22
Mariculture

Aviti Mmochi

Opposite page: Sea cucumber pens, village-based aquaculture of sea cucumbers in Tampolove, southwest Madagascar. © Garth Cripps.

INTRODUCTION

Aquaculture is the cultivation of aquatic animals and plants in natural or controlled marine or freshwater environments, whereas mariculture is restricted to marine and estuarine (brackish) waters. On a worldwide scale, aquaculture is a fast-growing industry, showing a 12-fold increase between 1980 and 2010, or average annual growth of 8.8 per cent (FAO 2012). Recent statistics show that growth has slowed, with food fish annual production rates decreasing from 9.5 per cent (1990-2000) to 6.2 per cent (2000-2012) (FAO 2014). World production through aquaculture increased to 90.4 million tonnes in 2012 (66.6 million tonnes food fish and 23.8 million tonnes aquatic plants; FAO 2014) with about 50 per cent of production originating from mariculture (Figure 22.1). This is in stark contrast with the global levelling off in harvests from capture fisheries, at about 80 million tonnes per year since the mid 1990's (FAO 2014).

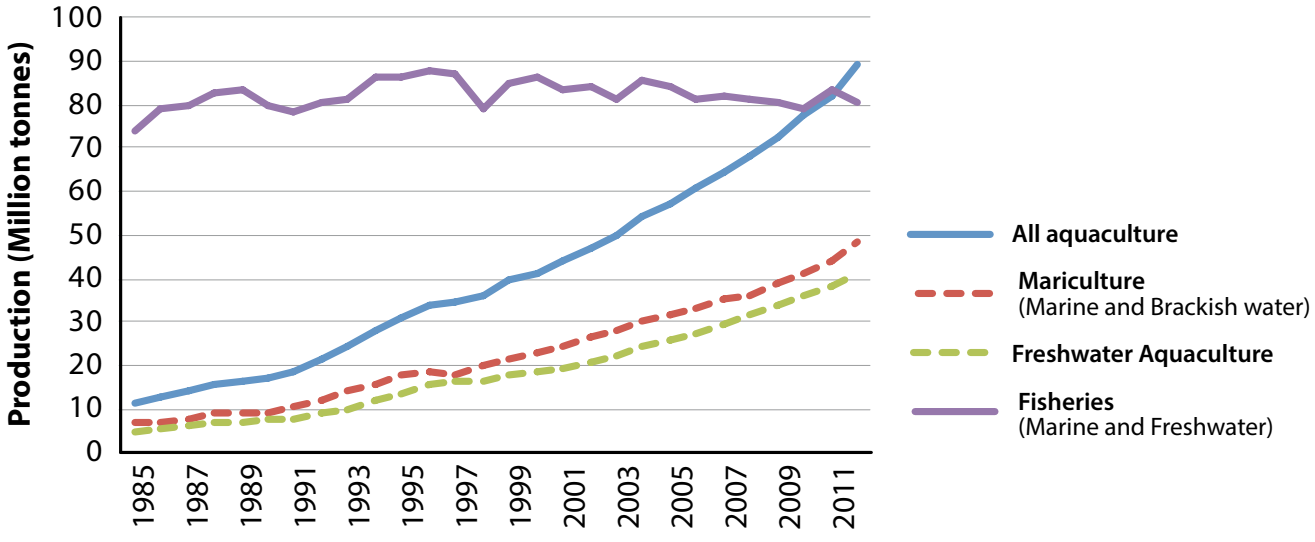


Figure 22.1. Growth in world production by capture fisheries compared to aquaculture between 1985 and 2012 (FAO 2013).

The FAO categorizes aquaculture production by 'inland waters' (such as lakes with their floodplains, reservoirs, rivers, wetlands and coastal lagoons) and 'marine areas'. In this study, the FAO categories are followed, whereby all aquatic plants and animals cultured in marine areas (marine and brackish waters, but excluding inland waters) are considered mariculture products. Production statistics are submitted annually to the FAO by the governments of member countries; these statistics are summarized on an online database (see www.fao.org), from where it can be accessed as summaries of production figures by species, areas or time units. As for fisheries data (see Chapter 21) the FAO aquaculture summaries are based on 'official' statistics, which may exclude the production of smaller mariculture initiatives, or those in remote areas. Data from these initiatives may either not be available (for example, not incorporated in country reports submitted to the FAO) or may have been misreported under categories for capture fisheries, particularly if based on export data or originating from local fish landing sites or markets. Thus production tonnages are indicative only, and underestimate actual tonnages.

World mariculture production in 2012 was 53 million tonnes, of which aquatic plants (mainly seaweeds; wet weight) made up 44 per cent, followed by mollusks (28 per cent), various groups of finfish (23 per cent) and crustaceans (7 per cent) (Figure 22.2). Asian countries dominated mariculture production (90 per cent), whereas African countries contributed only 0.4 per cent or 0.18 million tonnes (Figure 22.3a). Egypt is by far the largest producer of farmed fish in Africa (0.88 million tonnes in 2012), but most farming occurs in inland waters around the Nile, for tilapia and mullet. Excluding data from Egypt, Tanzania (including Zanzibar) produced 89 per cent of mariculture products in Africa in 2012, mainly seaweeds (Figure 22.3b). Red seaweed *Eucheuma denticulatum* makes up the bulk of cultured seaweed in Tanzania, whereas *Kappaphycus alvarezii* and *K. striatum* are also farmed (Msuya and others, 2014); the market price of dried seaweed remains low at 0.17 US$/kg (Bryceson and Beymer-Farris 2011). Other SW Indian Ocean countries among the eight highest mariculture producers in Africa were Madagascar (4 per cent; mainly tiger prawn *Penaeus monodon*) with a value of approximately US$ 65 million in 2006 (Iltis and Ranaivoson 2011), and Mauritius (0.3 per cent; mainly red drum *Scyanops ocellatus*).

Growth of mariculture provides many social and eco-

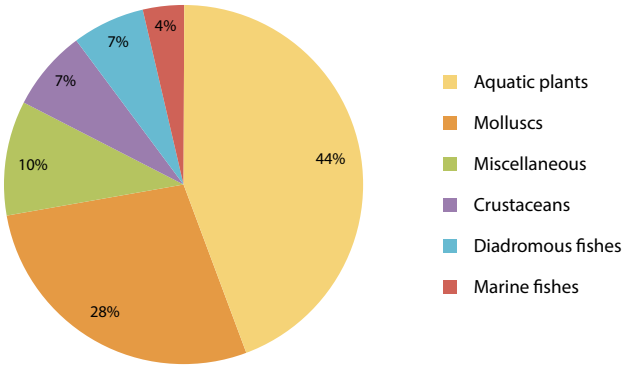


Figure 22.2. World mariculture production by culture group in 2012 (FAO 2013).

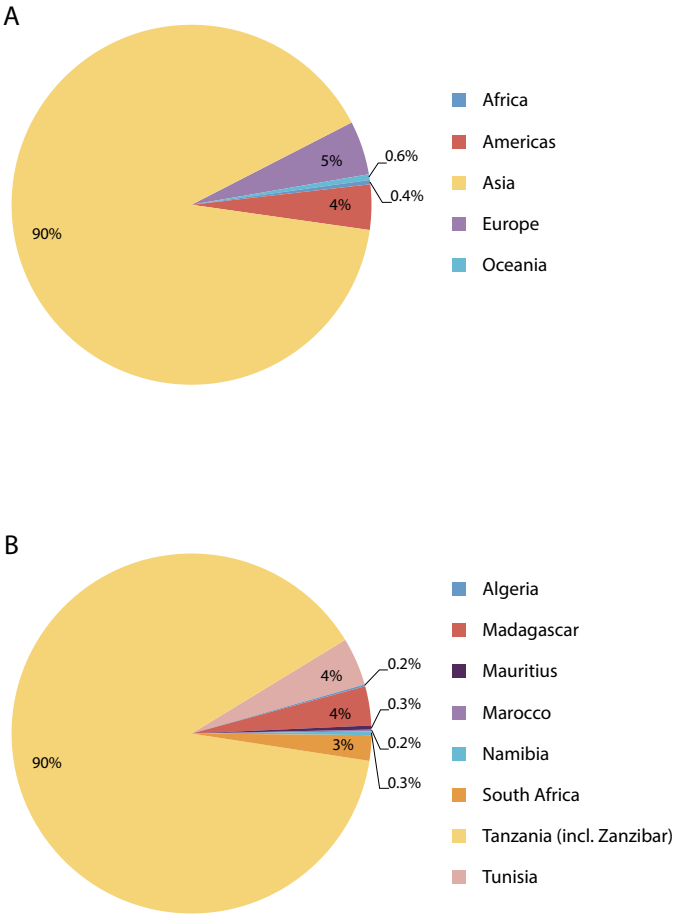


Figure 22.3. Mariculture production in 2012 **(A)** by continent, and **(B)** by the eight leading African countries.

nomic opportunities as well as challenges (HLPE 2014). Benefits to local communities may include better food security, increased income and employment opportunities (Troell and others, 2011). Apart from producing affordable food fish for local consumption, it may generate revenues from sales on national and international markets. Mariculture production in the region doubled between 2000 and 2003, but with the exception of seaweed in Tanzania, it has since remained relatively stable at 24 000 tonnes, with production of marine fish and prawns declining in some countries (Troell and others, 2011). Despite the inconsistent performance, there appears to be a general feeling of optimism around future prospects (Troell and others, 2011).

This chapter describes mariculture in Tanzania, Kenya, Mozambique, Madagascar, Mauritius, Seychelles and the French Indian Ocean territories of Reunion and Mayotte. There are no reports of mariculture in Comoros and Somalia and most mariculture activities in South Africa are restricted to the south and west coasts, outside the FAO statistical area 51 (Western Indian Ocean) addressed in this chapter. The emphasis is on the history and development of the mariculture sector, species groups cultured and production trends. The environmental, social and economic impacts of mariculture are highlighted together with successes, gaps and challenges.

MARICULTURE PRODUCTION BY COUNTRY

Tanzania

Mariculture production in Tanzania is dominated by the seaweed sector (Msuya 2013), which has shown continued growth since the early 1990s (Figure 22.4). *Eucheuma* and *Kappaphycus* are red seaweeds produced for the high-value extract known as carrageenan, which is used as a stabilizer, emulsifier or thickening agent in food additives, cosmetics and pharmaceutical products (Bryceson and Beymer-Farris 2011). In 2013, a wet weight of 157 386 tonnes of seaweed was reported to the FAO, ranking Tanzania as the 9th largest exporter of aquatic plants in the world at 0.66 per cent (FAO 2014). Seaweed contributes 7.6 per cent of Zanzibar GDP, 2nd after cloves (47 per cent) among cash crops in 2009 (National Bureau of Statistics 2011). However, the seaweed is sold raw to processors in Europe and America with very little value-adding taking place in Tanzania.

Seaweed farming trials using the local strain of *Eucheuma* started in Zanzibar in the 1970s. Since then, there have been many mariculture initiatives, including governmental, private sector and by NGOs or donors, to grow and improve the sector (Table 22.1). Commercial farming using seed and technology transfer from the Philippines expanded during the 1990s in Zanzibar, followed

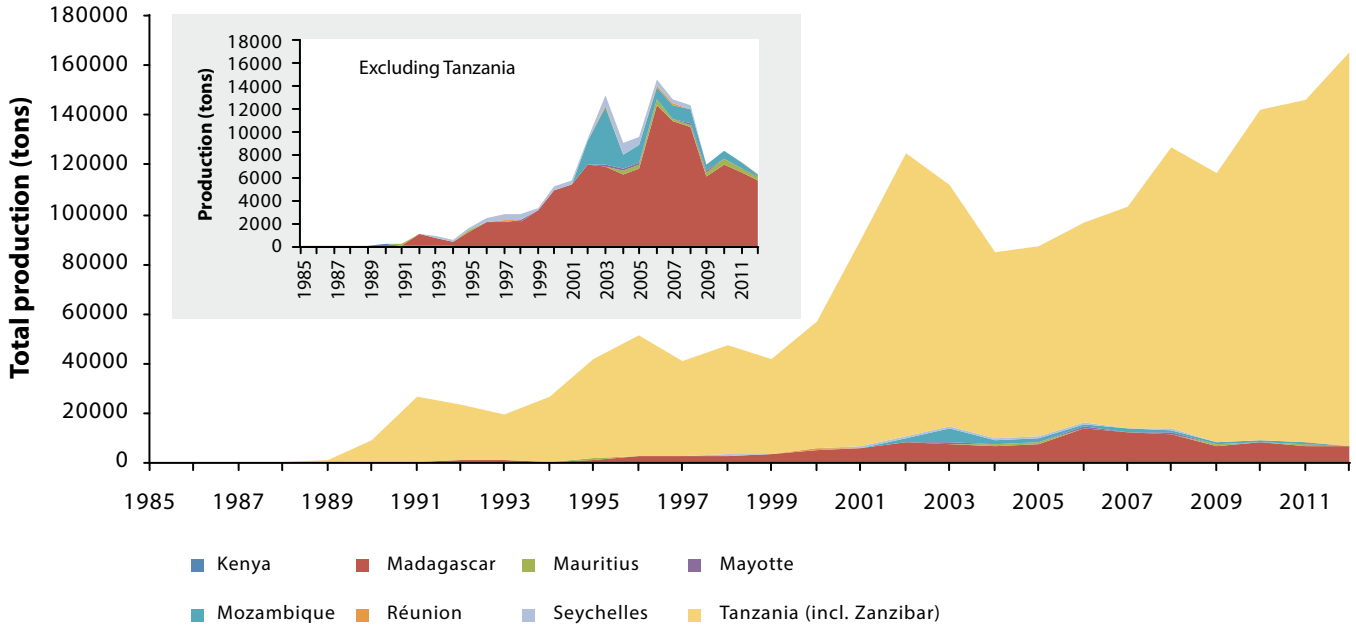


Figure 22.4. Total reported mariculture production in the SW Indian Ocean between 1985 and 2012.

Table 22.1. A chronology of major advances in mariculture in Tanzania.

1980s	• Seaweed culture experiments • Research on cage culture of rabbit fish (*Siganus*)
1990s	• Commercial seaweed farming by private sector starts in Zanzibar • Seaweed farming introduced to Tanga and Bagamoyo (1992-1994) and to Mtwara, Lindi, Mafia and Kilwa (1995 - 1996) • Integrated mariculture and biofiltration experiments at Makoba
2000-2005	• Mariculture project on milkfish farming • Workshop on "Advances in mariculture" Zanzibar in 2004 • Crab fattening experiments • Shellfish farming piloted • Pilot studies of small-scale / commercial finfish culture in ponds
2006-2014	• Shellfish, pearl farming and entrepreneurship develops • Initiatives to add value to seaweed industry • Sea-cucumber farming experiments in Pemba • Production of prawn postlarvae in 2009 • Sponge farming experiments in Zanzibar • Experiments with marine tilapia farming in Zanzibar • Tilapia acclimatization for mariculture

by introduction of the technique at mainland sites (Figure 22.5). Some 88 per cent of the people involved in seaweed farming in Zanzibar are women. The sector provides local women with an opportunity to contribute to their households and local economies.

Seaweeds are cultured in shallow subtidal areas over sandy bottoms along the coast. An off-bottom culture method has also been introduced, in which cuttings are tied to lines strung above the sea bottom. This method reduces seaweed die-offs caused by tidal and seasonal fluctuations in water quality, and works well at Pemba Island (Msuya 2011). Seaweed is fast-growing and crops are harvested every 6 weeks. It is dried, and the unprocessed product is sold to middlemen who export it. Dried seaweed can be stockpiled to take advantage of market fluctuations, but villagers depend strongly on the income generated and therefore tend to sell immediately after drying. Seaweed production is irregular because weather changes sometimes lead to die-offs, or international markets become saturated, affecting the prices that can be obtained. The die-offs often occur during the long rain season, when farmers can lose up to 3 out of 8 harvests that make up an annual cycle (Msuya and others, 2007).

There remains a large disparity between the low prices paid to farmers for dried seaweed in Tanzania (approx. 0.17 US$/kg) and the high market price for refined carrageenan (30-50 US$/kg) for *E. denticulatum* (Bryceson and Beymer-Farris 2011). To increase bargaining power and achieve higher prices for dried seaweed, women farmers are collectively organizing themselves through cooperatives (a good example being the Chole Society for Women's Development, on Mafia Island). Some value-adding in Tanzania is achieved at a small scale, for instance through the development of cosmetics and foodstuffs. Processing facilities for carrageenan have also been suggested by Zero Emissions Research and Initiatives and Zanzibar Seaweed Cluster Initiative (Msuya 2011) to increase value, through direct sale and export of carrageenan to international markets.

Threats from seaweed farming are often aesthetic, especially where farms are sited along the lower fringe of the intertidal and shallow subtidal, particularly in Zanzibar, in areas where tourism generates most income. The eco-

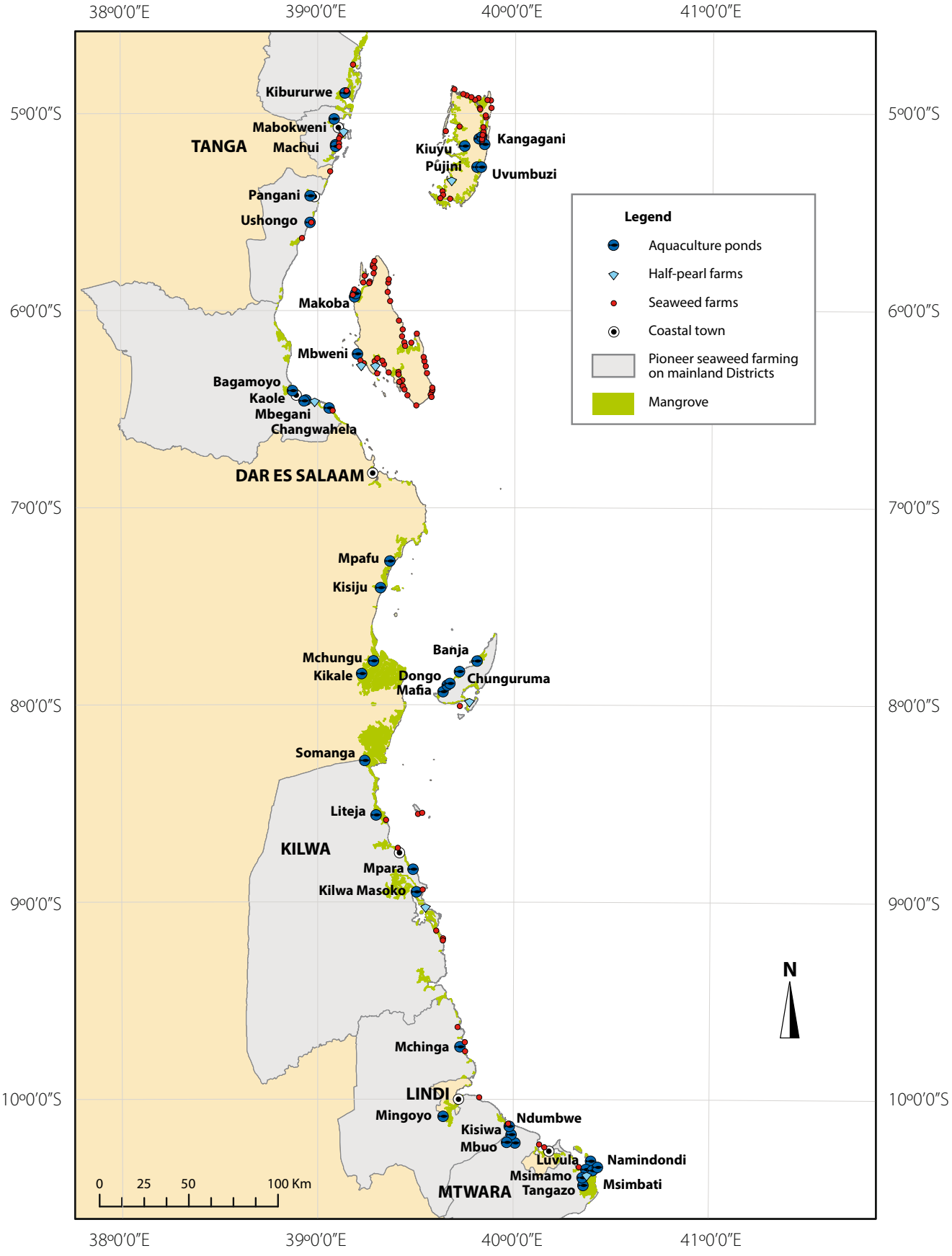


Figure 22.5. Map of the Tanzanian coast showing villages practicing mariculture of finfish, shellfish/half pearls and seaweeds.

BOX 22.1 COMMUNITY-BASED SEA CUCUMBER AND SEAWEED CULTURE IN SOUTHERN MADAGASCAR



Seaweed farming, Lambaora, southwest Madagascar. © Garth Cripps.

Sea cucumbers (*Holothuria scabra*) and red "cottonii" seaweed (*Kappaphycus alvarezii*) are well-suited to Madagascar's extensive shallow coastal lagoons, where simple production methods can be used at low running costs. Farmers require minimal initial training, and importantly, farming methods cause negligible adverse environmental impacts. Sea cucumbers (known as trepang after processing) are in high demand as a delicacy and health food on Asian markets, while red seaweed is widely used in food and cosmetics industries as a texturing agent. Nevertheless, the lack of technical and marketing skills were major obstacles to the development of aquaculture in the isolated villages of southern Madagascar. Blue Ventures, a science-led social NGO, worked with the the University of Toliara's Marine Science Institute (IHSM), local seafood exporter Copefrito and aquaculture company Indian Ocean Trepang (IOT) to establish a model community-based aquaculture hub in southern Madagascar. The group collaborated to provide assured access to markets, develop hatchery technology and supply, and assist with start-up costs. Training programmes helped to build the technical, financial and managerial skills needed by fishermen and women to manage their own aquaculture businesses – to date over 700 farmers have been trained. Community-based aquaculture with strong NGO and private investor support proved to be a success, providing new sources of income, and allowing improved access to food and education, while alleviating pressure on fisheries and marine biodiversity. (http://www.blueventures.org).

logical impact appears to be relatively mild, because seaweed culture does not require chemicals or feeds. Nevertheless, possible impacts are changes in the benthic meiofauna and microfauna, invasion of the farmed species to the wild, deforestation (resulting from the demand for wooden pegs on which to attach the ropes), introduction of plastics (tie ties and ropes) and user conflicts.

Rabbitfish (*Siganus sutor*) cage culture started in the 1980s (Table 22.1). Milkfish (*Chanos chanos*) farming started in 1998, when stray specimens that invaded ponds showed high tolerance to salinity variation. By 2007 there were an estimated 100 milkfish ponds in Tanzania (Sullivan and

others, 2010). A project conducted at Pemba Island, Mtwara and Tanga regions improved milkfish farming to producing an average of about one tonne per hectare (Mmochi 2010). Milkfish farming is now practiced in all coastal districts in Tanzania (Figure 22.5), using methods described in a milkfish culture manual (Requintina and others, 2008). Several tilapia species have shown tolerance to brackish and marine environments under experimental conditions, with fastest growth at salinities between 20 and 25 ppt (Hassan 2011, Nehemia and others, 2013). The total amount of finfish cultured in Tanzania remains unclear.

Shellfish farming started in 2004, supported by international aid organizations, and includes pearl farming and shell jewelry making activities (Table 22.1). Experimental pens for black-lipped pearl oyster (*Pinctada margaritifera*), winged pearl oyster (*Pteria penguin*), *Isognomon* species and *Anadara antiquata* were established in the intertidal in Bweleo, Fumba and Nyamanzi, in Zanzibar. Half pearls were first produced on a floating raft or line system in Zanzibar, and farms have spread to Pemba, Mafia Island and mainland sites (Figure 22.5). Around 1 000 half pearls valued at US$ 10 to 20 each were produced in 2012 (Mmochi, pers. obs.). Mud crab (*Scylla serrata*), sponge and sea cucumber farming are in an experimental phase (Vaterlaus and Bumbak 2011). Crab fattening at subsistence level occurs in several districts. The mainland Ministry of Livestock and Fisheries Development has expanded to include an aquaculture department, to enhance further development of the sector. On Mafia Island, a local company Alpha Krust Ltd constructed a 300-hectare prawn farm operation in 2003, producing prawns for the export market.

Kenya

Mariculture in Kenya has made some progress over the past decades, through development of simple innovative technologies, such as construction of inexpensive ponds, pens and cages. Culture species that need limited water management and feed low in the food chain (milkfish, mullets, mud crabs, penaeid prawns) have been studied (Mwaluma 2002, Wakibia and others, 2006, Mirera and Ngugi 2009, Mirera 2009, 2011, 2014). Prawn pond culture started in the late 1980s at Ngomeni Prawn Farm with funding from the FAO (Mirera 2011). The farm produced substantial quantities of prawns (Figure 22.6a), and provided technical assistance for the development of two satellite farms (Wampare's prawn farm and Kwetu Training Centre prawn farm) before it collapsed after donor funds were withdrawn. Milkfish and mullet were also harvested from the ponds.

Mud crab farming in Kenya can be traced back to the late 1990s, when it was introduced at Kwetu Training Centre (close to Mombasa) as a livelihood and mangrove conservation tool. Some level of success was achieved by introducing mud crabs to local communities, although farming was hindered by a lack of knowledge of their biology and unreliable funding (Mirera 2011). Juvenile and sub-adult crabs for grow-out are collected in intertidal areas, and sold to farmers at lower rates than market size crabs. Culture systems comprise mainly floating and dive-in cages, or pens made from mangrove poles (Mirera 2014).

Oyster culture at Gazi Bay and Mtwapa creek in the 1990s resulted in the production of 10 million oysters (*Crassostrea cucullata*), but the project was discontinued because of a lack of markets for the product. Seaweed culture initiatives at Gazi Bay and Shimoni, based on floating raft technology brought across from Tanzania, suffered a similar fate.

Despite some growth in the sector, mariculture in Kenya has not realized its economic or ecological potential, because of several reasons: conflicting government policies; impact of donor driven conservation projects; lack of capital investment; lack of access to international markets; and limited technological expertise. Most mariculture produce over the last decades were not reflected in national production statistics. Harvests were mainly for subsistence and sale to tourist hotels and restaurants (Mirera 2011). The Government has promoted mariculture of prawns, finfish and crabs (KMFRI 2010), and in 2012 the World Bank approved US$ 35 million for the Kenya Coastal Development Programme (KCDP) including aquaculture development (www.un-foodsecurity.org).

Mozambique

Mariculture in Mozambique has a chequered history, despite the potential competitive advantages of a long coastline and climate ranging from sub-tropical in the south to tropical in the north (Omar and Hecht 2011). Industrial scale prawn farming was first tried in the late 1980s, when the "Pilot Project for Coastal Shrimp Aquaculture" was set up by the UNDP and government and executed with FAO technical assistance. The farm near Maputo produced yields of 2.5 tonnes per hectare per year of *Penaeus indicus* during the project lifetime, and laid the foundation for the development of culture technologies

BOX 22.2. SEED PRODUCTION AND FISH STOCK PROPAGATION



Sea cucumber pens, village-based aquaculture of sea cucumbers in Tampolove, southwest Madagascar. © Garth Cripps.

Seed production is a major hurdle for the development of mariculture in the SW Indian Ocean. Madagascar is a pioneer country in holothurian aquaculture with a research programme that started in 1999, leading to the creation of a commercial hatchery, Holothurie SA (MHSA) (Rougier et al. 2013). The availability of *H. scabra* locally solves the need for the communities to invest in a hatchery that requires a considerable technical knowhow. Once the source of juveniles is secured, holothurian farming (the grow-out of juveniles in sea pens in natural lagoon habitat) requires an acceptable initial investment, no feeding or nutrient input, and little supervision from farmers other than in safeguarding stocks from environmental disturbances, predation and poaching. Community groups purchase juveniles from MHSA at a price subsidised by project donors, and are responsible for growing the juveniles to market size (minimum of 350 g). Market-ready adults are then sold back to MHSA for processing and export.

Acclimatization and growth performance studies of Rufiji tilapia (*Oreochromis urolepis*), Pangani tilapia (*O. pangani*) and *Tilapia zillii* in a marine environment have shown faster growth in brackish and seawater compared to freshwater in Tanzania. *O. urolepis* were made to spawn at different salinities, and fry were grown to fingerlings. Best reproduction performance was achieved at a salinity of 15, while growth performance peaked at 25. Hatchery development to produce acclimatized tilapia for farming in brackish and seawater is being considered. Other hatcheries for fish (red drum cobia) are located in Reunion and Mayotte.

Several private prawn farms in Madagascar have their own hatcheries, for instance, Aquamas farm at Soalala produces its own *P. monodon* post-larvae for on-growing (maximum of 20-30 million post-larvae per month). Prawn hatcheries also operated at Aquapesca in Mozambique and Alphakrust Shrimp Farm on Mafia island in Tanzania, but their present status is unclear. Two prawn hatcheries in Seychelles operated for nearly 20 years, but production ceased in 2008.

(Rafael and Ribeiro 2002). It was privatized in the mid-1990s, and more private investment in industrial scale prawn farming at Quelimane followed during the same period (Hecht and others, 2005). Two industrial scale farms were operational in 2008 namely Aquapesca at Quelimane and Sol & Mar at Beira, while a third, Indian Ocean Aquaculture at Pemba, was dormant. Total prawn production in 2010 was estimated to be around 1 200 tonnes (Omar and Hecht 2011), about double the quantity reflected in the national statistics reported to the FAO in that year (Figure 22.6b).

The Mozambique action plan for the Reduction of Absolute Poverty (2001-2005) promoted small-scale mariculture (or coastal aquaculture) as a means to contribute to food and nutritional security and socio-economic development. In spite of this, small-scale mariculture has not really been successful (Ribeiro 2007), and is presently limited to scattered prawn, fish and seaweed farming operations. Small-scale prawn farms of 4-6 ha produce between 250 kg to 10 t of tiger prawn *P. monodon* per year under extensive conditions in Beira and Angoche areas. Fish farming in Nampula produce mullet and milkfish in polyculture with tilapia, where ponds are supplied by tidal exchange and fish rely on natural productivity for food. Seaweed farming (*Eucheuma* and *Kappaphycus*) in Cabo Delgado and Nampula is promoted by NGOs as part of a wider programme of assisting coastal communities. Marketing the dried product (approximately 160 tonnes per year) remains problematic because of the distance to the buyers in Zanzibar, but surveys have shown extensive suitable areas for bottom culture by peg and line method in Nampula.

Marine fish farming in cages for dusky kob (*Argyrosomus japonicas*) and cobia *(Rachycentron canadum*) were initiated in 2009 in Pemba Bay by Aqua Pemba Lda. Currently the project is fully vertically integrated with laboratory, hatchery, rearing pens and processing facilities (http://www.hik.co.za/).

Madagascar

Commercial prawn farming for *P. monodon* commenced in the early 1990s and has received regular financial, technical and infrastructure support from NGOs especially Blue Ventures and foreign investors (Robinson 2011). Productivity exceeded 8 000 tonnes per year between 2006 and 2008, but collapsed to 3 000 tonnes in 2009 (Figure 22.6c), when the combination of increased international competition, declining shrimp prices and rising cost of energy and fishmeal resulted in a severe crisis (Iltis and Ranaivoson 2011). Production has since recovered. Pond farming takes place behind mangrove areas along the northwest Madagascar coast where mangroves have come under threat through erosion, siltation and related effects from ponds constructed on salt flats. An aquaculture plan guides the development of the sector, and promotes small-scale commercial and family-based prawn culture. It includes protocols for identifying appropriate culture sites and biosecurity (Shipton and Hecht 2007).

Seaweed (*Eucheuma* and *Kappaphyccus*) farming was introduced after 1998 and is the second largest contributor to mariculture production in terms of income after prawns (Figure 22.6c). It is popular in northeastern Madagascar, where most farmers are women. Dried seaweed is exported. Some environmental effects are deforestation for timber to make drying platforms and for the hard wood stakes onto which seaweeds are attached, introduction of the farmed species, and shading of the substrate. Culture of the blue-green alga *Spirulina* is a new activity being trialed in southwest Madagascar.

Culture of sea cucumber (*Holothuria scabra*) started in 1999 through funding and scientific cooperation between the government and Belgian Universities (Eeckhaut and others, 2008, Erikson and others, 2012). Between 1999 and 2007 the project developed technology and facilities (hatchery, nursery site and sea pens) at Toliara to produce juveniles and grow them to commercial size. Farms are mostly on the southwest coast, where local communities rear sea cucumbers while NGOs and a start-up company condition and export the boiled and dried product (Iltis and Ranaivoson 2011). Farms have expanded since 2010, with production in weight and income rising steadily, except for the effect of cyclone Haruna in 2013 (Rougier and Razafinama 2013).

Overall, mariculture in Madagascar is recently-established, with most production systems post-dating the 1990s. Other than prawn farming, many activities have not moved beyond the pilot phase, despite suitable natural conditions and technically successful results (for instance oysters, milkfish, *Artemia*). Plausible explanations include economic isolation, insufficient training, and degraded road infrastructure (Iltis and Ranaivason 2011).

Seychelles

Prawn farming in Seychelles was first established on Coetivy Island in 1989 by the Islands Development Company

Ltd and managed by the Seychelles Marketing Board. The farm comprised two hatcheries and around 200 ponds with a total area of 80 hectares, and at its peak in 2004 it produced about 1 200 tonnes of *P. monodon* (Figure 22.6d). Production had declined to just 400 tonnes by 2007, and ceased altogether in late 2008, citing high operational costs and insufficient post-larvae numbers for stocking grow-out ponds as the primary reasons (Lesperance 2011).

Pearl oyster farming started in 1995 and continues at Praslin in the Curieuse Marine National Park. Oysters are suspended on ropes attached to long lines or are inserted into the pouches of "kangaroo nets" (Hecht 2013). The quality of the pearls harvested has improved over the years, and some of them are used as jewelry on local markets whereas the remainder is exported to Japan and Australia (Central Bank of Seychelles 2006). Annual production statistics are not reported to the FAO.

Mariculture development in Seychelles is constrained by a poor understanding of the sector, reliance on capture fisheries for protein supply, lack of investment and scientific or technical capacity, and the absence of a properly defined legislative and regulatory framework (Lesperance 2011).

Mauritius

Mariculture in Mauritius dates back to French colonial times when juvenile marine finfish were collected from the wild and fattened in cages or pens (Lesperance 2011). A mariculture programme at the Albion Fisheries Research Centre developed innovative technologies during the 1990s, but private sector and government support were modest. A cage-culture farm in the Mahebourg lagoon has been in operation since 2001, and produces red drum in circular floating cages. The farm employs about 65 workers, and produced about 500 tonnes of fish in 2010 (Figure 22.6e). Farmed fish are consumed locally or exported. The culture of other species, such as seabream (*Rhabdosargus sarba*), has also been tried in cages. A mariculture sector development plan (2007) identified 21 sites for cage aquaculture; though few of these have been exploited because of a lack of investment.

Reunion and Mayotte

Reunion and Mayotte islands have aggressively pursued mariculture development over the past two decades, to offset undersupply from local fisheries (Lesperance 2011). These developments were spearheaded by the "l'Association Réunionanaise de Développement de l'Aquaculture" (ARDA) and AQUAMAY (the Mayotte Aquaculture Development Association) with support from IFREMER. Three species are farmed, namely red drum, goldline seabream, and cobia, and by 2008 several farms produced cultured fish on a commercial basis. Production trends for the two territories (Figure 22.6f) highlight a recent decline in finfish culture in Reunion. ARDA and AQUAMAY have some of the most advanced technologies in the region in seed and feed production and cage culture.

ENVIRONMENTAL IMPACTS OF MARICULTURE

Potential environmental impacts from mariculture expansion are in general determined by the characteristics of the culture systems (species, intensity, technology etc.) and site characteristics including nature of the seascape and landscape, waste assimilating capacity, waste loadings, other users, etc. (Troell and others, 2011). Collection of seed from the wild may put pressure on wild populations, or alter community structure by removals of new recruits (Ishengoma and others, 2011). Many high-end farmed species such as prawns and salmon are carnivorous, requiring more protein than herbivores and omnivores. Using fishmeal to feed farmed species may stimulate fishers to harvest more - usually species lower down the food chain. Instead of reducing fishing pressure on wild stocks, mariculture can therefore potentially increase it, through a high demand for fishmeal. Between 2007 and 2012, fish used as animal food remained fairly constant, ranging between 19.9 and 24.5 million tonnes (FAO 2014). Nevertheless, finding food for farmed species (whether for fish or land animals) is a global challenge, where interconnections between mariculture, fisheries, crops and livestock farming can act as impediments or opportunities for increased resilience (Klinger and Naylor 2012, Troell and others, 2014).

Clearing mangrove areas to build ponds for finfish mariculture is still practiced, and if left uncontrolled, may lead to loss of mangrove common property, and a reduction in ecosystem services (for instance nursery and filtration functions). Mangrove cuttings are used as pegs to hold lines, poles to construct drying racks for seaweed farming, or to construct cages for crab farming. The extent of clearance of mangrove areas in the region is presently unknown, but removal of mangroves to accommodate prawn farms

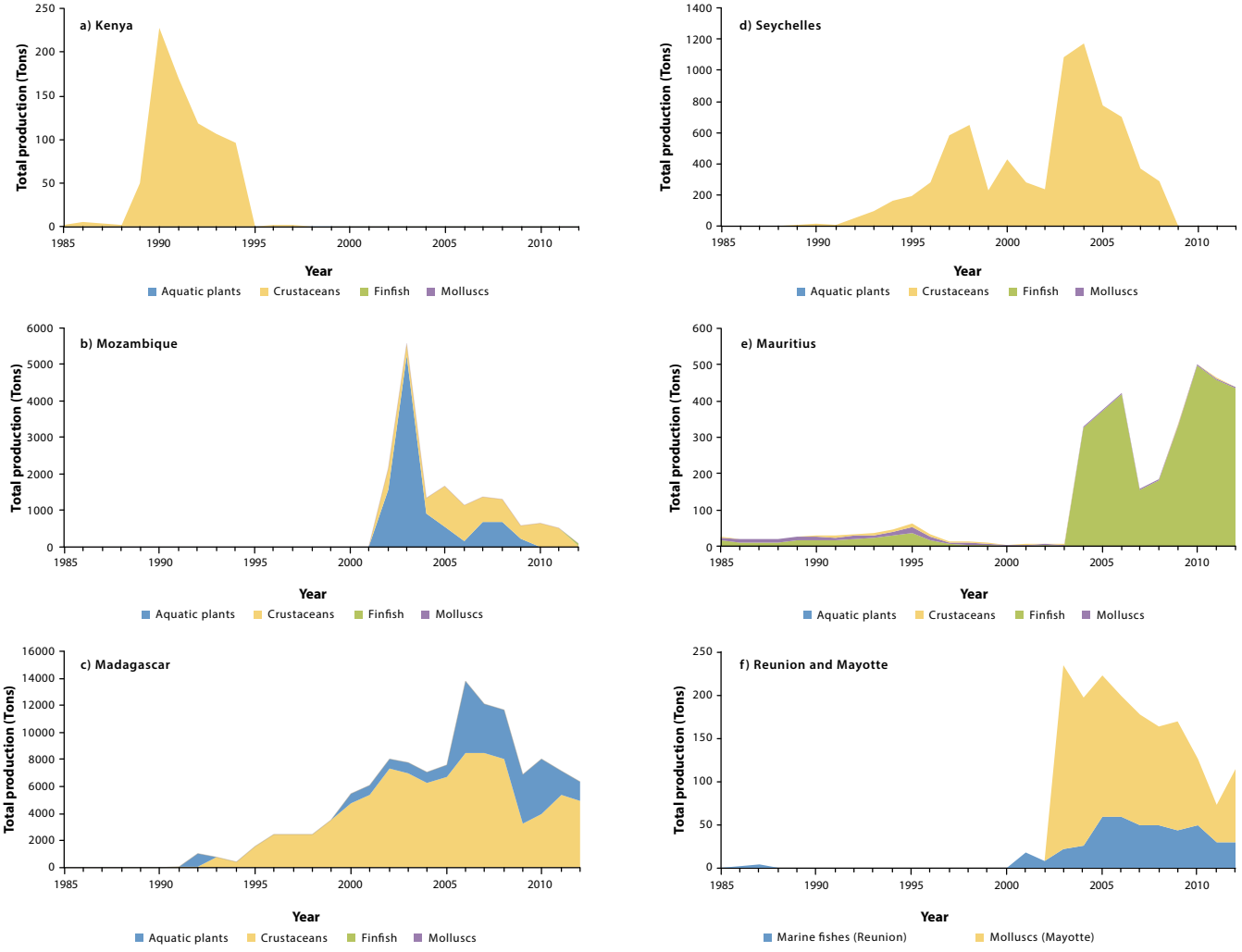


Figure 22.6. Mariculture production by species groups for the period between 1985 and 2012 for Kenya, Mozambique, Madagascar, Seychelles and the French territories of Reunion and Mayotte.

has stimulated controversy in Rufiji (Tanzania) and Quelimane (Mozambique).

Pond mariculture development in the intertidal can cause eutrophication and pollution through effluents of wastes, chemicals and pharmaceuticals, especially where farming takes place on a large scale, and controls over effluents are inadequate. Farming systems can give rise to spreading of diseases or antibiotic-resistant bacteria to other farms and wild stocks during water exchange (Gräslund 2004). Moving genetic materials between water bodies may introduce alien species and threaten indigenous populations. There have been reports of invasive species such as *Hypnea* and tilapia (*Oreochromis* species) in the region, mostly through aquaculture and marine transportation.

Seaweed mariculture competes with tourism for beachfront space and access routes, because neither farmers nor tourist operators recognize boundaries of public properties. Seaweed farms may affect aesthetics and therefore the marketing potential of popular tourist areas, whereas hotels may impede access to areas used by farmers by blocking off beachfront areas. Such conflicts can be moderated through marine spatial planning that includes broad stakeholder participation. One option is to integrate mariculture with tourism activities by making it a part of tourist attractions, for example, oyster farm tours and an annual oyster festival offered in Knysna, South Africa.

CHALLENGES TO MARICULTURE DEVELOPMENT

The UNDP classifies Mozambique (178th), Tanzania (160th), Comoros (159th) and Madagascar (155th) as having a low HDI (Indicators by Country, 2014; www.hdr.undp.org/en). This implies high poverty levels, inadequate nutrition

and health services, high adult illiteracy and a lack of trained people, technical expertise, research and education. The development of a mariculture industry within this setting is a challenge, particularly when extension systems fail to disseminate technical know-how required for farming and marketing (Troell and others, 2011). Targeted human resource or capacity development is therefore essential for the establishment of the mariculture sector.

Mariculture development may take place along different pathways, depending on the available infrastructure, capital means and technical ability of potential farmers. Extensive mariculture is based on food supply by natural resources; it is often suitable for small farms in the SW Indian Ocean region, where farmers do not have access to capital and technical skills. Intensive mariculture is based on provision of external food, and the cost of input per kilogramme of fish produced is higher; hence this system is suitable for larger, technologically-advanced investors culturing high value products for export (notably prawn or abalone farms). Whether farming uses extensive or intensive systems, or is targeted at local, tourist or export markets, it is important that robust impact assessments are undertaken, before construction is approved, to assess potential effects of farms on the environment and socio-economic systems, including food security and poverty alleviation.

Weak business skills among farmers and lack of market access place economic constraints on mariculture development. Funding agencies and NGOs can play important bridging roles. There is a clear role for the private sector in facilitating small-scale farming as a part of its strategy, through identifying new products, seeking opportunities for value adding, introducing new processing technologies and securing market access and shares (Troell and others, 2011). A good example of NGO involvement comes from southwest Madagascar, where local communities rear sea cucumbers, supported by NGOs that handle conditioning, marketing and export (Iltis and Ranaivoson 2011).

Governance systems are often opaque, with many different policies that lack coordination among ministries, or are even contradictory. A prospective farmer might need permission from ministries responsible for land, environment, water, forestry (mangroves), and fisheries. Such a protracted process discourages the development of community-based aquaculture. Improved governance systems to encourage and support prospective farmers would stimulate mariculture.

Finding a balanced trade-off between mariculture and conservation is another challenge. An Ecosystem Approach to Aquaculture (EAA, FAO 2010) is defined as "a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems". It implies a transition from traditional piecemeal planning and decision-making to a more holistic approach of integrated and adaptive management. For example, pond mariculture can easily affect mangrove conservation and salt-water intrusions. Therefore, site selection and farming methods (including disposal of wastes from the farm) are important in determining the health of mangrove stands, and their ability to buffer the coast against rising sea levels.

Bryceson and Beymer-Farris (2011) proposed an integrated 'rights-based' and 'ecosystem' approach to address the interests of the local communities and small-scale farmers, because it combines citizens knowledge with conventional science, and will moderate underlying political-economic and social issues related to the industry. Within such a system, all stakeholders need to be consulted when coastal zone development is undertaken. The development of new technologies jointly with stakeholders is important, but projects should avoid subsidies, as these create unsustainable industries (Troell and others, 2011).

Retaining biological (or genetic) diversity can be challenging in areas where seeds are imported from elsewhere. Most cultured finfish and seaweeds are widely distributed in the SW Indian Ocean, but when they are transported between areas, they can contribute to the spread of diseases, facilitate biological invasions, or reduce genetic variability (Responsible Aquaculture Foundation 2013, Keightley and others, 2015).

CONCLUSIONS

Mariculture in the SW Indian Ocean is still in an early developmental phase, with the exception of seaweed culture in Tanzania (especially Zanzibar), where production and farming methods have grown substantially over the past two decades. The growth in seaweed farming faces some constraints related to a buyers monopoly (namely the low prices paid to farmers for dried seaweed), and therefore low economic returns. It is important that the influence of markets on seaweed mariculture development be addressed, either through establishing a strong collective bargaining position, or by adding value to products through

further processing before export.

There have been numerous attempts by NGOs, developmental organizations and governmental research organizations in the SW Indian Ocean region to stimulate mariculture growth through demonstration projects, or establishing small farms or centers for technology transfer. Very few initiatives extended much beyond the lifetime of the projects, whereafter momentum was lost. Whereas the impediments to sustainable projects may differ (particularly the lack of skills, technology, infrastructure etc.), a common problem appears to be the remoteness of most of the SW Indian Ocean region from large urban centers and foreign markets. Without access to foreign markets, local food security is the main driver for mariculture. Where this is the case, mariculture still competes with established food production activities such as capture fishing and agriculture, instead of complementing them – after all, it is much easier to catch a fish than to culture it. A paradigm shift is therefore required at community level.

Prawn farming takes place on an industrial scale in Madagascar, Mozambique and Tanzania. Large-scale prawn farms are capital intensive, and require companies or owners with financial and technological means to succeed; their products are mostly exported. Several large farms have been operational in Madagascar and Mozambique since the 1990s (see above), but their success have been tempered by the recent (since 2008) global economic slowdown and the spread of white spot disease. Nevertheless, the model of industrial scale farms that form a node for economic activity (possibly smaller farms or related industries in their vicinity) and employment could be investigated.

Mariculture undoubtedly has high growth potential in the SW Indian Ocean over the next decade, as it starts from a relatively low base, and is generally supported by local communities, investors, NGOs and governments. The many constraints to growth mentioned throughout this chapter need to be overcome. An example of progress is provided by sea cucumber farming in southwest Madagascar, where collaboration between farmers (rearing), NGOs (technology) and business (marketing) has proved successful (see above, and in Rougier and Razafinama 2013).

Mariculture in the SW Indian Ocean region is presently at an important junction: it can either develop along a planned path supported by good governance, private sector investment, and NGO support; or it can spread unchecked, to gradually fill the gap left by decreasing returns from capture fisheries.

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