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# Stock status and some biological aspects of *Lethrinus lentjan* (Lacapede, 1802) from the south coast of Kenya

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## Abstract

The Pinkear Emperor (*Lethrinus lentjan*, Lacépède, 1802) is among the three demersal species dominating fish catches in the artisanal fishery on the Kenyan coast. Available data indicate that total landings of *L. lentjan* have declined over the past decade due to possible over-exploitation. This paper provides a brief account of the stock status of this species and biological aspects including length-weight relationship, body condition, and reproduction from a total of 575 fish specimens sampled. Sampling was done at Msambweni, Shimoni, Majoreni and Vanga fish landing sites on the south coast of Kenya from September 2016 to February 2017. Individual total length (TL, cm) and body weight (BW, g) was measured on site while some specimens were dissected for sex and gonad maturity analysis. Mortality, exploitation rate, length-weight relationship, condition factor, fecundity, and size at maturity ( $L_{50}$ ) were determined. Length frequency analysis indicated that *L. lentjan* was exploited above the optimum level, at  $E = 0.55$  (exploitation rate). Growth was allometric with the length exponent ( $b = 2.95$ ) being significantly  $<3$ . Mean fecundity was  $89,573 \pm 9,841$  eggs/female/year. Gonadosomatic index was highest in January ( $2.08 \pm 0.20$ ) suggesting a possible peak spawning period at this time. The study provides a brief scientific overview of *L. lentjan* as a baseline for future in-depth biological studies of this species along the Kenyan coast.

**Keywords:** Stock status; length-weight relationship; condition; reproduction; allometric growth; south coast of Kenya

## Introduction

Lethrinids are among the most commercially important group of fishes on many tropical coasts (El Gammal, 1988) and are considered a good source of animal protein for the communities of the western Pacific and the Indian Ocean (Carpenter and Allen, 1989). Hicks and McClanahan (2012) reported that *L. lentjan* accounted for 22% of the total catch on the south coast of Kenya and forms one of the top 3 species landed along with *Siganus sutor* (Valenciennes, 1835) and *Leptoscarus viagiensis* (Quoy and Gaimard, 1824). However, as reported for other species, there is a concern that landings of this

species along the Kenyan coast have declined over the years (Kaunda-Arara *et al.*, 2003). Moreover, *L. lentjan* is exploited at levels that have led to both recruitment and growth overfishing (Hicks and McClanahan, 2012). These findings are consistent with those of a more recent study that examined decadal trends in Kenyan artisanal fisheries revealing that the decline of catches in the coral reef fisheries have quadrupled since the mid-1980s (Samoilys *et al.*, 2017). Few studies on stock status and biological aspects have been conducted on fish species in Kenya (Nzioka, 1979; Ntiba and Jaccarini, 1990; Kaunda-Arara and Ntiba, 1997; Kulmiye *et al.*,

2002; Kaunda-Arara *et al.*, 2003) Generally, no comprehensive stock assessment and biological studies of *L. lentjan* have been conducted on the Kenyan coast. This presents a challenge to management efforts, as adequate data and information is not available (Fondo and Sigurðsson, 2004). This study therefore provides a brief overview of biological aspects of *L. lentjan* on the south coast of Kenya as a baseline for in-depth future studies on this important commercial species.

in labelled containers for 48 hours. The gravimetric method of Holden and Raitt (1974) was then used to estimate the total fecundity of each fish specimen.

### Data Analyses

The LWR by sex was expressed as a logarithmic transformation of the equation:

$$W = aL^b \text{ (Pauly, 1983)}$$



Figure 1. A map showing the location of the landing sites of Mkunguni, Shimoni, Majoreni and Vanga on the south coast of Kenya.

## Materials and Methods

### Data Collection

This study was conducted at Vanga, Mkunguni, Shimoni and Majoreni fish landing sites on the south coast of Kenya (Fig. 1). Fish samples were collected in the months of September through to February 2017. Individual fish TL in cm and BW in g were measured and LWR and condition factor determined. Some fish specimens were dissected to determine sex and gonad maturity using macroscopic observation. Determination of gonad maturity followed the guidelines from Ntiba and Jaccarini (1990) and those modified by Kulmiye *et al.* (2002). The whole ovary of each fish specimen was excised, weighed and preserved in Bouins solution

where  $W$  is the body weight,  $L$  is the total length, ' $a$ ' is the intercept, and ' $b$ ' is the slope of the regression line. Condition factor was calculated using the formula for relative condition factor:

$$(Kn):Kn = W/\hat{W}$$

where  $W$  is the weight of an individual fish and  $\hat{W} = aL^b$  is the computed length-specific mean weight from the LWR as described in Le Cren, (1951).

Fishing mortality ( $F$ ), Exploitation Rate ( $E$ ) and growth parameters  $K$  and Asymptotic Length  $L_\infty$  were estimated using Length-Frequency Analysis (LFA) in the

FAO ICLARM Stock Assessment Tool (FiSAT) II package (Gayanilo *et al.*, 2005). ELEFAN 1, a sub-package in FiSat II was used to estimate the von Bertalanffy growth parameters  $K$  and  $L_{\infty}$  as applied by Kaunda-Arara *et al.* (2003). Gonadosomatic Index (GSI) was calculated using the formula described in Wootton (1990):

$$\text{GSI} = \text{Gonad Weight} / (\text{Body Weight} \times 100).$$

The fish specimens were sorted according to size classes of 4 cm interval and the number of individuals of each maturity stage recorded according to size class. Gonad maturity stage III and above were considered sexually mature for both males and females. The percentage of mature individuals in each length class was then calculated and cumulated. Delta Graph Win (Ver. 5.6.2) software was then used to determine the length at massive maturity  $L_{50}$  by curve fitting the data to the following logistic equation as applied by Obota *et al.* (2016):

$$L_{50}: M(TL) = 100 / (1 + \exp(-a \cdot (x - b)))$$

where 'a' is a constant and 'b' is the  $L_{50}$ .

### Statistical Analyses

The differences in mean  $Kn$  and GSI between sexes and between months sampled were tested using the non-parametric Kruskal-Wallis test. Post hoc pair-wise comparison was used to confirm the actual differences between variables. These tests were conducted using the statistical software STATISTICA version 7. The relationship between fecundity and TL of females was analyzed using regression, and the same analysis was conducted for the relationship between BW and fecundity. The Analysis of Co-Variance (ANCOVA) test was used to test whether there was any significant difference between the slopes of the regression of the LWR for the males and the females. Data were subsequently pooled to give one regression equation for both male

and female specimens. The slopes were then tested for significant difference from 3.0 using a one sample t-test as described in Townend (2013). Chi-square test of goodness was used to test whether the sex ratio of the population conformed to the ideal sex ratio of 1:1. These tests were conducted using MINITAB statistical software version 17. Significance level for all tests was assigned at  $p < 0.05$ .

### Results and Discussion

A total of 575 fish specimens were sampled from September 2016 to February 2017. Results of some population parameters of this species derived from the length frequency are presented in Table 1. The growth coefficient  $K$  of 0.25/yr obtained in this study suggests that the growth of *L. lentjan* in Kenyan waters is much slower than that recorded in the waters of Tanzania (1.00/yr) (Benno, 1992) and Yemen (0.48/yr) (Aldonov and Druzhinin, 1979). Enberg *et al.* (2008) attributed differences in the rate of growth to differences in environmental parameters such as temperature, seasonality and ecological parameters, particularly population density and anti-predatory behavior. As these parameters were not investigated in the present study, it is possible that any or a combination of these could explain the observed differences. According to Gulland (1971), the exploitation rate ( $E$ ) indicates the level of exploitation of a stock; lightly exploited ( $E < 0.5$ ) and strongly exploited ( $E > 0.5$ ), based on the assumption that fish are optimally exploited when  $F = M$  or  $E = 0.5$ . Therefore, the  $E$  value of 0.55 determined in this study indicates that the exploitation rate for the *L. lentjan* stock on the south coast of Kenya is slightly higher than this. However, it is noted that Hicks and McClanahan (2012) reported much higher exploitation values of  $F = 4.29$  and  $E = 0.82$  for *L. lentjan* in Kenyan waters, which may be related to the fact that samples in their study were largely collected within the lagoon and inshore fishing grounds.

Table 1. Estimated growth, mortality and exploitation parameters for *Lethrinus lentjan* on the south coast of Kenya.

Parameter	Value
Asymptotic length ( $L_{\infty}$ )	55.00
Curvature of growth ( $K$ )	0.25
Total mortality ( $Z$ )	1.32
Natural mortality ( $M$ )	0.60
Fishing mortality ( $F$ )	0.72
Exploitation rate ( $E$ )	0.55

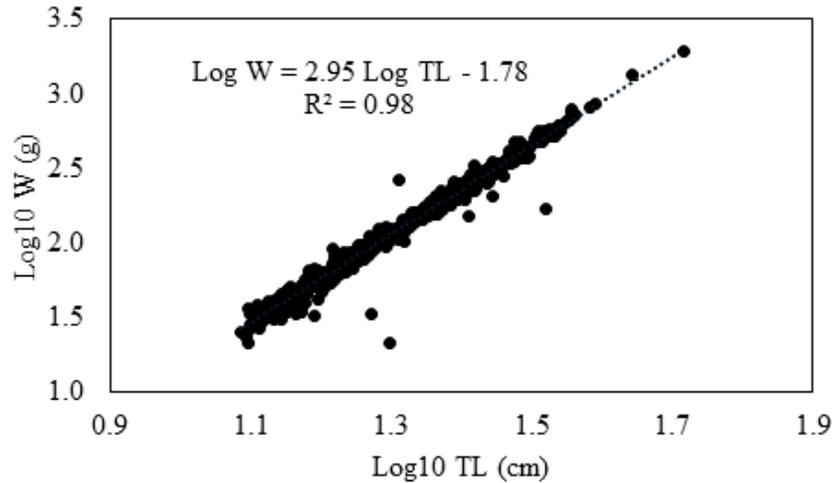


Figure 2. Length-weight relationship based on pooled data for *Lethrinus lentjan* sampled on the south coast of Kenya during the study period.

Mixed sex data was used to determine the LWR (Fig. 2) described by the equation  $\text{Log } W = 2.95 \text{ Log } TL - 1.78$  ( $n = 413$ ,  $r^2 = 0.98$ ,  $p < 0.05$ ). The  $b$  value for mixed sex in this study was 2.95 while that for males ( $n = 154$ ) and females ( $n = 259$ ) was 2.92 and 2.97, respectively. These  $b$  values were significantly less than 3 ( $t = -50.81$ ,  $p < 0.05$ ) indicating negative allometric growth; that is, the fish became slimmer as length increased (Riedel *et al.*, 2007). Letourneur *et al.* (1998) also reported  $b$  values of less than 3 for this species in the coral reefs and lagoons of New Caledonia. However, Mbaru *et al.* (2010), reported a  $b$  value of 3.183 for *L. lentjan* on the Kenyan coast for samples collected throughout the year. Samples in the present study were only

collected during the North East Monsoon (NEM) season. According to Biswas (1993) and Armin *et al.* (2005)  $b$  values for the same species may vary due to geographical differences, seasonal variations in environmental parameters such as temperature, salinity, nutrition, gonadal development and physiological state at the time of sampling. These factors are likely to explain the observed differences.

The  $Kn$  for females ranged from 0.62 - 1.40 with a mean of  $1.00 \pm 0.01$ , while that of males ranged between 0.34 and 2.16 with a mean of  $1.03 \pm 0.01$ . Results of the Kruskal-Wallis test indicated significant differences in mean  $Kn$  between months for males ( $df = 5$ ,  $H = 15.91$ ,  $p$

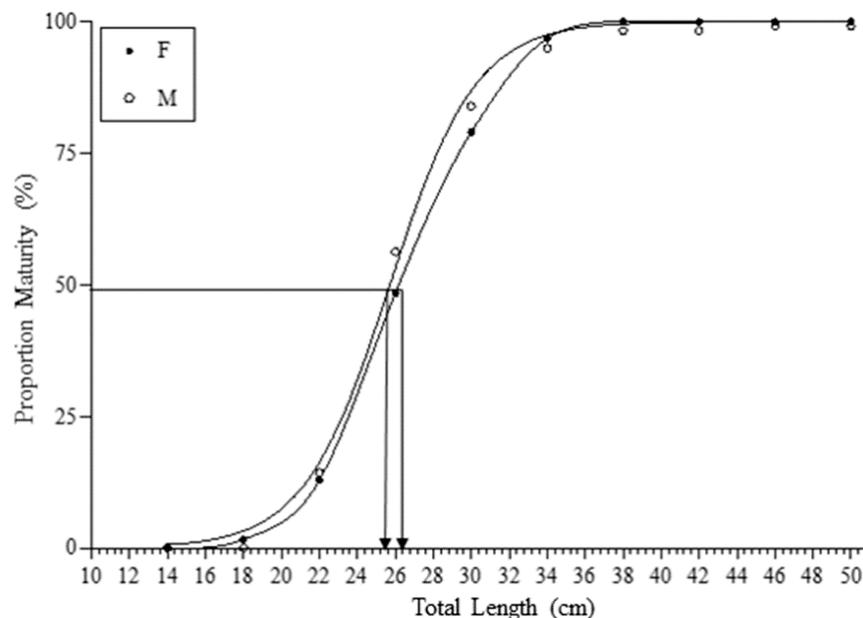


Figure 3. Percentage proportion of mature *Lethrinus lentjan* in relation to their Total Length sampled on the south coast of Kenya over the study period. Arrows indicate value of  $L_{50}$ .

< 0.05) and females ( $df = 5, H = 14.84, p < 0.05$ ). This is indicative that both males and females were in a good physiological state. The variation in  $Kn$  for both males and females during the study may be due to several factors such as differences in maturity stages, type of food consumed, the extent of muscular development and amount of fat reserve (Barnham and Baxter, 2003).

The mean TL of *L. lentjan* was  $21.54 \pm 0.26$  cm and the average weight was  $180.74 \pm 7.26$  g. The smallest specimen measured 12.20 cm and weighed 25.30 g, whereas the largest individual measured 52.0 cm and weighed 1,913.0 g. Length at 50% maturity ( $L_{50}$ ) for male and female *L. lentjan* was 25.8 cm. and 26.2 cm, respectively (Fig. 3). A total of 54 males out of 154 (35%) and 85 females out of 259 (32.82%) had attained this length. This was different from other studies on *L. lentjan* where, for example, Toor (1964) reported an  $L_{50}$  of 30 cm and 28.7 cm standard length (SL) for males and females, respectively in Indian Ocean waters, while Grandcourt *et al.* (2011) reported an  $L_{50}$  of 24.6 cm and 27.7 cm fork length (FL) for males and females, respectively in the southern Arabian Gulf. These differences could be related to fishing pressure on this species in various areas as suggested by Lappalainen *et al.* (2016) who noted that  $L_{50}$  is a potential indicator of fishing pressure in fish stocks. However, environmental factors such as food availability may also have

an effect (Reznick, 1993). The smallest female with ovaries in a mature condition (Stage III and IV) measured 21.6 cm and weighed 160.4 g, while the smallest male in a mature condition (Stage IV) measured 18.7 cm and weighed 93.5 g.

Only 35% of the male and 32% of the female specimens in this sample had attained the  $L_{50}$  (25.80 cm and 26.2 cm, respectively) indicating that the majority of the fish were caught before attaining maturity. This suggests growth overfishing characterized by small immature fish in the catch (Amponsah *et al.*, 2016). This is probably due to the use of beach seines within lagoons in some fishing grounds at Majoreni, one of the sampling sites in this study. The beach seines used by fishers at Majoreni are less than 2-inch mesh size, with a 'kakaban' code end which limits the escape of juveniles. Fishing in Majoreni and Vanga mostly occurs in mangrove swamps and shallow inshore fishing grounds which are critical habitats for juveniles (Carpenter and Allen, 1989; Kimirei *et al.*, 2011). On the other hand, fishers in Shimoni and Mkunguni usually exploited deeper waters outside the reef, and therefore landed bigger sized fish compared to Majoreni and Vanga.

The mean GSI for females was higher ( $0.97 \pm 0.08$ ) than for males ( $0.21 \pm 0.22$ ). Differences were highly

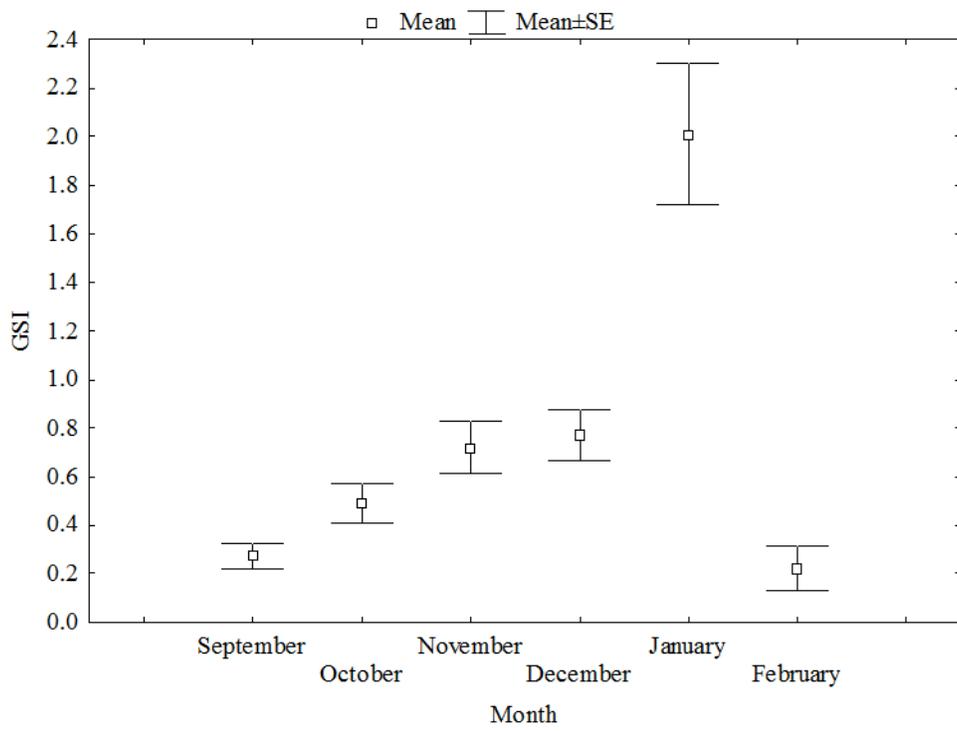


Figure 4. Mean ± SE gonadosomatic index of *Lethrinus lentjan* on the south coast of Kenya over the study period.

significant ( $H = 37.91$ ,  $df = 1$ ,  $p < 0.05$ ). Differences also existed in the mean monthly GSI for combined sexes ( $H = 70.12$   $df = 5$   $p < 0.05$ ). An increasing trend was observed from September peaking in January, and a decline in February. January had the highest GSI, with a mean of  $2.08 \pm 0.20$  (Fig. 4), and February had the lowest mean GSI of  $0.22 \pm 0.08$ . Monthly variations in GSI provide a reasonable indicator of reproductive seasonality of fish with spawning time often identified from changes in the GSI (Arruda *et al.*, 1993). This is based on the assumption that gonad weight increases during times of spawning due to the swelling and ripening of oocytes (Taylor and McIlwan, 2012). This explains the steady increase in GSI for the species in this study from September peaking in January, and a sudden decline in February. Females sampled in January had the highest GSI suggesting that they had ripe oocytes and were ready to spawn. This compares well with the January-February peak spawning reported for the species in east African reefs by Nzioka (1979) and Currey *et al.* (2009) in the Australian Great Barrier Reef. In other studies, *L. lentjan* has been reported to spawn almost throughout the year with two main peaks (Mobiha, 1991). Since sampling did not cover the entire year in the present study, this could not be confirmed from the data collected. However, the occurrence of individuals in different gonadal maturity stages in all monthly samples over the study period suggests that *L. lentjan* is a multiple spawner. Similar results were reported by Currey *et al.* (2009) for this species.

Fecundity ranged between 90 to 380,364 eggs with a mean of  $89,573 \pm 9,841$  eggs/female/year. The females ranged from a TL of 20.6 to 52.0 cm and 124.4 g to 1,913.0 g in individual BW. This differs from the findings of Toor (1964) who reported that the fecundity for *L. lentjan* in Indian Ocean waters ranged between 12,146 – 77,922 eggs. This variation could be due to several environmental factors such as temperature, sunlight, and weather (Jonsson and Jonsson, 1999). Simple linear regression of fecundity and TL, and fecundity and BW showed a weak significant positive relationship, even after log transformation (i.e.  $\text{Log } F = 6.24 \text{ Log } TL - 4.43$  ( $n = 94$ ,  $r^2 = 32.50$ ,  $p < 0.05$ ) and  $\text{Log } F = 2.00 \text{ Log } BW - 0.378$  ( $n = 94$ ,  $r^2 = 32.70$ ,  $p < 0.05$ )). A total of 413 individuals were sexed; 154 males (37.29%) and 259 females (62.71 %). There were more females than males (Table 2), and females also dominated throughout the length classes with a female:male sex ratio of 1: 0.59, which was significantly different from the expected 1:1 (Chi square test,  $\chi^2 = 26.70$ ,  $df = 1$ ,  $p < 0.05$ ). The frequency of occurrence of males and females in the various size classes all showed no significant difference ( $p < 0.05$  in all cases) in sex ratio, except in size classes 20.00 - 23.99 and 24.00 - 27.99 cm. Results indicate that males attained smaller sizes than females, with the largest male being in the 36.00 - 39.9 cm size class while the largest female was in the 48.00 - 52.99 size class.

This study established that *L. lentjan* in the waters of the south Kenyan coast had a relatively slow growth

Table 2. Sex ratio of various size classes of *Lethrinus lentjan* sampled on the south coast of Kenya over the study period.

Size class	No. of males	No. of females	Sex ratio	Chi-square value	P-value
12	15	23	1: 0.65	1.68	0.19
16	46	67	1:0.69	3.90	0.05
20	24	48	1: 0.5	8.00	0.01
24	30	67	1: 0.45	14.11	0.00
28	24	35	1: 0.66	2.05	0.15
32	14	13	1: 1.08	0.04	0.85
36	1	4	1: 0.25	1.80	0.18
40	0	0	-	-	-
44	0	1	-	-	-
48	0	1	-	-	-
Total	154	259	0.59:1	29.70	0.00

rate compared to other regions. The stock was also being exploited above the optimal rate, and this, coupled with the fact that the species is a slow grower, can easily lead to overexploitation. Growth overfishing was also apparent catches made up of over 60% immature individuals. Higher GSI values in January suggest peak spawning at this time, however, the occurrence of individuals in various gonadal maturity stages in monthly samples is indicative of multiple spawning. There is a need to enforce fishing regulations such as restriction on mesh size and destructive fishing gears such as beach seines commonly used in some parts of the Kenyan coast. This will prevent the capture of juvenile fishes and instead allow them to recruit into the fishery. Mesh size and gear type restrictions will also avoid damage to critical habitats such as sea grasses and corals that are important for fish survival. In addition, there is a need for research on gear selectivity to enable recommendation of suitable mesh sizes. There is also need for longer term studies on reproduction of this species covering the whole year and to cover other parts of the Kenyan coast to establish whether the species is a multiple spawner.

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