Seychelles Mariculture Master Plan

Aquaculture Fact Sheet

Black-Lipped Pearl Oyster

Pinctada margaritifera

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1. Background

Common Names

Black-lipped pearl oyster	*English*
Zwit	*Seychelles Creole*

Biology and ecology

The black-lipped pearl oyster, *Pinctada margaritifera*, is a bivalve mollusc of the Pteriidae family. It has a wide Indo-Pacific range extending from Baja California in the eastern Pacific Ocean to the east coast of Africa, and the Red Sea and Mediterranean Sea (Figure 1) (Yukihira *et al*., 2006). The species occupies lagoons, bays and sheltered reef areas with low turbidity to a depth of around 40m, in warmer tropical waters (Sims, 1992). Oysters are epifaunal, and attach to hard substrates such as rocks and other oysters' shells using byssal threads (Pouvreau *et al*., 1999; Yukihira *et al*. 1999; El-Sayed *et al*., 2011; Razek *et al*., 2011).

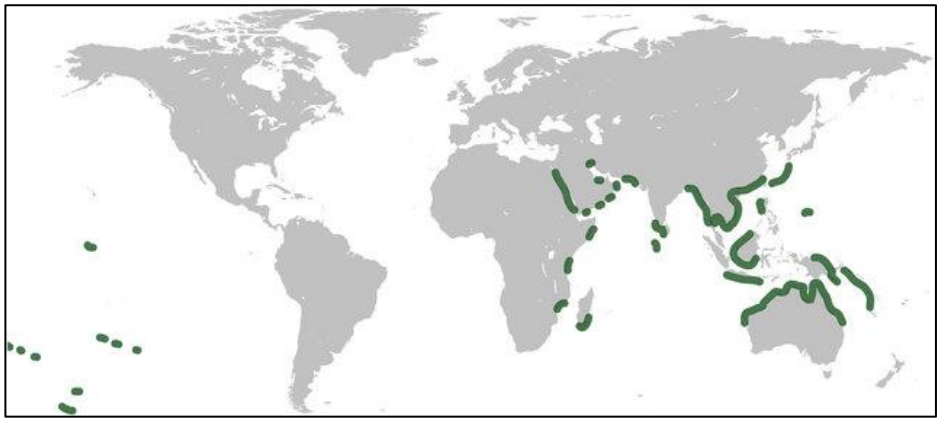

Figure 1: Natural distribution of black-lipped pearl oyster (Source: Ktalav, 2015).

Black-lipped pearl oyster is a bivalve, and has two shells that house and protect its soft tissue, which are black externally and iridescent internally (Figure 2). The internal shell is formed by layers of nacre, a calcareous substance which is deposited by the epithelial tissue beneath the shell in a process of biomineralization (Nudelman *et al*., 2008; Joubert *et al*., 2010). This forms the internal shell, which in this species has a black, non-nacreous border. The layer of nacre is known as 'Mother-of-Pearl'. The mantle shells can also produce pearls within the soft tissue, by depositing layers of nacre on a small solid substance, however this is rare in wild pearl oysters (Figure 2B) (Sims, 1992; Yukihira, *et al*., 1999).

The black-lipped pearl oyster is among the largest of the pearl oysters, and reaches a maximum recorded size of 146mm shell width, with tissue mass reaching 5.5 to 8.8g (Yukihira *et al*., 1999). The majority of growth occurs within the first two years, reaching up to 120mm, where after growth continues in the form of increasing shell thickness with continuous secretion of nacre throughout the oyster's life (Sims, 1992).

The black-lipped oyster pearl is a filter feeder, with zooplankton and phytoplankton being its primary source of nutrition, however, this method of feeding is non-selective and it also ingests items such as mud and inorganic material (Sims, 1992).

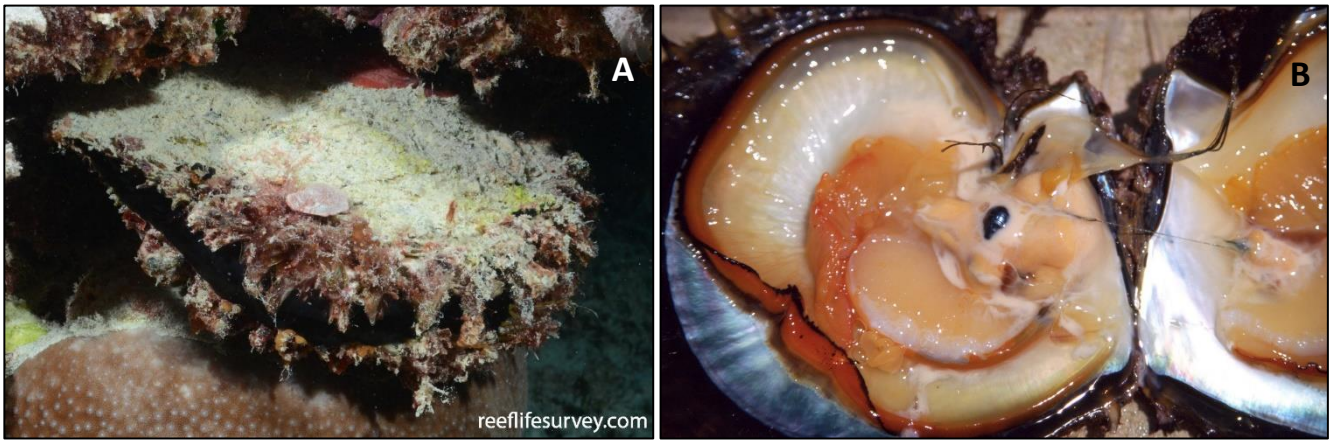

Figure 2: A) Black-lipped pearl oyster in the wild; and B) Internal soft tissue of black-lipped pearl oyster with pearl (Source: Idris Lane; Reef Life Survey).

The black-lipped pearl oyster is slow-maturing relative to other species of pearl oyster. Individuals begin to mature at one year, however sexual maturity is reached at an age of two years, between 100 and 120mm shell diameter. This species is predominantly a protandrous hermaphrodite; all juveniles mature as males and some undergo sex change from a size of approximately 90mm (Pouvreau *et al*., 2000). Smaller size classes are thus dominated by males, with the sex ration becoming more even at four to five years old (Sims 1992; Pouvreau *et al*., 2000). The species is a broadcast spawner, releasing eggs and sperm into the water column where eggs are fertilised. It spawns in warmer waters, and is an opportunistic spawning species; spawning can occur year-round or seasonally, depending on favourable environmental conditions (Pouvreau *et al*., 2000).

Fisheries

Pearl oysters are harvested for Mother-of-Pearl, the nacreous internal layer of the shell (Figure 3A). Black-lipped pearl oyster and silver-lipped pearl oyster (*P. maxima*) are the two pearl oyster species, with thick layers of nacreous shell, and have therefore been heavily harvested throughout their distributions. Black-lipped Mother-of-Pearl has been harvested to make jewellery, decorations, tools such as fishing hooks and knives, decorative inlays and buttons (Figure 3A, B) (Razek *et al*., 2011; Ktalav, 2015).

Figure 3: A) Mother-of-pearl; B) Jewellery; and C) Buttons produced from Mother-of-Pearl (Source: Luméa, 2019; People.com; Amazon.UK).

Black-lipped pearl oysters are harvested by hand at depths up to 40m. The increase in foreign demand for Mother-of-Pearl in the 1800s for use as buttons and inlays led to intensive harvesting of black-lipped pearl oyster for its nacreous shell, and as a result many populations have declined significantly (Dalzell and Adams, 1997; Ellis and Haws, 1999; Razek *et al*., 2011; Ktalav, 2015).

Demand for Mother-of-Pearl declined in the 1950s largely due to the increased manufacturing of plastic buttons (Ktalav, 2015); pearl oysters are however still harvested throughout their distribution. While species-specific pearl

oyster catches are not recorded, the global harvest of pearl oyster shell has shown an increase from the early 2000s, with a recorded harvest of 1 170 tonnes in 2016 (Figure 4) (FAO, 2018). A large proportion of oyster collection is artisanal, and it is likely that the actual harvests are higher than those reported. The resurgent increase in demand for Mother-of-Pearl products places further pressure on wild stocks of this species.

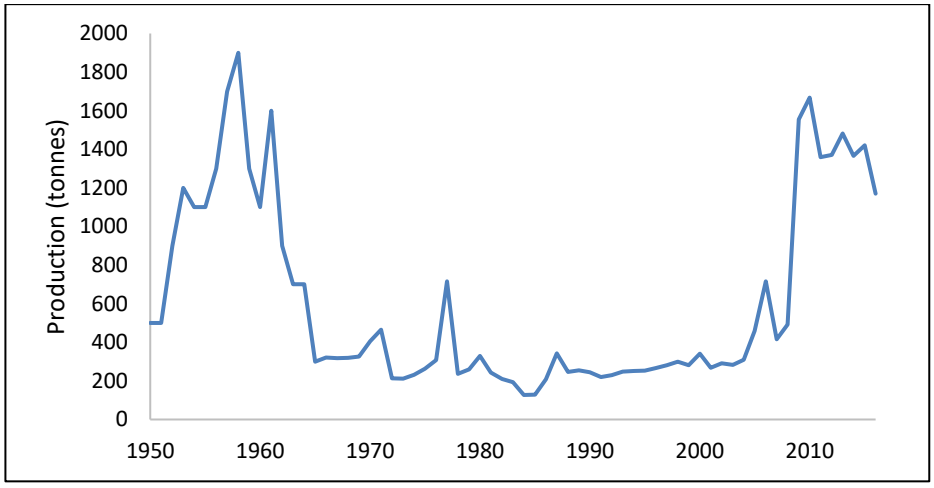

Figure 4: Global fisheries production of pearl oyster shell, 1950 to 2016 (FAO, 2018).

Consistent high-quality pearl production involves a complex culture process. The demand for pearls therefore cannot be met by wild-harvested pearl oysters, but depends on production of aquaculture production of pearl oysters. This can in addition supply the market for Mother-of-Pearl products

Aquaculture

The technique of producing cultured pearls was first developed in Japan in 1893 by Kokichi Mikimoto. Black-lipped pearl oysters are used to culture 'black pearls', as the mantle of this species produces a darker nacre (Figure 5). Culture of black-lipped pearl oysters to produce black pearls was first developed in French Polynesia in the 1960s. This industry grew rapidly from the early 1990s, and French Polynesia is currently the largest global producer of black pearls (Lane *et al*., 2003; FAO, 2018). Black pearls produced in French Polynesia are known as 'Tahitian Pearls'.

Figure 5: Black pearls (Source: ARK).

Global marine pearl culture increased rapidly in the early 2000s, however, production has decreased since 2011, with a total production of approximately 40 tonnes in 2014 (Figure 6) (FAO, 2016; Zhu *et al*., 2019). China previously dominated production of marine pearls, however, this production decreased from 2010, and Japan is currently the largest producer of marine pearls (Figure 7) (FAO, 2016; Zhu *et al*., 2019). French Polynesia remains the largest global producer of black pearls, with production of approximately 15 tonnes in 2014 (FAO, 2016; Zhu *et al*., 2019). Black pearls are cultured at lower production volumes by other countries including Japan, China and Fiji, the Cook Islands, Papua New Guinea and Seychelles.

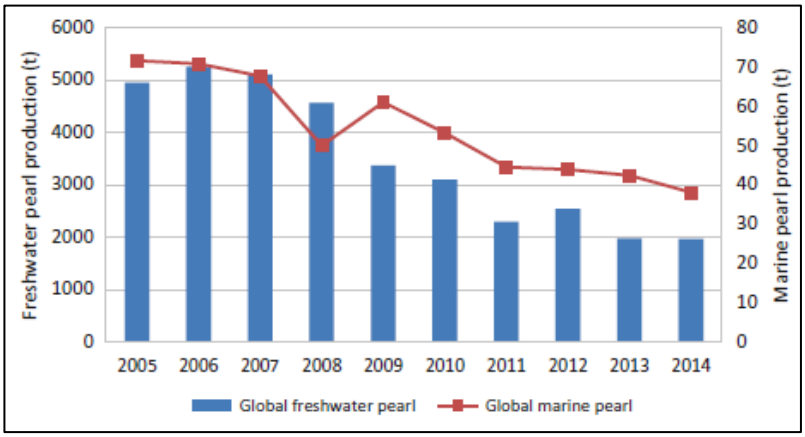

Figure 6: Global pearl culture production, 2005 to 2014 (FAO, 2016; Zhu *et al.*, 2019).

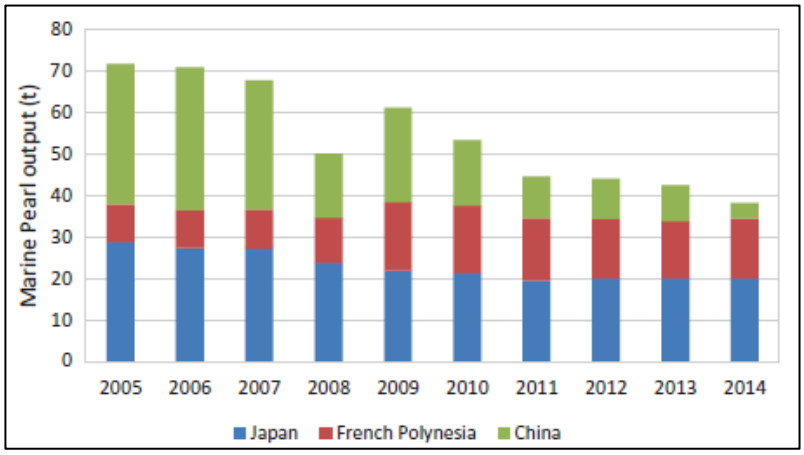

Figure 7: Aquaculture production of marine pearls per country, 2005 to 2014 (FAO, 2018; Zhu *et al.*, 2019).

In Seychelles, black pearl farming began in 1995 off Curieuse Island of Praslin. Currently, approximately 2 000 pearls are produced per annum which supply both export and domestic markets. These are cultured from black-lipped pearl oysters on submerged rafts. Spat for grow-out is not produced in hatcheries but collected from the wild using surface longlines, limiting the yield and consistency of production.

2. Technical approach to aquaculture Production

Production cycle

The production cycle for black-lipped pearl oysters is shown in Figure 8. Juvenile oysters are produced in land-based hatcheries and grown out on sea-based longlines to a size at which they can be grafted to produce pearls. Grafting involves implantation of a spherical bead of shell material (the nucleus) and a piece of mantle tissue.

After grafting they are returned to suspended longlines, submerged rafts or submerged long lines. The use of hatchery-reared rather than wild-caught spat allows for year-round production of seed oysters and a more regulated production of pearls. The land-based tank systems are typically a combination of pump-ashore Recirculating Aquaculture Systems (RAS) and flow through systems. The water that is pumped ashore is filtered before entering the tanks to remove pathogens and to provide optimal water quality for the oysters. Similarly, effluent water leaving the tanks is cleaned in accordance with the relevant Seychelles Aquaculture Standard and global best practice.

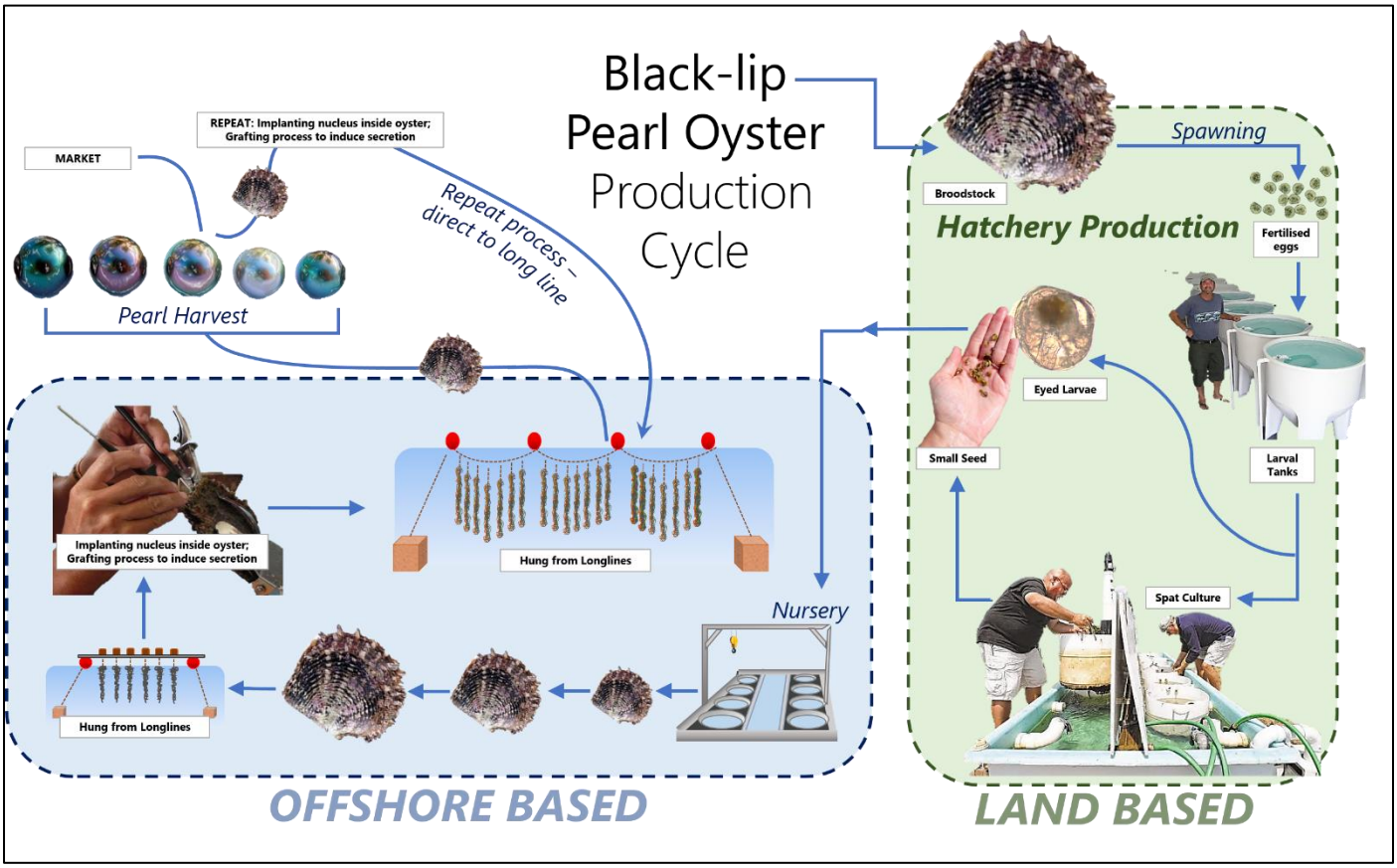

Figure 8: Production cycle for black-lipped pearl oyster.

Broodstock and spawning

The original broodstock is collected from wild populations. Reproduction of pearl oysters under controlled conditions mainly depends on the availability of mature females, which unfortunately are not naturally abundant. *P. margaritifera* is a protandric hermaphrodite, developing as a male during the first 2 years (<80mm). There is no evidence of an effect from abiotic and biotic factors on gender during this phase. Later, pearl oysters progressively change to females, reaching a sex ratio close to 1:1 in specimens older than 8 years. At this stage, gender is apparently influenced by environmental parameters, but particularly by stress. Consequently, females are more abundant in farmed populations than in wild populations, where stress levels are much lower.

Controlling reproduction involves broodstock conditioning, induction of spawning, cultivation of larvae, settlement of eyed larvae, and nursing of early spat. Once the life cycle of black lip pearl oyster has been closed, broodstock can be collected from pocket panels of suspended sea-based oyster long-lines and transferred to spawning tanks. Broodstock are placed first into quarantine tanks, with relatively high water flow rates and filtering levels, for two months. Throughout this process they are monitored for signs of infections or diseases (Dijkema, 1992; McGladdery *et al*., 2007). When the quarantine process is complete, broodstock are moved to land-based spawning tanks, and are induced to spawn using thermal shock (Alargarswami *et al*., 1989; Ky *et al*., 2013). Eggs and sperm are released into the water where eggs are fertilised. The spawning process can be carried out every month.

Larviculture, nursery phase and grow-out

Viable fertilised embryos are collected from spawning tanks and transferred to larval rearing tanks at a density of 5 larvae per millilitre. Larvae undergo metamorphosis and approximately 18 days after hatching, spat settle on a substrate (Pit and Southgate, 2000). Early spat are transferred to land-based nursery tanks for the first nursery phase, where they remain until they reach a size of 2mm, approximately two months after hatching. During the land-based larviculture and nursery phases, larvae are provided with microalgae suspended in the water column. Microalgal

organisms are introduced in overlapping phases to meet nutritional requirements as larvae develop and grow, and can include *Isochrysis* and *Chaetoceros* species (Martínez-Fernández and Southgate, 2007; Ky *et al*., 2013).
At 2mm in length, larvae are transferred to spat bags suspended on sea-based longlines for the second nursery phase. They remain in the spat bags for 12 months, after which they are transferred at a size of 50mm to lantern baskets suspended on longlines, where they remain for a further 12 months until they reach a size of 100mm when they are ready for grafting (Figure 9) (Pouvreau and Prasil, 2001; Fong *et al*., 2005). Throughout the sea-based phases of aquaculture, oysters are regularly hand cleaned to remove any biofouling from their shells.

Figure 9: Pearl oysters suspended in sea-based lantern nets (Source: National Geographic).

Seeding and harvesting

At 100mm, oysters are grafted for the first time. This is a surgical procedure that involves the insertion of a graft, a piece of mantle epithelial tissue of approximately 2mm taken from another oyster, and a nucleus, small nacre bead, into the 'pearl pocket' in the gonads of the receiving oyster's soft tissue. The mantle graft is first inserted into the pearl pocket, and the nucleus is inserted into the graft. The mantle epithelial cells of the graft tissue multiply to form a pearl sack around the nacre nucleus (Ellis and Haws, 1999; Cochennec-Laureau *et al*., 2010; Gueguen *et al*., 2013). Following grafting, oysters are returned to pocket panels on longlines for the pearl to form. The pearl sack of epithelial tissue continues to secrete nacre and layers of nacre are deposited on the nucleus, forming a round pearl (Gueguen *et al*., 2013). After 18 months, a pearl of approximately 10mm diameter is harvested (Figure 10).

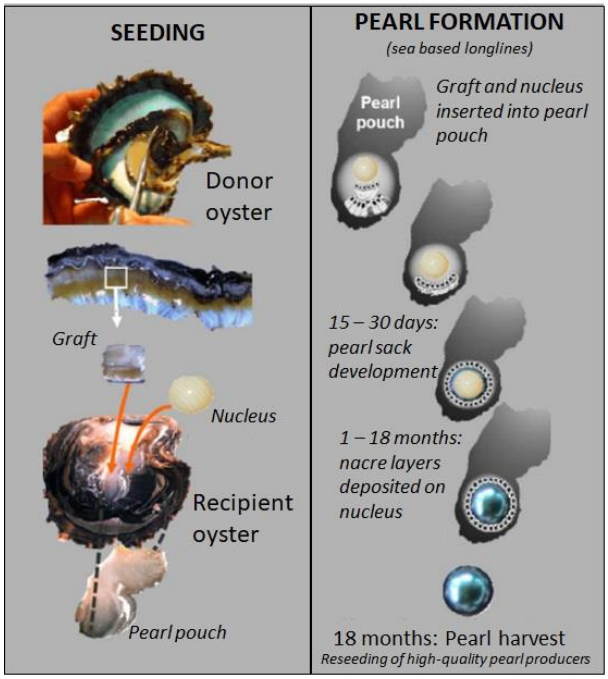

Figure 10: The seeding process in pearl culture (Adpated from: Gueguen *et al*., 2013).

Pearl grafting (or seeding) is a complex and technical procedure, and seeding technicians with a high level of expertise are required to minimise post-seeding mortality of oysters and nucleus rejection rate, and to produce pearls of high-quality colour and grade (O'Connor, 2002; Mamangkey *et al*., 2010; Johnston *et al*., 2018).

To harvest pearls, oysters are removed from long lines and the pearl is carefully extracted from the soft tissue by a technician by making an incision in the pearl sack, avoiding damaging the oyster (Figure 11). Oysters producing high-quality pearls can be reseeded; another, larger nucleus is inserted into the existing pearl sack and the oyster is returned to longlines for a further 18 months. Each oyster can be seeded up to four times, with pearl size increasing with each harvest (Table 1) (Ellis and Haws, 1999; Fong *et al*., 2005; Johnston *et al*., 2018).

Oysters that are not reseeded can be used for other products; the adductor muscle is removed for consumption, and shells are cleaned for selling as Mother-of-Pearl.

Figure 11: Black pearls from Seychelles (Source: www.blackpearlseychelles.com).

Table 1: Average size and weight of marketable pearls with each successive seeding (Johnston *et al*., 2018).

Seeding	Size (mm)	Weight (g)
First	10.0	0.80
Second	11.5	1.00
Third	12.5	1.10
Fourth	14.0	1.30

Longline site

A sea-based site for longlines should be chosen based on optimal environmental parameters to maximise survival, health and growth of oysters, and quality and yields of pearls. Sites should be 25 to 35m depth, with water temperatures of 25 to 30°C, clean and clear water, a slight current to allow water exchange and food transport, without too much current. Additionally, security measures may be required as pearls are a valuable product (Ellis and Haws, 1999).

Invertebrate species, such as sea cucumbers and sea urchins, can be ranched below the pearl longlines in a form of integrated multi-trophic aquaculture (IMTA). The organic waste from oysters, faeces and pseudofaeces, can serve as a food source for the ranched invertebrates increasing growth, survival and residency, and thus increasing yields. This

provides bioremediation of the sediment below the longlines as excess nutrients are consumed and removed from the system (Chopin *et al*., 2012; Buck *et al*., 2018).

Oyster health

At all stages of the production cycle, care is taken to ensure oyster health and welfare. Minimising stress is key to reducing susceptibility to disease and infections, and is done by maintaining optimal production and environmental parameters including stocking densities, feeding regimens, water quality and temperatures among others, as environmental stress is linked to reduced immunological defence and resultant infections in cultured invertebrates (Malagoli *et al*., 2007; Kuchel *et al*., 2011). Bacterial infections, such as ricketsailles and those of *Vibrio* species, and viral infections, such as viral oyster oedema disease (OOD), have been reported in cultured black-lipped pearl oysters (Kuchel *et al.*, 2011). The risk of such infections can largely be reduced by maintaining a high standard of hatchery and nursery conditions, disinfecting systems, and ensuring that best practices are followed during handling, such as for cleaning and seeding (Subhash and Lipton, 2010; Kuchel *et al.*, 2011).

3. Market for black-lipped pearl oyster products

Black pearls are the main product produced from black-lipped pearl oyster farming, with meat and Mother-of-Pearl being of lesser value. Pearls are high-value products used mostly for jewellery. The global value of pearls is increasing, with a total a of USD 11 984.3 million spent on pearls globally in 2014, an increase of 48% from 2009; and total expenditure is expected to continue growing at a similar rate (Figure 12) (IPSOS, 2014).

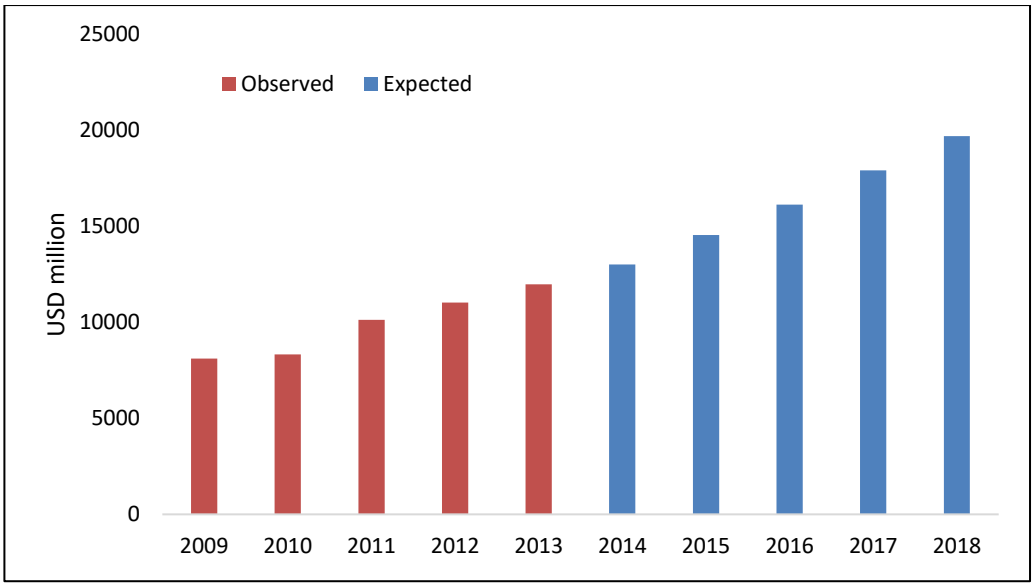

Figure 12: Total observed (2009 to 2013) and expected (2014 to 2018) global annual expenditure on pearl products (IPSOS, 2014).

The average individual value of saltwater and freshwater pearls is also showing an increase globally. The value of saltwater pearls is substantially higher than freshwater pearls, with average price of USD 31.40 per piece in 2013 (Figure 13) (IPSOS, 2014). The most valuable saltwater pearls are South Sea white pearls, from the silver-lipped pearl oyster in the South Pacific Ocean, particularly Australia and Indonesia, followed by Tahitian pearls, and then white Akoya pearls produced mostly in Japan (Zhu *et al*., 2019). Freshwater pearls, cultured in mussel shells, are produced in China, Japan and the USA, and have a lower value due to high volume production.

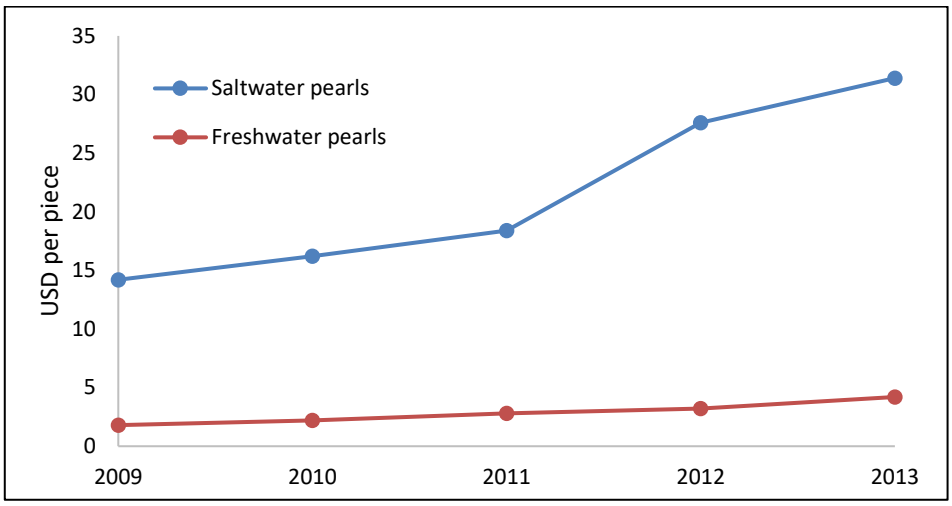

Figure 13: Average pearl price per piece in global market, 2009-2013 (IPSOS, 2014).

Black-lipped pearl oysters produce pearls of a variety of colours, including light silver, dark grey, green and black (Figure 14), making these pearls valuable and sought after globally. The value of pearls varies with quality and size, and 95% of revenue from a pearl culture facility is normally generated from 5% of pearls, with the remainder being of lower value (Haws, 2002; Johnston *et al*., 2018). Small increases in high-value pearls can thus result in large increases in production value. Tahitian pearls are graded according to shape, size, colour, lustre, surface perfection. Nacre thickness and weight relative to the nucleus is also a factor in increasing value. (Ky *et al.*, 2013), with A-grade pearls carrying the highest value (Table 2). Importers and retailers additionally tend to have a graded system that they apply when purchasing pearls.

Figure 14: Pearls of a variety of colours produced by black-lipped pearl oyster (Source: Certified Jewellery; National Geographic).

Table 2: Grading system of black-lipped pearl oyster pearls (Strack, 2006; Taylor & Strack, 2008; Kishore *et al*., 2014; Johnston *et al*., 2018).

GRADE	SHAPE	LUSTRE	SIZE (8-20mm)	SURFACE PERFECTION	COLOUR
A	Round 	Very high lustre	Larger than pearls in other grades	Very minor to no imperfection (less than 5% of total surface area)	Very bright and attractive colouration
B	Round to semi-baroque; Semi-baroque 	High lustre	Variable, but generally larger than pearls of C and D grades	Minor surface imperfections, usually less than 30% of the total surface	Brightly coloured
C	Baroque 	Variable (Medium lustre)	Variable	Notable surface imperfections that may include blemishes, dents, bulges, and circles	Variable
D	Uneven shapes/presence of circles 	Dull	Variable	Major surface imperfections, more than 60%	Variable

The increasing value of marine pearls is due to declining global production (Figure 6), increasing demand for jewellery products with the improving global economy and increasing sales channels, and improving the quality of pearl jewellery products (IPSOS, 2014).

Most black pearls produced in Seychelles are sold mostly to tourists. Some pearls are used to make jewellery within Seychelles, while some are exported to Australia for jewellery manufacture and reimported to Seychelles for sale. Given the high value of black pearls globally, the market demand for Seychelles black pearls and the increasing global demand for pearls, there is good reason to increase pearl production in Seychelles.

4. Suitability for aquaculture in Seychelles

The species

Black-lipped pearl oyster is indigenous to Seychelles. Broodstock can be obtained from local waters for use in aquaculture facilities. The culture techniques for the species are well-developed.

Environmental and oceanographic conditions

The environmental conditions of Seychelles waters, such as temperature and salinity, are optimal for the survival and growth of black-lipped pearl oysters (Hecht, 2016). The species has been successfully cultured in sea-based facilities in Seychelles waters since 1995, demonstrating this suitability.

A number of factors have to be considered when selecting an area and sites for longline culture. The Seychelles inner islands in particular provide a suitable marine environment; this region falls outside of the cyclone belt, and is less affected by the strong seasonal south east monsoon than the outer islands (Chang-Seng, 2007; ASCLME, 2012; UNEP,

2004). The oceanographic conditions are well within the optimum range for successful longline culture. Average current speeds are high enough to ensure water circulation among lines, allowing food to reach all individuals and dissolving particles, without being too strong for the structure and the carrying out of farming activities. Dissolved oxygen levels are above the threshold required by oysters (Ellis and Haws, 1999).

Access to markets

Pearl products are small, lightweight and non-perishable; as such they are easily transported to domestic and export markets.

Seychelles' level of transport infrastructure and location in the middle of the western Indian Ocean makes it ideal for aquaculture production for global markets. It has access to markets in Europe, the USA, Africa and Asia, via air and sea transport, and is able to receive imports of supplies, such as feed and technical equipment, from high-quality suppliers around the world. It also has access to local markets as products can be transported within and between islands.

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