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Annual Report 2014-2015 Financial Year

Stock Assessment of Small and Medium Pelagics: Status of Ring Net and Reef Seine Fisheries along the Kenyan coast

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Cover Image: Typical ring net catch, photo by Cosmas Munga

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DOCUMENT CERTIFICATION

Certification by Assistant Director of Directorate of Fisheries

I hereby certify that this report has been done under my supervision and submitted to the Director.

Signature____ Date _______July, 2015_____________

Name____

CERTIFICATION BY DIRECTOR:

I hereby acknowledge receipt of this Report

Signature _____________________________Date _______July, 2015_______

Name____

Preamble

The ring net and reef seine fishing gears are the best candidate for targeting the small and medium pelagic fisheries resources. Although these gears should target the small and medium pelagic from relatively offshore fishing grounds, their use has been raising mixed reactions over claims of being used in inshore areas, landing of under-sized individuals, with environmental implications. This led to the formulation of the final draft Ring Net Fishery Management Plan to advocate for the proper use of this gear. The management plan however, was formulated without adequate scientific data and information. Under Component 1 of the Kenya Coastal Development Project (KCDP), funds have been made available to conduct research so as to gather adequate scientific data on the spatio-temporal catch composition, and some aspects of the biology of selected target species. This will directly contribute to the KCDP Project Development Objective (PDO) of improving management effectiveness and enhancing revenue generation of Kenya's coastal and marine resources, as well as the Global Environmental Objective (GEO) of strengthening conservation and use of coastal and marine biodiversity. A period of 12 months was set aside to conduct shore-based catch assessment in fishing areas where ring net and reef seine fishing are conducted.

This annual technical report therefore, provides a six months observation, analysis, conclusion and recommendations for the small and medium pelagic assessment. The findings should be treated as indicative only since the process of data collection did not cover the proposed 12 months. It is our hope that after the successful completion of this work, adequate data would be made available for a more reliable and comprehensive report that will add value to the draft final Ring Net Fishery Management Plan and the Small and Medium Pelagic Management Strategy.

Dr. R.K. Ruwa
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Abstract

The use of ring nets and reef seines has become common along the Kenya coast. Scientific data for these fishing gears is still inadequate despite already having the draft final Ring Net Fishery Management Plan, and the small and medium pelagic management strategy in place. The aim of this study was to conduct a baseline study for the ring net fishery to support the fishery management plan to be in line with Ecosystem Approach to Fisheries (EAF) recommended by the FAO. In order to contribute to scientific information so as to add value to these management plans, a series of shore-based catch assessment surveys were conducted for Vanga, Gazi, Takaungu, Kilifi and Uyombo areas along the Kenyan coast where ring net and reef seine fishing are practiced. Growth parameters, mortality estimates, selection analysis, yield models and species-gear-site combinations were determined using standardized methods. Results indicated relatively low catch-per-unit-effort (CPUE, Ring net: 296.5 ± 38.3; Reef seine: 55.1 ± 7.7 kg vessel^{-1} day $^{-1}$) and this differed ($p < 0.05$) among the fishing areas studied. Catch composition was different attributed to differences between the vessel-gear. The overall species richness was higher for the reef seines compared to the ring nets. Majority of the species landed were demersal and reef associated species, and mostly under-sized individuals. In view of the narrow range of natural mortality coefficient, E_{MSY}, $E_{0.1}$ and E_{opt}, recorded herein, it could be indicative that size and growth rate do not influence natural death in the small and medium pelagics. Long-term data surveys are needed for more robust findings. These current findings should therefore, be treated as indicative with more data likely to make a better informed status of the ring net small and medium pelagic fisheries resources.

Key words: Ring net, Catch-Per-Unit-Effort, Catch composition, Growth, mortality, Kenya

1.0 Introduction

The small and medium pelagic fishery in Kenya is multi-species, multi-gear and multi-fleet. Fishing gear used include: cast nets, gill nets, beach and reef seines, hook and line vertical line, long line and trolling line, and more recently the use of ring nets (Government of Kenya, 2012, 2014). Ring net is a surrounding gear similar to a purse seine net. It floats on the surface by a cork line strung with cork floats, and is hung vertically in the water column by a heavily weighted lead line. Like the purse seine, ring net has purse rings along its lower edge (Samoilys et al., 2011). When the use of ring nets became rampant in the Kenya coastal waters, the legal framework (Fisheries Act Cap 378, Rev. 2012) did not have any clauses or regulations governing the use of ring nets in Kenya (Pers. comm.). The use of this gear could cause a management challenge and though no scientific assessment was conducted in the use of this gear, the State Department of Fisheries (SDF) considered it a suitable and acceptable gear without any further statutory action.

Ring nets which are relatively affordable were therefore, allowed and perceived to be the suitable gear for targeting surface dwelling and migratory pelagic fish species of high commercial value and this was, expected to reduce pressure on the artisanal-dominated reef fisheries while enhancing the economic benefits to the fisher communities.

Unlike other fishing gear which target small and medium pelagic, the use of ring net has been associated with conflicts due to its perceived environmental and socio-economic concerns in addition to landing unknown catch composition (Maina et al., 2013). Preliminary research findings indicate that the gear catches demersal species on outer reef slopes and small pelagic sprat, sardine and anchovy in bays and deep lagoons when in season in addition to dominant fish families of Carangidae, Scombridae and Sphyraenidae (Okemwa et al. 2009, Munga et al. 2010, Samoilys et al. 2011). Thus the fishery has various gaps in scientific information, as it is characterized by various conflicts, necessitating the need for formulation of a management plan.

This study therefore, sets out to collect preliminary scientific information to feed into the draft final Ring Net Management Plan and hence addresses some or most of the existing conflicts. In order to achieve this, 12 months (Febraury to December 2014, and January 2015) was set aside to conduct shore-based catch assessment in addition to implementation of the ring net observer program in order to obtain more data and information on the small and medium pelagics.

1.1 Broad objective of the study

The aim of this study was to conduct a baseline study for the ring net fishery to support the fishery management plan to be in line with Ecosystem Approach to Fisheries as recommended by the FAO. The specific objectives of this study are:

i. to determine the spatial and seasonal abundance, distribution patterns and composition of catch associated with ring net and seine net fishing gears; and
ii. to assess the stock status of the most abundant target fish species: Sphyraenidae (*Sphyraena jello, S. obtusata* and *S. flavicauda*); Scombridae (*Rastrelliger kanagurta*); and Hemiramphidae (*Hemiramphus far*).

1.2 Rationale of the study

So far, no comprehensive study is available on the composition and stock status of the small and medium pelagic fishery, and therefore the inability to formulate any concrete management regulations and bench marks to manage the fishery. The current information available on ring net gear is based on short term exploratory assessments and there is a complete lack of biological and stock status information of key target and commercial species. A draft final ring net fishery management plan, and small and medium pelagic management strategy have been concluded awaiting gazzettement all geared towards sustainable utilisation of the small and medium fisheries resources. The ring net draft final management plan lacks adequate scientific information to guarantee an Ecosystem Approach to Fisheries (EAF) management, and so is the small and medium pelagic management strategy. The Kenya Coastal Development Project (KCDP), under Component 1, has provided the support to carry out a comprehensive study on the small and medium pelagic species so as to fill up this missing gap. This study therefore, directly contributes to the KCDP Project Development Objective (PDO) of improving management effectiveness and enhancement of revenue generation from Kenya's coastal and marine resources. It also aims at implementing Global Environment Objective (GEO) of strengthening conservation and utilization of coastal and marine biodiversity.

2.0 Materials and methods

2.1 The study area

The study area is along the Kenyan coast where ring net and reef seine fishing are practiced (Fig. 1). Specifically this study was conducted in Vanga area (Mijira, Mwamba-mkuu, Mwezi, Sii and Bunju fishing grounds), and Gazi, south coast Kenya; Takaungu and Kilifi (Bofa and Kwa-ngala fishing grounds); and Uyombo (Sansuri fishing ground) in north coast Kenya (Fig. 1(b)). In these fishing areas, except Takaungu and Uyombo, ring net fishing is conducted throughout the year, as fishing grounds in these areas are not affected by the seasons since they are sheltered from the open sea.

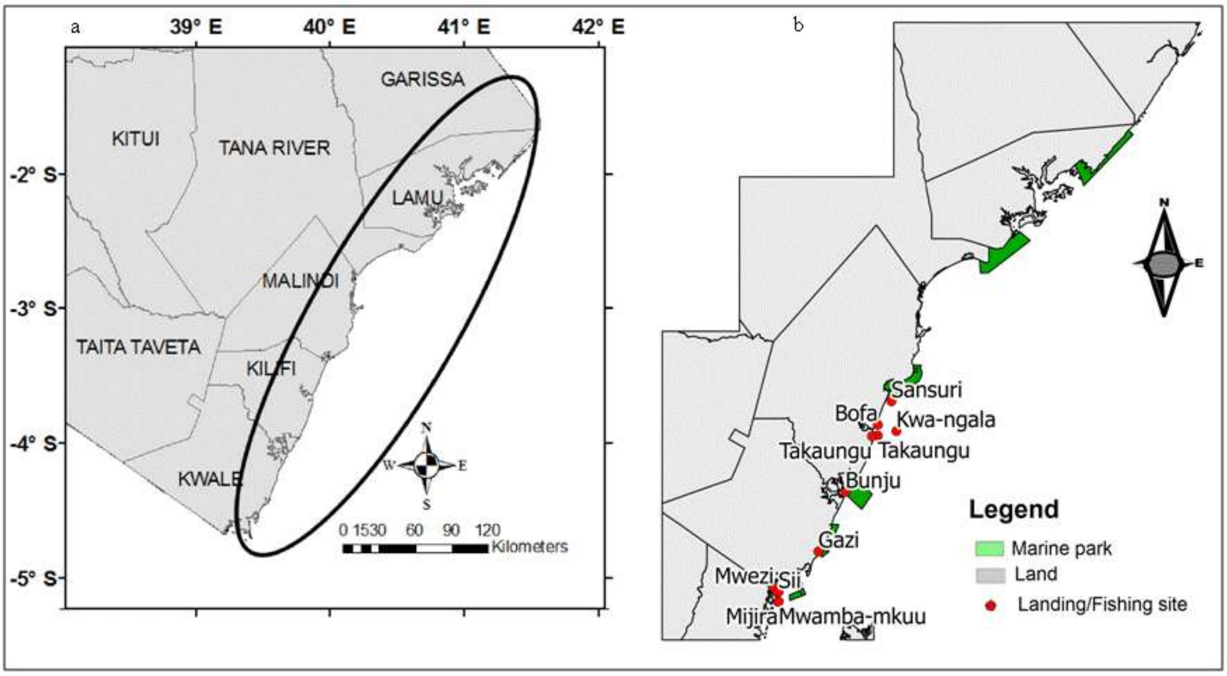

Figure 1. A map showing the entire Kenya coast (a) and ring net and reef seine fishing grounds (b) reported in this study.

2.2 Data collection

Before the actual data collection, stakeholders' consultative meetings were conducted in Vanga, Gazi, Takaungu and Kilifi to gain stakeholder support for the research activity. These consultative meetings involved ring net boat owners, fishermen, respective Beach Management Units (BMUs) representatives, fish dealers and staff from the State Department of Fisheries (SDF). The discussions involved a brief introduction of the Kenya Coastal Development Project (KCDP) fisheries components on Monitoring Control and Surveillance (MCS), co-management, fisheries research, aquaculture and quality assurance. The discussions concentrated on the fisheries research in particular stock assessment of small and medium pelagic where until now more data and information are still needed for the completed draft final ring net management plan, and the small and medium pelagic management strategy. The discussions were followed by in-depth description of the shore-based catch assessment activity that would be conducted by different research teams, one based in south coast and another in the north coast covering initially a total of four fish landing sites. Researchers would conduct their work from the shore where sampling of the catch would be carried out using catch assessment data forms. Detailed biological sampling would be conducted for certain identified priority fish species. The implementation of the ring net observer program would involve boarding of the ring net boats by trained members of the research team so as to ascertain the exact fishing grounds and to record as much information on the fishing activities while at sea. While in the meetings in the different areas, ring net stakeholders were informed that the aim of deploying ring net observers was not to impose restrictions on their fishing activities and therefore fishers were not expected to fear the onboard observers. After the explanation on the entire research activity, members in all the initial four fishing areas expressed their views on the activity and asked questions for clarification, as well as pledging support for the activity.

The study was carried out for 6 months (February, March, April, May, June and December 2014) by shore-based catch assessment and 2 months observer activity (February and March 2015). In order to understand characteristics of the ring net and reef seine, interviews for fishers were conducted. The actual sampling involved shore-based random assessment of artisanal catches for all boats targeting small and medium pelagics at Vanga, Gazi, Takaungu, Kilifi areas and Uyombo area further to the north coast of Kenya. Before enumeration of catch data, details such as boat type, crew size (number), fishing ground names, fishing duration (hours) and total catch (kg) were recorded. A representative proportion of the catch was taken as a sub-sample and then separated into different species, weighed and individual fish total length (cm) taken. Species identification was done using available keys (van der Est, 1981; Smith and Heemstra, 1986; Lieske and Myers, 1994). The individual fish total length was measured to the nearest cm using a fish measuring board.

2.3 Data analyses

2.3.1 Catch-Per-Unit-Effort

The nominal catch-per-unit effort (CPUE) by fishing area was calculated based on daily catches divided by the number of fishers and number of fishing hours and expressed as kg fisher^{-1} hr^{-1} (Munga et al., 2014), and total fish catches by gear type divided by number of vessels for each day expressed as and kg vessel^{-1} hr^{-1}. The daily catches per vessel were used to determine the total annual fish landings based on the total number of fishing gears from the marine fishery frame survey of 2014 (Government of Kenya, 2014), and total number of fishing days in a year. Total catches of the most abundant and target fish species were calculated from totals of all catch assessments for the entire sampling period from a total of 31 ring nets and 89 reef seines (Government of Kenya, 2014) operating along the Kenya coast. Species proportions (relative abundance) were calculated from fish sub-samples taken during the catch assessment campaigns. These proportions were used to raise the individual fish species total catches by day, month (maximum of 20 fishing days), and by year (maximum of 10 fishing months). These annual total catches were used to estimate the spawning stock biomass for determination of stock status of the most abundant and target pelagic fish species.

2.3.2 Growth parameters

The von Bertalanffy (1938) growth parameters were determined for the most abundant medium pelagic species. The length frequencies of these specie were used for estimation of growth parameters (asymptotic length (L_∞) and curvature of growth (K)) using ELEFAN-I routine in FiSAT-II software and based on the von Bertalanffy Growth Formula (VBGF):

$$L_t = L_\infty \left(1 - e^{-K(t-t_0)}\right)$$

2.3.3 Mortality estimates

Length-Converted Catch-Curve was used to estimate total mortality coefficient (Z) using the parameters L_∞ and K as inputs as follows:

$$Ln\left(N_i / \Delta t_i\right) = a + b \bullet t_i$$

where N is the number of fish in length class i, Δt is the time required for the fish to grow through length class i, t is the age (or the relative age, computed with t_o = 0) corresponding to the mid-length of class i, and where b, with sign changed, is an estimate of total mortality coefficient (Z).

Following estimation of Z, the routine was used to estimate the natural mortality coefficient (M) using Pauly (1984a) empirical formula:

$$Ln(M) = -0.0152 - 0.279Ln(L_\infty) + 0.6543Ln(K) + 0.463Ln(T)$$

The current fishing mortality coefficient (F_{CURR}) was estimated as $F=Z\text{-}M$ while the current exploitation rate (E_{CURR}) was calculated as a ratio of F to Z (F/Z).

2.3.4 Selection analysis

Catch curve analysis was extended to the estimation of probabilities of capture and selection by backward projection of the number that would be expected if no selectivity had taken place (N'), using:

$$N_{i-1}' = N'_i \cdot e^{(Z\Delta t)}$$

where Δt is defined above and

$Z = (Z_i + Z_{i+1})/2,$

$Z_i = M + F_i,$

$F_{i-1} = F_i - X,$ and

$X = F$ / (no. of classes below $P_i +1$);

and P_i is the first length group with a probability of capture equal to 1.0, and whose lower limit is an estimate of L'. From these results, probabilities of capture by length were computed from the ratios of N_i/N'_i.

To estimate selection parameters, $L_{25\%}$, $L_{50\%}$, $L_{75\%}$ based on the logistic curve. It was assumed selection to be nearly symmetrical, the following logistic equation was used:

$$Ln((1/P_L)\text{-}1) = S1 - S2 \cdot L$$

where P_L is the probability of capture for length L, and

$L_{25} = (ln(3)\text{-}S1)/S2$

$L_{50} = S1/S2$

$L_{75} = (ln(3)+S1)/S2$

according to methods described by Pauly (1984a; 1984b: 1990).

2.3.5 Beverton and Holt Y/R and B/R analysis

The analysis of relative yield-per-recruit model was based on Beverton and Holt (1966) model, modified by Pauly and Soriano (1986) and assuming knife-edge selection. Relative yield-per-recruit (Y'/R) was computed from the equation:

$$Y'/R = EU^{M/K}\left(1-\frac{3U}{(1+m)}+\frac{3U^2}{(1+2m)}-\frac{U^3}{(1+3m)}\right)$$

where

$U = 1-(L_c/L_\infty)$
$m = (1-E)/(M/K) = (K/Z)$
$E=F/Z$

Relative biomass-per-recruit (B'/R) was estimated from the relationship

$B'/R = (Y'/R)/F,$

Reference exploitation rates; E_{MAX}, $E_{0.1}$ and $E_{0.5}$ were estimated by using the first derivative of this function. Plots of Y'/R vs E (=F/Z) and of B'/R vs E, from which E_{MSY} (exploitation rate which produces maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of relative yield-per-recruit is 1/10th of its value at E=0) and $E_{0.5}$ (value of E under which the stock has been reduced to 50% of its unexploited biomass) were estimated according to Beverton and Holt (1966), Pauly (1984a), Pauly and Soriano (1986) and Silvestre *et al*. (1991).

Four indicators were selected for comparison between the simulated population and the assessment model outputs. These were virgin biomass B_0, *MSY*, the ratio of current biomass B_{CURR} to B_{MSY}, and the ratio of current effort to optimum equilibrium effort E_{CURR} to E_{MSY}. In the assessment model results, B_0, was estimated as K while *MSY* was estimated by substituting B_{MSY}. In the data simulator, B_0, was a constant determined by the input parameters while *MSY*, B_{MSY} and E_{MSY} were constant for a given value of steepness.

Further yield scenario modeling carried out to measure the current state of the fishery relative to the associated reference points using the following indicator of stock status implemented in the Yield Model of MRAG Ltd (Branch et al., 2000):

i) B_{CURR} / B_{MSY}
ii) F_{CURR}/ F_{MSY}
iii) $Yield_{-per-}R/FishableB_o$ *(at* F_{CURR}*)*
iv) $Yield_{-per-}R/SSB_o$ *(at* F_{CURR}*)*
v) $Yield_{-per-}R/FishablehB_o$ *(at* F_{MSY}*)*
vi) $Yield_{-per-}R/SSB_o$ *(at* F_{MSY}*)*

Table 1 shows the parameters that were used as input to the yield model and their sources:

Table 1: Population parameters and Yield Analysis based on Biomass Estimates of selected most abundant pelagic fish species along the Kenya coast.

Parameter	*S. jello*	*S. obtusata*	*S. flavicauda*	*R. kanagurta*	*H. far*	Source/Method
von Bertalanffy growth parameter (L_∞)	51.6	60.7	38.4	42.2	48.00	This study
von Bertalanffy growth parameter (K)	0.45	0.64	0.40	0.39	0.28	This study
Length-Weight Parameters: Alpha (L-W)	0.0108	0.00413	0.00822	0.0041	0.0005	Froese and Pauly (2015)
Length-Weight Parameters: Beta (L-W)	2.884	3.131	3.083	3.304	3.576	Froese and Pauly (2015)
Natural mortality (M): Females and Males	0.88	1.06	0.88	0.85	0.66	This study
Size at massive maturity (L_{m50})	30.00	40.20	22.00	24.00	25.00	Froese and Pauly (2015)
Age at massive maturity (t_{m50})	1.94	1.70	2.13	2.16	2.63	Froese and Pauly (2015)
Size at first maturity (L_m)	25.00	30.00	19.2	19.90	19.30	Froese and Pauly (2015)
Age at first maturity (t_m)	1.47	1.07	1.73	1.64	1.84	Froese and Pauly (2015)
Age at first capture (t_c)	0.59	0.34	0.42	0.54	1.23	Froese and Pauly (2015)
Size at first capture (L_c)	12.00	12.00	6.00	8.00	14.00	This study
Spawning Season	All year	All year	All year	All year	All year	Froese and Pauly (2015)
Fishing Season	Jan-Dec	Jan-Dec	Jan-Dec	Jan- Dec	Jan-Dec	This study
Fishing mortality (F)	2.05	2.8 4	1.20	0.78	0.57	This study
Natural Mortality (M)	0.88	1.06	0.88	0.85	0.66	This study

2.3.6 Catch composition and species diversity

The multivariate non-metric multi-dimensional scaling (MDS) technique was used to identify if vessel-gear-area combinations differed in catch composition based on Bray-Curtis similarity using PRIMER v6 software (Clark and Warwick, 2001). The differences in catch composition were further tested using ANOSIM. SIMPER analysis identified which species mostly influenced the dissimilarity. The catch species diversity for vessel-gear combination by area was analysed using rarefaction curves which determined the expected number of species encountered in a given sample size of individuals landed. The size differences by species of fish individuals between fishing areas was tested using either parametric ANOVA test or non-parametric Kruskal-Wallis test where the conditions were appropriately met. All the univariate tests were conducted using STATISTICA v7 software.

3.0 Results

3.1 Characteristics of ring nets and reef seines

A total of 11 fishers using ring nets were interviewed, out of which 17 responses on mesh sizes were obtained (some fishers used a ring net with 2.0 inch mesh size). The 0.5 inch mesh size is the most used (approximately 59%) followed by the 1.0 inch mesh size at 24% (Table 2). A total of 11 fishers using reef seines were interviewed, out of which 15 responses on mesh sizes were obtained (some fishers used a reef seine with 2.0 inch mesh size). The 0.5, 1.0 and 2.0 inches mesh-sized reef seines were mostly used (80%) (Table 2). The ring nets recorded a smaller mesh range size of between 0.25 and 1.5 inches compared to reef seines of range size of between 0.5 and 2.5 inches. Ring net gear length ranged between 100 and 240 m and a depth range of between 16.6 and 40 m.

Table 2. Gear, mesh size ranges and vessel sizes associated with ring nets and reef seines.

		Mesh size ranges						Gear/vessel variables		
Mesh size	n	0.25	0.5	1.0	1.5	2.0	2.5	Mean gear length (m)	Mean gear depth (m)	Mean vessel length (m)
No. of ring nets	17	1	10	4	2	0	0	155 ± 34	25.6 ± 5	9.7 ± 1.2
No. of reef seines	15	0	4	4	2	4	1	-	-	-

3.1 Ring net fishing grounds

This was a six month shore-based catch assessment and a two month onboard observer of the small and medium pelagic fisheries resources targeting the ring net and reef seine nets. Table 3 shows the fishing areas and respective fishing grounds with coordinates where these fishing gears were deployed. A total of 32 fishing grounds were recorded for the ring nets and reef seines. Vanga had a total 13 fishing grounds, Gazi (7), Kilifi (8), Takaungu (3) and Uyombo (1). Geographical coordinates of a total of 6 fishing grounds for Vanga, 3 for Kilifi, and 1 for Uyombo were recorded during the onboard observer activity sessions.

Table 3. Ring net fishing areas and the respective fishing grounds and coordinates recorded during catch assessment and onboard observer activity (fishing grounds with a star* mark are bordering with Tanzanian waters)

Fishing area	Fishing ground	Southings	Eastings	Mean depth m
Vanga	Bunju*	04.04308^0	039.68665^0	Not recorded
	Mijira	04.75389^0	039.24929^0	Not recorded
	Mwamba-mkuu	04.75244^0	039.25410^0	Not recorded
	Mwezi*	04.66164^0	039.22351^0	Not recorded
	Minyaani*	04.69330^0	039.24306^0	Not recorded
	Mwarembo	Not recorded	Not recorded	Not recorded
	Sii	04.69039^0	039.25311^0	Not recorded
	Kitungamwe	Not recorded	Not recorded	Not recorded
	Mbayayi	Not recorded	Not recorded	Not recorded
	Moa	Not recorded	Not recorded	Not recorded
	Shimoni	Not recorded	Not recorded	Not recorded
	Jironi	Not recorded	Not recorded	Not recorded
	Mwakwarara	Not recorded	Not recorded	Not recorded
Gazi	Chale	Not recorded	Not recorded	Not recorded
	Doa	Not recorded	Not recorded	Not recorded
	Kinondo	Not recorded	Not recorded	Not recorded
	Mpunga	Not recorded	Not recorded	Not recorded
	Msangani	Not recorded	Not recorded	Not recorded
	Munje	Not recorded	Not recorded	Not recorded
	Funzi	Not recorded	Not recorded	Not recorded
Kilifi	Bofa	03.60844^0	039.89677^0	Not recorded
	Kwa-ngala	03.05530^0	039.68168^0	Not recorded
	Takaungu	03.67795^0	039.89651^0	12
	Matsangoni	Not recorded	Not recorded	Not recorded

	Shariani	Not recorded	Not recorded	Not recorded
	Mlangoni	Not recorded	Not recorded	Not recorded
	Kilifi Bay	Not recorded	Not recorded	Not recorded
	Tororo	Not recorded	Not recorded	21
Takaungu	Kilifi	Not recorded	Not recorded	Not recorded
	Kitangani	Not recorded	Not recorded	Not recorded
	Mkondoni	Not recorded	Not recorded	Not recorded
Uyombo	Sansuri	04.44935^0	039.14171^0	20

3.2 Ring net and reef seine catches from shore-based assessments

In Gazi between 1 and 13 vessels per day were recorded compared to between 1 and 4 vessels in Vanga and Kilifi, and at least 1 vessel in Takaungu and Uyombo per day. For the 2 months onboard observer activity, at least 1 ring net vessel was sampled in each day at Uyombo for the month of March 2015. Total fish landings differed according to area. Over the sampling period, Vanga recorded the highest total catch of 19,787 kg contributed mostly by the mashua-ring nets. This was followed by Kilifi with 11,292 kg mostly by reef seines. Total catches for Takaungu was the least at 1,937 kg. For Uyombo, a total of 4,545 kg was landed during a single catch assessment. However, the catch-per-unit-effort (CPUE) was highest for Uyombo (1.04 kg fisher^{-1}hr^{-1}) followed by Takaungu (0.07 kg fisher^{-1}hr^{-1}) and Kilifi (0.03 kg fisher^{-1}hr^{-1}). On the other hand, Vanga and Gazi recorded the lowest CPUE each at 0.02 kg fisher^{-1}hr^{-1}.

3.3 Estimated annual total catches of small and medium pelagics

The current number of ring nets in use along the Kenya coast is 31 (Government of Kenya, 2014) with an estimated CPUE of 55.1 ± 7.7 and 296.5 ± 38.3 kg vessel^{-1} day^{-1} for ring nets and reef seines respectively. Assuming a total of 20 days in a month with a total of 10 fishing months, gives an annual total catch estimate of between 1,600,840 and 2,075,760 kg from ring nets, and between 843,720 and 1,11, 840 kg for reef seines. The overall total annual catch of small and medium pelagic was estimated between 2,444,560 and 3,193,600 kg. With a current market value of Kenya Shillings 100 per kg of fish, this gives an estimated total market value for small and medium pelagics of between USD 2,355,067 and 3,076,686 annually. Total annual landings of the selected most abundant medium pelagic species of *Sphyraena jello, S.*

obtusata, S. flavicauda, Rastrelliger kanagurta and *Hemiramphus far* were calculated based on respective relative abundance from the daily total catches (Table 4).

Table 4. Annual total catches of the most abundant pelagic fish species estimated from shore-based catch assessment campaigns.

Species	Family	Proportion from ring nets (%)	Proportion from reef seines (%)	Annual total catch (kg)
Rastrelliger kanagurta	Scombridae	12.5	9.5	322,917
Sphyraena flavicauda	Sphyraenidae	13.5	3.5	282,502
Sphyraena jello	Sphyraenidae	3.5	12.0	181,950
Sphyraena obtusata	Sphyraenidae	3.5	3.5	98,649
Hemiramphus far	Hemiramphidae	-	7.0	68,601

3.4 Species composition

The overall number of fish species sampled in this study was 192 from a total of 15,150 individuals landed. A total of 102 species from 4,340 individuals was sampled from canoe-reef seines, 125 species from 10,467 individual sampled from mashua-ring nets (annexes 1 and 2). Twenty species with the most number of individuals sampled from mashua-ring nets (Fig. 3a) constituted seven medium pelagic species: *Sphyraena flavicauda, Rastrelliger kanagurta, Sphyraena obtusata, Sphyraena jello, Caranx armatus, Euthynus affinis and Rastrelliger brychysoma,* seven were small pelagic species: *Stolephorus delicatulus, Sardinella sp2, Harengula humeralis, Sardinella gibbosa, Sardinella neglecta* and *Decapterus macrosoma*, and the rest six were demersal-reef associated species. The most abundant species sampled from canoe-reef seines (Fig. 3b) composed of eight medium pelagic species: *Sphyraena jello, Rastrelliger kanagurta, Hemiramphus far, Sphyraena obtusata, sphyraena putnamiae, Sphyraena flavicauda, Chirocentrus dorab* and *Hemiramphus lutkel*. The species *Sardinella gibbosa* made up the only small pelagic species in this vessel-gear category, and the rest eleven species composed of demersal and reef associated species.

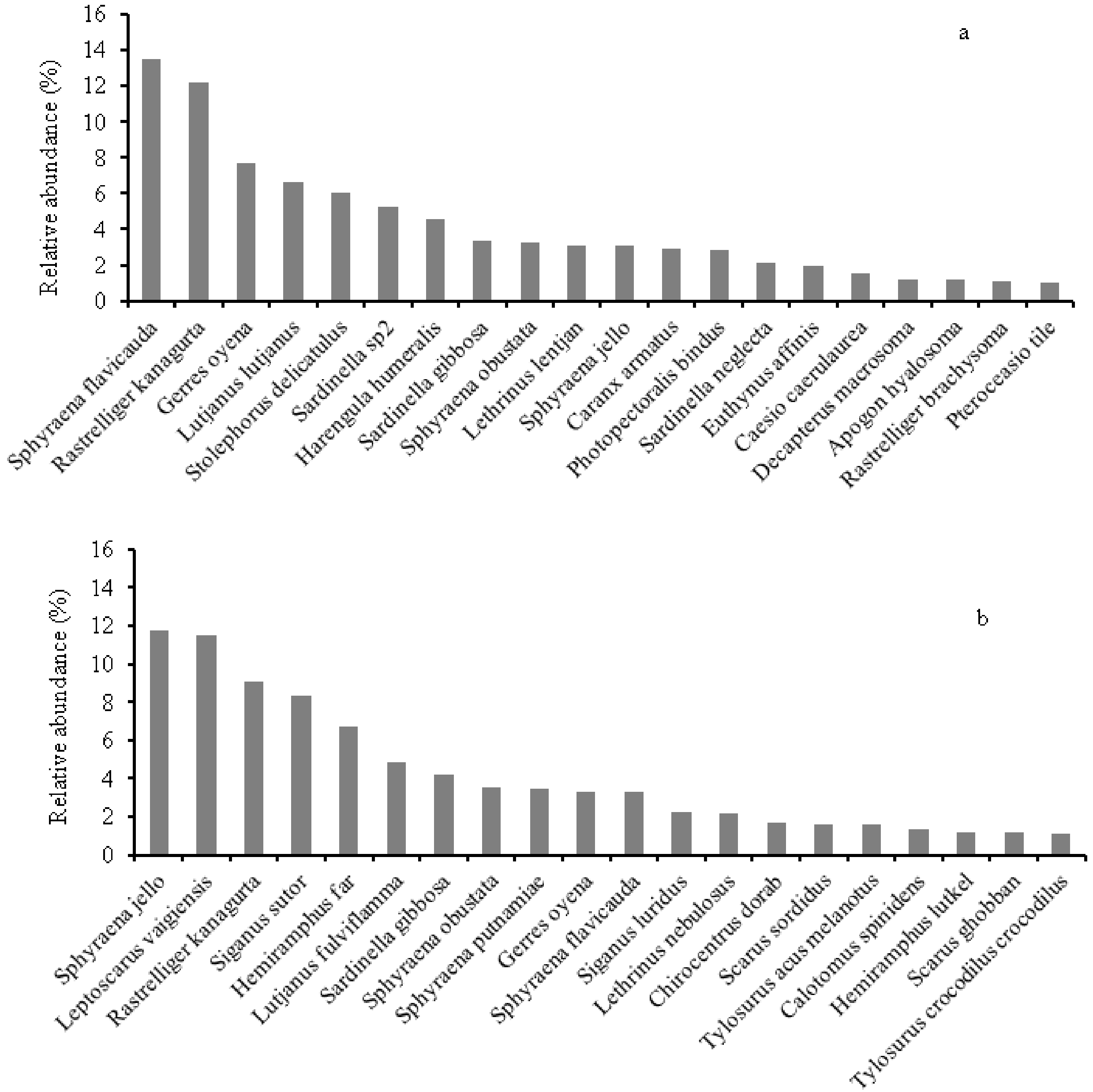

Figure 3. Top twenty most abundant species sampled from (a) mashua-ring net and (b) canoe-reef seine during the study period.

The MDS plot (Fig. 4) shows a distinct separation of catch composition between mashua-ring net and canoe-reef seine catches, and these also to some extent showed separation between fishing areas. Results of 1-Way ANOSIM indicates significant difference in catch composition between mashua-ring net and canoe-reef seine ($R = 0.572$; $p = 0.001$). The pair-wise comparison tests (Table 5) confirmed which vessel-gear combinations significantly differed in catch composition ($p = 0.001$ to 0.048).

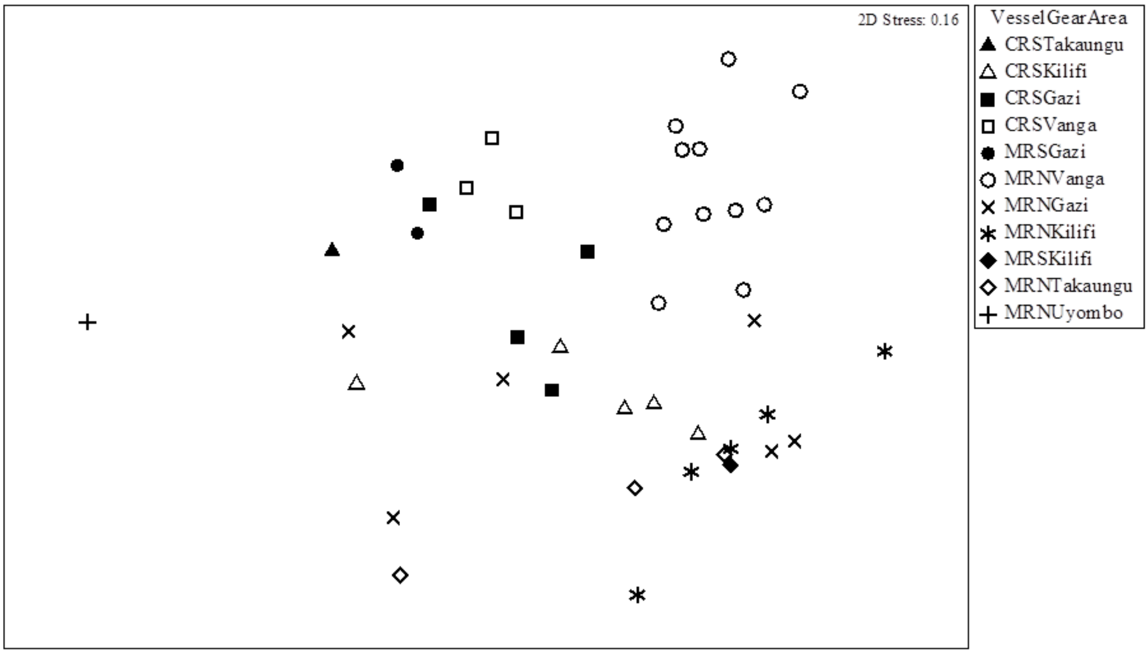

Figure 4. Non-metric MDS plot showing the composition of catch by gear-vessel-area combinations based on species abundance for the shore-based assessments during the study period. (CRS = Canoe-Reef Seine; MRN = Mashua-Ring Net).

Table 5. Results of pair-wise comparison tests showing significant differences in catch compositions between vessel-gear-area combinations from shore-based catch assessments during the study period. (CRS = Canoe-Reef Seine; MRN = Mashua-Ring Net).

Vessel-gear combinations	R statistic	p-value	Possible perm.	Actual perm.	Number ≥Observed
CRSKilifi, CRSVanga	0.662	0.036	56	56	2
CRSKilifi, MRNVanga	0.837	0.001	4368	999	0
CRSGazi, MRNVanga	0.765	0.003	1365	999	2
CRSGazi, MRNKilifi	0.619	0.008	126	126	1
CRSGazi, MRNTakaungu	0.491	0.029	35	35	1
CRSVanga, MRNVanga	0.856	0.003	364	364	1
CRSVanga, MRNGazi	0.296	0.048	84	84	4
CRSVanga, MRNKilifi	0.856	0.018	56	56	1
MRSGazi, MRNVanga	0.953	0.013	78	78	1
MRSGazi, MRNGazi	0.313	0.036	28	28	1
MRSGazi, MRNKilifi	0.964	0.048	21	21	1
MRNVanga, MRNGazi	0.636	0.001	12376	999	0
MRNVanga, MRNKilifi	0.824	0.001	4368	999	0
MRNVanga, MRNTakaungu	0.894	0.003	364	364	1

Results of 1-Way SIMPER (Table 6) shows the difference in catch composition between mashua-ring net and canoe-reef seine in Vanga was due to more abundant *Leptoscarus vaigiensis*, *Hemiramphus far, Sardinella gibbosa, Siganus sutor, Tylosurus acus melanotus*, *Chirocentrus dorab* and *Hemiramphus rutkel* in mashua-ring nets, and more abundant *Sphyraena flavicauda, Lutjanus lutjanus, Rastrelliger kanagurta, Harengula humeralis, Stolephorus delicatulus, Sardinella sp2* and *Lethrinus lentjan* in canoe-reef seines.

Table 6. One-Way SIMPER Analysis: Species contributing to the dissimilarity in terms of abundance (%) between canoe-reef seine *Vs* mashua-ring net in Vanga area (in bold). The average dissimilarity was 90 %

	Canoe-reef seine Vanga	Mashua-ring net Vanga		
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%
Sphyraena flavicauda	25.67	**125.36**	8.43	9.37
Leptoscarus vaigiensis	**84.00**	0.00	8.10	9.00
Hemiramphus far	**87.67**	0.00	8.04	8.93
Gerres oyena	41.67	69.27	5.95	6.61
Lutjanus lutjanus	2.00	**63.36**	4.20	4.66
Rastrelliger kanagurta	0.00	**52.91**	3.95	4.39
Sardinella gibbosa	**27.67**	4.09	3.41	3.78
Siganus sutor	**39.67**	1.27	3.39	3.77
Harengula humeralis	0.00	**43.18**	3.30	3.66
Stolephorus delicatulus	0.00	**57.45**	3.28	3.64
Sardinella sp2	0.00	**50.36**	2.95	3.28
Lethrinus lentjan	6.33	**29.64**	2.42	2.69
Tylosurus acus melanotus	**22.33**	0.00	2.19	2.43
Caranx armatus	9.67	27.64	2.05	2.28
Chirocentrus dorab	**24.67**	0.00	2.05	2.28
Hemiramphus lutkel	**17.00**	0.00	2.03	2.26
Photopectoralis bindus	0.00	**26.73**	1.90	2.11

Results of 1-Way SIMPER (Table 7) shows the difference in catch composition between canoe-reef seines and mashua-ring nets in Gazi was due to more abundant *Leptoscarus vaigiensis*, *Sphyraena putnamiae*, *Lutjanus fulviflamma* and *Siganus sutor* in canoe-seine nets.

Table 7. One-Way SIMPER Analysis: Species contributing to the dissimilarity in terms of abundance (%) between canoe-reef seines *Vs* mashua-ring net in Gazi area (in bold). The average dissimilarity was 83 %.

	Canoe-reef seine Gazi	Mashua-ring net Gazi		
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%
Leptoscarus vaigiensis	**47.00**	2.50	11.21	13.48
Sphyraena putnamiae	**24.50**	3.83	11.04	13.27
Sphyraena flavicauda	16.50	5.17	7.07	8.50
Lutjanus fulviflamma	**47.50**	0.00	6.57	7.90
Siganus sutor	**43.50**	0.17	6.54	7.86
Rastrelliger kanagurta	10.75	9.50	6.21	7.46

Results of 1-Way SIMPER (Table 8) shows the difference in catch composition between canoe-reef seines and mashua-ring nets in Kilifi represented by all fish species in bold.

Table 8. One-Way SIMPER Analysis: Species contributing to the dissimilarity in terms of abundance (%) between canoe-reef seines *Vs* mashua-ring net in Kilifi area (in bold). The average dissimilarity was 75 %.

	Canoe-reef seine Kilifi	Mashua-ring net Kilifi		
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%
Sphyraena jello	**100.40**	61.80	15.63	20.84
Sardinella gibbosa	19.80	**60.20**	11.88	15.84
Rastrelliger kanagurta	70.00	93.20	11.70	15.61
Sphyraena obtusata	29.40	55.20	8.84	11.78
Sardinella neglecta	0.00	**45.20**	5.60	7.47
Rastrelliger brachysoma	0.00	**23.20**	3.18	4.25
Pteroceasio tile	0.00	**20.40**	2.80	3.73
Lethrinus mahsena	7.00	0.00	2.01	2.68
Sphyraena putnamiae	**10.20**	0.40	1.78	2.37
Siganus luridus	**14.00**	0.00	1.63	2.18
Scarus sordidus	**8.40**	0.00	1.49	1.98
Siganus sutor	**13.60**	0.00	1.46	1.94

3.4 Species diversity by fishing vessel with gear and fishing area combinations

The highest species diversity of catch (Fig. 5) was recorded for canoe-reef seine in Vanga closely followed by canoe-reef seine and mashua-reef seine in Gazi. The lowest species diversities were associated with mashua-ring net in Gazi, and mashua-ring net in Kilifi. The use of mashua-ring net in Uyombo, the latest fishing area sampled also recorded relatively low species diversity. Catches from canoe-reef seines for Vanga and Gazi were the most diverse, landing highest expected number of fish species from 5 species in less than 20 individuals to more than 15 species in 140 of individuals landed. Catches from mashua-ring net for Gazi and Kilifi were the least diverse, landing less than 5 species in less than and more than 20 of individuals landed.

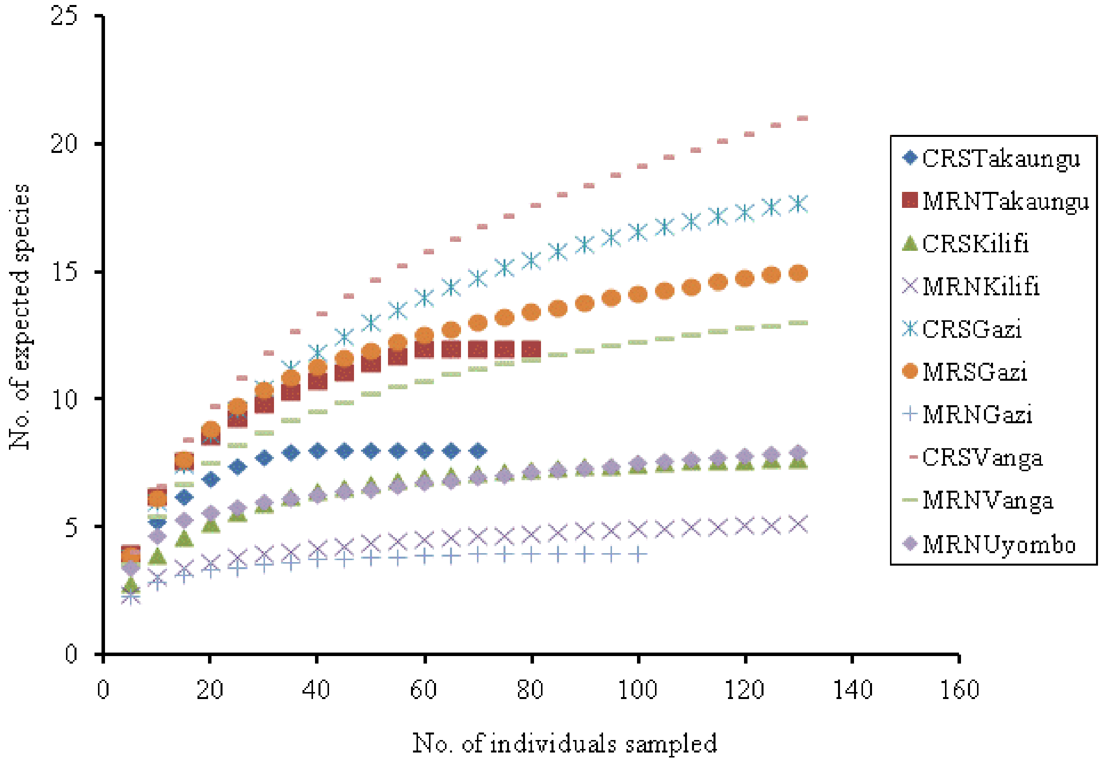

Figure 5. Rarefaction curves indicating the expected number of species caught in the different fishing areas with gear-vessel-season combinations over the sampling period. (CRS = Canoe-Reef Seine; MRN = Mashua-Ring Net).

3.5 Size frequencies of the most abundant fish species by vessel-gear combination

Sphyraena flavicauda individuals sampled from mashua-ring net ranged between 6.7 and 36 cm total length, and those sampled from canoe-reef seine ranged between 10 cm and 31 cm total length. Individuals from canoe-reef seine were significantly larger (21.5 ± 0.28 cm) than those from mashua-ring net (16.5 ± 0.08 cm; ANOVA: df = 1; f = 277.100; p = 0.000). Most of the individual sampled from mashua-ring net were in the range of between 10 and 20 cm, while majority of those sampled from canoe-reef seine ranged between15 and 25 cm (Table 9).

Samples of *Rastrelliger kanagurta* individuals from canoe-reef seine were significantly larger (20.72 ± 0.17 cm) than those sampled from mashua-ring net [18.16 ± 0.10 cm: Kruskal-Wallis: H (1, N = 1665) = 154.096; p = 0.000)]. The size range for samples from canoe-reef seine was between 12 and 30 cm compared to between 8 and 31 cm for mashua-ring net. Most of the individuals sampled from mashua-ring net measured between 14 and 18 cm, compared to 16 and 24 cm recorded for the canoe-reef seine.

In mashua-ring net sizes of *Sphyraena jello* ranged between 13.5 and 35 cm, and between 12.0 cm and 40 cm in canoe-reef seines. The canoe-reef seine individuals (24.2 ± 0.2 cm) were significantly large than the mashua-ring net individuals (23.0 ± 0.2 cm) as indicated by results of Kruskal-Wallis: H (1, N = 819) = 22.349; p = 0.000. Individuals of *Sphyraena obtusata* ranged in size between 12.1 and 37.0 cm in canoe-reef seine, and between 18.0 cm and 34.0 cm in mashua-ring nets. Samples from mashua-ring net were significantly larger (25.6 ± 0.3 cm) than those from canoe-reef seines (23.9 ± 0.3 cm) (ANOVA: df = 2; f = 18.330; p = 0.00002). *Hemiramphus far* was also abundant but only sampled in canoe-reef seine with a size range of between 15.0 and 40.0 cm, and a mean size of 27.0 ± 0.2 cm total length.

Comparison of representatives of most abundant demersal species of *Gerres oyena* and *Lethrinus lentjan* indicated significant differences in sizes of individuals between the vessel-gear combinations ($p < 0.05$). *Gerres oyena* were significantly larger in canoe-reef seines than in mashua-ring net; and *Lethrinus lentjan* were significantly larger in mashua-ring net than in canoes-reef seines ($p < 0.00$ both cases; Table 9). The rest of the abundant species measured less than 20 cm total length in either of the vessel-gear combination (Table 9).

Table 9. Comparison of sizes of other abundant commercial fish species by vessel-gear combination (NS = not significant at $p < 0.05$)

Species	Mashua-ring net	Canoe-reef seine	Df	F-statistic	p-value
Gerres oyena	13.4 ± 0.1	14.6 ± 0.12	1	31.403	0.000
Lethrinus lentjan	15.55 ± 0.18	14.12 ± 0.29	1	33.638	0.000
Caranx armatus	19.00	-	-		-
Siganus sutor	19.00	-	-		-
Lethrinus nebulosus	-	14.49 ± 0.43	-		-
Siganus sutor	-	17.91 ± 0.23	-		-
Caranx armatus	-	15.10 ± 0.13	-		-
Lutjanus lutjanus	-	12.43 ± 0.40	-		-
Sphyraena putnamiae	-	26.17 ± 0.49	-		-

3.6 Some aspects of stock status of the most abundant pelagic fish species

Sphyraena obtusata was the largest (L_∞ = 60.7; K = 0.64) in terms of growth among the small and medium pelagics while the smallest was *S. flavicauda* (L_∞ = 38.4; K = 0.4.) resulting in a growth performance index (Φ') of 3.373 and 2.771 respectively (Table 10). The natural mortality coefficient (0.66 to 1.06) within a narrow range whereas the fishing mortality coefficient varied considerably (0.57 to 2.84) between species. The fishing mortality coefficient was highest for the largest species (*S. sphyraena*, *S. obtusata*). The length at first capture recorded a narrow range (8.0 to 14.4 cm TL) but was highest for *S. obtusata* and *S. sphyraena* (14.0 and 12.0 respectively). All exploitation rates were within a narrow range of 0.427 and 0.470 for E_{MSY}, 0.340 to 0.369 for $E_{0.1}$ and 0.261 to 0.286 for E_{opt}.

Table 10. Population and exploitation parameters and biomass estimates of selected most abundant pelagic fish species targeted by ring nets and reef seines along the Kenya coast.

Exploitation parameter	*S. jello*	*S. obtusata*	*S. flavicauda*	*R. kanagurta*	*H. far*
von Bertalanffy growth parameter (L_∞)	51.6	60.7	38.40	42.2	48.0
von Bertalanffy growth parameter (K)	0.45	0.64	0.40	0.39	0.28
Total mortality coefficient (Z)	2.93	3.90	2.10	1.63	1.23
Natural mortality coefficient (M)	0.88	1.06	0.88	0.85	0.66
Fishing mortality coefficient (F)	2.05	2.84	1.20	0.78	0.57
Length at first capture (L_c)	12.0	14.40	8.00	8.00	8.00
Ratio of L_c/L_∞	0.23	0.23	0.21	0.19	0.17
Current exploitation rate (E_{CURR})	0.700	0.730	0.580	0.480	0.470
Exploitation rate at MSY (E_{MSY})	0.470	0.469	0.457	0.442	0.427
Exploitation rate tangent to yield curve at 10% of origin ($E_{F0.1}$)	0.355	0.354	0.369	0.359	0.354
Optimum exploitation rate (E_{opt})	0.281	0.286	0.274	0.269	0.261
Ratio of M/K	2.00	1.66	2.20	2.18	2.36
25% selection length ($L_{25\%}$)	20.40	20.10	12.40	14.40	22.70
50% selection length ($L_{50\%}$)	22.10	22.00	13.80	15.60	24.10
75% selection length ($L_{75\%}$)	23.70	23.90	15.20	16.80	25.50
Steady state biomass (annual catch)	182.0	98.70	282.50	322.90	68.60

3.7 The current stock status of selected pelagic fish species

Yield-per-Recruit analysis and Biomass-per-Recruit (fraction of unexploited biomass) analysis showed that the Maximu Sustainable Yield (MSY) for *Sphyraena jello* is attained at a fishing effort (F_{MSY}) of 1.1 (Fig. 6a). This effort yields 25% of the fishable biomass leaving behind 13% of the unexploited or virgin Spawning Stock Biomass (SSB/SSB_0). The current fishing effort ($F_{CURRENT}$ = 2.1) yields 23% of fishable biomass and a SSB/SSB_0 of 4% . Therefore, the virgin SSB (SSB_0) of *S. jello* in the Kenyan inshore waters is estimated at 1000 t from the current SSB ($SSB_{CURRENT}$) of 40 t. The fishing effort (F) that leaves the SSB above the threshold value (SSB_{LIMIT}) of 20% was 0.8 meaning SSB is a more preacutionary reference point compared to MSY.

MSY For *Sphyraena obtusata* is attained at a F of 0.8 yielding 23% of the fishable biomass and leaving behind 23% of SSB_0 (Fig. 6b). The $F_{CURRENT}$ of 2.8 yields a lower fishable biomass of 15% FB/FB_0 and is leaving behind SSB at only 1.8% of SSB_0. The $SSB_{CURRENT}$ of *S. obtusata* in the inshore waters was estimated at 49.3 t. Thus the virgin SSB is about ~2, 700 t. A fishing effort (F) not exceeding 0.8 is required to maintain SSB above the threshold value ($SSB_{LIMIT=20\%}$) which is in the same levels as $F_{MSY.}$

The $F_{CURRENT}$ of *Sphyraena flavicauda* estimated at 1.2 corresponds to 10.9% and 7% of unexploited levels of FB and SSB respectively (Table 11, Fig. 6c). MSY is attained at a lower F ($F_{MSY)}$ of 0.5 that results to an increase in FB and SSB to 14.5% and 27% of unexploited levels. The $SSB_{CURRENT}$ of *S. flavicauda* in inshore waters was estimated at 141.3 t hence the SSB_0 was about 2,019 t. A fishing effort (F) not exceeding 0.6 is required to maintain SSB above the threshold value ($SSB_{LIMIT=20\%}$) which is above $F_{MSY.}$ F_{MSY} is therefore a more precautionary reference point compared to SSB.

The $F_{CURRENT}$ of *Rastrelliger kanagurta* was estimated at 0.8 indicating that the current yield and SSB represents 16% and 14% of FB_0 and SSB_0 respectively (Fig. 6d). The SSB_0 of *R. kanagurta* in Kenyan inshore waters was estimated at ~1, 154 t from the $SSB_{CURRENT}$ of 161.5 t. MSY is attained at a lower fishing effort (F_{MSY}=0.6) which yields 17% of FB_0 and maintains 21% of SSB_0, just slightly above the SSB threshhold levels.

The $F_{CURRENT}$ of *Hemiramphus far* was estimated at 0.5 corresponding to 15% FB_0 and 26.7 % SSB_0 (Table 11, Fig. 6e). MSY is attained at a slightly higher F of 0.6 but results to a reduced proportion of 21.1% SSB_0 and little effect on yield (15.1% FB_0). The $SSB_{CURRENT,}$ estimated at 34.3 t (26.7 % SSB_0) in inshore waters leads to an estimated 128.5 t SSB_0 of *H. far* in the Kenyan inshore waters.

Results of the rate (%) at which $F_{CURRENT}$ exceeds above (+) or falls bellow (-) F_{MSY} indicate differential exploitation levels for the most commonly caught pelagic species in the inshore coastal waters are shown in Table 11.

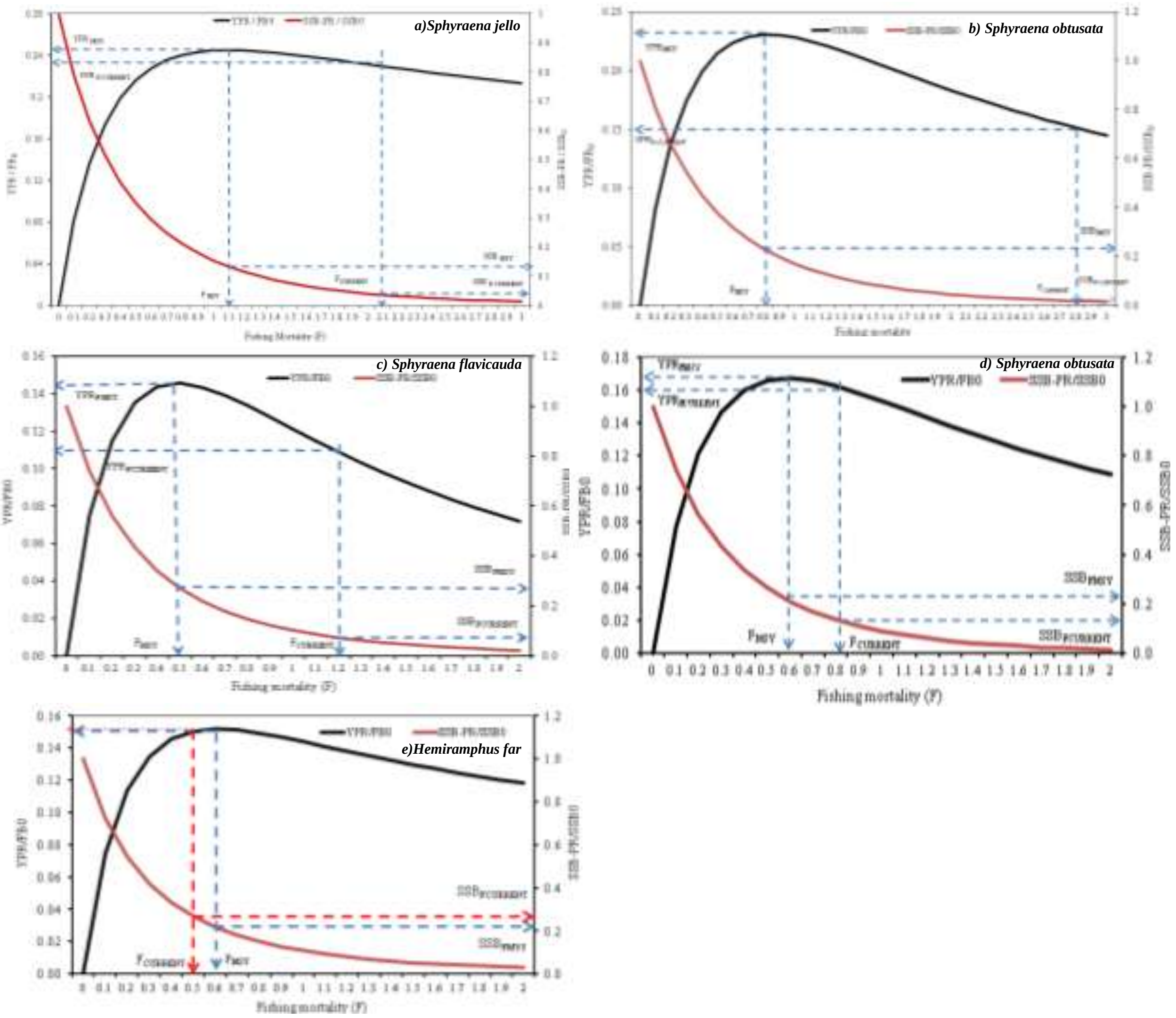

Figure 6: **The effect of changes in fishing mortality on Yield-per-Recruit and average Biomasses-per-Recruit (fraction of unexploited biomass) for a) *Sphyraena jello*, b) *Sphyraena obtusata*, c) *Sphyraena flavicauda, d) Rastrelliger kanagurta, and e) Hemiramphus far.***

Table 11. Some aspects of stock status of commonly caught pelagic species of inshore waters of the Kenyan coast. Rate (%) at which $F_{CURRENT}$ exceeds (+) or falls below (-) fishing effort that produces maximum sustainable yield (F_{MSY}).

Species	$F_{CURRENT}$	F_{MSY}	SSB/SSB_0 at $F_{CURRENT}$	SSB/SSB_0 at F_{MSY}	Stock status
S. jello	2.1	1.1	0.036	0.133	Higher fishing pressure (+91%)
S. obtusata	2.8	0.8	0.018	0.230	Higher fishing pressure (+250%)
S. flavicauda	0.8	0.6	0.137	0.211	High fishing pressure (+140%)
R. kanagurta	1.2	0.5	0.072	0.271	Overfishing (+33%))
H. far	0.5	0.6	0.262	0.217	Optimal fishing (-16.7%)

4.0 Discussion

The fishing areas of Vanga, Gazi, Takaungu, Kilifi and Uyombo were selected because they are important areas where small and medium pelagic species are targeted by both ring nets and reef seines (Government of Kenya, 2014). A total of 32 fishing grounds in the five fishing areas were recorded, with most of the fishing grounds located in Vanga in the south coast. The fishing grounds in Vanga were the most productive followed by those in Kilifi. Uyombo was equally relatively productive since higher landings were recorded compared to Gazi and Takaungu from a single catch assessment campaign. Although Vanga recorded the highest total landings, CPUE was the lowest and highest for Uyombo further north of Kenya coast. The low CPUE in Vanga was attributed to relatively higher number of fishers and fishing vessels compared to a single ring net vessel that was sampled in Uyombo. Vanga area is preferred in ring net fishing as the gear is easily operated in the sheltered fishing grounds. Vanga also is the home of most of the ring net fishers. The most abundant fish species landed by both ring nets and reef seines were somewhat similar in composition (Figs. 3a&b). Both fishing gears were associated with medium pelagics being the most abundant species as well as some species of small pelagic and a considerable number of demersal and reef associated species. This is an indication that although both gears target both small and medium pelagic, fishers have the tendency to capture other alternative demersal fish species to cover up for fuel expenses. High number of small pelagic among the 20 most abundant species were recorded in ring net landings compared to a single species (*Sardinella gibbosa*) recorded in reef seines. On the other hand, more demersal species were recorded in reef seine landings compared to the ring nets. Meanwhile, the mean ring net gear length did not conform to the proposed regulation of between 200 and 300 m long, but the mean width conforms to that of between 20 and 30 m proposed in the regulation.

The total annual fish landings from this current study was also compared with past recorded total annual landings obtained from Kenya Marine and Fisheries Research Institute (KMFRI, 2001 – 2008 unpublished data), and that reported from the Fisheries Annual Statistical Bulletin (Government of Kenya, 2010), and the final draft Ring Net Management Plan. Findings from these comparisons indicated higher current estimates of small and medium pelagic fisheries resources than all the previous estimates.

Catches were found to differ in composition depending on the vessel-gear-area combination (Fig. 4 and Table 5). This difference in catch composition was attributed to landing of different most abundant species by the different vessel-gear-area combinations.

Further, this difference in catch composition was attributed to accessibility to different fishing grounds. For example, the species *Sphyraena flavicauda* in Vanga was more abundantly landed by mashua-ring nets compared to canoe-reef seines (Table 6). The same species was landed slightly in similar abundances in Gazi by both mashua-ring nets and canoe-reef seines (Table 7).

The significant differences between gear-species combination could be due to more more abundant *Leptoscarus vaigiensis, Hemiramphus far, Sardinella gibbosa, Siganus sutor, Tylosurus acus melanotus, Chirocentrus dorab* and *Hemiramphus rutkel* in mashua-ring nets, and more abundant *Sphyraena flavicauda, Lutjanus lutjanus, Rastrelliger kanagurta, Harengula humeralis, Stolephorus delicatulus, Sardinella sp2* and *Lethrinus lentjan* in canoe-reef seines.

Species catch diversity was dependent on the fishing area and to some extent on vessel-gear combination as well. Vanga area was associated with the highest species diversity of catches especially with canoe-reef seines. This was attributed to availability of most fishing grounds that are sheltered from the open seas and are therefore more accessible compared to Takaungu and Kilifi areas with less number of fishing grounds that are more exposed with limited access to fishers especially during the rainy Southeast Monsoon (SEM) season.

Differences in catch composition for gear-site combination were due to more abundant *S. jello, S. putnamiae, S. luridus, S. sordidus* and *S. sutor* in canoe-seine nets, and more abundant *Sardinella gibbosa, Sardinella neglecta, Rastrelliger brachysoma* and *Pteroceasio tile* in mashua-ring nets as found out in this current study.

Length frequency analysis of the most abundantly landed small and medium pelagic species (*Sphyraena flavicauda, S. jello, S. obtusata* and *Rastrelliger kanagurta*) for both mashua-ring net and canoe-reef seines showed differences in sizes of individuals landed by the two vessel-gear combinations, suggesting that the different vessel-gear caught different sizes of individuals. This may be attributed to differences in fishing grounds accessed, as well as differences in mesh sizes of the fishing gears. The mashua-ring net landed larger numbers of both species but of smaller sizes compared to those landed by canoe-reef seines. Other species: *Gerres oyena* and *Lethrinus lentjan* both demersal species also showed size variations between the two vessel-gear combinations.

Based on the growth performance index, *S. obtusata* and *S. jello* exhibited better growth than the other abundant pelagics and hence they are likely to withstand high fishing pressure. Though they may be highly vulnerable, they are likely to be more resilient to fishing. In view of the narrow range of natural mortality coefficient, E_{MSY}, $E_{0.1}$ and E_{opt}, it could be indicative that size and growth rate do not influence natural death in the small and medium pelagics (Mace and Sissenwine, 1993).

The family Clupeidae (*Sardinella* sp, *Stolephorus delicatulus, Sardinella gibbosa* and *Harengula humeralis*) despite being pelagic are not listed as candidate ring net taxa according to the final draft Ring Net Fishery Management Plan. This means that majority of the species were not a target for the ring net, and therefore could be viewed as bycatch. These species included the demersal reef and reef-associated species. In addition to recording a high diversity of catch, majority of the demersal reef and reef-associated species were under-sized and juveniles. This may have an implication on future recruitment of fish stocks if this is allowed to continue.

The final draft Ring Net Fishery Management Plan has clearly stipulated all the candidate ring net pelagic species as a target. All ring net catches are expected to be dominated by the pelagic taxa and mostly the Carangidae (trevalies), Scombridae (tuna and mackerels), Sphyraenidae (barracudas), and Hemiramphidae. Even though these species were among those abundantly landed, the majority of taxa recorded were demersal species (see appendices 1and 2). This implies that either majority of the fishing grounds accessed were not appropriate for the ring net gear. The relatively lower catch-per-unit-effort (CPUE) was also directly related to the poor quality of the catch since most individuals were juveniles and under-sized, especially for the case of Vanga area. It was observed that, the bigger mashua-ring net vessels landed even smaller individuals in most instances than the smaller canoe-reef seines further raising more questions on the use of ring nets particularly in Vanga area.

Results of stock status indicated that four out of five most abundant pelagic fish species have been undergoing overfishing in the Kenya inshore waters with their $F_{CURRENT}$ exceeding fishing effort that produce maximum sustainable yield (F_{MSY}) by 30 - 250% (see Table 11). However, the current study only focussed on some inshore fishes (small fishes that are migratory with differences in biological vulnerabilities of growth and life spans) which could have accounted for a small proportion of the Kenyan coastal entire fishery. Additionally, the study herein only involved ring nets and reef nets, with room for more focus on other gears which could give more robust results. Thus the accuracy of these estimates could be assessed further and compared with a wider scope in the near future.

Sphyraena obtusata with an $F_{CURRENT}$ 250% higher than F_{MSY} is experiencing higher fishing pressure followed by *S. flavicauda* ($F_{CURRENT}$ = 140% F_{MSY}), and *S. jello* ($F_{CURRENT}$ =

$91\%F_{MSY)}$. *R. kanagurta* is under overfishing status while *H. far* is being expoited just below the optimum levels ($F_{CURRENT}$= 16.7% F_{MSY}).

The current SSB for all the species is below the threshold value (SSB_{LIMIT}) of 20% of virgin stock (SSB_0) except for *H. far* which recorded 26.7% of SSB_0 indicating occurrence of recruitment overfishing further confirmed by the big proportion catch falling below the L_{50} size classes (Fig. 6). SSB at less than the assumed 20% SSB_0 safe level would lead to collapse in the stock. Management strategies for these species should target to maintain SSB above 25% of the unexploited level (SSB_0) to ensure fisheries sustainability by availing suffiecient spawning stock. Reduction of the SSB to less than 20% of its unexploited level is often considered to be undesirable on stock conservation grounds (Sissenwine and Shepherd, 1987). Maintaining the level of F at below F_{MSY} is mostly recommended than at F_{MSY} for economic and ecological benefits. Adjusting fishing effort to slightly below F_{MSY} levels for the four overfished species would leave SSB/SSB_0 above threshold levels except for *S. jello* that would require further reduction of F to 0.8 to maintain SSB above threshold levels. The results from this analysis indicate F_{MSY} and SSB could be useful reference points for managing these species with SSB being a more precautionery reference point. Spawning stock biomass is and exploitable biomass have been used to assess the status of the stock. The parameters describing these fisheries should be re-evaluated annually when more information becomes available and upadte the 'Yield' software simulations run again to improve the management outputs.

5.0 Conclusion and Recommendations

The small and medium pelagic fisheries resources are targeted by both ring net and reef seine fishing gears. The contribution from these fishing gears in terms of annual total landings and economic value is significant and substantial to the Kenyan artisanal fishery sub-sector. Differences in terms of catch composition and CPUE between these fishing gear types exist, and these differences are dependent on the vessels used and fishing areas. The current study showed that species *S. jello* and *S. obtusata* are currently undergoing overfishing in the inshore waters as indicated by higher current fishing mortalities than that at Maximum Sustainable Yield (MSY). The current SSB of 40 t (*S. jello*) and 49.3 t (*S. obtusata*) are much lower than the recommended 20% of Steady State Biomass (SSB) of 1,000 t and 2,700 t respectively, which are supposed to be maintained. Thus it is recommended that the current fishing be reduced.

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Annex 1. Species list of mashua-ring net catches during study period

Number	Species	Number sampled	Relative abundance (%)
1	*Sphyraena flavicauda*	1410	13.47
2	*Rastrelliger kanagurta*	1273	12.16
3	*Gerres oyena*	802	7.66
4	*Lutjanus lutjanus*	697	6.66
5	*Stolephorus delicatulus*	632	6.04
6	*Sardinella sp2*	554	5.29
7	*Harengula humeralis*	475	4.54
8	*Sardinella gibbosa*	346	3.31
9	*Sphyraena obustata*	345	3.30
10	*Lethrinus lentjan*	326	3.11
11	*Sphyraena jello*	321	3.07
12	*Caranx armatus*	304	2.90
13	*Photopectoralis bindus*	294	2.81
14	*Sardinella neglecta*	226	2.16
15	*Euthynus affinis*	208	1.99
16	*Caesio caerulaurea*	156	1.49
17	*Decapterus macrosoma*	127	1.21
18	*Apogon hyalosoma*	123	1.18
19	*Rastrelliger brachysoma*	116	1.11
20	*Pteroceasio tile*	107	1.02
21	*Hyporhamphus affinis*	93	0.89
22	*Decapterus macarellus*	92	0.88
23	*Naso thynnoides*	85	0.81
24	*Pseudocaesio chrysozona*	83	0.79
25	*Harengula tragula*	76	0.73
26	*Tylosurus crocodilus crocodilus*	71	0.68
27	*Naso tuberosus*	70	0.67
28	*Sphyraena acutipinnis*	69	0.66
29	*Leiognathus lineolatus*	62	0.59
30	*Leiognathus minuta*	60	0.57
31	*Caranx melampygus*	58	0.55
32	*Sphyraena putnamiae*	42	0.40
33	*Harengular umeralis*	41	0.39
34	*Leiognathus berbis*	35	0.33
35	*Anchoviella commersoni*	31	0.30
36	*Scomberomorus plurilineatus*	30	0.29
37	*Apogon novemfasciatus*	29	0.28
38	*Chorinemus tol*	26	0.25
39	*Lutjanus fulviflamma*	26	0.25
40	*Scomberomorus leopardus*	26	0.25
41	*Scomberoides tol*	24	0.23
42	*Apogon nigripes*	23	0.22
43	*Siganus luridus*	17	0.16
44	*Siganus sutor*	17	0.16
45	*Dussumieria elopsoides*	16	0.15
46	*Mulloidichthys vanicolensis*	16	0.15
47	*Leptoscarus vaigiensis*	15	0.14
48	*Rhonsiscus stridens*	15	0.14

49	*Saurida gracilis*	15	0.14
50	*Caesio teres*	14	0.13
51	*Scolopsis bimaculatus*	14	0.13
52	*Secutor insidiator*	14	0.13
53	*Lutjanus russelli*	13	0.12
54	*Pelates quadrilineatus*	13	0.12
55	*Caranx ignobilis*	12	0.11
56	*Chirocentrus nundus*	12	0.11
57	*Leiognathus sp*	12	0.11
58	*Pterocaesio sp*	12	0.11
59	*Upeneus tragula*	12	0.11
60	*Amblygaster sirm*	11	0.11
61	*Hemiramphus dussumieri*	11	0.11
62	*Lethrinus sanguineus*	11	0.11
63	*Lethrinus nebulosus*	10	0.10
64	*Upeneus taeniopterus*	10	0.10
65	*Lenthrinus lentjan*	9	0.09
66	*Pterocaesio pisang*	9	0.09
67	*Xanthichthys lineopunctatus*	9	0.09
68	*Auxis thazard*	8	0.08
69	*Elagatis bipennulata*	7	0.07
70	*Monotaxis grandoculis*	6	0.06
71	*Pectoralis bindus*	6	0.06
72	*Pellona ditchela*	6	0.06
73	*Sardinella longiceps*	6	0.06
74	*Caesio tile*	5	0.05
75	*Chelio inermis*	5	0.05
76	*Gerres oyena*	5	0.05
77	*Loligo sp*	5	0.05
78	*Parexocoetus mento*	5	0.05
79	*Caesio xynodonta*	4	0.04
80	*Caranx speciosus*	4	0.04
81	*Platax orbicularis*	4	0.04
82	*Plectorhinchus gaterinus*	4	0.04
83	*Scomberomorous commersoni*	4	0.04
84	*Aluterus monoceros*	3	0.03
85	*Lethrinus elongatus*	3	0.03
86	*Lethrinus mahsena*	3	0.03
87	*Nemipterus sp.*	3	0.03
88	*Oxycheilinus bimaculatus*	3	0.03
89	*Parapeneus heptacanthus*	3	0.03
90	*Parupeneuse barberinus*	3	0.03
91	*Spratelloides delicatulus*	3	0.03
92	*Calotomus spinidens*	2	0.02
93	*Chanos chanos*	2	0.02
94	*Hypoatherina temminckii*	2	0.02
95	*Leiognathus (Karalla) daura*	2	0.02
96	*Myripristis murdjan*	2	0.02
97	*Nemipterus bipunctatus*	2	0.02
98	*Parupeneus macronema*	2	0.02
99	*Pomadasys maculatum*	2	0.02
100	*Pterocaesio marri*	2	0.02
101	*Rastrelliger faughni*	2	0.02

102	*Thalassoma hebraicum*	2	0.02
103	*Thalassoma lunare*	2	0.02
104	*Acanthurus dussumieri*	1	0.01
105	*Anampses melieagrides*	1	0.01
106	*Anampses twistii*	1	0.01
107	*Apogon sp*	1	0.01
108	*Aprion virescens*	1	0.01
109	*Caesio sp*	1	0.01
110	*Decapterus punctatus*	1	0.01
111	*Gerres filamentosus*	1	0.01
112	*Leiognathus elongatus*	1	0.01
113	*Lethrinus fulviflamma*	1	0.01
114	*Lethrinus miniatus*	1	0.01
115	*Parupeneus bifasciatus*	1	0.01
116	*Platex pinnatus*	1	0.01
117	*Pletorhinchus pictus*	1	0.01
118	*Pomadasys stridens*	1	0.01
119	*Pseudodax moluccanus*	1	0.01
120	*Saurida undosquamis*	1	0.01
121	*Scolopsis ghanam*	1	0.01
122	*Siganus canaliculatus*	1	0.01
123	*Siganus stellatus*	1	0.01
124	*Upeneus macronema*	1	0.01
125	*Upeneus sulphureus*	1	0.01
Total		10467	100

Annex 2. Species list of reef seine catches during the study period

Number	Species	Number sampled	Relative abundance (%)
1	*Sphyraena jello*	510	11.75
2	*Leptoscarus vaigiensis*	499	11.50
3	*Rastrelliger kanagurta*	393	9.06
4	*Siganus sutor*	363	8.36
5	*Hemiramphus far*	290	6.68
6	*Lutjanus fulviflamma*	209	4.82
7	*Sardinella gibbosa*	182	4.19
8	*Sphyraena obustata*	153	3.53
9	*Sphyraena putnamiae*	149	3.43
10	*Gerres oyena*	145	3.34
11	*Sphyraena flavicauda*	143	3.29
12	*Siganus luridus*	97	2.24
13	*Lethrinus nebulosus*	94	2.17
14	*Chirocentrus dorab*	74	1.71
15	*Scarus sordidus*	71	1.64
16	*Tylosurus acus melanotus*	68	1.57
17	*Calotomus spinidens*	59	1.36
18	*Hemiramphus lutkel*	51	1.18
19	*Scarus ghobban*	50	1.15
20	*Tylosurus crocodilus crocodilus*	47	1.08
21	*Lethrinus lentjan*	42	0.97

22	*Lethrinus mahsena*	39	0.90
23	*Lutjanus lutjanus*	32	0.74
24	*Dussumieria elopsoides*	29	0.67
25	*Caranx armatus*	29	0.67
26	*Hyporhamphus dussumieri*	27	0.62
27	*Upeneus tragula*	25	0.58
28	*Caesio tile*	25	0.58
29	*Lethrinus sanguineus*	24	0.55
30	*Chelio inermis*	23	0.53
31	*Plectorhinchus gaterinus*	22	0.51
32	*Lethrinus harak*	20	0.46
33	*Apogon nigripes*	20	0.46
34	*Abudefduf sexfasciatus*	20	0.46
35	*Saurida gracilis*	18	0.41
36	*Parupeneus macronema*	18	0.41
37	*Euthynus affinis*	16	0.37
38	*Siganus canaliculatus*	15	0.35
39	*Lutjanus sanguineus*	14	0.32
40	*Pomadasys furcatus*	13	0.30
41	*Mulloidichthys vanicolensis*	13	0.30
42	*Caranx ignobilis*	12	0.28
43	*Siganus stellatus*	11	0.25
44	*Caesio caerulaurea*	10	0.23
45	*Scomberomorus plurilineatus*	9	0.21
46	*Thalassoma hebraicum*	8	0.18
47	*Pelates quadrilineatus*	8	0.18
48	*Parupeneuse barberinus*	8	0.18
49	*Lethrinus elongatus*	8	0.18
50	*Hyporhamphus affinis*	8	0.18
51	*Gerres oyena*	7	0.16
52	*Upeneus barberinus*	6	0.14
53	*Parupeneus forskali*	6	0.14
54	*Acanthocybium solandri*	6	0.14
55	*Scolopsis bimaculatus*	5	0.12
56	*Plectorhinchus schotaf*	5	0.12
57	*Lethrinus miniatus*	5	0.12
58	*Trachinotus blochi*	4	0.09
59	*Scomberomorus leopardus*	4	0.09
60	*Plectorhinchus flavomaculatus*	4	0.09
61	*Upeneus macronema*	3	0.07
62	*Thunnus albacares*	3	0.07
63	*Strongylura leiura*	3	0.07
64	*Scolopsis ghanam*	3	0.07
65	*Rhynchobatus djiddensis*	3	0.07
66	*Novaculichthys taeniourus*	3	0.07
67	*Amblygobius phalaena*	3	0.07
68	*Acanthurus triostegatus*	3	0.07
69	*Trachinocephalus myops*	2	0.05
70	*Silago sihama*	2	0.05
71	*Scomberoides tol*	2	0.05
72	*Scarus caudofasciatus*	2	0.05
73	*Priacanthus hamrur*	2	0.05
74	*Parupeneus indicus*	2	0.05

75	*Parupeneus bifasciatus*	2	0.05
76	*Naso brevirostris*	2	0.05
77	*Lutjanus russelli*	2	0.05
78	*Lethrinus olivaceus*	2	0.05
79	*Lethrinus borbonicus*	2	0.05
80	*Leptoscarus variagatus*	2	0.05
81	*Hypoatherina temminckii*	2	0.05
82	*Diagramma pictum*	2	0.05
83	*Cociella crocodilus*	2	0.05
84	*Anampses caeruleopunctatus*	2	0.05
85	*Acanthurus sp*	2	0.05
86	*Upeneus vittatus*	1	0.02
87	*Synodus gracilis*	1	0.02
88	*Siganus sordidus*	1	0.02
89	*Scomberoides commersonianus*	1	0.02
90	*Pteroceasio tile*	1	0.02
91	*Pletorhinchus pictus*	1	0.02
92	*Plectorhinchus sordidus*	1	0.02
93	*Parupeneuse heptacathus*	1	0.02
94	*parupeneus barberinus*	1	0.02
95	*Loligo sp*	1	0.02
96	*Lethrinus bohar*	1	0.02
97	*Kyphosus cinerascens*	1	0.02
98	*Istiophorus platypterus*	1	0.02
99	*Equulites elongatus*	1	0.02
100	*Dascyllus trimaculatus*	1	0.02
101	*Caesio teres*	1	0.02
102	*Acanthurus dussumieri*	1	0.02
Total		4340	100