Catch characteristics, gears, and fishing effort in reef fisheries: rabbit and emperor fish at Nyali landing site, Mombasa, Kenya

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Abstract

Coral reefs are some of the most productive marine ecosystems, comprising a wide range of fish biodiversity and other marine organisms. Reef fisheries influence the ecosystem health, productivity and sustainability. The present study contributes to knowledge on the reef fish species, their sizes and the gears used with emphasis on *Siganus* spp. and *Lethrinus* spp. due to their importance as indicator fish families in the coral reef ecosystem. To achieve the goal, the study determined catch per unit effort (CPUE) of reef fishes by using in-depth key informant interviews targeting fishers and fish traders. Descriptive statistics was used to summarize the data, while single factor Analysis of Variance (ANOVA) was used to evaluate differences in weight for different fishing gears. Findings revealed that 20 fish families with 32 fish species were recorded dominated by Siganidae contributing 19% and Lethrinidae contributing 18%. Lethrinidae and Siganidae were dominant in hand lines, basket traps and long lines. Average sizes were 22.81 cm for Siganidae and 20.4 cm for Lethrinidae. Overall, a fisher landed an average 5.4 kg day^{-1}. There was a significant difference in the weight of fish harvested using different fishing gears, with basket traps, handlines, long lines and handlines landing the highest catches with 13, 11 and 10 fish families respectively. The results of this study are essential in catch assessment of reef fisheries and contribute to the formulatin of measures on conservation and management of coral reef ecosystems and the sustainable utilization of the Blue Economy.

Key words: species composition, fishing gears, fish sizes, catch per unit effort, coral reef ecosystem

Introduction

Coral reefs are among the most productive marine ecosystems comprising a range of fish diversity and other marine organisms (Parravicini *et al.,* 2021). Concerns have emerged globally, on the future of coral reef ecosystems as they are threatened by climate change and local anthropogenic impact such as use of destructive fishing gears and overexploitation (Parravicini *et al.,* 2021).

Demersal reef fisheries are important, contributing approximately 45 % of the total marine fish caught in Kenya (Okemwa *et al.,* 2018). Additionally, the unclassified demersal finfish group in the reef ecosystem contribute an extra 5%, while the rest includes other groups such as pelagic species (35%), molluscs (9%), and crustaceans (3%).

At the South Coast of Kenya, standard fishing gears commonly used by artisanal fishers in the coral reef ecosystem catch a wide variety of fish species (Samoilys *et al.,* 2011). Different fishing gears target specific fish families and size classes.. Basket traps primarily target Siganidae, Lethrinidae, and Leptoscaridae, while gillnets are more selective towards Siganidae, Lethrinidae, Batoidea, Nephropidae, and Scombridae, with 49% of the catch consisting of juveniles in the targeted families. Handlines catch fish from the families Lethrinidae, Epinephelidae, Carangidae, and Scombridae, whereas spear guns target Octopodidae, Batoidea, and Muraenidae. Beach seines are effective in capturing Siganidae, Lethrinidae, Clupeidae, and Scaridae. The dominant fishing gears reported in published literature include basket traps, gillnets, handlines, spear guns, and beach seines (Samoilys *et al.,* 2011).

A frame survey conducted by the State Department for Fisheries, Aquaculture and the Blue Economy revealed that the dominant fishing gears used in the reef ecosystem include basket traps (3169), gillnets (3956), hand lines (4132), and spear guns (1007), while beach seines recorded the lowest number (139) (Samoilys *et al.,* 2017).

Siganidae and Scaridae families dominated most of the catch by all gears except for handlines (Samoilys *et al.,* 2011). Approximated catches of *Siganus* spp. were 44.8% of total catch and 47.3% were *Leptoscarus* spp. Hand lines catches were dominated by *Lethrinus* spp., estimated to be about 49.9%. Handlines and basket traps contributed most of catches in the reef ecosystem, while spear guns contributed the least (Samoilys *et al.,* 2011).

Sustainable management of reef fisheries has been challenging to implement due to limited stock assessment, insufficient information on the catch composition and limited data to support science-based management (Okemwa *et al.,* 2018). Other challenges facing reef resources include; unregulated fishing activities, use of destructive fishing gears (Tuda *et al.,* 2016) and climate variability (Jury *et al.,* 2010). These challenges have led to declining stocks, yield, sizes, species richness, and species composition in coral reef ecosystems (Tuda *et al.,* 2016).

The present study aimed at providing data and information on types of coral reef fish species, their sizes, fishing gears and Catch Per Unit Effort (CPUE) which are essential in catch assessment and contribute to formulation of management and conservation measures for the coral reef ecosystems.

The objectives the study were: i) to identify the fish species caught, with a focus on Siganidae (rabbit fish) and Lethrinidae (emperor fish); ii) to investigate the fishing gears employed to catch reef fish, particularly those targeting Siganidae and Lethrinidae; iii) to determine the size distribution of reef fish, specifically Siganidae and Lethrinidae; and iv) to calculate the Catch Per Unit Effort (CPUE) of fish landed at Nyali landing site.

Materials and methods

Study area

The study was conducted for 15 days, between June and July 2021, at Nyali landing site located on the mainland North of Mombasa County, Kenya (Fig. 1). Nyali landing site is located between latitude 4°30′ - 4°35′S and longitude 39°22′ - 39°27′E North of Mombasa County, Kenya.

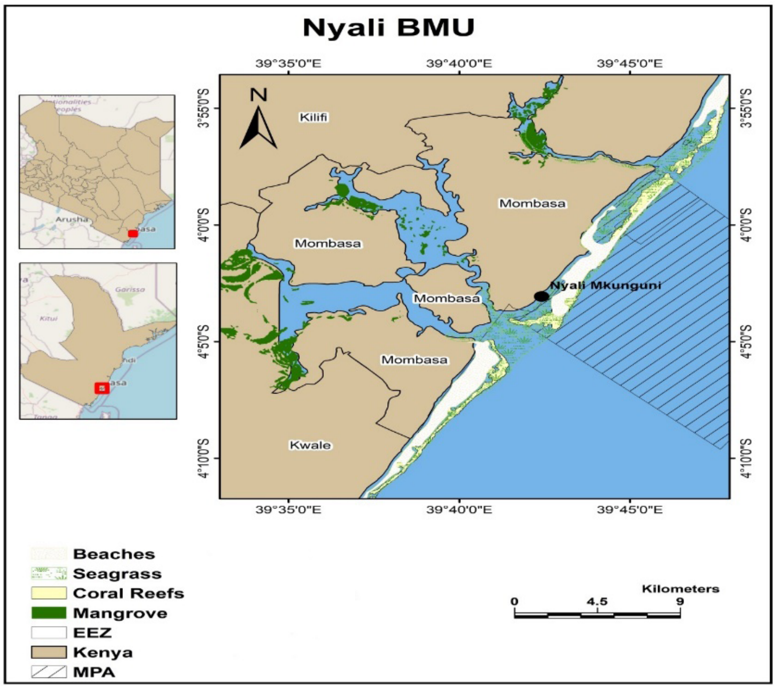

Figure 1. Map of Kenya coastline showing Nyali landing site, coastal Kenya (Source: Authors).

Respondent sampling

Respondents were selected through purposive sampling. A pre-designed questionnaire (Annex 1) was administered to the fishers and owners of fishing vessels at the landing site. Out of the total 85 questionnaires administered, 78 (91.8%) were deemed suitable for analysis, as they contained all the basic data required. The remaining questionnaires with missing data were excluded from the analysis due to incomplete information.

Catch sampling

Catch data was collected at the landing site during the survey. The data included types of fishing gears used by different fishermen, number of fishermen and the fishing ground, weight of fish landed in kilogram (kg), number of trips made by different fishers per day, types and sizes of fish species caught using different gears.

Fishing vessels were randomly selected to represent the entire fish caught by different fishers. One of the fishers, either the captain or a fisherman in the same vessel was interviewed as guided by the questionnaire after weighing the total catch. Approximately a quarter of the total fish catch was randomly sampled, and the fish species therein identified using Anam and Mosdarta's (2012) fish identification guide. For each species in the sample, the total lengths of 2 to 5 individuals were measured to the nearest centimeter using a tape measure and recorded.

Data analysis

Data was entered into Microsoft Excel for analysis. Pivot tables were utilized to interpret the data, and the results were visualized using tables and bar graphs. Descriptive statistical analysis was performed to summarize the data. Single-factor analysis of variance (ANOVA) test was conducted to determine significant differences in catch weight among different fishing gears, . The total catch weight of fish landed by each gear recorded daily over the 15-day sampling period was entered into separate columns in an Excel spreadsheet, each column representing a different gear type. The one-way ANOVA was then performed to test for significant differences in catch weight across the fishing gears. Subsequently, a post-hoc analysis was carried out to identify which specific gear types exhibited statistically significant differences in catch weight.

Results

Fishing gears

Seven gear types were noted to be commonly used by fishers at Nyali landing site (Fig. 2). Basket traps and hand lines were the gears of choice for majority of the fishers. "Basket traps were ranked as the most dominant gear utilized to exploit coral reef fisheries, representing 57% of the gear utilized, followed by handlines (18%), long lines (17%), stationary gill nets (4%)

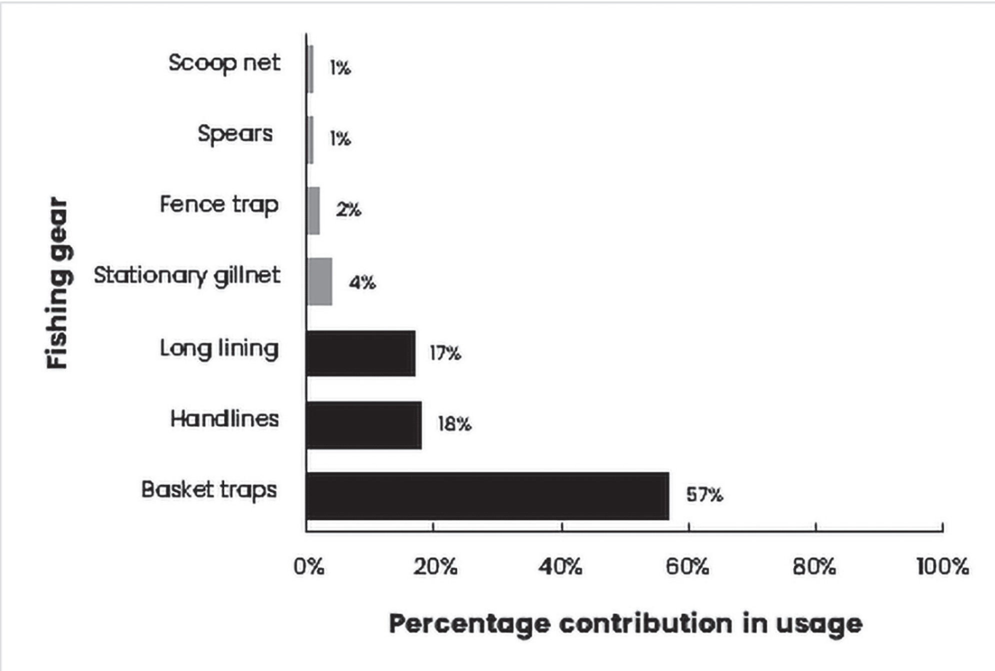

Figure 2. Percentage contribution of various fishing gears used by fishers at Nyali landing site, coastal Kenya.

and fence traps (2%), while spears and scoop nets each accounted for the lowest proportion at 1% of the fishing gears used at the study site. On contribution to total landings, basket traps landed the highest proportion of the catch i.e., 323 kg followed by long lines (133 kg), stationary gill nets (88 kg), hand lines (76 kg), fence traps (36 kg), spears (7 kg) and finally scoop nets (4 kg)

Different fishing gears targetted different fish families (Table 1). A total of 20 fin fish families were landed; basket traps landed 13 families, long lines landed 11 families, handlines landed 10 families, stationary gill nets landed 1 family, while spears landed 3 families. Fence traps and scoop net did not catch any finfish families, but each landed 2 non-fin fish families (Fig. 3).

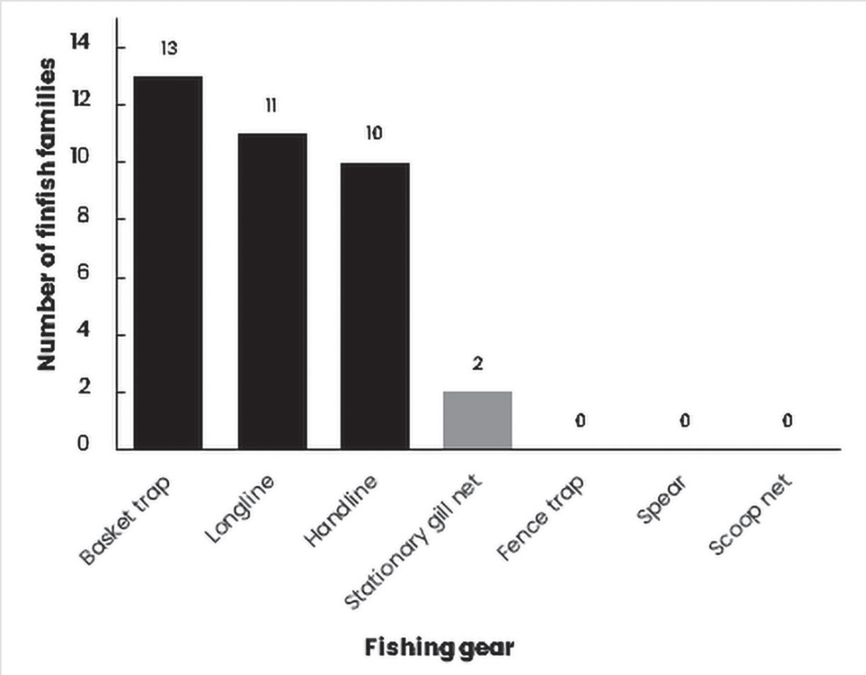

Figure 3. Number of finfish families landed by different fishing gears at Nyali landing site, coastal Kenya.

Catch composition

Based on the pooled data, 20 finfish families were recorded from a sample of 32 fish species. The top ten families constituted 88% of the total fish landed and were dominated by Siganidae (19%) and Lethrinidae (18%) (Fig. 4). Other finfish families included Mullidae (goatfish), Lutjanidae (jobfish), Mugilidae (mullet), Terapontidae (grunter), Clupeidae (sardines), Muraenidae (moray eels), and Carangidae (shrimp scads). Non-finfish families, including Octopodidae (octopus), Penaeidae (prawns), and Palinuridae (lobsters), contributed 12% of the total catch.

There were differences in catch composition from different fishing gears (Table 1). Up to 82.5% of Siganidae family, mainly *Siganus sutor* was caught using basket traps, 10% by hand line and 7.5% by long line. Up to 41.46% of Lethrinidae, mainly *Lethrinus lentjan (L. lentjan)* was landed by hand line, 46.34% by basket traps and 12.2% by long line.

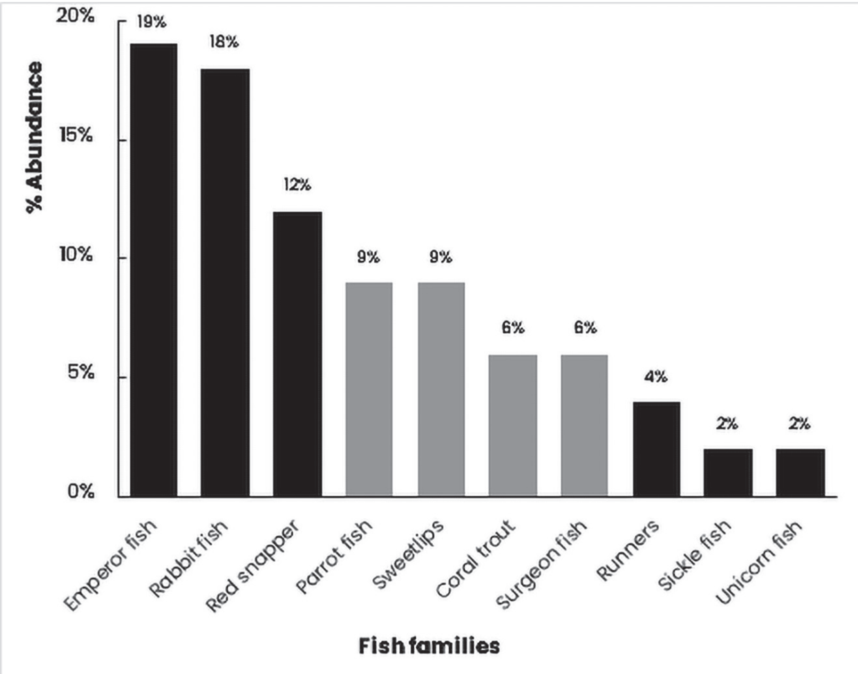

Figure 4. Abundance of the 10 most abundant finfish families.

Table 1. Catch composition of different gears at Nyali landing site.

GEAR TYPE	TYPE OF FISH FAMILY CAUGHT
Hand lines	Key indicators fish families; emperor fish and rabbit fish and other fish families such as red snapper, coral trout, sickle fishes, parrot fish, job fish, goat fish and sweetlips
Basket traps	Key indicators fish families; rabbit fish and emperor fish and other fish families such as parrot fish, goatfish, red snapper, unicornfishes, coral trout, sickle fishes, spade fishes, runners, lobsters, rubber lips, grunt, moray, prawn, surgeon fish and job fish
Fence traps	Sardines, prawns
Stationary gillnet	Parrot fish, mullets, sardines
Long line	Key indicators fish families; Emperor fish and rabbit fish and other fish families such as runners, red snappers, moray, unicorn fish and parrot fish
Spears	Lobsters, moray, octopus
Scoop nets	Octopus, prawns

Fish sizes

The sizes of key fish families and other finfish families varied from one gear to another (Fig. 6). The mean total length of fin-fish caught during the study was 26.68 cm. The average total length of Siganidae (rabbitfish) varied by fishing gear, with fish caught by basket traps, hand-lines, and longlines measuring 22.44 cm, 18.31 cm, and 23.72 cm, respectively.

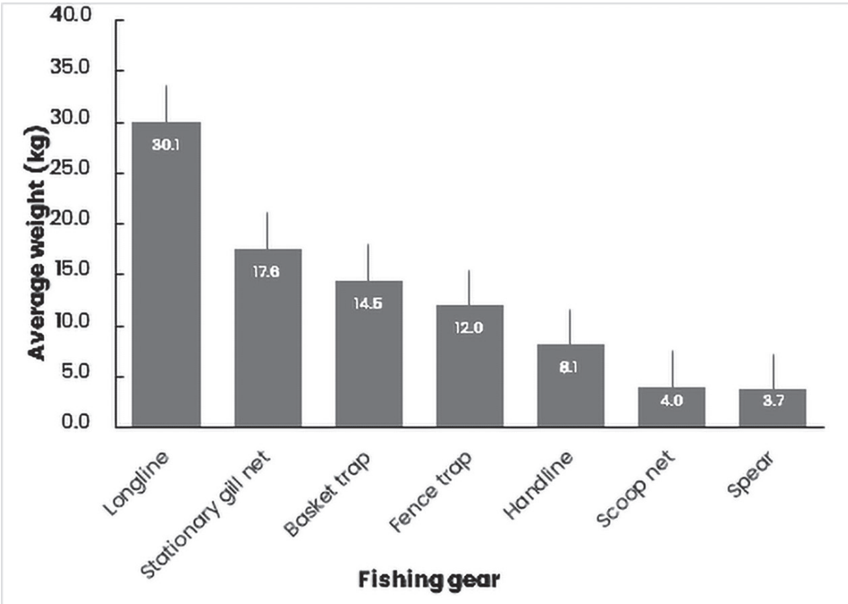

Figure 5. Average catch per gear at Nyali landing site, coastal Kenya.

Table 2: Variation of catch volumes and catch per unit effort among different fishing gears.

Type of gear	Average catch weight (kg)	Average number of fishers	Catch per unit effort (kg fisher^{-1} trip^{-1})	Total catch (kg)
Long line	30.1 ± 2.98	4 ± 0.50	7.5 ± 2.83	323
Stationary gillnet	17.6 ± 3.64	3 ± 1.11	5.9 ± 2.64	88
Basket trap	14.5 ± 1.35	3 ± 1.35	4.8 ± 0.75	133
Fence trap	12.0 ± 5.29	2 ± 1.41	6.0 ± 3.46	36
Hand line	8.1 ± 0.99	2 ± 0.58	4.05 ± 0.96	76
Scoop net	4.0	2	2.0 ± 2	4
Spear	3.7 ± 0.33	1 ± 0.47	3.7 ± 2.14	7

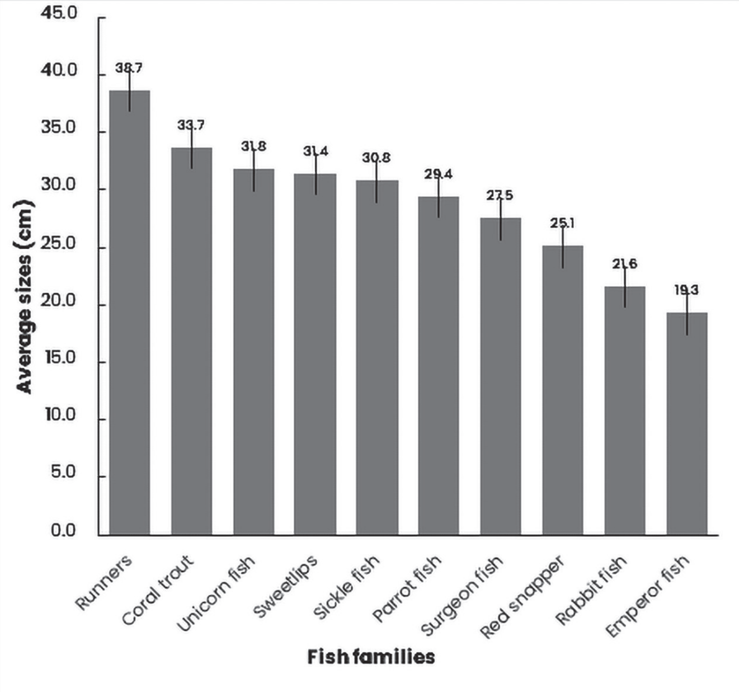

Figure 6. Average sizes of 10 most abundant finfish families.

Table 3. Singe-factor ANOVA comparing catch rates among different fishing gear types. The results revealed a highly significant effect of gear type on catch (*p* < 0.005).

ANOVA: Single Factor						
Groups	**Count**	**Sum**	**Average**	**Variance**		
Basket trap	15	595	39.67	563.02		
Hand line	15	145	9.67	47.38		
Long line	15	211	14.07	375.78		
Stationary gillnet	15	88	5.87	117.84		
Fence net	15	36	2.40	42.40		
Spear gun	15	11	0.73	2.35		
Scoop net	15	4	0.27	1.07		
ANOVA						
Source of Variation	*SS*	*Df*	*MS*	*F*	*p value*	*F crit*
Between Groups	17267.96	6	2877.99	17.52	<0.005	2.19
Within Groups	16098.8	98	164.27			
Total	**33366.76**	**104**				

Table 4. *p*-values for post-hoc pairwise comparisons for different fishing gear types.

	Basket trap	**Long line**	**Handline**	**Stationary gill net**	**Fence trap**	**Spear**	**Scoop net**
Basket trap		0.003199	0.00024	6.62 E-05	2.39 E-05	1.82 E-05	1.59 E-05
Long line				0.166928	0.041141	0.018822	0.015546
Stationary gill net					0.299858	0.089815	0.06661
Handline		0.418918		0.263506	0.004816	0.00019	0.000102
Fence trap						0.348949	0.22931
Spears							0.337705

The average sizes of emperor fish caught by hand lines was 18.70 cm, basket traps 21.65 cm and long line 21. 35 cm. The largest rabbit fish was 30 cm caught by long line while the smallest size was 17 cm caught by basket traps. The largest fish caught during the study was a *Carangoides armatus*, measuring 46 cm in total length, while the smallest fish was a Lethrinus lentjan, with a total length of 16 cm.

In this study 25 cm total length was considered as the size of first maturity. Approximately 75.76% of Siganidae and 82% of Lethrinidae landed by basket trap were below 25 cm total length. All species from Siganidae and 98.08% Lethrinidae fish families landed by hand line were below 25 cm total length. Fifty percent of Siganidae and 87.5% of Lethrinidae landed by long line were below 25 cm total length. The lengths of 26 % of the key fish families (Lethrinidae and Siganidae) was less than 19 cm and were considered as juvenile species in this present study. In this study 25 cm total length was considered as the size of first maturity.

CPUE

Long lines recorded the highest average catch (30.1 kg), followed by stationary gill nets (17.6 kg) and basket traps (14.5 kg). The lowest average catch recorded (3.7 kg) was harvested using spears (Fig. 5). Overall, fishers landed an average of 5.4±2.04 kg fisher^{-1} day^{-1}. All the fishers made a single trip per day, with the average number of fishers per vessel being greater in long line and least in spears (Table 2). The CPUE varied in different fishing gears with long lines recording the highest CPUE and scoop nets having the lowest CPUE.

Discussion

The aim of this study was to determine the variation of the catches of common reef fish families including Siganids and Lethrinids at the Kenya coast. The study noted seven gear types in use at Nyali fish landing site. Basket traps and handlines were the most dominant gears used in the coral reef while scoop nets and spears were the least used gears. Samoilys *et al.* (2017) identified five gear types commonly employed by small-scale fishers along the Kenyan Coast: gillnets, basket traps, handlines, spear guns, and beach seines. However, at Nyali landing site, beach seine which is considered illegal gear was not recorded.

In the present study, basket traps, handlines, and long lines yielded the highest catch, primarily targeting species from the families Lethrinidae and Siganidae. At the species level, *Siganus sutor* was the main species caught by basket traps, while *Lethrinus lentjan* was the dominant species caught by hand lines. These findings are consistent with a similar study conducted in Kenya by Tuda *et al.* (2016), which reported that basket traps mainly caught *Siganus sutor* and *Scarus sordidus*, while beach seines primarily captured *Lethrinus nebulosus*, *Lutjanus fulviflamma*, and *Leptoscarus vaigiensis*. Further, Tuda *et al.* (2016) reported that hook and line predominantly caught *Lethrinus mahsena* and *Lethrinus lentjan*, and that species from the families Siganidae and Leptoscaridae constituted a significant proportion of the catch from basket traps and beach seines."

Gillnets, beach seines, handlines, spear guns and basket traps were the most dominant fishing gears used in similar coral reef ecosystems at Lombok Island in Indonesia (Campbell *et al.,* 2018; Humphries *et al.*, 2019). In the same study, Siganids dominated spear gun catches while Lethrinids dominated by hand lines catches, an indication that different fishing gears target different species.

It was evident that Nyali landing site was moderately diverse in reef fish species but with a small number dominating the catch. Similarly, a study by Gell and Whittington (2002) shows that most tropical reef fisheries are characterized by a high diversity of species, but with a relatively small number dominating the catch. A related study by Musembi *et al.* (2019) show that species from Siganidae, Scaridae and Lethrinidae dominate catches in Kenyan small-scale fisheries from a sample of 41 fish families from 85 fish species. This is important since these fish families represent the most abundant and commercially important species of the Kenyan small-scale fisheries.

There was variation in the average sizes of finfish species. *C armatus* had the largest size of 46 cm while *L. lentjan* had the least size of 16 cm total length. This was different compared to a study by Musembi *et al.,* (2019), where *Scarus ghobban* had the largest size of 32.60 cm total length and *L. lentjan* had the least size of 8.8 cm total length. The result of the present study shows that the catch sizes of reef fish have increased, which can be attributed to the presence of an adjacent marine park where fishing activities are prohibited. The marine park serves as a protected area, allowing fish to grow to larger sizes without being subjected to fishing pressure. As these fish mature and their populations increase within the protected area, they may eventually migrate to the adjacent fishing grounds, contributing to the observed increase in catch sizes (McClanahan *et al.,* 2001).

This phenomenon, known as the "spillover effect," has been documented in various marine protected areas worldwide (Gell and Roberts, 2003; Halpern, 2003). The spillover of adult fish from no-take zones to surrounding fishing areas can help replenish fish stocks and support local fisheries. The findings of this study provide further evidence for the effectiveness of marine protected areas in promoting the recovery and sustainability of reef fish populations."

In the present study, the average total length of finfish caught was estimated to be 26.68 cm**.** The length of 60% of the catch was less than 30 cm, indicating that the small-scale fishery is based on small to medium-sized species. In a different study, Tuda *et al.,* (2016) recorded an average size of 21 cm total length of catch at South Coast of Kenya. The length of 91% of those catches was less than 30 cm total length indicating that small-scale fishery was based on small-medium sized species.

Catch per unit effort at Nyali landing site showed that fishers landed an average of 5.4 ± 2.04 kg fisher^{-1} day^{-1}. This CPUE is notably higher than the 2.8 ± 0.2 kg fisher^{-1} day^{-1} reported by Tuda *et al.* (2016) for the South Coast of Kenya. The higher CPUE in the current study suggests that the presence of a marine park in the adjacent areas of the fishing ground might have contributed to an increase in fish populations, resulting in improved catches (McClanahan *et al.*, 2001; Kaunda *et al.*, 2004).

Gear comparisons in the present study, revealed varying catch per unit effort (CPUE) across different fishing methods. Stationary gillnets had the highest CPUE at 5.9 ± 2.64 kg fisher^{-1} day^{-1}, followed by basket traps at 4.8 ± 0.75 kg fisher^{-1} day^{-1}, hand lines at 4.05 ± 0.96 kg fisher^{-1} day^{-1}, and spears at 3.7 ± 2.14 kg fisher^{-1} day^{-1}. These findings are comparable to those reported by Tuda *et al.* (2016) in a similar study, where the CPUE for each gear was as follows: basket traps 2.0 ± 0.1 kg fisher^{-1} trip^{-1} hook and line 4.2 ± 0.7 kg fisher^{-1} trip^{-}, gillnets 3.0 ± 0.5 kg fisher^{-1} trip^{-1}, spear guns fisher^{-1} trip^{-1}, and monofilament 4.1 ± 1.2 kg fisher^{-1} trip^{-1}. Comparing the two studies, it is evident that the CPUE has increased for all gear types, with the exception of handlines.

The overall increase in CPUE across most gear types suggests an improvement in the availability of fish resources in the study area. This increase could be attributed to various factors, such as the implementation of effective fisheries management measures, the presence of marine protected area adjacent to the study area, or favorable environmental conditions (Russ & Alcala, 2004; Worm *et al.*, 2009). However, the decline in CPUE for handlines warrants further investigation to identify the underlying causes and potential implications for the sustainability of this particular fishing method.

Conclusion and recommendations

The sizes of fish harvested from the studied coral reef ecosystem have been contributed by lack of capacity among fishers on the use of sustainable fishing gears such as basket traps, handlines, and stationqry gill nets with the recommended mesh size. Awareness creation on the importance of using sustainable fishing gears, provision of sustainable fishing gears and training fishers on how to use fishing gears will promote sustainable fishing.

CPUE have increased from 2.8 ± 0.2 kg fisher^{-1} day^{-1} (Tuda *et al.*, 2016) to 5.4 kg fisher^{-1} day^{-1}, indicating high dependence of fishery resources by the local communities for food and income. Overdependence on fishery resources can be reduced by providing alternative sources of food and income to the local communities such as seaweed farming, carbon trading, and bee keeping.

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Annex 1 . Questionnaire

Local knowledge and socio-economic questionnaire

Name of respondent..Tel:...

Site:...Date...

Gender: ☐ Male ☐ Female

Age: ....

Level of education:...

1. What activity are you involved with in the sea?...

2. How frequently do you go out at sea to fish?...

3. How many years have you been involved in fishing?..

4. What type of fishing gear do you use? ....

5. Do other fishers use the same fishing gear as you? If not name at least five fishing gears they use for fishing (in order of the most used)?

6. Name at least five types of fish families (species) you catch (in order of the most caught)?

7. Do other fishers catch the same species as you? If not name at least five fish families (species), they catch(in order of the most caught)?