Studia Marina 2026, 39(1): 41-45
Short communication

UDC 594.1(497.8)
DOI 10.5281/zenodo.20377848

First record of natural pearl formation in the invasive bivalve *Pinctada radiata* (Leach, 1814) from the Adriatic Sea

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ABSTRACT

Pearls are formed naturally within mollusks and are valued for their aesthetic, cultural, and economic significance. Although most pearls available today are cultured, natural pearls remain rare. This study documents two naturally produced pearls in *Pinctada radiata* from a shellfish farm in Boka Kotorska Bay, Montenegro, confirming the species capacity for natural biomineralization. This finding complement previous findings from Bahrain, where a variety of natural pearl types have been documented in this species. This finding also highlights the ecological and potential economic importance of *P. radiata*, and suggests possibilities for further research, sustainable and responsible utilization of this species in newly colonized areas.

Keywords: mariculture, pearls, oysters, Boka Kotorska Bay

Pearls are a unique type of gemstone, as they are formed through natural processes within mollusks, unlike most other precious stones. Due to their beauty and long-standing presence in various cultures, pearls hold an important place in the history of adornment and art. Pearls develop as a defensive response to irritants that become lodged within the soft tissues of the mollusk.

Bivalves from the genus *Pinctada* are commercially cultivated throughout the Indo-Pacific region, primarily for the pearl industry. Global cultured pearl production is estimated to be over 2000 metric tons, with more than 98% from freshwater mussels, cultured mainly in China (Southgate, 2024).

Cultured pearls are produced through human intervention by surgically inserting a mantle tissue pieces (*saibo*) from a donor oyster into the gonad or the mantle of a recipient oyster. Donor oysters are individuals with high quality nacre (mother of pearls), as such nacre will form the present cultured pearl. Following the implantation, the *saibo* forms a pearl sac. Adding a bead is optional, with its shape and size depending on the shell and implantation site. Once formed, a pearl sac can be reused, and re-beading is done if the first pearl is of good quality (Hänni, 2012). Contrary to cultured, natural formation of pearls is very rare (<1% of oysters).

The nacre of pearls is composed of about 5% of protein, so-called "conchiolin" and upwards of 90% of calcium carbonate (Wada, 1981). The quality of a pearl is judged mainly from four aspects: color, size, shape and smoothness. The factors that affect the quality of pearl include environmental factors, structural factors and genetic factors (Zhang *et al*., 2024).

Here we report two naturally produced pearls in *Pinctada radiata* (Leach, 1814) from the shellfish farm "Ljuta", in Boka Kotorska Bay (42.474281 N, 18.763432 E). At the farm, Mediterranean mussel (*Mytilus galloprovincialis* Lamarck, 1819) and European flat oyster (*Ostrea edulis* Linnaeus, 1758) are cultivated, while *Pinctada radiata* occurs as a fouling organism on aquaculture structures such as pergolars, ropes, and buoys.

On 17th December 2025, during routine farm maintanance activities, shellfish farmer Luka Milošević accidentally observed two specimens of *P. radiata* containing pearls. Both *P. radiata* specimens were adults cca. 45 mm in height. The pearls were whitish in color, smooth, and round (diameter: 4.289 mm and 4.832 mm) (Figure 1). The pearls are preserved and owned by farmer Luka Milošević. Up to our knowledge, this is the first record of natural pearls in *P. radiata* from the Adriatic Sea.



Figure 1. Two natural pearls from *Pinctada radiata*, Boka Kotorska Bay

P. radiata is an allochthonous and invasive species, first observed in Montenegrin coastal waters in 2016 in Marina Porto Montenegro, Boka Kotorska Bay (Petović & Mačić, 2017). After first finding, the species has successfully colonized the bay, particularly mussel and oyster farms, where it has become one of the dominant fouling organisms (Petović, 2018; Nikolić *et al*., 2024).

Contrary to sister taxa (e.g. *P. fucata*, *P. margaritifera*, *P. maxima*), *P. radiata* has rarely been used for pearl cultivation. *P. radiata* was introduced to Greece for pearl cultivation, but this practice was later abandoned because it proved to be economically unprofitable (Serbetis, 1963). However, the Abu Dhabi Pearls project confirmed in January 2010 that *P. radiata* can be used to culture pearls. Since then, about 150,000 pearls have been produced, around 25% of very good to excellent quality, typically 5–8 mm in size and varying in shape and color, with no post- harvest treatment (Al-Alawi *et al*., 2020).

First naturally produced pearls by *P. radiata* in Mediterranean Sea were found in the Saronic Gulf (Kalopissis, 1981). Before that it was belived that *P. radiata* does not

produce natural pearls - “it does not produce the characteristic pearls of tropical seas” (Parenzan, 1974 cited in Kalopissis, 1981).

Recent studies on natural pearls from *P. radiata* in Bahrain, Arabian Gulf, have documented a range of pearl types (Al-Alawi *et al*., 2023; Vaz *et al*., 2023; Mane *et al*., 2025). Using techniques such as microscopy, radiography, spectroscopy, and chemical analysis, these studies have provided detailed insights into their internal structures and composition, confirming their natural origin and distinguishing them from cultured pearls.

In conclusion, pearls from *P. radiata* represent a rare but noteworthy example of natural pearl formation, contributing to the broader understanding of both natural and cultured pearl development.

Recent observations in Boka Kotorska Bay show that this non-native species, despite its invasive status, is capable of producing natural pearls under local environmental conditions.

These finding points to the ecological and potential economic importance of *P. radiata*, and suggest possibilities for further research, sustainable and responsible utilization of this species in newly colonized areas.

Although this finding is of considerable scientific importance and provides new insights into pearl formation in marine bivalves, the occurrence of an invasive species requires careful ecological consideration. Regular monitoring of population dynamics, reproductive stages, and dispersal pathways is essential in order to better understand its establishment and spread. Preventing anthropogenic translocation between sites should be considered a priority management measure. Furthermore, targeted removal through controlled scientific harvesting may represent a useful tool for limiting the expansion of *P. radiata* in the Adriatic Sea while simultaneously enabling further scientific investigation.

ACKNOWLEDGEMENT

Many thanks to shellfish farmer Luka Milošević for informing the Institute about this finding and for granting permission to publish it.

Declaration of competing interest

Due to her position as Technical Editor of Studia Marina, Slađana Nikolić was not involved in the peer review process of this manuscript. The complete editorial responsibility for this paper was assigned to Editor in Chief.

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Received: 28.01.2026
Revised: 18.05.2026
Accepted: 01.06.2026

Prvi nalaz prirodnog formiranja bisera kod invazivne školjke *Pinctada radiata* (Leach, 1814) u Jadranskom moru

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SAŽETAK

Biseri se prirodno formiraju unutar mekušaca i cijenjeni su zbog svog estetskog, kulturnog i ekonomskog značaja. Iako je većina bisera dostupnih danas kultivisana, prirodni biseri su i dalje rijetki. Ova studija dokumentuje dva prirodno formirana bisera kod vrste *Pinctada radiata* sa uzgajališta školjki u Bokokotorskom zalivu, Crna Gora, potvrđujući sposobnost ove vrste za prirodnu biomineralizaciju. Ovi nalaz dopunjuje prethodna istraživanja iz Bahreina, gdje su dokumentovane različite vrste prirodnih bisera kod ove vrste. Takođe ističe ekološki i potencijalni ekonomski značaj vrste *P. radiata*, i ukazuje na mogućnosti za dalja istraživanja kao i za održivo i odgovorno korišćenje ove vrste u novo kolonizovanim područjima.

Ključne riječi: marikultura, biseri, ostrige, Bokokotorski zaliv