Seychelles Mariculture Master Plan

Aquaculture Fact Sheet

Collector Urchin

Tripneustes gratilla

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by Advance Africa Management Services

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1. Background

Common Names

Collector urchin *English*
Zoursen *Seychelles Creole*

Biology and ecology

The collector urchin *Tripneustes gratilla* belongs to the family Toxopneustidae. It is widely distributed throughout the tropical, subtropical and warm-temperate Indian and Pacific Oceans, from the east coast of Africa and the Red Sea to the west coast of Central and South America, and latitudinally from Japan and Hawaii to New Zealand (Figure 1) (Lessios *et al*., 2003; Cyrus *et al*., 2014a). It is a shallow water sea urchin, generally occurring at 0 to 30m but can be found as deep at 75m (Lawrence, 2007; Lawrence and Agatsuma, 2013). Its favoured habitats include sea grass beds, coral reef areas, and reef lagoons (Muthiga, 2005; Lyimo *et al*., 2011).

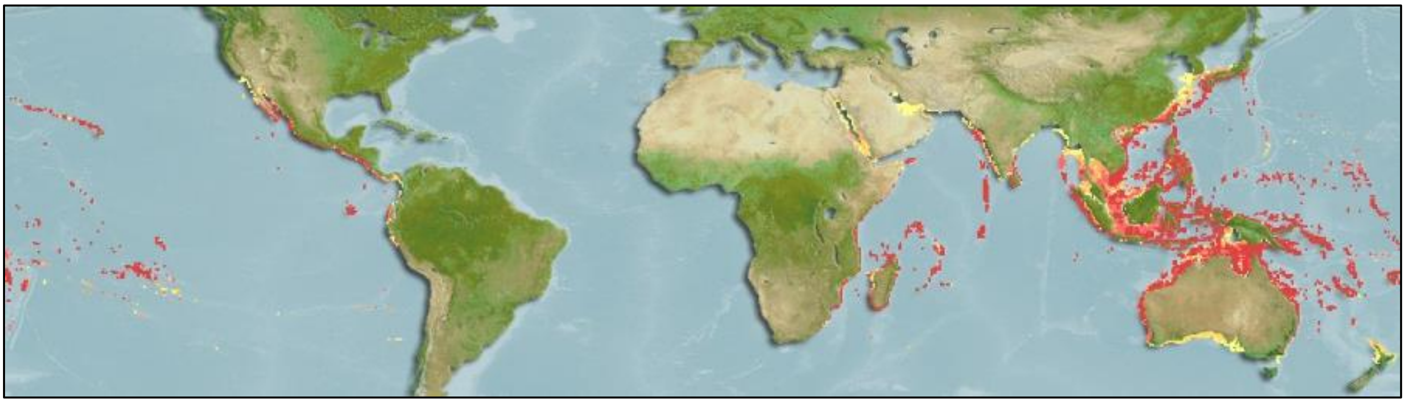

Figure 1: Natural distribution of collector urchin (Source: Aquamaps, 2016).

The collector urchin has a spherical, slightly flattened, body made up of a hard test, consisting of calcareous plates, and external movable spines extending from the test which are used for protection, locomotion and trapping of food particles from the water column (Toha *et al*., 2017). Tubular feet equipped with suckers are used for attachment, locomotion and defence (Toha *et al*., 2017). The test has two major openings: the peristome on the lower surface where the mouth opens; and the periproct on the upper surface, which forms the anus (Figure 2A) (McBride, 2005; Toha *et al*., 2017). Collector urchins generally reach a maximum size of 100mm in diameter and 155mm in height, although they have been recorded as large as 160mm diameter (Eklöf *et al.*, 2009; Rahman, 2014). The external colouration of collector urchins varies widely, but it is generally dark brown or maroon-purple in colour, with pale brown or orange to white spines (Figure 2B) (Toha *et al*., 2015).

The collector urchin is a generalist herbivore, consuming a broad range of detritus, algae and seagrasses across its distribution (Dy *et al*., 2002; Vaitilingon *et al*., 2003; Lyimo *et al*., 2011; Lawrence and Agatsuma, 2013). It forms an important ecological component of marine ecosystems, as its grazing controls macroalgal communities (Lawrence 2001; Brundu *et al*., 2016).

The collector urchin is a fast-growing, early-maturing species, reaching sexual maturity in under a year at a diameter of 50mm (Lawrence and Agatsuma, 2007; Dworjanyna and Pirozzi, 2008; Juinio-Meñez *et al*., 1998), with a maximum age of two years (Shimabukuro, 1991; Lawrence, 2001). The species is gonochoristic; each individual matures as either a male or female and no sex change occurs (Lawrence, 2013). Reproductive systems of both males and females are divided into five gonads, which are similar in appearance in both sexes (Bruce, 1988). The species spawns once or twice annually, at different times in different regions, with year-round spawning observed in equatorial areas

(Maharavo, 1993; Vaitlingon, 2005; Lawrence, 2013). During spawning, eggs and sperm are released into the water column where eggs are fertilised (Laurence, 2013).

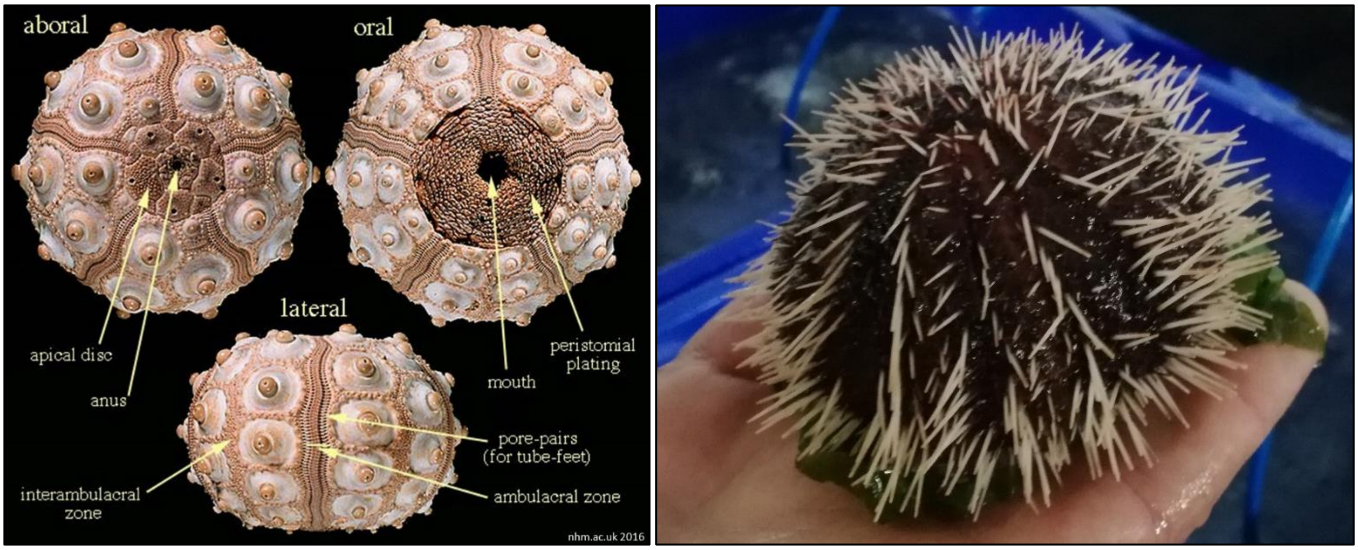

Figure 2: A) Skeletal morphology of echinoids (Source: NHM.AC.UK, 2016); and B) Live collector urchin.

Fisheries

Sea urchin species are highly valued for their roe, which is known as 'uni' (Figure 3). Globally, sea urchins have been subject to intense exploitation and overfishing and, consequently, most of the world's major sea urchin fisheries are in decline (Siikavuopio *et al*., 2007; Cyrus *et al*., 2014b). Production from Indo-Pacific sea urchin fisheries peaked in 2002 at 90 784 tonnes, and has since declined with a production of 55 446 tonnes in 2016 (Figure 4) (FAO, 2018). Production is dominated by Chile, which accounted for an average of 68% of total catches from 1980 to 2016, followed by Japan, Canada, Fiji, USA, Australia and Mexico (Andrew *et al*., 2002; McBride, 2005; FAO, 2018). The majority of sea urchins are exported to Japan, with smaller amounts being consumed domestically in some areas such as USA and Chile (McBride, 2005).

Most global sea urchin fisheries operate in cold-temperate regions, such as Norway, and catches are dominated by temperate and cold-water species, such as the green sea urchin (*Strongylocentrotus droebachiensis*) (Dworjanya and Pirozzi, 2008). However, tropical and subtropical urchin species are harvested in Australia, particularly purple sea urchin (*Heliocidaris erythrogramma*), white sea urchins (*H. erythrogramma*), black sea urchin (*Centrostephanus rodgersii*) and collector urchin (Commonwealth of Australia, 2011a, b; Mos *et al*., 2011). Collector urchin is the dominant fisheries species in the Philippines, making up the majority of country's total urchin catch which peaked at approximately 1 100 tonnes in 1992, following which it collapsed (Andrew *et al*., 2002).

Figure 3: Uni in the sashimi trade (Source: Stefánsson *et al*., 2017).

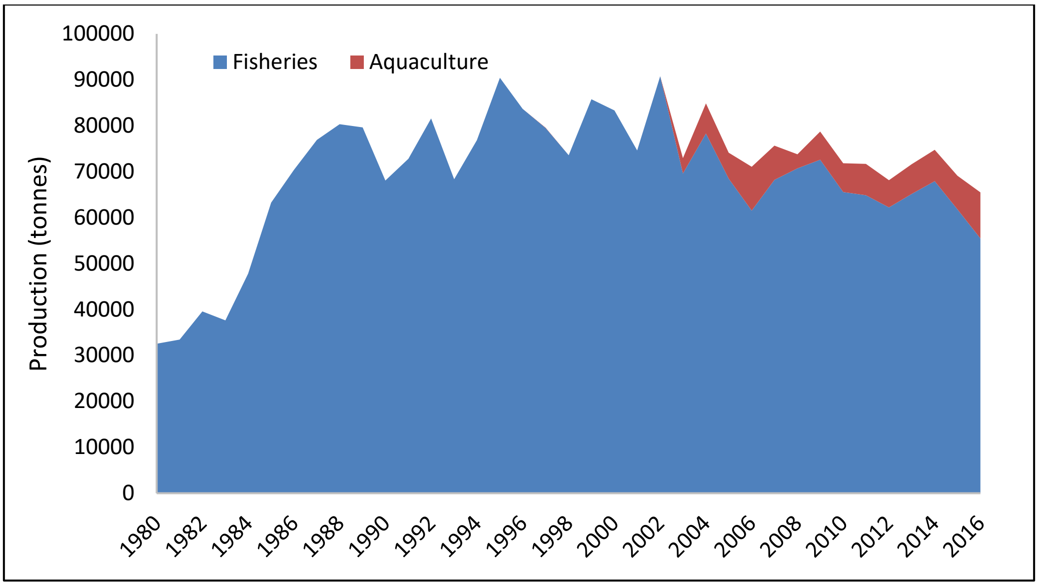

Figure 4: Indo-Pacific sea urchin production, 1980 to 2016 (FAO, 2018).

Collector urchins are harvested using SCUBA diving, freediving, collection by hand from intertidal or nearshore areas, as well as dredging or drag-netting (Nofima, 2016). The major fishing countries for collector urchins include Chile, Japan and the USA (Nofima, 2016). Specific catch data is not available for collector urchin; however, population collapses of the species have been observed following overfishing (Juinio-Meñez *et al.*, 2008). The collector urchin is an ecologically important species, and declining populations are likely to result in major changes to benthic community structure (Lawrence 2001).

Aquaculture

Sea urchin aquaculture was first developed and implemented in Japan in 1968, to address the gap between Japanese demand for sea urchin roe and production by harvest fisheries (McBride, 2005). The Philippines started focusing on collector urchin aquaculture in the 1990s following fisheries collapse and lack of supply to meet the demand (Andrew *et al*., 2002; Juinio-Meñez *et al*., 2008). Sea urchin aquaculture has since expanded to Australia, European and South American countries (Andrew *et al*., 2002; McBride, 2005; Mos *et al*., 2011, 2012). While Japan is the dominant market for uni, there is demand for sea urchin products in various forms in other countries, such as Chile and the USA, and these countries therefore produce products for domestic and export markets (McBride, 2005).

Currently, collector urchin is cultured in a number of regions including Japan, the Philippines, Australia, Russia and South Africa (Juninio-Meñez *et al.*, 1998; Shokita, 2001; Dworjanyna and Pirozzi, 2008; Nofima, 2016). Japanese sea urchin farming consists largely of stock enhancement, whereby hatchery produced juveniles are reared in land-based nursery facilities (

Figure 5) and then restocked into their natural habitat for harvesting by fisheries (Mos *et al*., 2011). To a lesser extent, juveniles are also grown out to market size in sea cages (McBride, 2005).

The collector urchin is the focal species of the Philippines' sea urchin farming (Andrew *et al*. 2002), where nursery-reared juveniles are grown out in net or bamboo cages (Juinio-Meñez *et al*., 1998; Ungson, 2006). Some collector urchin aquaculture facilities in the Philippines rely on the growing out of wild-caught juvenile urchins in cages, rather than those produced in hatchery facilities (Ungson, 2006); this adds fishing pressure to wild stocks.

Figure 5: Collector urchins grazing on *Ulva* in tank.

2. Technical approach to aquaculture production

Production cycle

Collector urchin can be farmed either entirely in land-based systems or can also be ranched under fish cages or pearl long lines (Figure 6). Adult urchins (broodstock) are captured from the wild and held in land-based tanks, where they spawn and produce eggs. After hatching, urchins remain in a land-based facility during their larval and juvenile phases followed by grow-out of juveniles to market size in land-based tank systems, or by ranching or in suspended ladder cages at sea (Figure 6**Error! Reference source not found.**). Sea urchin gonads are the export product. To optimise yield, sea urchins are harvested based on maturity and gonadosomatic index (GSI, the relative proportion of the body made up by gonads). Gonad index reaches its highest at a diameter of 7cm, and this index does not increase thereafter making 7cm an optimal harvest time (Muthiga, 2005; Toha *et al.*, 2017).

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 urchins. Similarly, effluent water leaving the tanks is cleaned in accordance with the relevant Seychelles Aquaculture Standard and global best practice.

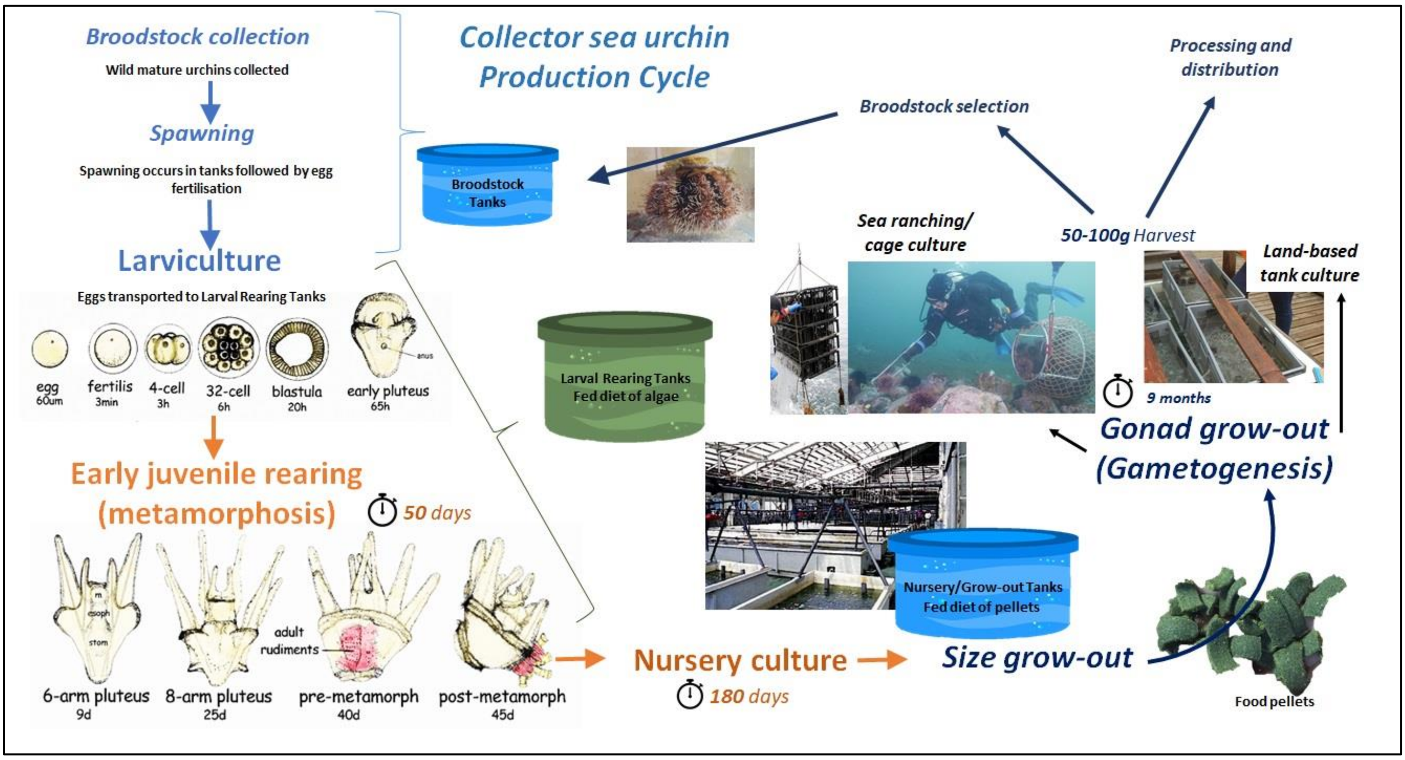

Figure 6: Production cycle of collector urchin.

Broodstock and spawning

Mature collector urchins of 50 to 70mm test diameter are collected from wild populations during the spawning season (Scholtz *et al*., 2013). They are placed first into quarantine tanks for one to four weeks to ensure that no disease or parasites enter the system. When the quarantine process is complete, broodstock are moved into broodstock holding tanks (Figure 7). Broodstock are fed a diet of *Ulva*, a soft macroalgae constituting part of their natural diet, supplemented with formulated pellet feed.

Once broodstock have acclimated to captivity, they are transferred to spawning tanks. They can be induced to spawn using environmental cues of water temperature and photoperiod, and by means of potassium chloride (KCl) solution injection (Hagen 1996; Liu *et al*., 2010; Scholtz *et al*., 2013). Collector urchin spawning is based on the lunar cycle, and broodstock can be induced to spawn every four to eight weeks, allowing a large reproductive output and product yield (Juinio-Meñez, 2002; Mos *et al*., 2011). Eggs and sperm are released into the water column where fertilisation takes place. Fertilisation can be observed using a microscope, and when >95% of eggs are fertilised, excess sperm is removed by gently washing embryos in filtered seawater and transferring them to larval rearing tanks (Mos *et al.*, 2011).

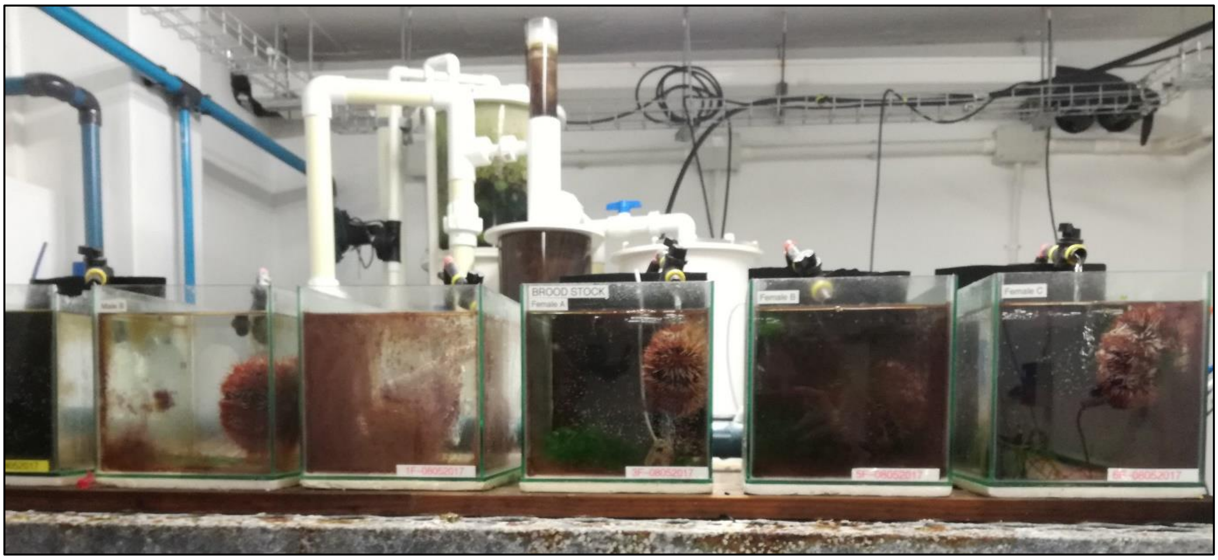

Figure 7: Collector urchin broodstock in land-based broodstock holding tanks.

Larviculture and nursery phase

Fertilised eggs are stocked into larval rearing tanks at a density of 5000 larvae per litre (Dworjanyna and Pirozzi, 2008, Mos *et al*. 2011; Scholtz *et al*., 2013). Larvae hatch approximately 20 hours after fertilisation, and begin feeding at around 3 days after fertilisation (Dworjanyn and Pirozzi 2008; Lovatelli and Sarkis, 2010). A variety of microalgae is provided to simulate the natural larval diet and meet their nutritional requirements (Figure 8A) (Lovatelli and Sarkis, 2010; Scholtz *et al*., 2013). After hatching, larvae are initially planktotrophic, swimming and consuming phytoplankton in the water column. Approximately 30 days after hatching, larvae settle using tubular feet to attach to a surface (Brundu *et al*., 2016). Prior to this stage, settlement plates coated in benthic diatom algae for feeding are provided in the tank as a cue to induce settling (Figure 8B) (Dworjanyna and Pirozzi, 2008; Mos *et al*., 2011). Settled larvae undergo metamorphosis and approximately 60 days post-hatch, larvae are fully metamorphosed benthic juveniles of 5mm diameter, and are transferred to nursery tanks (Dworjanyn *et al*. 2007; Dworjanyna & Pirozzi 2008). Settled juveniles are reared in nursery tanks, feeding on a mixed diet of seaweed (*Ulva*) and formulated feed, until they reach a size of 10mm, after approximately another 2 months, at which point they are moved to grow-out facilities (Lovatelli and Sarkis, 2010).

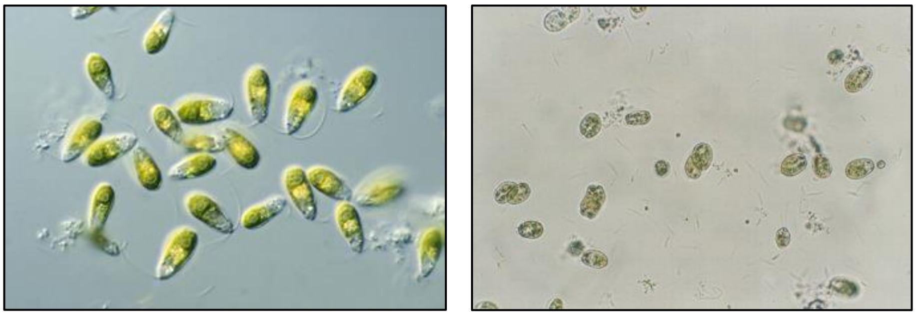

Figure 8: Example of microalgae feed for collector sea urchin larvae: A) Green flagellate algae *Dunaliella tertiolecta*; and B) Marine diatom algae *Chaetocerus gracilis* (Source: Lovatelli and Sarkis, 2010; Scholtz *et al*., 2013).

Grow-out and harvesting

Following the nursery phase, collector urchin juveniles are transferred to grow-out facilities where they are reared for approximately eight months until they reach sexual maturity at approximately 70mm diameter. At this stage urchins typically have a gonadosomatic index (GSI) of 15%, at which point they have sufficient roe (uni) for market (Lawrence, 2013). Harvesting is optimal when gonads are in the growing or premature stage, as market value is highest with lower gametes (McBride, 2005).

Land-based tanks

Collector urchin juveniles are transferred into land-based flow-through tanks. The urchins are typically placed in smaller crates within a larger tank system, to allow for more surface area for settlement, and water flows through the crates (Figure 9). Land-based grow-out is an intensive culture system, and can produce 50 to 90kg of urchin per m^3 (Partos, 2011). During this phase, urchins are fed with a combination of *Ulva* and artificial formulated pellet feed.

Figure 9: Collector urchins in land-based grow-out tanks.

Sea cages

In this production system, collector urchin juveniles are transferred into suspended ladder cages in the sea and fed with a diet of *Ulva* and formulated feed which is placed into cages by divers, or by bringing cages out of the water (Figure 10).

If sited correctly, water flow through the cages is high, and high stocking densities and yield are achievable without requiring the more resource-intensive land-based tanks. Aggregation of sea urchin adults in cages may increase reproductive output, indicated by good gonad yields, with synchronized gonadal development, thereby enhancing fertilization success and larval production (Junio-Meñez, 2002), as well as offering benefits to timeous harvesting for achieving maximum gonadal size at harvest.

A disadvantage of these systems is the difficulty in accessing them for feeding and cleaning, and marine biofouling can occur with smaller mesh sizes (Barker, 2010).

Figure 10: Harvesting of sea urchins grown in sea-based floating ladder cages (Source: Urchinomics.com).

Sea ranching

Nursery-reared collector urchin juveniles are stocked onto the ocean substrate for their grow-out phase, to be harvested once they reach market maturity. Areas suitable for sea ranching are usually shallow (<25m), intertidal areas with sandy or muddy substrates, a sufficient level of organic matter for feeding, and a relatively low abundance of urchin predators (Ungston, 2004). Before stocking, the carrying capacity of each potential ranching site is assessed to determine appropriate stocking numbers. Juveniles are then stocked at a size of 10mm, usually into enclosed structures, such as hapa nets or sea pens, to reduce the risk of predation (natural predators include parrotfish, triggerfish, sea stars and *Cassis* species – Tertschning, 1989; Mahon and Parker, 1999; Eklöf *et al*., 2009). At 50mm, the sea urchins are moved into open areas and harvested by divers when they reach a market size of approximately 70mm.

Juveniles can also be stocked below sea cages holding finfish, such as snapper and grouper, or below oyster longlines, in a form of integrated multi-trophic aquaculture (IMTA). The organic waste, in the form of faeces and by-products, as well as uneaten fish food, provides high-nutrient food for collector urchins feeding from the sediment, improving growth and survival as well as residency of urchins. This co-culture makes grow-out of urchins more efficient, and is ecologically beneficial as the urchins provide bioremediation of the sediments below the cages by using excess nutrients from cage culture for energy and growth (Chopin *et al*., 2012; Buck *et al*., 2018).

Both cages and land-based tanks provide higher yields due to greater feed conversion ratios, fewer mortalities due to a lack of predation, and the fact that animals do not move away. Sea ranching is, however, advantageous over these methods in terms of costs, including that of labour and infrastructure building and maintenance.

Feed

In land-based systems, collector urchins are fed soft macroalgae, *Ulva* species, which are high in protein and have been demonstrated to result in high growth rates (Lawrence, 2013; Shpigel *et al*., 2018). Relying on wild harvested *Ulva* is limiting, due to limited availability, seasonal variation in quantity and quality, biosecurity issues, and the environmental impact of harvesting *Ulva* (Cyrus *et al*., 2014a, b). *Ulva* can be produced in land-based facilities as a form of IMTA, with nutrient-rich effluent water from urchin tanks being used downstream in *Ulva* culture, to promote growth of *Ulva* and simultaneously treat water by removing some level of nutrients before it is discharged.

The natural diet of *Ulva* alone is not sufficient for maximising growth and gonad yield, and as such *Ulva* can be supplemented with formulated feeds that are nutritionally correct and consistent, with a high protein content (Figure

11) (Lawrence and Lawrence, 2004; Gibbs 2011; Cyrus *et al*., 2014a, b). This allows for production high-quality gonads of a large size and consistent colour, increasing marketability (Cyrus *et al*., 2014a, b).

Feeds differ to those developed for finfish; pellets must sink, as urchins are benthic feeders, they must be of the correct shape and surface for feeding, and must last for up to a week without negatively impacting the environment to allow time for it to be consumed (Nofima, 2016). These feeds can include natural diets such as *Ulva* as a feeding stimulant to increase consumption rates (Cyrus *et al*., 2014a).

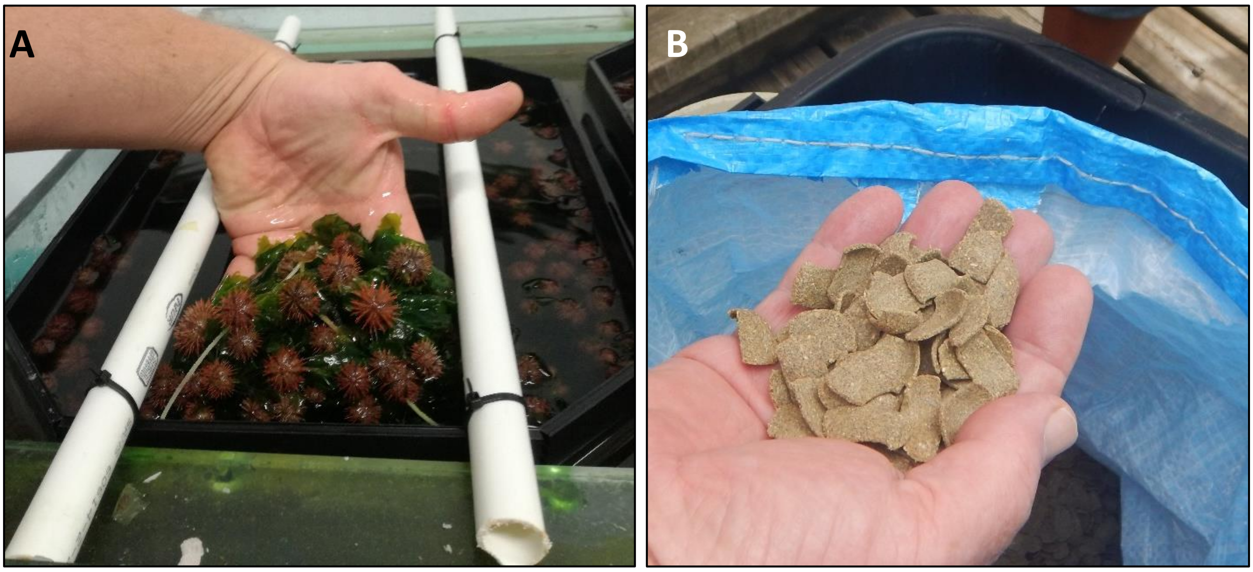

Figure 11: A) Collector urchins grazing on live *Ulva*; and B) Artificial pellet feed formulated for collector urchin.

Sea urchin health

It is important to provide a clean and hygienic hatchery environment, to prevent diseases, infections and parasites in hatchery-reared collector urchins. Controls are therefore used to ensure the health of urchins within the land-based system, and to ensure that all juveniles used for stocking are healthy (James *et al.*, 1994; Ivy and Giraspy, 2006). Before release of juveniles into grow-out areas, strict checks for disease and parasites should be carried out to avoid introduction of harmful organisms to the wild stock (Robinson, 2014).

Sea urchins are susceptible to fungal and viral diseases in their larval and juvenile phases, and as adults if they have lesions on their body wall resulting from stress or injury (Gilles and Pearse; 1986; Tajima and Lawrence, 2001; McBride, 2005).

Efforts are taken to ensure minimal stress of urchins at all stages of production, including during transportation and acclimation, by maintaining optimal environmental parameters, stocking density and cleanliness of facilities, to reduce the risk of infection.

3. Market for collector urchin products

The sea urchin gonad, uni, is highly popular in the sashimi trade and is among the most sought-after seafood products in Asia and the Mediterranean. They are mostly consumed raw, but can also be salted, pickled or cooked (Figure 12). The global market demand is estimated at 60 000 to 70 000 tpa (Stefánsson *et al*., 2017). Japan is the dominant market, accounting for approximately 80-90% of global sea urchin demand, which is still growing (Stefánsson *et al*., 2017). Other consumers of sea urchin products include France, Korea, Chile, Spain, Italy and New Zealand (Monfort, 2002; Andrew *et al.*, 2002; James *et al.*, 2016; Stefánsson *et al.*, 2017).

The majority of sea urchin produced globally, through fisheries and aquaculture, is exported to Japan, and Chile, Russia, USA and Canada are the biggest suppliers (Miyata, 2010; Stefánsson *et al.*, 2017). Smaller domestic markets exist and are growing, such as in Chile, USA and France. Chile consumes approximately 10% of its sea urchin production, and 5-10% of Californian fisheries production is consumed in the USA (Roa, 2003; McBride, 2005).

Figure 12: Prepared sea urchin dish in A) Hokkaido, Japan; and B) San Diego, USA (Source: kimi-tourguide.blogspot; Localadventurer.com).

In the globally dominant market of Japan, the total sea urchin supply (imports and local production) is categorised into four major product forms: live sea urchins, fresh or chilled uni, frozen roe, and dried, salted or brined uni. Fresh or chilled uni is the most valuable processed form, consisting of individual sea urchin lobes (Figure 13) (Miyata, 2010; Brown and Eddy, 2015). Processing of whole sea urchins to produce uni or roe adds value to the product, and processed sea urchin uni is one of the most valuable seafood products, and can carry prices of over USD 100/kg (McBride, 2005). Much of the uni that the USA exports to Japan is produced in Chile and Canada, and imported by and processed in the USA (Brown and Eddy, 2015).

Figure 13: Prepared trays of fresh uni, the lobes of sea urchin gonads.

The value of sea urchin products is largely dependent on the size and quality of the gonads, with taste, colour, shape and firmness contributing to the perception of quality and value (Unuma, 2015). The most commercially valuable urchin gonads are large, bright yellow or orange in colour, and contain few to no gametes (not harvested during spawning season) (Robinson *et al.*, 2002; Sphigel *et al*., 2004; Cyrus *et al*., 2014a). The variability of wild harvested sea urchin gonads means that only a portion of urchins will fetch a good market price, whereas cultured urchins can be grown to increase the size and quality of gonads, and can be harvested at the right size, allowing consistency in production (Unuma, 2015). A consistently high-quality, high-value product can be achieved through the use aquaculture techniques and high-quality diets (Seymour *et al.*, 2013).

Collector urchins produce high-quality uni with excellent market acceptance (Cyrus *et al.*, 2014a). It is commercially important species in various countries, including Japan, and is considered to be a premium seafood (Cyrus *et al.*, 2014a, b). Aquaculture of collector urchins is a means to produce uni to meet the growing demand in a sustainable way.

4. Suitability for aquaculture in Seychelles

The species

Collector urchin is indigenous to Seychelles waters and is permitted for aquaculture production. The species has a high market value. The demand for sea urchins cannot be met from capture fisheries. Sea urchin farming technologies are well researched and developed, and feeds have been formulated to produce high gonad yield (Cyrus *et al.*, 2014a, b; Nofima, 2016). The collector urchin is fast growing and can reach market size in under a year, and under optimal farming conditions the roe can make up 24% of total body mass. It is well suited to land-based rearing as well as for sea-based grow out practices (Juinio-Meñez *et al.*, 1998; McBride, 2005; Lovatelli and Sarkis, 2010).

Environmental and oceanographic conditions

Seychelles waters offer optimum environmental conditions for the survival and growth of ranched collector urchins (Robinson, 2014).

Seychelles waters are also well suited to sea-based cage culture of finfish species, and longline culture of pearls, due to ideal oceanographic conditions (Hecht, 2016), which allows for integrated multi-tropic aquaculture (IMTA). The substrate under sea cages and longlines serves as an ideal location for ranching of urchins as excess organic matter from these operations (such as faeces and uneaten food) can provide a nutrient-rich environment for high growth and survival rates in urchins. Collector urchin farming also offers an ecological advantage to the region; sea urchins are benthic grazers and maintain ecological balance, they can thus offer bioremediation of the sediments below cages longlines, improving the sustainability of sea-based farming (O'Leary and McClanahan, 2010; Chopin *et al*., 2012; Purcell *et al*., 2012; Buck *et al*., 2018).

Access to markets

Sea urchin export requires a high level of logistical infrastructure, as high-quality fresh products should reach export markets within seven days of harvesting. Seychelles' level of transport infrastructure and its location in the middle of the western Indian Ocean makes it well-suited to aquaculture production for global markets. Seychelles has access to markets in Europe, the USA and Asia, via air and sea transport, and is able to receive imports of supplies, such 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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