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The Queen Is Dead, Long Live the Queen: The Vanishing of *Pinna nobilis* and the Onset of the Congeneric *P. rudis* (Mollusca: Bivalvia)

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Abstract: The bivalve mollusc *Pinna nobilis*, endemic to the Mediterranean Sea, since 2016 is vanishing from the whole basin because of an infection by multiple pathogens that caused mass mortality events. In the Eastern Mediterranean some little populations seem to be resistant to the infection. These individuals could represent the only possibility for the species to recolonize now desert habitats. Thus, according to the recommendations of IUCN, the looking for living specimens of *P. nobilis* is a priority. As a result of a monitoring activity carried out in 2022-2024, along the Ionian cost of Apulia, in Southern Italy, the species has completely disappeared leaving only empty shells. Concurrent to the vanishing of *P. nobilis*, its congeneric *P. rudis*, resistant to the infection, seems to be taking advantage, becoming more common and colonizing habitats once exclusive of *P. nobilis*. In fact, from different areas of the Mediterranean, the sightings of *P. rudis* are increasing, together with the discovering of individuals exhibiting morphological traits that are a mixing between the two species. In some cases, these morphological features are not easy to detect, anyway the presence of these hybrids, resistant to the infection, is important for the conservation of the species.

Keywords: *Pinna nobilis*; *Pinna rudis*; endangered species; mass mortality; Ionian Sea; Mediterranean Sea

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Pinna nobilis (Linnaeus, 1758), the pen shell, and the congeneric *P. rudis* (Linnaeus, 1758), the spiny/rough fan mussel, are two molluscan species of the family Pinnidae that inhabit the Mediterranean Sea [1]. A third species of this family, *Atrina fragilis* (Pennant, 1777), is rarer in the Mediterranean, preferring detritic bottoms at depths up to 600 m [2].

P. nobilis is endemic to the Mediterranean [3] while *P. rudis* has a subtropical affinity, and it is mainly present along the Atlantic African coasts [4]. They are sibling species whose distribution in the Mediterranean partially overlaps [5]; in fact, although the priority habitats are different, their bathymetric distribution is widely shared [6]. In particular, *P. nobilis* preferentially inhabits seagrass meadows, including dead matte of *Posidonia oceanica*, macroalgal canopies, muddy and sandy bottoms and detritic patches in rocky bottoms, at depths up to 60 m [3,7]; *P. rudis* is thermophilic and colonizes gravel and rocky bottoms even though its presence has been reported also from *P. oceanica* meadows [8].

These species are both strictly protected by EC directives, national laws, and are listed in the Annex II of the Barcelona Convention as threatened or endangered. Since 2016, *P. nobilis* is suffering the infection of different pathogens, *Haplosporidium pinnae* among all, that have caused mass mortality events throughout the Mediterranean Sea [9,10] and now the status of the species, assessed by the red list of the International Union for the Conservation of Nature (IUCN), is: Critically Endangered [11].

Along the coasts of Apulia, in Southern Italy, *P. nobilis* was historically largely distributed. In the Taranto marine area [12,13], until 2018 this species was very abundant with more than 10,000 individuals present in the two basins of the Mar Piccolo and in the Mar Grande (Figure 1). In 2016 an important translocation activity was carried out to move nearly 2,000 specimens from an area outside

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the Mar Grande, where the Port Authority of Taranto realized a "sediment tank" deputed to host sediments dredged in an area of the port. The entire population was transferred into an area of the Mar Grande where a numerous "natural" population was already present, settled over an extensive dead matte of *P. oceanica* [14] (Figure 2).

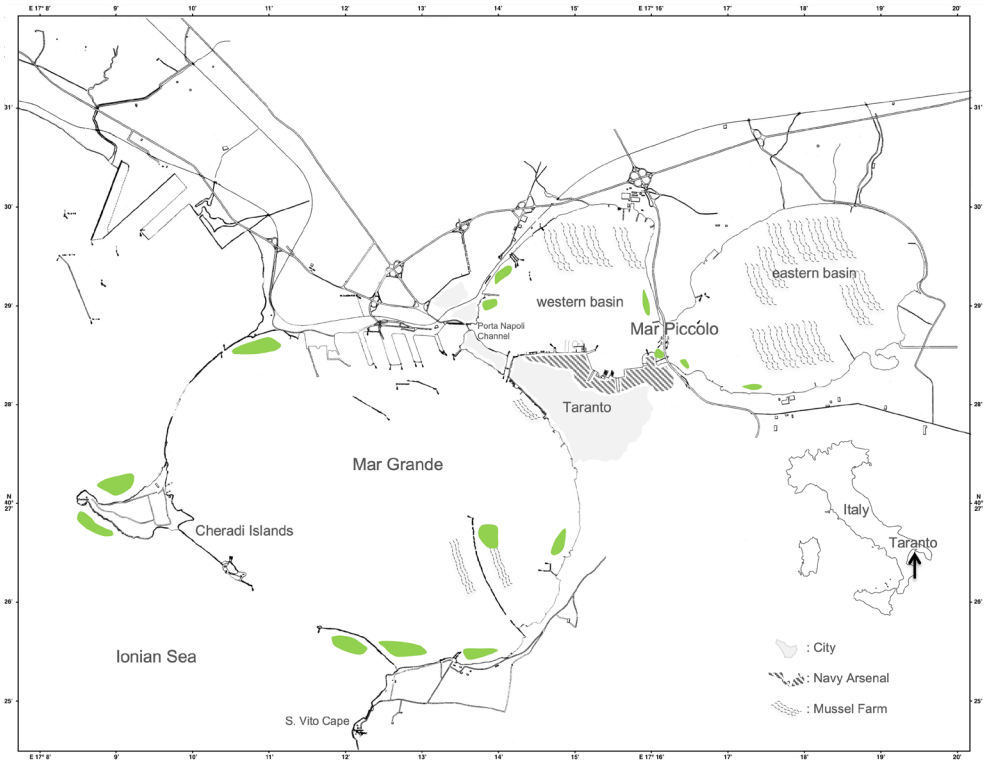

Figure 1. Map of the Taranto marine area. The green blocks indicate the distribution of living *Pinna nobilis* populations until 2018.

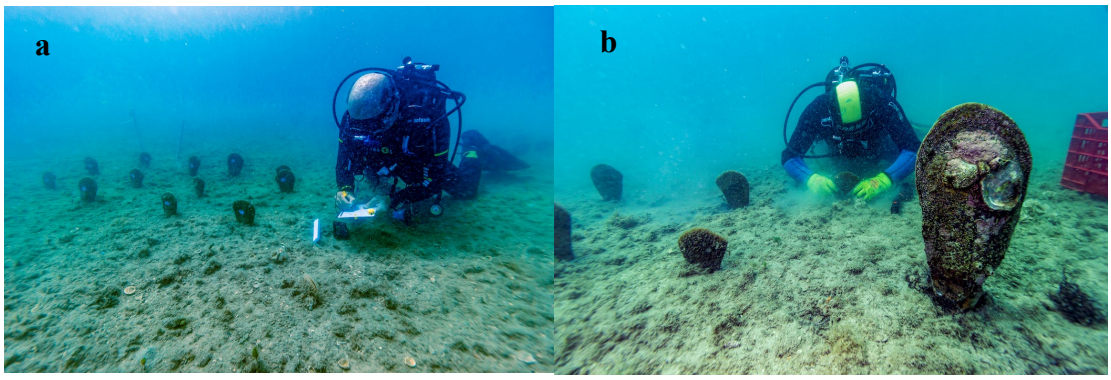

Figure 2. Two moments of the relocation activities of a population of *Pinna nobilis* in the Mar Grande of Taranto: (**a**) Data collection of the newly placed specimens; (**b**) Placement of a specimen in the new site.

Starting from the spring of 2018, in a very short time, thousands of specimens died both in the Mar Piccolo and Mar Grande and in 2019 less than 10 living specimens were observed during the monitoring activities carried out by the SCUBA divers of the CNR IRSA of Taranto (Figure 3). The cause of this mass mortality was ascribed to *Haplosporidium pinnae* [15,16] like already reported for the same events in the Western Mediterranean [17].

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Figure 3. In 2019 in the Mar Piccolo of Taranto a few living individuals were surrounded by many empty shells: (**a**) One living specimen in the eastern basin of the Mar Piccolo (-4m); (**b**) Many dead specimens in the western basin of the Mar Piccolo (-3.5 m).

A very similar situation we found at the Archipelago of Tremiti Islands, in the Southern Adriatic Sea, where the local *P. nobilis* population was reported in a good health until the summer of 2019 [18]. Notwithstanding, in September 2019, during a survey organized with the cooperation of the Coast Guard Maritime Directorate of Pescara, a diffuse mortality was observed with very few living individuals at sites with depths over 20 meters and water temperature of 13-15°C (Figure 4). The mantle biopsies of some moribund specimens revealed the presence of *Mycobacterium* sp. and *Haplosporidium* sp. [19].

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Figure 4. In 2019 at Tremiti Islands, a widespread mortality of *Pinna nobilis* was observed with a few survivors: (**a**) Capraia Island, loc. Secca della Vedova; living specimen (-27 m); (**b**) Canale Travicello, moribund specimen in *Posidonia oceanica* meadow (-6 m).

In this very frustrating scenario, the empty shells maintain their important ecological function as ecosystem engineers [20]. According to [21], an ecosystem engineer has the capacity of modifying, maintaining and/or creating habitats. The fan mussel's shells, remaining erect and anchored to the substratum, act like isles of biodiversity on sandy or muddy bottoms, attracting many benthic sessile and vagile organisms. When the individual is alive, only the superior margin remains clean, due to the activity of the mantle, instead the empty shells are completely colonized also in their internal side (Figure 5). That is why the collection of empty shells is still prohibited and subject to heavy fines.

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Figure 5. An empty shell of *Pinna nobilis* in the Mar Piccolo of Taranto (February 2019) is colonized by many species of algae and invertebrates and offers refugee to a small fish.

Concurrent to the quite complete vanishing of *P. nobilis*, the sightings of *P. rudis* are increasing, mentioned both in scientific literature [8,22,23] and social media, suggesting that this species could benefit from the disappearance of its sister, also colonizing habitats that in origin were exclusive of *P. nobilis*.

We observed the first signs of this trend at Pantelleria Island (Sicily Channel, Mediterranean Sea), in October 2022. We have never seen specimens of *P. rudis* in all our dives in Taranto, Tremiti and many other Apulian sites; and only sporadic observations are reported from these localities, as evidence of its rarity. Considering the few dives made on the seabeds of the island, the finding of 11 living specimens of *P. rudis*, plus one dead, in our opinion is a relevant number (Figure 6).

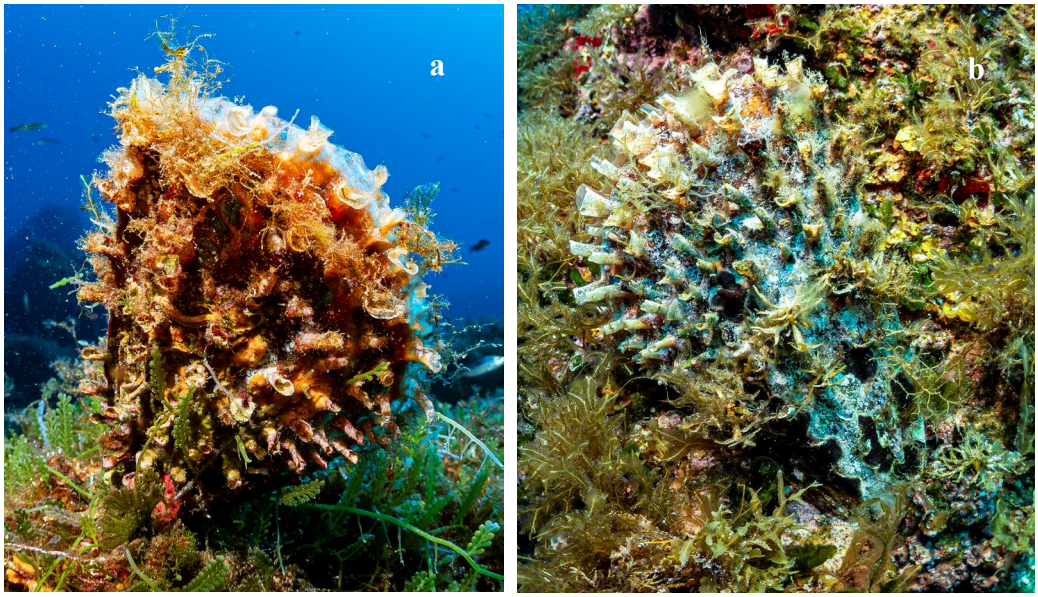

Figure 6. A notable number of living individuals of *Pinna* rudis was observed at Pantelleria: (**a**) Secca Campobello (-25 m) (**b**) Large size individual at Baia di Campobello (-18 m).

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Besides, for a long time, we did not seen healthy individuals of *P. nobilis* as well. Living specimens of both species were present there, together with few empty shells and all of them were found on rocky or coralligenous bottoms. After a more careful observation, the individuals initially recognized as *P. nobilis*, despite they exhibited shells and size typical of the adults of such species, the coloration of the mantle was different; it was not the typical pink [24], but iridescent with dark belts, more similar to that of *P. rudis* (Figure 7). During the dives, we have observed other individuals exhibiting morphological traits, like the shell ornamentations, the size, and the coloration of the mantle, that seemed to be a mixturse between the two species (Figure 8). According to [25], it is possible that they could by hybrids. We did not perform mantle biopsies, to confirm this hypothesis, and even though the putative hybrids exhibited morphological traits quite different from the hybrids showed in [25], these findings are very interesting and deserve more in-depth investigations.

Figure 7. The posterior margin of a putative hybrid of *Pinna nobilis* x *Pinna rudis*. The peculiar coloration of the mantle is well visible. Pantelleria, Secca Campobello (-28 m).

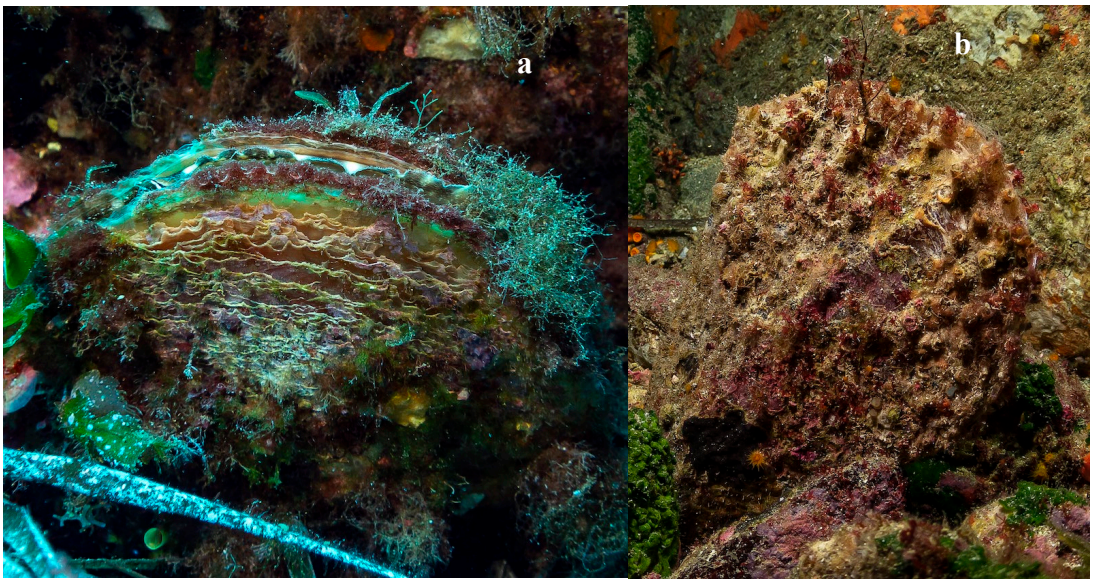

Figure 8. Putative hybrids of *Pinna nobilis* and *P. rudis* at Pantelleria: (**a**) Secca Campobello (-28 m) (**b**) Cala Tramontana (-22 m).

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At our knowledge, the first documented reports of *P. rudis* in Apulia—and in the Province of Taranto in particular—are dated in summer 2023. Two specimens were reported in a social media forum from a locality 20 km far from Taranto [8], while we have "discovered" a third at San Vito, a locality nearby the city of Taranto, thanks to the notify of the Diving Center "Taras Sub". The latter specimen was very difficult to see, settled into a little hole among the coralligenous rocks, the shell completely covered by organisms (Figure 9).

Figure 9. *Pinna rudis* at San Vito, Taranto, hardly visible in the coralligenous bottom (-27 m).

The first reports of *P. rudis* follow the consistent vanishing of its sister from the seabeds along the Apulian coast of the Ionian Sea. In 2022- 2024 we carried out a monitoring activity aimed to discover any survivors of *P. nobilis* in this area, by investigating 15 sites along the coast in the province of Taranto. We carried out both dives in the meadows of *Posidonia oceanica* and underwater linear transects of 200-300 meters at three depths, 5, 15 and 25 meters. The utilization of underwater scooters allowed us to survey more than 15 km of sea bottom per each depth. No living individuals were observed, and 67 empty shells were registered, most of them at 15 m of depth and outside the *P. oceanica* meadows (Figure 10). In a similar study, extended to the entire south-eastern coast of Apulia [26], the same situation is reported, confirming the total disappearing of the species from the Apulian seabeds.

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Figure 10. One of the 67 empty shell of *Pinna nobilis* observed during the monitoring activity along the Apulian coast of the Ionian Sea.

At present, this situation is widespread in the whole Mediterranean. Recent studies report that also in areas considered safe environments for the species, after a period of resistance, the survivors were impacted by a mass mortality [27]. Little unaffected populations holdout, especially in the Eastern Mediterranean [28–30]. These individuals could play a crucial role for the natural recolonization of the impacted areas, but, at the same time, according to [25], these survivors could be hybrids, not purebred individuals of *P. nobilis*, and the non-correct identification may cause problems regarding the conservation of the species. This issue must be better understood together with the plausible rise of *P. rudis* populations that opens new perspectives of study.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Video S1: Pinna nobilis dead, MP Taranto 2021.

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