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Cover image: Ponta Rasa mangrove, Inhaca Island (© José Paula, 2005)

Status of the mud crab fishery in Kenya: A review

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Abstract

Most indigenous coastal populations (70%) have a high dependency on, and preference for, marine fisheries. However, most fishers are financially handicapped and thus do not invest in the fisheries that require relatively high financial capital (to purchase fishing gears and vessels). A higher proportion of fishers depend on near shore fisheries that are easily accessed by foot or dugout canoes. In Kenya, mud crabs are fished mainly by men and to a lesser extent by women and children due to the accessibility of the fishing areas by foot. This makes mud crabs a key fishery that is easily accessible for exploitation by most coastal artisanal fishers for subsistence and commercial purposes. Mud crabs have been a delicacy in the local tourist hotels for a number of years. In addition, the previously minimal export market for mud crabs from Kenya has increased drastically over the last two decades. The requirement for wild mud crab seed in aquaculture has also increased over the last decade. The demand for all sizes of mud crab to meet the requirements of the different market chains in Kenya require effective management approaches to guide exploitation of the fishery. The development of Beach Management Units (BMUs) as outlined in the National Oceans and Fisheries Policy of 2008 and the Fisheries Management and Development Act of 2016, if well implemented, enhance management of the fishery. Further, adoption of the new Constitution (2010) and establishment of county and national governments calls for harmonization of roles to address localised management issues such as for the mud crab fishery, that is currently declining in small mangrove creeks.

Keywords: Mud crabs, exploitation, artisanal fishers, export, aquaculture, management

Introduction

Mud crab (*Scylla serrata)* is a decapod crustacean that spends most of its life in the mangrove environment throughout its range. It has high meat quality and nutritional value hence its fishery forms a significant economic activity in coastal areas in the tropics and sub-tropics. They form an important source of food and income for most local communities (Keenan *et al*., 1998; Keenan, 1999; Le Vay, 2001; Bonine *et al*., 2008). A number of communities along the East African coast are involved in mud crab fisheries although, due to the nature of the fishery, it is difficult to collect reliable data which can provide information on catch rates and trends (Barnes *et al*., 2002; Richmond *et al*., 2006; Mirera, 2011).

Globally, artisanal mud crab (*Scylla spp.*) fishers use several methods for capturing the crabs, which have changed over time (Bonine *et al*., 2008). The methods for capture are generally similar throughout the tropics but the techniques may differ somewhat from one region to another depending on habitat complexity and traditions of fishers (Perrine, 1978; Le Vay *et al*., 2001; Ochiewo, 2006; Bonine *et al*., 2008). The dominant capture methods include: baited crab pots; baited traps; hooked wooden/metal rods; baited lines attached to a pole; scoop nets; head lights/torches with scoop nets; gill/seine nets; intertidal collection by hand; and baited lift nets (Hill *et al*., 1982; Overton *et al*., 1997; Le Vay *et al*., 2001; Barnes *et al*., 2002; Walton *et al*., 2006; Lebata *et al*., 2007; Bonine *et al*., 2008; Mirera *et al*., 2013).

In Kenya and East Africa in general, burrow fishing is a common technique of collecting market size (above 0.5kg) crabs for sale, and sub-adult (0.1-0.5 kg) crabs for cage and pen culture (Muthiga, 1986; Barnes

et al., 2002; ACDI/VOCA, 2005; Mahika *et al*., 2005; Richmond *et al*., 2006; Fondo, 2006; Fondo *et al*., 2010; Mirera, 2009, 2011). This fishing technique requires considerable experience to manage, otherwise, crabs are damaged thus reducing their market value (Mirera and Mtile, 2009; Nirmale *et al*., 2012). Fishers frequently check burrows inside their respective fishing territories and collect individuals found on, or buried in, the sediment (Mirera *et al*., 2013).

Population studies of mud crabs in Kenya have previously indicated a fishery that was previously only lightly exploited with potential for improved income generation if sustainably managed (Muthiga, 1986; Mirera, 2011, 2012; Fondo *et al*., 2010). However, site- or region-specific declines in catches have been observed in some assessments in Kenya and East Africa (Mahika *et al*., 2005; Fondo, 2006; Richmond *et al*., 2006). Based on the capture details from artisanal fishers in Kenya, there has been a drastic decline in the number of market size (0.5 kg) crabs being collected from small creeks over time, and this has affected exporters of the product, forcing them to diversify to other products (Mirera *et al*., 2013; Roy Aseka, pers com; Fig. 1). The mud crab fishery occurs throughout the year with small seasonal variations in quantities of landings (Muthiga, 1986; Onyango, 2002; Mirera *et al*., 2013). Recruitment into the fishery also occurs throughout the year with no specific peaks (Mirera, 2014).

Objectives and scope of the review

The main objective of this review is to assess the level of exploitation of the mud crab fishery in Kenya, its potential to meet the livelihood demands of coastal communities, and management interventions that could ensure sustainable utilization. The assessment has been based on the available literature on mud crab fishery production, exploitation methods and management interventions. The review also considered available databases on mud crab production, stock assessment and other related studies such as tagging experiments. To understand the management approaches, policies and other legal documents related to fisheries management, including the constitution of Kenya 2010, were considered. The different aspects of the fishery have been compared to studies on similar fisheries elsewhere in the world. To conclude, we identify knowledge gaps related to the development and exploitation of the fishery, and management interventions needed to ensure sustainability.

Mud crab diversity

More than four decades ago, the genus *Scylla*, was considered monotypic globally, irrespective of clear

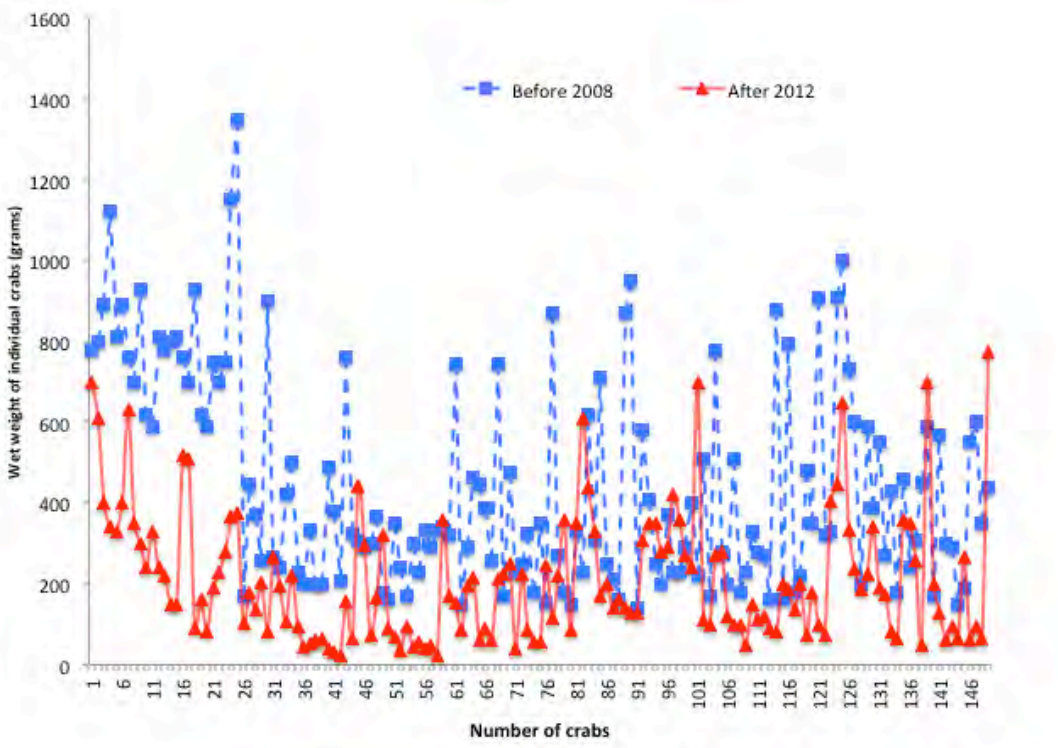

Figure 1. Comparative assessment of the size frequency of mud crabs caught by fishers at Mtwapa creek before 2008 and after 2012 (Data source: Kwetu Training Centre records, IFS and WIOMSA tagging experiments).

morphometric differences (Serene, 1952; Ong, 1964). However, it was revised in the last decade and a total of four species were identified (Keenan *et al*., 1998). The four species of mud crabs now globally accepted are *Scylla serrata*, *S. paramamosain*, *S. tranquebarica* and *S. olivacea*. Of the four species, only one (*S. serrata*) has been identified in Kenya (Fratini and Vannini, 2002) through samples taken from Mida creek, Gazi Bay and Lamu. However, only few genetic studies have been done in this area to provide clear indications on the exact number of mud crab species along the Kenya coast. Using the morphometric differences, there are indications of a second species in Kenya, suggesting that more research on mud crab systematics is required (Mirera, 2011). Based on the demand for mud crab in mariculture development (Mirera, 2011; Moksnes *et al*., 2015), adequate research is required on species diversity to enable informed management decisions on stocks, habitat change, mariculture technology development, and hatchery establishment.

Mud crabs and the mangrove environment

Mangrove tree formations contribute to the marine food web through their production of detritus and commercially important species of marine animals (crabs, fish and shrimps) are known to spend at least part of their life cycle there (Nagelkerken *et al*., 2008; Mirera *et al*., 2010). Indeed, for decades adult/market size mud crabs (*S. serrata*) in Kenya have been harvested from holes in mangrove swamps during the day at low spring tides by expert fishers (Fondo, 2006; Mirera, 2011; Mirera *et al*., 2013). Crab populations are typically associated with mangroves globally and are at times used as indicators for mangrove habitat condition (Hill *et al*., 1982; Walton *et al*., 2006). They are abundant in estuaries and mangrove swamps at some stage in their life cycle (Muthiga, 1986; Overton *et al*., 1997; Onyango, 2002; Walton *et al*., 2006). Mangrove habitat utilisation begins when crabs settle out from the plankton developmental stage of instar 1, and may continue to the adult stage when they move out for spawning in deep waters (Walton *et al*., 2006; Mirera, 2014).

Juvenile mud crabs are common in intertidal mangrove habitats, on mudflats or in mangroves stands (Hill *et al*., 1982; Mirera, in press) while larger crabs are found in mangrove channels, near the shore or in burrows. During low tides, individual crabs are found in burrows on the mud within the mangrove roots or basal mangrove tree holes (Nandi and Dev Roy, 1991; Barnes *et al*., 2002; Fondo, 2006; Mirera *et al*., 2013). The burrows have also been observed to harbour crabs that are almost at the stage of moulting. Burrow occupancy has been used to study crab abundance and utilization of the mangrove forest and is rated at 5-10% based on the area and region (Barnes *et al*., 2002; Fondo, 2006).

Harvesting strategies and methods

Artisanal fishers engage in mud crab fishing in Kenya both during the day and night. Most of the catch is not landed at gazetted landing sites as stipulated in the Fisheries Management and Development Act of 2016. In most cases the fishery is operated without the use of vessels by fishers on foot moving within the mangrove forest covering large areas in a day with no specific landing areas. Most of these fishers operate without a fishing license and therefore do not declare their catch at designated landing sites due to fear of being caught for contravening the law. This is coupled with the fact that most of the small and micro-landing sites are not gazetted and are inaccessible (National Oceans and Fisheries Policy, 2008), suggesting that only localized management strategies like Beach Management Units (BMUs) would be effective in managing the fishery.

Mud crab fishers are known to accumulate harvests at home before sale, thus making catch records at landing sites unattainable and misleading (Mirera *et al*., 2013). Lack of appropriate records and management protocols for the fishery, despite the well-stipulated regulations in the National Oceans and Fisheries Policy 2008 and the Fisheries Management and Development Act 2016, could be responsible for the apparent low current catch levels. Previous studies have shown that harvested crabs in Kenya are consumed at family level, sold to private homes or tourist hotels, or exported (Muthiga, 1986; Mirera, 2011; Moksnes *et al*., 2015). The implication is that harvest records in Kenya and East Africa in general are based on information from mud crab intermediaries, or buyers, but not at the fish landing sites as required by law (Fisheries Management and Development Act, 2016). Thus there is a likelihood of under estimation of catches of up to 40% (Mirera *et al*., 2013). The accumulation of mud crabs over a number of days before being taken to the market also leads to loss of individual weight and mortality, and reduced value of the fishery. This has inflicted large losses to mud crab exporters who depend on fishers to supply them with live mud crabs for sale.

As a result of the harvesting characteristics of the fishery, it becomes complicated to determine an accurate

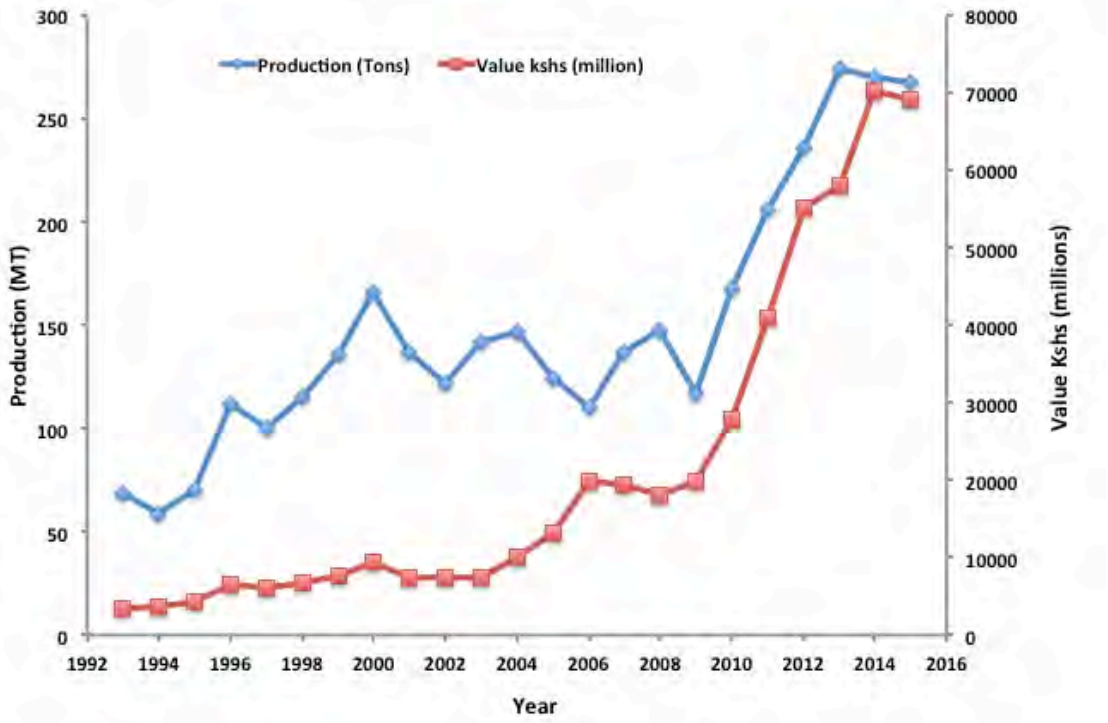

Figure 2. Mud crab (*Scylla serrata*) fishery production (MT) trends and catch value (Ksh) along the coast of Kenya for the period 1990 to 2015 (Data source: Fisheries annual statistics database 1993-2013, and Fisheries catch statistics data for 2014-2015): 1USD = 102Kshs.

CPUE for mud crabs, with most studies relying on information from market intermediaries, or hole counts and interviews with crab fishers (Horrill *et al*., 1996; Barnes *et al*., 2002; Fondo, 2006; Ochiewo, 2006; Richmond *et al*., 2006).

The choice of a fishing area and method for mud crab fishers depends on the target crabs being fished and the skill and equipment required. More than 60 % of the fishers fish for adult mud crabs in burrows within the mangrove swamps at low tide using traditional hooks and sticks. Other fishers use baited traps, scoop nets or seine nets along the seaward mangrove fringe and channels. Almost all crab fishers practice fishing by foot with limited use of equipment, but with a wide local knowledge of the fishing area (Jones *et al*., 2008; Ochiewo *et al*., 2010). Fishing is never random, it follows specific patterns, mainly depending on the knowledge of the fisher of preferred mud crab areas where the harvest is likely to be high, or on visiting hereditary burrows (Dumas *et al*., 2012; Mirera *et al*., 2013).

Crab fishing in Kenya mainly occurs during the early morning rather than later in the day or in the evening. Fishing is mainly influenced by tidal regimes irrespective of the fishing technique applied (Moser *et al*., 2005; Mirera *et al*., 2013). Fishers prefer to fish during low spring tides and return at high spring tides with only limited fishing taking place during neap tides (locally known as *maji mafu*). Mud crabs found in burrows at neap tide are usually in the moulting period, or have just moulted, and have no market value in Kenya, despite the recently developed market for such crabs in Asia (soft shell crabs). Moulted crabs collected at neap tides are mainly consumed at the family level.

Recent trends in mud crab capture fishery and markets

Mud crab fisheries production has increased over the years from 90 MT in 1990 to more than 250 MT from the year 2013. Despite small annual variations, there has been a constant increase in mud crab landings with small drops seen in 2001-2003 and 2006-2008 respectively (Fig. 2). The value of the catch has constantly increased possibly as a result of diversification in market outlets for the product. Increased demand from the local tourism industry and export markets has resulted in an observed increase in mud crab fishing effort, and capture of small sized crabs in Kenya and East Africa (Barnes *et al*., 2002; Mirera, 2011; Mirera *et al*., 2013). Larger volumes of mud crab production observed after 2008 could be associated with the demand in the export market (Ochiewo, 2006; Mirera, 2011, 2014).

Currently the mud crab catch-per-unit-effort (CPUE) has been estimated at 0.25-1.7 kg/hr/fisher and each fisher can spend between 2.5-5.0 hr/day fishing (Mirera *et al*., 2013). The individual weight of crabs caught currently range between 0.25 and 0.9kg, which is a significant decline from the 0.5-1.5kg per crab caught 2-3 decades ago (Muthiga, 1986; Onyango, 2002). The capture of crabs of more than 0.5kg individual weight has declined over the last four years in small creeks (Roy Aseka, per com; Fig. 1). Mud crab fishing by foot fishers is mainly influenced by spring tides, however time spent and frequency of fishing may also be affected by market demand. According to Barnes *et al*., (2002), fishers will move for long distances to look for crabs depending on the market demand and need for food at the family level, implying that fishing skills, and the ability to move faster and further in the mangrove forests, could contribute to good catches. In addition, a crab fisher could either make two fishing trips/week as in the case of Chole Island in Mafia, Tanzania (Barnes *et al*., 2002) or fish daily during spring tides as in Kenya (Mirera, 2014; Mirera *et al*., 2013) so as to meet the market demand and family needs.

In Kenya, Lamu County is ranked the highest producer of mud crabs at 48.2%, followed by Kwale (26.4%), Mombasa (11.2%), Kilifi (11.9%) and Tana River (2.3%) (Government of Kenya, 2014). The main mud crab areas include Vanga, Shimoni, Majoreni, Ngomeni, Gongoni, Kurawa, Mkokoni, Kiunga and a number of the many Lamu Islands (Muthiga, 1986; Government of Kenya, 2014; Fig. 3). Most of the areas producing mud crabs occur in three counties (i.e. Lamu, Kwale and Kilifi). The lower percentage contribution of mud crab by Kilifi County could be associated with the fact that most crabs are consumed at local tourist hotels in Malindi and Watamu, and are thus not reflected in the catch data. The high contribution of mud crab landings from Mombasa, which has only small mangrove creeks compared to the other areas, could be as a result of more efficient monitoring of landings due to its proximity to the headquarters of the regulating agency, or due to the double entry of catches from other counties that have been brought to the market in Mombasa as a main coastal hub. Generally, there has been an increased demand for mud crabs both for the domestic and the export market leading to a drastic decline in the size of mud crabs captured in creeks such as Mtwapa, Kilifi, Tudor, and Mida over time (Fig. 1; pers obs). Even though the number of the juvenile crabs is high in the same creeks, there are indications that recruitment into the fishery is declining as a result of fishing pressure (Mirera, 2017).

Socio-economic Characteristics

Fishing for mud crabs is an important livelihood activity for many households along the coast of Kenya. It has been ranked as a key artisanal commercial fishery that requires stock assessment for improved management (KCDP, 2013). Mud crab fishers in Kenya account for 2.9 - 3.5% of the total number of fishers (12,915 fishers) in marine waters (Government of Kenya, 2014). However, the precise number of fishers in this fishery is difficult to establish since most of them do not acquire a fishing license. The average household size of crab fishers in Kenya is about 6.8 persons and similar to what has been recorded for other artisanal fisheries (Ochiewo *et al*., 2010; Mirera, *et al*., 2013). This implies that conservatively, the fishery directly supports more than 2,600 people, and more than 20,000 people indirectly through different supply chains and linked activities such as hotels, restaurants, transport, export, education, eco-tourism and research, among others.

The crab fishery has a limited number of entrants due to the extensive skills required and the harsh mangrove environment where it's practiced. As a result, over the years men aged between 23 and 55 years have dominated the fishery. The scenario is different in the artisanal finfish industry where age composition of fishers ranges between 15 and 45 years (Fulanda *et al*., 2009). Further, crab fishing skills are passed on from one generation to another (heredity), and in some cases from close friends through peer learning. This naturally limits exploitation of the fishery. Such limitations constitute a self-regulating mechanism for the fishery (Mirera *et al*., 2013). Self-regulation can be positive because with relatively limited effort and awareness it is possible to manage the fishery effectively, since participants are conversant with each other at a local level, and local management interventions could succeed if well administered. However, it may be negative since most of the fishers are related to each other making disclosure of non-compliance difficult. Involvement of mud crab fishers in BMU hierarchies may help address issues of compliance to regulations in the fishery.

According to government statistics, the value of landed mud crabs has continually increased from 1993 to 2015 (Fig. 2). In 2015, the fishery was valued at about 70 million Kshs (70,000USD), contributing between 3.5 – 5.5 % of the total value of Kenya's marine fisheries (Government of Kenya, 2014; KCDP, 2015). Such an increase in value may encourage entry into the fishery or increase the frequency of fishing, thus increasing fishing effort

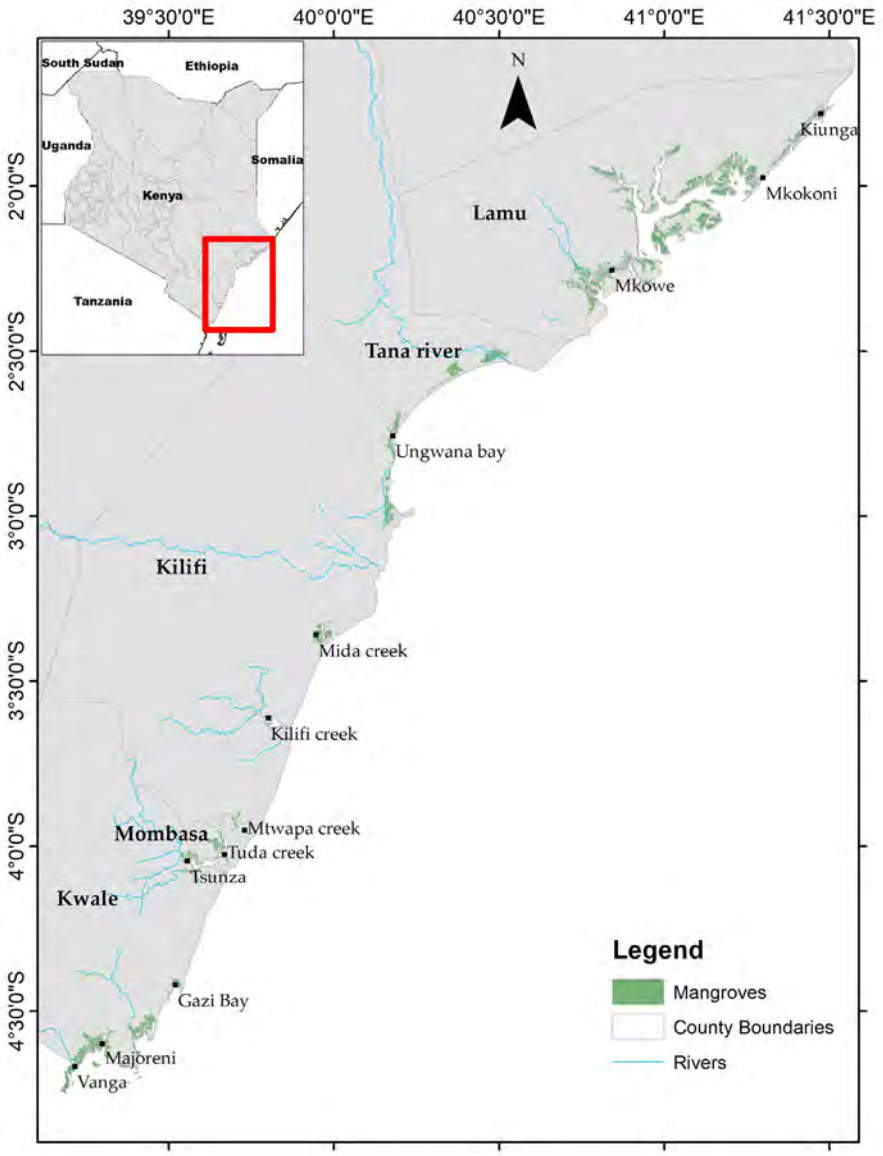

Figure 3. Map of the Kenya coast showing the different counties and mangrove areas where mud crab fishing is practiced.

that may have negative impacts on available stocks. The crab fishery in Kenya has a complex market chain that involves middlemen at different stages, resulting in relatively low profitability for ordinary fishers (Mirera *et al*., 2013). The crab price on the open market varies from 0.2-0.5 USD/kg when sold to locals for home consumption, to 2-5 USD/kg when sold to private homes and in tourist hotels, and 8-15USD/kg when sold for export (Mirera *et al*., 2013). Such price variations are mainly associated with differences in the size of crabs sold and the nature of the market.

To popularize the eating of crab, local tourist hotels have innovatively developed special crab eating techniques, which include a small traditional club for shell breaking, a bib, a small hand towel, and a traditional pot with warm water for occasional hand cleaning (Mirera *et al*., 2013). A good example of the cultural value of mud crabs comes from the island of Kosrae in the Federated States of Micronesia, where adult mud crabs make up a central part in family feasts and are used as gifts to visitors. This has ensured that residents/fishers receive good prices for their crabs (Bonine *et al*., 2008).

Recently, a local community in Kenya has introduced an innovative value addition technique to improve the value of the product sold in their own eco-restaurant located in the mangrove forest on Mida Creek. Crab meat is used to make samosas that are sold at the restaurant by the Dabaso Conservation Group. They are able to make 4 crab samosas from one crab weighing

0.5-0.8 kg. Each of the samosas are sold for 200Ksh (2USD) thus increasing the value one crab to 800Ksh (8USD) (Misinga, pers com). This is four times more than a kilo of fresh mud crab sold in the local market by fishers. This suggests that even without the export market where prices are high, innovative value addition of crabs in the local markets can create employment and enhance income to the local communities through direct marketing to the public. Further, it is noted that mud crabs are mainly served in coastal hotels and there is potential to expand the market to inland hotels in major towns such as Nairobi, Nakuru, Eldoret and Kisumu, among others. Exploitation of such potential will improve the value of the fishery and bring profitability to the fishers.

Emerging Issues

In the last two decades there has been much interest in mud crab farming in Kenya. However, there are no hatcheries to provide seed for the industry (Mwaluma, 2002, 2003; Mirera, 2009, 2011). All the crabs used in fattening (adult lean crabs) and grow out (juvenile and sub adult) are collected from the wild (Mirera and Moksnes, 2015). Recent studies have shown that collection of juvenile crabs occurs in the intertidal boundary zones and are accessible to a wide range of collectors, including women and children who usually do not penetrate deep into the mangrove forests to catch bigger crabs (Mirera *et al*., 2013). The development of mud crab aquaculture targeting all stages of mud crab creates a new challenge to management of the fishery. The ability to collect juveniles easily compared to adults creates a risk of over-exploitation from aquaculture if no management interventions are put in place (Mirera, 2011).

Further, there is an increased mud crab export market in Kenya, mainly to Singapore, Dubai and China. This has encouraged the exploitation of undersized (less than 0.5kg) crabs in an effort to meet the market demand. High mortalities in the transportation and export process lead to wastage of the harvested resource. The current export value chain provides the importer with the authority to decide on what percentage of shipped mud crab is declared fit for their market. Local exporters have no agents in the importing destinations to confirm the state of shipped crabs, and therefore relies on importers to provide information on the state of crabs upon arrival. This could allow for the exploitation of exporters and a consequent loss of value to the fishery, with negative implications for the livelihoods of fishers and the economy.

This underscores the need to re-organize the mud crab fishery in all respects, including monitoring compliance with minimum size limits, ensuring fishers are licensed, recording landings properly, improving collection and storage of the crabs before marketing, and instituting a reliable system to monitor shipments in importing countries.

Legal Framework and Management Status

In the last five years, a co-management approach was adopted in Kenya to support the management of fisheries resources through the establishment of BMUs. According to the Fisheries Management and Development Act 2016, a BMU is defined as an organization of fishers, fish traders, boat owners, fish processors and other beach stakeholders who traditionally depend on fisheries activities for their livelihoods. The BMU was established to ensure structured community participation in fisheries management through supporting conservation, management and development of their local areas. This involves participation in the Interagency Monitoring Control and Surveillance Unit that is established by the Permanent Secretary in the relevant Ministry. BMUs have the right to manage a specific co-management area, impose levies and charges in these areas, manage the proceeds of these, and have a responsibility to protect marginalized groups such as youth and women working in their areas of jurisdiction.

Despite the fact that BMUs are working well, their mandates have not been fully achieved due to limited capacity (resources and personnel) to create awareness and provide monitoring and surveillance for the various fisheries resources, including mud crabs. They lack capacity to track down artisanal mud crab fishers as they do not land or operate at designated landing sites (Mirera *et al*., 2013). To reach mud crab fishers requires extra resources, time and incentives for patrols, to create awareness on the need for landing in designated sites, and to obtain the required operational license. It is therefore necessary to ensure active involvement of experienced/knowledgeable artisanal mud crab fishers in top BMU management structures to facilitate support for the process, and help to unlock the potential of the fishery through knowledge and information sharing (Steel *et al*., 2005; Laurens, 2012).

The Forest Conservation and Management Act of 2016 provides an avenue for co-management of forests in Kenya. The Act allows for the creation of forest user groups (communities who want to use forest areas for

their livelihoods) and recognizes forest communities (communities who have a traditional association with forests either through livelihoods, religion or culture). These are operationalized through the establishment of Community Forest Associations (CFAs) that are legally recognized and registered with the Kenya Forests Service (KFS), giving communities the mandate to manage a given forest area. If the two community management mechanisms mentioned above are well coordinated, they have the potential to greatly assist with the management of the mud crab fishery. However, currently the BMU and CFA systems work independently to meet the needs of the mother ministries. The Forest Conservation and Management Act of 2016 does not mention BMUs, nor does the Fisheries Management and Development Act of 2016 mention CFAs, even though CFAs and BMUs were already in existence.

The adoption of the new constitution in 2010 provided for a devolved system of government. The fisheries sector was devolved to the county system of government and most of the fisheries management officers previously stationed in the former provinces and districts under the national government were moved to the County administration. Currently, there is no clear structure in place for the management of artisanal fisheries even though the Fisheries Management and Development of 2016 indicates that the County should be responsible for this, including the establishment of BMUs. In the absence of strong structures in County government, artisanal and inshore fisheries management and compliance is jeopardized. Further, the linkage between the national and county government is weak and leading to much time being required to harmonize and achieve the required management interventions for the fishery. Considerable effort is still needed to ensure that the existing policy and legal instruments are optimally utilized to manage fisheries in Kenya.

As observed in southeast Asia decades ago, all size classes of mud crab in Kenya and East Africa are also becoming the target of the fishery through the development of mud crab aquaculture (Le Vay, 2001; Onyango, 2002; Mirera, 2011). However, there are currently no policies or regulations in Kenya that focus on the collection of wild mud crabs (juveniles, sub-adults and adults) for aquaculture. The situation may be aggravated further by the increased global demand for soft shell mud crabs with no size requirements (Mirera, 2014). There is need for focused research to assist with management of the fishery to ensure sustainability (KCDP, 2013).

Effective management policies for the crab fishery may also need to address protection of under-sized, spawning, and moulting crabs to help reduce over-exploitation threats on the resource, while promoting sustainable utilization of the fishery.

Even though the CPUE for crabs has remained relatively stable, this may be misleading in terms of assessing stock status. Fishers target preferred crab habitats in the mangroves based on the traditional knowledge gained in the fishery, such as burrows or mangrove tree holes that are replenished during high tides. Based on the skewed nature of harvesting the fishery, the CPUE may not represent the status of the overall crab stocks since all sites are not fished equally while some other potential habitats may be unknown to the fishers (Mirera *et al.*, 2013). Therefore, diversity in potential crab fishing sites based on the local knowledge of fishers may require further research and harmonization for effective site-specific management of the fishery.

Management Recommendations

Currently, most artisanal mud crab fishers are not obliged to register as fishers since they never land their catch at designated landing sites. Most crab production estimates are taken at market outlets, which tend to under-estimate overall catch (Mirera, 2011). To improve on monitoring of the fishery, it is suggested that an effort is made to register all artisanal mud crab fishers in the same manner as in other fisheries, and as required in the Fisheries Management and Development Act of 2016. Also, that crab fishers land their catches at designated landing sites. These changes could be brought about by actively recognizing and including mud crab fishers in the local BMU management structures, as it is a unique fishery where compliance to regulations will require internal expertise and incentives.

It is evident that management of the mud crab fishery is complex and the relevant policies and regulations (National Ocean and Fishery Policy, 2008; Fisheries Management and Development Act, 2016; BMU Regulations; Forest Conservation and Management Act, 2016) have not been successful in achieving a well-managed fishery (Ludwig *et al.*, 1993). Managers may need to navigate the issues of effective management in the system by developing a strategic management matrix for the fishery, as argued by Perfilova and Alizade (2012). Deliberate effort is needed to harmonize the operations of national and county

governments so that compliance with the relevant legislation can be achieved. Further, there is need for capacity building in the county governments (as crucial partners) since they are required to make county fisheries management plans for inshore fisheries. However, the Fisheries Management and Development Act 2016 gives autonomous power to the Kenya Fisheries Service to approve the management plans developed by counties and guide the monitoring and surveillance of the fishery.

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References

ACDI/VOCA (2005) Sub-sector and value chain analysis for mud crabs Tanga coastal belt, ACDI/VOCA project report. 58 pp

Barnes DKA, Dulvy NK, Priestly SH, Darwall WRT, Choisel V, Whittington M (2002) Fishery characteristics and abundance estimates of the mangrove crab *Scylla serrata* in southern Tanzania and northern Mozambique. South African Journal Marine Science 24: 19-25

Bonine KM, Bjorkstedt EP, Ewel KC, Palik M (2008) Population characteristics of the mangrove crab *Scylla serrata* (Decapoda: Portunidae) in Kosrae, Federated States of Micronesia: Effects of harvest and implications for management. Pacific Science 62: 1-19

Dumas P, Leopold M, Frotte L, Peignon C (2012) Mud crab ecology encourages site-specific approaches to fishery management. Journal of Sea Research 67: 1-9

Government of Kenya (2014). Statistics on Fishery landings along the Kenyan coast 1997-2013. Fisheries Department

Fondo EN, Kimani EN, Odongo DO (2010) Status of mangrove crab fishery in Kenya, East Africa. International Journal of Fisheries and Aquaculture 2(3): 79-86

Fondo EN (2006) Effects of mangrove deforestation on mangrove crab fishery. Final Report WIOMSA MARG 1, 52 pp

Fulanda B, Munga C, Ohtomi J, Osore M, Mugo R, Hossain MY (2009) The structure and evolution of the coastal migrant fishery of Kenya. Ocean & Coastal Management 52: 459-466

Fratini S, Vannini M (2002) Genetic differentiation in the mud crab *Scylla serrata* (Decapoda: Portunidae) within the Indian Ocean. Journal of Experimental Marine Biology and Ecology 272: 103-116

Hill BJ, Williams MJ, Dutton P (1982) Distribution of juvenile, sub-adult and adult *Scylla serrata* (Crustacea, *Portunidae*) on tidal flats in Australia. Marine Biology 69: 117-120

Horrill CJ, Darwall WRT, Ngoile M (1996) Development of a marine protected area: Mafia Island, Tanzania. Ambio 25: 50-57

Jones JPG, Andriamarovololona MM, Hockley N, Gibbons JM, Milner-Gulland EJ (2008) Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. Journal of Applied Ecology 45: 1205-1212

KCDP (2013) Data gap analysis and prioritization of key commercial species for stock assessment: Component 1-Sustainable management of fisheries resources. KCDP report, 79 pp

KCDP (2015) Artisanal fisheries catch assessment database for the year 2013-2015. Component 1 – Sustainable management of fisheries resources

Keenan CP (1999) Aquaculture of the Mud Crab, *Genus Scylla*, Past, Present And Future. In: Keenan CP, Blackshaw A (eds) Mudcrab Aquaculture And Biology. Proceedings of an International Scientific Forum, Darwin, Australia, 21-24 April 1997. Aciar Proceedings No.78, Australian Centre For International Agricultural Research, Canberra, Australia, pp 9-13

Keenan CP, Davie PJF, Mann DL (1998) A revision of the genus *Scylla* De Haan, 1833 (Crustacea: Decapoda: Brachyura: *Portunidae*). Raffles Bulletin of Zoology: 217-245

Laurens JM (2012) Changing behaviour and environment in a community-based program of the Riverside community. Procedia-Social and Behavioural Sciences 36: 372-382

Lebata MJHL, Le Vay L, Primavera JH, Walton ME, Binas JB (2007) Baseline assessment of fisheries for three species of mud crabs (*Scylla spp*.) in the mangroves of Ibajay, Aklan, Phillippines. Bulletin of Marine Science 80: 891-904

Le Vay L (2001) Ecology and management of the mud crab, *Scylla* spp. Asian Fisheries Science 14: 101-111

Le Vay L, Ut VN, Jones DA (2001) Seasonal abundance and recruitment in an estuarine population of mud crabs, *Scylla paramamosain*, in the Mekong Delta, Vietnam. Hydrobiologia: 231-240

Ludwig D, Hilborn R, Walters, C (1993) Uncertainty, resource exploitation and conservation: lessons from history. Science 260: 17-36

Mahika C, Mhitu H, Kuboja B (2005) Rapid assessment of abundance and biomass of the mangrove crab (*Scylla serrata*) and its mariculture development on the Tanga coast. Report prepared for ACDI/VOCA Tanzania's Smallholder Empowerment & Economic Growth through Agribusiness & Association Development (SEEGAAD) Project, Tanga, Tanzania, 44 pp

Mirera DO (2009) Mud crab (*Scylla serrata*) culture: Understanding the technology in a silvofisheries perspective. Western Indian Ocean Journal of Marine Science 8: 127-137

Mirera OD (2011) Trends in exploitation, development and management of artisanal mud crab (*Scylla serrata*-Forsskal-1775) fishery and small-scale culture in Kenya: An overview. Ocean & Coastal Management 54: 844-855

Mirera OD (2012) Population dynamics and small-scale aquaculture of mud crab (*Scylla serrata*) in East Africa. Technical project report submitted to IFS, 25 pp

Mirera OD (2014) Capture-based mud crab (*Scylla serrata*) aquaculture and artisanal fishery in East Africa – Practical and ecological perspective. PhD thesis, Linnaeus University Dissertations No 159/2013. ISBN: 978-91-87427-70-1

Mirera, OD (2017) Intertidal mangrove boundary zones as nursery grounds for the mud crab, *Scylla serrata* (Forsskal-1775). African Journal of Marine Science, 39: 3, 315-325

Mirera OD, Mtile A (2009) A preliminary study on the response of mangrove mud crab (*Scylla serrata*) to different feed types under drive-in cage culture system. Journal of Ecology and Natural Environment 1: 7-14

Mirera DO, Kairo JG, Kimani EN, Waweru FK (2010) A comparison between fish assemblages in mangrove forests and on intertidal flats at Ungwana bay, Kenya. African Journal of Aquatic Science 35: 165-171

Mirera OD, Ochiewo J, Munyi F, Muriuki T (2013). Heredity or traditional knowledge: Fishing tactics and dynamics of artisanal mangrove crab (*Scylla serrata*) fishery. Ocean & Coastal Management. 84: 119-129

Mirera OD, Moksnes P-O (2015) Comparative performance of wild juvenile *Scylla serrata* (Forsskål) in different culture systems: net cages, mangrove pens and earthen ponds. Aquaculture International 23: 155-173

Moksnes P, Mirera OD, Lokina R, Ochiewo J, Mahudi H, Jiddawi N, Hamad M, Troell M (2015) Feasibility of extensive, small-scale mud crab (*Scylla serrata*) farming in East Africa. Western Indian Ocean Journal of Marine Science, 14 (1&2): 23-38.

Moser S, Macintosh D, Laoprasert S, Tongdee N (2005) Population ecology of the mud crab *Scylla olivacea*: a study in the Ranong mangrove ecosystem, Thailand, with emphasis on juvenile recruitment and mortality. Fisheries Research 71(1): 27-41

Muthiga NA (1986) Edible crabs of Kenya. Kenya Aquatica Bulletin 3: 61-65

Mwaluma J (2002) Pen culture of the mud crab *Scylla serrata* in Mtwapa mangrove system, Kenya. Western Indian Ocean Journal of Marine Science 1: 127-133

Mwaluma J (2003) Culture experiment on the growth and production of mud crabs, mullets, milkfish and prawns in Mtwapa mangrove system, Kenya. Final Report for WIOMSA MARG 1, 27 pp

Nagelkerken I, Blaber SJM, Bouillon S, Green P, Haywood M, Kirton LG, Meynecke JO, Pawlik J, Penrose HM, Sasekumar A, Somerfield PJ (2008) The habitat function of mangroves for terrestrial and marine fauna: a review. Aquatic Botany 89: 155-185

Nandi NC, Dev-Roy MK (1991) Burrowing activity and distribution of *Scylla serrata* (Forskal) from Hooghly and Matla estuaries, Sundarban, West Bengal. Journal of Natural History and Society 88: 167-171

Nirmale VH, Gangan SS, Yadav BM, Durgale P, Shinde KM (2012) Traditional knowledge on mud crab; ethnoecology of *Scylla serrata* in Ratnagiri coast, Maharashtra. Indian Journal of Traditional Knowledge 11: 317-322

Ochiewo J (2006) Harvesting and sustainability of marine fisheries in Malindi-Ungwana bay, Northen Kenya Coast. Final Report WIOMSA MARG 1, 44 pp

Ochiewo J, De La Torre-Castro M, Muthama C, Munyi F, Nthuta JM (2010) Socio-economic features of sea cucumber fisheries in southern coast of Kenya. Ocean & Coastal Management 53: 192-202

Ong KS (1964) Early development stages of *Scylla serrata* Forsskal (Crustacea *Portunidae*), reared in the laboratory. Proceedings of the Indo-Pacific Fisheries Council 6 (2): 135-146

Onyango SD (2002) The breeding cycle of *Scylla serrata* (Forsskal 1755) at Ramisi river estuary, Kenya. Wetlands Ecology and Management 10: 257-263

Overton JL, Macintosh DJ, Thorpe RS (1997) Multivariate analysis of the mud crab *Scylla serrata* (Brachyura:

Portunidae) from four locations in Southeast Asia. Marine Biology 128: 55-62

Perfilova O, Alizade Y (2012) Educational innovation for ecological assessment of the effectiveness of wildlife management. Procedia-social and Behavioural Sciences 46: 1284-1289

Perrine D (1978) The mangrove crab (*Scylla serrata*) on Ponape. Marine resources Division, Ponape, East Caroline Islands, Trust Territory of the Pacific Islands, 88 pp

Richmond MD, Mohamed A, De Villiers AK, Esseen M, Levay L (2006) Smallholder Fisheries Enterprises Trials, Rufiji District, Tanzania. Final Report. Rufiji Environment Management Project (REMP), IUCN Eastern Africa Regional Office, Nairobi, Kenya, 114 pp

Serene R (1952) Les especes du genere Scylla a Nhatrang (Vietnam). Proceedings of the Indo-Pacific Fisheries Council 3: 133-137

Steel BS, Lovrich N, Lach D, Fomenko V (2005) Correlates and consequences of public knowledge concerning ocean fisheries management. Coastal Management 33: 37-51

Walton ME, Le Vay L, Truong LM, Ut VN (2006) Significance of mangrove-mudflat boundaries as nursery grounds for the mud crab, *Scylla paramamosain*. Marine Biology 149: 1199-1207