TECHNICAL REPORT No. 03 – REVIEW OF AQUACULTURE, GOVERNANCE AND DEVELOPMENT OF SMALL-SCALE 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
AU-IBAR	African Union Inter-African Bureau for Animal Resources
EIA	Environmental Impact Assessment
EC	European Commission
FAO	Food and Agriculture Organisation of the United Nations
FCR	Feed Conversion Ratio
FSU	Fisheries Support Unit
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
Neg	Negligible
Nei	Indicate “not elsewhere include”
spp	indicates "several species"
UAE	United Arab Emirates
UNCTAD	United Nations Conference on Trade and Development
WAPI	World Aquaculture Performance Indicators (FAO)

1. Summary

Aquaculture has been around for millennia but only started to contribute significantly to the global food supply and rural livelihoods about 30 years ago. Whereas aquaculture provided just 7% of fish for human consumption in 1974, this share had increased to 26% in 1994 and 54% in 2018 with 114.5 million tonnes of production, and it is expected to increase by 62% by 2030 (FAO, 2020).

The Indian Ocean Rim Association (IORA) 22 members states represented together 26.2 million tonnes of aquaculture production, representing 17% of the world volume production in 2018[1]. The development of aquaculture in the IORA region is also recent, the production multiplied almost 6-fold over the past two decades to represent almost USD 39 billion to IORA members states economy in 2018 (FAO). Analysis of the type of aquaculture and species used show the predominance of small-scale aquaculture and the ascendancy of 6 species, over the 80 cultured, representing 80% of the Indian Ocean production (in volume)

But all member states of IORA are not at the same development stage of their aquaculture, five countries alone represent 69% of the Association's production and some countries have almost no aquaculture activities. The member states can be shared into three thematic categories:

a. "Mature aquaculture sector development": countries where the aquaculture sector represents more than 30% of national fisheries products with important sector development and dynamism.
b. "Emerging aquaculture sector": countries still have low or no aquaculture production but with an important potential for development. In these countries, the aquaculture sector remains nascent and with low levels of production even if some timely development can be noticed.
c. "High technical aquaculture development": Some members of IORA have chosen to develop aquaculture species with high value (based on their national market or for export). This form of aquaculture requires infrastructure and important technical and technological skills.

This disparity has several roots causes, from size of the country and its population, areas suitable for aquaculture, traditional social structure in rural areas, development approaches, market dynamisms and accessibility and experiences of aquaculture production. The different experiences between members of IORA offer opportunities to share lessons learnt on the approaches of aquaculture development, the drivers, the successes, and the pitfalls.

From an analysis of past experiences, some key requirements for sustainable and viable projects can be observed. Five requirements can be discerned:

a. Good environment for aquaculture development and governance;
b. Structures and inputs for small-scale aquaculture development;
c. Knowledge and technology – Strengthening human capacity and communication;
d. Support for business investment and economic development;
e. Sustainability approach.

These are described and discussed in this report in the form of technical guidelines and prerequisites for aquaculture development.

[1] France became the 23rd member of IORA in December 2020. It has not been possible to incorporate the production figures for France in this report considering the fact that this activity started in September 2020. Nevertheless, in the relation to Section 5 on "Governance and Sector Development Approach", experience and some examples are drawn from Reunion, France.

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 will support the implementation of the IORA Action Plan (2017-2021) with an allocation of EUR1 million over three years. It will offer 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 will strengthen 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 project 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. Following the review, a separate report will present some existing initiatives in small-scale rural aquaculture with several selected examples of successful and unsuccessful aquaculture development projects. Some of these examples will be 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 is the general review of aquaculture in the IORA region. Firstly, it presents the latest (2018) statistics of aquaculture production in the IORA region and its Member States (MS) tracing its value and trends since 2000. The report proceeds to categorise aquaculture in IORA in terms of its organisation, its social and its economic aspects dealing with various features including farming systems and technology used, employment (including gender), food supply and nutrition as well as poverty alleviation. Next it examines governance and approaches to the development of the aquaculture sector including some of the lessons from past experiences and key problems in some of the approaches used. It then proceeds to provide technical guidelines and prerequisites for aquaculture development including environment, structures, inputs, knowledge and technology, support for business investment and the sustainability approach. Finally, it provides some brief overall comments and observations. The report is supported with several tables and numerous figures as well as an informative appendix of aquaculture production at a species group level in IORA countries.

3. General review of aquaculture in the IO area

Capture fisheries volume of production has been stable since the 1990s, but global fish production has been steadily increasing to meet the growing global demand for table fish. In 2018, the fisheries and aquaculture sector had reached record levels of production, trade, and consumption, to the level of an average consumption of 20.5 kg per year per capita.

Aquaculture now accounts for 44% of global fish production, and 54% of global fish consumption. Aquaculture production is expected to increase by 62% by 2030 (FAO).

In addition to contributing to national food security through regional supplies, aquaculture provides essential social and economic benefits such as job creation in rural and peri-urban areas. More than 100 million people depend on this economic activity and all activities related to the farming, harvesting, processing of aquaculture products, as well as associated commercial activities, generate income for households and contribute to the countries' economies.

The Indian Ocean (IO), the third largest ocean in the world, is one of the world's major shipping routes and plays a major economic role in international trade and transport. The Indian Ocean Rim Association (IORA), established on 7 March 1997, is an intergovernmental organization composed of 22 Member States[2]. These countries, located on the Indian Ocean coast, cover a maritime area of nearly 68.56 million km^2, stretching from the coastal states of South Africa in the west to Australia in the east, along the East coast of Africa along the Persian Gulf, India and Southeast Asia.

In addition to their social and cultural diversity, they are distinguished by their size and economy and represent a total population of 2.7 billion people.

In addition, this vast maritime area offers many opportunities for food subsistence and sustainable economic development.

Due to this strategic geographical position, the IORA member States have chosen to develop a blue economy, whose objective is to promote sustainable growth as well as the development of employment opportunities based on the region's inland waters and maritime activities.

For IORA "The objective of the Blue Economy is to promote smart, sustainable and inclusive growth and employment opportunities within the Indian Ocean region's maritime economic activities. The Blue Economy is determined to initiate appropriate programs for: the sustainable harnessing of ocean resources; research and development; developing relevant sectors of oceanography; stock assessment of marine resources; introducing marine aquaculture, deep sea/long line fishing and biotechnology; and human resource development; among others "[3].

In this context, a number of challenges need to be addressed. First, economic growth must be promoted through responsible production and consumption. Second, promoting social integration and improving people's livelihoods. Finally, ensuring the sustainability of aquatic, marine and coastal areas' activities through their preservation.

[2] Australia, Bangladesh, Comoros, India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Oman, Seychelles, Singapore, Somalia, South Africa, Sri Lanka, Tanzania, United Arab Emirates, Yemen

[3] https://www.iora.int/en/priorities-focus-areas/blue-economy

Against a background of growing global demand for fish, intensive capture fish production is leading to the depletion of natural fisheries resources and raises the issue of overfishing and the effects of climate change. Aquaculture therefore represents activities to be supported by IORA Member States in order to adapt the production level to the increasing demands of aquatic animals as part of an integrated future fish production sector.

Aquaculture is a major component of the blue economy approach "which offers huge potential for the provision of food and livelihoods, and will, under the Blue Economy, incorporate the value of the natural capital in its development, respecting ecological parameters throughout the cycle of production, creating sustainable, decent employment and offer high value commodities for export" (IORA website).

Beyond food security, aquaculture is an important source of employment for rural people and offers opportunities to develop production models resilient to climate change impacts.

3.1 Global aquaculture production

3.1.1. World aquaculture production

The aquaculture industry has been growing rapidly over the past 30 years and continues to expand. It contributes to food security and social equity through poverty reduction. The increase in world fisheries' production is explained by the increase in the importance of aquatic food, although there are large differences in consumption in different regions. Aquaculture is therefore a valuable food resource, particularly in densely populated developing countries.

In 2018, global aquaculture produced 114.5 million tonnes, including 82.1 million tonnes of fish and 32.4 million tonnes of aquatic algae. The analyses that follow are from FAO Fishery and Aquaculture Statistics (2020) which present data up to 2018 and which were analysed with FAO's Fishstat.

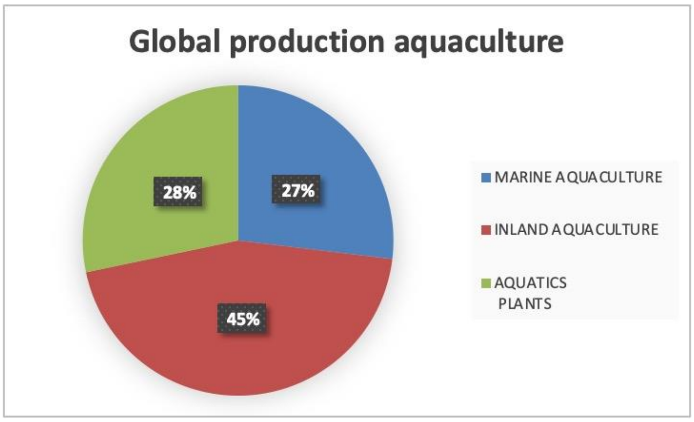


Figure 1: Share (in %) of world aquaculture production (source: FAO. 2020)

Inland aquaculture accounts for most of the aquaculture production (by volume), contributing to about 45% of the total, followed by seaweed (28%) and marine aquaculture (27%).

3.1.2. IORA member states production

In 2018, the total aquaculture production of the IORA member States represented 23.4 million tonnes, or 17% of the world volume (Figure 2). The major share of IORA aquaculture production is divided between continental aquaculture and aquatic plants. As in the contribution of aquaculture to the global food fish supply, inland aquaculture in IORA plays a dominant role using natural surface waters, rivers and lakes, and artificial installations, such as reservoirs and ponds (including ponds with salty or brackish water).

In the IORA countries, aquatic plants account for 41% of its total aquaculture production. Of the total aquaculture production, 13.72 million tonnes come from freshwater aquaculture (58%) and 0.09 million tonnes from marine aquaculture[4] (Figure 3).

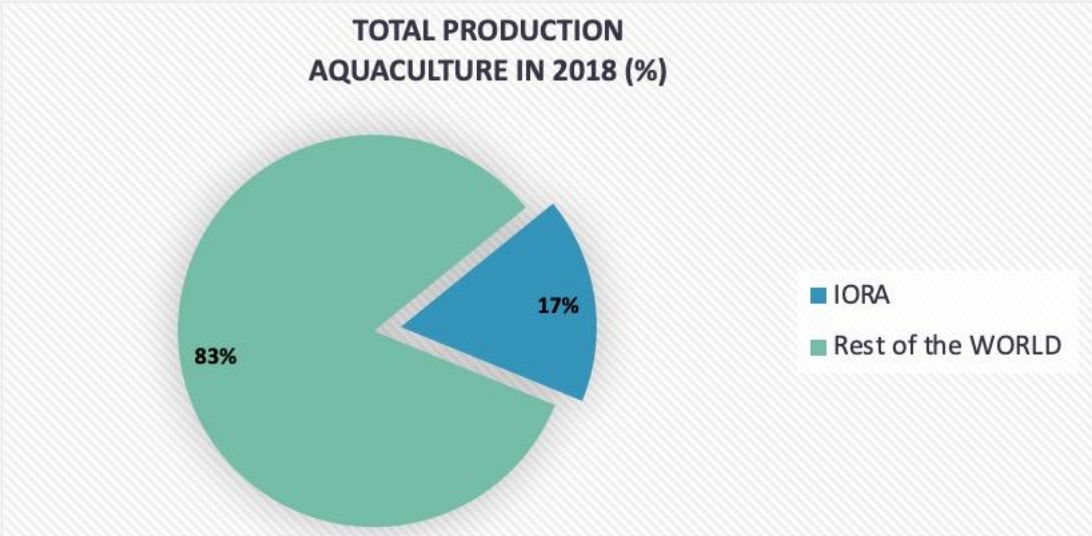


Figure 2: Graphic representation of IORA countries contribution to world aquaculture production (source: FAO. 2020).

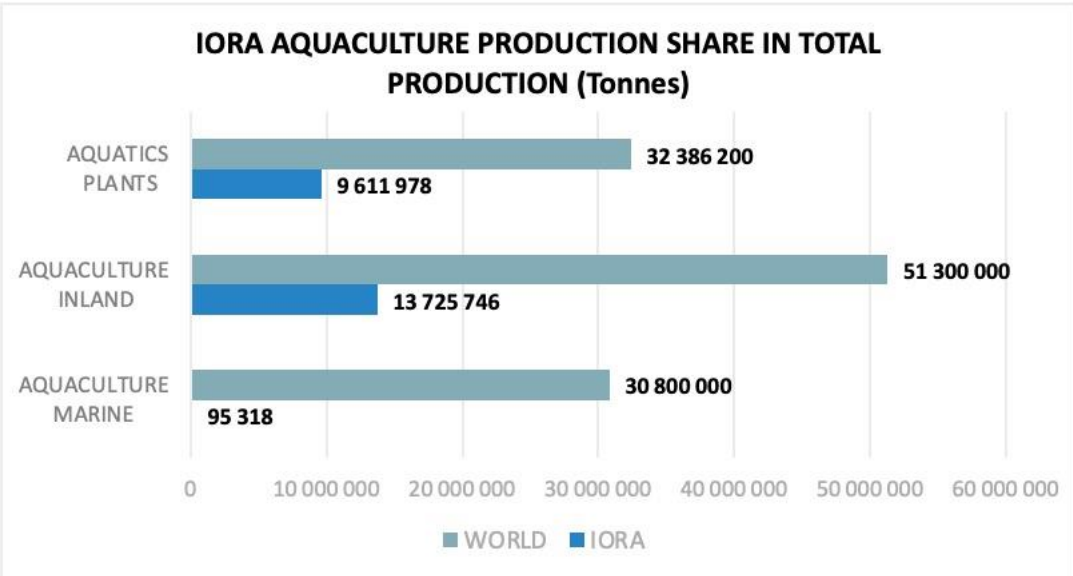


Figure 3: Comparison of IORA countries aquaculture production with world production (source: FAO. 2020).

[4] "Marine Aquaculture" considered as aquaculture done in the ocean, directly in tidal areas and open water, but not aquatic plant production which is separated in the graphic (mostly in tidal areas) and not aquaculture done in pond with salty of brackish water. See 1.3 for more details of production according to environment.

IORA countries presented a very low share of marine aquaculture production in comparison with the global marine aquaculture production.

3.1.3. Aquaculture share in total fishery production

Globally, aquaculture now plays a greater role than capture fisheries to food security, providing 54% of global fish consumption. The aquaculture sector has experienced rapid growth in a context of increasing globalization and the adaptation of aquatic production areas to meet distribution and consumption needs. Capture fisheries, on the other hand, are facing a “plateau” of production (in volume) for more than a decade.

For IORA countries, the total aquaculture production represents 46% of fisheries products (aquaculture and fisheries source). Aquaculture represents more than half of fisheries production for three of its members. However, important disparities exist and 1/3 of IORA countries have almost no aquaculture production (Figure 4 and Table 1).

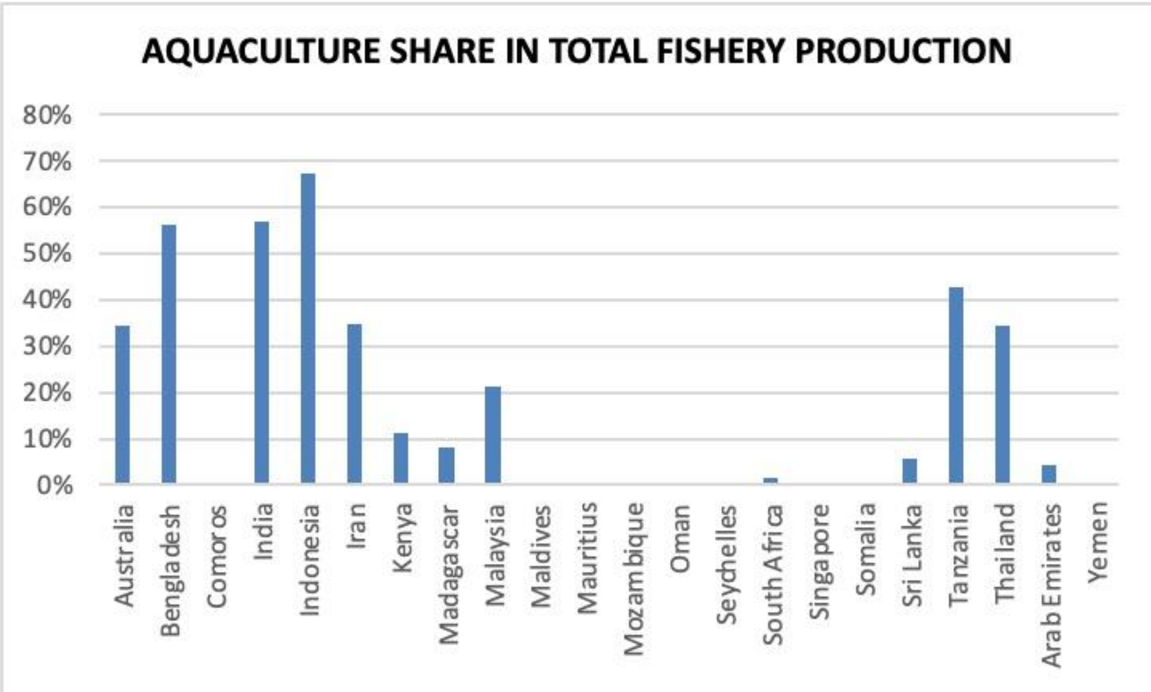


Figure 4: Share of aquaculture (in %) in the capture fisheries and aquaculture production of IORA members (source: FAO. 2020).

Table 1: The Six IORA members where the share of aquaculture in total fishery production are above 34%

IORA COUNTRIES	AQUACULTURE SHARE of TOTAL FISHERY PRODUCTION
Indonesia	67.14%
India	57.06%
Bangladesh	56.24%
Tanzania	42.84%
Iran	34.66%
Thailand	34.29%

Source: FAO. 2020

3.2 Evolution of aquaculture production (1980 to 2018)

World aquaculture production of farmed aquatic animals presented high annual growth rates at 10.8 percent and 9.5 percent witnessed in the 1980s and 1990s, respectively, and have slowed gradually in the third millennium to an average production growth of 5.3 percent per year in the period 2001–2018. For IORA member countries, a similar trend can be observed with an aquaculture production that has doubled every 5 years since late 1980s.

This growth is the result of technological innovations, the expansion of the aquaculture area and the availability of fish seeds of appropriate quality.

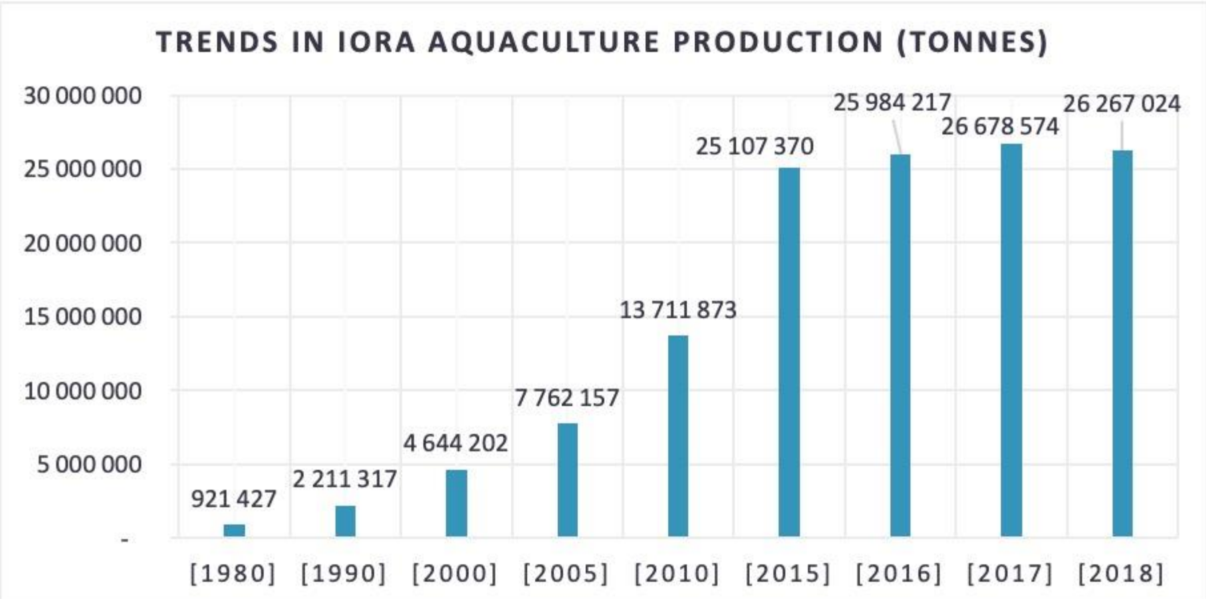


Figure 5: Data on evolution of aquaculture production (in tonnes) from 1980 to 2018 (source: FAO, Global aquaculture production 1950-2018).

From a production of less than one million tonnes in 1980, the IORA has grown in 2018 to almost 26.3 million tonnes (Figure 5). The members countries have therefore followed the general growth trend by consolidating their share to the global aquaculture production over the past two decades. Over the period 2009–2018 two members of IORA represented the higher world aquaculture production growth rates: Indonesia (with + 12.4 percent of growth) and Bangladesh (with + 9.1 percent).

This aquaculture growth was not seen in all IORA Members states.

3.3 IORA member states aquaculture production

3.3.1 Informative data by country

In 2018, the total aquaculture production of IORA countries was 26.2 million tonnes, representing 46 % of aquatic products.

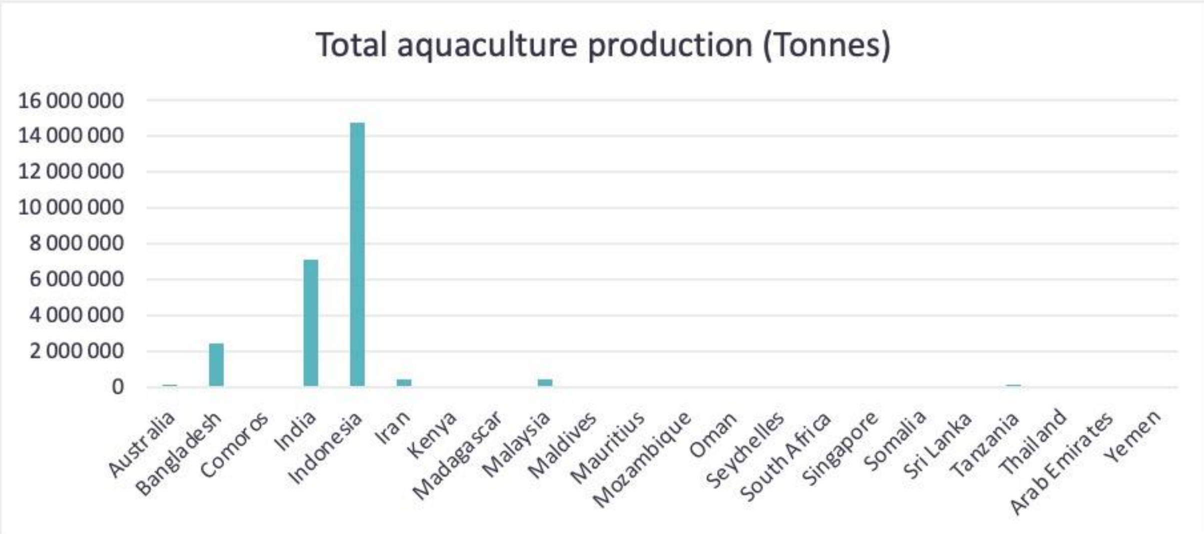


Figure 6: Aquaculture production for IORA members (in tonnes) (source: FAO. 2020).

Five countries, presented in figure 7 below, account for 69.26% of the production of IORA member countries:

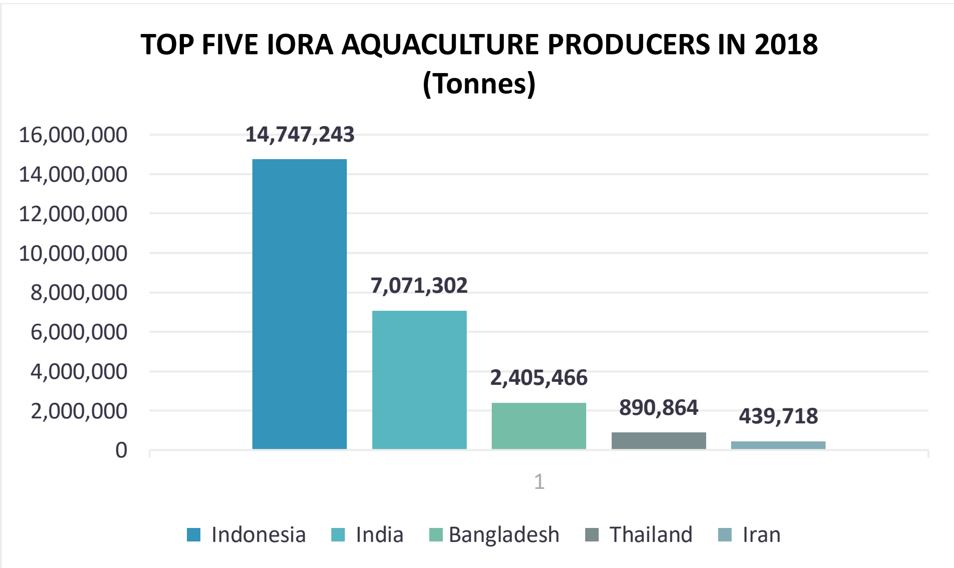


Figure 7: Aquaculture production (in tonnes) of the 5 main IORA producers (source: FAO. 2020).

The countries with the dominant production are Indonesia, India, Bangladesh, Thailand, Iran and Malaysia (Table 2). They each represent production of above 350 000 tonnes per year. Two countries have production of above or equal to 100 000 MT per year (Tanzania and Australia). All other IORA members have production of less than 30 000 MT/year.

This disparity has several roots causes, from size of the country and its population, areas suitable for aquaculture, traditional social structure in rural areas, development approaches, market dynamisms and accessibility and experiences on aquaculture production. The second part of the report will analyse these disparities.

Table 2: Production data of IORA Members and comparison with population and size of the country

IORA COUNTRIES	Total aquaculture production (Tonnes)	Kgs of aquaculture production per km^2 of land	kg of aquaculture production per inhabitants
Australia	96 797	13	3,94
Republic of Bangladesh	2 405 466	17963	15,06
Union of Comoros	Neg.	-	-
Republic of India	7 071 302	2378	5,28
Republic of Indonesia	14 747 243	8074	55,72
Republic of Iran	439 718	269	5,45
Republic of Kenya	15 524	27	0,31
Republic of Madagascar	12 708	22	0,50
Malaysia	391 976	1193	12,60
Republic of Maldives	40	133	0,08
Republic of Mauritius	2 069	1019	1,64
Republic of Mozambique	1 835	2	0,06
Sultanate of Oman	451	2	0,10
Republic of Seychelles	Neg.	220	1,04
Republic of South Africa	7868	6	0,14
Republic of Singapore	7 438	10890	1,30
Republic of Somalia	Neg.	-	-
Republic of Sri Lanka	30 920	478	1,46
Republic of Tanzania	117 008	132	2,14
Kingdom of Thailand	890 864	1741	12,87
United Arab Emirates	3 350	40	0,35
Republic of Yemen	100	0.2	0,0036
Total IORA	26 242 638	1275	11,56

Source: aquaculture production: FAO. 2020 / Population: FAO / Land area: World bank

The table shows some different measures of aquaculture production between the IORA member States. The disparities are also linked to important variability in the dimension of the country and the population (as shown in the last two columns). The differences will also be impacted by inland water resources, climate, rainfall, coastal area, economic exclusive zone, etc.

3.3.2 Share of marine and inland aquaculture by country

Of the total aquaculture production of the IORA countries, almost 58.5% comes from continental aquaculture, 41% from aquatic plants and the rest from marine aquaculture.

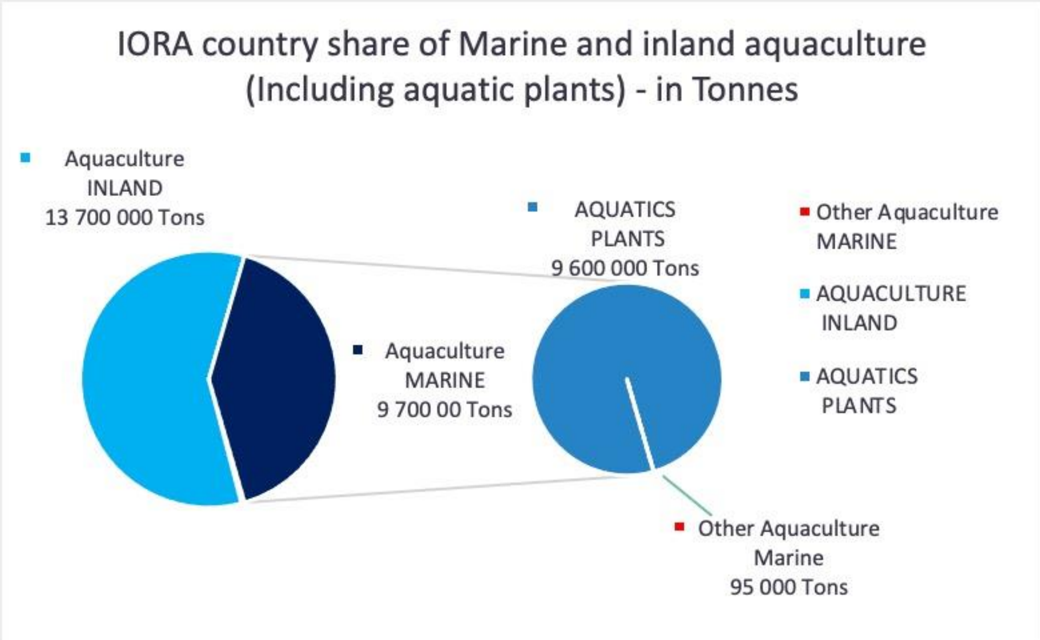


Figure 8: Share of aquaculture production (in tonnes) of marine and inland activities of IORA (source: FAO. 2020).

India, Indonesia and Bangladesh are the dominant freshwater aquaculture producing countries.
If we consider the medium (and the species, see 1.4) used for aquaculture activities, we have the following categories:

- Fresh water aquaculture[5]
- Brackish and salt water aquaculture (also called "marine")

There are important differences in the share (%) of freshwater aquaculture and sea water to the national aquaculture production of IORA countries and these are presented in the two following figures together with the important share of aquatic plant production activities.

[5] "Freshwater (or inland) aquaculture refers to raising and breeding aquatic animals in ponds, reservoirs, lakes, rivers, and other inland waterways" (https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/freshwater-aquaculture)

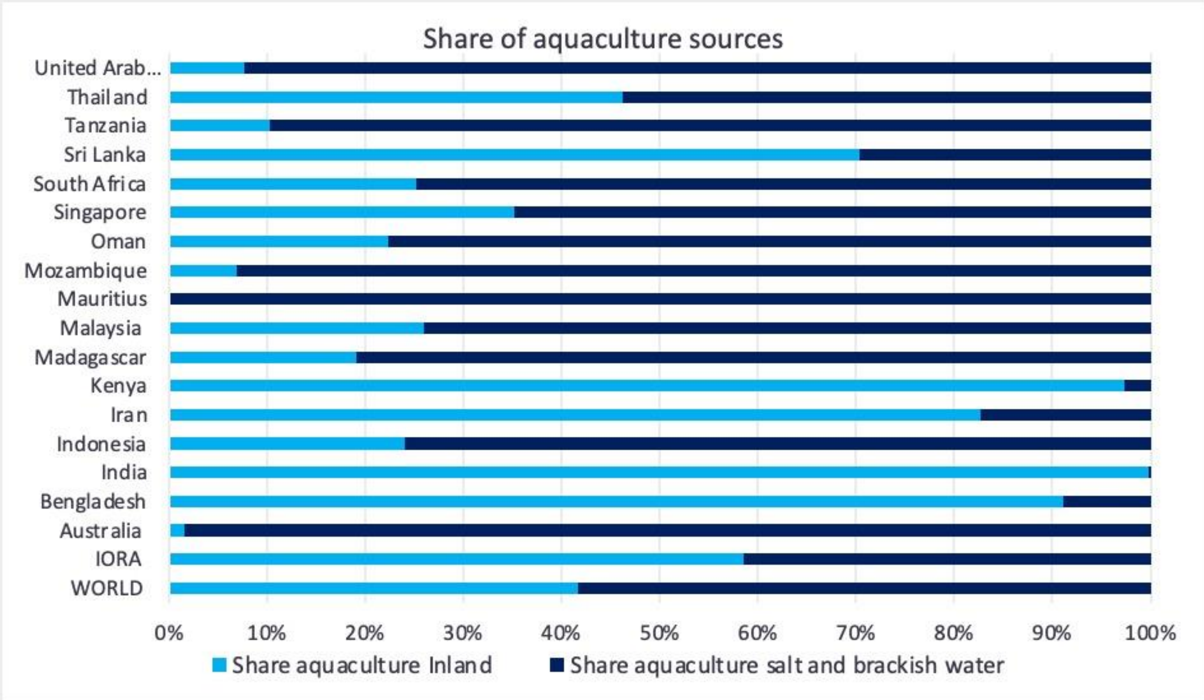


Figure 9: Share (in %) of marine and inland aquaculture production of IORA countries (FAO. 2020).

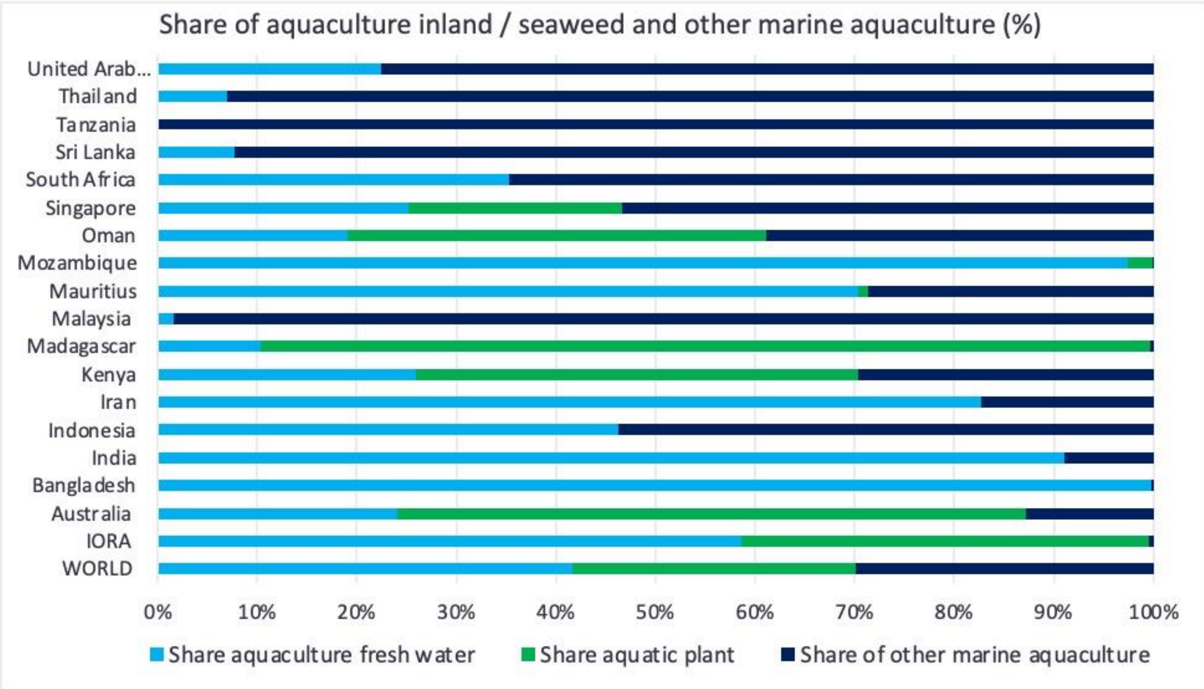


Figure 10: Share of marine and inland aquaculture production separated from aquatic plants (FAO. 2020).

The variability in aquaculture production of IORA member states is not only on volume but also on type of aquaculture developed.

While IORA states' share of fresh water aquaculture is almost 20% higher than the global percentage, still only 6 of 17 (35%) of the IORA states listed above have primarily freshwater aquaculture (Figure 9 and 10).

The rest (65%) of the countries present an aquaculture development based on salty or brackish water: even if this represents less in volume, aquaculture from marine sources cover the major share of aquaculture development strategies.

This choice of aquaculture developed is mainly base on 3 factors:

- Farming condition
- The market for the production (local or export)
- The country environmental specificities (small island, fresh water available, climate, etc.)

Figure 11: Fry of Chanos chanos from Indonesia (Photo: Pierre-Philippe Blanc).

3.4 IORA aquaculture data by species:

Aquatic species produced in aquaculture vary according to environmental and farming conditions and the objective of production. There is a great diversity of raised and cultivated species. Fish farming is the most varied sector, with 82 species and sub-species. Next come bivalves, crustaceans, molluscs, algae and other aquatic species such as sea cucumbers. Algae also represent a significant and increasing volume of aquaculture production.

According to domestication control on the different species, 3 categories of aquaculture can be found:

- aquaculture where domestication is mastered (abilities to produce seeds, fry or post-larvae);
- aquaculture with juveniles or seeds collected in the wild;
- aquaculture where only fattening is done (use of sub-adult or adults collected in the wild).

Domestication and control of juvenile production give opportunities to get improvement on selection, diseases and parasite control and grow out stage management.

In this document, the species will be grouped into 9 categories according to their specificities and environment (using FAO's WAPI species grouping methodology[6] with one change so as to separate marine and freshwater crustaceans).

Table 3: Number of aquaculture species in IORA countries by category

Environment	Categories	Number of species in IORA countries
Marine aquaculture	Marine fishes	> 35
	Marine crustaceans	> 16
	Molluscs	> 14
	Miscellaneous aquatic animals	> 5
Marine and inland aquaculture	Diadromous fishes	> 15
Inland aquaculture	Freshwater fishes	> 47
	Freshwater crustaceans	> 7
	Miscellaneous aquatic animals	> 3
Marine and inland aquaculture	Aquatic plants	> 4

Source: FAO. 2020

Some types of aquaculture representing important volumes of production depend on few species (like aquatic plants, diadromous fishes and to some extent marine crustaceans). These categories are linked with the good technical knowledge and improvements of aquaculture production. Another factor favouring the predominance of few species can be for their resistance to difficult environments and/or the basic technical knowledge needed for production.

Analysis of IORA countries' aquaculture species categories, genera and species are presented in Table 4 (next page).

Table 4: Categories and names of species used in aquaculture in IORA countries

Categories	Species details*		
Marine fishes	Acanthopagrus bifasciatus Acanthopagrus latus Argyrosomus japonicus Bolbometopon muricatum Caranx (ignobilis, sexfasciatus, spp.) Chinchards, carangues nei Cromileptes altivelis Dicentrarchus labrax Eleutheronema spp.	Epinephelus (coioides, fuscoguttatus, lanceolatus, malabaricus, tauvina, tukula, spp.) Gnathanodon speciosus Lateolabrax japonicus Lutjanus (argentimaculatus, erythropterus, goldiei, johnii, spp.) Mycteroperca bonaci Plectropomus maculatus Rachycentron canadum	Rhabdosargus sarba Sciaenops ocellatus Scophthalmus maximus Seriola dumerili Siganus (canaliculatus, spp.) Sparidae spp. Sparidentex hasta Sparus aurata Thunnus (alalunga, spp.) Trachinotus botla
Marine crustaceans	Acetes japonicus Fenneropenaeus spp. Merguiensis spp.	Litopenaeus (vannamei, stylirostris, spp.) Metapenaeus (monoceros, spp.) Penaeus (esculentus, indicus, japonicus, monodon, plebejus, semisulcatus, spp.)	Panulirus spp. Portunus (pelagicus, spp.) Scylla (olivacea, serrata, spp.)
Molluscs	Anadara granosa Clams nei Crassostrea gigas	Haliotis spp. Mactre spp. Meremix meremix	Ostrea edulis Pecten spp.

[6] http://www.fao.org/3/ca9245en/ca9245en.pdf

Categories	Species details*		
	Crassostrea madrasensis Geloina expansa	Modiolus modiolu Mytilus (galloprovincialis, spp.)	Perna viridis Saccostrea spp.
Miscellaneous marine	Holothuria (scabra, spp.) Pinctada margaritifera Pterioidea spp.	Pyura stolonifera Tateurndina ocellicauda	
Diadromous fishes	Anguilla (australis, japonica, reinhardtii, spp.) Channa marulius Chanos chanos Ellochelon vaigiensis	Ellochelon vaigiensis Lates calcarifer Mullets spp. Mugil cephalus	Oncorhynchus (tshawytscha, mykiss, spp.) Oreochromis niloticus (cross breed) Oreochromis mossambicus Salmo (salar, trutta, spp.) Salvelinus fontinalis
Freshwater fishes	Acipenser baerii (sturgeon) Barbonymus (gonionotus, schwanenfeldii, spp.) Bidyanus bidyanus Catla catla Chanidae spp. Chitala chitala Cirrhinus mrigala Clarias spp. Climbing gourami Ctenopharyngodon idella Cyprinidae nei Cyprinus carpio Helostomatidae Helostoma Hemibagrus nemurus	Heteropneustes fossilis Hypophthalmichthys (molitrix, nobilis, spp.) Hypsibarbus spp. Labeo (dussumieri, rohita, spp.) Leptobarbus hoevenii Liparis coheni Maccullochella peelii Macquaria ambigua Micropterus salmoides Monopterus (albus, notopterus, spp.) Oreochromis (aureus, niloticus, spp.) Osphronemidae Osphronemus goramy Osteobrama belangeri	Osteochilus hasselti Oxyeleotris marmorata Pangasianodon hypophthalmus Pangasius (pangasius, spp.) Perca fluviatilis Piaractus brachypomus Probarbus jullieni Scortum barcoo Siluriformes Systomus sarana Tenualosa ilisha Tor tambroides Trichogaster pectoralis Wallago (attu, spp.)
Freshwater crustacean	Astacidae, Cambaridae Cherax (quadricarinatus, destructor, cainii, spp.)	Macrobrachium (rosenbergii, malcolmsonii, spp.)	
Miscellaneous other	Hoplobatrachus rugulosus	Trionyx sinensis	Other frog species
Aquatic plants	Eucheuma spp. Gracilaria spp.	Kappaphycus alvarezii Ulva lactuca	

Source: FAO. 2020
*note: only main species are listed, the order is alphabetical. The scientific names were preferred but some species were described with generic name as in the FAO database.

3.4.1 General data on species

The species cultivated within the IORA countries are presented below in 8 groups: aquatic plants, diadromous fishes, freshwater crustaceans, freshwater fishes, marine crustaceans, marine fishes, molluscs and various aquatic animals (miscellaneous marine and miscelleneous other of Table 4).

The share of production is presented on the following figures (with and without seaweed production as that can represent very high volume but low value, see 1.5)

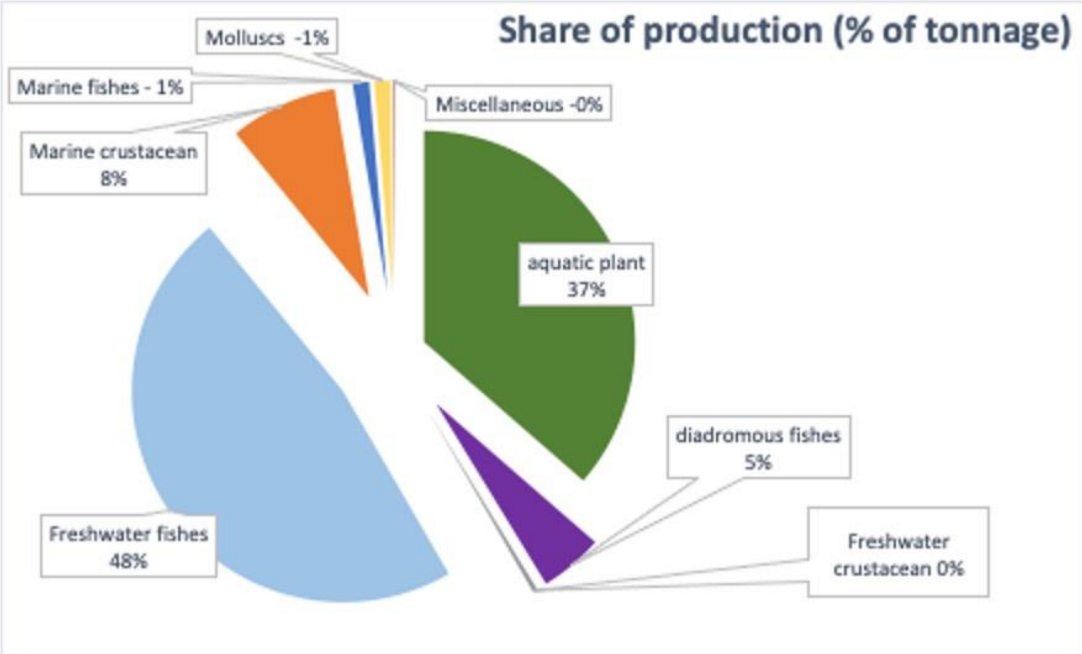


Figure 12: IORA share (in %) of aquaculture production by species categories in 2018 (FAO. 2020).

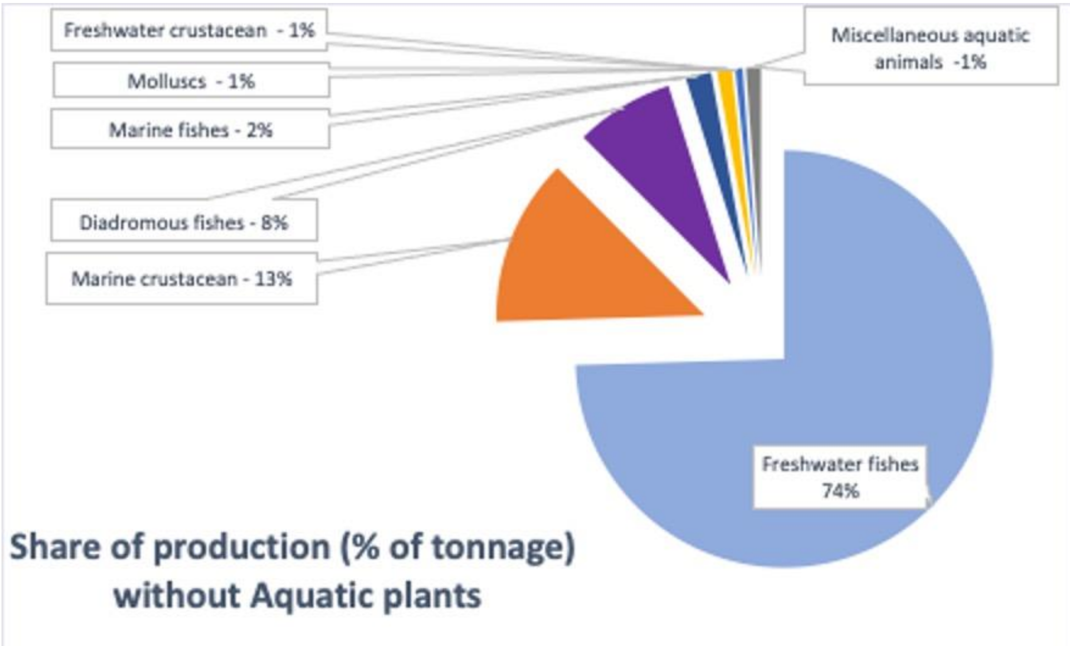


Figure 13: IORA share (in %) of aquaculture production by species categories, excluding aquatic plants, in 2018 (source: FAO. 2020).

In 2018, freshwater fish represented the largest component of aquaculture production of about 48% (by volume), followed by algae (37%) and marine crustaceans (8%). If aquatic plants are removed, the production consisted of: 75% freshwater fish, 13% marine crustaceans and 8% diadromous fish.

3.4.2 Evolution of distribution by species since 2000

The production of freshwater fish, aquatic plants and marine crustaceans has increased sharply since 2000. These hardly existed in the beginning of the century. In 20 years, significant changes have taken place in the species cultivated.

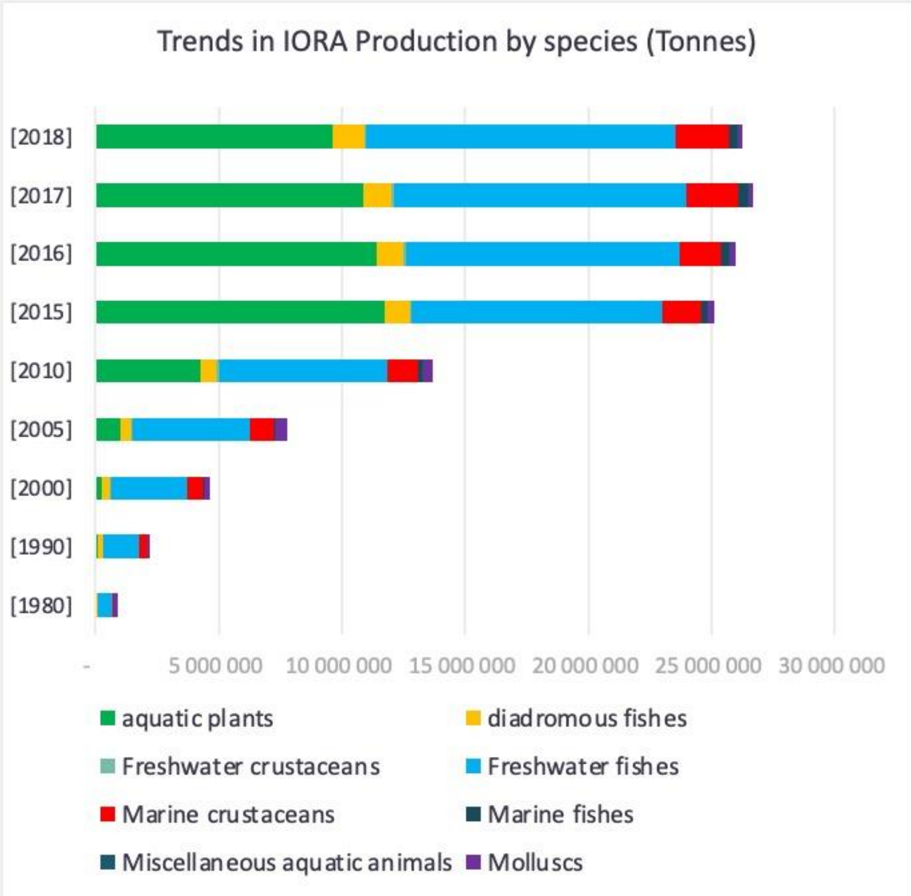


Figure 14: IORA evolution (from 2000 to 2018) of aquaculture production (tonnes) by species categories (source: FAO. Global aquaculture production 1950-2018).

In the last 10 years, the production volume almost doubled for 6 of the 7 groups: aquatic plants, diadromous fish, freshwater fish and crustaceans, marine fish and crustaceans. Only the production of" miscellaneous aquatic animals" and molluscs decreased.

In the decade before 2010, freshwater fishes were the most produced group and the production of aquatic plants had been increasing considerably. Diadromous fish and marine crustaceans had also been experiencing a significant increase in production.

These changes over only 2 decades indicate the dynamism of the sector and its development. The next decade should show similar levels of change.

3.4.3 Main species of IORA aquaculture production

Of a total of more than 80 species used to produce the 26 million tonnes of IORA aquaculture production (see Table 4), only few species, with or without grouped subspecies, represented the majority of production in 2018. Table 5 below gives the production by species or groups of similar species (such as for carps or groupers).

Table 5: IORA aquaculture production (tonnes) by species categories in 2018

Category	Species or group of species*	Production of IORA countries (tonnes)	% of IORA production
Aquatic plants	Eucheuma spp.	9 314 751	36%
Freshwater fishes	Other	4 411 982	17%
Freshwater fishes	Carps	3 634 735	14%
Freshwater fishes	Catfishes	2 697 798	10%
Marine crustaceans	Shrimps	2 135 859	8%
Freshwater fishes	Tilapias	1 753 117	7%
Diadromous fishes	Chanos chanos	878 048	3%
Marine fishes	Other	286 425	1%
Diadromous fishes	Trout and salmon	244 178	1%
Aquatic plants	Kappaphycus alvarezii	174 665	1%
Aquatic plants	Gracilaria spp	120 876	0%
Diadromous fishes	Tilapias (mozambicus or mix breeds)	98 812	0%
Freshwater crustacean	Fresh water shrimps	95 710	0%
Diadromous fishes	Barramundi	58 452	0%
Marine crustacean	Crabs	45 847	0%
Freshwater fishes	Snakeheads	37 519	0%
Marine fishes	Groupers	27 171	0%
Marine fishes	Snappers	15 528	0%
Diadromous fishes	Mullets	7 579	0%
Marine fishes	Pompano	2 364	0%
Aquatic plants	Other	1 687	0%
Diadromous fishes	Other	682	0%
Marine crustaceans	Other	643	0%
Diadromous fishes	*Anguilla* spp. (eel)	352	0%
Freshwater crustaceans	Crayfish	283	0%
Miscellaneous species	All	Neg	Neg

*Note: Except “other” representing all remaining species
Source: FAO. 2020

Six aquaculture species (or group of species) represent 80% of IORA country aquaculture production (in volume). These species are:

- ***Eucheuma spp.*** A seaweed representing 97% of aquatic plant production in 2018 and more than 1/3 of all IORA countries’ aquaculture production;
- **Carps**, consisting almost 1/3 of freshwater fishes’ production and 14% of IORA total volume of sector production. Several species (of genera *Cyprinus*, *Hypophthalmicthys, Ctenopharyngodon*) and subspecies are concerned (see Table 4);
- **Catfishes**, with one million tonnes per year less than carps’ production figure, represent the third more important group of IORA aquaculture production. Several species (of genera *Clarias*, *Pangasus, Pangasianodon*) and subspecies are concerned (see Table 4);

- **Marine shrimps**, with 8% of IORA aquaculture production, the group has several species but 98% of production is from only two species (*Litopenaeus vannamei* representing 82%, and *Penaeus monodon* 15%, of marine shrimp production);
- **Tilapias,** primarily from freshwater aquaculture, have an increasing importance in IORA representing 7% of its volume. Several species (of genera *Oreochromis*) and subspecies including specially bred *'niloticus'*;
- ***Chanos chanos***, known as "milkfish", completes this list of main species of importance providing 3% of its volume;

Figure 15: Seaweed farming (Eucheuma spp.), Zanzibar, Tanzania (Photo: Pierre-Philippe Blanc)

3.5 Economic value of aquaculture production for IORA

Overall fish production of IORA countries in 2018 was about 179 million tonnes, with a total value estimated to be about US $ 401 billion, of which 82 million tonnes (about US $ 250 billion) originated from aquaculture production (FAO Fishstats). The value of a tonne of aquaculture fish is worth more than a tonne of captured fish (considering total production and total capture).

This growing importance of aquaculture production and its value go together with improvement of the value chains and market access to increase its social and economic benefit.

- "Competition between producers on the market and lower production costs, due to improvements in the efficiency of farming systems, have led to notable price reductions. These have been achieved through technological progress, improved farm management and economies of scale allowing for better return on investment despite lower sale prices."[7] -

[7] A Global Perspective of Aquaculture in the New Millennium, Sena S. De Silva, (2001) School of Ecology and Environment, Deakin University, Australia

The IORA member states have all experienced production growth over the past 20 years (with some few exceptions where some past commercial aquaculture was stopped i.e., Seychelles, Yemen). But at the level of IORA, all together, the total value of aquaculture production has increased 9-fold in 3 decades.

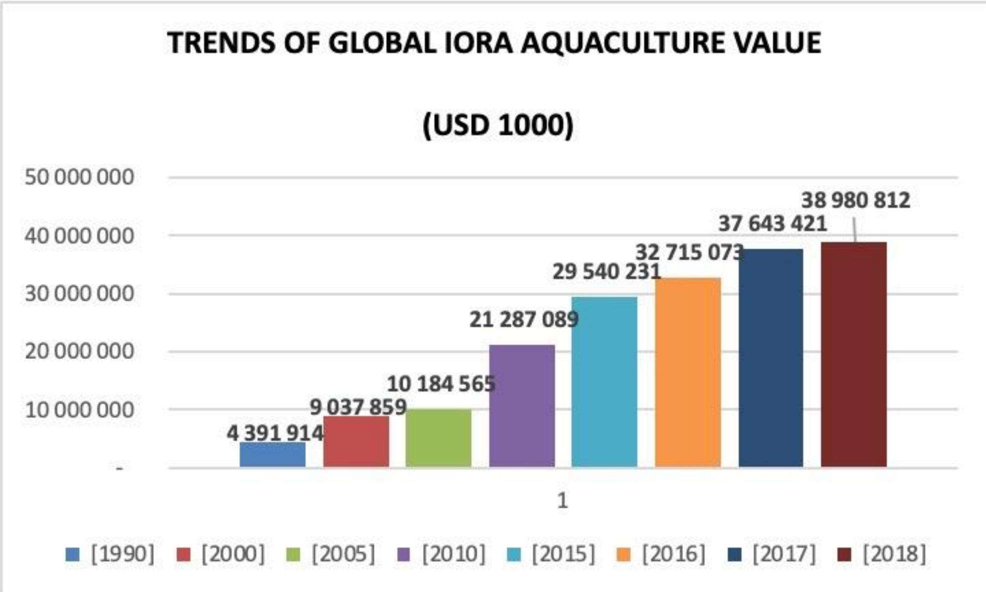


Figure 16: Value (in USD 1000's) of IORA aquaculture production from 1990 to 2018 (source: FAO. Global aquaculture production 1950-2018).

The value of IORA aquaculture products in 2018 amounted to USD38.9 billion, an increase over USD30 billion since 2000 (Figure 17).

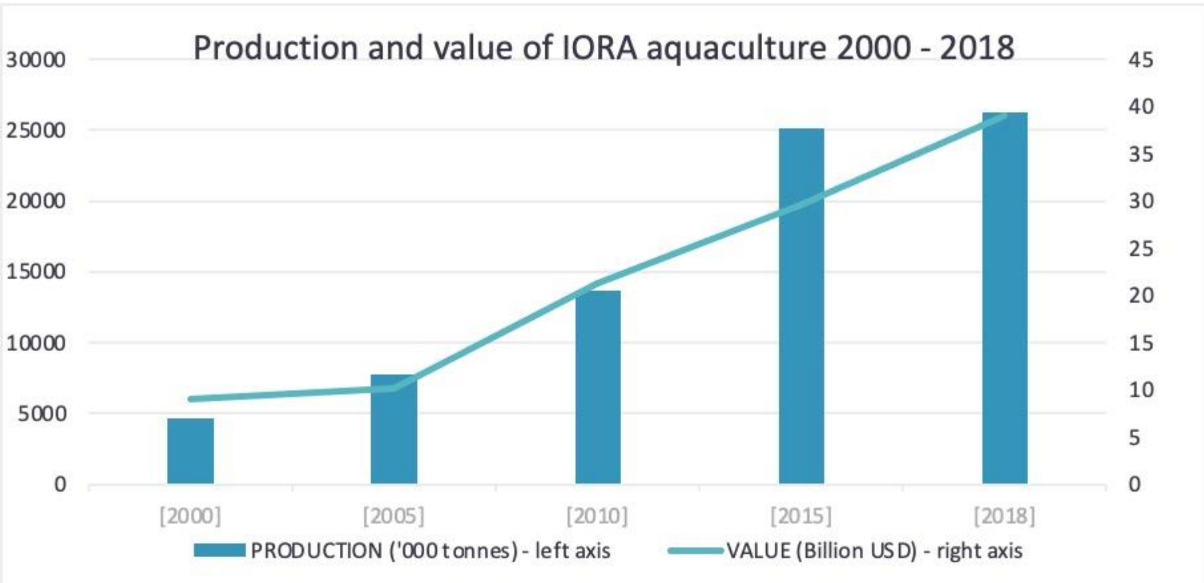


Figure 17: IORA aquaculture production ('000s tonnes) and value (USD billions) from 2000 to 2018 (source: FAO. Global aquaculture production 1950-2018).

Over the 4 last years, the value of aquaculture increased by 30% while the total production increased, over the same period, only 5%. Value chain improvement, development of aquaculture products for high value markets and reduced production costs were three causes for this increase of value.

3.5.1 Economic data for individual countries.

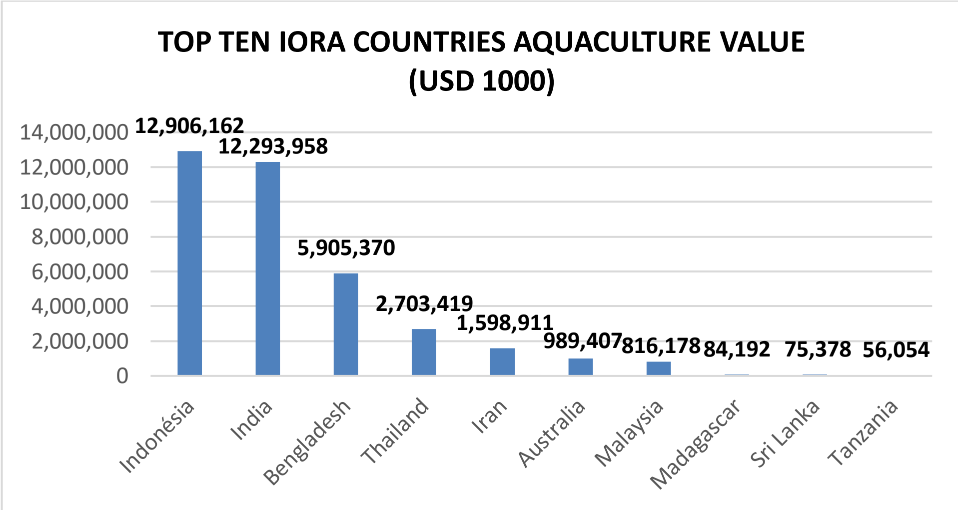


Figure 18: Aquaculture production value (USD 1000s) for the top ten IORA producer countries in 2018 (source: FAO. 2020. Fishery and Aquaculture Statistics. FishstatJ).

Almost 91% of the total economic value from aquaculture production of the IORA countries are from 5 countries: Indonesia, India, Bangladesh, Thailand and Iran. Differences are linked with volume of production but also on type of production (species and market targeted). These differences can be traced to the type of aquaculture (commercial/artisanal) and its development[8].

The following figure illustrates the impact of aquaculture production on the national economy of IORA member states in terms of their Gross Domestic Product (GDP) (countries are ranked by the annual value of their aquaculture production, data of 2018).

[8] Note: International and national economic reviews do not monitor at the same level of detail the data for subsistence, artisanal and local production.

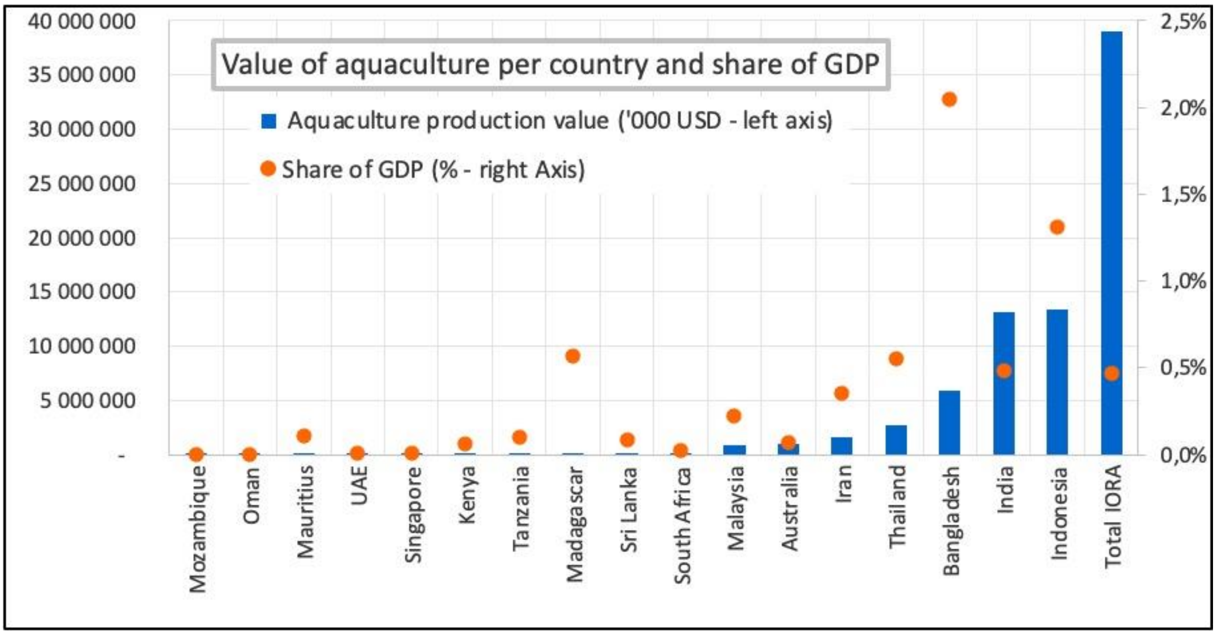


Figure 19: Aquaculture production value (000's USD) and share of GDP (%) of IORA countries in 2018
(source: FAO. 2020 and International Monetary fund for GDP).

Some countries are above the IORA member average value of 0.47% of GDP. These are the 4 main producers in volume and value but also Madagascar with the export of commercial shrimps' aquaculture.

Some countries, even with low aquaculture production present already a significant share of their GDP highlighting the possible future impact of aquaculture development.

3.5.2 Economic data, type of production.

Value does not always correspond to the quantity of species produced. In fact, some species will have more or less value, depending on their use, consumption or export opportunities, according to world demand.

Regarding the values of the production of IORA countries, even if freshwater fishes, representing the higher volume of production does also represent the higher total value; it is not the case for aquatic plants and other categories.

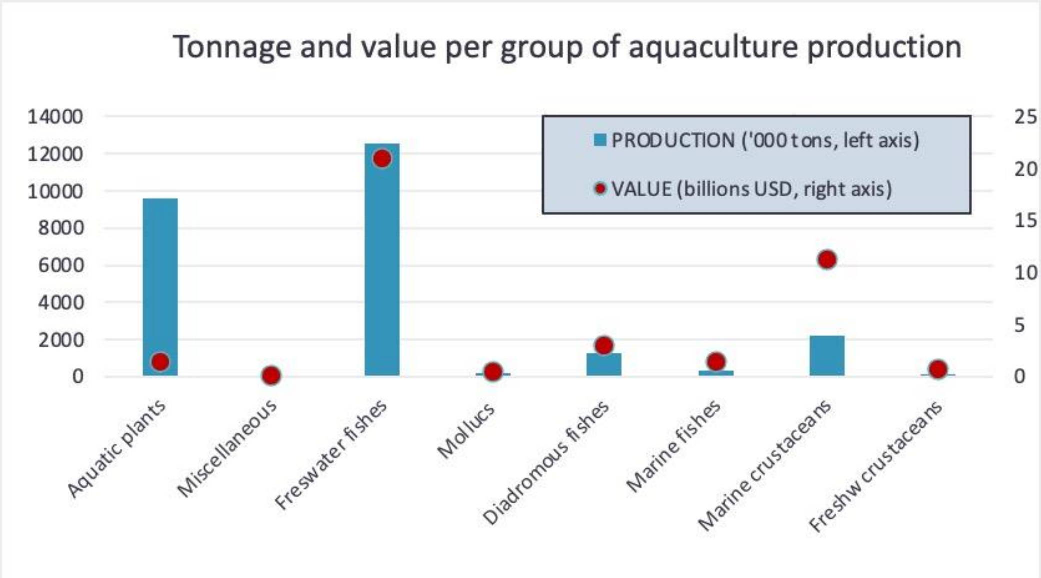


Figure 20: IORA aquaculture production (000's tonnes) and value (USD billions) by species category groups in 2018 (source: FAO. 2020).

Freshwater fish provide the highest value by species in the IORA countries (54%), followed by marine crustaceans (29%). The remaining 20% is split between diadromous fish, marine fish and aquatic plants.

The values of production are not similar, there is not the same investment needed, the same cost of inputs and the same finished product value and market. There is, undoubtedly, a link with value and production and technical and inputs needed for the production (there is no "easy money"). The choice of production is thus a strategic choice according to the country, the level of technical knowledge, the investment conditions and the market targeted.

The data of IORA countries are processed to get an indication of "value per tonne" of the member states' production, to illustrate this further (see Figure 21). It ranks the categories of aquaculture product accordingly to their value.

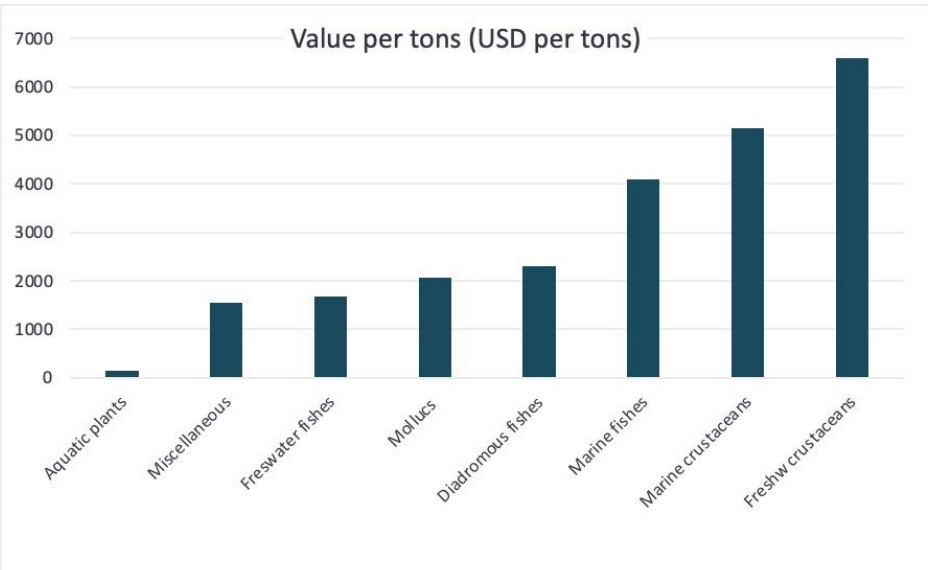


Figure 21: IORA value (USD) per tonne of species category groups ordered from lowest to highest in 2018 (source: FAO. 2020).

It is to be noted that the value per tonne results from database compilation of production and value of species per country. Errors of data collection and accuracy of collection of economic value are increased on compilation of the data. Furthermore, the aquaculture production categories can group species of high value and some with lower value (like “Mollusc” production mixing abalone and artisanal clams). Thus, the data of value per tonne are indicative and provided primarily to illustrate the differences.

Sea-weed production, representing a significant volume of aquaculture production, has by far the lowest value per tonne. Some export or niche market products can present value impact per tonne up to 30 times more important for same volume of production. This is the case for crustacean production and carnivorous marine fishes.

A detailed presentation of the **IORA aquaculture production and value by species categories** is provided in **Annex A.**

4 Categorizing IORA aquaculture into organisation, social and economic aspects

4.1 Organization of production: type of farms, of production and technology used

4.1.1 Farming systems

The aquaculture systems of IORA countries are mostly characterized by their types of practice and their access to technology.

Mostly earthen ponds rather than tanks, raceways and cages are used in inland aquaculture. Traditional practices are determined by local conditions. Mainly fish, but also freshwater crustaceans including shrimps, crayfish and crabs are produced. Many natural surface waters (rivers and lakes) and man-made water installations such as reservoirs and ponds are possible aquaculture sites.

Coastal aquaculture is carried out in saline waters in areas close to the sea and involves artificial structures, such as coastal ponds for raising crustaceans, finfish, molluscs, and seaweeds. Mariculture, or marine aquaculture, is carried out in open sea. It is often difficult to separate mariculture from coastal aquaculture, especially for fish which can be produced in coastal ponds or cages in the sea. Some aquaculture is done in tidal areas as sea-ranching (such as pens or support structures for sea-cucumbers, molluscs, giant clams) or as delimited farms (on structure, such as for seaweeds, sponges).

Aquaculture can take several different forms and operate at various scales. It can vary from subsistence-level 'backyard' fish farming in the family pond to the industrial-scale production of thousands of tonnes from a single site, often destined for export markets. Aquaculture systems have mainly been characterised by their productivity, for example, from simple pond farms to high yield re-circulation systems.

"In the context of rural development, classification based on a combination of ownership, management, labour and markets is more appropriate" (Edwards, 2013).

It is important to emphasize that categorizing aquaculture in terms of scale of operation has been used to guide aquaculture policy and development interventions (Belton and Little, 2011). However, the concept of small-scale aquaculture/stakeholders varies from country to country and embraces different criteria, of which farm size is the most common indicator. With a single indicator such as farm size, small-scale definitions also vary between farming systems with regard to farmed species and applied technology.

The following categories of aquaculture systems, adapted from Oswald and Mikolasek 2016[9] and a joint AFD, GIZ, EC report 2018[10], will be used in this report:

[9] Oswald O, and O. Mikolasek 2016. Le secteur piscicole en Afrique subsaharienne: des outils de financement adaptés aux enjeux? Techniques Financières et Développement, 2016.

[10] AFD, GIZ, EC 2017. Opportunities and challenges for aquaculture in developing countries", Joint report.

Table 6: Categories of aquaculture systems

	Industrial	SME*	Small scale	Subsidence
FAO Typology	Large scale, commercial	SME enterprises	Small-scale aquaculture enterprises	
Production items	Tanks (flow/re-circulated), cages, pond arrays	Tanks (flow), ponds, cages	Mainly ponds, lagoons, tanks, small cages/pens	Ponds (rain-filled or seasonal filling), pens, paddy fields
Management	Financial management with on-farm technical support	Mainly family members, with some professional assistance	Mainly family, possibly with some professional assistance	Family only or community share
Market type	100% sales, including export	Mainly sales, both local and regional	Mixed sales and subsistence	Fully subsistence, little or no sales
Legal status	Operated as a limited company	Limited company or association, independent or none	Sole trader/farmer, or none	Little or no legal status as operators
Access right to land and water	Legal concession for use	Land owned by the operator or family, or rented	Access to land through customary or family rights	

* SME: Small Medium Enterprise
Source: Adapted from Oswald and Mikolasek, 2016 and AFD, GIZ and EC 2017

4.1.1.1 Industrial aquaculture

Industrial aquaculture is a highly controlled commercial activity. Most companies are usually vertically integrated, they have their own broodstock and hatcheries, and often have post-harvest processing facilities. High-density stocking of animals (usually concentrated on only one species) requires high-level environmental management and control - an increasingly automated process. Such systems include coastal ponds usually used to produce shrimp and some finfish or the use of sea cages (increased in Asia, but also increasingly popular in Africa, especially in larger lakes). In all intensive aquaculture models, animals are fed special feeds, and water quality is often optimized to get a good growth rate. All of this requires high technical knowledge, substantial investment and has to support important running costs (feed, electricity, labour, maintenance, expertise and management capabilities, etc.). Therefore, intensive aquaculture usually focuses on high-value species to ensure a good profit margin.

Most of the production is for export. But in the recent years, some local niche markets are emerging in the local middle class or the local tourism industry. Industrial aquaculture can be an important factor in economic growth, especially if it generates foreign income from exports. It can also generate employment opportunities, but these opportunities are usually skilled and the employment opportunities per unit of production are low.

Evidence also shows that commercial aquaculture development and intensification can lead to increased elite capture of resources that negatively affect access and entitlements of the poor (Toufique and Gregory, 2008).

Examples in IORA of industrial aquaculture production include: the shrimp industry (Indonesia, Thailand, Madagascar, Mozambique, India, Tanzania, Australia); part of catfish and tilapia production (Indonesia, India, Thailand, Bangladesh), and; that of marine carnivorous fishes (Singapore, Australia, Oman, UAE).

4.1.1.2 Small to medium enterprise aquaculture

SME aquaculture is characterized by its high level of entrepreneurship. Although the productivity per unit area may not be very high, the operations of small and medium-sized enterprises (especially when operating in groups or associations) can be distributed in a wide area and greatly promote the production of local fish. They also tend to have a high degree of entrepreneurship and innovation ability, and bear carefully calculated financial and technical risks. They often look for different opportunities, such as developing hatcheries to diversify into new species, production systems or increase of vertical integration. Production systems usually require some investment in water management and environmental control. The density of juvenile fish is very high and they are usually reared in some form, including fertilizing the pond (to increase natural feed production), using other feeds, and adjusting water levels and water quality.

The production level exceeds the natural carrying capacity of the water body and artificial feeding is given for termination stage and/or according to the environment natural feed supply. The most common type of semi-intensive system for finfish is ponds, usually made of mud, sometimes lined with clay, and fed by streams or other water sources. This is a common solution in inland areas. For shellfish, sea cucumber or seaweeds, pens, rafts, longlines and trestle bridges are used in the intertidal zone and the sub-tidal zone. Organized fishing is usually carried out, with a longer value chain than extensive aquaculture, and fish are usually sold in local villages and towns or even neighbouring countries, especially in Africa. In Asia, the value chain of this semi-intensive aquaculture including local cities can be longer and better organized. The aquaculture of small and medium enterprises tends to grow rapidly, be full of vitality, and able to diversify into new production plans and markets. However, expansion and growth may not benefit all, and increasing intensification may introduce environmental and socioeconomic challenges.

Examples of SME aquaculture in IORA include: an important part of catfish and tilapia production (Tanzania, Indonesia, India, Thailand, Bangladesh, Mozambique, Madagascar); part of the milkfish production (Malaysia, Indonesia, Sri Lanka), and; some mollusc production (Australia, Malaysia, Thailand, South Africa).

4.1.1.3 Small-scale commercial aquaculture

Small-scale aquaculture provides an opportunity to diversify small-holder farming activities at the family level or at a community level. It can be the main activity of some farmers or part of a combination of different activities. With small units of production (pond, cage, pens, reservoir or lake), small-scale aquaculture is considered as commercial when part, or all, of the production is sold.

Technical level is often simple and there are no or little inputs (artificial feed, chemical, other). Production densities are often based on environment carrying capacities and yields are low. Seeds are collected from the natural environment or sometimes purchased from existing local hatcheries. It is often described as a 'low-input and low-output' model presenting several possible improvements.

Small-scale commercial aquaculture will be an income-generating component of livelihood strategies, thus supporting incomes and increasing resilience to external changes. It usually depends upon there being a dynamic local market or it can be driven by commercial buyers for processing for export or for niche markets.

Examples of small-scale commercial aquaculture in IORA include: an important part of freshwater fish production (all IORA member states); seaweed production (Indonesia, India, Tanzania, South Africa), and sea-cucumber (Madagascar and under actual development in Maldives, Mozambique, Tanzania).

4.1.1.4 Subsistence aquaculture

Subsistence aquaculture has similarities to small-scale aquaculture. It is incorporated into other small-scale operations of family or community farms, but on a smaller scale, technically simpler and production is only used for family or community consumption. It is characterized by almost no investment in infrastructure and grow-out activities. Usually, it involves low-density stocking of juveniles in backyard ponds (of only hundreds of square meters) or community-owned bodies of water (dams or natural ponds). The juvenile fish may come from a local hatchery, but they may also be harvested from the wild and raised in captivity. There is no additional feeding than natural feed production of the pond or pens. As a result, the yield is very low, and the growth is slow. Harvesting is usually carried out continuously (often not harvested at once but larger animals are harvested regularly and smaller animals are released), and consumption is carried out by the family or the direct local community. It is often an environmentally effective production model, especially when combined with other agricultural activities (such as rice and fish production), and it can make households and communities more resilient to economic or environmental impacts.

In all the following parts of the report "Small-scale aquaculture" will group "small-scale" and "subsistence" aquaculture as one.

4.1.2 Value chain approach

An important feature of current aquaculture production is the formation of a value/commodity chain, which links different stakeholders in the process of providing inputs, producing, processing, distributing, and ultimately consuming the final product. The value chain is structured along the final product/commodity and the target final consumer needs. The characteristics of aquaculture production create conditions for restricting or strengthening the organization and governance of the value chains. In general, when buyers represented by retailers and supermarkets, play a leading role in influencing the production and distribution of final products, the aquaculture value chain can be classified as buyer-driven. However, when examining the interrelationship between two continuous links in the value chain, there may be multiple governance and coordination mechanisms, from free market relations to network relations to vertical integration relations.

Therefore, aquaculture value chains vary considerably between the different countries, farmed products, farming systems and environments.

Consequently, the numbers of people involved along different value chains also varies with the associated degrees of complexity, from a simple household subsistence aquaculture operation through to a globalized value chain involving several steps of product processes.

Most of the time, mainly in small scale aquaculture, the value chain can present several levels of complexity and intermediaries as stated in a 2016 report on small scale aquaculture made by FAO and Worldfish: "Local and global aquaculture value chains originating from small-scale aquaculture production tend to be more fragmented and involve a higher number of stakeholders".

In contrast, aquaculture value chains oriented around large commercial-scale production are better organized, less fragmented and better able to address food safety, product quality and environmental standards imposed by buyers in domestic and export markets. These monoculture value chains producing products for export markets can be complex but all stakeholders and activities can be easily identified. In many cases, the monoculture or high value products (crabs, shrimps, carnivorous fishes) from aquaculture value chains are buyer-driven for local niche markets (i.e., in Singapore, United Arab Emirate, Mauritius, Australia) or for export (i.e., shrimp aquaculture in Madagascar and Tanzania but also Thailand, Indonesia, Bangladesh).

It is more difficult to define a model of value chain in the case of integrated aquaculture (aquaculture-agriculture systems, ponds or dams seeding, polyculture) where the value chain can be multiple with parts of the production for auto-consumption or sold as fresh but also some processing steps of conservation (brine, dry, smoked) or even supply to the value chain dedicated to export market or local transformed product. The use of the aquaculture production is often dependent on opportunities that are not regular.

4.1.3 The importance of small-scale aquaculture

"The bulk of aquaculture is rural and subsistence, it plays a major role as a provider of direct and indirect employment to the rural poor" Sena S. De Silva, School of Ecology and Environment, Deakin University, Victoria, Australia.

At global level, it is estimated that 60 to 80% of the production of aquaculture is made by small-scale and very small-scale producers. That 80% of the production is made on production structures of less than 3 ha.

Small-scale aquaculture provides an opportunity to diversify small-holder farming activities at the family level. As such, it competes with other crops for land, labour and cash, and the farmer must combine those different crops to get the best income. Integrating fish farming with other forms of agriculture has several positive impacts for example, in better yields, improved (and natural) pest management, more efficient use of water, and spreading cashflow demands and income. At this scale, aquaculture may not be considered an enterprise as such, except when it becomes the main crop. However, it will be an income-generating component of livelihood strategies, thus supporting incomes and increasing resilience to external changes. It usually depends upon there being a dynamic local market for farmed fish.

But the world figures presenting small scale aquaculture as the dominant aquaculture models is mostly driven by the historic development of aquaculture and the predominance of Asia in world production. Indeed, small-scale stakeholders dominate the number of jobs generated by the aquaculture industry in Asia, where aquaculture is locally operated by rural communities.

Other national sector development models can be found with predominance of other types of aquaculture, like in Latin America, where the sector is still dominated by larger-scale operations, even if today a development of small-scale operators is starting to appear around the existing businesses.

In IORA member states, we can find the predominance of small-scale operators in the East part of the Indian Ocean (south-east Asia area). Larger-scale operations are found in countries in transition and industrialized countries (in some cases, some small-scale structures have started to develop their activities in recent years). It is the case in Australia, the middle east area, Mauritius and Singapore, for example.

For the Africa part of the Indian Ocean, Brummett, Lazard and Moehl (2008) suggest that more than 90 percent of African fish farmers operate one or a few earthen and family-owned ponds with a surface area less than 500 m^2, with annual production of 300–1 000 kg of fish per hectare or 15–50 kg per crop. But some commercial farms have also been launched in several countries (Tanzania, Seychelles, Madagascar, Mozambique, Réunion island) though their numbers are limited and their experiences have often not been followed.

According to a report made by FAO and Worldfish (2016), in Indonesia and Bangladesh, small scale aquaculture dominates and represent more than 60% of employment. While small-scale aquaculture value chains generate higher overall levels of employment, small-scale aquaculture contributes less than 30 percent to total aquaculture production.

Based on subsistence and local markets, small scale aquaculture can be also a source of production for export. Indeed, in some countries, the aquaculture market is divided between companies that are increasingly contributing to production and small-scale producers. The productions of several small-scale units are thus collected to be processed for export.

Examples following this organization include: the seaweed sector in Indonesia and Zanzibar; an important part of the shrimp production in Thailand and Bangladesh, and; some of the production of sea-cucumber in Madagascar.

Processing and/or exporting companies are supporting the small-scale production sector to get the quantity of product needed for their specific markets. Providing technical support, seeds and/or feed, the commercial companies are a real catalyst of the sector development.

4.1.3.1 Strength of small-scale aquaculture

Development of small-scale aquaculture has many advantages. Firstly, its products have a high nutritional value and generally meet local market demand. In addition, the activities are sustainable and have less impact on the environment. Also:

- It generates income at the household level, thus facilitating financial balance of households;
- It is a source of independent work and income impacts on social status and, more broadly, contributes to GDP growth;
- It is decentralized and contributes to the empowerment of local communities, strengthening community traditions and values;
- It is a relatively accessible activity for smallholders because it uses low-cost inputs and can be carried out in rural areas;
- It also generates employment opportunities, particularly in intensive production areas;
- It is flexible and adaptable to a changing environment, due to low investment;
- It offers different technological options that are relatively easy to adopt, apply and adapt;
- In many small-scale structures, the aquaculture activities are combined with other production activities ("vegetable-fish-livestock" or polyculture of fishes or family-pond scheme) or are based on seasonal land use on plots that would have otherwise remained idle, creating extra income and diversification of earnings.

4.1.3.2 Weaknesses of small-scale aquaculture

Small producers, often characterized by low productivity, participate in aquaculture activities in many countries. Aquaculture is a means of sustaining livelihoods and family businesses and requires some expertise. Small farms are usually run by individual families that produce small amounts. Therefore, their productivity tends to be weak. Small producers must also face difficulties related to limited access to land, water, financial resources and equipment, which often results in low productivity and income. They are also vulnerable to external factors such as climate change or market demand. To continue to develop, many challenges must be faced. The first is to increase the supply of social and economic services to rural and urban populations around the world.

Some external factors can have important impact on a small-scale production sector, like shrimp diseases in Thailand in the mid 2010's or the increase of water temperature and the variation in international market price for the seaweed farmers of Zanzibar, in recent years.

Furthermore, this sector is influenced by many factors, like use of land and water availability, climate change, associated with increasing globalization.

The needs of compliance to international standards can also be mentioned. Globalization has generated new markets for aquaculture products, but requires stricter food security standards and traceability. These requirements are often difficult to put in place for small scale structures.

Smallest producers are faced with new constraints related to export, because they are disadvantaged due to their poor capacity to influence the market or the conditions imposed by the commercial companies buying their products.

As they contribute to households' income, small scale aquaculture practices and strategy must therefore be adapted to changing climatic conditions and market evolution.

Figure 22: A farmer on his farm (sea-water) on Pemba island, Tanzania (Photo: Pierre-Philippe Blanc).

4.2 Employment

Aquaculture is an important source of employment for millions of people all over the world, especially those living in rural communities in inland and coastal areas where there may be more limited employment options. Despite its importance, there are limited data and studies on employment in the global aquaculture industry (Ahmed and Lorica, 2002; FAO, 2010a).

Globally, the fishing and aquaculture sector is a major source of employment. "Worldwide, approximately 59.5 million people were engaged in the primary fisheries sector in 2018, of which approximately 20.5 million were engaged in aquaculture "[11].

Overall, the highest numbers of aquaculture workers are in Asia, representing 85% of the world total, followed by Africa 9% where numbers have steadily increased. Overall, employment in aquaculture is increasing around the world and in countries bordering the Indian Ocean while employment in fishing has been declining all over since 2010.

Officially, figures show that women account for 19 % of the people engaged in the primary fisheries and aquaculture sector in 2018.

Type of people employed by the aquaculture sector:

- Hatchery
- Nurseries
- Farms / households
- Feed mills,
- Inputs suppliers
- Middle traders
- Processing
- transport

4.2.1 Number of people employed in the aquaculture sector

The aquaculture sector has to be considered as a whole. It is not sufficient to consider the production level alone. All employment along the value chain has to be considered.

Employers at the farm level include those who operate hatcheries, nurseries, and grow-out production facilities, as well as part-time and temporary workers employed on aquaculture production premises. Employers at other links of the aquaculture value chain include input suppliers, middlemen and domestic fish distributors, processors and exporters. The number of people employed in aquaculture varies from country to country, but data suggests that previous values based on data reported to FAO may be underestimated. In 2010, a Hishamunda and Zhou study presented estimates with figures of more than double the FAO ones for the number of jobs generated by global aquaculture and related activities.

[11] The state of world fisheries and aquaculture, FAO, 2020.

One of the main difficulties relates to estimating the extent of division of small-scale aquaculture activities. Many jobs and activities are informal (family-based, community-based, not declared or are linked with non-aquaculture activities).

As an example, the production of small tilapias (less than 150g per piece) in Mozambique, produced and sold in local coastal markets in the centre of the country, were found in neighbouring countries Zimbabwe and Malawi. The product was travelling two to four hundred kilometres, fresh, salted or dried with the participation of important numbers of stakeholders, involving local transport[12].

Another difficult estimation step is to evaluate the indirect employment. It has been estimated that in Australia, for example, three indirect jobs are created for each direct employment in aquaculture sector (de silva, 1999).

Aquaculture value chains create jobs that would not exist without aquaculture. Most of the time, these jobs are still not sufficiently evaluated in data available.

4.2.2 Aquaculture and women

"Women play a significant role in aquaculture value chains. Employment of women in aquaculture value chains was estimated to range between 40 and 80 percent and women were found to be active in post-harvest activities in aquaculture value chains in many countries and to assume important roles in household-based aquaculture such as feeding, managing ponds and marketing products" (FAO/Worldfish, 2016).

Women's role as labour in the aquaculture sector is important although their function is often under-recognized and paid at a lower level. In some cases, aquaculture has become a way to their autonomy. The example of seaweed development in Zanzibar gave to women the opportunities to have a direct income, their numbers represented more than 80% of the "farmers".

In most of IORA member states, women play critical roles at different stages of aquaculture value chains. The functions and roles they assume differ between countries, farming systems and value chains. In general, women are not often directly involved in hatchery and nursery operations but are involved more in grow-out aquaculture production and play key roles in the processing and marketing of aquaculture products. In many developing countries, especially those in South Asia and Southeast Asia regions, it is common for women and men to work together to improve their household-livelihood portfolios. In countries in transition or industrialized, women can represent more than half of the workers in laboratories and hatchery operations (e.g. Singapore, Australia).

In some countries, women's participation in economic activities is restricted due to cultural and/or religious prohibitions. However, there is room for increasing women's involvement through supporting homestead aquaculture where ponds are constructed adjacent to the homestead such as in Bangladesh or with the development of aquaculture models with part-time work such as in the Zanzibar seaweed industry.

"A gender analysis of the fisheries and aquaculture value chains would be beneficial to policymakers to better understand and increase the visibility of women's work and roles in the sector. (…) Greater insight into family, community and work-related gender interactions would help to inform

[12] Author field observation

policymaking and address some of the existing inequalities in the economic, social and political spheres." UNWOMEN 2020[13].

4.3 Social and economic contribution of aquaculture

"It is widely considered that aquaculture contributes to global and regional food supplies, improves national food security, generates household income, contributes to national and global gross domestic product (GDP), creates direct and indirect employment for rural populations, and contributes to national and international trade. Aquaculture development, especially small-scale aquaculture, can contribute to rural development, for example through efficient use of water, efficient use of farm products and other resources, diversifying livelihoods, utilizing family and rural labour, and enhancing social harmony and gender equity" (Edwards, 1999).

4.3.1 Aquaculture and poverty alleviation

Small scale aquaculture can directly contribute to provide fish and incomes to part of the vulnerable population. Subsistence farming developed in Africa (see 4.1.1.3 and 4.1.1.4 of this report) and in Asia show a direct example - as homestead aquaculture. The development of seaweed aquaculture in Indonesia and in Tanzania-Zanzibar provides extra income to hundreds of thousands of poor rural people.

Furthermore, the contribution of aquaculture to rural poverty alleviation can be assessed by examining direct involvement of the poor in aquaculture value chains. Indeed, aquaculture indirectly reduces poverty by involving poor and small-scale stakeholders in various activities. In Bangladesh, many poor people work in fish fry fishing and seafood processing plants (FAO/Worldfish, 2016). In Indonesia, Thailand and other countries, rural poor people are employed in processing plants and engage in various activities related to aquaculture. In addition, there are many small-scale participants directly involved in various value chains. Many of these actors are not poor, but may be vulnerable, earning income as small rural enterprises, engaged in aquaculture production and other livelihood activities. Women, often a vulnerable group, are actively involved in aquaculture (see 4.2.2. of this report).

Another dimension for understanding the link between aquaculture and poverty alleviation is fish food security. Fish is the lowest-cost animal protein and it can be supplied via aquaculture production. With both public-based and market-based interventions, global aquaculture has been developing rapidly in the last five decades and now contributes 50 percent of world food fish supply (FAO, 2016). With the exception of some export-oriented commodities, the majority of aquaculture production in developing countries is consumed domestically. Aquaculture development can also help to lower fish prices, making fish accessible to poor and small-scale stakeholders in both rural and urban areas.

4.3.2 Aquaculture and food fish supply and nutrition

As aforementioned, aquaculture accounts for about 50 percent of food fish production for human consumption locally and globally. Global aquaculture production has been increasing sharply in the last three decades or more, but it is unclear how this remarkable increase in global production has affected fish consumption and nutrition of local people in developing countries, especially the poor[14].

[13] UNWOMEN 2020. Women's economic empowerment in fisheries in the Blue Economy of the Indian Ocean Rim. Baseline Report produced with support of Department of Foreign Affairs and Trade, Australia.https://www.unwomen.org/-/media/headquarters/attachments/sections/library/publications/2020/womens-economic-empowerment-in-fisheries-in-the-blue-economy-of-the-indian-ocean-rim-en.pdf?la=en&vs=5204

[14] Aquaculture big numbers, World Fish and FAO 2016

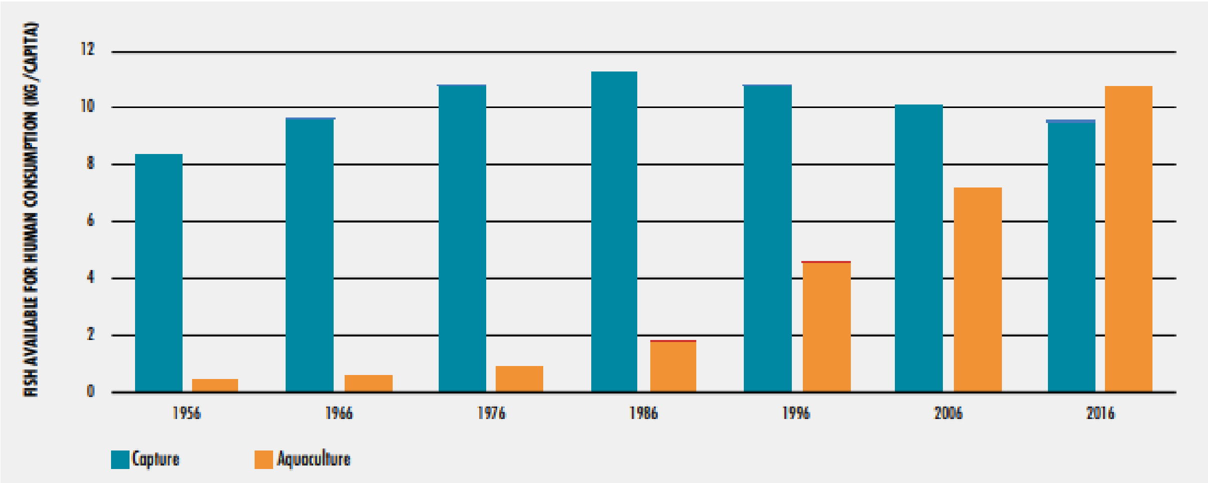
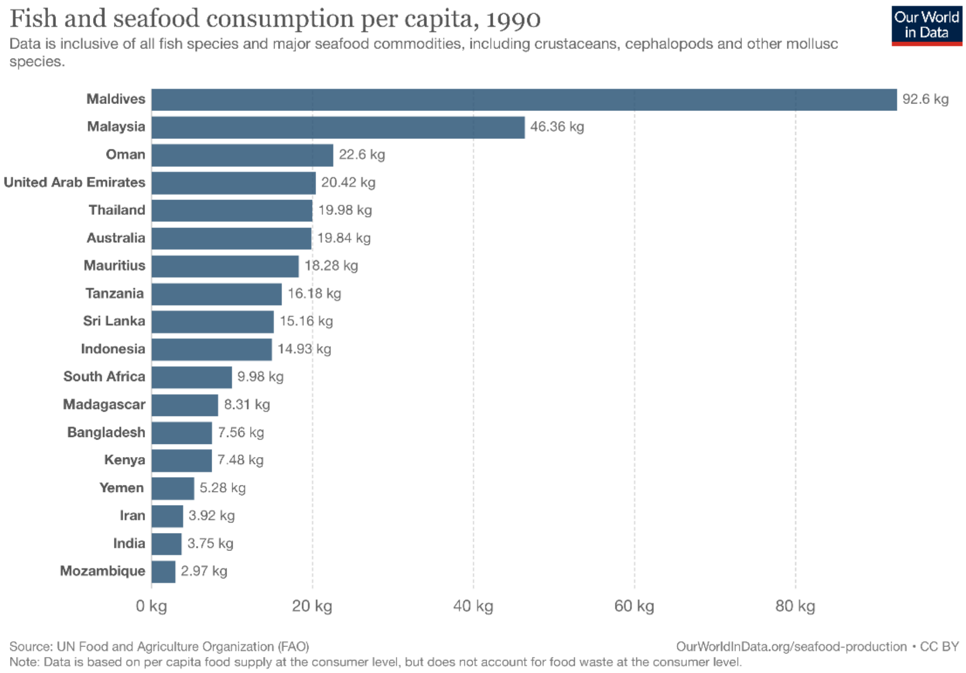


Figure 23: Fish available for human consumption (kg/capita) from aquaculture and capture fisheries (source: FAO, 2020 – World aquaculture performance indicator).

Across IORA member states, there are some disparities. The quantity of fish consumption per capita has increased in most of the countries except for some African countries were a diminution can be observed (see Figure 24).



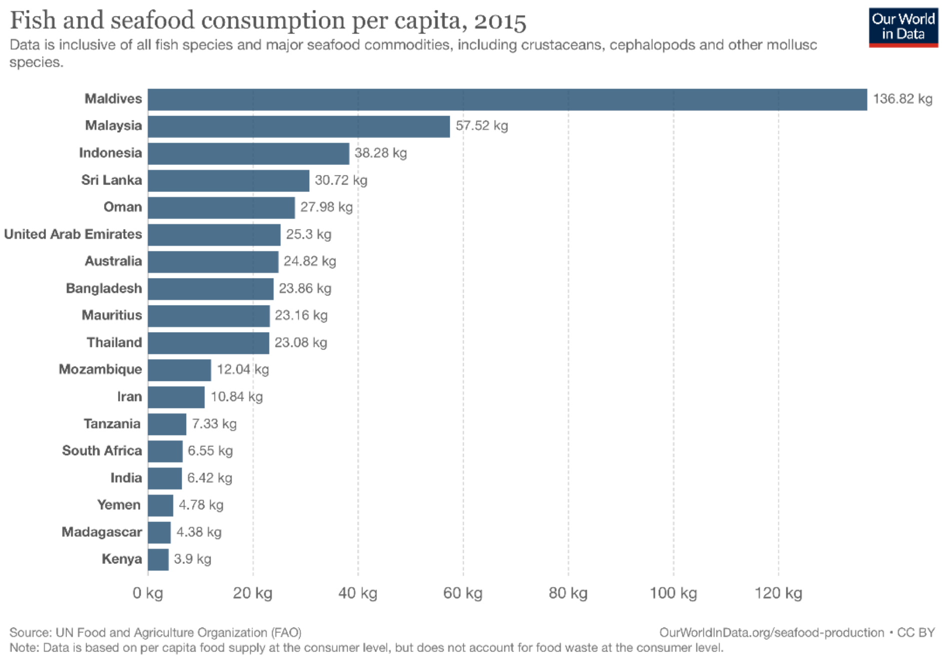


Figure 24: Fish and seafood consumption per capita in 1990 and in 2015 of several IORA member countries (source: FAO data processed by ourworldwithdata.org).

Important disparities exist between countries linked with their tradition, the availability of fish and the history. But it can be noticed that all IORA countries with important aquaculture production have increased their consumption of fish per capita per year (with one exception, Maldives).

Local contributions to communities' economies and consumption are not well documented and often neglected. In 2002, Ahmed and Lorica showed that aquaculture development has positive income and fish consumption effects in developing countries. However, there was limited empirical evidence to support the view that aquaculture provided vital nutrition to poor households and contributed to poverty alleviation, thus improving the overall welfare of poor people in developing countries.

Observations made by J. Cai, K. Quagrainie and N. Hishamunda in 2017, are more precise on aquaculture contribution for local nutrition: "What is produced is mostly consumed domestically, including by the poor, which serves the improved nutrition and food security objective of aquaculture development".

At the overall national level, although capture fisheries production has stagnated or declined, per capita fish consumption has been increasing in most countries with active aquaculture development. The increase in fish consumption seems to have been supported by the annual increase in aquaculture production. It can be also considered that fish sales enable rural people to purchase other staple foods and enhance overall food security. On average, the development of aquaculture has increased fish consumption. However, there is limited information to analyse the impact on different stakeholder groups (such as the poor, women and children). The differences, if this information existed, would possibly further highlight the importance of development of small-scale aquaculture.

4.3.3 Incomes from aquaculture activities

Generally speaking, in most countries, the income levels of aquaculture employees are also thought to be higher than those in the fishery sector and other primary-sector industries. Some studies in China, Vietnam and India show that the average income of a fish farmer was almost always twice that of a fisher.

In many small-scale structures, the aquaculture activities are combined with other production activities ("vegetable-fish-livestock" or polyculture of fishes or family-pond scheme) creating extra income and diversification of earnings.

4.3.4 Other social and economic impacts of aquaculture

Sectors in an economy are interdependent. Thus, besides contributing to economic growth directly through its own value adding and employment creation, an economic sector can also indirectly contribute to the economy through its impacts on other sectors.

Development of aquaculture will not only increase its own output (and value adding), create more jobs and pay more wages and salaries (seasonal work and commercial aquaculture), but it can also stimulate output in other sectors.

Input-output

On the one hand, a sector in an interdependent economy may need to buy materials from other sectors as inputs for its own production. Aquaculture farms purchase working items, feed and fertilizers from specialized feed and fertilizer companies or from local producers. On the other hand, the sector's products may be sold to other sectors as inputs for their production. For example, some aquaculture farms are specialized in bait production for the sport fishing industry.

Backward linkages

Traditionally, agriculture sectors are deemed as having limited backward-linkage impacts on the rest of the economy, because their major inputs are labour and lands (Hirschman, 1958). Yet, as it tends to adopt intensive or semi-intensive production technologies that require significant intermediate inputs, especially feed, commercial aquaculture is increasingly generating strong backward linkages. In modern aquaculture in Africa, feed generally represents between 60 and 65 percent of the variable costs and 45 to 63 percent of total costs (Hishamunda and Manning, 2002; FAO 2017, 2018). This backward linkage will be expressed by the needs of supply of the industries developing their economic activities to provide inputs to the aquaculture sector (feed, fertiliser, drugs, nets, plastic containers) or for actors of the value chain (transport, storage, processing)

Income

Employees of aquaculture farms (seasonal and commercial activities) may use their wages and salaries to purchase goods and services from other sectors, thereby stimulating these sectors' development.

5 Governance and sector development approach

5.1 Trend of aquaculture development

Between the IORA member states, the development of aquaculture has not followed the same model, the actual disparities in production and importance of the aquaculture sector illustrate different approaches and different country pre-requisites for the sector's development.

As in all categorization, some simplifications have to be made. IORA member states can roughly be divided in three categories:

a. Mature aquaculture sector development
b. Emerging aquaculture sector
c. High technical aquaculture development

5.1.1 Mature aquaculture sector development

Asia is by far the world's leader in aquaculture production, producing more than 80% of the world's total aquaculture output. The sector's development is still growing and dynamic. Most member states of IORA from the eastern and northern part of the IO are in the category of "Mature aquaculture sector development". It is the case of Bangladesh, India, Indonesia, Iran, Malaysia and also Thailand.

Their aquaculture sector provides more than 30% of national fisheries products. The 15 last years have seen spectacular development and dynamism, framed by pre-existing favourable conditions[15].

- People and rural communities performant in agriculture had adopted aquaculture as income and business opportunities. Traditional and/or cultural approaches had included aquaculture and production;
- Dynamic small-scale aquaculture and value chain organization;
- Governance and policies tracking and accompanying sector development;
- Active production of quality feed and seeds with distribution networks;
- Resilience of the sector to external impacts and adaptation to new markets (mid 2010's shrimp disease events, the adoption of new species or shifts of species);
- Part of the sector development was led by commercial aquaculture, often linked with small-scale aquaculture.

[15] Note: The following list is not exhaustive, there are socio-economic differences between the countries in this category. The grouping was done to resolve the 3 aquaculture development approaches and capture the situation between IORA member states.

5.1.2 Emerging aquaculture sector

This category groups many IORA members states. All states within this category still have low or no aquaculture production but with an important potential for development. Most of the western Indian Ocean can still be considered in this group (Comoros, Kenya, Madagascar, Maldives, Mozambique, Seychelles, Somalia, Tanzania and Yemen).

After several decades of development projects and national development plans, the aquaculture sector remains nascent and with low levels of production even if some timely development can be noticed.

Previous developments were most of the time not of resilient economic models and have not acted as effective sector development incentives. But they are often the proof of the potential of aquaculture in future for these countries because the socio-economic impact of their production can represent an important country success. Examples of these include:

- Seaweed development in Tanzania-Zanzibar;
- Shrimp farming in Madagascar (only 2 company remaining after market dropping in 2008 and disease outbreak of 2012), in Seychelles (activities have stopped in early 2000's), in Tanzania, in Mozambique (severely impacted by 2011 disease outbreak);
- Freshwater cage farming in Kenya and Tanzania (recent but active development).

5.1.3 High technical aquaculture development

Some members of IORA have chosen to develop aquaculture species with high value (based on their national market or for export). This form of aquaculture requires infrastructure and important technical and technological skills. In this development model are countries like United Arab Emirates, Oman, South Africa, Mauritius, Singapore and Australia.

With active support of the research sector and often leading the set-up of aquaculture production for new species, this specialized aquaculture model focuses on carnivorous fishes, innovative techniques and/or niche markets products.

In a 2015 compilation of IORA Member countries' capacities in the blue economy provided by the IORA Secretariat, the answers of Singapore on the country development prospects present maybe one of the best examples of the direction followed to develop the sector with this model. It can be found in the following (among others):

- "To get participation of the private sector through funding demonstration models of technology application. Agro-technology parks are also available;
- Research will focus on high value productive species in the areas of breeding, farming, feed development, and disease control. Health status assessment (e.g., diagnostic kits) and the development of environmentally controlled and automated hatchery and production systems will also be addressed;
- In ornamental fish culture, areas for development are in intensive farming systems that maximize production, water quality management, and automation;
- Total area devoted to agro-technology parks (around 300) will be 2,000 ha with some 1,500 ha of usable farmland in the upcoming years. All basic facilities such as water and electricity will be provided by the government;
- Other hatchery-related technologies which will also have to be concurrently researched and developed by the Marine Aquaculture Centre (MAC) of the Agri-Food and Veterinary Authority of Singapore (AVA), the main body developing and harnessing technology in the sector, are:

- Fish reproduction technology- to close the reproductive cycles of key marine food fish species.
- Selective breeding - to improve brooder fish quality.
- Live fish larval food production - to improve the nutritional quality of live larval food, develop and improve culture techniques for common live food micro-organisms such as algae and rotifers, and to identify other alternative live food.
- Inert larval feed supplements - to develop formulated larval feeds that can supplement or even eventually replace expensive live larval food.
- In fish biotechnology and other upstream molecular applications e.g. genetic selection to facilitate fish breeding, development of fish vaccines and diagnostic kits. "

The development approach above illustrates the full support to get high value products and to develop technical and technological knowledge toward this goal.

It includes all carnivorous marine fish production in UAE, Oman and Singapore (groupers, snapper, crabs) or the abalone industry in South Africa, the red drum (*Sciaenops ocellatus*) cages in Mauritius and Réunion island. The trout, crayfish, oyster aquaculture, closed-system shrimp aquaculture developments in these countries also are considered here.

One of the characteristics of these production systems are also their high value for small production tonnages. Their production techniques are sophisticated and expensive but the countries have important national demand that can offer high prices or niche export markets.

It is to be noted that some small-scale aquaculture and low-trophic species aquaculture also exist in this group of countries. High technical aquaculture production systems are also developed in Asian member countries of IORA and even in some countries of western IO.

5.2 Lessons from the past experiences

5.2.1 Mature aquaculture sector development

Examination of the mature sector development category can provide important information to determine or define what are the keys points and actions to consider for the development of the aquaculture sector. Even if aquaculture has now reached an important position as a globally significant contributor to food production, the aquaculture sector in this category is in constant evolution and adaptation. The continuous growth in IORA member states within this category shows that, at national level, lessons of sustainability and sector development can be considered.

The pre-existing favourable conditions listed in 5.1.1 can be found at different levels in most of the countries of this category.

According to Sena De Silva and al.[16], the lessons learnt from Asian aquaculture could be broadly grouped under at least the five following general headings:

- Enabling policy, macro-economic conditions and legislative environment. This can be critical for sector development;

[16] « Success Stories in Asian Aquaculture », 2010, Sena S. De Silva, F. Brian Davy

- Empowerment of farmers and/or communities (role of social cohesion and farmer organizations);
- Effective linked institutions; partnering, communication, and dissemination systems;
- Efficacy of resource usage;
- Opportunistic behavioural changes.

An important lesson from past experience is the adaptive capacity or the ability of the production systems in these countries to evolve in a diversity of contexts. Indeed, several challenges have gone along with the development of the aquaculture sector. From environmental impacts (deforestations and salinization of land during the 1990s, flooding of production areas, erosions issues, etc.), the diseases and the markets changes (export bans, prices drop, new opportunities, etc.), to the adoption of new species and development of new production techniques, the dynamic and adaptive capacity of the sector has overcome these issues.

Development of flexible supportive aquaculture services has been another different example of success. For example, the case of backyard hatcheries, primarily in Thailand, has enabled the Thai shrimp and mariculture sector more generally to maintain its global leadership for decades. Also, the ability to make shifts to other appropriate species or even temporarily cease farming activity for one or more production cycles are the hallmarks of these systems. Farmers are the flexible back-bone of much Asian aquaculture.

Furthermore, the scientific and technological advances, the reactivity of the technical supports and their access to farmers was largely through the organization of government institutions, universities and private sector technical and scientific support three to four decades ago so as to place aquaculture on a firm footing. For example, the sector became independent of wild caught seed stock of many cultured species, and correspondingly, the management levels improved resulting intensification of the practices. Introduction of new species, disease management, good practices and genetic improvements also illustrates that good science support and development of new technology continues to be an important driver of success.

Understanding and guiding improved partnerships and related forms of social organization have been another key to success, for instance, in the revival and sustainability of small-scale shrimp farming on the east coast of India. This evolving and expanding cooperative problem-focused approach assisted the small-scale shrimp farmers to work together to deal with water quality, shrimp health, and now market access[17].

Effective institutional linkage and communication connected communities and farmers with government, private sector initiatives and other stakeholders of the value chain. This empowerment of farmers and communities through social and local organization seems to have been one of the major strengths for partnering, communication, and dissemination systems.

The emancipation and control of farmers was adapted to their needs and environment, developing robust but simple and easily transferable/adoptable production systems based on appropriate levels of technology that permitted flexibility and adaptation to change.

[17] « Success Stories in Asian Aquaculture », 2010, Sena S. De Silva, F. Brian Davy

And beside the human capacities, an important ingredient for success are adequate resources, particularly financial capacities such as finance access at farmer level and investment conditions for production and value chain development.

But other lessons to consider from past experiences are also the negative impacts and mistakes done. This raises the need to prepare for unforeseen environment impacts as well as the inconstancy of aquaculture development and its socio-economic impacts.

- ⇨ Environment and ecosystems

Potential environmental impacts from aquaculture expansion are in general determined by the characteristics of culture systems (species, intensity, technology, etc.) and site characteristics (nature of the landscape and seascape, waste assimilating capacity, waste loadings, other users, etc.).

Accelerated development in the last three decades has created negative environmental impacts, such as extensive mangrove conversion to ponds, changes in hydrologic regimes in enclosed waters due to proliferation of aquaculture structures, and discharge of high levels of organic matter into coastal waters. Similarly, the increasing deterioration of coastal water quality resulting from the discharge of domestic, agricultural and industrial wastes into coastal waters has affected aquaculture production and profitability. The introduction of management measures to mitigate deteriorating coastal water quality and the adverse environmental impacts of aquaculture development has now become a matter of urgency to the region.

Furthermore, aside organic matter pollution, aquaculture structures can be the source of biological pollution (pathogens and genetic alteration) and chemicals (antibiotics, antifoulants, disinfectants, etc.).

Some important environmental and pollution disasters have been made during the development of the sector. Together with some irreversible environmental and ecosystems degradation, a very negative image of aquaculture at international level was given (impact on market and support for sector development).

The answer was the development of national and international “best management practices”, “codes of conduct”, and “development criteria” etc., to guide the aquaculture industry and individual farmers towards sustainability. The market now also forces the industry to develop various standards, such as guiding principles and labelling schemes (e.g., the Aquaculture Dialogue, WWF), and various tools are being used for analysing performance and conformance (Ecological Footprints, GAPI, Life Cycle Analysis, FishPrint, livelihood analysis, etc.). In addition, international organizations have developed a broader systematic perspective on aquaculture, i.e. “Ecosystem Approach to Aquaculture” (EAA) (FAO, 2010).

Important efforts were made but current management of aquaculture is still far from being integrated or carried out within a broader ecosystem perspective, jeopardizing its own development in some regions.

- ⇨ Socio-economic negative impacts

Environmental impact, disease spread, market changes (price, demand, export agreement, etc.) had regional and/or local important socio-economic impacts such as farmers losing their activities, or the sector collapsing leaving a number of victims in its wake.

Aquaculture development can bring important negative results for communities and countries when the activity is negatively impacted by external factors.

These considerations have to be taken into account in sector development planning, mainly with the increasing threat of climate change. Resilient and adaptive systems need to be cogitated in advance.

5.2.2 Emerging aquaculture sector

"Modern freshwater aquaculture was introduced to the African Continent five decades ago with the aim to improve the economic and nutritional well-being of people. With the exception of Egypt this effort has due to various reasons not proved successful" (Hecht, 2000; FAO, 2000; Moehl *et al.*, 2005, Brummett *et al.*, 2008).

Seychelles are an example. "The main reasons why mariculture has not developed further in Seychelles is principally because of a generally poor understanding of the sector, the reliance on the artisanal capture fishery for protein supply, the absence of a sector "champion", an uncompetitive investment environment, lack of scientific and technical capacity and the absence of a properly defined legislative and regulatory framework within which the industry can develop in a structured manner" (Hecht, 2009 in A. D. Lesperance 2011); Considerable steps have been taken towards the development of aquaculture since, including an aquaculture policy, master plan , environmental and social impact assessments, environment management plans, training of key personnel, and set up of a broodstock facility, and preparation of aquaculture regulations. Progress beyond the experimental stage has been slow (N. Gordon, 2019) though now poised for advancement (Commonwealth Secretariat 2020).

Past experiences across the emerging aquaculture sector have outlined several aspects to consider for aquaculture development: Social, economic and governance considerations have shown failures and weaknesses to support the development of the sector.

5.2.2.1 Social aspects and traditions

Unlike many Asian countries, the countries with emerging aquaculture sectors have often limited historical tradition in aquaculture and in spite of the region's natural endowments, including untapped land, water, coastlines and human resources, African aquaculture remains in large undeveloped.

One of the main reasons is that few social scientists have looked at international aquaculture development, according to Stead (2005). A World Bank report in 2005 had similar conclusions. Indeed, development of aquaculture has mainly targeted fishers' communities underestimating their willingness to consider aquaculture as a viable livelihood. Despite the same resource-base, aquaculture may not be an obvious alternative to fishing. Indeed, aquaculture has mainly an "agriculture approach" with the need of time, business management approach with costly inputs and daily care in order to harvest, several months later, the result of the work done. It is, in many countries, far off the job satisfaction related to strong fishing traditions.

Social consideration and interaction with aquaculture development are now a core thematic approach of sector analysis. Some reports focusing mainly on this aspect have more recently been produced: "Social and economic performance of tilapia farming in Africa" (FAO, 2017), "Social and economic dimensions of carrageenan seaweed farming » (FAO, 2013); "Socio-economic factors affecting the successful implementation of aquaculture projects in Zimbabwe " (R. Gono, J. Muzondiwa, I. Chihanga and P. Manhondo, 2020) among others.

We can see this negative effect while examining some successful examples of the development of small-scale aquaculture:

- Seaweed development in Zanzibar has been supported by women while fishermen stayed away from it;
- Freshwater aquaculture development has been considered as a possible diversification activity in areas with strong agricultural background like in west Kenya, north Tanzania and central Madagascar.

Another social aspect to consider, based on strong community traditions, is the preference of local markets for products from fisheries. Aquaculture products are often considered as less tasty, less healthy or cheap fishes (see 5.2.2.2).

5.2.2.2 Economic aspects and market

Besides these social considerations most development programs have underestimated the need to consider the economic and market-related aspects prior to aquaculture introduction. Most of the early sector development support was oriented towards a “subsistence” aquaculture model, considering mainly the possible supply of additional protein and not the economic dimension of the activities (see 5.3.1.).

The economic consideration to accompany the sector development can have several limitations:

- The business approach of the aquaculture activities: several operations need investment of time and money from pond or pen or cage construction, through seeding and management to harvest. The farmers need to adopt a business approach and estimate and consider their production costs to optimize their activity. Many development projects have been provided technical support for pond preparation and management but have not prepared the farmers in respect of the economic consideration of this new activity. This has in many instances led to disappointment to having ruined all efforts. Aquaculture is just the combination of “water + fish + time + local wastes used as feed” as many small-scale sector development approaches still refer;
- Access to finances, investment aspects: the farmer needs to have money to build the infrastructure for aquaculture, to buy seed (fry, larvae or fingerlings) and to buy feed. Incentives or access to interesting loans have to accompany the sector’s development;
- Markets and market access has to be considered prior to activity development.

Three other negative drivers for aquaculture development are:

- Strong traditional habits on the consumption of fishes and, even today, the product of aquaculture is considered as lower (in quality, taste, health benefit) than fisheries products. This strong belief is a barrier for aquaculture development in some regions;
- Poor infrastructure networks that do not give opportunity to access profitable markets;
- Lack of information acts as a development barrier. The producers, or intermediaries, do not have knowledge of possible markets, prices or opportunities at the local or regional level.

To support sector development, it appears that development programs need to consider the whole value chain of the activity for well-targeted support to help develop business skills among farmers, develop markets and improve connections to input and output markets. Funding agencies need to have longer-term commitment and must periodically re-focus their efforts in order to build the sector. Research priorities include the identification of opportunities for small-scale producers. Monitoring and evaluation improve the impact of funding. There is a need to facilitate local market development and, through Information and communication technologies, the dissemination of information on market prices. An important step of communication at regional and national level can promote both the activity and the product for people adhesion and local market opportunities.

5.2.2.3 Sector governance

The lessons from the past experiences show that many efforts were made to design and adopt aquaculture policies and legislation. But many of these policies have not been an active support of the sector development. Supported by many international development projects, the policies and legislations were in many components some “copy and paste” of other countries ones and, in addition, have tried to include components to avoid adverse sector development impact (strict environmental considerations, code of conducts constringent, important regulation and controls). The direct consequences were a legal framework not adapted to the needs of the stakeholders and the countries specificities, plus, conditions of sector development sometimes impossible for small scale aquaculture and restrictive for bigger structures.

One of the reasons that FAO pointed out in a 2009 report is that there were, at the time, difficulties in assessing the overall impact of aquaculture on the economy, poverty alleviation and food security of countries. When feasible, assessing the impact of aquaculture on these factors was still qualitative (Kennedy, 2003). Policymakers did not always view qualitative assessment as an acceptable measure for the relevant national plan or for a development agenda, which may help explain the limited support that aquaculture had in many countries.

Another aspect of governance is the technical knowledge of aquaculture by government officers. In countries with no degrees in aquaculture or studies courses in the domain (see 5.2.2.4), most of nationals with studies or knowledge of aquaculture techniques have opportunities in government institution far from the field. As a result, there is little technical knowledge (and/or practical operational knowledge) at the extension services or in contacts with farmers. The understanding of constraints and needs was not efficient, and the sector development had often poor support.

Furthermore, the countries with aquaculture sector in development have often built their governance framework on the existing fisheries ones. The policies and the government task forces are often managed under a common Fisheries policy, which led to poor support for developing the aquaculture sector. It is one of the main reasons that aquaculture has been slow to develop in Europe. The issues for aquaculture are closer to industry development and business support than resources management. The governance framework needs to support these aspects and act as “facilitator” for business development. In some countries, like Tanzania in the last 2 years, important legislation efforts were made to differentiate fisheries and aquaculture so that the latter can be fully developed through policies specifically promoting aquaculture expansion.

The role of government is undoubtedly the most variable element in the aquaculture development equation. To create an enabling environment but also, in many countries, to be the medium for technical and financial initiatives for aquaculture’s sector development, the governmental role has to go beyond mere “policing” of the sector’s activities. Its role has to be developed, so that it encompasses working hand-in-hand with practitioners and can be reactive to the constraints and opportunities of the sector.

5.2.2.4 Technologies and technical aspects

There is a general lack of trained people, technical expertise, research and education. Thus, it is important to focus on capacity development. Development of Centers of Excellence, or Technical Centers, is one way to assemble expertise.

- “The educational background of most farm managers and workers is low. Just 10% of farm managers have degrees in aquaculture, and only 31% have completed secondary school. Only 13% of the farmers surveyed had received any training in basic business management. Different skill levels exist across the small-scale commercial farm labour force and farmers learn most often from each other (cross-farmer learning)". (study in Kenya – Van Duijn A. and al, 2018).

This need of technical knowledge is also found in government institutions, where the knowledgeable people (trained overseas, with a Diploma in Aquaculture) are rarely working in farm or sector field development. Their level of study gives them positions in government institutions, far from the use of their technical expertise (see 5.2.2.1).

As a result, and because it is a new sector, today extension/ dissemination systems are lacking, which prevents the spread of technical know-how, information and the exchange of ideas (including translation of research knowledge).

Beyond expertise, it takes all stakeholders to make the development happen. The technical knowledge, the research and the development needs to build a framework of interaction between government institutions, universities and the private sector, in many cases. Many development projects are focusing on these aspects these last years with, for example, the centre for aquaculture research for freshwater aquaculture in Chokwe in Mozambique or the plan for a national mariculture centre near Dar es Salaam in Tanzania. Focus is also on building some basic and university studies on aquaculture to provide national technicians for both the private and public sector. Most of the members of IORA in this category have no, or few, options to undertake studies in aquaculture in their universities.

Appropriate technologies need to be implemented in the country and understood and promoted both by the private and the public sector. An important experience from the past and from countries with mature aquaculture systems is that the technology for aquaculture development should be adapted to the country, its field constraints and its strengths. Simple innovative technologies in pond and/or cage construction that are less costly, with selection for culture of organisms that need limited water management and feed low in the food chain (e.g., milkfish (*Chanos chanos*), mullets (*Mugil cephalus*), catfishes (*Claria spp*), etc), or/and local species, should be preferred.

This technical knowledge cannot be only for the production stage. Development of aquaculture is the development of a mix of expertise to provide seed, feed, services and knowledgeable people for production and processing.

Marine and inland aquaculture cannot develop without seed and feed (and other inputs). The technologies development should consider the value chain and not only one stage that, for small-scale aquaculture, will not function without local and adapted inputs.

5.2.2.5 Environment and ecosystem

To avoid possible adverse impacts of sector development on the environment, aquaculture systems that are promoted should have minimized impacts on biodiversity (Diana 2009) and have reduced footprints with respect to inputs of resources, water and energy inputs, as well as waste outputs (Pelletier et al., 2011). Our increased scientific understanding and environmental awareness should enable us to avoid reproducing the errors associated with the expansion of some forms of aquaculture. But legislation and policies should also be adapted to the level of the sector development and the impact of the industry. Too often the environmental legislations made prior to aquaculture development are so restrictive that they cannot, and are not, applied to the small-scale sector; and are an important limitation factor for commercial investment and initiative.

Tools for analysing broader sustainability aspects need to be in place (ecosystem approach, life cycle analysis, vulnerability analysis, etc.). This understanding of ecosystems and the monitoring of them will be an important tool to adapt the environmental measures to go along sector development. It can be in several phases, following the growth of the activities. Ways to involve local communities in technology development should be investigated and all stakeholders involved, rather than just unilateral expertise. Greater focus should be on needs-based research, on how to create public awareness and identify risks. Indeed, there is a need to consider and plan for how climate change may affect mariculture and inland aquaculture so that measures can be taken to improve ecosystem and social resilience.

5.2.2.6 Commercial aquaculture

There is today a strong belief that the aquaculture sector has to be considered as a whole and that commercial aquaculture can have an important role in developing sustainable small-scale farming. Furthermore, recent projects try to create linkage between corporate business, foreign development aid and small-scale farmers' development. A mariculture hatchery project developed in Zanzibar in 2019 is following this approach.

Beside this approach there are the needs of seeds and feed, as the means to reach a critical production mass for attracting investors. Another reason is to attract technologies and technical expertise.

The past experiences of commercial aquaculture development in western I.O. were successful in some countries and have produced an important part of national aquaculture production (and still are in some countries). Indeed, commercial shrimp aquaculture was developed in Madagascar, Seychelles, Mozambique and Tanzania. But after more than 3 decades, it can be concluded that despite some important benefits for the countries (production, economical, technical and even social), no small-scale farming development has directly resulted from these activities. Furthermore, these farms were not strong enough to resist market changes and diseases outbreaks. Of the 10 biggest farms of the area, only 4 are still operating.

5.2.3 High technical aquaculture development

The development of this aquaculture is recent and mostly since less than 20 years. Many of the species cultivated are at the early stage of technologies and technical development, and are still under improvement (both technically and for production costs). Some species are cultured at fattening stage because the reproduction process is not yet feasible in hatchery or because the first development stages are too long and costly for aquaculture (like tuna fattening, some production of lobster and marine carnivorous fishes).

One of the main lessons from past experiences is that these high technical (and technological) aquaculture developments need strong institutional and financial support. The investment needs some guaranties and economical mechanisms to be in place so as to attract new projects and expertise. Most of the countries of IORA that are in this category either get strong government support and/or support of investment.

Even with a strong support, some countries have faced some difficulties arising from public reluctance for the product or for the industry development.

It was the case in Mauritius and La Reunion for marine cage culture (mainly of red drum *Sciaenops ocellatus*). An inadequate public participation during the early planning and development phase of the farm has hampered its development. Strong reluctance of public society for the development of offshore cages (because of concerns with regard to impact on ecosystems, attracting sharks, etc.) have stopped further developments and even forced the only farm in La Réunion to close.

Finally, these countries are still facing some difficulties to get as good market acceptance for their product as similar wild fishes. The consumer still has a traditionally strong support of wild fish catches and sometimes a negative idea of aquaculture production.

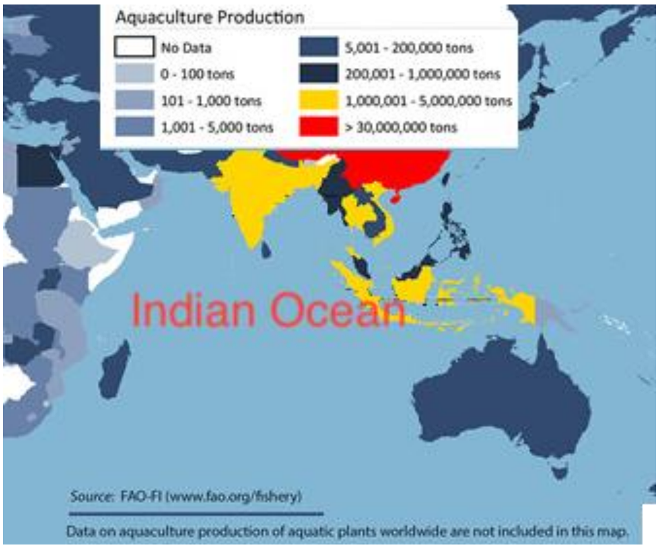


Figure 25: Aquaculture production in the Indian Ocean (Map from FAO data)

5.3 List of key problems and sector development approach

5.3.1 Changes in approaches of international funding agencies

In the 1960s and 70s, most projects were targeting the subsistence farmer, often the "poorest of the poor". Small fishponds with basic aquaculture management were promoted and financed. Most of the effort was to create some pilot model with an objective that spontaneous initiatives would copy the model and increase the production. Furthermore, given the resource limitations of this target group, early efforts to expand subsistence fish farming adopted structures that subsidized many services and fostered government dependence. By the end of the 1990s, aquaculture was often seen with disillusionment - another "failed effort". Millions of dollars had been invested in the sub-sector, yet the returns on this investment seemed poor at best. Some actual development programs still follow this approach and thousands of ponds are sometimes dug across the country in the name of subsistence aquaculture.

In mid of the first decade of 2000, FAO and the World Bank started to consider the business aspects of aquaculture development and to emphasize private-sector involvement (FAO, 2006b in FAO 2008; Hecht, 2007). This was in order to create an economic and technical emulation to accompany the local and investment initiatives. These development projects considered markets opportunities, the value chain approach and were not only based on the production stage. The objective is still to bring changes in the farming system, to bring successful experiences and technologies and establish functional "clusters" of production where a group of small investors can achieve economies of scale by working together (mainly for inputs needed, seeds and feed), creating new services and attracting high-paying markets.

Another change was to emphasize the need to consider the environment in the sector development. A number of national and international guidelines, e.g. "best management practices" and "codes of conduct", have been developed to guide the industry and individual farmers towards sustainability. FAO developed a broader systematic perspective of environmental consideration for aquaculture development, called "Ecosystem approach to aquaculture" (Soto et al., 2010). Aquaculture initiatives needed to be reconciled with conservation needs and sustainable use of natural resources.

The international agencies have also included consideration of climate change for all approaches of aquaculture development. Environmental and ecosystems sustainability have become an unavoidable aspect of the development approach, there is a need for developing and managing future food production systems in ways that the resilient provision of multiple ecosystem services is ensured.

The threats of climate change on ecosystem balance and the sector's development can present many aspects and consequences, from increase of water temperature, changes of rainfall patterns (drought and/or heavy rains with erosion or flood events), extreme climate phenomena (cyclone, storms), acidification of the oceans, and sea level rise. But they can also have economic and social impacts: migration, loss of coastal communities' livelihoods, etc. Some countries are already facing impacts of climate events.

Development of aquaculture needs to consider the climate change impacts and build resilient models (disaster risk reduction and adaptation). The sector needs to improve prevention, mitigation and responses to the challenges brought by climate change in the next decades.

Innovative solutions can be considered as promotion of knowledge and research to strengthen capacities. A comprehensive disaster management plan can be considered at national and regional level, including prevention and preparedness and measures for risk reduction. Cooperation and coordination at regional and international level also increase knowledge and actions to build resilience of production models, communities and infrastructures.

5.3.2 External studies and key problems

Recent studies on small scale aquaculture are reporting similar problems in different countries with the emerging aquaculture sector. Many reports are available[18]. The main comments are:

- Lack of availability of good quality feed; the price of commercial feed in relation to farmer's financial capacity and willingness to invest;
- Unreliable and variable costs in seed supply and feed, unreliable quality of the seeds and feed;
- Inadequate credit facilities;
- Poor technical and management knowledge among farmers (including business management skills and records to understand cost of production), partially the result of limitations of extension services (expertise and manpower available);
- Complexity of regulatory environment;
- Poor infrastructure (roads, power, water);
- Inadequate investment in research, capacity building and information dissemination;
- Lack of zoning of aquaculture areas; land not being available in the best locations; competitive uses of water;
- Socio-economic aspects;
- Lack of technical knowledge.

[18] Review and analysis of small-scale aquaculture production in East Africa Summary and Recommendations. Van Duijn, Van der Heijden, Bolman and Rurangwa, 2018; Mariculture in the WIO region Challenges and Prospects. WIOMSA, 2009; Study on the Potential of Aquaculture in ACP countries An Overview Report of the Three Regions. William Leschen, David Little, 2014.

5.3.3 IORA 2015 questionnaire

In 2015, the IORA Secretariat compiled information on IORA Member countries' capacities in the Blue Economy with particular reference to aquaculture, which included: Existing regulatory frameworks; Research and development technical support; Human resource development and capacity building; Business entrepreneurship, and; Actual development prospects. The compilation listed the strength and weaknesses of the aquaculture sector and presented Centres of Excellence where these existed. The "weaknesses" listed across all IORA countries with nascent aquaculture sector could be grouped and summarised as:

- Lack of experience and technology / lack of proper technologies;
- Technological needs / Need for technical training;
- Lack of information access;
- Uncoordinated promotion of aquaculture activities / local perception that mariculture is an environmental threat;
- Need of expertise studies / lack of local expertise;
- Needs of mapping of area potential for aquaculture;
- Needs of disease control program / diseases of different kinds / cost of disease control is high;
- Lack of finance and investment / lack of funding to fish farmers;
- Needs of feed development / cost of feed (imported) / quality of feed;
- Lack of proper frameworks to guide the sector / weak aquaculture policies / weak policies and legal frameworks / low supportive regulations for aquaculture / lack of supporting policies and legislation / lack of quality control systems for products;
- Insufficient natural broodstock / costs of seeds / availability of fingerlings;
- Economic difficulties resulting from limited infrastructure / poor road facilities throughout the country / high transportation costs within the country / poor access to markets / poor waste treatment facilities / high expenditure for fish transportations / poor road networks;
- Inefficient farm management / high operational cost;
- Lack of empowerment;
- Poor economic situation of the country overall;
- Weak research and training programmes / lack of funding for additional research on aquaculture / lack of scientific data on aquaculture.

The answers can be grouped in coherent categories of weaknesses that are impacting aquaculture development or restraining the sector at the threshold of further development. Five years later, most of the countries in the emerging aquaculture sector, as described in the earlier sections of this report, are still in a similar situation and many of the same weaknesses still exist.

5.4 Technical guidelines, prerequisites for aquaculture development

"Aquaculture has failed to develop adequately in many parts of the developing world, producing unsatisfactory and often ephemeral results. Experts agree that limited or lacking economic incentives for aquaculture activities has been one of the major causes of its poor, sluggish and short-lived performance" (FAO, 2009).

The past experiences and the situation in the countries after years of aquaculture development, gave lessons on changes needed for the sector development frameworks and the prerequisites needed. Furthermore, the experiences of countries with mature aquaculture sectors give substantial information on sector development mechanisms and on mistakes to avoid. Developing these triggers and driving factors can set a pathway for the way forward and ultimately achieve the overall goal of increasing sustainable aquaculture production.

The objective of this section of the report is to provide a synthesis of the best enabling environment for the development of aquaculture intending to create emulation based on the conception that success is magnetic - it will attract more investors, many of whom will also be successful.

The hard part is getting the start correct. This means minimizing risk and maximizing the chance of success. The consideration of the local socio-economic situation should be a good first point to adapt communication on the sector's development and get initiatives from communities ready to understand the aquaculture activities, but also in particular, the constraints of this production.

Whilst not wishing to stifle innovation, in the early development stage, it is advantageous to use proven technology in locations where socio-economic and biophysical standards best match. First initiatives can be the basis for larger and more diverse national programs. As the plan develops, the economies of scale will change and more services will be attracted to support producers.

It is difficult to give strict guidelines, rather these are common outlines based on the literature and the author's practical experience. The strengths and weaknesses exposed in previous sections of this report show that aquaculture sector's development in 23[19] member states of IORA is experiencing dynamic and complex development trends, influenced by several internal and external factors.

Aquaculture is not just a matter of producing fish – it is part of a complex value chain that is itself influenced by a range of environmental, societal and governmental factors that make the difference between a successful or failed initiative. This section is designed to examine these factors, focusing on small-scale aquaculture, and emphasising the consideration of some key requirements for sustainable and viable projects. The key points include:

- ⇨ Good environment for aquaculture development and governance;
- ⇨ Structures and inputs for small-scale aquaculture development;
- ⇨ Knowledge and technology – Strengthening human capacity and communication;
- ⇨ Support for business investment and economic development;
- ⇨ Sustainability approach.

5.4.1 Good environment for aquaculture development and governance

The role of government will undoubtedly be the most variable element in the aquaculture development equation. The suggested roles for government range from zero involvement to complete control of aquaculture depending on development phase and area of intervention. To create a suitable environment for aquaculture development considering the base of small-scale actors together with the commercial ones, national governments need to make crucial decisions concerning the sector, particularly in regard to its role in extension services and active participation in regional and inter-regional institutions. Governments also need to establish suitable policies to facilitate and augment aquaculture development and, most of all, remain alert to the establishment of fair legislation and not be subject to the pressure of various lobbyists. The regulatory frameworks have to be fair whilst being responsible and responsive to identifiable problems and constraints and have to remain adaptative to react to sector issues. For this reactivity, the sector needs to be monitored and followed by the responsible government institution in close relation with the private sector and the research sector.
Such "to do lists" are already in place in most of IORA countries but at different levels of implementation and effectiveness. The important part is to have a coherent policy and regulation

[19] France became the 23rd member of IORA in December 2020. It has not been possible to incorporate the production figures for France in this report. Nevertheless, in the relation to Section 5 on "Governance and Sector Development Approach", experience and some examples are drawn from Reunion, France.

framework, adapted to the sector's field, value chain and market situation that is effectively implemented.

Public-Private Partnership

The governmental role has to go beyond mere "policing" of the sector's activities and be developed, so that it encompasses working hand-in-hand with practitioners. Actual development projects go further, considering that to be more effective than in the past, government should make investments in partnerships, where appropriate and needed, in order to solve common problems. It is the strategy of the "PPP" approach (Public-Private-Partnership). One of the best examples that can be given is the partnership made for the development, including investment, of seawater irrigation systems for shrimp culture in Thailand (Tookwinas & Yingcharoen, 1999) or the multispecies mariculture hatchery of Zanzibar (South Korean development agency funded, set-up by FAO, 2019). These examples essentially encompass the establishment of cultivated/culture areas, supplying the required infrastructure. Oriented to provide seeds and irrigation to all initiatives, including the small-scale ones, it reflects a policy seeking to expand aquaculture activities without creating only industrial clusters.

Land Planning

Land planning and mapping is essential to focus development in areas where the environmental and socio-economic situation will be in line with aquaculture development and supporting activities. This planning of "potential area for aquaculture" will be one of the sector sustainability levers (see 5.4.5) and a means of providing great impetus for rapid aquaculture development. Including natural resource planning, accompanied by the provision of appropriate infrastructure (roads, market access, extension services, electricity, laboratories for analysis, and inputs providers, etc.), it can have a strong influence on activities development. Incentives and tax advantages are also other tools to support these demarcations of culture areas. Proper land planning can also solve a common problem for small-scale structures (see also later) which is the access to land and waterbodies for earning livelihoods dependent on aquaculture and agriculture activities.

Policies and regulation need to consider clear and established access to land tenure and water rights, allied to a transparent, fair and supportive permitting framework. Successful aquaculture is dependent upon use of a good site that has controlled access to suitable water resources. In the case of marine and coastal farms, this might mean accessing high-value coastal land or sea space in areas that often have considerable alternative value (tourism or other development). Therefore, securing long-term tenure is essential, with full support from the government body allocating production rights. On land, ensuring land tenure is equally important, and development of pond farming or other forms of extensive or semi-extensive aquaculture are highly dependent upon a reliable access to suitable water resources. Therefore, robust agreements to access and share water need to be established in advance. All medium- and long-term investment (not only for commercial aquaculture but also small-scale ones and some activities within the value chain) need to be built on trust of environmental and land access guaranties.

Recognition to the sector

It is important, and crucial, that governments give sufficient recognition to the sector. It is well-established that the sector has almost always played second or third fiddle to agriculture and fisheries, for instance. While recognizing that, in most countries, agriculture and fisheries contributes more than aquaculture to the GDP, it is timely that governments recognize both the contribution and the development potential of the sector, providing the recognition it deserves in national planning and policy development. This should be at all levels, from government position to fields actions, considering professional groups and cooperation.

A way of recognition is maybe to provide a governance framework not under the existing fisheries ones. The policies and the government task forces are often managed under a common Fisheries policy, which, in some countries, led to poor support for developing the aquaculture sector. Important legislation efforts can be made to differentiate fisheries and aquaculture so that the latter can be fully developed through policies specifically promoting aquaculture expansion (done in Tanzania for example). Maybe to foresee the prevision of aquaculture development in some countries where the potential is significantly greater, the ministries, department or laws can change their name of "Fisheries and Aquaculture" (or often only "Fisheries") into "Aquaculture and Fisheries".

Policy and regulation

A strategic aquaculture policy requires strategies and development plans at national level. Food security and economic growth are two main objectives that are commonly promoted for aquaculture.

An enabling environment has to be considered broadly. The support of a project, the support of sector development should be structured by dedicated policies and a national development strategy through legislation, regulation, and commitment of the government.

The policy and regulation framework needs to cover or foresee most sector development aspects. It is difficult to build it on a nascent sector and many times the country has developed a detailed sector development framework that is too complex for the country situation and socio-economic situation. Such a framework, not fully adapted to nascent initiatives, is not supportive and can even be a factor limiting the development. For example, the need of Environmental Impact Assessment (EIA) for setting an aquaculture activity that cannot be complied by small-scale actors.

The policy and regulation framework has to go along with the sector's development and be reactive to overcome international needs (for export) and potential sector issues. While not an exhaustive list, some initiatives in this direction can include:

- A study and mapping of the aquaculture development areas;
- Strong communication on sector support. Sector development needs a strong positive support by the population (public, communities) on its approach. Often, we can see that aquaculture projects suffer from insufficient support;
- Incentives and special sector support that can be considered within the government's toolbox for economic and investment development. But subventions can also have adverse impacts as illustrated in a study in 2014 (William Leschen, David Little, 2014) comparing the impact of government subventions in development projects. Two groups of farmers were followed over 5 years. At the end of the survey, 91% of the farmers without subvention were still operating and only 15% of the farms with subvention had reach a profitable economic stage;
- A strong sustainable environmental approach. Aquaculture development can quickly suffer from bad environment conditions (pollution, negative environment impact). For a sustainable development, this environmental approach has to be well thought out and structured within adapted policies and legislation;
- Implementation support and monitoring with skilled officers. If there is lack of monitoring, the government cannot accompany the sector's development and be reactive in a sector that can be heavily impacted by external factors;
- Supporting a stakeholder platform and encouraging cooperation and association measures. From producers and/or private sector association to universities, the involvement of

government institutions on sectorial platforms gives opportunities to increase exchanges of knowledge and reactivity reinforcing general communication on sector development, strategy, constraints and ongoing initiatives and projects.

As a conclusion, it can be said that it is paramount for the private sector to play the major role in developing the aquaculture sector. However, governments must provide initial supports in developing the industry. Private sector needs a "secure development environment". This secure environment will be supported and promoted by government's initial support through adapted policies that will structure the development and the sustainability of the investment by private actors. Communication and support at local and regional level will also be an important trigger for sector development.

Table 7: Policies, legislation and regulations to accompany aquaculture sector development stages and local socio-economic situations

Objective	Example of domains
Policies to support the business aspects:	○ Secure investment ○ Incentives, if needed to start the operations ○ Clear land laws and policies ○ Access to markets ○ Import of needed equipment or inputs (feeds, broodstock) ○ Loans access and support ○ Structure to develop producer association/cooperative ○ Improve institutional framework/administrative procedures ○ Communication on sector development for private sector actors
Policies to support a sustainable sector development approach:	○ Aquaculture legislation ○ Support hatchery development and feed production (incentive, support, dedicated projects) ○ Establish priorities zoning ○ Proper regulation on environment and aquaculture environment approach ○ Monitoring, enforcement and control (disease, environment, and other aspects of legislation) ○ Legislation and/or code of conduct on disease prevention, diagnosis, control and treatment. Including import control and quarantine ○ Access and use of water policies (access right, prioritizing aquaculture zones) ○ Support a laboratory for disease analysis ○ Development of a university degree in aquaculture ○ Extension services
All action to bring positive image of aquaculture	○ Government communication ○ Promotion/support of aquaculture products ○ Strong advocacy alliance amongst stakeholders/aquaculture lobby

Objective	Example of domains
	o Government officers trained in aquaculture, aquaculture disease aspects and dedicated institutions accompanying aquaculture development

Source: Author's examples

5.4.2 Structures and inputs for small-scale aquaculture development

There are some inputs that often have to be developed upstream to support aquaculture sector development and outputs of support projects. International organisations (FAO, 2009, 2014) recommend getting support of commercial and business-oriented enterprises that can support two of the important levers for sector development: quality of seeds and performance of feeds. The small-scale sector can thus have access to these inputs for their development. A balance has to be found between cost of these inputs (and their level of technological needs in relation to the technical complexity of the production model) and the small-scale sector needs and possibilities. It can be that the semi-intensive model of production, proposed to absorb the price of high-quality seed and costly feed is not easily the solution for rural areas (Mikolasek Olivier, Oswald Marc; 2016).

- **Feed**

The lack of high quality and affordable feed appears in most reports as a limitation factor for aquaculture development. The physical attribute of the feed (extruded, pellet, floating or sinking slowly, the leeching factor, time available for animal while in water) and its composition (quantity of protein, mix of vitamin and minerals, nutritional value) must be considered. The FCR (Feed Conversion Ratio) will be one of the best indicators to evaluate the efficiency of the feed - an indicator measuring the quantity of feed needed to produce 1kg of "fish". All species do not have the same needs in nutrition, feed for carp is not the same as that for tilapia or grouper – it is also not the same price, and FCRs are different.

In commercial aquaculture, the cost of feed will be often the main production cost (above human resource and above energy costs). In small scale aquaculture, extensive and semi-extensive models can use feed only on the last part of the production process, relying otherwise on natural feed production of the pond (or the environment) and/or on water fertilisation. But for any model, feed remains the main component of production improvement to upgrade the production model and to increase production.

That is why feed needs to be available for farmers, supply of feed needs to be part of the development plan. Feed must be adapted to the species and production model. The feed source can be imported or local or both. Price and logistic issues are not the same for imported or local feed. For local feed production, the fluctuating prices of raw materials are a problem, some farmers also produce their own feed.

Together with feed quality issues, some related issues include: importation, regulation and incentives; logistic of feed or raw material; proper knowledge of feed formulation; technological aspect of feed production; economic model of aquaculture production; capital access to buy feed, and; technical knowledge on use of feed (frequency, quantity and control).

Good quality feed at a reasonable price is critical to the success in many aquaculture projects.

- **Seeds**

The lack of high quality and affordable seed is often the second main limitation factor for aquaculture development. Often the quality of the seed is variable, and it is perceived as being too expensive. Seed quality has a direct impact on the level of early mortality and the growth rate of the cultured species. Seeds can come from the wild but this often comes with much variability in quality and availability jeopardising the success of aquaculture farms relying on them. Domestication of species are always an improvement for the development of the culture of those species. Production of seeds in a hatchery requires technology and has a cost.

Seed improvements are still an ongoing process and the technology and technical knowledge advances remain very dynamic. Generally, aquaculture is still in its early stage of development and scientific research is very active. It is considered that the aquaculture sector in IORA is based on the culture of some 200 aquatic species but new species (mainly tropical ones) are still being domesticated or are the subject of research studies to be able to reproduce and culture them successfully. The genetic improvement of cultured aquatic organisms is also under development and has considerably lagged behind other food production sectors (i.e., plant crops and animal husbandry). Amongst species reared, some improvement in performance has been achieved globally through genetic selection in only few groups (salmonids, tilapia, shrimps) but so much more needs to be done.

Hatcheries provide seeds at any season and in quantity. Quality is also more homogenous and improved. Genetic selection is one of the tools to improve quality and growth rate (genetically selected tilapia "niloticus" can reach more than 10 times the size of the natural wild strain in almost the same time of culture). Other improvements for farmers can be SPF (Specific Pathogen Free) seeds or SPR (Specific Pathogen Resistance) seeds or sex conversion (use of hormones to produce only male animals).

The challenge of cultivating improved seeds are the cost of the animal and the need of technical knowledge (and often the need for improved production systems to make most of its harvest potential). As for the feed, the seed quality and price have to be adapted to the local production model.

- **Laboratory and disease management**

Disease is a threat for aquaculture. National policy must exist to reduce and eliminate this threat (import and control of disease according to international/regional regulations, code of conduct and controls).

Some diagnostics can also be developed to secure the aquaculture development, through analysis laboratories (government or private).

- **Infrastructure**

All support in road, port development (if feed imported or products exported), electricity and security will support the development of the sector. Good infrastructure networks will improve production and input logistics and also market access for finish products (see 5.4.1).

- **Extension services**

Capacity of extension services is often considered as a needed prerequisite. Extension services availability in the production area and their knowledge to understand and support the activities can be an important pillar of the framework for sector development (see 5.4.1 and 5.4.3).

5.4.3 Knowledge and technology – Strengthening human capacity and communication

“The main cause for the upsurge in the sector has been the transformation of aquaculture from an “art” form to a “science”” (S. De Silva, 2001). This brought many advantages, ranging from less dependence on wild stock to the development of techniques that optimized yields, such as polyculture, or enabled the achievement of higher yields with lower inputs.
However, the field is still undergoing continuous technological progress. News species are cultivated every year, and progress has also been made in growth, animal husbandry, reproduction and genetics. In addition, aquaculture is a very diverse activity that can include from plants, invertebrate to reptile breeding in all types of aquatic environments. Obviously, this diversity has its pros and cons. On the positive side, the diversity of the industry not only allows it to adapt to changing consumer needs, but also to respond to the changing environment and local situation. On the negative side, one can consider the magnitude of effort required for research, development, and marketing, and these efforts must be dedicated to each potential product to make it technically and economically feasible.

As a consequence, for countries with an active plan for the development of the aquaculture sector, there is increased need of knowledge and technology at field level to improve the production model. Furthermore, the development of the sector needs to be accompanied with scientific support and research, from experts and universities, to follow improvement and adapt them to field situations.

This need of knowledge is important both in the public sector that will support and enforce aquaculture activities as well as in the private sector that in most cases start new activities. The country will need skilled peoples to work in the sector. Development of specialized training up to university degree to offer these future knowledge-intensive workers has to be considered upstream of all major aquaculture development. Another tool to extend knowledge are government or sector technical centers and with the support of the research area (through dedicated aquaculture centers or through existing university structures) to answer to this need.

It is relevant, at this point, to highlight the main technical needs and advances that are needed by the sector so that it can meet the production improvements required, sustainably. Foremost amongst these are:

- **Quality and price of the seeds**: set-up hatchery, improve quality of the seeds, adapt genetic selection to field production techniques and not only on pure performance data.

Indeed, highly genetically improved tilapia imported from foreign countries are selected for intensive environment and high-quality feed but they will not express 50% of their potential in earthen ponds with local feed. Such choice may not be economically or financially supportable for local production system. Importation of genetically improved seeds or a local genetic program may be required to breed fish that are adapted to local production techniques and technologies and that evolve with the local sector development practices.

- **Quality and price of the feed**: Dietary developments represent an area that has made significant progress particularly in respect of improved effluent quality and reductions in protein content. However, the sector will be able to realise the envisaged growth only if the feed is adapted to the particular species and to the model of culture. Often there are only few choices of feed for the farmers: imported ones that are very expensive and need to be bought in significant quantities, and; local ones that are derived from chicken or pork feed and not adapted both physically (feed that sinks or dissolves rapidly in water) and in nutritional value. Technical knowledge on the use of feed is also an important component - farmers often reduce feed quantities or quality concerned with the cost but at significant loss of production and overall financial or economic feasibility.

- **Disease**: Disease is clearly recognized to be one of the most significant constraints to aquaculture production and trade, affecting both economic and socio-economic development in many countries of the world. As an example, in IORA countries, within the shrimp culture sector, disease is currently considered to be the single most important limiting factor on production and has already heavily impacted countries like Thailand, India, Mozambique, Iran and Madagascar.

The cause(s) of epizootics are usually complex and difficult to pinpoint. Experience in trying to control aquatic disease outbreaks demonstrates the importance of taking all components of the production system into account, the interconnection of the culture environment with the wild ecosystem as well as movement of animals (at national and international level). Controlling aquatic diseases requires a level of understanding that is often lacking in farmers, from extension support and from key decision-makers. Protocols must therefore be developed for addressing the needs in this regard for sustainable culture within national, regional or international contexts. Detailed Codes of Practice have been developed by international organizations to address minimizing the risks associated with introduction and transfer of live aquatic organisms. These Codes of Practice provide a good starting point for conceiving appropriate national fish health legislation and related regulations.

- **Production techniques and improvement**: lack of knowledge and skills, is one of the key issues. Ranging from lack of monitoring and/or knowledge of animal husbandry techniques for improving water and feed management to lack of business attitudes, these are constraining the development of most farmers. Most farmers do not have a well thought out business plan and/or lack of technical skills, such as pond and cage construction, water quality monitoring and site selection. Furthermore, knowledge and skills regarding planning of production cycles is often lacking.

- **Improving value chain**: After the production stage, all steps of the value chain have to be considered to get the full value of aquaculture production. Product conservation, transformation, reduction of wastes and losses, use of by-products, packaging, etc. are areas where important technical knowledge and improvements are required to adapt to sector development.

- **Improving education, training and extension:** The education and training need of aquaculture, as well as the extension service requirements, will be different within the regions, following the degree of sectoral development. For example, in countries with mature aquaculture development, training and education is fairly satisfactory at the farmer level, this being an ongoing activity facilitated by regional bodies such as NACA. In most regions, extension workers have a very strong commodity and/or discipline-oriented background. In view of the envisaged aim, that aquaculture should move rapidly towards sustainable development, a more holistic approach would need to be superimposed over the classic methodology. Regional institutions are likely to play an increasingly important role in providing guidance at the national level in this regard.

However, in most nations with nascent aquaculture development, the needs of education and training are important. Aquaculture is often a new activity; the farmers have no background and one of the biggest impediments to successful aquaculture development is seen as being the lack or improper extension of technology. Many IORA countries, in this category, have no training or university courses in aquaculture and depend fully on foreign inputs of knowledge for the increase of technical and technological knowledge of both the local public and private sector.

The issues concerning education, training and extension are closely linked to capacity building and the development of human resources. This aspect requires to be accelerated within the aquaculture sector if it is to maintain its growth momentum in an environmentally sustainable milieu. In view of the rapid development of communication and information technology, the sector will have to be increasingly innovative in methods of disseminating knowledge.

Communication:

- **To the public:** The public's perception of a sector influences policy formulation and development, both directly and indirectly, of that sector. A proper, pragmatic, structured communication strategy is essential to all development, and particularly for primary production sectors. In 1997, the sentence of Murthy "the public's perception of aquaculture has all but tarnished the sector and, in some nations, public outcry has resulted finally in major policy changes" is still actual when analysing the Mauritius debate on cage aquaculture in 2019.

  Today also, the sector has to attempt to clean this tainted image and endeavour to correct the public view on aquaculture. The message in this regard should be that aquaculture is essential to meet human demand for aquatic products and will continue developing as a sector that minimally perturbs the environment, that it can be a gross environmental cleaner, a prudent user of primary resources, and a producer of healthy and nutritious food of high consumer acceptability.

- **To the sector stakeholders:** Interconnection needs to be built between stakeholders connecting public and private sector, producers and value chain actors with decision makers, researchers and science with sector production. Stakeholders' platforms are the main channel for information and knowledge exchanges required to get a coherent development framework. Building community groups, associations, groups of producers, business groups, private sector actors, branch representatives, or other groups of stakeholders need to be supported to accompany sector development because it will channel and structure the communication, access to information, and sharing among group members. For example, the small-scale shrimp farmer groups of India were in a better position at the time to gain these benefits compared to the situation when they were unorganised (De Silva and Davy, 2009).

5.4.4 Support for business investment and economic development.

The Food and Agriculture Organization of the United Nations (FAO) believes that promoting aquaculture as a business could yield adequate and solid benefits from the sector, thereby leading to its sustainable development.

- First to secure investment. Both for commercially oriented aquaculture and for small scale infrastructure the investment and labour done to set up activities should be secured and protected to encourage farmers and investors to start activities;
- Guarantee long-lasting development. It includes policies, regulation, property rights, incentives, "protection" of the activities, export and import policies (if needed);
- All effort to promote aquaculture products is articulated as marketing approaches.

Promoting aquaculture as a business invariably calls for political support. Indeed, the willingness of governments and funding agencies to support aquaculture usually depends on how they value the sector's contribution to food security and poverty reduction, whether actual or potential. Both the government and funding agencies determine the level of support provided to the industry based on the industry's potential contribution to the national economy.

This approach supports that aquaculture development should be mainly private sector driven. The approach is today shared by many funding agencies and development actors. It is the one presented in a joint report of AFD, GIZ and EU in 2017 ("Opportunities and challenges for aquaculture in developing countries").

Business models break the development approach of subsistence aquaculture. Considering the value of production in relation to infrastructure investment and production costs, this development model also emphasizes the need of national support for some prerequisite structures (logistic network, investment support, availability of quality inputs as feed and seed) to start activities. Sustainability approach is also supported by a business plan of cost reduction and return on investments together with the development of the activity to a critical size to create demand and stimulate offers.

Access to capital:

Access to capital and cash liquidity is one of the most commonly stated constraints to aquaculture development. It is therefore important that financial structures are in place to provide responsible and reasonably priced lending to project beneficiaries as they expand, especially when the project might be focusing on other elements rather than financing, such as technical development, risk minimisation or capacity building. So long as aquaculture proponents are able to present a well-considered business case for borrowing, financing is not usually a particular constraint. However, small- scale farmers may lack the credibility and collateral for accessing formal credit, sometimes resulting in unfavourable borrowing conditions from informal sources. It may be a useful project intervention to both develop the capacity of such proponents to prepare business plans as well as to facilitate lending linkages along the value chain" (AFD, GIZ, EU, 2017).

Market oriented:

Considering aquaculture as an investment option, as with all solid investments, a proposal should only be transformed into action if, through comprehensive market and business planning, it proves to be profitable. Profitable aquaculture enterprises and aqua-businesses can assume any scale of operation, from micro to industrial. But, at any size, they must be market-driven. For smaller operations, this implies the need for firms to band together to achieve an economic critical mass: forming clusters, putting down services and attracting better markets. A market and business orientation embodies the new approaches to aquaculture as an investment that can make positive impact on the developmental objectives of Governments.

5.4.5 Sustainability approach

Development of a sector cannot be completed without including an appropriate framework for its sustainability. This last paragraph will list the four main components that will frame aquaculture's sustainability:

- Market and value chain consideration;
- Socio-economic consideration;
- Environment and ecosystem;
- Climate change.

Market and value chain consideration

The first target for investment is to be lucrative and economically visible. Export markets or niche markets are often preferred to show the possibilities of sector development. Often local and regional markets are not the first priority of development projects even if their potential can be significant and a source of important activity. The reasons behind this often relate to the limited data available to monitor these markets and an important part of their economy can be informal. It has to be considered, however, that these local and regional markets are often less challenging for small-scale aquaculture development (no or less international standards and certification to meet, consume species that feed lower in the trophic level, have small product requirements and less product processes after harvest). Also, these markets can provide a substantial step of development of the sector as was the case in IORA countries with mature aquaculture development or as it appears to stimulate local sector development, aside commercial aquaculture, in east Africa.

A good understanding of existing aquaculture and its value chains, together with the opportunities for, and constraints to, development is a necessity. Successful production of aquatic products is just one part of the value chain. In order to succeed long term, aquaculture needs to be profitable and it is essential that reliable markets are secured with a potential value chain that ensures financial viability for all participants. This aspect needs serious consideration during the design phase of sector development, as it might influence key design criteria, such as: species selection (reflecting market demand, price and seasonality); system design (which in turn influences input costs, margins and risk); production scheduling, and; processing and transformation. Value chain analysis is now an established tool for assessing the equity and integrity of the steps that increase value along the marketing chains and designing interventions to address any issues found.

Socio-Economy considerations

Small-scale aquaculture is a rural development activity that has to be rooted within the social, traditional and economic framework of the area where it occurs. All projects that do not take into account the local communities and their social structure with regard to local aquaculture development actions will jeopardize their sustainability. The history of development is rich in examples of failures because of local socio-economic mechanisms that where not foreseen. It is even more important in initiatives that need to change the habits of use of marine and inland waters that are also traditionally important.

Environment and ecosystems

Aquaculture uses primary resources, has to compete with other prospective users and is not always environmentally friendly. The degree of "environmental friendliness" depends on various factors, such as the farming system, the location, and how a particular aquaculture practice conducts its activities, among others. The aquaculture sector will develop, thrive and be sustained only if it can ensure environmental integrity. The sector will need to take a different emphasis, that of long-term environmental, social and economic sustainability, and adapt its goals to these requirements. Environment and ecosystems impacts are now one of the main sustainability considerations in countries with mature aquaculture sector development. These components need to be included early in the development of new activities without being a major limiting factor for small-scale initiatives.

Climate change

Aquaculture operations are often located in lowland areas along rivers and estuaries and in coastal and marine areas. These areas are highly vulnerable to the effects of climate change such as sea-level rise, increasing intensity and frequency of storms and floods as well as changes in average temperature and precipitation. Climate change and variability affects aquaculture in different ways and aquaculture is also a factor contributing to climate change via releasing greenhouse gases from aquaculture intensification and conversion of natural wetlands into aquaculture systems.

"Fish and shellfish farming of course are also affected by climate change" (FAO, 2007). Climate change and variability is likely to affect aquaculture stakeholders involved in the sector in different ways. Rising sea levels could result in serious inundation of aquaculture areas, while extreme floods caused by upstream water flows during rainy seasons can have serious effects on aquaculture practices. Climate change can also hamper farmed aquatic species by exposing them to a range of pests and pathogens

while decreasing their disease-resistant capacity. Increase of temperatures have already some impacts on pathogens on seaweed farming in Tanzania. Increase of temperature and ocean acidification are expected to have impacts on the aquatic environment that supports aquaculture production as well as the farming operations themselves. In general temperature increases will increase productivity but it will also increase algal blooms in coastal areas and inland waters bodies and impact local ecosystems. Increased storms and cyclones directly impact infrastructures and threaten aquaculture production. Changes in rainfall pattern can be a major local threat to an aquaculture sector that depends on an operation needing constant water availability.
Direct impacts could cause damage to aquaculture facilities and reduction in aquaculture productivity and revenue. Indirect impacts include increasing aquaculture production costs and modifying food chains and food webs in aquaculture-based aquatic ecosystems.

Climate change can also create opportunities for aquaculture development. For example, areas inundated due to sea-level rise may be no longer suitable for agricultural-based farming systems and could be used for aquaculture. In some areas Integrated Agriculture-Aquaculture (IAA) can be viewed as a strategy to cope with drought and water scarcity due to climate change. With correct choice of species and culture model, aquaculture can offer production activities in areas that have to change its traditional production activities because of major environment changes.

It is essential to build adaptive capacity through improving education and governance and by empowering communities to determine how best to build a resilient and adaptative aquaculture sector.

Figure 26: A woman carrying the harvest of seaweed farming and passing along a pen of a sea-cucumber farm in Zanzibar (Photo: Pierre-Philippe Blanc).

6 Concluding observations and comments

With states leading world aquaculture development and countries with no aquatic farming, the differences of the IORA member state aquaculture sector offer a wealth of information and learning opportunities on the triggers and drivers for setting up a profitable and sustainable aquaculture development strategy.

The first conclusion is that aquaculture development has to consider small-scale initiatives that are representing the core of the activities, in volume and in socio-economic outcomes. But it has to be considered together with commercial level development and public framework development; this threesome has to be interconnected on a sustainable view.

This “interconnection” can be described in technical considerations that define the needs and supports for establishing a profitable aquaculture sector. Five areas of action need to be considered for strategic sustainable development of the sector:

i) First, a good environment for aquaculture development and governance is required to support initiatives and sustain activities, to link public and private sector strengths, to plan development and access to the land, to recognise the sector and support it through dedicated planning, policies and regulation;

ii) Infrastructure, support services and inputs for small-scale aquaculture development must not be neglected as these will directly impact economic viability and provide a pathway for improvement. Upstream development should take place that foresees the supply of appropriate, adapted feed and seeds, aquatic animal health, infrastructure for logistic and technical needs and extension services firstly at a local level and then at a national level;

iii) A long-term strategy that advances national knowledge and technology to accompany the development of the sector and strengthen human capacity and communication should built to ensure adaptability and future improvement. Knowledge and technology at field level is needed to adapt and improve production models to the actual situation (rather than clumsy “copy and paste” high technology from other models) taking due consideration of the local technological, social and economic situation. Local research, improvement of education and training should go together with sector development. A sustainable approach requires consultation, continuous public and private communication on the strategy, the framework, actions undertaken, feedback and adjustment;

iv) Framed by the three previous elements, the strategy needs initiatives that support business investment and sector economic development: access to the capital, market-oriented approach, security of tenure, security of investment in land and infrastructure. These will guarantee long-lasting development and promote the activity and the product;

v) Finally, an emerging activity cannot be left on its own. The strategy must consider that there are many pitfalls on the way towards sustainability: aquaculture development sustainability must be built within a framework of continuous consideration of the local situation and the strengths and weaknesses with regard to its four key pillars: markets and value chains; socio-economic situation; the environment/ecosystem impacts; and climate change.

Small-scale aquaculture development is an opportunity to develop productive activities, enhance country development (mainly in rural areas) and often offer new economic dynamism in communities and areas relying on agriculture or fisheries. However, aquaculture is a “culture”, a farming activity, that must consider the complexity of technicity, natural environment and social and economic triggers especially when it is a nascent activity.

Between IORA members states' past experiences and learning opportunities on aquaculture development there is material to complete Confucius' quote by "Give a man a fish and he will eat for a day. Teach a man to farm fish and he will eat for a lifetime."

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ANNEXE A: Aquaculture production of IORA countries by species groups

Note: All data are from FAO database FishstatJ, FAO. 2020. Fishery and Aquaculture Statistics. Global aquaculture production 1950-2018

1. Aquatic plants

World global production of aquatic plants has tripled in the last 20 years, from 10.6 million tonnes in 2000 to 32.4 million tonnes in 2018. This trend is also confirmed for the countries of the IORA.

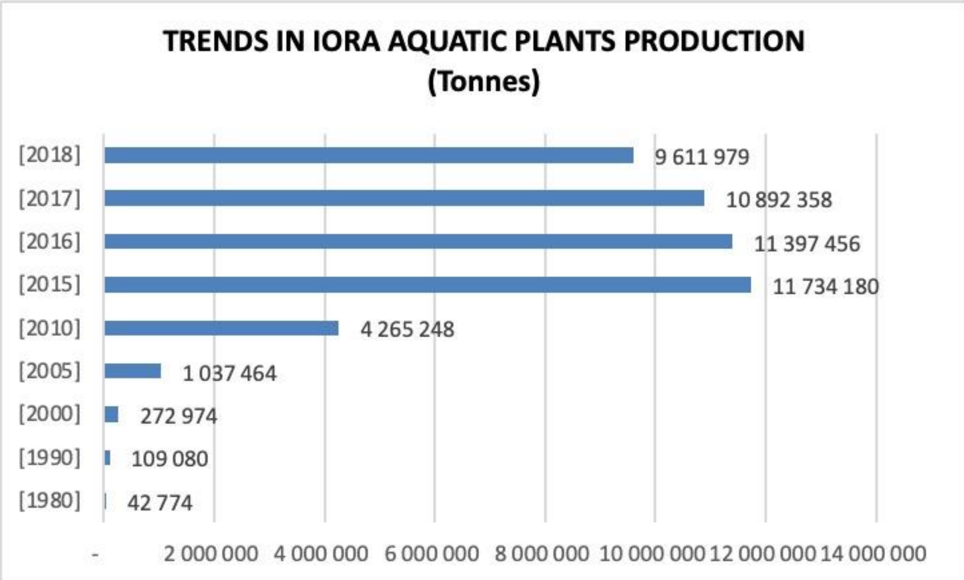
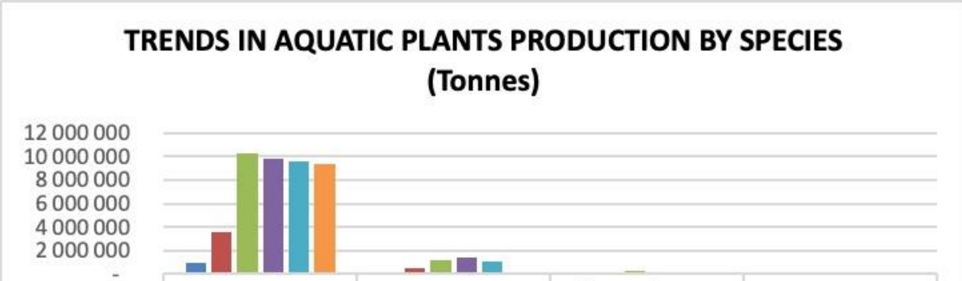


Figure 27: Aquatic plants production – IORA states – In tonnes (FAO, 2020)

Between 1990 and 2018, the production of aquatic plants increased by a factor of 88. However, it has decreased by nearly 20 % from 2015 to 2018. Issues of climate change are one of the factors for this decrease (increase of temperature level and intensification, in frequency and importance, and disease events). International market price (stable and local decline) is also an important factor contributing to the decrease.



	Eucheuma spp	Gracilaria spp	Kappaphycus alvarezii	Other
[2005]	941 823	45 433	42 640	7 568
[2010]	3 543 282	520 271	200 128	1 567
[2015]	10 301 284	1 160 234	271 360	1 302
[2016]	9 828 354	1 360 400	206 200	2 502
[2017]	9 623 704	1 063 874	203 918	862
[2018]	9 314 751	120 876	174 665	1 687

Figure 28 : Trends in aquatic plants production by species – IORA states – In tonnes (FAO, 2020)

Several species of aquatic plants are cultivated in the IORA countries. The main cultivated algae are dominated by *Eucheuma spp.* The three other species are the varieties *Gracilaria spp., Kappaphycus alvarezii* and *Ulva lactuca*.

Three IORA countries are important producers. Indonesia produced 94% of aquatic plants in 2018 (9,320,298 tonnes). The remaining 6% was produced by Malaysia (174,083 tonnes) and Tanzania (104,550 tonnes). The value of aquatic plants is quite low in relation to the volume produced. Thus in 2018, the value of 9.6 million tonnes was USD 1.4 billion.

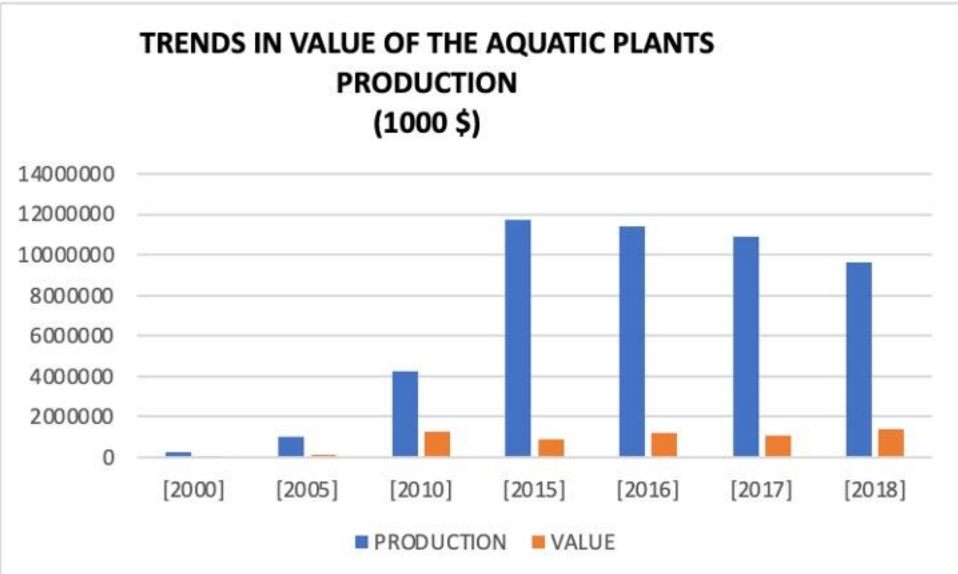


Figure 29: Value (USD) of aquatic plant production (tonnes) between 2000 and 2018 – IORA states (FAO, 2020)

2. Diadromous fishes

Diadromous fishes are able to grow in seawater and freshwater environments and tolerate varying levels of salinity. These specificities allow their production in an important range of different environments. Furthermore, these species are known to be “more resistant” to environment variation, giving them an advantage for aquaculture practices.

Between 2000 and 2018, the production of diadromous fish in the IORA countries followed the world growth and adapted to the demand. The production volume of diadromous fishes has doubled in less than 10 years.

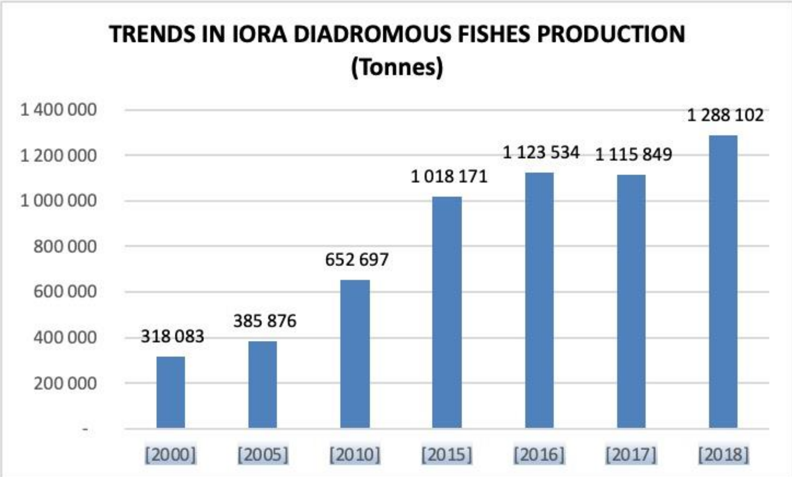


Figure 30: Diadromous fishes production – IORA states – In tonnes (FAO, 2020)

The species of diadromous fishes cultivated in the IORA countries are the *eels* (*Anguilla* spp) with three different species, *Chanos chanos* (milkfish), the *trouts* and *salmons*, which have 4 species, the *tilapias* mainly the species *Oreochromis mossambicus* which lives in polyhaline water (but more productive *tilapia* species have also been cross-bred with polyhaline species to develop salt water resistance), the mullets with 4 species and others. For some groups of these species, movement to freshwater is essential for successful breeding and/or spawning. The choice of habitat will therefore condition their production.

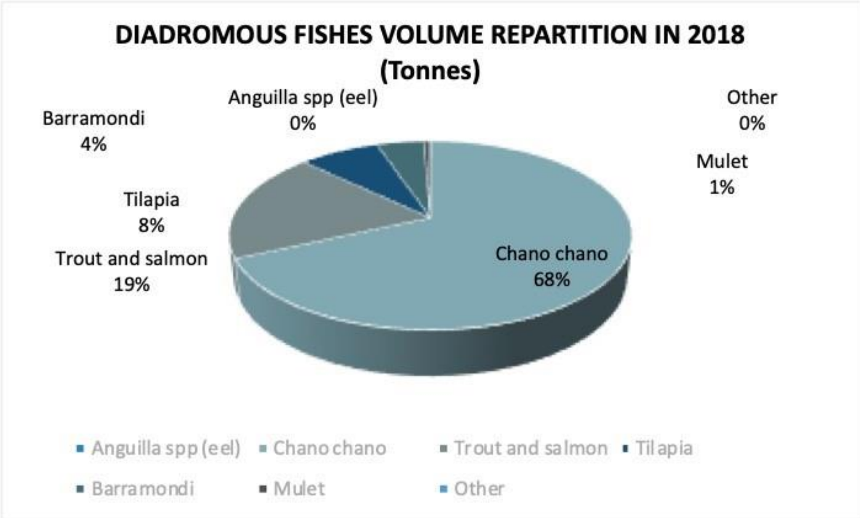


Figure 31: Diadromous fishes production per group of species – IORA states – In % (FAO, 2020)

In IORA area, *Chanos chano* represents 68% of diadromous fishes' production, *trout* and *salmon* 19%, diadromous *tilapia* 8% and *barramundi* 4.5%. Of the 22 IORA countries, 15 produce diadromous fish in their aquaculture activities.

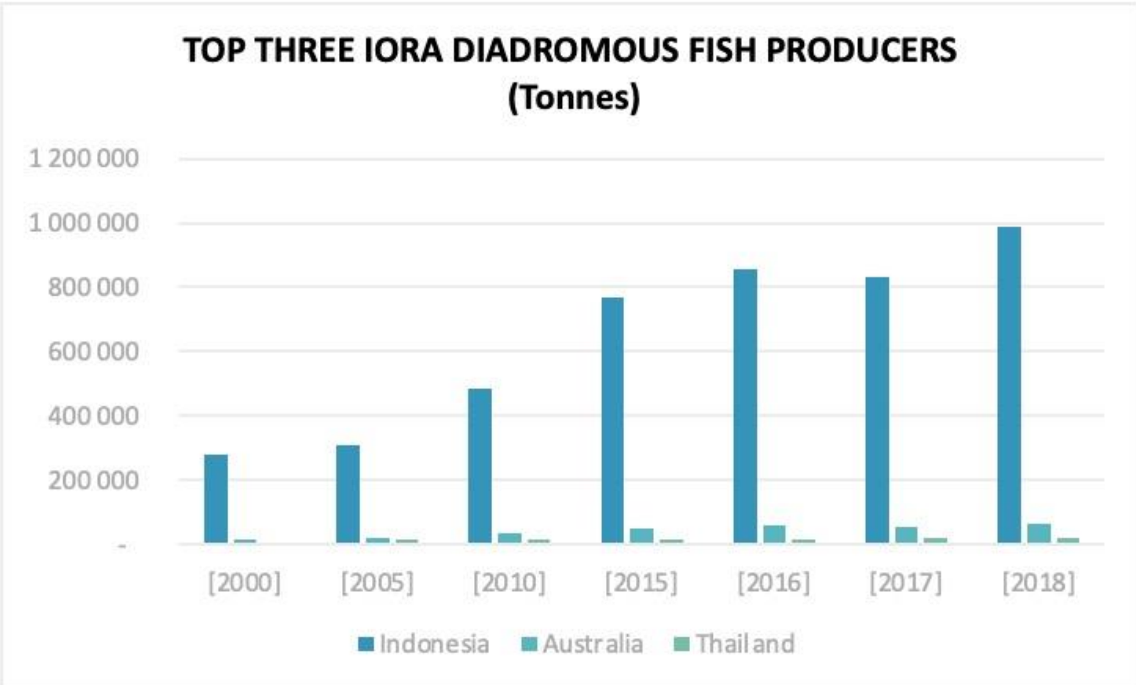


Figure 32: Main countries producing diadromous fishes – IORA states – In tonnes (FAO, 2020)

The main producer is Indonesia, followed by Australia and Thailand. Between 2000 and 2018, Indonesia increased its production by a factor of 3.5.

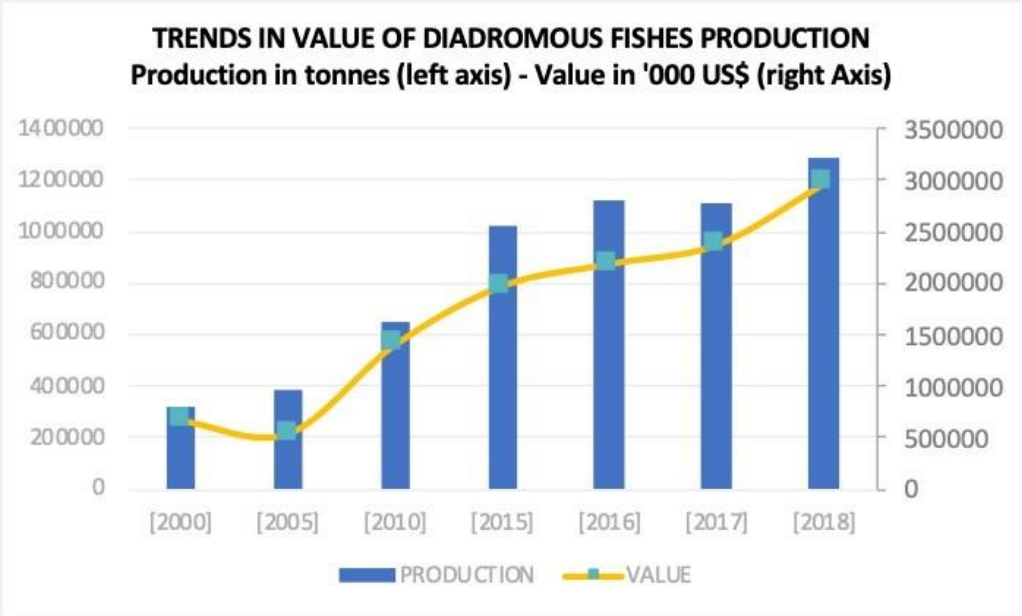


Figure 33: Value and production of diadromous fishes between 2000 and 2018 – IORA states – In tonnes and thousand dollars (FAO, 2020)

Production and value regularly increased between 2000 and 2018. It can be noticed that recently value increased quicker than production. In 2018, the value of 1kg of aquaculture produced diadromous fish was 20% higher than in 2015. Value chain improvements and market access are the main reason of this increase in value.

Figure 34: Chanos chanos, Tanzania (Photo : Pierre-Philippe Blanc)

3. Freshwater crustaceans

The freshwater crustaceans' category is composed of 4 species of crayfish and 3 species of freshwater shrimps. Freshwater crustaceans' production tripled from 2000 to 2005 and remained more or less stable since. The total volume stayed low in comparison with other categories and was dominated by giant shrimps (*Macrobrachium* spp.) representing almost 99% of the production of freshwater crustacean. Half of the IORA countries produce freshwater crustaceans.

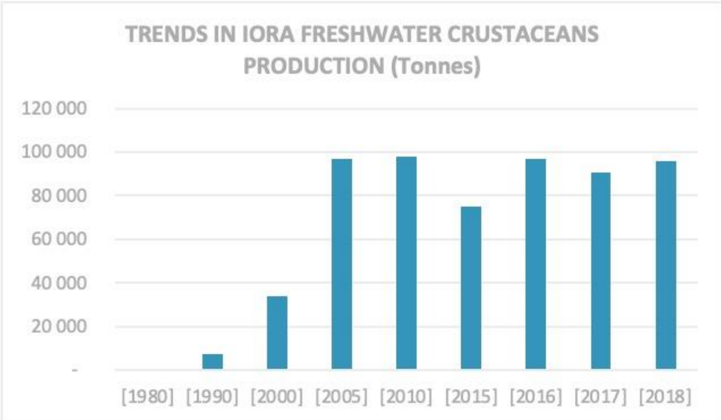


Figure 35: Production of freshwater crustaceans from 1980 to 2018 – IORA states – In tonnes (FAO, 2020)

As of 2018, 95% of the production came from Bangladesh, followed by India (almost 5%) and Indonesia. Bangladesh increased its production of freshwater crustaceans by a factor of 5 between 2000 and 2018. The overall IORA production of freshwater crustaceans remained relatively stable since 2005. Production increased significantly between 2000 and 2005. In 2005, 96,900 tonnes were worth USD 0.44 billion, while in 2018 95,900 thousand tonnes were worth USD0.63 billion (an increase of 43% in value). It is still a high value production.

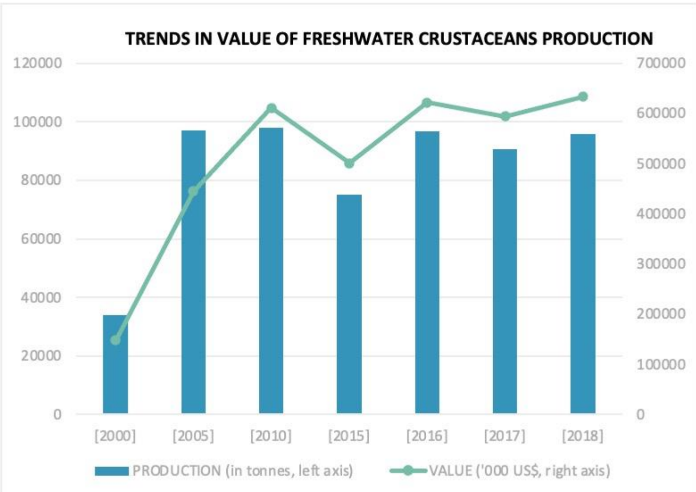


Figure 36: Production and value of freshwater crustaceans from 2000 to 2018 – IORA states – In tonnes and thousand USD (FAO, 2020)

4. Freshwater fishes

The freshwater fishes reared in the IORA countries are divided into 5 main groups: carp, catfish, tilapia, snakehead and other. They represent more than 49 cultivated species and subspecies. "Other" species are local species or mixed species from dams and marshes aquaculture.

Freshwater fish represent the largest aquaculture production category of IORA.

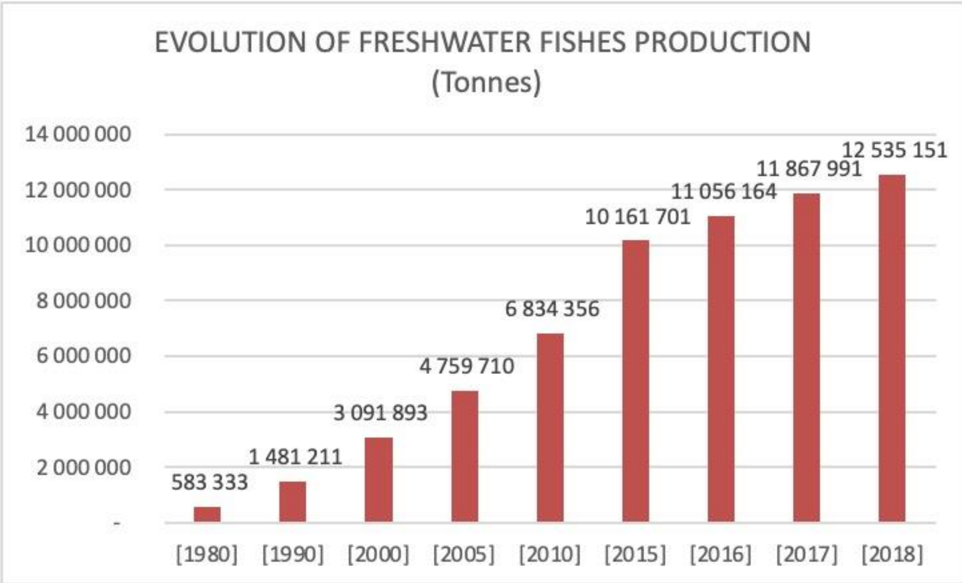


Figure 37: Production of freshwater fishes between 1980 and 2018 – IORA states – In tonnes (FAO, 2020)

The production of freshwater fishes in IORA countries has quadrupled in 18 years reaching a total volume of 12.5 million tonnes in 2018.

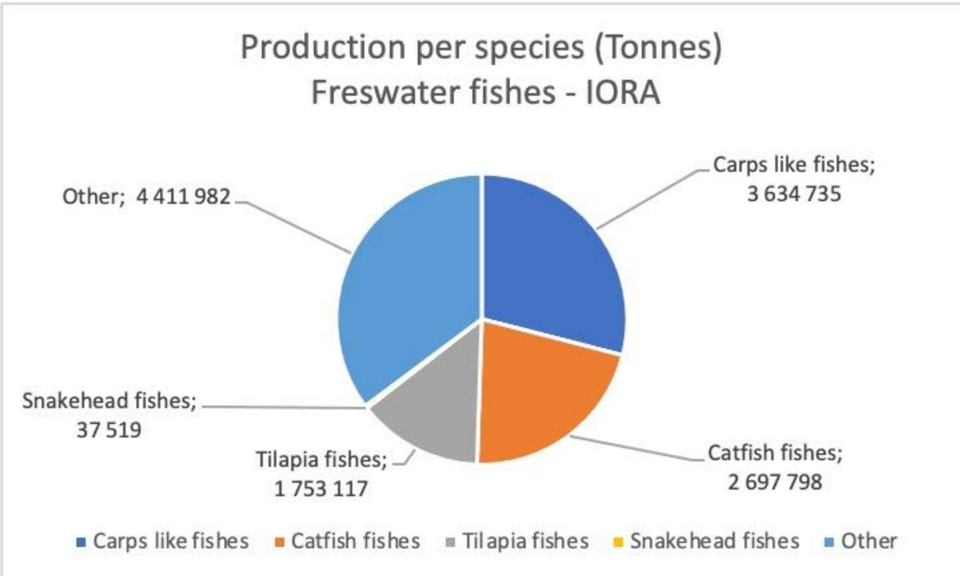


Figure 38: Production of freshwater fishes per group of species – IORA states – In tonnes (FAO, 2020)

A mix of local species ("Other") constitute 34% of the production, carps constitute 29%, catfish 22% and tilapias 14%. Of IORA countries, 80% produce aquaculture freshwater fish.

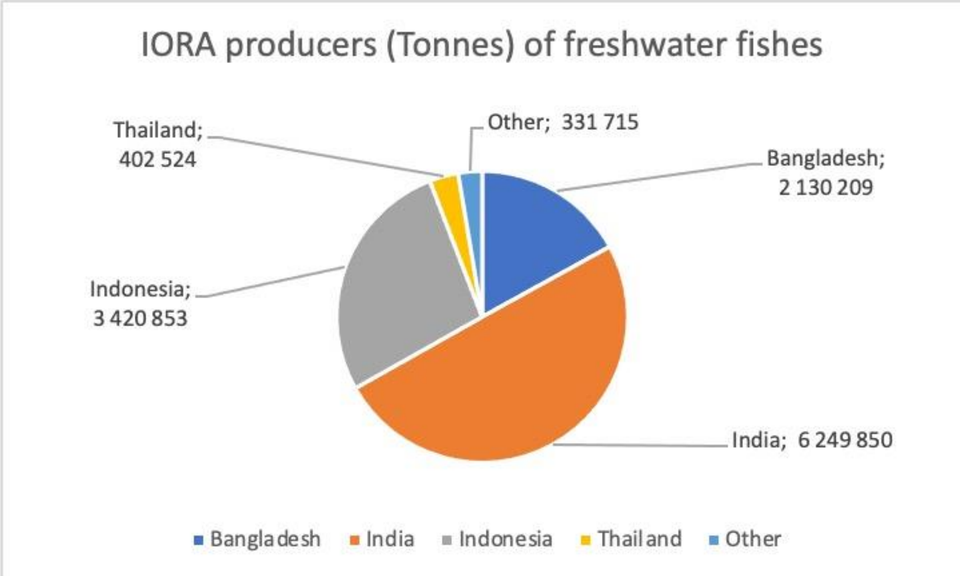


Figure 39: Main countries producing freshwater fishes – IORA states – In tonnes (FAO, 2020)

India accounts for 50% of the production (5.6 million tonnes of *carps* and 0.6 million tonnes of *catfish*), followed by Indonesia (27% mainly constituted of *catfish*) and Bangladesh for 17% (1 million tonnes of *carps*, 0.5 million of *catfish* and 0.3 million of *tilapia*).

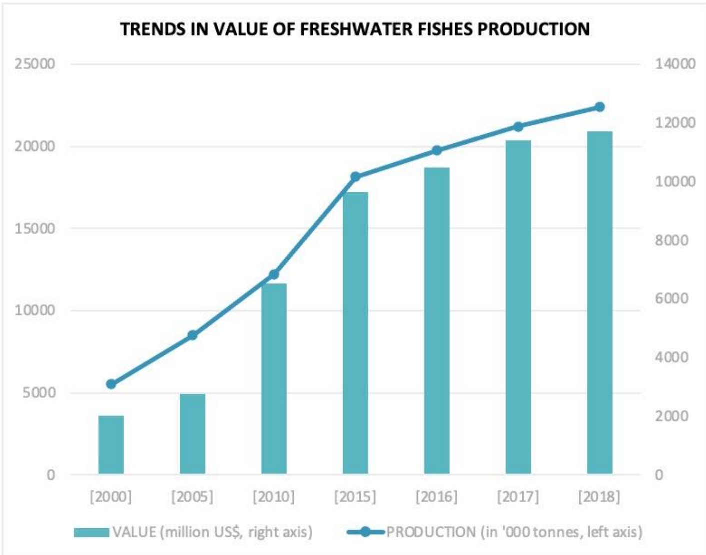


Figure 40: Production and value of freshwater fishes – IORA states – In thousand tonnes and millions USD (FAO, 2020)

The value and production of freshwater fish also significantly increased over the last 20 years. The value per unit (average price) however remained similar over 2 decades. Reduction of production costs with improvement in selection and feed, together with value chain improvement, gave flexibility for this production to increase while retaining a stable price.

5. Marine crustaceans

The production of marine crustaceans by the IORA countries is divided into 3 groups. Shrimp is the main one while the rest of the production is shared between crabs and other marine crustaceans.

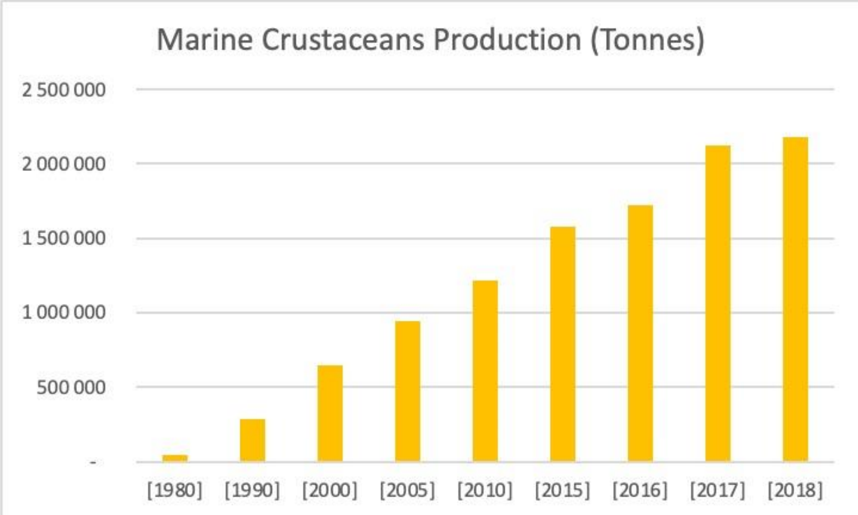


Figure 41: Production of marine crustaceans between 1980 and 2018 – IORA states – In tonnes (FAO, 2020)

The production of marine crustaceans has doubled in 10 years and amounted to 2.1 million tonnes in 2018. The evolution of the production over time is linked to the development of the sector and to improvements in domestication as well as genetic selection.

The marine crustaceans produced are mainly shrimps, representing 98% of the production of this category. The remaining 2% of IORA country production of marine crustacean are crabs and a marginal production of lobsters (since 2010, representing between 100 to 1000 tonnes).

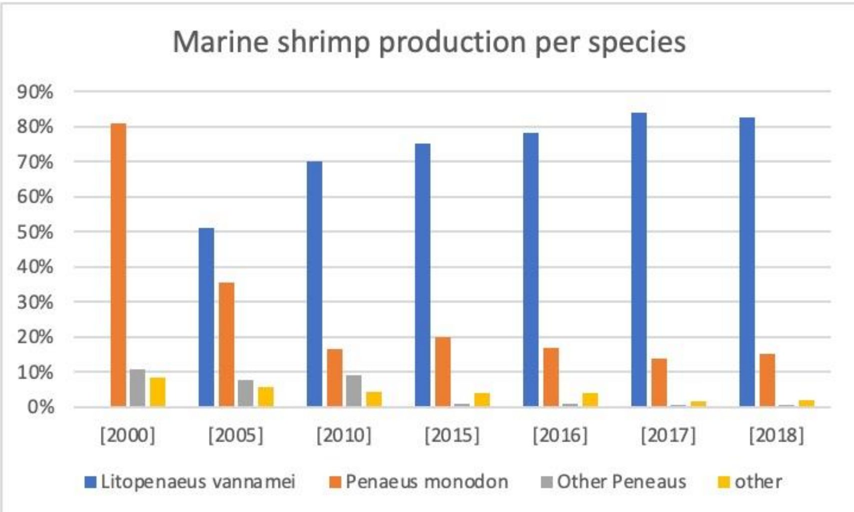


Figure 42: Production per species of marine shrimp production between 2000 and 2018 – IORA states – In % of species production in the category (FAO, 2020)

Overall, the distribution between shrimp species now remains the same after the important change occurring in early 2000's when the main producer countries shifted black tiger shrimp production (*Penaeus monodon*) for white-leg shrimp (*Litopenaeus vannamei*). This second species was domesticated in late 90's and, more resistant in ponds, some genetic selection programs started to reinforce this predominance. Advantages included effective closed-cycle breeding which is not given by the black tiger shrimp where breeders are still collected in wild environment for a major part of the actual production. Diseases outbreaks have impacted the production and the changes of species and model of production.

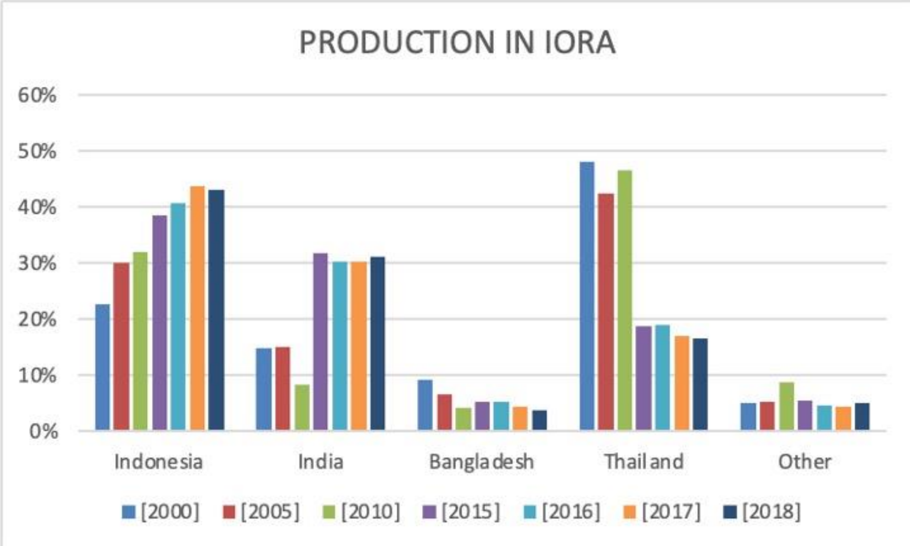


Figure 43: Production by main producer countries of marine crustaceans between 2000 and 2018 – IORA states – In % of total IORA production (FAO, 2020)

The main producing countries are India, Indonesia and Thailand. Changes in production over years are related to market access or opportunities (India and Indonesia) and diseases events (Thailand).

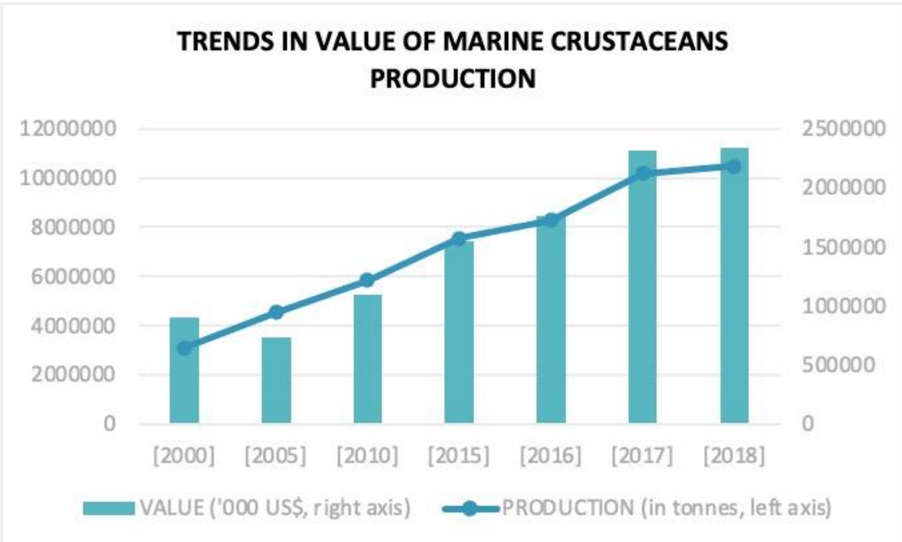


Figure 44: Production by main producer countries of marine crustaceans between 2000 and 2018 – IORA states – In % of total IORA production (FAO, 2020)

Marine crustaceans also experienced a steady increase of their market value, almost tripling between 2000 and 2018 together with an increase in production. Marine crustaceans remain one of the categories with higher value per unit (USD/kg) though slightly less than freshwater crustaceans.

6. Marine fishes

There are more than 25 main species of marine fishes raised in the farms of the IORA countries, of which many are carnivorous species (snapper, grouper, sea bass, pompano, others). The production is very low, in volume, compared with other aquaculture production. The sector is divided into two modes of production:

i) Ponds with sea-water or small floating cages holding local species (collected from the wild), fed and harvested (Bangladesh, India and Indonesia main production). Species are carnivorous (those in cages mainly) or are species feeding on plankton or other organic sources;

ii) Tank aquaculture (with possible grow-out phase in cages or also in tanks) with important technology and technical knowledge needs for reproduction and grow-out.

The cost of production of these species can be very high (feeds have very high levels of proteins and stocking density is low). This largely explains why there are changes in species with changes of production from year to year. Much aquaculture is carried out only in the fattening stages.

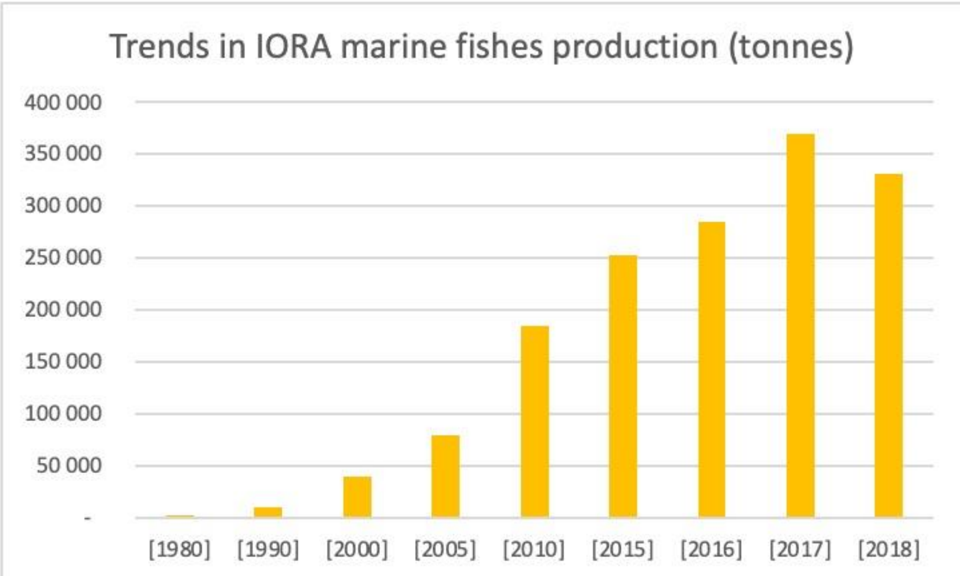


Figure 45: Production of marine fishes between 1980 and 2018 – IORA states – in tonnes (FAO, 2020)

The production of marine fish has increased 8-fold from 2000 to 2018, from 39.76 thousand tonnes in 2000 to 331.48 thousand tonnes in 2018.

The 3 main groups of species are:

- *Groupers* (8% of the production)
- *Snapper* (5% of the production)
- *Pompano* (1% of the production)

It should be noted that countries return heavily aggregated data on the production of marine fishes to the FAO and 200,000 tonnes are not described at species or group level (FAO Database).

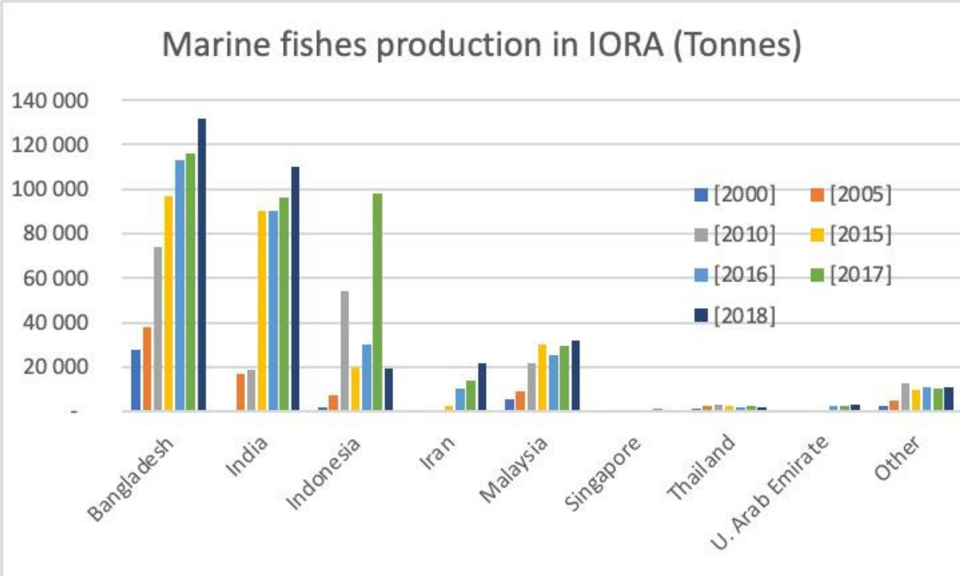


Figure 46: Main countries producing marine fishes and their production between 2000 and 2018 – IORA states – in tonnes (FAO, 2020)

About half of the IORA countries produce marine fishes. Bangladesh, India and Indonesia are the largest producers.

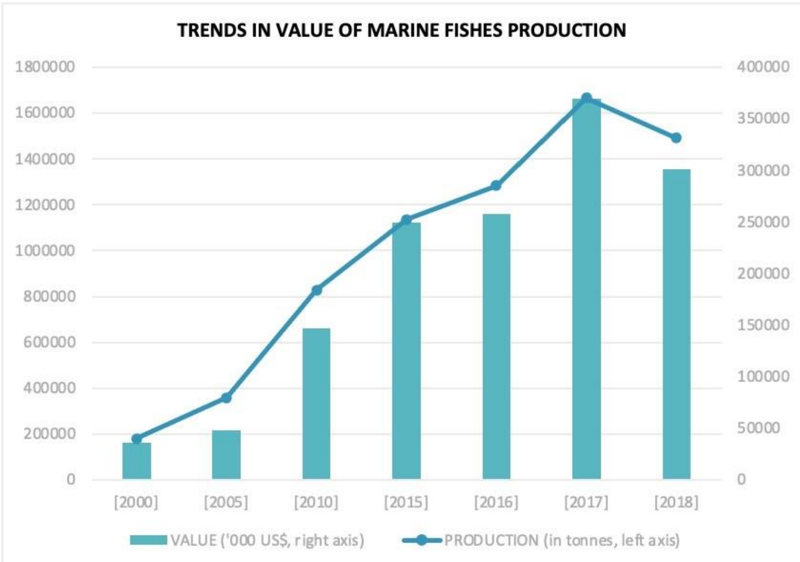


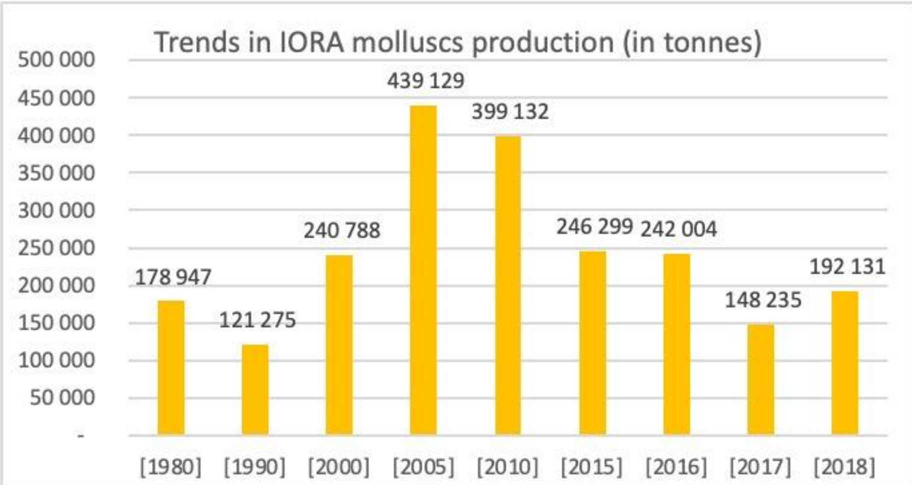
Figure 47: Value and marine fish production between 2000 and 2018 – IORA states – in tonnes and thousand dollars (FAO, 2020)

The value of this category of production is high, with an average of more than twice the price of other fishes (fresh water and diadromous) per kg.

7. Molluscs and miscellaneous aquatic animals

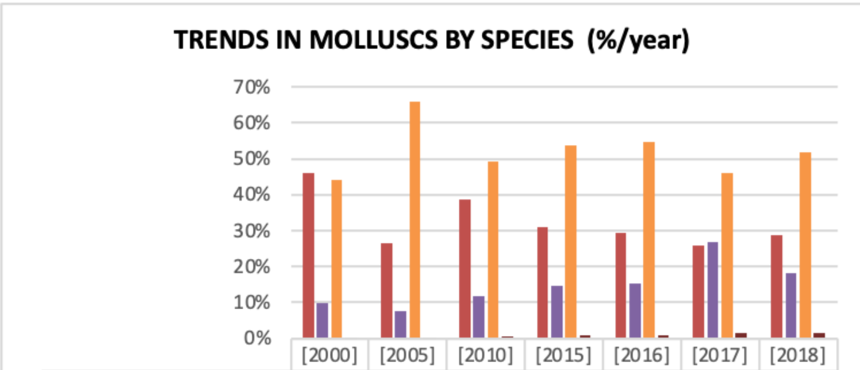
- **<u>Molluscs</u>**

Molluscs include several species of clams, oysters and mussels, as well as "high value" species such as abalone.



<u>Figure 48: Production of molluscs between 1980 and 2018 – IORA states – in tonnes</u> (FAO, 2020)

In 2018, the production of the IORA countries amounted to 192,131 tonnes. It has halved in the space of 10 years. Mussels represent the higher volume (see below).



	[2000]	[2005]	[2010]	[2015]	[2016]	[2017]	[2018]
Clams (several species	46%	27%	38%	31%	29%	26%	29%
Oyster (seveeral species)	10%	7%	12%	15%	15%	27%	18%
Mussels	44%	66%	49%	54%	55%	46%	52%
Other (abalone, ...)	0%	0%	0%	1%	1%	1%	1%

<u>Figure 49: Mollusc production, per species, between 2000 and 2018 – IORA states – in % of total molluscs' productions</u> (FAO, 2020)

In the IORA countries, mollusc production is divided into 3 main species. *Mussels* constitute 52% of molluscs' production, followed by *clams* (29%), then *oysters* (18%). The main IORA shellfish producing countries are Thailand which produced 45 318 tonnes of *mussels*, 26 700 tonnes of *clams* and 21 000 tonnes of *oysters* in 2018. Next of the important producing countries come Indonesia and Malaysia.

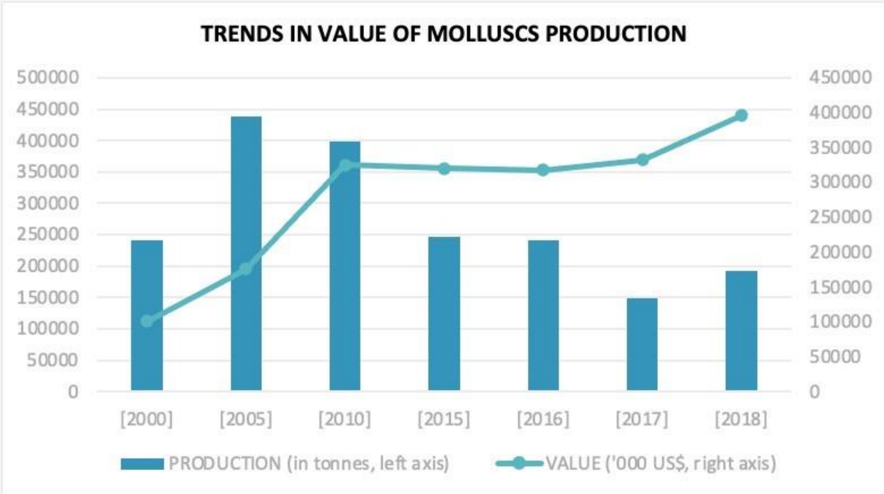


Figure 50: Molluscs production, volume and value, between 2000 and 2018 – IORA states (FAO, 2020)

The production trend of molluscs regularly decreased from 2005 to 2018. However, this product increased in value during the same period to the extent that 240.8 thousand tonnes were worth USD 0.1 billion in 2000, while 192.1 thousand tonnes had a value of USD 0.39 billion in 2018. Two kinds of production can be observed: some high value species (such as *Abalone*) representing about 25% of the total value while representing less than 1% of the production; and some clams (mainly *Anadara granosa* or *blood clams*) representing the higher volume of aquaculture production but significantly less in price than abalone. Within IORA countries, in value, South Africa and Australia represent the higher part of this category while representing only 9% of IORA wide production of molluscs.

- **Miscellaneous aquatic animals**

Miscellaneous aquatic animals are grouping various aquaculture production as sea cucumber, pearls, frog and turtle. They constitute niche markets together with ornamental fishes. All these categories have been grouped as their production in IORA countries is low in comparison with other aquaculture categories. Fresh water and marine water species of the concerned categories have also been grouped. The production of *Holoturia* spp. (sea-cucumbers) is included in this category. Sea-cucumbers are a nascent aquaculture production made in pens with “sea-ranching” techniques. The product has an important high value niche market offering great opportunities for development in IORA countries. Madagascar, Zanzibar, Maldives have already included sea-cucumber in their aquaculture sector development plans.

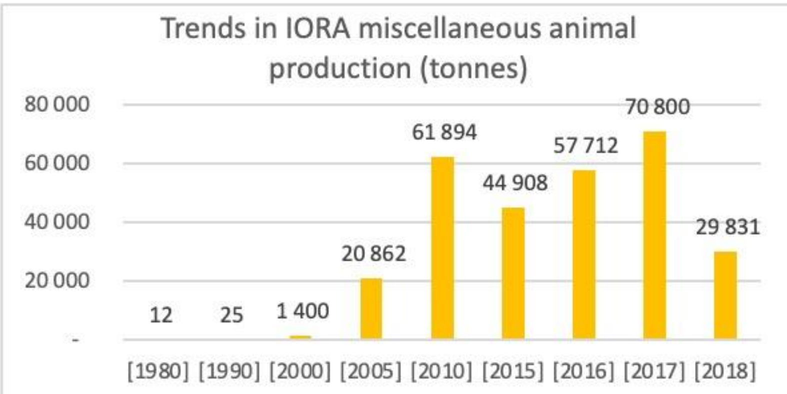


Figure 51: Miscellaneous aquatic animal production, volume in tonnes, between 2000 and 2018 – IORA states (FAO, 2020)