Impact of a ring net fishery in the inshore marine waters of Kilifi on the reproductive biology of six pelagic fish species

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Abstract

Ring nets are modified purse seines used for pelagic fishing along the Kenya coast. This method is however associated with potential negative environmental implications in inshore and shallow fishing grounds. Biological impacts on selected pelagic species caught in the marine waters of Kilifi were investigated during the Southeast Monsoon season (SEM) in April, May and September 2014, and the Northeast Monsoon season (NEM) in October and November 2014, and March 2015. *Amblygaster sirm, Rastrelliger brachysoma*, *Sardinella gibbosa, Rastrelliger kanagurta*, *Hemiramphus far* and *Sphyraena obtusata* were the most abundant species caught by the ring nets and comprised 68.9 % of fish catch composition. Analysis of ring net impacts on the fish sizes and maturity status were conducted for the NEM and SEM seasons. The catch composition for *A. sirm* in October comprised of 53.3 % juveniles and 53.4 % juveniles for *S. obtusata* in November. High percentages of *H. far* (78.3%) and *S. obtusata* (58.9 %) were captured in September. Incidences of undersize fish for *A. sirm*, *S. gibbosa*, *R. kanagurta* and *R. brachysoma* were observed across the seasons. Sex ratios for *A. sirm*, *R. brachysoma*, *R. kanagurta* and *S. obtusata* in the NEM season deviated from a normal ratio of 1:1 with more males observed. Females were dominant in the catch for *H. far* (1: 1.28) but the ratio was not different for *S. gibbosa* (χ^2 = 5.564, df = 1, p = 0.21). Males were dominant for *A. sirm* (1: 0.8) and *S. gibbosa* (1: 0.7) in the SEM season but the ratios were not different for *H. far*, *S. obtusata*, *R. brachysoma* and *R. kanagurta*. Differences in sex ratios were attributed to fish migrations and reproductive processes. Ring nets fished relatively offshore during the NEM season and targeted mainly spawning aggregations in stage IV. Immature fish in stage I and II which comprised of juveniles were harvested within sheltered inshore waters in the SEM season. Use of ring nets to target juveniles and spawning aggregations may disrupt recruitment processes. To enhance sustainable management of the ring net fishery, there is a need to develop harvesting strategies based on the information on stock status of the target fish.

Keywords: ring nets, reproductive biology, impacts, Kilifi

Introduction

Ring nets are modified purse seines used in coastal fisheries to target small pelagic fish, mostly in the families Carangidae, Clupeidae, Scombridae and Sphyraenidae (Halland Roman, 2013). In the Philippines, ring nets are used in conjunction with Fish Aggregating Devices (FADs) to improve productivity but are associated with capture of undersize fish (Malig *et al*., 1991). Ring net fishing was introduced in Kenya in the 1990s from Pemba, Tanzania and embraced by the State Department of Fisheries, Aquaculture and Blue Economy (SDFA&BE) as a means to access offshore fish resources (Government of Kenya, 2005). However, lack of a regulatory framework to guide its operations has since raised concerns about environmental degradation and overfishing (Government of Kenya, 2005; Okemwa *et al*., 2017). The fishery is associated with fishing in the inshore waters, targeting spawning aggregations, fishing of immature undersize fish and causing physical damage to the benthic habitats (Maina, 2012; Samoilys *et al*., 2011). Although capture of spawning and immature fish has been reported, no comprehensive studies have been undertaken on the Kenyan coastline and particularly in the inshore marine waters of Kilifi to evaluate impacts of ring nets on target pelagic stocks which form 73%

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of the landings (Okemwa *et al.,* 2017). The purpose of the present study was therefore to determine the impact of ring nets on spawning and juvenile fish of selected target species with high catch composition in the NEM and SEM seasons. This will provide scientific data to inform management decisions on the ring net fishery and enhance environmental conservation and ensure sustainable utilization of the target fish stocks.

Takaungu - Mlangoni, Takaungu and Vuma. The area experiences two seasons; the Northeast Monsoon(-NEM) which runs from October to March each year and is characterized by calm, sunny and dry weather conditions, and the Southeast Monsoon (SEM) covering April to September and dominated by strong winds, rough sea conditions and heavy rains(McClanahan, 1988; Munga, 2008).

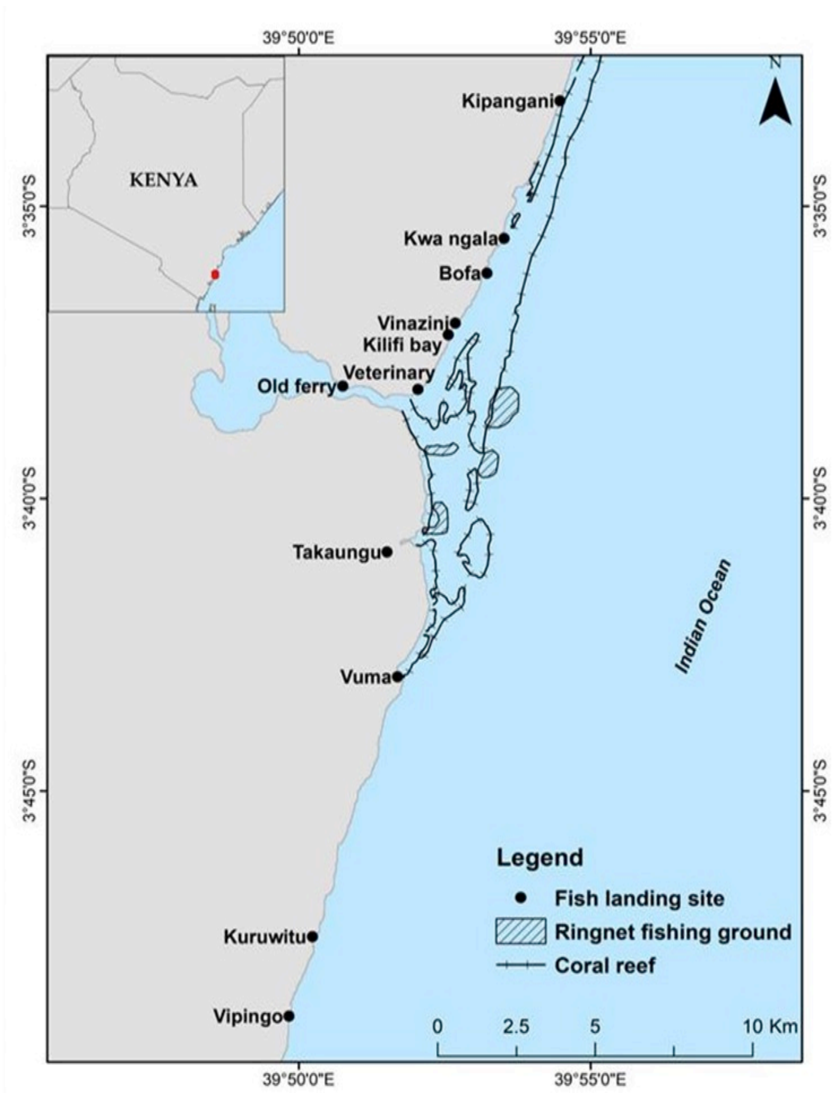

Figure 1. Map of Kenya showing fish landing sites and ring net fishing grounds in Kilifi, Kenya.

Materials and methods

The study area

The study was located in the inshore marine waters of Kilifi County located along the Kenya coastline. These waters are administratively managed by the Beach Management Units (BMUs) of Kuruwitu, Takaungu, Kilifi Central and Bofa (Fig. 1). The fishing grounds comprised of Kilifi - Mlangoni, Bofa, Kwa-Ngala,

Data collection

Biological data and information on ring net operations were collected at the landing sites and fishing grounds. The data were collected in the NEM season in October, November 2014 and March 2015, and September 2014, April and May 2015 in the SEM season. Fish landed by three vessels using ring nets were sampled during the study period based on preliminary data from fisheries surveys (Government of Kenya, 2016). Fish species were identified using published literature (Anam and Mostrada, 2012) and the online database, Fishbase (2018) (http//www.fishbase.org). Samples of six species were used to determine size structure by measuring individual total length (TL) to the nearest 0.1 cm on a measuring board (Kahn *et al*., 2004).

Individual fish were dissected to determine their sex and gonad maturity status following standard procedure. Gonads were categorized into 5 stages; Stage I (Immature), II (Maturing), III (Mature), IV (Ripe) and V (Spent) according to West (1990). The proportion of juveniles of each species was determined by the number of individuals below their respective length at first maturity (L_{mat}) as per information in Fishbase.

Fishing crew were accompanied to the fishing grounds to obtain data on fishing locations and distances to the nearest shoreline as recommended by Munga *et al.* (2010) in a study of ring net fishing at Kipini fishing grounds. Deployment points of selected ring nets in the common sites were captured using a Geographical Positioning System (GPS) device and latitudes and longitudes recorded.

Data analysis

Seasonal (NEM and SEM) data on fish size structure, sex ratios and gonad maturity status were analyzed using MS Excel® and Statistica8.0 software. Percentage (%) species composition of fish caught in the NEM and SEM season were determined. The proportions of stage I-V for each species for both the NEM and SEM season were determined for seasonal comparisons. The number of males and females of each species were used to compute sex ratios which were tested for significant difference from the expected 1:1 ratio using the Chi-squire (χ^2) test (Zar, 1999). Significance was determined at $\alpha = 0.05$ for all statistical tests.

Results

Fishing grounds description, gear use and operation

Deployment points of ring nets were randomly referenced for common fishing grounds: Kilifi - Mlangoni (03°39.17'S and 039°52.51'E; 03°39.24'S and 039°52.38'E); Takaungu - Mlangoni (03°40.37'S and 039°52.28'E); Takaungu (03°39.06'S and 039°53.23'E; 03°39.14'S and 039°53.20'E); and Bofa (03°38.07'S and 039°52.513'E; 03°38.50'S and 039°53.32'E). Kipangani, Kwa-Ngala, Vuma and Vipingo grounds were fished during calm conditions. The ring nets measured 160 - 280 m long and18 - 28 min depth with net mesh sizes of 0.5 inches (12.7 mm) and fished at depths of between 30.0 ± 9.0 m in the NEM season and 15.0 ± 3.0 m in the SEM season. Plastic containers filled with beach sand were used as sinkers with floats attached to the top rope to prevent the net from being in contact with the sea bottom. The ropes passed through rings attached at the lower part of the net and were pulled together to close the bottom before the catch was hauled onto the boats.

Species composition and structure of sampled fish

Seasonal and average catch composition for *A. sirm, R. brachysoma*, *S. gibbosa, R. kanagurta*, *S. obtusata* and *H. far* are presented in Table 1. The catch composition of the selected species comprised 69.0 % of the total ring net landings. *S. obtusata and R. kanagurta* comprised

Table 1. Seasonal and average % species composition of selected species.

	Seasonal species composition (%)		
Species	**NEM**	**SEM**	**Average landings**
S. obtusata	25.1	28.8	27.0
R. kanagurta	19.6	13.6	16.6
R. brachysoma	6.1	14.2	10.2
H. far	5.0	1.8	3.4
S. gibbosa	2.8	13.8	8.3
A. sirm	1.6	5.3	3.5
Others*	39.8	22.5	31.0

Others:* Represents percentage combination of pelagic and demersal fish landed in small proportions by the ring nets for both seasons.

Table 2. Seasonal mean lengths, numbers, estimated size at maturity and % proportion below L_{mat} of targeted pelagic species.

Species	Seasonal mean sizes (cm)					% proportion below L_{mat}	
	NEM	n	SEM	n	L_{mat}, cm	NEM	SEM
A. sirm	18.8 ± 4.7	92	19.0 ± 3.7	219	15.0	10.8	5.7
R. brachysoma	23.2 ± 2.3	342	19.7 ± 2.7	537	17.0	0.4	2.0
S. gibbosa	16.3 ±1.65	150	15.8 ± 2.2	552	12.8	1.4	3.1
R. kanagurta	24.1 ± 2.6	791	21.9 ± 2.6	670	19.9	4.1	4.3
H. far	31.0 ± 1.4	72	22.7 ± 4.5	69	26.5	0	78.3
S. obtusata	23.0 ± 4.1	1329	24.7 ± 4.5	1327	22.9	37.6	29.8

a high proportion in the landings with 27.0 % and 16.6 % respectively. A smaller proportion of catches grouped under other species constituted 31.0 % and comprised a mixture of both pelagic and demersal species.

Table 2 shows seasonal (NEM and SEM) average sizes and percentages of fish individuals for *A. sirm, R. brachysoma*, *S. gibbosa, R. kanagurta, H. far* and *S. obtusata* captured below L_{mat} by ring nets. The proportions (%) of the species captured below L_{mat} during the months in each season are presented in Fig. 2.

The results for *A. sirm* showed more individuals caught below L_{mat} during the NEM season in the months of October (53.3 %) and a few in November (7.4 %), and during SEM season, a small proportion were captured in April (11.7 %). Based on the average lengths in the NEM season (18.8 ± 4.7 cm), 10.8 % of the individuals were below L_{mat} and the SEM season (19.0 ± 3.7 cm) had 5.7 % below L_{mat}. The fish sizes landed in both seasons were not significantly different (ANOVA, F = 0.14; p = 0.706).

The majority of *R. brachysoma* individuals attained a mature size at harvest except a few below the L_{mat} in March (1.2 %) and April (6.0 %). The sizes of fish caught in the NEM season (23.2 ± 2.3 cm) and SEM season (19.7 ± 2.7 cm) were different.

A few individuals for *S. gibbosa* were below L_{mat} (12.8 cm) in March (1.6 %), September (9.4 %) and November

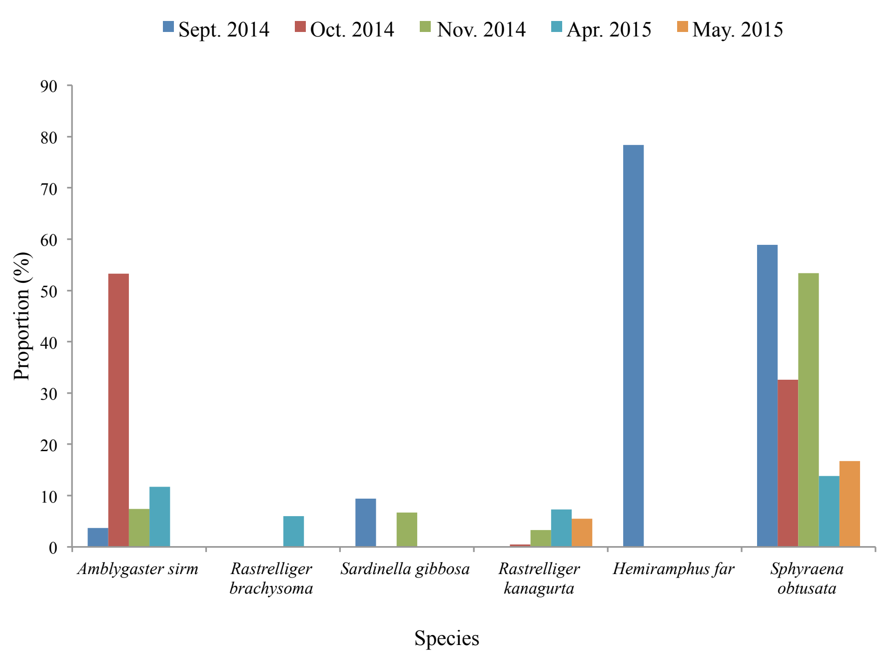

Figure 2. Proportion (%) of individuals below size at maturity for various species in different months.

Table 3. Proportion (%) of individuals in various gonad maturity stages (I-V) in the NEM and SEM seasons (NEM = Northeast monsoon; SEM = Southeast monsoon).

Species	Season	% proportion of gonad maturity					n
		I	II	III	IV	V	
A. sirm	NEM	9.0	2.8	11.7	19.0	57.5	89
	SEM	35.2	16.8	6.4	7.5	34.1	219
R. brachysoma	NEM	1.4	0.7	2.1	49.5	46.3	287
	SEM	31.7	5.7	4.7	12.2	45.7	385
S. gibbosa	NEM	20.5	0.0	2.4	28.5	48.6	139
	SEM	23.2	44.8	6.4	10.4	15.2	464
R. kanagurta	NEM	0.5	0.6	1.7	58.3	38.9	673
	SEM	31.6	23.5	15.3	10.4	19.2	539
H. far	NEM	0.0	13.6	21.5	35.4	29.5	73
	SEM	47.7	18.7	9.0	23.2	1.4	69
S. obtusata	NEM	67.2	16.5	2.1	6.2	8.0	943
	SEM	53.7	23.4	10.4	7.4	5.1	1240

(6.7 %). The results show that a small proportion of individuals in the NEM season (1.4 %) and SEM season (3.1 %) were caught below size at maturity. Based on the results, it is apparent that the species was harvested at different sizes across the seasons (ANOVA, F=5.98; p <0.05).

R. kanagurta individuals captured during both seasons were mostly above the L_{mat} but a few were below this size in October (0.5 %), November (3.3 %), March (8.6 %), April (7.3 %) and May (5.5 %). The findings showed that a few individuals were captured below size at maturity in the NEM season (4.1 %) and SEM season (4.3 %). According to the results, the species was fished at different sizes in the NEM season (24.1 ± 2.6 cm) and SEM season (21.9 ± 2.6 cm).

H. far individuals assessed in the NEM season attained size at maturity at capture but in the SEM season, 78.3 % of the individuals were captured below L_{mat} in the month of September. Based on the results, the species was fished at different sizes in the NEM season (31.0 ± 1.4 cm) and SEM season (22.7 ± 4.5 cm).

The majority of *S. obtusata* were captured below size at maturity during the NEM season (37.6 %) during the months of October (32.6 %), November (53.4 %) and March (26.9 %). In the SEM season, 29.8 % were captured below L_{mat} with a majority being observed in September (58.9 %). The mean sizes of fish individuals landed in the NEM season (23.0 ± 4.1 cm) and SEM season (24.7 ± 4.5 cm) indicated fishing vulnerability of the species at various sizes.

Sex ratios

Males were dominant in the NEM for *A. sirm* with a sex ratio of 1: 0.4 which deviated from the normal 1: 1.The males were also dominant in the landings in the SEM season (χ^2 = 2.215, df = 1, p = 0.137, n = 163). Male *R. brachysoma* were more common during the NEM season (1: 0.8; χ^2 = 4.77, df = 1, p< 0.05, n = 287), but both sexes were equally captured in the SEM season (1: 1.1).

An equal number of males and females were landed for *S. gibbosa* with 1: 0.8 ratio in the NEM season (χ^2 = 5.564, df = 1, p = 0.21, n = 143) but males were dominant in the SEM season at a ratio of 1: 0.7(χ^2 = 10.515, df = 1, p< 0.05, n = 309). Landings for *R. kanagurta* had more males in the NEM season at a ratio of 1: 0.7 (χ^2 = 29.672, df = 1, p< 0.05, n = 974) but both sexes were equally captured with a 1: 1.1 ratio in the SEM season.

Females were observed to be more frequent for *H. far* in the NEM season with a ratio of 1: 2.8 but were equally harvested in the SEM season at a ratio of 1: 1.0. Samples of *S. obtusata,* were dominated by males

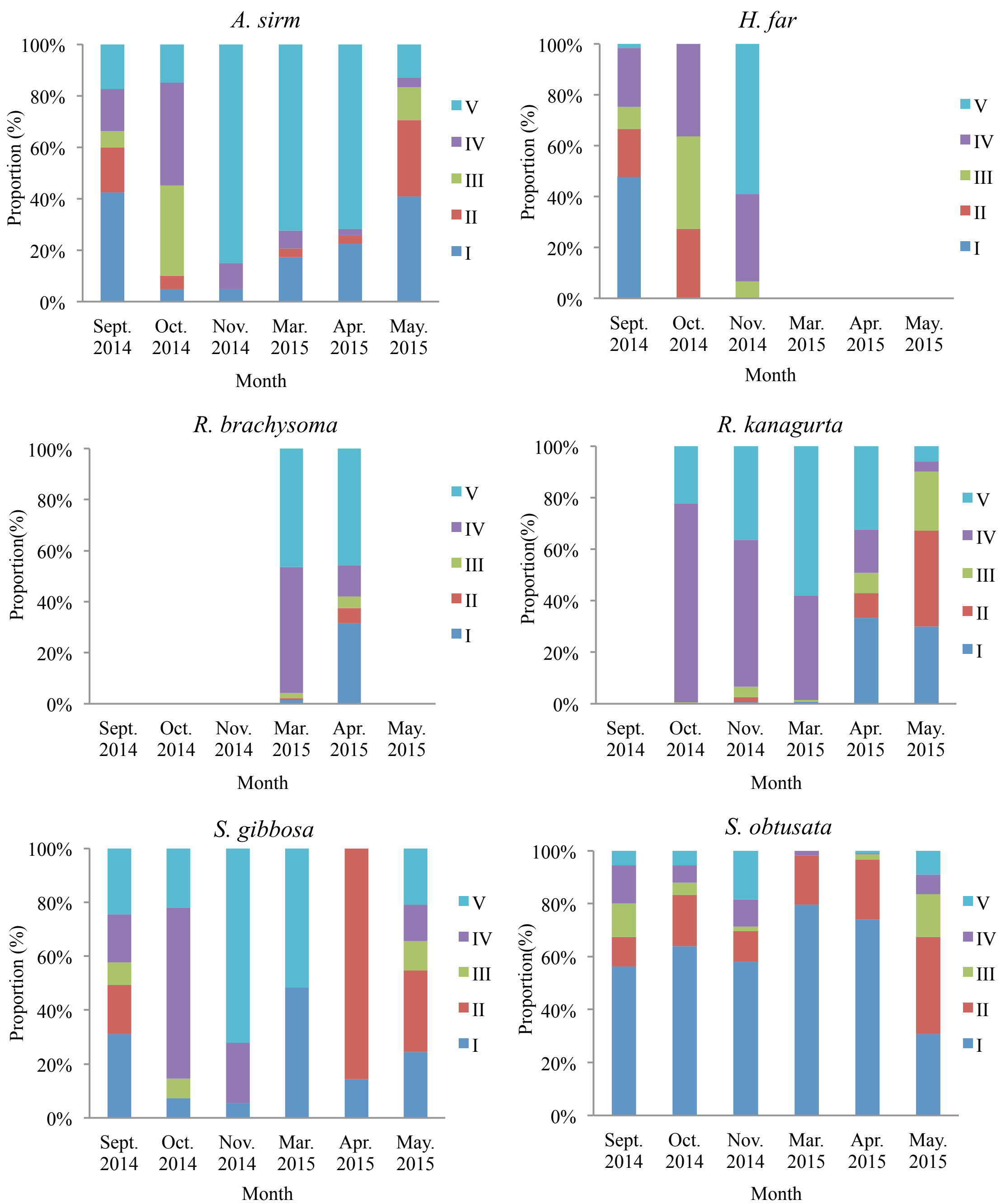

Figure 3. Proportion (%) of individuals in various gonad maturity stages (I-V) in different months.

in the NEM season at a ratio of 1: 0.86 (χ^2 = 5.564, df = 1, p< 0.05, n = 1011) but equal numbers of males and females were harvested in the SEM season at a ratio of 1: 1.0.

Gonad maturity status

The gonad status of various species collected during the NEM and SEM season are presented in Table 3, whereas proportional trends across months are shown in Fig. 3. Most *A. sirm* captured in the NEM season were in stage V (57.5 %) while in SEM season most were in stage V (34.1%) and I (35.2 %). High proportions of stage V individuals were observed in March (72.4 %), November (85.0 %) and April (71.8 %). More individuals were also observed in stage I (42.5 %) in September, and stage III (35.0 %) and IV (40.0 %) in October.

R. brachysoma in the NEM season had more individuals in stage IV (49.5 %) and V (46.3 %) in March. The observations made in the SEM season indicated more individuals in stage I (31.7 %) and V (45.7 %) landed in April.

Gonad assessment for *S. gibbosa* in the NEM season comprised mostly of individuals in stages IV (28.5 %), V (48.6 %) and I (20.5 %).The majority of the individuals in stages I (48.4%) and V (51.6%) were observed in March, and stage IV (63.4%) in October. The assessment carried out in the SEM season comprised mostly of individuals in stage I (44.8 %) and II (23.2 %). During this season, the months of April and September had the highest proportions of individuals captured in stages II (85.7%) and I (31.1%) respectively.

The assessment of gonads for *R. kanagurta* in the NEM season showed more individuals in stages IV (58.3 %) and V (38.9 %). During this season, a high proportion of individuals in stage IV were observed in March (40.6 %), October (77.1 %) and November (57.1 %). The majority of individuals in stage V were observed in March (57.9 % and November (36.3 %). The assessment carried out in the SEM season showed more individuals in stages I (31.6 %) and II (23.5 %). The majority of the individuals in stages I (33.4 %) and V (32.4 %) were captured during the month of April.

Assessment of *H. far* gonads in the NEM season indicated most individuals in stage IV (35.4 %) and V (30.0 %) which occurred during the months of October and November, respectively. The results in the SEM season indicated more individuals in stage I (47.8 %) and IV (23.2 %) which were captured in September.

The assessment of gonads for *S. obtusata* in the NEM season indicated the majority of the individuals in stage I (67.2 %). The individuals were captured mostly in the months of October (64.0 %) and November (58.0 %). High proportions of individuals observed in the SEM season were in stages I (53.7 %) and II (23.4 %). The majority of the individuals in stage I (74.0 %) were captured in April, and stage II (53.7 %) in September.

Discussion

The results of the current study show that ring nets were used in shallow grounds near the coral reef areas during the SEM season and in slightly deeper coastal waters in the NEM season. The coral reef areas serve as feeding, breeding and nursery grounds for most tropical fishes and fishing with ring nets within these areas are likely to impact on fish recruitment (McClanahan, 1988; Robinson *et al*., 2008). Harvests of undersize, immature and hydrated fish were observed during the months fished during the NEM and SEM seasons.

Fish catches in the NEM season included fish captured before they attained maturity sizes (Fishbase, 2018). Catch composition of *A. sirm* and *S. obtusata* comprised had more than 50 % below L_{mat} in October and November respectively. Juveniles are reported to aggregate to feed as calm conditions in the sea prevail (Morais *et al.,* 2010). Schools of juveniles were likely to have been targeted and harvested by the ring nets as they move from the nursery grounds into the open waters. A small percentage of undersize fish were recorded for *R. brachysoma*, *S. gibbosa* and *R. kanagurta* in March, October and November. The incidental catches of the juveniles probably occurred as they accompanied aggregations of adult fish to the feeding grounds or while in transit to spawning sites (Robinson *et al.,* 2008). The fishermen were observed to target aggregating fishes which were surrounded and harvested irrespective of sizes (pers. obs. first author; Samoilys *et al*., 2011). The calm sea conditions in the NEM season made it possible for ring net fishers to access and operate in the offshore waters (pers. obs. first author; Munga *et al*., 2010).

The rough and windy conditions in open waters in the SEM season pushed ring net fishing into the shallow and sheltered grounds. The operations of the ring nets at the sites impacted greatly on *H. far* and *S. obtusata* with more than 50 % of the catches below their respective maturity sizes. The aggregations of juveniles were likely to have been surrounded and harvested by the ring nets while transiting to feeding grounds (Robinson *et al.,* 2008). Small percentages of undersize fish were also observed in this season for *A. sirm*, *R. brachysoma*, *S. gibbosa* and *R. kanagurta*. The incidental catches of the juveniles are predicted to have occurred while aggregating together with shoals of adult fish moving to feeding grounds or spawning sites (Morais *et al.,* 2010). The sheltered grounds fished in the SEM season also serve as breeding and nursery grounds for most reef and reef-associated fish where young fish are subjected to fishing mortalities (McClanahan, 1988). Harvest of juveniles in the SEM season probably occurred as a result of fishing within the nursery grounds using small mesh size nets.

Ring nets used in both the NEM and SEM season harvested both adult and juvenile fish as a result of mesh size dimensions of the nets which measured 0.5 inches (12.7 mm). The sizes are designed to maximize fish catch and allow easy offloading onto the vessels, but they prevent escape of young fish. Although the ring nets increase fishing efficiency and increase catch, they are non-size selective and capture all sizes of fish (Okemwa *et al.,* 2017).

The study on biological and socio-economic aspects by Munga *et al.* (2010) on ring net fishing off Kipini fishing grounds on the Kenyan coast also reported the harvesting of juvenile fish. Despite government recommendations for 2-inch (50.8 mm) mesh size nets for use by the ring nets to curb the harvest of undersize fish, the fishermen are yet to adopt this requirement (Government of Kenya, 2012). Post-harvest losses, low fish quality of gillnetted fish and reduced catch due to the escape of small but mature pelagic fish are some of the reasons given for opposing the use of 2-inch mesh size nets (Okemwa *et al*., 2017).

Though the majority of species harvested comprised mostly of adult fish across the seasons, the small proportion of juveniles impacts on fish recruitment. The extent of juvenile mortality in the total stock could cause disruption of fish recruitment to the spawning stock (Robinson *et al*., 2004; Prince *et al.,* 2015). To enhance the sustainability of ring nets and reduce harvest of juveniles, the introduction of a 'closed season' in October - November is proposed as a result of this study. A ban on ring net fishing within shallow and sheltered grounds in the SEM season is also proposed to protect young fish in the nursery grounds.

However, fishers would have to be engaged in alternative fisheries or occupations to cushion them from the loss of livelihoods likely to occur as a result of changes in marine fisheries management regulations. There is need to enhance sustainable livelihoods options for the fishermen through capacity and skills development, value addition, access to capital assets and credit facilities, all of which depend on an understanding of the socioeconomic context of artisanal fisheries (Cinner *et al*., 2009; Morara *et al.,* 2015).

Sex ratios in the NEM season for *A. sirm*, *R. brachysoma*, *R. Kanagurta* and *S. obtusata* deviated from the natural ratio of 1: 1 with more males being harvested. Males and females were equally captured for *S. gibbosa* but more females for *H. far*. In the SEM season, more males were harvested for *A. sirm* and *S. gibbosa* but the ratios for *H. far*, *S. obtusata*, *R. brachysoma* and *R. kanagurta* were not significantly different.

The high catches of males observed for the majority of selected target species in the NEM season were probably as a result of aggregation within the feeding grounds while the females were in transit to spawning sites (Robinson *et al.,* 2004). Fishing with ring nets within sheltered grounds would likely have subjected males and females equally to fishing mortality as they both participate in reproduction processes within spawning sites. The difference in the numbers of males and females captured in the seasons could be associated with spawning activities, time spent at spawning sites and migrations to feeding grounds (Robichaud and Rose, 2003; Hamilton *et al.,* 2007).

Gonad assessment results showed a high proportion of mature and heavily hydrated fish in stage IV and individuals in stage V (spent) in the NEM season. Spawning fish in stage IV were high in October and November for *A. sirm*, *R. brachysoma*, *R. Kanagurta*, *H. far* and *S. gibbosa*. Some individuals observed in March, November and October had spawned before they were captured. According to the results, the majority of the species spawned in the NEM season which peaks in October - November, except for *S. obtusata* which is likely to spawn from April - July (Robinson *et al.,* 2004). The shoals of fish which aggregated for the purpose of spawning during this season became susceptible to ring nets that actively fished in the open waters. The temporal and spatial spawning activities for most fishes are reported to occur in NEM season and are known to be fished intensively by the fishermen as they aggregate to spawn in reef areas (Robinson *et al.,* 2004; Robinson *et al.,* 2008). The high catches of hydrated and translucent (spent) fish occurred as a result of prevailing stable sea conditions in the NEM season that allowed accessibility and operation of ring nets in the open waters.

A high proportion of immature (stage I) specimens of *S. obtusata* was harvested in October and November. During this period ring net fishers actively fished in the open waters and were likely to have targeted the aggregations of juveniles moving to the feeding grounds (Robinson *et al.,* 2004).The findings of the study on maturity status of the target fish are in agreement with the study undertaken by Munga *et al*. (2010) which assessed the maturity status of fish landed by a ring net off Kipini fishing grounds.

Gonads observed in the SEM season comprised mostly of immature (stage I) and maturing (stage II) fish in April and September among all the selected species, especially for *S. obtusata*. The catches of immature fish are attributed to ring net fishing within the nursery grounds to shelter against windy conditions in the open waters (Okemwa *et al*., 2017). The immature fish were likely to have been harvested while aggregating in the nursery grounds or on transit to feeding grounds (Robinson *et al.,* 2004).

The majority of immature fish were caught within the nursery grounds before attaining sexual maturity and participating in the spawning process (Johannes, 1988). Ring net fishing on the immature fish denied them the opportunity to participate in fish recruitment and rebuilding of stocks. Exploitation of hydrated and immature fish is likely to cause negative implications on fish population growth and recruitment leading to unsustainable stocks (Johannes, 1988; Johannes *et al.,* 1999; Prince *et al.,* 2015). The Ring Net Fishery Management Plan (RFMP) proposed only one ring net on the Kilifi fishing grounds for sustainable management of the fishery, but according to the present study, eight ring nets fished during both the NEM and SEM season. The increase in fishing effort coupled with intensive fishing on spawning aggregations and the capture of immature specimens may not be sustainable and is likely to impair the target stock. However, little is known about the distribution and abundance of these stocks offshore, outside the reach of this artisanal fishery (Okemwa *et al*., 2017).

Though ring net fishing continues to be adopted to increase fish catches from Kenya's inshore marine waters, the findings of the present study indicated the need for management measures to control exploitation of juveniles and spawning aggregations. It is suggested that the local BMUs integrate ring net-specific fishing zones and closed seasons in their by-laws to enhance sustainable management and utilization of the fish resources. Fishing communities have played an active role in sustainable management of fisheries resources through the establishment of community conservation areas where fishing activities are restricted (Maina *et al*., 2011). These approaches have positively enhanced community responsibility and ownership towards conservation and management of the resources.

In Kenya, non-governmental organizations (NGOs) and researchers create awareness on resource management among the fishing community through participatory monitoring and research approaches (Alidina, 2005). Kuruwitu Community Managed Conservation Area (KCMCA) is an example of a marine conserved area established by the fishing community to promote sustainable utilization and management of coastal marine resources.

More research is needed to establish the stock status, spawning potential and fishing mortalities of ring net target fish. The findings will provide information on whether the fished stocks have the potential to spawn and rebuild based on the current fishing pressure. This will form a basis for formulation and implementation of sustainable management measures for ring net fishing in Kilifi marine waters and along the Kenyan coastline.

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