

RESTORATION OF THE SILVER-LIPPED PEARL OYSTER *Pinctada maxima* (Jameson, 1901) IN PHU QUOC MARINE PROTECTED AREA, VIETNAM

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ABSTRACT: The silver-lipped pearl oyster has been exploited by fishermen in Vietnam for a long time, mainly serving as a material for encrusting with mother of pearl in traditional lacquer painting. Recently, the increased demands of the oyster shells for production of fine arts make this species more vulnerable and becoming locally extinct in many areas, including in Phu Quoc islands where the species was abundant in the past. The restoration was conducted at Hon Vang islet, southern Phu Quoc islands, using spats produced in the hatchery in Con Dao islands. Around 45 million spats were released in 2017 and 2019. Monitoring the growth indicated that the restored pearl oysters reached the size of $80,08 \pm 10,02$ mm after 2 years and $124,12 \pm 17,74$ mm at 3 years old. The restored population in December 2019 included different size groups ranging from 11–20 mm to 161–170 mm at which size some oysters would be mature, according to past studies on pearl oysters' reproduction. In terms of management, the participation of private sector in oyster restoration exhibited a useful policy of MPA authorities in engaging local stakeholders in management of marine resources. In addition, expansion of restoring areas to include deeper waters is needed and use of “pearl oyster gardens” for tourist purpose is encouraged.

Keywords: silver-lipped pearl oyster, restoration, growth monitoring, Phu Quoc MPA, private sector

INTRODUCTION

Phu Quoc islands belonging to Kien Giang Province, Vietnam, are positioned in the eastern part of the Gulf of Thailand. The waters bordering the islands are characterized by habitat diversity with large areas of seagrass beds (more than 10,000 ha), fringing coral reefs (470 ha) and some mangroves. Fisheries and tourism are target economic sectors of the island district (Vo Si Tuan 2013).

Coral reef fisheries in Phu Quoc islands is small-scale, comprising more than 100 hookah diving boats for catching grouper (adult for food and juvenile for cage culture) and benthic invertebrates (abalone, sea cucumber, pearl oyster, Penguin's wing oyster, flag pen shell, Indian volute, and noble volute), 15 line fishing boats for mainly catching jacks, and 15 boats using barrier net for catching fusilier. In recent years, highly valuable mollusks as abalones and pearl oysters were over-exploited under continuous pressures of extensive diver fishing, taking advantage of recent development of night diving for fishing in most reef areas (Tuan and Long 2016).

The silver-lipped pearl oyster, *Pinctada maxima* (Jameson, 1901), has been a pride of local communities in Phu Quoc islands where many old people told stories related to richness of the pearl oysters in reefs and deep channels between certain islands as well as magic accidents caused by diving to collect pearl oysters in the past. Recently, pearl oysters are exploited incidentally during diving fishing, mostly in remote areas. A previous study (Vo Si Tuan 2013) as well as annual reef monitoring at 10 sites during 2017-2019 (unpublished data), indicated that no pearl oysters have been observed in the wild environment of Phu Quoc Marine Protected Area since early 2000s. The restoration of the silver-lipped pearl oysters meet not only requirement on resource conservation but also perspectives of local people. These ideas have encouraged scientists of the Institute of Oceanography and the owner of Ngoc Hien Phu Quoc Pearl Company to join efforts in attempting to restore this impressive living resource in Phu Quoc islands, which are also named as “Pearl Islands”. All activities have been carried out in collaboration based on volunteer labor without any formally funded project.

METHODOLOGY

Study site: Restoration site was located in Phu Quoc islands at Hon Vang islet (9.92778°N and 104.01994°E) where the Ngoc Hien Pearl Company had managed a 20 ha reef area for conservation and diving tourism (see Fig. 1). The ReefCheck transect method (Hodgson *et al.* 2006) was used to record cover of benthic components at two depths (6 m and 8 m) to describe substratum types in the restoration site, including hard corals (HC), soft corals (SC), dead corals covered by algae (DCA), coralline algae (CA), turf algae (TA), fleshy seaweeds (SW), sponges (SP), rock (RC), sand (SD), rubble (RB), silt (SI) and others (OT). The measurement of benthic cover with point sampling was made in four replicates of 100 m transect at each depth. Benthic components that lay directly below the tape were recorded at 0.5 m intervals (40 data points per 20 m transect segment).

Spat release and growth monitoring: Pearl oyster spats were produced in the hatchery of Ngoc Hien Phu Quoc Pearl Company at Con Dao islands, located in the offshore waters eastward of South Vietnam (see Fig. 1). The grills (mesh plates) where spats settled densely (Fig.2) were transported by air to Phu Quoc and then installed on the sea floor at the restoration site. In the total, approximately 45 million spats were released twice

per year in 2017 and 2019. Scientific divers conducted monitoring of the growth of pearl oysters by collecting oysters dispersing naturally inside the restoration site (Fig. 3) in June 2017 (n = 26), April 2018 (n = 86) and December 2019 (n = 51). As the project depended on volunteer labor, timing of these collections was not planned in advance.

The density of spats was counted using a magnifying glass in five incidentally selected square frames of 1 cm² for 10 grills with 90 cm² area of each grill. The total number of spats of each releasing time was calculated by using the following equation:

$$\text{Total number} = \text{average density per cm}^2 \times 90 \text{ cm}^2 \times \text{number of installed grills.}$$

At each monitoring time, scientific divers collected all oysters which were observed in a belt transect of 100 m x 5 m, stretching from 6 to 8 m in depth. The specimens were measured as outlined by Hart *et al.* (2016). Dorso-ventral measurement (DVM) and anterior-posterior measurement (APM) (see Fig. 4) were carried out in the laboratory of the Institute of Oceanography at Nha Trang city and DVM was used to monitor growth of the restored pearl oysters. The DVM was also done for the spats released the first time, but size estimation was made by staff of Ngoc Hien Phu Quoc Pearl Company for the spats of other releases.

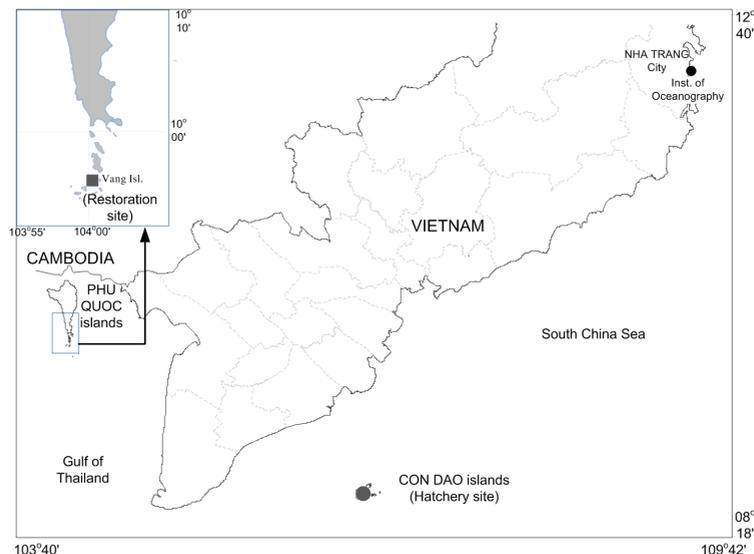


Figure 1. Map of southern part of Vietnam indicating the study sites.

*Restoration of the silver-lipped pearl oyster *Pinctada maxima* (Jameson, 1901)*



Figure 2. Grills covered by spats.



Figure 4. The dorso-ventral measurement (DVM) and anterior-posterior measurement (APM) of an oyster.



Figure 3. An oyster settled in the restoration site.

RESULTS AND DISCUSSION

Description of the restoration site

The restoration site was the western part of coral reefs bordering Hon Vang islet. The reefs were characterized by the difference of hard coral abundance with higher coverage in the shallow (33% at 6 m) and poorer in the deep waters (15% at 8 m). In contrast, soft corals become more common in the deeper water (0.6% at 6 m and 3.8% at 8 m).

Sponges were observed as a common biological feature but no coralline and turf algae nor fleshy seaweeds were recorded. The rock and sand substrata exhibited their dominance (total coverage ranging between 60 and 80%) among non-biological features, considering no silt was found at the site (Fig. 5). Qualitative observation also recorded existence of some gorgonians, Penguin's wing oyster *Pteria penguin*, pen shell *Pinna bicolor* and the oyster *Isognomon isognomum*.

The substratum at the restoration site was quite consistent with the habitat of silver-lipped pearl oysters in Western Australia as mentioned in a publication of Department of Fisheries, Western Australia (2016), indicating that a hard rock substratum on which individual oysters attach themselves was critical. In addition, a hard substratum with small crevices, covered by a fine layer of sediment was a shared habitat of the oysters and other marine assemblages, including hydroids, sponges, ascidians, soft corals, sea pens and crinoids.

Restoration practice and initial outputs

The first release of pearl oyster spats was conducted on February 24, 2017, the second release on November 16, 2017, the third on April 26, 2019, and the fourth on October 15, 2019. Spat size of the first release was 3.93 ± 0.62 mm and ranged between 3 and 5 mm for most releases, except in April, 2019 (1–2 mm). The number of released spats depended on availability from hatchery and increased over the experimental period, from 1, 1.45 up to 20.4 and 26.143 million for the 1st, 2nd, 3rd and 4th time, respectively. Following the releases, young oysters would grow and disperse according to their natural behavior inside and maybe outside the restored areas.

The data series collected in June 2017 indicated that the first released spats were growing well, reaching the average size of 18.27 ± 0.64 mm ($n = 26$) after 4 months (4.56 mm per month), around 85% with the size range of 11–30 mm (Fig. 6a). The

sizes measured in April 2018 (Fig. 6b) exhibited two size groups of restored oysters, the first dominated by the size range of 51–70 mm (mean = 60.82 ± 10.33 mm, $n = 45$) and the second with the main size range of 91–110 mm (mean = 99.85 ± 12.94 mm, $n = 41$).

The structure of restored oyster population in December 2019 became more diverse with the size groups ranging between 11–20 mm and 161–170 mm (Fig. 6c). The smallest group was dominated by the size range 11–20 mm (mean = 17.08 ± 2.84 mm, $n = 12$), the second assumed to be in the range of 71–90 mm (mean = 80.08 ± 10.02 mm, $n = 13$ and the biggest (100–170 mm) without a clear dominance (mean = 124.12 ± 17.74 mm, $n = 25$).

Assuming that there existed four series of sizes (using average sizes mentioned in text) corresponding to four times of spats released into the restoration site, the growth of restored oysters could be explained. As seen in Table 1, the restored oysters reached an average size of approximately 125 mm after nearly 3 years (series 1) and 80 mm after 2 years (series 2). The annual growth rate of oysters belonging to series 3 and 4 could not be estimated due to short time for series 4 and the small size of spat in series 3, which probably explains that they seem to form one mixed size group. More detailed analysis indicated that the pearl oysters of series 1 had grown to almost 100 mm after 14 months, but the oysters of series 2 had grown to 61 mm in only 6 months. This suggested that growth rate of the pearl oysters may vary among different

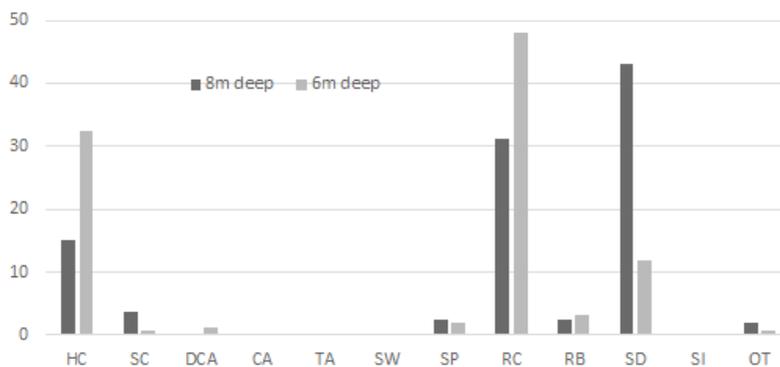


Figure 5. Average covers (%) of benthic substratum at the restoration site with notes: hard corals (HC), soft corals (SC), dead corals covered by algae (DCA), coralline algae (CA), turf algae (TA), fleshy seaweeds (SW), sponges (SP), rock (RC), sand (SD), rubble (RB), silt (SI) and others (OT)

Restoration of the silver-lipped pearl oyster Pinctada maxima (Jameson, 1901)

seasons besides allometric changes in growth rate at different sizes and stages in their life cycle.

The monthly average growth calculated in Table 1 presented fast growth of the pearl oysters (approximate 9 mm per month) with both series 1 and 2 during the period from late 2017 to early 2018. The pearl oyster grew slower in later periods, especially in 2019 when size of both young and adult oysters increased only 1–2 mm per month, in average. It was, therefore, assumed that the period from late 2017 to early 2018 exhibited favorable environment for oyster growth. The differences of growth rate over time have been observed in a previous study (Hua Thai Tuyen and Vo Si Tuan 2000) in Central Vietnam where monthly growth of restored oysters could reach 9–11 mm per month sometimes for both young and adult oysters, but became slower during August to October 1997. Unfortunately, no recent environmental data are available for further discussion on marine environmental changes in Phu Quoc islands. However, in 2019 there was increased sea surface temperature causing a severe coral bleaching in this area (Phan Kim Hoang *et al.* 2020), which might also have affected oyster growth rate

The figures on growth indicated that the restored oysters had grown normally when comparing with that in Western Australia where young oysters grew quickly, with males maturing at 3–4 years old and at a length of 100 to 120 mm (Department of Fisheries, Western Australia 2016). The growth rate of the restored oysters in Phu Quoc islands was considered slower than that of wild harvest pearl aquaculture in Western Australia where two years old oysters reached the size of 150–200 mm (Wells and Jernakoff 2006). Other studies also indicated faster growth of the pearl oysters, reaching sizes of 100–160 mm after two years (4.17–6.67 mm/month) as recorded by Sagara and Takemura (1960) and records of Hancock (1973) with the size of 180–190 mm after 2 years (7.5–7.9 mm/month). In comparison with the above studies, it can be noted that the best growth was for oysters inhabiting the depth range of 30–40 m in sand and rubble substratum (Wells and Jernakoff 2006).

Comparison of growth rates of the pearl oysters under culture conditions in other localities in the region indicated the faster growth of the restored oysters in Phu Quoc islands. This study found oysters in the size range of 100–170 mm (mean = 124.12 ± 17.74 mm) after nearly three years' restoration.

In comparison, the theoretical maximum sizes (L_{∞}) calculated by the von Bertalanffy Growth Function for the silver-lipped pearl oysters cultured in Papua, Indonesia was only 168.38 mm (Lee *et al.* 2006) and in Thailand equaled 168 mm (Traithong *et al.* 1996). These values of cultured oysters were much smaller than those of oysters restored in Central Vietnam, with $L_{\infty} = 260$ mm (Hua Thai Tuyen and Vo SI Tuan 2000), and in the wild environment of Western Australia, with L_{∞} ranging between 194 and 210 mm (Hart and Joll 2006).

Concerning reproduction in the wild, a review from the Department of Fisheries, Western Australia (2016) indicated that the male oysters in Western Australia matured at 3–4 years old and at a length of 100 mm to 120 mm. By the time the individuals in an age cohort had reached about 170 mm, about half had changed from male to female. Most oysters larger than 190 mm were female. An earlier study (Rose *et al.* 1990) also showed maturation of male oysters at the size of 110–120 mm. If these maturation sizes are accepted, the restored oysters in Phu Quoc islands, with 47.1% of the individuals reaching the size of more than 100 mm, and where some had reached the size of 170 mm in December 2019, might include male and female individuals, and that they possibly become mature after three years' growth in the restoration area.

Challenges and perspectives

Established in 2010 by Kien Giang Province People's Committee, Phu Quoc Marine Protected Area (MPA) has conducted many activities for marine conservation and step by step improved its management effectiveness. Basically, seagrass beds and coral reefs remained in a good condition without severe degradation in the last decade. Habitat-based tourism has developed quickly and contributed significantly to local livelihood and district economy. Overfishing has, however, still been problematic, especially under high pressure of fishing by hookah diving. All reef benthic resources have nearly disappeared in the MPA, even in the strictly protected zones (Tuan and Long 2016). The participation of the private sector, such as the activities performed by Ngoc Hien Phu Quoc Pearl Company at Hon Vang, exhibited a useful policy of MPA authorities in engaging local stakeholders in management and restoration of marine resources. Planning and enforcement to protect

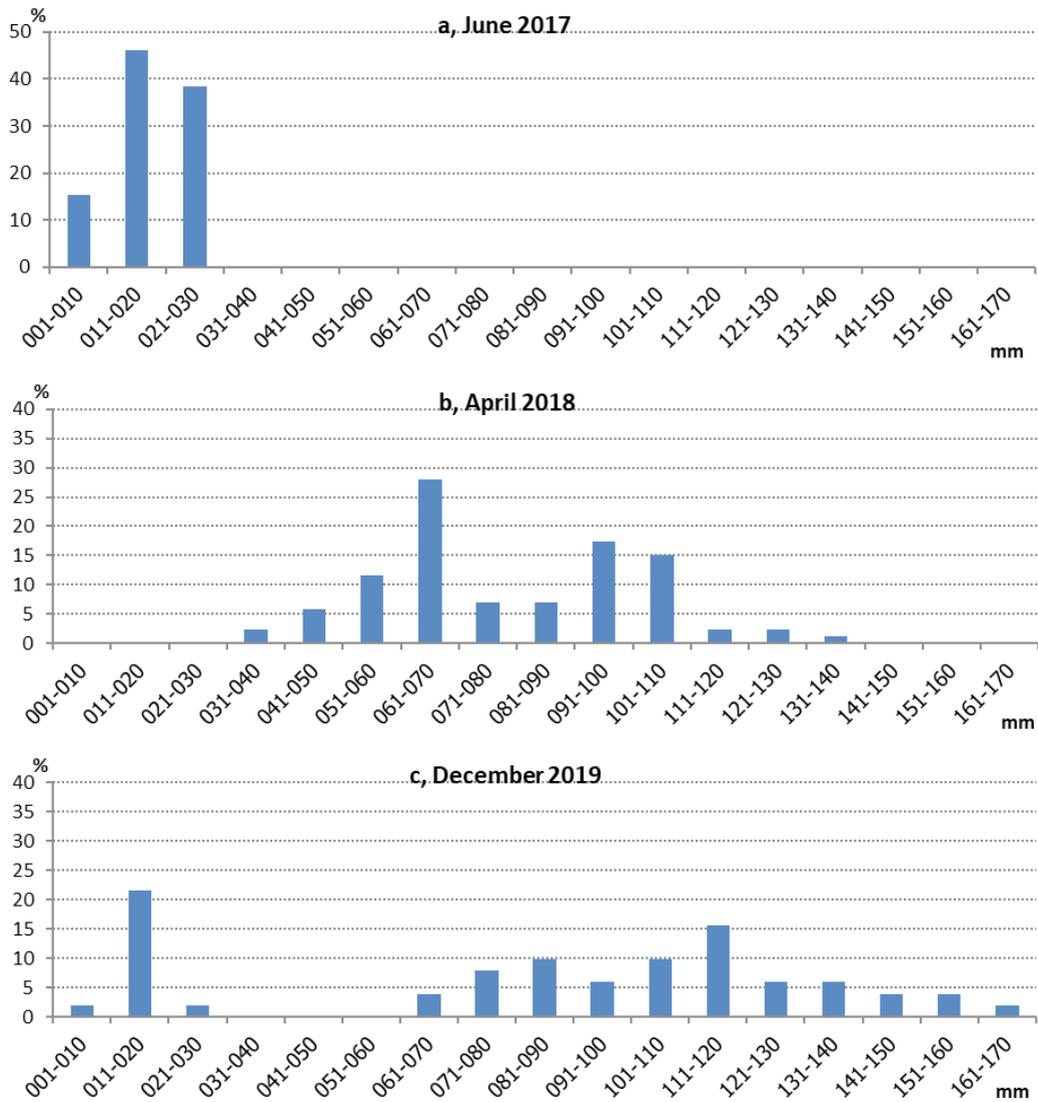


Figure 6. Size structure of the restored pearl oysters in Phu Quoc islands.

Table 1. Size (mm) and monthly growth (mm) of spats released and of restored oysters, in average recorded by growth monitoring.

| Time | Series 1 | | Series 2 | | Series 3 and 4 | |
|--------------------------------------|--------------|----------------|--------------|----------------|----------------|--------------|
| | Average size | Monthly growth | Average size | Monthly growth | Average size | Average size |
| 2017 Feb (1 st release) | 3.93 | | | | | |
| 2017 June | 18.27 | 3.57 | | | | |
| 2017 Nov (2 nd release) | | | 3-5 | | | |
| 2018 April | 99.85 | 8.16 | 60.82 | 9.47 | | |
| 2019 April (3 rd release) | | | | | 1-2 | |
| 2019 Oct (4 th release) | | | | | | 3-5 |
| 2019 Dec. | 124.12 | 1.21 | 80.08 | 0.96 | | 17.08 |

Restoration of the silver-lipped pearl oyster Pinctada maxima (Jameson, 1901)

efficiently “no take zones”, taking advantage of a participatory approach, will be critical for the future management of the MPA.

As the plan has been approved by MPA authority, Ngoc Hien Phu Quoc Pearl Company will continue to manage the reef site, including patrol, surveillance and enforcement for long term conservation and tourism. Scientists from the Institute of Oceanography continue to contribute support to monitor not only restored oyster population but also changes of reef community, and to conduct training and consultation for further conservation activities, for which some funding has recently been obtained (PEER Project, Grant 618 in 2021). The Company also has plans for continuous restoration of the pearl oysters and other overexploited species.

The results of this study, including the existence of young and mature individuals, demonstrated the initial success in restoring a population of silver-lipped pearl oysters in Phu Quoc islands. Its distribution is still limited within a small area with the depth maximum around 10–12 m. As mentioned, the pearl oysters inhabit in a wide range of depth up to 90 m with the most appropriate growth between 30–40 m deep (Wells and Jernakoff 2006), there are plans to expand the sites for restoration to cover deeper waters.

The silver-lipped pearl oysters have been exploited in Vietnam for a long time, mainly as a material for traditional lacquer painting with mother

of pearl inlays. Recently, their shells are used in high value fine arts and a raw shell pair with the size of 20 cm is priced around US\$ 40 in the souvenir market. The Red Data Book of Vietnam (VAST 2007) categorized *P. maxima* as a vulnerable species due to the severe decline of population and local extinction in some areas. Recent restoration is a good beginning step and can be considered as a good practice for upscaling not only in Phu Quoc islands but also in other MPAs. It is hoped that Phu Quoc district will engage more local stakeholders to develop a number of “pearl oyster gardens” in and nearby reef areas where visitors can dive and enjoy peaceful and safe life of the silver-lipped pearl oysters in their wild environment. This scenario will be good not only for nature conservation but also for local livelihood.

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