TECHNICAL REPORT No. 08 – EXAMPLES OF EXISTING INITIATIVES IN SMALL-SCALE RURAL AQUACULTURE IN THE IORA REGION

‘TECHNICAL ASSISTANCE TO IORA FOR THE IMPLEMENTATION AND COORDINATION OF IORA ACTION PLAN ON FISHERIES, AQUACULTURE AND MARINE ENVIRONMENT’

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ABBREVIATIONS AND ACRONYMS

AFD	Agence Française de développement – French development agency
DoF	Department of Fisheries
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
GIZ	Gesellschaft für Internationale Zusammenarbeit – German development agency
IORA	Indian Ocean Rim Association
IO	Indian Ocean
MS	Member States
NACA	Network of Aquaculture Centres in Asia-Pacific
USD	United States Dollars

1. Summary

Following a previous technical report (No 3) presenting a general review of governance and development of small-scale aquaculture in IORA region, this report examines some initiatives in small-scale and rural aquaculture development and includes four detailed case studies in the IORA region. The four examples have been selected to cover different sector development schemes according to the importance of the technicality, the natural environment and social and economic triggers that have driven their development or brought their failure. The choice of the case studies takes also into account the diversity of experience and success of member states within IORA. Carrageenan seaweed farming in Tanzania, sea cucumber sea-ranching in Madagascar, bivalve aquaculture in Thailand and marine cage tropical aquaculture in France (Réunion island) present four illustrative value-chain developments within the Indian Ocean. Each study provides a comprehensive account of the development of small-scale aquaculture with focus on the social and economic dimensions. The case studies are analysed in a general context taking into account various perspectives (e.g., technical, economic, social and institutional). Issues, constraints and challenges are highlighted. Potential steps forward are recommended. Despite the considerable information and knowledge provided by the studies, there are still many unknowns about small-scale farming, especially on the economic performance and the social organisational triggers. Further study is therefore needed to fill the information and knowledge gaps.

2. Introduction and methodology

The Indian Ocean Rim Association (IORA) and France through the Agence Française de Développement (French Development Agency) (AFD) signed a Memorandum of Understanding (MoU) on the 9th of March 2020 for “Strengthening the Capacities of IORA in Promoting the Blue Economy and Fisheries Management”.

The partnership supports the implementation of the IORA Action Plan (2017-2021) with an allocation of EUR1 million over three years. It offers expertise, training, networking and material resources to decision makers, officials and experts working to promote regional cooperation in blue economy and fisheries management issues. In addition, the project strengthens the capacity of the IORA Secretariat.

The overall objective of the technical assistance (TA) is to “support IORA and its Member States in the coordination and implementation of the Action Plan on Blue Economy and Work Plan of IORA CGFM, with a strong focus on fisheries, aquaculture and protection of marine environment.”

One of the specific objectives of this TA is “to promote sustainable aquaculture development”. In the context of this objective, the activity 3.1 “Promote small-scale rural aquaculture” is planned as part of the IORA Action plan.

The methodology adopted within that activity is to undertake a general review of aquaculture in the IORA region with a brief study and presentation of governance and background for development of small-scale aquaculture and, in a separate report, to present some existing initiatives in small-scale rural aquaculture with selected examples of successful and unsuccessful aquaculture development projects. Some of these examples are developed in detail to present the mechanism of success or failure of small-scale rural aquaculture development. The two reports will subsequently be the subject of presentation, discussion, and revision in workshops and/or webinars on small-scale aquaculture development with a view to assist in decisions on training activities and/or other initiatives such as technical support to some IORA MS pilot projects.

The present report provides some existing successful and unsuccessful initiatives in small-scale and rural aquaculture with four case studies to show the detail of their development.

Following an introduction and methodology to contextualise the report within the AFD technical assistance to IORA, the report provides the approach used and the criteria for the choice of examples of small-scale and rural aquaculture. It then provides a summary of twelve (12) aquaculture initiatives of which four (4) are subsequently presented in detail as annexes for the report. The report ends with some concluding observations and comments.

3. Preparation of this document

3.1. Approach

The objective of the present report is to present practical case studies of small-scale aquaculture farming and value chain development within the Indian Ocean region. These small-scale aquaculture sector developments analyse present concrete applicable examples to illustrate the general review of governance and development of small-scale aquaculture in IORA region[1]. Together, the two reports draw a general review of small-scale aquaculture development and of its potential in the IORA region. The disparities of sector development and experience within IORA Member states offer a base for practical analysis and of examples to illustrate and demystify this segment and the regional aquaculture industry. It provides interested stakeholders with objective data on the status of small-scale aquaculture and its potential for growth as well as the difficulties to implement changes and assure the sustainability of the sector.

Twelve examples are presented in a summary form to illustrate the diversity of aquaculture experiences. Of these, four detailed case studies were made:

- Carrageenan seaweed farming in Tanzania;
- Sea-cucumber sea-ranching in Madagascar;
- Marine cage aquaculture in France (Réunion island) ;
- Bivalve aquaculture in Thailand.

For these examples, the analysis of the approach and the constraints considers the socio-economic approach, the governance and background of their development. The aim of the analysis is to point out the triggers and drivers of their success or failure.

This report first presents the criteria used to select the four case studies. Then each case study is presented in a four page summary format with an overview of the i) Sector main facts (production, species, economic value, number of farmers and information on finished products) – ii) Sector overview considering the history of the activity, the farming technology, the value chain, government and institutional support, the environmental and social impacts – iii) Challenges and steps forward that list and present mains issues for the sustainability or the future development of the activity.

[1] Blanc, P., 2021. Review of aquaculture, governance and development of small-scale aquaculture in the IORA region. IORA/AFD Technical Assistance – Technical Report No. 3, March 2021, COFREPECHE. 90pp.

3.2. Choice of case studies

3.2.1. Definition of small-scale commercial farming sector

This study has focused on small-scale commercial aquaculture farming. This sub-sector within aquaculture was defined as follows:

- A small-scale commercial fish farm is managed as a for-profit business by either an individual or a group (e.g., a cooperative);
- The individual or group invests capital in the enterprise (time of work can represent an important part of the capital);
- Cash returns on investment are the main criterion of success;
- Individual farmers produce less than 50MT per annum (group production can be above 50 MT per annum as long as the individual production is less than 50 MT per annum);
- Production takes place in open or closed systems and in stand-alone or integrated systems.

3.2.2. Literature and field studies

Currently, available data on the small-scale producer segment is often inadequate. The availability of multiples sources of data and literature have driven choice of some case studies. The production and the countries' production where important information was available were selected in order of preference. Updates from published reports, grey literature, peer-reviewed scientific articles, national and international statistics were used.

This information was supplemented by the field experience of the author and his personal work records.

3.2.3. First list of field studies and selection

A first list of possible case studies was chosen according the following criteria:

- Examples within the Indian Ocean;
- Experience of a member state of IORA;
- Small-scale aquaculture;
- To cover different sector development schemes in terms of technicality, the natural environment and the social and economic background;
- Illustration of different triggers that have driven their development or brought their failure;
- To take into account the diversity of experience and success of member states within IORA;
- To be at different stages of development ("nascent", "mature", "failed");
- To present different situations of future development: important potential of development, issues on sustainability, in decline or extinct.

The twelve small-scale aquaculture sector examples selected where the following:

- Seaweed in Zanzibar;
- Sea-cucumber in Madagascar;
- Tilapia in Kenya;
- Tilapia in Mozambique;
- Fresh water aquaculture in Bangladesh;
- Coastal aquaculture in the Mekong River delta (Mangrove crab and shrimp);
- Crab aquaculture in Madagascar;
- Indian fresh water aquaculture development ;
- Marine cage aquaculture in France (Réunion Island) ;
- Shrimp farmers in India;

- Shellfish (bivalve) culture in Thailand;
- Semi-aquaculture of octopus in Zanzibar.

4. Cases studies

4.1. Summary of the small-scale aquaculture case studies examined

Seaweed in Tanzania (Selected)

Seaweed farming support on the late 1980's developed artisanal aquaculture to become an important industry contributing significantly to the economy of the Zanzibar Islands. Comparatively, Zanzibar was reported the third biggest exporter of seaweed after the Philippines and Indonesia in the year of 2012. More than 30,000 people were involved in seaweed production and more than 80% of seaweed farmers were women. Seaweed farming today has declined and needs to be re-invigorated and its model strengthened to make it sustainable and to develop the existing assets.

Sea-cucumber Madagascar (Selected)

Growing demand of sea-cucumber for the Chinese market has developed an innovative model of aquaculture in south Madagascar. From hatchery to associations of farmers, the production has initiated important developments. Similar initiatives have recently started in several Indian Ocean Countries.

Sea-cucumber farming in Madagascar has huge potential but the model still needs to show its sustainability and development. Sector governance and diversification are expected to accompany the future steps of its growth.

Tilapia in Kenya

A model of small-scale aquaculture development supported by commercial initiatives has brought encouraging results (mainly in central Kenya and Lake Victoria). Tilapia aquaculture today is responsible for a significative increase in aquaculture production in Kenya. Industrial and small-scale aquaculture are sharing this activity and developing with increasing interactions. The value chain still needs articulation to adapt to the needs of market access of these new production systems. Some important barriers (seeds, technical, capital access, feed, governance) need to be addressed to accompany this sector's development allowing it to reach a sector size that will encourage further private investments.

Tilapia in Mozambique

Over the last 20 years several projects have been implemented and supported for the development of fresh water rural aquaculture. In the early 2020s, the sector still presented a marginal level of production and less than 4000 farmers. The potential for development still requires important margins of improvement. The production and the sector's development seem to not have found a successful development pathway, yet. Important development projects are now in implementation to enhance the conditions for re-invigorating small-scale inland aquaculture.

Fresh water aquaculture in Bangladesh

Small-scale aquaculture plays an important role in rural poverty reduction. Pond culture represents the mainstay of aquaculture in Bangladesh, accounting for 85.8% of total recorded production and 57.7% of the area under culture. The Mola Promotion Program in Bangladesh and other supporting projects have been important for the promotion and support of this development. Social organisation and local initiatives have supported the sector's development. Structural barriers and environmental issues are today weakening the sector's sustainability.

Coastal aquaculture in the Mekong River delta (Mangrove crab and shrimp)

Coastal aquaculture plays a very important role to the Mekong River Delta of Viet Nam. In early 2000s the government of Vietnam started an ambitious plan of development of small-scale coastal aquaculture. In a decade, the area under aquaculture production had increased by 98% and the production by 350%. Driven by dynamic market development and strict sector governance, the system is also facing important economic and environmental risks that can jeopardize its sustainability.

Crab aquaculture in Madagascar

After several years of development and the support of projects, crab aquaculture production stays based on use of wild seed and on fattening activities. The aquaculture of this species is still poised on the edge of its potential for development.

Indian fresh water aquaculture development

From polyculture models, artisanal aquaculture development, community initiatives, seed management and integration of aquaculture in horticulture or rice production, the last 25 years of India's significant aquaculture development has been supported by a structured diffusion of scientific information/technologies from research to the farming community.

Marine cage aquaculture in France (Réunion Island) (Selected)

Introduction of new technologies and imported species brought a small-scale aquaculture model adapted to local environmental conditions within the space available. With important institutional and financial support, the model developed but also struggled to build its value-chain and economic base. External media-driven events unfortunately brought up important public opposition. The production model has finally failed and has jeopardized all future marine aquaculture initiatives on the island.

Shrimp farmers in India

Empowering small-scale farmers through a cluster-based approach has led to a phenomenal increase of area under shrimp farming. The sector was contributing to around 80% of the total shrimp production of the country in late 2000s. The communities' organisation has fostered a successful social link that has set up an innovative governance system with institutional structure and controls.

Bivalve culture in Thailand (Selected)

From traditional farming to implementation of more sophisticated and traditional based methods, bivalve-mollusc culture represents now more than 20% of total coastal aquaculture production of the country. Its development is almost entirely oriented to the local market and needs to build on its success to diversify (in species and markets) and to find a sustainable pathway to tackle environmental and food safety issues.

Semi-aquaculture of octopus production in Zanzibar (Selected)

Octopus, targeted by men and women by gleaning with spears on foot in shallow waters or skin diving on deeper reefs, is vital to local economies but the resource is threatened. Several communities have started to implement fisheries closures. From this first success in total capture and average capture size, community management was implemented with buried shelters for octopus and zone surveillance against poachers. With only 3 to 4 collections per year, directly in the buried pots, the average size increased between 1.5 and 2.5kg (instead of an average weight of 350g before resource management) and a significant yield improvement. Area with semi-aquaculture management went from less than 200 hectares in 2015 to more than 3000 in 2018.

4.2. Detailed case study presentations

According to criteria of selection and the quality and the variability of data available, four cases studies were selected:

- Carrageenan seaweed farming in Tanzania (see Annex A);
- Sea-cucumber sea-ranching in Madagascar (see Annex B);
- Marine cage aquaculture in France (Réunion island) (see Annex C);
- Bivalve aquaculture in Thailand (see Annex D).

Each case study follows the same format in 4 or 5 pages including the following information:

- Sector main facts presentation actual and maximum production, species, economic value, number of farmers and information on finish products ;
- Sector overview presentation considering the beginning of the activity, the farming technics, the value chain presentation, government and institutional support, the environmental and social impacts;
- Challenge and steps forward that list and present mains issues for the sustainability or the future development of the activity;
- Several photographs of the situation and farming operations.

5. Concluding observations and comments

IORA member states share a vast tropical ocean, their communities have long term relationships with the sea and aquaculture is a natural and significant development pathway for the future of the area. IORA members states, through their past experiences have a wealth of learning opportunities with practical cases and much learning material to illustrate success and failures in aquaculture development projects. The variability of experiences on the artisanal and small-scale aquaculture sector allows some understanding of the mechanisms that brought about the development, or the decline of the activity. The present report contains twelves examples, four of which have been developed to present the different socio, economic, governance and environmental elements that go along with sector development and at the same time illustrating issues, constraints and challenges along the way to sustainability.

This report accompanies and illustrates the general review of governance and development of small-scale aquaculture in the IORA region, technical report produced in the context of the Technical Assistance[2]. It shows, from a practical point of view, that the complexity, technicality, natural environment, social and economic triggers especially when at a nascent phase of aquaculture development, cannot provide a standardized development framework for all aquaculture development initiatives. These case studies represent a sample to illustrate some different options, challenges and opportunities that can exist; it also gives an overview of activities within the same appellation of small-scale aquaculture.

[2] Ibid, page 6.

Carrageenan seaweed farming in Tanzania, sea cucumber sea-ranching in Madagascar, bivalve aquaculture in Thailand and marine cage tropical aquaculture in France (Réunion island) present four illustrative value-chain developments within the Indian Ocean. Each study is at a different stage of development, with different social and economic schemes and with different external support. It is also production for local or export markets, with different value and opportunities. This gives an opportunity for a quick illustration of the variability that exists, the different reasons for success, the constraints faced, and the improvements needed. The other examples that are not fully developed and detailed show that this variability is even greater and likewise the needs to go further on small scale aquaculture development in the IORA region. The opportunities are numerous, the possibilities important and the experiences in the region are inspiring.

In conclusion, it should be pointed out that this information sharing shows that there are many ways to develop small scale aquaculture. There is no single solution, and various measures need to be designed to adapt to existing conditions and needs. As always, careful preparation and extensive consultation are key steps for successful intervention, support and long-term impact.

ANNEX A: Carrageenan seaweed farming in Tanzania

CARRAGEENAN SEAWEED FARMING
- TANZANIA -

Sector main facts

Production: maximum of 15 100 tonnes of dry sea-weed reached in 2012, decreasing to a stagnant production of 11,000 tonnes of dry product between 2016 and 2018. Tanzania is the third largest producer (behind Indonesia and Philippines). Zanzibar island produces 98.7% of Tanzania's production (FAO, 2018)

Species: The production is dominated by one species: *Eucheuma denticulatum* (spinosum of the trade) and a minor production of *Kappaphycus alvarezii* (cottonii of the trade).

Economic value: Seaweed holds the first position among marine exports produced by Zanzibar, and a second position among the foreign currency earning crops (RGoZ, 2005; MACEMP, 2009; RGoZ, 2010; Msuya, 2011a; MANR, 2011; Msuya et al, 2014).

Number of farmers: 31,000 farmers living on the coast of Tanzania (Msuya et al. 2014). But the figures go to 60 000 people when considering indirect work and seasonal ones (Msuya, private communication 2018), 80 percent of whom are women.

Finished Products: the dry seaweed is marketed for its high-value extract known as carrageenan which is used as stabilizer, emulsifier, or thickening agent in various food additives, cosmetics, and pharmaceutical products


Farmer collecting her seaweed – Zanzibar (FAO)

Sector details

Beginning of the activity

Seaweed exports from Tanzania to Europe can be traced back to the 1930s (Mshigeni, 1998) - Seaweed farming techniques were introduced to women living on Zanzibar Island in the 1970s (Semesi and Mshigeni, 1977). In 1985, Dr Mshigeni conducted the first farming experiments in three localities in Tanzania and Zanzibar. From these initial results, two experimental farms were established on the east coast of Zanzibar. In the early '90s, commercial seaweed farming expanded in islands of Zanzibar and onto the mainland coast. The first documented production and export activity took place in 1990, when 808 tonnes were exported. Production increased over the years, reaching over 15 thousand tonnes by 2012 (Msuya 2006; 2009). Most production is from Zanzibar while mainland Tanzania's output is less than 1 000 tonnes.

The farming techniques

- The most common method used is the off-bottom method in shallow subtidal waters of one foot depth at the lowest tide. In this case, the farming takes place in shallow lagoon locations, well protected from open sea conditions. There is a need of daily tidal variations in the lagoon that result in good water flow and tidal flushing and absence of any direct freshwater flow into the lagoon.

Lines of about 10 to 15m and selected pieces of seaweeds are fixed every 10 to 20 cm. The lines are stretched off the bottom by two pegs driven into the sea floor. This basic farm set-up is common in all Tanzania production. To increase productivity, a floating line system using water bottles for floats can be used to avoid the seaweed lying on the sand.

The farmer will harvest the sea-weed regularly, there are up to eight production cycles per year. The farms can only be tended by farmers when the lowest tides occur during daylight hours. This means that farmers can tend their crops for periods of about one week, twice per month.

- Another production mode is possible: the floating line method in deeper waters of at least two meters depth at mean sea level. These methods offer better growth results (up to 2 to 3 time higher per day according to Msuya) and address the disease problem caused by salinity fluctuations or important temperature fluctuation. However, the floating line method is new to Tanzania and raise some social and organizational aspects.
- Yield: about 12 ± 3.2 tons/ha/yr (Msuya, 2013)

The value chain

After harvest: Traditionally, seaweed is dried-on palm fronds and cloth material placed directly on the ground. Ground drying results in poor quality, so drying racks that elevate the drying surface off the ground are recommended as a best practice to improve the quality of the final product. Seaweed takes from two to three days to dry in sunny weather, but drying may take up to seven days in rainy seasons. Upon drying, the seaweed is sorted and shaken to remove dirt and sand. It is then stored at home or sold directly depending on the harvest volume.

Seaweed drying – Zanzibar (PPh

The farmers sell the dried seaweed to local buyers who export it raw to overseas companies that process the seaweed and sell the extracts to other interested countries.

Therefore, seaweed is farmed in Tanzania for export only, although there are isolated occasions where some people use it as salad. The seaweeds are processed to extract a phycocolloid called carrageenan that is used as a gel and emulsifier in a number of industries including pharmaceutical (e.g. making toothpaste), cosmetic, textile, and food (e.g. in ice cream, yogurt etc.).

Governance and institutions support

Seaweed farming in mainland Tanzania is regulated under the Fisheries Act, Fisheries Policy and other fisheries regulations. In 2019 the government implemented modifications to the Fisheries Act and Fisheries Policy to clearly outline the sections on mariculture and seaweed farming. The government of mainland Tanzania produced a Seaweed Development Strategic Plan (SDSP) (MNRT, 2005).

The governments of mainland Tanzania and Zanzibar have played a significant role in the development of seaweed farming through their departments in the Ministries of Natural Resources and Trade and Industry. The governments provide a link between farmers and exporters with a role in negotiation of prices with buyers and control of taxes, revenue, and the importation of seaweed strains for cultivation. These efforts to promote free trade in order to protect farmers from monopolies has supported the development of the sector according to development studies (MNRT, 2005; Msuya, 2006; Msuya et al., 2007; ACDI/VOCA, 2005).

Eucheuma denticulatum – Zanzibar (FAO)

Efforts have also been made to provide farmers with seed money for the purchase of farming materials. These initiatives, however, should be implemented strategically through negotiations with the buyers who will eventually purchase and export the seaweed.

The governments' efforts have been implemented through programmes such as the Marine and Coastal Environment Management Project (MACEMP) and the establishment of small credit systems such as Savings and Credit Cooperative Societies (SACCOS) and Village Corporative Banks (VICOBA).

Practical examples: Through its Department of Fisheries and Marine Resources (ZDFMR), the government of Zanzibar advises farmers to work jointly with the companies and agree on the mode of conducting business prior to engaging in production. Farmers must sign agreements to confirm that the seaweed will be purchased by the exporters. The ZDFMR can provide guidance to farmers for the signing of agreements.

Through MACEMP, the government of Zanzibar is also assisting villagers with the testing of new methods of farming, the acquisition of boats for the transport of seaweed, and the construction of a warehouse in Chwaka village. Through PADEP, the government has contributed to the renovation of seaweed storage rooms and the opening of shops for seaweed farming materials.

Environmental Impact

Seaweed culture was encouraged in the region because it is considered an environmentally sustainable enterprise (Msuya, 1993; Nanyaro, 2005).

Seaweed farming units cover a limited area along the lower fringe of the intertidal zone and do not require chemicals or feeds. These aspects demonstrate how the ecological impact of seaweed farming is minimal (Torre-Castro, 2006; Eklöf, 2008).

However, there are rising concerns that it may reduce abundance and biomass of flora and fauna in the underlying seagrass beds where it is cultivated (Eklof et al. 2005) and trampling of sediment and seagrass from farmer foot traffic can be important in some areas.

Mangrove poles are often used for the pegs, creating additional concerns of impact on mangrove stands in proximity to seaweed farming areas.

Social Impact

Thanks to attributes such as relatively simple farming techniques, low requirements of capital and material inputs, and short production cycles, carrageenan seaweed farming has become a favorable source of livelihood for smallholder farmers or fishers generating substantial socio-economic benefits to marginalized coastal communities.

Seaweed farms – Zanzibar (PPh Blanc)

More than 90% of Zanzibar coastal seaweed farmers are women (Nanyaro, 2005). Seaweed farming provides women with an opportunity to contribute to their household economies. This empowers women and increases gender equality because women are often excluded from many economic activities (Nanyaro 2005; Msuya et al. 2005).

Entry to seaweed farming is unrestricted. Any inhabitant from a coastal village can establish a farming location wherever space is available.

Challenges and steps Forwards

Improvement of the value chain outputs

There is a huge disparity between the prices paid to producers for dried seaweed in Tanzania and the market price for refined carrageenan. The farmers are receiving only between 0.6 to 1.2% of the price per kg of carrageenan product on the international market (personal communication; Institute of Marine science, Zanzibar 2019). One of the reasons is that the largest part of seaweed produced has been exported unprocessed.

- Refined iota carrageenan from spinosum is made only by the alcohol precipitation process.

In 2008, a value addition initiative began under Zanzibar Seaweed Cluster Initiative (Msuya 2011; Msuya et al, 2014;). Currently a small fraction of the produced seaweed is transformed into powder which assumes higher value compared to former unprocessed one.

- 1kg of seaweed powder is sold at TZS 10,000/= (USD 6) compared to a TZS 500/= (USD 0.3) for 1kg of raw seaweed (Msuya).

However, the challenge is how to upscale value addition initiatives in order to accommodate both local and international market demands. Therefore, the seaweed sector requires not only increased production for high export volume but also embracing value addition initiatives for increasing crop economic returns and farmers' income.

⇨ Action ongoing: farmer to collectively organize through cooperatives / setting of local processing facilities

Species selection

Several cultured seaweed species are to be found in Tanzania. *Eucheuma denticulatum* and *K. alvarezii* continue to be the most widely farmed species. Recently, serious problems have been caused by widespread die-offs of *K. alvarezii* experienced in many areas in Tanzania. This situation has created negative impacts for farmers, exporters, and the country at large. Unfortunately, the world market has a preference for *K. alvarezii* over *E. denticulatum* because of its thicker carrageenan. Farmers have tried to grow *K. alvarezii* but increase of temperature and heavy rainfall during the rainy season negatively impact the production. Many farmers have thus resorted to the lower priced species. These problems have discouraged some farmers, particularly men, who have returned to low-paying activities and to fishing.

Farmer with its harvest – Zanzibar (PPh Blanc)

⇨ Action ongoing: Change to floating line method in deeper waters to support the development of this species.

Conflict of use of intertidal zones

- The expansion of tourist hotels along many parts of the coast has caused seaweed farmers to lose access to important farming areas in the intertidal zone and drying areas on the upper shoreline.
- Some intertidal zones are also available only with boat access and women do not have traditionally access to boats.
- Traditional access conflicts, as community / village rules do not give easy access to some areas.
- Conflicts with fisher landing sites or low tide fishing/collecting activities are also a source of loss of farming areas.

⇨ Action ongoing: Spatial planning and government planning to preserve rights and access to production areas.

Social challenges

The sector is today dominated by women. Traditionally, women have not been present in marine activities, have no access to boats and do not learn to swim. Furthermore, cultural and religious structures in coastal areas of Tanzania, have given women little access to business and technology-improvement initiatives.

⇨ Action ongoing: farmers to collectively organize through cooperatives, and support of women empowerment. A project to promote and support developments of floating line method in deeper waters to support production with better yield.

Climate change and diseases

Since 2012, production decline has been observed. Some production areas stop for several months during the hot season. This decline is attributed to a multitude of factors, including climate change-induced stress, which increased water temperatures in the hot season from below 30 °C in the 1990s to 38-40 °C in 2019 and was associated with disease outbreaks, such as "ice-ice" (Hayashi et al. 2010; Msuya 2011; Cottier-Cook et al. 2016). Coupled with the pressure of disease outbreaks, farmers have also faced the additional challenge of epiphytic filamentous algae (EFA) (Msuya and Porter 2014).

⇨ Action ongoing: Change to floating line method in deeper waters to support production without disease and with better yield.

Seaweed farms – Zanzibar (PPh Blanc)

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ANNEX B: Sea-cucumber sea-ranching in Madagascar

SEA CUCUMBER SEA-RANCHING
- MADAGASCAR -

Sector main facts

Production: 98.8 tonnes of production of sea-cucumber in 2017 (FAO, 2018)

Species: *Holothuria scabra. The animals are called, sea-cucumber or sandfish*

Economic value: 951 000 USD according to FAO database. But the data do not reflect production level (personal notes)

Number of farmers: 354 families in 2017 but impacting more than 1500 peoples considering indirect work and seasonal one (Blue venture, 2019 and IOT, 2017). A majority of farmers are women

Finished Products: dry products (Cooked and eviscerated). The finished product is called "trepang"

Sector details

Beginning of the activity

A sea-cucumber mariculture project was launched in Madagascar in 1999 (Jangoux et al. 2001). From 2000 to 2004, the University of Toliara (Institute of Fisheries and Marine Science – "IHSM" for its French acronym) the first phase was to produce juveniles in the hatchery. The second part (2004-2008) had ensured pre-growth technical operations in external ponds and grow-out phase in the natural environment.

Sandfish sea-ranching pen during spring tide – (PPh Blanc)

In March 2008, the project evolved from its experimental roots into the commercial domain with the creation of Madagascar Holothurie Société Anonyme (MH.SA), the first private company based on sea-cucumber aquaculture in Madagascar (Eeckhaut et al. 2008; Robinson and Pascal 2009). Today a commercial hatchery is producing juveniles in the south of the Island (Indian Ocean Trepang – IOT). Several actors are, since January 2007, organizing and developing production with the method of sea-ranching. The main actors are IOT and a non-government organization (NGO) (Blue Ventures and Trans'Mad-Développement (TMD)). Today several initiatives have developed a community-based farms management system. Based on the sea-ranching approach with pens in shallow coastal lagoons, this nascent activity has shown important development opportunities and also listed important threats of this aquaculture approach.

The farming techniques

The farming technique is called "sea-ranching": Enclosure pens of 100 to 1000 m^2 are built in shallow coastal lagoon areas. Pens are 30 to 70cm high and buried in the sand (20cm to 30cm deep to prevent sandfish borrowing under).

- Animals are stocked at juvenile stage (around 20g) and are harvested above 400g.
- The growth can be around 1.5g/day and animals require 10 to 12 months of culture to reach harvest size.
- Carrying capacity: around 200g to 250g of sandfish/m^2 but it will depend on the quality of the sediment. A good sediment area can carry 500g of sandfish/m^2.

The method used in Madagascar models are based on monthly (or every 2 months) stocking and monthly (or every 2 months) harvesting withing each pen (several generations of animals are sharing the pen). This approach reduces the risks of robbery and allows the farmers to have regular incomes from its activity.

The farmers of a same community group their pens together and share the constant watch needed to avoid robbery (mainly at night) and sometimes the pen construction. These community farmer associations allow the sea-ranching approach to group their needs of juveniles and their harvest. The higher volumes allow better pricing and management.

- Yield for a $1000m^2$ pen: monthly (or every two months) harvest will depend on the carrying capacity of the sediment. Volume at harvest can be above 100 animals of 400g for a $1000m^2$ pen.

- Management work for a $1000m^2$ pen: 2 people are needed for the daily activities. Harvest may need an extra taskforce. The regular tasks and maintenance are brushing the net to avoid the biofouling and controls (and sampling) are done to check if the animals are present, in good condition and the traps placed for the predators (mainly crabs) are checked and preys collected.

The farms can only be tended by farmers when the lowest tides occur during daylight hours. This means that farmers can tend their crops, around 2 to 4 hours per day, for a period of 4 to 6 days, twice per month.

Harvest and sampling are done at night as sandfish bury under the sediment during daytime.

- Polyculture of sea-cucumber and seaweeds can be done (same environment, same work organization), increasing possible economic activities.

The value chain

Some buyers prefer to receive the sandfish (i.e. sea-cucumber) fresh because they will do the processing themselves. Others prefer to buy the sandfish already processed.

The processing of sandfish is not technically difficult, but it requires much time and labour - it requires gutting the sandfish, boiling them in pots of water, scrubbing them to remove their chalky outer layer and then salting and drying them in the sun to remove the water. The end product becomes very dry and hard, and if placed in a plastic packet or bucket that is sealed - they will last for a very long time before they lose quality.

H. scabra harvest size (PPh Blanc)

- After processing, the dry product will represent less than 5% of the animal weight alive.

It is better for the farmer to process the sandfish to get a better price.

The method of community management in Madagascar allows farmers to gather volume of products and to check with the different buyers the best price. Trepang can be stored and so wait for better buying opportunities if these are available.

There is no consumer market in the country itself, neither in the region. All Madagascar production is dedicated to export. China accounts for 99% of the world market of sea-cucumber.

According to the size and the process quality, the product will be ranked between "A grade" (very good one) to "D grade" (pieces of animals). The price will differ accordingly.

The product will not go into other processing, it will be sold as is and the consumer will re-hydrate it for several hours before use in its dish preparation.

Dry sea-cucumbers (PPh Blanc)

For the last 10 years, the price has increased globally following the depletion of wild resources.

- The price depends on the species of sea-cucumber, *Holothuria scabra* is a much-appreciated product and its price is around USD 40 to USD 90 per kg dry. In a Chinese market, one kilogram of *Holothuria scabra* will fetch up to USD 300.

Governance and institutions support

Mariculture is relatively recent in Madagascar and was only recently regulated by Law No. 2015-053 of 16 December 2015 in the Fisheries and Aquaculture Code. The Decree n°2016-1493 and the legislation n°2018-026 regulating aquaculture activities were subsequently added to this Code. Whereas there are special decrees for some aquaculture species (e.g. crabs and shrimps) there is nothing for sea-cucumber activities.

The existing legislation is mainly based on commercial aquaculture and the communities-based model are on the borderline of the existing governance policies as the activity is considered more as artisanal than commercial and because government institutions do not have strong presence in coastal villages.

In a way, these particularities contribute to the development of community-based sea-ranching initiatives as the registration process, required environmental impact assessments, the official controls and process requirements mentioned in the existing legislations are not required today. But it also leaves open all adverse aspects of sector development and sustainability (social, environment impacts, interactions with sea-cucumber capture activities and quality and safety of finished products).

- A study of the community-based aquaculture in the area in 2018 stated that "the lack of adequate policy and regulations, resulting in poor coordination among institutions, is identified as one of the main stumbling blocks for community-based aquaculture development" (Atewerhan et al., 2018).

- There is government consideration for the sector as stated in a "Blue Policy Letter" in 2015 from the Ministry of Fisheries and Marine Resources where the report has a special paragraph on sea-cucumber aquaculture stating that this sector, with other export-oriented aquaculture activities, "will be the country's growth drivers in the longer term".

H. scabra larvae, Auricularia stage (PPh Blanc)

A stronger support of the sector was already advocated in a report in 2010 from the Indian Ocean Commission but seems to still be pending. This support should be taking into account the community and small-scale dimension of the operators and be separate to the main existing regulations for aquaculture which consider commercial scale and impose legal authorization, pre-studies and other costly requirements that may jeopardize actual sector development.

Environmental Impact

It is an aquaculture without chemicals or feeds limiting the possible ecological impact. In addition, because of their burrowing and feeding behaviour, sea-cucumbers play an important role in the marine ecosystem as they stir up the alluvium and thus facilitate the oxygenation process for other species. They feed on small particles of algae, sand and other waste. In this way, they recycle other nutrients and contribute to the enrichment of the marine environment. In addition, the eggs, larvae and young sea-cucumbers are a source of food for other marine species including fish, crustaceans and molluscs.

- Ecologically, they are an essential component of sustainable marine ecosystems in the tropics, consuming the waste products of other organisms.
- Experiments have shown (Wolkenhauer S. M., 2008) that sea-cucumbers play a beneficial role for sea grass beds (in productivity and density). Another beneficial environmental impacts could be the reproduction events of mature aquaculture sandfish in the grow-out pens which could participate in the repopulation of the natural environment and fulfil the functions described above.

An adverse effect was mentioned by Atewerhan and al (2018) considering a possible habitat alteration by the effects of burrowing of sea-cucumbers and habitat destruction by farmers during cage construction, maintenance, and harvesting.

Social Impact

Sandfish sea-ranching uses relatively simple farming techniques but there is a need of capital to buy juveniles and there are important risks of robbery. The community should be organized and have good cohesion between its members. This group management gives opportunities for isolated communities to increase their business opportunities in other domains than sea-cucumber.

The activity brings substantial socio-economic benefits to marginalized coastal communities and opportunities to increase their livelihood.

The sector is also presenting, today, an involvement of more than 50% of women, providing an opportunity to contribute to their household economies and their empowerment.

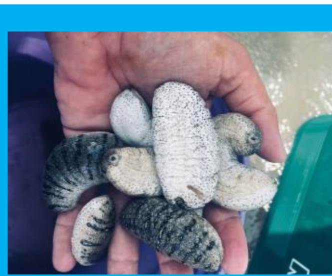
Challenges and steps Forwards

Problems of thief

The problem of theft concerns sea-cucumber aquaculture in particular. It is considered by the villagers to be the primary risk factor that can block the development of this activity. Theft can be committed by people who do not live in the village, by villagers or by members of the aquaculture team themselves (GASSI Développement – ProGeCo for COI, 2010).

The risk of theft is aggravated by the fact that it is impossible to differentiate between wild and farmed sea-cucumbers, as a thief who is not caught in the act can always claim to have picked them up in the wild. The present legislation and policies do not protect aquaculture activities as there is no traceability requirements between collection as against production in market part of the value chain; there is no registration of fishing activities, farms or collectors and no temporal or spatial segregation of the two activities of fisheries and aquaculture.

Furthermore, the robbery aspects can weaken the development of the activity within the community association if the farm organization does not have a strong social and traditional recognition inside the community to avoid erosion of trust and the increase conflicts among community members (Rougier et al. 2013, Slater et al. 2014).



Juveniles, stocking of pen (PPh Blanc)

⇨ Action required: Strengthening governance, registration and control.

Conflict of use of intertidal zones

- Conflicts with fishers at landing sites or between low tide fishing/collecting activities.
- Increased privatization and expansion of mariculture to common resource areas could limit access to other essential marine resources.
- Some intertidal zones are also available only with boat access and women do not traditionally have access to boats.

- Traditional access conflicts, as community / village rules do not give easy access to some areas.

⇨ Action required: Spatial planning and government plan to preserve right and access to production areas.

Access and use of the land

Today sea-cucumber farming is confined to remote villages with community-based management and until now, no conditions have been specified and required for the use of the land.

With the development of the activities, sea-cucumber farming will have to consider policy and legislative frameworks to provide authorizations to temporarily occupy, in the spatial sense, the shores of the sea, the sites which can, without inconvenience, be temporarily withdrawn from the use of all, to be assigned to a private or privileged use. But the policy framework will equally need to consider and protect the community-based model of the sector's development.

⇨ Action: Strengthening governance, registration and control (for example, In the Philippines, village aquaculture groups/associations are given preferential rights for 25 years, renewable, over an area of up to 250 ha, compared to 50 ha for individuals. The heirs have the right of pre-emption, during the remaining term, if they are qualified for the trade).

Challenges in building sound business partnerships

Existing initiatives in *H. scabra* farming in Madagascar are managed by a partnership of private sector, NGO and communities. The financial needs (for farm material and for regular stocking of juveniles) as well as organizational skills and business access make difficult for communities to develop sea-cucumber farming by themselves. Future projects will most probably depend on a combination of governments, development NGOs, and private business partners support and for finance, set-up, capacity building, organization and market access. To avoid negative experiences related to power imbalances in terms of financial and human resources and information, there is a need to identify an optimum mix of partners that are willing to engage in open and transparent communication, which must be preceded by a detailed needs assessment (Newell et al. 2012). From this, policies and regulation should be strengthened to protect this multi-stakeholder's partnership both for communities and for the investments involved.

⇨ Action required: Strengthening governance, registration and control.

Impact of capture activities

(see "problems of thief")

A temporary closure or area bans of wild sea-cucumbers fishing and collection would reduce the risk of theft of farmed animals, thus reassuring operators who want to invest in aquaculture. It would also allow a biological rest of the *H. scabra* stocks.

Protection of aquaculture activities and investors should be considered within governance to identify and separate wild capture and aquaculture production.

⇨ Action required: Strengthening governance, registration and control.

Diversification of juveniles' suppliers and market exporters

Today, there is only one hatchery producing sea-cucumber juveniles in Madagascar. To avoid tying the sector's development on the capacities and the control of a single provider, and to avoid possible monopoly effects; the sector should have mechanisms to protect farmers and investors over the long term on juvenile supply and pricing.

The same approach could be considered with regards to exportation actors and pricing.

⇨ Action required: Strengthening governance, registration and control.

A community farm in south-west Madagascar with the watch tower in the center (Blue Venture)

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ANNEX C : Marine cage aquaculture in France (Réunion Island)

MARINE CAGE AQUACULTURE
- REUNION ISLAND -

Sector main facts

Production: maximum of 50 tonnes per year between 2003 to 2011. After 2013: none

Species: two species were tested, the Red Drum (*Sciaenops ocellatus*) and the Cobia (*Rachycentron canadum*). Only the first one has reached production phase

Economic value: the production was representing up to 22 % of island aquaculture production. For a total production value of 500 000 €

Number of farmers: a maximum of 6 employees and around 30 people were working directly or indirectly with marine cage aquaculture on the island

Finished Products: Fresh fish for local consumption

Cages in Saint Paul Bay – Réunion Island (ARDA)

Sector details

Beginning of the activity

The species, originating from north Mexico and south USA was introduced in Réunion island in 1999.

The red drum has interesting characteristics for farming, in particular rapid growth (1 kg in less than a year), it is a hardy species with low susceptibility to diseases (Lazo et al., 2010; Sandifer et al., 1993) and has the potential to reach large commercial sizes.

The project was supported by an association ARDA (Association Réunionnaise pour le développement de l'aquaculture) which was created in 1998 under the impetus for regional development with the support of European funds. Its mission was to develop fry production techniques for new tropical species with the support of the French Research Institute for Marine Science (IFREMER). The funding included public support (local, state and Europe).

A company was created in 2000, Aquamarine de Bourbon, to operate the pilot farm and bring it to commercial stage.

The capacity of production of the island was estimated to be of a maximum 400 to 500 tonnes. The main constraint is the availability of sheltered bays to protect aquaculture activities from the sea swell (Réunion island does not have significant areas of coral reefs and shallow water).

The production infrastructures reached a capacity of 4 cages of 12m diameter and one of 8 m diameter for a total production of 50 to 70 tonnes.

Despite some strengths and good opportunities represented by dynamic structures and public support, the marine aquaculture production faced several threats for its future development mainly from economic conditions with no available market to absorb the production at higher prices.

In addition to these economic problems, 7 sharks attacks in 2011 generated a media frenzy against the farm, which was accused of concentrating sharks near the coast. The negative public opinion was the tipping point, the society changed its management and subsequently declared bankrupt in 2012 and all activities ceased in 2013.

The farming techniques

Fingerlings production of red drum takes about 60 to 65 days to get juveniles of 2 to 3g from eggs. The survival rate is around 25%. Algae and rotifer production are needed to feed the hatchery stage.

For cage production, circular cages of 250 m^3 and 565 m^3 were used. The cages had the technologies to be immersed to 15 m depth in case of cyclone events. They were placed in a sheltered bay in an area of 40 to 50m depth with an extra net to avoid sharks.

- Density: fish were kept at a density of 15 kg/m^3 for pre-growth stage and then 25 kg/m^3 for grow out stage.
- Survival was around 80%.
- Pellet feed was used, with a Feed Conversion Ratio (FCR) of 1.6 in first stages of grow-out and then 1.8, giving an average of 1.75 for the cycle.
- Harvest size was reached in 145 days for 300g, 190 days for 500g and 260 days for 900g animals.


Broodstock Sciaenops ocellatus – Réunion Island (ARDA)

The value chain

The fish were sold fresh directly to retailers. The island is not self-sufficient in fish and imports an important part of its needs, “an average of 40 % of the local consumption is supplied by imports of fish products” (EU, 2015). However, the fish market in Réunion island relies on cheap products, the demand for elaborate fish product is limited. The "Ombrine" (French name of Red Drum fish) product was new and was not recognized by the consumer. According to a study made in 2005 by IFREMER, “The Réunion island consumer is not interested in local products, but rather in frozen low-cost products from the Asian market (mainly Vietnam)”.

Export potential is limited by the high production cost and the cost of air freight. Thus, for Reunion Island, the ceiling for red drum production was estimated to be around 70 tonnes (according to CRPM, 2005) in relation to the context (inability to reduce cost of air transport and production, limited potential for absorption by the local market).

In addition, the processing solutions seemed limited. It is a large-headed fish, which affects the yield, since the resulting fillets with skin represent 40-45% of the initial weight. Scales are a drawback (difficulty of removal and personal time loss) and are also a constraint for local processing.

To face these constraints, a campaign of communication and marketing was undertaken and slowly the marine cage aquaculture started to create a local market for its products and absorb the 50 tonnes of production.

Governance and institutions support

The marine cage aquaculture received public financial support for investment and for inputs (fry and feed). These supports had several functions: incentive for starting an activity with low recognition from the banking sector, compensation of high cost of inputs.

More than the strong government support for economic sector development, the island has also special public policies supporting its local development. The remote situation of the island and the high level of unemployment increases these supports. Furthermore, La Réunion has an administrative statute of EU’s Outermost Regions allowing the application of special supports through Common Fisheries Policy.

For the start of the activity, a global initial investment of € 300.000 was needed. Seventy percent (70%) of this amount was provided by European Fund managed by the region. Public scientific and technical support was provided by the government institution IFREMER to transfer and adapt the hatchery technology and import selected broodstock from its projects in the Caribbean French islands. Additional scientific support was provided to develop submersible cage models.

In addition, project funding support was provided for technical assistance that the project provided to Mayotte Island and Mauritius as cooperation and collaboration on Sciaenops ocellatus aquaculture development.

Promotion of Red Drum products – Réunion Island (ARDA)

Finally, of the €50 000 investment for the marketing campaign, 45% was supported by the European Union.

Environmental Impact

From the report of CMUB (Conseil maritime Ultra-Marin du basin sud de l’Océan Indien), the marine cage aquaculture presented several risks:

- Risk of pollution of the marine environment by physico-chemical and bacteriological contamination during aquaculture operations (pesticides, antibiotics, eutrophication, etc.);
- Risk of introduction and development of non-native species during aquaculture operations;
- Aquatic animal health risk (Spread and transfer of pathogens: parasites, bacteria, viruses, etc.)

Other risks are listed in a study of Red Drum cage aquaculture in Mayotte Island (Chary K., 2020):

- Changes in food webs (attraction, aggregation of species around cage). A review of the impacts of fish farms in Norway showed that feed not consumed by farmed fish is the main attraction factor for wild fish (Uglem et al., 2014). Attracted species may also benefit from the habitats provided by the farm structures and be responsible for secondary attractions of predatory species (Callier et al., 2018).

However, the 3 studies made on sharks in Réunion Island have not concluded as to a direct implication of the fish cages on the shark attacks of 2011:

- Studies on shark: Between October 2011 to January 2015, the CHARC programme (Knowledge of the ecology and habitat of two coastal shark species on the west coast of Réunion), subsidized by public funds and conducted by the Institut de recherche pour le développement (IRD); Between July 2015 and May 2017, the EcoReco-Run study (Ecology and Behaviour of Coastal Sharks of Reunion Island) have analysed the trophic ecology, reproductive biology, dynamics and genetics of the populations; and in September 2017 saw the start of the ongoing EURRAICA research project (Study of Sharks and Rays on the Reunion Island Coast).
- 22 shark attacks were recorded between 2012 and 2019. “This means that Reunion, an island that measures just 970 square miles, was responsible for over 16% of the world’s fatal attacks between 2011 to 2017” (Macdonald J., 2017)

Aquaculture Red drum on sale – Réunion Island (Témoignage)

Social Impact

As an economic activity, the marine fish farm was offering new economic activities for several island operators (researchers, a local market outlet to the island fish feed processing plant, employment opportunities).

As a new activity, the marine cage aquaculture had to face reluctance with local fishermen. This hostility remains as in 2011 newspaper articles we can read: “fishermen in the bay are adamant that fins are being seen more often than before the farm was installed” (Le JIR, 2011).

The 2011 important media coverage of the shark problems and the possible implication of the farm has severely affected the population of Reunion; 10 years later, the personal opinions are still strong.

Red Drum (Sciaenops ocellatus) – WWF database

Challenges and steps Forwards

Use of public subsidies and economic perspectives

FranceAgrimer wrote in 2019: “The major difficulty with the red drum production scheme lies in the fact that the fry production structure, which has been funded with public funds from the outset, was intended for a period of start-up and structuring of the sector. The economic results of the latter did not allow it to take control of fry production on its own account”

The same challenge appeared in Mayotte Island where the marine cage aquaculture sector has recently collapsed with the end of public subsidies.

The development of marine fish farming has been initially driven by technical aspects, the economic side has been neglected or underestimated in the sector development. It’s the conclusion of Mariojouls C. et al. on their studies of red drum aquaculture in French Overseas Territories. The economic perspective should be emphasized or at least included in a long-term approach of sector economic independence and development.

FranceAgrimer concluded its comments by “It should be noted that in the south-western sub-region of the Indian Ocean there is a totally private structure, without any public support, installed in Mauritius (Ferme Marine de Mahébourg - FMM) which has a complete hatchery-rearing-processing sector for tropical red drum"

Need to build possible future marine aquaculture development

Today there is no marine aquaculture in Réunion Island. All possible projects seem impossible because of strong public opposition to a future project and because of the absence of a technical structure to accompany the sector development. Everything will need to be built from the beginning.

Today the assessment by FranceAgrimer is negative: "Marine fish farming offers little scope for development and Réunion has few competitive advantages over its regional competitors (…) Onshore marine aquaculture seems to be the only possible development path, on medium-sized projects, oriented towards aquaponics in brackish waters".

But as an island, use of the sea for aquaculture seems a natural further development. The future projects may need to focus on completely different production activities than cages culture to be able to be considered.

Furthermore, Reunion Island have high-quality technical and scientific training facilities and the academic certificates that are awarded are recognized (FAO, Smart Fish 2015). There are a wide range of education and training institutions to be found in Reunion (e.g. IFREMER, CCI, CRITT, CIRAD, the University of Reunion, IUT, ARVAM etc.). These institutions provide training in fisheries, aquaculture, post-harvest management, production sanitation issues, as well as undertaking a range of research activities. These assets should be oriented to practical marine production sector development in the South East Indian Ocean area.

Development of local market

There are 800 000 inhabitants in Réunion Island representing a potentially interesting market for aquaculture. But the consumption of fish is lower than all other islands in the Indian Ocean. There is no tradition of eating fish and there is no special request for good quality fish products (the main market is for imported basic frozen cube fish meat).

Production costs are too expensive and export is not an option. The development of a niche market, inside the island, for a locally produced fish seems one of the main prerequisites for future local development of aquaculture production.

Red drum fish farm in Mauritius – (https://www.youtube.com/watch?v=zi0bUVwFdsc)

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ANNEX D: Bivalve aquaculture in Thailand

BIVALVES AQUACULTURE
- THAILAND –

Sector main facts

Production: The production grew progressively to reach 100 000 tonnes in 1998, 200 000 tonnes in 2001 and a maximum of more than 350 000 tonnes in 2003 and 2004. Decreasing then to around 200 000 tonnes per year (Sampantamit et al., 2020). Bivalves represent more than 20% of the country's aquaculture production. Thailand represents more than 50% of IORA countries' bivalve production.
In 2018, the production was the following (FAO, 2018):

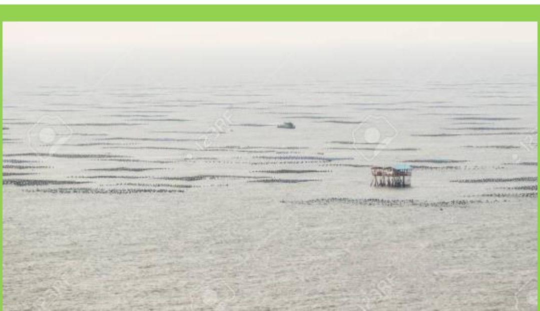
- Mussels: 45 318 tonnes
- Oysters: 21 041 tonnes
- Cockle: 26 708 Tonnes

Species: Bivalves are a large class of molluscs (grouped into "shellfish" category). Major species are the green mussel *Perna viridis*, the blood cockle *Anadara granosa*, and 3 species of oyster (*Saccostrea cucullata, Crassostrea belcheri, and Crassostrea iredalei*). The horse mussel *Arcuatula* is also produced in limited amounts for animal feed.

Economic value: around USD 137 million according to FAO database in 2018

Number of farmers: 6 000 farms dedicated to bivalve production in 2015. Representing over 16 000 ha of land used (Sampantamit et al., 2020)

Finished Products: Mainly marketed fresh but part can be sold as shucked meat, bottled in brine, or frozen. Almost total production is for local consumption



Oyster farms in the sea – (Laorattanavech – Stock Photo)

Sector details

Beginning of the activity

There is a long traditional activity of consuming and collecting shellfish in Thailand. According to Chalermwat et al., "Shellfish have been farmed in Thailand for over 100 years".

The aquaculture of oysters was already recorded in the 30's with the use of stones to collect and grow oysters spat in shallow waters. It is believed that immigrants from China first began culturing oysters in Chon Buri, Rayong and Chanthaburi Provinces (Brohmanonda P. et al., 1988). Same observations were made for green mussels where aquaculture practices were already reported in the '20s and for cultured cockles since 1900 (Tookwinas, 1983).

In the 80's, the aquaculture practices were stimulated, and also got some government support, as overfishing had created a shortage of shellfish product for the domestic market in Thailand (Mutarasint K. and Potaros M., 1988). In late 1985, the government supported the development of a hatchery at Prachuap Khiri Khan Fisheries Station where pilot scale experiments were conducted on promising shellfish species. Production through transplantation had been initiated in the south of Thailand and on the Andaman Sea coast. Better production techniques have been introduced and yields have increased; but the species remain the same and few diversifications were successfully implemented.

The farming techniques

Mussels: Two species of mussels are cultured in Thailand - the Green Mussel and the Horse Mussel. Most farming presently occurs on low gradient offshore areas with muddy or silty bottoms in the upper part of the Gulf of Thailand. Rearing takes place on stakes, set about one metre apart from one another in natural spawning areas, to which spat attach and grow. Once a culture has started some stakes may be re-located depending upon phytoplankton availability. No thinning-out is practiced during the growing period. A crop is harvested in about 8 months by pulling-out the stakes and removing the mussels. Production is about 40 tons/ha. Mussel spawning normally occurs in the period September. Harvest time takes place in June or July at the beginning of the rainy season.

Another traditional method is to extend the wings of fish traps to collect green mussels. In late '80s, fish traps were providing about two-thirds of total green mussel production but less than 10% of the production in the 2000s.

Non-traditional culture systems that utilize rafts and long lines have also been adopted for green mussel production in Thailand. Raft culture was introduced in the late 1980s and is practiced in several major mussel growing regions (Chaitanawisuti and Menasveta, 1987).

Long line techniques were developed by the Department of Fisheries and the Kasetsart University Research Station, and this technology has significant potential to further increase mussel production.

Oysters: Three species are cultivated in Thailand, a small oyster and 2 large species. Farming presently occurs in shallow coastal waters with muddy bottoms through several parts of the Gulf of Thailand and in only a few locations in the Andaman Sea. Several production models coexist:

- Traditional rock culture still exists (or blocks or rubble spaced in rows of about 0.5 to 2 metres, a mat of bamboo can be used to prevent the rocks from sinking).
- Use of cement poles (with a wooden rod in the centre to ease the harvesting), cement pipes or wooden poles are replacing and improving traditional technics. The length of the pole depends on the water level and are placed in rows with approximately 1 metre between pole/pipe.

Mussel farm – (Wasan Gredpree – stock photo)

- Trays of about 80-100 cm with an upright side of 2.5 cm in height, mounted on stakes approximately 30 cm above the bottom. This production method is used for grow-out stage with initial animals of 3.5-4.5 cm in length for placement in the trays.
- The culture by suspension, with better production yield, was introduced from Japan and Korea (higher initial investment and higher daily labour and management requirements). A raft structure is built and secured by anchors in an area of around 10m depth. A suspension line, hung from the raft, is prepared with shells with spat attached (15-20 cm intervals between them). The shells (with 2-4 oyster spat) are isolated from the wire with a small section of bamboo.

All oyster production methods rely on natural inoculation by spat; most occurs during September through November, but some also occurs earlier. Oysters are harvested at about 10 months of age when sizes of 6 to 14 cm are reached. About 4 oysters/100 cm2 (rock and poles) of substrate area are collected. Yields normally range between 1 and 3 kgs/m2 of surface area of water in a production location. Prime harvest times are usually during June and July.

Cockle: Blood cockles are a shallow water species, on tidal flats within coastal and estuarine areas. Cockles prefer a fine muddy substrate that allows them to create shallow burrows for protection. Cockle pens are made of small bamboo slats approximately 50 cm in height and typically cover an area of 1-2 hectares. Harvesting occurs after 1-2 years when the cockles reach a diameter of 4 cm (or 25 gm) and is performed manually using a self-propelled mud-ski or a metal cockle rake.

Oyster farm in Chanthaburi – (Ngamsom/Alamy stock photo)

- All cultures often employ full-time guards to prevent theft, sometime with the use of guardhouses. The farmers have also to check for and irradicate predators from the culture area. Predators are starfish, gastropods (mainly *Thais spp., Natica maculosa* and *Melongina spp.*) and many fishes feed on molluscs.

The value chain

Bivalves have long been an important source of food for the Thai people who consume approximately 2.15 kg of these products each year on a per capita basis (FAO 2018).

Most of the crop is purchased directly by brokers and wholesalers at the production locations. The product is mainly for national markets and sold fresh, dry or boiled.

- Green mussels are generally marketed fresh. They are modestly priced compared to other bivalve species sold for human consumption. This makes the green mussel also an inexpensive source of animal protein (for shrimp aquaculture for example).
- The small rock oyster *Saccostrea cucullata* is typically sold as shucked meat in local markets, bottled in brine, or frozen for sale in more distant locations (Tiensongrasmee 2000).
- Big oysters are typically sold fresh and "shell-on" to local restaurants, shucked for sale in local markets, or preserved by smoking or brining. The "big oyster" currently represents the only bivalve product exported by Thailand to markets in Singapore and Hong Kong.
- Cockles are exclusively produced for the domestic Thai consumer where they are sold fresh in markets throughout the country.

Governance and institutions support

Bivalve aquaculture in Thailand has generally been viewed as a small-scale traditional activity that produces seafood for local markets. This perception allowed the industry to evolve in a relatively uncoordinated manner, and the Thai government has had relatively little direct involvement in shellfish development planning.

Harvest in a Cockle farm – (Rassameesritrakool – stock photo)

However, the government actions have accompanied the development of the sector through timely initiatives and a dynamic research and development involvement. One of the strengths of this support is the national experience on the aquaculture sector and issues: Thailand's policies and institutions are designed to support aquaculture activities which are today representing more than 35% of country fishery production in volume but more than 56% in value (Fisheries Statistics, DOF,2015).

In the '80s, when wild stock started to severely decline, several actions were done by the department of fisheries (DOF), mainly through the institution of Brackish Water Fisheries Division (BWFD), to support bivalve aquaculture sector development. Between them, we can list:

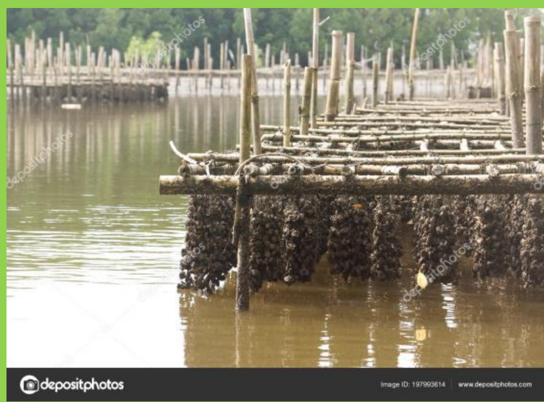
- Coordinated efforts to transfer bivalve hatchery technology from industrialized countries to Thailand were initiated in the early to mid-1980s (ICLARM 1985);
- Pilot farms development to introduce new technologies of technique (as the experiments on hanging oyster culture);
- Support to the development of a hatchery station where research and pilot scale experiments were conducted on promising molluscan species;
- Transplantation to open new production areas started in 1979 for mussels and cockles.

But the efforts were emphasized after the '90s to find solutions and sector organisation to face the impact of environmental degradation on bivalve production and to reduce the issues of food safety of this production for the consumers.

The Fish Inspection and Quality Control Division (FIQD) of the Department of Fisheries, implemented a survey of coastal water quality and classified potential shellfish growing areas. A classification scheme using criteria such as the presence of pathogenic bacteria, the incidence of shellfish biotoxins, and the occurrence of heavy metals was developed. This classification scheme includes three zones (A, B and C) to facilitate the evaluation of growing water quality. Zone "A" includes areas where shellfish are produced for immediate human consumption, while shellfish from "Zones "B" and Zone "C" are subject to sterilization by boiling or cooking to destroy pathogenic bacteria.

In 1998, after a voluntary ban of Thai mollusc exports to Europe (European Union 2000), a "bivalve production and sanitation program" was organized by FIQD. Four fish inspection centres were established in Bangkok, Samut Sakorn, Songkla, and Surat Thani provinces. These centres perform microbiological, biotoxin and heavy metals analysis on the flesh of bivalves and are responsible for the inspection and certification of bivalve mollusc processing establishments and laboratory testing of seafood products.

The Thai government has also put significant resources into improving sanitary conditions and upgrade of landing sites, de-shelling stations, and processing plants with also implementation of safe product handling practices, and organization of regular sanitary inspections.



Oyster farm in mangrove area – (Weerapat)

Furthermore, depuration policies for bivalves destined for export have been implemented in conjunction with research designed to determine the most appropriate conditions for these operations in Thailand (Areerat and Gannarong 2000; Gannarong et al. 2001). The development of microbial risk assessment protocols has been done (Lee & Younger, 2002), and the design and implementation of Seafood HACCP plans within processing plants has been given a high priority by both the public and private sectors (Kirativiriyaporn 2000).

Environmental Impact

Environment impacts from bivalve aquaculture are limited. Bivalves are filter-feeder animals that will feed on the effluents and biological charge of the water.

The impact that can be considered are:

- The faeces accumulation under the farms that can create an area of accumulation of organic matter and impact the local ecosystem;
- Impact on adjacent sensitive ecosystems with high biodiversity (Sampantamit and al, 2020);
- Sediment dispersion during harvesting of blood cockles, that can negatively affect adjacent ecosystems (including neighbouring oyster culture) by increasing water column oxygen consumption and by clogging other bivalves gill filaments;
- Disease impact. Concentration of animals in an area increases risk of outbreaks that can affect wild

populations.

Oyster farm Ban Ang Sila – (Jampapha – Stock Photo)

Social Impact

Bivalve farming is important in Thailand and provides significant economic benefits to rural and peri-urban coastal communities, it also benefits specific demographic groups such as women who can suffer from low incomes and limited economic opportunities (Szuster & Flaherty, 2004).

Even if the fisheries sector tends to be dominated by males throughout Thailand with female participation generally limited to part-time activities, processing or retail activities (Brugere et al., 2001), the aquaculture of molluscs presents a high level of female participation in farm ownership that benefits women with relatively low levels of education and limited economic opportunities. (Szuster and al, 2008).

Challenges and steps Forwards

Environment

The main challenge is the quality of the growing environment. Pollution impacts are the main threat for the sustainability of the sector. It has already heavily impacted bivalve aquaculture development in the past. Environmental challenge can present several aspects:

Water quality deterioration, caused by pollution from land-based activities such as waste water discharge from domestic, industrial, agricultural and aquacultural activities surrounding production areas, is a major concern (Gannarong et al. 2000; Anon. 1998a). These problems have resulted in bloom events, oxygen depletion, chemical pollution or increase of suspended solid contents and directly affected mollusc culture and disturbed shellfish and benthic organisms in general.

First pollution records were reported in early '70s with the impact on Mae Klong and Phetchabuti rivers with wastewater from sugar factories that destroyed cockle beds in Phetchaburi and Samut Songkhram provinces. Similar impacts appeared later in other bays in the northern part, the culture beds gradually deteriorated and growth rate decreased while mortality rate increased.

At present, cockles are primarily cultivated in southern Thailand as a result of poor water quality conditions in the Upper Gulf of Thailand. Furthermore, Thailand does not have enough natural seed; seed is imported from Malaysia.

In early '80s already, traditional mussel production areas (near the mouths of major rivers such as the Bang Pakong, Chao Prya, Mae Klong and Tha Chin in the inner Gulf of Thailand) were threatened by increased urbanization and industrialization. These areas have become increasingly polluted and efforts have been made to introduce green mussels in other areas such as Sawi, Phangnga, and Nakhon Bays.

The government of Thailand has set up important control and measures to assess production areas.

Mangrove area deterioration: mangrove forests formerly served as an important nursery ground and feeding area for juvenile shellfish (oysters, mussels, crabs and shrimps) (Wattayakorn et al. 1999). However, excessive cutting of the mangrove forests along with uncontrolled massive development of mariculture led to decreasing water quality and problems with sedimentation (Tookwinas & Youngvanisset 1998). In addition, mangrove forests and waterways have long been used as convenient sites for disposal of sewage and waste water (Boto 1992).

Mangroves are known to effectively trap both suspended particles and dissolved nutrients (Hogarth 1999). Therefore, setting up mangrove strips as primary filters of pollution and sediment can act as efficient resilience management for shellfish resources and culture.

Restauration of mangrove areas have started or is ongoing in many areas to rebuilt this threatened ecosystem.

Food safety issues. Important production areas in the Gulf of Thailand receive runoff from four major rivers that drain the majority of the Thai landmass. A substantial amount of industrial and municipal effluent is entrained within this runoff, and bivalves grown in the Upper Gulf of Thailand are susceptible to contamination from heavy metals, faecal coliforms, agricultural or shrimp aquaculture chemical wastes and toxic dinoflagellates. These issues threaten sustainability of many production sites located near major population centres, and are one of the main concerns to guarantee some export quality bivalves as market opportunities for the sector's development.

Mussels – (Shawei26)

- Toxic algae: Bivalves are filter-feeders and are particularly susceptible to sudden blooms of phytoplankton organisms, which can occur in nutrient-enriched coastal areas and may contain biotoxins that are hazardous to human health. These toxic algae blooms are frequently referred to as 'red tides' in the popular literature. Paralytic shellfish poisoning (PSP) is one of the most serious diseases associated with red tides, and consumption of shellfish exposed to red tide blooms can result in high human mortality. Such events have already appeared with the consumption of wild green mussels (Chalermwat & Lutz 1989).

Chemicals: With Thailand's bivalves, there is particular concern of the presence of organochlorine pesticides (Cheevaporn et al., 2005) and increased concentrations of heavy metals in growing waters, sediments and shellfish flesh (Menasveta & Cheevaparanapiwat, 1981, Cheevaporn & Menasveta, 2003). More than only food safety issues, if the polluted water moves into the production area serious losses of bivalves can occur. Bacterial contamination and toxins: Another well-recognised problem associated with shellfish culture is the contamination of shellfish with domestic sewage that contains human pathogenic bacteria and viruses, which causes diseases such as typhoid fever and hepatitis. Research has highlighted such potential health and environmental issues related to bivalve cultivation in peri-urban areas (Vuddhakul et al., 2006).

FIQD have started an important program on marine evaluation of growing areas for pollution, classification into approved harvesting areas, and monitoring to improve public health safety. Together with efforts to reduce river and bay pollution up-stream, further improvements may be required to emphasize effort on the artisanal value chains which still remain aside in food safety measures and improvement actions.

Cockles – (Pimpaeng S.)

Natural disasters

With the climate change impact, occurrence of natural disasters will occur (such as heavy rainfall, severe storms, and drought). Events that can impacts bivalve culture directly: freshwater influx from rivers and streams during the rainy season, which lower salinity; abrupt change in air temperature may cause sudden mortality of algae which can cause decrease of oxygen in the water; lower flow from the river with more concentrated pollutants; or infrastructure damages on the farms with storms, wind, waves.

Such climate events have to be forecasted to increase the sector resilience.

Disease and Parasites

Disease or parasites can cause mass mortality and outbreaks. Ho and Yoosukh wrote in 1994 that there have been few published reports on these issues. Today it is still the case, Thailand's bivalve aquaculture does not suffer a lot from aquatic animal diseases or parasites.

However, arrival of a new disease or parasite, and not appropriate surveillance to mitigate its impact, can be a major threat for the sector.

Market

Bivalves are a local market product, very little of the production is exported. To increase possibilities of diversification and income to the producers, one means is to increase the amount of value added to the product through processing and marketing; another one is to open export markets.

The Thai shellfish sector is implementing more rigorous management and certification processes supporting these futures opportunities.

This effort is accompanying recent development of new molluscan aquaculture species with export importance such as *Babylonia aereolata* and *Haliotis asinine*.

Availability of seeds

Oysters – (Photolife Y.)

All Thailand bivalve aquaculture rely on wild spats for seed production; however, it leaves the industry susceptible to shortages when unfavourable environmental conditions exist in spat collection areas, as already observed in cockle and large oyster's aquaculture activities.

Effort for development of hatcheries will need to be continued for the sustainability of the activities.

Technicity and method of production

The sector is mainly using traditional and semi-traditional grow-out techniques, efforts to improve production yield and quality have to be followed both for the sector development and its sustainability.

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