Western Indian Ocean JOURNAL OF Marine Science

Volume 18 | Issue 2 | Jul – Dec 2019 | ISSN: 0856-860X

Chief Editor José Paula

Western Indian Ocean JOURNAL OF Marine Science

Chief Editor **José Paula** | Faculty of Sciences of University of Lisbon, Portugal

Copy Editor **Timothy Andrew**

Published biannually

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ISSN 0856-860X

Cover image: *Macrophthalmus depressus* at Saco da Inhaca, Mozambique (© Jose Paula, 2014)

Small-scale milkfish (*Chanos chanos*) farming in Kenya: An overview of the trends and dynamics of production

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Abstract

A number of donor-funded projects by NGOs, government departments and faith-based organizations have piloted milkfish farming along the coast of Kenya at different scales with the aim of addressing poverty and food security at the community level. This paper provides an overview of the history of milkfish farming, organisation of operations, funding, farmers trends, and production dynamics, using both secondary and primary data. Primary data were obtained from quantitative and qualitative assessments covering 26 community milkfish farming groups, while secondary data were obtained from the grey literature and donor-funded project reports. Additional primary data were obtained through 9 key informant interviews covering three coastal Counties, and focus group discussions (8-10 members) at all the community milkfish farms. The study established that milkfish farming could be traced back to the early 1980's as a by-product of the prawn farming intervention by FAO, and later in other private farms that practised prawn farming. Community/village based small-scale milkfish farming was initiated about two decades ago using organised community groups (OCGs) as the entry point. The number of OCGs undertaking milkfish farming fluctuated with availability of donor funds and increased significantly between 2007 and 2015 with an increase in earthen pond farming area from 0.9ha to 6.8ha over this period. However, the scale of production remained low. Annual milkfish production increased from less than 50kg in 2005 to a maximum of 3.2 tons in 2015. Milkfish farming has not attained production levels that can address poverty and food security issues; a fact that was associated with the lack of reliable milkfish seed for stocking culture facilities. Harvests from existing farms are sold at the farm gate and in nearby market centres with a few communities venturing into opening fish shop outlets to sell their produce.

Keywords: Milkfish; scale; farming; dynamics; production

Introduction

The contribution of aquaculture to total fish production has steadily increased over the years due to the recruitment of additional species of aquatic animals and plants for culture, leading to this food production sector becoming the fastest growing in the world (FAO, 2016). Globally, aquaculture accounted for 44.1% of total production from capture fisheries and aquaculture in 2014, increasing from 31.1% in 2004 and 42.1% in 2012 (FAO, 2016; FAO, 2012). Tilapia, milkfish, catfish, carps and marine molluscs have been observed to contribute significantly to global aquaculture output from fresh and marine waters, (FAO, 2017; Naylor *et al*., 2000). Aquaculture employs a large number of people, especially in developing countries (FAO, 2003; Rana *et al*., 2009; FAO, 2012).

Whereas aquaculture production is increasing globally, there are large regional differences. In 2010 significant food fish aquaculture production took place in Asia (53.3 million tons, representing 89 % of world production) and Europe (2.5 million tons, 4.2 %) while Sub-Saharan Africa contributed only 0.6 % of the global output (FAO, 2012). Unlike many Asian countries, Sub-Saharan Africa has a limited history in aquaculture, which still remains largely under developed (Brummett and Williams, 2000; FAO, 2012).

http://dx.doi.org/10.4314/wiojms.v18i2.2

As mariculture development in the Western Indian Ocean countries remains slow (Troell *et al*., 2011), there is a need for investments in research and extension to ensure development of the sector in order to improve income and food availability for poor coastal communities (Mirera, 2011a). However, at the same time, the integrity of the environment must be maintained (Ronnback *et al*., 2002; Mirera, 2009; Mirera and Ngugi, 2009; Mirera, 2016). In this context there is a conflict between the mariculture methods commonly employed in Sub-Saharan Africa and traditional capture fisheries, as mariculture is based to a large extent on collecting seed stock (Milkfish, mud crabs, prawns) and feed from the wild (de Boer and Longamane, 1996; Mgaya *et al*., 1999; Carle'n and Olafsson, 2002; Rice, 2003; Mirera, 2011a).

To counter these negative impacts, it is preferable to cultivate low-trophic-level marine species like milkfish, even though they fetch a low price and are not suitable for export. Globally, milkfish production is ranked 9th in quantity produced and contributes 3.63% of world aquaculture production, excluding China (FAO, 2017).

Milkfish culture has attracted considerable attention for marine finfish farming in East Africa because it tolerates wide environmental conditions, and seed is available from the wild (Mirera, 2011a). Some progress has been made in milkfish research in the western Indian Ocean (WIO) by establishing seasonal growth rates in earthen ponds, feed formulation and composition, response to feeds in laboratory conditions, fingerling occurrence, and tolerance to varied water quality in intertidal ponds (Mirera, 2016, 2011a; Mirera and Ngugi, 2009; Mirera, 2007; Mwaluma, 2003; Mwangamilo and Jiddawi, 2003; Mmochi *et al*., 2002).

This study provides information on the history and organisation of milkfish farming in Kenya, the scale and dynamics of production, farming systems, factors influencing the industry, production trends and marketing systems.

Materials and methods

Kenyan milkfish farming is diverse and is influenced by the history of milkfish farming, farming systems used, inputs and scale, approaches to milkfish farming, gender, literacy, funding aspects, trends in production, culture area and marketing of the harvest. A combination of methods was employed to obtain primary and secondary data that was analysed to provide results discussed in this study.

Secondary data

Data from several project reports, farm records and the grey literature was collected in an attempt to better understand production per unit area, changes in farming area and groups, annual production statistics and farming systems. The reports were sourced from different organisations and projects that have undertaken milkfish farming along the coast of Kenya. Data and reports were obtained from the Kenya Marine and Fisheries Research Institute (KMFRI), Kwetu Training Centre, Coastal Oceans Research and Development in the Indian Ocean, East Africa (CORDIO-EA), State Department of Fisheries, Aquaculture and Blue Economy, OCGs where farming has taken place (farm records), and donors that have directly implemented projects at a local level. Data from these sources were combined with that from published literature to calculate production per unit area, trends in different areas, and annual production and donor support over time.

Primary data

Semi structured interviews were administered during focus group discussions with farmers and key informants to collect quantitative and qualitative data. Focus group discussion were conducted in 26 OCGs (OCGs have 20-70 members) undertaking milkfish farming in the three counties of Kilifi, Mombasa and Kwale. This tool provided descriptive statistics on the farmers, gender distribution among the OCGs, literacy levels, age, farming systems, types and sources of inputs like feed and seed, stocking cycles, scale of production, annual production trends and marketing aspects of the harvested milkfish.

The focus group discussions enabled a deeper understanding of small-scale milkfish farming in Kenya since it was designed to verify estimated productivity data in different project reports and the grey literature.

Key informant interviews engaged major players in the small-scale milkfish farming industry from each of the farming counties. The key informant interviews were used to capture how an individual relates different variables to each other within a system as a way of exploring individual beliefs (Axelrod, 1976). The tool aimed to establish the drivers behind milkfish farming in Kenya, lessons learnt, and community perceptions on the scale of milkfish farming in relation to the eradication of poverty and ensuring food security. The key informants were drawn from the communities and NGOs working in the respective counties. Semi-structured interviews using closed and open-ended questionnaires were used to collect data from the key informants. The questions focused on the scale of production of milkfish, role of funding, lessons learnt, main drivers informing participation in milkfish farming, challenges, management of milkfish enterprises, and market systems.

Results

History of milkfish farming in Kenya

The history of milkfish farming on the coast of Kenya is three pronged: (a) Private/ none governmental organizations (NGO); (b) government departments; and (c) community interventions. Private farmers, NGOs and government departments became aware of the potential for milkfish farming through the FAO-funded prawn farm project at Ngomeni, Kenya in the early 1980s. Milkfish production was an un-intended by product from the initial prawn farms. It was considered a low value fish that was given to farm workers and the local community for free or at minimal prices. Almost two decades after the collapse of the FAO prawn farm, Mwaluma (2003) working at the Kwetu Training Centre on mud crab experiments, observed milkfish fingerlings in an intertidal mud crab pen that had limited water exchange at neap tides, and recommended investigation of the species for aquaculture.

The study led to the development of small-scale community milkfish farming that followed a different approach to that of the FAO and private prawn farming enterprises. In agreement with Mwaluma (2003), communities exploiting intertidal mangrove resources observed fish in the intertidal mangrove pools at neap tides where there was minimal tidal exchange. During such periods children fished in the pools to obtain fish for domestic consumption. Some of these areas were deepened in Makongeni village, Gazi Bay with support from local conservation and development NGOs, leading to diverse fish communities in the artificially created mangrove pools (Table 1). Thus, small-scale fish farming developed in intertidal earthen ponds of around 120m^2 in size. The ponds were fertilised with organic manure (Table 2). The initial farming process established that 33.3% of the species stocked did not survive to harvest, and only 20% recorded significant growth, including milkfish (Table 3).

Farming systems and management

Milkfish is farmed in earthen ponds that are constructed in intertidal mangrove flats free of mangrove trees. The ponds are fed naturally by the rising tides, and drained completely at harvest during low tides using standpipes fixed at the bottom of the ponds. Water height in the ponds is modulated using overflow pipes that are fitted with screen nets to control predators and fish escapes from the ponds at high spring tides. More than 80% of the farmers stock milkfish extensively and fertilize ponds using organic manure. However, all the farmers feed their fish with formulated feeds and fertilize ponds using organic manure if donor funding is available.

Farmers use seine nets in the natural mangrove channels/pools to obtain fingerlings for stocking ponds. Previously, farmers had challenges in identifying the culture species at stocking, but constant training has

Table 1. Fish species found at Makongeni, Gazi Bay Intertidal pools during a random survey using screen nets.

Local name (Swahili)	Common name	Scientific name/family
Mkizi	Mullets	*Crenimugil crenilabils*
Kole kole	Trevally	*Carangoides orthogranus*
Kidara	Jack/Trevally	*Carangoides dinema*
Chaa	Silver belly	*Gerres sp.*
Ngagu	Grunt	*Terapon Jarbua*
Bunju	Puffer fish	*Arothon spp.*
Kiunga	Snapper	*Lutjanus argentimaculatus*
Kamba	Prawns	*Peneaus Monodon*

Table 2. Species of fish stocked in Makongeni intertidal earthen ponds to test survival and growth.

Local Name	Common Name	Scientific/family name
Mwatiko	Milkfish	*Chanos chanos*
Mkizi	Mullets	*Crenimugil crenilabis*
Chaa	Silver belly	*Gerres spp.*
Bunju	Puffer	*Arothron spp.*
Nyembe nyembe	Sweeper	*Pempheris oualensis*
Ngagu	Grunt	*Terapon Jarbua*
Kole kole	Trevally	*Carangoides orthogramus*
Chuchungi	Halfbeak	*Hermiramphus spp.*
Kamba	Prawns	*Peneaus monodon*
Kisumba	Barracuda	*Sphyraenidae*
Kiunga	Red snapper	*Lutjanus argentimaculatus*
Tuguu	Surgeon	*Acanthuridae*
Pamamba	Grunters	*Haemulidae*
Dizi	Scavangers	*Lethrinidae*
Kidara	Jack/Trevally	*Carangoides dinema*

enabled farmers to perfect their identification skills and they are now able to stock only milkfish as the preferred species. Due to seasonality and the inability to obtain enough fingerlings, 70% of the existing fish ponds in each group have one crop in a year, and in most cases the stocking densities are low (1.5-2 fish/m^2). Farmers are only able to produce two crops per year and at a stocking density of 3 fish/m^2 when there is donor funding to mobilise resources for seining of fingerlings at the required time. Information from focus group discussions indicated that farmers in OCGs are able to attain 100% attendance in weekly farmers meetings if donor funding is available, while only 40-50% attendance is registered in the absence of donor support.

More than 70% mortality was experienced in the farms at inception of community milkfish farming due to poor location of fishponds and predation from carnivorous fish and birds. Currently the farmers lose 30-40% of the stocked fish due to bird predation and poor water quality, especially in the earlier stages of production, and water management to control extreme water quality parameters at neap tides during the dry season (January–March). Key informant interviews indicated that losses of fish through bird predation and poor water management could be reduced to below 15% if donor funding is available to employ guards.

Farming and production dynamics

Small scale milkfish farming is undertaken in the three coastal Counties of Kwale, Mombasa and Kilifi. The number of OCGs participating in milkfish farming has increased over time from 9 in 2007 to 26 in 2015 (289%). Consequently, the area covered by milkfish ponds increased from 0.9ha in 2007 to 6.8ha in 2015 (Figure 1).

Despite the expansion in the number of communities involved, ponds and culture area, production per square meter has remained significantly low with slight increments over the years, while the quantity produced is inconsistent and related to the availability of donor funds (Figure 2, 3; Table 5). Production per unit area has varied between 0.06-0.2kg fish/m^2 in 2007 and 0.08-0.45kg fish/m^2 in 2015, with increasing annual production. Consequently, total milkfish production has increased from less than 0.05 tons annually in 2005 to more than 3.2 tons in 2015, generating direct income of USD7,600 per year. In comparison with other mariculture species on the coast of Kenya, milkfish production accounts for about 13.2% of the total production from mariculture (Figure 4).

Table 3. Summary of fish stocked, mortalities observed and average size (g) harvested after six months of culture in earthen ponds at Makongeni, Baraka Conservation group mariculture site.

Local name	Common name	Stocking size (g)	Mortality noted	Average size at harvest (g)
Mwatiko	Milkfish	8	No	350
Mkizi	Mullet	5	No	28
Chaa	Silver belly	20	Yes	10.5
Bunju	Puffer	22	Yes	-
Nyembe Nyembe	Sweeper	10	Yes	-
Ngagu	Surgeon	8.5	Yes	21.3
Kole kole	Trevally	11.5	Yes	-
Chuchungi	Halfbeak	4	No	15
Kamba	Prawns	3	No	40
Kidara	Jack/Trevally	2.5	Yes	-
Kiunga	Red snapper	5	Yes	96
Pamamba	Grunters	6	Yes	80
Dizi	Scavengers	3	No	15
Tuguu	Surgeon	2.5	Yes	28.1
Kisumba	Barracuda	5	Yes	-

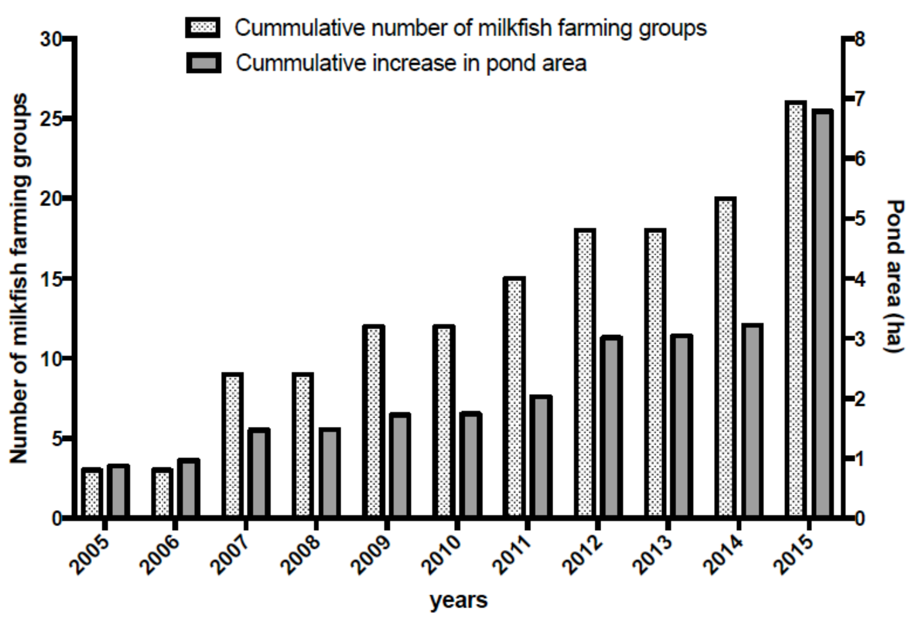

Figure 1. Cumulative increase in (a) number of communities undertaking milkfish farming, and (b) pond area used along the Kenyan coast. (Source: Mirera, 2007; Mirera and Ngugi, 2009; Grey literature from Kwetu training centre mariculture reports, community production records, KCDP baseline assessment statistics, State of mariculture WIOMSA report)

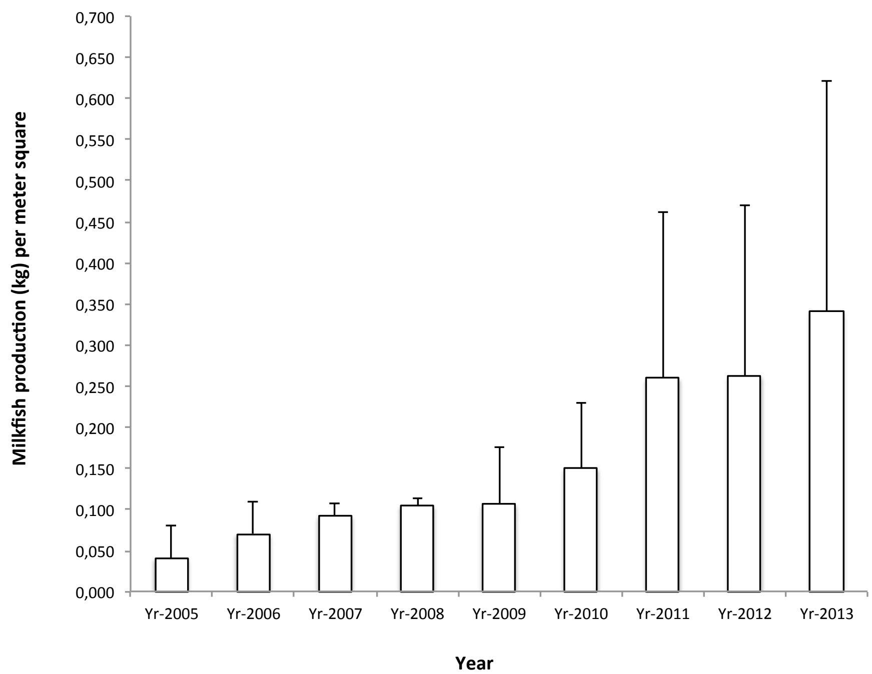

Figure 2. Change in small-scale community-based milkfish (*Chanos chanos*) production (kg/m²) along the coast of Kenya between 2005 and 2013. (Source: Mirera, 2007; Mirera and Ngugi, 2009; Grey literature from Kwetu training centre mariculture reports, community production records, KCDP baseline assessment statistics, State of mariculture WIOMSA report)

An increment in the number of entrants into milkfish farming and changes in farming area between 2005 and 2013 was observed to be directly proportional to the number of new donors supporting milkfish farming (Table 4). Several donors supported development of milkfish farming in 2007 leading to a higher number of entrants and a large percentage of the area under milkfish farming (33.3%). Also, the amount of funds available for milkfish farming research had a direct impact on the increase in production (kg/m²), but did not significantly impact on the number of communities participating in farming, or an increase in culture area. Donor or research support increased the spread of milkfish farming technology to other

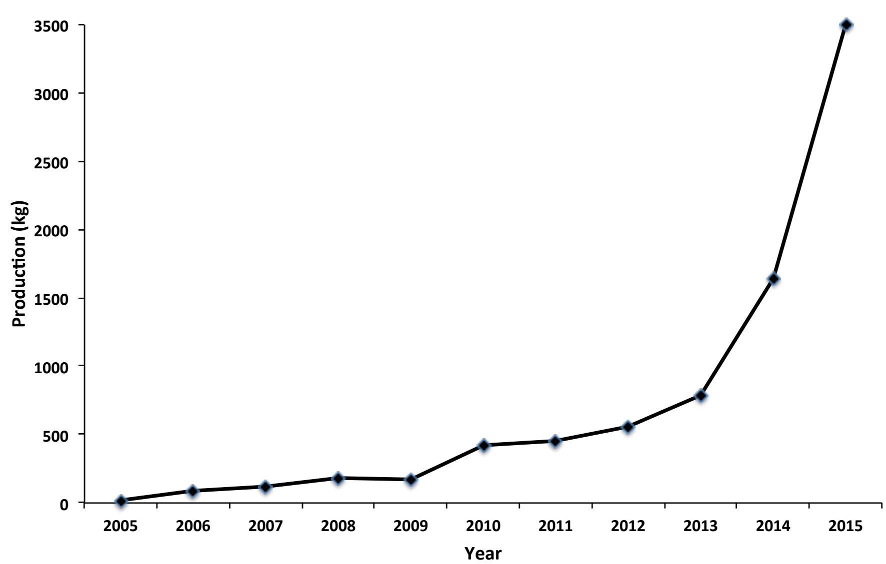

Figure 3. Trend in milkfish production along the coast of Kenya between 2005 and 2015. The figures are based on the total harvests by the different villages along the coast of Kenya. (Source: Mirera, 2007; Mirera and Ngugi, 2009; Grey literature from Kwetu training centre mariculture reports, community production records, KCDP baseline assessment statistics, State of mariculture WIOMSA report)

Table 4. Details of new community entrants into milkfish (*Chanos chanos*) farming in relation to source of funds for development and research between 2005 and 2013. (Source: project related reports and KCDP baseline survey report)

Year	Percentage of new entry into milkfish farming	New development funds available to support milkfish farming	New research funds available for milkfish farming
Base year 2005	11.5	Sida Sarec through CORDIO EA,	None
2006	0	None	None
2007	23.1	Toyota conservation, Diakonie – Tsunami, FAO, Rufford grant, WWFEFN	WIOMSA, CHE
2008	0	None	None
2009	11.5	ReCoMaP, UNDP	None
2010	0	None	None
2011	11.5	CAST Italy	NCST
2012	11.5	CDTF/KCDP	KCDP
2013-2015	30.8	KCDP/FAO	KCDP

* FAO – Food and Agricultural Organisation of the United Nations, UNDP – United Nations Development Program, KCDP – Kenya Coastal Development Program, CDTF – Community Development Trust Fund, ReCoMaP- Regional Coasts Management Programme, NCST – National Council for Science and Technology, CHE – Commission for Higher Education, WIOMSA – Western Indian Ocean Marine Science Association, CORDIO EA – Coastal Oceans Research and Development Indian Ocean, East Africa.

areas. For example, milkfish farming at Kibokoni was initiated through a National Council for Science and Technology (NCST) funded research project in 2013, while CAST introduced milkfish farming at Ihaleni.

Socio-economic aspects of milkfish farming

Milkfish farming is the most common type of mariculture activity practised along the coast of Kenya, compared to seaweeds, artemia, mud crab or prawn farming. Milkfish farming is practised in the intertidal mangrove flats which are designated government lands in all coastal counties except Lamu and Tana River. Through the Kenya Forest Service (KFS), the goverment has introduced user rights in intertidal mangrove flats for aquaculture development, as a strategy to improve mangrove management while developing the aquaculture sector in the country. In all farming areas milkfish culture is extensive and farmers operate on a small-scale level using conventional fish farming methods in ponds ranging between $120m^2$ and $1,200m^2$.

OCGs have a mixed composition of men and women. Percentage of women representation in milkfish farming ranged between 40 – 80 % depending on counties; the highest being in Kwale, Kilifi and Mombasa respectively. The mean age of farmers in OCGs was 40 years with the eldest being 79 and the youngest 18. Most farmers were middle aged (36-65), while youths (18-35) comprised 37%, and the elderly (above 66) formed 3 %. About 63.7% of the farmers had attained a primary level of education and 2.8% had no education at all. 28.2 % had obtained secondary education, 2.5 % madrassa (Islamic education), and 2.8% tertiary education.

Milkfish farming supports more than 1 400 people directly, and about 3000 indirectly, through small-scale businesses, seed collection, and Motocycle "poda poda" transport. It was observed that milkfish farming had led to the development of infrastructure such as roads, which were non-existent in some communities before the milkfish farming project (e.g. Kibokoni). The percentage of children going to school also improved over the years in some villages where milkfish farming was introduced.

Small-scale milkfish farming initiatives along the coast of Kenya have been facilitated by government and NGOs which have directly funded the projects

Table 5. Aquaculture production and employment in selected villages along the coast of Kenya between January 2005 and December 2013.

Village	Aquaculture production (kg)									Employment (on farm-jobs) 2013 x (a, b)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Makongeni baraka shelf help group	4.6	15.7	45.8	56.9	33	256	150	350	480	20 (4, 16)
Kwetu Training Centre (NGO)	12.2	41.46	-	18	70	100	160	80	60	8 (6, 2)
Majaoni youth development group	-	30	76	91.65	48	30	95	32	40	13 (10, 3)
Abent youth group	-	-	-	10	22	31	45	48	60	17 (13, 4)
Kibokoni, Umoja self-help group	-	-	-	-	-	-	-	38	116	70 (15, 55)
Ihaleni Conservation group	-	-	-	-	-	-	-	8	25	20 (13, 7)
Total	16.8	87.2	121.8	176.6	173	417	450	556	781	148 (61, 87)

Source: Mirera, 2007; Mirera and Ngugi, 2009; Grey literature from Kwetu training centre mariculture reports, community production records, KCDP baseline assessment statistics.
Note: x (a, b) = Total (Men, Women).

or offered guidance while doing research and training/extension. About 81% of the milkfish farmers had received support for their interventions, while 19% had not received any support (Table 4).

A market for milkfish is locally available even though prices are low (2.4 – 3.5 USD/kg). Most of the harvested milkfish are sold at the farm gate, and in rare cases in local markets and in fish shops owned by the farmers themselves that have been developed through support from the Kenya Coastal Development Project (KCDP). The local farm gate and fish shop market includes consumers from within the villages, dealers, hotels and fish mongers.

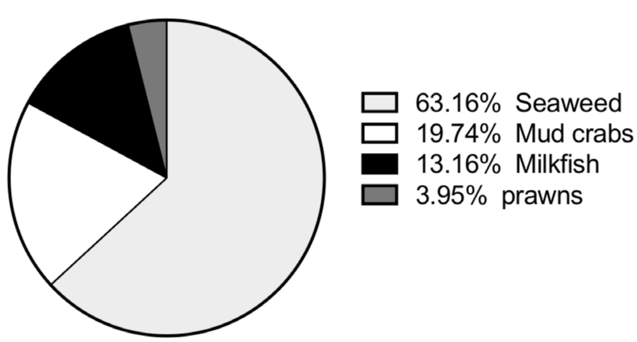

Figure 4. Current annual mariculture production in Kenya showing percentage contribution by species.
(Source: State of mariculture WIOMSA report)

Discussion

History of milkfish farming in Kenya

Coastal communities have fished in intertidal mangrove pools for fish and shellfish for centuries to meet their subsistence needs. Over the years, communities have developed significant traditional knowledge concerning their environment. However, with increasing population and the increasing number of widows and orphans, intertidal resource harvesting in Kenya has in recent years experienced entry of children and women to meet the emerging and expanding family needs (Mirera 2011b; Mirera *et al*., 2013). This increase in pressure on resources is likely to lead to serious problems of over-exploitation in the future. Even though most fishers are aware of the consequences of juvenile fish and shellfish collection for food in the mangrove pools, few are ready to take action – an example of the tragedy of the commons (Hardin, 1968).

Although marine fish farming is generally a small-scale activity in Kenya, it has the potential of becoming one of the highest producing sectors if the initial FAO commercial prawn farming interventions could be effectively developed (Mirera, 2011b). Fish farming in intertidal earthen ponds has rapidly developed over the last one and half decades as a small-scale intervention (Mirera, 2011b). However, milkfish was initially a by-product from private prawn farm activities and no studies were done to understand growth and survival of the fish. In this study together with previous studies, several species were observed to use mangroves as nursery grounds (Mirera *et al*., 2010; Huxham *et al*., 2004). Of the 15 species stocked in this study, milkfish, grunters and mangrove red snapper recorded good growth in intertidal earthen ponds. Milkfish had the highest growth of the three and has been found in large numbers within the mangrove creek channels in previous research studies in Kenya (Mirera, 2011a).

Initial attempts of small-scale milkfish farming involved the use of small earthen ponds (120m^2) constructed in open intertidal mangrove flats (Mwaluma, 2002; Mirera and Ngugi, 2009; Mirera, 2011a). The sizes of ponds remained constant from inception until 2015 when commercial milkfish ponds of 1,200m^2 were constructed with support from the KCDP. Thus, the scale of milkfish production has largely remained at the pilot stage and only minimal production was attained from the many development interventions dedicated towards milkfish farming in Kenya. According to Woltering *et al*. (2019), a major problem that undermines efforts to achieve scale in development projects is the fact that pilot projects are set up and managed in very controlled environments that do not reflect the reality at scale. Research and development organizations working on poverty alleviation and food security face growing scrutiny to demonstrate a return on investment from their work, especially in developing countries (Hurst *et al*., 2017; Moyo, 2010)

Farming systems and management

For the last four decades milkfish has mainly been farmed in intertidal earthen ponds. During spring high tides when intertidal mangrove flats are flooded with ocean water, milkfish ponds are allowed to fill using overflow pipes and standpipes. A number of fish species enter the ponds with this sea water, and initially farmers stocked both herbivorous and carnivorous fish together in the same ponds. In the absence of milkfish hatcheries that are able to supply quality seed, all the farmers stocked mixed fish species in ponds, and had limited ability to identify milkfish and separate them from other species. Predation between species was therefore high leading to high mortalities in culture ponds. Also, the more sensitive species died due to fluctuations in water parameters like salinity and temperature which were not effectively monitored at the initial stages of small-scale milkfish farming.

Management of milkfish earthen ponds has previously been minimal and limited to preparation of ponds for stocking using lime, fertilisation with organic manure, stocking, sampling and harvesting of fish. This led to low production of fish per unit area. However, with improved management that included water exchange at spring high tides, artificial fertilizers, feeding, proper fish identification at stocking, and predation management, production per unit area and production capacity has been enhanced. Feeding of milkfish has been progressively improved from the use of non- formulated feeds such as wheat bran to the use of formulated feeds, although the quality of these formulated feeds still needs to be improved (Mirera, 2008). Improved management has resulted in higher production and the consequent increase in fish sales at the farm gate or in the OCGs shop outlets.

Even though management of earthen ponds has improved and some positive progress observed in milkfish production, significant effort is required to attain quantities that can adequately contribute to food security and poverty alleviation in Kenya. Woltering *et al*. (2019) underscored the fact that agricultural innovations, such as improved seed, better management systems and practices, and collaborations need to be tested at pilot scale, and once successful, they must be scaled-up to address the envisioned size of the problem. However, in the case of milkfish farming in Kenya, most projects never scale-up to achieve the expected impact, since support ends after the demonstration phase (Cooley and Howard, 2019; Spicer *et al*., 2018). This could be associated with the fact that the number of donors and projects has doubled, while the project terms and budgets have significantly reduced in the last decades (Cooley, 2018).

In order to allow milkfish farming to contribute to food security, growth and development in the long term, it should be sustainable - not only technically feasible and economically viable but also environment-friendly, socially equitable and introduced at the required scale. Challenges that need to be addressed to allow sustainability include ensuring constant seed supply, quality feed, increasing production per unit area, and increasing the scale of production (Woltering *et al*., 2019; Platon *et al*, 2006).

Production dynamics

Small-scale aquaculture has been seen as a way of improving food security and other welfare aspects of poor coastal communities (Ahmed *et al*., 1999; Ahmed and Lorica, 2002). Being a capital-intensive venture, aquaculture development needs financial support to be effective in poor households in coastal East Africa. In the current study, the increment in number of aquaculture farmers (groups) and farming area was found to be closely related to the increase in donor funds supporting milkfish farming, especially through livelihood and mangrove conservation projects. This suggests that milkfish farming could contribute meaningfully to the food and nutritional status of people through income, employment and consumption linkages (Ndanga *et al*., 2013; Holdren, 2011; Ahmed and Lorica, 2002).

In Africa, government and donor-driven aquaculture projects have most often targeted small-scale farmers in an attempt to ensure food security at the household level (Jamu *et al*., 2012; Brummett *et al*., 2008; Hishamunda, 2007; Moehl *et al*., 2005). The same has happened in Kenya, where despite the increase of culture area under milkfish farming over time, production/m^2 and the scale of production has remained low with small and inconsistent increments over the years dependent on the availability of donor funds. It should also be noted that the presence of research funds significantly increased milkfish production/m^2, but did not increase the scale of production. Observing these trends, Beveridge *et al*. (2013), Brummett *et al*. (2008), and Hecht (2006) argued that the extensive nature of aquaculture systems in Africa has limited investments in the sector and thus impacted supply of quality inputs and the scaling-up of enterprises.

The current study observed that there were annual increments in milkfish production over the years until 2013, but still less than 1 ton of fish was produced, a fact that was associated with the small-size of ponds used in the farming, an inability to stock fish to the required densities, and poor feeding strategies. This indicates that most interventions in Kenya have either remained at pilot or research scale, and have not been able to move to the next level of meeting the food security objective. Despite the importance of scaling research or pilot projects to meet development objectives, successful examples are scarce; a factor discouraging further donor funding into research and development. Scaling is assumed to occur spontaneously or organically when pilot scale projects are successful (Wigboldus and Brouwers, 2016; Chandy *et al*., 2013). According to Buntaine *et al*. (2013), this is a result of donor impatience to see on-the-ground results that directly link adoption to impact, thus encouraging research and development projects related to agriculture to focus on simple and visible inputs and outputs, rather than on form and function (Maru *et al*., 2018; Spicer *et al*., 2014).

Rey-Valette *et al*. (2008) argue that aquaculture production and sustainability is a continuous process; a 'journey' rather than a destination in terms of a sustainable, final and ideal aquaculture product. Compared to the Philippines, for example, milkfish culture is in its infancy in Kenya (Mirera, 2009; Bombeo-Tuburan and Gerochi, 1988). Milkfish farming can be traced back to the 1940's in south-east Asia when production was relatively low at around 0.007kg/m^2, but this has increased progressively over time to 0.06kg/m^2 and the industry is considered sustainable (Bombeo-Tuburan and Gerochi, 1988).

Socio-economic aspects of milkfish farming

Since its initiation, community milkfish farming has been embraced as a major livelihood activity and a motivator for the conservation of mangrove forests along the coast of Kenya. Indeed, the co-management approach has been adopted in community milkfish farming; as advocated for mangrove systems in the Forest Act of 2007 and 2016, respectively. According to Slater *et al*. (2013), the social and economic drivers that determine if farmers choose aquaculture as a livelihood option include gender establishments, social network strength, material style of life and the time available for a supplementary livelihood. Another key driver of milkfish farming along the coast of Kenya is population growth. The coastal region of Kenya has a population of 3.3 million people, growing at the rate of 2.9% per annum according to the 2009 census (Republic of Kenya, 2010). In addition to this natural population growth, the coastal areas also experience significant immigration due to the diverse livelihood opportunities like fishing, tourism, business and hospitality. This large population depends heavily on the catch of the small scale and subsistence fishers, whose catch has declined over time (Malleret-King *et al*., 2003; Mangi and Roberts, 2006). To meet the fish deficits and be able to feed families milkfish farming has been embraced mainly by the youth and women. This finding is similar to that observed elsewhere where the growing strength of domestic markets due to a rising demand for fish by middle class populations is cited as one of the factors enabling aquaculture development in Africa (FAO, 2016; Tschirley *et al*., 2015; Hecht, 2006).

Significant progress has been made in developing technologies for improved milkfish farming, but there are still limitations hindering development of the industry. This study found that most milkfish farming is carried out in the intertidal areas that are 95% government-owned, with minimal private land ownership. Even though the communities have traditionally used these areas, they lack tenure rights to encourage them to invest or significantly modify these areas for aquaculture development. Further, most areas lack legal access routes due to blockage by private investors who own the sea front. The situation is further confused by conflicting mandates and legislation concerning control of areas where milkfish farming takes place. For example, intertidal areas are the responsibility of the Kenya Forest Service if they are bordering or contain mangrove trees, while the National Environment Management Authority, Ministry of Lands and Planning, and the Department of Fisheries Development, Aquaculture and Blue Economy currently also claim authority over the same areas. The new Constitution of Kenya (2010) which created a system of National and County government provides another dimension of uncertainty with regards to sea-based aquaculture areas. Indeed, FAO (2016) underscores the significance of land tenure in development of agriculture, fisheries and forestry. The uncertainty with regard to land tenure in coastal Kenya is considered a major hinderance to the scaling-up of donor-dependent interventions, ensuring that they remain temporary and struggle to reach economic sustainability, as alluded to by Woltering *et al*. (2019).

Milkfish market and trade

Marine fish forms a popular delicacy in the traditional diet of the coastal people in Kenya. According to Karuga and Abila (2007), the main market segments for capture marine fish in Kenya include the domestic/institutional fish market, the domestic processed fish market, the export processed market, and the fishmeal market, with household fresh fish market and hotel/restaurant fish markets being important outlets. However, no market value chain assessment has been done for farmed fish (freshwater and marine) at the coast. This study established that farmed milkfish market outlets were mainly from the farm gate, targeting household members and the surrounding villages, and fish are sold fresh. Recently, with increased production, some farmers are diversifying markets to local shop outlets to reach other clientele, often in the frozen form. Farmers have opened shop outlets and store milkfish in cooler boxes, selling to community members, local hotels or institutions like schools, colleges or companies. These market outlets offer the highest potential for growth, and therefore income generation to the farmers, and thus may need to be nurtured in the future.

The household fresh fish market segment tends to be most useful to the villagers in need of daily food, as it operates throughout the year, irrespective of season. The prices for farmed fish vary according to season with higher prices (2.5-3.0 USD/kg) realized during the season when capture fisheries are less active, compared to the seasons when capture fisheries are more active (1.8 – 2.5 USD/kg). To capitalize on this, farmers could schedule their harvest and sell produce when prices are better. The market for milkfish, mainly relying on demand from local communities, appears to be more resilient, as it is not affected by the market dynamics associated with tourist hotel industry or export market, for example. This suggests that farmed marine fish could have enormous market potential if the current domestic segment can be fully exploited, in addition to opening other market segments available for marine fish along the coast and inland.

Conclusion

The findings of this study show that milkfish farming is undertaken through OCGs. Milkfish production has progressively increased in terms of quantity produced and area farmed, while production per unit area is still low. Farming is practiced at subsistence level, and extensively, contributing more to the food security of the communities, rather than to economic gains. Milkfish farming needs to be scaled-up for economic benefits. Entry into milkfish farming is mainly driven by existence of donor funds rather than benefits gained from successful interventions; a fact that has led to stagnation of production, despite significant efforts from development/ conservation organizations and government. Current production is sold either at the farm gate or in local outlet shops, initiated by farming groups.

Milkfish farming is faced with challenges such as relying on wild caught seed, leading to the inability to stock ponds at appropriate stocking densities. There are also challenges related to fish feeds with most being produced locally and containing inadequate nutrients. There is a need to assess the existing extension frameworks and provide appropriate options that can address the existing challenges of low production and dependency on donor funds if the milkfish farming sector is to grow. Further, a more thorough analysis of the economics of rural, small-scale milkfish farming is required to understand the current status and trajectory. With the enhanced production and availability of input supplies (mainly seed and feed), it is suggested that the milkfish industry can provide sufficient food and income requirements to local fish farmers in Kenya.

Acknowledgements

This work would not have been possible without the secondary data and grey literature and or donor/ project reports dealing with milkfish farming along the coast of Kenya. The information was obtained from technical project reports/donor reports and archived data. In particular, appreciation goes to the Kenya Marine and Fisheries Research Institute, Kwetu Training Centre, Kenya Coastal Development Project, Community Development Trust Fund, Regional Coasts Management Programme, United Nationals Development Programme, Food and Agricultural Organization of the United Nations, National Council for Science and Technology, Commission for Higher Education, Western Indian Ocean Marine Science Association, Coastal Oceans Research and Development Indian Ocean – East Africa, CAST Italy, Diakonie Germany, World Wildlife Fund, Toyota Conservation Grant, Rufford Grant, and Pwani and Moi Universities. Further appreciation goes to all the communities undertaking milkfish farming who provided valuable information during the study.

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