

# Conservation insights from morphometric and demographic monitoring of *Patella ferruginea* in northern Sardinia MPAs

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## INTRODUCTION

*Patella ferruginea* Gmelin, 1791 is an endemic limpet of the Mediterranean Sea and is currently considered the most endangered marine species listed in the EU Habitats Directive (92/43/EEC). Its distribution has been drastically reduced by human collection for ornamental, food and bait purposes and is now largely restricted to protected or inaccessible coastal areas. *P. ferruginea* is a protandric species, has a very low growth, and similarly to the majority of species belonging to *Patella* genus, it has certain morphometric plasticity, bringing the shell to have two different forms (*rouxi* and *lamarcki*).

This study, carried out in collaboration with La Maddalena Archipelago National Park — which provides crucial logistical and financial support — aims to evaluate the population density and structure of *P. ferruginea* within the Park between 2024 and 2026. Furthermore, the collected data were compared with those from previous surveys (2018) conducted in two other MPAs in northern Sardinia: Asinara National Park and Tavolara–Punta Coda Cavallo MPA.

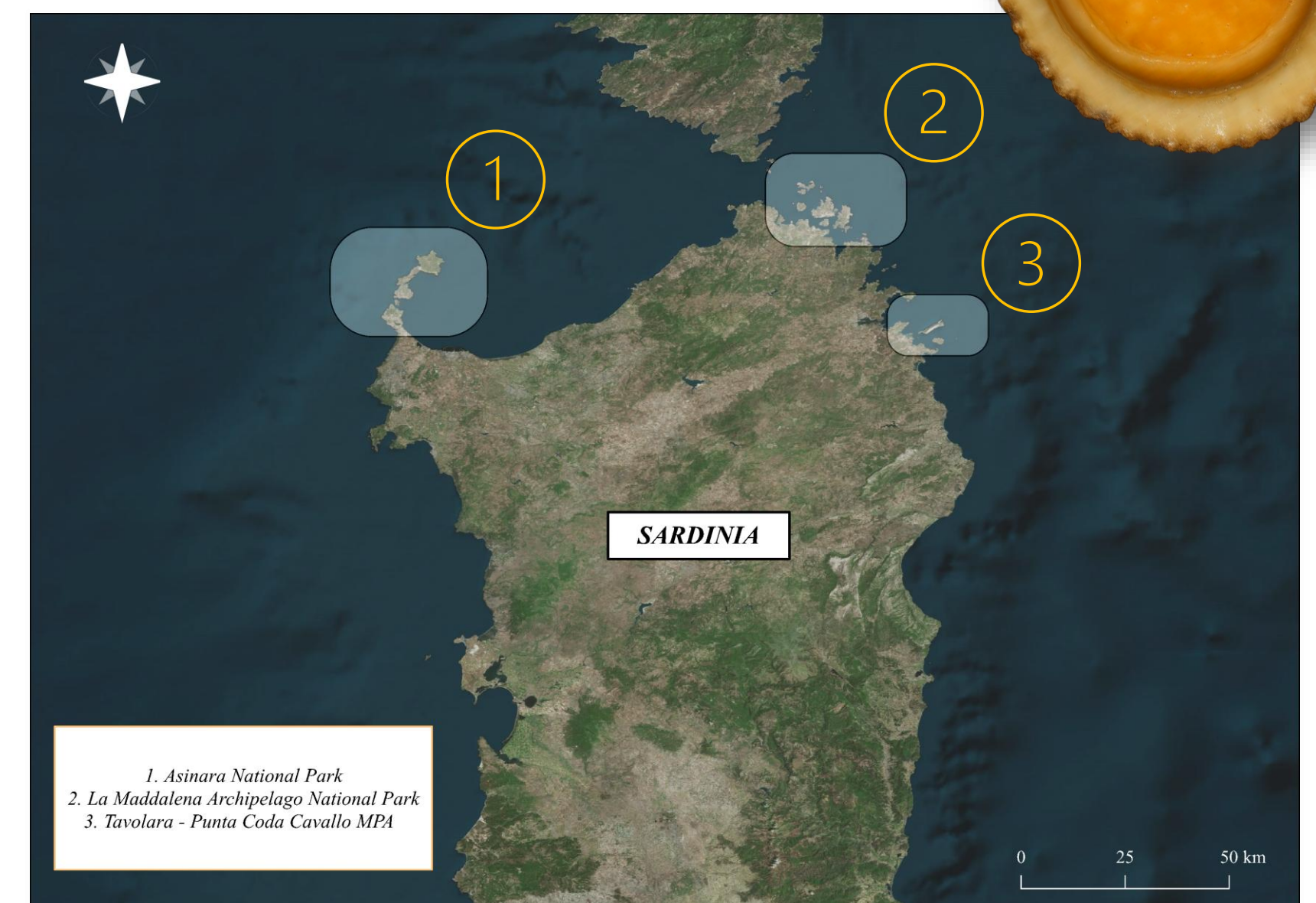


Figure 1: Study area

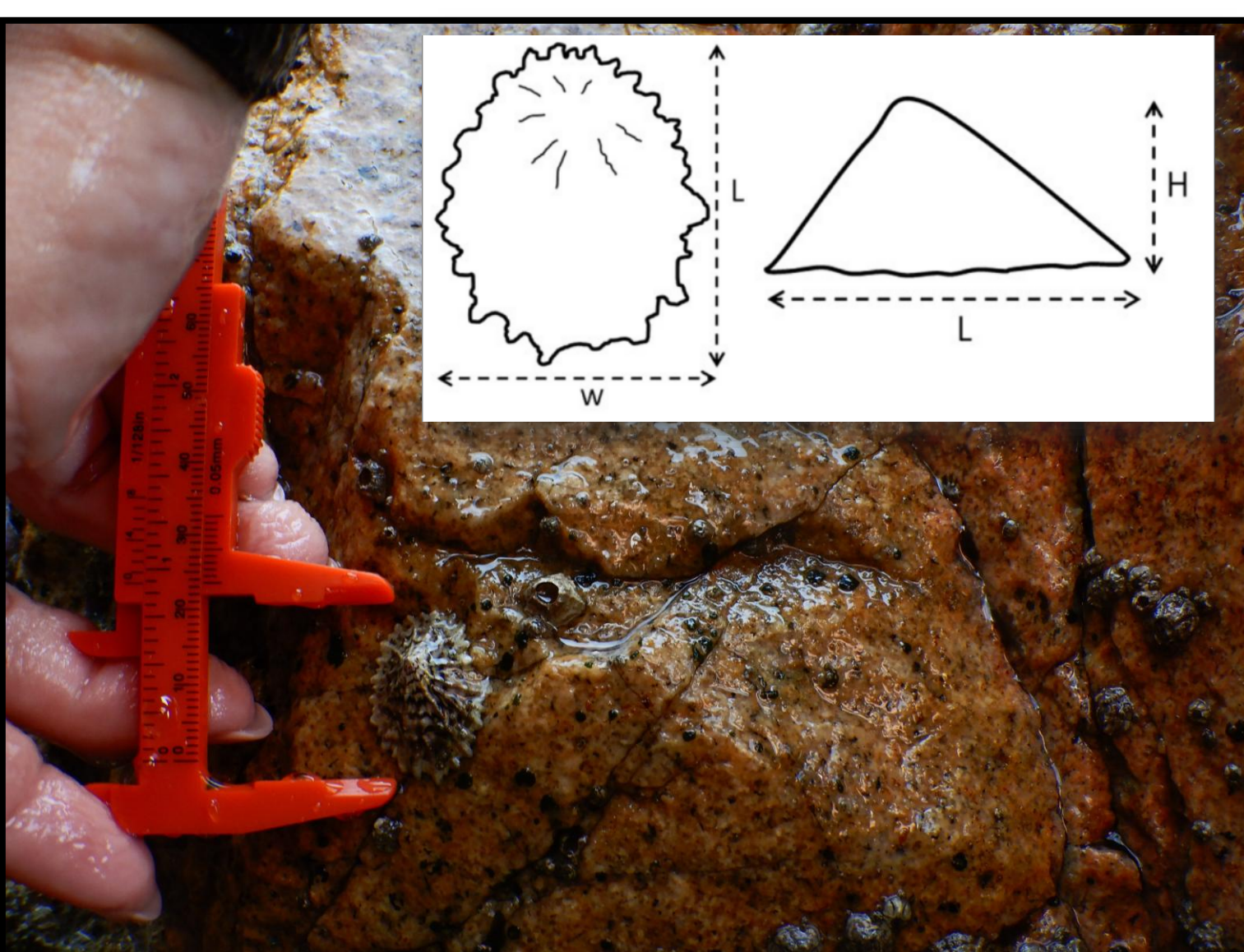


Figure 3: Biometric measurements of *P. ferruginea*. Photo by Riccardo Senigaglia



Figure 3: Non-lethal tissue sampling from a specimen of *P. ferruginea*. Photo by Riccardo Senigaglia

## MATERIALS AND METHODS

A complete census of the smaller islands and representative transects on the main islands have been performed. All individuals were georeferenced and measured using biometric parameters (length, width, height) (Fig.2). Morphotypes (*rouxi* vs. *lamarcki*) were identified based on the ratio of shell height to shell length ( $H/L > 0.37 = \textit{rouxi}$  morphotype), and sex was determined based on the length of the shell. Non-lethal samplings (Fig.3) for further genetic analyses were conducted in compliance with ISPRA guidelines, which stipulated that no more than 10% of the detected population could be sampled. Samples were obtained using sterile instruments, preserved in 70% ethanol, and subsequently stored under refrigeration to ensure molecular integrity.

Following sampling, each individual was carefully relocated to its original *home scar*. Biometric and geographic data were digitized and processed in QGIS (v.3.30.2) to generate distribution and spatial density maps. Statistical analyses were performed using RStudio. Sex ratio and biometric differences among sexes and sites were analyzed using Chi-squared, Kruskal-Wallis, and Dunn's post-hoc tests with Bonferroni correction.

## RESULTS AND DISCUSSION

During the first survey phase in La Maddalena (summer–autumn 2024), a coastal section of 3,709 meters was surveyed, in which 205 individuals were recorded, corresponding to a linear density of approximately 0.055 individuals per meter (Fig.4). The *rouxi* morphotype was dominant with 175 individuals (85%). The comparison with data from previous surveys (2018) in Asinara NP and Tavolara MPA showed a similar dominance of morphotypes with Asinara NP registering 91.9% of the *rouxi* morphotype. Preliminary statistical analysis showed that sex distribution was not uniform (Chi-squared,  $p < 0.001$ ). The Kruskal-Wallis test then revealed significant differences in shell length according to sex ( $p < 0.001$ ), confirmed then by the Dunn test.

The population in La Maddalena had the highest proportion of females (78%) with 160 individuals, 35 males and 10 immature individuals (Fig.5), and overall larger specimens were recorded in this site, likely due to their isolation, full-protection marine reserve status, and high exposure to wind and wave action.

At the spatial scale, comparisons among sites revealed significant differences for all biometric variables (Tab.1). Specifically, the mean shell length in Tavolara was  $49.6 \pm 17.1$  mm, lower than in Asinara NP ( $53 \pm 17.8$  mm) and La Maddalena ( $50.7 \pm 14.7$  mm) (Fig.6). Tavolara also had the highest proportion of males (27.4%), which probably affected the size differences, as males are generally smaller than females.

The distribution of immature individuals was the same at all sites and did not appear to affect morphometric variability.

Higher densities were found in less accessible areas that are more exposed to wave action. The concentration of males and immatures near female-dominated hotspots confirms the limited larval dispersal and the crucial role of local recruitment.



Figure 4: Spatial distribution of female, male, and immature samples in relation to the total concentration of specimens.

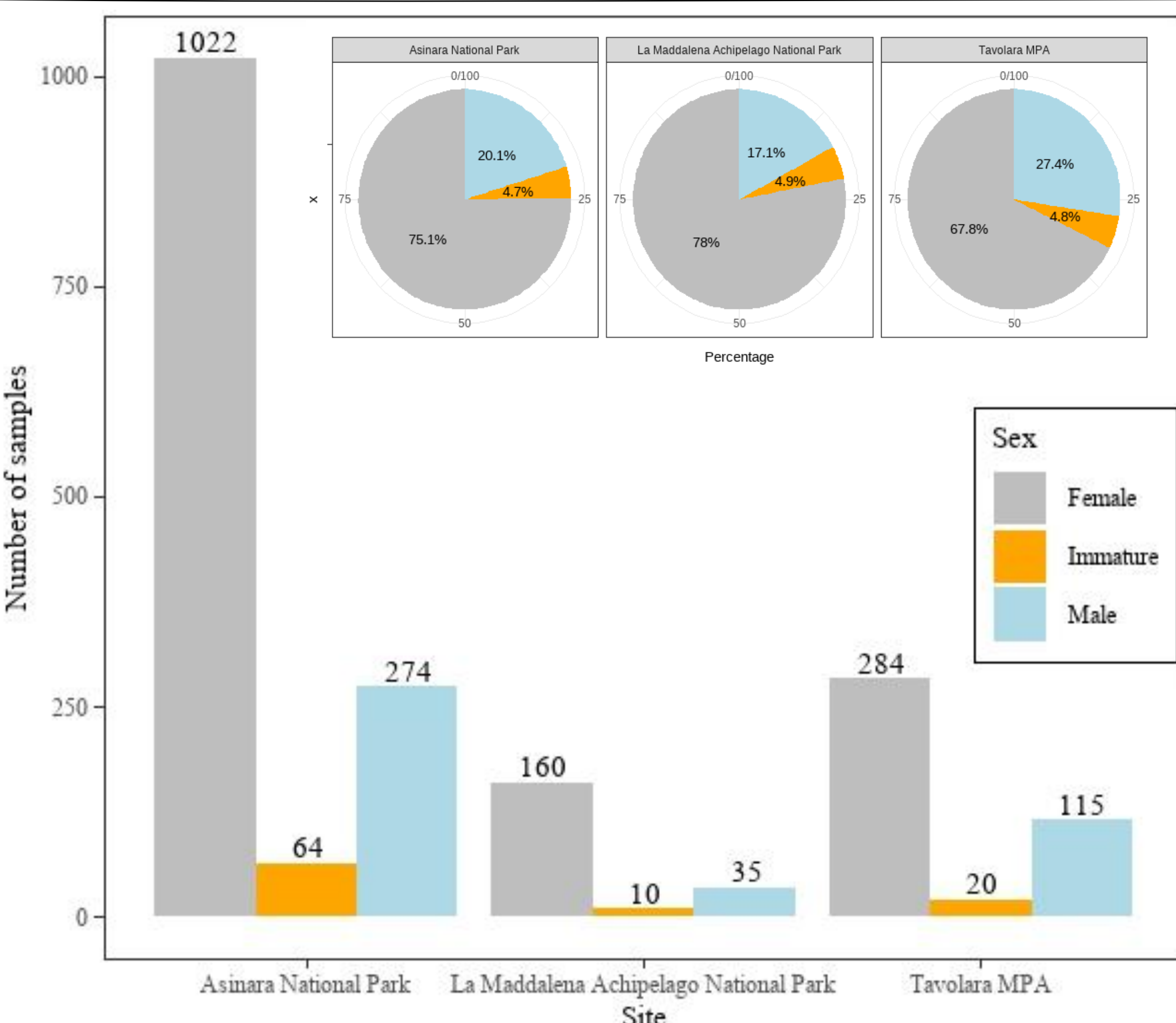


Figure 5: Population structure and percentage of *P. ferruginea* across the three marine protected areas.

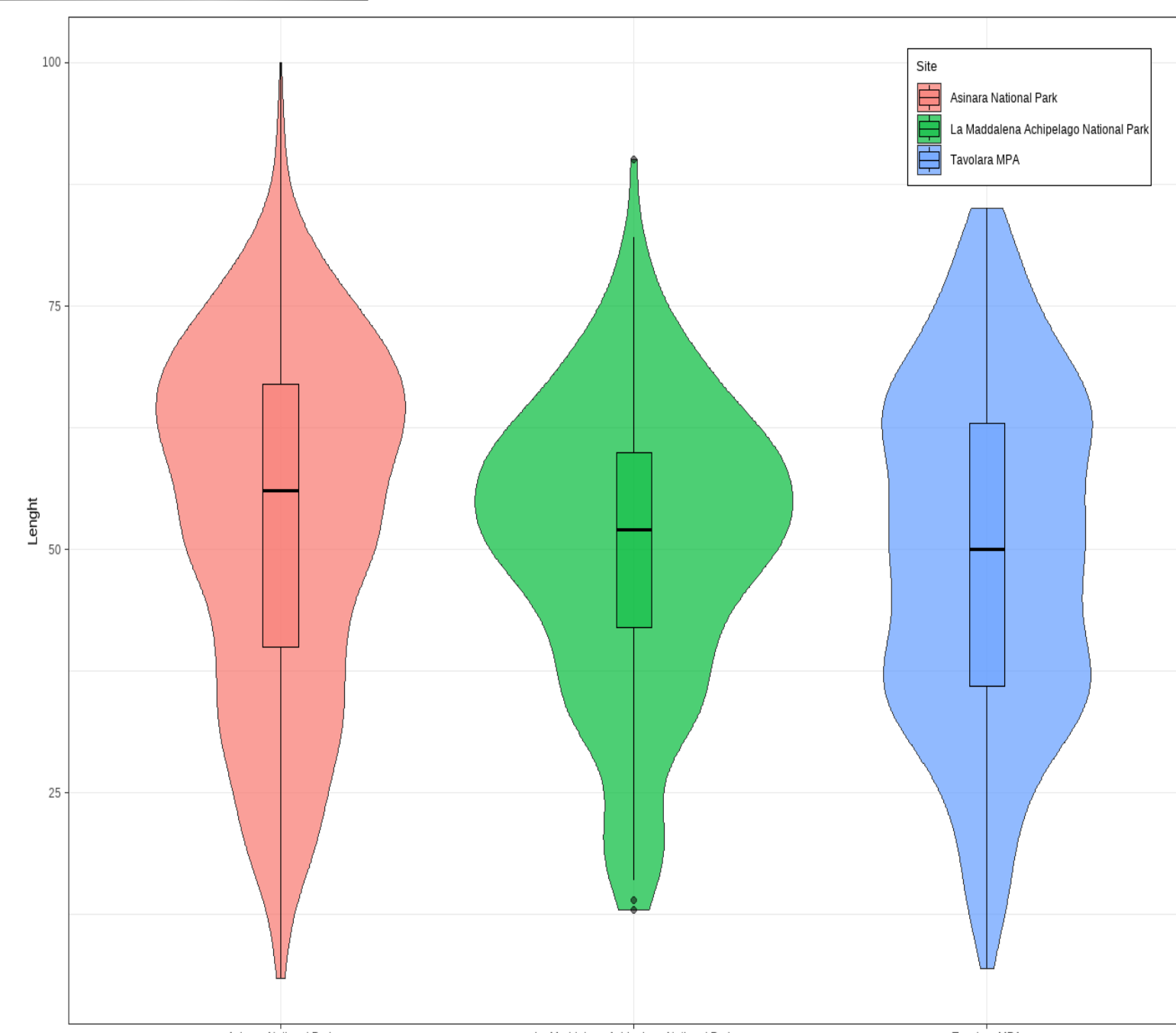


Figure 6: Violin plots of shell length (mm) across three marine protected areas.

Variable	Comparison	p-value	Significance
Length	Asinara vs La Maddalena	0.0268	Yes (borderline)
	Asinara vs Tavolara	0.0002	Yes
	La Maddalena vs Tavolara	1.0000	No
Width	Asinara vs La Maddalena	0.3192	No
	Asinara vs Tavolara	0.0001	Yes
	La Maddalena vs Tavolara	0.1709	No
Height	Asinara vs La Maddalena	0.1526	No
	Asinara vs Tavolara	<0.0001	Yes
	La Maddalena vs Tavolara	0.0138	Yes

Table 1: Post-hoc comparisons (Dunn test with Bonferroni correction).

## CONCLUSIONS

This study provides first insights into the morphometric and demographic structure of *Patella ferruginea* in La Maddalena Archipelago, allowing comparison with Asinara NP and Tavolara MPA. Results show spatial differences linked to accessibility and wave exposure, but further surveys, including non-protected sites, are needed to obtain a complete picture. Despite possible underestimation due to natural factors, these findings represent a solid baseline for conservation. Continuous monitoring in 2025–2026 will be essential to strengthen the dataset and support effective management of one of the most endangered Mediterranean invertebrates.