Fishery characteristics and stock status of *Lethrinus lentjan* in selected fishing areas along the Kenya Coast

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Abstract

Small scale fisheries is dominant along the Kenya coast characterised by multispecies, multigear and multi-fleet and therefore prone to over-exploitation. The success of fisheries sustainable management is dependent on life history traits of the target stock. This study was aimed to characterize the small scale *lethrinus* fishery as well as determine its current stock status. Monthly shore-based catch assessments for fisheries and biological data were collected from October 2020 to September 2021 from selected fish landing sites along the Kenya coast. A total of 22 species belonging to the genus *Lethrinus* were recorded over the study period. Overall Msambweni fishing area had the highest landings of the genus *Lethrinus*, accounting for more than 69%, and the overall contribution of *Lethrinus lentjan* to the overall total fish landings was 25%. Female individuals of *L. lentjan* were more abundant than males, with an overall sex ratio of 1:1.53, which differed significantly from the expected ratio of 1:1. *Lethrinus lentjan* recorded a negative allometric growth with an asymptotic length (L_∞) and growth coefficient (K) of 51 cm and 0.46 y^{-1}, respectively. The total mortality (Z) was 2.07, the natural mortality (M) was 0.963, and the fishing mortality (F) was 1.10 with an exploitation rate of 0.53. The recorded E value of 0.53, in this study, was slightly higher than the optimum exploitation rate of E = 0.5, indicating an exploited fishery. Therefore, the study recommends that the management system of this fishery should be revised carefully.

Keywords: Relative condition factor; Length-weight relationship; Stock status; Exploitation rate; Kenya coast

Introduction

The pink-ear emperor (*Lethrinus lentjan*) belongs to the family Lethrinidae (Eschmeyer et al., 2017). Carpenter and Allen (1989) reported that this species is native to saline waters of the Indo-West Pacific, with the exception of Tanzania and Australia, where it occurs both in saline and briny environments due to its limited geographic distribution. *Lethrinus lentjan* is among the three fish species that are frequently landed, and the other two species are *Siganus sutor* and *Leptoscarus viagiensis* with similar outcomes (Hick & McClanahan, 2012). There are declining concerns about the catches of *L. lentjan* along the Kenya coast due to its high commercial value (Kaunda-Arara et al., 2003). The unstable *L. lentjan* stock within the Indo-Pacific region, is of a great concern globally, including Kenya. The artisanal fishery of *L. lentjan* along the Kenya coast is critically affected by the degradation of breeding and nursery grounds, as a result of poor enforcement of fisheries management measures and the lack of adequate and reliable data (Kulmiye et al., 2002).

Majority of artisanal fish species along the Kenya coast are over exploited, with *L. lentjan* reporting a significant decline (Hicks & McClanahan, 2012). Lethrinids are exploited in the artisanal fishery and form an essential food source throughout their distribution because of their relatively high abundance in artisanal landings (Carpenter and Allen, 1989). For instance, along the Kenya coast lethrinids, when combined with siganids, constitute about 40 % of the artisanal landings (Kaunda-Arara et al., 2003). Fish landings have been declining over the years with some commercially important fish species considered over-exploited (McClanahan et al., 2008; Hicks & McClanahan, 2012). This decline was also confirmed by Samoilys et al., (2017) who investigated the decadal trends in Kenya's artisanal fisheries. Because of the high species diversity, obtaining species-specific catch data has proven difficult resulting in the

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misidentification of some species. This makes species-specific regulation difficult due to a lack of adequate life-history data information. Therefore, the vulnerability of the over-exploitation of many exploited species, makes the multi-species management strategies unreliable and difficult to implement (Currey et al., 2013).

The family Lethrinidae commonly known as emperors are the most species in the small scale fisheries landings along the Kenya coast (Mbaru, 2012). Other most speciose fish species in the small scale artisanal landings are the families Scaridae and Siganidae. These families together with Lethrinidae contribute 75% of the artisanal catches in weight. The species *L. lentjan* dominates in catches from basket traps set in reef lagoons along the Kenya coast (Mbaru, 2012). There has been increased fishing pressure in the coastal and marine artisanal fisheries along the Kenya coast (Government of Kenya, 2016). Similar trends have also been observed with the number of landing sites. Previous studies have reported that declining artisanal catches are not only due to overfishing but also the degradation of habitats, the use of destructive fishing gear, and the unprecedented effects of global warming (McClanahan, 2008; Tuda & Wolff, 2015; Samoilys et al., 2017).

Fisheries data from FAO application FishStatJ software statistics, indicate that the annual global landings of scavengers (lethrinids) increased rapidly in the 1970s but later declined to about 84,000 metric tons in the 1990s (Trianni, 2016). The increase in fish landings, have been reported in many studies conducted to assess life history traits of lethrinid species targeted in both commercial and traditional fisheries (Grandcourt, 2002; Trianni, 2011; Currey et al., 2013). Lethrinids are abundant and dominate the coral reef fisheries throughout the tropical and sub-tropical Indo-Pacific regions (Carpenter & Niem, 2001). Lethrinids contributes a significant portion of artisanal catches as a source of food in the western Pacific and Indian Ocean regions (Vasantharajan et al., 2014) and thus provide a livelihood for the dependent fisher communities. This study therefore, provide more insight on the extent at which *L. lentjan* is exploited in selected fishing areas along the coast of Kenya to fill in the gap on direct fisheries management thus, providing management recommendations for sustainable exploitation of its artisanal fishery.

Materials and methods

Study Area

The study was conducted at selected fish landing sites in Shimoni (latitude 4.6472° S, longitude 39.3804° E), Msambweni (latitude 4.4653° S, longitude 39.4813° E), and Malindi (latitude 3.2192° S, longitude 40.1169° E) along the coast of Kenya (Figure 1). These fish landing sites are representative of the artisanal fishing areas along the Kenya coast (Ogongo et al., 2015; Munga et al., 2013). These selected fish landing sites heavily rely on fishing and subsistence farming as the primary source of income (McClanahan et al., 2005; Agembe et al., 2010). The fishing grounds of these sites are characterized by the existence of mangrove bays, seagrass meadows, and coral reefs, and are reported to have a rich biodiversity. The monsoon seasons of northeast monsoon (NEM) and southeast monsoon (SEM) both have an impact on the artisanal fishing activities of these landing sites.

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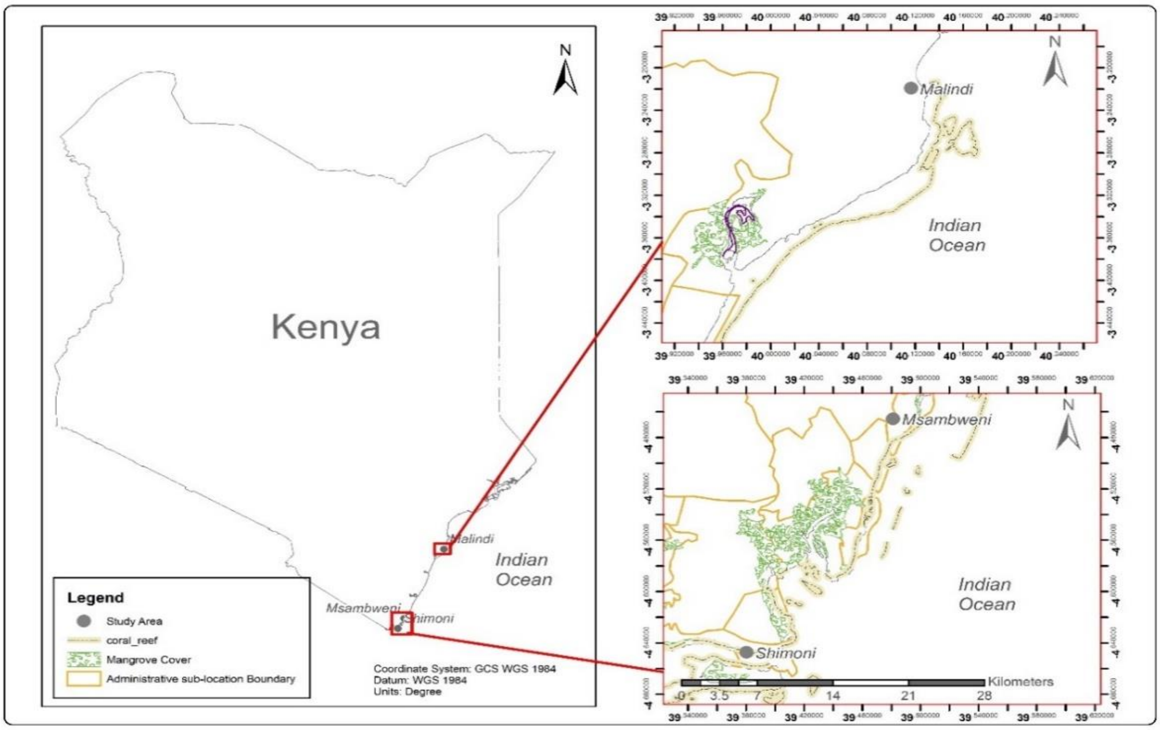

Figure 1. A map of the study area showing the location of Msambweni, Shimoni, and Malindi fishing landing sites along the Kenya coast

Data Collection

Shore-based catch assessment data for artisanal fisheries landings was collected randomly from fishermen at the fish landing sites of Malindi, Msambweni and Shimoni from October 2021 to September 2022. Both fisheries and biological data were collected daily by trained data collectors with assistance from representatives of the respective beach management units (BMUs) of the fish landing sites. Species identification was done using the taxonomic keys according to Carpenter et al., (1997). Fisheries catch data included individual fish total length (TL, cm), individual fish weight (Wt, g) using a graduated fish measuring board to the nearest 0.1 cm electronic weighing balance to the nearest 0.1 g, respectively. Fish specimens for sex determination and gonad maturity levels were bought from fishermen and transported to the laboratory for macroscopic work. In the laboratory, each individual fish specimen was dissected for sex and gonad maturity determination using macroscopic observations based on Ntiba and Jaccarinni' s (1990) gonad maturation protocol with modifications from Kulmiye et al. (2002) (Table 1).

Table 1. A summary of the macroscopic description of the various gonadal maturation stages of *Lethrinus lentjan* as described by Kulmiye et al., (2002)

Physical Characteristics		
Gonadal stage	**Male gonads**	**Female gonads**
Stage I Immature	The testes are long, slim, and threadlike translucent features occupying approximately 33% of cavity	Protracted, thin, and threadlike features, ovaries occupy 33% of the abdominal cavity and are color red
Stage II *a* Developing	Ribbon-shaped , greyish-white in color taking up to half of the abdominal cavity	Firmly shaped like ribbon, color pink, taking almost half of the cavity with invisible oocytes
Stage II *b* Recovering	Similar to stage II *a* but larger in size and firmer	Same as stage II *a* but softer and fluffier to touch
Stage III Maturing	Milt oozes out when cut on the surfaces and occupies 70% of the abdominal cavity. Broad and thick, dark white in color, and has visible blood vessels on the outside,	Ovaries are thick and wide, occupying 70 % of the abdominal cavity. Red or reddish brown in color with clear blood vessels. Oocytes are visible via the wall of the ovary
Stage IV Ripe	Increased in size, with 90% of the abdominal cavity covered. When pressed slightly milt excludes. Color white.	Occupies 90% of the abdominal wall and is elongated. Vanished vessels and clear visibility of the oocytes through the ovary wall
Stage V Running	Milt runs out on minimal pressure. The testes is completely enlarged, covering nearly the entire abdominal cavity	Ovary is totally expanded with a granular surface taking up nearly the entire abdominal cavity
Stage VI Spent	Testes reduced in size and it is loosely. The walls are not soft but creased. Milt does not exudes out by gentle pressure and blood vessels can be seen from outside	There are oocyte remains. Ovary is red in color and wrinkly. Thick ovary wall

Data Collection and Statistical Analyses
Biological Aspects and Stock assessment

Monthly total landings of all emperor species from artisanal fishermen were used to estimate the proportional contribution of the species *Lethrinus lentjan* across the selected fish landing sites of Malindi, Msambweni and Shimoni. Using the following formula, the proportional contribution of each emperor species in the genus *Lethrinus* and the species *L. lentjan* was calculated for each selected fish landing site:

Percentage contribution = Total catch of individual species / Total catch of all species ×100…….. (i)

Determination of Sex Ratio

The monthly sex ratio of males to females of *L. lentjan* was determined and the overall sex ratio was calculated using the formula:

Overall sex ratio = Total number of males/Total number of females

The Chi-square (χ^2) was used to test for significant differences between sex ratio using the formula:

$$\chi^2 = \sum (O-E)/E \text{……………………. (ii)}$$

Whereby; χ^2 = Chi-square; O = observed values; E = expected values

Length-Weight Relationship

The length-weight relationship (LWR) by sex was determined by the equation:

$$W = aL^b \text{ ……………………………… (iv)}$$

Where *W* is the individual weight (g), *L* is the individual total length (cm), '*a*' is the intercept and '*b*' is the regression slope. To perform the analysis, the data were logarithmically transformed according to Jobling, (2002) to give a straight-line relationship as follows:

$$\text{Log}W = \log a + b\log L \text{ ……………… (v)}$$

Therefore, the level of significance was tested using the one-sample t-test (Townend, 2013).
Relative condition factor (*Kn*) which determines the general well-being of a fish was calculated as:

$K_n = W/\hat{W}$ ………………… ……… (vi)

Where W denotes the observed weight of fish and $\hat{W} = aLn$ indicates the mean calculated weight of each fish length explained by Le Cren, (1951).

Determination of Stock Status

The determination of population parameters and stock status was performed using TropFishR package (Taylor and Mildenberger, 2017). The Von Bertalanffy's growth parameters (VBGF) of *L. lentjan* that is, growth coefficient K and the asymptotic length (L_∞) were estimated using ELEFAN with a genetic algorithm ("ELEFAN_GA"). The estimation of both mortality coefficients and exploitation rate (E) were calculated from the VBGF parameters. Using the updated formula version by Kaunda-Arara et al., (2003) and Sarr et al., (2013), of the linearized length-converted catch curve (LCC) from Pauly's (1983), the instantaneous rate of total mortality (Z) for the *L. lentjan* was computed as follows:

$$\text{Log}\left(\frac{N_i}{dt_i}\right) = a + bt \text{……………………..} \quad (vii)$$

Where N_i is the number of individuals in length class i, dt_i is the time required by the fish to grow in class i, a is the intercept, b corresponds to $-Z$ and t is the relative age (age – t_0).

The natural mortality (M) was calculated based on the empirical equation by Then et al., (2015), which is an update from Pauly's (1980) equation.

$$M = 4.118K^{0.73}L\infty^{-0.33} \text{…………………} \quad (viii)$$

The fishing mortality (F) and exploitation rate (E) were obtained based on the relationships of Gulland, (1971):

$$F = Z - M \text{………………………………} \quad (ix)$$

Where, Z is the total mortality and M is the natural mortality. The exploitation rate (E) was calculated by the formula:

$$E = \frac{F}{Z} \text{………………………………………} \quad (x)$$

The calculated E was then compared to a reference value of 0.5, representing the upper level of a sustainably exploited stock (Gulland, 1971). The value of F was also compared to the fishing mortality value at maximum sustainable yield (F_{MSY}), defined by Zhou et al., (2012) as:

$$F_{MSY} = 0.87M. \text{………………………………} \quad (xi)$$

The Shapiro-Wilk was used to test for the normality of the data. When the assumptions were not met an alternative non-parametric Wilcoxon rank test was used. The one-sample t-test was also used to test for any significant difference from 3.0 between the slopes of the linear regression of LWR for both male and female specimens of *L. lentjan* according to Townend, (2013). The data were pooled to provide a single regression equation for both sexes. The differences in mean *Kn* and between months sampled were tested using the non-parametric Kruskal-Wallis test. Chi-square test of goodness was used to test whether the sex ratio of the population differ from the expected sex ratio of 1:1. These tests were applied using the R statistical software version 4.2.3, and the significant levels for all tests were set at $p < 0.05$.

Results

Relative contribution of the genus *Lethrinus* in the artisanal fishery

The contribution of species of the genus *Lethrinus* to the overall total artisanal landings of all emperors varied across the selected fish landing sites, with Msambweni contributing the most abundantly at 69% (9,416 kg) of all emperor artisanal landings, and Shimoni making the least abundant contribution with 5% (704 kg). The species *Lethrinus lentjan* accounted for 25% (3,404 kg) of the *Lethrinus* landings by weight, with Msambweni accounting for 21% (2,850 kg), Malindi (4%; 527 kg), and Shimoni at 0.2% (26 kg) making the least contribution (Figures 3a and b).

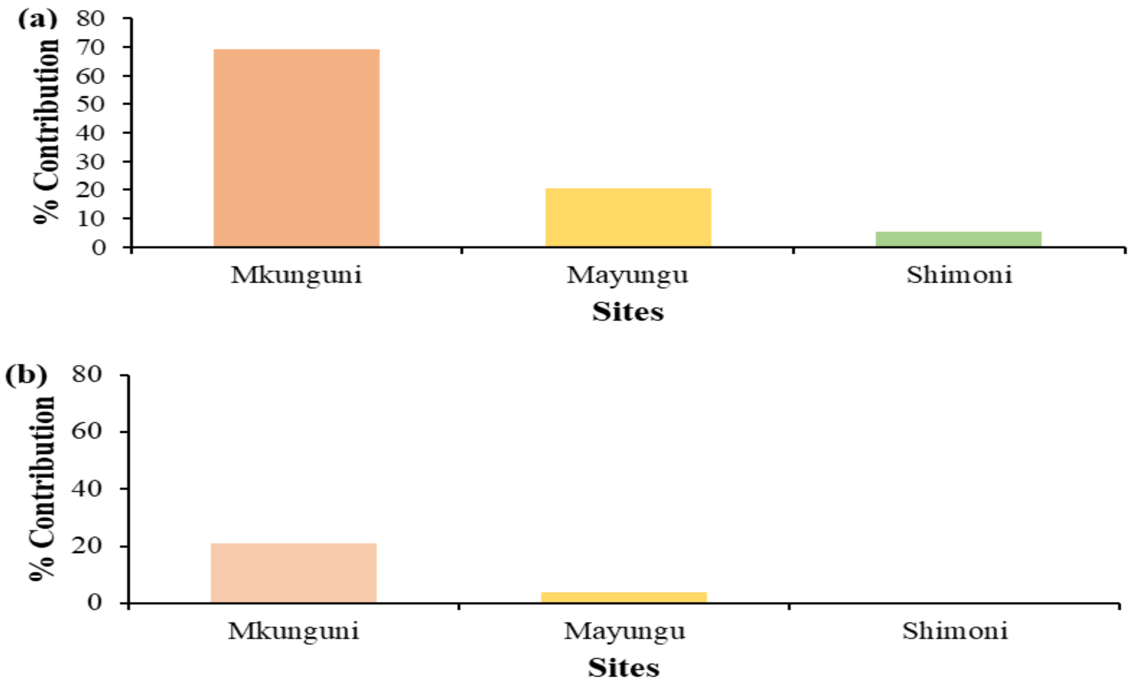

Figure 2. Overall artisanal landings by fish landing site (a), and relative contribution of *Lethrinus lentjan* by landing site (b) sampled over the study period

Length-weight relationship

The individual length and weight data for both sexes were transformed. *L. lentjan* linear regression was computed to show the LWR described by the following equations:

Log W = - 3.98 + 2.92 Log TL (n = 118, r^2 = 0.96, $p < 0.05$) for males, and
Log W = - 4.21 + 2.99 Log TL (n = 180, r^2 = 0.97, $p < 0.05$) for females.

The b-value for isometric growth of *L. lentjan* was significantly lower than 3.0 for both males and females (t = 74, $p < 0.05$; t = 599, $p < 0.05$, respectively), indicating negative allometric growth. LWR for combined data was defined by the equation: Log W = -4.098 + 2.96 Log TL (n = 298, r^2 = 0.96, $p < 0.05$) (Figure 4). The slopes were significantly different from 3.0 (p = 0.004).

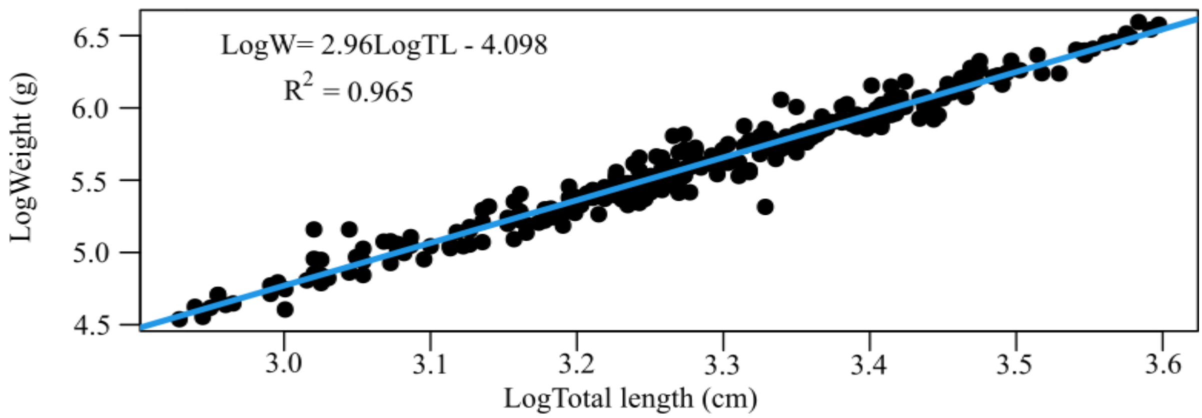

Figure 3. Length-weight relationship of *Lethrinus lentjan* from artisanal landings sampled over the study period

Relative condition factor

The mean relative condition factor of both male and female *L. lentjan* individuals was highest in the months of February (1.08 ± 0.02), and October (1.02 ± 0.01) with a slight decline in the remaining observed months. The mean monthly *Kn* varied between the months sampled, and results of Kruskal-Wallis test indicated that there were significant differences in mean *Kn* between the months sampled (show results of test). The mean values of *Kn* for males were higher in February and October followed by a decline in May and September with an overall mean of 0.991 ± 0.008. Females also showed a similar trend with the highest mean during the month of February, October, and January and August the least, and an overall mean of *Kn* of 1.01 ± 0.006 (Figure 5).

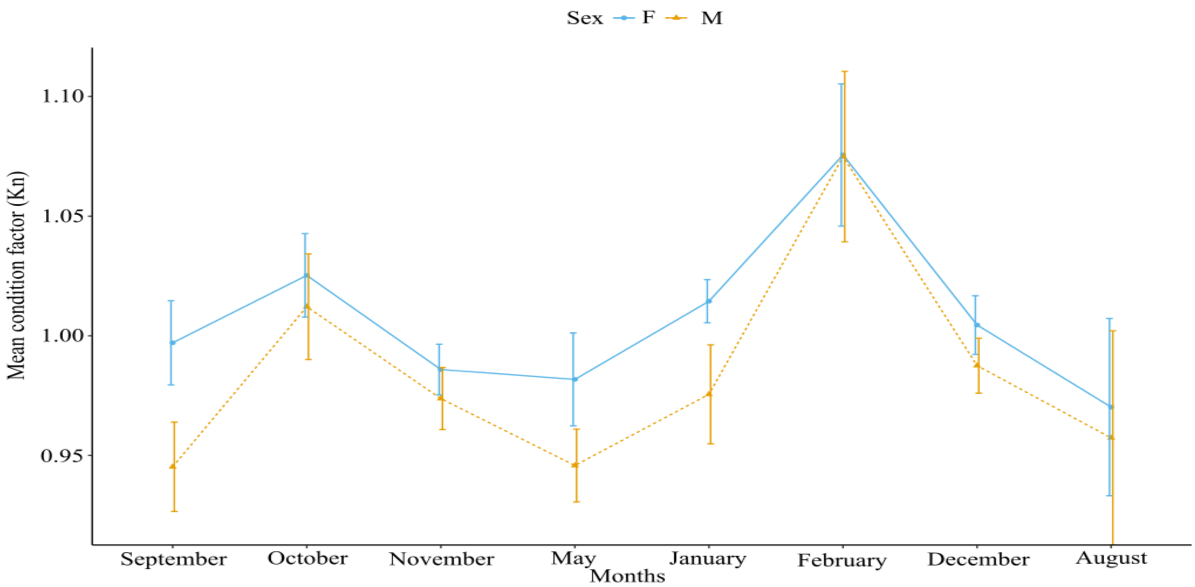

Figure 4. Monthly relative condition factor (*Kn*) of *Lethrinus lentjan* by sex sampled from artisanal landings over the study period

Size distribution

The length frequency distribution of *Lethrinus lentjan* showed females were more dominant than males. Males dominated larger size classes (34 - 40 cm) while females dominated smaller sizes (15 - 28 cm) (Figure 6).

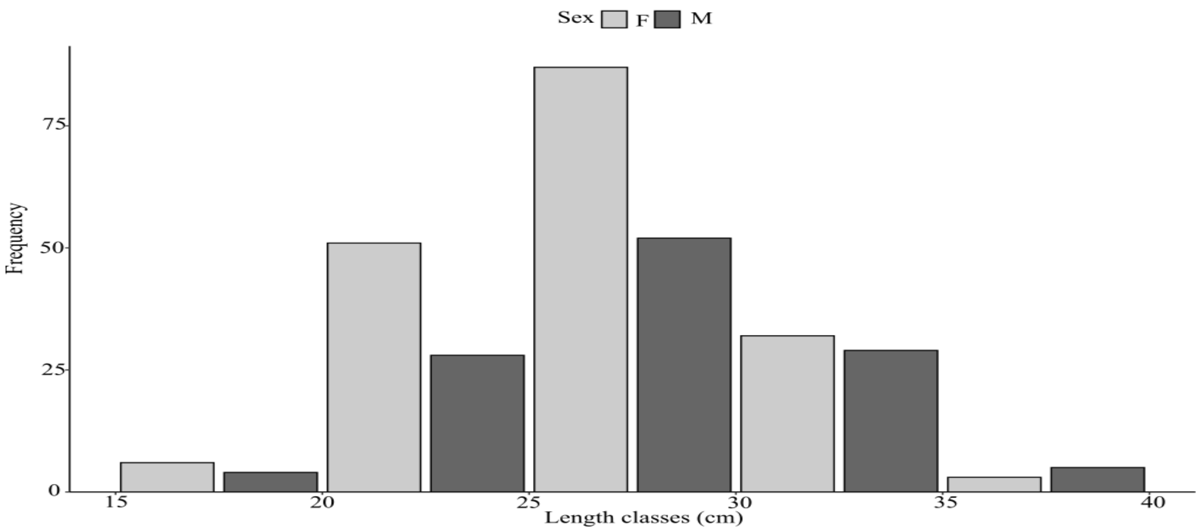

Figure 5. Length frequency distribution of *Lethrinus lentjan* individuals by sex sampled over the study period

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Sex ratio and size at sexual maturity

The sex ratios and monthly gonad distribution were determined based on a total of 298 specimens (males = 118; females = 180) of *L. lentjan* sampled over the study (Table 3 and Figure 7)). The overall sex ratio of males to females was 1:1.53, with results of the Chi-square test showing substantial variation from the expected ratio of 1:1 (χ^2 = 12.487, df =1, p = 0.0004).

Table 2. Monthly and overall sex ratio of *Lethrinus lentjan* individuals sampled over the study period

Months	No. of fish	No. of males	No. of females	% of males	% of females	Sex ratio M: F
January	57	20	37	16.95	20.56	1: 1.85
February	32	13	19	11.01	10.56	1: 1.46
May	17	6	11	5.08	6.11	1: 1.67
August	5	2	3	1.69	1.67	1: 1.5
September	11	4	7	3.39	3.89	1: 1.75
October	47	17	30	14.41	16.67	1: 1.76
November	67	27	40	22.88	22.22	1: 1.48
December	62	29	33	24.58	18.33	1: 1.14
Overall	**298**	**118**	**180**	**100**	**100**	**1: 1.53**

The monthly distribution of gonadal phases (I-VI) of *L. lentjan* individuals, were observed in the samples collected (Figure 7). Female individuals collected from October to February prevailed in the ripe and running gonad maturity stages of IV and V, which mostly occurred together in October, December, and February, at 16.2%, and 18.6%, 21.6%, and 20.0%, 10.8%, and 10.6%, respectively. Stage II appeared in almost all the months except in May but were highest in January with 35.7 %. Stage I individuals predominated in January (38.5%) with the lowest recording in August and December, but absent in September and October. Stage III was highest in October (25%) and lowest in September (5%) but was absent in August. The spent gonad maturity stage VI appeared only in the months of May, October, with a high peak in November (71.4%). On the other hand, male maturity stages showed that stage I predominated in January and February with the same value of 40%. Stage II appeared in almost all the months except December but dominated with 28.5% in November. The majority of the males collected during the monthly samples occupied either the stages II and III, which prevailed together in the months of October (14.3% and 10%) and February (19% and 20%). The stages IV and V prevailed in the periods from October to January but did not appear in August, and the ripe stage was absent in February. Moreover, stage VI started to appear in September (5.8%), increased until November (52.9%) but was absent in December.

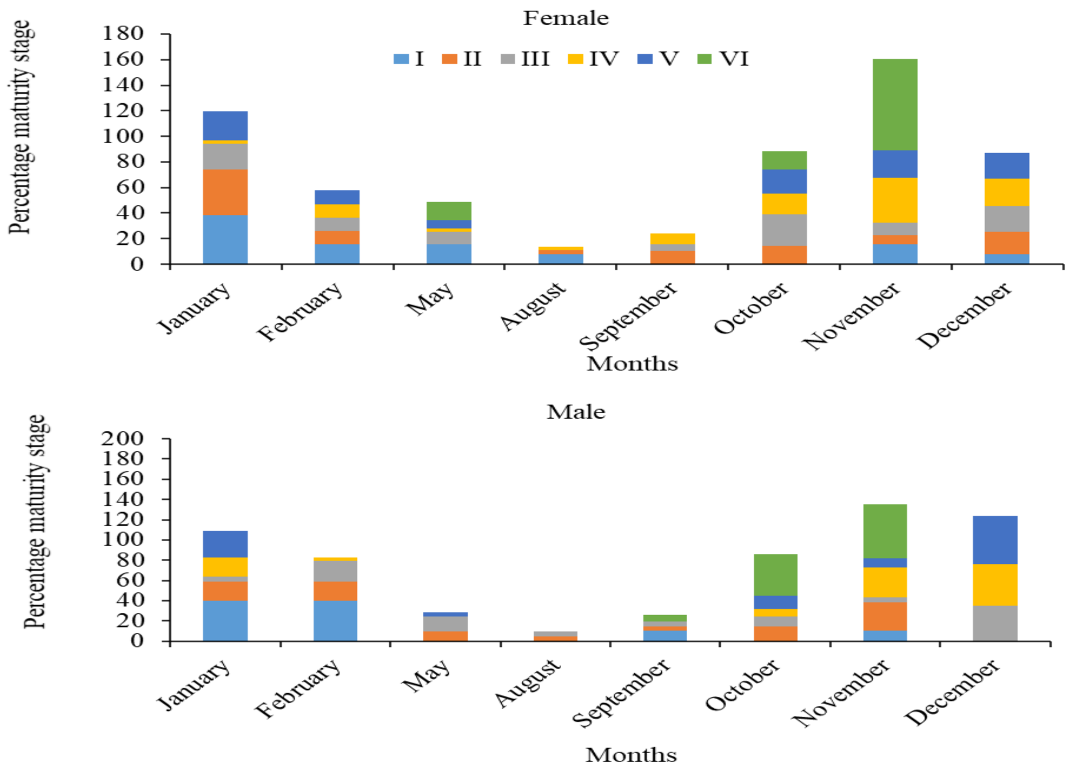

Figure 6. Monthly distribution of maturity stages of *Lethrinus lentjan* sampled over the study period

Mortality and selectivity

A total of 2,097 individuals with length measurements ranging between 10.5cm and 46.5 cm were used in this analysis. The Electronic Length Frequency Analysis (ELEFAN) method produced the Von Bertalanffy growth parameters for asymptotic length ($L\infty$) and growth coefficient (K) as 51cm and 0.46 year^{-1} respectively. The instantaneous natural mortality (M) estimated using the Empirical formula was 0.96, while the fishing mortality, the difference between Z and M was 1.10 and the exploitation rate (E) was 0.53 (Table 4).

Table 4. Comparisons of population parameters from different studies showing mortality and exploitation rates for *Lethrinus lentjan* (- dash means unavailable data)

Parameters	Value (Mrombo et al. 2019)	Value (This study)	Fish base
Z	1.32 y^{-1}	2.07 y^{-1}	-
M	0.60 y^{-1}	0.96 y^{-1}	-
F	0.72 y^{-1}	1.10 y^{-1}	-
E	0.55 y^{-1}	0.53 y^{-1}	-
K	0.25 y^{-1}	0.46 y^{-1}	0.7 y^{-1}
$L\infty$	-	51cm	34.1cm(fork length)

Figure 8 shows the instantaneous total mortality Z value of the slope derived from the linearized length-converted catch curve as 2.07. The selectivity function of the catch curve estimated a length at 50% probability of first capture (L_{50}) of 25.3 cm, assuming a trawl-like fishery.

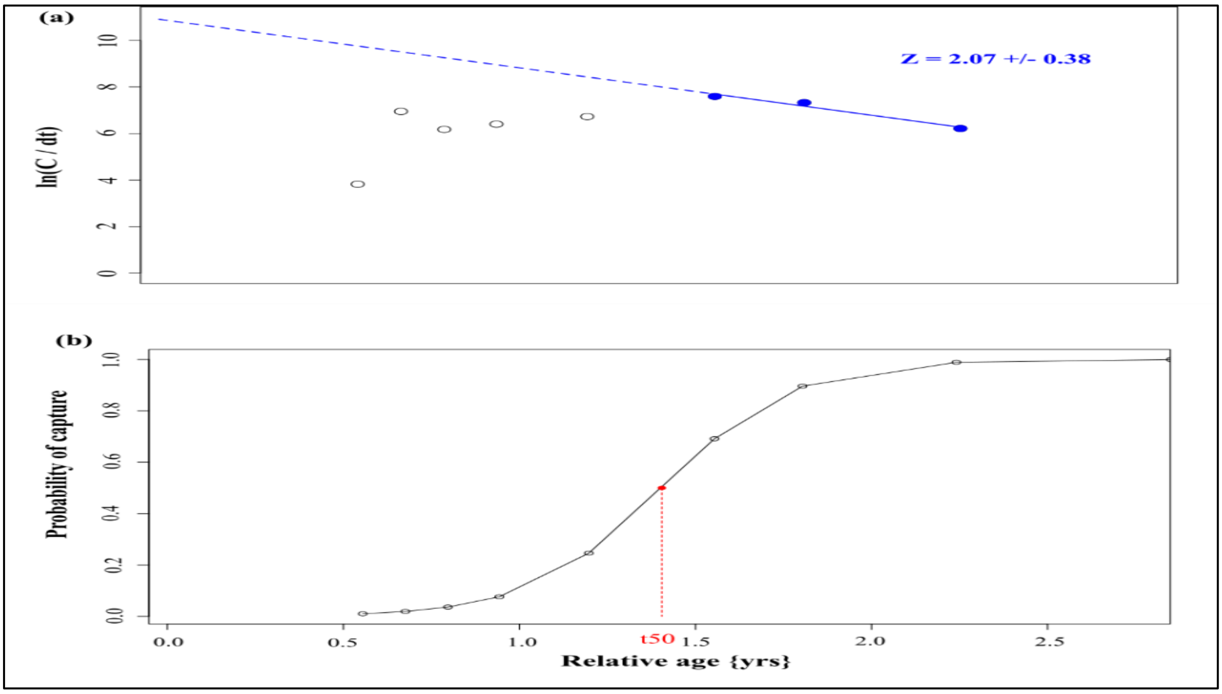

Figure 7. The length-converted catch curve showing total mortality (Z) of *Lethrinus lentjan* over the study period (a) and probability of capture of *L. lentjan* as estimated from the backward extrapolation of the descending arm of the catch curve (b).

The Cohort Analysis (CA) showed that smaller classes were under-represented in the catches but had more survivors, while larger size classes were higher in catches and low survivors. A low natural mortality was observed in the length group from 28.5cm to 34.5cm. The vulnerability to fishing pressure of fish individuals, increased from 19.5 cm with a peak at 34.5 cm where the highest fishing mortality (1.10) was observed (Figure 9).

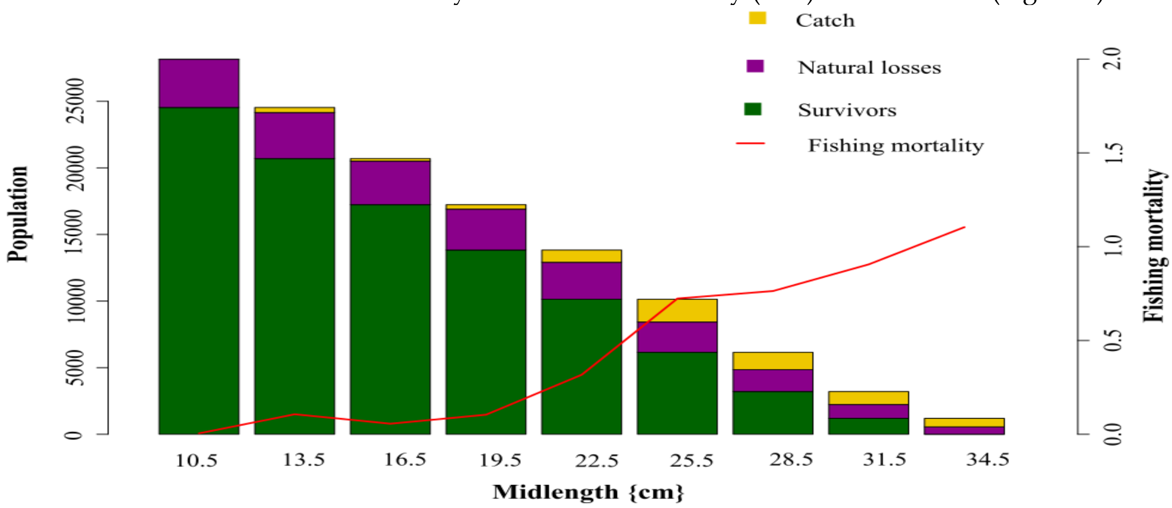

Figure 8. Length-converted cohort population analysis in numbers and fishing mortality rate per length class for *Lethrinus lentjan* sampled over the study period

Yield and biomass per recruit and biological reference points

The estimation of biological references of yield and biomass per recruit as a function of fishing mortality are presented in Table 5 and Figure 10a. The current fishing mortality (1.10 $year^{-1}$)

in the estimated population was lower than fishing mortality that produces the highest yield per recruit (F_{max}) (5.0 year^{-1}) predicted to give maximum relative yield per recruit, but closer to fishing mortality that results in 50% reduction of the biomass compared to the unexploited population ($F_{0.5}$) (1.06 year^{-1}). The exploitation level ($E_{0.1}$) at which the marginal increase in relative yield per recruit is 10% of its value at E = 0 was 0.557 whereas the exploitation level ($E_{0.5}$) corresponds to 50% of the relative biomass per recruit of an unexploited stock was 0.514. The maximum allowable limit of exploitation level (E_{max}) that gives the maximum relative yield per recruit was 2.42.

Table 5. Biological reference levels of *Lethrinus lentjan* estimated from the length-based yield per recruit model (Thompson and Bell 1934)

F_{01}	F_{max}	F_{05}	E_{01}	E_{max}	E_{05}
1.152	5	1.062	0.557	2.419	0.514

The yield and biomass per recruit isopleth diagram is represented in Figure.10b. The fishing effort and selectivity of *L. lentjan* stock are mostly exploited at a larger size and a much higher fishing effort. The descending curve shows the decrease in biomass/recruit as fishing mortality increases. Additionally, the ascending curve illustrates the small increases in yield when fishing mortality is increased beyond $F_{0.1}$=1.15.

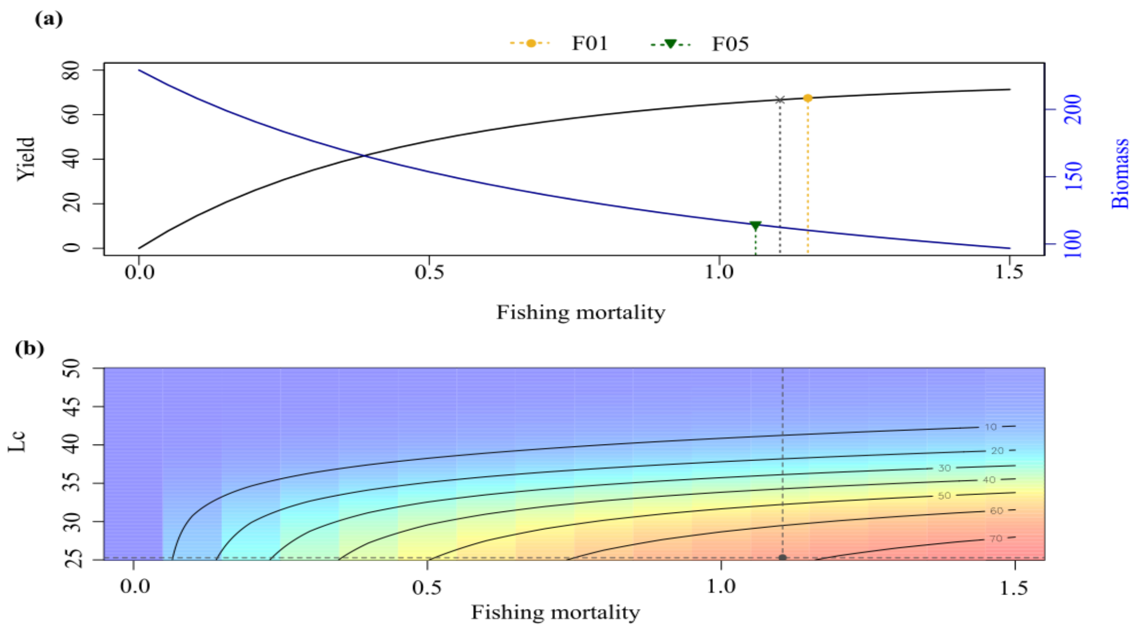

Figure 9. Curves of yield and biomass per recruit for *Lethrinus lentjan* indicating the yield and biomass per recruit for a range of fishing mortality values (a) and an isopleth diagram of the relative yield per recruit as a function of relative size at first capture and fishing mortality (b)

Discussion

Contribution of *Lethrinus lentjan* landings in the small-scale fishery

Generally, small-scale fisheries are multi-species due diversity of habitat types making the fishery to be multi-gear and multi-fleet. In the Indo-Pacific region, small-scale fisheries generally utilize mixed habitats such as seagrass beds and coral reefs, which contribute to species diversity. Thus, fishing in Kenya is an illustration of a multi-species fishery. The species *Lethrinus lentjan,* along the coast of Kenya is targeted by both commercial and subsistence fishers, making this species to have a high demand (Sadovy, 2005; Government of Kenya, 2016). As a result, efforts to ensure the sustainable exploitation of the fishery of *L. lentjan* is critical in fisheries management. The present study revealed that about 26% of *L. lentjan* landed in the overall total landings of the genus *Lethrinus*, with Msambweni having highest landings and Mayungu with the lowest landings along the Kenya coast. The variations in the species of *Lethrinus* landings could be due to the spatial differences in fishing pressure, habitat distinctiveness, and recruitment variability (Agembe et al., 2010). This is similar to Hicks and McClanahan (2012) who reported about 20 % of the overall total landings in a previous study along the Kenya coast. This makes *L. lentjan,* along with *Siganus sutor* and *Leptoscarus viagiensis,* the most abundant of the three frequently landed fish species. This finding is similar to other findings observed in Madagascar (Davies et al., 2009).

The immediate change in the composition of species demonstrates that Kenya's artisanal fisheries can no longer be identified as biodiverse and that some species are already reported as commercially extinct (Samoilys et al., 2017). Mangi et al., (2007) reported no categorization of landing sites according to the number of fishers. Isaac et al., (2015) reported that the kind of vessels accessible to fishermen affects their fishing grounds and tactics. Therefore, it affects the variations in catch composition. This is clearly understood for multi-species small-scale fisheries. Several species have been reported to dominate catches due to the increasing and selective pressure in recent years (Hicks & McClanahan, 2012; Samoilys et al., 2017).

Sex ratio and size distribution

The expected male to female ratio of 1:1 was not observed in the current study, but rather a significant deviation skewed in favour of females was observed for the overall sex ratio for the *L. lentjan* in this study (χ^2 = 12.487, df = 1, p = 0.0004; Table 2).. Similar overall sex ratio results in favour of females have been reported in previous studies. In Kenyan waters, Kulmiye et al., (2002) and Mrombo et al., (2019) reported sex ratios of 1:1.10 and 1:0.59, respectively. Also, a study conducted in the Indonesian waters revealed a sex ratio of 1:2.06 (Restiangsih & Muchlis, 2019). The present study recorded a sex ratio very different from that observed in the Red Sea Jeddah region of 1:7.98 for same species (Younis et al., 2020). The dominance of females could be could be attributed to the fact that several lethrinids exhibit sex reversal and are considered protogynous hermaphrodites. Younis et al. (2020) reported histological studies demonstrating that *L. lentjan* experiences sex reversal because of the existence of both testicular and ovarian tissues in the same gonads. The appearance of male sex cells in the female gonads, provides conclusive evidence that the species first grows and develops as females before changing sex to become males. The deviation in the overall sex ratio obtained in this study and those discovered in other scientific literature might be explained by differences in the *Lethrinus* species studied, the environment of the study area, and the sampling periods.

Furthermore, the high percentage of male and female ripe and running gonads observed in this study from October to December, with only a few appearances of spent fish, suggests that *L. lentjan* has a long spawning season along the Kenya coast. This compares well with the prolonged October and February spawning peaks reported for *L. harak* along the coast of Kenya by Kulmiye et al., (2002). Generally, the main spawning period for *L. lentjan* varies widely from place to place. In other studies, *Lethrinus* species have been reported to spawn throughout the year (Younis et al., 2020). In the Indian Ocean waters, it is reported to occur twice a year, from December to February and June to March (Toor, 1968). Similarly, Nzioka (1979) reported that spawning activity in fishes of the family Lethrinidae occurred all year round, with two prominent peaks on the East African coast in September/October and January/February.

More findings by Currey et al., (2009) reported a spawning peak in Australian Great Barrier Reef in January/February. However, the appearance of *L. lentjan* individuals in various gonadal maturity stages sampled during the present study suggests that this species is a multi-spawner, as Currey et al., (2009) reported. These records prove that the main spawning period for *L. lentjan* varies widely depending on the study area affected by different seasonal patterns (Al Areeki et al., 2007). The females dominated smaller size categories, while the males were dominant in the larger size classes. Since *L. lentjan* is considered to be protogynous, males are generally larger than females. The behavioural changes might influence the females during sex reversal, as well as when one gender becomes more susceptible to specific fishing gear. This could also indicate size-selective fishing mortality, which results in sperm limitation due to the differential loss of larger, older males (Grandcourt et al., 2010).

Condition factor and length-weight relationship

The condition factor (*Kn*), as well as the length-weight relationship (LWR), are essential in fisheries assessment studies because they provide specific information about the growth and well-being of fish in their natural habitat (Aura et al., 2011). According to Le Cren, (1951), length-weight relationship is described to evaluate whether fishes' growth is allometric or isometric. The present study found that both sexes had a *b* value of 2.97. The estimated *b* value of *L. lentjan* was significantly less than 3, thus exhibiting negative allometric growth. This means a relatively reduced body weight as the fish grows. The value of the slope obtained was within the typical species range ($2.5 < b > 3.5$). As observed, negative allometric growth confirms similar results for this species. Karuppasamy, (2018) reported a *b* value of less than 3 for the species from Indian Ocean waters, with Mrombo et al., (2019) also reporting a *b* value of 2.0. However, the same species was reported to have isometric growth with a slope value of 3.02 by Mbaru et al., (2011) and Vasantharajan et al., (2014) in Kenyan coastal and marine waters. The actual relationship between the variables is not constant over the years; thus, the parameters of the length-weight relationship may vary significantly due to biological factors, food availability, temporal and sampling factors, health, and sex (Armin et al., 2005).

The average condition factor was almost one, which proves that the environmental conditions on the Kenya coast are conducive and suitable for the growth of *L. lentjan* sampled over the study period. Pre-spawning maturation could have contributed to the highest values of *Kn* observed in both males and females during October and February. Furthermore, the slight monthly variations in values of *Kn* for this species may be due to changes in the physio-chemical conditions as well as seasons, type of food consumed, and fat stored (Barnham & Baxter 2003). Additionally, the nutritional needs of the fish, which were not considered in the present study, may also be responsible for the monthly variation of *Kn*, (Obuya et al., 2018). However the present study, was unable to specify which of the aforementioned factors resulted in the obtained results. Furthermore, the steep decrease in values of *Kn* from November to May corresponds to the appearance of the spent fish. Previous research found that *Lethrinus* species spawn over long periods of time and lay their eggs in large numbers throughout the remaining months, with different spawning peaks in various environmental conditions. Similarly, Kulmiye et al., (2002) reported a postulated extended spawning season for *Lethrinus harak* (Forsskal, 1775) along the coast of Kenya throughout the year, with two phases in October and February.

Stock status of *Lethrinus lentjan*

Managing fisheries resources requires an understanding of different population parameters, including asymptotic length (L_∞), growth coefficient (*K*), mortality rates, and exploitation rate (*E*). Information on fish population dynamics, species composition and mortality coefficients are important. Results of mortality coefficient support the amount of fish biomass lost in the natural habitat due to ecological factors such as aging and diseases within the events of natural losses and fishing pressure (Younis et al., 2020). The results of this study revealed *Z, M, F*, and *E* to be 2.07, 0.963, 1.10, and 0.53, respectively. In contrast, Grandcourt et al., (2006) reported different mortality coefficients of 0.56, 0.20, and 0.36 for *Lethrinus nebulosus* in the Southern Arabian Gulf for *Z, M*, and *F*, respectively. These variations show that the mortality coefficients differ between study locations depending on fish species, environmental factors, and level of fishing.

The exploitation rate (*E*) usually provides a clear indication of the state of stock, with the exception that the optimal value of $E = 0.5$, which suggests that the sustainable yield is optimized when F = M (Gulland, 1971). However, the results of the current study showed that fishing mortality ($F = 1.10 year^{-1}$) was higher than the natural mortality ($M = 0.96 year^{-1}$), and E was 0.53, which is above the expected value suggesting a slightly overexploited stock.

Total and natural mortality (Z and M) values were 2.07year^{-1} and 0.96 year^{-1}, respectively, higher than Mrombo et al. (2019), who recorded Z of 1.32 and M of 0.60. They were, however, comparable to those reported by Zaahkouk (2017), which were 1.52 and 0.35, respectively. However, the total mortality in this study was lower than that of Hicks and McClanahan, (2012) along the Kenya coast. Natural mortality may vary across species due to density-dependent (predation, availability of food) and density-independent (diseases, natural calamities) phenomena in different locations. The mortality and exploitation rate estimates of *L. lentjan* reported in other studies were lower (Great Barrier Reef, Z = 0.18; Seychelles, Z = 0.142; Southern Arabian Gulf, Z = 0.44) compared to other areas with minimum fishing efforts and a wider range of fishing locations (Grandcourt et al., 2007; Currey et al., 2009). Although lethrinid catch rates have declined along the Kenya (Kaunda et al., 2003), these species still account for a significant proportion of total landings.

The growth parameters obtained in this study (L_∞ and K) are also essential in determining the stock stability of exploited fishery. The current study found L_∞ of *L. lentjan* of 51cm, which was within the range of previous studies. The same results were reported in Saudi Arabia by Kedidi et al., (1984). L_∞ was estimated at 56.95 cm by Zaahkouk et al., (2017) from Egyptian waters and 55.6 cm by Mohammed (2007) from Yemen's Red Sea coast. However, in the Jeddah region, Wassef, (1991) found a lower value of 49.4cm, with Grandcourt (2011) reporting a much lower value of 33.9 cm in the Southern Arabian Gulf. The current growth coefficient (K = 0.46y^{-1}) for this species, on the other hand was similar to those reported in Yemen (0.48y^{-1}) (Aldonov & Druzhinin 1979). However, the value of K in this study was higher than the reported 0.28y^{-1} and 0.25y^{-1}, respectively, by Zaahkouk (2017) and Mrombo (2019). Additionally, the estimated value in this study was lower than 0.70y^{-1} and 1.00y^{-1} recorded, respectively, in Arabian waters (Grandcourt, 2011) and Tanzanian waters (Benno, 1992).

Previous studies conducted on other reef fish genera such as *Lutjanus* and *Plectropomus* have found differences between genera in the growth coefficient constant (K) (Currey et al., 2013; Prince et al., 2015). This is possible because of the variations in habitat and exploitation choices, which can affect growth rates (Gust et al., 2002). Furthermore, these differences could be due to different geographical locations for the same species, variations in environmental conditions, sampling techniques, and computations (Soumaïla Sylla et al., 2016).

Conclusion

The results of this study established that the fishery of *Lethrinus lentjan* is currently experiencing overfishing above the optimal level required for 50 % relative biomass per recruit of the unexploited stock ($E_{0.5}$ = 0.51). Additionally, *L. lentjan* was a highly targeted species accounting for more than 20% of the total landings compared to other landed species, therefore vulnerable to overfishing. The present study provides more insights in formulation of management recommendations for the *Lethrinus* artisanal fishery along the Kenya coast. Moreover, negative allometric growth was observed for *L. lentjan* with an overall b value less than 3 and a relative condition factor almost close to 1 which proves that the species is in a healthy state. Given the fact that *L. lentjan* makes the highest proportion in the overall commercial fish landings, its stock is at a risk. Therefore, this study recommends an immediate management action *L. Lentjan* artisanal fishery along the Kenya coast to reduce the fishing pressure.

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