Studia Marina 2024, 37(1): 32-40 UDC: 639.42(262.3)(497.16)
Short communication DOI: 10.5281/zenodo.12770947

Biometric features of non-indigenous rayed pearl oyster, *Pinctada radiata* (Leach, 1814) (Bivalvia: Margaritidae) in the Boka Kotorska Bay

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ABSTRACT

In this paper results about biometric parameters of non-indigenous rayed pearl oyster in the Boka Kotorska Bay are present. Research was performed on shellfish farm in settlement Ljuta since November 2021 to April 2022. Most individuals were juveniles, with shell height less than 17 mm. Regresion analyses showed strong correlation between all tested variables (shell length-shell height; shell width-shell height; shell width-shell length; total weight-shell height), while *b* coefficient showed negative allometric growth between all tested variables, expect between variables shell length-shell height. Morphometric indices additionally displayed characteristics of shell shape in rayed pearl oyster.

Keywords: *Pinctada radiata*, morphometry, aquaculture, Adriatic Sea, Montenegro

INTRODUCTION

The rayed pearl oyster, *Pinctada radiata* (Leach, 1814) is an epifaunal suspension feeder of the subtidal zone and a fouling species. Species is usually up to 65 mm in length but longer individuals are not rare (CIESM, 2005). It is a protandric hermaphrodite, sex inversion occurring in shells 32 – 57 mm, while sexual maturity happens at a size of 17 mm (CIESM, 2005; Tlig-Zouari *et al*., 2010). Gonad maturity is controlled by temperature, while shell morphology varies with salinity. It is characterised by the wide variability in shape, strength of sculpture and shell colour. In general the shell is fragile, compressed and inequivalve, outline almost quadrate, higher than long. Lives from very shallow to the mid-water depths (CIESM, 2005).

Species is originally from the Indo-Pacific. It is lessepsian migrant which has successfully spread throughout the whole Mediterranean Sea since its first record from Egypt in 1874 (Monterosato, 1878). In terms of spread, species is considered as one of the worst invasive species in the Mediterranean Sea (Streftaris & Zenetos, 2006), and according to

Katsanevakis *et al*. (2014) there has not been reported any major negative impact of *P. radiata* on marine ecosystem services or biodiversity. Potential pathways of species dispersal are: global shipping, marine debris, water currents (Hmida *et al*., 2021), as well as introduction for aquaculture purposes (Deidun *et al*., 2014).

In Montenegrin coastal waters *P. radiata* was reported for the first time in 2016 from Porto Montenegro marina in Boka Kotorska Bay (Petović & Mačić, 2017). Species colonized many aquaculture sites in the Bay (e.g. Sveta Nedelja, Dražin vrt, Orahovac) (Petović, 2018) and very quickly became one of the dominant fouling species along the aquaculture farms (personal observation), what can have negative consequences on the production of indigenous farming species if we have in mind that one of the significant obstacles to effective and sustainable production in marine aquaculture is biofouling (Dürr & Watson, 2010).

Intense growth of the human population and fact that food availability is decreasing worldwide, make aquaculture sector as important food source in the near future (Gvozdenović *et al*., 2020), so diversification in this sector is of global importance. In various regions of the Indo-West Pacific, *P. radiata* is harvested for its edible muscle, nacreous shell, and capacity to produce pearls (Carpenter & Niem, 1998). The species has been intentionally introduced for aquaculture purposes in the Mediterranean Sea, mainly in the 1960s and 1970s (Deidun *et al*., 2014). Regarding this, *P. radiata* can be considered as very interesting bivalve species for aquaculture, so knowledge of biological and ecological characteristics of the species are essential.

This study focused on biometric characteristics of *P. radiata* population sampled on shellfish farm in the Boka Kotorska Bay (south-east Adriatic Sea), as one of very first morphometry study of the species along the Adriatic Sea.

MATERIAL AND METHODS

A total of 317 individuals were sampled between November 2021 and April 2022 (Table 1) from culture ropes at shellfish farm on the location Ljuta – Boka Kotorska Bay (42.474361 N, 18.763421 E) (Fig. 1). Sampling was done by hand at depth about 2 m. Specimens were transported to the laboratory, cleaned from fouling organisms and measured (Fig. 2).

After measuring all individuals were discarded. Following biometric parameters

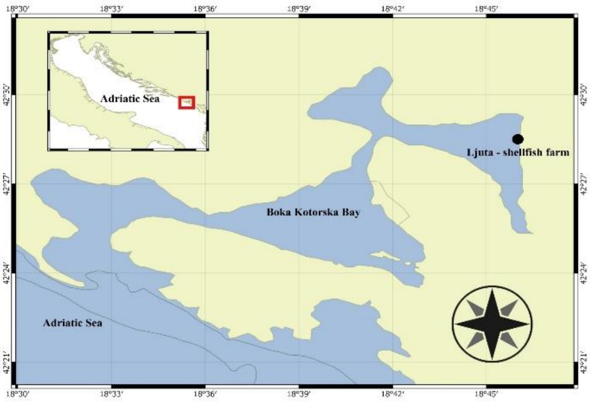

Figure 1. Black circle shows sampling location, shellfish farm in settlement Ljuta

Figure 2. *Pinctada radiata* specimens prepared for measuring

were measured: shell height (SH), shell length (SL), shell width (SW) and total weight (TW). SH was measured as maximal dorsal-ventral axis, SW as maximal lateral axis and SL as maximal anterior-posterior axis (Lodola *et al*., 2013). Shell measurements were taken using a digital vernier caliper (precision 0.1 mm), while total wet weight (TW) was measured using a digital balance (precision of 0.01 g). The specimens were grouped into 5-mm size classes by SH. Morphometric relationships were performed using linear and power regression analyses. The SL-SH, SW-SH and SW-SL relationships were described using linear regression $Y = aX + b$, while power regression $Y = aX^b$ was used for the TW-SH relationship, where a is the intercept of the regression line and b is the coefficient of allometry. The relative growth between variables (isometry vs allometry) was analysed through the allometry coefficient – b. In relationships between the same type of variables (both linear) isometry occurs when b is 1 and in relationships between distinct types of variables (linear and ponderal) isometry occurs when b is 3 (Vasconcelos *et al*., 2016).

Table 1. Number (N) of sampled individuals through sampling period

Month	N
November 2021	142
December 2021	81
January 2022	42
February 2022	0
March 2022	10
April 2022	32
Total	**317**

With aim to further analyse and characterize species morphology, four morphometric indices were calculated through the following equations (Caill - Milly *et al*., 2012; 2014):

- Elongation index = SH/SL
- Compactness index = SW/SL
- Convexity index = SW/SH
- Density index (or weight ratio) = TW/SL

RESULTS

Average values of *P. radiata* shell measurements are given in Table 2. Most individuals were juveniles with 71.60% exhibited SH values less than 17 mm (Fig. 3). SH values ranged between 4.9 mm and 71.5 mm, with an average SH value of 14.8 ± 6.0 mm. SW values ranged between 1.0 mm and 21.2 mm, with an average SW value of 4.0 ± 1.8 mm. SL values ranged between 5.2 mm and 63.3 mm, with an average SL value of 14.8 ± 5.8 mm. TW values ranged between 0.01 g and 43.5 g, with an average TW value of 0.90 ± 3.41 g.

The biometric parameters were subjected to regression analyses and all tested variables (SL-SH; SW-SH; SW-SL; TW-SH) were strongly correlated ($R^2 > 0.70$) (Fig. 4). The relative growth between variables was analysed through the b coefficient. The b coefficient showed negative allometric growth between all tested variables, expect SL-SH where b coefficient was 1.15 – positive allometric growth.

The morphometric indices (elongation, compactness, convexity and density) of *P. radiata* are compiled in Table 3. Overall, the elongation index (SH/SL) presented an average value of 1.00, ranging from 0.72 to 2.06. The compactness index (SW/SL) presented an average value of 0.26, ranging from 0.10 to 0.47. The convexity index (SW/SH) presented an average value of 0.26, ranging from 0.10 to 0.39. The density index (TW/SL) presented an average value of 0.04, ranging from 0.002 to 0.68.

Table 2. Biometric parameters of *P. radiata*; SH – shell height, SW – shell width, SL – shell length, TW – total weight. Data presented as average ± SD

Month	N	SH (mm)		SW (mm)		SL (mm)		TW (g)	
		Range	Average	Range	Average	Range	Average	Range	Average
November 2021	142	4.9 – 71.5	14.6 ± 7.5	1.0 – 21.2	3.7 ± 2.2	5.2 – 63.3	14.5 ± 7.2	0.01 – 43.5	1.01 ± 3.94
December 2021	81	5.5 – 27.5	14.5 ± 4.9	1.2 – 8.6	14.1 ± 1.5	6.2 – 27.2	14.6 ± 4.8	0.04 – 2.17	0.59 ± 0.49
January 2022	42	9.1 – 23.5	15.3 ± 4.2	1.9 – 6.7	4.2 ± 1.3	9.1 – 23.1	15.5 ± 3.8	0.43 – 1.13	0.79 ± 0.25
February 2022	0	/	/	/	/	/	/	/	/
March 2022	10	10.5 – 23.1	15.2 ± 4.4	3.1 – 6.5	4.5 ± 1.2	10.2 – 20.5	15.3 ± 3.4	0.50 – 1.00	0.74 ± 0.14
April 2022	32	9.1 – 23.5	15.3 ± 4.2	1.9 – 6.7	4.1 ± 1.3	9.1 – 23.1	15.6 ± 4.0	0.40 – 1.10	0.80 ± 0.24
Total	317	4.9 – 71.5	14.8 ± 6.0	1.0 – 21.2	4.0 ± 1.8	5.2 – 63.3	14.8 ± 5.8	0.01 – 43.5	0.90 ± 3.41

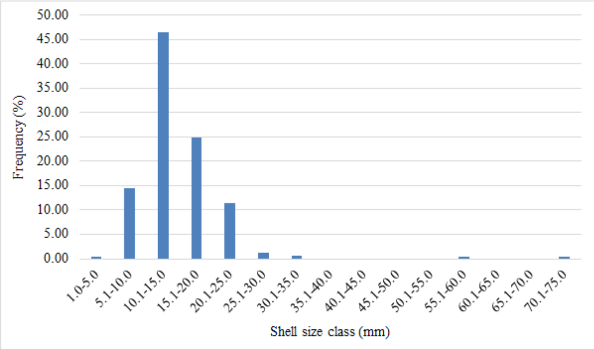

Figure 3. Size class distribution of *P. radiata* specimens according to SH (shell height)

DISCUSSION

Studies on bivalve shell morphology and its morphometric relationships are frequently used for diverse purposes. Knowledge of bivalve variability is important to the effective mariculture of these organisms (Ghozzi *et al.*, 2022). Bivalves are known for their phenotypic plasticity of shell morphometrics (Tlig-Zouari *et al.*, 2010; Vasconcelos *et al.*, 2016; Ghozzi *et al.*, 2022). Variations in morphometric characteristics of *P. radiata* depends on environmental conditions e.g. wave action, salinity, temperature (Beaumont & Khamdan, 1991; Tlig-Zouari *et al.*, 2010; Bellaaj-Zouari *et al.*, 2012; Rajaei *et al.*, 2014; Moussa, 2018).

In the present study, most investigated specimens were juveniles – SH values were less than 17 mm, what is related to the fact that *P. radiata* juveniles dominate on shellfish culture ropes in the Boka Kotorska Bay. Domination of juveniles and smaller individuals was also observed in population from Secchitella around Linosa Island by Lodola *et al.* (2013). According to Theodorou *et al.* (2019) *P. radiata* has the potential to become a predominant bio - foulant on aquaculture farms. Numerous juveniles during most of the year, as well as adult specimens favours the fact that *P. radiata* is reproducing and has achieved established population in the Boka Kotorska Bay. In Croatia, first established population of *P. radiata* was recorded on a fish farm on the Mljet island (Gavrilović *et al.*, 2017). Established populations in Albania are also reported (Gerovasileiou *et al.*, 2017).

SH/SL	1.00 ± 0.13
SW/SL	0.26 ± 0.05
SW/SH	0.26 ± 0.05
TW/SL	0.04 ± 0.05

Table 3. Morphometric indices (elongation, compactness, convexity and density) of *P. radiata*; SH/SL – elongation, SW/SL – compactness, SW/SH – convexity, TW/SL – density. Data presented as average ± SD

The regression analyses revealed high correlation coefficient between all tested characters, what is in accordance with other *P.*

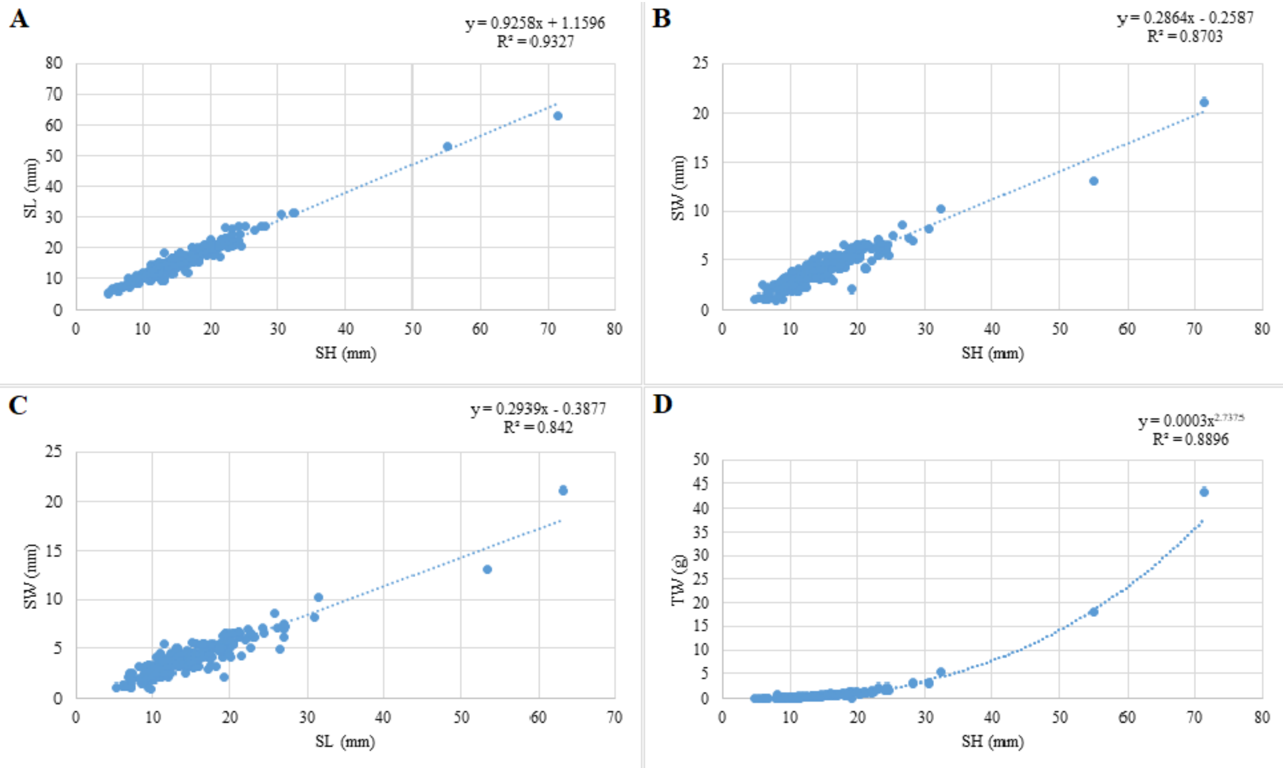

Figure 4. Correlation between: **A** – SL and SH; **B** – SW and SH; **C** – SW and SL; **D** – TW and SH of *P. radiata*; SL – shell length, SH – shell height, SW – shell width, TW – total weight

radiata populations among Mediterranean (Bellaaj-Zouari *et al*., 2012; Lodola *et al*., 2013; Hassan *et al*., 2018). Negative allometric growth which was observed, expect between SL-SH variables, showed that specimens tend to be longer and higher than thicker i.e. symmetrical. Negative allometric growth between variables TW-SH implies on fact that the weight had a slower relative growth rate that is the specimens tend to be higher. We should have in mind that most specimens were juveniles, and according to Saucedo & Montefortc (1998) shell in the genus *Pinctada* is changing from a symmetrical shape in juveniles to an oblong shape in adults. In some bivalve species relative growth appear to be characteristic of their genus e.g. the predominant positive allometries in the genus *Acanthocardia* and predominant isometries and negative allometries in the genus *Donax* (Vasconcelos *et al*., 2016). As far as the biometric analysis is concerned, the most appropriate biometric descriptor for *P. radiata* is shell height (Londola *et al*., 2013). SW as descriptor should not be overlooked, as according to Hwang *et al*. (2007) SW is considered as the most important morphological character in the aquaculture of pearl oyster species since it greatly affects the number and size of the inserted pearl nuclei.

As *P. radiata* already established populations across almost all Mediterranean, its invasive potential should be evaluated. According to Theodorou *et al*. (2019), the gametogenic cycle as well as growth and survival in relation to the local environmental conditions have to be estimated in order to evaluate the local adaptation and forecasting the future expansion and invasion pattern of the species.

ACKNOWLEDGEMENT

Many thank to farmer Luka Milošević for cooperation and help in the field work, and to colleague Mitar Mandić for assisting in the laboratory.

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Received: 30. 04. 2024.
Accepted: 20. 05. 2024.

Biometrijske karakteristike alohtone biserne ostrige, *Pinctada radiata* (Leach, 1814) (Bivalvia: Margaritidae) u Bokokotorskom zalivu

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SAŽETAK

U ovom radu su predstavljeni rezultati biometrijskih parametara alohtone biserne ostrige iz Bokokotorskog zaliva. Istraživanje je sprovedeno na uzgajalištu školjki u naselju Ljuta od novembra 2021 do aprila 2022. Većina jedinki su bile juvenilne, sa visinom ljušture manjom od 17 mm. Regresiona analiza je pokazala jaku korelaciju između testiranih varijabli (dužina ljušture-visina ljušture; širina ljušture-visina ljušture; širina ljušture-dužina ljušture; ukupna masa-visina ljušture), dok je *b* koeficijent pokazao negativan alometrijski rast između svih testiranih varijabli, osim između varijabli dužina ljušture-visina ljušture. Morfološki indeksi su dodatno prikazali karakteristike oblika ljušture biserne ostrige.

Ključne riječi: *Pinctada radiata*, morfometrija, akvakultura, Jadransko more, Crna Gora