Managing coastal pelagic fisheries: A case study on the small-scale purse seine fishery in Kenya

Gladys M. Okemwa[a]*, George W. Maina[b], Cosmas N. Munga[c], Elizabeth Mueni[d], Mwaka S. Barabara[d], Stephen Ndegwa[d], Pascal Thoya[a] and Nicholas Ntheketha[d]

[a]Kenya Marine and Fisheries Research Institute, P.O. Box 81651-80100 Mombasa, Kenya;

[b]The Nature Conservancy, Africa Regional Office. P.O. Box 19738-00100 Nairobi, Kenya;

[c]Technical University of Mombasa, Department of Environment and Health Sciences, Marine Sciences Section, P.O. Box 90420 - 80100 G.P.O. Mombasa, Kenya;

[d]State Department for Fisheries and The Blue Economy, P.O. Box 90423-80100 Mombasa, Kenya;

*Corresponding author: gokemwa@kmfri.co.ke (G.M.O);

Other authors: gwmaina@tnc.org (G.W.M), cosmasnke2001@yahoo.com (C.N.M), emuenibf@yahoo.com (E.M), barabaraside@yahoo.co.uk (M.B), ndegwafish@gmail.com (S.N), pthoya@kmfri.co.ke (P.T), mwanzanick@yahoo.com (N.N).

Abstract

Balancing sustainability and conservation concerns with the socioeconomic needs of small-scale fishers is a dilemma that is commonly faced by fisheries managers. In this paper, we present a case study on managing the developing small-scale purse seine (or ring net) fishery introduced to Kenya by migrant fishers. The fishery, which primarily targets coastal pelagics in offshore waters, was deduced to have the potential of reducing fishing effort on nearshore demersal reef fish stocks while enhancing fisheries production and fisher livelihoods. The expanding fishery elicited much controversy resulting in resource use conflicts related to gear competition and concerns about the environmental impacts of the gear. We detail the consultative planning process that was undertaken to develop a gear-based management plan spanning over 10 years from 2004 to 2016. We briefly document the catch dynamics and evolution of the fishery, and further detail the challenges and key outcomes of the decision-making process. Regulatory measures agreed by stakeholders include restrictions on gear dimensions as well as spatial restrictions defining the distance and depth of operation. Effective implementation and enforcement of the measures will require collective action from all stakeholders. Future considerations should focus on harmonization of proposed measures in transboundary areas.

Key words: Ring net, small and medium pelagics, management plan, migrant fishers, Western Indian Ocean

1. Introduction

Small-scale fisheries play an important role in food security and income for coastal communities worldwide, particularly in developing countries (Berkes et al., 2001; Béné et al., 2010; Isaacs, 2016). The fisheries are characterized by low capital investment, use of simple fishing gears, small dominantly un-motorized vessels and tend to concentrate in shallow nearshore areas (FAO, 2016). Globally, small-scale fisheries are exhibiting excess fishing effort, overfishing, and habitat degradation driven by high population growth rates and poverty levels (Worm et al., 2009; Fenner, 2012; Batista et al., 2014). Consequently, resource use conflicts regarding access to fishing grounds, competition over declining fisheries resources and markets abound (Bennett et al., 2001; Pomeroy, 2007; Murshed-e-Jahan et al., 2014).

Balancing sustainability and conservation concerns with the socioeconomic needs of fishers is a dilemma that is commonly faced by fisheries managers (Salas et al., 2007; McClanahan et al., 2008; Mumby and Steneck, 2008; Cinner, 2009). Assessment and management of small-scale tropical coastal fisheries is inherently complex (Pauly, 1989; Andrew et al., 2007; Batista et al., 2014), since they are open access, multi-species, multi-fleet and multi-gear in nature (Berkes et al., 2001; Van der Elst et al., 2005; McClanahan et al., 2008; Salas et al., 2008; Worm et al., 2009). Consequently, adoption of conventional management approaches based on quantitative stock assessments is often not practical, while gear-based and area-based approaches are viewed as suitable (Cinner et al., 2009). Effective management and governance of small-scale fisheries is further constrained by inadequate scientific data (Mora et al., 2009; Dowling et al., 2016), weak monitoring and enforcement capacity (Nielsen et al., 2004; Gutierrez et al., 2011), lack of political good will (Ludwig et al., 1993; Pauly et al., 2002; Carbonetti et al., 2014), limited alternative livelihood sources (Davies et al., 2009; Daw et al., 2012), and external factors such as climate change (Brander et al., 2010; Graham et al., 2011).

The complexities discussed above are well documented in Kenya (Glaesel, 2000; Kaunda-Arara and Rose, 2004; Mangi and Roberts, 2007; McClanahan et al., 2008, Cinner, 2009; Evans, 2009; Cinner et al., 2012a; Samoilys et al., 2017). The number of small-scale fishers involved has increased from about 9,000 in 2004 to over 13,400 in 2016 (Government of Kenya, 2016a). The fishers land approximately 90% of the estimated 9,000 MT that is produced annually (ASCLME, 2012; Le Manach et al., 2015). Pelagic fish production ranges between 977 MT to 2,096 MT annually, accounting for 27% of the total catches (Maina and Osuka, 2014). In comparison, the annual global pelagic fish production is estimated at 7.7 million tonnes (FAO, 2016). Small and medium pelagic species range in size from 10-20 cm and 20-60 cm in total length respectively (Fréon et al., 2005), and contribute over 50% of the global marine catches (FAO, 2016).

Kenya's National Oceans and Fisheries Policy emphasizes the distribution of fishing effort to the offshore resources and targeting of new and under exploited stocks to realize economic viability and resource sustainability (Government of Kenya, 2008). Thus, the emerging small-scale purse seine fishery which targets pelagic fish resources in offshore areas was endorsed as a strategy that would help alleviate fishing pressure on demersal reef fish stocks while enhancing fisher livelihoods by increasing fishery production. As the use of small-scale purse seines became widespread, resource use conflicts emerged due to heightened concerns about resource competition, overexploitation and the environmental impacts of the gear (Ochiewo, 2004). To mitigate the conflicts, a consultative decision-making process was initiated by the State Department of Fisheries to develop a gear-based management plan for the small-scale purse seine fishery. In this study, we briefly describe the evolution and characteristics of the developing fishery. We further detail the consultative process as well as the challenges experienced and lessons learned from decision-making process. Finally, we discuss future considerations to ensure effective implementation of the Plan.

2. Methodological approach

2.1. Study area

The Kenya coastline (Fig. 1) measures approximately 640 km long and is fringed with coral reefs, mangroves, sea grass beds and intertidal mudflats which support a high diversity of fish and other biota. The continental shelf ranges between 5 and 10 km wide with depths reaching up to 200 m (UNEP, 1998). The climate is tropical with a long rainy season experienced between March and May, and a short rainy season between November and December. Seasonality in oceanographic conditions along the coast is driven by alternating southeast and north easterly winds which influence the sea conditions as well as fishing activities (McClanahan, 1988; Obura, 2001). Relatively calm and warm waters are experienced during the northeast monsoon (NEM) season from November to March, and this coincides with high fishing activity due to more accessible sea. The strong currents, rough and cool sea conditions during the southeast monsoon (SEM) restrict most small-scale fishing operations to shallow nearshore fishing grounds (Maina et al., 2008). The seasons and weather also affect fish migration patterns, changing the behaviour of fishers with respect to target species and fishing methods (Mangi et al., 2007). Sea surface temperature is generally higher during the NEM season, fluctuating between 27 to 28°C and lower temperatures ranging between 24.5 and 25.8°C are recorded during the southeast monsoon (SEM) season, (UNEP, 1988; Obura, 2001).

The small-scale purse seine fishery is currently open access and there are no specific controls or regulations on the use of the gear in Kenya. The Fisheries Management and Development Act (2016) provides an overarching framework for the development of fisheries management plans; which allows for subsidiary legislations arising from such plans to be developed and gazetted. There has been a steady evolution in decision -making from a 'top down' centralized approach towards a participatory and adaptive co-management approach through establishment of Beach Management Units with specific area-based mandates (Government of Kenya, 2007; Cinner et al., 2012b). Additionally, marine protected areas (MPAs) play an essential role in sustaining and replenishing reef fish populations (McClanahan and Mangi, 2000; Kaunda-Arara and Rose, 2004), and provide an avenue for ecosystem-based management as stipulated by the Wildlife Conservation and Management Act (Government of Kenya, 2013).

2.2. Characterization of the small-scale purse seine fishery

Data collection: Existing literature was collated and reviewed to gather information on the evolution of the fishery, augmented with information obtained through a series of stakeholder consultations. Data for characterizing the fishery was based on biennial frame surveys (2004-2016) conducted by Kenya's State Department for Fisheries (Government of Kenya, 2016a), as well as catch assessment surveys conducted in Shimoni, Gazi, Vanga, and Kipini from 2008 to 2014 (see Fig. 1 for locations). The catch parameters recorded for each vessel sampled (representing one fishing trip) included fishing gear used, fishing grounds, number of crew onboard, and total weight of the catch. The entire landed catch was sampled for species composition and sizes for most gears. However, a sample of approximately 10-20 % of the total catch in weight (see Stotbutzki et al., 2001) was scooped using a 20 litre plastic bucket to sample the species composition of exceptionally large catches. The fish were then sorted to species level using identification guides (Smith and Heemstra, 1986; Lieske and Myers, 2001), counted and fork or total length (cm) measured.

Data Analysis: The nominal catch per unit effort (CPUE) was estimated as kg/vessel/day and kg/fisher/day. The annual value of the small-scale purse seine fishery landings and the number of household members directly supported by the fishery was estimated using the average CPUE assuming a boat activity coefficient (BAC) of 20 days per month (a probability that fishers will be actively fishing for at least 20 days in a month) for the total number of vessels reported during frame survey estimates.

Three measures of diversity: species richness expressed as the total number of species, Shannon-Wiener diversity index (*H'*) (Shannon, 1963) and *k*-dominance curves (Lampshead et al., 1983) were used to describe the species composition of the fish catches. The use of multiple measures of diversity is generally preferred to evaluate gear selectivity and competition (e.g. Stergiou et al., 1996; and to understand ecosystem impacts (e.g. Greenstreet and Rogers, 2006; Pillans et al., 2007; Zhang et al., 2009). Plotting of *k*-dominance curves was based on the percentage cumulative abundance against log species rank to graphically compare the species selectivity of the small-scale purse seines against other fishing gears.

2.3 Stakeholder consultations towards development of management objectives and measures

Stakeholder perceptions were documented throughout the consultative process through focus group and plenary discussions in various meetings to elicit views and perceptions on issues related to the fishery into two thematic groups: ecological/biological impacts and socio-economic impacts. Nine major consultative meetings with stakeholders including scientists, policy makers, fishery resource managers, fish traders, small-scale fishers, sport fishers, conservation groups, and representatives of the tourism industry were held between 2005 and 2016, with participation ranging between 20 and 100 people. In addition, fifteen technical working group meetings including four high-level policy meetings were held during the same period. The emerging issues were further prioritized and mitigation measures formulated consultatively.

3. Characteristics of the small-scale purse seine fishery in Kenya

3.1. Gear operation

The small-scale purse seine gear, commonly referred to as a ring net in East Africa, consists of a surrounding net made of nylon twine of varied lengths, widths and mesh sizes (FAO, 2001; Samoilys et al., 2011). A float or surface rope is attached to the net with a series of floats to provide buoyancy, and a shorter lead rope weighted with brass or lead rings spaced every 3 to 4 m along a foot rope or purse line is attached to the lower edge of the net (Fig. 2). The net also has a central bag or punt (with a smaller mesh) in which the fish concentrate during “pursing” or hauling as the two wings are hauled together. The net dimensions vary with lengths ranging between 90-300 m, widths ranging from 15-30 m and mesh sizes ranging from 0.25-11 inches.

During fishing operations, a single motorized vessel ranging between 8 and 15 m in length is used, powered by a 40 to 60 hp outboard engine. A crew of 9 to 45 fishers are involved in the fishing operations depending on the size of the vessel and net. The crew divide into smaller teams with assigned roles that include visual searching of fish schools, net deployment and hauling. The searching team uses various indicators to locate fish aggregations such as flocking seabirds, fish activity within the surface waters through snorkeling or SCUBA diving. The fishing depths are reported to range from 9.9 ± 1.6 m to 54.4 ± 2.7 m and operating between 2.6 and 10.5 nautical miles offshore (Munga et al., 2010). The deployment team quickly lowers the net, at times tying gunny bags with 2 to 3 kg of beach sand to the foot rope to increase sinking speed. The searching team slowly encircles the net around the school of fish after which the purse-line is slowly hauled until the bottom of the net closes. When the last 10 to 15 m of net is remaining in the water, the net is pulled on board thereby concentrating the fish in the smaller-sized meshed bag. The fish are then hauled from the pursed sections of the net into the boat.

3.2. Evolution of the fishery

The fishery evolved as an adaptation of beach seines and was introduced to migrant fishers in Tanzania in 1975 by Greek fishers (Brownell, 1982). The migrant fishers introduced the gear to south coast of Kenya at Vanga in the early 1990s, and later spread to Gazi and Msambweni at the south coast of Kenya; and further north towards Mtwapa, Kilifi, Watamu, Malindi and Kipini (Fig. 1). The fishery is generally characterized by seasonal migrations of fishing units between local fishing grounds in response to various factors including the migration patterns of target species and seasonal conditions which may affect the accessibility of some fishing grounds (Fulanda et al., 2009; Crona et al., 2010; Wanyonyi et al., 2015, 2016). During the SEM season, the fishers prefer to fish within sheltered and relatively accessible fishing grounds and migrate to other fishing grounds when weather conditions improve during the NEM season. For example, fishers from Vanga migrate to Gazi and Kipini, while fishers from Malindi migrate to Kilifi (pers. obs. authors). Fishing grounds in Vanga are however relatively sheltered and tend to be fished throughout the year.

3.3. Catch and effort dynamics

The small-scale purse seine gear yields higher catch rates compared to other gears and also requires the highest fishing effort in terms of number of fishers involved per vessel (Table 1). Among the study sites, catch rates range from 9.4 kg/fisher/day in Gazi (Maina et al., 2008), 15.1 kg/fisher/day in Shimoni-Vanga and 15.4 kg/fisher/day in Kipini (Munga et al., 2010). At Vanga, small-scale purse seine account for 75% of the total landings sampled by weight compared to 4% in Shimoni and 41% in Gazi (Fig. 4). The results indicate that the gear is highly efficient and is likely to compete with other gears that target the same resource if used within the same fishing grounds. The fishing effort in terms of number of fishers increased from 15 in 2004 to 861 in 2016 (Government of Kenya, 2016a). Likewise, the number of gears also increased from 1 in 2004 to 40 in 2016, with 71% of the total number operating in Kwale

County (Fig. 3). The total annual production of the small-scale purse seine fishery, during the main fishing season (November-March), is conservatively estimated at ~1,082 MT valued at USD ~1.1 Million (USD$ = KES 100). This implies a contribution of approximately 12% of the total marine fisheries catches in Kenya, which is produced by 7-10% of the total number of fishers. Assuming an average fisher household dependency of 7.7 (Degen et al., 2010), small-scale purse seine fishers support ~7,400 household members.

Table 1. Summary of nominal catch rates and effort dynamics of major fishing gears targeting small and medium pelagics at the south coast of Kenya

Gear	Kg / Vessel / Day		Kg / Fisher / Day		No. Crew / Vessel	
	Mean	Std Err	Mean	Std Err	Mean	Range
Small-scale purse seines	**349.13**	**37.1**	**15.1**	**2.30**	**31**	**9-45**
Large mesh gillnets	33.71	11.91	8.25	0.86	4	2-6
Reef seines	45 .65	19.24	4.16	0.26	8	2-16
Small mesh gillnets	16.49	2.52	7.23	0.28	3	1-8
Beach seines	14.0	3.24	2.77	0.07	6	4-13
Handlines	8.18	0.84	4.53	0.12	2	1-5

3.4. Species composition of small-scale purse seine catches

Small and medium pelagic species constitute an average of 73% of the small-scale purse seine catches. The dominant pelagic species captured include Carangidae (8 species: *Caranx ignobilis*, *Carangoides ferdau*, *Carangoides gymnosthetus, Carangoides bajad*, *Caranx sexfasciatus*, *Seriola lalandi, Gnathanodon speciosus, Elagatis bipinnulatus*), Sphyraenidae (3 species: *Sphyraena jello*, *Sphyraena forsteri, Sphyraena obtusata*), Scombridae (6 species: *Euthynnus affinis, Thunnus albacores*, *Katsuwonis pelamis*, *Auxis thazard, Scomberomorous commersoni*, *Scomber japonicas*), mackerels: *Rastrelliger kanagurta*, Hemiramphidae sp and Belonidae sp (Fig 5). The species composition of the landed catches varies between fishing grounds. For example, the landed catches in Shimoni-Vanga and Kipini are dominated by Carangidae, Scombridae and Sphyraenidae albeit in different proportions, while landed catches in Gazi are dominated by Scombridae. However, demersal reef species constitute between 16% and 38% of the total catches in biomass at the sites, and include Lutjanidae, Siganidae, Lethrinidae, Acanthuridae, Haemulidae, Drepanidae, Mullidae, Gerridae and Mugilidae. Night time fishing for sardines (Clupeidae) and silversides (Atherinidae) using lamps also occurs.

On average the total number of species captured daily per vessel was similar to handlines but was among the lowest overall based on pooled data (Table 2). The *k*-dominance curves of species captured revealed that small-scale purse seines have a higher dominance with relatively fewer species when compared to most of the other gears (Fig. 6; Table 2). This is likely due to the schooling nature of the target species. However, there are seasonal variations in the diversity and species richness of the catches, with a higher diversity of fish species being captured during SEM season (Table 2). The gear exhibits higher species diversity during the SEM season, in contrast to other gears which catch a higher diversity of species during the NEM season. From a management perspective, the higher species diversity during the SEM season may reflect the tendency for small-scale purse seine fishers to shift closure to shallower less turbid areas inshore, where they capture reef associated species when the catchability of their target species is reduced due to rough sea conditions. This may also occur when fishers modify other gears used in shallow areas, such as reef seines or beach seines, to operate like small-scale purse seines. The modified nets are often confused with the small-scale purse seines, and this has been a conflict issue when they fish within the shallow coral reef areas and encroach into marine reserves.

Table 2. The diversity small-scale purse seine landings in comparison to other small-scale fishing gears used in south coast of Kenya.

Gear	No. Families/ Vessel / Day		No. Species/ Vessel / Day		Total No. Species		Shannon Wiener Diversity (*H'*)		
	Mean	Max	Mean	Max	NEM	SEM	NEM	SEM	Mean (SD)
Small-scale purse seines	**3**	**7**	**3**	**10**	**12**	**20**	**1.5**	**2.6**	**2.0 (0.78)**
Basket traps	3	8	4	13	71	40	2.8	2.7	2.8 (0.1)
Beach seines	5	8	7	11	15	27	2.1	2.2	2.2 (0.03)
Large mesh gillnets	3	5	2	5	11	8	1.7	1.4	1.6 (0.21)
Spearguns	5	8	6	14	67	41	3.2	2.7	2.9 (0.35)
Small mesh gillnets	3	12	4	17	37	27	2.9	2.3	2.6 (0.44)
Handlines	2	7	3	14	75	58	3.3	3.0	3.1 (0.21)

4. Stakeholder consultations, management objectives and measures

Stakeholder participation has been emphasized as an important component of the decision making process (Jentoft and McCay, 1995; Gleason et al., 2010, 2013; Fox et al., 2013; Sayce et al., 2013). The stakeholder consultative process to develop a management plan for the small-scale purse seine fishery in Kenya was undertaken over 10 years (Fig. 7). A temporary suspension of the fishery was instituted in 2004 by the Minister of Fisheries, and a Taskforce was convened to conduct a rapid assessment of the fishery and provide recommendations on the way forward. Representation in the Taskforce included resource managers, scientists, the fishing industry (both commercial and recreational), and advocacy groups. Guided by recommendations from the Taskforce, a smaller Technical Working Group was constituted in 2010 to spearhead drafting the management plan and stakeholder consultations. Following a process of stakeholder consultations and deliberations that took about 8 months, the Taskforce recommended development of a management plan for the gear.

Perspectives on use of the gear were mixed among different stakeholder groups (Table 3). Those supporting the gear argued that it has a high potential for increasing fish production, thereby increasing food security and enhancing the livelihoods of local fisher communities. On the other hand, those against the gear argued that many of the perceived benefits from the fishery were relatively short-term and would potentially result in longer-term negative effects such as overfishing if not well managed. Interestingly, the gear was more tolerated in the southcoast, particularly in Vanga, Shimoni, and Gazi and less tolerated in the northcoast areas of Kilifi, Watamu, and Malindi where resource use conflicts were more intense. In 2002, incidents of resource use conflicts were observed at the northcoast of Kenya in Kilifi and Malindi (see Fig. 1) which further intensified during 2004/2005. Fishers from those areas complained that the high volumes of fish landed by small-scale purse seine fishers would lead to overfishing, and was resulting in unfair market competition due to flooding of local markets and plunging of fish prices. Concerns of overfishing by small-scale purse seines have been documented elsewhere e.g. Sri Lanka (Maldeniya and Dayaratne, 1991), and Philippines (Green et al., 2004). No comprehensive assessment of the fishery has been undertaken in Kenya or the WIO region to provide such evidence; however, there is ongoing work to establish population and exploitation parameters of some key target species (Munga et al. 2015). Other stakeholders were also concerned about the deployment of the gears within shallow areas close to reefs or in proximity to marine reserves leading to breakage of coral and capture of juveniles and non-target species, many of which would be discarded. The use of sandbags as sinkers was also suspected to be having detrimental effects on the benthic environment.

Table 3. Stakeholder concerns on the small-scale purse seine (ring net) fishery in Kenya.

Stakeholder Group	Concerns
Other small-scale fishers	• Sharing of fishing grounds, resulting in competition for space and gear

	• Oversupply of fish in the market and unfair market competition • Targeting of reef associated species and spawning aggregations
Recreational sport fishers	• Overexploitation of target pelagic fish species competing with recreational fishery • Sharing of fishing grounds
Tourism sector	• Fishing marine reserves and recreational areas
Environmental advocacy groups	• Destruction of fish habitats through snaring of nets on corals • Fishing in marine reserves and nearshore areas • Targeting of reef associated species and spawning aggregations

In developing the management objectives and measures for the Plan, it was appreciated that scientific data on the fishery and biological status of the target stocks was limited. Guided by the FAO Code of Conduct for Responsible Fisheries (FAO, 1995), the precautionary approach was adopted due to limited availability of scientific information. This was augmented by integrating an adaptive management approach in respect to future improvements in scientific data and information on the fishery. The hierarchy of the Plan showing management objectives and the proposed actions jointly agreed by stakeholders is presented in Fig. 8. The overall objective of the Plan is to enhance responsible exploitation of coastal pelagic fish stock by regulating sustainable fishing practices that minimize resource use conflicts while providing long-term biological and socio-economic benefits including food security, employment creation, and national revenues. The regulatory measures include restrictions on gear dimensions (depth and width) and spatial controls. The spatial controls will help to control fishing effort by limiting the fishing depth to a minimum 30 metres within designated zones and a specified distance from coral reef areas to ensure the fishery is operated well beyond the coral reef slope and therefore not targeting reef fish species or operating with known areas of spawning aggregations e.g. in Msambweni at the southcoast (Maina et al., 2013, see Fig. 1). Species that periodically aggregate to spawn are likely to be targeted by the fishery, which can lead to overexploitation (Sadovy de Mitcheson, 2008). To support enforcement of spatial controls, mandatory use vessel tracking devices during fishing is stipulated. Research to track and map out the small-scale purse seine fishing activities is also being undertaken to inform this measure. Setting of output based catch controls such as a Total Allowable Catch (TAC) for key target species was not done due to uncertainties in stock assessment (Munga et al., 2015). Although the Plan provides for setting such controls, such measures are technically difficult to enforce.

There were mixed views on the proposed measures. Fishers engaged in the fishery were concerned that the zoning measures would limit access to certain fishing grounds, while other small-scale fishers generally had a positive reaction and acknowledged that the measures would help in reducing resource use conflicts by limiting encroachment to shallow reef areas and the capture of reef fish. There was also a general concern from the technical experts that were consulted that Plan would require considerable investment in monitoring and enforcement for compliance, which may be challenging given the limited resources. Towards this, the Plan defines institutional arrangements for implementation with clear roles, and proposes the establishment of a committee to steer the implementation process. However, effective implementation will be under-pinned on the collective action and commitment from all stakeholders towards contributing to the technical, financial and human resources needed. Collaboration and strong partnerships among all stakeholders will be crucial in ensuring compliance to meet the monitoring, control and surveillance (MCS) capacity needs. However, there will be need to strengthen local level governance by building capacity to enhance compliance and self-policing among the beach management units (BMUs).

Towards gazettement, the Plan has been subjected to various stages of vetting and approval by the County and National levels of governments in 2014, and efforts are underway to develop the subsidiary legislations in line with the new Fisheries Management and Development Act (Government of Kenya, 2016b).

5. Key lessons learned

Decision making for data-poor small-scale fisheries is generally challenging due to inadequate information and technical capacity to formulate effective harvest strategies (Dowling et al., 2014). In this case, adoption of a precautionary approach which takes into consideration a multiplicity of social, cultural, economic and political management objectives may be the only realistic option (McConney and Charles, 2008; Smith et al., 2009). This case study demonstrates the strides made in Kenya, towards a more holistic and participatory approach in the management of an emerging small-scale purse seine fishery. The results of this study provided a baseline for decision-making, and highlighted areas of uncertainty for precautionary management. The following experiences and lessons can serve an example to other countries tackling similar management issues:

- Emerging fisheries have a multitude of uncertainties due to inadequate data, therefore precautionary and adaptive measures should be undertaken early during the developmental stages;
- The management planning process can be constrained by bureaucracy and uncertainties about funding which can pro-long the duration. Consequently, the high expectations for immediate action from stakeholders can be diminished leading to mistrust and suspicion. For example, government officials were at times suspected to be lax and accused of having direct economic interest on the fishery (Standing, 2008). Thus, goodwill from all concerned parties is essential. This should be augmented by a committed technical team of individuals who are willing to put in the time and hard work to maintain momentum, despite any drawbacks.

- Due to competing interests, stakeholders will have divergent opinions some of which can derail the planning process. Maintaining transparency in the decision-making process is critical and requires continuous communication and engagement with the industry and other stakeholders.
- Building the information base to support decision making in the management of an emerging fishery is crucial. Therefore, an effective data collection and monitoring system should be established early. Dowling et al., (2014) note that appropriate management indicators and precautionary trigger levels should be identified during the early developmental phases of a fishery. This assessment contributes some and essential fishery indicators on the CPUE and species composition which will be useful for monitoring the performance of the fishery. Size-based indicators such as the mean length and maturity size of key target species are also important for the future monitoring of the fishery.

6. Future considerations

Future considerations should focus on building capacity for fisheries practitioners on the application of decision support tools (e.g. Dowling et al., 2016). This will be useful in developing cost effective management actions. In the long term, regular feed-back and consultations with fisheries managers, scientists, fisher communities and other stakeholders as more knowledge on the fishery is attained will support the revision of the management controls. Effort should also be put towards the harmonization of measures in transboundary areas due to the migratory nature of small-scale purse seine fishers within the Western Indian Ocean region.

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References

ASCLME, 2012. National Marine Ecosystem Diagnostic Analysis. Kenya. Contribution to the Agulhas and Somali Current Large Marine. Ecosystems Project. 64 pp.

Andrew, N.L., Béné, C., Hall, S.J., Allison, E.H., Heck, S., Ratner, B.D., 2007. Diagnosis and management of small-scale fisheries in developing countries. Fish Fish. 8, 227-240.

Batista, V.S., Fabré, N.N., Malhado, A.C.M., Ladle, R.J., 2014. Tropical Artisanal Coastal Fisheries: Challenges and Future Directions. Reviews in Fisheries Science & Aquaculture, 22, 1-15.

Béné, C., Hersoug, B., Allison, E.H., 2010. Not by Rent Alone: Analysing the Pro-Poor Functions of Small-Scale Fisheries in Developing Countries Development Policy Review, 28, 325-358.

Bennett, E., Neiland, A. Anang, E., Bannerman, P., Rahman, A.A., Huq, S., Bhuiya, S., Day, M., FulfordGardiner, M., Clerveaux, W., 2001. Towards a better understanding of conflict management in tropical fisheries: Evidence from Ghana, Bangladesh and the Caribbean. Mar. Policy, 25, 365-376.

Berkes, F., Mahon, R., McConney, P., Pollnac, R., Pomeroy, R.S., 2001. Managing small-scale fisheries: Alternative directions and methods. IDRC, Canada, 320 pp.

Brander , K., 2010. Impacts of climate change on fisheries. J. Marine Syst. 79, 389-402.

Brownell, W.N., 1982. Tanzania baseline study. SWIOP/WP/3 Document, RAF/79/065/WP/03/82. http://www.fao.org/docrep/field/255085.htm#Contents

Carbonetti, B., Pomeroy, R., Richards, D.L., 2014. Overcoming the lack of political will in small-scale fisheries. Mar. Policy, 44, 295-301.

Cinner, J., 2009. Poverty and the use of destructive fishing gear near east African marine protected areas. Environ. Conserv. 4, 321-326.

Cinner, J.E., McClanahan, T.R., Graham, N.A.J., Pratchett, M.S., Wilson, S., 2009. Gear-based fisheries management as a potential adaptive response to coral bleaching. J. Appl. Ecol. 46, 724-732.

Cinner, J.E., McClanahan, T.R., Graham, N.A.J., Daw, T.M., Maina, J., Stead, S.M., Wamukota, A., Brown, K., Bodin, Ö., 2012a. Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Global Environ. Change, 22, 12-20.

Cinner, J.E., Daw, T.M., McClanahan, T.R., Muthiga, N., Abunge, C., Hamed, S; Mwaka. B., Rabearisoa, A. Wamukota, A., Fisher, E., Jiddawi, N., 2012b. Transitions toward co-management: The process of marine resource management devolution in three east African countries. Global Environ. Change, 22, 651-658.

Crona, B., Wanyonyi, I., Ochiewo, J., Ndegwa, S., Rosendo, S., 2010. Fishers' migration along the Kenyan coast Implications for management of coastal fisheries. Policy brief, Western Indian Ocean Marine Science Association (WIOMSA), Zanzibar (Tanzania). 10 pp.

Davies, T.E., Beanjara, N.,Tregenza, T., 2009. A socio-economic perspective on gear based management in an artisanal fishery in south west Madagascar. Fish. Manag. Ecol., 16, 279-289.

Daw, T.M., Cinner, J.E., McClanahan, T.R., Brown, K., Stead, S.M., 2012. To fish or not to fish: Factors at multiple scales affecting artisanal fishers' readiness to exit a declining fishery. PLoS ONE 7(2): e31460.

Degen, A.A., Hoorweg, J.,Wangila, B.C.C. 2010. Fish traders in artisanal fisheries on the Kenyan coast. Journal of Enterprising Communities: People and Places in the Global Economy 4, 296-311.

Dowling, N.A., Dichmont, C.M., Haddon, M., Smith, D.C., Smith, A.D.M., Sainsbury, K. 2014. Guidelines for developing formal harvest strategies for data-poor species and fisheries. Fish. Res. 171,130-140.

Dowling, N.A., J.R. Wilson, M. Rudd, E.A. Babcock, M. Caillaux, J. Cope, D. Dougherty, R. Fujita, T. Gedamke, M. Gleason, N. Gutierrez, A. Hordyk, G.W. Maina, P.J. Mous, D. Ovando, A.M. Parma, J. Prince, C. Revenga, J. Rude, C. Szuwalski, S. Valencia, and S. Victor. 2016. FishPath: A Decision Support System for Assessing and Managing Data- and Capacity-Limited Fisheries, in: Quinn II, T.J. Armstrong, J.L. Baker, M.R. Heifetz, J., Witherell D. (Eds.), Assessing and Managing Data-Limited Fish Stocks. Alaska Sea Grant, University of Alaska Fairbanks. http://doi.org/10.4027/amdlfs.2016.03

Evans, L.S., 2009. Understanding divergent perspectives in marine governance in Kenya. Mar. Policy 33,784-793.

FAO, 1995. FAO Code of Conduct for Responsible Fisheries Rome, FAO. 1995. 41 p.

FAO, 2001. Fishing Gear types. Ring nets. Technology Fact Sheets, in: *FAO Fisheries and Aquaculture Department* [online]. Rome. Updated 13 September 2001. http://www.fao.org/fishery/geartype/250/en (Accessed 10. 06. 17)

FAO, 2016. The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome. 200 pp.

Fenner, D., 2012. Challenges for managing fisheries on diverse coral reefs. Diversity 4: 105-160.

Fox, E., Poncelet, E, Connor, D., Vasques, J., Ugoretz, J., McCreary, S., Monié, D., Harty, M., Gleason, M., 2013. Adapting stakeholder processes to region-specific challenges in marine protected area network planning. Ocean and Coast. Manag. 74, 24-33.

Fréon, P., Cury, P., Shannon, L., Roy, C., 2005. Sustainable exploitation of small pelagic fish stocks challenged by environmental and ecosystem changes: A Review. Bull. Mar. Sci. 76, 385-462.

Fry, D.H., 1930. Fish Bulletin No. 27. The Ring Net, Half Ring Net, or Purse Lampara in the Fisheries of California. 66 pp.

Fulanda, B., Munga, C., Ohtomi, J., Osore, M., Mugo, R., Hossain, M.M.Y., 2009. The structure and evolution of the coastal migrant fishery of Kenya. Ocean and Coast. Manag. 52, 459-466.

Glaesel, H., 2000. State and local resistance to the expansion of two environmentally harmful marine fishing techniques in Kenya. Soc Nat Resour 13, 321-338.

Gleason, M., McCreary, S., Miller-Henson, M., Ugoretz, J., Fox, E., Merrifield, M., McClintock W., Serpa, P., Hoffman, K. 2010. Science-based and stakeholder-driven marine protected area network planning: A successful case study from north central California. Ocean and Coast. Manag. 53, 52-68.

Gleason, M., Fox, E., Ashcraft, S.,Vasques, J., Whitemane, E., Serpa, P. Saarman, E., Caldwell, M., Frimodig, A., Miller-Henson, M., Kirlin, J., Ota, B., Pope, E., Weber, M., Wiseman, K., 2013. Designing a network of marine protected areas in California:

Achievements, costs, lessons learned, and challenges ahead. Ocean and Coast. Manag. 74, 90-101.

Government of Kenya, 2007. Fisheries (Beach Management Units) Regulations, 2007 (Legal Notice 402). Government Press, Nairobi.

Government of Kenya, 2008. National Oceans and Fisheries Policy, Ministry of Fisheries. Government of Kenya, Nairobi.

Government of Kenya, 2013. The Wildlife Conservation and Management Act, 2013. The Government of Kenya. Special Issue. Kenya Gazette Supplement No. 18/ (Acts No. 47). Nairobi, 27th December, 2013. Government Printer, Nairobi.

Government of Kenya, 2016a. Marine artisanal fisheries frame survey report. Government of Kenya Fisheries Department, Nairobi 104 pp.

Government of Kenya, 2016b. Fisheries Management and Development Act 2016.

Green, S.J., Flores, J.O., Dizon-Corrales, J.Q., Martinez, R.T., Nuñal, D.R.M., Armada, N.B., White, A.T., 2004. The fisheries of Central Visayas, Philippines: Status and trends. Coastal Resource Management Project of the Department of Environment and Natural Resources and the Bureau of Fisheries and Aquatic Resources of the Department of Agriculture, Cebu City, Philippines. 159 pp.

Greenstreet, S.P.R., Rogers, S.I., 2006. Indicators of the health of the North Sea fish community: identifying reference levels for an ecosystem approach to management. ICES J. Mar. Sci. 63, 573-593.

Gutiérrez, N.L., Hilborn, R., Defeo, O., 2011. Leadership, social capital and incentives promote successful fisheries. Nature, 470, 386-389.

Jentoft, S., McCay, B., 1995. User participation in fisheries management: lessons drawn from international experiences. Mar. Policy, 19, 227-246.

Kaunda-Arara, B., Rose, G.A., Muchiri, M.S., Kaka, R., 2003. Long-term trends in coral reef fish yields and exploitation rates of commercial species from costal Kenya. WIO J. Mar. Sci. 2, 105-116.

Kaunda-Arara, B., Rose, G.A., 2004. Effects of marine reef national parks on fishery CPUE in coastal Kenya. Biol. Conserv. 118, 1-13.

Lieske, E., Myers, R., 2001. Coral Reef Fishes, Collins Pocket Guide, Revised ed. Harper Collins Publishers, London.

Lambshead, P.J.D., Platt, H.M., Shaw. K.M. 1983. The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. J. Nat. Hist. 17, 859-874.

Le Manach, F., Abunge, C.A., McClanahan, T.R., Pauly, D., 2015. Tentative reconstruction of Kenya's marine fisheries catch, 1950-2010, in: Le Manach, F., Pauly, D. (Eds.), Fisheries catch reconstructions in the Western Indian Ocean, 1950-2010. Fisheries Centre Research Reports 23(2). Fisheries Centre, University of British Columbia. pp. 37-51.

Ludwig, D., Hilborn, R., Walters, C., 1993. Uncertainty, resource exploitation, and conservation: lessons from history. Ecol. Appl. 1, 548-549.

Maina, G.W., Obura, D., Alidina, H., Munywoki, B., 2008. Increasing catch in an over-exploited reef fishery: Diani-Chale, Kenya, from 1998 to 2006, in: Obura, D.O., Tamelander, J., Linden, O., (Eds.), Ten years after bleaching - facing the consequences of climate change in the Indian Ocean. CORDIO Status Report. Coastal Oceans Research and Development in the Indian Ocean/Sida-SAREC. Mombasa. pp 309-320.

Maina, G.W, Samoilys, M.A., Alidina, H., Osuka, K. 2013. Targeted fishing of the shoemaker spinefoot rabbitfish, Siganus sutor, on potential spawning aggregations in southern Kenya, in: Robinson, J., Samoilys, M.A. (Eds.), Reef Fish Spawning Aggregations in the

Western Indian Ocean: Research for Management. WIOMSA/SIDA/SFA/CORDIO. WIOMSA Book Series 13.

Maina, G.W., Osuka, K., 2014. An EAF baseline report for the small and medium pelagic fisheries of Kenya. in: Koranteng, K.A, Vasconcellos, M.C., Satia, B.P. (Eds.), Baseline Reports - Preparation of management plans for selected fisheries in Africa: Ghana, Kenya, Liberia, Mauritius, Mozambique, Nigeria, Seychelles, Sierra Leone and Tanzania. FAO EAF-Nansen Project Report No. 23 EAF-N/PR/23. pp 22-89.

Maldeniya, R., Dayaratne, P., 1991. Recent development of small-scale purse seine fishery for small tunas in the southern coastal waters of Sri Lanka. National Aquatic Resources Agency Report. 6 pp.

Mangi, S., Roberts, C.M., 2007. Factors influencing fish catch levels on Kenya's coral reef. Fisheries Manag. Ecol. 14, 245-253.

McClanahan, T.R., Hicks, C.C., Darling, E.S., 2008. Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. Ecol. Appl. 18, 1516-1529.

McClanahan, T.R., Mangi, S., 2000. Spillover of exploitable fishes from a marine park and its effect on the adjacent fishery. Ecol. Appl. 10, 1792-1805.

McClanahan, T.R., 1988. Seasonality in East Africa's coastal waters. Mar. Ecol. Prog. Ser. 44, 191-199.

McLean, B., Glazewski, J.I., 2009. Marine Systems, in: Environmental Management in South Africa, Second Edition. Strydom, H.A., King, N.D. (Eds.), Mifflin Publishing Company. pp 455-478.

McConney, P., Charles, A., 2010. Managing small-scale fisheries: Moving towards people-centered perspectives, in: Grafton, R. Hilborn, R. Squires, D. Tait, M.,Williams, M. (Eds.), Handbook of Marine Fisheries Conservation and Management. New York: Oxford University Press, pp. 532-545.

Murshed-e-Jahan, K., Belton, B., Viswanathan, K.K., 2014. Communication strategies for managing coastal fisheries conflicts in Bangladesh. Ocean and Coast. Manag. 92, 65-73.

Mora, C., Myers, R.A., Coll, M., Libralato, S., Pitcher, T.J., 2009. Management Effectiveness of the World's Marine Fisheries. PLoS Biol. 7(6), p.e1000131.

Mumby, P.J., Steneck, R.S., 2008. Coral reef management and conservation in light of rapidly evolving ecological paradigms. Trends Ecol. Evol. 23, 555-563.

Munga, C.N., Kimani, E.N., Odongo, D., Mututa, W., Ndegwa, S., Mzee, S., 2010. Biological and socio-economic assessment of ring net small-scale purse seine fishing off Kipini part of the Malindi-Ungwana Bay, Kenya. 34 pp.

Munga, C.N., Okemwa, G.M., Kimani, E.N., Wambiji, N.W., Aura, C.M., Maina, G.W., Manyala, J.O. 2015. KCDP Project. KMFRI Research Report No.OCS/FIS/2014-2015/X

Nielsen, J.R., Degnbol, P., Viswanathan, K.K., Ahmed, M., Hara, M., Abdullah, M.R., 2004. Fisheries co-management- an institutional innovation? Lessons from South East Asia and Southern Africa. Mar. Policy 28, 151-160.

Obura, D.O., 2001. Kenya. Mar. Pollut. Bull. 42, 1264-1278.

Ochiewo, J., 2004. Changing fisheries practices and their social implications in south coast Kenya. Ocean and Coast. Manag, 47,389-408.

Pauly, D., 1989. Biology and management of tropical marine fisheries. Resour. Manag. and Optim. 6, 253-271.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R. and Zeller, D., 2002. Towards sustainability in world fisheries. Nature, 418, 689-695.

Pillans, S., Ortiz, J.C., Pillans, R.D., Possingham, H.P., 2007. The impact of marine reserves on nekton diversity and community composition in subtropical eastern Australia. Biol. Conserv. 136, 455-469.

Pomeroy, R., Parks, J., Pollnac, R., Campson, T., Genioe, E., Marlessy, C., Holle, E., Pidoh, M., Nissapai, A., Boromthanarati, S., Hue, N.T., 2007. Fish wars: Conflict and collaboration in fisheries management in Southeast Asia. Mar. Policy 31, 645-656.

Salas, S., Chuenpagdee, R., Seijo, J.C., Charles, A., 2007. Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fish. Res. 87, 5-16.

Sadovy de Mitcheson, Y., Cornish, A., Domeier, M., Colin, P.L., Russell, M., Lindeman, K.C. 2008. A global baseline for spawning aggregations of reef fishes. Cons. Biol. 22, 1233-1244.

Salas, S., Chuenpagdee, R., Seijo, J.C., Charles, A., 2007. Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fish. Res. 87, 5-16.

Samoilys, M.A., Maina, G.W., Osuka, K., 2011. Small-scale fishing gears of the Kenyan coast. CORDIO East Africa and USAID, Mombasa (Kenya). 36 pp.

Samoilys, M.A., Osuka, K., Maina, G.M., Obura, D.O., 2017. Artisanal fisheries on Kenya's coral reefs: Decadal trends reveal management needs. Fisheries Research 186, 177-191.

Sayce, K., Shuman, C., Connor, D., Reisewitz, A., Pope, E., Miller-Henson, M., Poncelet, E., Monie, D., Owens, B., 2013. Beyond traditional stakeholder engagement: public participation roles in California's statewide marine protected area planning process. Ocean and Coast Manag. 74, 57- 66.

Shannon, C.E., Wiener,W., 1963. The Mathematical Theory of Communication. University of Illinois Press, Urbana, 125 pp.

Smith, M.M., Heemstra, P.C. (Eds.) 1986. Smith's Sea Fishes. Berlin, Springer-Verlag, 1047 pp.

Smith, D., Punt, A., Dowling, N., Smith, A., Tuck, G., Knuckey, I., 2009. Reconciling approaches to the assessment and management of data-poor species and fisheries with Australia's harvest strategy policy. Mar. Coast. Fish., 1, 244-254.

Standing, A., 2008 “Corruption and industrial fishing in Africa” 7 U4 Issue 7.

Stergiou, K.I., Petrakis, G., Politou, C.-Y., 1996. Small-scale fisheries in the South Euboikos Gulf (Greece): species composition and gear competition. Fish. Res. 26, 325-336.

Stobutzki, I., Miller, M., Brewer, D., 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environ. Conserv. V28, 167-181.

UNEP, 1998. Eastern Africa atlas of coastal resources. United Nations Environmental Programme, Nairobi. 119 pp.

Van der Elst, R., Everett, B., Jiddawi, N., Mwatha, G., Afonso, P.S., Boulle, D., 2005. Fish, fishers and fisheries of the Western Indian Ocean: their diversity and status. A preliminary assessment. Philos. Trans. A. Math. Phys. Eng. Sci. 15, 263-284.

Worm, B.R., Hilborn, J.K., Baum, T.A., Branch, J.S., Collie, C., Costello, M.J., Fogarty, E.A., Fulton, J.A., Hutchings, S., Jennings, O.P., Jensen, H.K., Lotze, P.M., Mace, T.R., McClanahan, C., Minto, S.R., Palumbi, A.M., Parma, D., Richard, A., Rosenberg, A., Watson, R., Zeller, D., 2009. Rebuilding Global Fisheries. Science 325, 578-585.

Zhang, C., Kim, S., Gunderson, D., Marasco, R., Lee, J.B., Park, H.W., Lee J.H., 2009. An ecosystem-based fisheries assessment approach for Korean fisheries. Fish. Res. 100, 26-41.

FIGURE CAPTIONS

Fig. 1. A map of Kenya showing the main fishing grounds used by small-scale purse seine fishers along the Kenya coast.

Fig. 2. Illustration of a small-scale purse seine net (adapted from Fry, 1930).

Fig. 3. Temporal trends in small-scale purse seine fishing effort (number of vessels and fishers) in three Counties of the Kenya coast. No data was collected on the number of fishers in 2008.

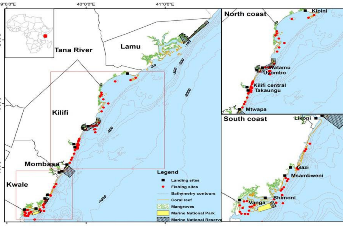
Fig. 4. Percentage contribution of different fishing gears to the total landings in Shimoni, Vanga and Gazi, southcoast of Kenya.

Fig. 5. The general composition of small-scale purse seine catches landed at Shimoni-Vanga and Gazi in the southcoast and Kipini in the northcoast of Kenya, from 2008-2014.

Fig. 6. Comparison of *k*-dominance curves of the catch composition of common fishing gears used in south coast of Kenya.

Fig 7. Evolution of the developing small-scale purse fishery in Kenya and the management planning process

Fig. 8. The hierarchy of Kenya's small-scale purse seine fishery management plan, showing the overall objectives (tier 1), specific objectives (tier 2) and management measures (tier 3). Shaded boxes depict regulatory measures.



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Tana River
Lamu
Kilifi
Mombasa
Kwale
-100
-50
-300
-500
-2000
-600
-1000
North coast
Kipini
Watamu
Uyombo
Kilifi central
Takaungu
Mtwapa
South coast
Likoni
Gazi
Msambweni
Shimoni
Vanga
Legend
Landing sites
Fishing sites
Bathymetry contours
Coral reef
Mangroves
Marine National Park
Marine National Reserve