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Distribution of the Mediterranean ribbed limpet, *Patella ferruginea* Gmelin, 1791, along the Ligurian coast and the potential of these findings for conservation actions

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Abstract

Patella ferruginea is a limpet endemic to the Western Mediterranean Sea. It is presently considered the most threatened marine macroinvertebrate in the region and has been included in several international conservation directives. Its populations were widespread throughout the Western Mediterranean in the late Pleistocene period, and remained broadly distributed until the 19th century. Presently this species is confined into small populations in a few restricted areas due to human harvesting for food and baits, construction of coastal infrastructures and the effects of seawater pollution. In particular, the species is reported as presently disappeared from the whole of the Italian continental coast and measures are in progress to reintroduce the species through translocation and reproduction in controlled conditions along the Ligurian coasts of the Northwestern Mediterranean.

Recent surveys implemented in the framework of the present work along the Ligurian coasts, to assess the most suitable sites for reintroduction, resulted in the discovery of 32 specimens of this endemic limpet, which previously was thought to have vanished from the area. These findings shed new light on the ability of species to naturally disperse, the relevance of the measures set in place to restore presently rarefied populations and may provide information to aid in the selection and management of sites within the Natura 2000 Ecological network.

Keywords: *Patella ferruginea*; distribution; Ligurian Sea; conservation.

Introduction

The Mediterranean ribbed limpet, *Patella ferruginea* Gmelin, 1791, is an endemic species of the Western Mediterranean Sea, presently considered the most threatened marine macroinvertebrate in the region (Ramos, 1998). It is included in the list of the strictly protected species in Annex IV of the CEE Habitat Directive 92/43. It is also recognized as an endangered or threatened species through international conventions including the Bern Convention-Annex II and the Barcelona Convention-Annex II. Finally, the status of *P. ferruginea* is recognized by individual countries, and as such, it has been categorized in the Spanish Catalog of Endangered Species as “in danger of extinction”, is protected by law in France through the decree of 26 November 1992 and under the Italian

Marine Strategy framework (D.lgs. n. 190, 13th October 2010) if was recently proposed that *P. ferruginea* be a target species used to define the “Good Environmental Status” of a specific location.

P. ferruginea populations were widespread throughout the Western Mediterranean in the late Pleistocene (Tyrrhenian period) era and primarily maintained this range until the 19th century (Laborel-Deguen & Laborel, 1991a). Presently, they are confined into small populations in few restricted areas (Doneddu & Manunza, 1992; Guerra-Garcia *et al.*, 2004; Bava, 2009; Espinosa *et al.*, 2009; Table 1) due to human harvesting for food and baits, construction of coastal infrastructures and seawater pollution. The species is easily accessible to humans since it generally resides in the high mid-littoral zone, but can also be found in the supra-littoral (Paracuellos *et al.*,

Table 1. Density of *P. ferruginea* in localities along the Mediterranean coast in which the species persists. *only adults (>30 mm) were identified.

Country	Location	Mean density	Assessment method	Authors
Morocco	National Park of Al Hoceima (Cala Iris Islet)	0.23 ind/m	Whole stretch of coast	Bazairi <i>et al.</i> , 2004
Algeria	Rachgoun Island	3–10 ind/m ²	Transects (20 m)	Taibi <i>et al.</i> , 2013
Algeria	Habibas islands	4.8 ind/m	12 Transects (10 m)	Espinosa, 2009
Tunisia	Zembra & Zembretta Islands	0.1–8.5 ind/m	30 Transects (10 m)	Zarrouk <i>et al.</i> , 2016
Tunisia	North-East Tunisian coast	0.025–4.5 ind/m ²	Stretches of different length	Tlig-Zouari <i>et al.</i> , 2010
Spain (North Africa)	Ceuta	2.34 ind/m	170 Transects (10 m)	Rivera-Ingraham <i>et al.</i> , 2011
Spain	Alboran Island	0.42 ind/m	Whole stretch of coast	CMA-JA 2014
Spain (North Africa)	Melilla	2.8 ind/m*	Whole stretch of coast	Guallart <i>et al.</i> , 2013
Spain (North Africa)	Chafarinas Islands	4.82 ind/m*	Whole stretch of coast	Guallart & Templado, 2016
Spain (North Africa)	Peñón de Vélez de la Gomera	0,13 ind/m*	Whole stretch of coast	Orozco <i>et al.</i> , 2013
Spain	Algeciras Bay	0.07 ind/m	Whole stretch of coast	Espinosa <i>et al.</i> , 2005
France	Marine Park of Scandola and surroundings (Corsica)	0.79 ind/m	146 Transects (10m)	Laborel-Deguen and Laborel 1991a
France	Cap Corse/Bastia harbour (Corsica)	0.2 ind/m ²	-	Vela <i>et al.</i> , 2007
Italy	Maddalena Archipelago (Sardinia)	0.028 ind/m	73 Sectors (425m)	Cossu <i>et al.</i> , 2006
Italy	Ceraso Cape (Sardinia)	0.12 ind/m	Stretches of different length	Cristo and Caronni 2008
Italy	Gulf of Olbia (Sardinia)	0.023 ind/m	Whole stretch of coast	Cristo <i>et al.</i> , 2007
Italy	Sinis Peninsula MPA (Sardinia)	0.02 ind/m	Stretches of different length	Coppa <i>et al.</i> , 2012
Italy	Ligurian coasts	0.005 ind/m*	Stretches of different length	Present study

2003; Guerra-García *et al.*, 2004; Casu *et al.*, 2006), and the low mid-littoral (Casu *et al.*, 2004). Espinosa *et al.* (2014) and Luque *et al.* (2018) provided an exhaustive review of its recent overall Mediterranean distribution. Today, populations of different size are reported along the coasts of Maghreb (Fguiri *et al.*, 2007; Tlig-Zouari *et al.*, 2010; Bazairi *et al.*, 2012; Taibi *et al.*, 2013, among others), in the Strait of Gibraltar (Espinosa *et al.*, 2009), along Alboran Island (Paracuellos *et al.*, 2003) and in the south of Spain (Espinosa *et al.*, 2005; Moreno & Arroyo, 2008; Guallart & Templado, 2012; CMA-JA, 2014). Conspicuous populations of some thousands of specimens are presently found along the North African coasts, such as those identified in Ceuta (Rivera-Ingraham *et al.*, 2011), Melilla (Guallart *et al.*, 2013), the Chafarinas Islands (Guallart & Templado, 2016), Cala Iris Islet, National Park of Al Hoceima, Morocco (Bazairi *et al.*, 2004), Peñón de Vélez de la Gomera (Orozco *et al.*, 2013), the Habibas Islands (Espinosa, 2009; Boumaza & Semroud, 2001), and Zembra Island (Espinosa & Bazairi,

2009; Zarrouk *et al.*, 2016). An overview of the reported densities of *P. ferruginea* in different localities along the Mediterranean coasts is provided in Table 1.

In France, the species is considered extinct along the continental coasts but has been reported to be present in Corsica, within and surrounding the Marine Park of Scandola (Galéria region) at Cap Corse, and in the Strait of Bonifacio (Laborel-Deguen & Laborel, 1991a; Laborel-Deguen *et al.*, 1993; Blacher *et al.*, 1998; Pascal, 2002; Vela *et al.*, 2007). In Italy, the species is predominantly restricted to some archipelagos and particularly some areas of Sardinia. Its presence has been reported in the Egadi Archipelago, the Sicily Channel, and in the Island of Lampedusa (Scotti & Chemello, 2000). In the Sardinia coasts (Porcheddu & Milella, 1991) quite dense populations have been recorded inside the Maddalena Archipelago (Cossu *et al.*, 2006), the Ceraso Cape (Cristo & Caronni, 2008), the Gulf of Olbia (Cristo *et al.*, 2007) as well as in the Sinis Peninsula Marine Protected Area (MPA) (Coppa *et al.*, 2012). In each of these localities, populations of the species sum up to some

hundred specimens.

In the North Tyrrhenian Sea, *P. ferruginea* is scantily distributed and records are episodic. Appelius (1869), Terreni (1981), Porcheddu & Milella (1991) record its presence in the Montecristo, Gorgona and Capraia Islands (Tuscan Archipelago). Records of its presence along continental Italian coasts are very scarce and relatively old, as they were published several decades ago. Terreni (1981) reported its presence along the continental seashore, near Livorno. Near the Promontory of Piombino, a few dozen specimens were recorded by Biagi & Poli (1986), along several hundred meters of coastline, while Curini-Galletti (1979) reported one specimen in Castiglione della Pescaia (Grosseto).

Along the Ligurian coast (North Ligurian Sea), the species has been presently reported as missing by Espinosa *et al.* (2014), although the presence of the species in the pre-historic era is supported by records of *P. ferruginea* shells in the Arene Candide cave (Ghisotti, 1997). Although no *P. ferruginea* shells are present in the north Italian Natural History Museum collections, *Patella* spp. Harvesting for human consumption in the 19th century has been reported as a cultural tradition in the area (Parona, 1898; Zolezzi, 1940). The most recent information concerning the presence of *P. ferruginea* in the Ligurian coast dates back to a personal communication by Leonardo Tunesi (Porcheddu & Milella, 1991) who recorded a single specimen along the Portofino Promontory (before the Portofino MPA was established). Consequently, *P. ferruginea* is presently considered absent or sporadic and is no longer able to establish stable populations in the area.

This species has received a large degree of interest in the last decade and actions have been implemented in order to restock endangered populations and re-establish populations where they are presently extinct. For example, in Spain, between 2002 and 2017, 28 technical and scientific projects were founded for increasing knowledge of *P. ferruginea* and planning its conservation along the Spanish coasts (MMAMRM, 2008; Luque *et al.*, 2018). In France, the Accord RAMOGE (<http://www.ramoge.org>) was implemented to foster collection of *P. ferruginea* records along the Ligurian Sea coastline. Also, in Italy, interest in this species has increased over the last few years. Within the framework of the Italian Marine Strategy, Regional Agencies for Environmental Protection (ARPAs) have started to perform surveys focused on the distribution *P. ferruginea*, among other species.

The RE-LIFE project (LIFE15 NAT/IT/000771) is a recently implemented conservation strategy funded by the LIFE Programme (EC), which began in 2016 and aims to reintroduce *P. ferruginea* to three Ligurian MPAs (Portofino, Cinque Terre and Bergeggi, all Natura 2000 sites) through adult transplantation from the Tavolara-Capo Coda Cavallo MPA in Sardinia and by the active introduction of juveniles obtained from controlled reproduction in a laboratory setting. The main aim of this study is to report and evaluate the presence of *P. ferruginea* along the Ligurian coast, evaluating the implications of their distribution and how they relate to conservation strategies outlined in the framework of the RE-LIFE project.

Material and Methods

A survey to assess the presence of *P. ferruginea* along the Ligurian coast was performed in the framework of the RE-LIFE project in order to fulfill Italian Marine Strategy requirements. The survey was performed in several MPAs and in additional specific Ligurian sites, by the University of Genoa and ARPAL (Regional Agency for Environmental Protection, Liguria), in collaboration with Outdoor Portofino. Prospections and censuses were performed by swimming along the coast. All detected specimens were measured along their major and minor shell axis with a vernier caliper and the GPS position of each specimen was registered.

In the summers of 2017 and 2018 the team from the University of Genoa performed a survey in Portofino, Bergeggi and Cinque Terre MPAs. In each site, the whole A Zone (no-take, no-entry Zone) of the Portofino MPA (Cala dell'Oro), the whole A and B (no-take) Zones of the Bergeggi MPA and one of the two A Zones of the Cinque Terre MPA (Capo Montenero) were prospected.

In the summer of 2018 ARPAL monitored three stretches (west, center, and east) of coast (each 250 m long) in four sites along the Ligurian coast, according to the Marine Strategy guidelines. These included: Punta Mesco (the second A Zone of Cinque Terre MPA), Portovenere (La Spezia), and Celle Ligure (Savona). In addition, three randomly situated findings occurred in the Portofino MPA (C Zone), in Pontetto (around 10 km from Genoa port) and in the Cinque Terre MPA (C Zone, Manarola).

Results

Surveys along the Ligurian coast detected a total of 32 specimens of *P. ferruginea*. Each specimen was recorded and measured (Table 2). The maximum diameter of the shell of all specimens ranged between 30 mm and 68 mm (53.67 mm \pm 11.24, avg. \pm st. dev.). The distribution of the species was extremely scattered with large variability. The largest number of specimens were recorded within Cinque Terre MPA, in which 25 limpets (16 in Punta Mesco and 9 in Capo Montenero) were found along approximately 1000 m of monitored coast. In the other sites, very few individuals (1 or 2 in Celle Ligure, Pontetto, Portofino and Portovenere) were recorded for a total of 6 specimens over 4750 m of linear coast investigated (Fig. 1).

Discussion and Conclusions

P. ferruginea cannot be considered completely absent from the Ligurian coast, as previously reported (Espinosa *et al.*, 2014). In fact, the present study not only confirmed the presence of the species in the Portofino MPA area, as reported by Porcheddu & Milella (1991), but also reported the presence of over 30 individuals scattered along other stretches of the Ligurian coast. Throughout the survey, small specimens (<30mm) were not found. This is

Table 2. Data from surveys performed by Genoa University and Regional Agencies for the Environmental Protection, Liguria (ARPAL) in 2017-2019. Size refers to the maximum diameter of the shell.

Site	Number of specimens	min Size (mm)	max Size (mm)	Avg size \pm SD (mm)	Total coast length investigated (m)	Substrate
Bergeggi MPA	0	-	-	-	1100	Dolomite/ Limestone
Celle Ligure	1	-	-	65	750 (250x3)	Conglomerate
Pontetto	1	-	-	30	Casual finding	Limestone
Portofino MPA (A Zone: Cala dell'Oro)	1	-	-	30	1400	Conglomerate
Portofino MPA (C Zone: Punta del Faro/ Cala Olivetta)	1	-	-	50	Casual finding	Conglomerate
Cinque Terre MPA (A Zone: Punta Mesco)	16	45	68	58.5 \pm 7.31	750 (250x3)	Sandstone
Cinque Terre MPA (C Zone: Manarola)	1	-	-	48	Casual finding	Concrete (port pier)
Cinque Terre MPA (A Zone: Capo Montenero)	9	38	65.4	53.4 \pm 10.4	270	Sandstone
Portovenere	2	32	45	38.5 \pm 9.2	750 (250x3)	Limestone
Total	32	30	68	53.67 \pm 11.24	5770	

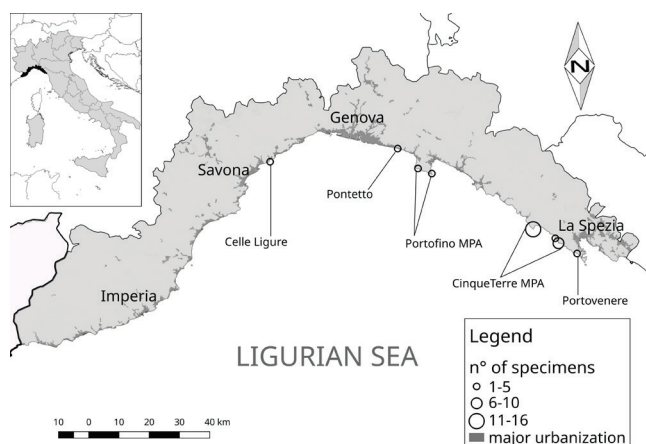


Fig. 1: Distribution map of *P. ferruginea* along the Ligurian coast. Symbols refer to ranges of abundance.

probably due to the difficulties associated with detecting small sized specimens, which are sometimes camouflaged on their substrate (Guallart *et al.*, 2017).

Apparently, a relative hotspot for the species in Liguria is the Cinque Terre MPA, where only the A Zone has been investigated so far. Here, specimens were present at moderate densities (0.025 ind/m), a phenomenon that could be linked to the proximity of this area to the Tuscan archipelago and coast, where the presence of the species has been reported by several authors (Appelius, 1869; Curini-Galletti, 1979; Terreni, 1981; Biagi & Poli, 1986; Porcheddu & Milella, 1991). It could further indicate the regular arrival of larvae from this population. It could also be related to the substrate morphology mostly sandstone in the area. However, *P. ferruginea* was observed by many authors living on substrates of different nature (granite, sandstones, carbonate rock, rhyolite, adesite,

dacite, limestones) as has been summarized by Luque *et al.* (2018). In the light of these findings, Luque *et al.* (2018) hypothesized that other factors, such as wave exposure, acclivity, texture, microbial biofilm and human accessibility, rather than the mineralogy of the rocks, affect the distribution of this species.

Another potential driver to be considered in order to understand the distribution of these specimens refers to the protection level of the coastline. So far, most prospections have been performed in the A Zones of MPAs, but we cannot exclude the presence of this species in areas characterized by lower protection levels, or even in non-protected areas. Level of protection is likely not the only safeguard for the species. Additionally, low accessibility to the coast could theoretically prevent threats to the species (Coppa *et al.*, 2012; Espinosa *et al.*, 2014). For these reasons, future surveys are now planned not only in the B and C Zones of Ligurian MPAs, but also in other areas of low accessibility to humans because of military use, acclivity or long distance from beach areas. Additional support is expected by citizen science, through the launch of sight recordings (*e.g.* through the RAMOGE Agreement).

Present findings will not only contribute to increasing knowledge about the present distribution of the species but will also have implications for the implementation of conservation and restoration measures, such as those envisaged within the RE-LIFE project. In fact, these findings accomplish three major objectives. (i) They corroborate the presence of a local population, although it is highly reduced in numbers, and probably depends on of the arrival of larvae from other nearby more abundantly populated areas. Consequently, (ii) the findings strengthen the need for implementing protection plans within the framework of the EU Habitat Directive (Council Direc-

tive 92/43/EEC) and the EU Natura 2000 ecological network. Further, (iii) they provide valuable information to direct site selection for the implantation of juveniles for repopulation. Thus, allowing conservation efforts to assess the effects of protection levels and substrate features, as planned in the framework of the RE-LIFE project.

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