Egyptian Journal of Aquatic Biology& Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(4): 1233 – 1249 (2025)
www.ejabf.journals.ekb.eg

The Importance of Small Mediterranean Islands as Refuge for the Endangered Species as *Patella ferruginea*: Case of Sebiat Island

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ARTICLE INFO
Article History:
Received: May 30, 2025
Accepted: July 15, 2025
Online: July 18, 2025

Keywords:
Patella ferruginea,
Marine Protected Areas,
Sebiat Island,
SW Mediterranean

ABSTRACT

The aim of this study was to validate the biodiversity potential and assess the conservation value of Sebiat Island (also known as Gerardi Island), with a view to its possible integration into the Mediterranean small islands network. The results revealed the presence of a relatively large population of *Patella ferruginea*—724 individuals, with a density of 1.09 ind/m. The significant presence of juveniles is a critical indicator of active recruitment and population renewal within the study area. However, the absence of very large individuals suggests anthropogenic pressure, as poachers typically target specimens larger than 60 mm in length. In addition to *P. ferruginea*, several other endangered and ecologically important species were identified on the island. These include the red calcareous alga *Lithophyllum byssoides*, the brown algae *Cystoseira* spp., and fragile habitats such as vermetid bioconstructions formed by the sessile gastropod *Dendropoma lebeche*, as well as *Posidonia oceanica* meadows in the sublittoral zone. Given the island's rich biodiversity and ecological value, the establishment of a formal protection plan is recommended to ensure the long-term conservation of Sebiat Island and its unique marine habitats.

INTRODUCTION

Marine systems have been severely affected in recent years by increasing human pressure on coastal ecosystems and climate change **(Claudet & Fraschetti, 2010; Lejeusne *et al.*, 2010; Templado, 2014)**. The immediate effects on biodiversity are well known **(Coma *et al.*, 2009; Crisci *et al.*, 2011)**.

Marine Protected Areas (MPAs) restrict human activity for conservation purposes, typically to protect natural or cultural resources **(Cicin & Belfiore, 2005; Sala *et al.*, 2021)**.

MPAs play an important role in protecting and conserving global ocean ecosystems **(Gaines *et al.*, 2010; Lopoukhine & Dias, 2012; Kriegl *et al.*, 2021)**. Echoing the need for

greater protection, the IUCN World Conservation Congress in 2016 recommended the goal of protecting 30% of the ocean in 'highly protected' areas by 2030 **(UICN, 2016)**.

Since the Holocene, humans have continuously modified their environment to better suit their needs **(Poher *et al.*, 2016)**. These impacts are even more pronounced on small Mediterranean islands, where the flow and type of ecosystem services are constrained by insularity and heavily exploited by economic activities **(Aretano *et al.*, 2013)**. Moreover, small islands are areas of high ecological and heritage value, as well as tourist attractions for various visitors. Therefore, regulating visitor access is necessary to minimize human impact **(Viñals *et al.*, 2016)**.

Algerian islands are characterized by notable biodiversity richness **(Kallouche, 2018; Kallouche *et al.*, 2020)**. This biodiversity includes several endangered species, such as the Mediterranean ribbed limpet *Patella ferruginea* **(Frankiel, 1975; Espinosa, 2009; Kallouche, 2018; Kallouche *et al.*, 2020)**. This species is the largest Mediterranean limpet of the genus *Patella*, with shells exceeding 10 cm in diameter **(Christiaens, 1973)**. It is considered one of the most endangered marine invertebrates of the Western Mediterranean basin, where it is endemic. This molluscan gastropod is included in the annexes of endangered or threatened species under the Barcelona and Bern Conventions and the European Habitat Directive **(Templado *et al.*, 2004)**. In Algeria, it is declared a protected species in the official journal of the Algerian Republic **(JORAPD, 2006)**.

The most successful populations of this limpet have been recorded along the North African coasts and islands, including: the Chafarinas Islands **(Guallart & Templado, 2016)**; parts of Ceuta **(Riviera-Ingraham *et al.*, 2011; Ostalé-Valriberas *et al.*, 2023)**; Melilla **(Guallart *et al.*, 2013b)**; Alboran Island **(CMA-JA, 2014)**; and in Tunisia, the Zembra and Zembretta islands **(Zarrouk *et al.*, 2016)**. In Algeria, the highest densities have been reported on Habibas Island **(Boumaza & Semroud, 2001; Espinosa, 2009; Larbi-Doukara, 2019)**, Plane Island **(Espinosa, 2009; Kallouche *et al.*, 2020)** and Rachgoun Island **(Taibi *et al.*, 2014)**.

In Algeria, some small islands such as the Habibas Archipelago, Rachgoun, and Plane (Paloma Island) are known habitats for this species. However, other small islands have never been studied. The aim of this work is to highlight the biodiversity potential of Sebiat Island, contributing to its inclusion in the Mediterranean small islands MPA network. This would enhance its visibility, reduce human impacts, and promote its consideration as a new hotspot for *P. ferruginea*.

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MATERIALS AND METHODS

Study area

Sebiat Island (also known as Gerardi Island) is located in the southeastern Alboran Sea, within the western Mediterranean Basin (35°33'11"N, 1°11'56"W). This volcanic island lies 2.2 km off South Cap Figalo and just a few dozen meters from Sebiat Beach (Ain Temouchent, on Algeria's western coast), approximately 50 km from Oran (Fig. 1). Although relatively small, it is the fourth largest island in western Algeria, following the Habibas Islands, Rachgoun, and Plane (Paloma) Islands. The island covers an area of about 27,000 m², with a

maximum length and width of 250 x 150 m, and reaches a maximum elevation of approximately 17 m.

The island's western side is bordered by an abrasion platform featuring a vermetid reef. Its entire coastline is rocky, lacking any natural harbor or shelter for boats. Nonetheless, visitors and fishermen can easily access the eastern side. Additionally, seasonal sand movements caused by significant upwelling events can create a temporary natural bridge between the island and the mainland, further facilitating access. However, this bridge may disappear following strong downwelling events.

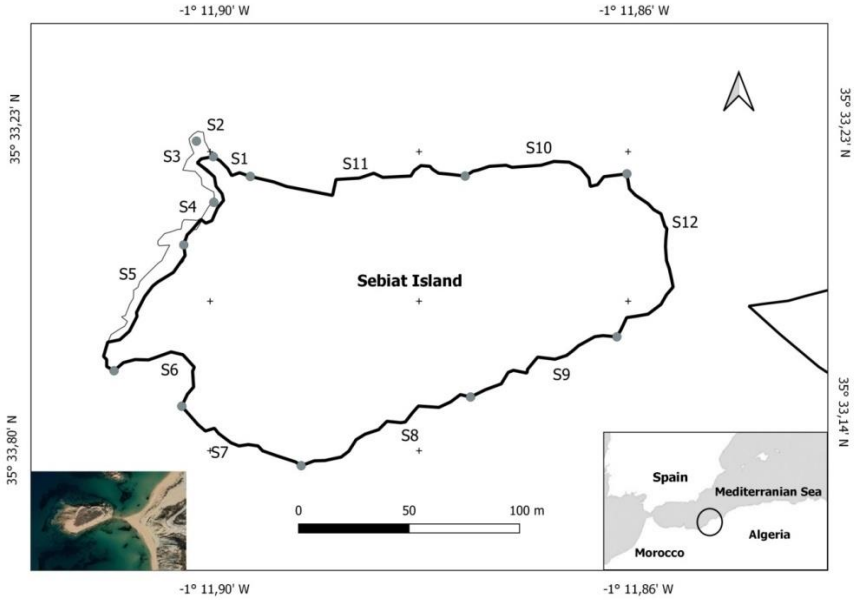

Fig. 1. Location of Sebiat Island and sampling sectors. Black line represents the shoreline of the island. The grey line represents the limit of mid-littoral

Methodology

The census of *Patella ferruginea* was conducted around the entire perimeter of Sebiat Island without detaching specimens from their rocky substrate. Surveys were performed by walking across accessible zones of the foreshore and by swimming in areas that were otherwise inaccessible. The fieldwork covered the entire rocky coastline and was carried out between May and August 2021.

The island's rocky coastline was divided into 12 sectors. These sectors were not evenly distributed but were instead determined based on landform features and their orientation in relation to marine currents (Fig. 1). The entire shoreline, between 0 and 50 cm above sea level, was carefully surveyed. All observed *P. ferruginea* specimens were recorded (N°ind) and measured using a caliper with millimeter precision. The maximum shell diameter (MSD) was used as the size parameter for each specimen.

In addition, several points along Sebiat Beach were surveyed by boat using a bathyscope to detect the presence of *Posidonia oceanica*. Other endangered species identified on the island included the gastropod *Dendropoma lebeche* and its biogenic reef, the red calcareous algae

Lithophyllum byssoides, and the brown algae *Cystoseira* spp. The locations of these populations were marked with GPS coordinates using a Garmin Etrex221X device and mapped accordingly.

Data analysis

The results highlight the distinction between the total number of specimens (N°ind) and adult abundance (N°ads), with specimens' measuring ≥30 mm MSD considered adults **(Guallart & Acevedo, 2006; Guallart *et al.*, 2013b; Guallart & Templado, 2016)**. Density was defined as the number of specimens or adults per linear meter of coastline (ind/m, ads/m). The average size of all individuals (ind size) and the average size of adults (ads size) were calculated for each sector of the island.

Special attention was given to the presence of juveniles (age 0+ and 1+ years), based on the criteria established by **Guallart and Templado (2016)**, as juvenile abundance provides key information about recruitment and the population's renewal capacity.

The data were tested for normality using the Shapiro-Wilk test and for variance homogeneity using Levene's test. Subsequently, one-way analysis of variance (ANOVA) was performed to detect variability between zones in terms of abundance and shell size.

Significant differences in abundance and mean shell size were determined at the $P < 0.001$ and $P < 0.05$ levels using ANOVA and the Kruskal-Wallis One-Way Analysis of Variance on Ranks. Duncan's and Tukey's tests were used for multiple comparisons between mean values when appropriate. Statistical analyses were conducted using STATISTICA software (StatSoft, STATISTICA Version 10).

Mapping

Quantum GIS (QGIS), an open-source GIS platform, was used to design customized maps featuring point, line, and polygon data. Data collected in the field were integrated into QGIS (version 3.10) to calculate the total coastal length and to produce spatial distribution maps of endangered species.

RESULTS

Abundance

A total of 724 specimens of *Patella ferruginea* were recorded in the whole coastline of the Sebiat Island (663.6m), which corresponds to a total density of 1.09 ind/m. Based on the size of the recorded individuals, 543 were considered probable adults (≥30 mm MSD) and 181 juveniles (<30 mm MSD). The whole adult's density is 0.81ads/m, and adults represent about 75% of total ferruginous limpets of the island.

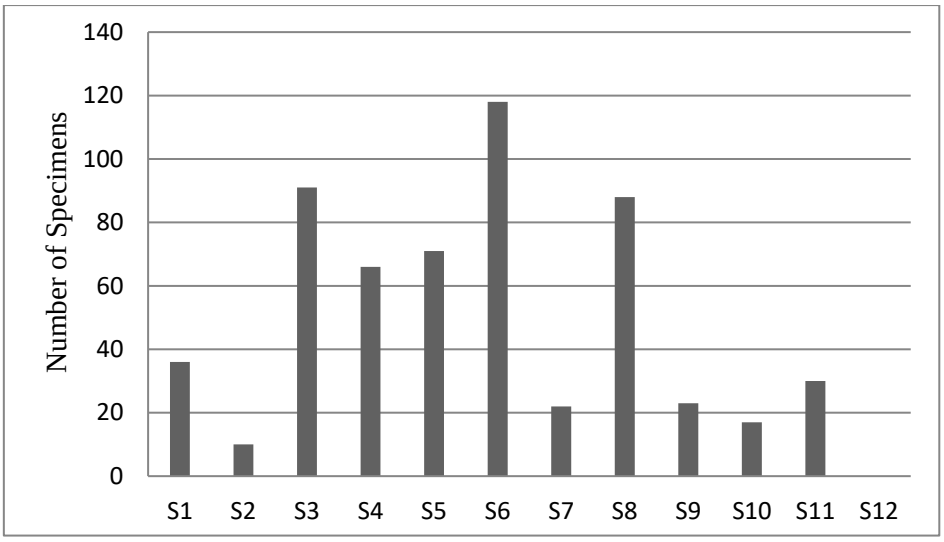

Fig. 2. The average adult abundance per zone (KrusKal-Wallys Test, p = 0,046).

The results of the analysis of variance in the 12 sectors studied showed a heterogeneous abundance of *P. ferruginea* based on its repartition area (Kruskal-Wallis One Way Analysis of Variance on Ranks; *P*= 0.046), and varied according to zones (Table 1 & Figs. 2, 3). The lowest density (<0.5 ind/m) was found in sectors 7, 10 and 11 (0.46ind/m, 0.25ind/m, 0.42ind/m and 0.4ads/m, 0.2ads/m, 0.42ads/m, respectively). On the other hand, the highest density was found in sector 3 (>4ind/m and 3ads/m) followed by sector 4 (~3ind/m and 1.67ads/m). Moreover, the absence of specimens was observed in sector 12, which is located in the Eastern zone of the island.

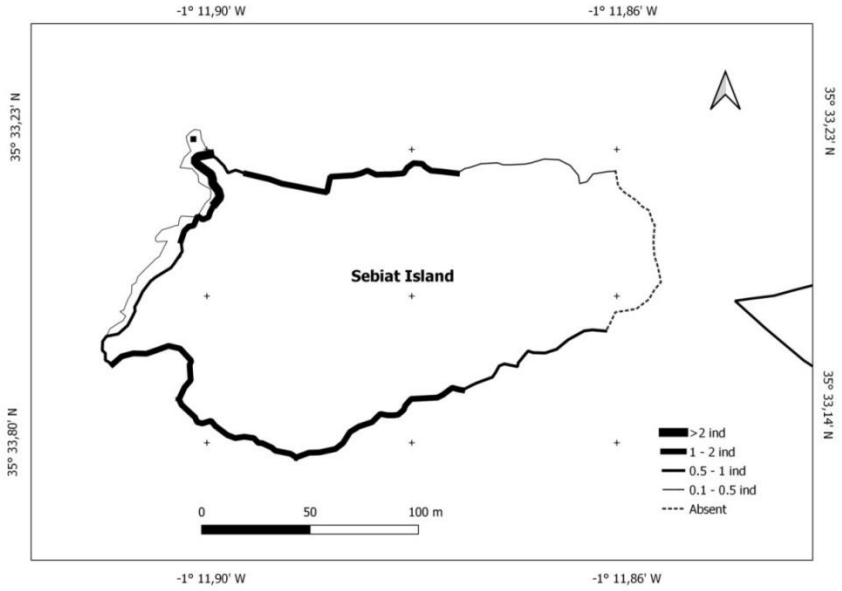

Fig. 3. Density distribution of *Patella ferruginea*on Sebiat Island

Size-length distribution

The average adult sizes (Fig. 4) for each zone, (Duncan test; one way ANOVA Tests; $P<0.001$), reveals the existence of two clusters: the first one comprises S1 to S7 (~40mm), and the second one from S08 to S11 (~50mm).

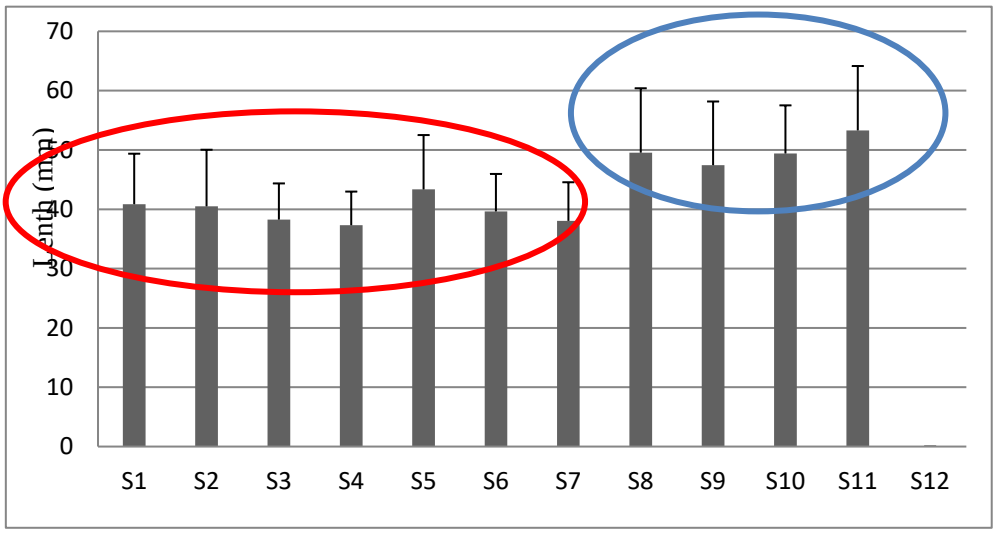

Fig. 4. The average maximum diameter (millimeter) for each zone (ANOVA, $P<0,001$). All Pairwise Multiple Comparison Procedures (Duncan test). Two clusters can be observed: The red is the smaller (around 40mm) and the blue is the bigger (about 50mm)

The results of the size classes (Fig. 5) indicate that the most dominant size class interval was the 30 to 50mm classes from sectors 1 to 7. However, in other sectors, this interval can be extended to 70mm in sector 11, which indicates that the dominant class was 65-70mm together with the absence of juveniles.

Concerning the size class < 30mm, corresponding to juveniles, a significant difference in abundance was observed between 0–5 to 5–10 and 25–30 (Tukey test).

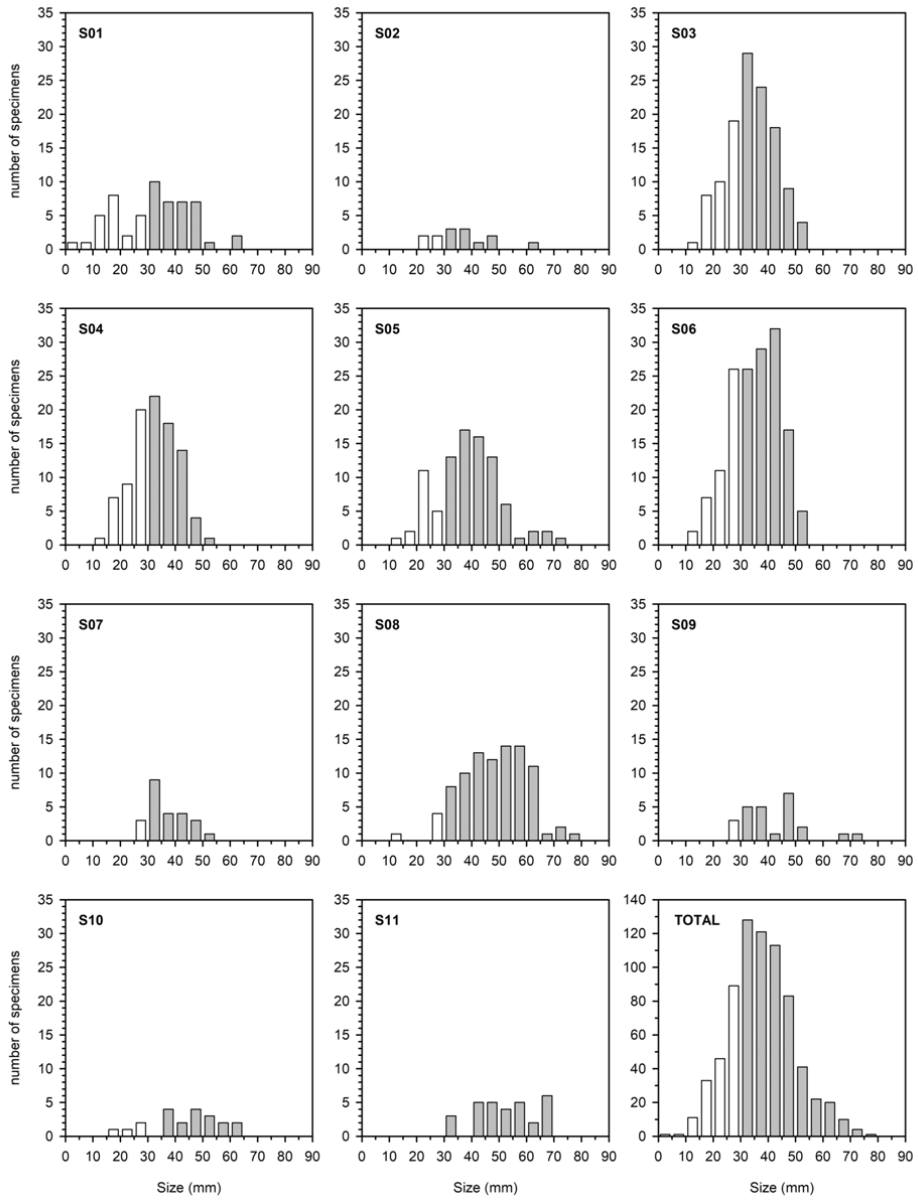

Fig. 5. Length classes for each sector. X-axes represent length classes and Y-axes represent the abundance. White columns indicate immature specimens (<30mm DM) and Grey columns correspond to adult specimens (≥30mm DM). Kruskal-Wallis Test (Tukey Pairwise Multiple Comparison, *P*<0,001)

Maximum size

The largest individuals, belonging to the size class 70-80 mm, were present only in sectors 5, 8, and 9 (Table 1 & Fig. 5). The largest specimen of *P. ferruginea* recorded on the island was 78mm and was located in sector 8. The overall average adult size was 42.5 mm, while the highest average adult size—53.3 mm—was recorded in one of the sectors (Table 1).

Table 1. Summary of *Patella ferruginea* census results by sector

Sectors	Sector Length (m)	Abundance		Density		Average length (mm)		Extreme length (mm)	
		N°ind	N°ads	(ind/m)	(ads/m)	ind size	Ads size	minimum	maximum
S1	40	56	34	1,40	0,85	32,41	40,86	5	65
S2	8	14	10	1,75	1,25	36,14	40,50	22	61
S3	28	122	84	4,35	3,00	34,46	38,26	12	54
S4	32,3	96	54	2,97	1,67	33,07	37,31	14	55
S5	72,2	90	71	1,24	0,98	39,20	43,35	15	72
S6	80	155	109	1,93	1,36	35,8	39,64	13	55
S7	52	24	21	0,46	0,40	37,12	38,04	26	54
S8	45,5	91	86	2,00	1,89	48,68	49,54	12	78
S9	38	25	22	0,65	0,58	45,92	47,43	28	72
S10	82,6	21	17	0,25	0,20	44,52	49,41	16	62
S11	70	30	30	0,42	0,42	53,30	53,30	32	70
S12	95	0	0	0	0	0	0	0	0
Total	663,6	724	543	1,09	0,81	40,05	42,5	5	78

Data include total number of specimens and adults (abundance), total density (ind/m), and adult density (ads/m) per sector (Fig. 1). Average shell sizes and size range (in mm) are also reported. No individuals were recorded in the eastern sector (S12).

Sex ratio

Based on sex ratio data from the Chafarinas Islands (Spain) **(Guallart *et al.*, 2013a)** and partially confirmed in northwest Italy **(Guallart *et al.*, 2023)**, the sex of *Patella ferruginea* specimens can be estimated from shell size classes:

- **28–40 mm**: specimens in this range are always males, corresponding to 249 individuals.
- **40–60 mm**: approximately 75% males and 25% females, corresponding to 194 males and 65 females.
- **60–80 mm**: an estimated 50% males and 50% females, corresponding to 17 individuals of each sex.
- **>80 mm**: specimens in this range, which are absent from our study, typically show a reversed sex ratio (25% males and 75% females).

These findings suggest the presence of a high proportion of juveniles—approximately 25% of the total population—indicating strong recruitment on Sebiat Island. Among adult individuals, the estimated potential sex ratio is approximately 85% males and 15% females.

Other endangered species

Fig. (6) illustrates the spatial distribution of other endangered and threatened species observed on Sebiat Island:

- Two brown algae (Phaeophyceae) species of *Cystoseira* were identified: *Cystoseira stricta* and *Cystoseira amentacea*. Both were found in Sectors 1, 2, 3, 4, 5, and 7.
- *Lithophyllum byssoides* surrounds most of Sebiat Island and is absent only at the extreme eastern side.
- The gastropod *Dendropoma lebeche* was observed in Sectors 5, 7, and 8. This species contributes to the formation of a biogenic reef in association with the red coralline algae *Neogoniolithon brassica-florida*. This reef structure, also known as a vermetid reef, forms a raised terrace along the western side of Sebiat Island and measures approximately 90 meters in length.

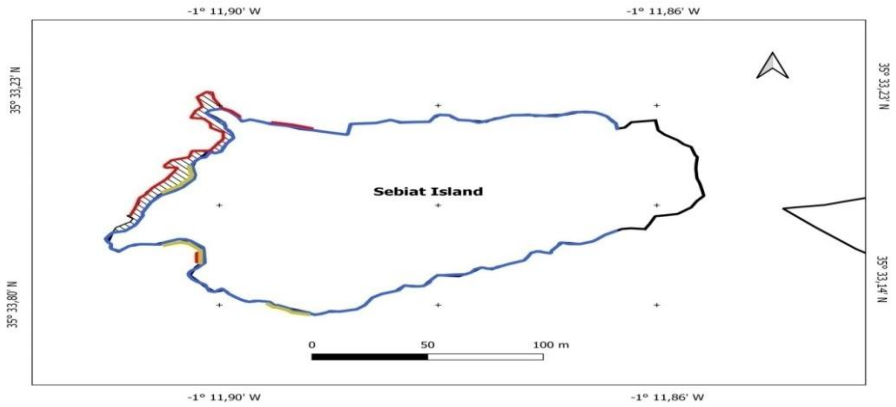

Fig. 6. Distribution of endangered species around Sebiat Island: the striped zone for abrasion platform with vermetid reef, yellow line for *Dendropoma lebeche*, red line for *Cystoseira* spp., and blue line for *Lithophylum byssoides*

DISCUSSION

Present data confirm that the Algerian coast hosts some of the most important populations of *Patella ferruginea*, and reveal the presence of a new hotspot for this endangered species—Sebiat Island—alongside known strongholds such as the Habibas Islands **(Boumaza and Semroud, 2001; Espinosa, 2009; Larbi-Doukara, 2019)**, Plane Island **(Espinosa, 2009; Kallouche *et al.*, 2020)** and Rachgoun Island **(Taibi *et al.*, 2014)**,

The population observed on Sebiat Island indicates that the species is relatively abundant. However, certain sectors show signs of human pressure. Notably, the absence of individuals exceeding 78 mm in shell diameter suggests potential harvesting of larger specimens by visitors. The few larger individuals recorded were located in inaccessible areas, hidden from plain view. A reduction in maximum size within *P. ferruginea* populations has frequently been linked to the collection of large specimens **(Tlig-Zouari *et al.*, 2010; Ceccherelli *et al.*, 2011; Coppa *et al.*, 2015)**. This relationship was recently demonstrated by **Ostalé-Valriberas *et al.*, 2022**. Nevertheless, in some cases, areas with very high population densities tend to show locally reduced maximum sizes for the species **(Guallart *et al.*, 2013b; Guallart & Templado, 2016; Luque *et al.*, 2018)**.

The presence of recruits, small adults, and individuals up to 70 mm in diameter indicates ongoing recruitment and the potential for effective reproduction. The presence of both males and females across different size classes suggests a stable population structure.

Population densities of *Patella ferruginea* vary significantly across the Mediterranean. In Italy and France, densities are generally low. Historical populations in Corsica and Sardinia **(Payraudeau, 1826)** are now reduced and fragmented **(Espinosa *et al.*, 2013)**. The species has nearly disappeared from mainland Italy and Sicily, although it has recently reappeared along the Ligurian coast **(Ferranti *et al.*, 2019)**.

According to Table (2), the highest densities have been recorded in Spanish territories such as Ceuta, the Chafarinas Islands, and Melilla. Morocco and Tunisia show moderate to high

densities, particularly in Zembra and Cala Iris. In Algeria—especially on Rachgoun, Plane, and the Habibas Islands, as well as Sebiat Island—densities are among the highest reported.

Our results confirm the presence of high population densities, a well-structured size distribution, and strong reproductive potential across several islands of western Algeria—namely Rachgoun Island, the Habibas Islands, Plane Island, and Sebiat Island **(Frenkiel, 1975; Boumaza & Semroud, 2001; Espinosa, 2009; Taibi *et al.*, 2014; Kallouche *et al.*, 2020; present study)**.

Table 2. Abundance of *P. ferruginea*in different geographic locations. References, mean total density, mean density of adults (>30mm) and methodology of the study are indicated

Locations	Authors	Total density (ind/m)	Adults Density (ads/m)	Methods
Mal di ventre (Sardinia, Italy)	Marra *et al*. (2016)	0,009 ind/m	-	Whole stretch of coast
Cap San Marco (Sardinia, Italy)	Marra *et al*. (2016)	0,004 ind/m	-	Whole stretch of coast
Asinara Island	Cossu and De Luca (2014)	0.16 ind/m		Whole stretch of coast
Chafarinas (Spain)	Guallart and Templado (2016)	-	4,82 ads/m	Whole stretch of coast
Alboran Island (Spain)	Paracuello*set al*. (2003)	0,6 ind/m	-	~2000m
Alboran Island (Spain)	Arroyo *et al*. (2011)	0,265 ind/m	-	423m
Peñón de Velez de la Gomera	Orozco *et al*. (2013)	0,43 ind/m	0,13ads/m	Whole stretch of coast
Ceuta (Spain)	Rivera-Ingraham *et al*. (2011)	4,09 ind/m	1,65ads/m	170 transects of 10m
Ceuta (Spain)	Ostalé-Valriberas*et al*. (2023)	7,31 ind/m	5,57 ads/m	4560m from 23600m
Melilla (Spain)	Guallart*et al*. (2013b)	2,8 ind/m	2,8ads/m	Whole stretch of coast
Zembra + Zembretta (Tunisia)	Zarrouk*et al*. 2016	1-8,5 ind/m	2,83ads/m	30 transects of 10m
Cala Iris Island Al (Hoceima, Morroco)	Bazaïri*et al*. (2004)	0,24 ind/m	-	Whole stretch of coast
Rachgoun Island (Algeria)	Taibi *et al*. (2014)	-	<3ind/m^2	2 transects of 20m (East and South)
Habibas Islands (Algeria)	Espinosa, 2009	4,8 ind/m	3,23 ind/m	12 transects of 10m
Habibas Islands (Algeria)	Doukara 2019 (Results of 2007)	1,5 ind/m	-	13 transects of 10 m
Plane Island « Paloma »	Espinosa, 2009	22ind/m	11,5ads/m	2 transects 10 m
Plane Island « Paloma »	Kallouche*et al*. in press	1.78 ind/m	1.51 ads/m	Whole stretch of coast
Sebiat Island « Gerardi »	present study	1,09 ind/m	0,81 ads/m	Whole stretch of coast

The variability in *Patella ferruginea* population size is influenced by several biotic and abiotic factors. However, in the case of Sebiat Island, the population appears to be mainly impacted by harvesting. In general, poachers tend to target individuals larger than 60 mm in maximum shell diameter, a size class where the sex ratio is biased toward females **(Espinosa *et al.*, 2006; Rivera-Ingraham *et al.*, 2011; Guallart *et al.*, 2013b; Zarrouk *et al.*, 2016)**. On

Sebiat Island, only 8.5% of specimens exceeded 60 mm, suggesting selective removal of larger individuals.

Limpets are commonly used as bait in recreational coastal fishing throughout the year. This may explain the decline of *P. ferruginea* observed near the island's vermetid reef, an area frequently accessed by fishermen. The western part of the island, in particular, is marked by an almost complete absence of limpets, as shown in Fig. (5). This absence could be attributed to low wave exposure, since the species typically favors environments with moderate to high hydrodynamics **(Guallart & Templado, 2016)**. Additionally, sand accumulation and its erosive action during storms may also negatively impact mid-littoral organisms.

In contrast, the highest number of *P. ferruginea* individuals was recorded in Sectors 3 and 4, where wave action is strong and poaching is limited due to the rugged, less accessible coastline. It is important to note that limpets are not commonly consumed in Algeria; their collection is often for decorative purposes, souvenirs, or simple curiosity.

Despite its small size, Sebiat Island hosts a dense and well-structured population of *P. ferruginea*, as illustrated in the graphs and maps. This finding supports the designation of Sebiat Island as a new conservation hotspot for the species. Protecting this site could benefit regional populations, as *P. ferruginea* exhibits low genetic differentiation across its range, forming what is described as a metapopulation **(López-Márquez *et al.*, 2024)**.

Notably, the establishment of a Marine Protected Area (MPA) alone does not always reduce human pressure. In many documented cases, limited human access has proven to be more effective than formal protection status in ensuring species persistence **(Guerra-García *et al.*, 2004; Espinosa *et al.*, 2009; Rivera-Ingraham *et al.*, 2011; Coppa, 2012)**. Therefore, for Sebiat Island, it is essential not only to include it in the network of Mediterranean small island MPAs, but also to ensure active surveillance, community awareness, and public education about the species' conservation status and ecological importance.

In addition, *P. ferruginea* may serve as an umbrella species, indirectly protecting other endangered organisms within its habitat **(Ostalé-Valriberas *et al.*, 2022)**. For example, the red calcareous alga *Lithophyllum byssoides*—which is highly sensitive to trampling—benefits from vertical rocky substrates that reduce human impact and support its survival.

Sebiat Island also hosts other important bioindicator species, including the brown algae *Cystoseira* spp. (mid-tidal zone) and the seagrass *Posidonia oceanica* (infratidal zone), as shown in Fig. (7). These species are indicators of good environmental health **(Pergent-Martini *et al.*, 2005)** and are located far from pollution sources. Moreover, *P. oceanica* plays a critical role in oxygen production and serves as a nursery for various fish species. These fish may later migrate to adjacent areas, helping to support unprotected zones and benefiting local fisheries and tourism **(Bedini *et al.*, 2021)**.

Finally, the presence of the endangered sessile gastropod *Dendropoma lebeche* and its contribution to the biogenic vermetid reef on the western side of the island further strengthens the case for protective measures **(Gordó-Villaseca *et al.*, 2021)**.

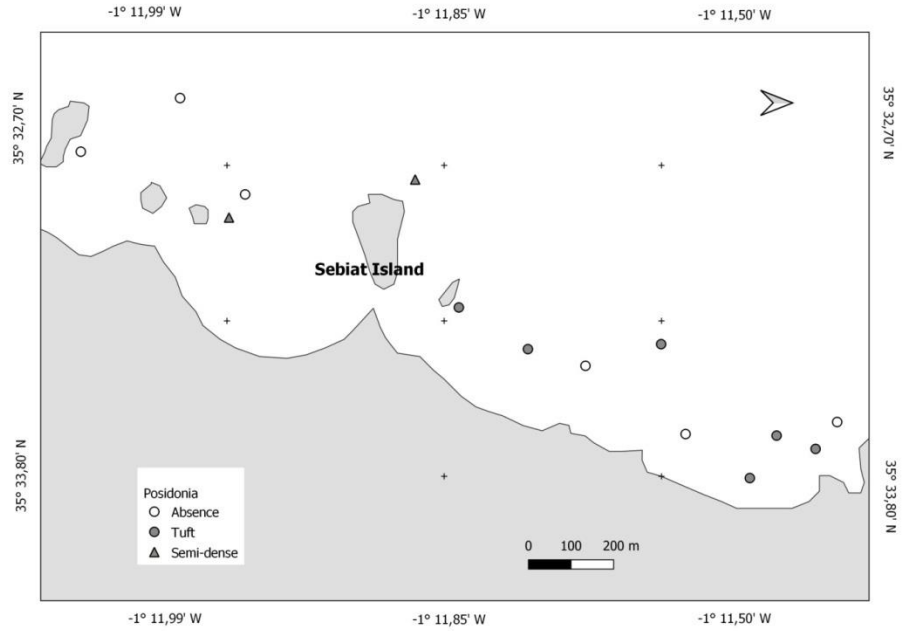

Fig. 7. Presence/absence and densities of *Posidonia oceanica* near Sebiat Island

CONCLUSION

Sebiat Island exhibits a high biodiversity potential. However, selective poaching (particularly the collection of large specimens), combined with biotic and abiotic pressures such as climate change and predation, and a naturally low population growth rate, may threaten the stability of the *Patella ferruginea* population. These factors could lead to a significant population decline if not addressed.

To prevent further decline, future Algerian environmental protection strategies should prioritize *P. ferruginea* by implementing a dedicated monitoring program, launching public awareness campaigns, and identifying new potential hotspots for the species. Additionally, Sebiat Island offers an opportunity to apply ecosystem-based management and sustainable development principles when evaluating economic activities in surrounding waters, such as aquaculture and eco-tourism.

Moreover, while Marine Protected Areas (MPAs) are not immune to the impacts of climate change, relatively pristine ecosystems tend to show greater resilience and recovery compared to more degraded or unprotected area. Therefore, effective management and the formal integration of Sebiat Island into the Mediterranean MPA network are essential. This would not only enhance marine biodiversity conservation but also allow the island to serve as a stepping stone for the dispersal and protection of *P. ferruginea* and other endangered species

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