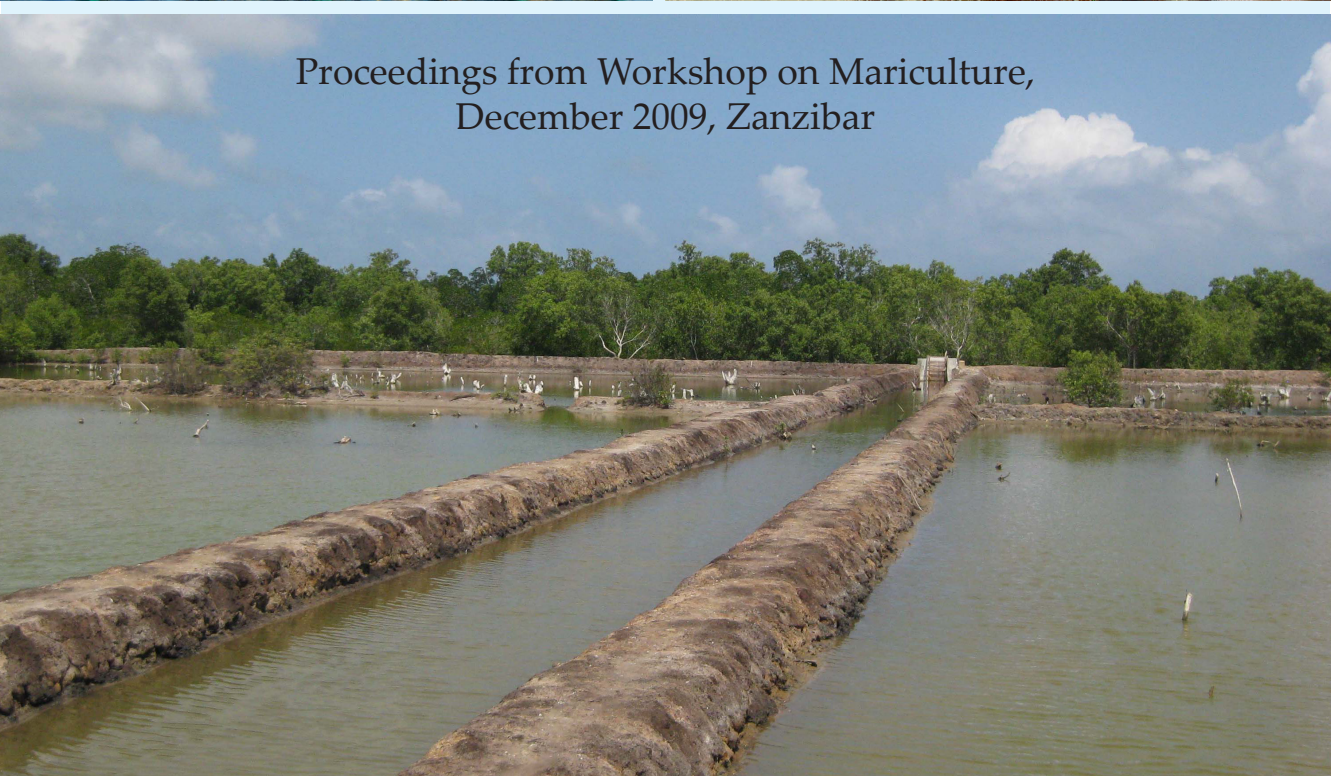


# Mariculture in the WIO region

## “Challenges and Prospects”



Proceedings from Workshop on Mariculture,  
December 2009, Zanzibar





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# **Preface and Acknowledgements**

## **The Mariculture Workshop**

The IFS/WIOMSA aquaculture workshop/training course was held 30 November-3 December 2009 in Zanzibar. The 30 participants originated from 17 countries, including countries within the WIO region, and from Europe, USA, New Zealand, The Philippines and Brazil. The general aims for the meeting were to discuss ongoing mariculture activities in the region from a sustainability perspective, to identify research priorities, and capacity building, i.e. knowledge sharing and to strengthen research links between researchers working with aquaculture and coastal zone management. The workshop contained group discussions as well as a number of shorter presentations on key issues. Short field visits to nearby aquaculture operations, including discussions with farmers, enabled participants to visualize some of the key issues facing aquaculture development in the WIO. The presentations given at the workshop can be accessed at a web site: [www.wiomsa.org](http://www.wiomsa.org)

This workshop was one in a series of workshops jointly organized by the International Foundation for Science (IFS) and the Western Indian Ocean Marine Science Association (WIOMSA) within the framework of a four year project (2007-2010) on strengthening partnerships in science for sustainable marine and coastal zone development, financed by the Swedish International Development Agency (Sida) and the Foundation for Strategic Environmental Research (Mistra). IFS and WIOMSA would like to extend their special thanks to the workshop Scientific Advisory Group for making the workshop into a success. Additionally, we would like to thank the Institute for Marine Science (IMS) for all support before and during the meeting and the Zanzibar Beach Resort Hotel for nice accommodation and a good meeting environment, and last but not least all the participants for their interesting presentations and active participation in the discussions.

## **Workshop Scientific Advisory Group**

Malcolm Beveridge, Ian Bryceson, Tom Hecht, Nils Kautsky, Aviti Mmochi, Frans Ollevier and Max Troell (scientific advisory group coordinator).





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# PART I: Introduction

## Mariculture in the Western Indian Ocean region

### *Introduction and Some Perspectives*

Max Troell<sup>1,2</sup>, Tom Hecht<sup>3</sup>, Malcolm Beveridge<sup>4</sup>, Selina Stead<sup>5</sup>, Ian Bryceson<sup>6</sup>, Nils Kautsky<sup>7</sup>, Frans Ollevier<sup>8</sup> and Aviti Mmochi<sup>9</sup>

Today aquatic products provide nearly 3 billion people with at least 15% of their animal protein intake and fish constitute the dominant source of animal protein in many island states and low income, food deficient countries (FAO, 2009; Smith *et al.*, 2010). The world's growing population consumes more and more fish and stagnating catches from our oceans cannot keep up (Pauly *et al.*, 2003; FAO 2009). The rapid development of aquaculture has to some extent enabled us to meet this growing demand and currently the aquaculture sector provides half of all fish destined for human consumption (FAO, 2009). However, the gap between demand and supply is increasing and so the pressure on aquaculture to meet this shortfall has led to development of the sector rising up political agendas worldwide. The aquaculture industry is the fastest growing animal production sector but the question is whether it can double in a sustainable manner (Soto *et al.*, 2008; Tacon & Metain, 2008) by 2020 to meet expected demand for fish products (Jacquet *et al.*, 2009). Another interesting question is what role Africa will play in future development of aquaculture, in particular to what extent can the expansion of marine aquaculture offer alternative or supplementary livelihoods to fishery dependent communities?

African fisheries make vital contributions to food security of 200 million people and provide income for over 10 million engaged in ancillary services like fish production processing and trade (NEPAD, 2005). Rising fish prices, resulting from e.g. decline in capture fisheries (or export, fishing agreements), illegal, unregulated and unreported fisheries by foreign vessels, together with climate change effects increasingly threatens food security in many African countries (FAO, 2004a; FAO, 2009). To maintain the 2005 per capita fish supply in sub Saharan Africa of 6.6 kg/person/year requires a 20 percent increase in production within 10 years and a 32 percent increase by the year 2020 (Delgado *et al.*, 2003; NEPAD, 2005; FAO, 2009). Juxtaposing the declining capture fisheries of the region, the high population growth rate in SSA and the current shortfall of fish emphasizes the need for rapid growth of the aquaculture sector (Hecht, 2006).

Unlike many Asian countries Africa (except Egypt) has limited historical tradition in aquaculture

and in spite of the region's natural endowments, including untapped land, water, coastlines and human resources, African aquaculture remains in large undeveloped. Modern freshwater aquaculture was introduced to the African Continent five decades ago with the aim to improve the economic and nutritional well being of people. With the exception for Egypt this effort has due to various reasons not proved successful (Hecht, 2000; FAO, 2000; Moehl *et al.*, 2005, Brummett *et al.*, 2008). One of the main reasons is that few social scientists have looked at international aquaculture development (Stead, 2005) thus there is little information on the drivers that underpin successful initiatives such as understanding attitudes, perceptions and fishers' willingness to consider aquaculture as a viable livelihood. Despite the same resource-base, aquaculture may not be an obvious alternative to fishing for e.g. fisherfolk. Their involvement may be limited by input costs, knowledge, management skills and job satisfaction related to strong fishing traditions (Ireland *et al.*, 2004, World Bank 2004).

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Thus besides technical prerequisites also social, economic and market-related aspects need to be considered prior to aquaculture introduction (World Bank 2004). Nonetheless, the development of aquaculture has recently gained momentum in some African countries, e.g., through stronger emphasis on private-sector involvement (FAO, 2006b in FAO 2008; Hecht, 2007). Still, most African countries have not yet explored the full potential and in 2009 the African Continent contributed only 1.3 % to global aquaculture production (Table. 1). Globally fresh water fish dominates but the share from marine aquaculture is increasing.

Table 1. Global aquaculture production in 2009 by continent and African aquaculture by continent (including plants, wet weight metric tonnes). Source: FAO, 2010.

Continent	Production
Africa	1 103 492
Americas	2 609 930
Asia	66 670 226
Europe	2 484 585
Oceania	176 370
<b>Total</b>	<b>73 044 603</b>

The oldest forms of coastal aquaculture in eastern Africa date back some 200 years to the “barachois” ponds in Mauritius (ITC, 1999). These coastal ponds with rocky walls providing semi-enclosures for extensive rearing of fishes, oysters and crustaceans are, however, no longer in production. Contemporary forms of coastal aquaculture in Africa include farming of seaweeds, shrimps, crabs, brine shrimp, abalone, edible bivalves, pearl oysters and fishes. Mariculture, i.e. the production of aquatic organisms in brackish and saline water, has the potential to bring new livelihoods to coastal dwellers, but it is important that this development follows a sustainable pathway, as it otherwise may threaten the livelihoods of many people that are more or less directly living from extraction or utilization of coastal natural resources. Thus, the question is not if the anticipated aquaculture expansion will take place in the coastal zone, because it most likely will, but rather how it will be achieved and what the resulting environmental and socio-economic consequences will be. There is a need for developing and managing future food production systems in ways that the resilient provision of multiple ecosystem services is ensured (Bennett & Balvanera, 2007), both at local and global spatial scales, and to embrace a multiple stakeholder perspective in its widest context (Soto *et al.*, 2010). The effects from climate change need to be considered and the challenge ahead also involves finding a balance between producing

affordable fish food for people in the region and introduction of export earning aquaculture activities. Full development of the aquaculture sector in the WIO requires effective governance and in some countries like Tanzania it is encouraging that aquaculture is being differentiated from fisheries so that it can be fully developed through policies specifically promoting aquaculture expansion. In Europe, one of the main reasons aquaculture has been slow to develop is that it has largely been managed under the Common Fisheries Policy, which led to poor support for developing the aquaculture sector.

Table 2. Main aquaculture producers in Africa in 2008 plus production from some African countries within the WIO region (including plants, wet weight metric tonnes) Source: FAO, 2010, Tanzania includes 102000 tons of seaweeds from Zanzibar.

African Countries	Production	Africa	Production %
Egypt	705 500	Brackish water	604 248 55
Nigeria	152 796	Freshwater	378 155 34
Tanzania	108 404	Marine	121 303 11
Uganda	76 654	<b>Total</b>	<b>1 103 706</b>
Madagascar	9 696		
Zambia	8 505		
South Africa	5 333		
Kenya	4 895		
Tunisia	4 214		
Mozambique	560		

## Overview of Aquaculture Development in Africa

Total fisheries production in Africa was in 2007 around 8 million tonnes and only 10.4% was provided from aquaculture (FAO, 2009). Freshwater fish totally dominates the aquaculture production and Egypt is by far the dominant producer providing over 60 percent of African aquaculture (Table 2). The sub-Saharan Africa region continues to be a minor player in aquaculture despite its natural potential. Nigeria is the leading producer with more than 143 thousand tonnes of cultured catfish, tilapia and other freshwater fishes (Table 2). Other cultured species of significance from Sub-Sahara region are tiger shrimp (*Penaeus monodon*) in Madagascar; *Eucheuma* seaweed in Tanzania (Zanzibar) and abalone (*Haliotis* spp.) in South Africa (Table 3). Egypt is today the second largest tilapia (*Oreochromis niloticus*) producer after China and the world's top producer of mullets (mainly *Mugil cephalus*). According to FAO statistics only around 34% of African aquaculture originates from

freshwater environments and the rest from brackish water (Table 1) (FAO, 2009). Although technically this production is classified as brackish water farming the bulk of the production takes place in inland water with only around 0-2 ppt salinity and often in locations that are a significant distance from the coast. While such activities may not directly impact on coastal ecosystems they may nonetheless impact indirectly.

## Coastal Aquaculture

Global mariculture has increased rapidly in the past three decades, with main production coming from Asia, Europe, and South America. Africa is the world's second-largest continent but its coastline is, due to absence of deep indentations of the shore, only 26,000 km long. However, this still offers plenty of opportunities for coastal aquaculture. Both East and West Africa have rich coastal ecosystems and productive estuaries, which may constitute key natural resources required for development of some forms of coastal aquaculture. However, African mariculture is underdeveloped and total marine production only reached 121303 metric tons in 2009, constituting around 11% of total African aquaculture production (Table 3). The fact that around 100000 tons of this consist of seaweeds from Zanzibar masks the low contribution of marine animal aquaculture in Africa. The investment in marine fin- and shellfish aquaculture has mainly been concentrated in South Africa (abalone), Madagascar and Mozambique (shrimps, *P. Monodon* and other penaeids), and Namibia (oysters) (FAO, 2006). More recent initiatives in East African island states, e.g., Le Reunion, Mauritius and Seychelles, include initial work on marine finfish like cobia, groupers and also on sea cucumbers (WIOMSA/IFS Mariculture Workshop, 2009). A characteristic of marine production in Africa has been production of high value species destined for international markets, or on species generating large biomass from low input (i.e. seaweeds). The latter does not directly provide vital protein for local consumption but does generate livelihoods and needed incomes.

Table 3. Average yearly growth in aquaculture production by groups of countries (production in million metric tonnes and change in percentage (%))

Continent/ Region	Production			Annual change	
	1985	1995	2005	1985-1995	1995-2005
Africa <sup>1</sup>	0.05	0.11	0.65	7.5	19.4
Sub-Saharan Africa	0.01	0.03	0.10	12.1	11.4
North Africa	0.04	0.08	0.55	5.9	21.9

<sup>1</sup>Egypt, Libyan Arab Jamahiriya and Sudan are also included in Near East. (Source FAO, 2009).

## Mariculture Development in Africa – Potential and Sustainability Issues

A significant part of the global aquaculture expansion is anticipated to take place in the oceans and coastal areas. Many coasts today, especially in tropical developing countries, experience increased pressure from human activities (Chuenpagdee and Pauly, 2004) and this is also true for the African continent. Expansions of aquaculture in these areas can bring needed socio-economic benefits, but these may come at the expense of an increased pressure on coastal ecosystems ability to produce various goods and services (Chua, 1997), eventually further jeopardizing people's livelihoods.

Potential environmental impacts from aquaculture expansion are in general determined by the characteristics of culture systems (species, intensity, technology, etc.) and site characteristics (nature of the landscape and seascape, waste assimilating capacity, waste loadings, other users, etc.). An aquaculture activity can provide livelihood alternatives and employment opportunities however few studies have considered details concerning the social dimension side alongside the production (FAO, 2008; Hishamunda *et al.*, 2009). However, the interactions with the environment from some aquaculture systems may, directly or indirectly, simultaneously impact negatively on existing livelihoods and people's well being (Primavera 1993; Naylor *et al.*, 2000). This raises the issue that sustainable livelihood options like aquaculture initiatives need to be reconciled with conservation needs. Extensive farming systems, e.g. traditional pond farming of milkfish/shrimps can, when expanded, also result in negative environmental impacts from habitat destruction, e.g. clearance of mangrove forest. A number of national and international guidelines, e.g. "best management practices" and "codes of conduct", have been developed to guide the industry and individual farmers towards sustainability but they seem to over-generalize and lead to qualitative goals, without specific means of measurement and monitoring. In addition to this the FAO are now developing a broader systematic perspective on aquaculture, i.e. "Ecosystem approach to aquaculture" (Soto *et al.*, 2010). This presents an interesting framework/strategy, which, if implemented, could bring about changes in human behavior with respect to understanding ecosystem's functioning and the need for developing institutions capable of integrating different sectors at multiple scales. The problem is, however, that they are guiding principles and are not being enforced.

Sustainability is a broad concept, but even so it needs to be reduced to specific actions to be useful as an objective for ongoing development of aquaculture. The main sustainability issues include maintenance of capital stocks (natural, human, and man-made capital), efficiency for generating maximum aggregate welfare and equity in distribution of welfare gains and costs (World Commission on Environmental Development, 1987). Maintenance of natural capital implies (1) secured, future provision of ecosystem goods and services to stakeholders across the entire socio-economic spectrum, and (2) avoidance of eroding resilience to natural and anthropogenic disturbance regimes (Jacobs, 1991). Earlier and also some recent developments of modern coastal aquaculture have focused to a large extent on environmental impacts at local scales. The industry is thus failing to incorporate the overarching essence of sustainability, a consideration of the ecosystem perspective stretching far beyond any farm border (regional to global) and including present and future generations of affected societies.

International aquaculture producers will increasingly establish themselves in coastal Africa, with the primary aim to supply markets in Asia, Europe and North America with marine crustaceans and marine finfish. These initiatives will be driven by the private-sector, with governments taking on a facilitating and monitoring role (FAO, 2006b). Challenges for mariculture expansion in the Western Indian Ocean region are many including structuring and implementation of good governance for the coastal zone. Aquaculture systems promoted should have minimized impacts on biodiversity (Diana 2009) and have reduced footprints with respect to inputs of resources, water and energy inputs, as well as waste outputs (Pelletier *et al.*, 2011). Our increased scientific understanding and environmental awareness should enable us to avoid reproducing the errors associated with the expansion of some forms of mariculture in e.g. South East Asia, which have proved to be detrimental from both ecological and social perspectives. One way to learn from such experiences is to ensure that future aquaculture

Table 4. Species and regions that dominate marine and coastal brackish water aquaculture production in Africa 2007. (Production in metric tonnes, (source FAO, 2009))

Species	Region	Production	Species	Region	Production
Giant tiger prawn	Indian Ocean, Western	9 171	Hooded oyster	Indian Ocean, Western	1
<i>Eucheuma</i> seaweeds nei	Indian Ocean, Western	8885	Indo-Pacific swamp crab	Indian Ocean, Western	1
Aquatic plants nei <sup>1</sup>	Atlantic, Southeast	2 900	Marine fishes nei	Indian Ocean, Western	1
Perlemoen abalone	Atlantic, Southeast	783	Blue mussel	Atlantic, Southeast	-
Red drum	Indian Ocean, Western	672	Brine shrimp	Indian Ocean, Western	-
Mediterranean mussel	Atlantic, Southeast	466	Carpet shells nei	Atlantic, Southeast	-
Indian white prawn	Indian Ocean, Western	347	Common cuttlefish	Mediterranean and Black Sea	-
European seabass	Mediterranean and Black Sea	249	Common sole	Mediterranean and Black Sea	-
Atlantic bluefin tuna	Mediterranean and Black Sea	216	European flat oyster	Atlantic, Southeast	-
Pacific cupped oyster	Atlantic, Southeast	168	European flat oyster	Mediterranean and Black Sea	-
<i>Gracilaria</i> seaweeds	Atlantic, Southeast	127	Giant tiger prawn	Atlantic, Southeast	-
Elkhorn sea moss	Indian Ocean, Western	69	Groupers nei	Mediterranean and Black Sea	-
Gilthead seabream	Mediterranean and Black Sea	60	Indian white prawn	Atlantic, Southeast	-
Gasar cupped oyster	Atlantic, Eastern Central	40	Kuruma prawn	Atlantic, Southeast	-
Cobia	Indian Ocean, Western	6	<b>Total</b>		<b>24 162</b>

<sup>1</sup> Aquatic plants nei = Seaweeds (Dry weight, in wet weight 95616 Tons).

development in the WIO gives due consideration to each of the three pillars of sustainability, that is, a balanced understanding of the social, economic and environmental components of aquaculture is required within an enabling governance framework.

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# PART II: Mariculture in East Africa - *An Overview*

## Main Challenges for Coastal Aquaculture Development in the WIO Region: *Who are the winners and losers?*

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Coastal aquaculture in the Western Indian Ocean (WIO) region began in the early 1800s with small “barachois” coastal enclosures in Mauritius (ITC, 1999). In the 1970s, small-scale attempts for aquaculture included experimental trials with fish, crabs, cockles, and oysters in Mauritius, South Africa, Kenya, and Tanzania. It was not until the late 1980s and early 1990s that large-scale developments began in the WIO region for export-oriented seaweed and prawn aquaculture. These are currently the two primary aquaculture production systems in the WIO region.

In order to illustrate the winners and losers of coastal aquaculture in the WIO region we analyze some of the social, ecological, political, and economic processes at various scales for seaweed and industrial prawn farming. We then provide insights into the governance aspects of coastal aquaculture developments by examining the various management approaches that have been proposed and tested. We conclude with recommendations for aquaculture development that may have the potential to benefit coastal resource users, aquaculture producers, as well as the coastal environments in the WIO region.

### Seaweed Farming

*Eucheuma* and *Kappaphycus* are red seaweeds produced for the high-value extract known as carrageenan which is used as stabilizer, emulsifier, or thickening agent in various food additives, cosmetics, and pharmaceutical products. Seaweed farming for export profits began in coastal Tanzania in 1989 and later spread to mainland Tanzania and Madagascar. Seaweed culture was encouraged in the region because it is considered an environmentally sustainable enterprise (Msuya, 1993; Nanyaro, 2005). Seaweed farming units cover a limited area along the lower fringe of the intertidal zone and do not require chemicals or feeds. These aspects demonstrate how the ecological impact of seaweed farming is minimal despite previous claims (e.g. Torre-Castro, 2006; Eklöf, 2008).

Tanzania is the world’s fifth largest exporter of red seaweed (Indonesia and the Philippines are by far the largest producers). Seaweed farming techniques were introduced to women living in Zanzibar Island in the 1970s (Semesi and Mshigeni, 1977). More than 90% of Tanzania’s

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

Despite the advantages of a small source of revenue for local women from seaweed farming, there is a huge disparity between the prices paid to producers for dried seaweed in Tanzania and the market price for refined carrageenan. Lower grade carrageenan prices range currently from 30-50 USD per kg and Tanzanian farmers receive less than 0.17 USD per kg of dried red seaweed (pers. comm. Juma Omar Haji, Department of Fisheries and Marine Resources, Zanzibar 2009). This is attributed to the fact that the total value of carrageenan products internationally is approximately \$10 billion USD (growing at about 3-5% per year) is accrued almost entirely by a few multinational corporations (Bryceson, 2002).

Access is another issue. The expansion of tourist hotels along many parts of the coast has caused seaweed farmers to lose access to important farming areas in the intertidal zone and drying areas on the upper shoreline. Many seaweed farmers have also experienced health problems related to the extensive amount of time spent in the inter-tidal zone tending to the seaweed farms and from carrying heavy loads of seaweed harvests for drying.

In response to some of these issues, mainly the need for better seaweed prices, women seaweed farmers in Tanzania are starting to collectively organize through cooperatives (e.g. Chole Society for Women’s Development on Mafia Island).

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This has been a somewhat successful venture for seaweed farming cooperatives in the Philippines where farmers are receiving substantially better prices for dried seaweed than in Tanzania, and may prove to be a promising development for the industry in the WIO region. We also suggest the WIO region should focus on establishing processing facilities for carrageenan, which is more valuable than the dried form of seaweed. This would allow local seaweed farmers to sell directly to the processing facility and obtain better prices, and coastal WIO countries would also be able to profit from the export of carrageenan to regional and international markets.

## Industrial Prawn Farming

Industrial prawn farming, particularly of the black tiger prawn (*Penaeus monodon*), produces a luxury food item for consumers primarily in the North. Despite the promise of enormous foreign exchange earnings from prawn farming exports, the dramatic role that the prawn industry has played in transforming coastal landscapes and livelihoods in tropical areas around the world has led to growing concerns over the social, economic, and environmental impacts associated with the industry (Vanderveest *et al.*, 1999). These impacts include the destruction of mangrove resources and the ecosystem services they provide. Many communities living adjacent to industrial prawn farms have lost access to and control of mangrove common property resources. Salinisation of groundwater and agricultural land near areas of prawn farming has occurred. Effluents of wastes and chemical and pharmaceutical treatments have caused eutrophication and pollution. The spread of farmed prawn diseases to wild prawns as well as antibiotic-resistant bacteria are also issues (Gräslund, 2004).

For the WIO region, prawn farming began in Malindi, Kenya and the island of Coëtivy, Seychelles in 1989. The project was unsuccessful in Kenya, and the farm in the Seychelles was in production for approximately six years. In 1997, a controversial prawn farming project was proposed for the Rufiji Delta, Tanzania, but was halted after popular protests and pressure by local people, researchers, journalists, and lawyers (Bryceson 2002). Madagascar and Mozambique currently have established industrial prawn farms. The first industrial prawn farm in Tanzania was established on Mafia Island in 2005 and is currently in operation. Corporations responsible for prawn farming in the WIO region have been criticized for land-grabbing, inadequate Environmental Impact Assessments (EIA), lack of consultation or consent with villagers living adjacent to proposed and constructed prawn farms, poor records of payment of compensation

and alienation of neighbouring villages, low wages and abuses of prawn farm worker's rights, and a leakage of profits out of WIO countries.

The overall benefits for industrial prawn farming have generally been short-term and accrued by "get-rich-quick" opportunists. This is primarily due to the fact that after a few years, polluted and diseased sites for prawn farming are often abandoned and foreign corporations move on to new areas leaving deforested and impoverished local communities behind. A case study of the Mafia Island prawn farm in Tanzania is indicative of these trends. Recent research has found that mangroves are increasingly being cleared for expansion, surrounding coastal waters are being polluted, wild populations of fish and crabs are periodically killed, and the majority of villagers and prawn farm workers feel disadvantaged and exploited by the project (Beymer-Farris *et al.*, Forthcoming).

## Conclusions

The case studies of export-oriented seaweed and industrial prawn farming illustrate the increasing disparity between the winners and losers of aquaculture developments in the WIO region. Although some steps have been taken by WIO countries towards more sustainable management of aquaculture development, the political-economic interests of foreign investors and the State are often prioritized. This is often at the expense of small-scale aquaculture producers, adjacent communities of aquaculture production sites, as well as the environments where these activities take place.

Despite the skewed past experiences of aquaculture in the WIO region, we believe that there is a potential for the development of some types of aquaculture to be more broadly beneficial in coastal areas. More recent and promising aquaculture developments in the WIO region include pearl oyster culture (Seychelles since 1994, and Zanzibar and Mafia since 2006) and other edible bivalves (cockles, mussels, oysters, etc.), fish farming of algal/detritus-feeders (mullet, milkfish), and herbivores (rabbit-fish). These small-scale aquaculture production systems are epitomized by the use of holistic technologies culturing organisms at low trophic levels. There are also lower incidences of chemical use and disease outbreaks, and wastes are utilized through integration which lessens the potential negative effects of effluents on the surrounding environment.

In order for these types of aquaculture developments to be considered "successful", the governance of these systems must be addressed. Various management approaches for aquaculture development have been proposed and tested

with varying outcomes (i.e. biotechnical, participatory, and co-management approaches). More recently, the “ecosystem-based approach” has been promoted by the FAO (Soto *et al.*, 2008). We argue that the focus of analysis within the “ecosystem-based” framework is on ecosystem health rather than local livelihoods despite the references to “social issues” and “people’s well-being”. As experience with industrial prawn farming has shown, management approaches that focus primarily on technological solutions to environmental problems will fail by not adequately addressing the underlying political-economic and social issues related to the industry.

We propose the integration of a “rights-based” and “ecosystem” approach to address the interests of small-scale aquaculturists and local communities in areas of aquaculture development in the WIO region. A combined approach would incorporate citizens’ knowledge with the conventional science of ecosystems while ensuring that human, workers, and land rights, social justice, and democratic processes in relation to livelihoods, endowments, entitlements and the capability status of coastal peoples are not only addressed, but practiced. As past experience in Southeast Asia has shown, local people must have more control over the market and value chains for aquaculture so that they can have power over their own development.

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# Overview of Aquaculture Activities in Tanzania

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Fish aquaculture in Tanzania is predominantly a freshwater-based activity. There are an estimated 14,100 ponds covering an area of 221.5 ha farming mainly tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and rainbow trout (*Onchorhynchus mykiss*) producing 1523 tonnes (dry weight) of tilapia and 7 tonnes (dry weight) of rainbow trout in 2004, (FAO, 2010).

The main form of marine aquaculture is that of red algae (*Kappaphycus alvarezii* and *Eucheuma denticulatum*) producing 5000 – 9000 t/yr (dry weight) of mostly *Eucheuma denticulatum* commencing in 1989. The seaweed farmed in subtidal lagoons experienced die-offs at certain times of the year related to high temperatures during the springtides of the hot season and low salinity during the rainy season (Mmochi *et al.*, 2005). The solution to this was found to be the floating line system, which is however hampered by tow net fisheries (Msuya *et al.*, 2007). The government is working hard to stop the type of fisheries, which may in turn help the seaweed industry. The farmed seaweeds are sold as cash crops to Belgium, France and USA.

Tanzania has a big potential for finfish and prawn mariculture. The total area identified as suitable for mariculture is estimated to at 3000 ha with potential to produce an estimated 11,350 tonnes (dry weight) of shrimp (FAO, 2006). From 1996 - 2004 an integrated mariculture pond system of finfish, shellfish and seaweed was developed at Makoba, Zanzibar (Bryceson, 2002; Mmochi *et al.*, 2002). From 2004, implementation of the various components of the system started through various partners (Rice *et al.*, 2006). Finfish (milkfish, mullet, rabbit fish and estuarine tilapia) and prawn farming started with backyard pond culture where fish were stocked and harvested continuously. In 2006, the first commercial type pond of 1 ha stocked with milkfish fingerlings was established and the first harvest of 1 ton/ha selling at 2000 USD was obtained. The studies in the pilot pond facilitated development of a manual for farming milkfish, complete with cost benefit analysis (Requintina *et al.*, 2008). In 2008, an EU funded project duplicated the commercial model pond in Bagamoyo to Pemba Island, Tanga and Mtwara

Districts. From 2009 another EU funded project started adding wind turbines to the model ponds to provide electricity for water pumping in order to improve water circulation, security as well as some fish processing. During the implementation of the EU projects 22 farmers were trained in fish farming and extension services and have in turn become trainers in each of the three districts. Their training has resulted into development of 43 ha of pond areas in 2009 alone. The training also resulted in increasing the price of the farmed fish from 1 to 2.5 USD/Kg through selective marketing in 2009. In the same year the best farmer produced an equivalence of 3 tons/ha or 7500 USD/ha. In 2008 the first ever prawn post larvae (PLs) were produced by private sector at Mbegani Fisheries Development Centre and are being sold to pond owners especially in Tanga region where milkfish fry and fingerlings are scarce.

Shellfish farming in Zanzibar started in 2004 using pens made by wooden pegs or fossil coral stones (Kite-Powell *et al.*, 2004) (Table 1). In 2005 half pearl farming was initiated. Unfortunately the pen culture of shellfish at the intertidal suffered mortalities probably for the same reasons as seaweeds. Accordingly, in 2006 the floating line system was adopted to shellfish and pearl farming leading to the first pearl oysters in Bweleo, Zanzibar. Currently, pearls are being farmed in Bweleo, Nyamanzi and Unguja Ukuu on Unguja Island and Mkoani in Pemba Island on Zanzibar, Mafia Island, Tawalani in Tanga and Mngoji in Mtwara. In Bweleo and Nyamanzi no take areas and village bylaws have been developed to ensure sustainability. Other forms of aquaculture that are developing are crab fattening, sea cucumber and sponge farming. The biggest challenge in most of the developing industry is the availability of fry/fingerlings, crablets and other seeds.

Table 1. Development of aquaculture in Tanzania

<b>Chronology of Aquaculture in Tanzania</b>		
<b>Year</b>	<b>Activity</b>	<b>Agent</b>
1950s	Tilapia farming in fresh waters	Private sector sponsored by FAO
1980s	Research on cage culture of rabbit fish ( <i>Siganus</i> )	Institute of Marine Sciences (IMS) sponsored by International Foundation for Science
1980s	Seaweed culture experiments	Prof Keto Mshigeni
1990's	Commercial seaweed farming in Zanzibar	Private sector
Mid 1990s	Environmental and Socio-economic impact studies on seaweed farming	IMS Sponsored by Canadian International Development Agency
1992 – 1994	Seaweed farming introduced to Tanga and Bagamoyo	Private Sector
1995 – 1996	Seaweed farming introduced to Mtwara, Lindi, Mafia and Kilwa	IMS sponsored by Rural Integrated Project Support
1996-2001	Integrated mariculture experiments at Makoba	IMS, National Center for Mariculture (Israel), Woodshole Oceanographic Institute (WHOI, USA) sponsored by Swedish International Development Agency and German Israel Fund for Research and International Development
2001- 2003	MASMA mariculture project milkfish farming	IMS – WIOMSA
2001	Bio-filtration experiments at Makoba	IMS, WWF and Tel Aviv University
2004	The stakeholders workshop on “Advances in mariculture”, Zanzibar, the beginning of mariculture extension.	IMS - WIOMSA
2004	Crab fattening experiments	Marine and Coastal Environment Management Program (MACEMP), IMS, ACDI/VOCA and Private sector
2004-2009	Sustainable Coastal Communities and Ecosystem (SUCCESS) pilots of small scale backyard and commercial finfish ponds culture	IMS, WIOMSA and Costal Resource Center of the University of Rhode Island sponsored by USAID and many partners.
2004	Shell fish farming	IMS-WHOI, McNight foundation, SUCCESS and Regional Programme for the Sustainable Management of the Coastal Zones of the Countries of the Indian Ocean (ReCoMaP)
2005 – to date	Shellfish, pearl farming and entrepreneurship	IMS-CRC-SUCCESS - TCMP, USAID, ReCoMaP, USAID-Tanzania and US State Department
2006 -date	Value addition to seaweed industry.	IMS, Innovation Systems and Clusters Program sponsored by Sida.
2007-Date	Scaling up for finfish and pearl farming	Private sector and government, IMS, ReCoMaP and WIOMSA.
2008	Cucumber farming experiments in-Pujini, Pemba	Private initiative
2009	Production of prawn PLs	Private Sector Initiative
2009	Sponges farming experiments in Jambiani, Zanzibar	Private sector initiative
2010	Wind turbines for pumping water and providing electricity to fish farms	IMS and WIOMSA sponsored by ReCoMaP

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# Mariculture Development in Kenya - An Overview

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Mariculture development in Kenya started three decades ago. The initiatives are undertaken by the Department of Fisheries and Kenya Marine and Fisheries Research Institute (KMFRI), which has shifted from one parent ministry to another over the period. Considerable progress has been achieved in the recent years including development of an aquaculture development strategy and streamlining of aquaculture as a key sector to achieve Kenya's Vision 2030.

Compared to freshwater aquaculture, mariculture has not yet developed to realize its economic, ecological and cultural potential, because of being visualized as a scientific research activity. Further to this, development of mariculture is greatly impacted by conflicting government policies and donor driven conservation projects. Despite the setbacks, in the last decade, mariculture has made progress through development of simple innovative technologies in ponds and cages construction that are less costly and selection for culture of organisms that need limited water management and feed low in the food chain e.g. milkfish (*Chanos chanos*), mullets (*Mugil cephalus*), mud crabs (*Scylla serrata*), seaweeds (*Eucheimia denticulatum*) and prawns (*Penaeus indicus* and *P. monodon*) (Mirera, 2009; Mirera and Ngugi, 2009, Wakibia *et al.*, 2006; Mwaluma, 2002). There have also been attempts to culture mangrove snapper (*Lutjanus argentmaculatus*) using acadja nets and targeting natural restocking of the system.

Initial attempts on mariculture along the Kenyan coast on record are the 80's ambitious Ngomeni Prawn Farm that covered 60 ha with funding from FAO through the Department of Fisheries (UNEP, 1998). Substantial productions were made from the farm and two satellite farms developed (Wampare's prawn farm & Kwetu Training Centre prawn

Table 1: Kenya Marine aquaculture production for different species for the period June 2009 – June 2010.

Species	Production centres/ communities	Market outlet	Production (tons)	Value (US \$)
Mud crab	3	-Tourist hotel -Private homes -Domestic	0.3265	1,306
Milkfish & mullet	6	-Domestic -On farm purchases -Local	1.76	3,520
Seaweed (dry)	1	-Dealers-export	2.0	320
Prawns	4	-Private homes -On farm purchases -local	0.250	1,167

farm) before it collapsed after donor funds being withdrawn. During the farming, milkfish and mullets were harvested as bycatch from the ponds. Other mariculture species that developed during the time included also seaweed farming (Gazi bay and Shimoni) and oyster (Gazi bay and Mtwapa creek) culture. These did not developed due to lack of elaborate good market outlets.

Due to capacity limitations and low extension services, most mariculture productions in the last decades went unrecorded and hence not reflected in national productions statistics. The harvests were for subsistence and some sold at local tourist hotels and restaurants.

The summary productions for various cultured species in the last one-year (June 2009 –June 2010) are indicated below (Table 1).

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# A Synopsis of the Current Status of Mariculture in Mozambique

Isabel Omar<sup>1</sup> and Thomas Hecht<sup>2</sup>

Mozambique has a coastline of 2780 km that extends from 26° 51'S to 10° 30'S with a climate ranging from sub-tropical in the south to tropical in the north. Mariculture in Mozambique has a chequered history. The potential for industrial scale prawn farming was realized as early as 1988 when the "Pilot Project for Coastal Shrimp Aquaculture" was set up by UNDP and the Government of Mozambique and executed with FAO technical assistance. The farm in the Maputo area had an area of 10 ha and was privatised in the mid 90's. The project laid the foundation for appropriate technological developments. During the project life, yields of 2.5 tonnes of *P. indicus* per annum per ha were attained (Ribeiro & de Sousa, 2001, Rafael & Ribeiro 2002). The first private investment in shrimp farming occurred in the mid 1990s in Quelimane (18° S) (Hecht *et al.*, 2005). Small-scale coastal aquaculture is of more recent origin. The potential of this sector to contribute to food and nutritional security and socio-economic development was first promoted in the Mozambique Action Plan for the Reduction of Absolute Poverty (2001-2005).

The Fisheries Research Institute (Instituto Nacional de Investigação Pesqueira-IIP) and the National Institute for Aquaculture Development (Ministry of Fisheries) have identified 30,000 ha suitable for industrial scale shrimp farming, 75% of which are located north of 20° S. These areas are free of any conflicting uses and do not impinge on any conservation or mangrove areas. In the Beira region some 10,200 ha have been identified as suitable for prawn culture, with an additional 6,100 ha in the Quelimane area and 2000 ha in the Pebane and Angoche areas. It is estimated that a further 170,000 ha may be suitable for shrimp farming in the northern regions (Ribeiro & de Sousa, 2001; Rafael & Ribeiro, 2002). Development is not limited to these areas. Where land is identified that does not conflict with conservation or traditional uses then the application process can proceed. For example, Indian Ocean Aquaculture has been established in Pemba in Cabo Delgado province. A study of the oceanography of Pemba Bay has recently been completed and this has paved the way for the development of marine fish farming in cages.

Small-scale mariculture is limited to seaweed farming in Cabo Delgado and Nampula and a few scattered fish and prawn farming operations. Seaweed farming (*Eucheuma spinosum* and *Kappaphycus alvarezii*) is promoted by two NGOs as part of wider programmes assisting coastal communities. Over 100 families are currently involved in seaweed production with an estimated output of around 160 tonnes (dry weight) per annum. Marketing the dry product still remains problematic and farmers in 2006 earned in the region of US\$ 60 / month (Ribeiro, 2007). Surveys undertaken in Memba and Nacala districts of Nampula province for seaweed farming revealed that over 830 ha is suitable for off bottom shallow water culture and 700 ha for raft and pole and line

culture. It is estimated that there are 700 to 1500 ha suitable for pole and line farming in Cabo Delgado (Ribeiro, 2007).

Small-scale prawn farming is limited to three farms (Marimo Lda., Prapesca Lda. and Fernando Momade). Two are in the Beira area, and one in Angoche. These farms range in size from 4 to 6ha and produce *Penaeus monodon* under extensive conditions. PLs are obtained from commercial hatcheries. Production varies between 250kg and just under 10 tonnes per annum per farm. Due to several constraints small-scale prawn farming has not really been successful (Ribeiro, 2007).

Small-scale fish farming is limited to two small operations in Nampula province, that produce mullet and milkfish in polyculture with *Tilapia*. Water to their ponds is supplied by tidal exchange and on-growing is sustained by natural productivity with yields of around 200 kg/ha/year (Ribeiro, 2007).

There are a total of three industrial scale prawn farms in Mozambique. In 2008 only two farms were in production, one in Beira (Sol & Mar) with approximately 160 ha of ponds and Aquapesca in Quelimane with 140 ha of ponds. Indian Ocean Aquaculture, in Pemba, with around 550ha of ponds is currently under administration and is dormant. Total prawn production in 2010 is estimated to be around 1200 tonnes (F. Ribeiro, BioGlobal Consultoria & Servicos Lda. March 2011, pers.comm).

Only extensive prawn farming is permitted with annual yields in two cycles ranging between 2.5 and 3.6 tonnes / ha. The tiger prawn (*P. monodon*) is more suited for the tropical coastal region north of 18° S, while the Indian white prawn (*P.indicus*) is better suited for the southern regions.

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Marine fish farming trials were initiated in 2009 in Pemba Bay. Aqua Pemba Lda. is currently completing the first pilot phase with cage farming of cobia (*Rachycentron canadum*) and Dusky kob (*Argyrosomus japonicus*). Disease free juveniles of cobia and kob were imported from Reunion and South Africa, respectively.

The legislative and regulatory environment for commercial and so is the foreign scale mariculture development is enabling and so is the Foreign Direct Investment incentives offered by Government (Hecht *et al.*, 2005).

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# A Synopsis of Marine Aquaculture in South Africa

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Marine aquaculture in South Africa falls under the umbrella of the Department of Agriculture, Forestry and Fisheries. Recognising that capture fisheries in South Africa are fully subscribed and offer very little in terms of new quota allocations, the Marine Aquaculture Development Section of the Department has been promoting the development of the mariculture sector aggressively. Significant progress has been made in a short time, consultations with industry have been initiated to develop an integrated fisheries and aquaculture development plan, application procedures have been streamlined and capacity within the department has been strengthened.

At present the sector is small but valuable, and is dominated by shellfish culture including oysters (*Crassostrea gigas*), mussels (*Mytilus galloprovincialis*) and abalone (*Haliotis midae*). Oysters have been farmed in South Africa since the 1950s and currently there are five operational farms that use either tidal rack systems or floating long lines. The largest farms are in Algoa Bay on the SE coast and two farms are situated in Saldanha Bay on the west coast, all using modified Spanish raft culture systems and New Zealand long lines. The production cycle from spat to market size is 6 months. Abalone farming in South Africa was preceded by a lengthy research phase, which started in the early 1980s. The first farms were established in 1992 and currently there are 14 farms, each producing between 25 and 235 tonnes pa. All farms, except one, are land based, pump ashore, flow-through systems using plastic or concrete tanks. Abalone are fed mainly on a complete extruded feed at a FCR of 1.1 to 1.2:1, which is supplemented on five farms with wild harvested kelp or farmed seaweed. Products are diverse (live, frozen, canned or dried) and 99% of total production is exported to the Far East. After a decade of sustained research, marine finfish farming is about to make rapid advances. The two main species are kob (*Argyrosomus japonicus*) and yellowtail (*Seriola lalandi*), while several other species are in experimental phases. There is also some interest in the farming of Atlantic salmon.

Except for one experimental cage farm, there are two land based, partial re-circulation systems that have started operating, while a third farm is in the construction phase. Land based aquaculture sites are limited and for the industry to expand requires a dedicated exploratory open ocean aquaculture programme. Seaweeds (*Ulva* and *Gracilaria*) are only produced on some abalone farms as an important supplementary feed source. In 2009 total mariculture production amounted to 3742.5 tonnes (Table 1), with a total value of US\$ 36.2 million. Abalone was the most important product and total production in 2009 was 913.58 tonnes contributing 91% (US \$ 32.88 million) to the total value of mariculture products (Britz *et al.*, 2009; DAFF, 2010).

South Africa has an active, multi-institutional mariculture research programme, funded by government and the private sector. The major constraints facing the development of the sector are the lack of institutional and human capacity, poorly funded research programmes, conflict with other coastal users and the high cost of coastal land. Government is now actively exploring the potential of aquaculture development zones. The sector is supported by rising demand for fish, declining fisheries and increasing fish prices. The value of current private sector development initiatives is currently estimated to exceed US\$ 45 million.

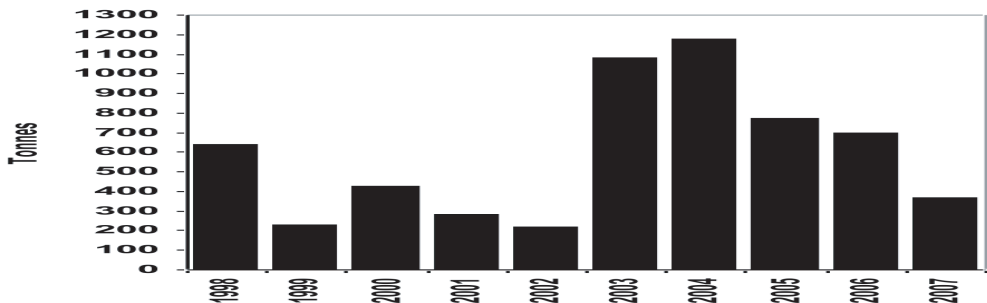


Table 1. South African marine aquaculture production (2005 – 2009)

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# A Synopsis of Marine Aquaculture in Madagascar

Jacques Iltis<sup>1</sup> and Eulalie Ranaivoson<sup>2</sup>

Unlike most countries in Southeast Asia, Madagascar is not a place where aquaculture in marine or brackish water is long-established. Almost all production systems currently in use only started in the 1990s or in the current decade and intend to meet food needs of developed countries. Moreover a number of activities have not moved beyond the pilot phase despite suitable natural conditions and technically successful results (oysters, milkfish, *Artemia*, etc). There are various explanations for this: economic isolation during the previous two decades, insufficient training, deferred international funding, degraded road infrastructure. Nevertheless, significant progress has been made in a short time.

In recent years, farming of Sea Cucumber (*Holothuria scabra*) has emerged on the South West coast, an area where the vast majority of the population must now adjust to a crisis involving both the environment and pauperization. *Holothuria* culture is an innovative activity in the WIO region and the experimental hatchery (located in Toliara, IHSM) focuses the attention of specialists, as well as the partnership between local communities in charge of the rearing phase, NGO's and the brand new start-up company in charge of conditioning and export. Seaweed farming is practiced by family groups in the North since the 1990s. Two species (*Euchema* and *Kappaphycus* sp.) are cultivated, then exported via a private company, in a context of growing demand for Carrageenans. Since some time, seaweed farming is also growing in coastal villages near Toliara. Culture of *Spirulina* also begins to develop in the South-West, as in the Highlands. Culture in ponds of the local strain *S. platensis* is now under control and the objective is to create farming units at village level. An international symposium on training and technology transfer regarding the culture of *Spirulina* was organized in Toliara (Bemiarana *et al.*, 2008). The potential value of this activity goes far beyond economic interests: it also aims to supplement the daily diet of poor families in regions where malnutrition and undernourishment are a common occurrence.

In a quite different context, Madagascar is the leading country in shrimp aquaculture in Africa while remaining one of the smallest producers in the world. Following FAO recommendations and feasibility studies, the Malagasy Government encouraged development of semi-intensive shrimp farming in the 1990's. The sector was stimulated by the shrimp fishing industry, so that farming consistently generated cash for the national economy for a dozen years (50 million Euros

in 2006 for an exclusive production of *Penaeus monodon*). However, increased international competition, declining shrimp prices and the rising cost of energy and fishmeal resulted in a severe crisis in 2008. Production then decreased, two of the six industrial farms stopped their activity while others slowed down. Only products with quality labels seem to resist the crisis. A first overall assessment can be made after 15 years of activity. In terms of environmental and social management, the semi-intensive farming system can serve as a business case for WIO countries. Mangroves are not threatened by development of rearing ponds which have been constructed upon extensive salt flats. However, the business model of a premium market is clearly under threat, and this despite a recovery plan launched recently.

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Table 1. Overview of mariculture production in Madagascar.

Species	Environment	Location	Technical conditions	Socio-economic conditions	Production (dry weight)	Potential for development
<b>Seaweed</b>	Subtidal zone	North SA VA Diana	Cuttings + planting (off-bottom line)	Seaweed culture 256 farmers (2007) conditioning and export company  Local communities supported by NGO	Nosy Ankaou : 2006 : 892 tons 2007 : 1232 tons  Starts 2010	Great potential  Technique easily accessible to fishermen + high international demand for Carraegeenans
	Subtidal and intertidal zones	South-West Atsimo-Andrefana Toliara				
<b>Spirulina</b>	Marine and brackish waters alkaline ponds and lakes	South-West Atsimo-Andrefana, Villages surrounding Toliara  Center West Menabe, Morondava	Either culture in controlled environment or collection in the wild + rearing	Experimental unit of production (550 m <sup>2</sup> ) + small scale units (coastal zone, Highlands)	Spirisud : 1070 kg  30 % local humanitarian distribution 70 % Local sale	Great potential  Technique easily accessible to fishermen + national market growing
<b>Sea cucumber</b>	Subtidal and intertidal zones : lagoons, seagrass	South-West Atsimo-Andrefana, Toliara	Hatchery (IHSM Toliara) + farms in the vicinity	Local communities supported by NGOs and development banks + private export company	Starts 2010  Hatchery : 7000 juveniles/ month  Farm : 600 adults/month	Great potential  Accessible techniques to fishermen + high international demand
<b>Prawn</b>	Intertidal zone off-mangrove areas mudflats, saltflats	North-West Diana, Sofia, Boeny  Center-West Menabe	Culture in controlled environment: hatchery + semi-intensive rearing	Agro-industrial groups 4 farms (2010) Total area of ponds : 2228 ha 5670 employees (2007)	Production for export only  8547 t (2007) 6100 t (2009)	International markets stagnating, competition from <i>P. vannamei</i>

# Mariculture Development in Seychelles and other Western Indian Ocean Island States: *An Overview of Challenges and Prospects*

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## Introduction

Seychelles has a relatively long history of prawn farming, which was established on Coetivy Island in 1989 by the Islands Development Company Ltd and the Seychelles Marketing Board and later taken over and managed by the latter. The farm comprised of two hatcheries and around 200 ponds and occupied an area of around 96 ha, and when in full production had a workforce of around 350 people (mainly Thai and Sri Lankan nationals). Production of *Penaeus monodon* (Black Tiger prawn) peaked at 1200 tonnes per annum in 2004, but by 2007 had declined to just under 400 tonnes (Fig. 1). Broodstock was imported from Madagascar and Mozambique. The product was held in high esteem internationally and locally (Hecht, 2009). For several reasons production at the prawn farm ceased in late 2008. Amongst others these included the high operational costs due to the location of the farm, which is situated approximately 300 km away from the inner islands and the difficulty to produce sufficient numbers of post larvae for stocking into grow-out ponds and other private sector interests. Much of the hardware of the farm has been sold, but the pond infrastructure remains available for future developments.

Pearl (oyster) farming in Seychelles was started in 1995 and continues on Praslin in the Curieuse Marine National Park. Black lipped oyster (*Pinctada margaritifera*), and the winged Oyster (*Pteria penguin*) are produced. Round pearls are mainly produced through Black lipped Oyster, while half pearls are produced by winged oyster. Nuclei are imported from Japan and Australia and implanted by foreign specialists (ITTAS 2004). Harvesting occurs two years after implantation and the size of the round pearls vary from 8 to 12mm. The nacre thickness is 1.2 ~ 1.5mm and the colour varies from black, greenish-black to grey (ITTAS, 2004). Spat collection occurs throughout the year, although October is the most productive time (ITTAS, 2004). The concession covers an area of around 19ha.

Prawn feed was and still is produced on Mahe and this feed is also exported to Madagascar and Tanzania.

The main reasons why mariculture has not developed further in Seychelles is principally because of a generally poor understanding of the sector, the reliance on the artisanal capture fishery for protein supply, the absence of a sector "champion", an uncompetitive investment environment, lack of scientific and technical capacity and the absence of a properly defined legislative and regulatory framework within which the industry can develop in a structured manner (Hecht, 2009). The problems listed above reinforce the importance of Government support if the sector is to sustain its own development.

Recent developments indicate a change in support for mariculture development in Seychelles from Government, the private sector (including tourism), civil society and NGOs (Hecht, 2009). With the sharp increase in global food and fuel prices in 2008 (IMF, 2008), which affected many small developing countries, such as Seychelles, a new strategy needed to be devised to address emerging food security concerns. Even though the emphasis was put on increasing agricultural production, mariculture was considered as one of the sectors which could potentially ensure food security and provide significant support for the socio-economic development of the country. Moreover, the decline in the tourism industry as a consequence of the global credit crunch, juxtaposed with declining tuna catches provided further impetus for Seychelles to recognise the importance of establishing new industrial sectors. For marine aquaculture to become a player in the economy of Seychelles requires a proper framework in the form of a sector development plan (Master Plan) to be put in place the necessary guidelines, a legislative and regulatory framework and investment incentives. The absence of a sector development plan can have adverse consequences. For example an oyster farming project with *Crassostrea gigas* did not materialise because the site selection process was undertaken without consulting other resource users and residents in the vicinity (Hecht, 2009). The new approach taken by Seychelles is to involve all key stakeholders in the development of the sector development plan right from its beginning (Hecht, 2009). Bryceson (2002) demonstrated the

consequences of inadequate public consultation on the development of a large scale prawn farming venture in Tanzania in 1999/2000.

Alongside a transparent process the sector development plan is adopting an Ecosystems Approach to Aquaculture (EAA). This approach has several definitions, but in the case of the sector development plan it refers to “the balance of diverse societal objectives, by taking account of the knowledge and uncertainties of the biotic, abiotic and human components of ecosystems including their interactions, flows and processes and applying an integrated approach within ecologically and operationally meaningful boundaries” (Soto *et al.*, 2008). Seychelles finds itself in the fortunate position to implement EAA because the usual industrial needs and demands that would have been present if an industry already existed are absent. Hence Seychelles has the ability to develop a sector in line with its international “green” image and this has immense marketing value.

## Mariculture developments in Mauritius: Challenges and lessons to be learnt

Mauritius has a more developed mariculture sector than Seychelles, though the approach adopted during its development may have brought about many unforeseen problems (O. Venkatasami, Albion Fisheries Research Centre, pers. com.). Mariculture in Mauritius dates back to the French Colonial times when juvenile marine fin-fish were collected from the wild and placed in Barachois for fattening. Intensive commercial mariculture technology was only introduced to Mauritius during the late 1980s and early 1990s

through a mariculture programme at the Albion Fisheries Research Centre funded by Japan (Hecht & Shipton, 2007). The project developed some innovative technologies. However the general consensus is that the project could have been more productive if it had received greater support from the private sector and Government (O. Venkatasami MAIFPS, pers. com).

Modern cage culture is restricted to a single farm (Ferme Marine de Mahebourg - FMM) in the Mahebourg Lagoon in the south-east of Mauritius. The farm produces Red drum (*Sciaenops ocellatus*) in 20 circular cages. The farm has been in operation since 2001, when several other species such as Goldline seabream /Natal Stumpnose (*Rhabdosargus sarba*) were being produced on a trial basis. Inadequate public participation during the early planning and development phase of the farm has hampered its development (Jerry Khee Choy, FMM, pers. com). The Mauritius Mariculture Sector Development Plan which was developed five years after the development of the farm emphasises the importance of public engagement during the farm planning phase. There is some degree of freshwater tilapia and ornamental fish farming in Mauritius but this is not part of the focus of this paper. In 2008 Mauritius produced some 175 tonnes of Red Drum (FAO 2010).

There is no doubt that Mauritius has great potential to expand the mariculture sector from where it is at present. The current goal of the fisheries authorities is to revise the Master Plan such that it will better cater for the actual needs and demands of the sector.

## The status and challenges for mariculture development in the Comoros

Although mariculture is non-existent in the Comoros the country has some potential that could be developed in future (UNEP, 2006; Hecht and Shipton, 2007). In particular the lagoons on the south west part of Moheli (20-30m deep) provide some very suitable sites for cage culture (Hecht and Shipton, 2007). Other culture organisms that could be considered for these lagoons include soft corals, pearl culture, sponge culture and sea cucumber ranching

However the development of a commercial mariculture sector in the Comoros is a long way off and would require an intense effort by Government to attract foreign investors and would have to be preceded by a more in depth assessment of opportunities.

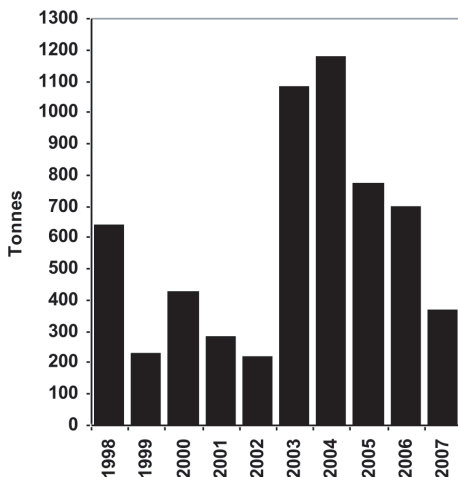


Figure. 1. Seychelles prawn production (1998 to 2007)

## The Status and Challenges for Mariculture Development in Madagascar

With the notable exception of the commercial penaeid prawn industry, mariculture in Madagascar can at best be described as being in its infancy (Hecht and Shipton, 2007). There has been significant input by development agencies such as JICA of Japan to develop technologies for the farming of seaweed, *Spirulina*, *Artemia* and brackish water tilapia but none of these have been successfully taken up by the private sector for commercial application. However, Madagascar was ranked fourth in Africa in terms of total aquaculture production with an output of over 11,200 tonnes in 2008 (FAO, 2010). Prawns were the largest contributor to mariculture production with 6750 tonnes (valued at US\$ 33,750 million), followed by seaweeds (1500 tonnes dry weight valued at US\$ 203 million).

Since 2007 the prawn farming industry in Madagascar has been guided by the Shrimp Aquaculture Master Plan (Hecht and Shipton, 2007). Strategies in the document include protocols to promote sustainable small-scale commercial and family based prawn culture, and the identification of appropriate culture and biosecurity technologies and protocols. With a coastline of more than 4,800 km Madagascar has significant opportunities for mariculture development

Although Madagascar has made significant progress in the past it still has many hurdles to overcome. The sector development plan needs to be reviewed and updated where appropriate and sustainable farming practices incorporated to ensure the best approach towards developing the mariculture sector. Furthermore, enhanced Government support to private investors will be a key factor in its future development (Hecht & Shipton, 2007).

## Reunion and Mayotte

Reunion and Mayotte Island are overseas territories of France. Both have been aggressive in developing aquaculture over the past two decades (ARDA, 2008). These developments have been largely due to the initiatives taken by the "l'Association Réunionnaise de Développement de l'Aquaculture" (ARDA) and AQUAMAY (the Mayotte Aquaculture Development Association) with support from IFREMER. As elsewhere, the undersupply of fish from the local fishery was the main driver of aquaculture development there (ARDA, 1999).

Marine finfish mariculture in Reunion started in 1999 with two species, viz. red drum (*Sciaenops ocellatus*) and Goldline seabream (*Rhabdosargus sarba*). There are several farms that produced red drum on a commercial basis in 2008 (ARDA, 2008). In 2006 production in Reunion amounted to 55 tonnes of red drum and one tonne of cobia (*Rachycentron canadum*) (ARDA, 2008), while in Mayotte some 130 tonnes of Red Drum were produced in addition to some experimental quantities of cobia and Goldline seabream (FAO 2010).

Initiatives by ARDA and AQUAMAY are ongoing to develop new and appropriate technologies for the advancement of offshore cage culture and to sustain the confidence of private sector investors.

## Acknowledgements

I should like to convey my gratitude to Professor Tom Hecht (Rhodes University, South Africa) who led the Scoping Survey in Seychelles and provided very useful information which was used to write this paper. I am grateful to the International Foundation for Science and the Western Indian Ocean Marine Science Association for providing financial support to attend the Mariculture Workshop in Zanzibar and the subsequent selection of this contribution for publication. I am also grateful to the scientific staff at the Albion Fisheries Research Centre in Mauritius for their valuable comments and information. Finally thanks to V. Lucas and N. Bristol from the Seychelles Fishing Authority for their time and help to review this paper.

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## PART III: Aquaculture and Sustainability - *Sharing experiences*

### Aquaculture and the Environment - *An Ecosystem Approach*

Max Troell<sup>1,2</sup>

Today, aquaculture constitutes the fastest growing food production sector globally and is widely regarded as the only means to meet the increasing demand for seafood (FAO, 2009). Aquaculture is, however, not a panacea for economic development, food production or livelihoods, and needs to be looked upon as one, among many other, economic activities with both positive and potential negative environmental and social impacts. Existing national and international “best management practices”, “codes of conduct”, and “development criteria” etc., have been developed to guide the aquaculture industry and individual farmers towards sustainability. The market now also forces the industry to develop various standards, such as guiding principles and labelling schemes (e.g. the Aquaculture Dialogue, WWF)), and various tools are being used for analysing performance and conformance (Ecological Footprints, GAPI, Life Cycle Analysis, FishPrint, livelihood analysis, etc.). What becomes clear is that no silver bullet exists and there is a need for tools that complement one another. In addition organisations such as the FAO have recently moved beyond their earlier established Codes of Conduct and are now developing a broader systematic perspective on aquaculture, i.e. “Ecosystem Approach to Aquaculture” (EAA) (FAO, 2010). When implemented, this strategy could force changes in human behavior with respect to understanding ecosystems’ functioning and the need for developing institutions capable of integrating different sectors at multiple scales. Current management of aquaculture is usually, like many other food production systems, far from being integrated or carried out within a broader ecosystem perspective.

The ecosystems approach (EA) adopted under the Convention on Biological Diversity in 1992 (UN CBD, 1993) forms the basis for the EAA. EA is defined as a “strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way”. The formulation of EAA specifically builds on the conceptual work carried out to develop the ecosystem approach to fisheries’ (EAF) (FAO, 2003), including the guidelines on human dimensions (FAO, 2008), as well as past initiatives related to planning and management for sustainable coastal aquaculture development (GESAMP, 2001).

#### Definition of EAA

During a FAO workshop in 2007 (FAO, 2008) the following definition of the EAA was agreed upon:

“An Ecosystem Approach to Aquaculture is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems”.

The set definition emphasizes that social and biophysical dimensions of ecosystems are inextricably related and that an ecosystem approach to aquaculture development would identify factors contributing to resilience of both dimensions. Adaptive management is an important strategy for building resilience.

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Table 1. Key principles for guiding the Ecosystem Approach to Aquaculture (from FAO, 2010)

Principle 1	Principle 2	Principle 3
Aquaculture development and management should take account of the full range of ecosystem functions and services, and should not threaten the sustained delivery of these to society.	Aquaculture should improve human well-being and equity for all relevant stakeholders.	Aquaculture should be developed in the context of other sectors, policies and goals.
This acknowledges that ecosystems provide vital services which underpin most human activity, and that we need to ensure that aquaculture does not threaten the sustained delivery of these services through damage of ecosystem functions. It is of course a great challenge to develop aquaculture in the context of ecosystem functions and services as this involves extensive knowledge about ecosystem functions, defining ecosystem boundaries and estimating farming practices impacts on assimilative and carrying capacity. Ecosystems function at a range of scales implying a need for a “nested” approach with different approaches to management according to scale. The mix of ecosystem services will depend on wider management practices and the trade-off among different services must be acknowledged.	This principle seeks to ensure that aquaculture provides equitable opportunities for development and equitable sharing of its benefits. Both food security and safety are to be promoted as key components of well-being.	Aquaculture development does not take place in isolation and this principle recognizes the need for multi-sectoral or integrated planning and management systems. This principle also acknowledges the opportunity of coupling aquaculture activities with other production sectors in order to promote materials and energy recycling and better use of resources in general.

(note: biodiversity underpin ecosystem functions and services but in addition to this we have a moral responsibility to preserve biodiversity – i.e. under the Biodiversity Convention (CBD).

Both the EAA and EAF have three main objectives: 1) ensuring human well-being; 2) ensuring ecological well-being; and 3) facilitating the achievement of both, i.e. effective governance of the sector/areas where aquaculture occurs and has potential for development. The prime goal of EAA is to overcome the sectoral and intergovernmental fragmentation of resources management efforts and to develop institutional mechanisms for effective co-ordination among various sectors active in ecosystems in which aquaculture operates and between the various levels of government. Three interlinked key principles been identified for guiding EAA (Table 1).

## Conclusions

Implementation of the Ecosystem Approach to aquaculture implies a transition from traditional sector-by-sector planning and decision making to a more holistic approach of integrated natural resource management and adaptive management. This requires tighter coupling of science, policy, and management, as well as strengthening of institutions. Aquaculture continues to grow and an ecosystem approach to aquaculture (EAA) is necessary to identify factors contributing to resilience of both the social and biophysical systems. It provides a way to plan and manage

aquaculture development that is integrated with other sectors at different scales, taking full account of environmental limits and the interests of other resource users and stakeholders beyond the aquaculture sector. It is important, however, that the ecosystem approach will be aimed for also by other sectors and not only aquaculture.

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# **Aquaculture and Climate Change:** *What are the challenges for the WIO Region?*

Malcolm C. M. Beveridge<sup>1</sup> and Michael J. Phillips<sup>2</sup>

## **Climate Change in the WIO Region**

Current climate change models predict an increase in average annual temperatures in the WIO Region in the order of 2-2.5° C by 2100 with similar increases in mean annual sea temperatures. Over a similar timescale, precipitation during December-February is expected to increase by 5-20% and decrease by 2-10% during June-August, with an increase in the frequency of unusual (storm, flood) events. Sea levels along the East African mainland coast are expected to rise by some 2-3 mm per year (i.e. by 1.6-2.4 cm by 2100) but rise by up to twice this much in Madagascar. In short, the region can expect to experience higher temperatures, especially in summer, increased precipitation and runoff during winter and reduced rainfall during summer. The climate-associated changes will interact with other pressures on natural ecosystems, such as pollution, to create changes in ecosystem structure and function and, almost certainly, loss of environmental services.

### **How climate change will impact on poor, fishery dependent coastal dwellers?**

Farmers, fishers and others who live in the WIO Region and who depend on these ecosystem services will be increasingly exposed to factors such as changes in abundance of fish and shellfish and in productivity of the marine environment. Livelihoods of those coastal dwellers that are highly dependent on such provisioning ecosystem services will be particularly sensitive to the increased exposure to risk. Those lacking the capacity to adapt (poor education, few skills or capital assets) will be especially vulnerable to unpredictable changes.

## **Aquaculture and Climate Change**

In assessing aquaculture - climate change interactions, it is necessary to take a value chain approach, which considers not only production but also the upstream (seed, feed production and transport) and downstream (processing, distribution and marketing) activities. The relationship between aquaculture and climate change is summarized in Fig. 1. Aquaculture, primarily through the energy associated with the procurement and use of essential inputs, through on-farm processes and through processing and distribution of products to markets, contributes to global warming potential by the release of carbon dioxide (CO<sub>2</sub>). CO<sub>2</sub> is also released if mangroves, sea grass and tidal salt marsh areas, which have the greatest long-term rates of carbon accumulation per unit area, are developed as pond or cage sites and methanogenesis known

to occur in pond sediments. Tools such as Life Cycle Assessment can help us understand and minimize effects on global warming potential. While perhaps not a major contributor to climate change, the aquaculture sector must nonetheless strive to minimize impacts by careful site selection and by reducing the most energy intensive steps, such as pumping, use of fishmeal and fish oil and post-harvest processing and distribution. These changes may be achieved through adoption of industry codes of practice, encouraged by fiscal and economic incentives and ethical consumers.

Fish and shellfish farming of course are also affected by climate change (Barange and Perry, 2007). Temperature changes can be expected to impact on the aquatic environment that supports aquaculture production as well as the farming operations themselves. In general temperature increases will increase productivity especially if concurrent with increased pollution from coastal settlement. Warming of coastal waters combined with eutrophication is likely to increase the incidence of harmful algal blooms, however, limiting bivalve and other types of culture. Moreover, above some critical point elevated temperatures will stress farmed aquatic animals, impacting on survival, reproduction, growth, production, and profits. Changes in temperature and precipitation will also affect global crop production by affecting the whole food chain and is thus likely to reduce the availability of fishmeal and perhaps other aquaculture feedstuffs. Changes in aquaculture species and in the geographic distribution of aquaculture production can thus be expected, benefiting some geographic areas at the expense of others.

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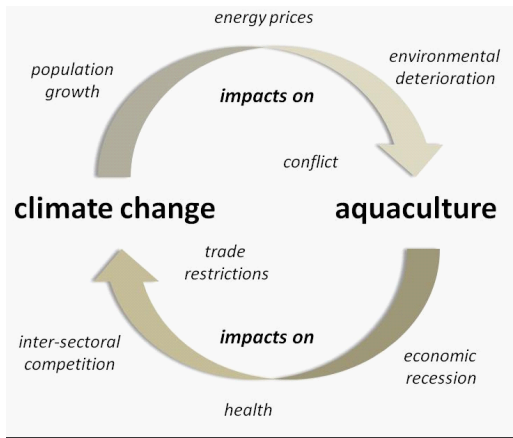


Fig. 1. The relationship between aquaculture and climate change. The figure illustrates that the impact of climate change on the sector and those who depend on it and vice versa is moderated by a range of external factors which may be occurring at the same time.

Although pH changes in the WIO region are expected to be less than in some other regions, ocean acidification will affect calcification, growth and production of shellfish and, consequently, economic viability.

Higher sea levels will both create and destroy opportunities for coastal aquaculture in the WIO Region through changes in coastal topography and saltwater inundation of coastal lowlands. Increased storminess may disadvantage the use of low-cost locally made cages in favour of expensive, imported cage technologies. As a result, cage aquaculture of low value species is likely to become economically less -viable

## Conclusions and Recommendations

Aquaculture – climate change interactions are broadly understood but difficult to quantify, especially at sub-regional scale. The sector must reduce its impacts on climate change through taking care over coastal development and by reducing key energy consuming steps throughout the aquaculture value chain. Climate change planning through use of tools such as modeling and scenario planning can help identify the most vulnerable geographic areas, technologies and sectors of society and help avert or reduce the incidence of many of the anticipated impacts. Models can predict sea level rises and how they will affect coastal populations and aquaculture infrastructure. Technological innovations such as more robust cages may also be expected to help reduce impacts but may prove prohibitively expensive, especially for the production of low value species with low profit margins.

However, the key action required in building adaptive capacity is to identify those coastal dwellers in the Region most vulnerable to climate change. Adoption of a resilience framework, in which the linkages between exposure to risk, sensitivity (i.e. dependence on different risk-associated livelihood activities) and adaptive capacity (e.g. education, assets, etc.) helps to identify the principal dimensions of vulnerability and the interventions needed to address vulnerability effectively. It is necessary to find ways to reduce exposure and sensitivity to climate change and other external risks. In addition, it is essential to build adaptive capacity through improving education and governance and by empowering communities to determine how best to achieve this.

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# Sustainable Aquaculture Development in Europe –

## *What's the message for East Africa?*

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The main message for East Africa from Europe to aid this region in fully realising its potential in developing a successful aquaculture sector is to build strong political will at different scales (international, national and local government organisations), have good relationships between private enterprises and universities, and establish local aquaculture expertise to ensure longer term engagement. This should be supported by a policy specifically for aquaculture that ensures national governments will provide the infrastructure, resources and investment needed for growth of this global sector.

The core policy that influences aquaculture production in Europe is the Common Fisheries Policy which is the European Union's instrument for managing both fisheries and aquaculture. Arguably, the main reasons that aquaculture growth has stagnated (total production of fish and shellfish increased by approximately 3% between 1995 and 1999 with little change between 2000 and 2006 – total production is about 1.3 million tonnes per year worth around 3 billion Euros (European Commission (EC), 2009) in Europe is because too much effort and money has been placed on managing capture fisheries despite wide acceptance that the shortfall in growing demands for seafood can be met through mariculture (Ojeda, 2010). That is not to say that aquaculture should be prioritised over fisheries but to highlight that insignificant attention has been paid to a sector that can contribute more to the quality of life for expanding coastal populations by offering a means for people to achieve food security and a source of income if market conditions allow. A community-led aquaculture development project for sea cucumber known as 'sandfish' (*Holothuria scabra*) is an example of an initiative that started in Tanzania in 2010 to determine whether local people are interested in farming a cash crop as an alternative or supplementary livelihood through a private business partnership (Stead and Slater, 2010).

Key constraints to growth in European aquaculture which are worth consideration by East Africa when developing a strategy to prioritise actions include: (1) unlevel playing fields, that is, it is difficult to obtain government leases for sites that can make production competitive (e.g. near to good transport links and major urban markets) and priority for coastal development is often given to other sectors like tourism, ports and renewable energy; (2) administration for obtaining leases is complex and can take a long time; (3) inadequate communication between different layers of government; (4) lack of market intelligence, and (5) poor aquaculture governance.

Solutions worth consideration by East Africa for mitigating against some of the above barriers that have slowed the desired rate of expansion for the European aquaculture industry are: (1) integrated coastal zone management and creation of level playing fields that give balanced consideration of aquaculture development needs; (2) effective communication and efficient integration of different administrative and legal procedures; (3) wider application of geographical information system (GIS) as an effective visualisation tool of aquaculture sustainability (environmental, social, economic and political indicators) to aid decision-makers; (4) empirical evidence of local, national and international markets based on robust business plans, and (5) adaptive aquaculture governance frameworks developed with and supported by targeted end-users.

Aquaculture as a business needs to make a profit to grow thus knowing about market demand and trends will be essential if East Africa wants to become a 'hub for aquaculture products' and be a serious player in this international sector. Factors that contributed to the initial rapid expansion of the European aquaculture industry and could be useful for East Africa to focus initial efforts on, albeit presented here in light of experience from developed countries, are: cutting-edge research sector, good biological, engineering and technological knowledge, and fostering world-leading business and entrepreneurial skills (Ojeda, 2010). In 2009, the European Commission published a 'Fresh impetus for the strategy for the sustainable development of European aquaculture' (EC, 2009) and in June 2010, Members of the European Parliament stressed that clearer rules, less red tape and research investment are needed if the European aquaculture sector is to expand. In conclusion and to quote one of the world's leading salmon producers from Norway, "successful aquaculture nations have availability of sites, favourable legislation and political will" (Myrseth, 2005 cited in Ojeda, 2010).

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# Using Mangroves for Aquaculture - Why should we?

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Although brackishwater ponds have been a major factor in mangrove loss in Southeast Asia where aquaculture is centuries-old, the “No Touch option” for mangroves is a luxury that most countries in the region cannot afford. So the question is not whether mangroves and aquaculture are compatible, but how best to integrate them so that mangrove services are maximized while some benefits from aquaculture remain? A review of “mangrove-friendly aquaculture” or MFA in Southeast Asia shows that while some technologies are traditional, others are government-driven (rather than research-based, to mitigate social conflict). MFA may be sited in subtidal waterways (e.g., seaweeds, bivalves) or the intertidal forest -- Hong Kong *gei wai*, Indonesian *tambak tumpang sari*, Vietnam mixed mangrove-shrimp farm systems and mangrove pens for mudcrab in Malaysia (Primavera, 2000) (Table 1).

The SEAFDEC Aquaculture Department has conducted studies following two models: a) mudcrab pens where aquaculture and mangroves are integrated in the same space, and b) mangrove filters where separate mangrove stands process effluents from adjacent shrimp ponds. Growth and survival of *S. serrata* in mangrove pens fed fish biomass only, and those given a pellet+fish combination were not significantly different (Primavera *et al.*, 2009). Economic analysis gave a 38.5% ROI and 2.6 yr payback period for pellets+fish treatment compared to 27.5% and 3.6 yr for fish alone. Economic performance of the pellets+fish treatment improved by increasing survival rate and pen area. Mangrove community structure showed that crab presence reduced mangrove species diversity, numbers and biomass of seedlings and saplings, but not trees. Therefore mud crab pen culture is recommended for sites

with mature mangrove trees, and low-cost pellets can reduce dependence on fish biomass.

The second study reports decreased nutrient (NH<sub>3</sub>-N, NO<sub>3</sub>-N, PO<sub>4</sub>-P, sulfide) levels within 6 hr after daytime draining of effluents into the mangrove stand, but only nitrate reduction was statistically significant (Primavera *et al.*, 2007). Based on nitrate loss, water volume drained, mangrove area etc., calculations show that 1.8-5.4 ha of mangroves are required to remove nitrate wastes from one ha of shrimp pond. Longer nipa palm leaflets and faster mangrove seedling growth (but not mangrove biomass) of experimental mangroves suggest N uptake by the mangrove macroflora. Previous studies give a range of 3-9 ha of mangroves needed to treat nitrogen wastes from one ha of shrimp pond. These figures

Table 1. Comparison of mangrove-friendly aquaculture technology in Southeast Asia.

	Technology, year started	Size, mangrove: water ratio	Objectives	Area covered, status
Hong Kong	trad. gei wai, mid-1940s	~10 ha ponds, 30:70	shrimp/fish prod., mangrove/wildlife conserv.	~250 ha, Ramsar site
Indonesia	trad. tambak, ca 1400s	1-4 ha ponds, mangrove on dikes, patches	food, fuel, fodder, fertilizer, soil stabilization	wide
Indonesia	state: silvo- fisheries, 1976	0.1-1 ha ponds, 60-85:40-45	solve forestry- fisheries conflict; mangrove conserv./rehab.	wide, eg. 6,600 ha in Cikiong, W. Java
Vietnam	state: mixed shrimp-mangrove systems, mid-1980s	750-3,200 m <sup>2</sup> ponds, 70:20:10 (housing)	relieve land conflict; mangrove rehab.	widespread
Philippines	govt: aqua-silviculture, 1987	<1 ha pens, <2 ha ponds, 80:20	mangrove conserv., fish production	experimental/verification
Malaysia	govt: mud crab pens, 1992	18 x 9 m pens	increase income	130 pens in Sarawak



approximate the earliest recommended ratio of 4 ha mangrove: 1 ha pond (Saenger *et al.*, 1983) required for a healthy ecosystem. [In contrast, the Philippines has the reverse ratio of 0.5 ha mangrove: 1 ha pond.] The use of mangrove filters reflects a major paradigm shift from the present practice of releasing untreated pond wastes to cleaning up before release, and will improve aquaculture sustainability. Adding mangrove services like coastal protection and fisheries could increase ratios. Therefore the aquaculture industry should conserve and/or rehabilitate mangroves as potential pond biofilters, as well as protective buffer zones.

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# Ecological and Institutional Considerations for an Expanding Sandfish (*Holothuria scabra*) Farming Industry

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Development in hatchery based sea cucumber aquaculture for production of beche-de-mer (dried sea cucumber body wall) for the Asian market present promising opportunities for Western Indian Ocean (WIO) countries. The recognized management struggle of the fishery and associated decline in stocks, depicted by closures of entire fisheries (Purcell, 2010), will undoubtedly bring with it an upswing in demand for cultured sea cucumber products. Through hatchery development there is also potential to assist in restocking of depleted wild stocks (Bell *et al.*, 2008). For nations in the WIO region the only species currently considered to provide a suitable alternative for hatchery based farming is the sandfish (*Holothuria scabra*), which is currently treated as a nominal taxon but is most probably a species complex (Massin *et al.*, 2009). This species commands a high market value, occurs naturally in high densities in near shore lagoon areas and has already acquired a fundamental base of research (e.g. Hamel *et al.*, 2001). Today there is an on-going farming enterprise for sandfish in Madagascar and one currently in development in Tanzania (personal communication, Matthew Slater, Newcastle University). In addition, there is a political interest in the WIO region to develop alternative and supplementary livelihood options along with supporting economic growth through aquaculture. In this context, sandfish farming is often promoted as a feasible economic activity for coastal communities.

Drawing on experiences from other parts of the world the initiation of a sea cucumber farming enterprise brings with it many considerations. Here, some potential ecological and institutional considerations are presented. With the anticipated increase of sea cucumber farming in the WIO region these considerations should be identified and addressed at an early stage so that a learning process can be incorporated into decision making for new enterprises. To form a foundation for discussion, a brief questionnaire was sent out to international experts in sandfish farming asking them to rank on a scale one to five how likely some ecological and institutional considerations are to be realized. Five scientists with leading insight and experience in the topic of sandfish farming responded to the questionnaire. According to their experiences (mostly from the South- and West Pacific) translocation of broodstock and initiation of an enterprise being based on inflated promises stand out as the most likely considerations to be realized (figure 1). That inflated promises are perceived as the most likely concern is worrying as it may lead nations and communities into taking unnecessary risk and can potentially damage the activity's reputation. To mitigate against these considerations being realized, and undermining the future potential for sandfish farming, it is concluded that sharing experiences to facilitate learning about how best to culture sandfish is important so that good examples are replicated and mistakes not repeated.

In the ongoing discussion regarding sandfish farming it is also important to highlight that technology cannot produce the bulk of species in the wild fishery, nor would it be economically feasible. Nations with overfished stocks should therefore not rely on technology development alone but instead strive towards understanding their fishery and implementing effective management (e.g. Friedman *et al.*, 2008). Not until this knowledge is available and acted upon should aquaculture be considered a suitable or viable option for a livelihood, as hatchery produced animals are likely to be fished or poached and production will not be at a scale to replace catches from the fishery in the near future. If sandfish farming does not live up to the seemingly inflated promises then it might give this activity a bad reputation for the day when there is better knowledge about it and it has a better potential to benefit both people and wild stocks in the region. Continuous open discussion and sharing of experiences will allow for evaluation and evolution of hatchery and farming practices. A priority for action should be to increase research on best-practice farming that takes into account the existing fishery and the social-ecological context.

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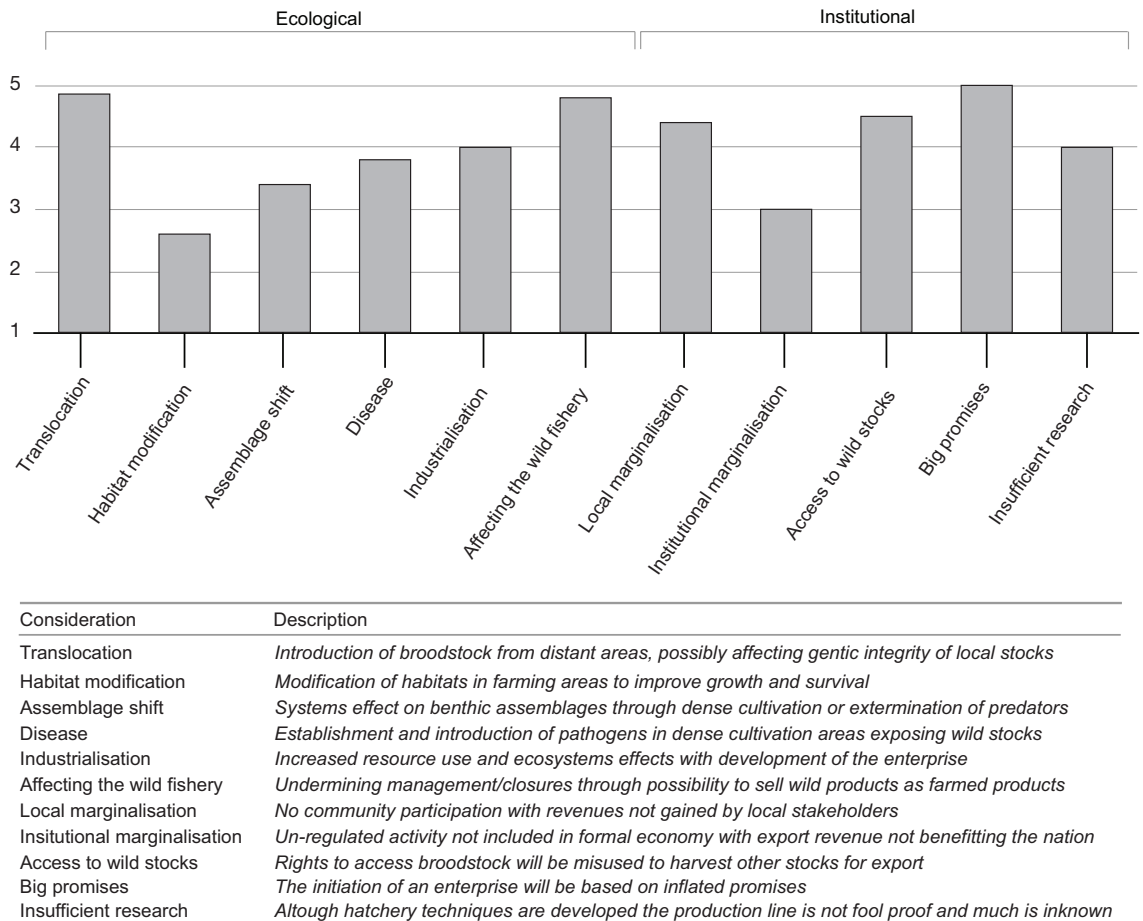


Figure 1. Mean ranking score of the likelihood of an ecological or institutional consideration being realized with the introduction of a sandfish farming enterprise. Score one (1) is "Not likely", three (3) is "Likely", and five (5) is "Very likely". Five professionals with leading insight and experience within this issue did the ranking.

# Life Cycle Analysis (LCA) of Aquaculture Systems

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Historical areas of concerns regarding aquaculture involve reduction of wild fish stocks, eutrophication in proximity to the fish farm, spread of parasites and disease, water degradation, habitat destruction, deforestation related to farm site and socio-economical concerns (Lewis *et al.*, 1997; Naylor *et al.*, 2000; Brummett 2007). Over the last decade, however, increased understanding about additional environmental consequences of the whole production lifecycle has been made possible through the application of life cycle assessment (LCA) to aquaculture systems (Pelletier & Tyedmers 2008). These studies have focused upon environmental implications of different feeds, different farming intensities, geographically different areas and food conversion ration vs. feed quality (Henriksson *et al.*, in press). This has also identified other problems related to different farming practices and allowed for better trade-offs when comparing the full environmental impacts of aquaculture systems.

Application of LCA to aquaculture systems has also shifted focus away from transportation towards production, which is related to the majority of environmental concerns. The environmental impacts differ widely between products, with generally higher impacts for animal products than vegetable products (Table 1). The potential for improvements is therefore much larger in production practices than transport distances. Great improvements are also possible in the handling of food, as 30-40 percent of global food supplies are currently being wasted (Godfray *et al.*, 2010).

LCA incorporate a range of impact categories, including: global warming, eutrophication, acidification, cumulative energy demand, abiotic resource depletion, biotic resource depletion, toxic effects, land use, water consumption, eutrophication, etc. This multi-faced approach enables decision makers to interpret several key areas of concern and weigh them against each other in each specific case. The results may be used for product development and improvement, strategic planning, public policy making, marketing, etc.

One of the major constraints of LCA is, however, its limited capacity to take into account socio-economical consequences, which are of high importance in many parts of Africa and any LCA should therefore not be the sole foundation of any decision-making process. The strength instead lies in the framework's ability to highlight where in the whole production chain that the largest environmental benefits are to be made in relation to investments. This approach is best conceived in conjunction with Life Cycle Costing (LCC), which applies a similar lifecycle approach, only from a monetary point of view.

Identifying energy efficient production systems may decrease the sensitivity of future food production systems to increasing energy prices and avoidance of similar fluctuating high food prices seen in recent years (Piesse *et al.*, 2009). These are problems that probably will intensify over the next century as oil reserves diminish. Farming practices relying heavily upon electricity production, such as abalone farming, are also related serious environmental concerns as many African countries rely heavily upon coal power; which supplies 43 percent of the continent's electricity production (IEA, 2010). Subcritical coal power-plants, common in the region, are especially associated with large acidifying effects, greenhouse gas (GHG) emissions and heavy metal pollution (Dabrowski *et al.*, 2008; IEA 2008).

Table 1: Greenhouse gas emissions from different food production systems.

Edible produce	CO <sub>2</sub> -equivalents (kg)
Beef	18-21
Salmon, farmed	1,8-3,3
Tilapia, intensive	1,5-2,1
U.S. Broiler	1,4
Wheat	0,5
Soy beans	0,25

Source: Pelletier & Tyedmers, 2008; Pelletier, 2008; Pelletier *et al.*, 2008; Pelletier *et al.*, 2009; Pelletier & Tyedmers, 2010; Pelletier *et al.*, 2010

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# The Marine Science Programme and its involvement in Aquaculture Development in Tanzania

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The Marine Science Programme started about 20 years ago and is part of the Swedish International Development Agency (Sida)/SAREC Bilateral Research Cooperation between Tanzania and Sweden. The general objective of this programme is to strengthen the research capacity within Tanzania, while at the same time supporting research aimed at developing techniques and strategies for sustainable use of coastal resources and preserving the health of coastal ecosystems.

In Tanzania, marine aquaculture is dominated by extensive rope cultivation of seaweeds and over 5% of the Zanzibar women are currently employed by the seaweed industry. "Euchemoid algae" are valuable for their content of carrageenan and the export of dried seaweed constitute an average of 20% of the Zanzibar export earnings. By comparison the cultivation of marine and freshwater fish is relatively small. However, aquaculture in Tanzania has a vast potential and could be expanded to provide both food and income for a great number of people. Therefore, one of the aims of the Marine Science Programme is to develop and broaden a range of aquaculture practices. Moreover, if aquaculture is to be utilised both efficiently and sustainably we need not only skilled personnel and improved methodologies developed for Tanzanian conditions, but we also need to have an efficient communication between developers and end-users that is not only a transfer of knowledge, but an on-going discussion on how to best implement acquired knowledge on site.

To contribute towards improving Tanzanian expertise in aquaculture, the Programme has supplied funds, projects and supervisors to students to graduate as MSc's and PhD's with in relevant research fields. This has also resulted in the publication of scientific papers on these subjects. The programme has established aquaculture demonstration units, supplied entrepreneurship training to fisherfolks, organised workshops for enhancement of collaboration, partnerships and linkages between the academicians/research with local community and industrial initiatives.

To contribute towards improving techniques, the Program is presently focusing on improving seaweed and coastal fish cultivation, promoting oyster farming and developing techniques for the cultivation of, for Tanzania, new species:

*Seaweed farming:* Research is focused on establishing reasons for a declining quality and quantity of "Eucheuma" seaweed, and to isolate strains with higher productivity, withstand stresses and grow in estuarine waters. Develop farming technology of new, agar producing, seaweeds so as to allow Tanzania to capture the commercial agar market.

*Milkfish farming:* Assist farmers in establishing wild milkfish larvae, fry and fingerling abundance distribution and seasonality. The knowledge gained has been crucial in the current development of aquaculture in Mtwara where in a span of less than a year since July 2009, over 20 hectares of ponds have been constructed and stocked. Provide on-site pond farming practices (hands on training to farmers).

*Oyster pearl farming:* Study the physiology of a black-lip pearl oyster (*Pinctada margaritifera*), to be able to develop of a hatchery, which is key to the emerging jewellery-making and half pearl farming led by small community groups of mostly women in Zanzibar, Pemba and Mafia Islands,

*Holothurian farming:* Develop farming of holothurian species now threatened by over harvesting.

*Freshwater fish cultivation:* Characterisation of the genetic diversity and mapping of existing wild and domestic Tilapia populations. Reinvigorate farming by selection of Tilapia strains with good performances in estuarine waters.

*Environmental issues:* A rising concern is the over utilisation of many marine and freshwater ecosystems as a result of the growing population coupled with pollution. Therefore, the Marine Science Programme is also focusing on environmental issues associated with aquaculture, e.g. including both the effects on the environment from aquaculture activities and effects of climate change on fisheries resources (e.g. prawn) and aquaculture (e.g. seaweed cultivation).

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# PART IV: Facilitation Mechanisms and Success Stories

## The Role of Commercial Aquaculture in Developing Sustainable Small Scale farming in the WIO Region

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Commercial scale marine aquaculture within the Western Indian Ocean (WIO) region remains a relatively limited activity which continues to shrink as the forces within the world economy dilute profits and harshly tax production inefficiency. Historically, the dominant sector within WIO aquaculture has been commercial shrimp farming. This has been typically characterized by industrial scale, high intensity investment through either the private and/or, in some cases, the public sector. Other private investment has been directed into a commercial fish farm and many other smaller scale initiatives of which many have failed.

In contrast to the above there has also been a higher increase in the number of non industrial aquaculture producers in the region over the same period. As an example, I will focus on seaweed production with specific reference to the large and significant industry developed in Zanzibar, where most development has taken place in small scale family owned farms, each typically involving two family members per unit (Msuya *et al.*, 2007). Essentially, the industry was initiated by foreign development organizations as a method for poverty alleviation through sustainable job creation and local community upliftment. This was facilitated by the increasing worldwide demand for carrageenan based thickeners in the commercial food industry (Mc Hugh, 2003). The production of seaweed on Zanzibar Island peaked at approximately 30 000 tons ([www.bcb.uwc.ac.za/pssa/articles/features/no60.htm](http://www.bcb.uwc.ac.za/pssa/articles/features/no60.htm)) and has now dropped considerably to around 10 000 tons per year with an approximate value of USD2.4M ([www.allafrica.com/201001261043.html](http://www.allafrica.com/201001261043.html)).

The rationale behind this drop in seaweed production is not clear but it does seem, from discussions with people and organizations involved in the industry, that the main driver was market price. It was simply that the middlemen buyers were not able to secure a price that paid an adequate wage to the farmers for their time and effort of production. Information from the Dept. Aquaculture, Mozambique, shows a similar problem, where an existing seaweed production project led to gainful employment of over a hundred small scale farmers in Pemba, Cabo Delgado. Sadly, this has failed and it probably equates to a further 200 people with no source of income. In Zanzibar, it appears that much of the surviving industry relies on foreign development organizations to provide ongoing funds and expertise to maintain the impetus. It remains unclear whether ongoing donor funding

is sufficient to offer sustainable support to this excellent initiative and hopefully the failure of the much smaller and less supported industry in Pemba, MZ is not indicative of the Zanzibar seaweed farming future.

The title of this paper suggests that there could be a possible linkage between corporate business, foreign development aid and small scale farmer development. Normally, these three unlikely bedfellows have mutually different ideologies and do not appear to offer complimentary opportunities. In fairness, the sore thumb in this triumvirate is the corporate business sector, who are normally focused on chasing profits or simply not interested in small scale farmer development. One can understand the pressure of performance placed on management by shareholders to generate returns on cash invested and this often translates into not seeing below the formal sector line to seek new ideas. One often hears of the development sector complaining that business is often blinded by capitalist ideology of quick returns in exchange for a more sustainable and/or broader development.

So where can we look in order to try and develop synergies between the two? I think it comes to light when the strengths and weakness of both versions of development are compared.

Capitalist corporations and business literally make the world work. Profit drives the world and should not be viewed as a source of evil, unless, of course those profits have been derived from overtly exploitative practices. We all want to see our money grow because if it doesn't, then the forces of inflation arrive and slowly consume it. For example if you live in a country with an inflation rate of 5% per year and you stash USD1000 under your bed, five years later that \$1000 will only be able to buy goods to the value of \$774! In other words, the

devaluing effect of time has ended in you making a loss on your cash, therefore adding some light as to why people invest in companies that seek profits. On the down side, many companies can operate in a manner in which no regard is taken into account for environmental degradation or short term profiteering. A good example here is when foreign fishing vessels come into an area, decimate fish stocks, make profits in their home countries but leave the local population in a destitute situation without the profits or the fish!

Development agencies also have positives and negatives but they may be a bit more difficult to assess from an external perspective. We are all well aware of foreign aid organizations that raise offshore cash (some maybe from the fishing profits above) to fund areas with little development. The chief rationale is to promote sustainable progress where issues affecting people and often their environment are addressed. On the downside, 'free' money can lead to corrupt activities where leaders are funneling the cash to themselves rather than to the end point communities who need it most. Furthermore, it could be argued that aid money can increase a sense of complacency and reliance; in communities with poor leadership or low appetite to empower themselves. This was recently demonstrated in the Afri-Euro Summit debate held in Tripoli 2010, where many African leaders called for more support for entrepreneurial activity and a consequent reduction in straight donor aid.

Thus, I'm questioning whether we could investigate a best-of-both approach where we integrate the two, to enhance the outputs and provide social improvement through profit generation. For this to work we need to start with a sustainable commercial aquaculture operation which could act as a node for downstream community development. The primary aim of the commercial operation would be to provide services through which it should make a profit. Such services would be to assist the small scale units with co-operative objectives such as procurement, processing and marketing. These should be developed through an agreement which specifies that the services be provided for in a transparent manner. For example, the farmer must be able to see the final prices that the commercial unit receives, including cost-of-sales, overhead and the agreed margin. This will build trust into the relationship which would support the small scale business to grow organically and to include an increasing number of participants which would eventually improve margins through co-operative economy of scale. The donor funders have to be part of the transparent process and would need to

be active in assisting the community to build trust. The donor funds should also not flow directly into the commercial entity otherwise we may endanger the trust process and would then be back at the start with further waste of funds.

This may sound idealistic, and it may not necessarily work as easily in practice as it should in theory, but it may represent something of a change from the current models where the communities do all the work and receive very little benefit. Greed remains the central problem and both parties have to recognize that each must make money, and if this balance is upset, then both parties will eventually fail. Our feeling is that in order to get true buy-in in the WIO region, commercial companies have to recognize that they have a role in local community upliftment through skills transfer and development facilitation. Corporate social investment becomes much more desirable if it can be combined with a profitable activity. In addition, donor funders may be able to reach further into communities and have a greater impact should they interlink resources with companies that have a shared vision and can see that there are additional benefits beyond the profit line.

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# Seaweed Farming in Western Indian Ocean Region - A Success Story?

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Seaweeds are multicellular macroalgae that contain gelling substances (carrageenan, agar, or alginates) that are extracted and used in pharmaceutical, cosmetic, textile and food industries. Seaweeds thus provide economic benefits through either harvesting of wild stocks or aquaculture. *Euचेuma denticulatum* ('spinosum') and *Kappaphycus alvarezii* ('cottonii') are economically important seaweeds in the Western Indian Ocean (WIO) region. Exporters purchase dried seaweeds directly from farmers, and then pack and export the products to the world market. Seaweed farming provides a source of income and employment opportunity, however, in the WIO region there are setbacks to this industry. The presence of market monopoly that ensures super-profits for very few multinational corporations, and yet the provision of low and falling prices to local farmers pose as shortcomings to the industry. For example, in Tanzania farmers were initially selling dried seaweeds at US\$ 0.32 per kg and later US\$ 0.06 per kg (Bryceson, 2002; Rönnbäck *et al.*, 2002). Natural factors such as diseases also pose limitations that reduce production, while the low prices paid to farmers may sometimes be due to poor drying techniques resulting in poor quality seaweeds that fetch even lower prices according to Msuya (2006).

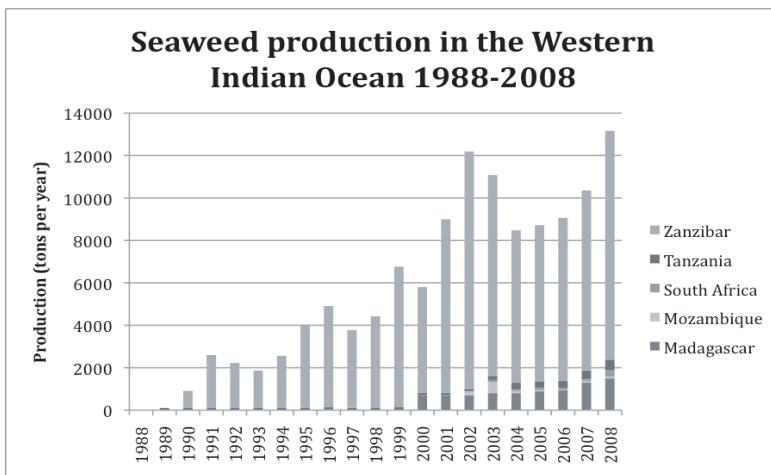


Figure 1: Seaweed Production (dry weight) in the WIO region (1988 – 2006)

Of the WIO region countries, Tanzania and Madagascar are leading, while initial trials have been carried out in Kenya, while Mozambique had basically abandoned production (Figure 1). Seaweed farming in Kenya passed the technical feasibility aspect through research by Kenya Marine Fisheries Research Institute (KMFRI) in the 1990s and early 2000s at Gazi and Wasini Island. Currently there are demonstration farms at community level which, KMFRI has established for commercial seaweed industry. 300 - 400 farmers are targeted, with expectations of expansion (Nyonje pers.com). Tanzania started seaweed farming industry in 1989, with production reaching over 11,000 tons (dry weight), mainly in Zanzibar. The current market price per kilogram varies with species: *K. alvarezii* fetches Tsh 360-400/kg DW, while *E. denticulatum* is sold at Tsh 170/kg DW.

Seaweed farming is largely a small-scale activity in Tanzania, and is practiced mainly by women in coastal areas: more than 20,000 people are involved in seaweed farming in Zanzibar. Seaweed represents an important earning of foreign exchange, which in 1994 Zanzibar contributed 27.3 % of foreign exchange income (Mshigeni, 1976; Bryceson, 2002; Msuya, 2005; Msuya 2006). Seaweed farming of *E. denticulatum* and *K. alvarezii* in Mozambique started in 1998 and carried out mostly at Murrebue, Pemba and at

Nampula, and involves about 2,000 farmers (80% women). Production varied from 500 tons (2003) and 140 tons (dry weight) in 2004. However, seaweed farming ended in 2005 in Pemba and 2009 at Nampula (Bryceson & Massinga, 2002; Ribeiro 2007; Omar pers.com). Madagascar has two other sources of seaweed for the world agar industry; *Gelidium* and *Gracilaria*. *Gelidium* is only available from wild species as cultivation attempts of this genus have not proved to be commercially viable (McHugh, 2002). *E. denticulatum* and *K. alvarezii* are farmed through off-bottom and broadcast method (*E. denticulatum*). At Nosy Ankaos Island community, 230 people are engaged in seaweed farming, and produce approximately 500 kg/farmer/month of dried *K. alvarezii* fetching US\$ 65. Madagascar is currently exporting 1,400 tons/year of dried seaweed to FMC Biopolymer, with export value of US\$ 650/ton (*K. alvarezii*) and US\$ 300/ton (*E. denticulatum*) (Clement, 2009).

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# Making Small-Scale Semi Intensive Shrimp Aquaculture Work on the Kenyan coast

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Almost half of the world's fish stocks have been fully exploited and while capture fisheries levelled out around 90 mmt the demand for fish has continued to increase (FAO, 2010). It is expected that aquaculture will help bridge this gap. Currently, about half of the fish directly consumed by humans is produced through aquaculture implying that the contribution of aquaculture to food security and job creation cannot be overemphasised (FAO, 2010).

Coastal aquaculture of penaeid shrimp in Kenya was attempted less than four decades ago (Rönnbäck, 2002). A survey to investigate the feasibility of prawn culture in Kenya was carried out by FAO in the 1980's. The criteria for suitability were soil type and capability to be watered by tides. The survey revealed that a total area of about 3900 ha along the Kenya coast were suitable for shrimp aquaculture. One of these sites was located in Ngomeni near Malindi where a 13.7 ha pilot farm was set up (Yap and Landoy, 1986). The penaeid shrimp species cultured at Ngomeni were naturally occurring *Penaeus monodon*, *Penaeus indicus* and *Metapenaeus monoceros*. In 1982 a production of 708 Kg ha<sup>-1</sup> was achieved. This dropped to 338 Kg ha<sup>-1</sup> yr<sup>-1</sup> between 1990 to 1997 after which the farm closed down due to land ownership tussles (Rönnbäck *et al.*, 2002). Currently a private developer cultures shrimp in one of the existing ponds.

Most of the area considered suitable for coastal aquaculture could not be watered by tides, ruling out extensive farming as a system of production. Thus semi intensive and intensive systems were recommended as suitable systems of production. These systems of production would require that shrimp be provided with supplementary feeds. Currently, no shrimp feed has been developed in Kenya and most raw materials like fish oil and soy beans will have to be imported as Kenya does not produce any of these. This will automatically make them very expensive. Therefore, shrimp feed remains a big hurdle for the development of this sector and yet it is very important to overcome it before semi-intensive culture of penaeid shrimp can take off in Kenya. In the meantime however, *Artemia salina* biomass (live food for shrimp) could be used in the initial stages as done in Shandong province in the People's Republic of China (Yap and Landoy, 1986), but feed for the grow-out phases would still remain the principal problem. *A. salina* is usually grown in salt ponds.

The seawater reservoirs in the salt farms of North coast Kenya could make excellent semi intensive shrimp farms without interrupting the salt farms operations. The only inputs would be shrimp larvae. The salt farms therefore remain as excellent sites where several demonstration farms could be developed at very little cost, although substantial structural changes with considerably deeper ponds would be necessary.

The construction of a hatchery is another prerequisite that is important for the development of shrimp aquaculture at the Kenya coast. The shrimp larvae in the wild would not meet the demand from potential farmers. The reliance on wild post larvae as a source of fry would have a negative impact on the shrimp fisheries in Kenya. A hatchery would therefore ensure a constant supply of adequate and healthy seed throughout the year (Yap and Landoy, 1986; Wanjiru, 2010). But efficient hatcheries involve highly sophisticated technology and are expensive to invest in and to operate, therefore only being economically feasible for fairly large scale production..

Semi-intensive shrimp farming at the Kenya coast remains a big possibility if and when the issues of shrimp feed, hatchery development and technical and extension support from the government are addressed. The Kenya government under *Vision 2030* (GOK, 2008) has recognised the importance of aquaculture and its potential to contribute to food security, poverty reduction and employment creation and is committed to supporting it (GOK, 2008). There is, therefore, considerable optimism for renewed efforts to re-initiate this sector at the coast.

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# Research on Integrated Coastal Aquaculture in Tanzania

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Research on integrated coastal aquaculture in Tanzania has focused on the culturing of finfish, shellfish and seaweed in different culture designs. The first such design was developed in 1996 at Makoba Bay in Zanzibar by the Institute of Marine Sciences. The Integrated Mariculture Pond System (IMPS) consisted of six ponds of 260 m<sup>2</sup> each that were stocked with finfish (*Siganus* spp. and *Chanos chanos*); shellfish (*Cardium* sp., *Pinctada margaritifera*, *Modiolus uariculatus* & *Isognomon isognomon*) and seaweeds. Two types of feed (25% and 32% protein) were formulated using local ingredients and fed to the cultured fish. The seaweeds (*Ulva reticulata*, *Gracilaria crassa*, *Kappaphycus alvarezii* and *Euचेuma denticulatum*) were stocked in the ponds and outflow channels. Pesticides and live food production were also studied. Modifications of the culture techniques were done in 2001-2004.

## Main Results of the Initial Studies carried out in 1996-2004

**Finfish:** Significant growth of the more hardy *C. chanos* was recorded while *Siganus* was dropped as a culture species as it did not thrive. Growth of *C. chanos* ranged from 1.4 with no feeding to 2.2 g d<sup>-1</sup> when fed the 32% protein feed.

**Shellfish:** Highest growth in ponds was observed in *I. isognomon* (hinge length increase from 40 -70 mm in 14 months) followed by *M. auriculatus* and *P. margaritifera*.

**Seaweed:** While no growth of seaweeds was recorded within the ponds, seaweeds planted in fishpond outflow channels showed statistically significant growth rates (specific growth rate, 1.5 – 4.0 % d<sup>-1</sup>) and their role as biofilters and for improving water quality was confirmed (N removal up to 6 g m<sup>-2</sup>d<sup>-1</sup>, protein content increase in *U. reticulata* from 19 to 26%, oxygenation of fishpond effluent water, pH restoration) (Msuya and Neori, 2002, Msuya *et al.*, 2006).

Table 1. Experiments on integrated coastal aquaculture in Tanzania, 1996 - 2010

Year	Type of integration	Reference
1996-2000	Finfish, shellfish and seaweed: In Ponds Finfish ( <i>Siganus canaliculatus</i> , <i>S. sutor</i> ), Shellfish ( <i>Anadara</i> sp., <i>Cardium</i> sp., <i>Pinctada</i> sp.) Seaweed ( <i>Euचेuma denticulatum</i> , <i>Kappaphycus alvarezii</i> , <i>Ulva fasciata</i> , <i>U. reticulata</i> , <i>Gracilaria crassa</i> , <i>G. salicornia</i> )	Mmochi <i>et al.</i> (2001)
2001	Finfish and seaweed: In Ponds Finfish ( <i>Chanos chanos</i> ) Seaweed ( <i>U. reticulata</i> , <i>G. salicornia</i> , <i>E. denticulatum</i> , <i>Chaetomorpha crassa</i> )	Msuya and Neori (2002)
2001-2004	Finfish, shellfish, seaweed, live food: In Ponds Finfish ( <i>C. chanos</i> , Mullet: <i>Mugil</i> sp.) Shellfish ( <i>Pinctada margaritifera</i> , <i>Isognomon isognomon</i> , <i>Modiolus uariculatus</i> ) Seaweeds ( <i>U. reticulata</i> , <i>G. salicornia</i> ) Mesocosm-Live food (rotifers, protozoa and copepods)	- - Msuya (2007), Msuya <i>et al.</i> (2006). Kyewalyanga (2003), Kyewalyanga & Mwandya (2002), Kyewalyanga & Mwandya (2004), Kyewalyanga <i>et al.</i> (2004)
	Water quality studies (pH, salinity, temperature, dissolved oxygen, sediment oxygen demand-SOD, nutrients, pesticide's affinity to adhere to soils-sorption, pesticides and polychlorinated biphenyls-PCBs)	Mmochi & Mwandya (2003), Mmochi <i>et al.</i> (2002)
2005-2010	Shellfish/pearl and seaweed- Shallow water and deep-waters farming: In open sea tidal flats Shellfish ( <i>Pinctada margaritifera</i> , <i>Isognomon isognomon</i> ) Seaweed ( <i>E. denticulatum</i> , <i>K. alvarezii</i> ) Seaweed & shellfish in the same systems-Alternating seaweed and shellfish lines or shellfish/pearl production in different setups	Msuya (2006)

**Pesticides:** Pesticide levels (e.g. organochlorine pesticides in biota) were below accepted limits for aquaculture and food consumption by man (Mmochi *et al.* 2002, Mmochi and Mwandya, 2003).

**Live food:** Successful production of rotifers, protozoa and copepods in concrete ponds was achieved. Number of rotifers ranged from 40 - 60 individuals ml<sup>-1</sup> depending on salinity and fertilisation regimes (Kyewalyanga and Mwandya, 2002, Kyewalyanga, 2003).

## Current Research and the Future of Integrated Coastal Aquaculture in Tanzania

Currently research in integrated aquaculture focuses on the integration of seaweed (mainly the commercially farmed *K. alvarezii* and *E. denticulatum*) with shellfish (and pearl) farming. Among farming methods tested are floating systems, and long lines, also in deep waters.

The future of integrated coastal aquaculture in Tanzania focuses on developing different innovative culture designs suitable to the environment and people of Tanzania. Integrating as many organisms as possible for the benefit of Tanzanians in general is a key to the success of integrated coastal aquaculture in Tanzania and the Western Indian Ocean Region.

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# Integrated Abalone/seaweed Farming in South Africa

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Research into seaweed and abalone aquaculture in South Africa began independently of each other in the early 1990s (Anderson *et al.*, 1996; Sales & Britz, 2001). Land based farming of abalone has grown substantially in the last two decades. Currently there are 12 commercial farms producing over 913 t per annum (DAFF 2010). Depending on location, several farms used freshly harvested kelp (*Ecklonia maxima*) as the major feed. Over 6000t per annum of kelp were harvested in the late 1990s for this purpose, and some kelp beds had reached maximum sustainable limits (Troell *et al.*, 2006).

Research into seaweed (*Ulva* and *Gracilaria*) aquaculture as feed for abalone started in 1995 on the southeast coast (where there are no kelp beds) using abalone waste water (Robertson-Andersson *et al.*, 2007). A growing body of evidence suggests that a mixed diet of kelp plus other seaweeds can give growth rates at least as good as artificial feed, and can improve abalone quality and reduce parasite loads (Naidoo *et al.*, 2007; Robertson-Andersson, 2007; Dlaza *et al.*, 2008; Robertson-Andersson *et al.*, in press).

Research on the potential for integrated abalone and seaweed aquaculture was initiated in 2000. On the one hand, integrated seaweed and abalone farming can provide supplementary feed, while on the other hand seaweeds provide the nutrient assimilation capabilities for farms to switch over to re-circulation mode, when threatened by harmful algal blooms (Robertson-Andersson *et al.*, 2007). Two other factors make integrated abalone / seaweed farming attractive. It can lead to a reduction in the harvesting of wild kelp and it has been demonstrated that abalone grow faster when their diet is supplemented with cultured seaweed (Naidoo *et al.* 2007; Dlaza *et al.* 2008; Robertson-Andersson *et al.* in press). There is a need to investigate ways to mitigate elevated levels of dimethylsulphoniopropionate (DMSP) in abalone fed on *Ulva* (IMTA cultured seaweed), which can affect taste, particularly in canned abalone (Smit *et al.* 2007; 2010). A few commercial integrated farms were initiated in 2006 and are currently operating successfully.

The cost benefit analysis of cultivating seaweeds on abalone farms was investigated firstly by way of a SWOT analysis (Bolton *et al.*, 2008) and by applying a differential Drivers-Pressure-State-Impact-Response ( $\Delta$ DPSIR) model to an integrated seaweed/abalone, multitrophic recirculating, aquaculture system and comparing it to a monoculture or multiculture (IMTA) (abalone and seaweeds) system. By applying this model it was possible to quantify the costs and benefits of the systems for both the environment and the farmer. There was a net gain in the adoption of the integrated system, estimated at ZAR 4.6 million yr<sup>-1</sup> (Nobre *et al.*, 2010).

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# Community Based Sea Cucumber Aquaculture in Madagascar

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## Introduction

Aquaculture techniques have been developed for sandfish (*Holothuria scabra*) with the primary goal of stock enhancement and re-stocking of overexploited wild stocks (Batteglene, 1999; James, 2004; Agudo, 2006). Recently there has been a growing trend to develop technologies for initiatives that aim to provide alternative sources of incomes for coastal communities. Sea pens have been used in various stages of sandfish aquaculture including, broodstock holding (Pitt *et al.*, 2001; Agudo, 2006) and release of hatchery-reared juveniles into sea pens to provide data on growth and survival to model potential effects of restocking in the wild (Pitt *et al.*, 2001; Purcell & Simetoga, 2008). In the Philippines (Bell *et al.*, 2008) and Indonesia (Tuwo, 2004), sea pens been used by fishers to grow-on undersized sea cucumbers as a means of adding value to their catch. However, the concept of utilising pens for sandfish ranching, to provide an alternative livelihood, is relatively recent.

Since January 2007, marine conservation organisation Blue Ventures (BV) has been pioneering sea pen based grow-out of hatchery-reared sandfish to assess the feasibility of this technique as an alternative livelihood strategy for indigenous Vezo communities within the Velondriake Locally Managed Marine Area (LMMA), a community-managed conservation initiative spanning 800 km<sup>2</sup> of marine and coastal environment. Preliminary field trials to test the grow-out of *H. scabra* in sea pens were conducted in January 2007 at Antserananangy in collaboration with the Women's Association of Andavadoaka and in January 2008 in the village of Ambolimoke. Juvenile sandfish were supplied by the University of Toliara's marine sciences institute (Institut Halieutique et des Sciences Marines; IHSM), which began hatchery and nursery production of *Holothuria scabra* in 1999 in collaboration with the Belgian universities of Mons-Hainaut and the Université Libre de Bruxelles (Jangoux, 2001). For each trial 200 juveniles (average weight 15 g) were stocked in 10 m x 10 m pens. After 11 months the survival rates were 79% and 80%, respectively, although the mean weight of individuals was low 139.9 g ( $\pm$  3.0 SE) and 185.9 g ( $\pm$  3.0 SE).

In March 2008, a partnership of representatives from IHSM, the Belgian universities, and private Toliara-based fisheries export company Copefrito SA, formed Madagascar Holothurie SA (MH.SA), the first private company in Madagascar based on sea cucumber aquaculture (Eeckhaut *et al.*, 2008). Building on the encouraging results of initial grow-out trials and the availability of hatchery produced sandfish juveniles from MH.SA, funding was obtained from ReCoMaP for a two year project to scale up the Velondriake holothurian aquaculture trials to 23 community groups within 4 villages in Velondriake, between September 2008 and September 2010.

## Methods

Satellite imagery and GIS habitat maps of Velondriake were used to create a list of candidate villages that possessed suitable habitat for sandfish, comprising shallow, sheltered areas with high levels of nutrients, including muddy substrata and seagrass beds (Hamel *et al.*, 2001; Agudo, 2006). Traditional ecological knowledge of fishers and village elders was used to identify zones adjacent to each village, which had previously supported populations of *Holothuria scabra*. Surveys conducted by field technicians assessed the key characteristics of the site, including approximations of the sediment type, grain size, seagrass species and indicator benthic species. Additional selection criteria included adequate sediment depth (at least 50 cm) suitable for pen construction, a minimum water depth of 10 cm at spring low tide and close proximity to the chosen village in order to facilitate maintenance and surveillance of the pens. The villages of Nosy Be, Ambolimoke, Anserananangy and Tampolove, located in the north, centre and south of Velondriake respectively, were selected for the project (Fig. 1). A number of different social group models were tested including clans (family lineages comprising of 25-50 people), groups of 3-4 households within the same family that traditionally fished and worked together and women's associations, in order to determine which demographic model proved most suited to adopting aquaculture. A series of community meetings were held in each village to explain the project and interested families were asked to select teams and give the names of the team leader to the village president. Basic demographic information was collected for each team including details of all members, their social organisation and relationship to each other and their primary

activities. The total number of farming groups involved in the project peaked at 23 comprising a total of 250 people, however by September 2010 the final number of groups was reduced to 15 (129 people). In two villages, the number of farming groups gradually increased throughout the project; in Ambolimoke where two of the clans decided to split into smaller family groups and in Tampolove where additional farming groups joined the project. In Nosy Be, only four families volunteered as many people undertake a seasonal migration to the north-west coast of Madagascar and therefore were unable to commit to the project. In Antseranangy, the project was limited to the involvement of the Women's Association of Andavadoaka and the site was eventually abandoned as the majority of sandfish failed to reach the minimum market size of 300 g after more than two years. In May 2010, sandfish culture in the village of Ambolimoke was discontinued due to lack of capacity of the majority of groups and prevalence of internal theft from sea pens.

Blue Ventures acted as an intermediary between the sandfish farming groups and MH.SA, and contracts were drawn up outlining the responsibilities of all parties. MH.SA was responsible for the production and delivery of 5-month old juveniles (approximately 15 g or 6 cm approximately 20 km south of Toliara, to the grow-out sites in Velondriake, approximately 250 km to the north. Over the two-year project, eight batches totalling 27 250 juvenile sandfish were delivered by MH.SA between 1 October 2008 and 22 September 2010. At the start of the project, the purchase price of juveniles from MH.SA was US\$ 0,44 per juvenile if collected at the hatchery and US\$ 0,55 if delivered. Project funding was used to subsidise the cost of juveniles for farmers as MH.SA were confident they could reduce the price to US\$ 0,20 per juvenile over the course of the two year project once increased hatchery production achieved economies of scale. Juveniles were supplied to farmers on credit at a subsidised price of US\$ 0,20 (with purchase credit advanced by project funds) with the agreement that the cost of juveniles would be reimbursed by the farmers at the point of harvest and sale. If general, the farmers retained 50% of the profits from sea cucumber sales, and 50% was used to re-pay the cost of juveniles. MH.SA was given exclusive rights to buy back all market-sized adults produced (minimum size 300 g) and was responsible for travelling to grow-out sites to purchase sea cucumbers and transport them to Toliara for processing and export. Sea cucumbers were graded into size categories of < 300 g (in cases where a small percentage of the harvested animals

fell below the minimum size), 300 – 450 g and > 450 g and average prices paid by MH.SA were US\$ 1.00, US\$ 1.11 and US\$ 1.39, respectively.

Project funding was used to cover the cost of pen materials, and a number of different pen materials and designs were experimented upon. The pens were designed to allow for multiple juvenile inputs throughout the year, to spread the risk of mortality and loss, as well as the anticipated financial benefits. A production model, based on literature reviews and data gathered in preliminary field trials, assumed an input of 300 juveniles every 4 months with 80% of the sea cucumbers reaching an average market size of 350 g after a maximum of 12 months. The pens were designed in order to maximise growth rates by ensuring that the total biomass in the pens did not exceed the natural carrying capacity of habitats for *Holothuria scabra*, believed to be between 225 and 250 gm<sup>-2</sup> (Batteglene, 1999; Purcell & Simetoga, 2008). The pens measured 25 m x 25 m<sup>2</sup>, with one quarter of the pen (12.5 m x 12.5 m) sectioned off to form a 156.25 m<sup>2</sup> juvenile pen and the remaining 468.75 m<sup>2</sup> as a grow-out pen. The process of transferring each batch from the juvenile pen into the grow-out pen, five months after input, ensured that the critical stocking biomass of 250 gm<sup>-2</sup> would not exceeded

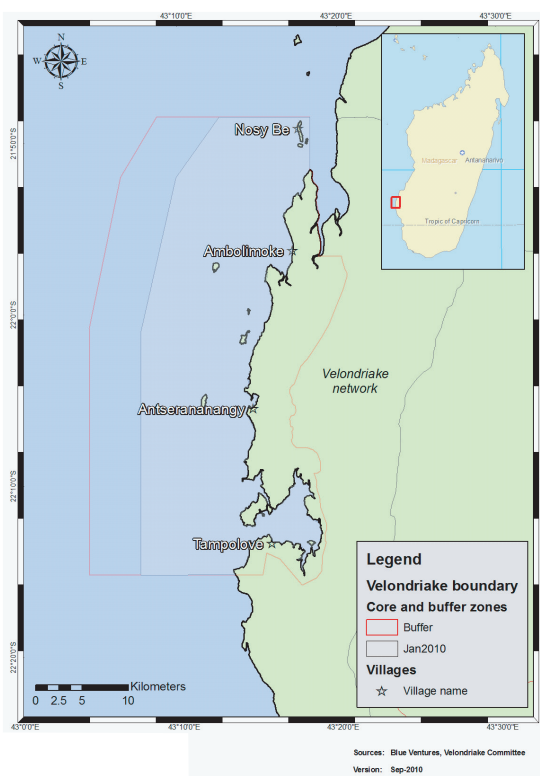


Figure 1: A map of the geographical location of the grow-out sites in the Velondriake Locally Managed Marine Area (LMMA).

in the juvenile or grow-out areas of each pen, which had a total biomass value of 39 kg and 117 kg respectively.

Blue Ventures was responsible for providing training and technical support to farmers throughout the project, including training in pen construction and maintenance, husbandry, social organisation and financial management. Logbooks were issued to each farming group to record details of all husbandry and maintenance activities together with accounts detailing the number of sea cucumbers delivered, sold, the amount of juvenile credit re-paid and the profits generated per group. Participatory monitoring, led by Blue Ventures, to provide data on growth and mortality was carried out on a monthly basis during spring low tides at night when sandfish emerge from the sediment to feed in accordance with their diurnal burrowing cycle. All of the sea cucumbers found during monitoring were counted and a sub-sample of 25% was weighed.

As theft was anticipated to be a major risk factor, a number of pre-emptive measures were put in place to prevent poaching. In each village, communities decided to designate the area surrounding the sea cucumber pens as a 'reserve', delineated by surface marker buoys, in which all fishing activities were banned and access on foot during low tide was limited to farmers and BV technicians. Social conventions, known as *dinas*, a key tool used in community-based management within the Velondriake LMMA, were created at village level and endorsed by the mayor of the commune. In addition to describing areas and access to the mariculture areas, each village defined their own procedures to deal with infractions or theft including monetary fines. Farming groups were actively encouraged to undertake surveillance at night during spring low tides to guard their pens against theft. Due to mistrust between farming groups, *rotas* were organised containing one member from each farming group.

## Results

Table 1 attempts to summarise the fate of the 27 250 juvenile sandfish delivered by MH.SA to the four villages between the 1st October 2008 and 22nd September 2010. Early on in the project, problems were repeatedly experienced during transportation of juveniles from the nursery to farming sites, a journey of over 250 km, which took a minimum of 14 hours by boat. During transportation and input of the first five batches of juveniles which were loaded into fish transport boxes which were then stacked within 1 tonne plastic fish harvest bins filled with seawater, a total of 3061 juveniles (11% of the

total number of sandfish delivered) were lost. On several occasions delays led to the boat arriving after the scheduled input time (morning spring low tide) resulting in sub-optimal release

conditions. Mortalities for the northern villages (Ambolimoke and Nosy Be) were exacerbated due to increased journey times (18-20 hours) and physical damage to juveniles, as the afternoons were generally windy with rough seas. After the passage of a tropical storm caused approximately 10% mortality juveniles on board, for the final three deliveries, juveniles were packed into 5L plastic bags of oxygenated seawater and transported in cool boxes by 4x4 to a central point (Tampolove or Andavadoaka). The juveniles for the northern villages were relayed by motorised boats which reduced the total transport time to 6-8 hours and only resulted in negligible mortality (<1%).

Additional technical problems that have affected the success of the project include the low quality of locally available pen materials used. The initial juvenile pens were constructed of doubled 10 mm nylon fishing net, however in an attempt to decrease material costs, the grow-out section of the pens was constructed using a single layer of 15 mm nylon fishing net. However the larger mesh size led to fish (Lutjanidae, Gerreidae and Plotosidae) becoming trapped in the base of the nets, attracting crabs, mainly *Thalamita crenata*, which ripped holes in the net through which sea cucumbers could escape. Thus sea cucumbers from the delivery on 24 February 2009 that had been transferred into the grow-out section, had to be moved back into the more secure juvenile section. As the nets were essentially 'ghost fishing' throughout their deployment it was eventually decided to remove the nets and replace them with specially imported 6 mm x 8 mm HDPE plastic mesh. However, the time delay incurred between ordering a container of mesh from China, shipping it to Toliara via Mauritius and re-constructing the pens meant essentially that all sea cucumbers delivered between 1 October 2008 and 12 May 2009 were stocked in the 12.5 m x 12.5 m juvenile pen. This had two major implications: firstly, by the time the pen model was fully operational it was never possible to fully test the low density production model, and secondly, analysis of data for growth and survival of these batches is subject to inaccuracies in analysis due to the mixing of cohorts.

For the initial inputs however growth rates were good with the majority of sandfish reaching a minimum market size of 300g within 8-12 months. In Ambolimoke, the first input of juvenile sandfish to four new 12.5 m x 12.5 m pens took place 1

October 2008 and benefitted from a combination of low stocking densities and a warm growing season. They reached an average size of 351.8 g ( $\pm$  3.1 SE) months after stocking. The low stocking densities were due to major mortalities during transportation by boat, resulting in only 422 of the 1200 juveniles delivered surviving 1 month post-release. The growth rate increased from 0.88 g day<sup>-1</sup> to a peak rate of 1.69 g day<sup>-1</sup> between 12 February and 12 March 2009, which are the hottest months of the year with water temperatures around 32° C. Growth rate started to decrease as water temperatures decreased to 25.6° C and as stocking densities approached 220 g m<sup>-2</sup>. A harvest and sale was organised with MH.SA to take place on the 29th June 2009, however due to bad weather being forecast and the public holiday making it impossible to obtain ice, the sale was delayed and an estimated 183 sea cucumbers were stolen in the interim period.

In Tampolove, the first delivered 1170 juveniles were stocked in six 12.5 m x 12.5 m pens on the 24th February 2009 and the fastest growing sea cucumbers (n = 223) were harvested after 9 months. By the 31st January 2010 (11 months after input), the remainder of sea cucumbers reached the minimum market size and a sale was organised for the 19th February 2010. However, in the interim period between the conducting the monitoring and MHSA arriving to purchase the market ready sea cucumbers, an estimated 929 individuals were stolen on 11th February 2010, and only 14 individuals (>300 g) remained for sale to MH.SA.

The two incidents of theft described above were the only reported cases of theft, accounting for 4% of the total number of sea cucumbers delivered. However, Ambolimoke monitoring data showed that numbers of large sea cucumbers continued to be slowly depleted from the pens over time.

Investigations revealed that internal theft from farmers was an on-going problem and the site was subsequently abandoned.

To date, only 5% percent of the juveniles delivered have been harvested and sold back to MHSA. However as the last four deliveries totalling 13 070 juveniles occurred between 2nd December 2009 and closing date of the project on the 22 September 2010, these individuals had not yet had a full 12 months to reach market size and therefore another year is needed before the project can be fully evaluated. Furthermore, the numbers of sea cucumbers remaining in pens (15%) is likely to be an underestimation of the actual population, since the last monitoring documented in this study was carried out at the end of the austral winter (September) when many sandfish remain fully buried in sediment, even at night.

## Discussion and Conclusion

Although sea cucumber farming was considered to be an ideal alternative livelihood for coastal communities, as it is a relatively straightforward activity, employing simple technology and requiring no additional inputs, the investment in terms of labour, required for farmers to adequately protect their stocks from theft, was grossly underestimated. Given the relatively long timescales involved for sea cucumbers to reach market size (8 - 12 months), it was difficult to motivate families to guard the pens at night, particularly before the economic benefits were demonstrated. The production model, in which juveniles were stocked at regular 4 month intervals throughout the year, further adds to the burden of surveillance as, a few months into production, farmers are required to guard their pens on a permanent basis in order to protect larger sea cucumbers present in the pens from theft. For pilot projects, it may be more prudent to give communities a single batch of a larger quantity of juveniles, so that surveillance effort is focused intensively on the final months of grow-out as sea cucumbers approach market size, to ensure that a high percentage of sea cucumbers are harvested and the economic benefits to communities are demonstrated.

Table 1: A summary of the fate of juveniles delivered by MHSA over the two-year project timescale.

	Ambolimoke		Antserananangy		Nosy Be		Tampolove		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
No. juveniles delivered	9900		650		4800		11900		27250	
Mortality ( transport/input)	1529	15	-	-	1532	32	-	-	3061	11
Reported thefts	183	2	-	-	-	-	929	8	1112	4
Number harvested	98	1	-	-	144	4	1100	10	1342	5
Estimated no. in pens	36	1	150	23	15	1	3882	34	4083	15
Total unaccounted for	8054	81	500	77	3109	65	5395	45	16972	62

A combination of factors is likely to account for the large percentage of sea cucumbers (62%) which remain unaccounted at the project close on 22nd September 2010, including: 1) escape from pens due to high densities when all sea cucumbers were restricted to the juvenile pen (on one occasion newly released juveniles held at densities of 360 g m<sup>-2</sup> were observed squeezing through the doubled 10 mm nylon mesh in an effort to disperse); 2) escape from pens due to poor maintenance by farmers failing to repair holes in the net or bury the net adequately; 3) mortality from natural predators such as crabs which were occasionally removed but not actively controlled and 4) poaching and illegal sale of sea cucumbers from pens by the farmers.

The issue of theft was exacerbated by a number of key issues in the project design. Firstly the model in which credit was extended to farmers to obtain juveniles, did not require any risk on their part and therefore did not engender responsibility among farmers. Furthermore, the low prices paid by MH.SA of approximately US\$1 – 1,39 per piece, from which juveniles costs were also deducted, often meant that it was more profitable for farmers to sell their sea cucumbers to traders in the neighbouring villages. Finally, the two week time delay enforced by MH.SA, between BV staff communicating the number and weights of market ready sea cucumbers to MH.SA them travelling to Velondriake to buy them, increased the risk of theft. The two cases of reported theft both occurred in the week prior to an organised harvest and sale.

The logistics of operating in a remote location, with limited communication over a wide geographical area, also proved challenging. During scaling from initial test pens to a development project involving 250 community members spread over 30 km of remote coastline, control over social and environmental variables affecting individual pens diminished, and the margin for – and likelihood of – human error increased. The project has demonstrated that larger farming groups such as clans and women's associations are not viable models due to the high number of beneficiaries and lack of leadership. The ideal number of people per group is between seven and nine, with equal representation from both genders to assure that husbandry and maintenance tasks are adequately carried out. Selection of community farming groups should focus on identifying beneficiaries that possess the capacity for social organisation and basic micro-business skills. In addition, high levels of training, supervision, community motivation and quality control are needed for both farmers and surveillance staff to ensure adequate maintenance, monitoring, evaluation and follow-up.

Although it is not yet possible to conclude that sea pen based grow-out of sandfish is able to provide the anticipated economic benefits to communities, the model should be given consideration in light of its potential for re-stocking wild *H. scabra*. Although sea pens do not aim to create permanent breeding populations, they can contribute to re-stocking of over-exploited stocks through larval export from protected spawning aggregations. Although the exact thresholds needed to avoid depensation (when reduced reproductive success due to depleted densities of breeding adults) decreasing below natural mortality) remain unknown for tropical sea cucumbers, Bell *et al.*, (2008) postulate that minimum densities of 10-50 individuals per hectare are needed over substantial areas with groups of >10 sea cucumbers in which individuals are separated by no more than 5 – 10 m. If juvenile stocking is staggered throughout the year and harvesting occurs above the size of sexual maturity for sandfish, 150-200 g (Conand, 1990; Hamel *et al.*, 2001; Bell *et al.*, 2008) during the reproductive season, which in Madagascar peaks between November and April, (Rasolofonirina *et al.*, 2005), at least a small percentage of the stock will be sexually mature, at sufficient densities and proximity for successful fertilisation.

Most restocking programmes focus on the release of sandfish into no-take zones (NTZs), and Purcell & Kirby (2006) estimate that in order to protect surviving sandfish as nucleus breeding populations for 10 years, NTZs would need to be 19–40 ha in area. As sandfish populations have limited gene flow, at the scale of tens of kilometres (Uthicke & Benzie, 2001; Uthicke & Purcell, 2004), a network of protected spawning biomass is needed to restore populations on a broad scale. In view of the lengthy timescales involved, the number of NTZs to provide connectivity between populations, the loss of fishing grounds to communities and the limited guarantee of benefits, it will be difficult to gain community acceptance for this model. Furthermore, the cost of restocking multiple no-take zones will be prohibitive in many cases (Bell *et al.*, 2008) therefore sea pen based mariculture may provide a more cost-effective means of achieving the same goal. Smaller quantities of juveniles, paid for by communities can be released over wider geographical areas ensuring connectivity between pens. Sea pens offer a more accurate means of monitoring survival and growth of juveniles post-release and future studies should focus on release strategies to improve survival. Finally, it is possible that the potential benefits of re-stocking may return directly to communities as in Velondriake, newly settled juveniles of 1-2 cm have been recently observed around the pens, providing initial evidence to support the re-stocking theory.

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# The Prospects of Pearl Farming in Tanzania

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The fisheries sector in Tanzania is one of the main contributors to the economy and main source of animal protein to a majority of the population especially those who live along the coastal areas. In Zanzibar marine fish production is about 24,000 tons of fish annually (DFMR, 2009) and twice of this amount is caught in mainland Tanzania. The fisheries sector has been negatively affected by the increase in population and use of disproportionate technology in fishing leading to increasing prices for both fish and its substitutes as well as decline in the resources. In order to reduce these pressures initiatives to increase fish supply and expand alternative income sources to local villagers small scale bivalve mariculture initiatives have been initiated since 1980s first through experiments and research (Dubi *et al.*, 2006, Kite-Powell *et al.*, 2004, Jiddawi, 1995, Kayombo, 1986). Currently bivalve culture is conducted by several community members along the coast of both mainland and Zanzibar as a profitable alternative activity (Mmochi and Jiddawi, 1996, Mmochi and Jiddawi, 2004, Jiddawi, 2008).

One of the alternative livelihoods introduced along the coast of Tanzania in mid 2000s is pearl farming. Pearls have fascinated humankind for thousands of years and its production is a thriving business for coastal communities in many parts of the world (Haws *et al.*, 2006). Pearl oysters have been prone to exploitation due to the considerable value of the pearls and the nacre, or "mother of pearl" of the shell, and because of the animal's sessile nature and tendency to occur in sufficient densities at shallow depths for relatively easy collection (Haws, 2002).

Half pearl farming is an initiative, which started in Bweleo village, Zanzibar in 2006. The technique was introduced through the SUCCESS, USAID project under WIOMSA support (Jiddawi, 2008). This activity is also conducted in Mafia Island (Southgate *et al.*, 2006) and Tawalani village in Tanga (Ishengoma, 2009). These are known as half pearls (*Mabe*) because they are formed when a plastic button is glued to the inside of a pearl oyster shell and subsequently covered with nacre (Haws *et al.*, 2006). Approximately 94 oysters were seeded at Bweleo during the first attempt and the first half-pearl harvests were done in November 2007. The oysters for pearl production were cultured on hanging lines suspended in the water column by floats. The first attempt for Mafia was seeding of 50 oysters.

Round pearls are the type of pearls most people are most familiar with. However, half-pearl farming is much simpler and less costly to get started, as well it is environmentally friendly as no feeds are required. Also the culture of pearls requires only live oyster shells to implant seeds, a good protected site and willingness to conduct this activity as the bivalves need to be cleaned every fortnight to remove the antifouling organisms (Haws *et al.*, 2006). The species used for pearl

farming in Zanzibar are the black-lip pearl oyster, *Pinctada margaritifera* and the winged oyster *Pteria penguin*. According to Ellis & Haws, 1999) it requires 9 months to produce sufficient nacre in *P. margaritifera* while it takes not less than 12 months in *Pteria penguin*.

Some preliminary trials in Mafia Island and Villages in Zanzibar, Tanga and Pemba have shown that these oysters are abundant and they are capable of reaching a large size when cultured, indicating good growth rates and the potential to produce pearls of a large size. The pearls produced are of high quality with very good coloration of gold, white and black depending where the button has been set on the shell. Within a few years since its introduction in Tanzania, half-pearl production has demonstrated the ability to be grown and be sold profitably. This livelihood activity has shown the potential that it can be disseminated more widely to other interested communities as it holds strong promise for the development of new livelihoods. It can also play a key role in encouraging the community to conserve their natural resources. Communities now have learnt that they can farm something precious from the sea and that is making them care more about its future (Southgate *et al.*, 2006).

The numbers of 'nuclei' that can be pasted into the host oyster shell vary depending on the size of the oyster. Also the methods of implanting vary, for instance, the method used to implant buttons in Mafia is by seeding about 4–5 hemi-spherical nuclei using anaesthesia with benzocaine (Southgate *et al.*, 2006). In Zanzibar, the live oysters are allowed to open their shells naturally before planting 2 to 3 seeds. Bamboo rafts or rafts made from ropes are used to hang the bags containing the seeded oysters (Jiddawi, 2008).

The long-term sustainability of pearl farming will depend on overcoming a number of challenges. First of all, there is a need to ensure the possibility of having constant reliable sources of cultured juvenile stock. Efforts so far tried are the establishment of underwater lines and rafts to collect spat in Nyamanzi (Ishengoma, 2009), the establishment of no-take zones in Fumba peninsula (Crawford, *et al.*, 2009) as well as introduction of hatcheries early this year (one in Zanzibar through a donation by Island creek oyster foundation, USA and one in Mafia through the ReCoMap and WWF projects). Other challenges include training of local extension agents, establishing local bylaws to support the no-take zones and creating a permitting process to guide farm development in a sustainable fashion.

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# Sponge Farming in Zanzibar, Tanzania

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In 2009, the first sponge farming initiative in East Africa was motivated by the successful spread of seaweed farming on Zanzibar during the past 20 years. It is assumed that cultured sponges can be alternative aquaculture products suitable for sustainable small-scale farming promising higher earnings compared to, for example, seaweed. The farming of sponges (Phylum *Porifera*), is especially suitable for remote coastal areas without access to advanced technologies and infrastructure (Adams *et al.*, 1995). Sponges can be farmed with simple methods (farms in shallow waters serviced from the surface using traditional fishing boats) and low-cost equipment (i.e. buoys, ropes, anchors). Moreover, the processing up to the final product can be carried out locally. Therefore, micro-farms run by families or co-operatives present a possible alternative of income for local communities, including those already involved in seaweed farming.

With reports dating back to early Greek and Egyptian societies it is known that sponges have long been used for bathing and cleaning purposes. Due to their superior quality compared to artificial sponges, the global demand for natural sponges today by far exceeds supply. To date, commercially available natural sponges almost exclusively originated from wild harvesting in the Mediterranean, the Gulf of Mexico and the Caribbean. Overfishing, pollution and diseases resulted in a rapid decline of natural populations and consequently in disrupting the sponge industry. Although methods for culturing sponges are known since the beginning of the 20th century, commercial sponge farming efforts have not been launched until the 1990s. Today, commercial sponge farms are operating in Pohnpei, Australia and New Zealand.

As a source of highly biologically active compounds, sponges have been in the spotlight of research for several years (Spikema *et al.*, 2005). Sponge species synthesizing bioactive compounds can be produced adopting similar methods as used for the cultivation of bathing sponges, offering the opportunity of a prospective diversification.

## Preliminary Experiments and Results

With great support from the local community, two test farms were built in the lagoon off Jambiani on Zanzibar's southeast coast. The first farm is located at the tail of a channel at an operational depth of 4 m to 9 m (due to the tidal range) and the second farm is located in a shallow area (1 m to 5 m). Optimal growth of three commercially interesting local species was so far obtained using lantern-style mesh baskets (see Kelly *et al.* (2004) for method

details). The strong current in the channel area causes high mortality and loss of sponge explants if the threaded line method (see Duckworth *et al.*, 2007 for method details) is applied. In mesh-panels (see Duckworth *et al.* (2007) for method details) significantly higher survival rates are obtained compared to the threaded line method, but growth is, depending on species, either slow or the sponges grow through the mesh loops. The threaded line method is, presumably due to reduced current and/or closer proximity to the bottom, more successful at the shallow site, resulting in average to very good growth of individual species. However, with regard to micro-farms run by local communities, the simplest method (i.e. threaded line) shall preferably be applied in an easily accessible area (i.e. without scuba gear and in close proximity to the shore).

## Future Development

The project is currently focusing on finding and identifying local sponge species of commercial value. In parallel, cultivability of such species will be investigated using different techniques (similar to those mentioned above) at different environmental conditions (e.g. depth, current, tidal exposure etc.). Commercially viable methods for the cultivation of at least two local species shall be developed by the end of 2012 including the acquisition of expertise for the management of sponge seedlings. Starting 2013, marinecultures.org will train independent farmers and actively support them in building micro-farms. The current test farms will be used for demonstration purposes and for the production of seedlings for emerging micro-farms. In the long term, marinecultures.org will assist farmers in commercializing and extending the range of their products

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# PART V: Discussion

## Mariculture Development in Western Indian Ocean –

### *Some conclusions from the workshop*

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Growth of mariculture in the WIO region could bring much needed benefits to local communities in the form of increased income and employment. Revenues will come from sale in national and international markets, but also production of affordable food fish for local consumption could be possible. Mariculture in the region currently mainly involves production of low value products such as seaweeds cultivated in shallow seas and to some extent fish produced in coastal low salinity ponds (i.e. milkfish and mullet), and production of higher priced species such as pond farmed shrimps and cage/tank farmed marine fish and molluscs (i.e. abalone and pearl oysters). While perhaps insignificant from a global perspective, mariculture production within WIO region doubled between 2000 and 2003. However, production has since remained more or less stable at around 24 000 tonnes. Production of seaweeds has continued to increase in Tanzania (Zanzibar), Mozambique and Madagascar, but has decreased by more than 30% in South Africa. Shrimp production has also been decreasing in Madagascar and Mozambique. At the same time, however, abalone production increased in South Africa. Culture of marine fish, mainly originating from the small island states of Mauritius and Reunion has also been declining.

Despite these ambiguous trends, there seems to be a general feeling of optimism around future prospects for mariculture development in the region, indicated by many small ongoing initiatives that are not visible in the statistics (c.f. country reports in this volume), but the slow rate of development and the most recent declines in production of some species indicate that there are still many challenges to be overcome. While some of these challenges are largely specific to mariculture, they are similar to those facing freshwater aquaculture development in Africa. These include identification of suitable technologies and species, infrastructure needs, investment strategies and enabling policies etc., and also emerging issues related to environmental and social sustainability. The development of mariculture in WIO region has benefited from the recent focus on the creation of an enabling policy environment for Small and Medium Enterprises (SMEs). New challenges in the form of climate

change effects, however, are emerging and these need to be considered when planning future aquaculture development strategies. Tools allowing for broader systematic analysis in the form of Life Cycle Analysis are developing also for aquaculture that, combined with livelihood analysis, could help shape development towards a more sustainable trajectory.

The workshop analyzed the recent development of mariculture in WIO region and focused the discussion around two important questions: 1) what kind of mariculture can develop in the WIO region and what are the research needs for identifying suitable species and systems from an environmental and social perspective and 2) what factors restrain or facilitate sustainable development of mariculture in WIO region? A number of issues identified and discussed under these two broad questions are summarized below and also listed in appendix (Appendix 1).

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## Identified issues for facilitating sustainable mariculture development in WIO region

### *Technology and resource inputs*

Appropriate farming technologies need to be implemented where e.g. feeds should not compete with human consumption. Affordable finance and infrastructure should be made available as well as development of extension services and sustainable seed supply. Better information on alternative high value species that might be cultured in the region is needed, as well as identification of options for local processing. New technologies should be developed jointly with stakeholders but projects should avoid subsidies, as these create unsustainable industries.

### *Environment and social considerations*

Tools for analyzing broader sustainability aspects need to be in place (ecosystem approach, life cycle analysis, vulnerability analysis, etc.). Thus, there is a need to analyze trade-offs between coastal aquaculture and conservation (including identification of benefit and benefit sharing mechanisms). Ways to involve local communities in technology development should be investigated and all stakeholders involved in the coastal zone need to be included in the planning. The political situation and corruption also need to be considered and greater focus should be on needs-based research, on how to create public awareness and identify risks. There is a need to consider and plan for how climate change may affect mariculture in the WIO region and also how IMTA (integrated multi-trophic aquaculture) can improve ecosystem and social resilience. Any strategy must include long term monitoring of the environmental capacity of projects/business and accountable environmental management reporting should be carried out by independent organization. Monitoring reports should include a wider stakeholder perspective.

### *Human resources*

There is a general lack of trained people, technical expertise, research and education. Thus, it is important to focus on capacity development. Development of centers of excellence is one way to assemble expertise. Today extension/dissemination systems are lacking, which

prevents the spread of technical know-how, information and the exchange of ideas (including translation of research knowledge). Political will/enthusiasm in government are needed to create an enabling environment. Beyond expertise, it takes all stakeholders to make the development work. Entrepreneurial human capital is a vital component, especially at the small-scale level. Cultural and gender issues are also very important.

### *Economic constraints*

There is a need for well-targeted support to help develop business skills among farmers, develop markets and improve connections to input and output markets. Funding agencies need to have longer-term commitment and must periodically re-focus their efforts in order to build the sector. Research priorities include the identification of opportunities for small-scale producers. Monitoring and evaluation improves the impact of funding. There is a need to facilitate local market development and, through ICT, the dissemination of information on market prices.

### *Governance and management*

A better governance framework that includes legislations, better identified role of governments, university and industry need to be in place. Poorly developed ICZM plans may restrain aquaculture development. Opportunities for sustainable aquaculture development need to be supported by government policies and there needs to be consistency among aquaculture initiatives. Local knowledge can facilitate aquaculture development and the use of Business Development Service (BDS) to assist Community Based Organization (CBOs). Industry councils act as intermediaries between stakeholders and politicians up to the level of minister and can therefore play a facilitating role, including the direction of scientific research.

### *Private Sector Role*

There is a clear role for private sector SMEs in facilitating small-scale farming as part of its strategy. They must also lead in seeking opportunities to add value through the value chain, by identifying markets for new products, introducing new processing technologies at the local level. There is a need for clarity about how the private sector is structured and what their needs are.

# Appendix 1

## *List of some major research needs/issues identified by workshop participants*

- Need for in depth study of overall sustainability of seaweed farming in WIO region and investigation of alternative algae species (i.e. other red seaweeds) as well as implementation of deeper water farming technologies. Investigate seaweed value adding opportunities.
- Identify new aquaculture candidate species, such as mangrove snappers and octopus, and carry out research out-from market value and feasibility perspectives. Especially suitable local aquaculture candidate species should be identified through local scoping studies.
- Recruitment studies for mud crab (*Scylla*) in order to optimize crab aquaculture and fisheries.
- More basic knowledge about how water quality and salinity effect fish/shrimp growth in ponds and about ecology and nitrogen fate or recycling. Impacts studies of stocking densities and water quality on shrimp production are needed.
- Investigate the general acceptance of aquaculture by coastal people and having a greater emphasis on local communities perspectives when planning (e.g. for tilapia farming).
- Develop suitable production technologies for milkfish and mullet, including post-harvest deboning techniques
- Investigate the suitability of community-based initiatives, hatchery technology transfer for sea cucumbers. A development and practice framework /strategy plan is needed to investigate if sea cucumber farming is a sustainable alternative to seaweed farming.
- Develop technology for floating and long-line farming of pearl and oyster farming, and options for developing technology for pearl farming hatchery. The social and economic benefits from promotion of pearl/oyster farming need to be analyzed and sustainability issues identified. Structures for local community involvement need to be developed together with market analysis.
- Develop sustainable cost-effective local feeds for small-scale mariculture operations.
- Investigate advantages and disadvantages of monocultures versus polycultures and Integrated Multitrophic Aquaculture (IMTA).
- Identify species resilient to irregular and limited (incl. low quality) feed inputs.
- Identify sustainable seed sources for different species.
- Increase the knowledge of where certain scales of aquaculture operations are suitable (applying a ICZM perspectives). Identify benefits and opportunities for implementing aquaculture regions/zones.
- Socio-economic and market analysis to identify most profitable/viable mariculture to local communities, benefits from farmer clusters (e.g. seaweed farmers)
- Identify how stakeholders should be involved in technology development and what the benefits are.
- Need for obtaining better understanding about enabling and disabling institutions that affect mariculture development.
- Improve the structure for information delivery and communication, i.e. from/to governmental agencies to/from local farmers, possibly through “participatory field schools”.
- In depth analyze of the initial focus on meeting local needs for food through aquaculture lead to export oriented focus? Including how both small and large scale should contribute to food security.
- Investigate the requirements for extension of small scale farming.
- Investigate how the different qualities and opportunities (resources, cultures, etc) of the different nations within the region will/may lead to different solutions (scales, systems, focus, ).
- How can local knowledge be built into the decision-making process?
- Focus on research to bring together production with auxiliary services and how commercial service industry can help small-scale farmers.
- Analyze how artisanal farming can counteract rise and falls in local demands and minimize negative externalities.
- Focus on capacity building. In most countries there are one or two aquaculture graduate school institutions, but the institutions lack the critical mass of capacity to make meaningful technological contributions.







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