

**REPRODUCTIVE CHARACTERISTICS OF DOUBLESPOTTED QUEENFISH,
SCOMBEROIDES LYSAN (ACTINOPTERYGII: PERCIFORMES: CARANGIDAE),
FROM SRI LANKAN WATERS: IMPLICATIONS FOR FISHERIES MANAGEMENT**

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Thulasitha W.S., Sivashanthini K. 2013. Reproductive characteristics of doublespotted queenfish, *Scomberoides lysan* (Actinopterygii: Perciformes: Carangidae), from Sri Lankan waters: Implications for fisheries management. Acta Ichthyol. Piscat. 43 (1): 7–13.

Background. The doublespotted queenfish, *Scomberoides lysan* (Forsskål, 1775), is one of the most important and highly priced food fishes popular for dry fish production in Sri Lanka. Knowledge of spawning pattern and season are important for the management of *S. lysan*. The biology of *S. lysan* is poorly known, however, and no specific management regime is available for this species in Sri Lanka. The presently reported study is the first attempt to understand the reproductive characteristics of *S. lysan* with implications for its management.

Materials and methods. Weekly samples, totalling 1429 specimens, were collected from Sri Lankan marine waters from January 2010 to December 2011, analyzed macroscopically, and their maturity stages identified. Sex ratio, size at maturity, length-class distribution, monthly distribution of maturity stages, fecundity, and the indices related to reproduction were examined. Statistical analyses were performed to determine relations between gonad weight, total length, fork length, and fecundity.

Results. Females were categorized macroscopically into five maturity stages, males into four (males mature slightly earlier than females). Spawning and spent stages of females were only available during June and September and significant peaks in the gonadosomatic index of males and females were also noted from these two months.

Conclusion. The spawning period of *Scomberoides lysan* in Sri Lankan waters shows two peaks, one in June and another in September. The present knowledge could be used in the formulation of management strategies intended to maintain the *S. lysan* stock at sustainable level. Such management measures could limit the catches of *S. lysan* during spawning season, allowing limited number of boats, closure of spawning area during spawning months, and harvesting small fish under 55 cm of low consumer demand should be discouraged.

Keywords: spawning season, size at maturity, fecundity, gonadosomatic index, *Scomberoides lysan*

INTRODUCTION

Spawning season and area, age at maturity, age at first reproduction, and fecundity are important parameters in reproductive biological studies (Jakobsen et al. 2009, Salcedo-Bojorquez and Arreguin-Sanchez 2011) and can be determined through the examination and classification of gonads into developmental stages (Mackie and Lewis 2001). Karolu-Riga and Economidis (1997) also state that observing the seasonal developmental changes in the gonads is the most suitable method for determining the reproductive cycle of fish. Reproductive seasonality was determined by monthly inspection of macroscopic and microscopic developmental stages and by gonadosomatic index (GSI) (Maartens and Booth 2005). An understanding of the reproductive biology of a species is a central aspect of providing sound scientific advice for fisheries management (Morgan 2008). Sivashanthini (2008) also

stated that the knowledge on length at maturity and spawning season helps to determine when and at which length the fish should be protected; it is therefore important for the proper management and conservation of fish stocks. The reproductive strategy of a species is a characteristic feature that is usually firmly associated within that species (Morgan 2008).

Queen fish are a group of tropical pelagic fishes that are widely distributed throughout the Indo-West Pacific, often in schools (Honebrink 2000) inhabiting inshore- and offshore reefs and estuaries (Durville et al. 2003, Griffiths et al. 2005, Froese and Pauly 2012). *Scomberoides lysan* (Forsskål, 1775), commonly known as doublespotted queenfish, leather jackets, or leather backs, inhabit pelagic neritic waters over sandstone with coral, mud, and sand in the coastal seas off Sri Lanka (De Bruin et al. 1994). These are economically important food fishes that are especially

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popular for dry fish production and have high export value in Sri Lanka (Thulasitha and Sivashanthini 2012) in addition to being popular in recreational fisheries (Honebrink 2000, Griffiths et al. 2005).

The reproductive dynamics of Talang queenfish, *Scomberoides commersonianus* Lacepède, 1801, was studied by Griffiths et al. (2005) in Northern Australian waters; but the biology of *S. lysan* is poorly known and no relevant information is available from Sri Lankan waters. There is no specific management regime for marine food fishes in Sri Lanka. Sivasubramaniam (1999) also stated that, in Sri Lanka, guidelines provided for the management of fisheries other than for whelks were relatively poor. The presently reported study is the first attempt to understand the reproductive characteristics of *S. lysan* in the Sri Lankan waters. The reproductive parameters such as sex ratio, length at first maturity, gonadosomatic index, hepatosomatic index, fecundity, spawning season, and spawning pattern were explained in the presently reported study.

MATERIALS AND METHODS

Samples of *Scomberoides lysan* were obtained between January 2010 and December 2011 from Sri Lankan waters (Indian Ocean, 79°–80°E, 9°–10°N). Samples were collected particularly from the marine areas off Jaffna, Trincomalee, Mannar, and Puttalam with the assistance of the Federation of Fishermen Co-operative Society's Union of the respective districts, at the depths not exceeding 100 m. Individuals were caught mainly by 177.8 mm 21-ply mesh drift-nets ('Katta valai' in Tamil) used particularly for queenfish. *S. lysan* were also caught using beach seines and trap nets ('Kalankatti valai' in Tamil) with mesh size of 63.5 mm fixed in shallow waters. All collected fish were brought to the laboratory in an icebox and analyzed. For each fish total length (TL) and fork length (FL) were recorded to the nearest 0.1 cm, and total mass (TW) was weighed to the nearest 1.0 g.

Sexes were separated by the examination of gonads as male, female, and unsexed. Sex ratio was determined from the number of specimens of each sex sampled every month and in every size group. To test the significant deviations from an expected 1 : 1 sex ratio for all male and female fish, the sex ratio values obtained every month were subjected to Chi-square test with Yate's correction (Zar 1999) employing the formula,

$$\chi^2 = \sum [(o-e) - 0.5]^2 \cdot e^{-1}$$

where: o = observed number and e = expected number.

All stages of reproductive maturity were determined using macroscopic examination of gonads (Mackie and Lewis 2001). The length at which 50% of fish were sexually mature was estimated for reproductively active fish including stages III, IV, and V. The maturity data were grouped into 5-cm size groups and the percentage occurrence of specimens in each size group was calculated. Size at first maturity was arrived at by plotting the percentage occurrence of mature specimens against total length class interval. A logistic regression curve was fitted to the data to estimate length at 50% maturity (L_{50}) by the

use of a non-linear least-squares procedure weighted by the number of fish in each length-class. The form of regression equation used was (King 1995):

$$P_m = 100 \cdot (1 + \exp[-r(L - L_m)])^{-1}$$

where: P_m is the percentage of mature individuals, r is the slope of the curve or rate of increase in maturity, L_m is length at 50% maturity, and L is the 5 cm length class. Probit analysis was performed using computer based 'R' software to estimate L_{50} .

Gonad weight (GW) was weighed to the nearest 0.001 g by an electronic balance (AND FY 300) and the gonadosomatic index (GSI) was determined by the most commonly used method in the literature (Kaunda-Arara and Ntiba 1997, Brown-Peterson et al. 2000, Griffiths et al. 2005) for both males and females using the formula:

$$GSI = 100 \times GW \times (TW - GW)^{-1}$$

Spawning season was determined by analyzing the macroscopic stages of gonads in detail and plotting the graphs of GSI against months and monthly distribution of maturity stages of males and females.

A monthly change in the hepatosomatic index (HSI) was also analyzed to determine the spawning time during the reproductive cycle. HSI were calculated as follows:

$$HSI = 100 \times LW \times TW^{-1}$$

where: LW is the weight of liver and TW is the total body weight.

Annual fecundity estimates were based on fish that had undamaged ovaries and showed no sign of previous spawning in that season (i.e., no loose, hydrated oocytes in the lumen of the ovary, Watson et al. 1992), no sign of post ovulatory follicles (POFs), and no signs of major atresia. Initially, 1 g portions from five of these fish were dissected from the anterior-, median-, and posterior regions of the gonad and weighed (± 0.0005 g). Analysis of variance (ANOVA) was used to compare the number of oocytes per 1 g between subsamples along the ovaries (in the anterior-, median-, and posterior regions). Because no significant differences ($P > 0.05$) were observed between regions, the medial gonad portions were weighed accurately and used for estimating fecundity by the gravimetric method (Hunter and Macewicz 1985). Annual fecundity was estimated from yolked oocytes (stages IV and V) from samples collected during spawning season.

The annual fecundity was related to the total length and ovary weight of fishes using the following relation (Bagenal 1967):

$$FE = aX^b$$

where: FE is the fecundity, 'a' is a constant, 'b' is the exponent derived from the data, and X is the total length and ovary weight of the fish. The following logarithmic transformation was used to obtain the regression lines of each relation:

$$\log FE = \log a + b \log X$$

Relations between ovary weight and fork length, and liver weight and fork length were also obtained for females. For males, relations of testes weight versus fork length, testes weight versus total weight and liver weight versus fork length were derived.

RESULTS

A total of 1429 *Scomberoides lysan* (668 males and 761 females) were collected and analyzed. The total length of males ranged from 18.0 to 81.6 cm and that of females ranged from 19.5 cm to 80.6 cm. Weights of males ranged from 21.6 to 2500.0 g and females from 25.0 to 3000.0 g.

Chi-square values calculated month wise showed that the sex ratio conformed to the expected 1 : 1 ($P > 0.05$) in months other than January 2010, March 2010, May 2010, June 2010, August 2010, January 2011, February 2011, March 2011, June 2011, July 2011, August 2011, October 2011, November 2011 and December 2011. Overall, sex ratio did not vary significantly from an expected 1 : 1 ratio, with slightly fewer males than females

(1.19 : 1, $X^2 = 0.865$, $P > 0.05$). The percentage of females in the monthly samples of *S. lysan* ranged between 30%–80% whereas males ranged between 20%–70%.

Ovaries of *S. lysan* composed of two Y-shaped lobes (Fig. 1), one located on the right side of the coelomic cavity and the other on the left. Ovaries and testes were classified according to their morphology as in the Tables 1 and 2.

It was found that fish smaller than 35 cm total lengths are always immature. Spawning stage was observed within the total length class of 50–55 cm and resting stage was observed within 60–65 cm total length class. This indicates that spawning occurs after attaining total length of 50–55 cm (Fig. 2).

Immature males and females are available throughout the year and fluctuate from one month to another, reach-

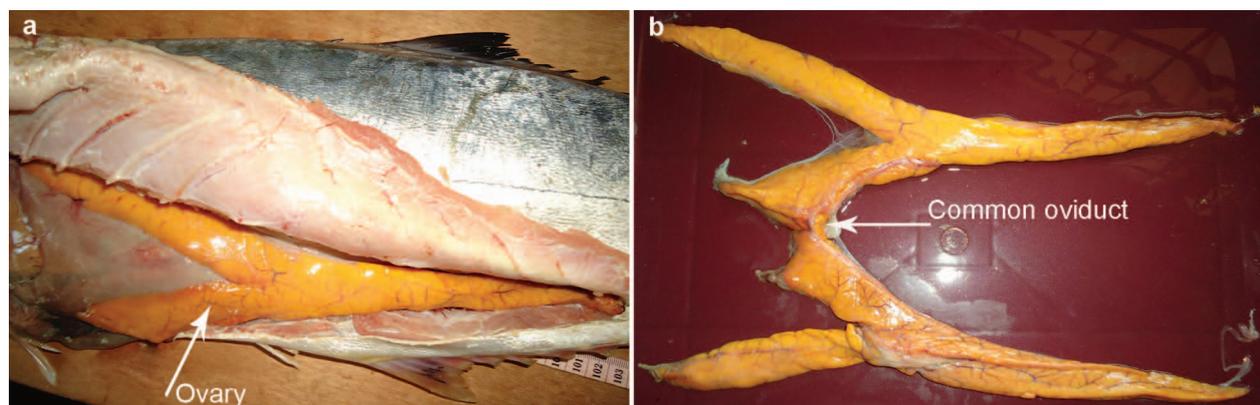


Fig. 1. Ovaries of *Scomberoides lysan*: right lobes (a) and whole ovary (b) with left and right lobes opens via common duct

Table 1

Description of macroscopic staging system for ovary of *Scomberoides lysan*

Maturity stage	Macroscopic character
I (immature)	Small, thread like ovaries without visible ova. Ovarian wall thin. Difficult to determine the sex.
II (maturing)	Medium size ovaries, usually translucent pink; flattened, flaccid and relatively inconspicuous. Oocytes are microscopic and smooth uniform appearance to the ovarian tissue.
III (mature)	Large, rounded ovaries occupying 75% to almost filling body cavity with prominent blood capillaries. Yellow to orange colour. Opaque oocytes are visible through the thin ovarian wall.
IV (spawning)	Ovaries are very large and swollen; the presence of translucent hydrated oocytes gives the ovaries a distinctive speckled or granular appearance through the thin gonad wall. Eggs may be released from the ovaries when pressure is applied.
V (resting/ spent)	Flaccid ovary; internal lumen very large, a few oocytes seen, yellow-brown bodies distinct; colour typically semi-translucent rose, purple; ovary wall thick, blood capillaries thick

Table 2

Description of macroscopic staging system for testes of *Scomberoides lysan*

Maturity stage	Macroscopic character
I (immature)	Small, strap/thread like, opaque with a smooth appearance and no milt is present in the transverse section.
II (maturing)	Larger than immature gonads, produce milt when squeezed.
III (mature)	Large, opaque and ivory or bone colour; exterior dorsal blood vessels are present; produces white milt when squeezed; milt visible in the outer areas of the transverse section.
IV (spawning)	Running ripe; similar to mature stage but more swollen and with larger exterior blood vessels. Milt released with little or no pressure on the abdomen or when testis is cut.

ing maximum length during September. Spawning stage females were available only during June and September and males during June, September and October (Fig. 3).

Probit analysis of proportion mature versus total length for males and females indicates that *S. lysan* males reached maturity at 55.4 cm total length while females reached maturity at 60.7 cm total length. At 70 cm total length, all males and females were mature (Fig. 4a and b).

Of the 761 ovaries analyzed by macroscopic staging system, 61% were immature, 15% were maturing, 3% were mature, 20% were spawning, and 1% was resting/or spent. Among 668 testes, 71% were immature, 10% were maturing, 4% were mature, and 15% were spawning.

Variation in GSI values throughout the study period (Fig. 5) explained that GSI values of females were always higher than those of males and that the index fluctuated with season, attaining a peak in September followed by

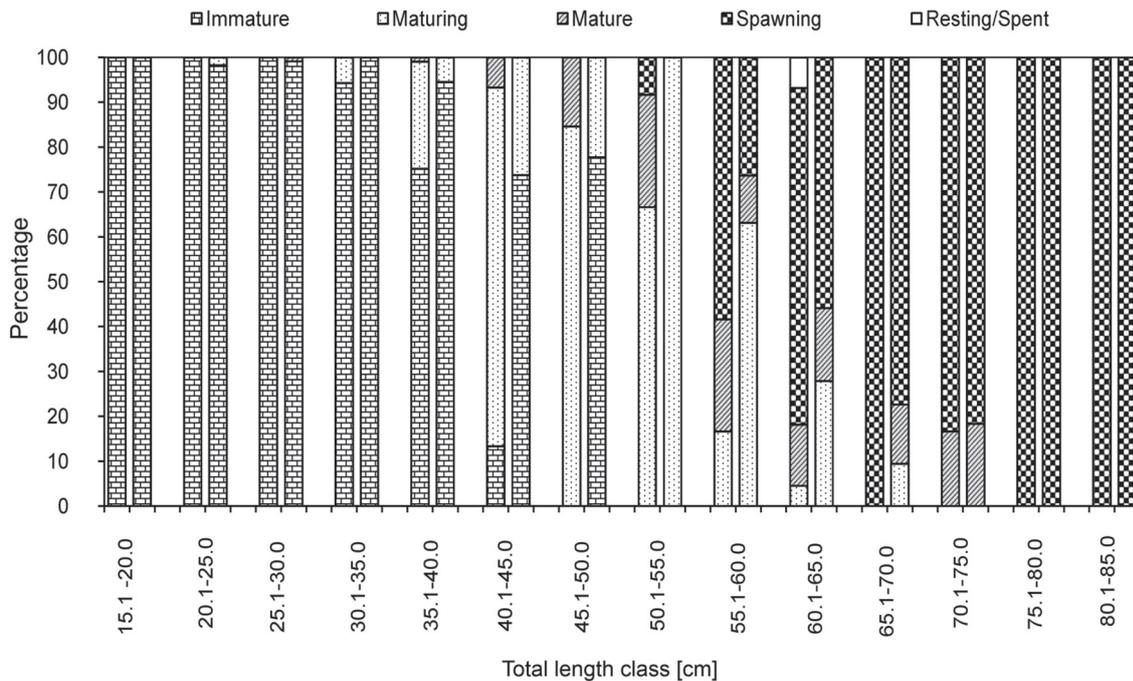


Fig. 2. Relative occurrence of respective gonad maturity stages in individual length classes of female and male *Scomberoides lysan* (F = female, M = male)

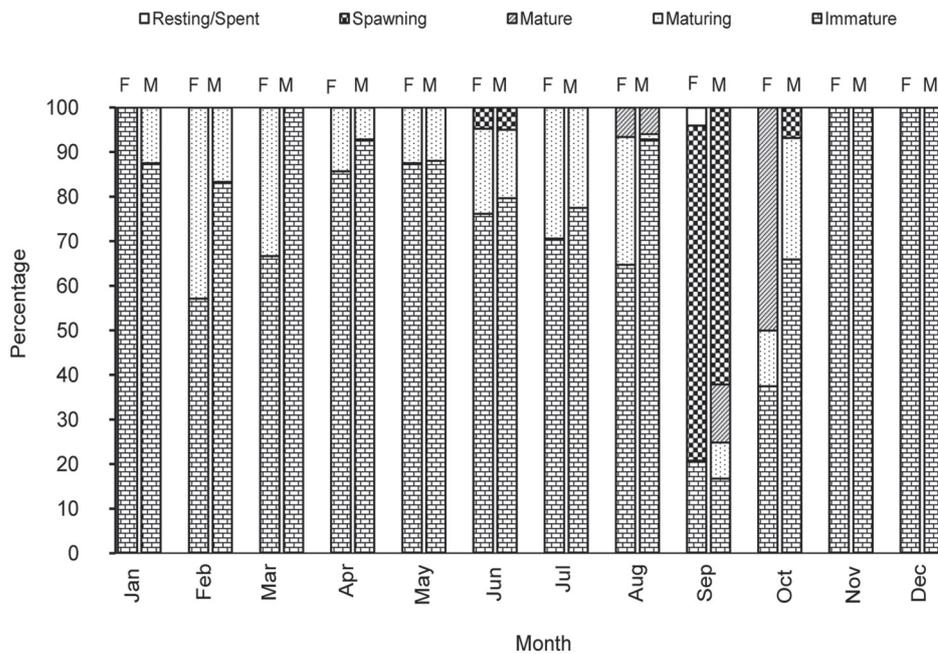


Fig. 3. Relative occurrence of respective gonad maturity stages in females and males of *Scomberoides lysan* sampled in consecutive months (F = female, M = male)

peaks in December, March, and June. The hepatosomatic index (HSI), determined in females (Fig. 5), showed similar seasonal patterns with the highest average of 2.05% in December followed by September.

Fecundity was calculated only for females above 40.5 cm total length during June and September. It varied from 24 655 (FL = 58.5 cm) to 82 562 542 (FL = 74.3 cm). Regression equations and regression parameters for relations between: ovary weight versus fork length, fecundity versus ovary weight, fecundity versus total length, and liver weight versus fork length for females are shown in Table 3.

Regression equations and regression parameters for relations between: testes weight versus fork length, testis

weight versus total weight, and liver weight versus fork length for males are given in Table 4.

DISCUSSION

Fish spawning in tropical seas is protracted and occurs in multiple batches whereas in temperate-climate regions fish spawns synchronously within a short period (Blaber 1997). In the presently reported study, GSI values of females and males explained that *S. lysan* had an intense spawning season in September followed by less reproductive activity during December, March, and June. It clearly explained that *S. lysan* spawn more than once a year in Sri Lankan waters. Macroscopic staging system also revealed that it spawns more than once in a year and may be termed a multiple

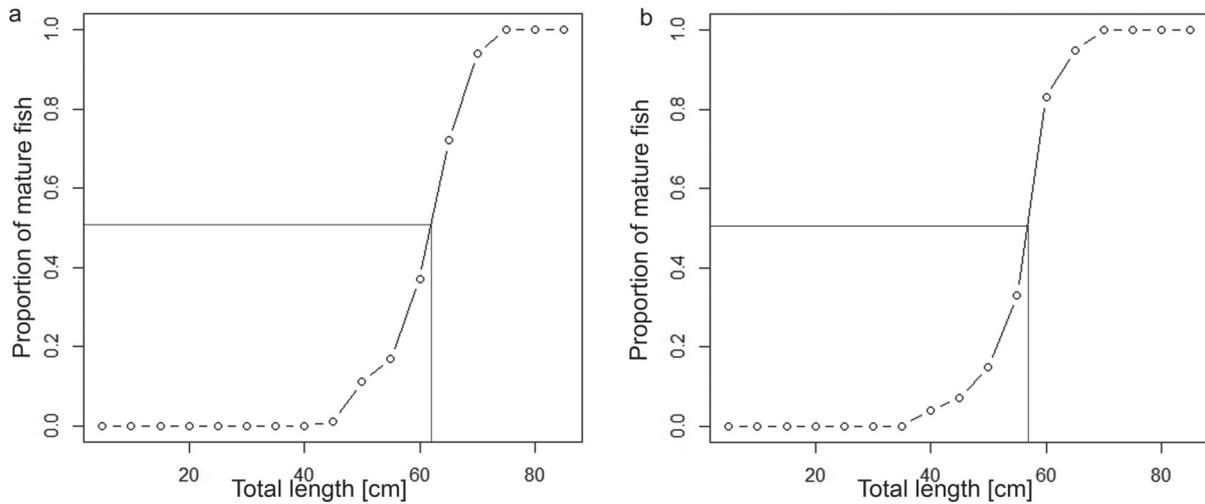


Fig. 4. The relation between the length of females (a) and males (b) of *Scomberoides lysan* and the proportion of sexually mature individuals

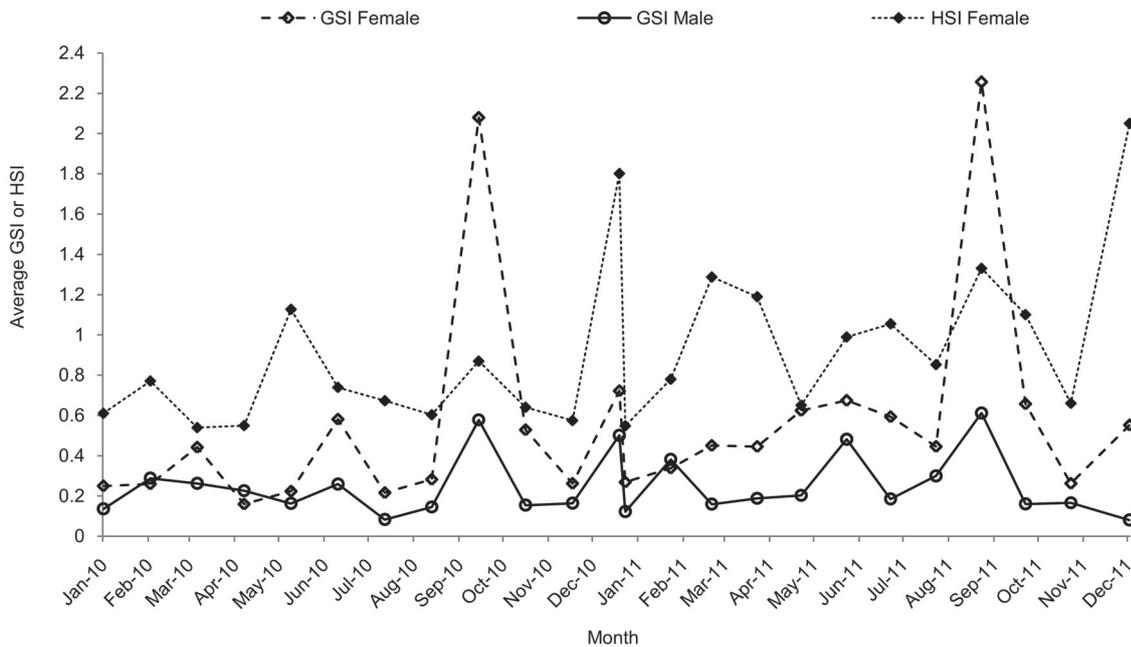


Fig. 5. Monthly average gonadosomatic index (GSI) of males and females and monthly average hepatosomatic index (HSI) of female *Scomberoides lysan*

spawner. Fecund fish were available only during June and September. It further supports timing and duration of the spawning season as reported in the presently reported study.

Honebrink (2000) stated that fecundity of bluefin trevally, *Caranx melampygus* Cuvier, 1833, from Hawaiian waters ranged from 49 000 (fish of 760 g) to 4 270 000 (fish of 6490 g). Griffiths et al. (2005) expressed fecundity of 1 327 827 for Talang queenfish, *Scomberoides commersonnianus*, in Australian waters. Fecundity of *S. lysan* in the presently reported study varies from 24 655 to 82 562 542. The exponential value is usually reported as "3" when fecundity is related to length and "1" when fecundity is related to weight. In this study an exponential value of 6.75 ($R^2 = 0.801$) obtained for fecundity versus total length is beyond the already reported value (2.3 to 5.3) for a great variety of fishes (Bagenal and Braum 1978).

Scomberoides lysan male attained maturity in a larger length class 55–60 cm and females attained maturity within the length class 60–65 cm. Size at maturity reported for *S. lysan* in this study showed that the capture of *S. lysan* shorter than 65 cm total length should be discouraged. Griffiths et al. (2005) stated that *S. commersonnianus* from Northern Australia mature at greater lengths (60–70 cm fork length). Availability of immature stages throughout the year and size variation among maturity stages also explained that this species spawns more than once a year.

Sex ratios vary among different fish species, and this variability may be due to true differences in the composition of local populations or it may be an artefact of sampling strategies rooted in seasons covered or gear biases. In the presently reported study the sex ratio differs significantly from 1 : 1 during most months. However, males of *S. lysan* were more numerous than females during the spawning period and such preponderance could be due to

migration of females to relatively deeper waters for spawning, or behavioural differences between the two sexes (Blaxter and Hunter 1982).

Spent females collected were very rare in this study, constituting only 1% of the total sample analyzed macroscopically. We hypothesize that the coastal, offshore and deep-sea fishery off Sri Lanka may not be currently exploiting spent individuals because females retreat to deeper waters prior to spawning, thus escaping capture by the fishery.

An exploited stock is renewed by means of recruitment through reproduction. If indiscriminate harvesting of a population occurs the number of fish that reach maturity could be reduced to such an extent that the reproductive capacity of the population is diminished. One way of mitigating this risk is to ensure that minimal fishing pressure applied to the populations before the fish reach maturity. Since *S. lysan* attain maturity at 60.7 cm these fish should not be caught up to that size. As the peak spawning season is September and June the breeding females of *S. lysan* should be protected during this period in order to maintain a sustainable fishery. Seasonal closure can be designed to protect key life stages of this species. The above implications in terms of the potential effect on the reproductive capacity of the stock would support management decisions and ensure long-term viability of *S. lysan* stocks along the Sri Lankan coastline. Disseminating these findings to fishermen through fisheries co-operative societies and the Ministry of Fisheries is an indispensable part of such a management decision.

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Table 3

Selected gonadosomatic relations of females of *Scomberoides lysan* from Sri Lankan marine waters

Relation	Logarithmic equation	<i>n</i>	R^2
OW–FL	$\log OW = 4.5 \times \log FL + 6.73$	760	0.7425
FE–OW	$\log FE = 2.4 \times \log OW + 2.46$	111	0.5581
FE–TL	$\log FE = 6.75 \times \log TL + 6.2$	22	0.8011
LW–FL	$\log LW = 3.183 \times \log FL + 4.49$	761	0.7465

OW = ovary weight; FL = fork length; FE = fecundity; TL = total length; LW = liver weight; *n* = number of fish examined; R^2 = regression correlation.

Table 4

Selected gonadosomatic relations of males of *Scomberoides lysan* from Sri Lankan marine waters

Relation	Logarithmic equation	<i>n</i>	R^2
TEW–FL	$\log TEW = 0.246 \times \log FL + 0.246$	668	0.9973
TEW–TW	$\log TEW = 1.423 \times \log TW + 3.78$	668	0.7328
LW–FL	$\log LW = 2.924 \times \log FL + 4.023$	668	0.6465

TEW = testes weight; FL –fork length; TW = total weight; LW = liver weight; *n* = number of fish examined; R^2 = regression correlation coefficient.

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