Original Article

Retained fish catches of artisanal fishers is dependent on fishing area, season and fishing gear type: A case study from the south coast of Kenya

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Western Indian Ocean JOURNAL OF Marine Science

Citation:
Mwakaribu A, Munga C, Dzoga M, Njihia P, Mulala D (2022) Retained fish catches of artisanal fishers is dependent on fishing area, season and fishing gear type: A case study from the south coast of Kenya. WIO J Mar Sci 21(2): 11-23 [doi: 10.4314/wiojms.v21i2.2]

Received:
January 29, 2022

Accepted:
September 30, 2022

Published:
February 27, 2023

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Abstract

The artisanal fishery is one of the sources of livelihood along the Kenya coast. Catches of retained fish of artisanal fishers between two fishing areas on the south coast of Kenya were compared. Artisanal fishers usually retain a portion of their daily catch which is reserved for family consumption while the rest is traded for cash to meet other family needs. This study hypothesized that retained fish catches were influenced by fishing area, fishing gear type and season. Daily fish landings and retained fish catches among artisanal fishers were monitored between August 2020 to July 2021 covering the South East Monsoon (SEM) and North East Monsoon (NEM) in Msambweni and Vanga fishing areas. A total of 60 fishers (30 for each area) were randomly selected and their retained catch monitored on a daily basis. The overall total fish landings were 23.3 tons and 210 tons in Msambweni and Vanga, respectively. The mean catch rate at Msambweni was 3.3 ± 0.12 kg.fisher^{-1}day^{-1} in the NEM season and 2.2 ± 0.09 kg.fisher^{-1}day^{-1} in the SEM season. Fish catch rates in Vanga was 8.5 ± 0.28 kg.fisher^{-1}day^{-1} in the NEM season and 7.9 ± 0.29 kg.fisher^{-1}day^{-1} in the SEM season. A total of 0.98 tons (only 4.2 %) of fish was retained *versus* 22.32 tons (95.8 %) not retained by the artisanal fishers in Msambweni, while in Vanga a total of 1.64 tons (only 0.78 %) was retained *versus* 208.36 tons (99.22 %) not retained. Retained fish catch varied significantly with season and type of fishing gear used ($p < 0.05$). Among the retained species in Msambweni, *Siganus sutor* made the highest contribution (53 %), followed by *Lethrinus mahsena*, (5.08 %). The species *Euthynnus affinis* and *Sphyraena obtusata* were mostly retained in Vanga with a contribution of 10.4 % and 10.2 %, respectively. The same retained fish species represented the most abundant species in the overall fish landings, however sizes were significantly smaller than those not retained by fishers ($p < 0.05$). Results of non-Metric Multidimensional Scaling (nMDS) ordination showed differences in species composition between fishing areas, seasons and fishing gear types with implication on fishers' retained catches.

Keywords: artisanal fisheries, food security, south coast of Kenya

Introduction

Studies by Fraval *et al.* (2019) indicate that one out of four people in sub-Saharan Africa is estimated to be undernourished as a result of food insecurity. Fish has been singled out to play a distinct important role in global food and nutrition security accounting for the most consumed source of animal protein and other nutrients in many low and middle-income countries (Reksten *et al*., 2020). According to FAO (2020), approximately 3.3 billion people across the world rely on fish for an integral part of their animal protein. Further, FAO (2020) indicated that fish is a fundamental source of animal protein for several African and Asian countries.

Coastal and marine artisanal fisheries play a significant role in supporting human wellbeing as well as maintaining food security (Schuhbauer and Sumaila, 2016). The sub-sector forms a critical source of food and income for many regions, especially developing nations (Lancker *et al*., 2019). Globally, artisanal fisheries contribute to nearly 50 % of the total capture fisheries production which provide the world's rapidly expanding population with a vital food source (Bennet *et al*., 2018). In Africa, coastal and marine artisanal fisheries provide about 19 % of the essential animal protein to local households and provide up to 80 % of household income which makes it a potential reducer of food insecurity and starvation (Samoilys *et al*., 2017; Chan *et al*., 2019). The marine fishery in Kenya is primarily artisanal (Kamau *et al*., 2021) characterized by low capital investment, the use of low technology, making short near shore fishing trips, and is normally undertaken by local individual household fishers (Monaco *et al*., 2017). Artisanal fisheries can be subsistence providing for local consumption of fisher households or commercial when it involves selling of fish for money (Batista *et al*., 2014). About 90 % of the small-scale fish landings along the coast is traded and consumed locally (FAO, 2020).

In Kenya where increasing population has increased the demand for food (Ogello and Munguti, 2016), about 1.3 million people face food insecurity and poor nutrition (USAID, 2020). Fish contributes to more than half of the total animal protein intake in Kenya (Aloo *et al.,* 2014). Along the Kenyan coast, more than 200,000 people meet their livelihoods through fishing and trading in fish and fish products (Matsue *et al*., 2014). On the south coast of Kenya, in particular, artisanal fisheries make a vital contribution to local community livelihoods. Fish is considered as the most readily available and affordable source of animal protein for the local communities (Aloo *et al*., 2014) but the contribution of small-scale fisheries towards food provision and improvement of livelihoods has been rarely considered (Obiero *et al*., 2019). Additionally, fishing households arguably consume more fish compared to non-fishing households (Bruyn *et al*., 2021). This study therefore, aimed to assess the composition of retained fish catches in selected fishing areas on the south coast of Kenya. The study hypothesized that retained catches of artisanal fishers is dependent on fishing areas, fishing gear types and seasons.

Materials and methods

Study area

This study was conducted in Msambweni and Vanga fishing areas on the south coast of Kenya. Msambweni is located more than 50 km from the city of Mombasa, situated at S 04046'53", E 039048'13" and Vanga further south at the border with Tanzania situated at S 04039'37", E 039013'11" (Ogongo *et al*., 2015; Fig. 1). Both sites started as small fishing villages but have been developing rapidly over time, characterized by improved infrastructure and increasing population. The sites are among the most active fishing areas in Kenya where the artisanal fishery is considered a major source of livelihood (Agembe *et al*., 2010). Fishing grounds in these areas have been reported to be rich in biological diversity and provide vital a food source and boosts the economy and wellbeing of the local fishing communities (KCDP, 2016). Fishing activities mainly occur within nearshore reef lagoons characterised by artisanal multi-gear and multi-fleet operators targeting and landing multiple species (Agembe *et al*., 2010), and are highly influenced by the warm north east monsoon (NEM) and cool south east monsoon (SEM) seasons.

Data Collection

Shore-based catch assessment for retained catches

A total of 60 fishers representing 60 fisher households (30 from each fishing area) were randomly selected through the assistance of respective beach management unit (BMU) representatives. Fishers were selected using a stratified sampling technique to represent the key fishing gears used at each fishing area. A total of four and six different fishing gear types were selected for this study in Msambweni and Vanga, respectively (Table 1). The details of each fisher household recorded included household size, age of the fisher and fishing experience.

Daily fish landings by weight and taxa were recorded for Msambweni and Vanga during the entire study period covering the SEM and NEM seasons. Shore-based catch assessment from the selected fishers were conducted by resident trained field assistants at the fish landing sites between August 2020 to July 2021. Recorded data included total weight of catch per fisher per day and catch retained, species composition and

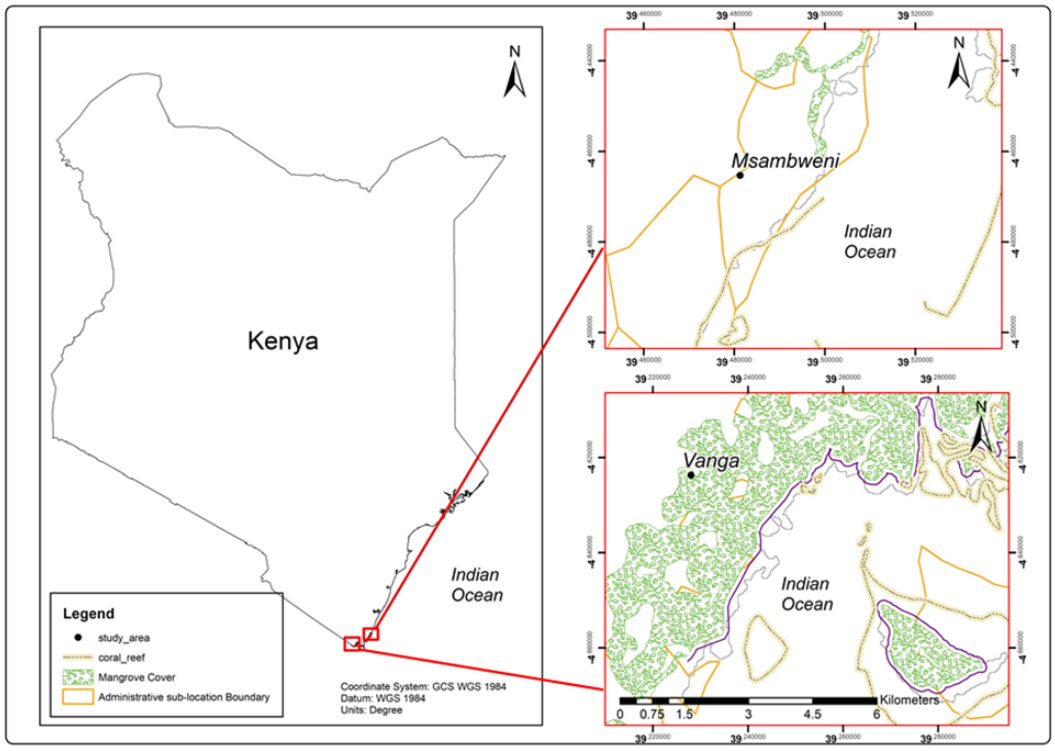

Figure 1. Location of Msambweni and Vanga fishing areas, south coast of Kenya, where retained fish for household consumption was monitored over the study period.

individual fish weight (g), and total length (TL, cm) measured using a graduated fish measuring board. Retained catches were entirely sampled for species composition since these represented smaller portions of the total catch per fisher.

Data and statistical analyses

Overall artisanal fish landings and fishing effort

The overall total fish landings were analysed for trends in relative abundance by taxa over time. The daily catch from the selected fishers was analysed for catch rate (kg.fisher^{-1}day^{-1}) by gear type, fishing area and season. Catch rate was calculated using the following formula (Samoilys *et al.*, 2017):

$$\text{Catch Rate} = \frac{\text{Mean total catch (kg) per day}}{\text{Mean fisher crew per day}} \quad \text{..... (i)}$$

To meet the requirements for the parametric ANOVA test, homoscedasticity of variance of means of the actual catch rate data was first confirmed using the Levene's test at $p > 0.05$. When this requirement was not fulfilled, data was log-transformed. If data still did not meet the ANOVA requirements even after transformation, the alternate non-parametric Kruskal-Wallis test was used. All tests were conducted using STATISTICA statistical software version 7 and significant differences were set at $p < 0.05$.

Fish species composition

Data from overall fish landings and retained fish catches from the 60 fishers was analysed for species composition. The multivariate non-Metric Multi-dimensional Scaling (nMDS) technique was used to identify if there was distinct species composition across fishing areas with seasons combined based on Bray-Curtis similarity using Primer statistical software version 6 (Clark *et al.*, 2014). The spatio-temporal differences in species composition were further analysed by 1-way Analysis of Similarity (ANOSIM) with combined fishing area-season as a factor where when *R* statistic approached 1, the differences in species composition was significant at $p < 0.05$.

Table 1. Number of fishers and household sizes surveyed by fishing area and gear type over the study period.

Fishing area	Gear type	Number of fishers	Mean household size	Total dependants
Msambweni	Basket traps	13	7	96
	Hand lines	13	6	79
	Gill nets	2	7	13
	Spear guns	2	6	12
Vanga	Ring nets	10	7	72
	Reef seines	11	7	80
	Spear guns	5	10	50
	Hand lines	2	7	13
	Gill nets	1	7	7
	Beach seines	1	13	13

One-way Similarity Percentage (SIMPER) analysis identified which fish species were most influential to the dissimilarity.

Results

Monthly total fish landings by fishing area and fishing gear

Basket trap and hand line fishers were the majority in Msambweni while ring net and reef seine fishers were the majority in Vanga. Despite being illegal, spear guns and beach seines were still in use with spear gun observed in both areas and beach seine in Vanga. Mean household size of selected fishers ranged between six and 13 members. The largest mean household size was 13 recorded for beach seine fishers in Vanga closely followed by an average household of 10 for spear gun fishers recorded in the same area (Table 1).

Total catch by fishing area, season and fishing gear type varied over the study period. In Msambweni, overall total landing was 23.3 tons and only 0.98 tons (4.2 %) was retained by the artisanal fishers. The NEM season recorded higher fish landings of 15 tons compared to 8.3 tons in the SEM season. Basket trap fishers recorded the highest catch while spear gun fishers recorded the lowest catch (Fig. 2a). Highest monthly total catch in basket traps was in the months of November (3.9 tons) and January (2.5 tons). Hand line was the second most productive gear in the area with highest catch observed in September (0.471 tons) and March (0.417 tons). For gill nets, September recorded the highest total catch with 0.383 tons, followed by February (0.332 tons). For spear guns, the highest monthly catch was recorded for September with 0.021 tons, with no catch recorded in the months of February, March and April (Fig. 2a).

The overall total fish landings in Vanga was 210 tons and 1.64 tons (0.78 %) was retained by the artisanal fishers. Seasonal fish landings in the area was higher for the NEM (112 tons) than the SEM (98 tons). In this area, ring net fishers recorded the highest catch while spear gun fishers recorded the lowest (Fig. 2b). For ring nets, highest monthly total catch was recorded in

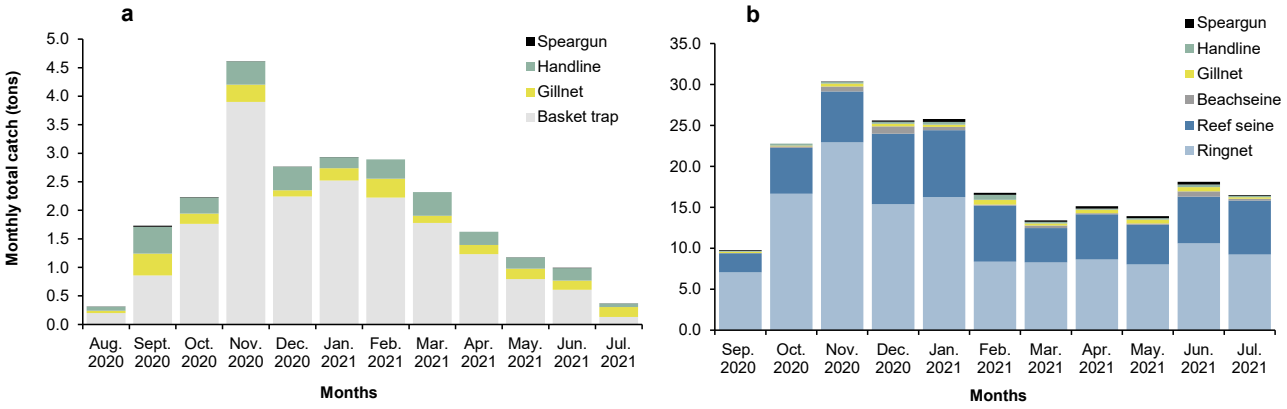

Figure 2. Monthly total fish landings sampled from the selected artisanal fishers by fishing gear type for a) Msambweni, and b) Vanga, south coast of Kenya.

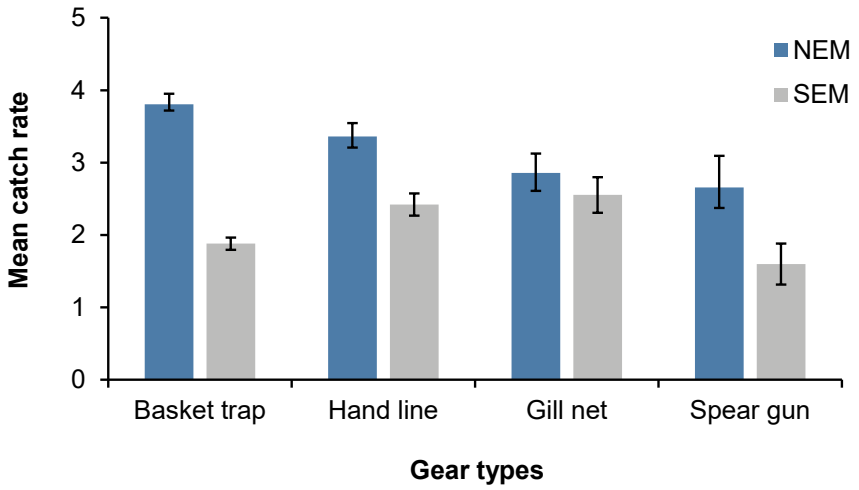

Figure 3. Fish catch rate (mean ± SE) by gear type and seasons in Msambweni, south coast of Kenya.

November with 22.94 tons. Reef seine nets followed with the highest catch in December with 8.62 tons, followed by January (8.15 tons). For gill nets, highest monthly total catch was recoded in February with 0.57 tons. Beach seine nets, among the least productive gear followed and highest total landings for this gear was recorded in December at 0.90 tons. For hand lines, February recorded the highest total catch with 0.61 tons followed by January (0.34 tons). For spear guns, the highest monthly catch was recorded for January with 0.36 tons with no catch recorded in the month of October.

Fish catch rates

Catch rate (kg. fisher^{-1}day^{-1}) varied by fishing area, season and fishing gear. In Msambweni, mean catch rate was 3.3 ± 0.12 kg.fisher^{-1}day^{-1} in the NEM season and 2.2 ± 0.09 kg.fisher^{-1}day^{-1} in the SEM season. In this area, catch rate was highest for basket trap in the NEM season (3.8 ± 0.15 kg) and least for spear gun fishers in the SEM season (1.6 ± 0.28 kg). Catch rate for basket traps was significantly higher in the NEM season than the SEM season (Kruskal-Wallis: p = 0.00, H =108.67) (Fig. 3). For hand lines, Kruskal-Wallis test indicated significant differences in catch rate across study sites and between seasons ($p < 0.05$; Fig. 3 & 4). The same test showed highly significant gill net catch rates in Vanga compared to Msambweni (p = 0.000) with higher catch rate recorded in the NEM than the SEM season but not statistically different (p = 0.915) (Fig. 3 & 4). For spear guns, results of Kruskal-Wallis test confirmed significantly higher catch rates in Vanga than Msambweni (p = 0.009) but they were statistically similar between seasons (p = 0.486) (Fig. 3 & 4).

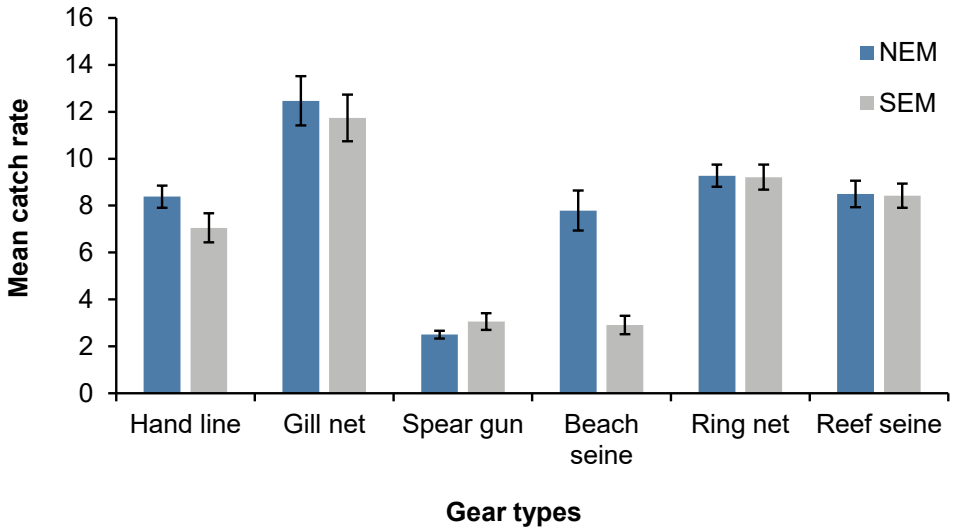

Figure 4. Fish catch rate (mean ± SE) by gear type and seasons in Vanga, south coast of Kenya.

In Vanga, overall mean catch rate was 8.5 ± 0.28 kg. fisher-^{1}day-1 in the NEM season and 7.9 ± 0.29 kg.fisher^{-1}day^{-1} in the SEM season. Fish catch rate in this area was highest for gillnet fishers (12.46 ± 1.05 kg), followed by ring nets (9.27 ± 0.48 kg) and lowest for spear guns (2.50 ± 0.16 kg). For beach seinse, catch rates were significantly higher in the NEM than the SEM season (1-way ANOVA: p = 0.00, df =1, f = 42.23) (Fig. 4). For ring nets and reef seines, results of 1-way ANOVA showed no significant differences in catch rates between seasons (p > 0.05 in all cases) (Fig. 4).

Overall fish species composition

An overall total of 372 fish species were sampled over the study period representing a total of 297 fish species recorded in Msambweni and a total of 172 species recorded in Vanga. Among the top 10 most abundant species in Msambweni, *Siganus sutor* made the highest contribution (58.4 %), followed by *Lethrinus mahsena* (7.8 %). *Siganus sutor* recorded a mean total length of 25.33 ± 0.04 cm with a range of 11.7 to 45.5 cm. The same species recorded a minimum weight of 34 g, maximum weight of 1,515 g and a mean weight of 235 ± 0.76 g. *Lethrinus mahsena* recorded a mean length of 25.16 ± 0.04 cm and mean weight of 313.92 ± 4.84 g. The species *Lethrinus variegatus* and *Calotomus carolinus* made the lowest contribution among the top ten abundant species (Table 2). In Msambweni, the overall mean size of fish not retained by fishers was significantly larger (25.78 ± 0.05 cm) than those retained (22.77 ± 0.08 cm; 1-way ANOVA: p = 0.000).

Among the top ten most abundant species in Vanga, *Sphyraena forsteri* made the highest contribution (23.9 %), followed by *Sphyraena obtusata* (13.7 %). *Sphyraena forsteri* recorded a mean total length of 18.68 ± 0.06 and a mean individual weight of 36.10 ± 0.24 while *Sphyraena forsteri* had a mean total length of 21.10 ± 0.19 cm and a mean individual weight of 58.82 ± 1.24 cm. The species *Hemiramphus far* and *Lethrinus lentjan* made the lowest contribution among the top ten most abundant species in the area (Table 2). In Vanga, fish sizes also varied where fish not retained by fishers were significantly larger (24.11 ± 0.19 cm) than those retained (20.98 ± 0.07 cm; p = 0.000).

Results of non-Metric Multidimensional Scaling (nMDS) ordination showed separation of species by fishing area with season combined (Fig. 5). Results of the 1-way ANOSIM test indicate a significant difference in species composition by fishing area with season combined (R = 0.224; p = 0.001). The pair-wise comparison test confirmed a significant difference existed between all fishing area-season combinations (p = 0.001 in all cases). One-way SIMPER analysis confirmed seasonal differences in species composition in Msambweni was

Table 2. Overall species composition and mean sizes of most abundant fish species.

Site	Species	Common name	Proportional abundance (%)	Mean length (cm)	Mean weight (g)
Msambweni	*Siganus sutor*	Shoemaker spinefoot rabbitfish	58.35	25.33 ± 0.04	234.89 ± 0.76
	Lethrinus mahsena	Sky emperor	7.84	25.16 ± 0.12	313.92 ± 4.84
	Lethrinus rubriopeculatus	Spotcheek emperor	3.70	20.22 ± 0.22	127.96 ± 2.57
	Lethrinus borbonicus	Snubnose emperor	3.28	21.33 ± 0.13	185.30 ± 3.56
	Lethrinus lentjan	Pink ear emperor	2.56	26.60 ± 0.17	304.26 ± 6.83
	Lethrinus harak	Thumbprint emperor	1.89	25.35 ± 0.33	244.17 ± 4.77
	Lutjanus fulviflamma	Black-spot snapper	1.73	21.03 ± 0.15	157.34 ± 3.79
	Parupeneus barberinus	Dash-and-dot goatfish	1.45	29.60 ± 0.25	351.43 ± 8.22
	Calotomus carolinus	Carolines parrotfish	1.34	26.12 ± 0.74	324.02 ± 5.86
	Lethrinus variegatus	Slender emperor	1.01	15.53 ± 0.11	55.27 ± 1.61
Vanga	*Sphyraena forsteri*	Bigeye barracuda	23.94	18.68 ± 0.06	36.10 ± 0.24
	Sphyraena obtusata	Obtuse barracuda	13.74	21.10 ± 0.19	58.82 ± 1.24
	Rastrelliger kanagurta	Indian mackerel	9.34	19.16 ± 0.15	76.0 ±1.60
	Gerres oyena	Common silver-biddy	5.75	17.65 ± 0.17	63.39 ± 1.20
	Pterocaesio tile	Dark-banded fusilier	5.14	20.40 ± 0.21	89.95 ± 2.0
	Decapterus macarellus	Mackerel scad	4.46	22.31 ± 0.21	121.65 ± 3.78
	Hemiramphus lutkei	Lutke's halfbeak	3.93	26.31 ± 0.08	81.50 ± 0.78
	Lethrinus lentjan	Pink ear emperor	3.69	18.54 ± 0.19	91.81 ±3.01
	Hemiramphus far	Black-barred halfbeak	3.20	26.86 ± 0.20	112.24 ± 3.49
	Decapterus macrosoma	Shortfin scad	2.43	19.27 ± 0.32	86.67 ± 4.55

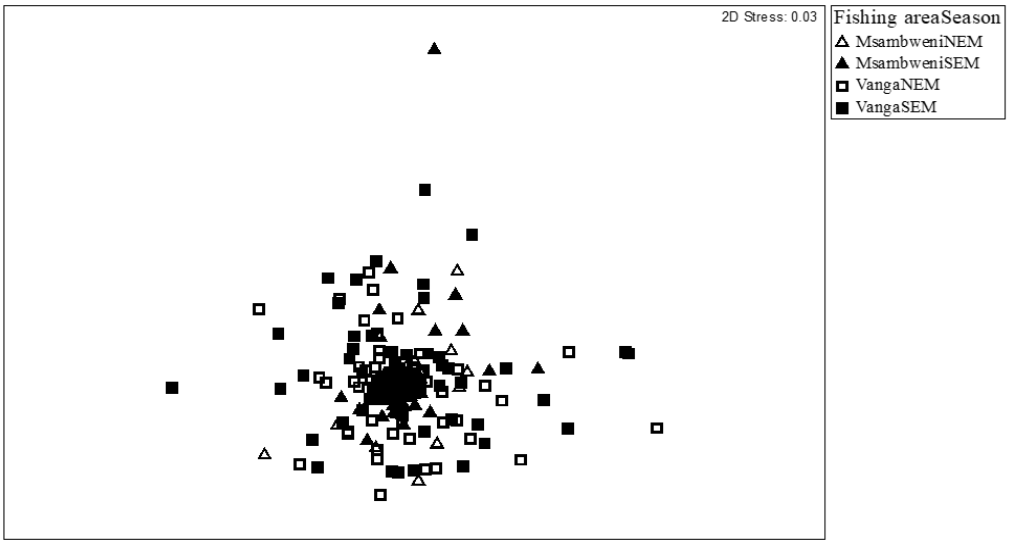

Figure 5. Non-metric MDS plots showing distinct catch composition of all fish species by fishing area with season combination based on species abundance from catch monitoring data over the study period.

attributed to more abundant *Siganus sutor* and *Lethrinus mahsena* in the NEM than the SEM season. In Vanga, seasonal differences in species composition was attributed to more abundant *Sphyraena forsteri* and *Sphyraena obtusata* in the NEM than the SEM and more abundant *Euthynnus affinis* in the SEM than the NEM season. The seasonal dissimilarity in species composition was 75.96 % in Msambweni (Table 3) and 95.55 % in Vanga (Table 4).

Species composition of retained fish

Overall, a total of 18,864 individuals weighing 2.63 tons (1.13%) from 284 species were retained by fishers in both study sites with 4,807 individuals weighing 0.98 tons of 174 species retained in Msambweni and 14,507 individuals weighing 1.67 tons of 170 species retained in Vanga. Among the top ten most retained species in Msambweni, *Siganus sutor* made the highest contribution (53 %), followed by *Lethrinus mahsena*, (5.08 %) and *Calotomus carolinus* (5.06 %). The species *Scarus rubroviolaceus* and *Acanthurus xanthopterus* made the least contribution among the top ten most retained species in the area (Table 5). Among the top ten retained fish species in Vanga, *Euthynnus affinis* made the highest contribution (10.4 %), followed by *Sphyraena obtusata* (10.2 %), *Sphyraena forsteri* (8.9 %) and *Decapterus macarellus* (8.2 %). The species *Lethrinus lentjan*, and *Caesio xanthonota* made the least contribution of retained species in the area (Table 5).

Table 3. SIMPER results showing seasonal differences and species contributing to dissimilarity in Msambweni with an average seasonal dissimilarity of 75.96 %.

	Msambweni NEM	Msambweni SEM		
Species	**Average abundance**	**Average abundance**	**Average Dissimilarity**	**Contribution (%)**
Siganus sutor	**44.08**	41.85	22.56	29.70
Lethrinus mahsena	**11.86**	6.43	7.31	9.63
Lethrinus rubriopeculatus	4.13	5.19	4.27	5.62
Lethrinus borbonicus	3.60	5.03	3.84	5.06
Lethrinus lentjan	3.49	4.00	3.44	4.53
Lethrinus harak	0.49	4.22	2.31	3.05
Lutjanus fulviflamma	1.04	3.53	2.19	2.89
Uroteuthis duvaucelii	2.99	1.34	2.11	2.78
Coryphaena hippurus	2.73	0.00	1.36	1.80
Parupeneus barberinus	1.31	1.27	1.20	1.58
Lutjanus gibbus	1.23	0.99	1.07	1.40
Calotomus carolinus	1.72	0.41	1.03	1.36
Lethrinus olivaceus	0.73	1.37	0.99	1.31

Table 4. SIMPER results showing seasonal differences and species contributing to dissimilarity in Vanga with an average seasonal dissimilarity of 95.55 %.

	Vanga NEM	Vanga SEM		
Species	**Average Abundance**	**Average Abundance**	**Average Dissimilarity**	**Contribution (%)**
Sphyraena forsteri	**15.81**	8.94	10.89	11.39
Sphyraena obtusata	**11.01**	5.48	7.60	7.96
Euthynnus affinis	4.36	**11.44**	7.40	7.75
Rastrelliger Kanagurta	9.07	3.88	6.04	6.32
Gerres oyena	2.64	6.53	4.37	4.57
Lethrinus lentjan	3.31	5.35	4.10	4.29
Pterocaesio tile	5.79	2.54	4.01	4.19
Chirocentrus nudus	2.65	5.37	3.87	4.05
Decapterus macarellus	3.36	4.43	3.74	3.91
Siganus sutor	3.28	3.94	3.46	3.63
Hemiramphus far	4.47	1.93	3.11	3.25
Hemiramphus lutkei	6.11	0.04	3.07	3.21
Lutjanus fulviflamma	2.26	2.09	2.11	2.21
Sphyraena putnamae	1.90	2.34	2.08	2.17
Carangoides orthogrammus	0.08	3.95	2.01	2.10

Results of non-Metric Multidimensional Scaling (nMDS) ordination combining fishing area with season showed distinct separation of catch samples of retained fish species by fishing area and to some extent by season (Fig. 6). Results of the 1-way ANOSIM test indicated a significant difference in catch composition across fishing area with season combination ($R = 0.105$; $p = 0.001$). Results of the pair-wise comparison test indicated significant difference in catch composition of retained catch across all fishing area with season combinations ($p < 0.05$ for all cases). One-way SIMPER analysis confirmed a significant difference in seasonal overall catch composition of retained species between Msambweni and Vanga. The overall seasonal dissimilarity in catch composition across Msambweni and Vanga was 96.75 %.

Table 5. Species composition and mean sizes of retained fish by fishing area on the south coast of Kenya over the study period.

Site	Species	Common name	Proportional abundance (%)	Mean length (cm)	Mean weight (g)
Msambweni	*Siganus sutor*	Shoemaker spinefoot rabbitfish	52.91	23.04 ± 0.07	177.96 ± 1.63
	Lethrinus mahsena	Sky emperor	6.52	20.45 ± 0.27	174.19 ± 8.73
	Calotomus carolinus	Carolines parrotfish	5.34	25.17 ± 0.26	317.40 ± 7.32
	Lethrinus borbonicus	Snubnose emperor	3.30	18.56 ± 0.17	119.04 ± 3.41
	Scarus ghobban	Blue-barred parrotfish	2.34	28.10 ± 0.88	450.48 ± 44.02
	Lutjanus fulviflamma	Black-spot snapper	2.16	22.34 ± 0.32	192.17 ± 10.69
	Acanthurus xanthopterus	Yellowfin sergeonfish	1.63	27.05 ± 1.21	4.2.21 ± 47.70
	Leptoscarus vaigiensis	Marbled parrotfish	1.61	23.06 ± 0.23	199.03 ± 5.26
	Lethrinus rubriopeculatus	Spotcheek emperor	1.53	20.36 ± 0.29	130.53 ± 7.32
	Scarus rubroviolaceus	Redlip parrotfish	1.30	28.98 ± 0.77	480.35 ± 39.63
Vanga	*Euthynnus affinis*	Mackerel tuna	13.34	49.08 ± 0.98	1596.99 ± 85.34
	Sphyraena forsteri	Bigeye barracuda	8.34	18.51 ± 0.04	35.34 ± 0.25
	Sphyraena obtusata	Obtuse barracuda	8.23	19.85 ± 0.12	51.05 ± 1.18
	Rastrelliger kanagurta	Indian mackerel	7.53	18.78 ± 0.11	72.08 ± 1.79
	Decapterus macarellus	Mackerel scad	5.23	21.61 ± 0.35	118.14 ± 4.66
	Pterocaesio tile	Dark-banded fusilier	4.52	19.99 ± 0.25	83.01 ± 1.93
	Hemiramphus lutkei	Lutke's halfbeak	4.32	26.31 ± 0.08	81.38 ± 0.77
	Hemiramphus far	Black-barred halfbeak	4.12	26.94 ± 0.22	113.68 ± 4.04
	Lethrinus lentjan	Pink ear emperor	2.85	18.26 ± 0.26	92.59 ± 4.27
	Chirocentrus nudus	Whitefin wolfherring	2.63	46.12 ± 1.21	336.90 ± 19.46

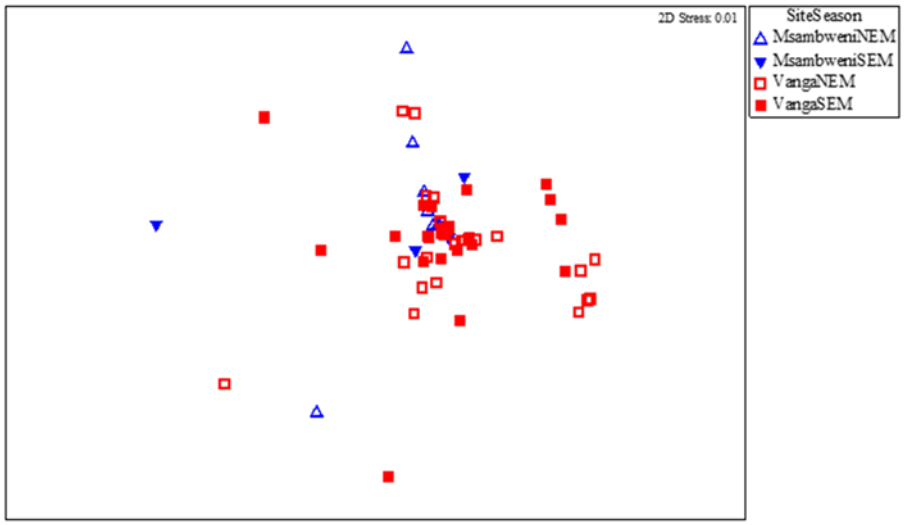

Figure 6. Non-metric MDS plots showing distinct catch composition of retained fish species by fishing area with season combination based on species abundance from catch monitoring data over the study period.

Results of non-Metric Multidimensional Scaling (nMDS) ordination showed to some extent distinct separation of catch samples of retained fish species by gear types (Fig. 7). The one-way ANOSIM test indicated a significant difference in species composition between fishing gear types ($R = 0.263$; $p = 0.001$). Results of the pair-wise comparison test confirmed significant differences in species composition between all fishing gear type comparisons ($p = 0.001$ in all cases) except for gillnet *versus* hand line, and spear gun *versus* beach seine ($p > 0.05$)

The most abundant fish species in the overall landings corresponded with the species that were retained by the artisanal fishers. One way SIMPER results confirmed that *Sphyraena forsteri* and *Sphyraena Obtusata* contributed highest to species seasonal dissimilarity among both landed and retained fish species in Vanga. In Msambweni, seasonal differences in species composition of both landed and retained catch were attributed to more abundant *Siganus sutor* and *Lethrinus mahsena*. The most common abundant species that were landed were in turn mostly retained by the fishers. These included *Sphyraena forsteri* and *Sphyraena obtusata* in Vanga and *Siganus sutor* and *Lethrinus mahsena* in Msambweni.

Discussion

The overall total fish landings during the NEM season was higher than the SEM season. Usually, artisanal

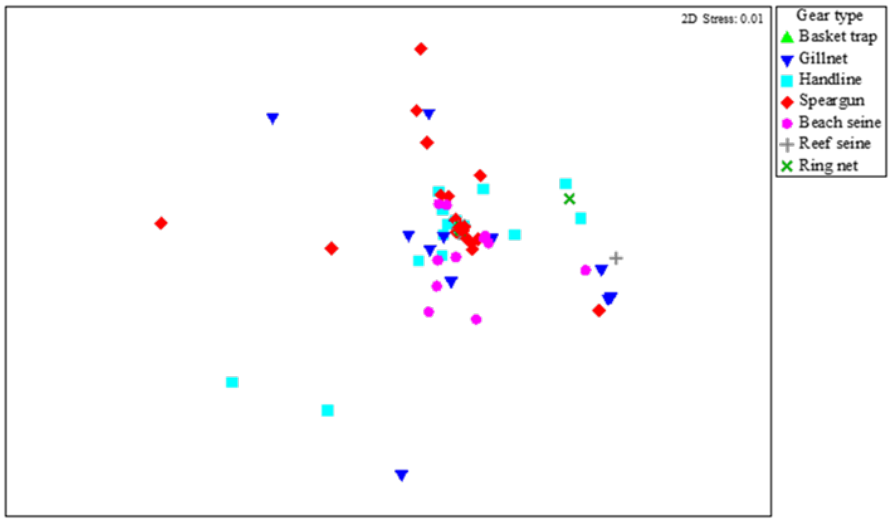

Figure 7. Non-metric MDS plots showing differences in the species composition of retained fish by fishing gears based on species abundance from catch monitoring data over the study period.

fish landings are affected by change of season where higher landings have been associated with the NEM season. This disparity of seasonal change in artisanal landings have previously been reported by other works (Munga *et al*., 2011; Okemwa *et al*., 2017). For both fishing areas of Msambweni and Vanga, higher fish landings were recorded during the NEM season especially in the months of November, December and January over the study period. Calm seas prevail in the warm NEM season favouring navigation enabling fishers to access offshore fishing grounds using small fishing boats that are mostly manually or wind-propelled (McClanahan, 1988). The warm NEM season also triggers spawning in many tropical fish species. As such, some fish species become an easy target for capture while in spawning aggregations (Robinson *et al*., 2008; Woesik, 2010; Maina *et al*., 2011). Lower fish landings in the SEM season, notable in September, May and June as observed in this study is likely due to limited access to offshore fishing grounds, and in this season, artisanal fishing activity is restricted to shallow and protected fishing grounds due to strong currents (Munga *et al*., 2011; Okemwa *et al*., 2017). Migration of fishers to other fishing grounds at the onset of the cool and rough SEM season also contributed to lower landings and reduced fishing activity especially in Vanga (Fulanda *et al*., 2009; Okemwa *et al*., 2017).

Catch rates for basket trap and hand line fishers recorded in this study were similar to those recorded by Musembi *et al*., (2019) in Gazi on the south coast of Kenya, while ring net catch rates were within the range of those presented by Maina *et al*., (2008) at Diani-Chale on the south coast. This study however, recorded slightly higher catch rate for reef seine net fishers compared to that recorded by Maina *et al*., (2008). Musembi *et al*., (2019) recorded higher catch rate for spear gun fishers compared to findings of this study. This study recorded higher catch rate for gill net and beach seine fishers than those reported by Maina *et al*., (2008). The variations in fish catch rates by fishing gear types could be as a result of differences in fish abundance, fishing technique, geographical location, fishing ground characteristics, fishing effort and other determinant factors of fish catchability (Maina *et al*., 2008; Purcell *et al*., 2020).

Fish catch rates are notably influenced by seasonal dissimilitude (Niella *et al*., 2017). In this study mean catch rates were higher during the NEM than the SEM season. This observation is in agreement with previous studies along the Kenyan coast (Munga *et al*., 2014; Kiilu *et al*., 2019; Dzoga *et al*., 2020). These findings have also been supported by Kamau *et al*. (2021) who reported higher fish catch rates from October to March for coastal and marine fisheries on the north coast of Kenya coinciding the NEM season. Vanga and Msambweni fisheries are largely artisanal, dependent on small non-mechanized fishing crafts. The lower fish catch rates during the SEM season were attributed to adverse rough sea conditions (Munga *et al*., 2014) while higher catch rates during the NEM season were driven by calmer waters which favoured fishing activities (McClanahan *et al*., 1988; Kiilu *et al*., 2019). However, the variation in mean catch rates for ring net and reef seine fishers was not significantly affected by the seasons. Ring nets and reef seines are relatively large nets which are used with larger outboard engine powered wooden boats (dhows) which ease navigation to offshore richer waters even in the cool and rough seas during the SEM season (Munga *et al*., 2014; Dzoga *et al*., 2020).

Artisanal fisheries of Vanga and Msambweni exhibited contrasts in terms of the catch composition of total sampled landings across seasons. In Msambweni, the species *Siganus sutor* and *Lethrinus mahsena* contributed to the dissimilarity between the NEM and SEM seasons. Overall species composition dissimilarity across seasons in Vanga was attributed to *Sphyraena forsteri* and *Sphyraena obtusata* which were more abundant in the NEM season and *Euthynnus affinnis* which was more abundant in the SEM season. Distinct separation in composition of retained species across fishing areas and seasons was to some extent evident. The overall dissimilarity in catch composition of retained fish species in Msambweni and Vanga was ascribed to more abundant *Siganus sutor*, *Lethrinus mahsena* and *Lethrinus borbonicus* in Msambweni during the NEM season, and more abundant *Euthynnus affinnis*, *Sphyraena forsteri*, *Gerres oyena*, *Lethrinus lentjan* and *Sphyraena obtusata* in Vanga during the SEM season. Additionally, retained fish species were to a larger extent influenced by catch composition of overall landings. The species *Siganus sutor* and *Lethrinus mahsena* which were mostly landed in Msambweni were also mostly retained by fishers. In Vanga, *Sphyraena forsteri*, *Sphyraena obtusata* and *Rastrelliger kanagurta* which were more abundant among the total sampled catch in Vanga were also mostly retained.

The variation in fish catch composition across fishing areas could have been exacerbated by factors such as existing critical habitats, sea conditions, gear types used, fishing pressure, fish recruitment, fishing effort

and depth (Agembe *et al*., 2010; Munga *et al*., 2014; Dzoga *et al*., 2020). In this study, a significant difference in catch composition of fish species across seasons was evident. The NEM season recorded the highest species diversity due to easy accessibility to better fishing grounds in the calm waters unlike the non-tranquil conditions of the SEM season (Munga *et al*., 2011). Fluctuating sea conditions influence fish species distribution and the ability of fishers to access offshore fishing grounds (Locham *et al*., 2010). In Msambweni, a shift in fishing technique of some basket trap fishers to the use of gill nets and some speargun fishers to the use of basket traps in the SEM season could have also contributed to the seasonal dissimilarity in catch composition (pers. obs.).

Dissimilarity in seasonal species composition between Vanga and Msambweni could have been caused by different fishing gear types and fishing locations. In Vanga, bigger wooden fishing boats capable of navigating to offshore fishing grounds using large fishing nets was associated mainly with pelagic fish species. On the contrary, the Msambweni fishery which involved the use of traditional canoes restricted to the nearshore was associated with demersal coral reef fish species. Additionally, Msambweni is dominated by basket trap fishers who target inshore fish families such as Siganidae, Lethrinidae and Scaridae while Vanga is dominated by ring net fishers who target pelagic species including Sphyraenidae, Scombridae, Carangidae and Lutjanidae (Samoilys *et al*., 2011). Choice of gear type depends on the experience of fishers, for example Msambweni fishers who were older by age compared to Vanga fishers mostly used basket traps, being traditionally experienced in using basket traps (Mangi *et al*., 2007). In contrast to Msambweni fishers who use traditional sail dhows which confined them in inshore waters within the reef areas, Vanga fishers have bigger wooden boats fitted with outboard engines which enable them to access different offshore fishing grounds with higher species diversity.

Conclusions

The findings of this study have revealed that overall fish landings to a large extent determine the composition of retained catches by artisanal fishers. This study also concludes that species composition and catch rates of retained fish catches, just like overall fish landings, are also affected by gear type, season and fishing area. Ocean tranquillity is a favourable driver of successful and productive artisanal fishing. Both overall fish landings and retained catches were higher during the NEM season than the SEM season. Total fish catch in Msambweni where basket traps and small canoes were dominant, were mostly composed of demersal coral reef species. In Vanga where large nets and wooden boats fitted with outboard engines were used, more pelagic fish species were landed. The most abundant species in the overall landings in the respective fishing areas made the highest composition of retained catches. Retained fish was less in the SEM season which was characterized by lower landings and fish catch rates compared to higher catch rates in the NEM season. Sizes of retained fish were significantly smaller than fish that was not retained by the fishers.

Acknowledgements

This study was supported by funding from the western Indian Ocean Marine Science Association (WIOMSA) through a MARG 1 research grant. We thank Vanga Beach Management Unit in Vanga, Mkunguni Beach Management Unit in Msambweni and the artisanal fishers who willingly provided details of their households and still accepted their daily catch sampled throughout the entire study period. Their cooperation played a great role in ensuring the success of this study. We thank our field assistants Mr. Joshua Omweri (Kenya Marine and Fisheries Research Institute) and Dennis Oigara (Vanga Assistant Fisheries Officer, Kwale County) for helping with daily catch data collection and species identification.

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