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REVIEW ON *PINNA RUDIS* (LINNAEUS, 1758) (BIVALVIA: PINNIDAE) PRESENCE IN THE MEDITERRANEAN

SUMMARY

Pinna rudis (Linnaeus, 1758) or the rough pen shell, has Atlantic-Mediterranean distribution, and prefers warmer waters and harder substrates. Species is threatened by different factors and it is listed on Annex II of the Bern and Barcelona Convention. Some changes in species distribution are evident, most probably related to climate changes. Until 2018 presence of this species in the Adriatic Sea had not been confirmed with certainty, when it was found for the first time in Boka Kotorska Bay, what also presents first certain findings of the species in the Adriatic Sea. In this paper review on species presence along Mediterranean coast is given. Collected data indicate that species is more common in west Mediterranean compare to east and north part, and that future monitoring and status of population is required.

Key words: Pinnidae, *Pinna rudis*, Mollusca, Mediterranean

INTRODUCTION

The Mediterranean Sea is a marine biodiversity hot spot with approximately 17,000 species (Coll *et al.*, 2010). It is under “pressure” of alien species due to different factors such as climate changes. According to Webster (2007), Garrabou *et al.* (2009) and Mačić *et al.* (2014) the seawater temperature increase in the Mediterranean has affected the distribution and abundance of native as well as alien species. Albano (2013) indicated that some molluscs species have been proposed as descriptors of change of the biodiversity of the Mediterranean Sea under climate warming forcing. The same author described the changes in distribution of *Echinolittorina punctata* (Gmelin, 1791) and *Eastonia rugosa* (Helbling, 1779) through Mediterranean and mentioned that some species such as *Pinna rudis* (Linnaeus, 1758) could be more difficult to monitor because of their cryptic habitat and low density. Oliverio (1997) found the *P. rudis* at unusually high latitudes in the Tyrrhenian Sea, what according to Albano (2013), gives some signal of change which are probably related to climate changes. Bearing in mind that it is known that the indigenous thermophilic species which inhabit warmer waters are able to appear in more northern and colder parts of the

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Mediterranean due to the global warming (Coll *et al.*, 2010), finds of *P. rudis* in the Adriatic Sea are not surprising.

Changes in marine ecosystem usually have several causes, and their joint effect with degrading pressures on the living world of the sea has a critical role in maintaining diversity of species, ecosystem health and achieving good ecological status. Seas and oceans hide huge quantities of waste under the surface, representing a global landfill for decades. Waste accumulation and poor pollution prevention is a threat that will increasingly cost the generations to come (Mandić *et al.*, 2018).

Studies on *P. rudis* population are scarce and one of the main reasons is most probably linked to the low population densities (García-March & Kersting, 2006). Because of that each individual is important for the population sustainability. Although species is distributed through the Atlantic Ocean and the Mediterranean, it is not common as *Pinna nobilis* (Linnaeus, 1758).

The aim of this paper was to collect all available literature data about *P. rudis* presence in the Mediterranean and to provide map about its distribution.

MATERIAL AND METHODS

Papers for this review were collected mainly through keyword searches of Google scholar databases. We focused on the peer-reviewed journal literature, and also included material from books, reports as well as conference papers. Based on available literature the map about *P. rudis* presence/findings in the Mediterranean is given. The references indicated near some country names means that the species is mentioned as occurring near this country but without a precise location. For clarity, those publications indicating the existence of *P. rudis* in the Mediterranean Sea without offering a precise locality have been excluded. For example, Cosentino & Giacobbe (2006) mentioned that individuals of *P. nobilis* and *P. rudis* were collected from North Africa and the West and East Mediterranean, including the Adriatic Sea, but did not mention from which region which species was collected, therefore this publication is excluded.

RESULTS AND DISCUSSION

The rough pen shell *Pinna rudis* (Linnaeus, 1758)

Classification (WoRMS, 2019)

Kingdom: Animalia

Phylum: Mollusca

Class: Bivalvia

Subclass: Pteriomorphia

Order: Ostreida

Superfamily: Pinnoidea

Family: Pinnidae

Genus: *Pinna*

Species: *Pinna rudis* (Linnaeus, 1758)

Synonyms (WoRMS, 2019)*Pinna chautardi* var. *annobonensis* (Alvarado & Alvarez, 1964)*Pinna elongata* (Röding, 1798)*Pinna ferrugines* (Röding, 1798)*Pinna ferruginosa* (Röding, 1798)*Pinna mucronata* (Poli, 1795)*Pinna paulucciae* (Rochebrune, 1883)*Pinna pernula* (Chemnitz, 1785)*Pinna rudis* var. *belma* (de Gregorio, 1885)*Pinna rudis* var. *blama* (de Gregorio, 1885)**Description**

The Pinnidae family is a small family of large, fan-shaped “pen shells”, belonging to order of Ostreida (Lemer *et al.*, 2016). The family includes two genera, *Atrina* and *Pinna* (Lemer *et al.*, 2014) and 61 species (Vásquez-Luis *et al.*, 2017), which live either completely or half-buried in sand, mud or gravel bottoms, anchored in the substrate by byssus threads.

The species are large in size, usually between 15 – 35 cm, but they can be up to 120 cm (*Pinna nobilis* Linnaeus, 1758) (Huber, 2010). Most species have an Indo-Pacific distribution, but some species have been reported from the Caribbean Sea, West Africa, the Mediterranean Sea, the North East Atlantic, and west of America (Vásquez-Luis *et al.*, 2017).

P. rudis (Linnaeus, 1758) is distributed throughout the warm waters of the Mediterranean Sea as well as the Atlantic Ocean (Poppe & Goto, 1993; Huber, 2010). It prefers gravel bottoms from below the low tide line down to 40 m (Poppe & Goto, 1993), but it is also found in *Posidonia* meadows (Garzía-March & Kersting, 2006).

The species is threatened by different factors, including anchoring, fishing, collection and habitat disruption (Tunesi *et al.*, 2006) and it is listed by Annex II of the Bern Convention as a strictly protected species and by Annex II of the Barcelona Convention as a threatened or endangered marine species.

Species can reach dimensions up to 50 cm (Garzía-March & Kersting, 2006). The external color of the valves is reddish brown. The valves are symmetrical, triangular, transparent at the ends and also very fragile with 5 to 10 radiating ribs, covered with large scales arranged in quite regular rows. Morphologically, *P. rudis* can be confused with *P. nobilis* juveniles but in *P. rudis* the shell is more triangular and robust with fewer and larger protruding scales.

Adult *P. nobilis* exceed the size of *P. rudis* and lose the protuberances on the surface of the shell. The mantle border is usually white and iridescent in *P. rudis* and pink in *P. nobilis*. The nacre lobes on the inner side of the valves are of a similar size in *P. rudis* (Garzía-March & Nardo, 2006).

Mediterranean records

Most authors, e.g., Poppe & Goto (1993), UNEP/MAP/MED POL (2005) and Huber (2010), mentioned that *P. rudis* is present only in the warmest area of the Western Mediterranean. Based on all collected data, it is evident that species is more abundant in western Mediterranean waters, especially along the Spanish coast. Data about *P. rudis* presence in the East Mediterranean are rare (Öztürk & Çevik, 2000; IOPR, 2003; El-Komi *et al.*, 2007; UNEP, 2011; Salomidi *et al.*, 2016; Aguilar *et al.*, 2018), while presence of species in the Adriatic Sea was certainly confirmed recently (Petović, 2018). Records of *P. rudis* through Mediterranean waters, based on all collected literature data, are given in Figure 1.

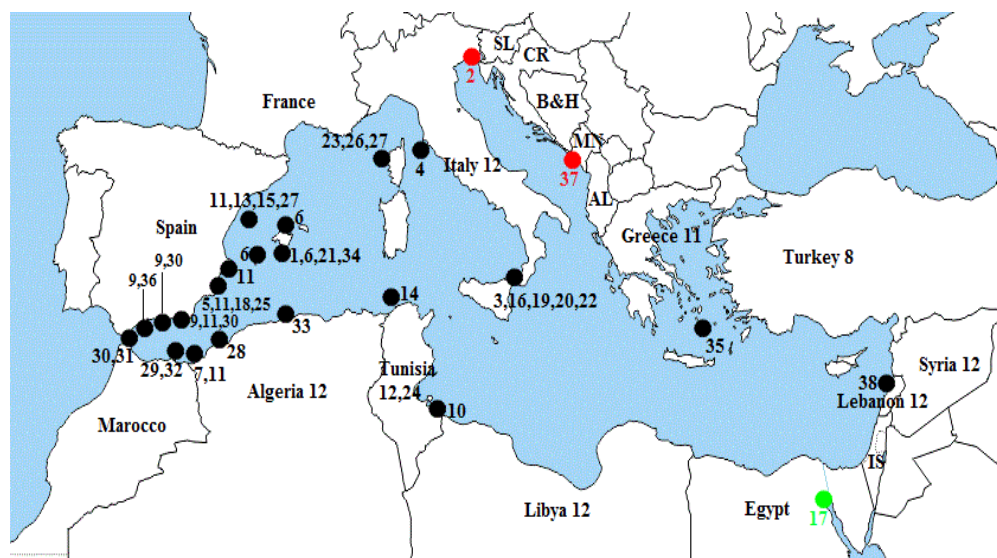


Figure 1. Mediterranean records of *Pinna rudis*. SL – Slovenia, CR – Croatia, B&H – Bosnia and Herzegovina, MN – Montenegro, IS – Israel.

1. Hidalgo (1917); 2. Stackowitsch (1984); 3. Giacobbe & Rinelli (1991); 4. Oliverio (1997); 5. Richardson *et al.* (1997); 6. Ballesteros (1998); 7. Guallart (2000); 8. Öztürk & Çevik (2000); 9. Templado (2001); 10. Mustapha *et al.* (2002); 11. Garzía-March (2003); 12. IOPR (2003); 13. Garzía-March & Kersting (2006); 14. Garzía-March & Nardo (2006); 15. Sempere *et al.* (2006); 16. Cosentino & Giacobbe (2007); 17. El-Komi *et al.* (2007); 18. Giménez-Casaldueiro *et al.* (2009); 19. Crocetta *et al.* (2009); 20. Giacobbe *et al.* (2009); 21. Jimenez *et al.* (2010); 22. Vazzana (2010); 23. Vicente (2010); 24. UNEP (2011); 25. Giménez-Casaldueiro *et al.* (2011); 26. Vicente & Trigos (2012); 27. Trigos *et al.* (2013); 28. Boumediene & Djillali (2014); 29. Espinosa *et al.* (2014); 30. García-Gómez *et al.* (2014); 31. Department of the Environment and Climate Change (2015); 32. Espinosa *et al.* (2015); 33. Bachertazi *et al.* (2016); 34. Nebot-Colomer *et al.* (2016); 35. Salomidi *et al.* (2016); 36. Urra *et al.* (2016); 37. Petović (2018); 38. Aguilar *et al.*, 2018

Spain (including Gibraltar)

Based on all collected data we found the highest number of *P. rudis* records along the Spanish coast, mainly southern part of the coast as well as Balearic, Columbretes and Chafarinas islands. Hidalgo (1917) reported *P. pernula* (synonym for *P. rudis*), for Cabrera islands. Richardson *et al.* (1997) examined *P. rudis* and *P. nobilis* shell on presence of *Pontonia pinnophylax* (Otto, 1821) in Carboneras, Aguamarga and Villaricos. Ballesteros (1998) reported *P. rudis* for the whole area of Balearic archipelago and mentioned that it is not abundant as *P. nobilis*. In soft sediments of Chafarinas islands, Guallart (2000) have been found mean density of *P. rudis* 0.7 ind./m², and rates *P. nobilis*/*P. rudis* of 4.6:1. Templado (2001) observed *P. rudis* in area between Gibraltar Strait and Almería Bay, with greater density of individuals respect to *P. nobilis*. Garzía-March (2003) report that the relative abundance of *P. rudis* grows southwards, and that species is abundant in the Almería seagrass meadows. Author has also been found species in the Moraira bay, the Chafarinas islands, Murcia and Almería, inside the meadow of *P. oceanica* coexisting with *P. nobilis*. Garzía-March & Kersting (2006) gave the data about distribution and density of *P. rudis* and *P. nobilis* in the Columbretes Islands Marine Reserve.

By island groups, authors observed the densest population in El Carallot (1 ind./100 m²), followed by L'Illa Grossa (0.3 ind./100 m²), La Ferrera (0.3 ind./100 m²) and La Forada (0.2 ind./100 m²). For the same area Sempere *et al.* (2006) indicate *P. rudis* as not so abundant species and gave morphometric parameters of some individuals. Jimenez *et al.* (2010) indicate *P. rudis* presence in area of Cabrera islands (Balearic islands). Giménez-Casalduero *et al.* (2011) listed *P. rudis* in coastal part of Murcia as protected species listed on Annex II of Barcelona and Bern Convention. In Columbrete islands low density of *P. rudis*, 0.3 ind./100 m², is reported by Trigos *et al.* (2013). Authors also reported that individuals are apparently separated from each others. Presence of *P. rudis* in area of Gibraltar is reported by García-Gómez *et al.* (2014) and Department of the Environment and Climate Change (2015). García-Gómez *et al.* (2014) indicate *P. rudis* on different types of substrates used in the construction of port structures and breakwaters (dolomitic quarried rock, cubic concrete block and concrete tetrapod) in the Strait of Gibraltar and the Mediterranean coast of Andalucía and Gibraltar, specifically in Ceuta, Tarifa, Algeciras, La Línea, Gibraltar, La Mamola and Motril, while in Department of the Environment and Climate Change (2015) *P. rudis* was listed for British Gibraltar territorial waters on sub-tidal rocky reef, both natural and artificial. Nebot-Colomer *et al.* (2016) in their study provides quantitative information on the population structure, age and growth of the pen shell in a marine protected area (Archipelago of Cabrera – Balearic islands) and due to the low densities observed, authors noted that each individual is important for the sustainability of the population. On the coastline between Punta de Calaburras and Calahonda presence of *P. rudis* is noted by Urrea *et al.* (2016). Although, during 2017 along Spanish coast mass mortality of

P. nobilis due to parasite infection was mentioned (Vázquez-Luis *et al.*, 2017; Martinović *et al.*, 2019), *P. rudis* was not affected (Vázquez-Luis *et al.*, 2017).

Marocco

In Marocco waters *P. rudis* is mentioned by (Espinosa *et al.*, 2014; 2015) in Cap des Trois Fourches (Northern Marocco). Espinosa *et al.* (2014) did characterizing of the marine biodiversity in Cap des Trois Fourches, while Espinosa *et al.* (2015) gave spatial distribution of dominant assemblages in order to allow the implementation of MPA in the Cap des Trois Fourches. In both studies *P. rudis* was listed as endangered species present in this area.

Italy (without Adriatic coast)

In IOPR (2003) species is just mentioned for the Italy and it is concluded that inventory on this species is one of future topic that should be developed. Oliverio (1997) observed *P. rudis* at unusually high latitudes in the Tyrrhenian Sea (Tuscan Archipelago). Five other studies listed species as present in area of Messina. Giacobbe & Rinelli (1991) examined shell of *Pinna nobilis* and *Pinna rudis* as habitat of the rare echinoid *Arbaciella elegans* (Ole Theodor Jensen Mortensen, 1910). Consentino & Giacobbe (2007) gave composition and structure of epizobiontic mollusc assemblages on both *P. nobilis* and *P. rudis* shell. Crocetta *et al.* (2009) listed the most common macro-molluscs, including *P. rudis*, in association with alien Mollusca along the Calabrian shores of the Messina Strait. Giacobbe *et al.* (2009) suggest that the occurrence of both *P. nobilis* and *P. rudis* in the Faro lake had in the ancient age a remarkable symbolic value, probably linked to the economic importance of the byssus production, and that the occurrence of these two protected species adds a high historical and cultural value to the ecological heritage of the protected area of Capo Peloro. Vazzana (2010) studied the Mollusks fauna occurring in the bottom sediment off Scilla (Messina Strait) and listed *P. rudis* as present in this area.

France

Only one location (Nature Reserve Scandola – Corsica) with *P. rudis* presence is listed for France (Vicente, 2010; Vicente & Trigos 2012; Trigos *et al.*, 2013). Results about *P. rudis* and *P. nobilis* monitoring in Nature Reserve Scandola are given in two reports (Vicente, 2010; Vicente & Trigos, 2012). Species is described as not so common and a few individuals are monitored since 2000 year. Vicente & Trigos (2012) indicate that most probably larvae of *P. rudis* originated from Spain and by sea currents arrived to the coast of Corsica. Trigos *et al.* (2013) reported low density of *P. rudis*, 0.25 ind./m² in this Nature Reserve.

Tunisia

In Tunisia IOPR (2003) and UNEP (2011) mentioned species without precise location. As for the Italy coast, also for Tunisia in IOPR (2003) this

species is just mentioned without precise locality, while UNEP (2011) just gave the list of Tunisia Mollusks including *P. rudis*. Mustapha *et al.* (2002) described Tunisian mega benthos from infra and circalittoral sites and found largely spread coverage of *P. rudis* and *P. nobilis* in El Bibane lagoon where authors also found very special kind of sponge reefs "buildups", recorded for the first time in the Mediterranean. Garzia-March & Nardo (2006) reported a dense population of both *P. rudis* and *P. nobilis* estimated to consist of more than 30 ind./100 m² in Galite Islands Marine Park.

Algeria

In Algeria waters IOPR (2003) also listed *P. rudis* without precise location, and indicate that inventory on this species should be developed in future. Boumediene & Djillali (2014) in their observation of the macrozoobenthos biodiversity of Oran coastal area indicate *P. rudis* as part of middle horizon biocenosis (3-15 m depth), while Barchertazi *et al.* (2016) observed a significant number of ecological, patrimonial, protected statuses, threatened, endemic and invasive species in their study about biodiversity of Agueli island, and mentioned *P. rudis* as protected one in this area.

Israel

Israel is the country for which any literature data about *P. rudis* presence was not found, even any data which just mention species as present on the Israel coast.

Egypt

In Egypt species is indicated in Suez Canal, but in El-Ein El-Sukhna station (El-Komi *et al.*, 2007) which is actually part of the Red Sea, so it can not be consider as Mediterranean record. When we have in mind only Mediterranean waters Egypt can also be considered as the country without any record of *P. rudis*.

Turkey, Syria, Libya

For Turkey, Syria and Libya only one record of each of the country was found, and in those sources, species was mentioned without a precise location (Öztürk & Çevik, 2000; IOPR, 2003). Öztürk & Çevik (2000) just indicate that three members of Pinnidae family, *P. rudis*, *P. nobilis* and *Atrina pectinata* inhabit the coast of Turkey. IOPR (2003) just mentioned *P. rudis* for Syria and Libya.

Lebanon

For Lebanon also IOPR (2003) just mentioned *P. rudis*, while Aguilar *et al.* (2018) in „Deep Sea Lebanon” publication, report *P. rudis* in area of Batroun in abundance of 1-10 ind./area in detritic sediments. In other investigated areas (Beirut, Jounieh, Sayniq and St. George) species has not been found.

Greece

Two literature sources were found for Greece. IOPR (2003) indicate species for Greece waters without a precise location. Salomidi *et al.* (2016) indicate *P. rudis* for Santorini island complex in the Aegean Sea (Nea Kameni island, Aspronisi island and south-west part of Thera island) in the study about getting qualitative and quantitative information on the current ecological state and future potential of the Santorini island as MPA.

Adriatic Sea (Adriatic coast of Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania)

Based on the available literature, there was only one record of the species for the Adriatic Sea, provided by Stackowitsch (1984) who reported *P. pernula* (synonym for *P. rudis*) from the Gulf of Trieste (Italy). This author mentioned a high abundance (approx. 5 ind./m²) and that all the individuals were dead, but did not give any pictures of individuals and did not provide any further discussion. Abundance, 5 ind./m² is quite questionable, as so high abundance was not mentioned for western areas where species is more common. By 2016 the presence of *P. rudis* in the Adriatic Sea had not at any point been confirmed with certainty (Prvan & Jakl, 2016).

First certain record of *P. rudis* for the Adriatic Sea is reported by Petović (2018). Author mentioned species (only empty shells) from Kostanjica to Risan (Boka Kotorska Bay) on muddy-sandy substrate at about 20 m depth. Petović (2018) indicate that presence of the species in the Bay is not a new, but in the literature was missing for an unknown reason. The first data on the macromolluscs of the Boka Kotorska Bay dates from the 1970s and 1980s (Stjepčević, 1967; Karaman & Gamulin-Brida, 1970; Stjepčević & Parenzan, 1980; Stjepčević & Parenzan, 1982). In these studies, only *P. nobilis* and *P. pectinata* (Linnaeus, 1758) were mentioned as representatives of the Pinnidae family. Petović & Marković (2017) and Petović *et al.* (2017) also listed these two Pinnidae species for the Boka Kotorska Bay. One of reasons why species was not earlier listed for the Boka Kotorska Bay and most part of the Adriatic Sea is that maybe authors confused it with other Pinnidae species, while on the other hand it is possible that authors did not record it simply because its less numerous populations and fact that prefers deeper water. Third reason can be related to the fact that species did not inhabit Adriatic Sea in the past, and that climate changes affect it spreading on the north.

CONCLUSIONS

Data about *P. rudis* populations are scarce, including its biology, ecology and distribution. Low population density is present at almost all sites where the presence is confirmed. Monitoring and status of the species populations, especially in the central, east and north Mediterranean is required, although low density and cryptic habitat hinders the monitoring. Trigos *et al.* (2013) suggested that MPAs are supposed to be the best environmental tool to guarantee the

protection of endangered species. Future step on the national level should be including of *P. rudis* on the list of protected marine species in Montenegro. Finding of *P. rudis* in Montenegrin waters and fact that species is listed by Annex II of the Bern Convention as a strictly protected species and by Annex II of the Barcelona Convention as a threatened or endangered marine species and that inhabits Posidonia beds and Reefs (habitats listed as priority in EU habitat directive), should have positive effects towards the soonest possible promulgation of MPA in Montenegro.

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