

**Sustainable Management of Coastal and Marine Resources:
What are the Future of Land and Sea-based Shrimp Farming in Eritrea?**

By

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Executive Summary

Eritrea is a nation in the Horn of Africa and has a total surface area of 124, 400 km² with over 360 islands and a 1200 km coastline along the western shores of the Red Sea.

Eritrea's population of 4.0 million people has a growth rate of 3.8% is expected to double in the next twenty-five years (UNPF 2001). The country won its independence in 1991 from Ethiopia after a bitter thirty-year struggle. After seven years of peaceful coexistence with Ethiopia, Eritrea resolved a two-year border¹ conflict in 2000, which was aggressively imposed on it by Ethiopia. However, the Horn of Africa region, including Eritrea is this time facing serious drought and internal political tensions that expose the countries of the region to resource scarcity and famine².

At present, the majority of the country's population depends mainly on agriculture and livestock for livelihood and income (SOE 2001), However, due to drought and outdated farming and animal husbandry practices that depend on unpredictable weather conditions, agricultural output has been far too low to provide for food security, thus causing chronic food shortages. This year in Eritrea alone, over a million lives are threatened by drought (FAO/WFP 2002). This drought together with the external aggression that involved huge financial and human resources, and the internal political discontent prevailing in the country, have aggravated the overall socio-economic

¹ The border issue is in the process of demarcation by an independent Eritrea-Ethiopia Border Commission.

² FAO/WFP Special Report: Crop and Food Supply Assessment Mission to Eritrea, Rome. October 3, 2002.

situation of the people, thus exposing the country to further dependency on imported and donated food supplies.

Eritrea's coastal and marine ecosystems are characterized by rich and diverse coral reefs, isolated mangrove forests, sea-grass beds, bays, beaches and pristine unpolluted waters that are at the critical juncture between development and conservation (UNDP 1998). These ecosystems represent a physical resource base for the potentially rich and unexploited marine fisheries. Moreover, the vast coastal areas with hot, humid and barren uninhabited flat lands, unsuited for agriculture due to saline soils and the deficiency of fresh waters, are appropriate for land-based aquaculture.

The marine fisheries sector of Eritrea has yet to contribute their share to the national economy. In the decade since independence the fisheries sector suffered from the absence of infrastructure, shortage of technical, human and financial input, the weakness of the local business community and the inconsistency in public policy. With full participation of domestic and foreign investment and clearly defined policy the marine resources development strategy should be geared to address three major issues: the provision of food security, the creation of employment opportunities, and the generation of foreign exchange. If properly developed and managed fisheries could be a reliable source of food security as is the case in many developing countries. 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 have a crucial role to play in the development of the national economy of Eritrea.

The central goal of my thesis is to examine the future of environmentally and economically sustainable shrimp aquaculture in Eritrea, considering perennial food insecurity and existing demands on the coastal and marine resources of Eritrea. My underlying objectives are to analyze the advantages and disadvantages of land- and sea-based shrimp culture and to present recommendations on environmentally and economically sustainable approaches to shrimp aquaculture that could, potentially, contribute to: food security, domestic employment opportunities, generation of foreign exchange, improved management of capture-fisheries in Eritrean waters. They also include, the development of marine sanctuaries and increased tourism, re-forestation of the coastal zone and re-establishment of tidal wetlands, and institutional capacity building.

I analyzed international market data, comparative case studies from Asian and Latin American countries, and scientific and technical information on shrimp culture. I have also employed the best available socioeconomic, geographic and marine resources information from Eritrea to evaluate the future of shrimp culture in Eritrea.

Aquaculture could provide a significant positive contribution to food security through extensive and semi-intensive systems of production in which natural feed for fish predominates. However, certain traditional and modern intensive aquaculture systems

have a negative impact on food security. This is due to their unsustainable use of live fish as feed. For example, in some cases the culture of 1 kg of a carnivorous cultivated food fish may require up to 5-6 kg of fresh wild fish for feed which are normally dried or fermented and used as food by poor people (Edwards 1997). This means that in aquaculture operations where the feed conversion ratio (FCR) is very high, the sustainability of the operation is low.

The fisheries sector, including wild-catch and cultured shrimp, is one of the potentially tangible resources that Eritrea could exploit for domestic and export markets. Sustainable development of the resources towards the production of export products generates a dependable source of foreign exchange earnings. Shrimp aquaculture might bring much-needed foreign earnings from exported shrimp, but this positive impact must be weighed against other social and environmental impacts. It can lead to losses in traditional livelihoods, marginalization of local residents and the erosion of their resources rights (Tobey 1998).

The development of aquaculture in Eritrea could also have the additional advantage of creating employment opportunities for Eritrean citizens. Long years of liberation war and border conflict have produced a large army that eventually needs to be demobilized³. The development of the fishery industry and aquaculture could open vast opportunities of employment, thus creating a dependable means of absorbing large numbers of ex-combatants and the general population. While economic development is

³ A demobilization program is in process through funds available from the World Bank.

often assumed to lead to increased social benefits for entire populations, but as many cases around the world have demonstrated, development often brings benefits for a few while leaving the majority of the population behind. Increasingly, social equity, benefits and poverty alleviation are being given a higher priority by governments, aid agencies, local communities, and societies (WWF/FAO 2002).

Aquaculture is a new phenomenon in Eritrea. It was introduced first by Dr. Gordon Sato⁴ in 1988 during the armed struggle. He experimented mullet culture and mangrove plantation and the sand taught Eritrean freedom fighters how to culture fish in ponds. Dr. Carl Hodges a retired scientist from Arizona, introduced commercial aquaculture in 1998 with the establishment of Seawater Farms Eritrea⁵ in Massawa. The company intends to expand land-based aquaculture operations. Aquaculture will, no doubt, play an important role in the country's economy in the future. However, as experience in other countries shows, potential social and environmental impacts may eventually emerge. The Macro-Policy – a public document issued in 1994 - states that measures will be taken to safeguard the marine environment against and fight pollution of the Red Sea in collaboration with the other littoral states (SOE 1994).

This thesis research has critically addressed these and other similar concerns and assessed the advantages and disadvantages of aquaculture, providing relevant examples on the social, economic and environmental impacts of shrimp culture from

⁴ Dr. Gordon Sato is Japanese-American retired scientist who has relentlessly supported Eritrea for more than 15 years with aquaculture and mangrove forestation with the objective of teaching young Eritreans the wisdom of utilizing marine resources for food production and environmental enhancement.

⁵ Seawater Farms Eritrea (SFE) is a joint venture company formed by the Ministry of Fisheries of the State of Eritrea and Seaphire International – a Phoenix, AZ based firm. SFE is engaged in integrated seawater farming involving: shrimp and tilapia culture, the cultivation a halophyte crop - Salicornia and the development of wetlands.

the experience of the some Asian and Central American countries with similar climatic conditions as Eritrea. The following recommendations are made for the development of sustainable aquaculture.

- Given the present situation of drought and food shortage in Eritrea, necessary measures must be taken to give priority to increase wild fish production and aquaculture operations in order to solve the problem of food security by introducing low-cost of capture and cultured species of fish and integrating them with shrimp farming. Aquaculture has to be carried out by integrating shrimp culture for the export and the Polyculture of different species of fish for the domestic market.
- By way of encouraging domestic and foreign investment in aquaculture and related businesses, it is essential for the state to improve the facilitation of investment procedures and to simplify the provision of land and other resources and investment benefits to ensure the involvement of the private sector without any restrictions.
- Eritrea has yet to utilize the comparative advantage it possesses conducive to the success of the shrimp industry such as: low production costs due to availability and reduced labor costs, open and attractive investment policy, two operating ports in the Red Sea, a new national carrier, three international airports, and the country's well-situated location within easy reach of prospective markets in the Middle East, Europe and the Far East.

- To make these comparative advantages feasible the government needs to make some policy adjustments by way of encouraging private investment through the provision of development loans at low interest rates and reductions on import tariffs of aquaculture inputs.
- Introduce institutional mechanisms and means of allocation of resources to involve artisan fishermen in land and sea-based aquaculture as the case may be, and to create an atmosphere conducive enough to enable them to fully participate in decision-making process pertaining to issues of their concern.
- The future of global shrimp market is uncertain. Possibly global demand for shrimp will continue to increase; assuming the present decline in price is temporary. It may also possibly happen that the continuous expansion of shrimp farming in developing countries will lead to continuing gluts. In both cases the final result will depend on the economic situation in the major shrimp consuming societies of the developed countries and the emerging economies. The trends, however, shows that an increase in production and the current price fluctuations will continue. This may not affect shrimp production in Eritrea as prices have been fluctuating for the last decade and will continue to fluctuate for the foreseeable future.

- Eritrea has yet to adapt environmental laws. At present there is no environmental law to regulate aquaculture albeit one chapter in the Fisheries Proclamation. In the absence of a regulatory mechanism it is tempting for aquaculture and other industries to exploit the situation and avoid the mitigation of externalities. The current shrimp farming enterprise has been operating on self-control basis with little government regulatory measures due to the absence of clearly defined regulations. If correct foundations are to be laid for aquaculture it is time for the government agencies to facilitate the enacting of the relevant laws.

I. ERITREA – BACKGROUND INFORMATION

A. Brief Description

i. Geographical: location and description

Eritrea, a country the size of England or Pennsylvania with an area of 124,000 sq. km², is located on the western coast of the Red Sea bordering Ethiopia, Sudan, and Djibouti in the region known as the Horn of Africa. Eritrea is situated in a strategically important part of the Red Sea.

Figure 1: A map of Eritrea



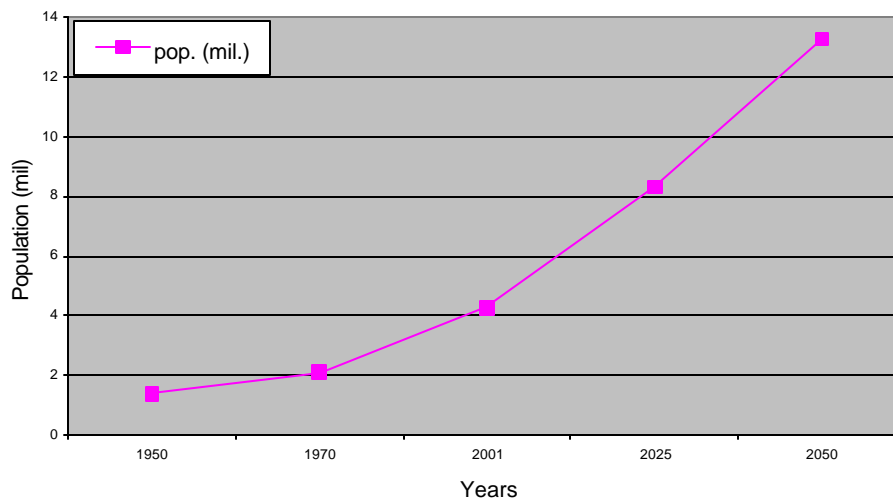
Geographically Eritrea is divided into three climatic zones: (1) The highlands (up to 2450 meters above sea level), (2) The midland (1500-2450 meters above seas level) and (3) The lowlands. In spite of the relatively small size of the country, within a short distance different climatic conditions are observed due to the differences in altitude. A

traveler from the capital Asmera to the port town of Massawa would experience three different climates in a distance of 115 km.

ii. Population

Eritrea has a population of about 4.2 million with an annual growth rate of 3.8% (UNPF 2001). The population has a diversity of nine nationalities and two religions, Islam and Christianity, living in harmony and tolerance with each other. Since 1950 the population of Eritrea has almost doubled every 25 years as shown in the figure below.

Fig. 2: Population growth in Eritrea from 1950-2050
(Source: UNFPA/US Census Bureau, 2000)



This was at a time when the country was engaged in a thirty-year old war of liberation from Ethiopia and when disruption of normal life and displacement were the norms.

Population projections for the next fifty years show that Eritrea's population will continue to almost double every 25 years⁶. Eritrea's population is growing at a fast rate,

⁶ In 1950 Eritrea had a population of 1.4 million and in 1970 2.1 million. Currently the population of Eritrea is 4.28 million ranking Eritrea as the 119 of 227 countries of the world as regards to population size.

for a country with a population density of less than 50 persons/km², which lost a large part of its active population⁷ in the three decades of war. However, to cope with the estimated population growth, the economy of Eritrea has to grow correspondingly to provide sufficient products and services.

The liberation war was a cause of migration and internal displacement of a large part of Eritrea's population. At independence in 1991 between 700,000 and 1 million of Eritrea's population lived abroad as refugees (SOE 1995). A large percentage of these refugees have since been repatriated⁸ and the remaining refugees in the Sudan are in the process of repatriation (SOE 2001). There are still a large number of refugees living in Ethiopia⁹, the Middle East, Europe and North America, most of them adopting the citizenship in their country of residence. The majority of refugees would return home either permanently or temporarily given a political and economic environment conducive for business and residence in the country.

In 2025 the population will grow to 8.32 million (ranking as the 101) and in 2050 the population is projected to triple its present size to 13.28 million (ranking as the 82). (Source: UNFPA, US Census Bureau).

⁷ It is reported that Eritrea lost over 75, 000 fighters and an unspecified number of civilians during the thirty years liberation war.

⁸ Since independence over 200,000 Eritrean refugees have been repatriated and the process is underway to bring back home all Eritreans living in the Sudan (SOE, G. o. t. S. o. E. (2001). Economic Growth and Poverty Reduction Strategy. Asmara, Government of Eritrea, Office of International Cooperation, Macro Policy and Economic Coordination.

⁹ The predicaments of citizens of Eritrea living in Ethiopia have been difficult during the recent border war with that country. Ethiopia had expelled over 75, 000 Eritreans and Ethiopians of Eritrean origin during the border war that lasted from 1998-2000.

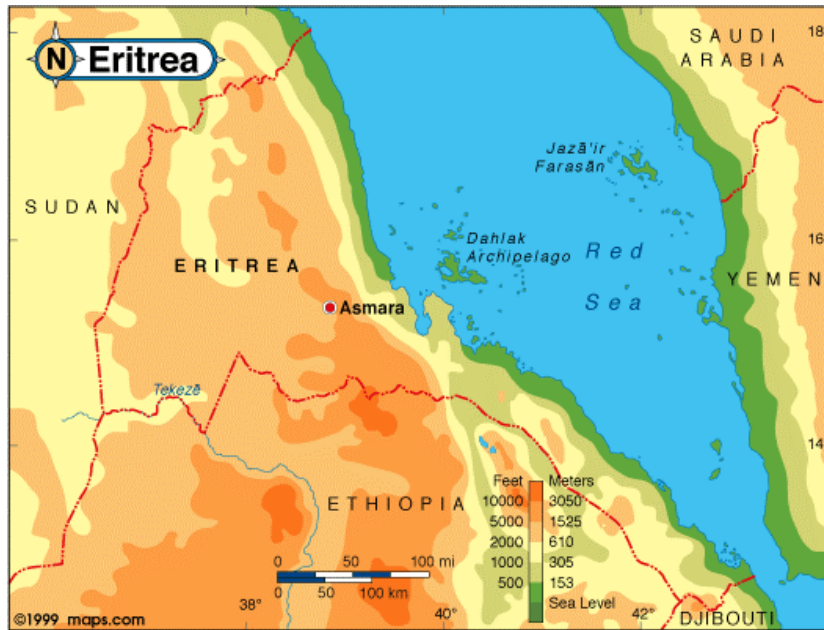


Figure 3: An elevation map of Eritrea.

Coastal Population: Eritrea’s coastal areas are sparsely populated. The coastal areas within 60-75 km of the Red Sea, the green, yellow and white strips in the above illustration (Figure 3), are estimated to be 601,300. This is the population estimate of the two coastal Regions. The two main population centers, namely Massawa and Asseb, have a combined population of about 60,000 while the island population is estimated to be 3,140 spread over four of the largest islands (MoLG 2002).

The urban population in the coastal areas is engaged in fish trade, cement production, salt works and port services while the rural population is engaged in fisheries, livestock husbandry, and cultivating for subsistence during the rainy season¹⁰. Seasonal nomads from the highlands move to the coastal plains when the coastal rains start. The island population is engaged fulltime in fishing activities while some families engage in livestock husbandry on a part time basis.

¹⁰ In some of the coastal areas, cultivation is carried out twice a year when floods from the highlands flush the coastal plains and during the coastal rainy season. But because of low productivity output is poor.

iii. Key historical events

Similar to other African nations, the formation of Eritrea is the result of 19th century European colonialism, but the people of Eritrea have a long history that goes back to ancient times as evident in archeological sites in the country. Eritrea, an Italian colony from 1880- 1941, did experience a long and difficult process of de-colonization following the defeat of Italy in World War II. While many African countries were called upon to prepare for their independence in the 1960s, Eritrea had to fight for its independence for thirty years. In 1941 Eritrea was a victim of Ethiopia's claim for outlet to the sea. As well, the West's conspiracy with Ethiopia during the cold war rivalry with the East complicated the process of Eritrea's independence and this delayed it for fifty years thus costing this small nation dearly in terms of human, financial, and environmental resources. After a protracted and complicated thirty-year war of independence, Eritrea liberated itself almost single-handedly with little or no outside help. The liberation war was, at last, successful but it was accompanied and complicated by intermittent drought that caused devastation to the environment and to the socio-economic fiber of the Eritrean society, with refugees scattered all in all the continents and the loss of fifty years of valuable time. Eritrea, which had a well-maintained economic infrastructure in the 1950s and early 1960s¹¹, is now one of the poorest countries in the world. Table #1 below shows the position of Eritrea in regards to the human development index and in comparison to the statistics of other states of comparable size and status (UNDP Reports, 1999).

¹¹ Eritrea's industry used to export products to Europe and the Middle East.

Development Indicators	Eritrea	Namibia	Nicaragua	Lebanon	Croatia	Denmark
Population (millions)	3.5	1.7	4.7	3.4	4.7	5.3
Area (Km ²)	121,320	825,418	129,494	10,400	56,542	43,094
Life Expectancy (years)	51.8	44.9	68.1	72.9	73.6	76.1
Human Development Index ¹²	0.416	0.601	0.635	0.758	0.803	0.921
GDP per Capita (US \$, 1999)	880	5,468	2,279	4,705	7,387	25,869
Adult Literacy %	52.7	81.4	68.2	85.6	98.2	100
Population with Adequate Sanitation %	13	41	84	99	100	100
Population; Improved Water Sources %	46	77	79	100	95	100

Source: UNDP Report, 1999

Table 1: Demographic and economic data of Eritrea compared to nations of similar size or situation.

iv. Post-independence political situation

Immediately after liberation, Eritrea embarked on an intensive reconstruction drive with the liberation army volunteering to continue serving without any form of payment for three years. The landmark achievements in the first seven peaceful years of independence, among others, were a UN-supervised referendum that formally ended Eritrea's de-colonization process, demobilization of half of Eritrea's liberation army and their integration into the society, rehabilitation of badly damaged infrastructure with emphasis in the rural areas, issuance of an Eritrean currency – *the Nakfa* - and the drafting of a new constitution.

The border conflict with Ethiopia that erupted in mid-1998 and lasted for two years disrupted the brief peace and tranquility that the people of Eritrea enjoyed after half a century of war and instability. All development programs that the country embarked on in the wake of independence were interrupted. The war had a devastating effect on the

¹² The highest is 0.939 (Norway) and the lowest 0.258 (Sierra Leone).

meager financial assets of the country and on the human, and environmental resources. This war has totally changed the political outlook of many Eritrean citizens in relation to its southern neighbor and has affected their political opinions on their own domestic affairs. The aftermath of the war led to economic downturn, drought, and famine followed by internal political discontent. The government, led by a single party, preferred to suppress these internal political moves towards basic democratic process on the grounds that they were inspired by foreign forces and were detrimental to national security. This widened the differences of opinion and created further frustration followed by opposition by prominent politicians from within the ruling party, to incriminations, and detention. These actions led to the dire condition, in which the country is situated at the present time.

v. Socio-economic conditions

Almost 80% of the population of Eritrea depends on agriculture and animal husbandry for livelihood. The majority lives in the highlands and midlands - which have relatively cooler and moderate climates, respectively. The rest of the population lives in the lowlands – which have a hot and humid climate – and are mainly engaged in nomadic life with partially engaged in agriculture. The coastal and island population is engaged in fishery related activities, salt works and port services. The fishing communities are engaged in fishing both for subsistence and for income. While the men are involved in the harvest of fresh and dried fish and shark fins where they go fishing for up to a few weeks, their spouses and children are engaged in the collection of marine products such

as shells, snail nail etc. for export to Yemen, Saudi Arabia and Sudan where they are used to produce traditional perfumes.

Due to the lack of fresh water, the hot and humid climate and the saline soil, little agricultural or other economically active production are carried out in the coastal areas of Eritrea, except for fishing that takes place mainly in the southern parts and artisan salt works all along the coast. Industrial salt works are carried out in Massawa and Asseb. After the demarcation of the maritime boundary between Eritrea and Yemen in 1999 (Kwiatkowska 2001), a fisheries agreement¹³ was signed to coordinate utilization of the fishery resources of the two countries and to facilitate the operations of fishermen in each other's countries. However, this agreement has not yet been implemented because the Yemeni government continues to debate the demarcation of the maritime boundary in spite of the independent commission's decision on the maritime boundary.

vi. Food Security

Eritrea is not yet self-sufficient in food production mainly because the long-lasting effects of the war of liberation and the recent border conflict with Ethiopia have negatively affected the production infrastructure and human and financial resources of the country. A large portion of the work force is either enlisted in the army, or lives overseas. Intermittent droughts have also had negative effect on food and livestock production. However, Eritrea's land resources could potentially support domestic consumption and additional export production if appropriate land policy was planned and implemented.

¹³ Eritrea -Yemen Bilateral Agreement signed in 2000 in Yemen but it was not implemented and now the relations of the two countries have cooled down due to Yemen's involvement in the tri-partite alliance with Ethiopia and Sudan against the Eritrean government.

The deficiency in domestic food production is offset by imported and donated foods. The main staple foods produced in Eritrea include cereals and legumes, the annual production of which is shown in the graph below (Figure 4).

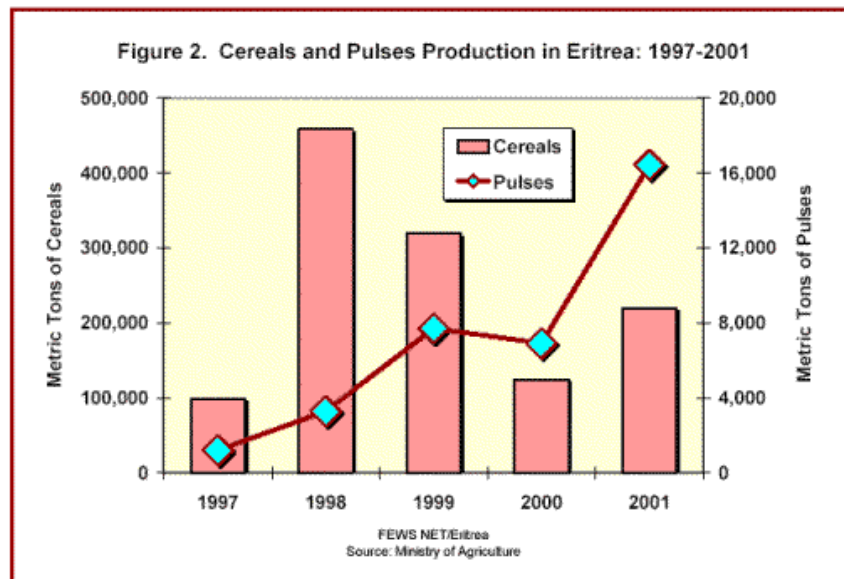


Figure 4: Cereal and pulses production in Eritrea 1997- 2001. (Source: MOA/FAO)

According to studies conducted by the Ministry of Agriculture of Eritrea and the Food and Agricultural Organization of the United Nations (FAO), the main caloric intake in Eritrea comes from lentils and chickpeas as shown in the illustration below (Figure 5). Fish is an insignificant component of the Eritrean daily diet. It is reported that the per capita consumption of fish in Eritrea is one (1) kg/capita/year, which is far lower than the world average of 16.4 kg/capita/year (Figure 6).

In 2000, per capita consumption of fishery products was as follows (in kg/capita/year): Japan – 69, S. Korea – 51, Philippines - 34, Spain – 33, US – 19, Bangladesh – 7, Egypt – 6, Algeria – 4, Sudan - 1 (FAO 2000). Eritrea’s per capita fish consumption is one of the lowest. In contrast to this low fish diet the contribution of fish in the daily diet in many regions is shown in the graph below as reported by FAO.

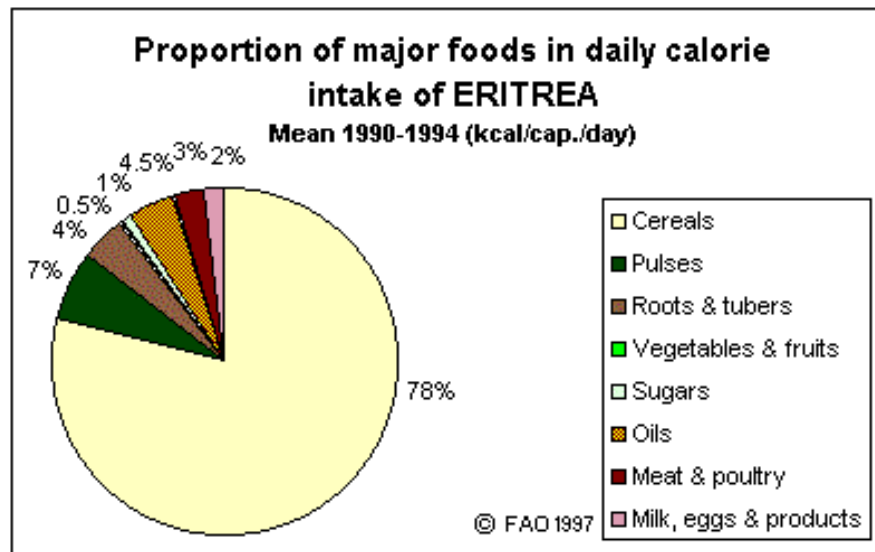


Fig. 5: Proportion of major foods in daily calorie intake in Eritrea

Role of Fisheries in Food Security

Seafood contributes to human nutrition more than any other food.

Fisheries are excellent sources of food security. Fisheries resources are the world’s most important source of animal protein, particularly important to the poorer segments of coastal societies. Fish contributes more animal protein for human consumption than beef and poultry combined. For many people in the developing countries, fish provides a good part of their basic needs of animal protein, and often is the cheapest or only affordable source of the vital nutrient. (Trott 2001)

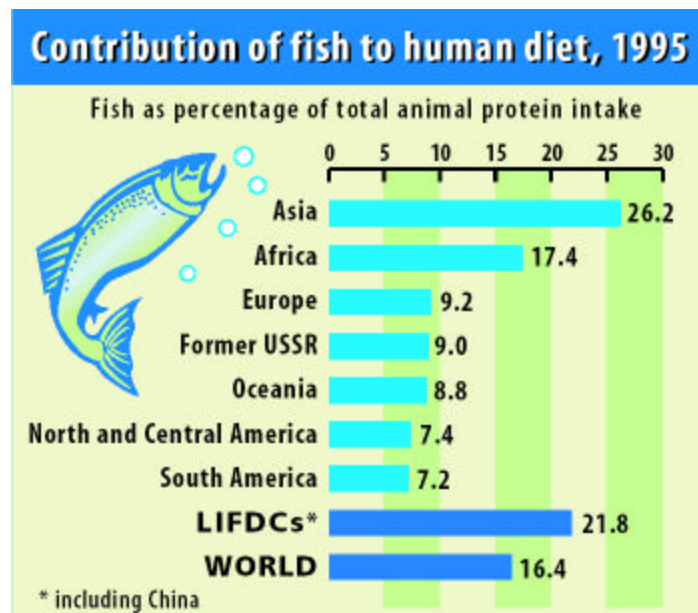


Fig.6: Contribution of fish in human diet, (FAO, 1995)

Achieving food security is recognized as an immense and urgent task by national governments, including the Government of Eritrea, and international organizations. The World Food Summit held in Rome in 1996 identified food security as a vital issue and has defined it as follows:

Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preference for an active healthy life.

The reality today, according to FAO:

More than 800 million people are food insecure, that is, they lack access to sufficient food to lead healthy and productive lives; 185 million pre-school children are seriously underweight for their age; micronutrient deficiencies are widespread with about 2,000 million people affected by iron deficiency, over 1,500 million people at risk of iodine deficiency, and 40 million children suffering from Vitamin A deficiency (FAO, 1996a).

This is true because fish provides important minerals and other components into the daily diet of humans according to a report by John Kurien.

Dietary intake of fish contributes to lysine; poly-unsaturated fats; minerals such as calcium, phosphorus, iron; vitamins A, B1, B2, B12, D, etc.; and trace elements like iodine and zinc. These nutritional attributes make fish a vital contributor to food security of the most deprived and vulnerable populations: the underweight pre-school children and those suffering from vitamin and micronutrient deficiencies. For them, easily digestible fish is indispensable; other natural animal or vegetable protein sources are poor substitutes on both nutritional and economic grounds.

Products like shrimp, lobsters and blue-fin tuna are the icons of highly profitable, value added international trade termed as “luxury consumption”. Products like anchovies, sardines and herring, are the icons of food security. Only such species can provide the volumes necessary to satisfy this need. What is required to ensure food security in the world today is the production of and trade for “nutritional consumption”.

Aquaculture and Food Security

Aquaculture has a positive role to play in improving food security and alleviating poverty, disease, and illiteracy, which are global menaces that are rampant in the developing world. Enhancing food security and alleviating poverty along with the provision of adequate health and educational services are global priorities that have not been adequately addressed. The Food and Agriculture Organization of the UN and Network of Aquaculture Centers in Asia-Pacific (NACA) in their February 2000 Conference on Aquaculture Development in the Third Millennium in Bangkok have declared an aquaculture development strategy covering, among other things, food security, poverty alleviation, and rural development. They declared that:

Aquaculture has a special role to play in achieving these objectives because, firstly, fish is a highly nutritious food that forms an essential, if not indispensable, part of the diet of a large proportion of the people in developing countries. Secondly, while aquaculture contributes to the livelihoods of poor farming households, particularly in areas of Asia where it is traditional farming practice,

there is a huge, unfulfilled potential, in most countries, as aquaculture is a relatively recent and undeveloped sector as compared to agriculture and animal husbandry.

In Eritrea and other developing countries aquaculture could improve food security and contribute to sustainable livelihoods of the poor by following the principles declared in the said conference through:

- Promoting aquaculture development for the poor communities;
- Introducing the farming systems of low-value fish affordable to the poor;
- Promoting the nutritional advantages of fish to the vulnerable groups of people;
- Using holistic participatory approaches to identify the poor and access their needs;
- Developing and extending- aquaculture technologies appropriate to the resources and capabilities of poor households;
- Developing small-scale aquaculture through public sector intervention;
- Empowering poor stakeholders to actively participate in policy decision-making.

vii. The Eritrean economy

At the end of Italian colonial rule in 1941 Eritrea had a well-established economic infrastructure, including a fisheries industry, which was initially dismantled by the British Military Administration in the forties and crippled by successive Ethiopian regimes.

What remained was later destroyed with the intensification of the war. The export sector, which used to send products to Europe and the Middle East in the 1950s and 1960s, was incapacitated by the nationalization policy of the former Ethiopian military regime in the 1970s.

After independence in 1991, the Provisional Government of Eritrea inherited obsolete infrastructure facilities and industrial machinery. In the years that followed an attempt was made to rehabilitate these facilities mainly with domestic resources. By mid 2001, 34 of the 39 public enterprises - most of them rehabilitated - were partly or fully privatized. Foreign investors were among the buyers or joint venture partners.

Following independence exports were limited to basic commodities and consumer products that did not generate the foreign exchange¹⁴ needed to import machinery, equipment and production inputs. Through the immediate rehabilitation of the existing industry, and government investment in strategic sectors of the economy, the emergency needs of the people and economic recovery for the long-term growth was initiated. In the years from 1994-1997 impressive economic growth of 7% was recorded until it steadily fell for the next three years with the outbreak of the border conflict in 1998. Since the cessation of the war the economy has again gained momentum and has started to improve (SOE 2001).

i. Trade Relations

The balance of payment of the country has been showing on the negative due mainly to the aftermath of the war and lately the recent border conflict that engaged a considerable amount of the country's human and financial resources. The effects of these wars will still linger in the years to come. With the cessation of hostilities the economic situation has shown some improvement. Exportable items such as fish, fruits and

¹⁴ The main trading partner was Ethiopia and the trading currency was the *Ethiopian Birr*.

vegetables, cotton and oil seeds, livestock, leather and leather products, textiles, marble, granite and silica sand are products with potential markets (SOE 2001). The import and export status for the years from 1997 – 2000 is shown in the table below.

Item/Year	1997	1998	1999	2000
Imports in US\$ (CIF)	489.5	526.8	506.9	360.2
Exports in US\$ (FOB)	53.1	27.9	26.3	19.7

Table 2: Trends of Exports and Imports for the Years 1997-2000 (Source: IMF/GOE/DOC, 2002)

B. How important are coastal resources to the Eritrean economy?

Eritrea’s northern coasts are flat plains stretching roughly 600 km to the north from Massawa and range from 25 to 40 km in width. The southern half stretching roughly the same distance from Massawa consists of flat plains, volcanic rocks and rugged hills. Overall these coasts consist of arid and semi-desert areas devoid of any vegetation except for some halophyte shrubs here and there and other types of trees along the banks of the dry river beds. There are some mangrove trees on the deltas of the seasonal rivers or marsas, as they are known locally. These coastal areas are of little economic use at the present time, except for some traditional cultivation activities on the deltas of the seasonal rivers.

In the 1960s, the coastal areas were economically active with agriculture, salt production and oil and gas explorations that were later interrupted with the intensification of the war in the 1970s. There were formerly commercial cotton, sisal and durra/millet plantations near Marsa Gulbub that were irrigated from the dam at Marsa Gulbub built by

the Barratollo Cotton Company based in Asmara. Remains of salt works are visible north of the village of Wokiro indicating the existence of a commercial salt works owned and operated by Italian companies. Some residents of Wokiro remember a large salt work, employing up to 500 workers, on the white plains north of Massawa as illustrated on the satellite map of the northern coasts of Eritrea (Figure7).



Figure 7: A satellite map of Eritrea (Source: Steve Drury, 2002).

i. Sea-based Resources

a. Marine Fisheries

The marine fishery resources of Eritrea consist of pelagic and demersal fisheries and reef fishes and crustaceans are extensive fisheries estimated to have a maximum sustainable yield of 60-80,000 metric tons annually as shown in (Table #3) below. This estimate is based on studies for commercial purposes carried out in the 1950s and 1960s. An attempt has been made by the Ministry of Fisheries to update and re-evaluate these studies through a continuous recording of all fish landings. A fisheries stock assessment

that covered about half of the territorial waters of Eritrea jointly carried out in 1997 jointly by the Ministry of Fisheries and the French Marine Research Institute (IFREMER) gives a rough estimate of the current stock of the Eritrea's fisheries¹⁵. Since the IFREMER study did not cover the whole territorial waters of Eritrea, this assessment must be expanded and combined with analysis of the daily landings.

The table below shows the distribution of species of Eritrean marine fisheries.:

Category	Species	Weight	% of total MSY
Coral Fishes	Grouper		
	Snapper		
	Emperor	5,000	5%
	Job Fish		
	Jack Fish		
Demersal Fishes		17-34,000	40%
Small Pelagic Fishes	Sardines	30-42,000	42%
	Anchovies		
Large pelagic Fishes	Spanish mackerel		
	Barracuda	5,000	6%
	Small Tuna		
Sharks	White tip Reef sharks	2-5,000	6%
	Black tip Reef sharks		
Crustaceans	Lobster	500	
	Crabs		1%
	Shrimp	500	
Total		60-80,000	100%

Source: MOFISH, 1998

Table 3: Composition of Eritrean marine fisheries

¹⁵ IFREMER is the French Marine Research Institute.

The nation's fisheries sector was very active throughout the 1950's and 1960's but declined in the following decades, but is now on the rise. It is now considered one of the main potential sectors of the nation's economy. The marine fisheries of Eritrea are composed of two complementary types of fishing, namely, artisanal and industrial fisheries. An Eritrean fleet of traditional wooden boats and fiber glass long-liners and trawlers are active to ensure a continuous supply for the domestic market while a fleet of foreign fishing vessels 25 – 35 m length operate in the Eritrea's EEZ for the export market.

1. Artisanal fishery

The artisan fishery consists of about 600 fishing boats centered in Massawa, Tio, and Asseb. This fishery may actually be growing with the completion of new fish landing facilities in Galalo, Tio, and Eddi financed through loan from the African Development Bank where fisheries infrastructure development is underway with the objective of establishing new fishing harbors along the coast between Massawa and Asseb (MOFISH, 1998). Development of this coastal area is expected to grow rapidly now that the Massawa commercial port has been expanded, the Massawa International Airport is almost complete to start operation, a new national carrier has started operation by April, 2003 and the travel time by road connecting Massawa and Asseb has been shorted to 10 hours and is to be asphalted in 2003-2004. The artisan fishery is targeting mainly the reef fishes and the middle-sized pelagic species.

2. Industrial fishery

Industrial fishery in Eritrea mainly consists of foreign fishing vessels and focuses on the demersal resources of the continental shelf usually in depths greater than 30m, beyond the limits of artisan fisheries. Industrial fisheries by foreign fishing vessels started in 1994 with the issuance of fishing licenses first to Egyptian, Saudi Arabian and Israeli companies and continued to operate till the end of 1996 when these licenses were withdrawn as shown by the drop in production in 1997 and 1998 (Table 4). The withdrawal was because these companies did not meet the requirements for long-term investment. Again in mid-1999, with the signing of bilateral fisheries agreements with the governments of Egypt and Saudi Arabia, licenses were reissued to fishing companies from these countries and fishing operations resumed, leading to increase in fish production as illustrated below (Table 4). These fishing operations and the export of fish by these companies continued till the 2003. The main species caught and exported included: lizardfish (28%), Jack (18%), threadfin bream (15%), grunts (9%) and catfish (7%), barracuda (5%), shrimp (4%) and others (7%) (MOFish 2000).

Foreign fishing companies were charged a royalty of 20% on the fish and 10% on by-catch calculated on preset unit values of gross tonnage of wild fisheries products. Two government inspectors (fishing officers) accompanied each fishing trip to verify the amount caught for royalty purposes, and to control that fishing methods and operations are carried out within the set laws. The charge on the by-catch was to discourage the fishing companies from increasing the amount of by-catch looking for targeted species.

This 10% charge was, however, waived if the companies show proof that they have utilized and not discarded the by-catch by selling or otherwise¹⁶.

3. Fresh Water Fisheries

Eritrea has no lakes or rivers that flow year round. In the last forty to fifty years drought has devastated the ecology of the country: those rivers that use to flow year round have now dried up. Some people remember when it was possible to see crocodiles and to catch fish in Mereb River on the border with Ethiopia¹⁷. The only fresh water bodies now available in Eritrea are the artificial reservoirs or dams built in the highlands for the purpose of collecting water for municipal and irrigation use¹⁸. The Ministry of Fisheries has introduced fresh water fish, such as tilapia; carp and catfish, in some of the reservoirs associated with these dams and is monitoring their progress.

4. Fish production and marketing

Eritrea's annual fish production is small compared to neighboring countries like Yemen and Saudi Arabia. Eritrea's potential estimate maximum sustainable yield (MSY) of marine fisheries has not yet been fully exploited. So far, only a quarter of this MSY is being harvested annually. With an increase in the production capacity and an improvement in the efficiency of the fishing effort, it would be possible to considerably

¹⁶ This is personal observation of the author while serving as Director General of the Department of Resources Management at the Ministry of Fisheries.

¹⁷ This is personal communication of the author with Seyum Ghebremariam who used to fish in Mereb River in the 1960s. He now resides in the US.

¹⁸ Due to high evaporation rates it is not feasible to built dams in the lowlands of Eritrea.

increase the annual catch to the limits of estimated MSY. Table # 4 shows the production trend for the past seven years.

Production (tons)	1994	1995	1996	1997	1998	1999	2000
Industrial Fisheries	2,275	3,262	2,454	38 ¹⁹	504	5,659	12,000
Artisan Fisheries	394	511	818	712	1,098	1,062	3,000
Total	2,669	3,772	3,272	840	1,602	6,721	15,000

Table 4: Marine fisheries production of Eritrea (source: MOFISH, 2000)

Most of the fish harvested was exported. The domestic consumption was 3,000 tons in 2000. The amount of exported fish for the three years (1998-2000) is shown in the table below.

Year	Exported Fish (MT)
1998	570
1999	5,900
2000	12,000

Table 5: Eritrea's export of fish. (MOFISH, 2000)

To address the role of fisheries in Eritrea's economy we need to examine the fisheries sector before and after the war of independence. Like other sectors of the economy in Eritrea, fisheries have been badly damaged by the war; therefore, the role that the fisheries sector has played in Eritrea's economy before and after the war varies.

¹⁹ No foreign fishing vessel licenses were issued in 1997 and 1998; figures shown are only for artisan fishing vessels.

5. The fisheries sector before independence

This pre-independence period can be divided into two sub-periods, the first spanning from the Italian colonial period until the early 1960s and the second covering the duration of the liberation war, which lasted from 1961 up to independence in 1991. During the first sub-period, fishing activities were first developed from subsistence levels using canoes and small plank boats under sail and oar. Motorized boats followed this in the 1950s. Fisheries developed rapidly, particularly the small pelagic fishery for sardine and anchovy, which makes up about 60% of the known fish resources in Eritrean waters. This small pelagic fishery was active along the Eritrean coast in the 1960s with production of up to 25,000 tons and an employment of up to 20,000 people, including seasonal workers. Exports of fish meal and dried fish were sent to Europe and Asia. Beach seining was the main fishing method, with one party of fishermen spreading the catch out on the beach to dry, and a second party, often including women, following behind to collect the dried product (Reynolds 1993).

The second sub-period is influenced by the intensification of the war in the second half of 1960s. This brought the fishery into decline and by 1975 production had ceased. There was also a large drop in production in 1967 due to the closure of the Suez Canal following the six-day Arab-Israeli war as shown in the graph below (Figure 7).

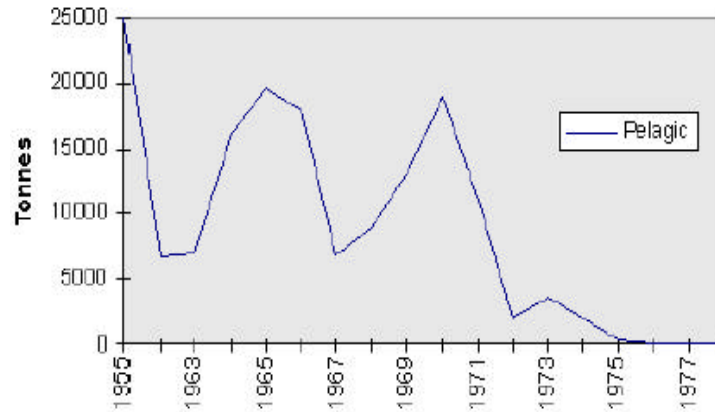


Figure 7: Trend of production of Small pelagic fish from 1955-1977 (Source: FAO, 1994)

Prior to the war of independence, there was also a fishery for demersal species, sharks, and crustaceans as shown in graph below (Figure 8). The most notable observation is the corresponding sharp increase in shark production for regional markets with the temporary closure of small pelagic markets in 1967 (FAO, 1993).

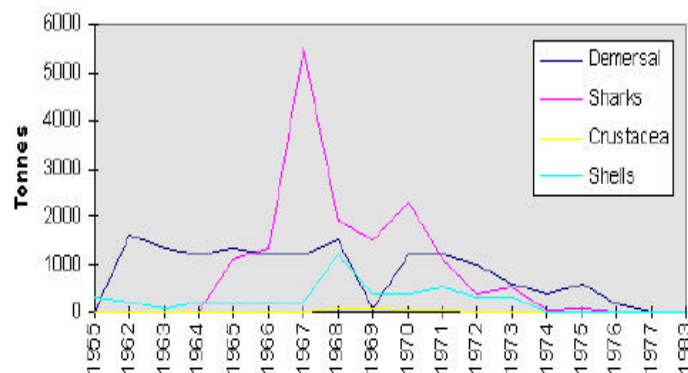


Fig.8: Production of demersal, sharks, crustaceans and shells from 1955-1977 (Source: FAO, 1994)

Not only were the functioning fisheries infrastructures destroyed and the fishing communities dispersed by the war, but also no effort was made by the then occupying Ethiopian regime to economically utilize the marine sector. The fisheries and other

coastal resources have been intentionally neglected for more than three decades, partly to undermine Eritrea's coastal wealth and partly due to the security situation. This is clearly elaborated by Mr. Saleh S. Meky, the former Minister of Fisheries, who said:

The deliberate isolationist policies of the Ethiopian Empire over-time, alienated our people from the sea-culture for so long that the present generation of Eritreans have only mystic and idealized relationship with the sea, which has little relevance to their daily lives. No other element in the history of our nation has touched our lives so deeply, while none is so remote from our thoughts that one wonders at the "success" of successive Empires in detaching us from what makes us what we are (MMR 1996).

6. The fisheries sector after independence

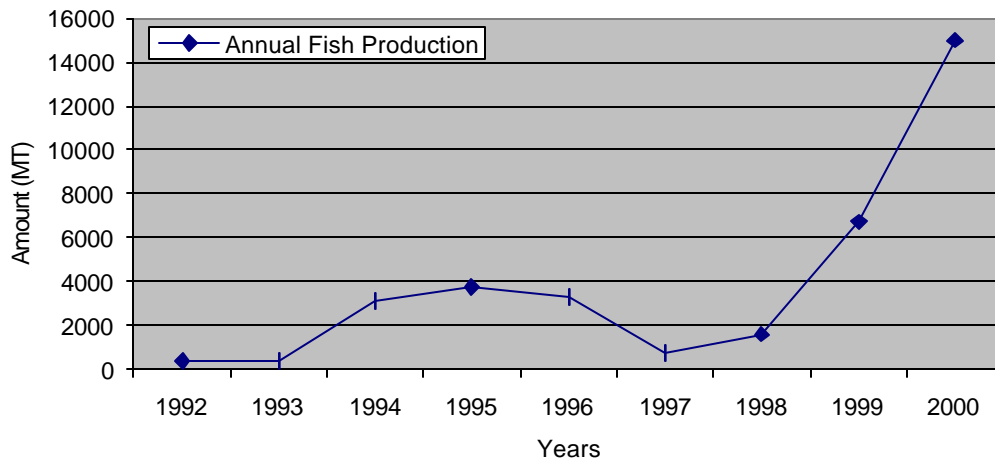
Fisheries management was re-established after independence with the inception of the Department of Marine Resources and Inland Fisheries at the end of 1991. The Department was established with the objective of creating an institution capable of organizing the fishing community, rehabilitating the fishing industry, and overseeing the overall management of the fisheries sector. The Department initially incorporated the aquaculture unit located within the Eritrean Navy. Dr. Gordon Sato²⁰ supported this unit, which was involved in the experimental cultivation of mullet in land-based ponds. This was the only fisheries-related activity when the Department was initially organized. The institutional development and the rehabilitation of fisheries infrastructure required the injection of badly needed development funds and expertise from multi-lateral organizations mainly the UNDP and FAO.

The revival of production started by supporting artisanal fishermen with badly needed inputs. The artisanal fisheries supplied the domestic market with fish and

²⁰ Dr. Gordon Sato is a Japanese-American scientist who has relentlessly supported towards the introduction of aquaculture during the struggle for independence starting in 1988 with his personal involvement and own resources.

eventually led to the exportation of fish to neighboring countries and to Europe. Later on, the Department began issuing fishing licenses to foreign fishing vessels as a means of deterring illegal fishing in Eritrean waters that was prevalent in the early years of independence. Gradually, production increased with the increase in licenses issued to artisan and foreign vessels as shown in the following graph (Figure 9).

Figure 9: Annual fish production of Eritrean fisheries from 1992-2000
Source: MoFish, 2001



As seen in Figure 9, the production capacity for the year 2000 was 15,000 tons. This was only one quarter of the estimated annual sustainable yield of 60,000 tons. Of the 15,000 tons produced, the domestic market consumed a reported 3,000 tons. The amount consumed by the fishing communities and the coastal rural areas was not reported.

The revenue received by the government was based on a charge of 20% royalty on the overall value of the exported amount of fresh unprocessed fish while 10% was charged for processed products. On this basis, an estimated average of about US \$ 2.5 million was earned from royalties for the year 2000. Fully operational processing plants

were projected to generate twice this amount of royalties, or \$ 5.0 million. Therefore, \$ 7.5 - 8.0 million (US) was estimated to be a quarter of the capacity of Eritrea's MSY, which is the sustainable, renewable fisheries. Additional benefits could be earned from employment, taxes and the development of support services such as construction and transportation.

b. Port services

Eritrea's two main outlets to the sea are the ports of Massawa and Asseb. They are vital sources of revenue for the nation and the main sources of employment and income generation for the urban population of the coastal regions. Due to the closure of the Ethiopia border, however, the port of Asseb has been idle for a few years. Given the location of these Eritrean ports in the Red Sea, however, there is a tremendous potential for the development of port services that in turn have the potential to boost Eritrea's international trade. When peace returns to the Horn of Africa region, and when the policy makers in the region start to plan in terms of economic values for their constituencies, these two ports can serve the neighboring countries of Ethiopia and Sudan and international shipping lines because they are ideally located in the southern and central parts of the Red Sea. Because of these factors, the government of Eritrea plans to convert the port of Massawa into a free trade zone and the port of Asseb into a transshipment port.

c. Tourism development

Rich and diverse coral reefs, bays, beaches and pristine unpolluted waters characterize Eritrea's coastal and marine ecosystems. In addition, the scenic Eritrean countryside, the cultural diversity and welcoming nature of the society could lead to the development of ecotourism as an alternative to fisheries development, which is relatively more destructive to the marine environment. Possible tourist markets include the Middle East, Europe and North America. Tourists from Italy, with whom Eritrea has a colonial linkage, are already frequent visitors to the islands.

d. Offshore oil and gas

Exploratory studies carried out in the 1960s indicate the potential for the development of oil and gas resources in Eritrea's coastal and continental shelves. After Eritrea's independence an American firm, Anadarko Oil Company, carried out an exploratory search for oil and natural gas and obtain encouraging results but its activities were interrupted with the eruption of the border conflict in 1998. In May 2001, the government of Eritrea signed with a US firm to explore petroleum and natural gas sources. The government is also interested in developing alternate sources of energy, including geothermal, wind and solar energies that are prevalent in the southern coasts of the country²¹.

²¹ Department of Commerce, USA,

ii. Land-based resources

a. Cement production

Currently the state owned Massawa Cement Plant, established in the 1950's, produces about 70,000 MT a year. There are vast sources of raw materials for the production of cement in the coasts south of Massawa and around Tio halfway along the route to Asseb. A number of attempts have been made to involve foreign investors, including one from South Korea, in cement industry but the attempts proved futile. The press recently reported that the government has made a deal with Pakistani investors to study the possibility of investment in cement production.

b. Salt works

Salt-works was an active industry in the 1960's when emptied oil tankers²² were loaded with salt to Japan and other destinations. There are two state owned salt production plants in Massawa and Asseb with a current combined production of about 250,000 MT a year. The Asseb plant has the potential to grow up to one million metric tons a year. Due to inadequate marketing and the conflict with neighboring Ethiopia, one of the main markets, the production capacity has not yet been achieved.

The high salinity of the Red Sea and the high temperatures in the coastal areas make salt production a viable industry that requires nothing but abundant solar energy and disposable land. The main markets for salt are southern and central Africa, Europe

²² Oil tankers come to Eritrea loaded with crude petroleum for the refinery in Asseb and on their way back to Japan or Europe they were loaded with salt from the salt for industrial purposes.

and Japan. With the injection of capital and introduction of technology, salt can be a basic raw material for a series of industrial products.

c. Aquaculture development

Aquaculture is relatively a new phenomenon to Eritrea. During the struggle for independence, Dr. Gordon Sato introduced aquaculture in Eritrea in 1988 by training members of the Eritrean Navy on how to culture fish in ponds. Under Manzanar Project he tested the production of mullet for human consumption, and experimented on the production of artemia cysts as feed for shrimp culture, which he expected to export. He also worked on the plantation of halophyte trees, mangroves, to forest the barren coastal areas of Eritrea. The objective of Manzanar Project according to Sato is “ the alleviation of poverty, hunger, environmental pollution, and global warming through seawater aquaculture and silviculture in deserts”. He still continues the mangrove forestation project to this day. He was recently awarded a 2002 Rolex Laureate for Enterprise in Japan for his practical mangrove forestation activities in Eritrea²³.

In the years after independence, a number of companies, including from Italy, showed interest in starting aquaculture activities in Eritrea but none of them have come forward. However, later in 1998 an American firm initiated an integrated shrimp-farming undertaking and the government of Eritrea fully supported the project. The venture is involved in land-based aquaculture and started commercial operation in 2000.

²³ Manzanar Project website: <http://www.tamu.edu/ccbn/dewitt/manzanar/manzmain.htm> accessed on May 9, 2003.

C. Current aquaculture development in Eritrea

i. Introduction

Dr. Carl Hodges of Planetary Design Corporation²⁴, a Phoenix, Arizona based firm initiated the concept of commercial aquaculture in Eritrea in 1998. The firm, after an identification mission, decided to start an integrated shrimp farming project and signed an agreement with the government of Eritrea to form a joint venture company -Seawater Farms Eritrea (SFE) - to operate the business of integrated seawater farming, mainly shrimp/tilapia culture, Salicornia farming and the development of wetlands. A pilot project was implemented for a year and a half and then in 2000 shifted to commercial scale after the results of the experimental phase were successful. In spite of many obstacles, including the lack of adequate aquaculture related experience, shortage of trained personnel, cost of importing expertise and technologies from Arizona and post larvae shrimp and Salicornia seeds from Mexico, and the problems created by the border conflict with Ethiopia, the company has registered remarkable progress in a short span of time. The firm is now producing shrimps and tilapia from its own hatchery, Salicornia seeds from its own fields in Eritrea and it has developed a wetland, home to over 180 species of seabirds, on a hitherto arid and dusty coastal landscape.

In 2000 the management of Seawater Farms Eritrea forecasted an export income of \$3-4 million in 2001, \$10 million in 2002 and \$40-50 million in 2003 and by 2005 \$100 million (Shillinger 2001). The company may not have been able to meet these projected plans given the cloudy atmosphere under which the farm was operating in

²⁴ Planetary Design Corporation was later renamed as Seaphire International. A new parent company under a different name is now managing the shrimp farming business in Eritrea.

2001- 2003 following the transition in the management of the farm. Although, no additional information was provided by the SFE to substantiate this forecast, it is an indication that Eritrea has the potential to earn substantial amounts a year from shrimp farming if an atmosphere conducive to aquaculture business is put in place.

ii. **Integrated Seawater Farming – Application of Systems Ecology**

Integrated seawater farming in Eritrea is a new system of aquaculture and is one of the few unique aquaculture undertakings around the world²⁵. Integrated seawater farming - **Systems Ecology**, which is the manifestation of the interaction between the atmosphere, the soil and its micro- organisms, and the primary producers (Salicornia, mangrove), involving both productive processes (plant growth, symbioses between plants and micro-organisms) and destructive processes (decomposition of feed by shrimp)²⁶. The operation of integrated seawater farming, which is based on the synergy of aquaculture and agriculture, has three main components – shrimp and tilapia culture, Salicornia farming and wetlands development. The initiator of this business enterprise, Carl Hodges, predicts that in the future tourism could be added to this integrated seawater farming as a fourth component thus utilizing the tourism development opportunities along the coastal areas of Eritrea. For the purpose of this thesis I focus only on shrimp farming, but brief descriptions are made on the other components.

²⁵ Personal communication with Carl Hodges

²⁶ Electronic source, website of Vrije Universiteit Amsterdam, Faculty Biology, Systems Ecology, Amsterdam, The Netherlands. http://www.bio.vu.nl/html/systems_ecology.html, access date: May 9, 2003

a) Shrimp and tilapia culture is carried out in cement and earthen ponds, respectively, as illustrated in Figure 11 on the following pages. Emphasis is made for the production of shrimp, due to its high value, as will be discussed in the following section.

b) Salicornia cultivation. *Salicornia* is a halophyte crop irrigated by the effluent waters from the shrimp and tilapia ponds. This is an application of industrial ecology by SFE where the effluents of aquaculture are directly utilized in irrigating agricultural fields. The nutrient loaded effluent waters are also good as fertilizers in the *Salicornia* fields²⁷. *Salicornia* seeds are extracted to produce edible oil, which can also be used as a raw material in the cosmetics industry. The solid extract from *Salicornia* is utilized in the production of fishmeal. The stem and the leaves of the *Salicornia* plant are used in the production of cardboard, fire logs and can also be used as a source of pulp in the paper industry if produced in large quantities. The tips of fresh *Salicornia* plant are eaten as a salad.

c) Wetlands development is the creation of an ecological garden in the middle of the desert solely from the excess effluents of the integrated seawater farming. A mangrove nursery at SFE (Figure 10) provides different species of mangrove. There are several species of mangroves that are used as a means of filtration, particularly to reduce nitrates and other toxins in a saltwater. Two species of mangrove are common in Eritrea: *Avicinia marina* and *Rhizophora mucronata*. They possess a number of unique peculiarities in the flora world, which make them adaptable to many environments.

²⁷ A personal communication with Carl Hodges.

Mangroves are plants that live in freshwater swamps, and along brackish and salt water shoreline areas. They have the ability to live in saltwater by straining freshwater from the saltwater through their roots. The cells in the roots take in water, but because the cells are so small, they do not allow the salt molecules to be absorbed. Introduction of mangroves is done by way of the seeds, which look like long pods that are fat at the bottom (root area) and skinny at the top (leaf growing area). Newly produced seeds float around on water tides and currents, until they finally come to roost. The seeds only need a short period of non-movement to start anchoring into mud, sand, or rock structures they often get trapped in between where they start to grow²⁸.



Figure 10: A nursery for mangrove plantation at the wetlands in SFE, Massawa (Source: SFE, 2001).

²⁸ Source: <http://saltaquarium.about.com/library/weekly/aa110600.htm>, access date, May 9, 2003.

iii. Shrimp Farming

Shrimp farming as a crucial part of the integrated seawater farming operations has three main component parts operated independently of each other. They are: shrimp hatchery, feed operation, and shrimp production. The technologies in all three components are new to Eritrea and at the beginning of the pilot phase almost everything was imported from abroad. Now three years into the operation of shrimp farming many of the necessary parts are either made or modified locally, thus the company by developing its own maintenance workshop and utilizing indigenous resources and knowledge, is trying to minimize expenses and to save valuable time wasted in waiting for imported items.

It might too early to assess the income generated by the government so far from the operations of this shrimp farm. The company is in its early phase and the past three to four years have been a period of establishment for the company. It is not yet clear how the authorities are regulating the operations of the company, as there have not been regulations pertaining to aquaculture until end of 2000.

a. Shrimp hatchery

In the beginning the company imported shrimp Post Larvae (PL), of the species *Penaeus Vannamei*, from Mexico. At one time 250,000 PLs were transported in a 700 liters container. The cost of the PLs from Mexico was \$ 8.00 per 1000 PLs, shipment cost \$ 5 per 1 Kg. Therefore, to import 250,000 PLs from Mexico the company had to pay \$ 5,500. Survival rate of the PLs imported in this way is as low as 50%, because of changes

in temperatures and pressure, damage due to movement during transportation and lack of oxygen (SFE, 2003).

The importation of foreign shrimp Pls is economically not viable and biologically unacceptable. This is due to the introduction of non-indigenous species, which could affect the wild stocks of shrimp if the exotic species somehow escape into the wild. If they happen to escape into the Red Sea these imported shrimp species compete for food and space with the wild populations of Red Sea shrimps. They could also genetically interact with the indigenous species. Movement of shrimp species for aquaculture can also increase the risk of spreading shrimp diseases. The spread of viral shrimp diseases such as White spot and Yellow head caused catastrophic, multi-million dollar crop losses in shrimp farms across Asia in the early 1990s (Naylor 2000).

In 2000 SFE started to build its own hatchery and a year later this new hatchery was put into operation, therefore the importation of shrimp Pls from Mexico was halted. The hatchery has an annual production capacity of 42,000,000 Pls, of the originally imported species *P. Vannamei* and the indigenous one *P. Indicus*, at a production cost of \$ 7.00 per 1000 Pls (SFE 2003). This is almost half the cost of imported Pls and with further research the cost could still be reduced to lower levels.

b. Shrimp feed operations

After importing shrimp feed during the start up period for the pilot project SFE opened its own feed plant and started to produce its own shrimp feed formula from local

and imported components. The main ingredients for the production of shrimp feed at SFE²⁹ are as follows:

- Fish meal - processed on site from offal and by catches.
- Algae - used for binding and as filler in the diet formulation by significantly reducing its ash content by acid treatment. Costs involved include manpower for harvesting, treatment/processing.
- Shrimp heads - are vital ingredients after treating them with acid.
- Brewer's yeast - a source of protein when there is shortage of fishmeal.
- Soybean- source of protein is imported when fish meal is scarce.
- Lecithin, ethoxyquin, vitamin premixes imported stuffs.

For 2003 the company has projected a production of 2.4 tons a day of shrimp feed³⁰. This makes an annual production of 876 tons and the total cost of production is estimated to be \$ 384, 660. Therefore, the cost of shrimp feed is \$0.44/kg and the feed conversion ratio (FCR) is 2.5:1 meaning 2.5 kg of feed gives 1 kg of shrimp (SFE 2003).

c. Shrimp production

Seawater Farms Eritrea has two types of grow out ponds, cement and earthen ponds. The cement ponds are circular and are of two sizes: 300 m² and 500 m². There are 124 of the 300-m² and 29 of the 500-m² cement ponds for a total of 153 circular cement

²⁹ Personal communication with Desale Berhe, the head of the Feed Operations Unit of SFE, now at the University of Arizona, Tucson, Arizona, USA.

³⁰ The excess feed is consumed by the tilapia culture operation and some of it is also sold to the poultry farms in the country.

ponds. There are several earthen ponds where shrimp and tilapia are cultured. Figure 11 below shows a partial view of the shrimp farm.

The PLs from the hatchery are sent to the nursery ponds where they mature for about three weeks. The survival rate at the nursery ponds is 75%. They are then distributed into grow out ponds where they mature to harvest size. Total cost of production is \$ 6,747.84/pond/year. Harvest per 300-m² ponds is 600 kg of shrimp per crop. Two crops are harvested year. Therefore, annual harvest per pond is 1200 kg/year and the cost of production is \$ 4.11/kg/year – this is the farm gate price of SFE shrimp. Other costs include processing and packaging of \$ 1.00/kg at a local processing plant and airfreight to Europe at \$ 2.70/kg. Therefore, total cost of shrimp production and airfreight is \$ 7.81/kg



Figure 11: A partial view of the shrimp farm in Massawa

Estimated annual sales of shrimp for 2003 is 190 tons and the expected revenue is \$ 1,803,100.00. From this it follows that the export price of the shrimp to Europe is \$ 9.5/kg, since freight costs to the Middle East is much lower the export price to the Middle Eastern countries will be lesser (SFE 2003).

iv. Species Cultured

The main species of shrimp cultured by Seawater Farms Eritrea is *Penaeus vannamei* introduced as post larvae from Mexico in the early period when the farm did not have a hatchery. Now that the farm has its own hatchery, the Pls are produced locally in Eritrea from brood stock of indigenous origin. Local specimens of the *Penaeus indicus* have been collected from the coastal areas of Eritrea and are now used in the reproduction ponds. In addition, there are also small quantities of *Penaeus monodon* introduced together with the *Penaeus vannamei*.



Figure 12: Shrimp (*P. Vannamei*) cultured at SFE (Source: SFE, 2000)

v. The rational behind shrimp culture in Eritrea

The focus on shrimp culture in Eritrea is driven by two factors:

First, the Red Sea is a nearly closed waterway with no perennial rivers flowing into it supplying fresh nutrients other than the seasonal streams that join it. The major source of

nutrients is the Indian Ocean through the southern inlet of Babb El Mendeb. Therefore the productivity of the Red Sea is greatly affected by this lack of continuous flow of nutrient carrying rivers thus affecting its productivity and salinity³¹.

It is believed that the Maximum Sustainable Yield (MSY) of Eritrea's marine fisheries resources is estimated to be about 60-80,000 metric tons per year. So far, a quarter of this amount has been harvested annually. Even if it is possible to harvest the maximum amount possible every year this harvest will generate a limited amount of revenue with no room for growth. It is estimated that the maximum value that the marine resources could create would be \$ 7.5-8.0 millions dollars a year. The development of one land-based shrimp farm production facility is claimed to generate a value in the range \$ 100 millions of dollars a year with the possibility of growth from additional activities of ancillary industry and the integration of aquaculture with seawater agriculture. The additional socio-economic advantages in terms of employment, revenue generation, infrastructure development and the provision of services for population settlement in the areas adjacent to the shrimp farms etc. could be enormous. This could cause environmental impacts, some known and others perceived, although little social impacts are expected due to the absence of settlements along the coastal areas.

Secondly, Eritrea is gifted with a long coastline and a number of archipelagos with a wide continental shelf that is home to abundant resources of fish and other marine resources. Eritrea's coastal and marine ecosystems are rich with diverse coral reefs, bays,

³¹ The Red Sea has one of the highest salinities of up to 4 parts per thousand (ppt).

beaches and clear unpolluted waters that represent a physical source base for the potentially rich and unexploited fisheries and could be a source for the development of eco-tourism. The developments of industrial marine fisheries will, no doubt, jeopardize these ecosystems, as is the case with most coastal fisheries in many parts of the world. It is necessary for policy makers consider maintaining these ecosystems by encouraging investment on the development of sustainable land-based shrimp farming, ecotourism, and artisan fisheries in place of industrial marine fisheries. Eco-tourism, if developed sustainably, could generate additional sources of foreign currency.

Fish and crustaceans – shrimp, lobsters and crabs – are not popular food items among the majority of the Eritrean population mainly because they have not been promoted as valuable foods. In addition, due to the limitations on population movements to the coastal areas during the years of the struggle for independence, the population had been deprived of exposure to the sea and thus has had little interaction with the coastal areas, the sea and seafood. The production of marine fisheries was almost halted in the 1980s during the war of independence. As a result the consumption of meat was preferred over that of fish and it became the main source of animal protein in the average Eritrean diet. In the last few years, however, as a result of campaigns for the consumption of seafood and due to the high prices of meat, demand for fish has been growing and its consumption increasing during the last four years.

II. OVERVIEW OF THE AQUACULTURE INDUSTRY

A. Shrimp Farming in General

i. Historical perspective

The cultivation of marine species is an ancient practice. Ancient Chinese manuscripts and Egyptian hieroglyphics indicate that these two ancient civilizations practiced intensive fish culture. The Romans followed their examples and developed aquaculture practices, and they are known to have cultivated oysters. The culture of oysters established by the Romans is the first known form of aquaculture that has continued in some form or another into the modern day. Fish farming in its modern form was first introduced in 1733 when a German farmer successfully gathered fish eggs, fertilized them, and then grew and raised the fish that hatched. After hatching, the fishlings were taken to tanks or ponds in which they were cultivated. Initially this "fish farming" was limited to freshwater fish. In the 20th century, new techniques were developed to successfully breed saltwater species³². Today, aquaculture has developed to the extent that it is contributing to the economies of many countries, including food security to developing nations and luxury seafood products to the affluent societies.

In many countries, with limited land and water resources, aquaculture is integrated with agriculture and industry where applicable. On the integration of aquaculture with agriculture *World Aquaculture* states:

Aquaculture evolved in societies pressed by the inabilities of natural and cultivated land and water resources to provide enough high quality protein foods for their increasing populations. The integration of agriculture, animal husbandry and aquaculture on farms in Asia created definable

³² Electronic sources from the website:
<http://www.newmex.com/platinum/data/light/whatis/historycapture.html>

aquaculture ecosystems, which closely resembled natural ecosystems, with their own structure, closely coupled nutrient-recycling pathways and ecological management. (Costa Pierce 2002).

ii. Classification of Aquaculture

Various criteria are used to classify and define different kinds of fish culture. Aquaculture can be classified on the basis of different chemical, physical and biological processes and systems of operations. It can be classified based on stocking, management and economic intensity systems, water salinities, environmental locations, feed qualities, feeding strategies, species stoking strategies, etc.

Criteria	Kind
Purpose of Culture	Human food Improvement of natural stock Sports and recreation Bait Industrial products
Nature of enclosure	Pond culture Cage and pen culture Raceway culture Raft culture Closed high-density culture Sea ranching
Source of fry	Natural waters Captured gravid females Hatching
Level of management intensity	Extensive Semi-intensive Intensive
Number of species stocked	Monoculture Poly culture
Water salinity	Fresh water Brackish water Marine water
Water movement	Running water Standing water
Water temperature	Cold water Warm water
Food habit	Herbivorous species culture Omnivorous species culture Carnivorous species culture
Combination with agriculture production	Rice-fish farming Poultry-fish farming Pig-fish farming

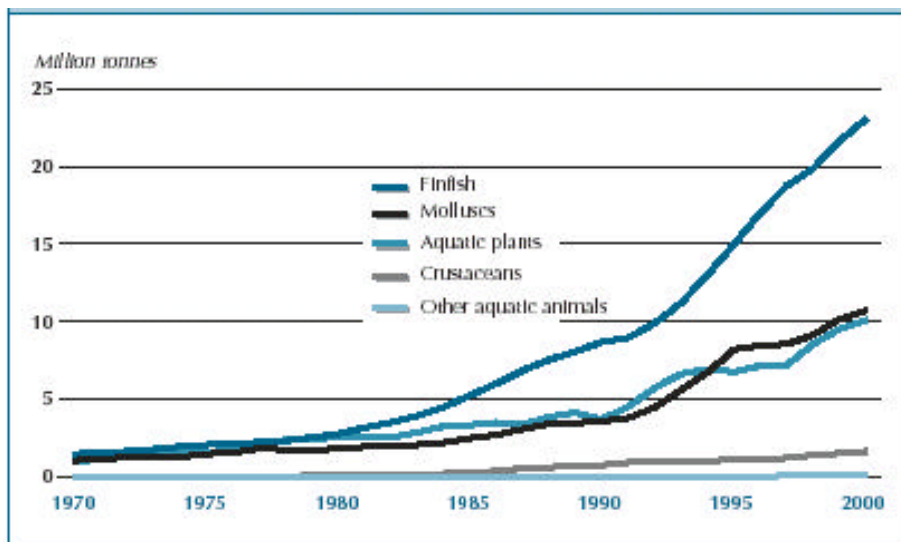
Table 6: Classification of aquaculture systems (Source: Shang, 1981)

It is also classified into land - based and sea- based systems. The classification of aquaculture in Table 6 is commonly practiced (Shang, 1981).

According to the classification of aquaculture systems as illustrated in Table 6, the Shrimp farming in Eritrea is pond culture, intensive in level of its management and practices polyculture in running marine warm waters, culturing herbivorous shrimp and fish species from its own hatcheries. It combines aquaculture and agriculture.

iii. Trends in Aquaculture Production

Despite fluctuations in supply and demand caused by the changing state of fisheries resources, the economic climate and environmental conditions, fisheries and aquaculture remain important sources of food, employment and revenue in many countries and communities (FAO 2000).



Aquaculture's contribution to global supplies of fish, crustaceans and mollusks continues to grow, increasing from 3.9% of total production by weight in 1970 to 27.3% in 2000 as illustrated here (Figure 13). Aquaculture is growing more rapidly than all other animal food producing sectors of the economy (FAO 2000).

Fig. 13: Trends of world aquaculture production by major species (Source: FAO, 2000).

During the past three decades, aquaculture has expanded, diversified, intensified and made technological advances. FAO recognizes the potential of this development to enhance local food security, alleviate poverty and improve rural livelihoods.

Scientific data on marine fisheries suggests that nearly half the established world fisheries are already fished or beyond their limit of sustainable yield. With the decline in world's capture fisheries, aquaculture will continue to expand if the increasing demand for fish and shellfish products is to be met. Aquaculture, in various forms, comprises about a quarter of the global food fish supply (Tobey et. al., 1998). Aquaculture activities have been developing while providing significant economic and social benefits with possible damage to the local ecosystems. There are several aquaculture industries, most notably shrimp farming in certain Asian and Central America countries that have significant environmental impacts. Such ventures have notably hurt the public image of aquaculture.

The main trend in aquaculture now is to improve that image and to move towards sustainability. One of the important realizations of this trend is that in order to achieve full market potential the environment must be protected, as environmental damage results in a decrease in production and possibly the collapse of the industry. A number of issues must be addressed to achieve sustainability, including the development of an integrated infrastructure and appropriate management and maximization of positive environmental practices.

a. Global

With the decline of world capture fisheries, aquaculture has been rapidly growing in the last decade. In 2000 global aquaculture production was 45.7 million MT by weight with a total value of over US\$ 56.5 billion (Figure 14). China was reported to have produced 71% of the total volume and 49.8% of the total value of production. The total global shrimp farming accounted for about 3.7% of the total yield and represented over 16.5% of the total revenue from aquaculture worldwide or 1.1 million tons worth, an estimated \$6.0 billion in 2000. The yield from shrimp farming alone represented about 2.6% of the total aquaculture output that year (WWF/FAO 2002).

Shrimp farming is one of the fastest growing and most lucrative components of the aquaculture industry. Shrimp farming has grown in production from 84,000 tons in 1982 to 712,000 tons in 1995 a 9-fold increase. Today, more than one-quarter of the shrimp consumed worldwide is produced this way, and the proportion is predicted to rise to 50 percent as shrimp farming expands and wild catches from over fished shrimp fisheries decline (Hagler 1997). Although shrimp farming is a valuable and growing industry, its development has been accompanied by increasing concerns over its social, economic and environmental impacts.

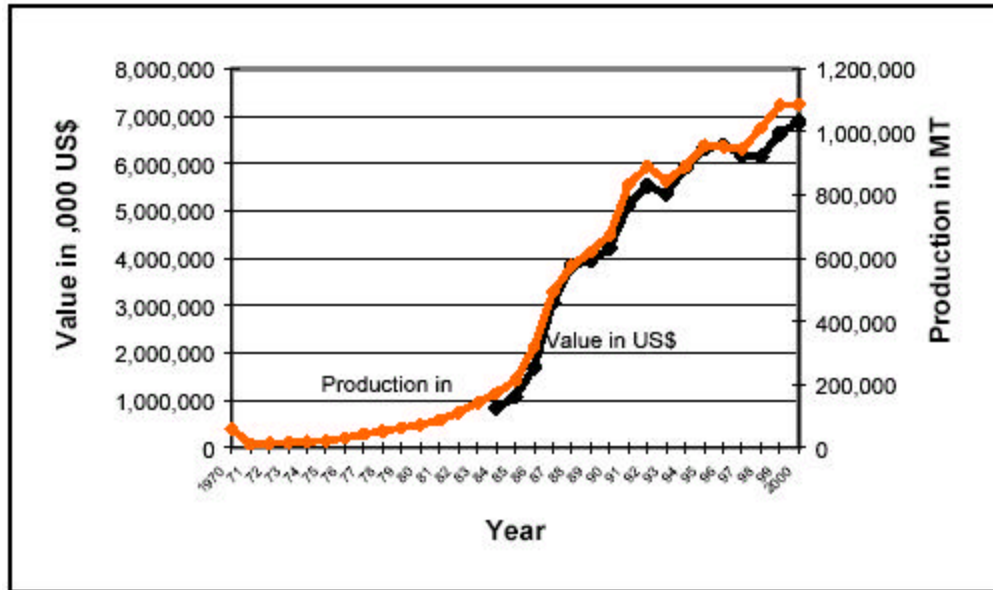


Figure 14: Global trend of cultivated shrimp production (FAO, 2002)

Asia dominated shrimp production in 2000 with seven of the top ten shrimp producing countries being from Asia accounting for 75 % of the global production. The major shrimp producing nations are Thailand (estimated 300, 000 MT in 2001) followed by China, Indonesia, India, Vietnam, Ecuador, Philippines, Bangladesh, Mexico and Brazil (FAO 2000).

b. Regional

Aquaculture for food production in Africa was introduced over 50 years ago.

A genuine potential for increased aquaculture production in Africa exists and is yet to be fully realized. The region produced 40,300 MT in 1997, having a value of \$102 million (Machena 2001). African aquaculture is primarily small-scale and rural. Small-scale finfish production can be estimated at 95% or 21,900 mt, with mean yield at 500

kg/ha/yr. Commercial production would be estimated at 11,350 MT with reported yields of 10 -15 MT/ha/yr. Constraints to development of aquaculture in Africa include:

- (1) The economy is based on rural cropping and livestock grazing,
- (2) Aquaculture must compete with other crops for basic inputs such as land, water, labor and nutrients (Machena 2001).

Aquaculture in Africa, as compared to the rest of the world, is fairly insignificant. The continent as a whole contributes a mere 0.4 percent (117,000 tons) of the total world aquaculture production. The African continent, however, exhibits considerable potential in terms of land and water, both with regard to inland, coastal and offshore resources. Aquaculture in the North African countries of the Mediterranean region has grown ten fold in the years from 1984 –1995 (Figure 15). They produce 67 percent of the total production for Africa, with Egypt alone contributing approximately 34 percent. The production in Sub-Saharan Africa amounts to 33 percent (39,000 tons) of the total production for Africa, or 0.2 percent of world production. The most important countries in the Sub-Saharan region are: Nigeria, Zambia, South Africa, Kenya, Tanzania and Madagascar³³.

³³ Danie Brink, Division for Aquaculture University of Stellenboch, South Africa. October 12, 2001.

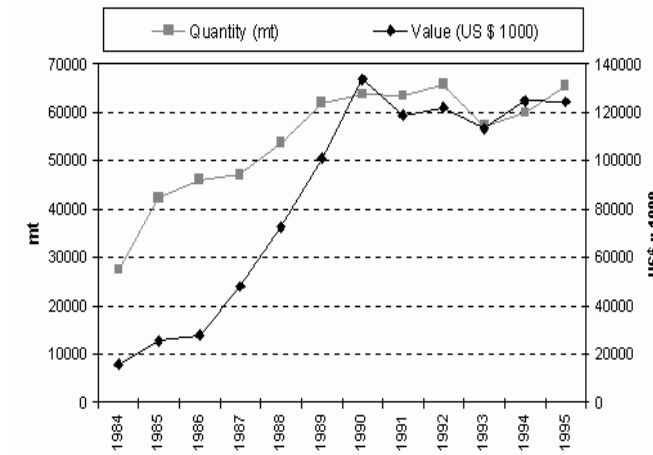


Fig 15: Aquaculture production trends in North Africa (Algeria, Libya, Morocco, Tunisia and Egypt).(Source: FAO, 2000)

The main species that are cultured in the Africa region are: tilapia, catfish, carp, cyprinids, mussels, oysters, shrimps and seaweed. Aquaculture development in developing countries is mainly reliant on a flow of technologies and capital from developed countries, with production in turn aimed at exports to developed markets.

c. National

Seawater Farms Eritrea, the only operating shrimp farm in Eritrea, started a pilot project in 1998 to test the practicability of shrimp culture and *Salicornia* farming in Eritrea and is now operating on a commercial scale seawater farming on a land about 2,000 ha (or 20 km²) in area. The shrimp production ponds include 153 circular cement ponds, 300-m² and 500-m² areas to be increased in number in the future. Each 300-m² pond produces 600 kg/crop of shrimp with two crops of production a year. The shrimp is exported to the Middle East and Europe after processing and packaging. With the ever-

increasing demand for shrimp, the market is expected to grow rapidly. Figure 20 shows the comparison of wild caught and cultured shrimp for the years 2000-2002.

iv. Major species cultured

Globally, the three main cultivated shrimp species (*Penaeus monodon*, *Penaeus vannamei*, and *Penaeus chinensis*) account for more than 82% of total shrimp production. The giant tiger shrimp (*Penaeus monodon*) is the major shrimp species farmed, accounting for 52% of total global shrimp production (WWF/FAO 2002). The main species in the new shrimp producing countries in Africa and the Middle East is *Penaeus monodon*, a species that occurs naturally in the region.

In Eritrea, the main species of shrimp cultured is *Penaeus vannamei*³⁴ a species introduced from Mexico as post larvae before the farm had its own hatchery. In addition, small quantities of *Penaeus monodon* were also introduced. A local variation, the *Litopenaus monodon* (Giant Tiger Shrimp-indigenous to Eritrea), has been collected from the coastal waters of Eritrea and is now used as brood stock.

B. Impacts of shrimp farming

i. Environmental impacts

Shrimp farming has steadily been growing in the developing countries of Asia and Central America during the last two decades. This growth is mainly inspired by the high demand for shrimp by affluent societies in Japan, the US and Europe and by the

³⁴ Sea Water Farms Eritrea website: <http://www.seawaterfarms.com>, 2002.

economic rewards that go along with shrimp production and distribution. However, the economic gains created from aquaculture in general, and shrimp farming in particular, were not achieved without direct or indirect impacts on the environment or the human, animal and plant communities that seldom share the economic returns associated with the aquaculture industry.

Environmental problems associated with shrimp farming vary depending on the type of farming system employed. Different shrimp culture technologies have different environmental impacts. Extensive systems requiring large land areas contribute most to mangrove clearance, while intensive systems contribute more to pollution problems through their high stocking densities and feed and chemical inputs (Neiland 2001).

Shrimp farming can contribute to the sustainable rural livelihoods of poor farming communities but it can also be very destructive with adverse social and environmental impacts if carried out in an intensive manner such as with industrial shrimp farming (Edwards 1999). The possible undesirable environmental impacts of shrimp farming are a concern of all stakeholders wherever shrimp farming is practiced. The stakeholders involved directly or indirectly in the shrimp industry are: the producers (including small-scale farmers, and industrial shrimp farmers), the community members, the government, financing agencies and environmental or citizen groups. These stakeholders' concerns differ depending on the economic and social impacts of the shrimp farms. While the shrimp farm owners, government officials and international financial institutions - whose main objectives are to create economic gains - prefer to downplay the possible

environmental impacts of shrimp farming as long as the shrimp venture is economically feasible. The World Bank/IFC's financing of shrimp farming projects worth \$ 890³⁵ million is an indication of the high degree to which funding institutions support shrimp farming and similar investment ventures.

The local communities residing in the areas where shrimp farming takes place and whose livelihoods are directly affected by aquaculture activities have different and possibly negative attitudes towards shrimp farming. As long as investments in shrimp farming and associated industries provide short-term economic and social benefits, the communities may have enthusiastic attitudes toward these investment. In most cases, governments present their aquaculture development plans to the communities in this way, in order to force people to give up their lands and resources to be used for aquaculture development in exchange for employment and other benefits. However, in the future, the real results of the industry and the effects of aquaculture activities will be felt as the economic and social gains are put in the balance with the adverse socio-economic impacts.

In developing countries, including Eritrea, where the shrimp industry is just starting, the gains from shrimp farms may not directly benefit the poor and the disadvantaged if the necessary measures are not put in place. The scenarios in many countries indicate that the main beneficiaries of large-scale commercial shrimp farming

³⁵ The financing was made in five countries from 1980 to 1997 including \$746.5 million to China, \$ 85.0 million to India and 31.0 million to Indonesia. Source: WB/NACA/WWF/FAO, Shrimp Farming and the Environment: Can shrimp farming be undertaken sustain ably? A discussion p aper.

are the farms owners who are often foreign investors who rarely care about the environment and the long-term needs of the local communities. These long-term needs of the communities include the food security, which could have been addressed through aquaculture. The truth of the matter as Randall E Brummett writes in *Environment,*

Development and Sustainability:

In Africa, large-scale commercial aquaculture seldom returns much economic benefits to the local community and hence often has little impact on food security or poverty for the approximately 85% of Africans who live in rural areas (Brummett 2000).

This is because the investors have profit considerations; therefore, they are reluctant to produce low value species that the poor can afford to buy. Instead, they prefer to produce high- value species for more lucrative export markets. The rural areas are thus deprived of economic benefits but are expected to share the effects of the development impacts in terms of sharing water and land resources and paying for land degradation and water pollution. Supporting small-scale rural investors in integrated aquaculture-based farming systems could thus improve both rural livelihoods and the environmental sustainability of African agriculture.

Environmental and citizen groups whose main goals are to protect the environment often oppose industrial shrimp farming. According to Greenpeace, for instance, one hectare of semi-intensive shrimp culture system in Colombia, producing about 4 tones of shrimp annually, requires the productive and assimilative capacity of between 38 and 189 hectares of natural ecosystem per year (Hagler 1997). This is based on Colombia's use of wild fish as sources of fish meal for shrimp aquaculture, which renders shrimp aquaculture an unsustainable business environmentally. Rosamond

Naylor and other authors in their article in *Nature* have other impacts of aquaculture on wild fisheries and that of wild fisheries on aquaculture, include:

The use of wild fish to feed farmed fish places direct pressure on fisheries resources. But aquaculture can also diminish wild fisheries indirectly by habitat modification, collection of wild seed stock, food web interaction, introduction of exotic species and pathogens that harm wild fish population, and nutrient pollution (Naylor 2000).

A study made by international organizations shows that environmental impacts of shrimp aquaculture in general arise from a wide range of interrelated factors including availability, amount and quality of resources utilized, type of species cultured, size of farm, farming systems management, and environmental characteristics at the location of the farm. The interactions arise because shrimp aquaculture relies heavily on environmental “goods and services” (WWF/FAO 2002). Some of the main environmental impacts caused by shrimp farming include:

Mangrove destruction, pollution of natural waters with nutrients, organic matter and sediments, Salinization of freshwater with pond effluents, use of bioaccumulative or toxic drugs, antibiotics, and other chemicals, wasteful use of fish meal, spread of shrimp diseases, trans-boundary, movements of genetic materials, exotic species and disease, biodiversity issues primarily arising from collection of wild seed (Boyd 2001).

Generally, shrimp aquaculture is perceived to be less harmful than agriculture, urban development and industrialization (Paez-Osuna 2001). While this may be true, adverse environmental impacts related to shrimp aquaculture could be examined as (a) caused during establishment of shrimp ponds and (b) the operation of the farms.

a. Impacts during construction phase

In most countries, shrimp farming is established in salt flats, marshes, mangrove areas and agricultural lands. Mangrove areas are converted into shrimp ponds by

destroying the mangrove trees as illustrated below Figure 16 (a) and (b). This makes mangrove forests the most notable ecosystems that have fallen prey to shrimp pond construction, with massive destruction of mangrove forests in Latin America and Asia (Hagler 1997). The picture is similar in many African countries, including Nigeria, Tanzania and Madagascar that have large areas of their coasts covered with mangrove forests.

The inhabitants of the mangrove forest of Nigeria, which covers about 600, 000 ha in the Cross River State and the Niger Delta, depend on fish and other mangrove resources for their livelihood. These forests rank as the largest in Africa and as the third largest in the world are now threatened by industrial shrimp farming sponsored by the World Bank/IFC and supported by the Nigerian government (WRM 2001). The destruction of mangrove for conversion into aquaculture ponds is characterized as “the aquatic equivalent of ‘slash and burn farming’ ” by the AAAS (Harrison 2000).

The direct destruction of mangroves and salt marshes for shrimp pond construction are impacts of greatest concern in many countries. Since many fish and crustacean species use these habitats as nursery areas and for shelter during early development, their conversion into shrimp ponds adversely threatens their survival and hence the productivity of these habitats.

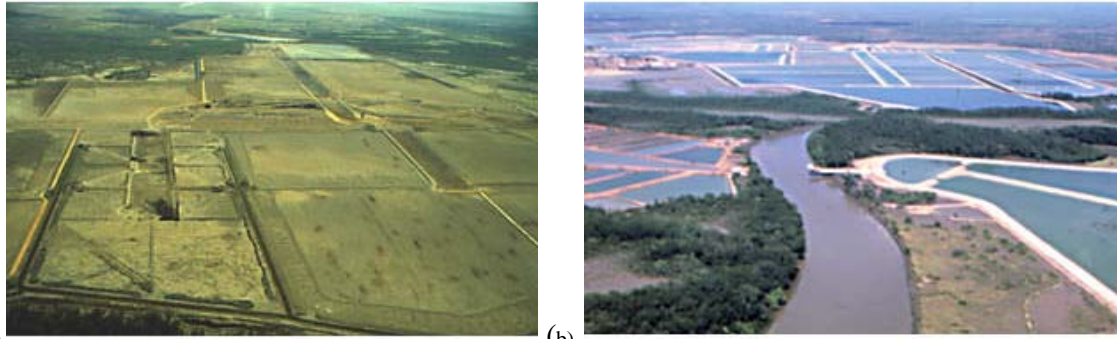


Figure 16: Shrimp ponds and their impacts on mangroves forests in Ecuador: (a) under construction, and (b) operational ponds. Source: <http://www.newmex.com/platinum/data/light/other/photo9.html>.

The destruction of mangrove forests is not an issue of concern for Eritrea at the moment, as most of the coastal areas of the country are dry, barren, and semi-desert, devoid of significant vegetation except along the mouths of the seasonal rivers. This is because the coastal areas are not appropriate for mangrove habitats due to the lack of fresh water and the high salinity of the seawater and the high temperatures of the coastal areas. Some mangroves forests are now prevalent along the deltas of the seasonal rivers and some lagoons that benefit from underground water lenses. In the past these patches of mangrove forests have been destroyed by the local communities for livestock feed, for construction purposes and as firewood. It is safe to conclude that at present there are not many mangrove forests to be endangered by the construction of shrimp ponds. On the contrary, the expansion of aquaculture in these barren coastal areas, producing fish and shrimp for domestic consumption and for export, could be an added advantage for food security and for income generation and ecological improvement of the desert coastal areas provided the concerns of other environmental impacts are properly assessed. If an integrated approach is chosen and mangrove trees are planted along with shrimp culture,

as Seawater Farms Eritrea initially planned, then shrimp farming may have a positive impact on the environment.

b. Impacts during operation:

The most commonly reported negative environmental impacts of shrimp farming are mainly attributed to intensive farming systems where shrimp pond effluents enriched in suspended solids, nutrients, and chlorophyll, biochemical oxygen demand (BOD), antibiotics, growth promoting chemicals and pesticides are discharged to adjacent coastal water bodies. Nutrient input to shrimp ponds by adding fertilizer and feed can result in the eutrophication of the waters receiving the shrimp pond effluents. Coastal shrimp farms are often located in areas of coral reefs and sea grass beds that are sensitive to eutrophication (Paez-Osuna 2001).

Different methods are employed to mitigate the impacts of shrimp pond effluents. The use of polyculture³⁶ in combination with shrimp aquaculture together with fish, macro algae and halophytes has been positively evaluated. Polyculture is utilized in China where ponds are stocked with different species of fish with different food habits in order to utilizing all the natural food available, thus maximizing fish production per unit area of pond surface, and at the same time filtering the effluents.

³⁶ Polyculture is the primary and secondary production of marine finfish and aquatic plants, marine finfish and shellfish, shellfish and shellfish or a combination of all three. Depending on the focus there are a number of application possibilities to consider.

Polyculture has been attempted during pilot phase and is in application in the commercial phase of shrimp farming in Eritrea. The culture of salt-water tilapia in the effluents of the shrimp ponds was found to be successful. Tilapia has the ability to scavenge the remnants of shrimp feed in the effluents from the shrimp ponds. The effluents from the tilapia ponds are then used for irrigating and fertilizing *Salicornia* fields. The rest of the effluents are flooded into the wetlands under development ³⁷.

Viral diseases are recognized as the biggest obstacle to shrimp aquaculture, and they indirectly have bearing on the environment. Organisms kept in high densities in farms and hatcheries are susceptible fungi and bacteria but viral diseases provoke the greatest losses in many countries, often causing the collapse of shrimp farms (Paez-Osuna 2001). The increased application of antibiotics in intensive shrimp aquaculture has brought concern about the possible effects of their release into adjacent natural ecosystems. It is recommended that shrimp farmers should reduce the use of chemicals and biological products because of the risks to the environment, human health and to production. Clearly, the use of certain antibiotics poses a risk of danger towards human health and some chemicals used in shrimp farming are likely to have a negative impact on the environment (Gräslund 2001).

Disease is by far the most serious threat to the sustainability of shrimp farm production. In Asia, various viral diseases have caused devastation of shrimp farms, such as in Taiwan in the late 1980's and in China in the late 1990's. Taura syndrome continues

³⁷ This is my personal observation at the Integrated Shrimp Farming in Massawa, Eritrea.

to cause serious mortality in many areas in Latin America where *P. monodon* is cultivated (Hambrey 1996).



The few foreign investors accrue major benefits and generate astounding profits at the cost of the society and the ecology. The local population tackles these ecological footprints. The foreign investors eventually abandon the farms, as in Figure 17 as soon as they accumulate enough profits or when bad weather or a devastating disease hits the farm (Hagler, 1977).

Figure 17. An abandoned shrimp farm in Honduras (Hagler, 1997)

The capture of wild seed to stock shrimp ponds is one of the highly debated environmental impacts associated with shrimp farming, since many extensive shrimp farming operations depend on wild-caught seed of penaeid species rather than hatchery reared post-larvae. All extensive shrimp farms in Asia and Central America collect wild seed to culture shrimp. By-catch from these operations is often high, and the consequences of these aquaculture operations on wild fisheries are enormous. In India

and Bangladesh, up to 160 fish and shrimp are discarded for every giant tiger shrimp (*Penaeus monodon*) collected to stock shrimp ponds (Naylor 2000).

Introduction of exotic species, also known as biological pollution, is another potential environmental impact of shrimp farming. The escape of these exotic species into the environment affects the stock of wild species. Experience has shown that farm escapees could hybridize with and alter the genetic make up of wild populations of species, which are adapted to their spawning grounds. The movement of stocks for aquaculture purposes could also increase the risk of pathogens.

The possible impacts of shrimp farming do not necessarily occur in every shrimp farm at the same time. Proper planning and good management practices could avoid some of these impacts. For instance, “two of these negative impacts, mangrove destruction and Salinization of freshwater can be avoided by good site selection and farm layout methods (Boyd 2001).

i. Social impacts of shrimp farming

Environmental groups and social justice groups resist the expansion of shrimp farming revealing a high social cost and a host of new complex environmental problems caused by shrimp farming. The social impact of shrimp farming is illustrated by an example in the Philippines, where there was a marked shift from extensive aquaculture for production of milkfish largely for domestic food supplies to the more lucrative export-oriented shrimp farming. The result has been not only the loss of a valuable protein source - milkfish - but also loss of valuable riceland due to conversion into, or Salinization by, shrimp ponds, both detrimental to the goal of national self-sufficiency in food (Hagler 1997).

The World Rainforest Movement’s viewpoint on the impact of shrimp industry on the local population is demonstrated by an example from Honduras. The installation of shrimp farms prohibits the local population to enter mangroves, lagoons, estuaries and the

Gulf of Fonseca. For the local populations, this implies a loss of access to their traditional sources of food; firewood and income, obliging them to "illegally" enter such areas, evading controls established by the companies. As a result between October 1992 and May 1998, nine fishers were found shot dead in the mangroves and estuaries near the shrimp farms. Their death has been related to shrimp farm surveillance (WRM 2001).

The conversion of agricultural lands and especially rice paddies into shrimp ponds is the other impact of shrimp farming, thus impacting on the lives of poor farmers in many shrimp producing developing countries. This phenomenon is common in Bangladesh, India, Thailand and other Asian countries. A survey made in Thailand and Vietnam shows that 50% of farmers in southern Vietnam and 66% in western Thailand claimed that the land on which they now have shrimp ponds had previously been used for rice (Lebel 2000). Shrimp farming and rice paddies also have land-use conflict that arises mainly by the effects of salinity from shrimp farming operations on their yields. The effects on poor rice-growing families have been exacerbated by the problems with declining productivity in what once was one of the most productive rice growing areas in Thailand (Lebel 2000).

C. Experience of other developing nations in shrimp farming

Four shrimp producing countries, two from Central America and two from Asia, are selected for comparison with Eritrea's shrimp farming. Eritrea is just entering the shrimp industry and so it is not yet considered a shrimp producing country. However, taking the selected indicators, the comparison is intended to examine the benefits that can be

achieved from the shrimp industry and the impacts that can be avoided, and it will assess the ways Eritrea can learn from their experience in shrimp farming. The objective of this comparison is to show the role of shrimp farming in the economic life of these countries and to show if shrimp farming can be operated in an environmentally sustainable, economically viable, and socially equitable manner. Since the table is not complete, it is difficult to make conclusions from the available information. Data is given for the years 2000-2002.

Table 7: Comparison of countries on shrimp production data and other indicators (FAO/WB/UNDP, 2000-2002)

#	Indicators/Countries	Eritrea	Mexico	Honduras	Bangladesh	Thailand
1	Area (Km ²)	125,000	1,972,550	112,090	144,000	514,000
2	Population (millions)	4.0	103.4	6,500,000	133,376,684	62,354,402
	Growth rate (%)	3.8	1.47	2.64	1.59	0.88
3	GDP per Capita (US\$)	740	9,000	2,600	1,750	6,600
4	Human Development Index	0.421	0.796	0.638	0.478	0.762
	HDI Rank, 2000	157	54	116	145	70
5	Number of Shrimp Farms	1	240	55	13,000	20,000
	Number of hatcheries	1	20	10	10	1,800
6	Pond Area (Ha)	10	14,000	12,000	140,000	80,000
7	Farm. Intensity (% Ex/S-Int/Int)	0/0/100	NA	NA	NA	5/70/25
8	Shrimp Prod. mt/y ('99/'01)	190	35,000	10,000	35,000	280,000
9	Productivity, kg/ha, (1999)	NA	3,000	NA	NA	2,500
10	Inv. in shrimp farming (US\$)	10.0	NA	NA	22.0	NA
11	Incomes from shrimp farms (mil. US\$/yr)	NA	28.0	80.0	NA	1,6000
12	Social Impacts -Employment		NA			
	- Permanent	100		12,000	20,000	100,000
	- Temporary	150			225,000	
13	Employment (per/ha)		NA	1.0	1.6	1.25
14	Income per hectare (US\$)		2,000	6,660	NA	20,000

From this, it is possible to compare the following criteria between these countries:

- Persons employed per hectare of shrimp pond - 1 for Honduras, 1.6 for Bangladesh and 1.25 for Thailand.

- Income generated per hectare of shrimp pond - \$ 2,000 for Mexico, \$ 6,660 for Honduras and \$ 20,000 for Thailand.

In regards to employment all three countries use few employees in their shrimp farms, but Thailand uses more labor /Ha than Honduras. Among the countries in Table 7 Eritrea has the highest population growth rate. Such a high growth rate might require focus on labor-intensive investments. It is reported that shrimp farming may be less labor intensive than say farming that aquaculture replaces. In this case it is up to the policy makers to make the decisions taking all factors into consideration. Regarding income per hectare, Thailand earns much more than all three countries at \$ 20,000/ Ha. The Thai system could be applicable to Eritrea, but the method used by Thailand has to be studied in detail to see if it could be adopted.

D. The debate over aquaculture

Aquaculture has become a contentious issue due to the fact that over the past decade it has grown tremendously, almost 10% yearly. As well, the social and environment impacts of aquaculture in many developing countries have been negative, in spite of the fact that it has been a steady means of income to the countries and the people directly employed in the sector. The major contenders of aquaculture are the producers (or the industry) that support its continuous development, on the one hand, and the environmental or citizen groups and the communities that are opposed to the development and expansion of aquaculture, on the other hand.

On global scale a consortium of international organizations including the World Bank, Food and Agriculture Organization of the United Nations (FAO), World Wildlife Fund (WWF) and the Network of Aquaculture Centers in Asia Pacific (NACA) have

prepared a report – Shrimp Farming and the Environment – with the objective of analyzing and sharing experiences on the better management of shrimp aquaculture in coastal areas. The Consortium Program, which took from 1999-2002, comprises complementary case studies on different aspects of shrimp aquaculture. The report recognizes aquaculture as an important economic activity in the coastal areas of many countries and offers a number of opportunities to contribute to poverty alleviation, employment, community development, reduction of overexploitation of natural resources, and food security in tropical and subtropical regions (WWF/FAO/WB/NACA, 2002).

Following are some contradictory views on aquaculture or shrimp farming.

i. The view of the producers

The view of the Global Aquaculture Alliance (GAA) is representative of shrimp producers and traders. The GAA, as an amalgamation of seafood producers and sellers, is an international, nonprofit trade association dedicated to advancing environmentally and socially responsible aquaculture. It recognizes that aquaculture is the only sustainable means of increasing seafood supply to meet growing food needs. One of its primary efforts is to establish standards of good practice for responsible aquaculture. To that end, the Alliance published *Codes of Practice for Responsible Shrimp Farming* (Boyd 1999).

The GAA presents two examples to illustrate the positive effect of aquaculture to the community. The first is the introduction of backyard hatcheries along pristine northwest coast of Bali in Indonesia where a community of six villages of 28,000

residents, who once made their living from subsistence fishing and corn, coconut, and grape farming, have undergone a dramatic transformation over the past decade (Heerin 2002).

One of the successes mentioned is the development of technology that simplified and standardized the breeding and seed production technology of milkfish. This technology made the process simple, reliable, and economically feasible enough to be transferred to back-yard hatcheries in the villages. A transfer of technology mechanism, which included a comprehensive instruction on the construction of hatchery facilities, larval rearing, harvesting, packing, and distribution of milkfish fry, was introduced. The subsequent hatchery investment boom resulted in job opportunities that expanded the horizons and incomes of the local people, and also attracted an estimated 5,000 workers from other areas. The GAA claims that this is a model that demonstrates the power of combining technology, local enterprise, and sustainable use of natural resources, which in this case were the pristine waters of the Bali Sea (Heerin 2002).

While this success could be true for the development of aquaculture at the community level, it may not be representative of aquaculture development by the foreign multi-national corporations that have invested in Indonesia. These corporations were attracted by the relatively cheaper land and labor and hassle-free regulations that have helped the farm owners to generate tremendous profit while causing significant damages to the local community and leaving untold ecological footprints to the fragile marine environment of Indonesia.

The other model contribution of shrimp farming mentioned by GAA as a positive social impact of shrimp farming was the creation of jobs by the shrimp industry in Honduras. The Grupo Granjas Marinas (GGM) of Choluteca – a Honduran affiliate of a US-based firm operating a set of five shrimp farms and allied industries in Honduras - is mentioned by the GAA as a case in point. Southern Honduras, where the GGM is stationed is one of the most economically depressed regions of the country where statistics show that over 65% of the households did not have access to basic services of water, sanitation, and primary education before the inception of the shrimp industry in the rural areas (Romero 2002) and where people have traditionally been engaged in subsistence activities such as fishing, cultivating basic grains, and raising chickens and hogs. Rural poverty is manifested mostly in the lives of women, with high mortality rates for mothers and infants. The majority of women are single mothers carrying the dual responsibility for their households, including income generation and childcare. The shrimp industry in Honduras now provides over 10,000 direct jobs where women, primarily in processing plants, occupy 25% of the jobs. 50% of GMM are women employed in the processing industry.

While these are positive developments of the shrimp industry, in general, and in the Honduras case, in particular, the overall benefits accrued at the country and regional levels need to be examined. While developments mentioned above can be positively attributed to shrimp farming, it is important to note that there are other social implications and environmental impacts of shrimp industry in southern Honduras that are not apparent to the casual observer.

ii. **The view of environmental groups and communities**

Greenpeace presents a representative view of the environmental groups that are opposed to the development of shrimp farming on the ground that it poses a threat to the livelihood of communities and the environment. Greenpeace refutes the fact that the shrimp industry promotes itself as a gain to the local economies, by attesting that it benefits mainly the few wealthy investors, at great loss to local people. It asserts that modern, intensive shrimp aquaculture provides limited employment opportunities for coastal residents and most of those jobs are typically poorly paid seasonal and non-skilled, offering no long-term job security. Greenpeace demonstrates an economic study conducted by researchers at Chittagong University in Bangladesh, which revealed that shrimp farming displaces more jobs than it creates. Cultivating 100 acres of land with rice employs 50 workers, the study found; cultivating shrimp on the same land employs just five workers. As a result, shrimp farming in Bangladesh's coastal Satkhira region displaced 40 percent of the area's 300,000 inhabitants into the country's overcrowded cities, the university study found (Hagler 1997).

In general, the social impacts of export oriented shrimp farming mainly affect those who reside in these areas and who make their living from the resources that are found there. According to environmental groups, these impacts arise primarily from pond construction and operation, and the severity of their threats increases as the number of farms increases in area and the intensity of cultivation per farm rises. During construction of shrimp ponds, mangrove forests are destroyed in many countries of Asia and Latin

America, thus depriving the environment of important breeding and nursery grounds for many fish, shellfish and a wide range of other wildlife species.

According to Thailand's state statistics, the country's shrimp farms have destroyed over 65% of the country's mangrove forests. The same situation is true for Ecuador where in a span of twenty years, 20% of the country's mangrove and 80% of its salt marshes have been destroyed by the shrimp industry (Hagler 1997). This shows that the world's largest shrimp producers are at the same time the world's largest mangrove forest destroyers.

Environmental impacts during the operation of shrimp farms include the pollution of the surrounding area with effluents that degrade the quality of adjacent water bodies, tidal and underground waters, the contamination of the water systems with artificial feed residues, pesticides and chemical additives, shrimp disease proliferation and the introduction of exotic species into the local ecosystem.

III. THE FUTURE OF SHRIMP AQUACULTURE IN ERITREA:

IS IT IN ERITREA'S ECONOMIC, SOCIAL AND ENVIRONMENTAL BEST INTERESTS TO CONTINUE INVESTING IN SHRIMP AQUACULTURE?

A. Investment in Eritrea

i. Investment Code of Eritrea

The Investment Center for Eritrea of the Ministry of Trade and Industry is responsible for all matters related to investment and is authorized to implement, in consultation with the pertinent Ministries and Departments. The Investment Proclamation, adopted in 1994, in theory, is attractive to investors. It opens all the sectors of the economy to foreign investment, reduces tax on profits, allows remittance of profits in foreign currency and minimizes customs duties on capital goods. However, investors complain of delays and inconsistency in the implementation of this proclamation, especially, during the screening of investment projects and in coordination with the relevant Ministries. Much is to be desired to improve the system. Investors are free to choose their partners, either the government, companies or individuals. Large investments in practice require local partners, such as, the government or its affiliated agencies, although the Proclamation does not require it.

There are no discriminatory visa, residence or work permit requirements for foreign investors. As a matter of fact it is a very smooth and fast process. Foreign investors do not face unfavorable tax treatment, denial of licenses, discriminatory import or export policies or inequitable tariff or non-tariff barriers. The investment proclamation permits foreign investors to freely remit profits, dividends, interest on foreign loans and fees related to technology transfer. Expatriate employees are guaranteed to remit savings

from their salaries. In practice, however, investors complain that things do not work according to the books due to the shortage of foreign currency caused by the war. It seems that there is discrepancy between what the Proclamation allows and its actual implementation.

ii. Foreign and domestic investment in Eritrea

As of December 2000, the Investment Center of Eritrea has licensed over 800 investment projects worth over \$ 550 million. Of this total the foreign component is \$ 217 million³⁸. Major investors come from the US, South Korea, Italy, Germany and China. The investment statistics for the three years from 1997-2000 is shown below (Table 8).

Item/Year	1997	1998	1999	2000
Foreign	53.3	12.2	11.5	8.3
Domestic	51.5	58.9	49.9	18.0
Total	104.8	71.1	61.4	26.3

Source: Eritrea Investment Center/DOC, 2002

Table 8: Investments in Eritrea 1997-2000

Table 8 shows decline in investment over the three-year period from 1997-2000. This was mainly due to the border war, which has affected Eritrea's economic performance.

³⁸ Source Investment center and Department of Commerce of the USA.

iii. Investment in the fisheries sector

In the early years after of independence many foreign investors have shown interest in Eritrea, but because of the absence of infrastructure none of them were able to come forward with concrete investment proposals. With improvement in the investment climate in the country, some investors have started to take practical steps but the border war of 1998-2000 and its aftermath have negatively influenced the investment environment in the country. In the years from 1997-2000 about \$ 20.0 million have been invested half of which came from foreign investors and the other half from government funds. They were mainly in boat building, processing facilities and fish farming from Australia, US, NL and Italy (EIC/DOC, 2002).

B. Eritrea's likely shrimp markets

i. Overview on the world shrimp markets

In the shrimp trade arena producers considered the years 1997-1999 to be the good old days because shrimp prices were high. Suddenly, in 2000, due to the entry into the market of Vietnam, Brazil and Mexico as major shrimp producers, with India, Taiwan and China making huge harvests, and finally with Thailand as the world's leading shrimp producer, supply raced ahead of demand and shrimp prices fell. By the last quarter of 2001, wholesale shrimp prices dropped 35%. After the September 11, 2001 attack on America, prices dropped to five-year lows. To make a bad situation even worse, in late 2001 and early 2002, an antibiotic scare hit the industry when German authorities discovered the antibiotic chloramphenicol in farmed shrimp from Asia³⁹.

³⁹ Bob Rosenberry, World Shrimp Farming, 2002.

The economic decline in Japan in the last few years led to lower demand for shrimp. This in turn led the producer countries to lower prices. The economic improvement in Europe helped raise the demand for shrimp, but the low level of the euro weakened any significant growth. At the end of January of 2002, the EU stopped all imports of shrimp from China due to the detection of antibiotics in cultured shrimp. This led other Asian countries to divert their shipments to other markets. Moreover, the problems of shrimp diseases that hit Ecuador and Central America in 1999 led to a decrease in production of cultured shrimp in 2000 and 2001 (FAO 2002). All these factors have affected the destabilization of the international market for shrimp at the beginning of 2002 thus causing the prices of shrimp to drop. Figure 18 below shows shrimp price fluctuations in the US and Japanese markets from 1993-2001.

These low shrimp prices have forced shrimp farmers to look for new technologies, new management strategies and lower production costs. Brazil reports production costs of a dollar per pound. Some new, small super-intensive farms in Central America say they can produce shrimp for \$0.95 a pound. Given low labor cost, the Chinese has a lower production costs⁴⁰.

⁴⁰ Rosenberry, 2002.

Shrimp prices Japan and USA

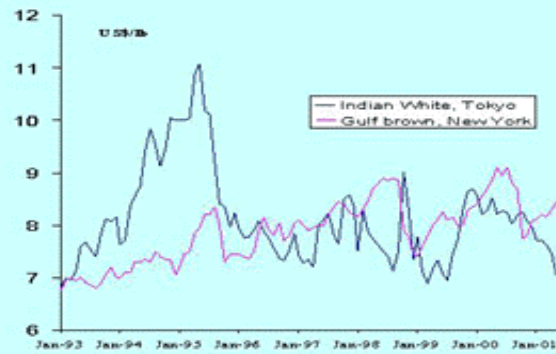


Figure 18: Wholesale shrimp prices in the US and Japan for 1993-2001. (Source: FAO, 2002)

ii. Major shrimp producers and importers

a. Major producers

As was mentioned earlier in this thesis, the major producing areas of cultured shrimp are Southeast Asian and Central American countries with over 80% of the global production provided by Asia. The five major shrimp producing nations are from Asia and are listed in Table 9. The amount they produce and the value they generate from the shrimp industry per year is shown.

#	Country	Production (MT)	Production ('000 US\$)
1	Thailand	300,000	2,125,340
2	China	218,000	1,308,000
3	Indonesia	140,000	847,430
4	India	53,000	394,000
5	Vietnam	70,000	320,000

Table 9: Major shrimp producing nations (Source: WB/FAO, 2002)

The map illustrated below (Figure 19) gives the main shrimp farming areas of the world as pointed out by FAO. As revealed in the map, the major shrimp producing countries are concentrated in southern and southeastern Asia and Central America and the southern parts of North America and northern parts of South America. Europe and Africa have little to contribute in industrial shrimp farming, although small-scale aquaculture may be common in Africa. While climate plays a central role in the distribution of shrimp farming, they are concentrated in developing countries due to cheap labor and abundant land and water resources and also because it contributes to food security. Due to its environmental impacts, shrimp farming is not encouraged by the stringent laws and regulations in the developed countries of the north.

Figure 19: World shrimp farming Areas (FAO, 2002)



World Shrimp Farming Areas

b. Major Importers

Most of the shrimp produced in the developing countries of Asia and Central America are exported to developed countries of Japan, the US and European Union (Figure 20). In 2000, industrialized countries accounted for over 80 percent of the total value of import. Japan retained almost 26 percent of the world total, valued at US\$ 14.8 billion, and followed by the United States, accounting for 16 percent of the total at a value of US\$ 9.4 billion. The European Union share in total world imports reached 36 percent. Shrimp is the most important commodity accounting for about 19 percent in value terms of international trade in 1999. This share has remained stable over the past 20 years (FAO 2002).

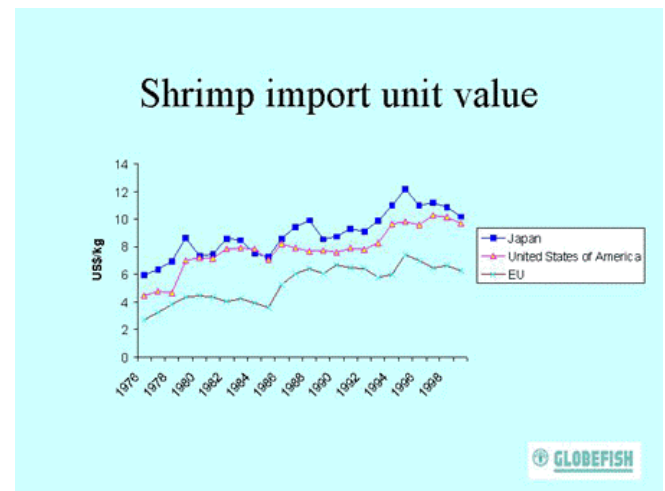
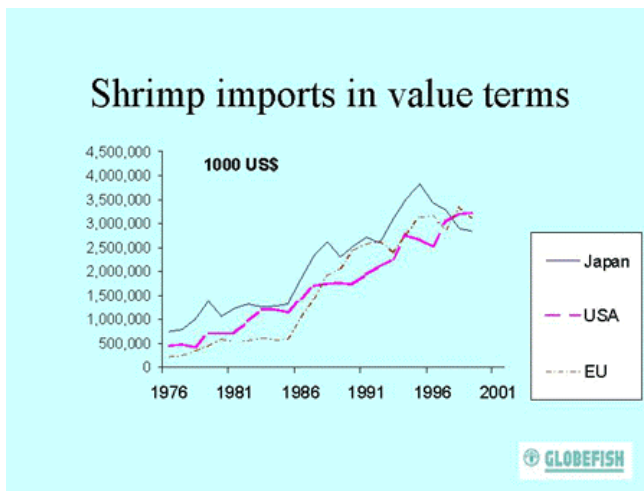


Fig. 20 Shrimp imports from Japan/US/EU 1976-2001 (Globefish, 2002) Fig. 21 Value in \$/kg of imported shrimp in J/US/EU, 1976-1998

Shrimp prices have also shown an increasing trend during the last 20 years when they have risen from \$2-6/kg to \$6-10/kg in 1998 (Figure 21). Prices have been fluctuating

depending on the economic situation in the importing countries and the supply and demand situation.

iii. Prices of shrimp

The consumption of shrimp has been on the decline in Japan (Figure 20), the largest shrimp consumer, for a decade now, mainly due to the economic situation in that country. The price of shrimp has been steadily decreasing on the global market for more than a year, with a few exceptions. As a result shrimp prices continue to decrease (WWF/FAO 2002). This will continue for some time until the economic slowdown in the major shrimp consuming nations improves. The major importers influence the international shrimp prices and supply and demand. Therefore, prices in other regional markets will be influenced by these major markets in Japan, the US and EU, with factors of distance and means of transport being considered.

The question arises then, if the prices of shrimp are on the declining trend (Figure 21), is it viable for developing countries like Eritrea to continue to produce shrimp and still depend on the shrimp markets of developed countries? There is, indeed, a risk as to what the economic situation in the future will look like, but these price fluctuations have been there all along and for all the commodities and will be there in the future. There will be ups and downs in the prices as shown in the graph shown below (Figure 22).

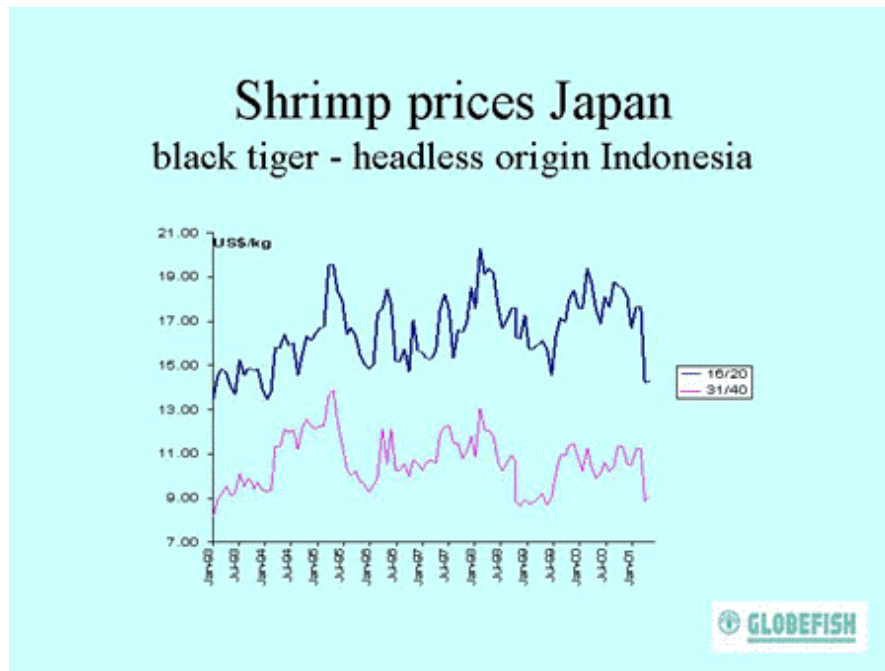


Figure 22: Shrimp price fluctuations in Japan from January 2000 to January 2001 (Globefish, 2002)

In this case Eritrea should diversify its market destinations. Markets in the other regions, such as the Middle East should be identified.

iv. Major species

Three species of cultivated shrimp dominate the global shrimp market. They are Giant tiger prawn (*P. monodon*), White leg shrimp (*P. Vannamei*), and Fleshy prawn (*P. chinensis*). These three species accounted for more than 82% of total shrimp production (FAO 2002).

v. Eritrea's marine fisheries markets

The traditional markets for Eritrea's marine fisheries products during the last 10 years after independence have been mainly the neighboring countries of Egypt, Saudi Arabia, Israel and Yemen for fresh and unprocessed fisheries product and the European Union and the Far East for processed fish/shrimp products and dried shark fins and sea

cucumber, respectively. In 2000, the main export destinations for Eritrean fisheries products were Egypt (61%) and Saudi Arabia (32%). Processed products were exported to the European Union with a share of 4% of the export while 3% was exported to Qatar (MOFish 2000). The figure below (Figure 23) shows the export trend of marine fisheries in Eritrea during the years 1998-2000. The demands for fisheries products by these markets have always been too high for the limited Eritrean fisheries supply to satisfy. Foreign fishing vessels, mainly from Egypt and Saudi Arabia, that operated under Eritrean licenses have produced over 90% of the total annual catches (MOFish 2000). These foreign operated fishing vessels paid a royalty of 20% of the total value⁴¹ of their catches to the government upon declaring their total catches in port before their departure to their home country.

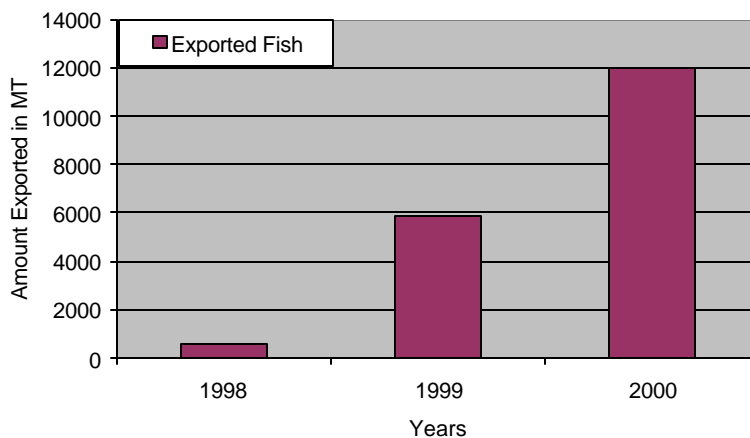


Fig. 23: Fisheries products exported from Eritrea by national and foreign companies 1992-2000

(Source: MOFISH, 2002)

⁴¹ The weight of each species of fish caught by these foreign vessels is multiplied by the pre-agreed price of each species to find the total value of the total catch per trip. This amount reported by the inspectors on board the fishing vessel is verified by the chief inspector in port and confirmed by the skipper of the vessel and the report send to the company for settlement of the designated royalty.

Two fishing inspectors from the Ministry of Fisheries accompany each fishing vessel during their fishing trips, with the objective of controlling the method and fishing grounds, verifying the species and amounts harvested and ensuring that all fishing operations are carried out within the limits of the set laws⁴².

The main problem encountered by Eritrean fisheries is poaching by foreign vessels, especially from Egypt and Yemen. From 1990 to 1997, over 60 Egyptian trawlers and hundreds of Yemeni artisan boats were caught while fishing illegally in Eritrean territorial waters. While some of the Egyptian vessels were returned to their owners with the payment of a fine, were not. All the Yemeni artisan boats were all returned to their owners. Although Eritrean coast guards carry out regular patrols many times, the poachers pass the days in the international waters of the Red Sea and enter the Eritrean waters by night. This has to some extent been deterred by the issuance of fishing licenses to the Egyptian fishermen, but it is difficult to verify that it has totally been stopped.

Shrimp caught by artisan and industrial fishers are also exported to Egypt and Saudi Arabia (MOFish 2000). The amount of shrimp exported from Eritrea from 1998-2000 is shown in the (Figure 24) below. The amount of shrimp shown for 2002 is for the first six months of the year. All of the products exported to Egypt and Saudi Arabia are whole shrimp packed with ice on board the fishing vessels and dispatched on board the vessels, while shrimp that is exported to Europe is processed and air freighted as fresh with ice (head-on, head-off or peeled). Frozen whole shrimp is also shipped in containers

⁴² Personal observation: During my duty as Head of the Resources Management Department from mid 1997 to end of 2000 I supervised all fishing operations; therefore, I was in a position to have a first hand experience of the control and regulatory mechanisms of fishing in Eritrea.

to Europe, mainly to Holland, and then distributed to Germany and Italy. Fresh shrimp is air freighted on board passenger flights to Germany and then distributed by trucks to the different destinations. Air transport remains the main stumbling block in the export of fisheries products from Eritrea, not only due to the space limits on the flights but also due to exorbitant freight rates demanded by the foreign airlines. The flying of a new flag national carrier - *Eritrean Airlines* – starting mid-2003, the opening of a new international airport in Massawa⁴³ and the completion of a smooth road joining Asseb to Massawa will facilitate the export of larger quantities of fisheries products by air.

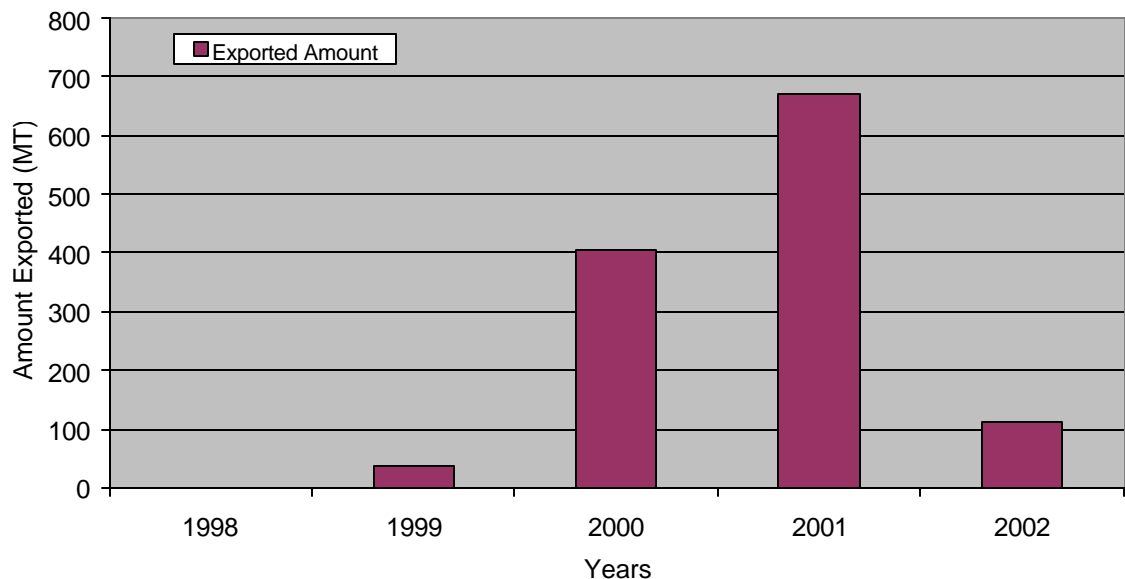


Figure 24: Wild-caught shrimp exported by foreign companies from Eritrea from 1998-2002. Figures for 2002 are for 6 months. (Source: MOFISH, 2002)

Wild-caught edible shrimp exported include seven species of the Penaeid family namely: Green tiger prawn, Giant tiger prawn, Indian white shrimp, Southern rough shrimp, Speckled shrimp, Western king prawn, and Kuruma shrimp (MOFISH, 2002).

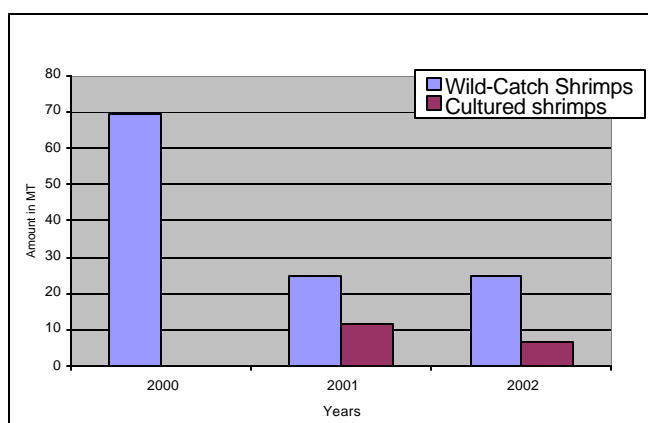
⁴³ This will be the third international airport in the country in addition to those in Asmera and Asseb.

vi. Eritrea's cultured shrimp trade

Eritrea started to produce cultured shrimp in 2001 with the operation of the commercial shrimp farming by Seawater Farms Eritrea in Massawa. During the last two years, small quantities of cultured shrimp have been exported to Germany and Saudi Arabia. These quantities, small as they seem, were neither able to satisfy the high demand for shrimp nor were they large enough to encourage the production of shrimp. The highly consuming societies of Europe and Japan are the potential markets for Eritrea's capture and cultured shrimps. The strategic location of the country, relatively, within a short distance from Europe, the Middle East and the Far East provides potential markets for Eritrean shrimps and other marine products, provided that the production capacities are increased and the means of transportation and other export infrastructure facilities improved. The European and Middle Eastern markets, which are already familiar with Eritrean marine fisheries products since 1996, are ideally located.

The illustration below (Figure 24) shows the amount of wild and cultured shrimp exported from Eritrea in 2000 –2002. The destinations are described above.

Figure 25: Comparison of wild and cultured shrimp exported from Eritrea in 2000-2002. Values for 2002 are for 6 m. (Source: MOFISH, 2002)



A. Application of case studies in the Eritrean context

i. Feasibility analysis of a shrimp farm in Eritrea

This analysis is based on the works of Engle, C. R., and Valderrama, D. (2001).

The objective is to analyze the feasibility of a shrimp farm in Eritrea. Some assumptions are made, including:

- The overall farm size is approximately 1750 ha⁴⁴; including shrimp production pond area of 350 ha. This is based on the allocation of 5 ha of land for 1 ha of grow out pond area.
- Annual shrimp production of 500 mt⁴⁵ is estimated based on shrimp production of 1428 kg/ha of pond.
- Shrimp prices are based on year 2000 average Eritrean shrimp prices
- Shrimp markets for Eritrean shrimp are assumed to be the Middle East and EU pe.

⁴⁴ 1 hectare (ha) = 10,000 m²

⁴⁵ 1 metric ton (mt) = 1000 kg

- Variable and fixed costs reflect the market situation in Eritrea.

Table 10: Enterprise budget for a shrimp farm in Eritrea (Engel, et.al. 2001)

Enterprise Budget for a 350 ha Shrimp Farm in Eritrea for year 2000 (in US \$)

Item	Description	Unit	Quantity	Unit Price	Total Cost
Gross Returns					
Shrimp	Size 71-90	Kg	153,272	7.15	1,095,895
	Size 41-50	Kg	305,723	8.9	2,720,935
Total Gross returns					3,816,830
Variable Costs					
Post-Larvae (PL)	Hatchery	1,000	100,000	5	500,000
Feed	25% protein	Kg	1,127,604	0.5	563,802
Fertilizer	Urea 46%	Kg	14,742	0.19	2,800
	18-46-0	Kg	3,629	0.3	1,089
	(NH ₄) ₂ SO ₄	Kg	47,628	0.17	8,097
Chemicals (if any)	Chlorine	Kg	1,134	2.8	3,175
	Alcohol	Liters	40	1.3	52
Labor		Annual wage	70	1800	126,000
Fuel		Liters	100,000	0.55	55,000
Electricity		kwh			25,000
Machinery	Rent	\$/hour			250,000
Equipment repairs		Dollars			75,000
Post-harvest handling	Ice	Kg of shrimp tails	458,995	0.07	32,130
	Transport	Kg of shrimp tails	458,995	0.07	32,130
	Processing	Kg of shrimp tails	458,995	0.4	183,598
Marketing	Air freight	Kg of shrimp tails	458,995	0.75	334,246
	Export Fees	Kg of shrimp tails	458,995	0.07	32,130
	Other Fees	Kg of shrimp tails	458,995	0.45	114,748
Interest on operating capital (12.5%)		Dollars	1,500,000	0.36	187,500
Total variable costs (TVC)					2,526,497
Returns above TVC					1,290,333
Fixed costs					
Depreciation		Dollars			175,000
Interest on investment		Dollars			50,000
Insurance		Dollars			75,000
Concession		Ha	500	2	1,000
Total fixed costs (TFC)					301,000
Total cost (TC)					2,827,497
Net Returns					989,333
Net Returns per unit area					2,826
Breakeven price at 1,311 kg/ha					
	- Above TVC	Dollars/kg			6
	- Above TC	Dollars/kg			6.16
Breakeven yield at \$8.31/kg					
	- Above TVC	Kg/ha/year			414
	- Above TC	Kg/ha/year			907

To evaluate the feasibility of the farm operations at the given conditions, a number of methods can be applied, one of which is breakeven analysis that shows how much shrimp must be produced and at what prices for the shrimp farm to be profitable. In this case, breakeven prices and breakeven yields are calculated as follows:

- Breakeven price above variable cost was calculated by dividing total variable cost by the total quantity produced in the farm. In this case the breakeven price above total variable cost was \$6.0/kg of shrimp produced. This indicated that shrimp production would be profitable as long as the price is above \$6.0/kg.
- Breakeven price above total cost was calculated by dividing total costs by the quantity produced in the 350 ha farm. In this case, breakeven price comes out to be \$6.16/kg. That means, as long as the price of shrimp is above \$6.16/kg, this operation is profitable in the long term, all annual variable and fixed costs will be covered at this price.
- Breakeven yield is calculated in a similar manner. Breakeven yield above variable cost is calculated by dividing total variable cost by price and then by the 350 Ha in the farm. This gives a value of 414 kg/Ha. This indicates that as long as production per hectare is above 414 kg, it is possible to raise shrimp in the short run.

- Dividing total costs by the price and then dividing by 350 ha in the farm, we find the breakeven yield above total costs. This gives a breakeven yield of 907 kg/ha. If production levels are above 907kg/ha, this operation will be profitable, even in the long run. At this level of production, there is enough production to be able to cover all variable and all fixed costs.

For a shrimp farm in Eritrea with the inputs and outputs as shown above (Table # 8), the breakeven analysis shows that the farm of 350 ha would be profitable. These are, of course, not the only criteria to indicate the profitability of a farm. But the limited information on the farm in Eritrea confirmed me the method of breakeven analysis.

Other methods of analyses could also be employed, including:

- Sensitivity analysis that shows the effect of varying prices/costs on profitability.
- Partial budget analysis that shows what effects small changes in management could have on the profitability of a shrimp farm.
- Investment analysis using three principal indicators, namely, payback period, net present value and internal rate of return.

ii. Comparative advantage of Eritrea's shrimp farming

This is an evaluation of Eritrea's comparative advantage in shrimp farming based on the analysis of a work by Bing-Hong Ling and others. The objective is to evaluate the comparative advantage of Eritrea in the production of shrimp based on the comparison of

shrimp farming in ten Asian countries. This example from Asia is taken, because Asian shrimp farmers provide 82% of the global shrimp production and Asia accounts for more than 60% of global shrimp exports since 1985 (Ling et al., 1999). This high shrimp production capacity in Asia is due to increased investment and the application of technological advances. This has contributed to rapid expansion of Asian shrimp culture, generation of foreign exchange earnings, and creation of opportunities for employment. The objective of this comparative analysis is: (1) To evaluate social opportunity costs of using domestic resources in developing shrimp farming and the consequences on foreign exchange earnings, (2) To examine its applicability to the Eritrean situation, and (3) To evaluate the comparative advantages of countries in producing and exporting shrimp using social opportunity costs.

The methods applied include, (1) comparison of shrimp production costs among ten Asian countries - Thailand, Indonesia, the Philippines, Malaysia, Vietnam, India, Bangladesh, Sri Lanka, China and Taiwan, and (2) analysis of the comparative advantage using the domestic resources cost (DRC) approach, taking into account opportunity costs of input factors, foreign exchange rates, and shrimp prices on the foreign market. The lowest production cost has Thailand with \$ 4.00 and the highest has Taiwan with \$ 7.50 per kg of shrimp. Comparatively, Eritrea's production cost or farm gate price is \$ 4.11/kg.

A country has a comparative advantage in the production of a given commodity if the social opportunity costs of producing, processing, marketing, and transporting an incremental unit of the commodity are less than the world prices. The DRC approach

permits comparison of the relative degree of efficiency in producing an identical exportable commodity among different countries.

$$\text{DRC} = \frac{\text{Cost of Domestic Input}}{\text{World shrimp prices} - \text{Cost of Foreign Input}}$$

The Resources Cost Ratio or RCR = DRC / E, where E is the exchange rate.

If RCR < 1, there is a comparative advantage in producing and exporting the particular commodity. Otherwise, RCR > 1 and RCR = 1 show a comparative disadvantage and neutrality, respectively. If one country has a lower ratio of RCR than another country, the former has a relatively higher comparative advantage than the latter in exporting the commodity.

The average prices in US\$ of shrimp exports are collected for three major markets—Japan, the US, and the European Union. The RCR indices of Asian shrimp exporting countries to Japan, US, and EU markets are estimated separately. Malaysia, Thailand and Sri Lanka get the maximum prices of over US\$ 14.00 in the Japanese market. China and Vietnam get the least - US\$ 5.00 in the US and EU markets, Vietnam – US\$ 6.00 in the Japanese. Average prices are \$ 11.00 in the Japanese, \$ 9.50 in the US and \$ 6.00 in the EU markets. The Eritrean expected export price in the EU and Middle Eastern markets is US\$9.50.

Exports from	Shrimp prices in importing countries (US \$)			
	US	EU	Japan	Middle East
China	5.00	5.00	-	-
Vietnam	5.00	5.00	6.00	-
Thailand	-	-	14.00	-

Malaysia	-	-	14.00	-
Sri Lanka	-	-	14.00	-
Eritrea	-	9.50	-	9.50

a. Conclusion:

The degree of comparative advantage in both shrimp production and export, influence a country's international competitiveness.

- All these Asian shrimp producers have a larger comparative advantage in exporting shrimp to Japan than to the US and the EU markets, largely because of the premium shrimp price received in the Japanese market. This indicates that Eritrea, in order to get a premium price for its shrimp has to start exporting its shrimp to Japan if it has not yet done so.
- Nearly all countries producing shrimp demonstrate comparative advantage, but Thailand, Indonesia and Sri Lanka have a stronger comparative advantage than the other Asian countries.
- The Chinese intensive shrimp farming system is comparatively neutral in the US market because of its high production costs as well as its low shrimp price per kilogram. This indicates that Eritrea has to lower its production costs to the minimum possible in order to compete against China in shrimp export.
- The information can be particularly useful in forming domestic shrimp policies. For example, competitive countries may seek to increase farming acreage areas, export market development, or both. Both cases are true for Eritrea, where it is necessary to increase the shrimp production areas and

therefore its export volumes. Moreover, it is also useful in making decisions in the provision of financial supports, short of subsidies, by national governments. This is vital for the success of shrimp farming, and includes: tax relief, investment tax credits to shrimp producers, development loans at low interest rates, and reductions on import tariffs on items used to produce exportable products such as shrimp feed and feed ingredients. These policy decisions may be alternative incentives to enhance the levels of comparative advantage in shrimp culture development.

b. Summary of Eritrea's potential

From the above analysis it follows that Eritrea's future in shrimp farming depends on a number of factors, including:

- **The introduction of advanced technology in shrimp farming by means of foreign investment.** Eritrea has adopted an open investment policy, but it needs to create an atmosphere conducive to foreign investors so that they can confidently participate in Eritrea's shrimp culture development. So far, a foreign investment of approximately US\$ 5.00 million by the American partners in Seawater Farms Eritrea and a correspondingly technology has been involved in shrimp farming. In spite of reservations on the part of certain government agencies and individuals on the success of shrimp farming in Eritrea, the country should fully engage in the development of shrimp farming by encouraging foreign and domestic

investments in shrimp farming and the transfer of shrimp technology into the country.

- **The availability of an industrious and cheap labor, vast underutilized coastal areas and open investment policy.** This creates an opportunity for Eritrea to have a positive comparative advantage in the production of shrimp for export at lower costs. One of the two factors that affect the degree of comparative advantage of exporting countries as shown above is opportunity cost. Cheap labor and abundance of undeveloped and uninhabited coastal areas – both available in Eritrea, influence opportunity cost.
- **Availability of shrimp export-markets and reasonable export prices for shrimp.** The ever-increasing demand for fisheries products by the regional and global markets, the accessible location of Eritrea to the major markets, and the attractive shrimp prices in the international shrimp markets put Eritrea in a comparative advantage in regards to shrimp farming. The major consuming markets of the Middle East, Europe and Japan are within easy reach from Eritrea. The US market may not be viable at the present time due to its distance.
- **Government's active intervention in some policy issues.** The Eritrean Investment Proclamation of 1994 provides some incentives for investors. Incentives such as, tax relief, investment tax credits and development loans at low interest rates for local shrimp farmers could facilitate the development of shrimp farming and thus encourage the export of shrimp.

IV. CONCLUSIONS AND RECOMMENDATIONS

Eritrea is a newly independent nation tackling enormous social, economic and environmental challenges. It is facing the huge task of reconstructing a country ravaged by a generation of war and drought. The country is part of a region facing acute food shortages and malnutrition. These enormous challenges are beyond the means of the nation to unravel them individually and outside support is not a sustainable long-term solution to these and other tribulations.

My thesis questions are:

What is the future of land and sea based shrimp farming in Eritrea and what are the advantages and disadvantages of shrimp farming? Can land based aquaculture be environmentally sustainable and economically viable in Eritrea, considering the perennial food insecurity and existing demands on the coastal and marine resources of Eritrea?

Eritrea has a long, dry, underutilized coastline. Marine fisheries resources are not fully utilized due to low production, lack of access to the major markets due to poor storage, transportation infrastructure facilities and excessively high freight costs. Moreover, even if the entire estimated sustainable yield of wild fisheries was fully exploited the income generated from marine resources is insignificant. But most of all it is also the lack of consistent, forward-looking national marine development strategy. Therefore, other means of production of fisheries products that takes into account the natural marine resources potential of the country have to be identified.

Experiences in many coastal nations demonstrate that land-based sustainable aquaculture can be one of the main sources for the generation national income and the creation of employment opportunities. There is high demand by the major industrialized communities for aquaculture products; therefore, shrimp farming, if undertaken in an

environmentally sustainable, economically viable and socially equitable manner could have important environmental and socio-economic benefits to the nation, including food security. Experiences have also shown that possible environmental and social impacts of shrimp farming can be minimized or even avoided if the proper ways of sustainable development are chosen. Then the question arises: should Eritrea continue investment in shrimp farming? What are the benefits and what are the impacts?

A. Should Eritrea continue to invest in shrimp farming, what are the benefit and the impacts?

i. General benefits and impacts of shrimp farming in Eritrea

The Government of Eritrea and its partners have to date invested several millions of dollars and have allocated land in prime areas for shrimp farming along the coasts of the fast growing town of Massawa. This is at a time when the country is facing a number of political, socio-economic and environmental challenges. Money spent in shrimp farming now and in the future is badly needed elsewhere in the economy. If shrimp farming does not earn the expected benefits in terms of economic, social and environmental values, and if the land and other resources used for this purpose does not satisfy the needs of the local and regional establishments and the local communities, then the government will have second thoughts about further investing in the industry. Therefore, there is an important decision to make in regards to shrimp farming.

Experience shows that, the following major environmental, economic and social problems characterize shrimp production in many Asian and Latin American countries.

- Destruction of mangrove forests causing loss of natural mangrove products and disruption and loss of shrimp and fish nursery and reproduction grounds,
- Excessive collection of wild Post Larvae and egg-laden female shrimp causing decline in shrimp population along the coastlines
- Excessive by-catch, and
- Displacement of rural farming communities by shrimp ponds.

As a matter of fact, shrimp farming in Eritrea may not cause the impacts mentioned above, for the following reasons. There are few extant of mangrove forests to be destroyed by shrimp farming. The only commercial shrimp farm in Eritrea has its own hatchery; therefore, there is no need to collect wild species of shrimp post larvae. The coastal communities do not practice fulltime agriculture, due to soil salinity and shortages of fresh water. Some parts of the coastal areas are cultivated on part time basis by nomadic populations that move into the coastal areas seasonally in search of grass and water for their livestock, but the major part of the coastal areas is barren and underutilized. Therefore there are not many settled farming communities to be displaced by shrimp farming activities. Table 11 below shows a list of environmental, economic and social benefits and impacts expected from a model shrimp farm in Eritrea.

Table 11: Summary of potential benefits and impacts of shrimp farming in Eritrea

#	Potential benefits of shrimp farming	Potential impacts of shrimp farming
1.	<p>Environmental Enhancement of the coastal ecology - the barren coastal areas - of Eritrea through forestation of mangroves and other halophyte trees and grasses by developing wetlands.</p> <p>Utilization of hitherto unusable land and seawater resources. Due to shortage of fresh water and saline soils these coastal areas are at present not used for any agricultural purposes.</p> <p>Conservation of fresh water through the use of seawater for culturing shrimp and fish and irrigating Salicornia fields.</p> <p>Reduction of pressure on fisheries through the production of shrimp and fish for export and domestic consumption</p> <p>The wetlands are already attracting hundreds of seabirds</p>	<p>Environmental The wetlands may become breeding grounds for malaria and other unwanted species of birds that may be a nuisance at the farm itself by competing for shrimp and fish .</p> <p>The use of seawater for irrigation and flooding of the wetlands may cause salinization of soil and groundwater.</p> <p>Coastal waters could be polluted by nutrient and chemical rich farm effluents through unforeseen circumstances such as leakage of dikes and breakage of canals by storms or flooding. Pollutants in farm effluents include: N, P, BOD, Cl, antibiotics, pesticides and other chemicals.</p> <p>Impacts of the escape of exotic species of shrimp and tilapia imported from Mexico into the marine environment may be enormous.</p> <p>Construction activities and erosion of farm facilities could result degradation of coastal areas and reefs.</p> <p>In the future the use of chemicals and antibiotics in shrimp ponds and fertilizers, chemical and “natural”, in Salicornia fields may cause pollution of marine environment and could cause human health hazards.</p>
2.	<p>Economic Generation of income for the country from the export of shrimp and other exportable aquaculture products.</p> <p>Introduction of new technology thus creating an atmosphere conducive for the fast growth of shrimp and associated industries including agriculture.</p> <p>Development of auxiliary industries that could influence the positive development of other sectors. For instance, in Eritrea excess shrimp feed could be used for the poultry, pig and dairy farms where shortage of feed is acute.</p> <p>Creation of investment atmosphere thus attracting highly needed capital, technology and expertise into the country.</p> <p>Facilitation of interaction in the international arena through trade and investment thus positively influencing the nation’s international economic cooperation and balance of trade.</p>	<p>Economic Foreign investors usually earn the major profits and other benefits from shrimp farming eventually repatriating their earnings to their countries of origin leaving the communities and the country with little benefits.</p> <p>Importation of feed, chemicals, fertilizers and other items require foreign exchange thus neutralizing the benefits gained from the sale of shrimps.</p> <p>The use of new technology usually creates dependency on expatriate expertise requiring the use of the company and the country’s incomes in foreign exchange from shrimp farming to pay for these expertises.</p> <p>The use of fish meal as shrimp feed not only competes with humans for consumption of fish but also renders shrimp farming an unsustainable enterprise when the FCR is high. The FCR ratio for SFE is 2.5:1.</p>
3.	<p>Social Creation of opportunities for employment in the Eritrean society including women in the processing industry.</p> <p>Contribution to food security through the production of fish food and creation of wealth to fight poverty and food insecurity.</p> <p>Creation of an atmosphere conducive for the improvement of the nutritional value of national diet , especially that of children and women through the provision of varieties of fish and shrimp in the market.</p> <p>Improvement of the social livelihood of the local population through employment.</p>	<p>Social The expansion of the shrimp farm northwards might causes disputes over land use rights t he nearby village communities if the expansion of the shrimp farm extends into their farmlands.</p> <p>Shrimp farm operations, even though they create jobs, they do not require large numbers of employees. Employment ranges from 0.1 to 1.0 persons per hectare. Labor needs at construction of shrimp ponds are limited once the ponds are constructed</p>

ii. Potential economic benefits and costs of shrimp farming in Eritrea

In order to appreciate the economic benefits and costs of shrimp farming for Eritrea certain assumptions are made.

- The shrimp farm in question should be part of an integrated seawater farm as is in operation in Eritrea at present. This farm includes activities such as tilapia and milk fish culture, Salicornia farming, shrimp hatchery, shrimp feed operation and wetlands development, in addition to shrimp farming, which are operated in integration with each other in order to utilize common resources such as labor, land, water and energy. For the purpose of this thesis research, I considered only the shrimp-farming component of the overall farm.
- The overall size of a shrimp farm to be considered is assumed to be 1750 ha of land. This includes 350 ha of shrimp production ponds, of different sizes and shapes⁴⁶. The rest of the land is to be used for auxiliary activities and support services, such as, canals, dikes, roads, workshops, Salicornia farms, hatchery, feed operation facility, wetlands and office facilities. This farm can be taken as a model for future expansion of shrimp farms in Eritrea.
- The annual production capacity of the farm is estimated to be 500 mt of shrimp for export and 1,000 mt of tilapia and milkfish for the domestic market.
- The farm is to be operated by a joint venture firm to be formed by domestic and foreign investors; therefore the benefits and costs of the farm are to be proportionally shared by the shareholders. (SFE was equally owned by the US firm and the government of Eritrea at the time of its formation).

⁴⁶ At present there are 124 of 300 m² and 29 of 500-m² circular cement ponds with a total area of 5.17 ha and a number of earthen ponds of different sizes and shapes as shown in Figure 10 (1 ha = 10,000 m²).

- While most of the inputs and employees of the farm are to be of Eritrean origin, technology and the required expertise in shrimp farming are sought from abroad.

Table 12: Economic benefits and costs of shrimp farming in Eritrea

#	Activity	Benefits	Costs
1	Production of 500 mt/y of shrimps and 1,000 mt/y of tilapia and milk fish	<p>1. This increases the national income from the export of shrimp by \$ 5.00 million annually. Moreover, the nation earns revenue of 10-15 % of this amount and other benefits such as tax from employees, and the multiplying effects of the incomes from the employees.</p> <p>2. Creates employment for about 500 persons (permanent and temporary staff) and other contractual services</p> <p>3. The production of 1,000 mt of fish for the domestic market increases the per capita consumption of fish by 30% and this improves the nutritional value of food thus contributing to food security.</p> <p>4. This doubles the annual production of shrimp and thus reduces the pressure on marine fisheries, positively affecting the long-term effects of marine fisheries.</p> <p>5. The dikes created by the shrimp farm may be useful in the retention of floodwaters for the farming communities.</p>	<p>1. The farm is located in the northern part of the port town of Massawa and therefore not far from residential and business centers. This may have detrimental effects in the future as the population of the town grows.</p> <p>2. The common resources used in the production of shrimp are land and seawater. While land in Eritrea is publicly owned and can be distributed at will by the state, the land used by the farm was in the past used on part time basis by the coastal communities and the nomadic population both for agriculture and as pastureland for their livestock. Although, a few communities are dependent on this land, user conflict may arise with time since there will be limited access for farming and for livestock grazing.</p> <p>3. About 100 families in the village of Emberemi and the Rashaida communities may be affected by this farm, which extends to their farming and grazing areas.</p> <p>4. Employment in shrimp farming is low compared to agriculture or other professions with only 0.1 –1.0 persons employed per hectare of shrimp farm. Given the amount of land used this employment is not that beneficial for Eritrea.</p>
2.	The shrimp farm will utilize a quarter of the farmland or about 5 km ² of land to be developed as wetlands into a mangrove forest.	<p>This wetland when fully developed will:</p> <p>1. Be home to about 500 bird species and other wildlife.</p> <p>2. Change the ecology of the dry coastal areas into a mini-forest of about 5 km² in a hitherto desert area and will have a positive effect on the micro-climate of the coastal environment..</p> <p>3. Serve as a collection ground for the farm effluents and will serve as a natural filter for these effluents before they join the sea through seepage,</p>	<p>The creation of the 5 km² wetland could be:</p> <p>1. Reproduction ground for mosquitoes and predatory birds that are nuisance at the shrimp farm and the residential areas of the town.</p> <p>2. Flooding or other natural disasters may be cause for the breakage of the dikes in the farm thus causing the flow of farm effluents into the sea which may be cause for pollution affecting wild fisheries.</p>

B. Recommendations

- Given the present situation of drought and food shortage, the government of Eritrea needs to take the necessary measures to give priority to aquaculture operations in order to solve the problem of food security by introducing low-cost herbivorous species of fish and integrating with shrimp farming.
- By way of encouraging domestic and foreign private investment in aquaculture and related businesses, it is essential for the government to facilitate the investment screening process by streamlining the regulatory process of the institutions that deal with foreign investment projects and to simplify the provision of land and other resources and investment benefits to ensure the involvement of the private sector without any restrictions and competition from the public sector. Higher rents for land and other taxes might, as well balance the generous incentives provided for foreign investors by the Investment Proclamation.
- Eritrea has yet to utilize the comparative advantage it possesses conducive to the success of the shrimp industry such as: low production costs due to availability and reduced labor costs, open and attractive investment policy, two operating ports in the Red Sea, a new national carrier, three international airports, and the country's well-situated location within easy reach of prospective markets in the Middle East, Europe and the Far East.
- To make these comparative advantages feasible the government needs to make some policy adjustments by way of encouraging private investment through the provision of development loans at low interest rates and reductions on import tariffs of aquaculture inputs.

- The government of Eritrea needs to introduce institutional mechanisms and means of allocation of resources to involve artisan fishermen in aquaculture and to create an atmosphere conducive enough to enable them to fully participate in decision-making process. Although both sea based and land based aquaculture operations could be beneficial in the case of Eritrea the land based operation might be easier and more beneficial taking into consideration that many coastal communities are involved in land based salt production. The system of land based aquaculture and specifically finfish production for the local market could be easily operated in a similar way as salt production is operated. The ponds used for the production of salt can alternatively used for the production of fish if the proper training on the operation of aquaculture is provided to the coastal population. The government or the cooperative of fish farmers can take the responsibility of producing and distributing fish fry's as is done in Egypt with the production of fresh water and brackish water culture of fish. In the same way this land-based system could be operated along the coastal areas on commercial scale.
- The future of global shrimp market is uncertain. Possibly global demand for shrimp will continue to increase; assuming the present decline in price is temporary. It may also possibly happen that the continuous expansion of shrimp farming in developing countries will lead to continuing gluts. In both cases the final result will depend on the economic situation in the major shrimp consuming societies of the developed countries and the emerging economies. The trends, however, shows that an increase in production and the current price fluctuations will continue. This may not affect

shrimp production in Eritrea as prices have been fluctuating for the last decade and will continue to fluctuate for the foreseeable future.

- Eritrea has yet to adapt environmental laws. At present there is no environmental law to regulate aquaculture albeit one chapter in the Fisheries Proclamation. In the absence of a regulatory mechanism it is tempting for aquaculture and other industries to exploit the situation and avoid the mitigation of externalities. The current shrimp farming enterprise has been operating on self-control basis with little government regulatory measures due to the absence of clearly defined regulations. If correct foundations are to be laid for aquaculture it is time for the government agencies to facilitate the enacting of the relevant laws.
- Until 2000 Eritrean tax regulations did not address income from fisheries, specifically. At one time this was a contentious issue between the concerned government authorities. The fisheries Proclamation does not specify the amount of royalty that fishing companies or processing plants are supposed to pay to the government as taxation for their products. The 20% royalty charged to foreign fishing vessels charged for fish they catch and 10% for the by-catch that they discard was negotiated on case-by-case basis by these figures were taken as standards. Moreover, aquaculture production and its revenue generation are not mentioned in any of the existing laws (at least until 2000). This is a relatively new activity, and might in the future be a means of generating revenue so the law must clearly specify the duties of these operating aquaculture. Since aquaculture could also have detrimental environmental and social impacts the companies must be made to answer for their actions by law.

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