# Rapid assessment of the Indian mackerel *Rastrelliger kanagurta* fishery in Kenya's coastal waters

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## Abstract

The Indian mackerel, *Rastrelliger kanagurta* is a highly migratory epipelagic species in the family Scombridae. The species plays a significant role in supporting the food security and livelihoods of coastal communities in the Western Indian Ocean. The exploitation status of *R. kanagurta* in Kenya's waters is uncertain. This study evaluated the *R. kanagurta* fishery using available catch data collected from 2014-2015 and 2017-2020. The study described the catch dynamics and utilized a suite of length-based approaches to derive diagnostic indicators of the exploitation status. Four gear types were documented that target the species, dominated by ring nets (79%) and reef seines (11%). Catch rates and selection patterns of fishing gears targeting *R. kanagurta* varied between gear types. Reef seines caught the highest proportion (80%) of immature *R. kanagurta* below size at maturity ($L_{50}$), while the lowest (0%) was by handlines and set gillnets. There were statistically significant differences in the proportion of *R. kanagurta* caught below $L_{50}$ between gear types and years. Overall, the spawning potential ratio (SPR) was within optimal levels at 0.48 and was above the target reference point of 0.4 during all years. The assessment provides a case study for the rapid evaluation of fishery performance for Kenya's data-limited fisheries.

**Keywords**: small-scale fisheries, length-based approach, gear selectivity, spawning potential, pelagic fish, data-limited fisheries

## Introduction

Small-scale fisheries (SSF) support food security and livelihoods for millions of coastal communities worldwide. In Kenya, SSF contributes approximately 90% of annual marine fisheries landings. An estimated 25,000 metric tons of fish are landed annually, of which pelagic species (including tunas and mackerels) constitute about 27% of this production. Mackerels, locally referred to as *Sehewa* or *Una*, are some of the key target species in Kenya's small-scale purse seine (ring net) fishery (SSPSF) which mainly targets small and medium pelagic species. The Indian mackerel *Rastrelliger kanagurta* is the dominant species landed along the Kenyan coast (Bett *et al.*, 2021). *It is a relatively short-lived species* occurring at depths ranging from 10 m to 100 m (often above 25 m) across the tropics of the Indo-West Pacific region (Akib *et al.*, 2015). Because the species moves in large aggregations, it is usually caught in high numbers providing an affordable and easily available source of protein for the coastal communities. Mackerels are generally marketed fresh, chilled or frozen. Studies assessing the fishery, biology, population dynamics, and exploitation status of *R. kanagurta* have been conducted in various regions of the Indian Ocean (Abdussamad *et al.*, 2010) and the Yemeni coast (Al-Mahdawi and Mehanna, 2010), with the earliest reported study being in Mozambique (Sousa and Gislason, 1985). However, the exploitation status of *R. kanagurta* stock in Kenya remains uncertain as information is limited.

Towards achieving the 2030 Sustainable Development Goals (SDGs), Goal 14.4.1 emphasizes the need to ensure that all fisheries are assessed and well-managed within biologically sustainable levels. However, assessing and managing small-scale fisheries remains challenging as the collection of reliable data is difficult due to the highly diverse vessel and gear types used, high diversity of species, and diffuse landing sites, some of which are located in remote, inaccessible areas where consistent data collection and monitoring is difficult (Pita *et al.*, 2019). Consequently, most small-scale fisheries are categorized as data-poor or data-limited. Data-poor fisheries arise when certain key parameters needed to run the quantitative models are either not available or are collected inconsistently (FAO, 2020).

Over the last decade, various length-based methods have been developed, which have made it possible to conduct simple diagnostic assessments of the exploitation status for data-poor fisheries (Froese, 2004; Cope and Punt, 2009; Hordyk *et al.*, 2015; Prince *et al.*, 2015; Froese *et al.*, 2018). These methods are now being integrated widely (Babcock *et al.*, 2013; Gough *et al.*, 2020; Prince *et al.*, 2020). This is because length-frequency data is easy to collect and is hence the most readily available stock parameter for most data-poor fisheries. This study applies selected length-based approaches to rapidly assess the exploitation and stock status of the Indian Mackerel *R. kanagurta* fishery, based on catch and length data collected over a 6-year period from 2014 to 2020 at selected landing sites along the Kenya coast. The specific objectives of the study were to assess annual changes in catch rates and selection patterns of fishing gears targeting *R. kanagurta* and to derive stock status diagnostics using a suite of length-based indicators.

## Materials and methods

### Data collection

Data used for this study was obtained from a catch sampling programme undertaken by KMFRI at selected landing sites along the Kenya coast. Key landing sites where *R. kanagurta* was recorded were four: two at the South Coast of Kenya (Vanga and Gazi) and two landing sites at the North Coast of Kenya (Takaungu, Mayungu, and Kilifi) (Fig. 1).

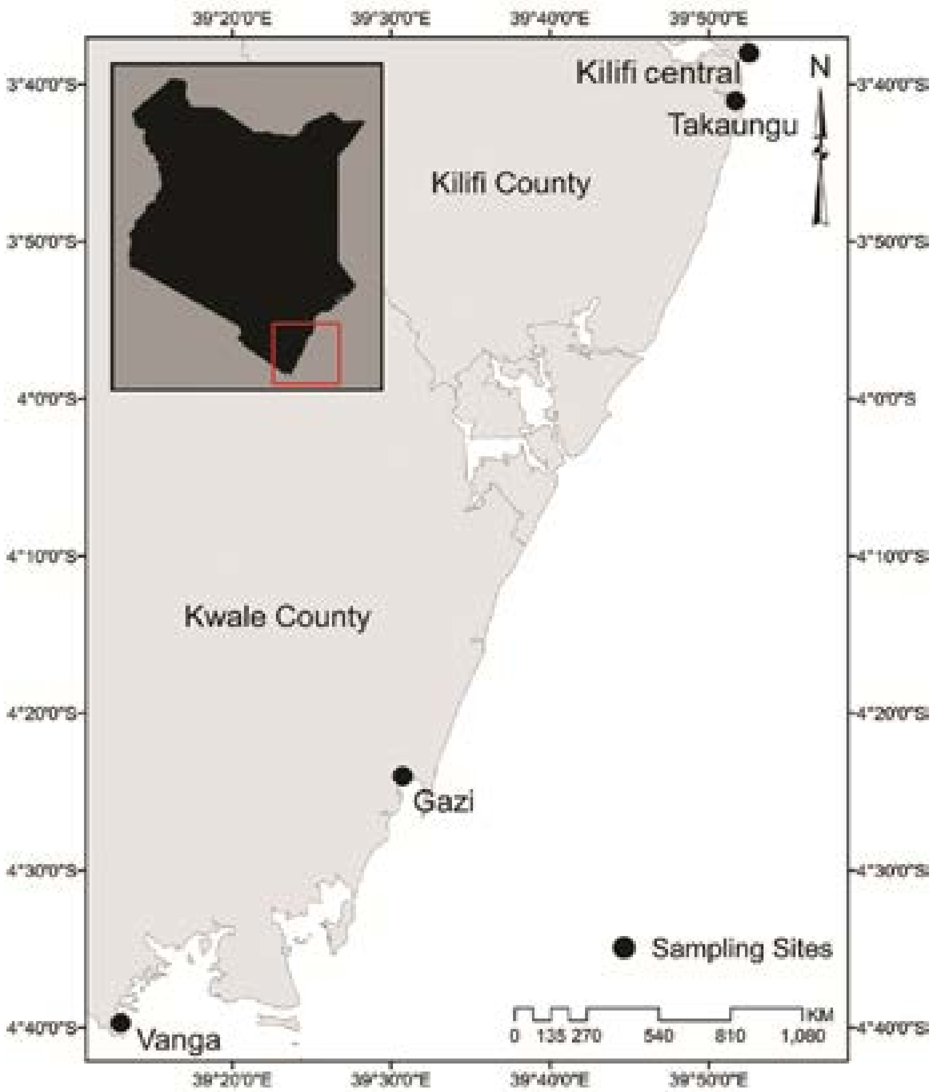



**Figure 1. Map showing the location of landing sites along the Kenya coast monitored during the study period** (Source: Authors).

The catch sampling programme entailed the collection of the following information for each sampled fishing trip: vessel and gear type used, number of crew, total catch (kg), and species. Fish were identified to species level and the total catch for each species component in each sampled trip was estimated by number and weight. The total length (cm) and body weight (kg) of each specimen was measured and then weighed using an electronic weighing balance to the nearest 0.1 cm and 0.1 kg, respectively. Total length was measured from the tip of the upper jaw (snout) with the mouth closed to the tip of the longer lobe of the caudal fin.

**Data processing and analysis**

A raising factor (rf) for each fishing trip was calculated to extrapolate the sampled catch and number of individuals caught to the total catch using the formula:

$$rf = W_t / W_s$$

where $W_t$ is the total weight of all the fish caught during a fishing trip and $W_s$ is the weight of the sampled fish.

The raising factor for each fishing trip was then multiplied by the total sampled weight of each species to estimate the total species weight in the catch. The data for all fishing trips which caught *R. kanagurta* was extracted for this assessment. The catch per unit effort (CPUE) for each fishing trip was standardized as kilograms per vessel (kg $vessel^{-1}$ $trip^{-1}$). Each length measurement was first rounded off to the nearest 1 cm. The length data were then grouped into 2 cm class intervals and a frequency histogram plotted to visualize the length distribution. Variation in mean length between gear types and between years was assessed using a one-way analysis of variance (ANOVA). If significant, a paired post hoc Tukey HSD test for unequal sample sizes was applied to identify the significant interactions.

The length-based spawning potential ratio (LB-SPR) model was then applied to quantify the spawning potential of the exploited population during each sampled year. Spawning Potential Ratio (SPR) is defined as the proportion of natural or unfished reproductive production left in a population when under fishing pressure. The ratio is a function of the relative fishing mortality (estimated as the ratio of fishing mortality to natural mortality, F/M), selectivity, and life history ratios (M/K and $L_m/L_\infty$). K is the von Bertalanffy growth coefficient, $L_m$ is the size at maturity, and $L_\infty$ is the asymptotic size (Hordyk *et al.*, 2015). The model defines maturity and selectivity ogives by logistic curves and estimates selection length at 50% ($SL_{50}$) and 95% ($SL_{95}$). The relative fishing mortality (F/M) is also estimated to compute SPR. The model considers an SPR of 0.40 and 0.20 as target and limit reference points for stock productivity as postulated by Hordyk and Carruthers (2018), and assumes an equilibrium state and asymptotic selectivity. In addition, the model assumes that the full spectrum of lengths in the population is represented in the sampled catch (Prince *et al.*, 2015). Length at 95% maturity ($L_{95}$) was calculated as $L_{50}$×1.15 following Prince *et al.* (2015). The Natural Mortality tool and LBSPR tool available at GitHub (2020) were used to estimate natural mortality and SPR. Table 1 provides a summary of the growth parameters used in the LBSPR model.

**Table 1. Growth parameters and maturity size for *Rastrelliger kanagurta* used in the LBSPR model**

| Parameter | Estimate (Source) |
|---|---|
| Natural Mortality (M) | 1.99 (Natural mortality tool) |
| Growth coefficient (year$^{-1}$) (K) | 1.3 (Froese and Pauly, 2023) |
| M/K ratio | 1.53 (Calculated) |
| Asymptotic length (L∞) | 39 (Froese and Pauly, 2023) |
| Size at 50% maturity ($L_{50}$) | 20.5 (Sousa and Gislason, 1985) |
| Size at 95% maturity ($L_{95}$) | 23.6 (Calculated) |

# Results

## Gear and vessel use

The data containing catches of *Rastrelliger kanagurta* represented 71 fishing trips consisting of 6,440 kg of *R. kanagurta* over the 6-year period. The main gear types catching *Rastrelliger kanagurta*were ring nets (94% of the sampled catch), and to a much lesser extent reef seines (5%) (Fig. 2).

Five vessel-gear combinations were identified, dominated by *mashua*-ring nets representing 59 fishing trips (84%). Canoe-reef seines represented five trips (7%), canoe-gillnet represented three trips (4%), fibre-boat-handline represented two trips (3%), canoe-handline and outrigger-handline represented one trip (1%) each. Catch per unit effort (kg vessel$^{-1}$ trip$^{-1}$) for *R. kanagurta* varied among the four gear types ranging from 2.7 kg ± 1.1 kg/trip for handlines to 101.9 kg ± 18.6 for ring nets (Table 2).

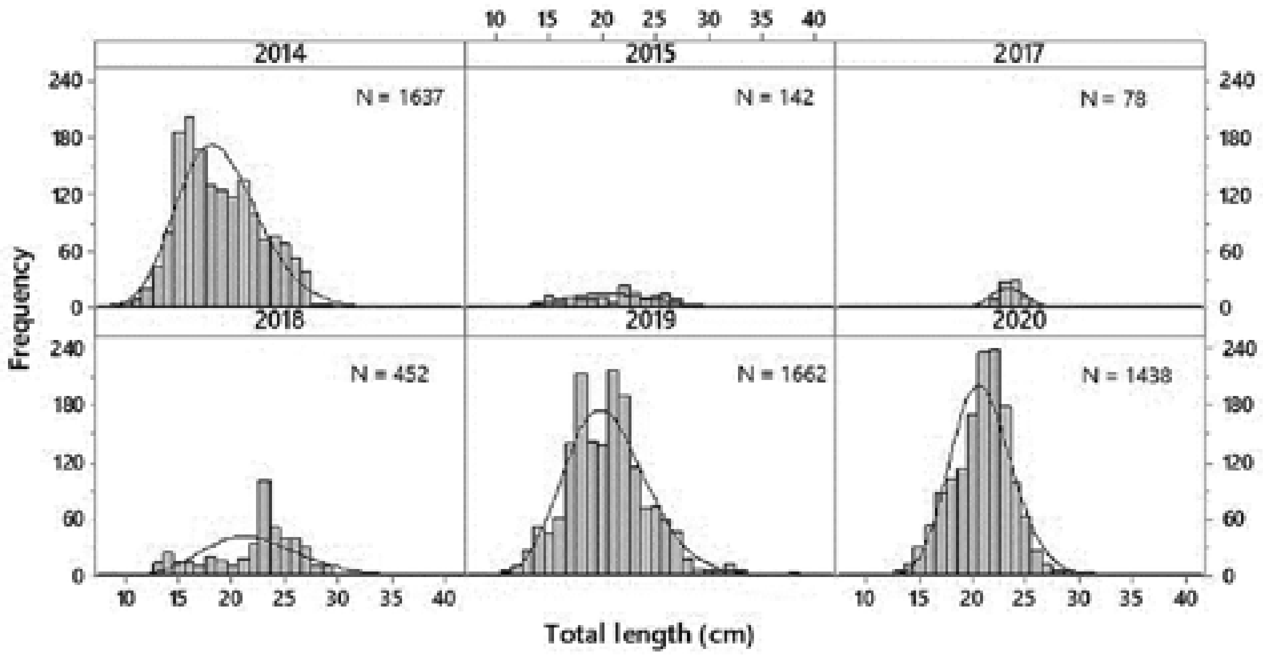



**Figure 2. Length frequency distribution of *Rastrelliger kanagurta* sampled from artisanal landings at three landing sites between 2014 and 2020 at three landing sites along the Kenya coast.**

**Table 2. Mean catch per unit effort (CPUE, kg vessel-1 trip-1), mean length (total length, cm) and the proportion below size at maturity ($L_{50}$) of *Rastrelliger kanagurta* caught by four gear types along the Kenyan coast.**

| Gear type | Proportion of total landings | Mean CPUE (kg vessel$^{-1}$ trip$^{-1}$) | Mean length (TL, cm) ± SE | % <$L_{50}$ |
|---|---|---|---|---|
| Handlines | 4% | 2.7 ± 1.1 | 23.9±0.2 | 10.1 |
| Gillnets | 6% | 9.6 ± 4.0 | 22.9±0.2 | 28.4 |
| Reef seines | 11% | 57.4 ± 15.3 | 20.6±0.1 | 80.0 |
| Ring nets | 79% | 101.9 ± 18.6 | 19.7±0.1 | 55.0 |
| All groups | 100% | 90.7 ± 17.5 | 20.2±0.1 | 33.9 |

***Length composition and selectivity***

The length distribution of *R. kanagurta* during the different years is shown in Figure 2. It was evident that the data was collected inconsistently with under-sampling occurring in some years e.g. 2015, 2016 and 2017. The overall mean total length was 20.2 cm (Table 1). The total length ranged from 6 cm to 35 cm (Fig. 3a).

Individuals ranging from 20 - 23 cm dominated landings accounting for 40% of the sampled catch. Results of the one-way ANOVA showed significant differences in mean sizes among the gear types ($p < 0.05$). The highest proportion of immature sizes (below $L_{50}$) was caught by reef seines constituting 80% of the sampled catch; while mature sizes dominated handline catches representing 90% (Table 1). On the other hand, the proportion of immature fish caught by ring nets was about 55% indicating a relatively balanced harvest.

***Annual change in mean length and spawning potential ratio***

Annual changes in the mean length of *R. kanagurta* remained stable over the 6-year period ranging from 18.9 ± 3.8 cm in 2014 to 23.4 ± 1.5 in 2017 (Figs. 3b and 4). Results of one-way ANOVA showed significant differences in mean length over time ($p < 0.05$); the post hoc Tukey HSD test revealed 2014 and 2017 as significantly different in mean size from the other years. The SPR for the entire study period was estimated at 0.48 indicating a relatively healthy state. Annual estimates of the SPR revealed that the fishery was above the target reference point of 0.4 during all the years (Fig. 5).

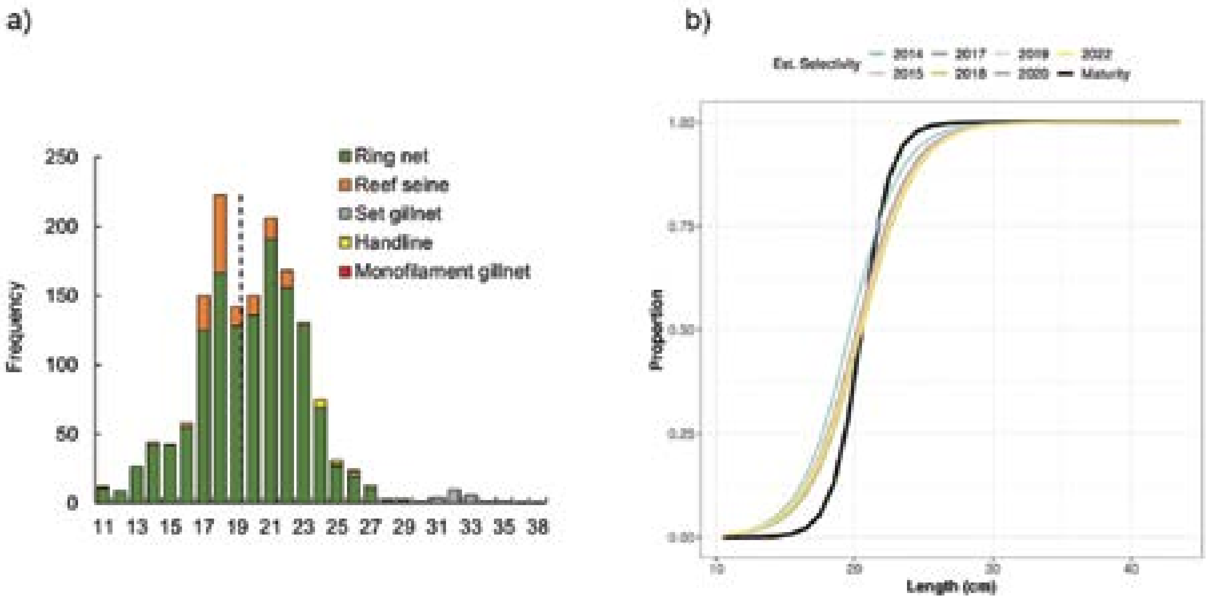



**Figure 3. Length distribution of *Rastrelliger kanagurta* artisanal fishery landings stacked along the Kenya coast during 2014-2020 stacked by gear type (a) and the maturity and selectivity ogives for the years sampled (b).**

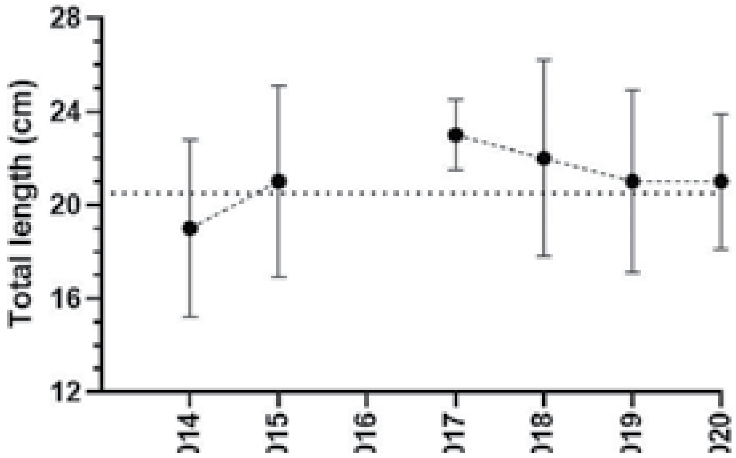
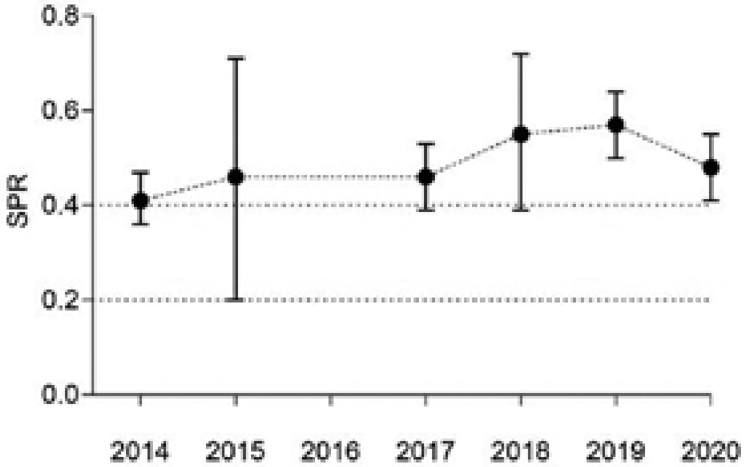



**Figure 4. Annual change in mean total length of Rastrelliger kanagurta in landed artisanal catches along the Kenya coast. Whiskers represent the minimum and maximum length. Dashed reference line represents the size at first maturity ($L_{50}$).**

**Figure 5. Annual trend in Spawning Potential Ratio (SPR) of *Rastrelliger kanagurta* sampled from artisanal landings in Kenya's waters between 2014 and 2020.**




## Discussion

The present study represents a first attempt to assess annual trends in the artisanal fishery targeting *R. kanagurta* in Kenyan waters. The species was mainly caught using ring nets, which had the highest catch rates compared to other gear types. Ring nets are known to be highly efficient in targeting schooling pelagic fish and are hence the most preferred gear type for targeting Mackerels. High catch rates of *R. kanagurta* by ring nets have been reported in Malaysia (Amin *et al.*, 2014) and in Indonesia (Arrafi *et al.*, 2016), similar to this study. Most of the *R. kanagurta* catches are landed at the South Coast of Kenya in Gazi and Vanga which is strongly influenced by the Pemba channel which has been reported to support small high numbers of small and medium pelagic species (Kizenga *et al.*, 2021). Observed length ranges were within the range reported within the Indian Ocean region (Ganga, 2010). The differences in mean sizes and proportions of mature fish among different gear types may reflect differences in catchabilities associated with accessibility to nearshore vs offshore fishing grounds.

## Conclusion and recommendations

The study shows that the *R. kanagurta* population was fished at optimal levels during the study period, indicating a low risk of overfishing. A major assumption of the study was that the data fully met the SPR model assumptions. The study demonstrates utility in the application of length-based approaches to rapidly diagnose the status of Kenya's data-poor fisheries to inform decision-making on research directions and precautionary management. The *R. kanagurta* fishery has been prioritized for further stock assessment under various ongoing initiatives. Going forward, the scope of assessment should be broadened to include other length-based indicators (LBIs) to further validate the findings of this rapid assessment. Continued catch and biological monitoring of the fishery is emphasized to improve the data quality, particularly with regard to sampling frequency and consistency.

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