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Review Article

Sustainable Aquaculture Development and its Role in Food Security and Economic Growth in Eritrea: Trends and Prospects

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Abstract

The contribution of aquaculture to world food production has increased significantly over the last few decades, and this sector now supplies nearly half of the total fish and shellfish used for human consumption. Considering its importance in the world food sector, it is widely recognized that the industry should become sustainable from every angle. As the catch of wild fish declines, aquaculture is the only way to meet the increasing demand for fishery products. However, some argue that aquaculture results in environmental pollution and diminishes wild fisheries resources, and that it should be stopped or conducted only in extensive farming systems. This view lacks global vision and long-term considerations, including the increasing global population and food demand. As many scientists have suggested, the future of aquaculture sector is challenged by the need to produce more fish for food security and nutrition in a sustainable manner entailing technical feasibility, social license, environmental integrity, and economic viability. Eritrea is a small country in Eastern Africa with 2,234 km coastline. Most of the coastline is gradually sloping beaches and shallow bays, a perfect environment for fish farming. Nevertheless, as in many African countries, aquaculture in Eritrea is a new form of agriculture and still at its early stage. Aquaculture practice started in Eritrea in 1987, but the first commercial aquaculture farm is Seawater Farms Eritrea (SFE), which was established in 1998. Based on my research findings at the coastline of the Red Sea (2002-2011, Massawa, Eritrea), factors such as feed availability, temperature and salinity have direct and important effects on the growth and production of cultured fish in Eritrea's aquaculture practice. Aquaculture in Eritrea, if properly developed and managed, could play key roles in food security and economic growth, as is the case in many developing countries, including China. Moreover, Eritrea is found at the very important strategic economic zone for China's new initiatives, such as Maritime Silk Road (MSR) or One Belt and One Road (OBOR) and South-South Cooperation (SSC). Indeed, aquaculture at Eritrea's coastline is one of the potential industries to be developed under these initiatives. Therefore, the purpose of this paper is to review sustainable aquaculture development in Eritrea and its role in food security and economic growth, presenting trends and prospects.

ABBREVIATIONS

EEEZ: Eritrean Exclusive Economic Zone; EPLF: Eritrean People's Liberation Front; MMR: Ministry of Marine Resources; NFC: National Fisheries Corporation; FRDD: Fisheries Resources Development Department; FRSD: Fisheries Regulatory Services Department; SFE: Seawater Farms Eritrea; IFFC: Integrated Farming of Fish-cum-Chicken; IFAD: International Fund for Agricultural Development; EMPC: Eritrean Marine Products Companies; COMSAT: College of Marine Science and Technology; TCP: Technical Cooperation Programme; MSR: Maritime Silk Road; OBOR: One Belt and One Road; SSC: South-South Cooperation

INTRODUCTION

The contribution of aquaculture to world food production has increased significantly over the last few decades and this sector now supplies nearly half of the total fish and shellfish used for human consumption [1]. Advances in culture techniques and the introduction of new species have contributed to the rapid growth of the aquaculture industry. The rapid growth of this sector has also brought forth the need to ensure that development is based on environmentally responsible practices, especially including those concerning feeds. Therefore, considering its importance in

the world food sector, it is widely recognized that the industry should become sustainable from every angle [2-5].

As the catch of wild fish declines, aquaculture is the only way to meet the increasing demand for fishery products. However, some argue that aquaculture results in environmental pollution and diminishes wild fisheries resources, and that it should be stopped or conducted only in extensive farming systems. This view lacks global vision and long-term considerations including the increasing global population and food demand. As many scientists have suggested, the future of aquaculture is challenged by the need to produce more fish for food security and nutrition in a sustainable manner entailing technical feasibility, social license, environmental integrity and economic viability [6].

Eritrea is a small developing nation in the Horn of Africa with total area 124,320 km2 and has a population of about 6 million. Eritrea is situated in a strategically important part of the Red Sea (Figure 1). Eritrea has 2,234 km coastline, most of is gradually sloping beaches and shallow bays with thickets of mangroves along the water's edge – and hence, a perfect environment for fish farming [7,8]. Aquaculture in Eritrea, if properly developed and managed, could be a reliable source of food security as is the case in many developing countries [9,10]. Therefore, the purpose of this paper is to review sustainable aquaculture development in Eritrea and its role in food security and economic growth, presenting trends and prospects.

OVERVIEW OF AQUACULTURE DEVELOPMENT IN ERITREA

Background of Eritrea's coastline

Eritrea has the 6th longest coastline in Africa, 2,234 km, with 1,151 km of it along its mainland and 1,083 km around its islands on the Red Sea (Figure 1). Eritrea has 356 islands scattered around its coastal waters, 20% of which are in the Dahalak Archipelago, with average water depth of 35 m [7]. The Eritrean Exclusive Economic Zone (EEEZ) consists of 78,703 km2 including the off-shore islands [11-14], which is more than half the size of Eritrea's total land mass (Figure 2). The temperature at the coastline is 25-30°C between November and April, when it starts to warm up, reaching temperatures of up to 45oC in June to September. Tidal fluctuations are small, ranging between 50 and 120 cm [7].

Aquaculture (only marine aquaculture) trends

Considering the perpetual dependence of Eritrea's economy on rain-fed agriculture and livestock husbandry, the potential abundance of under-utilized coastal areas, and the declining trend of marine fisheries at the global and regional levels, aquaculture may play a crucial role in the development of the national economy in Eritrea [9,10]. As mentioned above, Eritrea has a long seacoast with extensive arid and semi-arid land adjacent to the sea, which is a potential area for aquaculture. With the pristine waters of the Eritrean Red Sea and clean environment, aquaculture in Eritrea can have a strong competitive marketing advantage. A 'Clean and Green' image has allowed many aquaculture products to command premium prices. As the top priorities of the Eritrean government are producing food, generating employment, providing basic social services and earning foreign exchange to fuel economic development, this extensive coastal area has a great potential to contribute to these goals through the development of sustainable aquaculture [9,10].

As in many African countries, aquaculture in Eritrea is a

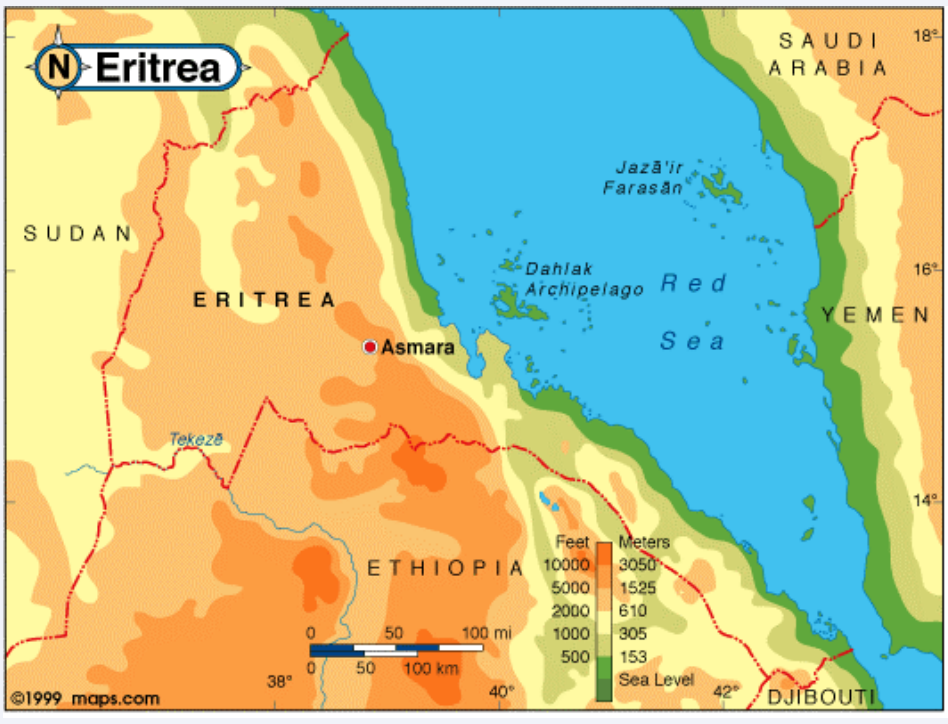

Figure 1 Map of Eritrea. Source: adapted from Hagos [10].

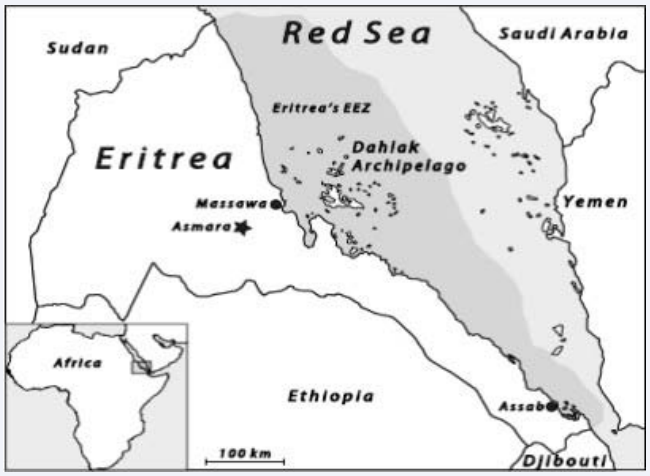

Figure 2 Map of Eritrea, showing physical setting for Eritrea's fisheries and coastline. Source: adapted from Grofit [14].

Figure 3 Integrated seawater farm; including inlet-canal, pumping station, physical filter ponds, shrimp ponds, outlet-canal, Salicornia research area, canals (finfish culture), Artemia ponds, technical support, feed-mill and office at Seawater Farms Eritrea (SFE), Massawa, Eritrea. Source: adapted from the 2nd International Symposium on Bio-fuels, March 31, 2010, Delhi, India.

new form of agriculture. In the year 1987-1988, an American - Japanese Expert, Dr. Gorden H. Sato, with the idea of self-reliance and food security, initiated the Manzanar project, and cultured mullet (*Mugil cephalus*) and milkfish (*Chanos chanos*) in the areas under-control of the Eritrean People's Liberation Front (EPLF) in the Northern Red Sea Region. Milkfish, mullet, brine shrimp, artemia (salina) and Nile tilapia (*Oreochromis niloticus*) were cultured in earthen ponds around the area of Agig, the northern tip of the Eritrean Red Sea bordering Sudan. Members of the EPLF navy have been engaged in the work under the supervision of Dr. Sato and Dr. Lou, a Chinese Aquaculture expert. Algal blooms were pumped into the fish ponds and served as the primary feed of the cultured species. Brine shrimp was grown in separate ponds and was pumped into the fish ponds to supplement the algal food. Algae that served as food for the brine shrimp and fish was grown using artificial (di-ammonium nitrate) and organic fertilizer. The culture system was not very complex and can be categorized as semi-intensive, as it was aided with aeration and supplementary feed. The ponds had paddle-wheel and propeller-type aeration systems. According to former staff (Ato Kibreab Solomon (Nifasu)), the Manzanar project during the armed struggle, oxygen, pH and ammonia measurements were regularly taken. Fish harvested from the ponds were used to supplement the diets of wounded fighters in nearby hospital.

After independence, efforts similar to the Manzanar project continued at a small scale, mostly in a research-oriented manner in the port city of Massawa and on Haleb Island (near the port city of Assab) under the Ministry of Fisheries. Small concrete ponds, net pens, earthen ponds and plastic-lined ponds were used to culture mullet and milkfish.

Seawater Farms Eritrea (SFE): The first commercial aquaculture farm in Eritrea is Seawater Farms Eritrea (SFE), which was established in 1998 as a 50/50% joint venture between the Eritrean Ministry of Fisheries and US-based company called Seaphire International, 10 km north of Massawa. With huge investment (over 20 million USD), SFE metamorphosed from a 3.6-hectare prototype farm to a 1000-hectare integrated seawater farm and supporting facilities over its 6 years of active existence. The farm had 153 circular concrete shrimp grow-out ponds with a total water area of 5 hectares, a shrimp hatchery facility, a small pathological and analytical laboratory, on site feed mill, over 140 hectares of interlinked earthen lakes fin-fish culture, canals and constructed wetland, about 200 hectares of developed agricultural fields for halophyte plants, maintenance workshops, and offices (Figures 3-6).

Implementation of the integrated Seawater Farms Eritrea is shown in Figure (3): first, seawater was channeled from the sea into shrimp and fish-farms. Nutrient-rich sea-water was used to grow salinity-tolerant, profitable species such as white-leg shrimp (*Penaeus vannamei*), Indian prawn (*Penaeus indicus*), Nile tilapia (*O. niloticus*) and milkfish (*Chanos chanos*) (Figure 4). The water from the shrimp and fish farms, enriched with organic matter, was channeled into large farms that grew halophytes (Salicornia) and mangroves (Figure 5). These species of crop and trees are highly tolerant of salt and can remove salt from the water and retain them in the bodies. The bodies and leaves, when

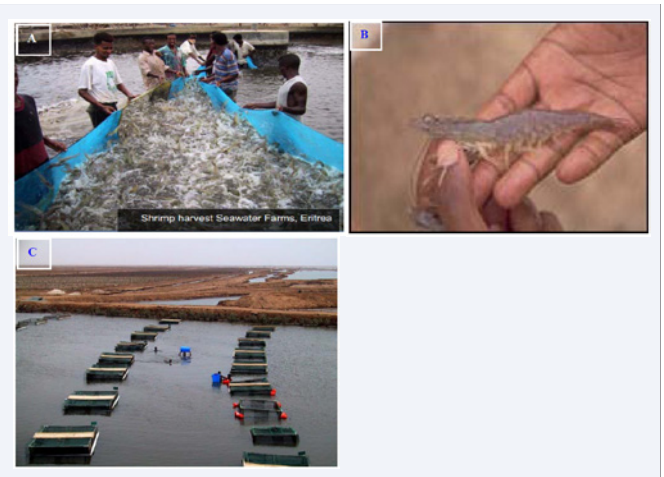

Figure 4 Shrimp harvest (A), Shrimp (P. Vannamei) cultured (B), and tilapia cage culture (C) at SFE, Massawa, Eritrea. Source: Documents of SFE (2003-2004)

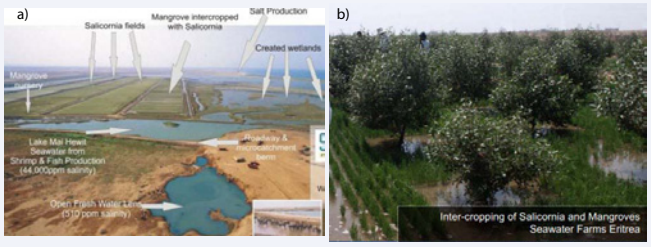

Figure 5 Halophyte plants agriculture, wetlands and saltpans (A), and halophyte plants agriculture (B) at SFE, Massawa, Eritrea. Source: Adapted from the 2nd International Symposium on Biofuels, March 31, 2010, Delih, India.

Figure 6 Feed-mill (A), feed ingredient processing (B), and feed production (C) at SFE, Massawa, Eritrea. Source: Habte-Michael Habte-Tsion, from documents of SFE (2003-2005).

processed, are suitable for human consumption, and can be fed directly to livestock such as goats and camels. The leftover roots help to stabilize the soil against erosion.

I was working in this company under supervision of an aquaculture nutritionist from the University of Arizona, USA (Dr. Sol Katzen); my main duties were feed formulation, developing research methodology for the experimental animals (shrimp, fin-fish, poultry, small ruminants, dairy cows and camels) and supervising feeding trails. During that time, Mercy Corps (an international NGO) was operating in Eritrea to provide relief from a devastating drought that threatened to destroy the sheep, goat, camel and cattle herds sustaining the village agriculture of the country. Thus, Mercy Corps requested that we develop feed for those animals. Further, Mercy Corps asked that we use mainly ingredients available within the country. Given the limitation of the economy, we began experimenting with the abundantly available seaweed, mainly sargassum and gracillaria, as well as a variety of halophyte plants. We developed a process to lower the salt content of those plants to the extent that 70% to 80% of the ruminant maintenance diets consisted of seawater-grown plants. We determined that the health and reproduction of the experimental animals were normal. The project was successful, and Mercy Corps began distributing the feed to the villages [15]. Based on my findings, the Fishmeal and Animal Feed Plant in Massawa and other small scale local feed mills (e.g., Azeb farm or Abrham Michael in Dubarwa) are producing these feeds [15] (Figure 6).

However, how attractive the SFE project might have been on paper, ultimately it came to an end due to various complex reasons (see sub-section below: "What went wrong with SFE?). Nevertheless, there is no doubt that highly experienced professionals in the field were recruited, and lessons were taken especially on the merits and drawbacks of the idea of integration for future initiatives.

Integrated Farming of Fish-cum-Chicken (IFFC): Another aquaculture project entitled Integrated Farming of Fish-cum-Chicken (IFFC) was conducted at a research level by the Ministry of Marine Resources (MMR). The IFFC Project, a research-based community development project, was established in 2010, 12 km north of Massawa, with about 5 hectares coastal area. IFFC was founded by local experts (Habte-Michael Habte-Tsion (the author) and Simon Z.-Mariam) previously active at Seawater Farms Eritrea (SFE). The project was funded by the government of the State of Eritrea and the International Fund for Agricultural Development (IFAD). The project, after the pilot study phase, was aimed at providing alternative livelihood or income-augmenting opportunities for the coastal communities to improve their living standards. This project was also aimed at coastal community development with sustainable and optimal use of resources. Thus, it can play a key role in food security for the poor coastal communities dispersed along the Eritrean coast of the Red Sea. Integrated fish farming is a low energy consumptive but high efficient aquaculture system. It is an effective way to develop marine water fish culture, and also it is a strategic measure for developing semi-intensive and integrated aquaculture systems. Integrated fish farming can play a promising role in solving the problem of fish scarcity.

Implementation of the system involves rearing chicken (broilers or layers) in pens beside or over the ponds, in the traditional way, in roughly the same conditions as ducks, generally at a density of 1,000 to 6,000 chickens/ha. The idea is outstanding in that when implemented and managed well, it is very effective: fish utilize the spilled-over poultry feed and their droppings, poultry droppings save the need for pond fertilization and fish feeding, no additional space is needed for poultry rearing, and fish, eggs and meat are produced in a single unit area and it ensures high profit with little input. Chicken manure used as food and manure in fish ponds are used in either the wet or dry form. The microbial decomposition of chicken manure enriches the water with nutrients, which contribute to nutrients for producing phytoplankton, zooplankton and, finally fish (mullet and milkfish) (Figure 7). During the experimental period, we checked samples of fish and there was no any incidence of Salmonella or other pathogens.

The research project was successful (e.g. the poultry experiment, both layers and broilers, was very successful), and was a platform for technology transfer to farmers and students from the College of Marine Science and Technology (Department of Aquaculture); notwithstanding some financial problems and electric installation delay (especially during summer it was hard to pump water; as a consequence, fish died). Next step of the project was further expansion by constructing more fish ponds

Figure 7 (A and B): Five-hectar integrated fish-cum-chicken farm (IFCF) research project, established by H.-Michael Habte-Tsion (project manager) and Simon Z.-Mariam (operation head) in 2010, Ministry of Marine Resources, Massawa, Eritrea. Source: Habte-Michael Habte-Tsion, from documents of IFCF (2011).

and poultry shelters separately and sterilizing the chicken-manure with quicklime before using it to fertilize the fish ponds, in order to avoid any incidence of pathogens from poultry-fish-human.

Aquaculture species in Eritrea

The major and potential species in the marine aquaculture of Eritrea include White-leg shrimp (*Penaeus vannamei*), Indian prawn (*Penaeus indicus*), Nile tilapia (*Oreochromis niloticus*), mullet (*Mugil cephalus*), milkfish (*Chanos chanos*), Red-sea pearl oysters (*Pinctada Pteriidae*), Red-sea cucumber (*Parastichopus californicus*), sea lobster (*Puerulus sewelli*), Artemia (*Salina*), halophyte plants (Salicornia and Mangrove). It can also be integrated with terrestrial animals such as poultry and ruminants.

Aquaculture production in Eritrea

The Seawater Farms Eritrea (SFE) employed almost 800 people, shipped premium shrimp to Europe or the Middle East and cultivated over 100 ha of the oil seed crop Salicornia, and was completing the planting of 100 ha of seawater forest. Additionally it created a 60 ha wetland, which welcomed over 200 species of birds and many other animals to a new home in the desert and kept the used aquaculture seawater from returning directly to the sea. The average annual shrimp production at Seawater Farms Eritrea in 2001-2003 was 14.32 tonnes with 71% exported to Europe and the Middle East (Table 1).

Seawater Farms Eritrea (SFE) has been able to market fresh-iced and frozen shrimp to the EU (France, Greece), Saudi Arabia, United Arab Emirates (UAE), and Egypt. SFE's shrimp has received excellent acceptance including in the countries like France, which has very demanding quality requirements. However, SFE was not able to fully exploit this high demand mainly because of limited production. Almost all of the buyers contacted look for consistency of both quality and supply of the product, to which SFE was unable to respond to constant supply.

Table 1: Shrimp aquaculture production (in tonnes) 2001-2003 at Seawater Farms Eritrea (SFE)[1].

Year	Export (t)	Local sales (t)	Total (t)
2001	9.84	1.59	11.43
2002	8.81	4.21	13.02
2003	11.50	6.73	18.23

[1]Source: SFE document, Massawa, Eritrea.

FISH CONSUMPTION LEVEL AND CONSUMPTION PREFERENCES IN ERITREA

Currently, the Ministry of Marine Resources, an agency of the government with stakeholders in the fish supply chain channel, is working on: (1) creating fish consumption awareness among the Eritrean public through the mass media; and (2) providing local distribution networks for easy access to consumers at affordable price. Moreover, the ministry with stakeholders has established many new distribution sites, mainly in the cities and towns. Likewise, to fulfill consumer demand, the Massawa Eri-Fish Processing Plant and Asmara Eritrean Marine Products Companies (EMPC) have been distributing fresh fish using cold storage equipped vehicles throughout the country. As a result, the consumption level for marine fish is increasing over time in future.

FISH PROCESSING STATUS IN ERITREA

The Eri-fish Processing Plant was established in 1995 in Massawa. It has processing capacity of 15 tonnes of fish and 4 tonnes of shrimp per day. It currently sells fresh and frozen fish products in the local and regional markets. Eritrean Marine Products Companies (EMPC) established Asmara and Assab branches in 1995 and 1998, respectively, and has been processing and distributing fresh fish to local markets and for export. EMPC Asmara is a processing and marketing company, operating a processing plant with a capacity of 10 tonnes of fish per day. Established in 2011, fish processing and depot plants in Gelalo, Tio, and Eddi have been playing essential roles in collecting fish harvested through artisanal fishing practices. The facilities of the EMPC and Eri-fish Processing Plant have been recognized as meeting the standards required for eligibility to export to the EU market [16]. These processing plants are also expected to play a vital role in aquaculture development.

KEY INSTITUTIONS FOR AQUACULTURE DEVELOPMENT IN ERITREA

The institutions for the fishery sector are: the Ministry of Marine Resources (MMR); the College of Marine Science and Technology (COMSAT); the National Fisheries Corporation (NFC) and its subsidiaries; the Regional Administrations of the Northern Red Sea and Southern Red Sea Regions; and the Artisanal Fishers Cooperatives. Based on their contribution to aquaculture development, two key institutions are described in this review, the MMR and COMSAT.

Ministry of marine resources (MMR)

The MMR has overall responsibility for the management and development of the fisheries resources (including aquaculture) of Eritrea within the legal framework provided by the Fisheries Proclamation (No.104/1998). The Ministry has two operational departments: the Fisheries Resources Development Department (FRDD), and the Fisheries Regulatory Services Department (FRSD); and two Divisions: Training and Human Resources Development; and Administration and Finance. The operations of the Ministry are decentralized into two regional branches, the Northern and Southern Red Sea Regions.

College of marine science and technology (COMSAT)

The COMSAT was established in June 2005 under the auspices of the Ministry of Marine Resources and Ministry of Education to fulfill the following objectives: (1) to produce graduates that will participate in the exploitation, management, and conservation of living marine and coastal resources, (2) to train seafarers that can serve in the maritime industry as engineers and to train technical personnel that can install, maintain, and repair engines and cooling equipment, and (3) to generate and disseminate knowledge on the marine and maritime resources of the Eritrean coast through research and publications. The college is currently offering four degree and five diploma programs in four academic departments: the Departments of Aquaculture, Applied Marine and Fisheries Science, Marine Biotechnology, and Marine Engineering [17].

POLICY FOR SHORT AND LONG-TERM AQUACULTURE DEVELOPMENT PLAN IN ERITREA

The Eritrean Constitution and macro-economic policies provide the wider policy and legal context for the development of the fisheries sector, including aquaculture. The policy goal is the long-term sustainable utilization of fisheries resources for the benefit of Eritrea and its people. The objectives are: (1) the provision of employment opportunities for the coastal population; (2) improvement of the livelihoods of artisanal fishers; (3) enhancement of food security; (4) increase in foreign exchange earnings through exportation of high-value fish and fish products, principally to the regional and European markets; and (5) sustainable and balanced use of fisheries resources, including aquaculture.

Following the report of the Symposium of the Ministry of Marine Resources in May, 2011, taking into account the given potentials and opportunities, a five-year plan has been developed out to introduce community-based aquaculture in seawaters [18].

CONSTRAINTS IN THE ERITREA'S AQUACULTURE DEVELOPMENT

Against the above opportunities for aquaculture development in Eritrea must be set multiple constraints to their realization. These bear on critical areas of general levels of capitalization, production, aquaculture-related infrastructure and services, marketing, and policy.

a. What went wrong with Seawater Farms Eritrea (SFE)?

SFE failed as a business venture because it failed to generate sustainable economic profit, which is the main measure of success of a commercial venture. Although each unit was projected to generate revenue and even profit the system as a whole generated little income. This eventually led to the failure and cessation to operate and manage the farm, as envisioned in its onset and development, as an integrated farm. Some of the drawbacks, mistakes and failure factors of SFE include:

- Lack of clear and binding national laws and regulations on aquaculture development in Eritrea at the time of inception of SFE.
- Although the theoretical project concept was well developed and attractive on paper, it was not successfully implemented on the ground. No thorough, truthful and professional techno-economic feasibility study was conducted.
- Poor job on site survey, analysis and selection.
- Arguable production strategy: Extensive, semi intensive, intensive and super-intensive farming systems are all being utilized in the aquaculture industry today. All have their merits and demerits, but selection of a system is associated with the availabilities of land, skilled labor and technology. SFE employed a super-intensive culture system that is at the peak of all culture systems, that demands the highest cost of development, operation, skill and technology, with a high risk. Super-intensive culture systems may be appropriate in the highly developed countries where land is very expensive and technological advancement is at its crest. Therefore, no thorough professional considerations were taken on the appropriateness of the production strategy in relation to cost of development, operation, return, risk, management, Eritrea's climate, economic, and technological advancement.
- Lack of responsible aquaculture practices, especially associated with the protocols of live animal importation, quarantine and bio-security measures. As a consequence viral disease in shrimp culture was introduced from abroad. We spent a lot of time (more than one year) and resources to eradicate or control the disease outbreak, by drying the whole farm and then using different chemical treatments. Unfortunately, we could not save the farm.
- Poor business management: SFE could not be regarded just as an aquaculture facility. It is rather a seawater-based integrated farm that integrated cultivation of shrimp, fin-fish and halophyte plants, and use of a constructed wetland all functioning in a coordinated, interdependent, integrated fashion. This integration was not well managed.

RATIONALE AND RECOMMENDATIONS FOR SUSTAINABLE AQUACULTURE DEVELOPMENT IN ERITREA

a. Rationale for sustainable aquaculture development in Eritrea

Eritrea has 1,151 km seacoast along the mainland and extensive arid and semi-arid land adjacent to the sea that has no or poor agricultural use. With the pristine waters of the Eritrean Red Sea and a clean environment aquaculture, in Eritrea can have a strong competitive marketing advantage. A 'Clean and Green' image has allowed many aquaculture products to command premium prices. Besides, as the top priorities of the Eritrean government are producing food, generating employment, providing basic social services and earning foreign exchange to fuel economic development, this extensive coastal area has a great potential to contribute to these goals through the development of sustainable aquaculture.

b. Recommendations for sustainable aquaculture development in Eritrea

1. For the development of a successful sustainable aquaculture industry in Eritrea and for the aquaculture industry to reach its full potential, a number of critical success factors

must be addressed and resolved. The government should incorporate and endorse aquaculture into national development plans and strategies and provide commitment to its development as one sector of the Eritrean National Development Strategy to contribute its share in Eritrea's foreign exchange earnings, food security and direct and indirect employment generation (e.g., it has been done in China). Given the availability of extensive coastal plain, unpolluted water, existing road infrastructure along the coast, relatively inexpensive labor, and some local aquaculture operation experience, aquaculture has a bright future and good potential for economic contribution.

2. The government needs to put a great deal of effort to lay the basic foundation for the development of sustainable aquaculture in Eritrea in terms of policy and regulations, by establishing administrative procedures for evaluation and approval of projects, developing Code(s) of Best Practice, by promoting increased dialogue and communication between all stakeholders including consultation with scientists (local and foreign aquaculture experts) and the experience of Seawater Farms Eritrea. This effort could take the form of a Technical Cooperation Programme (TCP) and could be drafted through the assistance of scientists (local and foreign aquaculture experts) and international organizations (e.g., FAO). The sustainable aquaculture development strategy and implementation plan for Eritrea must be drafted and developed so as to address these critical success factors in a framework of shared responsibility. The sustainable aquaculture development strategy will address, but is not limited to the following components: regulatory framework governing the placement, management and operation of aquaculture farms in Eritrea; environmental sustainability and interaction; resource allocation and access; product safety and inspection; research, training and development and technology transfer; access to financing; and aquaculture development implementations structure.

3. The government needs to allocate resources for sustainable aquaculture development, strengthen aquaculture related institutions including research center, monitoring, and regulatory systems.

4. Identify appropriate funding sources (grants) and technology for sustainable aquaculture development (e.g., in China). For instance, in 2013, the Chinese government initiated the concept of the "Silk Road Economic Belt and the 21st-Century Maritime Silk Road" (referred to as the One Belt and One Road (OBOR) concept) in tandem with launching the Asia Infrastructure Investment Bank (AIIB) in 2015, in which 57 countries have joined as members. The OBOR initiative is China's greatest international economic ambition, aiming at stimulating economic development in a vast region covering sub regions in Asia, Africa and Europe, which accounts for 64% of world population and 30% of world GDP [19]. The OBOR expected to promote the connectivity of Asian, African and European continents and their adjacent seas, establish and strengthen partnerships among the countries along the Belt and Road, set up omni-dimensional, multi-tiered and composite connectivity networks, and realize diversified, independent, balanced and sustainable development in these countries. While infrastructure development plays a central role, the OBOR initiative is a comprehensive one, including also policy dialogue, unimpeded trade, financial support and people-to-people exchange [19]. In addition, China-Africa-South America (CASA) trading routes have been rapidly promoted, with the development of container ports in the sub-Saharan region and South America, i.e. South-South Cooperation (SSC). SSC constitutes a new paradigm of development more relevant to African needs [20]. Thus, Eritrea is among the countries along these routes (initiatives), and aquaculture is one of the potential industries to be developed under these initiatives at Eritrea's coastline 5. Seawater Farms Eritrea should be taken only as a learning experience and not as an indication of aquacultural prospects in Eritrea.

In summary, Eritrea has long seacoast along the mainland and extensive arid and semi-arid land adjacent to the sea that has no or poor agricultural use. With the pristine waters of the Eritrean Red Sea and a clean environment; thus, aquaculture can have a strong competitive marketing advantage. Therefore, aquaculture in Eritrea, if properly developed and managed, could play key roles in food security and economic growth, as is the case in many developing countries, including China. Furthermore, Eritrea is found at the very important strategic economic zone for Chinese initiatives, OBOR and SSC. Indeed, aquaculture at Eritrea's coastline is one of the potential industries to be developed under these initiatives.

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