# Species composition, abundance and preliminary spawning potential Ratio (SPR) assessment for tuna and tuna like species: Some results from application of mobile phone -Catch Assessment Survey, Kenya

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## Abstract

This papers looks at data catch assessment survey data collected from the period June 2018-May 2019 with aim to strengthen the monitoring plans for tuna species and improve artisanal tuna data collection. A one-year electronic data collection using a mobile application was piloted at eleven (11) sites with landing sites as the primary sampling unit (PSU) and vessel gear combination as secondary sampling unit (SSU). A total of Composition of tuna and tuna tuna-like species in the sampled catches of sampled biomass of the pooled data indicate tuna species accounted for 38% out of which 5.6% were not identified to species level and 62 % were tuna like species out of which 4.5% were unidentified. The most common species of tuna and tuna like species were yellowfin tuna (*Thunnus albacares*); Kanadi kingfish (*Scomberomorus plurilineatus*); Kawakawa (*Euthynnus affinis*); Bullet tuna (*Auxis rochei*) and Frigate tuna (*Auxis thazard*). *Thunnus albacares* was the most abundant, contributing 29% of the total landings of the sampled catch. The mean length of sampled *Thunnus albacares* was 84.75±0.64 cm while the minimum and maximum length was 30.5 cm and 180 cm while that of *Scomberomorus plurilineatus* was 76.82±1.30 cm during the sampling period.

In data poor fisheries, it is difficult to estimate the stock biomass and exploitation rates and fishing mortality which is a measure of fishing pressure. Using length data of fish species length based spawning potential ratio (LBSPR) analysis was conducted to determine the fishing pressure from the different fishing methods. Targeting immature fish could result to a SPR value of 20% and below commonly termed as the limit reference while SPR value of 40% is at an optimum level. The results from this catch assessment survey contributes to enhancing monitoring of these key fish species and also an opportunity to strengthen the

monitoring plans for those species and gather more information on the size at maturity which is important in the SPR assessment.

## Rationale of the study

Good quality data, and timely analysis and interpretation is key to an effective fisheries resource management. In 2013-2016, the State Department for Fisheries Aquaculture and the Blue Economy (SDFA&BE) piloted Catch Assessment Survey (CAS) to help design sampling approaches for fish catches, fishing effort, and socio-economic data. An understanding of the status of a fishery Stock is key to determine the appropriate measures to be put in place to enable sustainable management. Therefore in stock assessments one or more biological characteristics of the stock are determined and used as indicators while setting reference value that define desirable conditions of the stock . However, in data poor fisheries, it is difficult to estimate the stock biomass and exploitation rates and fishing mortality which is a measure of fishing pressure.

Using length data of fish species length based spawning potential ratio (LBSPR) analysis can be conducted to determine the fishing pressure from the fishing methods. For example targeting immature fish could result to a spawning potential ration (SPR) value of 20% and below commonly termed as the limit reference while SPR value of 40% is at an optimum level. This preliminary assessment of the tuna species contributes to the enhancing monitoring of these species and the potential to assess other species not assessed in this phase. It also opportunity to strengthen the monitoring plans for all the species including acquiring important biological data such as size at maturity which is important in the SPR assessment.

## Objectives

The main objective of the pilot study was to assess the applicability and the use of mobile application in data collection and reporting towards enhancing artisanal tuna fisheries management. The study was expected to generate useful data to explore the use of LBSPR methodologies in tuna fisheries assessment.

## Sampling locations

This study was conducted in 11 selected landing sites in Kwale, Mombasa and Kilifi Counties in the coastal Kenya (Figure 1). The sampling strategy was priority for tuna and tuna like species as well as the most abundant species in the various boat-gear combinations in the eleven (11) as shown in Figure 1.

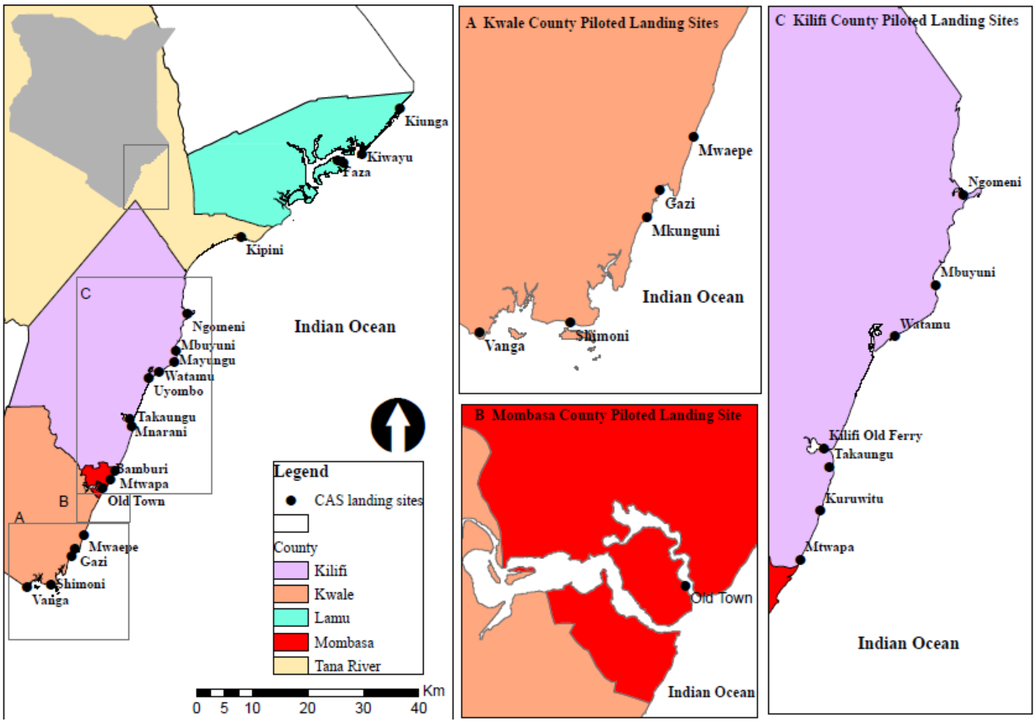



*Figure 1: Location of sampling sites in Kwale, Mombasa and Kilifi Counties, Kenya (Map courtesy Benson Macharia- Lamu)*

**Data collection**

The Survey design was based on selected landing sites from the existing Catch Assessment Survey (CAS) within four counties as well as tuna landing sites. Sampling was conducted in eleven (11) landing sites for tuna and tuna like species. These sites were representative of the tuna species caught in the artisanal tune fishery with different gear-vessel categories were considered within the selected sites.

Two (2) data collectors per each landing site were trained equipped with an android phone, measuring boards and weigh scale to the nearest 0.1g. The revised CAS sampling protocol was used during the sampling. Data was captured and submitted real time. The data collectors were expected to take photos of species that could not be identified during the sampling.

Tuna species were identified in selected fish landing sites from three counties (Mombasa, Kwale and Kilifi). Data was pooled from all the landing sites from the three counties and only the species with a sample size of $n \geq 100$ were considered for length frequency analysis. Length frequency distribution was first plotted for each of the identified species with the data pooled from all the landing sites (all gears pooled). Length frequency distribution analysed based on the gear where sample size was considered relatively substantial. Fish gear distribution was also analyzed for all the three counties combined

The five (5) tuna and tuna like species were considered for the LB-SPR approach Table 1

## Results and discussion

### Biomass composition and abundance

Total fish landed within the period is estimated at 81649.5kg (81.6 tons). Tuna and tuna like species amount to 39,760.8kg (39.8 tons) table 2. Most tuna species are caught in Kilifi County. Species of the family scombridae was most abundant in numbers 77.2% and contributing to 26.7 tons of the sampled catch. The billfishes sampled catch was estimated at 5439.2 kg (5.4 tons), which account for 13.7% of the sampled tuna and shark species. In overall tuna species contributed to 37.97% of the sampled artisanal catch tuna catch while tuna like species contributed 62.03%. Most of the sampled tuna catch was in Mombasa County (55.87%) which was mainly from artisanal longline. *Thunnus albacares* was most common with 32.14% sampled in Kilifi county, 25.14% in Kwale and 14.01% in Mombasa (Table 1)

*Table 1: Spatial distribution and abundance of tuna and tuna-like species in the sampled catches shown as the percentage of total biomass sampled within the three counties*

| Group | Species | Kilifi | Kwale | Mombasa |
|---|---|---|---|---|
| | | % | % | % |
| Tuna | *Thunnus albacares* | 32.14 | 25.14 | 14.01 |
| | *Euthynnus affinis* | 0.67 | 12.40 | 0.30 |
| | *Auxis thazard* | 0.02 | 4.83 | 0.00 |
| | *Auxis rochei* | 0.00 | 1.00 | 0.00 |
| | *Katsuwonus pelamis* | 0.00 | 0.26 | 0.14 |
| | Unidentified | 0.99 | 1.29 | 41.42 |
| Tuna-like | *Scomberomorus commerson* | 32.72 | 11.00 | 5.57 |
| | *Istiophoridae spp* | 13.78 | 20.84 | 5.91 |
| | *Scomberomorus plurilineatus* | 6.52 | 7.01 | 0.00 |
| | *Acanthocybium solandri* | 6.54 | 0.00 | 0.00 |
| | *Xiphias gladius* | 0.00 | 3.23 | 32.64 |
| | *Sarda orientalis* | 3.04 | 0.00 | 0.00 |
| | *Scomberoides tol* | 0.00 | 0.64 | 0.00 |
| | *Scomberoides lysan* | 0.04 | 0.00 | 0.00 |
| | *Scomberoides commersonnianus* | 0.00 | 0.01 | 0.00 |
| | Unidentified | 3.54 | 12.35 | 0.02 |

A total of 16 species were identified for length frequency analysis of which five (5) were tuna and tuna-like species. The most common species were Yellowfin tuna (*Thunnus albacares*), Kanadi kingfish (*Scomberomorus plurilineatus*), Kawakawa (*Euthynnus affinis*), Bullet tuna (*Auxis rochei*) and Frigate tuna (*Auxis thazard*). *The most sampled species for individual lengths were Thunnus albacares (29.05%), scomberomorus plurilineatus* and *Scomberomorus commerson* (26.40%, 5.86% ) Euthynnus affinis *(2.30%).* A*uxius thazard, Auxius rochei, and Katsuwonous pelamis* samples were <1% of the total samples for tuna species. 5.60% of the tuna species were not is]dentified to species level About 10% of the tuna catch sampled was not identified to species level.

## Length-frequency analysis

The different gears that caught the most sampled tuna and Tuna like species is shown in figure 2. Trolling lines mostly targeted *Thunnus albacares* (>70%), while *Auxius thazard* were caught in ringnet gear (>90%). *Auxius rochei* and *scomberomorus plurilineatus* were caught in different gears

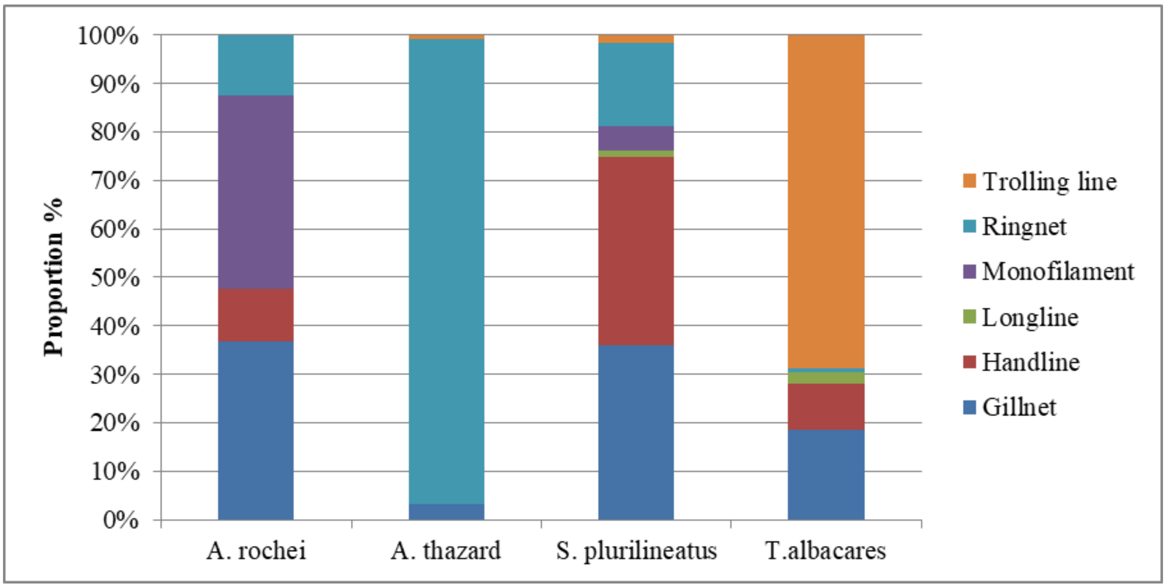



*Figure 2: Proportions of fish species caught in different gears*

**Yellowfin tuna (T*hunnus. albacares*)**

The species was targeted by various gears including trolling line, gillnet, handline, longline and ringnet. Of these gears, trolling line, gillnet, handline were selected for further analysis based on the sample size (at least $n \geq 100$). The mean length was 84.75±0.64 cm while the minimum and maximum length was 30.5 cm and 180 cm respectively. Length frequency distribution (all fishing gears pooled) (fig 3 a) revealed that two cohorts were targeted, the first cohort with a peak length of 59-64 cm and the second cohort with a peak length of 84-89 cm.

The size distribution from trolling gear did not differ much from the pooled data (all gears), with trolling line samples represented about 73% of the total sample size (all gears). The plot revealed that two cohorts were targeted by trolling line, the first cohort with a peak length of 59-64 cm and the second cohort with a peak length of 84-89 cm. The results further indicate gillnet gear targeted, fish of 59-64 cm and 99-104cm. Data from handline gear indicate three cohorts with peak lengths of 64-69 cm, 84-89 cm and 114-119 cm.

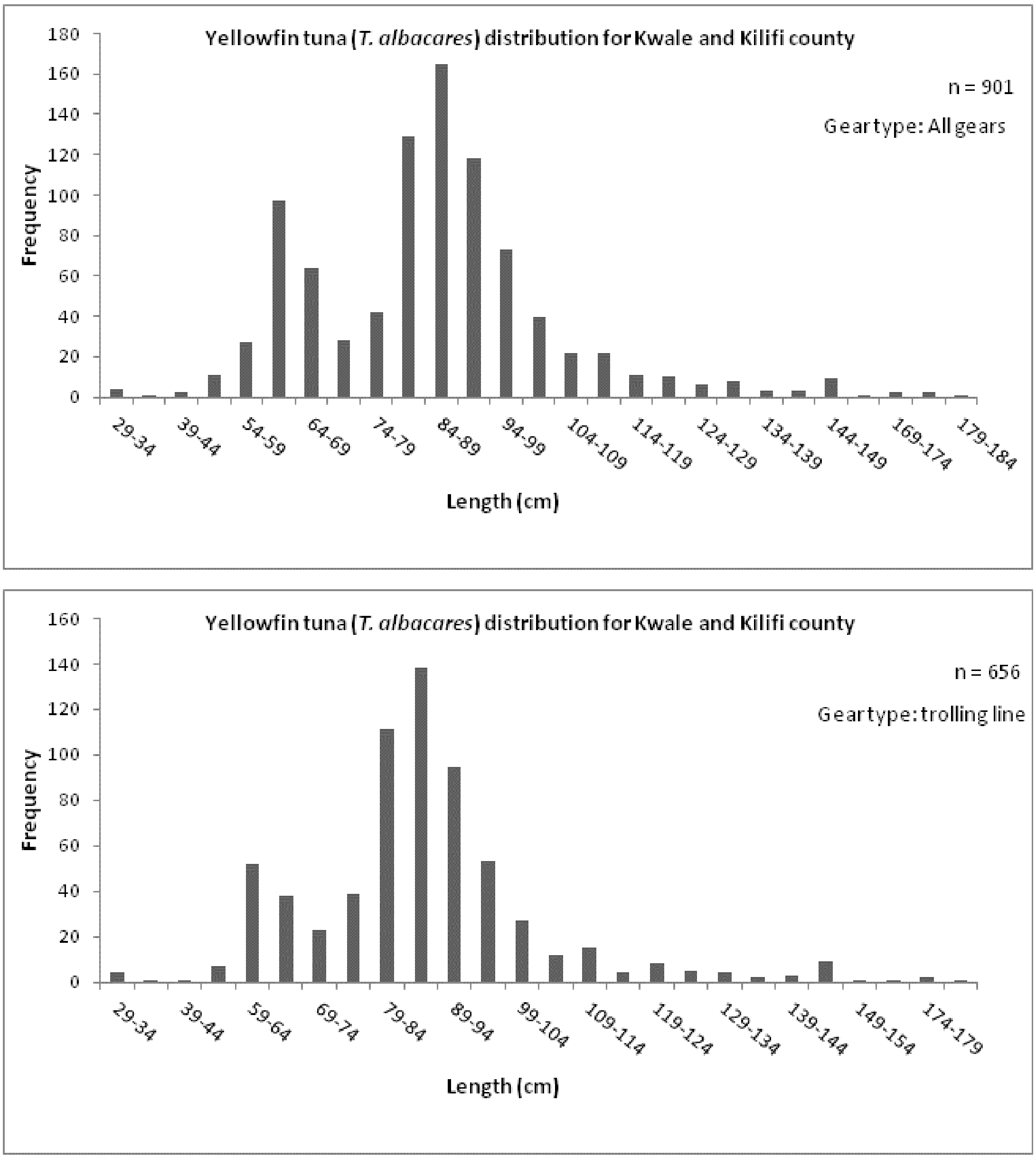



***Figure 3:*** *Yellowfin tuna (Thunnus albacares) length frequency distribution for data pooled for a) all the gears and b) trolling line with the data pooled from all the Kwale and Kilifi Counties*

**Kanadi kingfish (*Scomberomorus plurilineatus*)**

The mean length was 76.82±1.30 cm while the minimum and maximum length was 25 cm and 128.8 cm respectively during the sampling period. Length frequency distribution (all fishing gears pooled), suggests normal distribution of one cohort with a peak length of 84-89 cm.

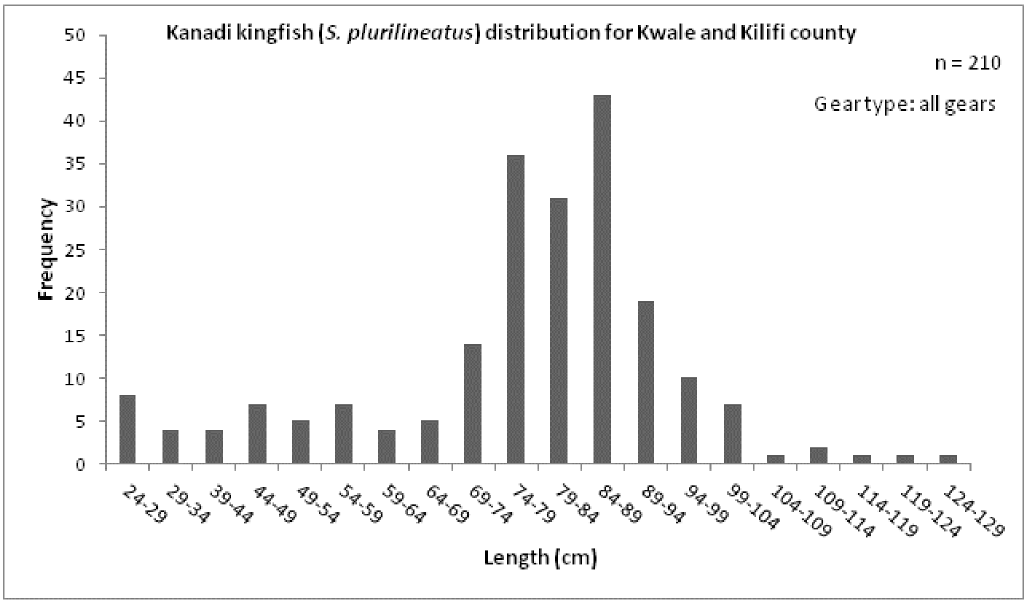



***Figure 4.*** *Kanadi kingfish (Scomberomorus plurilineatus) length frequency distribution for all the gears combined with the data pooled from all the counties.*

The species was targeted by various gears including handline, gillnet, longline, monofilament, ringnet and trolling line. The distribution suggests that two cohorts were targeted, the first cohort with a peak length of 44-49 cm and the second cohort with a peak length of 84-89 cm for samples caught in handline gear. Gillnet caught fish of length 79-84 cm and could be that bigger fish were the most targeted by this gear.

**Kawakawa (*E. affinis*)**

The mean length was 52.5±0.83 cm while the minimum and maximum length was 23 cm and 81cm respectively during the sampling period. Length frequency distribution (all fishing gears pooled) suggests that three cohorts were targeted with peak lengths of 30-32 cm, 48-50 cm and 58-62 cm. The species was targeted by various gears including ringnet, handline, gillnet, monofilament, trolling line but most of the catch was from ringnet. Size distribution from ringnet gear suggests three peak lengths of 34-36 cm, 46-50 cm, 60-62 cm and 66-68 cm. From the pooled data for all counties, size distribution from trolling line gear also suggest three cohorts could be targeted with peak lengths 36-38 cm, 48-50 cm and 60-62 cm.

**Frigate tuna (*A. thazard*)**

The mean length was 37.43±0.27 cm while the minimum and maximum length was 49 cm and 17 cm respectively during the sampling period. Length frequency distribution (all fishing gears pooled) peaked at 30-32 cm, 48-50 cm and 58-62 cm. The species was mainly targeted by two gears, ringnet and gillnet. Ringnet gear caught fish of lengths of 34-35 cm and 43-44 cm.

**Bullet tuna (*A. rochei*)**

The mean length was 35.81±0.59 cm while the minimum and maximum length was 29 cm and 45 cm respectively during the sampling period. The species was mainly targeted by ringnet (*n = 33*) with the distribution with a peak length of 34-36. The largest size range targeted was 44-46 cm.

**Estimation of Spawning Potential Ratio (SPR)**

The determination of the SPR value was conducted by using the Length-Based SPR model (LB-SPR) proposed by Hordyk *et al.*, (2014) which has been applied in small scale fisheries to aid in fisheries management (Prince et al 2015). The LB-SPR assessment technique requires life history ratios; M/K and $L_m/L_\infty$ ; where M is the rate of natural mortality, k is the von Bertalanffy growth co-efficient, $L_m$ is the size of maturity and $L_\infty$ is asymptotic size is important (Prince *et al.*, 2015) which must be known for the each species either from earlier studies or assessed during the study (Prince et al 2015).

**Data preparation and analysis procedure**

The use of the LBSPR Application require length composition data from the fishery and estimates of the life history parameters. The life history information was obtained from literature of existing studies in the WIO region including published and unpublished results or from FishBase (Table 1). The key steps include;

i. Uploading the data into the application
ii. Fitting of the model and ;
iii. Examining the results

The entire simulation design was carried out using the Barefoot Ecologist's Toolbox (https://www.barefootecologist.com.au/) that incorporates LBSPR package in R statistical programming language (R Core Team 2015).

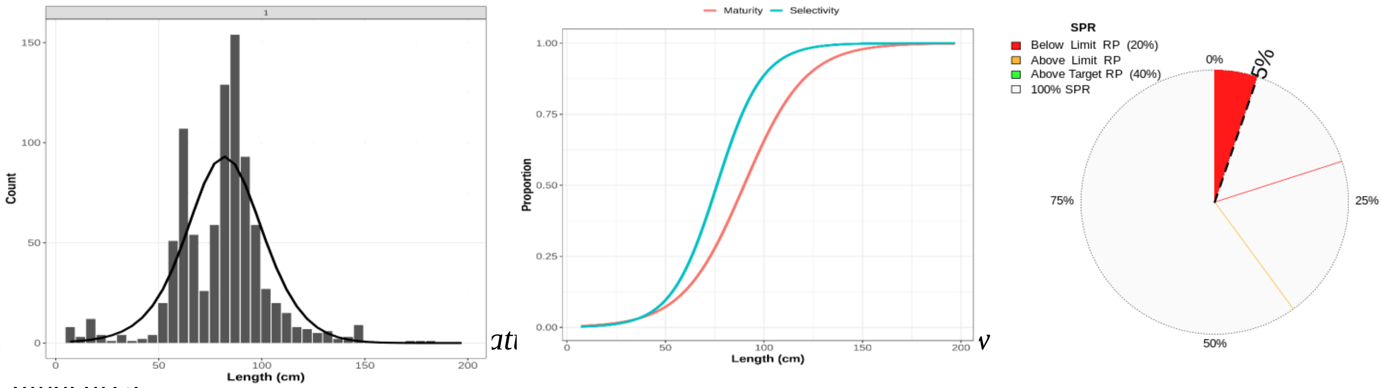
The species data prepared for the LBSPR assessment is shown in table 2

*Table 2.The parameter estimates used to assess demersal reef, tuna species and lobster species in Kenya: M/k—the ratio of natural mortality (M) and von Betalanffy growth coefficient (k), L∞—asymptotic size, L50%—size of 50% maturity, L95%—size of 95% maturity, n number of individual samples per species. (** indicate data sources used in the assessment)*

| **Species** | **n** | **L50** | **L95** | **L∞** | **K** | **M** | **M/K** | **References** |
|---|---|---|---|---|---|---|---|---|
| *Thunnus albacares* | 897 | 89.9 | 136.0 | 183 | 0.67 | 0.8375 | 1.25 | |
| *Euthynnus affinis* | 265 | 54.4* | 68.5* | 87.7 | 0.51 | 0.65 | 1.27 | Taghavi et al. 2010 |
| *Auxis rochei* | 264 | 23.6 | 34 | 57.4 | 0.61 | 1.18 | 1.93 | S. Jasmine et al.,2013 |
| *Auxis thazard* | 260 | 29.7 | 39.6 | 57.95 | 1.2 | 1.65 | 1.38 | Shubhadeep Ghosh et al. 2012 |
| *Scomberomorus plurilineatus* | 198 | 75* | 100 | 126.5 | 0.29 | 0.45 | 1.55 | Juan-Jorda´ MJ et al 2013; |

**Yellowfin Tuna *Thunnus albacares***

A total of 897 samples of Yellowfin tuna were assessed (Table 2). The length frequency distribution and maturity curve of *T. albacares* are shown in Figures 5.




F ati v
T. albacares

The length frequency distribution of the samples shows that the cohort used has a modal length of 65 – 90cm, and maximum length of 180cm. The estimates of the cohort were assessed at 89.9cm for 50% maturity and 136 for 95% maturity. The assumption of relative size of maturity and length at first maturity for Yellowfin tuna estimated that its growth asymptotes at an average maximum size of 183cm (Table 3). From these parameters the LB-SPR assessment model indicates that Yellowfin tuna becomes susceptible to fishing above its size of maturity and indication of ~5 times (F/M=4.56) more heavily than the optimum level required to produce the maximum sustainable yield. Consequently, the spawning potential is estimated at 5% which is below the limit recruitment level of 20%, which is required to stabilize the population (Prince *et al.*, 2015).

**Kawakawa *Euthynnus affinis***

A total of 265 samples of Kawakawa were assessed (Table 2. The length frequency distribution of the samples shows that the cohort used has a modal length of 41.3 – 63.4cm, and maximum length of 76cm. The length frequency distribution and maturity curve of *E. affinis* that are shown in Figure 6.

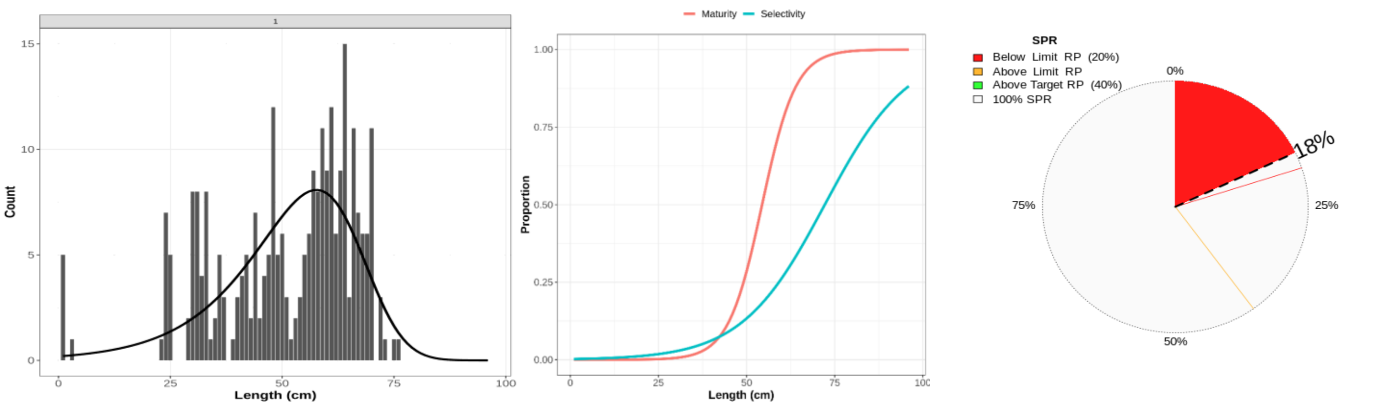


*Figure 6: a) Length frequency curves, b)Maturity at length curves and c)estimated spawning and reference points for E. affinis.*

The length frequency histogram shows a left skewed distribution with a standard deviation of 15.5744 and skewness (-0.90116), of the cohort in the LB-SPR assessment model (figure 6). The estimates of the cohort were assessed at 54.4cm for 50% maturity and 68.5cm for 95% maturity. The assumption of relative size at maturity and length at first maturity for Kawakawa estimated that its growth asymptotes at an average maximum size of 87.66cm. From these parameters the LB-SPR assessment model indicates that Kawakawa becomes susceptible to fishing below its maturity size with high proportions caught before maturity despite a high variation with sizes fished at maturity (Figure 6). Consequently, the spawning potential of the cohort is 18% (Figure 16), which is slightly below the limit recruitment level of SPR20%. However the LB-SPR estimates of fishing pressure (F/M) could be unrealistically high.

**Bullet tuna *Auxis rochei***

A total of 264 samples of Bullet tunas were assessed (Table 2. The length frequency distribution of the samples shows that the cohort used has a modal length of 51cm – 72cm, and maximum length of 120cm.

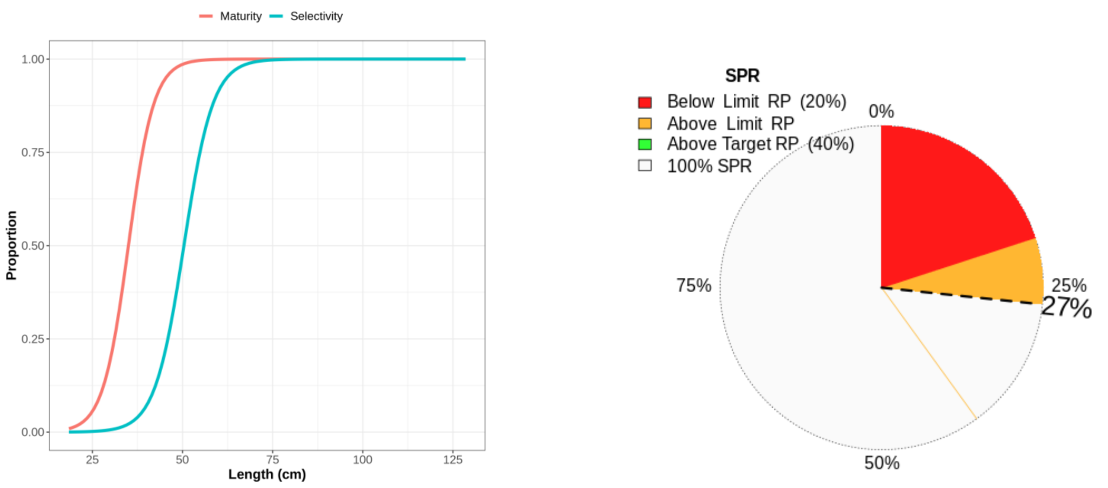



*Figure 7: a) Maturity at length curves and b)spawning and reference points for A. rochei*

The length frequency histogram shows a fairly distributed population in the LB-SPR assessment model and that Bullet tuna's maturity by length (cm) estimated from the samples, and the estimates of the cohort were assessed at 23.6cm for 50% maturity and 34cm for 95% maturity based on the data from other studies. The assumption of relative size of maturity and length at first maturity for Bullet tunas estimated that its growth asymptotes at an average maximum size 57.4cm .From these parameters the LB-SPR assessment model indicates that Bullet tunas becomes susceptible to fishing just about the same maturity sizes however, the full maturity is reached before they are fully selected by the fishery (Figure 7)

### Kanadi kingfish (Nguru borega) *Scomberomorus plurilineatus*

A total of 198 samples of Kanadi kingfish were assessed (Table 2). The length frequency distribution of the samples shows that the cohort used has a modal length of 73cm - 86.67cm, and maximum length of 120.5cm

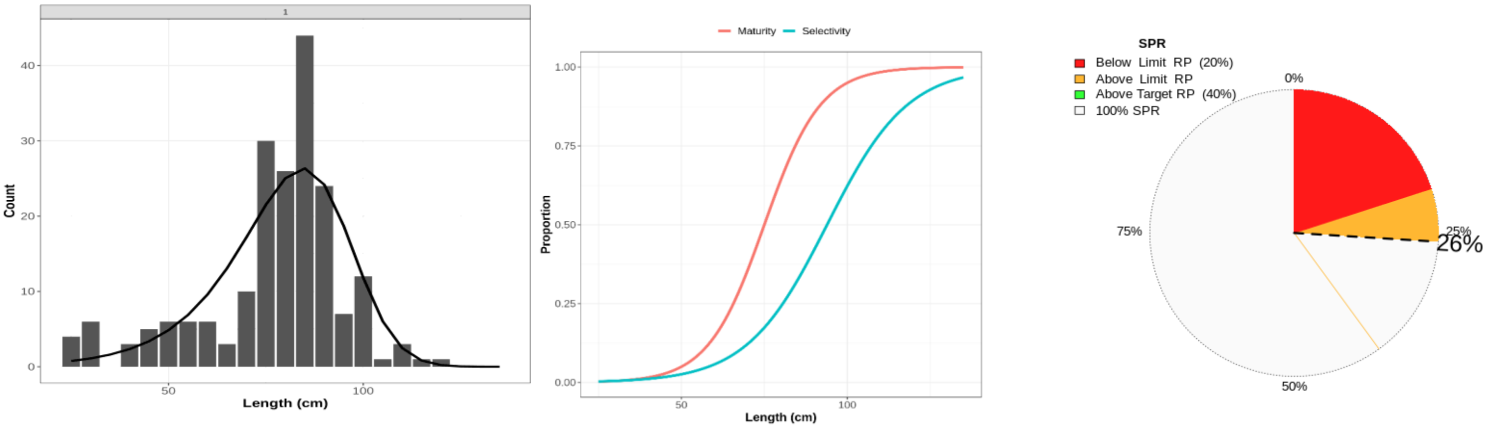



*Figure 8: a) Length frequency curves, b) Maturity at length curves and c) estimated spawning and reference points for S. plurilineatus*

The length frequency histogram shows a fairly distributed population in the LB-SPR assessment model (Figure 8). The estimates of the cohort were assessed at 75cm for 50% maturity and 100cm for 95% maturity. The assumption of relative size of maturity and length at first maturity for Kanadi kingfish estimated that its growth asymptotes at an average maximum size 126.5cm From these parameters the LB-SPR assessment model indicates that Kanadi kingfish becomes susceptible to fishing around the same size of maturity however, it attains full maturity before it becomes fully selected for the fishery and presently being fished at around ~5 times (F/M=4.68) more severely than the conditions required to produce the maximum sustainable yield (Table 10). Consequently, the spawning potential of the cohort is 26% (Figure 8) which is slightly above the limit recruitment level of SPR20%.

### Frigate tuna *Auxis thazard*

A total of 260 samples of Frigate tuna were assessed (Table 2). The length frequency distribution of the samples shows that the cohort used has a modal length of 34.37cm – 39.8cm, and maximum length of 49cm.

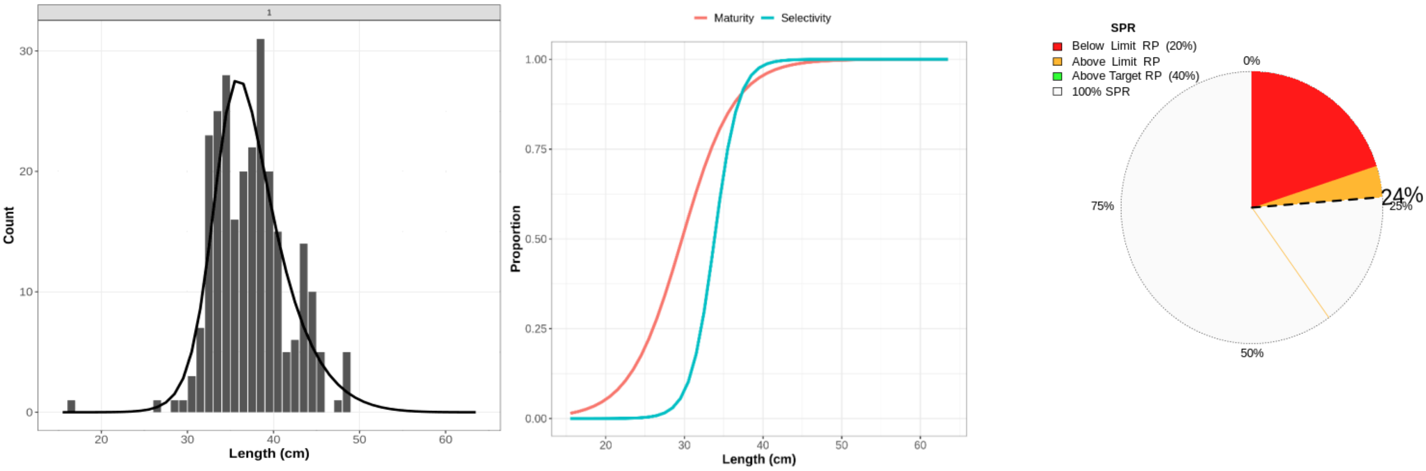



*Figure 9: a) Length frequency curves, b) Maturity at length curves and c)spawning and reference points for A. thazard.*

The length frequency histogram shows a fairly distributed population in the LB-SPR assessment model (Figure 29). The estimates of the cohort were assessed at 29.7cm for 50% maturity and 39.6cm for 95% maturity. The assumption of relative size of maturity and length at first maturity for Frigate tuna estimated that its growth asymptotes at an average maximum size 57.95cm (Table 12). From these parameters the LB-SPR assessment model indicates that Frigate tuna becomes susceptible to fishing around the same size of maturity however, just before it attains full maturity size, it becomes fully selected for the fishery (Figure 30) and presently being fished at approximately two and a half times (F/M=2.65) more heavily than the level required to produce the maximum sustainable yield. Consequently, the spawning potential of the cohort is 24% (Figure 31) which is slightly above the limit recruitment level of SPR20%.

## Discussions

The method of using length in the assessment of fisheries stock has been observed and tested as one of the simplest and most convenient design for gathering data in data-poor fisheries. However the results indicate the over estimation of F/M, hence an opportunity to enhance the sampling of the length measurements for most tuna and tuna like species including sharks. This is because fully robust SPR estimates require approximately 1000 samples (Prince, 2017) and in this study, the samples were all below n~1000 with considerably small sizes of samples of Kanadi kingfish (*S. plurilineatus*), n=198.

From the results, Yellowfin tuna (*T. albacares*), and Kawakawa (*E. affinis*) could be experiencing increasingly high levels of fishing over 3-6 times above the optimum conditions that maximize sustainable yield. The results indicate that the gears could be selecting the fishery before they attain L50% maturity with the model estimating spawning potential of 5% way below the limit SPR20% for yellowfin tuna, and 18% for Kawakawa. These findings indicate the need to enhance the sampling to capture all sizes in the population. In addition there is need to enhance management measures to boost the spawning potential of these tuna and tuna-like species, and prevent depletion of these stocks.

Based on the results Bullet tuna (*A. rochei*) SPR=100%, Kanadi kingfish (*S. plurilineatus*) SPR=26%, and Frigate tuna (*A. thazard*) SPR=24%, were assumed to experience moderately low fishing pressure, and hence had greater estimated proportions of spawning potential. In the circumstances of Bullet tuna and (SPR=100%, F/M=0) further monitoring is necessary for another assessment. In addition, the parameters $L_{\infty}$ for Bullet tuna could have been underestimated hence the LB-SPR model fit for SPR=1.

**Conclusions and Recommendations**

1. The use of mobile data has proved useful in monitoring of tuna fish catches and the timely reporting of data for coastal fisheries at species level.

2. Based on the available data, it appears that there are serious weaknesses as far as data collection in some counties, hence the need to improve on the coverage and possible encourage fishers to report their catch through simple logbooks.
3. Overall, this pilot phase data should serve as an indicator of important species within each of the covered landing sites (taking seasonality into account). Focus should then be directed to these important species in terms of collection of their biological data (length, weight, sex, maturity etc). This will particularly help in training and collection of more reliable biological data. However, species identification still remains a challenge in the artisanal data monitoring.

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