

Rayed pearl oyster *Pinctada radiata* (Leach, 1814) (Bivalvia: Pteriidae) in the eastern Adriatic Sea – recent observations

Zrakasta bisernica *Pinctada radiata* (Leach, 1814) (Bivalvia: Pteriidae) u istočnom dijelu Jadrana – novija opažanja

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Abstract

Adriatic Sea as a part of the Mediterranean is settled by many introduced species which extend their range northward. Among them is the rayed pearl oyster *Pinctada radiata*, a mollusk of Indo-Pacific origin that colonises habitats throughout the Mediterranean. *P. radiata* established a population in a fish farm on the island of Mljet in the Adriatic Sea, which was observed in 2017. To determine the status of the population, 48 specimens of *P. radiata* were randomly sampled from the ropes of a fish farm in 2019. Morphometric parameters were determined using a digital calliper. The recorded parameters showed that shell height ranged from 50.55 mm to 72.98 mm, shell length from 46.66 mm to 71.15 mm, and shell width from 19.98 mm to 58.54 mm. During additional visual survey in 2020 the presence of the spat within population at Mljet fish farm was not observed. It appears that only adult specimens are present, and it is unclear if the population is reproducing. In addition, *P. radiata* spat was observed in the shallow waters of Lokrum Island in 2021 and 2022, indicating the possibility of survival of larvae naturally dispersing from pre-existing populations. An adult specimen of *P. radiata* was also observed in Mali Ston Bay on two occasions, in 2009 and 2021. *P. radiata*, a highly adaptable species that tolerates a wide range of environmental factors, has successfully colonised new habitats.

Sažetak

Jadransko more dio je Sredozemlja pa ga naseljavaju mnoge vrste koje nakon ulaska u Sredozemno more šire svoj areal prema sjeveru. Među njima je i zrakasta bisernica *Pinctada radiata*, mekušac indo-pacifičkog porijekla. *P. radiata* uspostavila je populaciju koja je 2017. godine opažena na ribogojilištu na otoku Mljetu u Jadranskom moru. Radi utvrđivanja statusa populacije, 2019. godine 48 jedinki *P. radiata* nasumično je uzorkovano s konopa ribogojilišta. Morfolometrijski parametri određivani su digitalnim pomičnim mjerilom. Izmjerene vrijednosti pokazale su da se visina školjkaša kretala od 50,55 mm do 72,98 mm, duljina od 46,66 mm do 71,15 mm, a širina od 19,98 mm do 58,54 mm. Područje ribogojilišta Mljet dodatno je pregledano 2020. godine i pri tome među jedinkama nije uočena mlađ. Kako izgleda da su prisutne isključivo odrasle jedinke, nije jasno razmnožava li se populacija *P. radiata* na ovom području. Uz to, mlađ je uočena u plitkim vodama otoka Lokruma 2021. i 2022. godine, što ukazuje na mogućnost preživljavanja ličinki koje se prirodno rasprostranjuju iz prethodno uspostavljenih populacija. Po jedna odrasla jedinka *P. radiata* uočena je u Malostonskom zaljevu u dva navrata, 2009. i 2021. *P. radiata*, vrlo je prilagodljiva vrsta koja podnosi širok raspon čimbenika okoliša, pa je uspješno kolonizirala nova staništa.

KEY WORDS

Pinctada radiata
non-indigenous species
invasive species
Adriatic Sea
Croatia

KLJUČNE RIJEČI

Pinctada radiata
alohtone vrste
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Jadransko more
Hrvatska

1. INTRODUCTION

The construction of the Suez Canal in 1869 meant not only a shortened voyage for ships, but also a passage for allohtonous organisms. The removal of natural barriers allowed the spread of marine organisms from the Pacific/Indo-Pacific/Red Sea origin to the Mediterranean [1]. Once the organism arrives in a new,

suitable habitat, it may establish a population and possibly expand its range further. To date, nearly 1,000 species have been introduced from the Red Sea to the Mediterranean, and it appears that nearly half of them have established populations and continue to spread [2].

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Five years after the opening of the Suez Canal, in 1874, the malacologist Monterosato first described the pearl oyster *Pinctada radiata*, native to Indo-Pacific region as adapted in the Alexandria area (Egypt). *P. radiata*, most likely a circumtropical species is considered the first Lessepsian migrant [3] and is very abundant in the Levant Basin [1]. Due to its good adaptability and tolerance to a wide range of environmental factors as well as, its ability to disperse by ocean currents, *P. radiata* has successfully spread throughout the northern and western Mediterranean [4]. Humans have also contributed to the spread of *P. radiata*, either by deliberate introduction for aquaculture purposes, as in Greece [5,6], or by accidental introduction through ship fouling in France, and Italy (Gulf of Trieste, Adriatic Sea) [7,8]. The *P. radiata* is widely distributed in Greece and Italy and is considered an established species [9, 10]. Since 2015, numerous detections of pearl oysters have been recorded in Albania [11], and a successfully colonised pier was also discovered in the port in Montenegro [12]. The first record of *P. radiata* in Croatia consisted of two specimens found in the northern Adriatic Sea in 2006 [13]. The first established population was recorded in a fish farm on the island of Mljet, one of the southernmost Croatian islands [14]. The morphometric characteristics of the Mljet island *P. radiata* population are presented in this paper as well as recent records of the *P. radiata* spat in the Lokrum Island waters and earlier observations in the Bay of Mali Ston.

2. MATERIALS AND METHODS

The Adriatic Sea is the northernmost arm of the Mediterranean Sea, where waters from the Mediterranean Sea enter through the Strait of Otranto and continue along the eastern coast, spreading many organisms northward by passive transport. The influence of the waters of Otranto is greatest in the southernmost areas of the eastern Adriatic.

In June 2019, 48 specimens of *P. radiata* were taken at random from the ropes of a fish farm on the island of Mljet (Figure 1) at a depth of 4-6 metres. The samples were stored in a refrigerator, and morphometric parameters were measured after 48 hours. The morphological measurements were performed according to [15]. The morphometric parameters were determined using a digital calliper (accuracy 0.1 mm) and included shell length (SL), shell height (SH), shell width (SW) hinge length (HL), while wet weight (WWTOT), including shell weight and soft body weight, shell weight (WS), wet tissue weight (WWT), and dry tissue weight (WDT) were measured using digital balance (accuracy of 0.001 g). Dry weight was determined after 24 hours of drying the wet soft tissue in a dryer at 110 °C. Data were entered into tables, and averages were calculated using MS Excel.

To determine the presence of the spat within population at Mljet fish farm, an additional underwater visual census was conducted in June 2020.

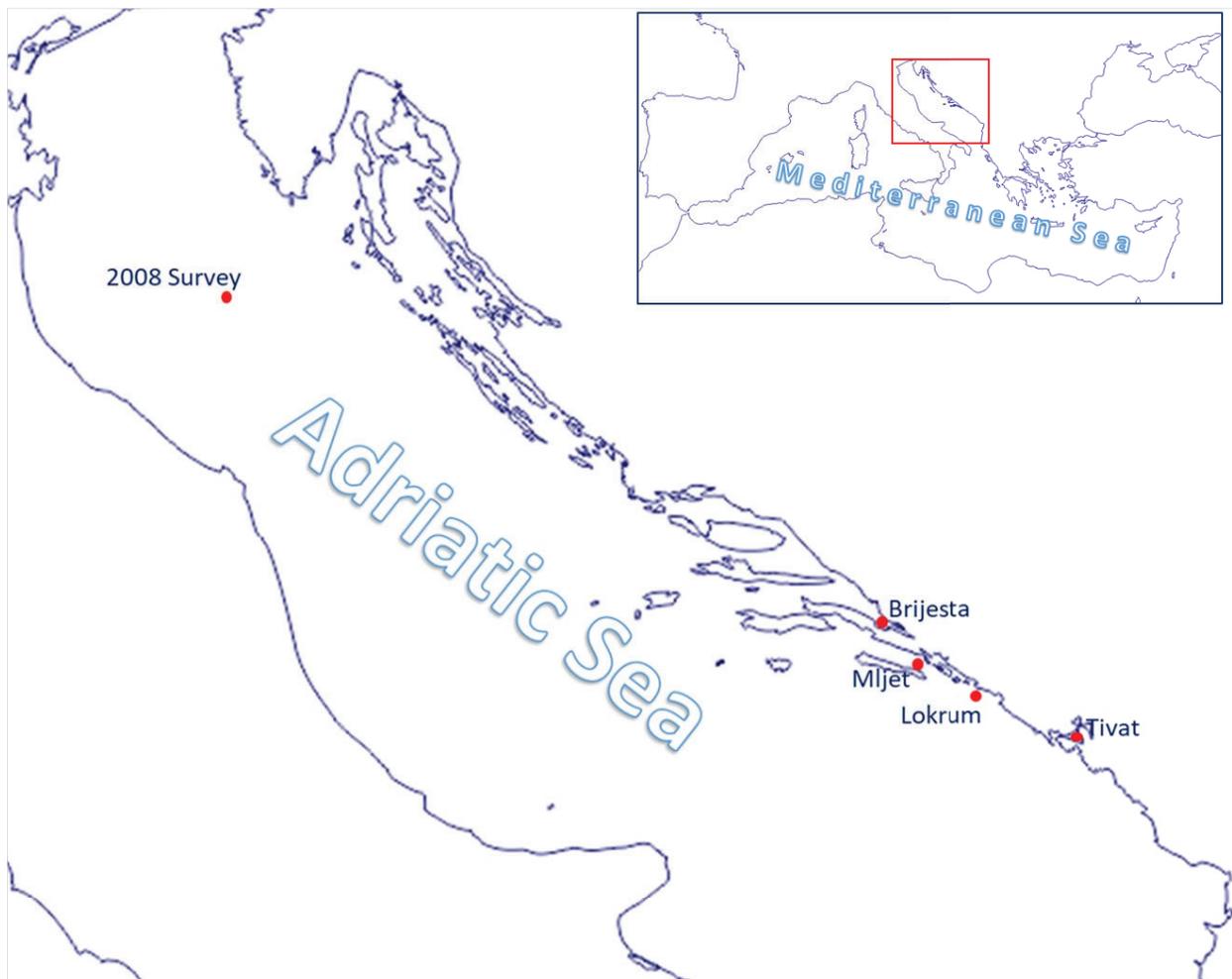


Figure 1 Geographical position of *Pinctada radiata* findings in Adriatic Sea: 2008 Survey- two juvenile specimens [13], Brijesta - adult specimens on two occasions (2009 Onofri, 2021 Franušić – oral communications), Mljet – established population [14], Lokrum – spat on more than one occasion, Tivat – established population [12]

In the waters of the island of Lokrum, 46 km southeast of the fish farm Mljet, sets of collectors for bivalve spat were anchored at three locations, in July 2021 and May 2022 (Figure 1). The collectors consisted of four 60×40 cm mesh polypropylene bags for vegetable storage and were attached to a rope in of two-meter intervals. In October 2021 and October 2022, the collectors were retrieved from the sea and immediately examined. Organisms settled on the collector bags were collected, fixed in ethanol and preserved. Species identification was performed in the laboratory.

On two occasions, divers found single specimens of *P. radiata* among other bivalves in the shellfish farms in Brijesta, Maloston Bay (Figure 1) (pers. comm. V. Onofri, 2009 and M. Franušić 2021).

3. RESULTS AND DISCUSSION

Specimens of *P. radiata* found attached with byssus threads to the farm ropes along with the native Mediterranean mussels at the Mljet fish farm (Figure 2) were sampled at random and 48 specimens underwent morphometric measurements.

The minimum, maximum and average values of biometric parameters of the specimens of *P. radiata* samples from Mljet fish farm are shown in Table 1.

Shell height ranged from 50.55 mm to 72.89 mm and shell length ranged from 46.66 mm to 71.15 mm, corresponding to the shell heights and lengths of the specimens from the 2017 survey at Mljet fish farm [14]. However, shell width values, which ranged from 19.98 mm to 58.54 mm, were much higher compared to shell widths from the 2017 survey (12.66-26.45 mm), so it appears that pearl oysters in this area grow much more with increasing shell width. The lack of smaller individuals suggests that there has been no spawning recruitment in the intervening period [14]. During the study around the island of Linosa in the Sicilian Channel (Italy), both adult and juvenile specimens were observed and a maximum size of 78.7 mm was recorded [15]. The average value of shell height (64.78 mm) corresponds to the average shell height of samples collected in 2017 [14] and those from the Aegean Sea [19], as well as samples from Turkey [20, 21] and Tunisia [22]. The biometric parameters measured in the samples collected in Montenegro, the nearest observed established population, were lower, the shell height ranged from 32 mm to 52 mm with an average shell height value of 38.3 ± 6.1 mm [12].

The average wet weight of the sampled oysters was 23.33 g (8.90 g - 37.30 g), which is significantly lower than the average of 50.09 ± 16.25 g measured for samples from the Gulf of Antalya in May [20].



Figure 2 Rayed pearl oyster, *Pinctada radiata* attached to the ropes at Mljet fish farm (south-eastern Adriatic, Croatia)

Table 1 Minimum, maximum and average values of biometric parameters of the rayed pearl oyster *P. radiata* samples (N=48)

	Shell height (mm)	Shell length (mm)	Shell width (mm)	Hinge length (mm)	Total Wet weight (g)	Shell wet weight (g)	Tissue wet weight(g)	Total dry weight(g)	Shell dry weight(g)	Flesh dry weight(g)
Mean	64.78	63.08	29.28	55.86	23.33	13.27	6.78	13.16	12.04	1.13
Standard Deviation	5.43	5.27	5.41	4.93	5.75	3.12	1.59	3.01	2.78	0.30
Minimum	50.55	48.66	19.98	44.15	8.90	4.69	2.77	4.68	4.26	0.42
Maximum	72.89	71.15	58.54	65.94	37.30	22.15	10.16	22.46	20.79	1.91

The size of the sampled individuals, as well as previous studies indicate perennial survival and adaptation of a relatively numerous population *P. radiata* is a protandrous hermaphrodite, and the first sexual maturity occurs at a size of 17 mm [16]. Since *P. radiata* has a well-defined annual reproductive cycle, in which temperature is probably the most important parameter for maturation and spawning [17] it can be assumed that all observed individuals are sexually mature. Potential offspring were not observed in the collected samples. The reason for the absence of juveniles is not clear. A visual survey of the population was conducted in 2021, and no juveniles were observed either, so it appears that oysters are not reproducing in the Mljet area. Since Mljet is directly exposed to the water masses coming from the Ionian Sea through the Strait of Otranto, bringing with them everything that cannot resist the currents, this could very well be an introduction path of the existing population on Mljet. The larval cycle of *Pinctada* spp. is 16-30 days, depending on genetics, temperature, food, and substrate availability, so it is possible that the potential spawning source is quite distant [18]. This is confirmed in October 2021 and in October 2022 during samplings of spat collectors in the waters of Lokrum Island, 46 km southeast of Mljet island. On those sampling occasions 6 specimens up to 10 mm in size were recorded at the collectors immersed from July to October 2021 and one specimen of *P. radiata* at the collectors immersed from May to October 2022. *Pinctada* is an epibiont that colonizes the substrate by attaching byssus threads, and it seems that it prefers anthropogenic substrates where it is a pioneer. It is also found in the area of Mali Ston Bay, an area where oysters and mussels are traditionally farmed and which is not directly exposed to incoming Adriatic currents. On two occasions, divers found a 90 mm and a 95 mm specimen amidst the native European flat oysters *Ostrea edulis*. The first specimen was found in 2009 (V. Onofri, oral communication), the second in October 2021 (M. Franušić, oral communication). Since these individuals are the oldest found so far in the Adriatic, and since they occur in the area of shellfish farming, it can be expected that the spread of the population would not go unnoticed. It appears that spat prefers previously uncolonized substrate [12, 14], so newly submerged buoys, ropes, farms, piers, etc. should be observed.

As a first Lessepsian immigrant [3] and highly adaptable and tolerant of a wide range of environmental factors, *P. radiata* has successfully spread throughout the Mediterranean [4]. It was accidentally introduced into the Adriatic Sea by ship fouling [8], but it appears that the primary route of introduction and spread for *P. radiata* is inter-basin connectivity, which allows natural dispersal [23]. Established and naturalized populations are expected to expand their range over time. In addition to the high reproductive potential and use of natural pathways and increasingly favourable temperatures, vessels, marine litter, or animals to which *P. radiata* individuals can attach will also contribute to the effective dispersal of the *P. radiata* and accelerate long distance spread. Impacts to native organisms and ecosystems, as well as to traditional shellfish farming should be expected in near future.

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