of body size within particular populations), which are affected by environmental change, ecological interactions, and in many cases, human exploitation, are an important indicator of the population status, which can be used comparatively across sites and through time to identify the forces controlling population dynamics. Size structures have also been used to track losses of large individuals from populations, which are often the target of exploitation by humans (HAEDRICH and BARNES, 1997; ROCHET and TRENKEL, 2003), as it occurs with limpets, which are collected as food or as fishing bait because of their large muscular foot (POMBO and ESCOFET, 1996; LINDBERG *et al.,* 1998).

In this sense, human exploitation can also decrease the reproductive output of intertidal invertebrate populations in which there is an increase in individual fecundity with body size (SEAPY, 1966; BRANCH, 1974, 1975; CREESE, 1980; LEVITAN, 1991; TEGNER *et al.,* 1996), and it is the case for *Patella ferruginea* (see ESPINOSA *et al.,* 2006). All of these considerations are especially true for broadcast spawners such as limpets that depend on high gamete concentrations to increase the probability for successful fertilization (HOCKEY and BRANCH, 1994) avoiding the ‘Allee’ effect.

Therefore, the aim of the study was to know in detail the population parameters as size frequencies and density and, after that, detect changes produced by pressure factors as human collecting, predation etc.

METHODOLOGY

Study area

The study was conducted on Habibas and Plane islands, located on the West coast of Algeria (Figures 1, 2) during April 2008. The islands are under the influence of atlantic waters from the Alborán Sea and they are located in the middle of the Almería-Orán oceanographic front.

Sampling methods

In Habibas islands four sectors were considered (East, South, West and North) and three delimited transect inside of each sector were established (Figure 1, Table 1).

In Plane island two transects were located approximately in the West and North areas, because the reduced size and regular shape of the island made difficult to establish different sectors. The specimens of *Patella ferruginea* found were measured with a calliper to the nearest mm on its longitudinal axis (GUERRA-GARCIA *et al.,* 2004) and the height of the shell also recorded (PORCHEDDU and MILELLA, 1991). The transects had 10 meters in length (LABOREL-DEGUEN and LABOREL, 1991; GUERRA-GARCÍA *et al.,* 2004), similar slope and were placed with a tape measure to follow the coast profile (Figure 3). Since small individuals < 20 mm (recruits) are difficult to detect (TEMPLADO *et al.,* 2006), care must be taken to observe this fragment of population.

On the other hand, a list of the main conspicous intertidal species, either macroalgae and macrofauna, and their relative abundance were recorded.

Data analysis

As with much ecological impact data (CLARKE and WARWICK, 2001), the assumptions for parametric statistics are not met with some of our data, which have severe departures from normality and equal variances. However, the ANOVA test is robust for deviation of normality and if the number of cases is high and balanced between groups it is possible to undertake the analysis although the condition of equal variances is not met (UNDERWOOD, 1997). Only one ANOVA test without equal variances was performed with the large dataset pooled in “Habibas” and “Plane” sites for mean sizes. The rest of the analyses performed were checked for homogeneity of variances using the Levene test and using logarithmic transformation when it was required to satisfy homocedasticity. Differences among means were examined *a posteriori* using the Student-Newman-Keuls test. Reducing data only to summary statistics such as mean sizes greatly reduces the information available to make comparisons (SAGARIN *et al.,* 2007).

Therefore, a multivariate MDS (non-metric multidimensional scaling) statistics was additionally used based on the UPGMA method (unweigh pair-group method using arithmetic averages) and Bray-Curtis similarity index to test for differences in size structures between sites. To test the ordination, the stress coefficient of Kruskal was employed (KRUSKAL and WISH, 1978). Multivariate analysis was carried out using PRIMER© 6.0 package.

RESULTS

A total of 1017 individuals of *Patella ferruginea* were recorded and measured on the different transects. From these, 577 were found in Habibas (120 m of distance surveyed) and 440 in Plane island (20 m of distance surveyed). The mean densities were highly variable depends of the transect (Table 2) from 0,8 ind/m to 35,3 ind/m with averages of 4,8 ind/m for Habibas and 22 ind/m for Plane island. There were not differences among sectors on Habibas islands dealing with densities ($F_{3,8}$=1,97; p=0,197) due to the extreme variability within sectors, although the North sector showed the greatest densities of *Patella ferruginea*.

The mean sizes were 4,45 cm (±2,59) in Habibas and 2,78 cm (±1,63) in Plane island, with a range from 2,4 cm (Plane 2) to 7,5 cm (E1) (see Table 2). The size structures for each island (Habibas and Plane) showed a different shape, since Habibas appear with many individuals belonging to the greater sizes, whereas they were very scarce or absent from Plane island (Figure 4A,B). In fact, statistical differences in size were found between both populations ($F_{1, 1015}$=140; p<0,001) and, additionally, two different and significant skew were detected (Table 3): a negative skew for Habibas population (many great specimens) and positive skew for Plane island (many small specimens). On the other hand, the size frequency distribution was leptokurtic (narrow and sharp) in both populations. Size frequencies at each site were highly variable (Figures 5, 6). Nevertheless, there were a lot of great individuals throughout and many recruits in the sites N1 and N3, as well as in Plane 2. Conversely, big specimens were scarce at sites Plane 1 and, specially, in Plane 2. Furthermore, differences in mean size through sites in Habibas were detected ($F_{11, 565}$=32,8; p<0,001) and SNK test showed different subsets of sites: E1 S3 W1 S2 N2 E3 W2 S1 W3 E2 N1 N3 (underlined sites belong to the same subset and are ordered by decreasing size from E1 to N3).

Recruits (<3 cm, see FRENKIEL, 1975; ESPINOSA *et al.,* 2006) were more abundant in Plane island (47,72%) than in Habibas (32,75%) (Table 3), whereas inside Habibas the North sector showed high number of recruits (Figure 6). Multivariate analysis clearly separated the populations of Plane island and those settled on the North sector of Habibas due to the presence of high recruitment at these sites and, subsequently, the different shape on size frequencies distributions (Figure 7).

The ratio H/L (Height/Length) of the shell were 0,46 (±0,1) for Habibas and 0,39 (±0,08) for Plane island and significant differences between both populations were found ($F_{1, 388}=29,45$; $p<0,001$) (Figure 8).

It can be observed shells of died individuals in terrestrial areas of the Habibas islands near of seagull nests (mainly *Larus cachinnans*) (Figure 9).

DISCUSSION

The densities found in Habibas and Plane islands are among the greatest in the Mediterranean (Figure 10) taking into account the data available in the literature: 0.79 ind/m in Corsica (LABOREL-DEGUEN and LABOREL, 1991), 0.7 ind/m in Zembra Island, Tunisia (BOUDOURESQUE and LABOREL-DEGUEN, 1986), 0.06 ind/m in Alborán island (PARACUELLOS *et al.,* 2003), 0.23 ind/m in Cala Iris islet, National Park of Al Hoceima, Morocco (BAZAIRI *et al.,* 2004), 0.08-0.14 ind/m in Algeciras

Bay, Spain (ESPINOSA *et al.,* 2005), 3.95 ind/m (only adults >30 mm) in Chafarinas islands (TEMPLADO *et al.,* 2006), 5.39 ind/m in Melilla (GONZÁLEZ-GARCÍA *et al.* in TEMPLADO *et al.,* 2006), 0.67 ind/m as an average in Ceuta (GUERRA-GARCIA *et al.,* 2004), 1.86-6.86 ind/m in some areas of Ceuta (ESPINOSA *et al.,* in press). In this sense, the Western islands of Algeria (together with the close sites of Chafarinas island and Melilla, and the more faraway site of Ceuta) represented the hot spot of the species in the Mediterranean, taking into account the dense populations settled also in Rachgoun island, whereas only one specimen was observed all around the Sridjina island in the eastern part of Algeria (FABRICE BERNARD per. com.) and the general low dense populations of Tunisia (FGUIRI HOSNI per. com.). Moreover, the perimeter of Habibas islands is around 10500 m (including the small islets) and, therefore, the total population of *Patella ferruginea* would be around 50400 individuals, considering the mean density recorded of 4,8 ind/m. Likewise, the whole population of Chafarinas islands is estimated in 51021 individuals and it is considered, presently, as one of the most important population of *Patella ferruginea* in the Mediterranean (TEMPLADO *et al.,* 2006). Therefore, the conservation of the population located in Habibas islands is a priority in order to preserve the species at global scale.
Furthermore, direct removal of organisms will have major effects at both local and regional scales and is likely to increase over the next 25 years, especially in developing countries where rapidly expanding human populations will put further pressure on resources (THOMPSON *et al.,* 2002), therefore, the future of *Patella ferruginea* populations in Algerian coasts are compromised if there are not important conservation measures and good management programs. Moreover, the presence of small oil spills through the shoreline (Figure 11) reflects the risk over the populations settled in the intertidal, as *Patella ferruginea*, under catastrophic events.

The evolution of the population in Habibas islands is positive through the last years because the study undertook by BOUMAZA and SEMROUD (2001) during summer of 1997 showed a mean density of

4.5 ind/m (over a 100 m of shoreline) and dominance of big specimens. After 11 years the mean density is 4.8 ind/m (over a 120 m of shoreline) and there is also occurrence of great specimens. The statement of Habibas islands as a marine reserve area in 2002 can be the main factor involved, taking into account the regression found in other populations through Mediterranean.

Furthermore, KEOUGH *et al.* (1993) found that size distributions on several species of molluscs between visited and protected sites were significantly larger at the protected sites, whereas some species were markedly less abundant at heavily visited sites and densities were affected as well. BRANCH and ODENDAAL (2003) pointed out the benefits of marine protected areas to preserve large and more fecund limpets that act as a focus for larval export via the rebalance of sex-ratio.

Human foraging of intertidal invertebrate resources has occurred since prehistoric times (ORTEGA, 1987; MANNINO and THOMAS, 2002). Despite shifts away from the use of intertidal populations as primary food resources, improved technology for accessing sites far from home and increases in human population densities have provided the means for these impacts to continue today (SIEGFRIED *et al.,* 1985; HOCKEY and BOSMAN, 1986; POMBO and ESCOFET, 1996; CASTILLA, 1999), and these impacts are expected to increase in the future (THOMPSON *et al.,* 2002). On the other hand, the sex distribution through sizes in *Patella ferruginea* makes this species extremely vulnerable to poaching (see ESPINOSA *et al.,* 2006), since the depletion of large, more fertile individuals, and also females in a higher proportion could bias the reproductive output to a complete collapse. Moreover, recent studies from fisheries have shown that exploitation of larger and older females can have disproportionate effects on populations (BERKELEY *et al.,* 2004; PALUMBI, 2004), and the removal of large limpets from the population may also be important if those animals contribute disproportionately to reproductive effort in a local population (KEOUGH *et al.,* 1993) as happens with *P. ferruginea* (see ESPINOSA *et al.,* 2006). In both, fishes and invertebrates, the reserve effect has been shown to favour an increase in the mean size of specimens (EDGAR and BARRETT, 1999) and, recently, in *Patella ferruginea* (ESPINOSA *et al.,* in press).

In this sense, the population of Habibas islands appears as a great reproductive population, which shows a good size frequencies distribution. On the other hand, the population from Plane island, although extremely dense, shows a relative absence of big specimens and it could be a factor that compromise the viability of the population in the next future. The presence of many recruits in Plane island in spite of the shortage of great sizes could be explained by the fact that the main winds in the region come from the North and West (BACHET *et al.,* 2007) and the marine surface stream associated could transport many larvae from Habibas to Plane island. Anyway, this contention must be verified by genetic studies.

The proximity of Plane island to the mainland, its absence of legal protection as marine reserve and the presence of important villages in front of the island in comparison with the situation of Habibas islands could be a reason for the sizes distribution observed, taking into account the expected human pressure by collecting. The specimens of Habibas and Plane island belong to the rouxi form of *Patella ferruginea*, i.e., conical shell with narrow ribs (PORCHEDDU and MILELLA, 1991), according with the H/L ratio observed (Figures 8, 12). The value was greater for Habibas than for Plane island, although it can be due to the smaller sizes recorded in Plane island, which have subsequent minor H/L ratios, since young specimens have more depressed shells either for rouxi and lamarcki forms. Anyway, the shells of *Patella ferruginea* observed were highly conical in shape and it can be an adaptative strategy to extreme desiccation (see BRANCH, 1981), since the upper intertidal of North African shores (with small tides) experienced strong surface temperatures during Summer and so, the water retained in the shell would be greater in order to maintain a low temperature and good oxygen exchange.

Other forces controlling population dynamic of *Patella ferruginea* in Algerian islands could be the predation by marine birds as seagulls. In fact, there are important populations of *Larus cachinnans* and *Larus audouinii*: 1340 and 690 individuals respectively in Habibas islands (BEN HAJ and BERNARD, 2005). Although predation by seabirds over *Patella ferruginea* has not been corroborated, LABOREL-DEGUEN and LABOREL (1991) indicated that seagulls could be important predators of the species. Additionally, TEMPLADO *et al.* (2006) also found shells of *Patella ferruginea* several meters over the intertidal in Chafarinas islands and those authors indicated the hypothesis of predation by seagulls.

Finally, the presence of some species of macroalgae (Table 4) considered as a bioindicators of clean waters as *Cystoseira tamariscifolia* and *Lithophyllum lichenoides* (BALLESTEROS *et al.,* 1998, 2007; MONTESANTO and PANAYOTIDIS, 2000) indicates that the intertidal and shallow ecosystems of Habibas islands are well preserved and greatly structured.

CONCLUSIONS

The intertidal ecosystems of Habibas and Plane islands are well preserved and are greatly structured. The populations of *Patella ferruginea* in Algerian islands are very dense, reproductive, well structured and represent a hot spot in the Mediterranean.

Their preservation is essential for the viability of the species at global scale and it makes necessary to develop appropriate conservation and management measures. In this sense, a monitoring programme needs to be implemented in the upcoming years together with a strict ban of collecting. Additionally, a plan of emergency about oil spills needs to be developed to avoid catastrophic events. Differences found between Habibas and Plane islands make to ask about the requirement for establishing a marine reserve in Plane island. Nevertheless, it would be necessary to undertake more specific studies in Plane island in order to know the conservational status of the environment.

ACKNOWLEDGEMENTS

This work was supported by Conservatoire de l'espace littoral et des rivages lacustres (République Française), Fondation Nicolas Hulot and Commissariat National du Littoral (République Algérienne Démocratique et Populaire) under the international program Petites Iles de Méditerranée 2008 (PIM).

REFERENCES

BACHET, F., BENHAJ, S., BERNARD, F., DELAUGE, J., HARMELIN, J., MANTE, A., PASCAL, M., TILLMANN, M., VELA, E., VIDAL, P. 2007. Réserve des Iles Habibas. Notes naturalistes. Petites Îles de Méditerranée. *Conservatoire de l'espace littoral et des rivages lacustres*. 106 pp.

BALLESTEROS, E., SALA, E., GARRABOU, J., ZABALA, M. 1998. Community structure and frond size distribution of a deep water stand of *Cystoseira spinosa* (Phaeophyta) in the Northwestern Mediterranean. *European Journal of Phycology*, 33: 121-128.

BALLESTEROS, E., TORRAS, X., PINEDO, S., GARCIA, M., MANGIALAJO, L., DE TORRES, M. 2007. A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. *Marine Pollution Bulletin*, 55: 172-180.

BAZAIRI, H., SALVATI, E., BENHISSOUNE, S., TUNESI, L., RAIS, C., AGNESI, S., BENHAMZA, A., FRANZOSINI, C., LIMAM, A., MO, G., MOLINARI, A., NACHITE, D., SADKI, I. 2004. Considerations on a population of the endangered marine mollusc *Patella ferruginea* Gmelin, 1791 (Gastropoda, Patellidae) in the Cala Iris islet (National Park of Al Hoceima-Morocco, Alboran Sea). *BolletinoMalacologico*, 40: 95-100.

BEN HAJ, S., BERNARD, F. 2005. Schema d'amenagement et d'orientations de gestion de la reserve marine des Iles Habibas. *Conservatoire de l'espace litoral et des rivages lacustres*. 95 pp.

BERKELEY, S.A., HIXON, M.A., LARSON, R.J., LOVE, M.S. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. *Fisheries*, 29, 23-32.

BOUDOURESQUE, C.F., LABOREL-DEGUEN, F. 1986. *Patella ferruginea*. In: Le benthos marin de l'ile de Zembra (Parc National, Tunisie). Eds.: (C.F. Boudouresque, J.G. Harmelin, A. Jeudy de Grissac). GIS Posidonie Publishers, Marseille. Pp.: 105-110.

BOUMAZA, S., SEMROUD, R. 2001. Inventaire de la population de Patella ferruginea Gmelin, 1791 des iles Habibas (Ouest Algerien). *Rapport du Congres de la Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée, 36: 361.*

BRANCH, G.M. 1974. The ecology of Patella Linnaeus from the Cape Peninsula, South Africa. 2. Reproductive cycles. *Transactions of the Royal Society of South Africa, 41, 111-160*.

BRANCH, G.M. 1975. Notes on the ecology of *Patella concolor* and *Cellana capensis*, and the effects of human consumption on limpet populations. *Zoologica Africana, 10, 75-85.*

BRANCH, G.M. 1981. The biology of limpets. *Oceanography and Marine Biology: an Annual Review*, 19: 235-379.

BRANCH, G.M., ODENDAAL, F. 2003. The effects of marine protected areas on the population dynamics of a South African limpet, *Cymbula oculus*, relative to theinfluence of wave action. *Biological Conservation.,* 114, 255-269.

CASTILLA, J.C. 1999. Coastal marine communities: trends and perspectives from human-exclusion experiments. *Trends in Ecology and Evolution,* 14: 280-283.

CLARKE, K.R., WARWICK, R.M. 2001. Change in marine communities: an approach to statistical analysis and interpretation. Primer-E, Plymouth.

CREESE, R.G. 1980. Reproductive cycles and fecundities of four common eastern Australian Archaeogastropod limpets (Mollusca: Gastropoda). *Australian Journal of Marine and Freshwater Research,* 31, 49-59.

EDGARD, G.J., BARRETT, N.S. 1999. Effects of the declaration of marine reserves on Tasmanian reef fish, invertebrates and plants. *Journal of Experimental Marine Biology and Ecology.,* 242, 107-144.

ESPINOSA, F. 2006. Caracterización biológica del molusco protegido Patella ferruginea Gmelin, 1791 (Gastropoda: Patellidae): bases para su gestión y conservación. Sevilla, Spain: University of Sevilla, PhD thesis, 329p.

ESPINOSA, F., FA, D., OCAÑA, T.M.J. 2005. Estado de la especie amenazada *Patella ferruginea* Gmelin, 1791 (Gastropoda: Patellidae) en la bahía de Algeciras y Gibraltar. *Iberus,* 23(2), 39-46.

ESPINOSA, F., OZAWA, T. 2006. Population genetics of the endangered limpet *Patella ferruginea* (Gastropoda: Patellidae): taxonomic, conservation and evolutionary considerations. *Journal of Zoological Systematic and Evolutionary Research,* 44: 8-16.

ESPINOSA, F., GUERRA-GARCIA, J.M., FA, D., GARCIA-GOMEZ, J.C., 2006. Aspectos of reproduction and their implications for the conservation of the endangered limpet, *Patella ferruginea. Invertebrate, Reproduction and Development.,* 49, 85-92.

ESPINOSA, F., RIVERA-INGRAHAM, G., FA, D., GARCÍA-GÓMEZ, J.C. In press. Effects of human pressure on population size structures of the endangered ferruginean limpet: towards future management measures. *Journal of Coastal Research*.

FRENKIEL, L. 1975. Contribution à l'étude des cycles de reproduction des Patellidae en Algérie. *Publicazione di la Stazione Zoologica di Napoli.,* 39, 153-189.

GUERRA-GARCIA, J.M., CORZO, J., ESPINOSA, F., GARCIA-GOMEZ, J.C. 2004. Assessing habitat use of the endangered marine mollusc *Patella ferruginea* (Gastropoda, Patellidae) in northern Africa: preliminary results and implications for conservation. *Biological Conservation.,* 116, 319-326.

HAEDRICH, R.L., BARNES, S.M. 1997. Changes over time of the size structure in an exploited shelf fish community. *Fisheries Research,* 31, 229-239.

HOCKEY, P.A.R., BOSMAN, A.L. 1986. Man as an intertidal predator in Transkei: disturbance, community convergence and management of a natural food resource. *Oikos,* 46, 3-14.

HOCKEY, P.A.R., BRANCH, G.M. 1994. Conserving marine biodiversity on the African coast: implications of a terrestrial perspective. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 4, 345-362.

KEOUGH, M.J., QUINN, G.P., KING, A. 1993. Correlations between human collecting and intertidal mollusc populations on rocky shores. *Conservation Biology.,* 7, 378-390.

KRUSKAL, J.B., WISH, M. 1978. Multidimensional scaling. Sage Publications, Beverley Hills, California.

LABOREL-DEGUEN, F., LABOREL, J. 1991. Statut de *Patella ferruginea* Gmelin en Méditerranée. *In*: BOUDOURESQUE, C.F., AVON, M. and GRAVEZ, V. (eds.), *Les Espèces marines à protéger en Méditerranée*. Marseille, France: GIS Posidonie Publishers, pp. 91-103.

LEVITAN, D.R. 1991. Influence of body size and population density on fertilization success and reproductive output in a free-spawning invertebrate. *Biological Bulletin. (Woods Hole),* 181, 261-268.

LINDBERG, D.R., ESTES, J.A., WARHEIT, K.I. 1998. Human influences on trophic cascades along rocky shores. *Ecological Applications,* 8, 880-890.

MANNINO, M.A., THOMAS, K.D. 2002. Depletion of a resource? The impact of prehistoric human foraging on intertidal mollusc communities and its significance for human settlement, mobility and dispersal. *World Archaeology*, 33, 452-474.

MONTESANTO, B., PANAYOTIDIS, P. 2000. The *Cystoseira* spp. From the Aegean Sea (north-east Mediterranean). *Journal of the Marine Biological Association of the United Kingdom,* 80: 357-358.

ORTEGA, S. 1987. The effect of human predation on the size distribution of *Siphonaria gigas* (Mollusca: Pulmonata) on the Pacific coast of Coast Rica. *Veliger,* 29, 251-255.

PALUMBI, S. 2004. Why mothers matter. *Nature,* 430, 621-622.

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.

POMBO, O.A., ESCOFET, A. 1996. Effect of exploitation on the limpet *Lottia gigantea*: A field study in Baja California (Mexico) and California (USA). *Pacific Science,* 50, 393-403.

PORCHEDDU, A., MILELLA, I. 1991. Aperçu sur l'ecologie et sur la distribution de *Patella ferruginea* (L.) Gmelin 1791 en mers italiennes. En: Les spèces marines à protéger en Méditerranée. Eds.: (C.F. Boudouresque; M. Avon; V. Gravez). GIS Posidonie Publishers, Marseille, pp. 119-128.

RAMOS, M.A. 1998. Implementing the Habitats Directive for mollusc species in Spain. *Journal of Conchology Special Publication,* 2, 125-132.

ROCHET, M.J., TRENKEL, V.M. 2003. Which community indicators can measure the impact of fishing? A review and proposals. *Canadian Journal of Fisheries and Aquatic Science,* 60, 86-99.

SAGARIN, R.D., AMBROSE, R.F., BECKER, B.J., ENGLE, J.M., KIDO, J., LEE, S.F., MINER, C.F., MURRAY, S.N., RAIMONDI, P.T., RICHARDS, D.V., ROE, C. 2007. Ecological impacts on the limpet *Lottia gigantean* populations: human pressure over a broad scale on island and mainland intertidal zones. *Marine Biology.,* 150, 399- 413.

SEAPY, R.R. 1966. Reproduction and growth in the file limpet, *Acmaea limatula* Carpenter, 1864 (Mollusca: Gastropoda). *Veliger,* 8, 300-310.

SIEGFRIED, W.R., HOCKEY, P.A.R., CROWE, A.A. 1985. Exploitation and conservation of brown mussel stocks by coastal people of Transkei. *Environmental Conservation,* 12, 303-307.

TEGNER, M.J., BASCH, L.V., DAYTON, P.K. 1996. Near extinction of an exploited marine invertebrate. *Trends in Ecology and Evolution,* 11, 278-280.

TEMPLADO, J., MORENO, D. 1997. La lapa ferrugínea. *Biológica,* 6, 80-81.

TEMPLADO, J., GUALLART, J., CALVO, M., CABEZAS, P., ACEVEDO, I., MACHORDOM, A., LUQUE, A.A. 2006. Inventario y seguimiento de

Patella ferruginea en España, así como la elaboración de una propuesta de estrategia de conservación de la especie. Informe final. Madrid, Spain: Ministerio de Medio Ambiente, Madrid, Report

THOMPSON, R.C., CROWE, T.P., HAWKINS, S.J. 2002. Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. *Environmental Conservation.,* 29, 168-191.

UNDERWOOD, A.J. 1997. Experiments in ecology: their logical design and interpretation using analysis of variance. New York: Cambridge University Press.

Table 1.- Location of sampling sites.

Sector		Transect	Coordinates
Habibas Islands			
	East	1	35°43.562'N/1°07.640'W
	East	2	35°43.497'N/1°07.759'W
	East	3	35°43.237'N/1°07.844'W
	South	1	35°43.154'N/1°07.970'W
	South	2	35°43.155'N/1°08.112'W
	South	3	35°43.322'N/1°08.215'W
	West	1	35°43.439'N/1°07.988'W
	West	2	35°43.518'N/1°07.981'W
	West	3	35°43.572'N/1°08.056'W
	North	1	35°43.653'N/1°07.635'W
	North	2	35°43.649'N/1°07.588'W
	North	3	35°43.665'N/1°07.597'W
Plane Island			
		1	35°46.291'N/0°54.174'W
		2	35°46.290'N/0°54.066'W

Table 2.- Populational datasets from each site. Transects have 10 m in length.

Site	Number of specimens	Density (ind./m)	Mean size (cm)	S.D.
E1	9	0,9	7,5	1,57
E2	8	0,8	5,1	1,91
E3	44	4,4	6,2	1,35
S1	32	3,2	5,6	1,95
S2	58	5,8	6,5	1,68
S3	9	0,9	7,1	1,07
W1	10	1	6,8	1,54
W2	13	1,3	5,6	1,48
W3	45	4,5	5,5	2,41
N1	65	6,5	3,8	1,99
N2	31	3,1	6,4	0,83
N3	253	25,3	2,8	2,33
Plane 1	87	8,7	4,2	1,67

Table 3.- Summary statistics for *Patella ferruginea* sizes (cm) by sites for all samples.

Site	N	N<30 (%)	Max	Mean	SD	Skew	SE Skew	Kurtosis	SE Kurtosis	Kurtosis type
Habibas	577	32,75	9,7	4,45	2,59	-0,284*	0,102	-1,408**	0,203	Leptokurtic
Plane	440	47,72	7,2	2,78	1,63	0,312*	0,116	-1,105**	0,232	Leptokurtic

*Skewness is considered significant when its absolute value is greater than 2*SE of Skewness

**Kurtosis is considered significant when its absolute value is greater than 2*SE of Kurtosis

Table 4.- List of main intertidal and shallow marine species of Habibas Islands.

	Species	Relative abundance
Macroalgae		
	Asparagopsis sp.	++
	Ceramium sp.	++
	Colpomenia sinuosa	+
	Corallina elongata	++
	Cystoseira tamariscifolia	+++
	Enteromorpha sp.	+
	Gelidium latifolium	++
	Jania rubens	++
	Laurencia obtusa	+
	Lithophyllum lichenoides	++
	Mesophyllum lichenoides	+
	Ulva sp.	++
	Valonia utricularis	+
Macrofauna		
	Actinia equina	++
	Astroides calycularis	++
	Chiton olivaceus	+
	Chthamallus sp.	++
	Dendropoma petraeum	++
	Eriphia verrucosa	++
	Osilinus turbinatus	++
	Paracentrotus lividus	+++
	Patella caerulea	+
	Patella ferruginea	+++
	Patella rustica	++
	Pinna rudis	+
	Siphonaria pectinata	++
	Thais haemastoma	++

+ Occasional, ++ Frequent, +++ Abundant

FIGURE LEGENDS

Figure 1.- Map of the study site showing the location of Habibas and Plane island. In Habibas the perimeter was divided into sectors. Red spots: sampling sites for Patella ferruginea. White spots: sampling sites by snorkelling for shallow marine species.

Figure 2.- Habibas islands.

Figure 3.- Transect located on the intertidal to sample Patella ferruginea populations.

Figure 4.- A. Size frequencies for Habibas islands. B. Size frequencies for Plane island. The data were pooled.

Figure 5.- Size frequencies for each site.

Figure 6.- Size frequencies for each site.

Figure 7.- MDS analysis based on size frequencies for the sites under study.

Figure 8.- H/L ratios in several populations of *Patella ferruginea*. Data from Sardinia by PORCHEDDU and MILELLA (1991). Data from Ceuta by ESPINOSA and OZAWA (2006). Red dotted line indicates the value of H/L ratio of separation between rouxi and lamarcki forms in Sardinian populations according with PORCHEDDU and MILELLA (1991). Blue dotted line indicates the value of H/L ratio of separation between rouxi and lamarcki forms in Ceuta populations according with ESPINOSA and OZAWA (2006).

Figure 9.- Shells of *Patella ferruginea* located near of seagulls nests.

Figure 10.- Presence of great specimens of *Patella ferruginea* in Habibas islands.

Figure 11.- Oil spill in the intertidal zone of Plane island.

Figure 12.- A. Lamarcki form of *Patella ferruginea*. B. Rouxi form of *Patella ferruginea*. C. Typical shell shape of *Patella ferruginea* in Algerian islands belong to rouxi form.

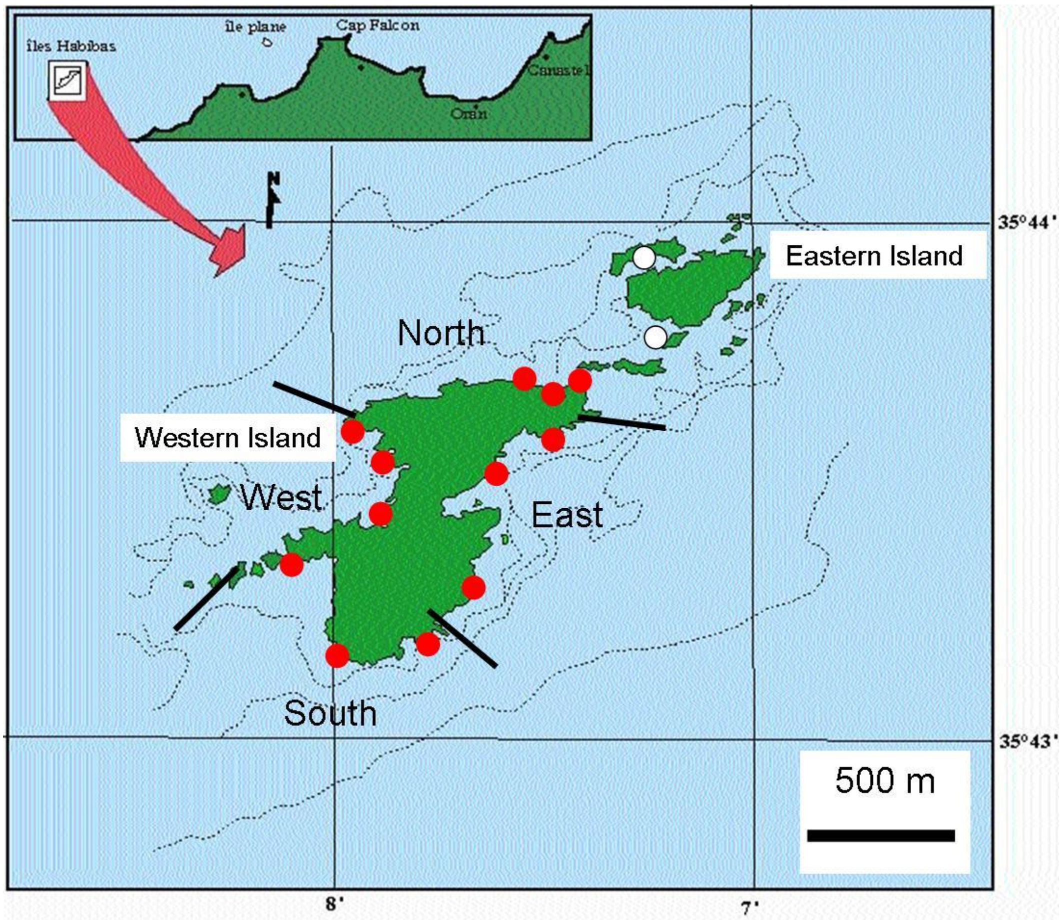


Figure 1

Figure 2

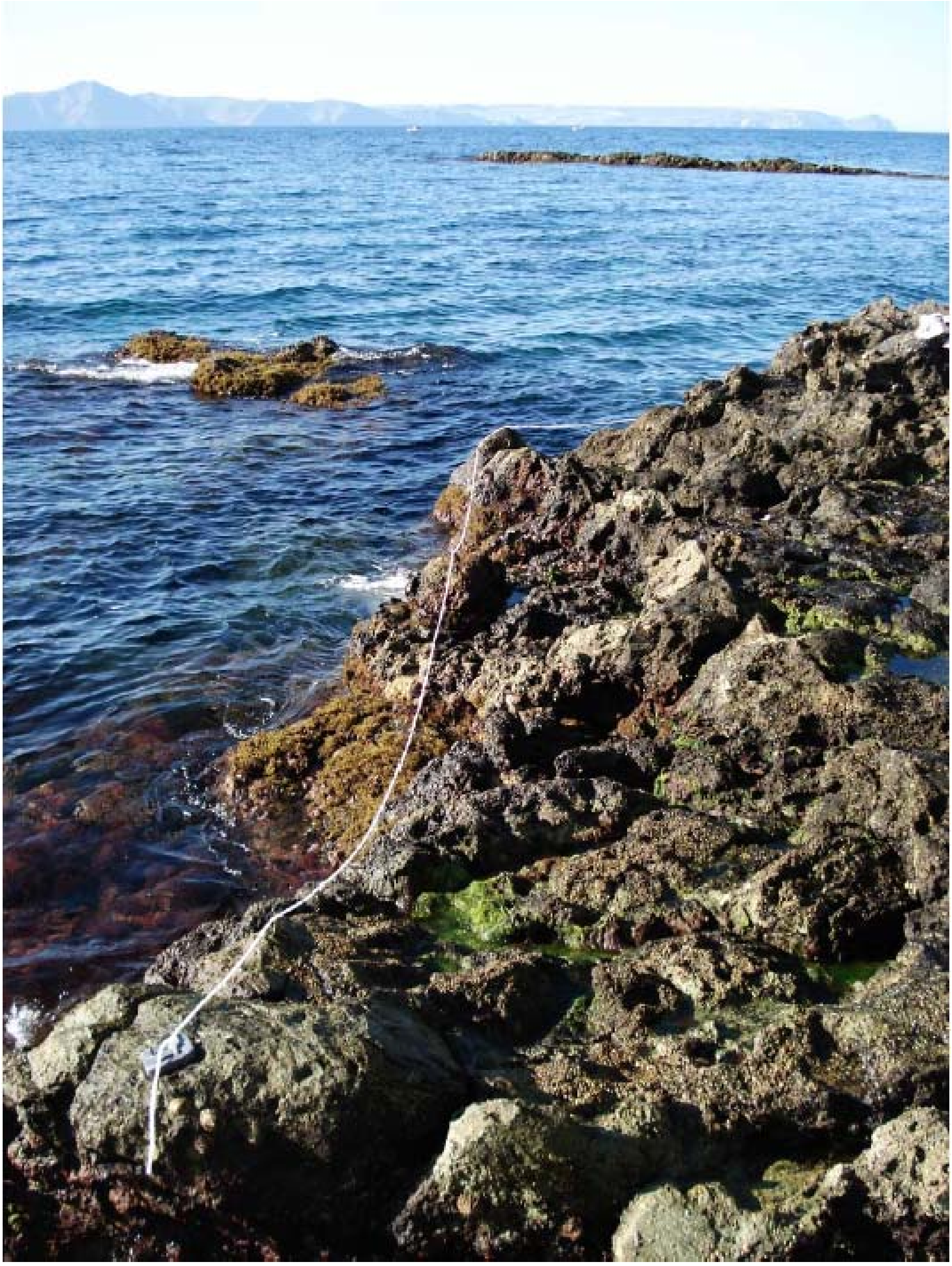
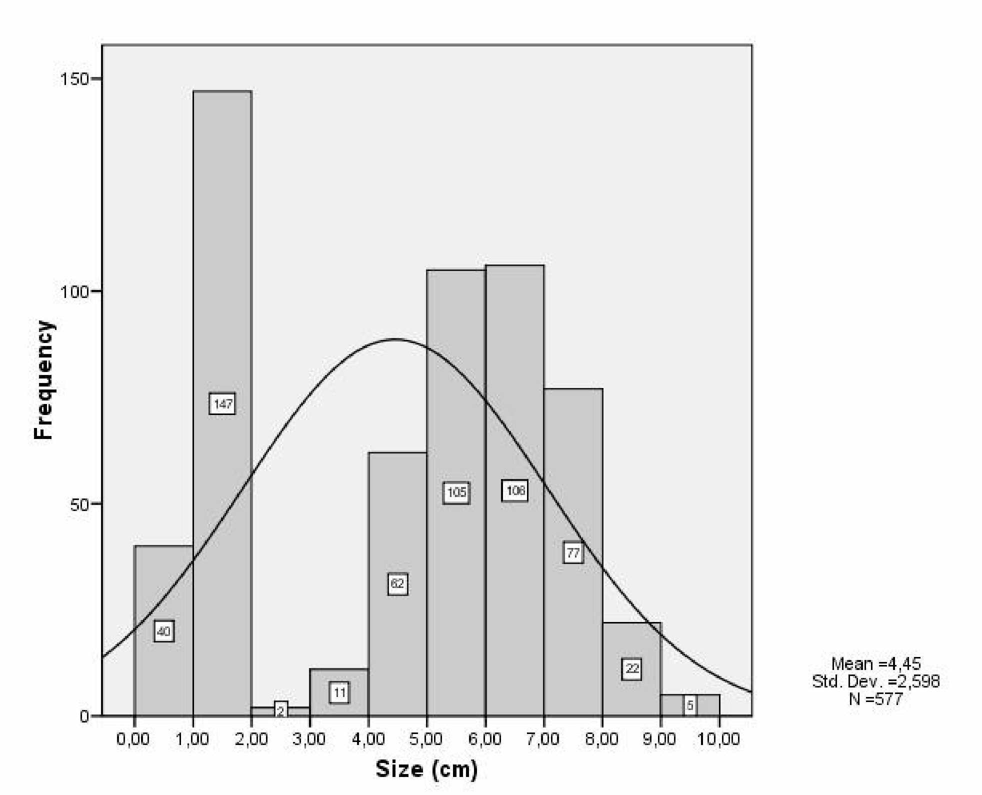


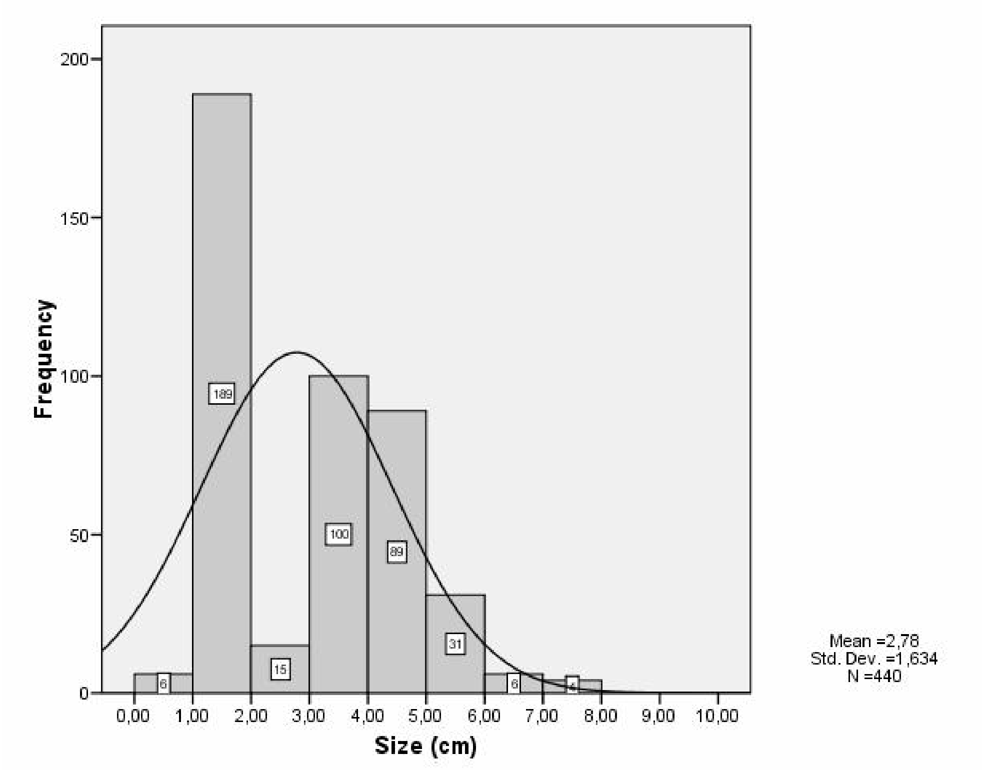
Figure 3

A



150
100
50
0
Frequency
147
40
2
11
62
105
106
77
22
5
0,00 1,00 2,00 3,00 4,00 5,00 6,00 7,00 8,00 9,00 10,00
Size (cm)
Mean =4,45
Std. Dev. =2,598
N =577

B



200
150
100
50
0
Frequency
6
189
15
100
89
31
6
4
0,00 1,00 2,00 3,00 4,00 5,00 6,00 7,00 8,00 9,00 10,00
Size (cm)
Mean =2,78
Std. Dev. =1,634
N =440

Figure 4

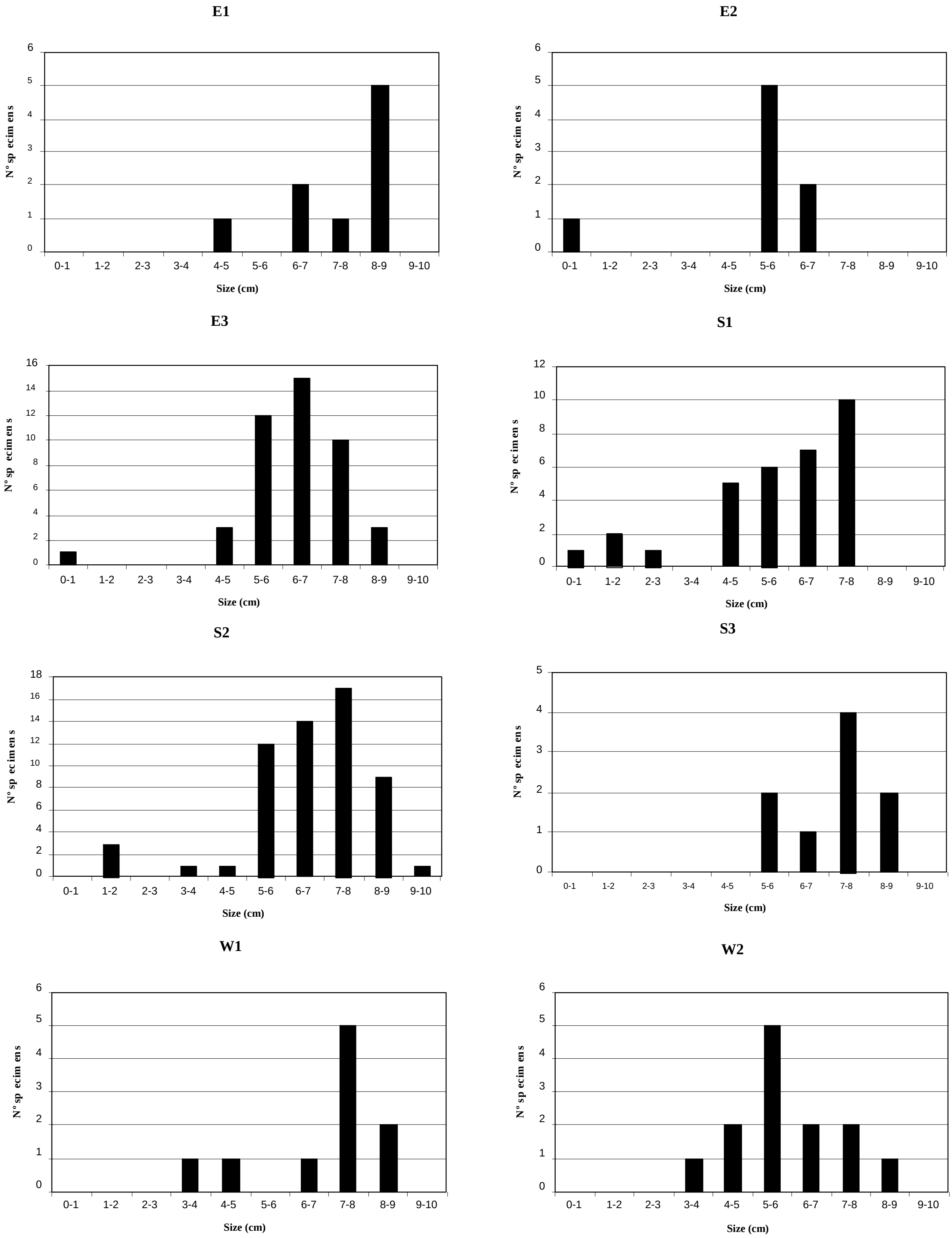

E1
E2
E3
S1
S2
S3
W1
W2
N° sp ecim en s
Size (cm)
0-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10

Figure 5

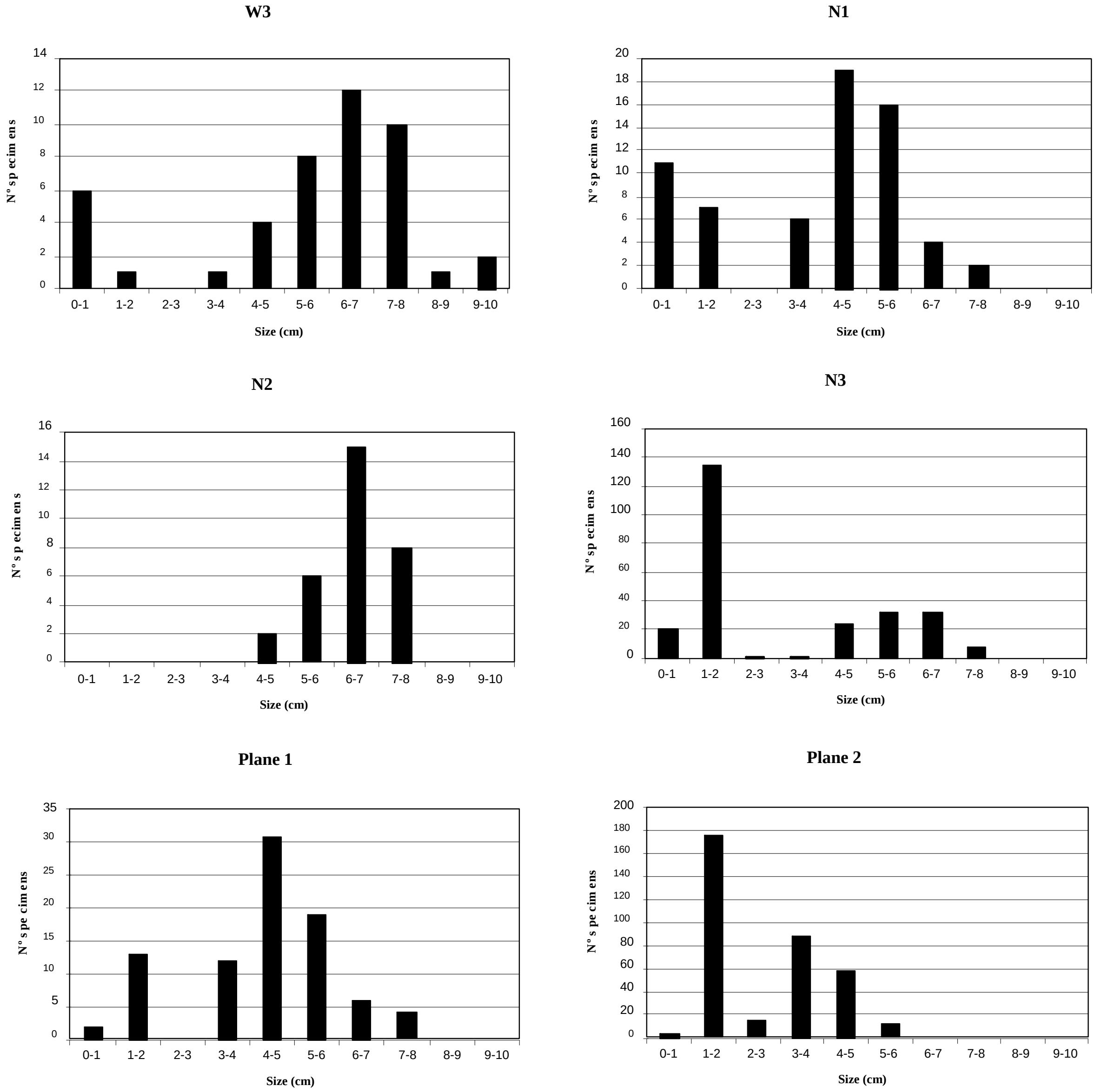

W3
N1
N2
N3
Plane 1
Plane 2
N° specimens
Size (cm)
0-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10

Figure 6

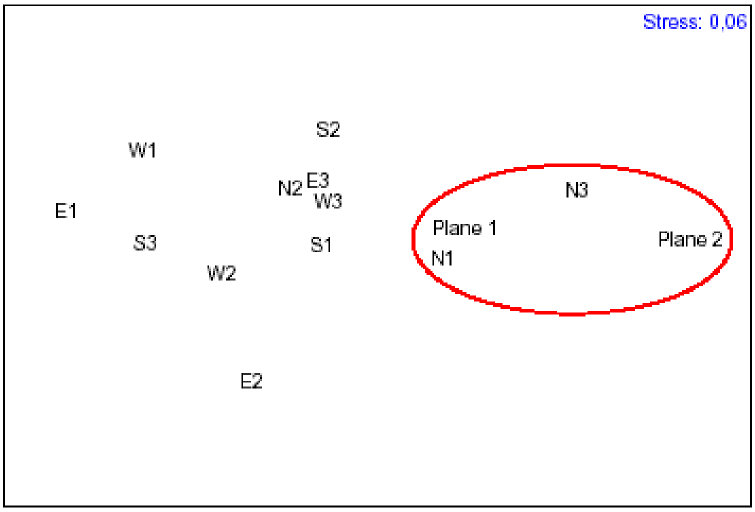


Figure 7

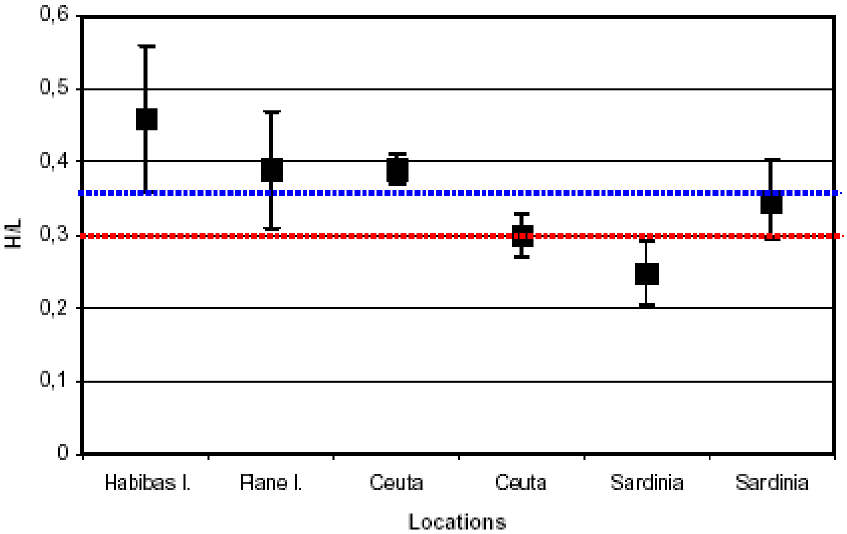


Figure 8

Figure 9

Figure 10

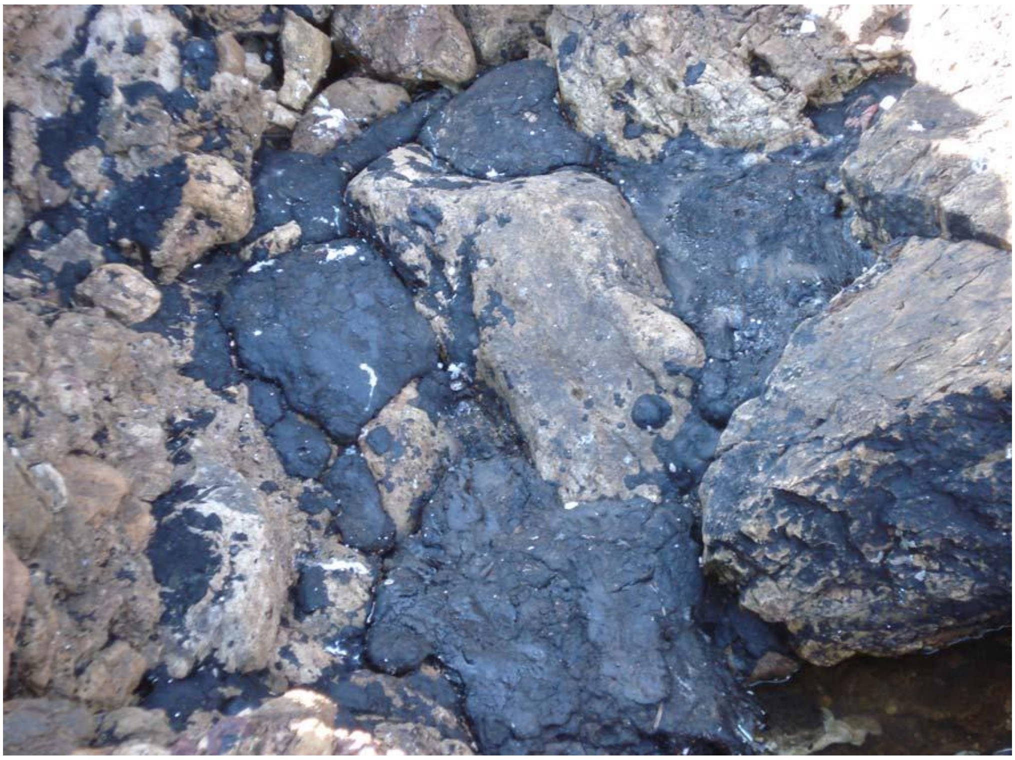


Figure 11

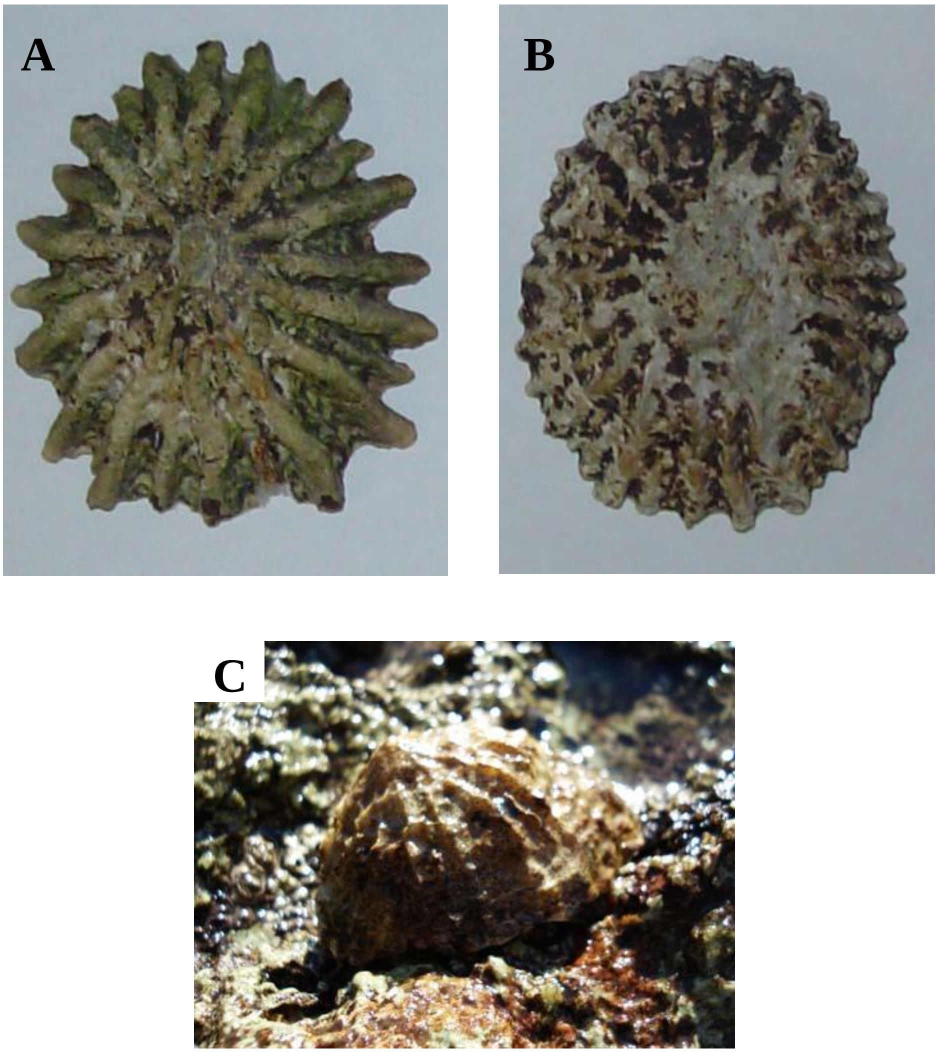


Figure 12

ANNEXES

MONITORING OF THE ENDANGERED LIMPET PATELLA FERRUGINEA (GIANT LIMPET) IN HABIBAS ISLANDS

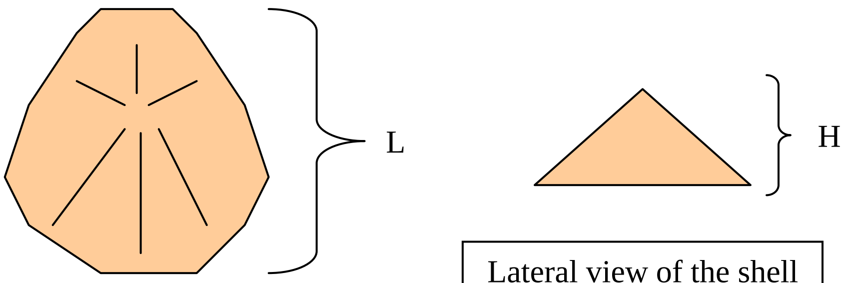
The protocol for monitoring *Patella ferruginea* populations essentially is similar to those proposed by Bachet *et al.* (2007) referred in *Réserve des iles Habibas. Notes naturalistes*. However, in order to simplify the collection of data it can be done several considerations.

Sampling sites

Due to the extreme variability of densities within Habibas islands, it would be necessary to establish different sites through the shoreline. At least, one site per sector (North, West, South and East). At each site, a transect of 10 m in length must be located, for example painting the adjacent rocks at the beginning and end of the transect, inserting screws into holes etc.

Data collection

All specimens of *Patella ferruginea* inside the transect must be counting and measured. The most important parameters are the length (L) and height (H) of the shell. Data must be collected using a calliper to nearest mm. The temporality should be one counting per year.



Lateral view of the shell

Dorsal view of the shell

Data analysis

The mean density (individuals per meter) for each site and size frequencies (number of individuals belong to the different size ranges from 0-10 to 90-100 mm) must be obtained. If substantial changes are detected, please inform to the authorities and/or research institutions.