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Some Aspects of the Reproductive Biology of the Thumbprint Emperor, *Lethrinus harak* (Forsskål, 1775), in Kenyan Coastal Waters

A.J. Kulmiye[1], M.J. Ntiba[2] and S.M. Kisia[3]
[1]*Department of Zoology,* [3]*Department of Veterinary Anatomy, University of Nairobi, P. O. Box 30197, Nairobi, Kenya;* [2]*Lake Victoria Fisheries Organisation, P. O. Box 1625, Jinja, Uganda*

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***Abstract*—**Some aspects of the reproductive biology of the thumbprint emperor, *Lethrinus harak*, (Forsskål, 1775) in Kenyan coastal waters were studied from April 1995 to March 1996. Six maturity stages were described for gonad development based on external features. For females, these stages were validated by histological examination of the ovary and by taking oocyte diameter measurements. Size-related discrepancy in male to female sex ratio was observed where males generally predominated in the smaller sizes and females in the larger sizes. *Lethrinus harak* has a prolonged spawning season extending from October to April with peaks in October and February. The minimum size at which 50 % of males and females attain first sexual maturity was estimated to be 24.2 and 26.4 cm total body length respectively.

INTRODUCTION

Fishes of the family Lethrinidae are indigenous to the tropical and subtropical Indo-Pacific region, from the South African Kwa Zulu Natal to the coast of Japan including Australian waters (Aldonov & Druzhinin, 1978; Rudy van der Elst, pers. commun.). Of the 39 species identified so far, only *Lethrinus atlanticus* occurs outside this area, in the Atlantic off West Africa (Carpenter & Allen, 1989). Lethrinids are commonly known as emperors or scavengers. For many nations they are one of the most commercially important group of fishes (El-Gammal, 1988). In Kenya, the Fishery Statistics Year Book of 1996 (FAO, 1998) lists lethrinids together with siganids as the most important marine fish, constituting about 31% of the total reef fish landings over the last five years. *Lethrinus harak*, a common inhabitant of a variety of reef flat and shallow lagoon habitats in its distributional range (32 °N–22 °S), is the most abundant and commercially important species among lethrinid fish on the south coast of Kenya (Kulmiye, 1997).

Studies on the biological aspects of the Lethrinidae family, including age, growth and mortality as well as food and feeding habits, have been carried out in the Pacific, Red Sea, and the Arabian Gulf (Walker, 1975, 1978; Aldonov & Druzhinin, 1978; Kuo & Lee, 1986 a, b; Al-Sayes et al., 1988; El-Gammal, 1988; Ibrahim et al., 1988 a; Morales-Nin, 1988; Sharma, 1990; Wassef & Bawazeer, 1990; Wassef, 1991; Ezzat et al., 1992; Brown & Sumpton, 1998; Laursen et al., 1999). Despite these studies, comprehensive investigations into the reproductive biology of lethrinids are restricted to a few species (Toor, 1968; Church, 1989; Ebisawa, 1990; Kuo & Lee, 1990; Wassef & Bawazeer, 1992; Essat et al., 1994). Nzioka (1979) has described the probable spawning seasons of some lethrinid species (part of the 21 families in the study) in East African waters by observing the seasonal occurrence of the

Corresponding author: AJK.
E-mail: akulmiye@uonbi.ac.ke

maturity stages of these fishes. Detailed knowledge on the reproduction of the family in this region is, however, lacking and the study reported here sought to investigate the reproductive biology of *L. harak*, including its spawning season, gonad maturity stages, sex ratio, and the size at which 50% of fish attain first sexual maturity.

MATERIALS AND METHODS

The fish samples used in the study were caught using beach seine nets off Gazi and Msambweni landing sites south of Mombasa, Kenya. Sampling was carried out fortnightly during spring tides for the study period April 1995–March 1996. Occasionally, additional sampling was done during neap tides when the required sample size of 50 fishes was not realised.

The total length of the fish was taken on a fish measuring board to the nearest millimetre. The total ungutted fish were weighed to the nearest gramme using a top loading digital balance. Fish were then dissected, sexed and the gonads removed and weighed to the nearest milligramme. After gross examination, the gonads were assigned to a maturity stage based on their external features such as size, colour, shape and texture following the protocols of Ntiba & Jaccarini (1990). For females, this assignment was later validated by histological examination and measurements of the oocyte diameters.

Oocyte counts were made on different regions of both lobes of the ovary (anterior, middle and posterior) to assess any difference in their numbers. Frequency distribution of oocyte diameters between regions of the same lobe and between the two lobes was also determined. An analysis of variance showed no significant difference in oocyte counts between the regions of the same ovary or between the two lobes ($P > 0.05$). There was also similarity in frequency distribution of oocyte diameters in all ovarian regions. In subsequent analyses, therefore, portions from the middle region of one lobe were cut and preserved in Gilson's fluid for oocyte size distribution analysis while the corresponding region of the other lobe was preserved in Bouin's fixative for histological studies. The Bouin's fixed material was dehydrated in graded alcohols, cleared in a mixture of absolute alcohol and xylene and further cleared in xylene. The material was infiltrated in two changes of paraplast wax before embedding in paraplast wax. Sections were cut at a thickness of 8–12 μm and stained in iron haemotoxylin and eosin.

A variance test of homogeneity of the binomial distribution was performed on both the monthly samples and the size-frequency distributions of males and females to verify whether there was significant difference in sex variation employing the formula (Snedecor & Cochran, 1989):

$$\chi^2 = (\sum p_i a_i - \bar{p}A)/(\bar{p}\bar{q})$$

where $p_i = a_i/n_i$, a_i = proportion of males or females in a size class or monthly sample, n_i = total number of males and females in a size class or monthly sample, $\bar{p} = A/N$, $\bar{q} = A/N$, A = total number of a_i, N = total number of n_i.

The overall sex ratio was calculated using the formula (Snedecor & Cochran, 1989):

$$\chi^2 = \Sigma(f - F)^2 / F$$

where f = observed, and F = expected.

The gonad-index (GI) was calculated by expressing the gonad weight as a percentage of the weight of ungutted fish (Hickling, 1970).

RESULTS

Sex and length distributions

Table 1 gives our results on the sex of the 812 specimens of *L. harak* collected during the study period, grouped by month. The overall sex ratio was 1:1.10 males to females, which shows no significant deviation from the expected 1: 1 (χ^2 = 1. 9704, d.f.1; $P > 0.05$). However, the sex ratios of the monthly samples showed that males and females alternately dominated the population during the sampling period. Catches were predominantly males in April, May, June, July and September, whereas females dominated in the remaining months, which coincide with the high spawning season. There was significant

Table 1. Sex ratio of *Lethrinus harak* in monthly samples during the study peroid (April 1995–March 1996)

Month	Total no. of fish observed	No. of unsexed fish	No. of males	No. of females	% of males	% of females	Sex ratio M : F
Apr 1995	93	0	55	38	59	41	1 : 0.69
May	11	0	7	4	64	36	1 : 0.57
Jun	66	4	32	30	48	45	1 : 0.94
Jul	43	1	27	15	63	35	1 : 0.56
Aug	42	3	17	22	40	52	1 : 1.29
Sep	91	0	58	33	64	36	1 : 0.57
Oct	77	1	33	43	43	56	1 : 1.30
Nov	104	2	50	52	48	50	1 : 1.04
Dec	97	0	43	54	44	56	1 : 1.26
Jan 1996	88	2	43	43	49	49	1 : 1.00
Feb	41	1	15	25	37	61	1 : 1.67
Mar	74	1	6	67	8	91	1: 11.2
Total	827	15	386	426	46.6	51.5	1 : 1.10

Table 2. Number of *Lethrinus harak* males and females and their sex ratios in relation to size classes

Size class (T.L. cm)	Total no. of fish observed	No. of unsexed fish	No. of males	No. of females	% of males	% of females	Sex ratio M : F
13–14.9	1	1	0	0	0	0	
15–16.9	3	2	0	1	0	33	
17–18.9	11	2	7	2	63.6	18.2	1 : 0.28
19–20.9	42	0	29	13	69.1	30.9	1 : 0.45
21–22.9	147	4	85	58	57.8	39.5	1 : 0.68
23–24.9	143	3	75	65	52.4	45.5	1 : 0.86
25–26.9	146	3	56	87	38.4	59.6	1 : 1.55
27–28.9	108	0	43	65	39.8	60.2	1 : 1.51
29–30.9	103	0	50	53	48.5	51.5	1 : 1.06
31–32.9	75	0	34	41	45.3	54.6	1 : 1.21
33–34.9	29	0	6	23	20.7	79.3	1 : 3.83
35–36.9	12	0	1	11	8.3	92.7	1 : 11.0
37–38.9	7	0	0	7	0	100	
Total	827	15	386	426	46.6	51.5	1 : 1.10

heterogeneity in the monthly sex distribution (χ^2= 69.200, d.f. 11; $P < 0.05$). The sex ratio for males and females in relation to size is summarised in Table 2 and the length frequencies are presented in Fig. 1. The size of the males ranged from 17 cm to 36.6 cm and showed a bimodal distribution with one higher peak in the 21–22.9 cm size class and a lower one in the 29–30.9 cm size class. The size of the females ranged from 15.8 cm to 38.8 cm and showed a unimodal distribution with one peak in the 25–26.9 cm size class. Comparison of the overall mean sizes of males and females in different size classes showed a very significant difference between the sexes ($t = 8.057$, d.f. 22, $P < 0.05$). The variance test of homogeneity of the binomial distribution of the sex in relation to size showed significant evidence of heterogeneity ($\chi^2 = 51.080$, d.f. 11; $P < 0.05$). The bulk of male frequencies (65.2 %) was below the 25–26.9 cm size class while that of female frequencies (67.3 %) tended to be above the 23–24.9 cm size class.

Length–weight relationship

The length–weight relationship of each sex was first plotted and its regression coefficient obtained

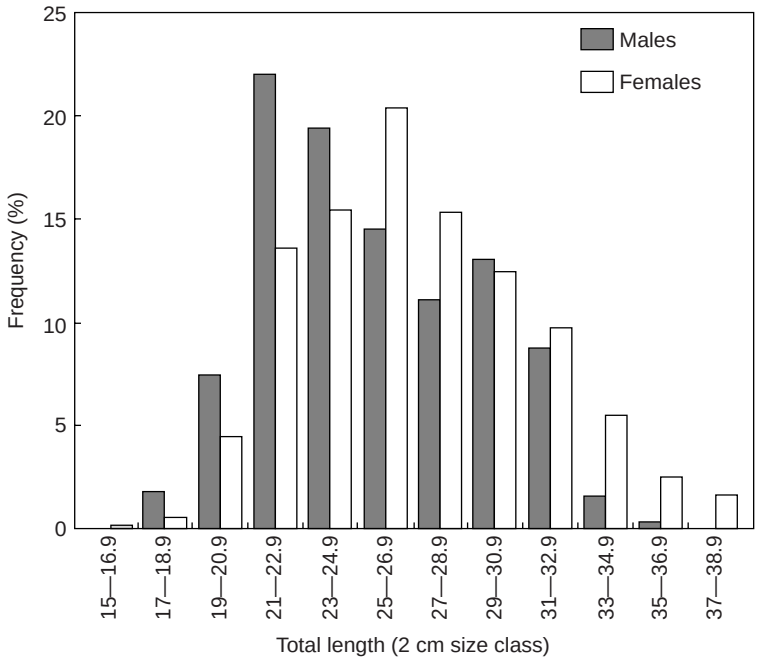

Fig. 1. Length frequency distributions of male and female *Lethrinus harak* from the coastal waters of Kenya collected during April 1995–March 1996

by the method of least squares using log-log transformed data. Student's *t*-test analysis showed no significant difference between the slopes of males and females (t = 1.381, d.f. 385, 425, P > 0.05). The length–weight data were subsequently pooled to give one regression equation for both males and females in the Kenyan coastal waters:

$$Log_{10}W = 2.9953Log_{10}L - 1.8267$$

$$r = 0.99, n = 812$$

where W is the total weight in g and L is the total length in cm.

Gonad maturity stages

Table 3 gives a description of the maturity stages for gonads in both males and females of *L. harak*. For males, only the macroscopic appearance of the testes is given, while both macroscopic and microscopic appearances of the ovary are shown for females.

Spawning season

The percentage occurrence of different stages of maturity in males and females in each month throughout the study period was calculated and the combined results for both sexes are presented in Fig. 2. Spawning activity, as indicated by the presence of individuals in the advanced stages of gonad development, was observed throughout the year. However, the delineation of the stages is not well defined since many fishes in different stages of maturity appeared in the monthly catches. The highest percentages of fish with mature gonads (stage 3) were caught in May, July, August, and November. Similarly, high proportions of fish with ripe (stage 4) gonads were obtained in April, May, June, October and March. The lowest number of fish with running gonads (stage 5) was observed in August. However, from September this number increased reaching a peak in October. From November up to April, running fish gonads steadied at a sizeable number with another high peak occurring in February. Spent fish (stage 6) were encountered in the catches in the period

Table 3. Description of maturity stages of *Lethrinus harak* gonads based on the modified gonad maturity schemes from Ntiba & Jaccarini (1990)

	Testes	Ovary	
Maturity	External Features	External Features	Histological Features
Stage 1 Immature Virgins	Long, slender and thread like translucent structures occupying about 33 % of the abdominal cavity.	Long, slender and thread like structures, red in colour also occupying 33 % of the abdominal cavity.	Largest oocytes have maximum diameter of 57 µm. Many oocytes have small nucleus relative to the size of thickly staining cytoplasm.Ovary wall is 63 µm thick.
Stage 2a Developing Virgins	Ribbon-like structures slightly bigger than Stage 1, greyish-white in colour occupying 50 % of the abdominal cavity.	Firm and ribbon like with slight increase in size, pink in colour and occupying 50 % of the abdominal cavity. Oocytes not discernible.	Largest oocytes have maximum diameter of 100 µm. Large circular nucleus with upto 12 nucleoli. Oocytes have no definite shape. Ovary wall is 95 µm thick.
Stage 2b Recovering	Same as those in stage 2a but slightly bigger and firmer.	Same as those in stage 2a but softer and plump to feel.	Same as Stage 2a except for the presence of many residual atretic oocytes.
Stage 3 Maturing	Broad and thick, dark white in colour, blood vessels visible externally, milt oozes out from cut surfaces and occupying 70 % of the abdominal cavity.	Broad and thick occupying 70 % of the abdominal cavity, red or reddish brown. Blood vessels visible externally. Oocytes visible through ovary wall.	Largest oocytes have maximum diameter of 158 µm. Many oocytes with cytoplasmic vacuoles present. Oocytes are contained in well organised ovigerous lamellae. Ovary wall is 254 µm thick.
Stage 4 Ripe	Further increase in size occupying 90 % of the abdominal cavity. White in colour. Milt oozes out on slight pressure.	Distended and occupying 90 % of the abdominal cavity. Blood vessels disappearing, oocytes can be seen clearly through the ovary wall.	Largest oocytes have maximum diameter of 318 µm. Many oocytes with cytoplasmic vacuoles still present. Largest oocytes are filled with eosophilic yolk granules. Ovigerous lamellae present but for some disappearing. Ovary wall is 270 µm thick.
Stage 5 Running	Fully distended, occupying almost all the abdominal cavity, exudes milt on slight pressure.	Fully distended with granular surface occupying almost all the abdominal cavity.	Largest oocytes have maximum diameter of 347 µm. Many oocytes have thickly staining yolk granules. Some late stage oocytes have oil globules in the cytoplasm. Ovary wall is 286 µm thick.
Stage 6 Spent	Shrunken and flaccid, walls are harder and wrinkled. No milt oozes out on pressure and blood vessels visible externally.	Ovary is not fully empty. Residual oocytes present. Flaccid and red in colour. Ovary wall is thick.	Largest oocytes have maximum diameter of 158 µm. Smaller oocytes have thickly staining cytoplasm. Numerous blood vessels at the periphery of the residual oocytes. Post ovulatory follicles present. Ovary wall is 111 µm thick.

December–February and again in April. The highest percentages of fish with developing or recovering gonads (stage 2) were obtained in the months of April, June, July, August, September, November, January and March. Immature fish (stage 1) were represented in the catches throughout the year except for May, August and October. From the above observations, it is apparently clear that *L. harak* populations at the Kenya coast have a prolonged spawning season with two peaks in October and February.

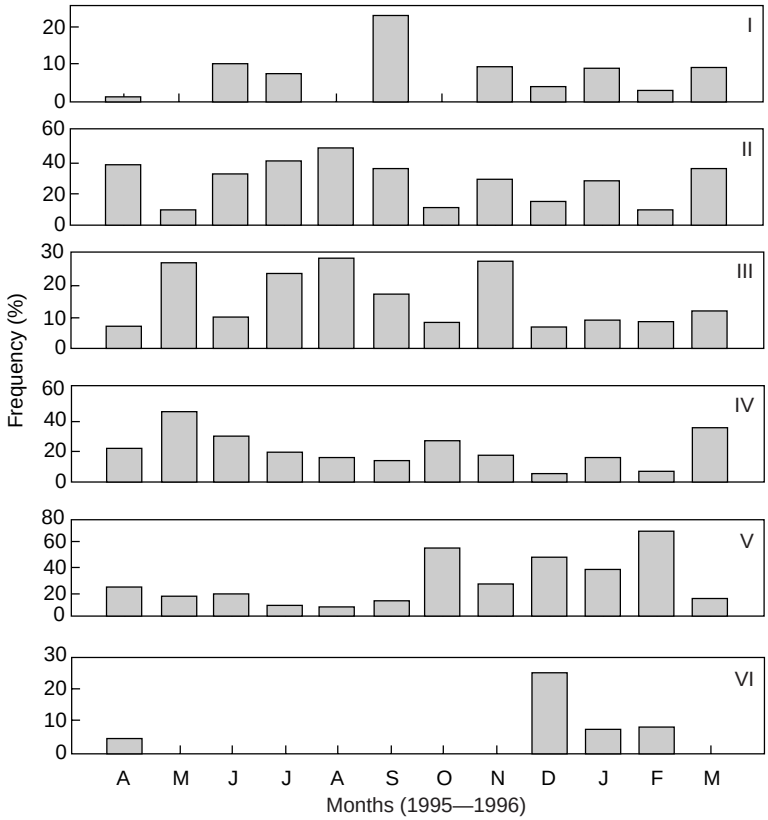

Fig. 2. Monthly percentage occurrence of the maturity stages of *Lethrinus harak*. Roman numerals (I–VI) represent maturity stages of gonads (sexes combined)

Gonad-index (GI)

The calculated mean monthly gonad-indexes for males and females are presented in Fig. 3. The GI values for females show a temporal trend somewhat similar to that of the monthly percentage occurrence of fish with running gonads (stage 5). Here, the GI rose sharply from low values in July reaching its highest peak in October. However, after this peak, the GI steadied with slight rises occurring every other month until April when the GI started falling sharply reaching its lowest values once again in July. Among the slight increases in GI values is another peak in February.

In contrast, the GI values for males show no similar marked patterns to those of the monthly occurrences of the different maturity stages (Fig. 3). High male GI values were recorded in May, July, October and February. Ignoring the May and July rises in the GI of males; both sexes show concurrent rises in October and February, which

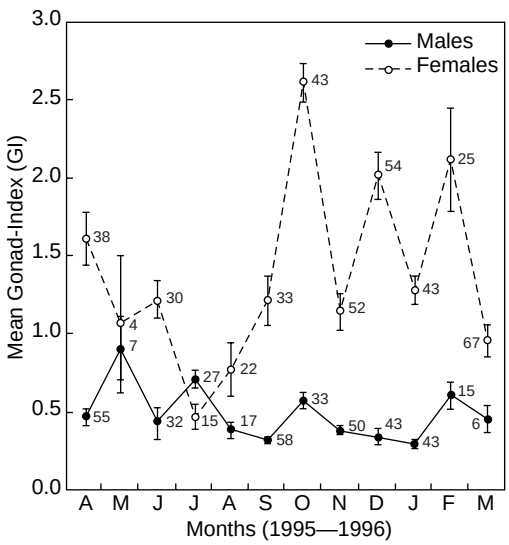

Fig. 3. Monthly mean gonad-index (GI) for *Lethrinus harak* males and females. Bars show ± SEM. Figures indicate number of males and females examined each month

coincide with the months with the highest percentages of fish with running gonads (stage 5). The peak in male GI in May could be a result of sampling discrepancy (the sample included seven mature male specimens with extremely heavy testes), while the one in July was probably caused by the onset of spermatogenesis.

Minimum size at first maturity

To determine the average size at which 50 % of *L. harak* males and females attain first sexual maturity (fish in stage 2 of gonad development and above were considered mature), the cumulative percentage of mature males and females, grouped into 2 cm-size classes, were calculated and plotted against the mid points of the size classes in Fig. 4. The figure shows that 50 % of males and females reach maturity at total body lengths of 24.2 cm and 26.4 cm, respectively. This indicates that males mature at a slightly smaller size than females.

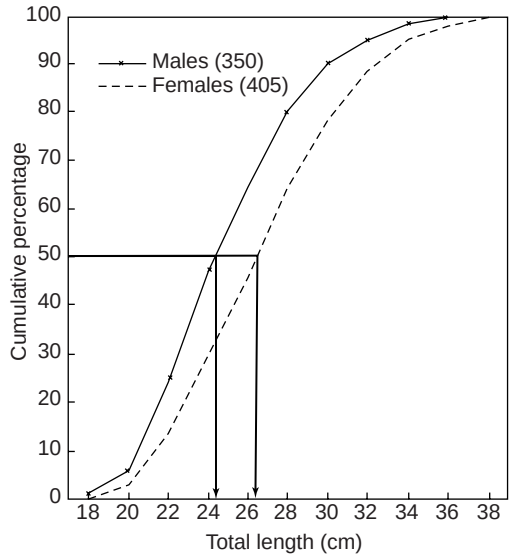

Fig. 4. Changes in the percentage of mature *Lethrinus harak* males and females with size, showing size at 50 % maturity. Figures show total number of mature males and females examined

DISCUSSION

The size of the largest *L. harak* specimen (38.8 cm) caught during this study is well below the maximum size (50 cm) reported for this species (Carpenter & Allen, 1989). It is not clear at this stage whether the variation is due to difference in environmental conditions or the impact of cumulative fishing pressure on the Kenyan population over the years. It is also possible that our samples came from one portion of the population since beach seining is carried out exclusively in the shallower areas of the lagoon habitat.

The overall sex ratio of *L. harak* in the catches at the Kenya coast did not show any significant deviation from the expected ratio of one male to one female (χ^2 = 1. 9704, d.f.1; P > 0.05). In contrast, monthly sex distributions were found to be heterogeneous (χ^2 = 69.200, d.f. 11; P < 0.05). Males were more in the landings than females during the period with the lowest spawning activity whereas the opposite was true during the spawning season. Similarly, the sex ratio for males and females grouped into 2 cm class intervals showed significant deviation from the expected ratio of one male to one female for most size classes. Generally, males predominated in the smaller size classes while females dominated in the larger size classes. The size class 23–24.9 cm total length (Table 2) separating the male-female preponderance coincides with the minimum size at which 50 % of males reach first sexual maturity (Fig. 4).

Although no individual fish with both ovarian and testicular tissues was observed in our histological studies, the predominance of males and females in the smaller and larger size classes, respectively, may be taken to suggest sex reversal from male to female soon after males attain sexual maturity. Similar female predominance in the larger size classes has been reported for *L. nebulosus* from New Caledonian waters (Loubens, 1980). The heterogeneity observed in the distribution of males and females in relation to size is inadequate to draw any conclusion as to the nature of sexuality in *L. harak*. However, this size-related discrepancy could not be related to gear selectivity since the method (beach seining) employed to catch samples was nonselective, active fishing gear capable of entrapping both sexes irrespective of size. The future work on this species should investigate and document with certainty, incidence of protandrous hermaphroditism especially in late spent stages of the ovary.

Protogynous hermaphroditism has been reported among some lethrinid species. Wassef & Bawazeer (1992), working on *L. elongatus* in the Red Sea, found that females predominated the younger groups while males were preponderant amongst the older ages and suggested sex reversal from females to males. Similarly, Young & Martin (1982) working on eight lethrinid species from Australian waters found evidence of protogynous hermaphroditism in all the species under investigation and strongly suggested that protogynous hermaphroditism is the usual mode of sexuality in lethrinid fishes. However, Ebisawa (1990) studying the reproduction of *L. nebulosus* in Okinawa waters (Japan) reported juvenile hermaphroditism although he did not rule out the possibility of protogyny.

Although hermaphroditism is quite common among coral reef and deep-sea fish communities, its ecological advantages to the species are not well known (Abu-Hakima, 1984). However, according to Jobling (1995), under reproductive conditions and mating systems where male body size is unimportant, it would be advantageous for an individual to reproduce as a male when small and later change sex to reproduce as a female as body size increases and consequently accommodating more eggs since body size and fecundity are correlated. In the case where male body size is important for mating and territorial defence, it is advantageous for an individual to reproduce as a female when small and then change sex to become a male as it increases in size since it is the largest male that secures the favours of the females under such conditions.

When ascertaining spawning season of a fish population, one approach is to conduct simultaneous egg and larva surveys as well as collection of juveniles in conjunction with the usual sampling procedures. Although it was not practicable to carry out these surveys in this study, the gross morphological criteria used to distinguish the six maturity stages assigned to gonad development, together with the cyclical changes shown by the gonad-index, do provide reliable evidence of spawning in *L. harak* off the Kenya inshore waters. The occurrence of high percentages of individual fishes with running gonads (stage 5) in the samples in, at least, seven consecutive months from October to April and the subsequent emergence of spent fish one month after the October peak through April suggests that *L. harak* population at the Kenya coast has a prolonged spawning season extending from October to April with two peaks occurring in October and February. The existence of a prolonged spawning season with two peaks is further confirmed by the cyclical changes in the female GI. Apart from showing two rises in October and February which coincide with the two spawning peaks, the male GI does not reflect the prolonged spawning season as exhibited by the female GI, the relative condition factor K_n (our unpublished data) and the seasonal occurrence of the maturity stages. This is understandable because gamete development is not reflected by this index in an identical way in both sexes. Male gonads are heavier at onset of spermatogenesis than at the completion of the spermatogenetic process due to the elimination of residual bodies resulting in lighter gonads at the peak of ripe male gamete storage. In contrast, female gonads accumulate weight gradually as they grow, resulting in heavier gonads at the peak of ripe female gamete storage (Stoumboudi et al., 1993).

Unfortunately, no published data on reproduction of *L. harak* are available in the literature. However, the information available for other lethrinid species can be used for comparison. Wassef & Bawazeer (1992) found that the longnose emperor, *L. elongatus*, in the Red Sea has a protracted spawning season spanning four months (May–August). Kuo & Lee (1990) reported that the common porgy, *L. nebulosus*, also has a prolonged spawning season extending from September to February in the Northwestern Shelf of Australia. Nzioka (1979), examining the gonads of East African reef fishes, postulates two spawning seasons for some lethrinid species in September/October and January/February. The present study partly agrees with his finding but the two seasons are not clearly discernible in the case of *L. harak*. It is possible that Nzioka's (1979) sampling was not comprehensive enough in lethrinids so that the continuous nature of spawning in this group was missed. It is also possible, as has been shown for *L. harak* in this study, that other lethrinids follow this general pattern of one prolonged spawning season spanning from October to April with small

species variation(s). Environmental cues are also known to trigger breeding. In the present study no such factors, which might affect spawning seasonality, were investigated. However, the spawning season of this species falls within the northeast monsoon period when the water temperature is high, cloud cover is minimum and the sea is relatively calm. McClanahan (1988) has reviewed the literature documenting distinct seasonal patterns in physical, chemical and biological oceanographic parameters in East African coastal waters and has shown a strong relationship of this seasonality with the monsoons.

The ever-increasing demand for fish products in the local and international markets and the degradation of breeding and nursery grounds, coupled with the poor/lack of management have led to dwindling catches/stocks. Reef and lagoon fish populations are most vulnerable to local extinction, and it is hoped that studies such as this one could be of use in formulating sound management measures for the sustainable use of these resources.

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