REPRODUCTIVE CHARACTERISTICS OF *Scomberoides lysan* (FORSSKAL, 1775) (PISCES: CARANGIDAE) FROM THE WATERS AROUND JAFFNA PENINSULA, SRI LANKA

By

THULASITHA WILLIAM SHANTHAKUMAR, B.Sc (Hons)

M.Phil

DEPARTMENT OF FISHERIES SCIENCE

FACULTY OF SCIENCE

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THESIS SUBMITTED TO THE UNIVERSITY OF JAFFNA THROUGH THE FACULTY OF GRADUATE STUDIES FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY IN FISHERIES SCIENCE

DEPARTMENT OF FISHERIES SCIENCE

FACULTY OF SCIENCE

UNIVERSITY OF JAFFNA

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SRI LANKA

2012

CANDIDATE'S DECLARATION

I hereby declare that the entire work embodied in this thesis has been carried out by me. The extent of this information derived from the existing literature has been documented and fully acknowledged at the appropriate places, the work is original and has not been submitted in part or full for any Diploma or Degree in this or any other University.

05/10/2012

Date

(Thulasitha William Shanthakumar)

Signature of the Candidate

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Certificate

This is to certify that the thesis entitled "Reproductive characteristics of *Scomberoides lysan* (Pisces: Carangidae) from the waters around Jaffna Peninsula, Sri Lanka" submitted to the University of Jaffna in the fulfilment of the requirements for the award of the Degree of Master of Philosophy in Fisheries is a record of original research work done by the candidate Mrs. Thulasitha William Shanthakumar under my supervision.

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Date

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Research Supervisor
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Faculty of Science,
University of Jaffna,
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- ✓ **Thulasitha, W.S.** and Sivashanthini, K. **2013.** Microscopic staging system used in the identification of Gonad developmental stages of *Scomberoides lysan. Journal of Fisheries and Aquatic Science.* 8(2): 355- 366.

- ✓ Sutharshiny, S., Sivashanthini, K. and **Thulasitha, W.S. 2013.**Lipid changes in relation to maturation and spawning of double spotted queen fish *Scomberoides lysan* (Forsskal, 1775). *Asian Journal of animal and veterinary Advances*, 8 (4):555-570.

- ✓ **Thulasitha,W.S.** and Sivashanthini, K., **2012**. Growth pattern and length weight relationship of *Scomberoides lysan* (Pisces: Carangidae) from the Northern waters of Sri Lanka. *Journal of Fisheries and Aquatic Science*, 7(1), 57-64.

Abstract

- ✓ **Thulasitha, W.S.** and Sivashanthini, K. **2013**. Estimation of growth parameters of tropical *Scomberoides lysan* (Carangidae). Proceedings of Ruhuna University 9th Science Symposium. pp. 21.

- ✓ **Thulasitha, W.S.** and Sivashanthini, K. **2012**. Variation in condition factor in relation to spawning season of double spotted queen fish *Scomberoides lysan* from the Sri Lankan waters. Proceedings of International workshop on Marine Fish 2012 (ICRD). pp11. ISBN 978-955-4543-02-7.

- ✓ **Thulasitha, W.S.** and Sivashanthini, K. **2012.** Occurrence of *Scomberoides lysan* (Forsskal, 1775) (Pisces: Carangidae) in relation to ovarian development in the waters around Jaffna Peninsula, Sri Lanka. Proceedings of Jaffna University International Research Conference (JUICE), pp 204. ISSN: 2279-1922.

- ✓ **Thulasitha, W. S.** and Sivashanthini, K. **2011**. Preliminary studies on Length – weight relationship of *Scomberoides lysan* (Frosskal, 1775) (Pisces: Carangidae) from the Point Pedro coastal waters, Sri Lanka. Proceedings of Jaffna Science Association, 18(01): 8. ISSN 1800-1289.

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(W.S. Thulasitha)

ABSTRACT

The present study was carried out to understand the reproductive characteristic features of double spotted queen fish, *Scomberoides lysan* during January 2010 to December 2011 from the waters around Jaffna Peninsula, Sri Lanka. Monthly random sampling was performed during the period and a total of 1534 *Scomberoides lysan* were collected from Paasaiyoor, Kurunagar, Ponnalai, Karainagar, Delft and Point Pedro landing centers. Macroscopic and microscopic analysis of ovaries confirmed that this species shows intense spawning during June and September. Hydrated and post ovulatory follicle stage oocytes and spawning stage testes were only available during June and September and gonadosomatic index further confirmed that an intense spawning season was in September followed by June. Fecundity varied from 24 655 to 82 562 542. The computer based linear regression statistical analysis for fecundity (FE) versus ovary weight (OW) and total length (TL) revealed equations of $FE = OW^{2.4} \times 288.40$ and $FE = TL^{6.75} \times 1584893$. Overall sex ratio did not vary significantly from an expected 1:1 ratio, with slightly less number of males than females (1.19:1, $X^2=0.865$, $P>0.05$). Probit analysis of proportion mature versus total length for male and female indicates that *S. lysan* male reached maturity at 55.4 cm total length while female reached maturity at 60.7 cm total length and the reverse von Bertalanffy equation expressed that the age at 50 % maturity for male and female are 2.27 years and 2.71 years respectively. The optimized values for K and L_∞ obtained by ELEFAN I for male and female was 0.41year^{-1}, 87.96 cm and 0.40 year^{-1}, 88.85 cm respectively. To protect the species in a sustainable level, *S. lysan* shall be protected during the peak spawning season September and June. The results obtained from the present study can be used in the management of *S. lysan* from the Sri Lankan waters to ensure the sustainable utilization and can be used in mariculture of this species.

1. Introduction

1.1 General introduction

Fish are one of the major groups of vertebrates, found in various types of aquatic habitats. Fish and fishery products provide a valuable source of animal protein and essential micronutrients to the human life. It contributes about 154 million tons to the world in year 2011 (Anonymous, 2012a). In Sri Lanka, it contributes about 384 670 metric tons in year 2010 and it provides about 2.14 % to the national export earnings (Anonymous, 2012b).

Major fish species of Sri Lanka include Seer, Paraw, Balaya, Kelawalla, Shark, Skate, Prawns, Lobsters, crabs and Sea cucumbers (Anonymous. 2012b). Among them carangids contributing to 5 % of total productions and one of the major fish groups that have high consumer demand in the local markets as well as in the export fisheries. Fig. 1 shows the major commercial groups of Sri Lankan fishes and their production data for the year 2010. Percapita consumption of marine dried fish is about 3.1 kg/ year in year 2009/ 2010 (Anonymous, 2012b).

The total fish production of Jaffna district in year 2010 was 20 890 metric tons and within that nearly 10 % was carangids (Anonymous, 2012b). Jaffna contributes about 6 % of the total fish production in Sri Lanka in year 2010 (Anonymous, 2012b)

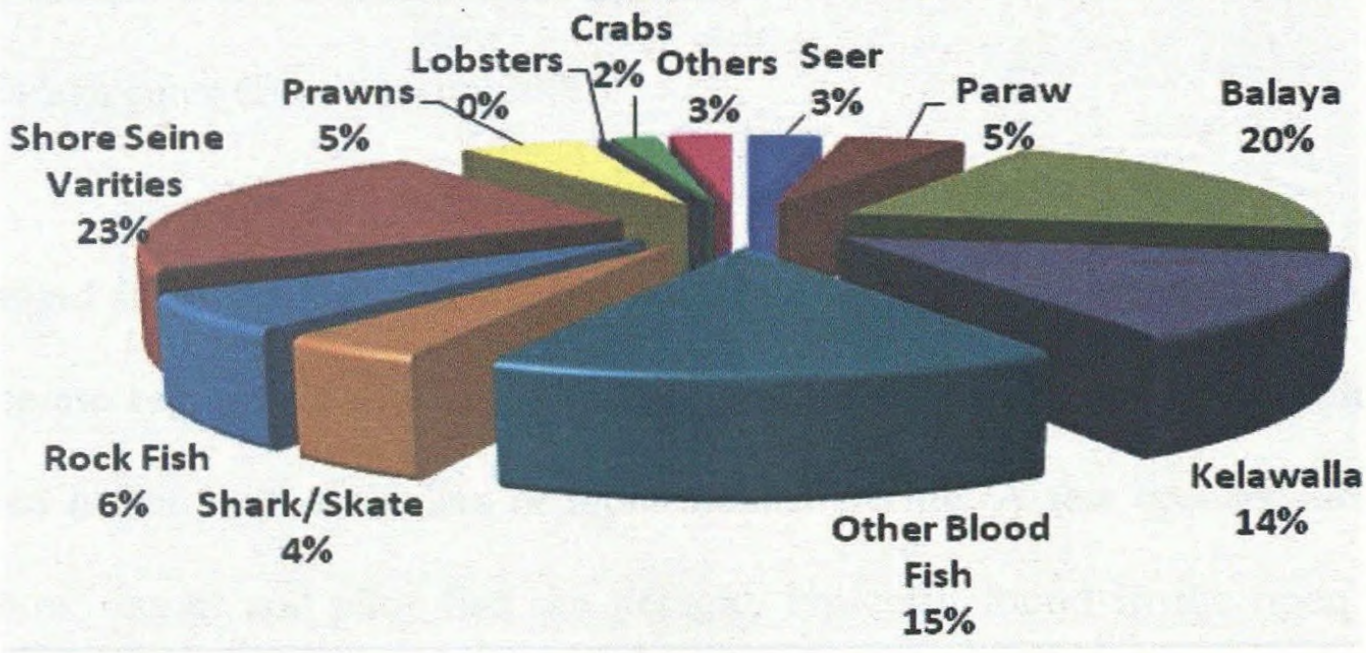


Fig. 1. Marine production in Sri Lanka by major commercial fish groups- 2010 (Source: Ministry of Fisheries and Aquatic resources development, 2012)

1.2 Carangid fishery.

Members of the family Carangidae represents about 5 % of the world's annual marine fin fish landings (Ditty *et al.*, 2004). The family Carangidae includes diverse marine fishes that are ecologically and economically important species such as jacks, scads, travelly, pompano, amberjacks and queen fishes. The group is heterogeneous, including genera of quite different shapes and appearances, from elongated and fusi form to high and laterally compressed body (Ginsburg, 1952).

The carangids are constituted by approximately 32 genera and 140 species (Katsuragawa and Matsuura, 1992). Thirty six species of carangids are having

high commercial value and these are most delicious food fishes available along the Indian coast (Persis *et al.*, 2009).

Carangid fishes inhabit marine and estuarine waters in tropical, subtropical and temperate regions of the world ocean (Bannikov, 1987). Most are either deep bodied neritic bottom feeders or more slender neritic. A few species such as the rainbow runner and pilot fish are pelagic, typically found in the open oceans. Carangids are found in all tropical and subtropical marine waters of the world, and some occur in temperate regions (Nair *et al.*, 2010). They are active swimmers and live in schools or small groups (Berry & Smith-Vaniz, 1978). The group is heterogeneous, including genera of quite different shapes and appearances, from elongated and fusiform to high and laterally compressed body (Ginsburg, 1952).

Carangids are suitable for caning, salting, drying, smoking and as fresh food fish. Although more acceptable than herrings for human food because of their large size, fewer bones, and less oil (Reintjes, 1979).

In addition, some carangid species show aquaculture potential due to their high consumer demand and ecological acceptance. Mariculture of Carangids is being practiced in several countries. Mariculture of Florida pompano (*Trachionotus carolinus*) has increased after the publication of a preliminary report on its biology, fisheries and farming by Berry and Iversen (1966). Several studies

reported that mariculture of carangids is possible and most work has been focused on *Trachionotus* species (*T. carolinus, T. goode, T. falcatus)* in United States and white travelly cultured in net cages in Japan (Ogawa, 1992). The greater amberjack *(Seriola dumerili)* is reported to have considerable aquaculture potential due to rapid growth rate and commercial value (Marino *et al.*, 1995).

Queen fish (*Chorinemus lysan*) is abundantly available in Bangladesh marine water but it has limited value in the fresh fish market due to less attractive in appearance and taste. This species might be provided an attractive source of raw materials for production of surimi (Kamal *et al.*, 2005).

1.3 Carangid fishery in Sri Lanka

It contributes about 4.5 % of the total marine catches (Anonymous, 2012b). They are popular food fishes range from small size to larger queen fishes and are utilized in several formats as fresh, salting and drying, smoking, or converted in to 'maldive fish' in Sri Lanka (De Bruin *et al.*, 1994).

James (1964) stated that good fishing grounds for the *Chorinemus lysan* are Kachchativu (79 0 31'E, 90 23' N) and Neduntivu (790 43'E, 90 34'N) off the Rameswaram coast (Palk Bay).

1.4 Queen fishery in Sri Lanka

Queen fishes are one of the economically important carangid food fishes popular for dry fish production and have high export value in Sri Lanka. These are also popular in recreational fisheries (Griffiths *et al*., 2005; Honebrink, 2000). Fig.2. shows dry fish production of *Scomberoides* sp in Viyapaari moolai, Point Pedro coast, Northern part of Sri Lanka. During 2009/ 2010, dried queen fishes were obtained forth place (about 6.25 %) in the average monthly household dried fish consumption in Sri Lanka. The retail price in Colombo suburb markets is about Rs. 788/= per Kg in year 2010 (Anonymous, 2012b). It is also imported to Sri Lanka due to the high consumer demand as in the form of dried fish; but the price of locally prepared dried fish (Rs. 590/=) is slightly higher than that of imported one (Rs. 567/=) (Anonymous, 2008; Anonymous, 2012b).

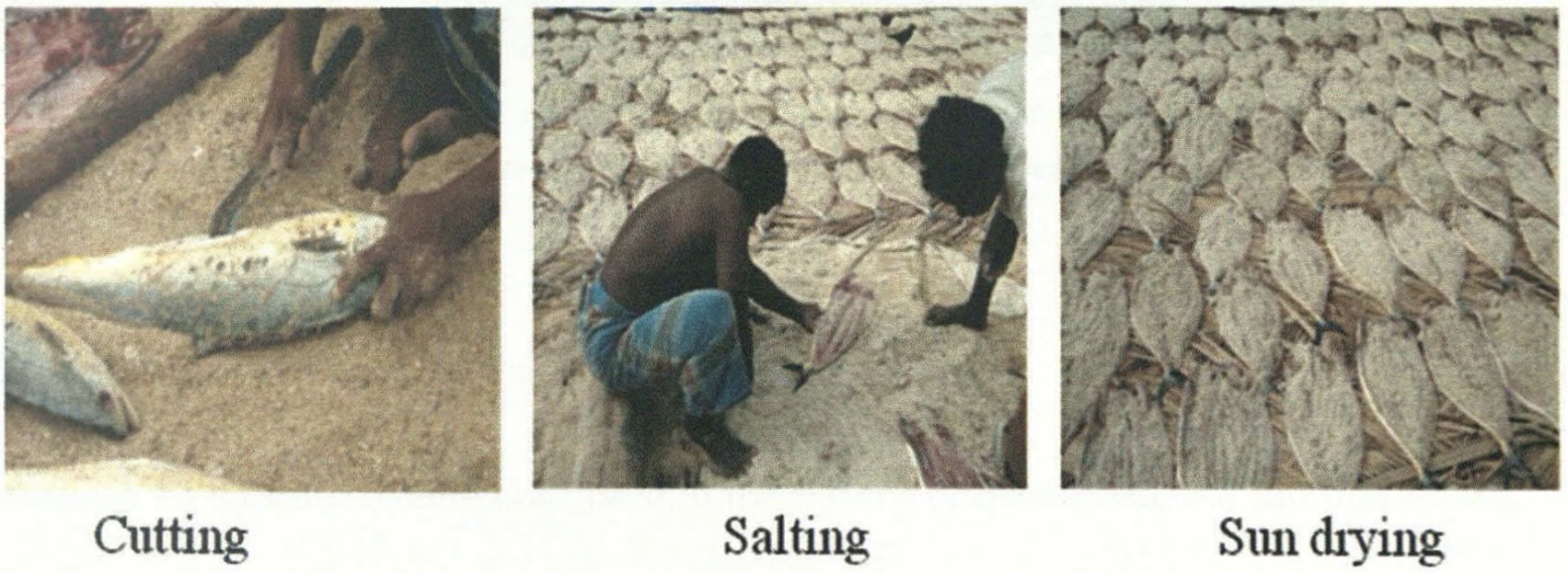


Fig. 2. Dry fish production of *Scomberoides* sp in Point Pedro, Northern part of Sri Lanka

1.5 Fishing gear used to catch Queen Fishes:

Various types of gill nets were used to catch queen fishes in the waters around Jaffna Peninsula. Drift set gill net (Fig. 3a) with 7" (17. 8 cm) mesh size and 21 ply is the specific gear used in Point Pedro, Delft, Karainagar and Kurunagar. But in Kurunagar there is no record for the catches of *S. lysan* by this net during the study period. Only the *S. commersonianus* were caught by this net. A trap net with 2 ½ i" (6.4 cm) mesh size and 1.2 cm mesh size, operated in shallow waters also used. In Tamil, it is referred as 'Sirahu valai' in the Jaffna lagoon area and in Karainagar it is called as 'Kalankatti valai' (Fig.3b).

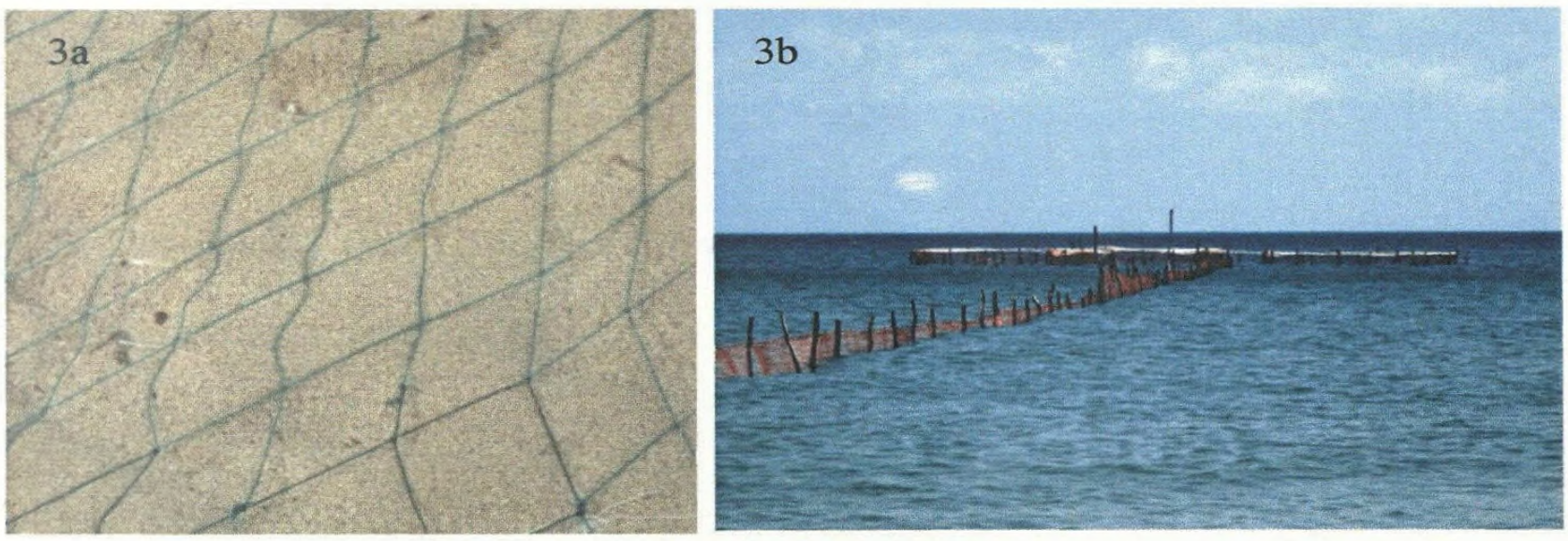


Fig. 3. Fishing gears used to catch queen fishes in the waters around Jaffna Peninsula. 3a- a portion of drift gillnet; 3b- Sirakuvalai (Shutharsan and Sivashanthini, 2011)

1.6 Fishing crafts used to catch queen fishes:

There is no specific fishing craft used in the fishery of queen fish, but in Point Pedro, Delft and Kurunagar fishermen use merchanised boats including few multi day boats equipped with 7' 21 ply drift gill nets. In the lagoon fishery, kattumaran and small vallam are being used to reach the trap nets and collect the fish by hand nets. Fig. 4.

shows some fishing crafts used in the carangid fishery.

Fig.4. Some fishing crafts operated in the waters around Jaffna peninsula.

1.7 Taxonomy and Classification

Kingdom: Animalia

Phylum: Chordata

Subphylum: Vertebrata

Class: Actinopterygii

Order: Perciformes

Suborder: Percoidei

Super family: Percoidea

Family: Carangidae

Genus: *Scomberoides*

Species: *S. lysan* (Forsskal, 1775)

1.8 Common Names

English : Double spotted queen fish, lesser queen fish, Leather jacket, Leather skin, Leather back,

Tamil : Katta paarai, Kola katta

Sinhala : Kattawa, Gona kattava, Katu bollu katava, Nil katava,

1.9 Synonyms (Froese and Pauly, 2012)

Synonym	Author
Chorinemus lysan	Forsskål, 1775
Chorinemus mauritianus	Cuvier, 1832
Chorinemus moadetta	Cuvier, 1832
Chorinemus orientalis	Temminck & Schlegel, 1844
Chorinemus sanctipetri	Cuvier, 1832
Chorinemus tolooparah	Rüppell, 1829
Lichia lysan	Forsskål, 1775
Lichia tolooparah	Rüppell, 1829
Scomber forsteri	Schneider & Forster, 1801
Scomber lysan	Forsskål, 1775
Scomberoides moadetta	Cuvier, 1832
Scomberoides orientalis	(Temminck & Schlegel, 1844
Scomberoides sanctipetri	Cuvier, 1832
Scomberoides tolooparah	Rüppell, 1829

1.10 Distribution and habitat

Queen fish are a group of tropical pelagic fish species that are widely distributed throughout the Indo-West Pacific region, often in schools (Honebrink, 2000) inhabiting inshore and offshore reefs and estuaries (Griffiths *et al.*, 2005; Durville *et al.*, 2003; Froese and Pauly, 2012). *Scomberoides lysan* is commonly known as double spotted queen fish or leather jackets or leather backs inhabiting in the pelagic neritic waters over sand stones with coral, mud and sand in between 2 to 100 m of Sri Lankan waters (De Bruin *et al.*, 1994). Distribution of *Scomberoides lysan* in the world was shown in Fig. 5.

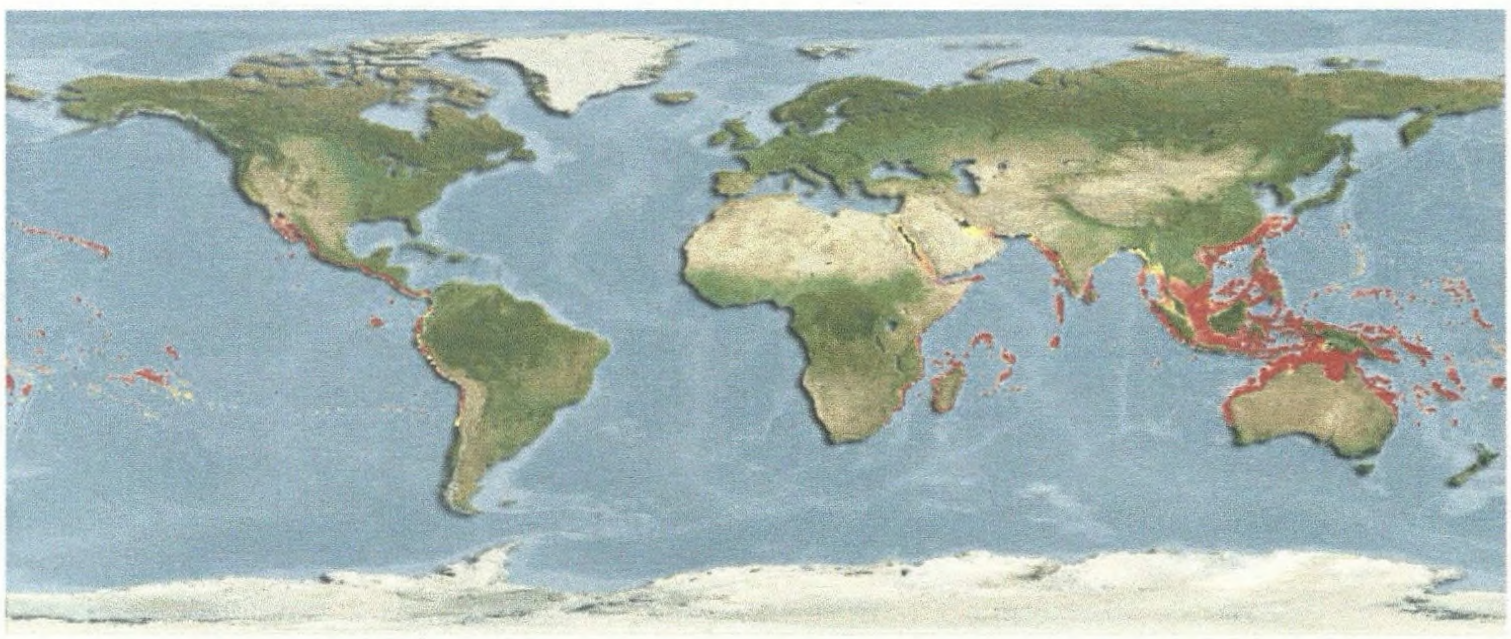


Fig. 5. Distribution of *Scomberoides lysan* throughout the world ocean.

Source: Froese and Pauly (2012). (www.fishbase.org.)

1.11 Scope of the present study

Queen fishes are economically important food fishes continuously exploited from the Sri Lankan waters without any management measures to ensure the sustainability. There is no information available about the biology, reproductive characteristics and the distribution of life stages of *S. lysan* in the Sri Lankan waters. This is the first attempt to,

- find out the length-weight relationship and condition factor
- collect information and provide detailed picture on reproduction of *Scomberoides lysan* including information about fecundity, spawning frequency, peak season of spawning, spawning pattern, ovulation pattern and size at maturity.
- provide suggestions to maintain stock at a sustainable level through Ministry of Fisheries and Fishermen Co-operative Societies.

2. Literature review

Carangids, particularly tropical fish species are poorly studied compared to Clupeiforms or Scomberoids (Clarke and Privitera, 1995). There are about 30 species of carangids reported from the Bay of Bengal. Sixty six species from 22 genera were recorded in Indian Ocean by Randal (1996). There are 20 genera of 49 species were recorded in Sri Lankan waters (De Bruin *et al.*, 1994); 36 species were recorded by Munro (1982). Eleven species of family Carangidae were reported and found in Sri Lankan lagoons and estuaries (De Silva and Silva, 1979). Genus *Scomberoides* comprises four species including *S. lysan, S. commersonianus, S. tala* and *S. tol* (Kimura *et al.*, 1998). All these four species of genus: *Scomberoides* were reported in western Indian Ocean (Fischer and Bianchi, 1984) and in Sri Lanka (De Bruin *et al.*, 1994 and Munro, 1955). Three species of genus: *Scomberoides* such as, *S. commersonnianus*, *S. lysan* and *S. tol* were recorded from the Jaffna lagoon (Nadaraja *et al.*, 2008).

However few studies were undertaken on queen fishes. *S. commersonianus* were reported to found abundantly in the inshore waters of tropical bay in the Gulf of Carpentaria, Australia (Blaber *et al.*, 2005). Age, growth and reproductive dynamics of *S. commersonianus* in the northern Australian waters had been studied by Griffiths *et al.*, (2005); and the population dynamics of this species in the same area has also been reported by Griffiths *et al.*, (2006).

Few studies were done on the gill parasites of *Scomberoides* sp. by various researchers (Ramasamy and Hanna, 1986; Ramasamy et al, 1985; Ramasamy et *al.*, 1995; Ramasamy *et al.*, 1987). Scale feeding behaviour of leather jacket was observed and reported by Major, 1973. The morphology of juvenile S. *lysan* and S. *tol* was studied by Kimura *et al.*, (1998).

The venom apparatus of *Scomberoides sanctipetri* was studied by Halstead and Danielson (1972); it consists of seven dorsal spines, two anal spines, their associated musculature, venom glands and integumentary sheaths.

Randall (1967) divides the Carangid family by diet into fish feeders and plankton feeders. Piscivorous carangids feed on anchovies, sardines and silver bellies; some other carangids feed on squids, cuttle fishes, crabs and prawns (Kasim, 2003). Holland *et al.*, (1996) stated that carangids are opportunistic carnivores, feeding by day and night on fish, crustaceans and cephalopods.

Length weight relationship and Condition factor

Various authors revealed that information on length-weight relationship (LWR) is required to determine the conversion of growth-in-length equations to growth-in-weight which can be used in stock assessment models; it can also be used in the estimation of biomass from length observations and estimation of the condition of the fish and this relationship is useful for comparisons between regions of life histories of certain species (De La Cruz Agüero *et al.*, 2011, Goncalves *et*

al.,1996, Froese and Pauly, 1998, Moutopoulos and Stergiou, 2002). The knowledge of LWR has an important role in the fisheries biology and population dynamics (Sivashanthini, 2008b). Measuring the weight of live fish in the field is very difficult and time consuming (Morato *et al.*, 2001). In addition, LWR are also important in fisheries management for comparative growth studies (Moutopoulos and Stergiou, 2002).

The knowledge of the relationship between length and weight of a fish species in a given geographic region is useful for estimating the condition of fish (Petrakis and Stergiou, 1995; Morato *et al.*, 2001). Condition factors are used to compare the condition, fatness or well-being of fish (Tesch, 1968; Froese, 2006) which explained that heavier fish of a given length are in better condition (Bagenal and Tesh, 1978) and to determine possible differences between separate unit stocks of the same species (King 2007). Froese (2006) stated that the relative condition factor proposed by Le Cren (1951) is suitable for comparing condition within a given sample. The condition factor is frequently used in the analysis of ontogenetic changes and for life history comparisons between regions (Simon and Mazlan, 2008). Sivashanthini and Abeyrami (2003) explained that studies on the variation in condition factor in relation to spawning season could be an important measure to identify the condition or well being of fish throughout its life span and it could be used in the management of fish species. Anyanwu *et al.*,(2007) stated that the condition factors of gravid females are usually higher but decreases after the eggs are shed.

Reproduction:

Reproductive strategy of a species is a characteristic feature and fixed for that species (Morgan, 2008). An understanding of the reproductive biology of a species is a central aspect of providing sound scientific advice for fisheries management (Morgan, 2008). Sivashanthini, (2008a) also stated that the knowledge on length at maturity and spawning season detects when and at which length the fish should be protected. Information on maturation and spawning of species will contribute to knowledge of their population dynamics and management of the stocks (Gabr *et al.*, 1998). Determination of the peak period of spawning , exploitation level, understanding the biological characteristics and life cycle of a species are important in the management and re-construction of a fish species (Saeed *et al.*, 2010). Therefore reproductive biological studies are important for the proper management and conservation of fish stock.

Spawning season and area, the age at maturity, the age at first reproduction and fecundity are the important parameters in reproductive biological studies (Salcedo *et al.*, 2011; Jakobsen *et al.*, 2009) and these parameters can be determined through the examination and classification of gonads into developmental stages (Mackie and Lewis, 2001). Karlou-Riga and Economidis, (1997) also states that observing the seasonal developmental changes in the gonads are the most suitable method for determining the reproductive cycle of fish.

A better understanding of spawning areas and seasonal spawning migrations requires basic information on the distribution of larvae, which is suggestive of the proximity of adult spawning concentrations (Houde, 1982).

Categorizing the ovaries into developmental stages and measuring the oocyte diameter distribution using histological staging system will provide detailed information on ovulation pattern, spawning season, and abundance of maturity stages. Oocyte growth and development are the important issues in the reproductive biological studies of fishes (Tyler and Sumpter, 1996). Ovarian development usually defines the spawning season and number of offspring produced during spawning (De Martini and Fountain, 1981). Stahl and Kruse (2008) stated that classification of ovaries into developmental stages is a prerequisite for setting annual catch quotas using a harvest rate strategy based on spawning biomass estimates.

Histological studies are important to invent new and effective methods for increasing efficiency of brood stock, increasing fish production and ultimately increase efficiency and higher fish are predicted. Mackie and Lewis (2001) explained that the most accurate and detailed means of staging of gonads is by microscopic examination of histological prepared sections of each specimen.

Descriptions of reproductive strategies and the assessment of fecundity are fundamental topics in the study of the biology and population dynamics of fish species (Hunter *et al.*, 1992). Within a stock, fecundity is known to vary annually,

undergo long term changes (Horwood *et al.*, 1986) and has been shown to be proportional to fish size and condition. Larger fish produce more eggs, both in absolute and in relative terms to body mass. For a given size, females in better condition exhibit higher fecundity (Kjesbu *et al.,* 1991). Fecundity is the number of ripened eggs found in the female prior to spawning (Bagenal and Braum, 1978); and it can be defined by several terms such as annual fecundity, total fecundity, potential annual fecundity, determinate fecundity, indeterminate fecundity, batch fecundity and relative fecundity (Hunter *et al.,* 1992).

Reproductive seasonality was determined by monthly inspection of macroscopic and microscopic developmental stages and by gonado somatic index (Maartens *et al.*, 2005). Honebrink (2000) stated that the spawning season for most species of carangids are fairly long, generally peaking during summer months. The reproductive dynamics of other species *S. commersonianus* was studied by Griffiths *et al.*, (2005) in the Northern Australian waters.

Age and growth

Age and growth parameters of fishes are important to identify the life span, age at maturity and spawning. Age determination in fish is essential in fisheries management decisions, and the procedures must be reliable and provide valid results (Casselman, 1987). Growth studies are an essential instrument in the management of fisheries resources because they contribute to estimates of production, stock size, recruitment and mortality of fish populations (Isaac, 1990).

For this reason, reliable estimates of the growth and mortality parameters of exploited fish populations are very important for their proper management (Pauly and Munro, 1984).

Age refers to the quantified period of time the fish lives whereas growth is the definite size change of fish between certain periods of time (De Vries and Frie, 1996). Direct methods of age and growth determination by counting the growth rings (Cailliet *et* al., 1986; Cailliet, 1990) are not suitable for the tropical fishes. Therefore, indirect method of age determination by conversion of length frequency data into age composition (Gayanilo and Pauly, 1997) is used.

Estimation of age and growth parameters in tropical fishes can be done by computer based software including, Length- based Fish stock assessment (LFSA) (Sparre, 1987), COMPLEAT ELEFAN (Gayanilo *et al.,* 1988), MULTIFAN (Fournier *et al.*, 1990), LFDA (Holden and Bravington, 1991) and FiSAT (Gayanilo and Pauly, 1997).

The biology of *S. lysan* is poorly known and there is no information available regarding their biology in Sri Lankan waters and no specific management regime is available for *S. lysan* species in Sri Lanka. Present study is the first attempt to understand the spawning of *S. lysan* as implications for management decision in the Sri Lankan waters which explains reproductive parameters such as sex ratio,

length at first maturity, gonado somatic index, Hepato somatic index, fecundity, spawning season and spawning pattern.

3. Materials and methods

3.1. Sampling

Monthly random samples of *S. lysan* were obtained between January 2010 and December 2011 from the northern Sri Lankan waters located in the Indian Ocean between 79° E to 80° E longitudes and 9° N to 10° N latitudes. Samples were collected from commercial catches from Kurunagar, Paasaiyoor, Ponnalai, Karainagar, Point Pedro and Delft (Fig. 6). Individuals were caught mainly by 7" (17.8 cm) 21 ply mesh size, drift nets ('Katta valai' in Tamil) used particularly for queen fish. Fish samples were also caught using beach seines and trap nets ('Kalankatti valai' and 'Sirahu valai' in Tamil) with mesh size of 2½" (6.4 cm) and 0.47 " (1.2 cm) fixed in shallow waters. All collected fish were brought to the laboratory in ice and analyzed.

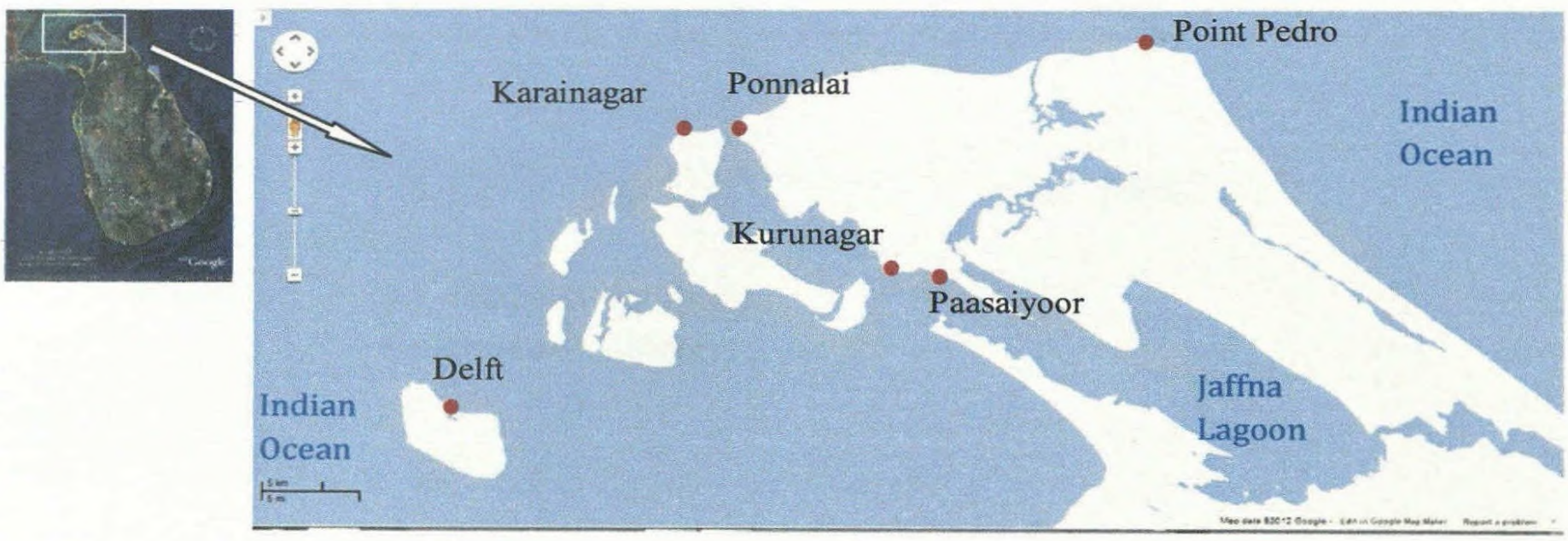


Fig 6. Sampling areas in the waters around Jaffna Peninsula.

3.2. Species identification.

Species identification was done using morphological characteristic features (De Bruin *et al.*, 1995; Munro, 1982 and Fischer and Bianchi, 1984) including shape and colour of the body, number and arrangements of blotches on the skin, type of scales, shape and number of fins, number of spines and soft rays present on each fin, number of gill rakers, position of mouth and eye.

3.3. Sex determination and sex ratio

It was difficult to identify the sex externally. 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 employing the formula,

$$\square^2 = \Sigma \left[(|o-e| - 0.5)^2 / e \right] \qquad \text{(Zar, 1999)}$$

Where o = observed number,
e = expected number.

3.4. Length – weight relationship

The relationship between the length and weight of a fish is usually expressed by the following equation:

$$W = a\,L^{b} \qquad \text{(Ricker, 1973)}$$

Where, W is the weight of the fish, L is the total length, "a" and "b" are two coefficients.

If a fish is growing isometrically (increasing in all dimensions at the same rate) and doubles in length, its weight will increase in relation to the increase in volume; that is by 8 (or 2^3) times (King 2007). In such cases, there is a cubic relationship between length (L) and weight (W) and 'b' is close to 3 in isometric growth, and 'a' is a constant determined empirically.

Weights and lengths of male, female and unsexed were log transformed and the resulting linear relationship fitted by the computer based linear regression analysis and the significance of the regression was assessed by General Linear Model Analysis of Covariance (GLMANCOVA) using MINITAB (Version 14) statistical software.

$$\text{Log } W = \log a + b \log L$$

The "b" values obtained for male, female and unsexed were tested by Student's t- test to see whether the 'b' values differ significantly from 3 or not (Zar 1999). Student's t-test was employed by dividing the difference between 'b' and '3' by standard error of 'b'.

Two sample t-tests were performed to compare the mean weight data of male and females to distinguish the significant difference between male and female.

3.5. Relative Condition factor

The monthly mean relative condition factor for males and females were estimated as follows:

$$Kn = W/\hat{W} \qquad \text{(Le Cren, 1951)}$$

Where, Kn = relative condition factor, W= observed weight and $\hat{W}$ = calculated weight (expected geometric mean for the observed length obtained from the length weight relationship parameters).

$$\hat{W} = a\, L^{b}$$

Where, a= proportional constant, b = exponent, L= total length of fish 'a' and 'b' value for male and female were obtained from the Length- weight relationship. Kn values of females and males were plotted against months. The mean relative condition factor for male and females were compared with their length by analysis of variance (ANOVA) using computer based Statistica software. The mean relative condition for each 10 cm class intervals was computed for males and females and plotted as box-whisker plots in order to find out the variation in condition factor with length.

3.6. Maturity stages of gonads.

Gonads were carefully removed from the body cavity and staged macroscopically according to Mackie and Lewis, 2001; Hunter and Macewicz, 1985 and West, 1990. Microscopic staging was done using standard histological sectioning (Clark, 1981; Ratcliffe, 1982). Sub samples of four specimens (2 male and 2 female) from each 10 cm total length size range were taken from each monthly sample and gonads of each specimen were taken for histological inspection. Small portions selected from each lobe

at different position were obtained and preserved in Formal saline and kept for 2-4 weeks.

Formal saline:

5 g of sodium chloride,

100 ml of Formalin 40 %

900 ml of Distilled water

Then tissue samples were washed with 25 % of alcohol and dehydrated by placing on graded alcohol series from 25 % to 100 %. After that they were placed in clearing agent Xylene (Xylene: Absolute ethanol = 1:3, 1: 1 and in pure xylene). Dehydrated tissues were embedded in paraffin, sectioned at 6 μm by microtome Reichert Jung (1165 Rotocut) and stained with liquid Haematoxylin and eosin and mounted with DPX. The prepared slides were examined and photographed through OPTIKA compound light microscope equipped with AIPTEK-AHD Z600 camera.

Histological classification of ovaries was based on the previous studies done by Mackie and Lewis (2001) on the narrow- barred Spanish mackerel *Scomberomorus commerson*, Griffths *et al.*, (2001) on talang queen fish *Scomberoides commersonianus*; Al- Absawy and Mohamed (2010) on *Merluccius merluccius*; Mohmoud (2009) on *Epinephelus areolatus* and *Lethrinus nebulosus*; Stalh and Kruse (2008) on the Walleye Pollock *Theragra chalcogramma* .Ovaries were staged on the basis of most advanced type of oocyte present regardless of their abundance (Wallace *et al.*, 1987; West, 1990; Baelde, 1996).

3.7. Monthly distribution of maturity stages

The percentage occurrence of identified maturity stages in relation to the respective months of both sexes, computed for both years were computed and represented graphically.

3.8. Length distribution of maturity stages

The percentage occurrence of identified maturity stages in relation to their length class of both sexes were computed and represented graphically.

3.9. Occurrence of maturity stages along the study area

The percentage occurrence of maturity stages of both sexes in respect to particular sampling sites and the percentage occurrence of length class were computed to identify distribution pattern of *S. lysan* in the northern Sri Lankan waters.

3.10. Size at maturity

The length at which 50 % of fish were sexually mature was estimated for reproductively active fish including stages III, IV, V and VI. The maturity data were grouped into 5 cm size groups and the percentage occurrence of the specimens in each size group was calculated. Size at first maturity was arrived by plotting the percentage occurrence of mature specimens against total length class interval. The form of regression equation used was (King 1995):

$$P=100/\ (1+exp^{[-r\ (L-Lm)]})$$

Where P is the percentage of mature individuals, r is the slope of the curve or rate of increase in maturity, Lm is length at 50 % maturity and l is the 1cm length class. Probit analysis was performed using computer based 'R' software to estimate L_{50}.

3.11. Gonado somatic index (GSI)

Gonado somatic index (GSI) was determined by the most commonly used method in the literature (Griffiths *et al.*, 2005; Brown-Peterson *et al*, 2000; Kaunda-Arara and Ntiba, 1997) for both males and females using the formula:

$$GSI = [(Gonad\ weight) / (Total\ weight - Gonad\ weight)] \times 100$$

The monthly average GSI values for both sexes were plotted against month and the fluctuating pattern was observed to identify the spawning season.

In order to find out spawning size by length, the mean GSI of each 5.0 cm length class intervals were plotted

3.12. Hepatosomatic index (HSI)

Monthly changes in the Hepatosomatic index (HSI) were also analyzed to determine the spawning time during the reproductive cycle. HSI were calculated as follows:

$$HSI = [(LW/TW)] \times 100$$

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

3.13. Fecundity

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 sign of major atresia. Initially, 1g portions from each ovary were dissected from the anterior, median and posterior regions and weighed accurately (± 0.001 g). Analysis of variance (ANOVA) was used to compare the number of oocytes per gram between sub samples 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).

$$\text{Fecundity} = \frac{\text{Number of eggs in sub sample}}{\text{Weight of sub sample}} \times \text{Weight of the paired ovaries}$$

Annual fecundity was estimated from yolked oocytes (stages IV and V). The annual fecundity was related to the total length and ovary weight of fishes by using the following relationship (Bagenal, 1967):

$$FE = a X^{b}$$

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

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

3.14. Ova diameter distribution

It was measured to the selected maturity stages. The diameter of ova of selected histologically prepared sections were measured to the nearest 0.01 μm using ocular micrometer equipped with compound light microscope and the percentage occurrence of each maturity stage oocytes were calculated in order to identify the ovulation pattern of *S. lysan.*

3.15. Linear relationship between testes weight versus fork length, liver weight versus fork length for males and ovary weights versus fork length, liver weight versus fork length for females

For males linear relationships between testes weight and fork length, testes weight and total weight and liver weight and fork length were obtained. For females, linear relationships between ovary weight and fork length, fecundity and ovary weight, fecundity and fork length were obtained.

3.16. Age and growth parameters

In order to estimate the age at maturity, growth parameters were estimated from the length frequency data using FiSAT II software.

The length frequency data were grouped sex wise into 5 cm class intervals, sequentially arranged for two years and used for estimation of growth. The following step wise procedures were adopted to estimate L_∞ and K.

- Preliminary estimation of asymptotic length (L_∞) and growth coefficient (K) using the initial estimates of L_∞ estimated by Powell Wetherall method.

- Estimation of an initial value for asymptotic length (L_∞) and Z/K (Z= total mortality and K= growth coefficient) using the Powell - Wetherall method (Powell, 1979; Wetherall, 1986).
- Estimation of probabilities of capture by detailed analysis of left ascending part of the catch curve using the preliminary estimation made on the asymptotic length (L_∞) growth coefficient (K) and computed time when the length is 0 (t_0).
- Correction of the original length frequencies using probabilities of capture (Pauly, 1986 a, b and c) for incomplete selection for length classes smaller than the first fully selected length through appropriate routine.
- Estimation of best optimize estimates of L_∞ and K through ELEFAN I routine (Gayanilo and Pauly, 1997) from the corrected length frequency data.

3.16.1. Estimation of L_∞ and K

(a). Powell- Wetherall method

Length frequency data were analysed by Powell - Wetherall method (Powell, 1979; Wetherall, 1986) by idetifying the smallest length fully recruited by the gear. This method is based on the following equation of Beverton and Holt (1956).

$$Z = K \times \{(L_\infty - L_{mean}) / (L_{mean} - L')\}$$

Where L_{mean} is the mean length of fish of length L' and longer, while L' is some length for which all fish of that length and longer are under full exploitation. As L' can take any value equal to and above the smallest length under full exploitation, above equation can give a series of estimates of Z, namely one for each choice of L'. This makes it possible to turn above equation into a regression analysis with L' as the independent

variable. A series of algebraic manipulation shows that above mentioned equation is equivalent to:

$$L_{mean} - L' = a + b*L'$$

where $Z/k = -(1+b)/ b$ and $L_\infty = -a/b$

Or, $b= -K/(Z/k)$ and $a = -b* L_\infty$

Thus, plotting $L_{mean} - L'$ against L' gives a linear regression from which 'a' and 'b' can be estimated and hence L_∞ and Z/K, of which above equation represents the simplest approach. The asymptotic length (L_∞) and the ratio of the coefficients of mortality and growth (Z/K) values were estimated by this method.

(b). ELEFAN I method

Length frequency data were analysed by Electronic Length Frequency Analysis, a computer based method (Pauly and David, 1981; Pauly, 1987) using the appropriate routines. This method attempts to combine the logic of the Peterson method and that of modal progression analysis with a minimum of subjective inputs. L_∞ and K values were obtained by this method.

3.16.2. Estimation of t_0

Value of t_0 was estimated by substituting the L_∞ and K in the following Pauly's empirical equation (Pauly, 1983).

$$\text{Log}(-t_0) \approx -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$$

Where -0.399, -0.2752 and -1.038 are constants derived from 153 triplets of t_0, L_∞ and K selected from the compilation of length growth parameters such as tom cover a wide diversity of taxa and size.

3.16.3. Age at maturity

Age at 50% maturity (t_{50}) was estimated from the inverse von Bertalanffy growth function, using the t_0, K, L_{50} and L_∞ values of *S. lysan*.

$$t_{50} = t_0 - (1/K) \ln [1 - (L_{50}/L_\infty)]$$

Where t_{50} is the age at 50% maturity, t_0 is the age at length 0, K is the growth coefficient (year -1) and L_∞ is the asymptotic length of the fish. The age estimates and von Bertalanffy growth parameters used in this study were based on the computations of ELEFAN I method using FiSAT II software.

3.16.4. Estimation of longevity

Longevity was obtained from the following equation (Pauly, 1983):

$$t_{max} = t_0 + 3/K$$

where t_{max} is the appropriate maximum age the fish of a given population would reach.

3.16.5. Growth performance index (Ø)

The growth performance index (Ø) for male and female was computed using the following equation (Pauly and Munro, 1984):

$$Ø = \log_{10} K + 2\log_{10} L_\infty$$

3.16.6. Reproductive load

Reproductive load or the ratio between mean size at first maturity and asymptotic length ($L50/L_\infty$) was computed for both fishes. L_∞ values obtained by ELEFAN I method were considered for computations.

4. Results

4.1. Sampling

A total of 1534 *Scomberoides lysan* (525 males and 590 females and 419 unsexed) were collected from Kurunagar, Paasaiyoor, Ponnalai, Karainagar, Point Pedro and Delft and brought to the laboratory inboxes of ice and analyzed. The total length of males ranged from 18 to 81.2 cm and females ranged from 19.5 cm to 80.6 cm. This is the new record of maximum length of both male and female in Sri Lankan waters. Weights of males ranged from 21.6 to 2650 g and females ranged from 25 to 3000g.

4.2. Species identification.

Plate 1 shows the morphology of *Scomberoides lysan.*

Plate 1. A double spotted queen fish *Scomberoides lysan*

Distinguishing characters of *Scomberoides lysan*:

Body oblong to elliptical, strongly compressed; upper jaw extends to posterior margin of eye in adults; snout pointed; lower jaw with 2 rows of teeth separated by shallow groove; gill rakers 3-8 upper, 15-20 lower and 12-27 on first gill arch. Two separate dorsal fins, the first with 6-7 spines followed by 17 to 19 soft rays; posterior soft dorsal

and anal fin rays consisting of semidetached fin lets; base of anal and second dorsal fins about equal in length; lateral line only slightly irregular; No scutes.

Colour: In life, body grey green dorsally, silvery grey to midline and silvery white ventrally; adults with a double series of 6 to 8 blotches above and below the lateral line, occasionally connected by narrow isthmus. Dorsal half of dorsal fin lobe abruptly and heavily pigmented; anal fin lobe white or pale yellow. Large individuals with greater than 60 cm total length, the ventral side of the body appears in yellow colour.

4.3. Sex determination and sex ratio

It was difficult to identify sexes externally. Therefore sexes were identified by observing the gonads. Individuals with total length less than 18.0 cm were not sexed because their gonads were not clearly seen. Plate 5(a), (b) and plate 6(a), (b) illustrate the location of ovary and testis of male and female respectively.

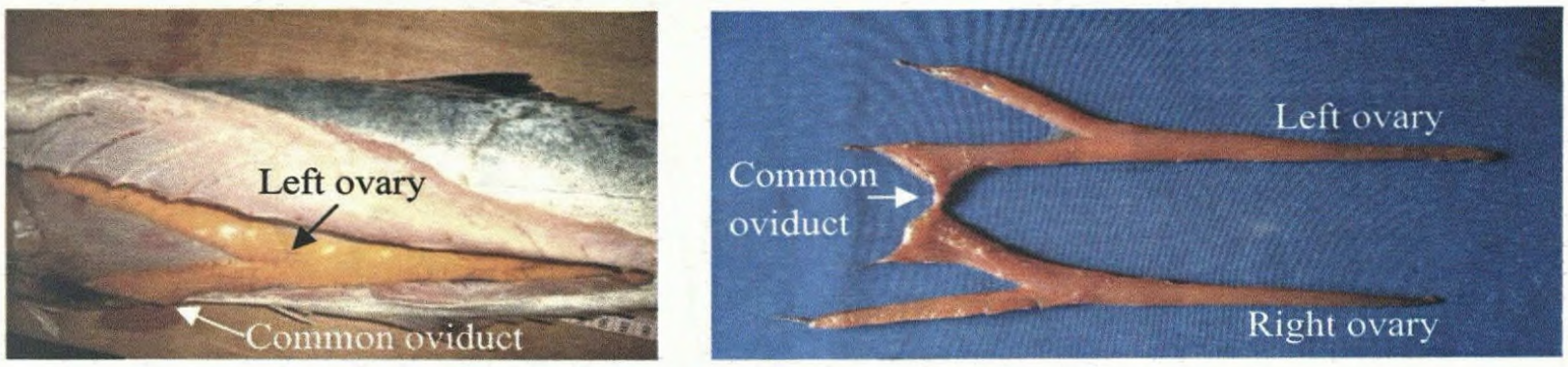


Plate 2. (a).Location of ovary in the female *Scomberoides lysan*; (b). Paired ovary of *S. lysan*

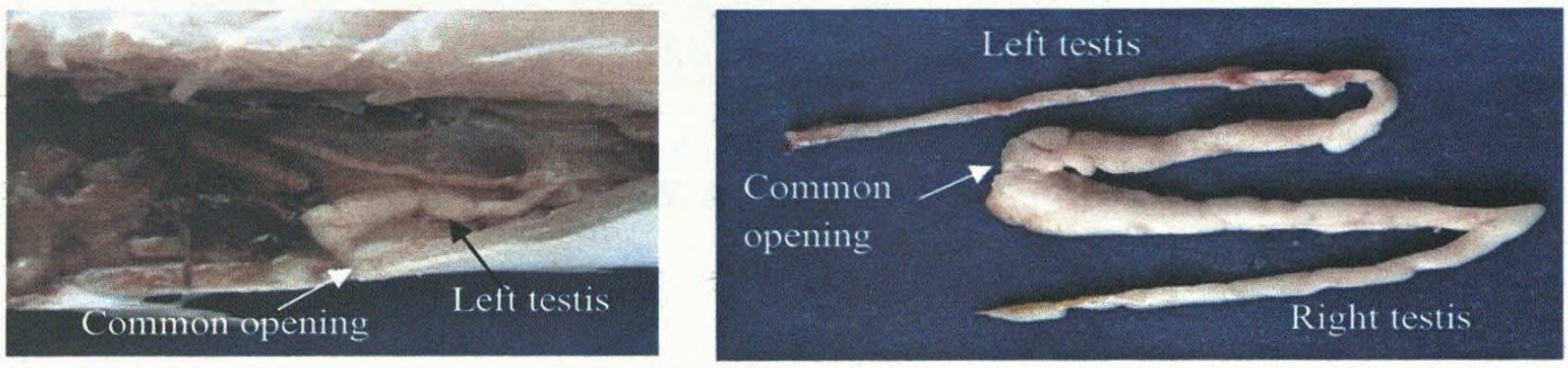


Plate3. (a). Location of testis in the male *Scomberoides lysan*; (b). Paired testes of *S. lysan*

Sex ratio

The number of fish examined every month and the male: female ratio of *S. lysan* from the pooled data is given in Fig. 7 and Table 1 respectively. Chi-square values calculated month wise showed that the sex ratio conformed to the expected 1:1 ($P>0.05$). Overall, sex ratio did not vary significantly from an expected 1:1 ratio, with slightly less number of 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 and 80 % whereas males ranged between 20 and 70 %.

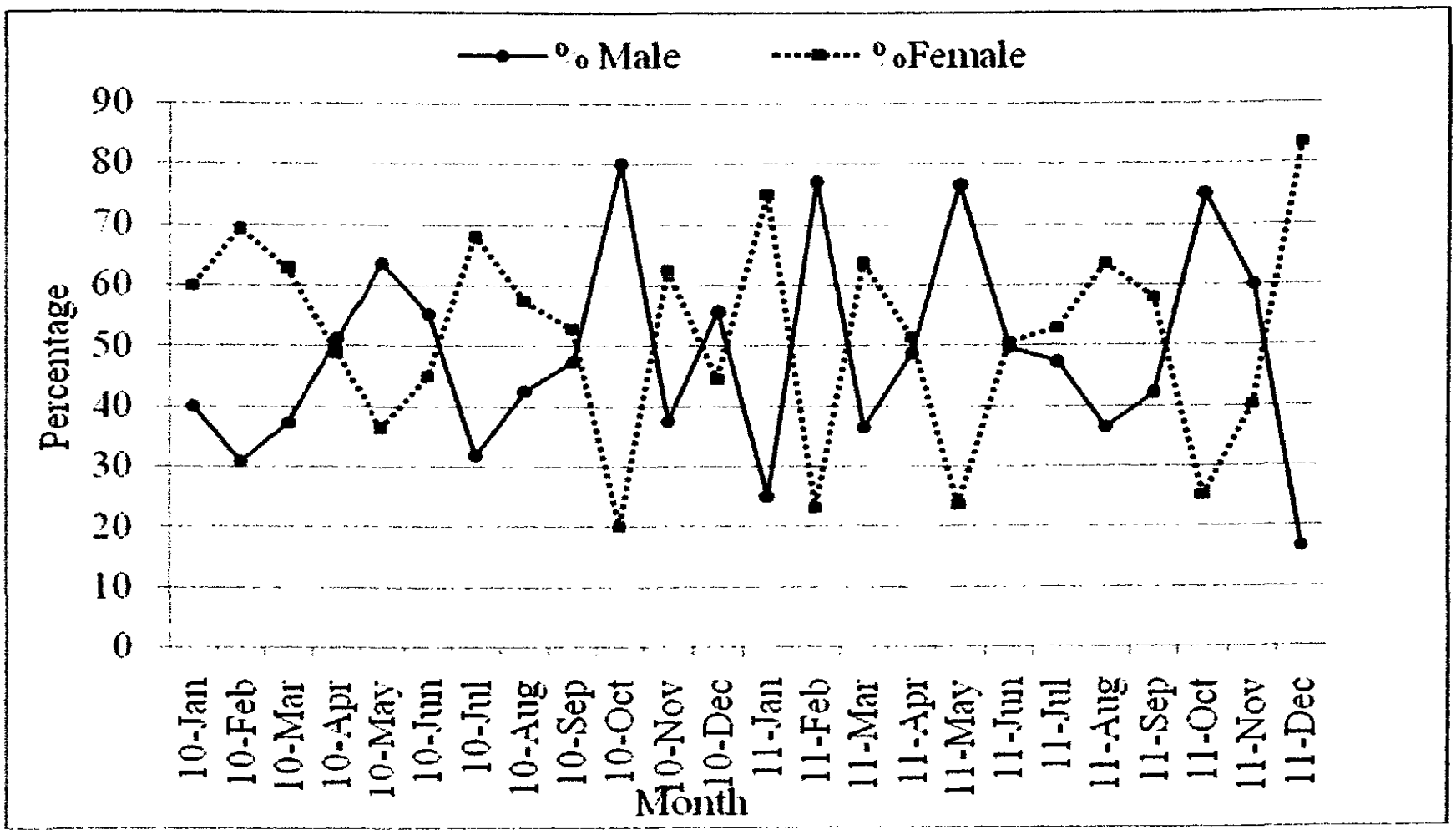


Fig. 7. Month wise sex ratio of *S. lysan* in the catches

Table 1. Month wise sex ratio of *S. lysan* (NS = Not Significant, S = Significant)

Month	No. of. male	No. of female	Total	% male	% female	Sex ratio (M:F)	Chi2 value	'P' value	NS or S
Jan-10	4	6	10	40.00	60.00	0.67	0.11	>0.05	NS
Feb-10	8	18	26	30.77	69.23	0.44	0.31	>0.05	NS
Mar-10	13	22	35	37.14	62.86	0.59	0.17	>0.05	NS
Apr-10	23	22	45	51.11	48.89	1.05	0.00	>0.05	NS
May-10	28	16	44	63.64	36.36	1.75	0.56	>0.05	NS
Jun-10	32	26	58	55.17	44.83	1.23	0.05	>0.05	NS
Jul-10	15	32	47	31.91	8.09	0.47	0.28	>0.05	NS
Aug-10	37	5	87	42.53	57.47	0.74	0.07	>0.05	NS
Sep-10	52	58	110	47.27	52.73	0.90	0.01	>0.05	NS
Oct-10	12	3	15	80.00	20.00	4.00	9.00	<0.05	S
Nov-10	12	20	32	37.50	62.50	0.60	0.16	>0.05	NS
Dec-10	10	8	18	55.56	44.44	1.25	0.06	>0.05	NS
Jan-11	4	12	16	25.00	75.00	0.33	0.44	>0.05	NS
Feb-11	10	3	13	76.92	23.08	3.33	5.44	<0.05	S
Mar-11	8	14	22	36.6	63.64	0.57	0.18	>0.05	NS
Apr-11	19	20	39	48.72	51.28	0.95	0.00	>0.05	NS
May-11	26	8	34	76.47	23.53	3.25	5.06	>0.05	NS
Jun-11	51	52	103	49.51	50.49	0.98	0.00	>0.05	NS
Jul-11	17	19	36	47.22	52.78	0.89	0.01	>0.05	NS
Aug-11	31	54	85	36.47	63.53	0.57	0.18	>0.05	NS
Sep-11	72	99	171	42.11	57.89	0.73	0.07	>0.05	NS
Oct-11	24	8	32	75.00	25.00	3.00	4.00	<0.05	S
Nov-11	15	10	25	60.00	40.00	1.50	0.25	>0.05	NS
Dec-11	2	10	12	16.67	83.33	0.20	0.64	>0.05	NS
Total	**525**	**590**	**1,115**	**47.09**	**52.91**	**1.12**	**0.02**	**>0.05**	**NS**

Figure 8 shows the lengthwise distribution of male and female *S. lysan*. Percentage of occurrence of female fall under length class categories 30- 35, 50- 55, 75- 80 and 80- 85 were dominated by females.

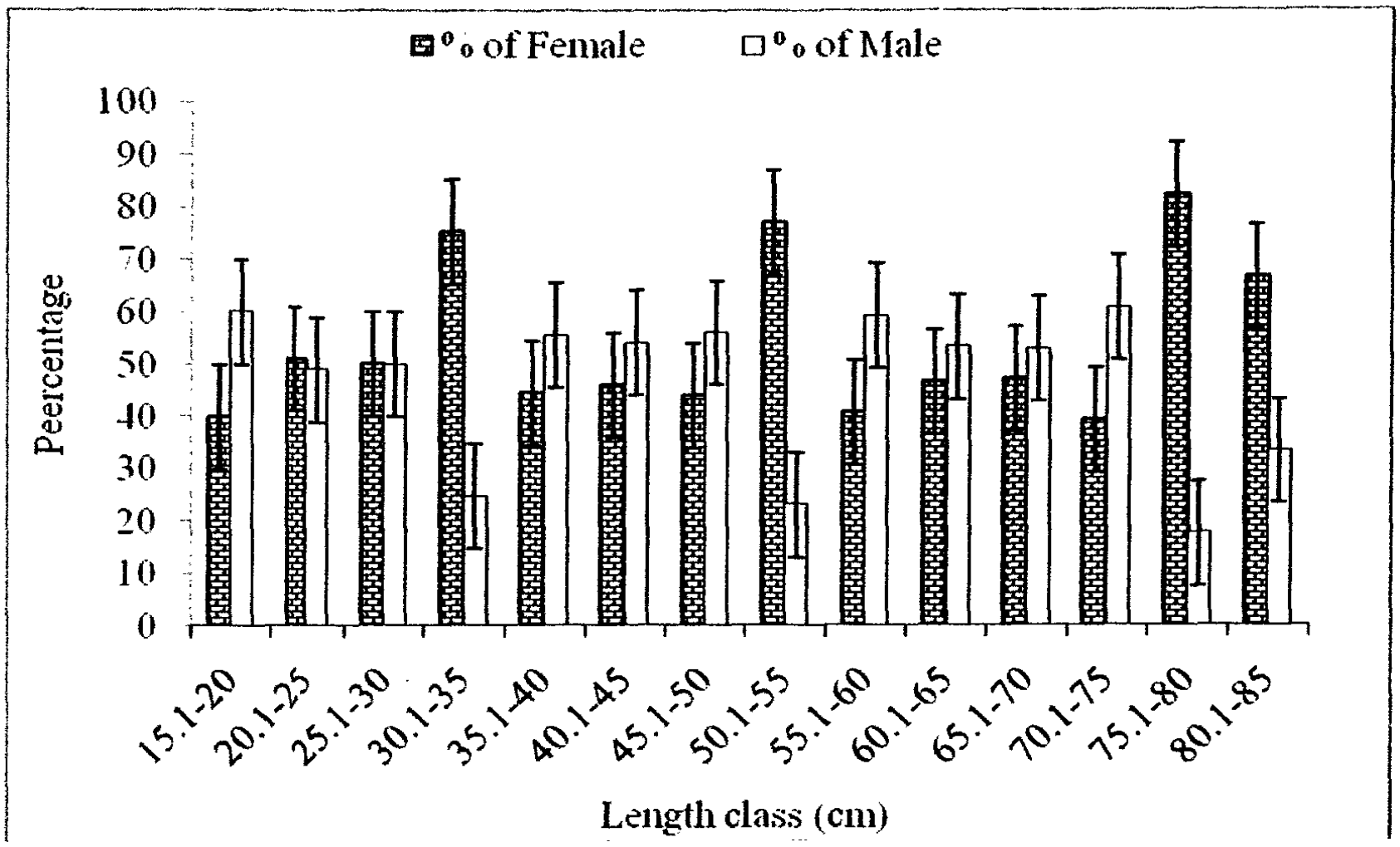


Fig. 8.Length wise distribution of male and female *S. lysan*

4.4. Length – weight relationship

A total number of 1534 *Scomberoides lysan* (525 males and 590 females and 419 unsexed) were analyzed. The total length of males ranged from 18 to 81.2 cm and females ranged from 19.5 cm to 80.6 cm. This is the new record of maximum length of both male and female in Sri Lankan waters. Weights of males ranged from 21.6 to 2650 g and females ranged from 25 to 3000 g. The estimates of the regression parameters for male, female and unsexed are given in Table 2. The relationship between length and weight of male, female and unsexed *S. lysan* are shown in Fig 9, 10 and 11.

Table 2. Length – weight relationship parameters of *S. lysan* (N = Number of observations, df= Degrees of freedom, 'b' = Regression exponent, 'a' = Constant, SS= Sum of squares, R^2 = Correlation coefficient)

Sex	N	df	Error estimate		R^2	'a'	'b'	Length range in cm
			df residual	SS residual				
Male	525	524	523	9.99	0.929	0.0112	2.82	18 to 81.6
Female	590	589	588	9.84	0.937	0.0087	2.89	19.5 to 80.6
Unsexed	419	418	417	4.19	0.864	0.0363	2.43	14.6 to 36.1

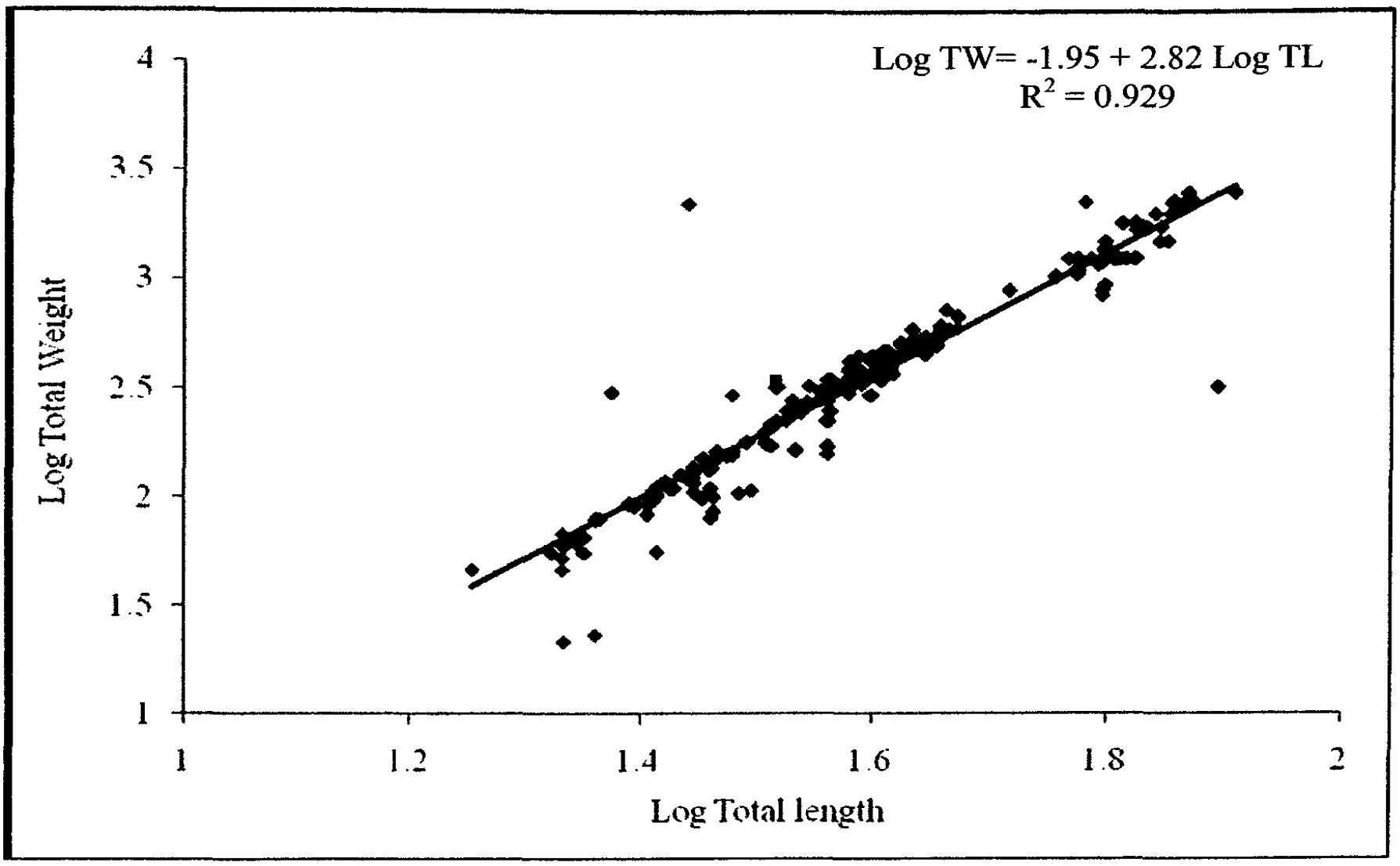


Fig.9. Relationship between log total length and log total weight of male *S. lysan*

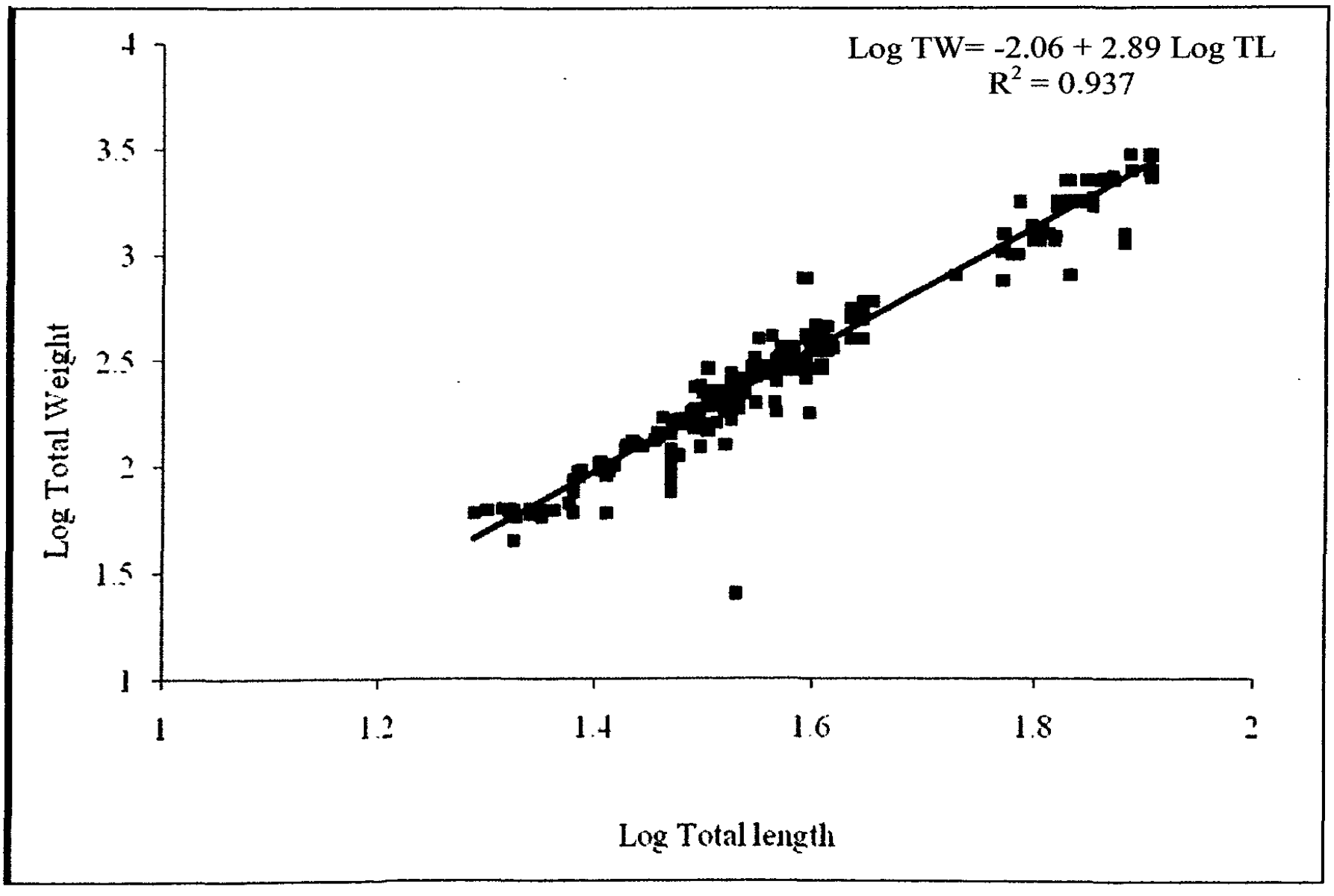


Fig.10. Relationship between log total length and log total weight of female *S. lysan*

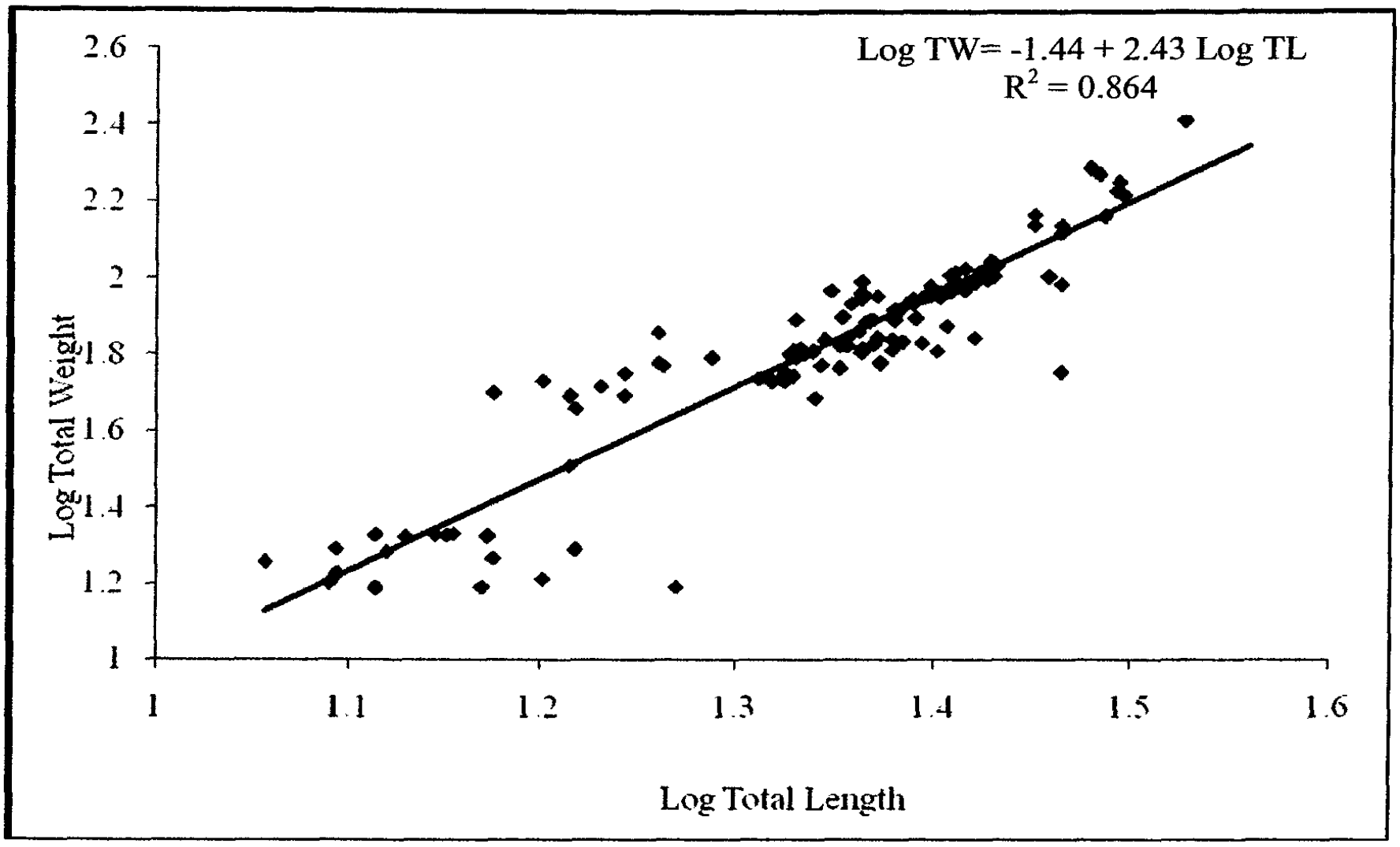


Fig.11. Relationship between log total length and log total weight of unsexed *S. lysan*

The results of student's *t* test to analyze the significance of variation in the estimates of 'b' for *S. lysan* from the expected value for the ideal fish (3.0) are as follows:

Male (2.82-3)/ 0.0302= 5.960 Significant (Computed $t_{\alpha\,(2),0.05,\,525>\,1.645}$)

Female (2.89-3.0)/ 0.0273 = 4.030 Significant(Computed $t_{\alpha\,(2)0.05,\,590\,>\,1.645}$)

Unsexed (2.43-3.0) / 0.0473 = 12.076 Significant (Computed $t_{\alpha\,(2)0.05,\,419\,>\,1.645}$)

Student t- test showed that the 'b' values obtained for male, female and unsexed were significantly different ($P<0.05$) from '3' indicating negative allometric growth for all categories.

Correlation coefficients (R^2) of 0.929 for males, 0.937 for females and 0.8640 for unsexed were also found to be highly significant ($p<0.001$) in all instances indicating good correlation between length and weight of *S. lysan.*

Comparison of regression co-efficient of male, female and unsexed using GLMANCOVA for the regression of log weight on log total length for *S. lysan* male, female and unsexed revealed that the 'b' values show significant differences ($P<0.05$) between each other.

Results of the two sample t-test showed that females were significantly ($P< 0.05$) heavier than males. The frequency distribution of total length for male, female and unsexed *S. lysan* individuals is shown in Fig.12.

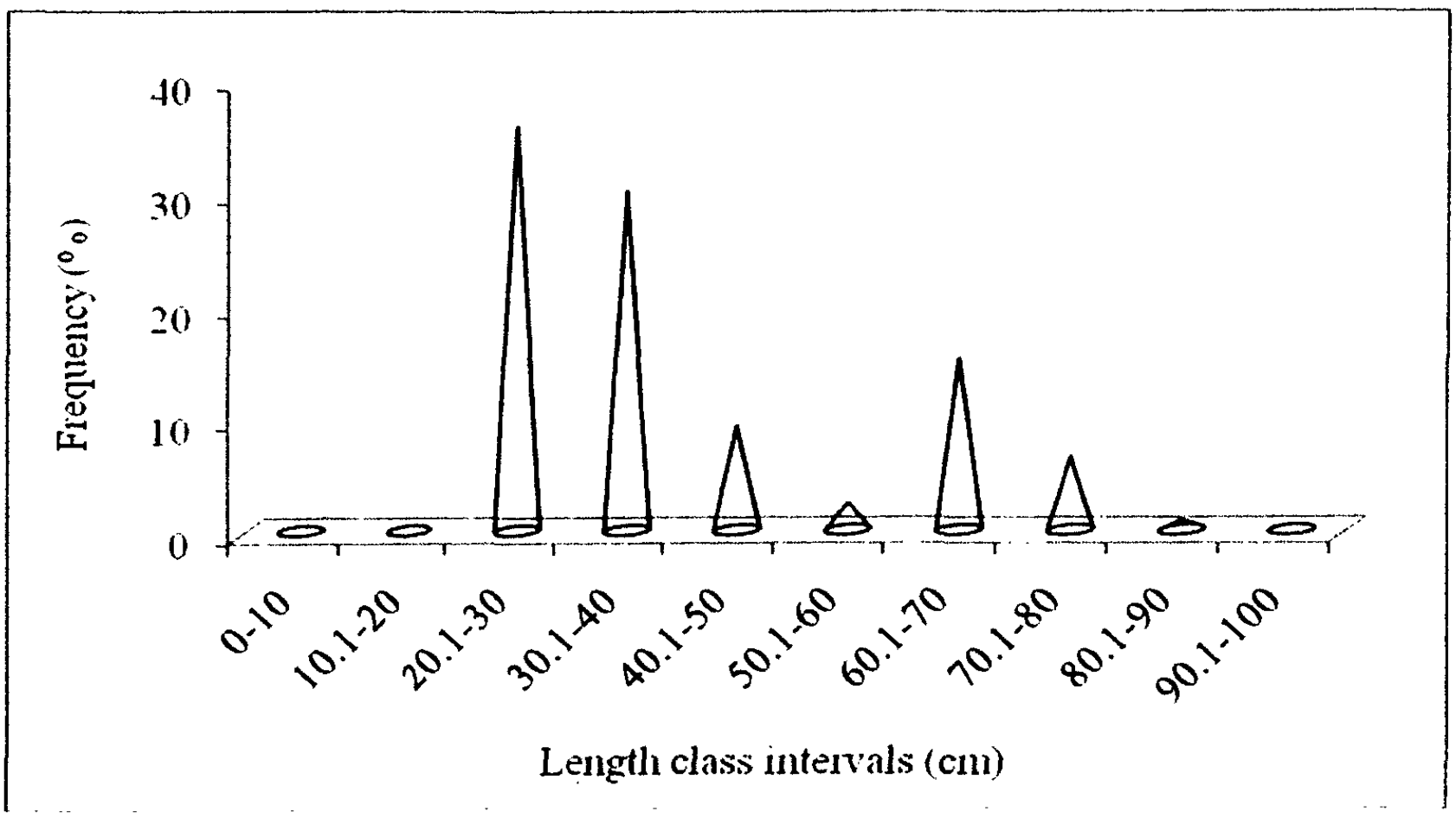


Fig.12 . Percentage frequency of total length distribution of male, female and unsexed *S. lysan*.

Highest percentage of frequency (35.75%) was observed for *S. lysan* individuals of 20.1 – 30 cm total length class interval.

4.5. Relative Condition factor (Kn)

The relative condition factor of males range from 0.101 to 1.846 and females range from 0.109 to 2.215. Monthly variation of mean relative condition factor (Kn) expressed low values in June and September in both years (Fig.13). Males and females followed more or less similar pattern of variation in Kn. Males had relatively higher mean Kn values than females during February to July and females had relatively higher mean Kn values than male during July to February in both years.

The relationship between mean relative condition with total length for males and females are represented in Fig. 14 and 15. It is explained that Kn values fluctuate with the increasing lengths. For females, there is no significant difference in Kn between length classes except 15 cm; for males, Kn value for 85 cm length class significantly differed from the Kn values of fish with less than 55 cm total length. Females show increasing pattern of Kn value from 25 to 45 cm total length and males show increasing pattern of Kn value from 25 to 35 cm total length. Both male and female show a drop in Kn above 75 cm length class. Table 3 shows the minimum, maximum and mean relative condition factor of male and female *S. lysan.*

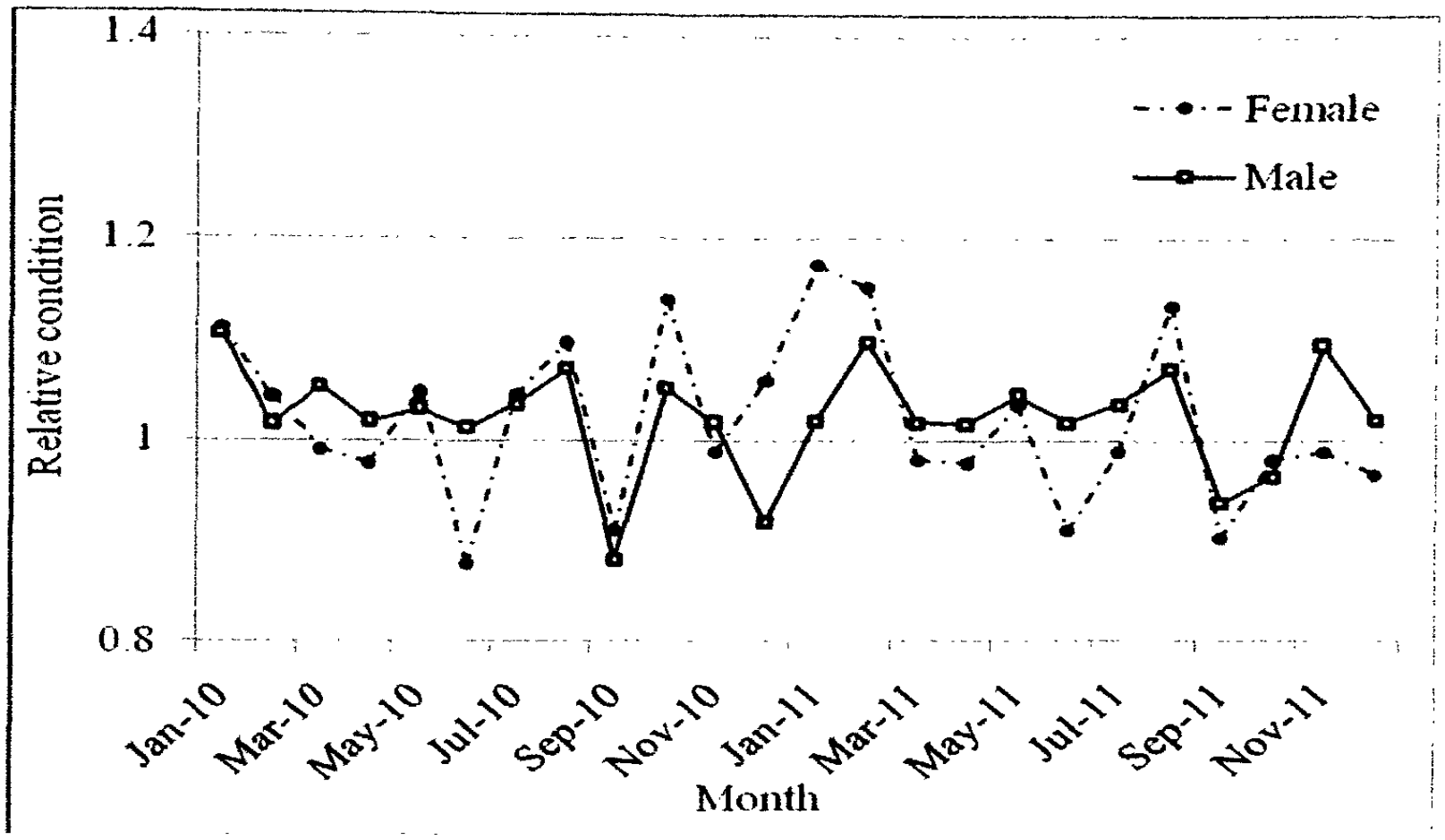


Fig.13. Monthly mean relative condition factor for male and female

S. lysan

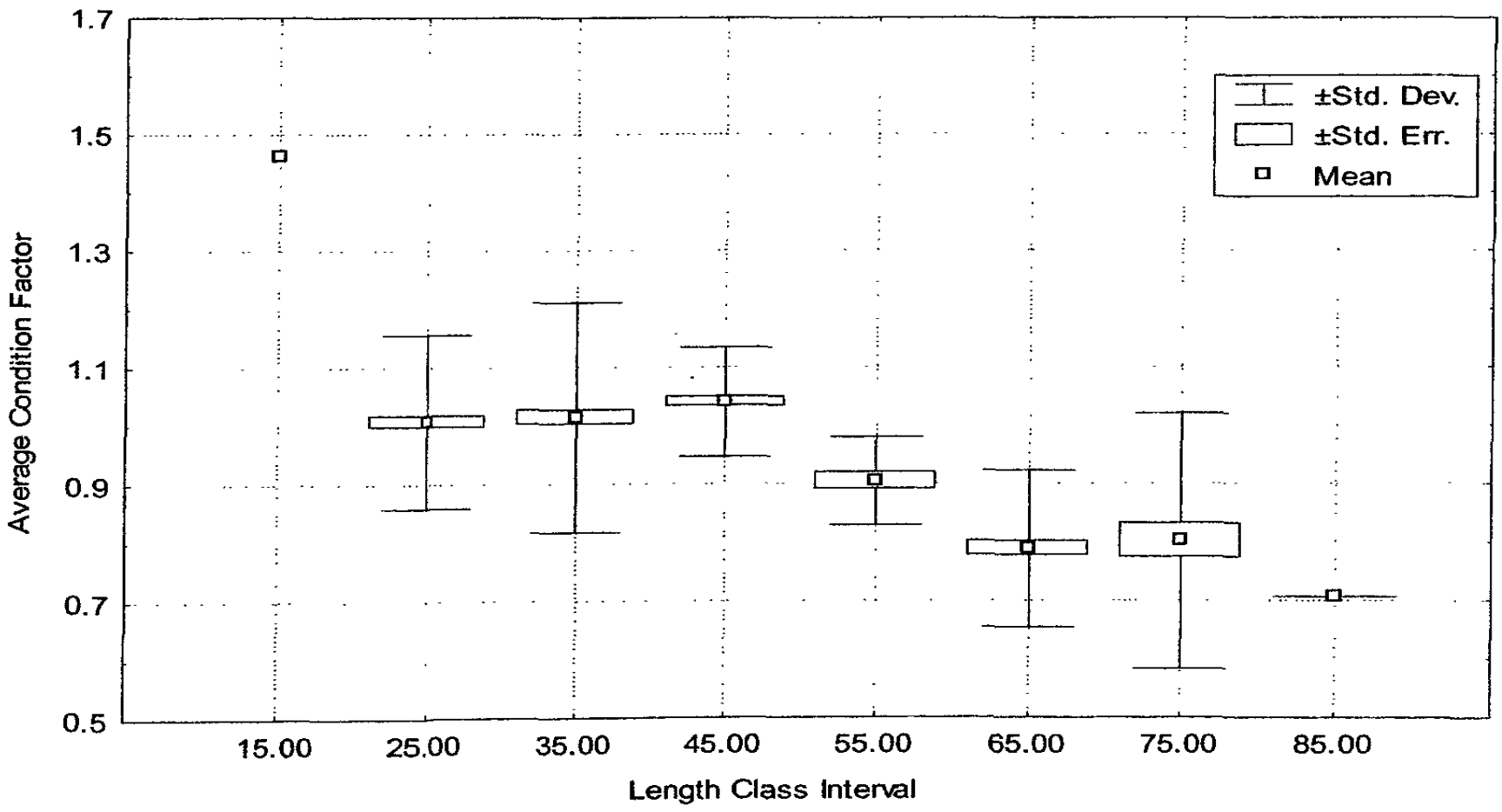


Fig.14. A mean relative condition factor at different total lengths of male *S. lysan*

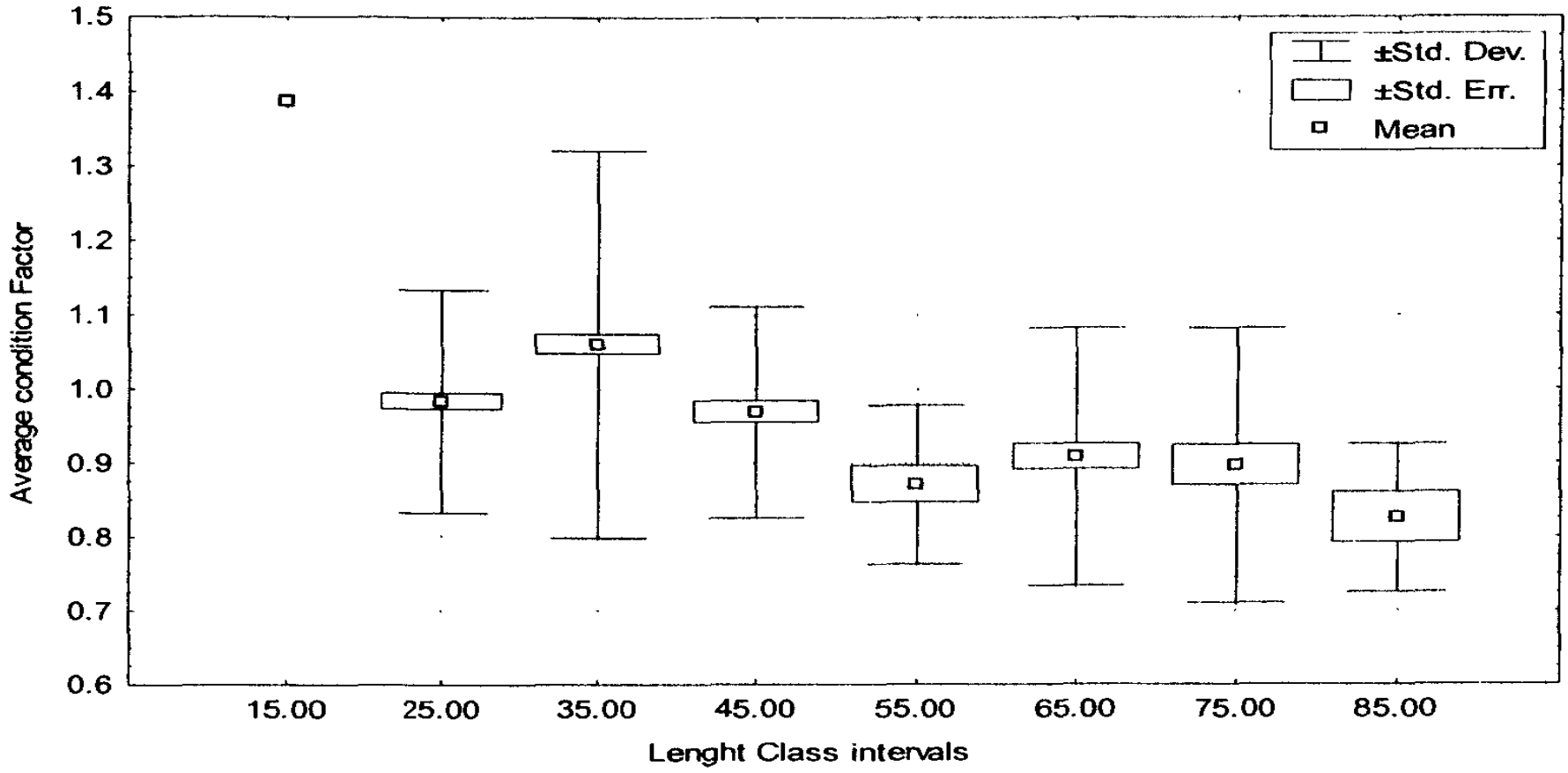


Fig.15. A mean relative condition factor at different total lengths of female *S. lysan*

Table 3. Minimum, maximum and mean Kn values of male and female *S. lysan*

Sex	Minimum	Maximum	Mean ± SD
Male	0.101	1.847	0.961±0.191
Female	0.109	2.215	0.998±0.220

4.6. Maturity stages of gonads.

Maturity stages of both male and female were categorized according to the macroscopic and microscopic features of gonads. Only five stages were identified by macroscopic features such as immature, maturing, mature, spawning and spent/rest; because it was difficult to differentiate the pre spawning and spawning stage ovaries macroscopically. However females were categorized in to seven stages such as immature (I), maturing (II), rest / developing (III), mature (IV), and pre spawning (V), spawning (VI) and spent (VII), macroscopically. The following developmental stages of oocytes were identified by microscopic examination: Chromatin nuclear stage, peri nucleolus stage, cortical alveolar stage, yolk globular stage, hydrated stage, post ovulatory follicle stage and the various atretic stages (degenerating) such as α, β, γ and δ.

For males only four stages were identified macroscopically and microscopically. The identified stages are immature (I), maturing (II), mature (III) and spawning. Spent males were not identified during the study period.

Description of ovarian developmental stages:

Stage I: Immature ovary

Macroscopic features: Small, thread like ovaries with pink and translucent colour; without visible oocytes. It is difficult to determine the sex morphologically in the earlier stage (Plate 4-A1).

Microscopic features: Two stages were identified such as chromatin nucleolar stage (Plate 4-A2 & Plate 5-A3) and perinucleolar stage (Plate5-A3 & A4). Chromatin nucleolar stage (CNS) is characterized by large spherical nucleus which occupies the greater portion of oocyte and strongly basophilic smooth cytoplasm appeared as dark purple in colour. CNS stage oocytes grow up to 50 µm. In the later stage they develop in to perinucleolus stage (PNS) which is characterized by the appearance of several nucleoli in the peripheral region of oval shaped nucleus. Cytoplasm is still strongly basophilic in nature and these stage oocytes reached 100 µm. Small spindle shaped follicular cells starts to proliferate and surrounds the oocytes. Weakly eosinophilic layer (precursor of zona radiata) also starts to appear between the follicular cells and oocytes. But in the later stage, large PNS oocyte may develop small vacuoles in the cytoplasm that is very close to the nucleus.

Stage II: Maturing ovary

Macroscopic features: Medium size ovaries usually appeared as translucent pink, flattened, flaccid and relatively inconspicuous. Oocytes were not visible through the ovarian wall. External surface was smooth and uniform in appearance (Plate 6-B1).

Microscopic features: The cortical alveoli stage (CAS) in which yolk deposition initiated. In this stage, cytoplasm becomes weakly basophilic nature and the nucleus is about half of the oocyte and still occupies a central position and it contains several nucleoli; Small clear staining yolk vesicles appeared throughout the mid and outer regions of the cytoplasm and forming a narrow row (cortical alveoli) near the periphery of the cytoplasm and clear staining oil droplets also appeared within the inner region of

the cytoplasm, increasing in number and size around the central nucleus. Follicular cells become enlarge and surrounds the oocytes. This stage of ovary also contains CNS and PNS oocytes. Large oocytes grow up to 150 µm (Plate 6- B2 and B3).

Stage III: Rest/ developing ovary

Macroscopic features: It is difficult to differentiate macroscopically with first time maturing stage. Colour is typically semi-translucent rose/ purple; the ovarian wall and blood capillaries are thick. But the lumen is large when made a transverse section. Few oocytes were observed in the late stage (Plate 7- C1).

Microscopic features: Second time developing ovary with several stage of oocytes such as CNS, PNS and CAS, but the dominating stage is depending on the season; Lamellae very thin; ovarian lumen is larger than fist time developing ovary. Some large oocytes reached 200 µm (Plate 7-C2).

Stage IV: Matured ovary

Macroscopic features: Large, rounded, yellow to orange coloured ovaries, occupying about 75 % to almost filling body cavity. Ovarian wall is thin and transparent. Small opaque oocytes can be seen clearly through the ovarian wall. Prominent blood capillaries also formed (Plate 8-D1).

Microscopic features: This stage starts with early YGS. In the early stage ovary is dominated by early YGS and Previtellogenic oocytes (PVO). YGS oocytes mature and grow, causing the lamellae to expand the lumen to decrease, and the tunica to stretch and thin. Vascular tissue becomes more common. In the later stage (Yolk globule stage/ advanced vitellogenic oocytes) yolk granules almost cover the cytoplasm; nucleus starts to migrate towards the periphery (also known as migratory nucleus stage) of the oocytes. 300 to 350 µm size oocytes dominate the ovary but few of them reached 450 µm. This stage of ovary also consists of CNS, PNS and CAS oocytes (plate 8-D2, Plate 9- D3) This stage ovary may also contains atretic stages (Plate 9- D4).

Stage V: Pre spawning ovary

Macroscopic features: It is difficult to differentiate from the stage VI spawning stage ovary by macroscopic analysis (Plate 10- E1).

Microscopic features: Large oil droplets increase in size and intermixed with the yolk globules. Nucleus starts to migrate towards the periphery of the oocyte. Hydrated oocytes and post ovulatory follicles were observed Zona radiata becomes enlarged and clear surrounding follicular cells also observed. Most of the oocytes in this stage were reached to 350 µm and considerable number of oocytes reached 400 to 450 µm (Plate 10- E2).

Stage VI: Spawning ovary

Macroscopic features: Ovaries are very large and swollen. The translucent hydrated oocytes give the ovaries a distinctive speckled or granular appearance through the thin ovarian wall. Eggs may be released from the ovaries when pressure applied (Plate 11-F1).

Microscopic features: Yolk granules become fused together and form yolk plates; nucleus migrates towards the periphery of the oocytes. Hydrated oocytes can be seen in the lumen. Yellow brown bodies and vascular tissue will become more prominent at this time and POF may be present if the fish has previously spawned. Most of the oocytes in this stage are reached to 350 μm and considerable number of oocytes reached 400 to 450 μm (Plate 11-F2). At the time of spawning ovulated eggs are found in the lumen and new POF are present in the periphery of the lamellae and few MNS, CNS, PNS may also present (Plate 12- F3).

Stage VII: Spent ovary

Macroscopic features: Flaccid and large ovaries usually grayish in colour. Lumen is very large.

Microscopic features: Post ovulatory follicles dominate the space; few CNS also present (Plate12- G).

Atresia stages of oocytes were recorded in matured, Pre spawning, spawning and spent stage ovaries (Plate (13 H1 & H2).

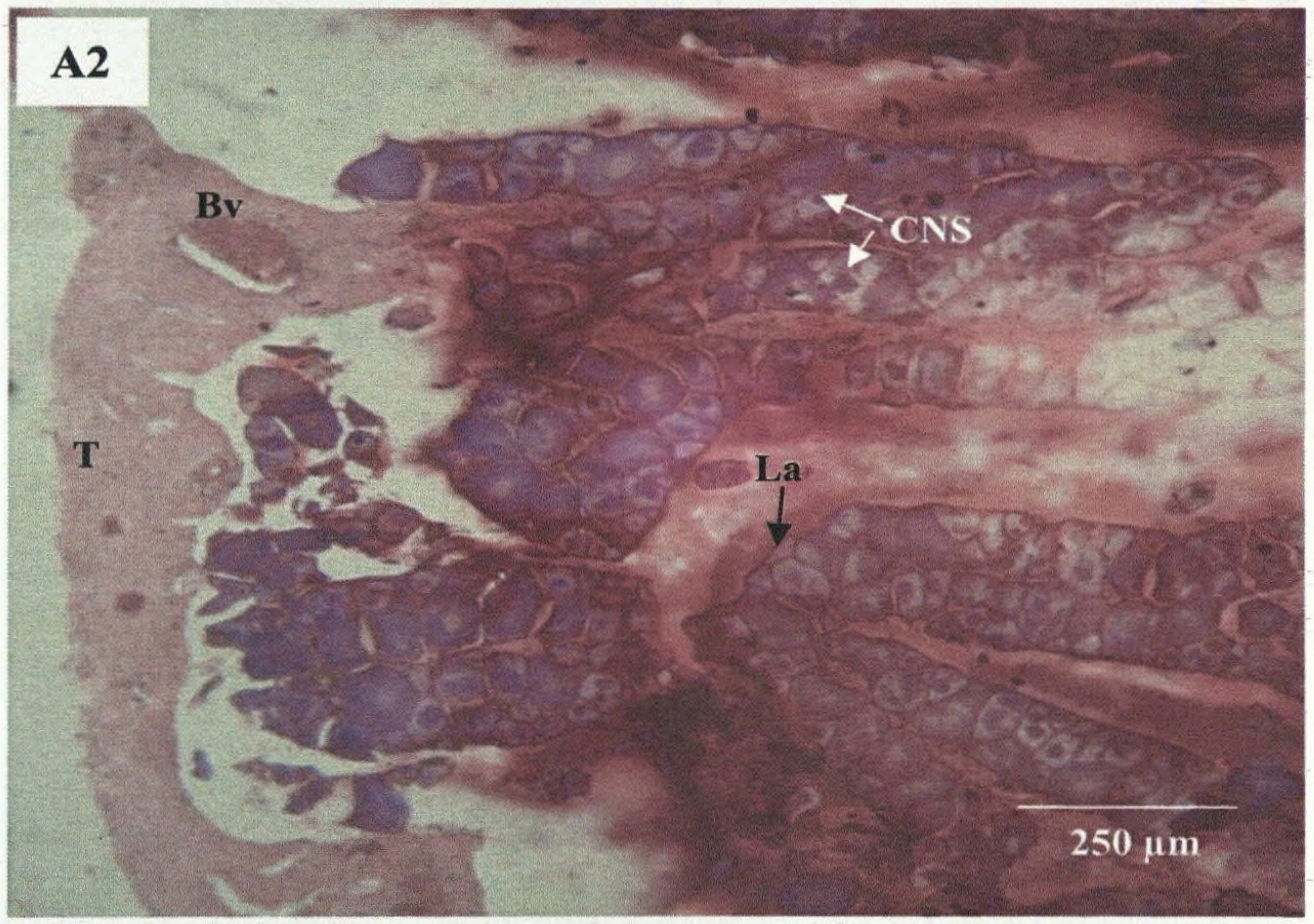


Plate 4: Stage I, Immature ovary
A- Whole view of immature ovary; A2- Transverse section of immature ovary. CNS- chromatin nucleolus, Bv- blood vessel, T- tunica, La- lamella (Total length of fish= 24 cm).

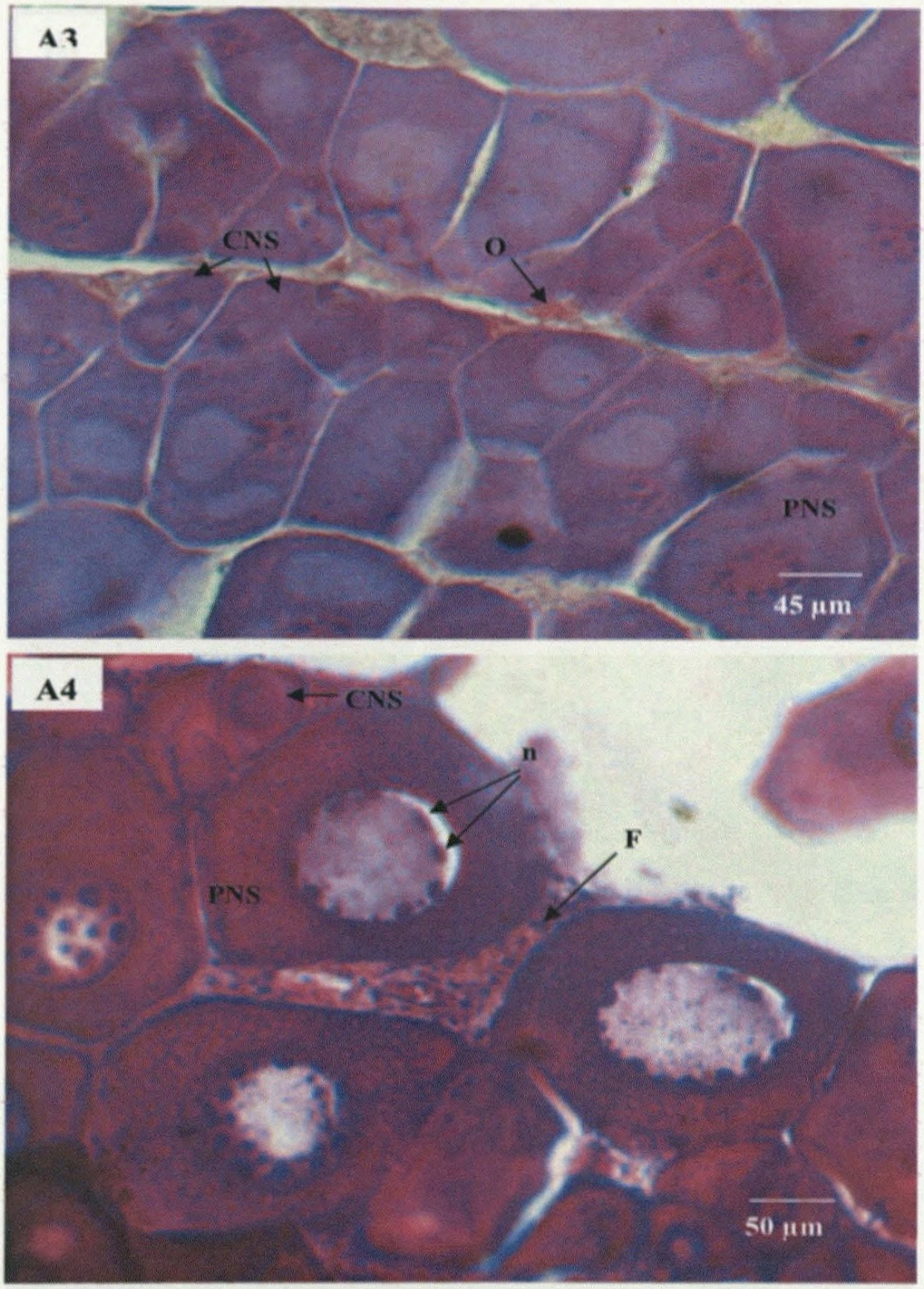


Plate 5: Stage I, Immature ovary

A3- Chromatin nucleolus stage; A4- Peri nucleolus stage. CNS- chromatin nucleolus stage, PNS- peri nucleolus stage, O- oogonia, n- nucleolus, F- follicular cells.

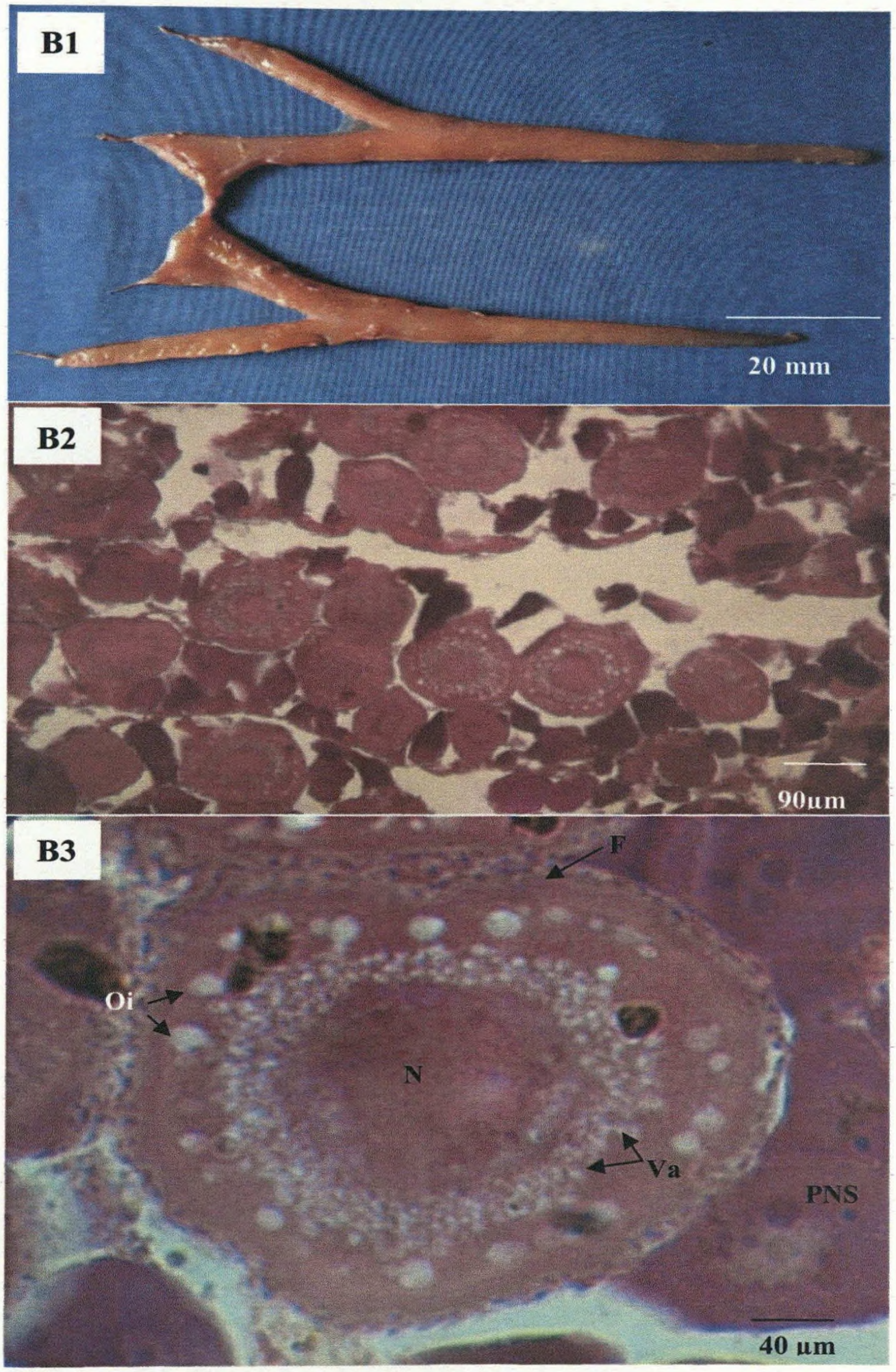
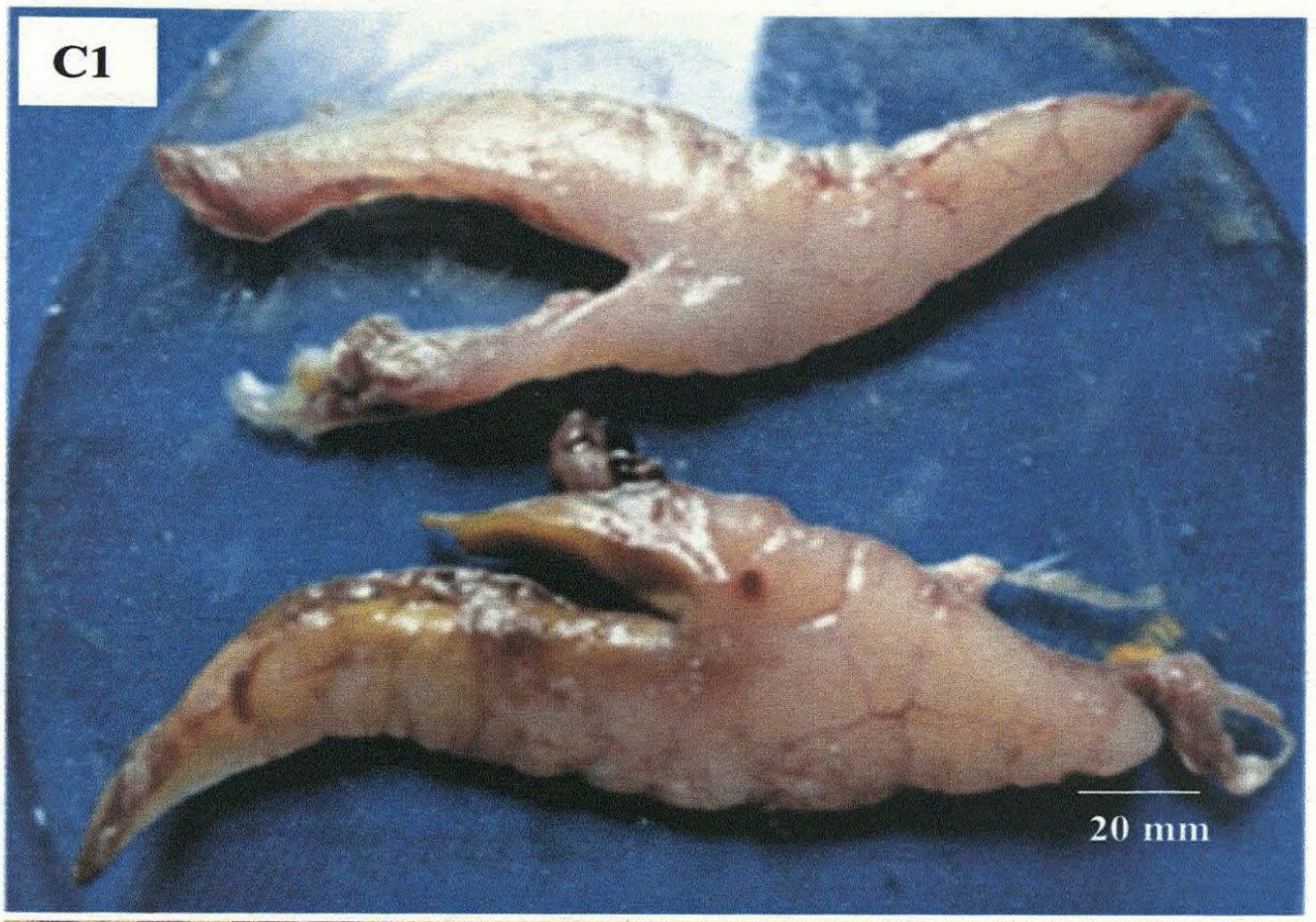


Plate 6: Stage II, Maturing ovary

B1- Whole view of maturing ovary; B2 & B3- Cortical alveoli stage ovary. PNS- peri nucleolus stage, N- nucleus, F- follicular cells, Oi- oil droplets, Va- vacuoles (Total length of fish= 48 cm).



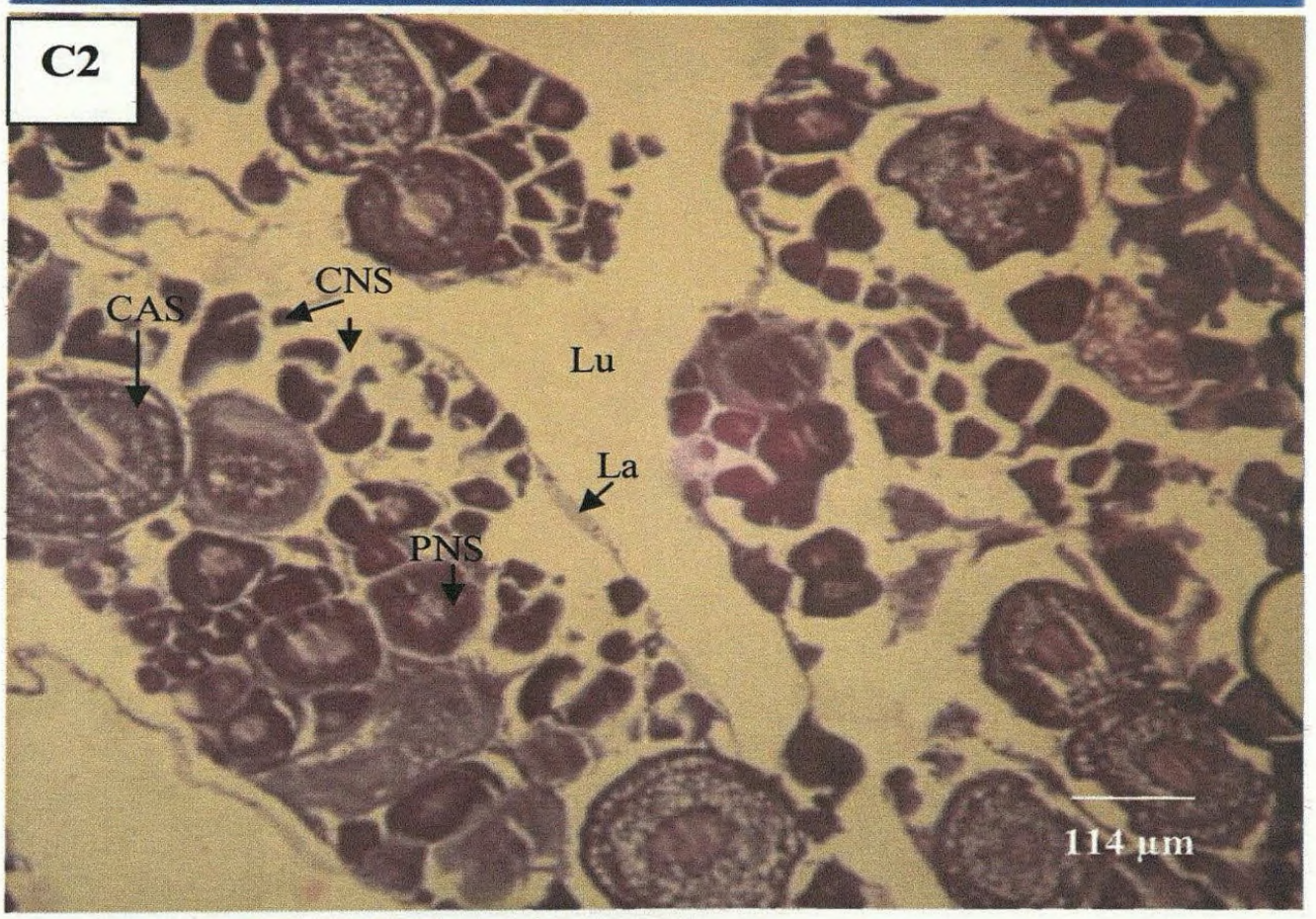
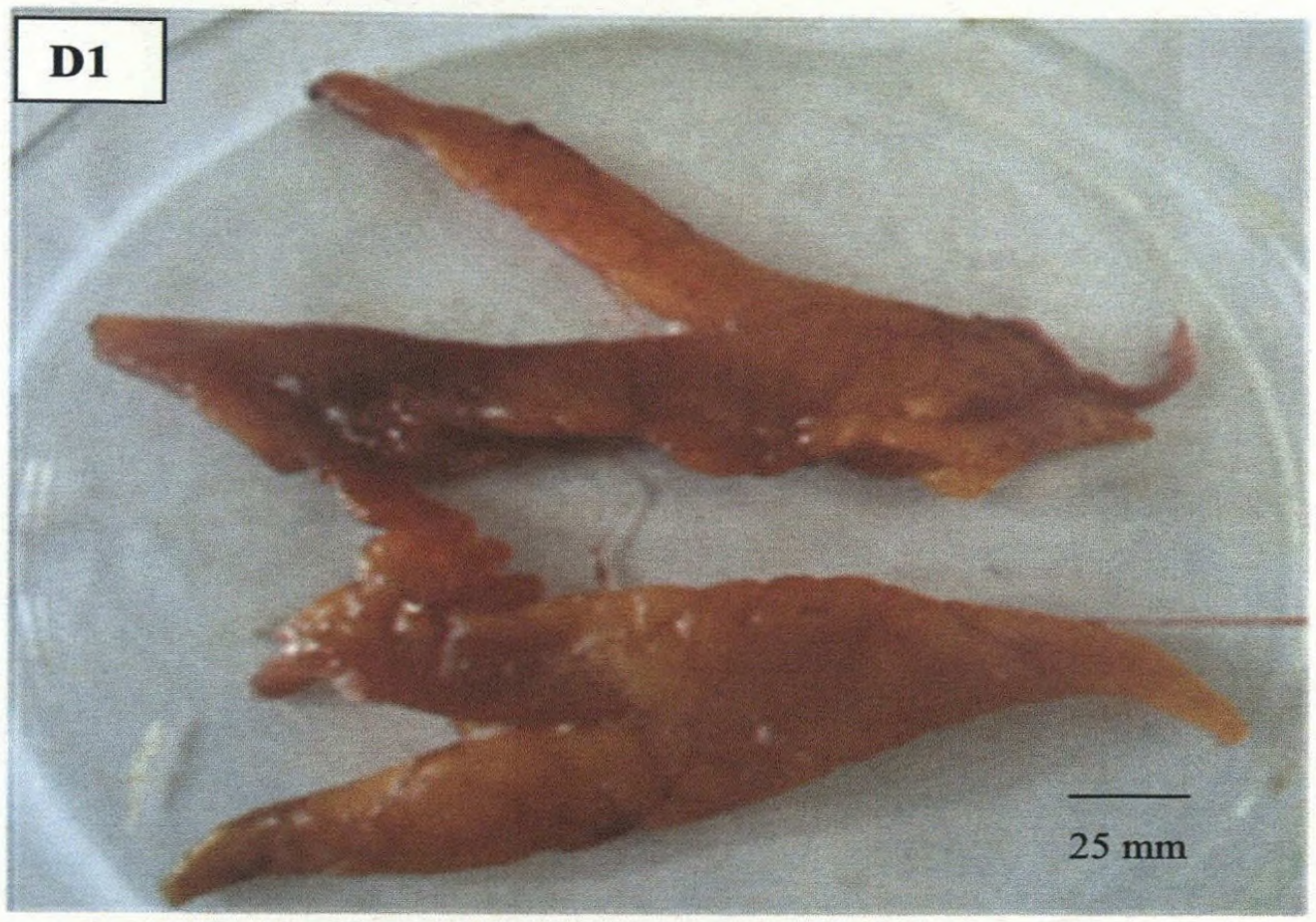


Plate 7: Stage III, Rest/ developing (maturing) ovary
C1-Whole view of rest/ developing ovary; C2- Cortical alveoli stage. CAS- cortical alveoli stage, PNS- peri nucleolus stage, CNS- chromatin nucleolus, Lu- lumen, La- lamella (Total length of fish= 71 cm)



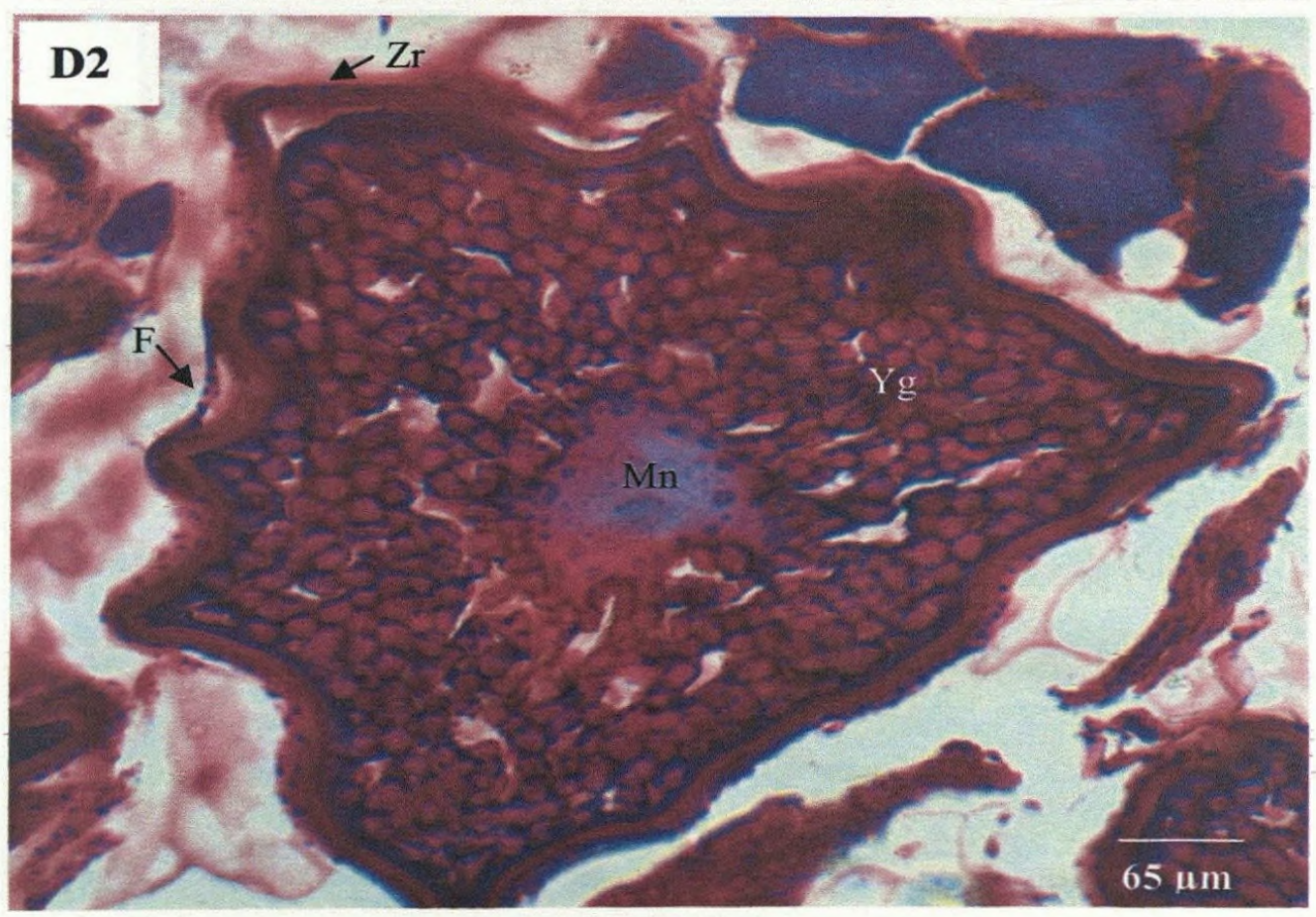
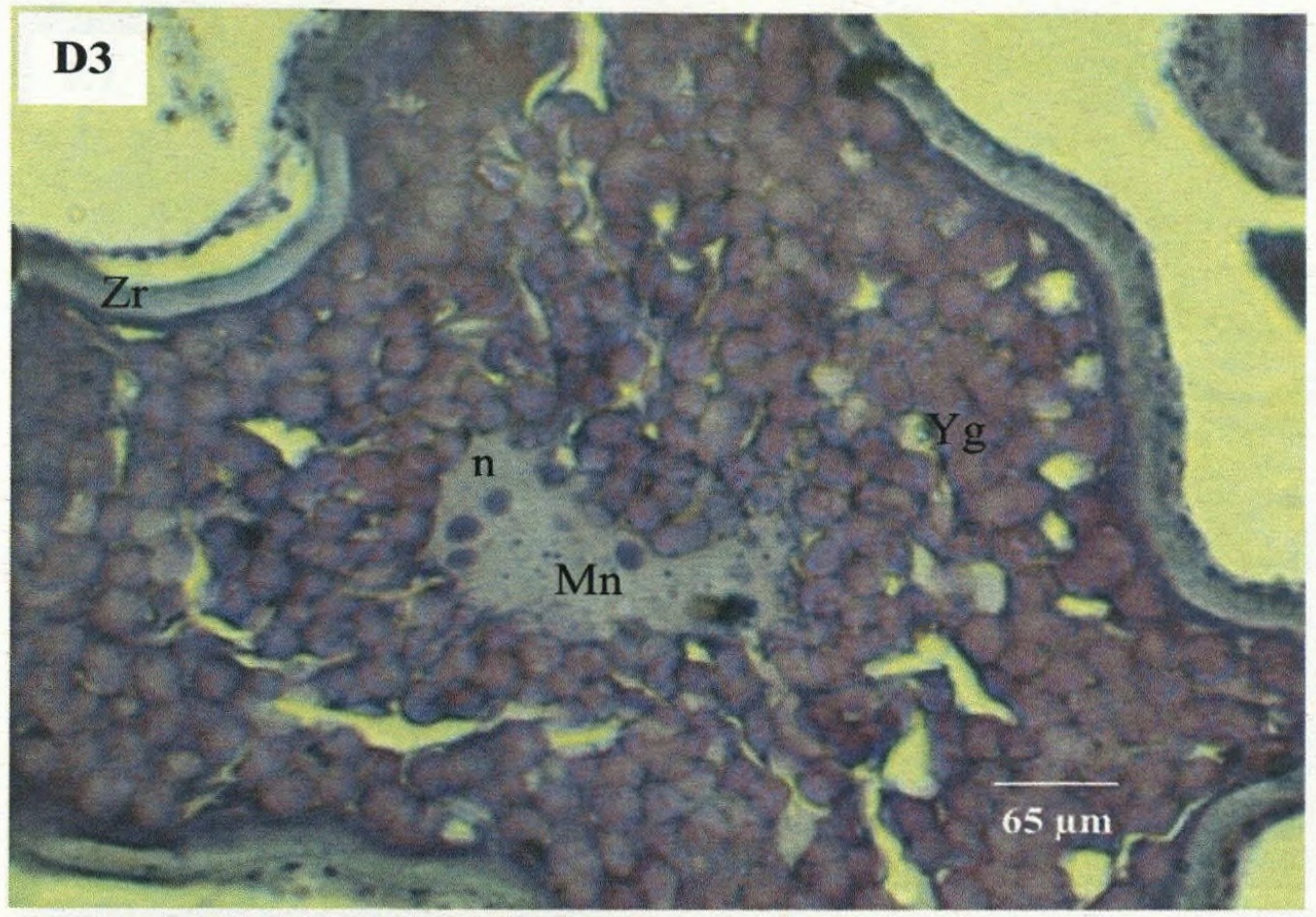


Plate 8: Stage IV, Matured ovary

D1- Whole view of matured stage ovary; D2- Yolk globule stage oocyte.
Yg- yolk globule, Mn- migratory nucleus, F- follicular cells, Zr- zona radiate
(Total length of fish= 68 cm)



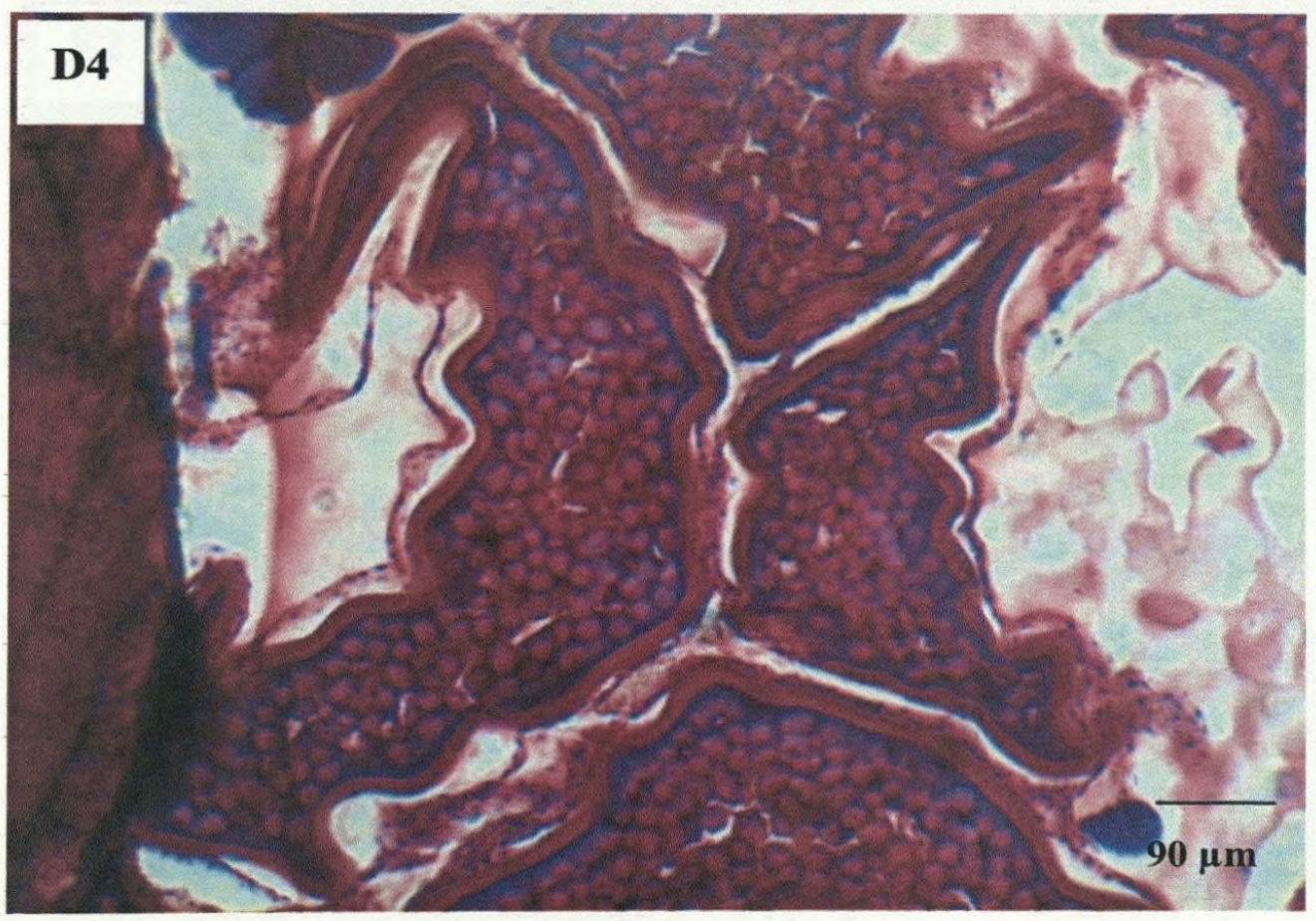
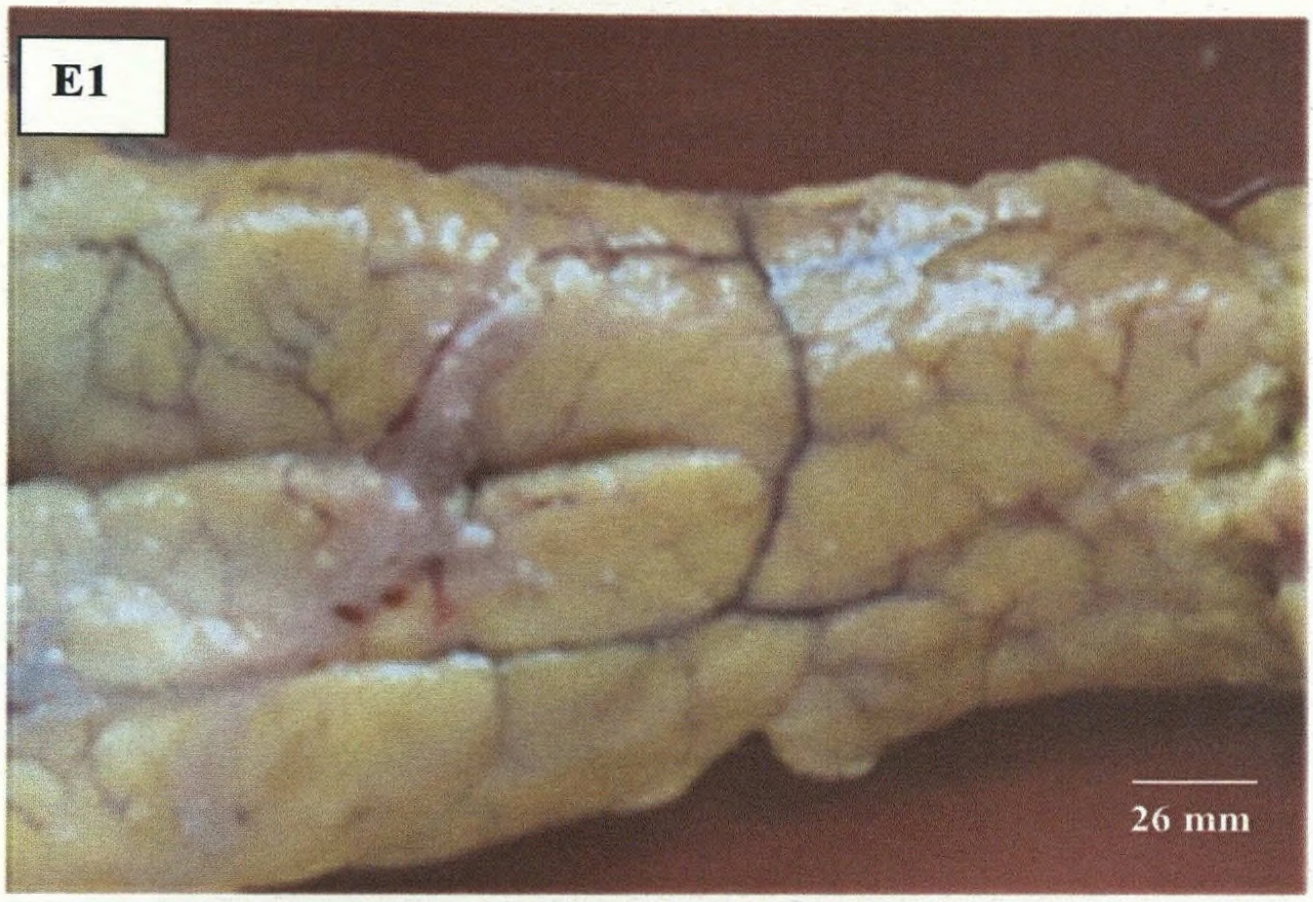


Plate 9: Stage IV, Matured ovary

D3- magnified view of mature oocyte D4- Atretic stages in matured ovary.
Yg- yolk globule, Mn- migratory nucleus, F- follicular cells, Zr- zona radiate
(Total length of fish= 68 cm)



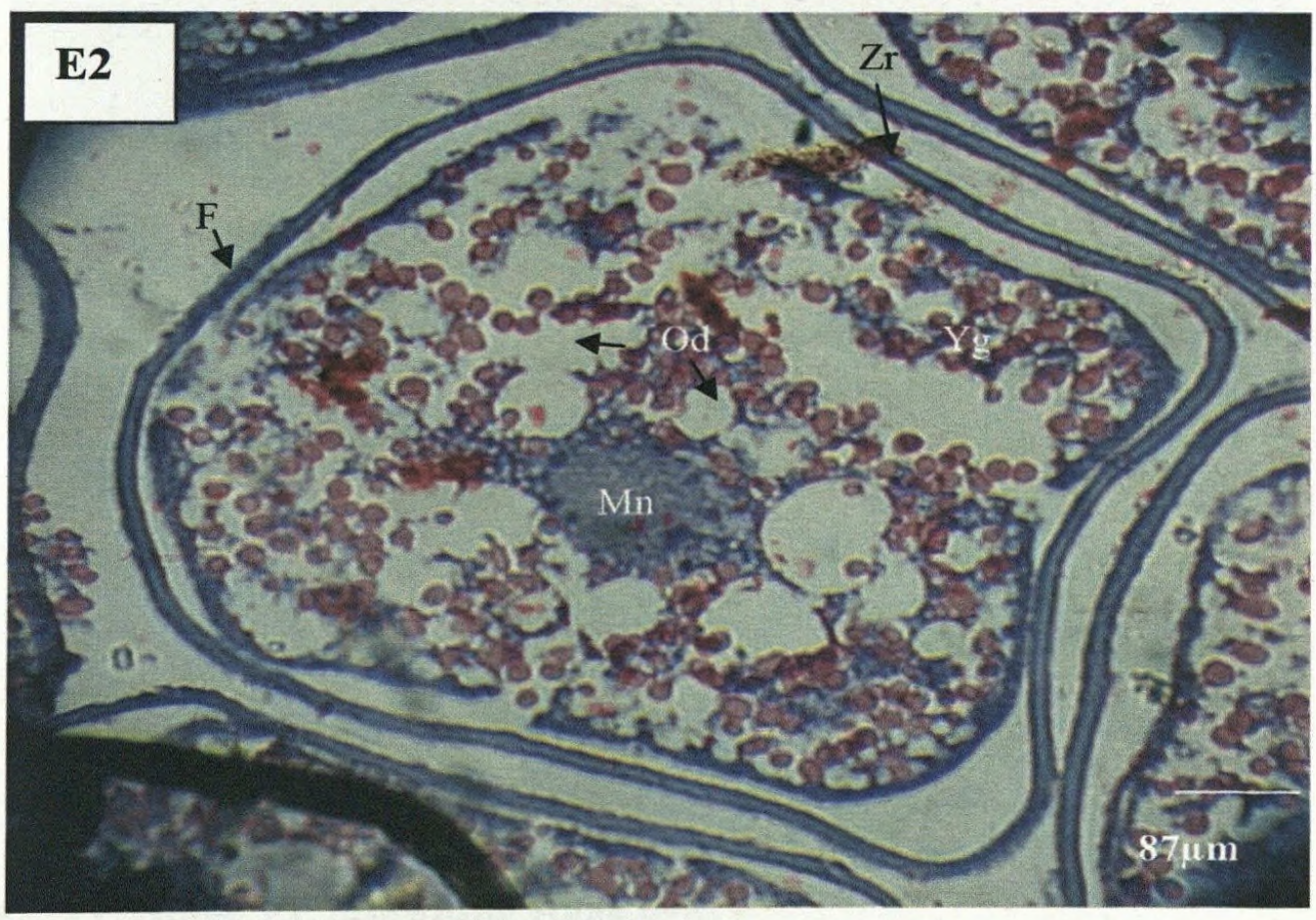
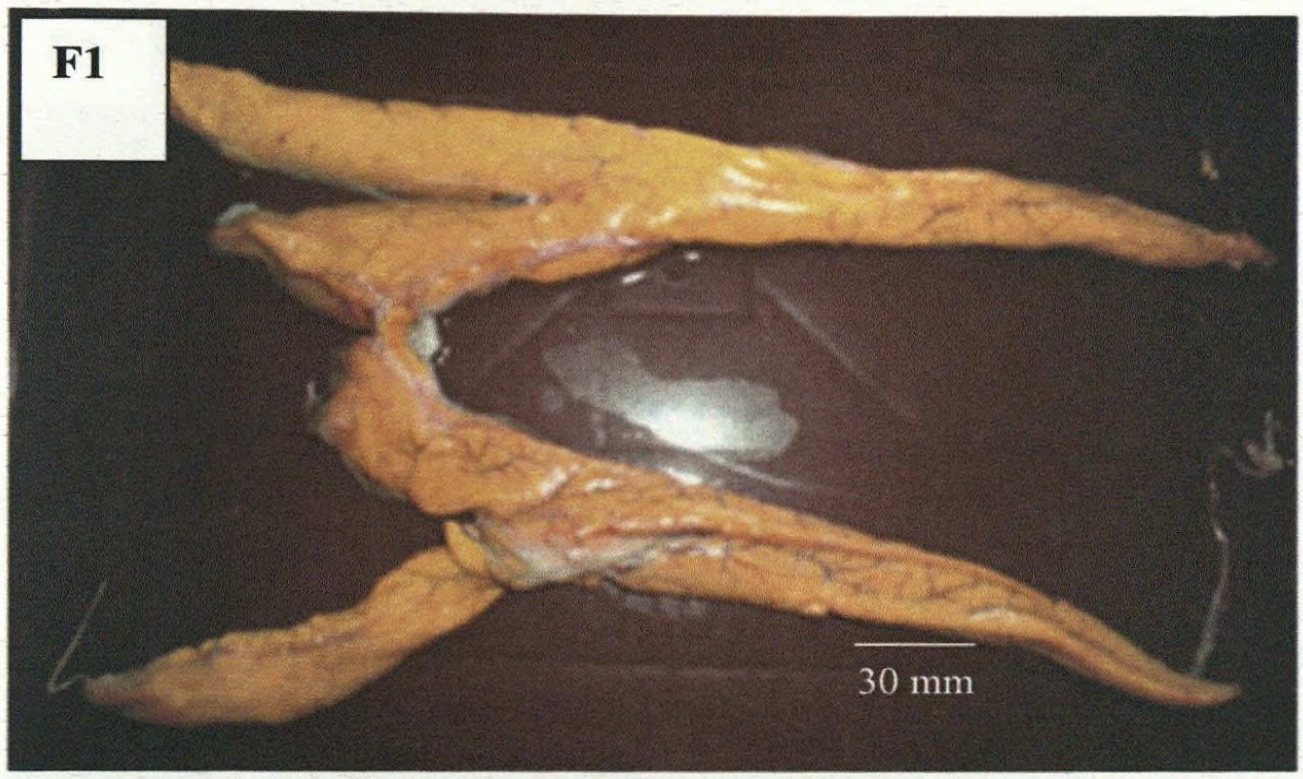


Plate 10: Stage V, Pre spawning stage ovary

E1- A portion of pre spawning ovary; E2- late yolk stage oocyte.
Mn- migratory nucleus, Yg- yolk globules, Od- oil droplets, Zr- zona radiata, F- follicular cells (Total length of fish= 78 cm)



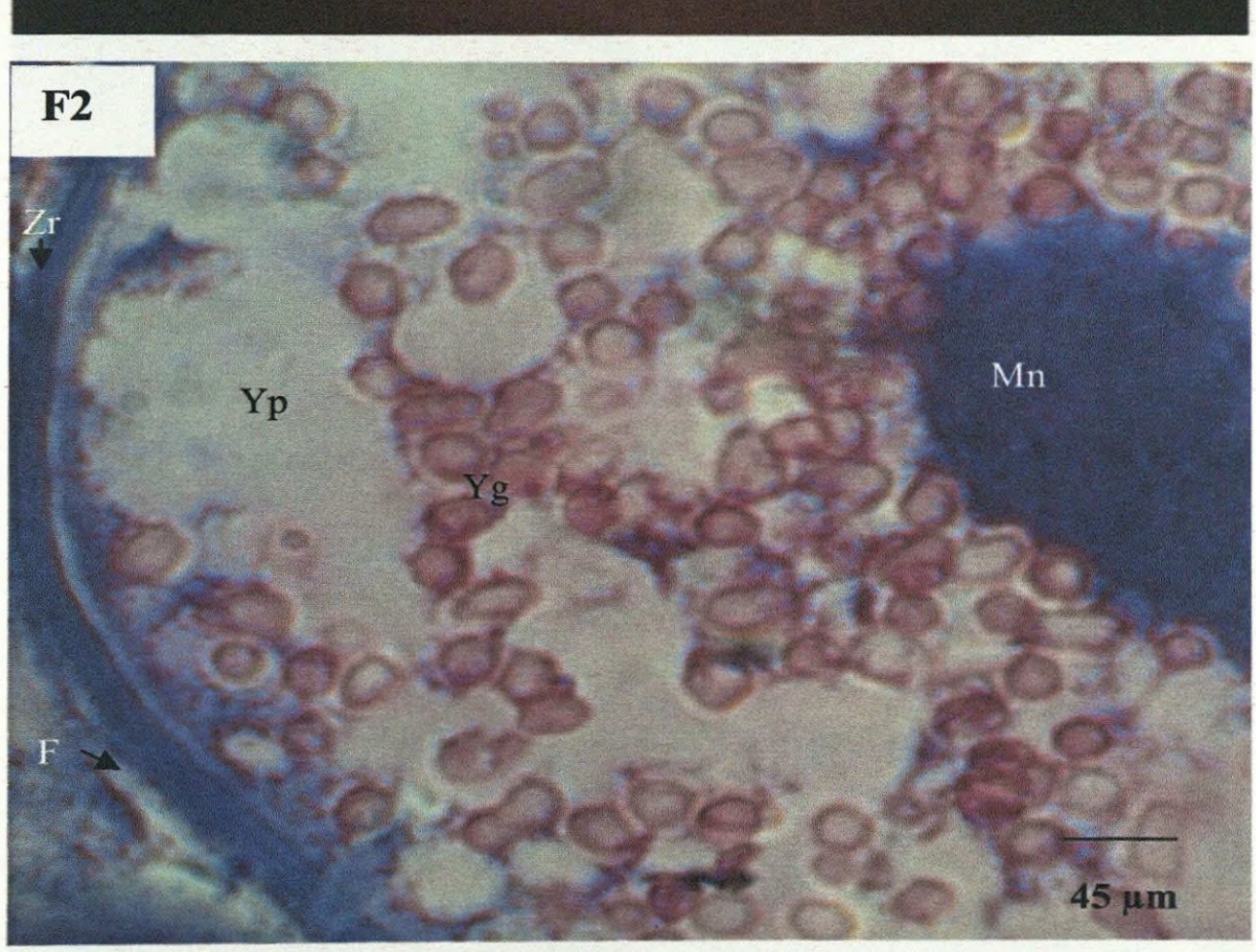
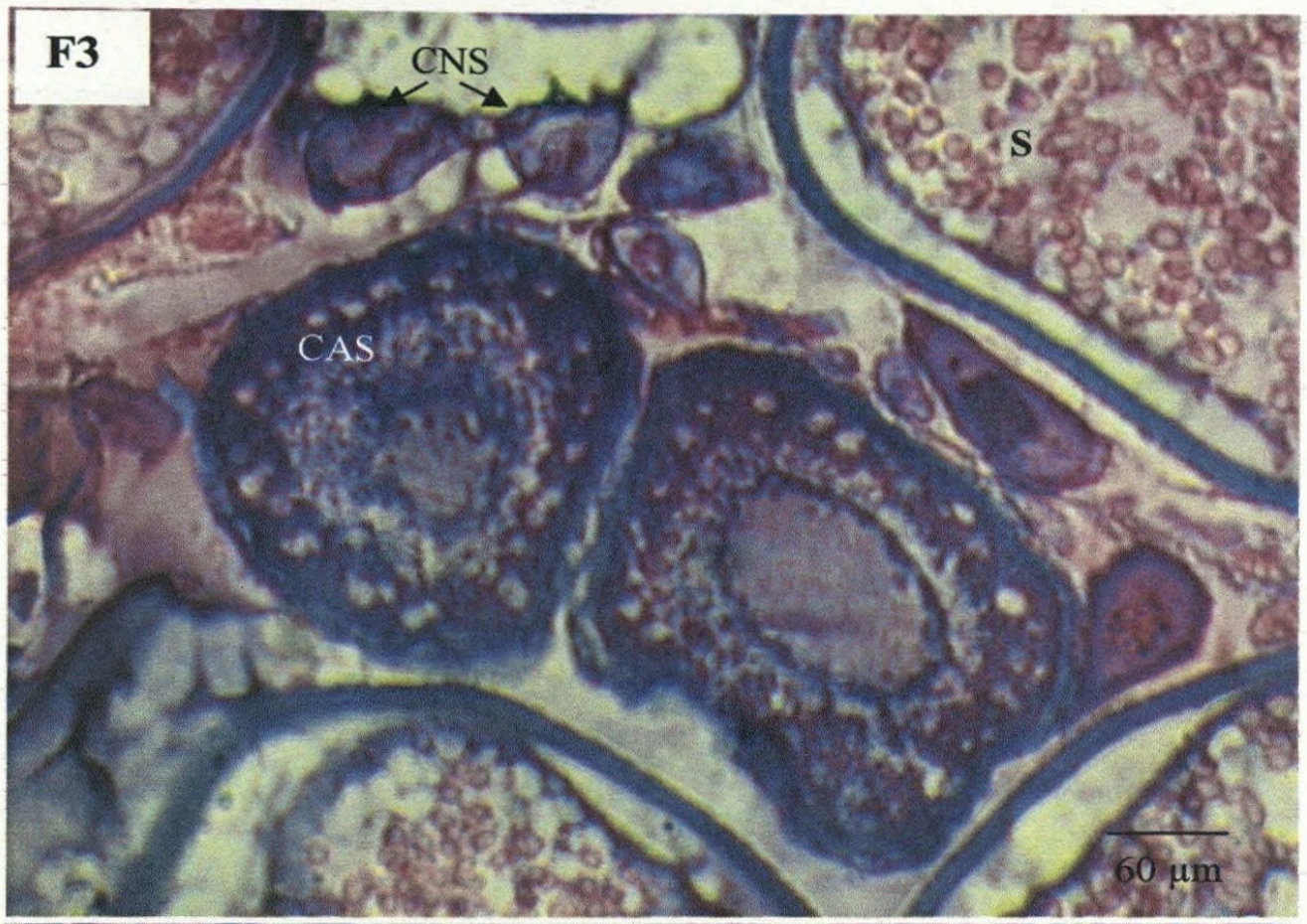


Plate 11: Stage VI, Spawning stage ovary
F1- Whole view of spawning ovary; F2- A portion of hydrated oocyte.
Yp- yolk plate, Yg- yolk granules, Mn- migratory nucleus, Zr- zona radiata, F- follicular cells.(Total length of fish= 80 cm)



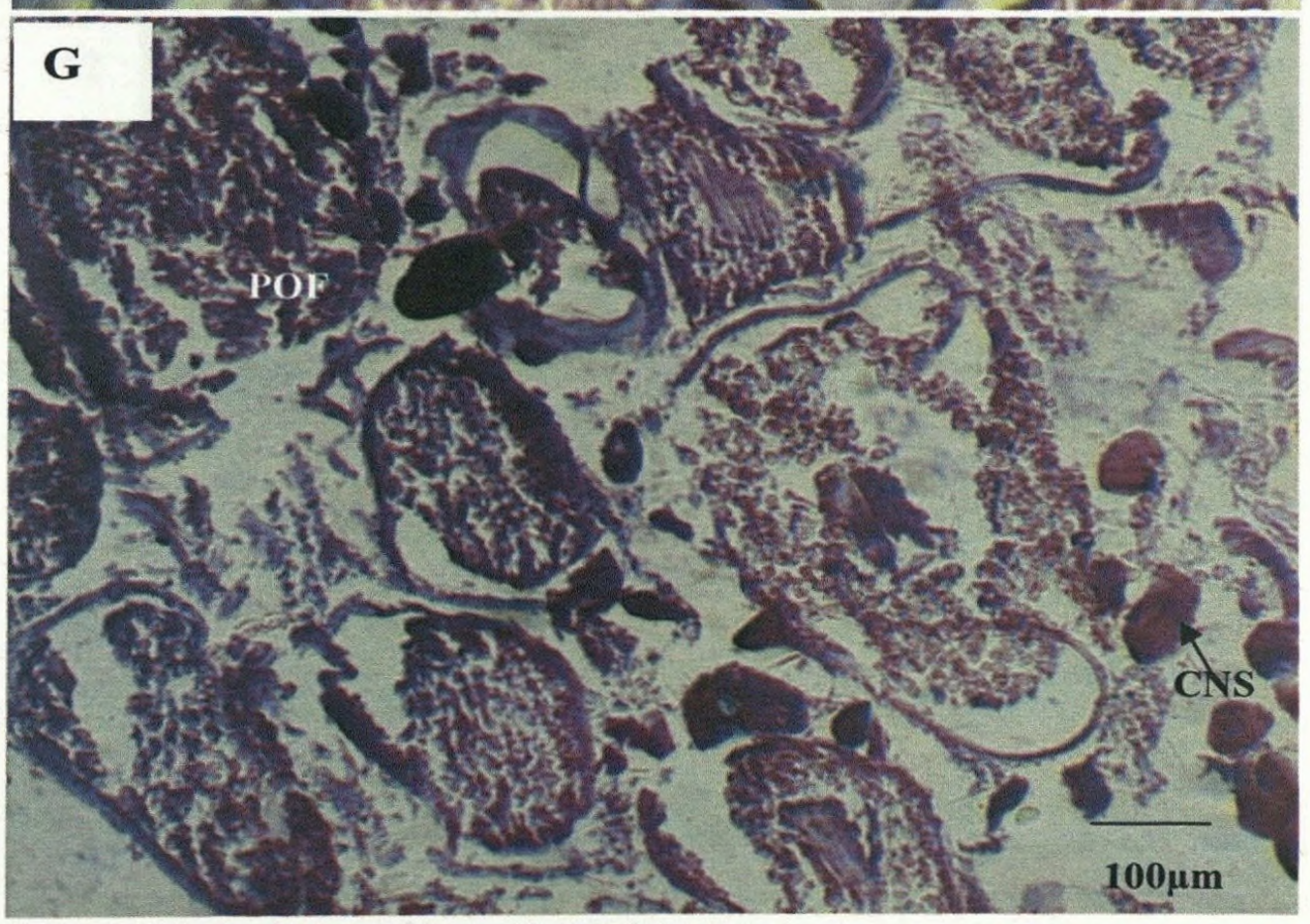
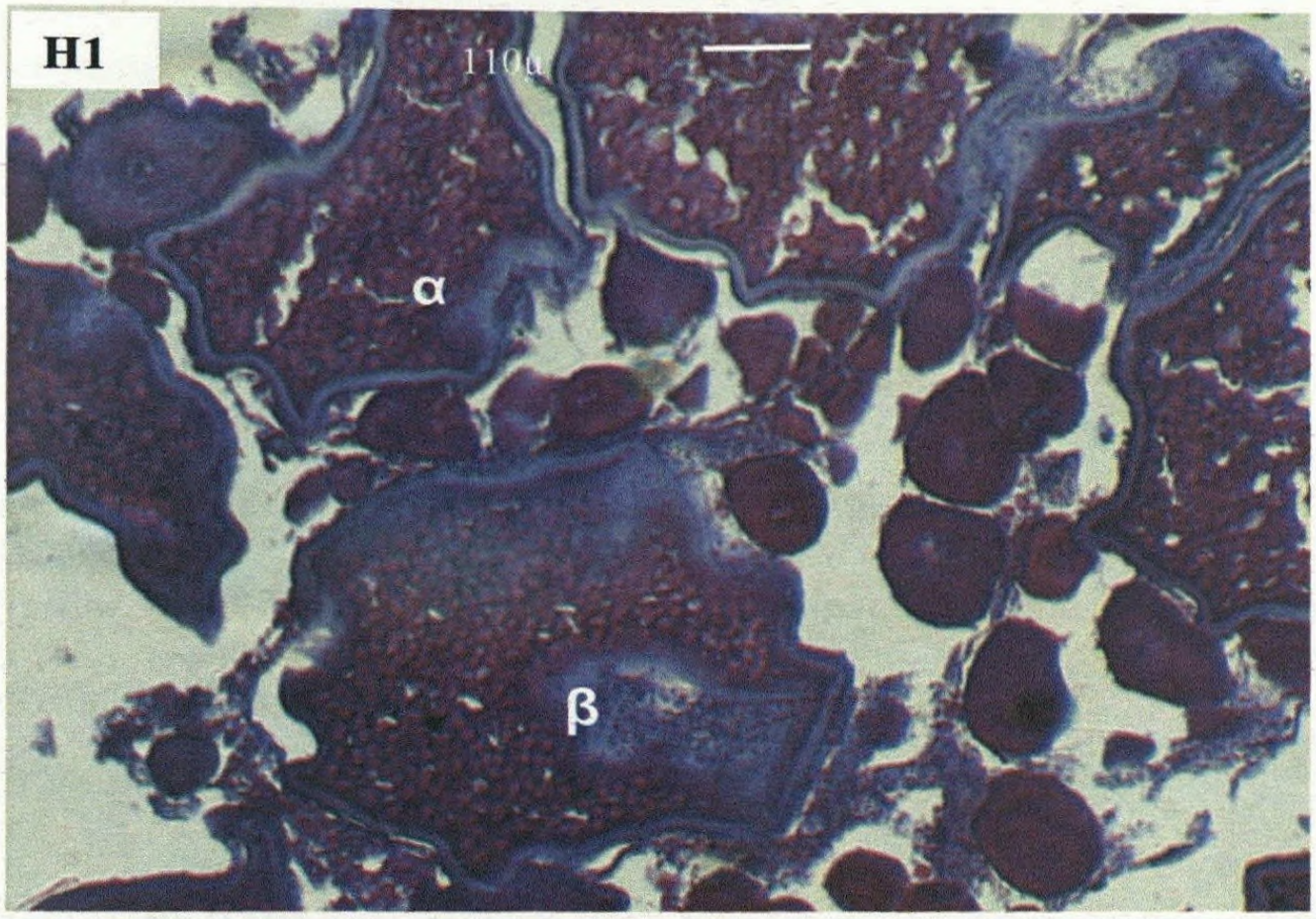


Plate 12 F3: Spawning stage; G: Stage VII, Spent stage ovary

G- Spawning stage ovary with different stages of oocytes; H- Degenerating post ovulatory follicles. POF- post ovulatory follicles, CNS- chromatin nucleolus stage



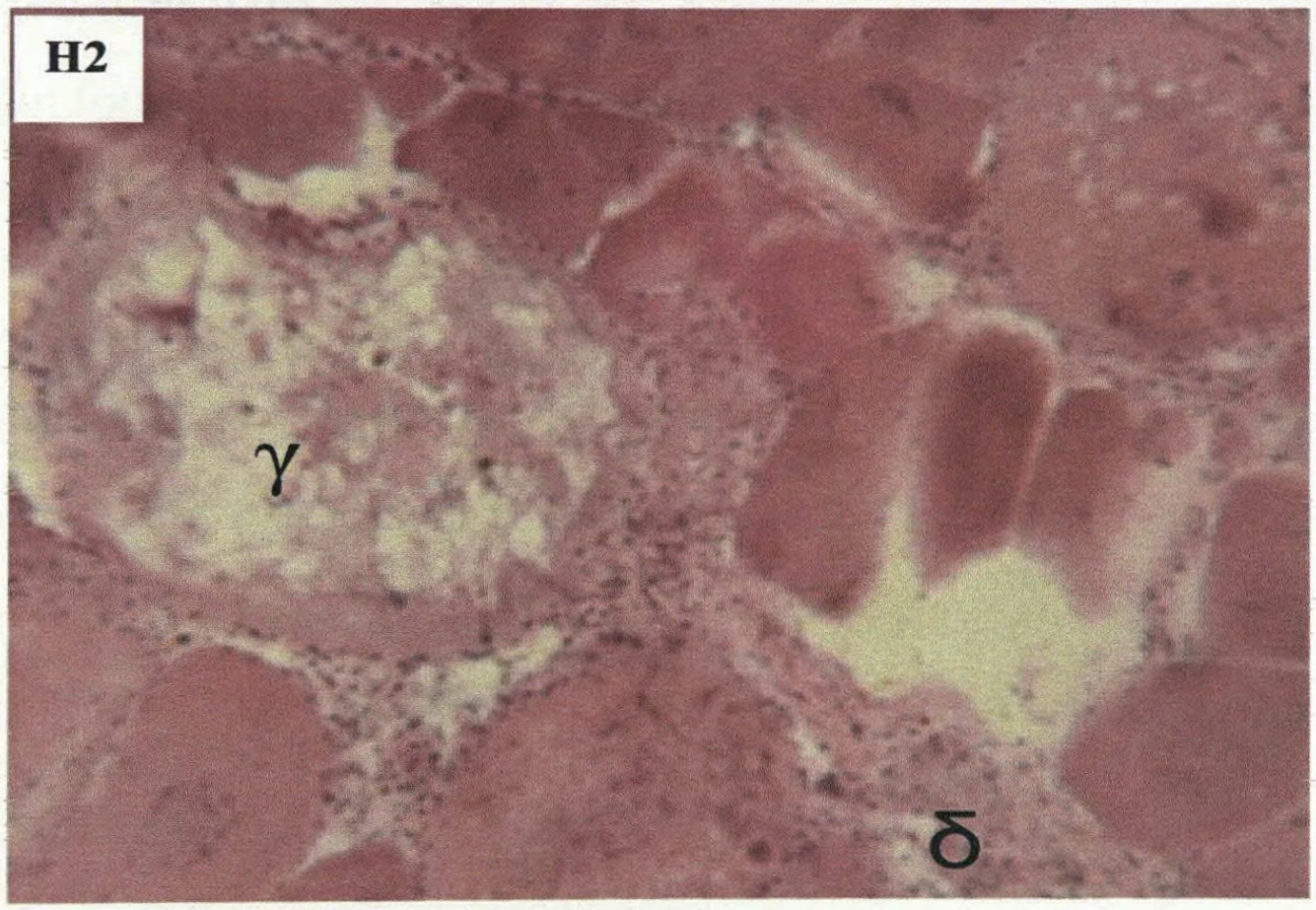


Plate 13: Atretic oocytes

H1- Histology showing α and β stage atresia; H2- Histology showing γ and δ atresia.

Description of testicular developmental stages:

Stage I: Immature testis

Macroscopic features: Small, strap/ thread like opaque testis with smooth appearance. No milt is present in the transverse section (Plate 14-J1).

Microscopic features: Testis contains spermatogonia and isolated pockets of spermatocrypts. These mainly contain spermatocytes. The central sperm sinus is small and empty (Plate 14-J2).

Stage II: Maturing testis

Macroscopic features: Larger than immature gonads and produce milt when squeezed (plate 15-K1).

Microscopic features: Spermatocytes are the prominent sperm tissues and spermatocrypts are larger than immature testis. Interstitial cells surround the spermatocrypts. Central sperm sinus is empty (Plate 15-K2).

Stage III: Mature testis

Macroscopic features: Large, opaque and ivory or bone colour testis. Exterior dorsal blood vessels were present and prominent. Produce white milt when squeezed and milt should be visible in the outer areas of the transverse section (Plate 16-L1).

Microscopic features: Spermatozoa and/ or spermatids are the dominant stages. The central sperm sinus may be small with a thick muscular wall and may contain little or no

sperm. However the peripheral sperm sinuses are well developed, prominent and filled with spermatozoa (Plate 16- L2 & Plate 18 N1).

Stage IV: Spawning testis

Macroscopic features: Running ripe stage. Testis is large in size similar to mature stage but more have swollen with lager exterior blood vessels. Milt is released with little or no pressure on the abdomen or when the testis is cut (Plate 17 M1).

Microscopic features: Testis is dominated by spermatozoa in the large peripheral and central sperm sinuses. Crypts of spermatocytes are uncommon and in some testis they confined to the most outer region of each lobe (Plate 17 M2 & Plate 18 M2).

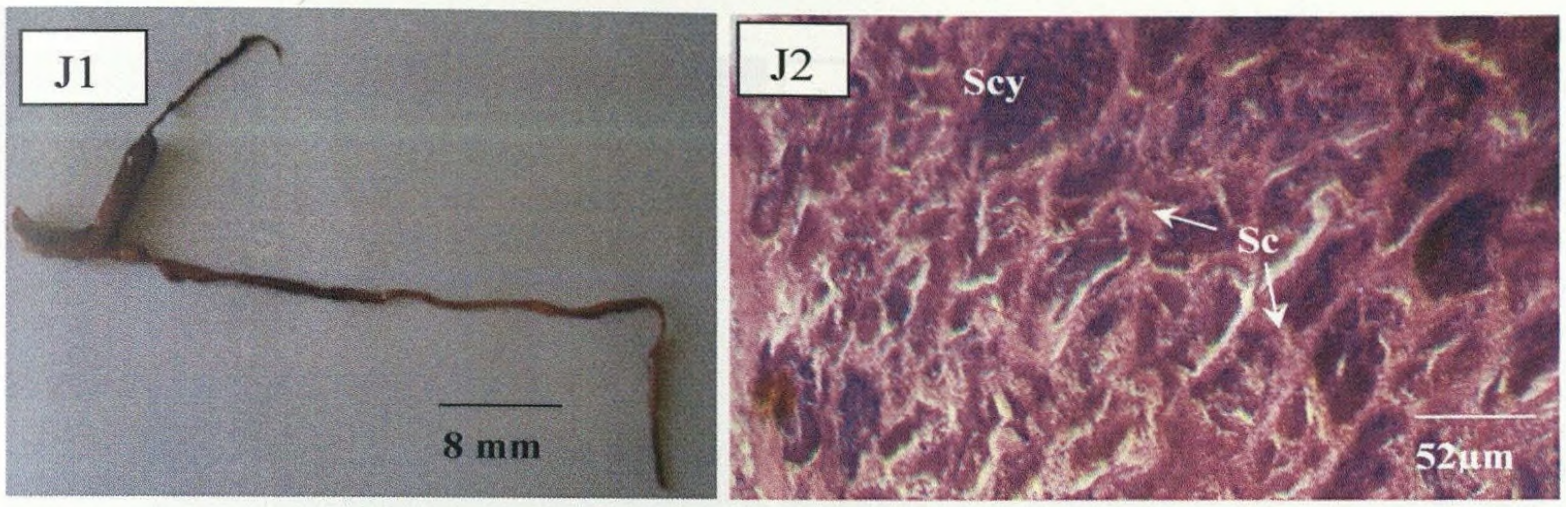


Plate 14: Stage I, Immature testes
J1- whole view of immature testis, J2- spermatocytes in spermatocrypts (Sc-spermatocrypts, Scy- spermatocytes).

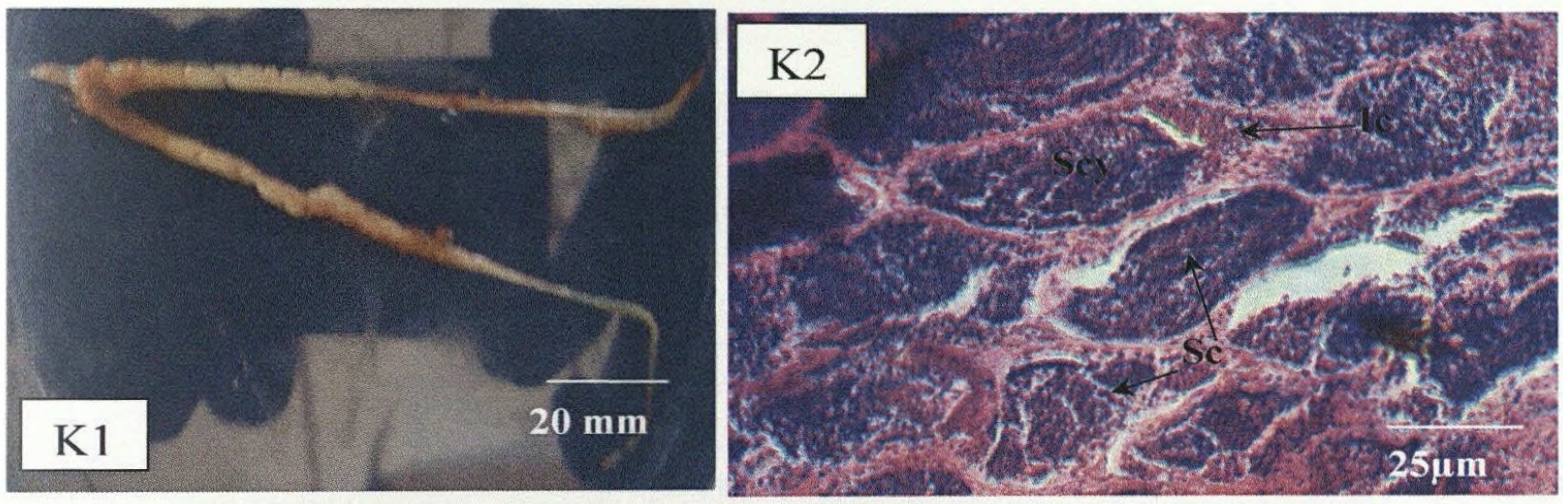


Plate 15: Stage II, Maturing testes
K1- whole view of maturing testis, K2- large spermatocrypts with spermatocytes (Sc-spermatocrypts, Scy- spermatocytes, Ic- interstitial cells).

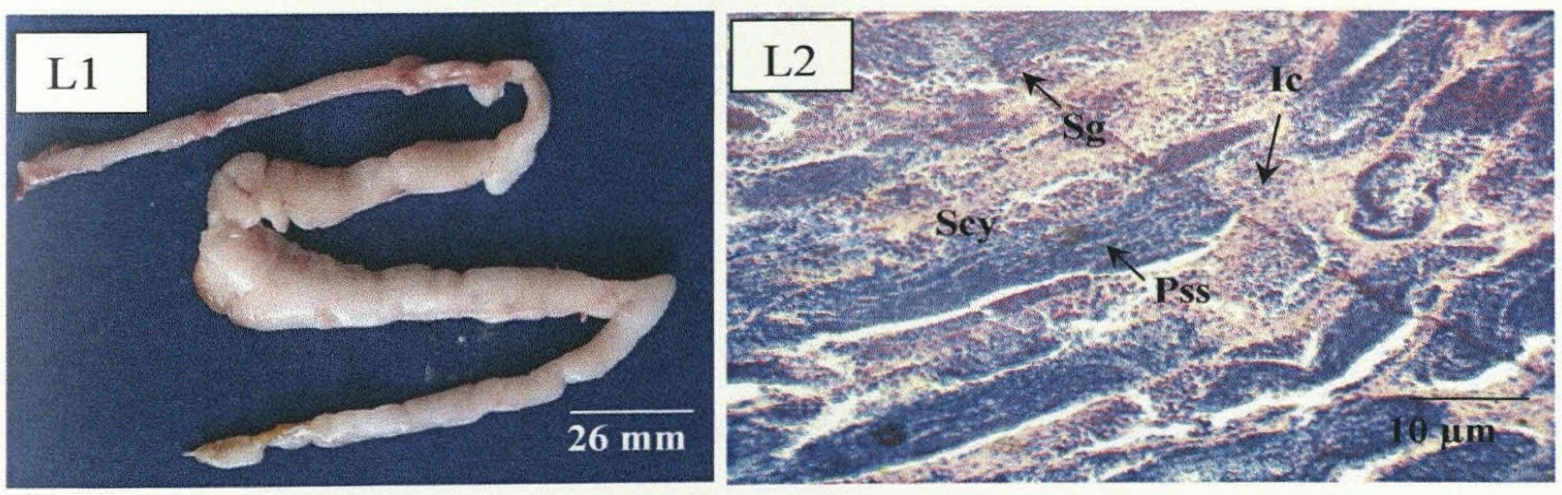


Plate 16: Stage III, Mature testes
L1- whole view of mature testis, L2- spermatocytes in peripheral sperm sinus (Sc-spermatocrypts, Scy- spermatocytes, Ic- interstitial cells, Sg- spermatogonia, Pss- peripheral sperm duct).

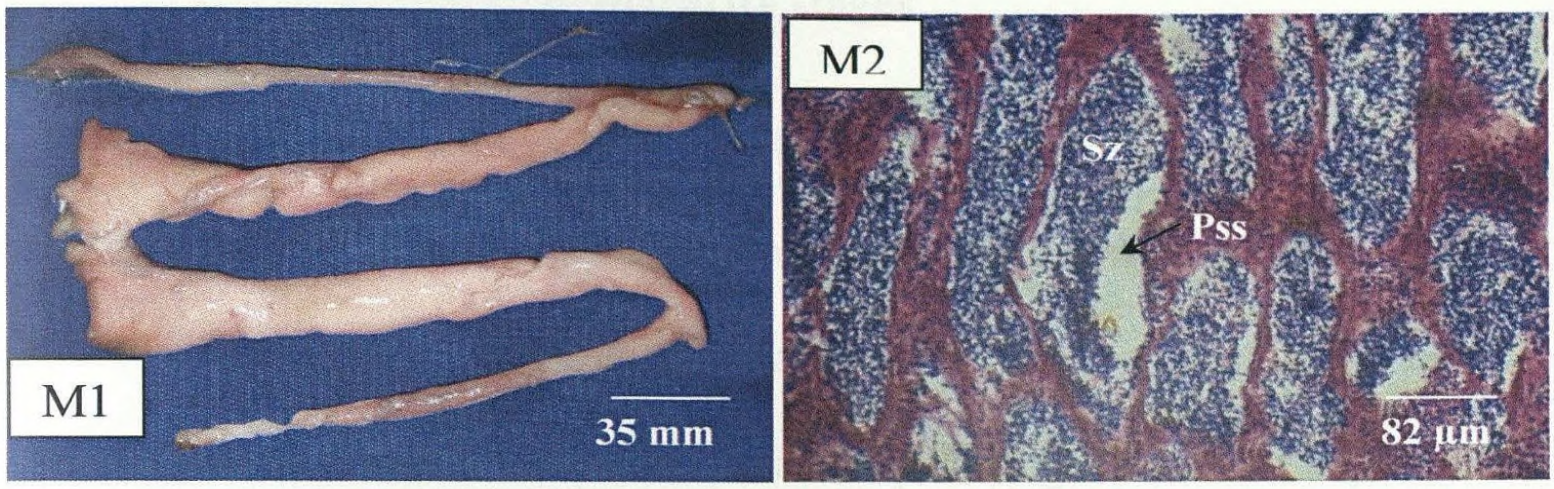


Plate 17: Stage IV, Spawning testes
M1-whole view of spawning testis, M2- showing spermatozoa in large peripheral sperm sinuses (Sz- spermatozoa, Pss- peripheral sperm duct, Css- central sperm duct).

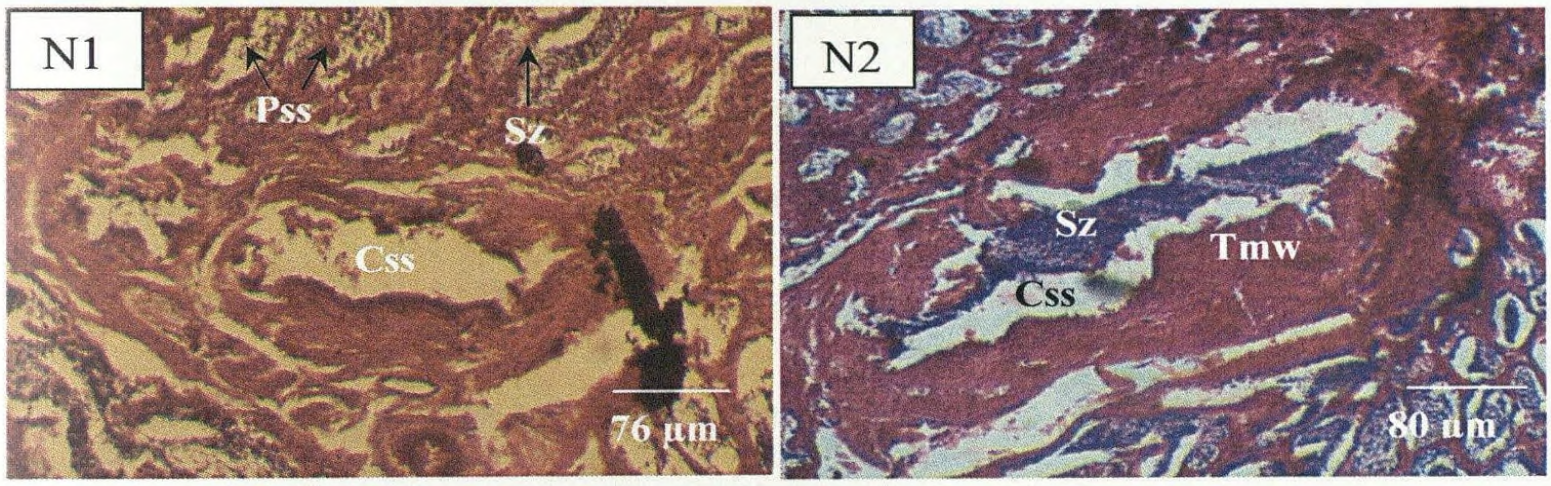


Plate 18: N1- Empty central sperm sinus and the presence of spermatozoa in peripheral sperm sinus; **N2**- A mass of spermatozoa present in the central sperm sinus (Sz- spermatozoa, Pss- peripheral sperm duct, Css- central sperm duct, Tmw- thick muscular wall).

4.7. Monthly distribution of maturity stages

Immature males and females were available throughout the year and fluctuate from one month to another and reached a maximum length during September (Fig. 16 and 17). During November, December and January only immature stages were available. Spawning stage females were available only during June and September and males during June, September and October; but small percentage of immature were also available during this period. Among the total catches in June, less than 50 % was in spawning condition. But in September it was greater than 50 %.

4.8. Length distribution of maturity stages

It was found that fish smaller than 35 cm total length was always immature. Spawning stage was observed above 50-55 cm total length class and resting stage was observed within 60 – 65 cm total length class. This indicates that the spawning occurs after attaining the total length of 50 – 55 cm (Fig. 18 and 19).

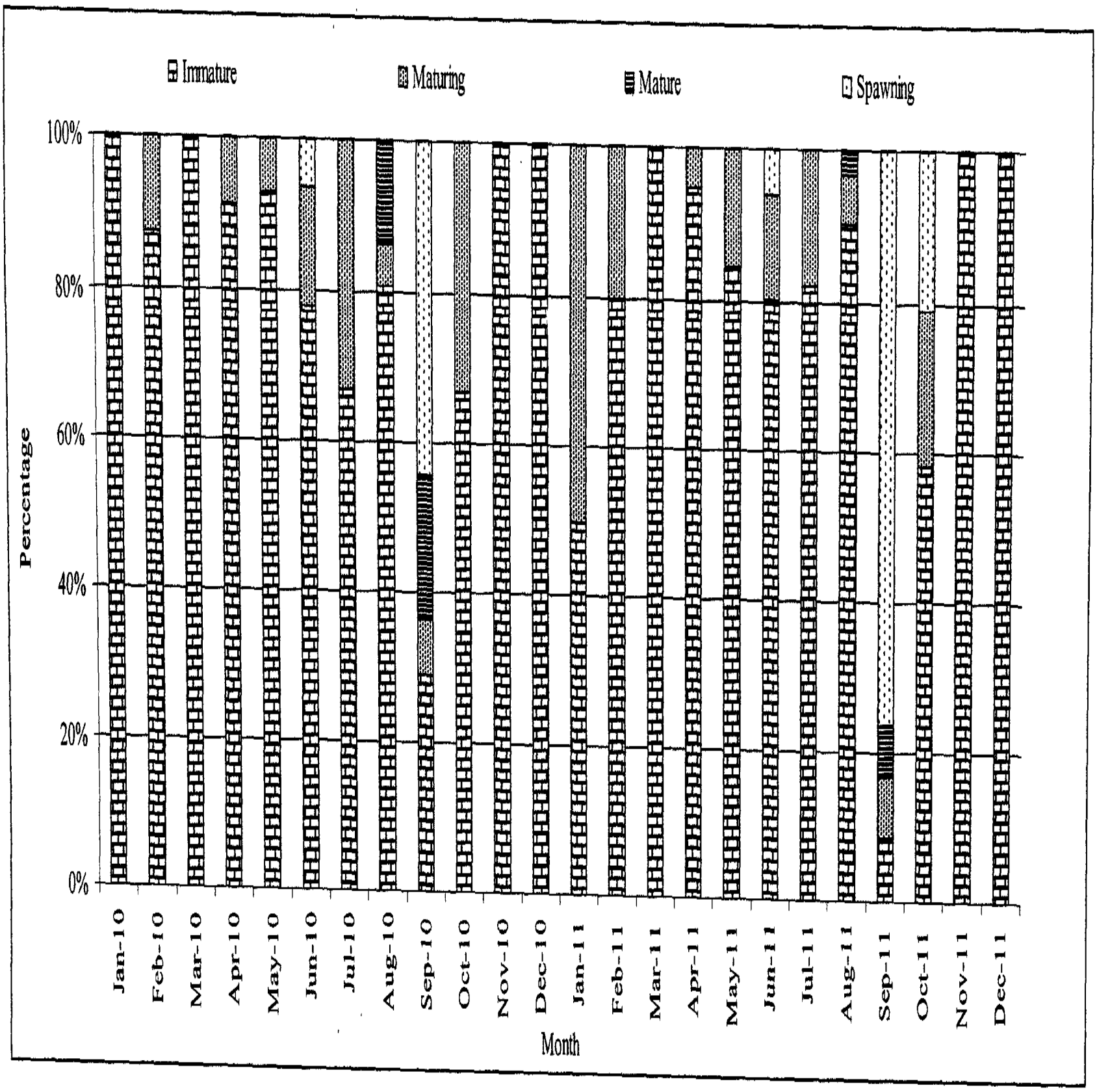


Fig.16. Monthly distribution of maturity stages of male *S. lysan* from January 2010 to December 2011

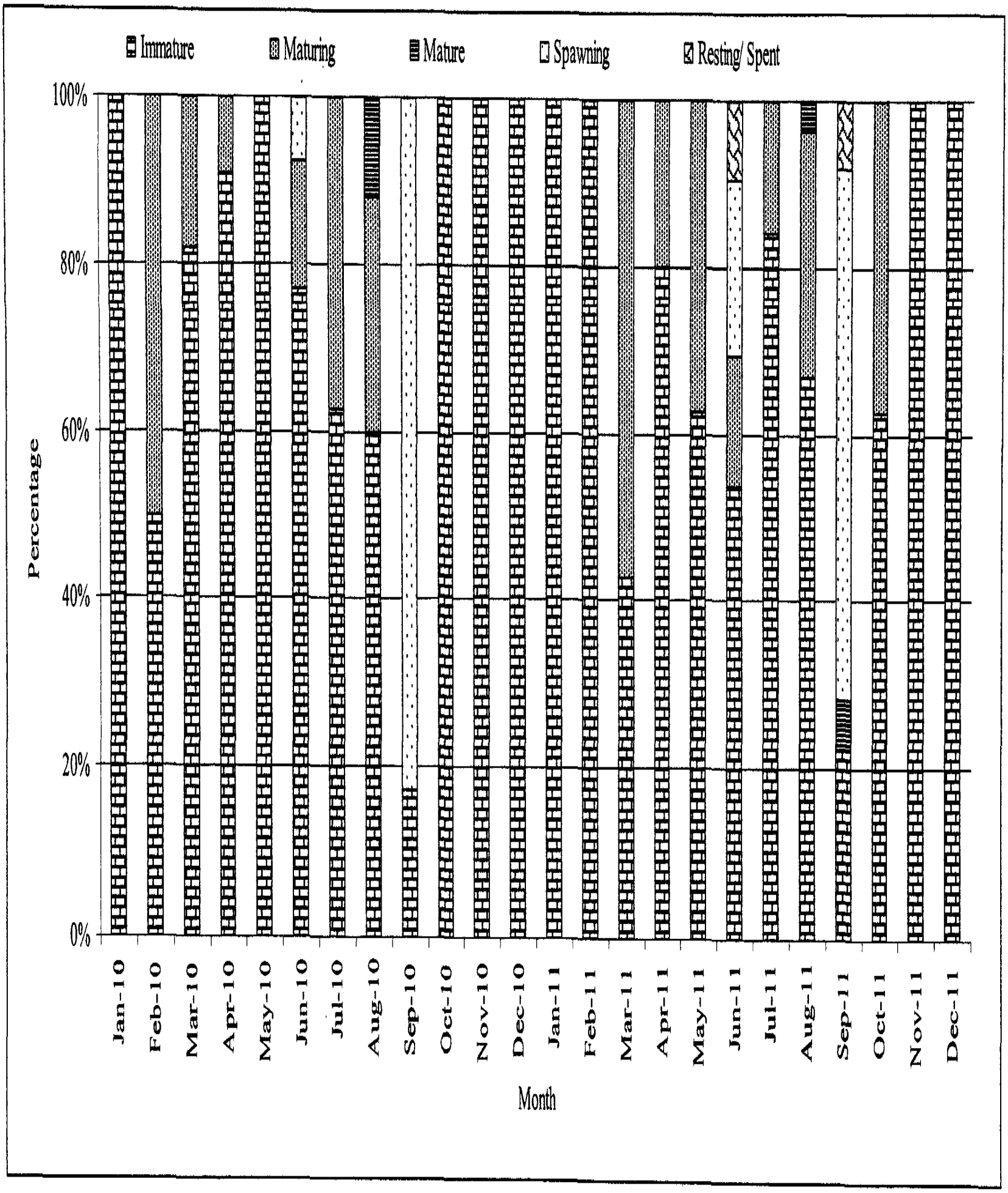


Fig.17. Monthly distribution of maturity stages of female *S. lysan* from January 2010 to December 2011

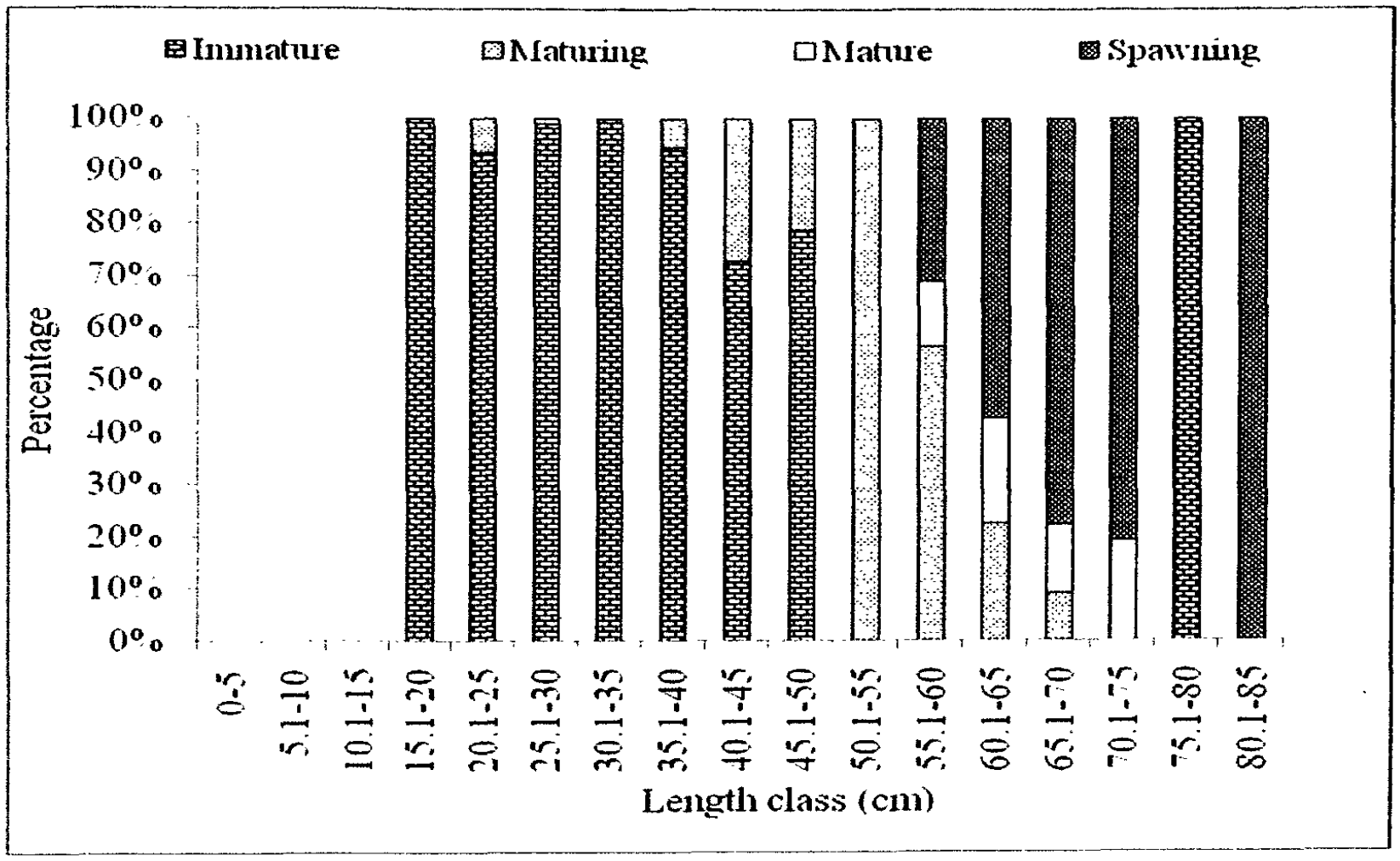


Fig.18. Length distribution of maturity stages of male *S. lysan*

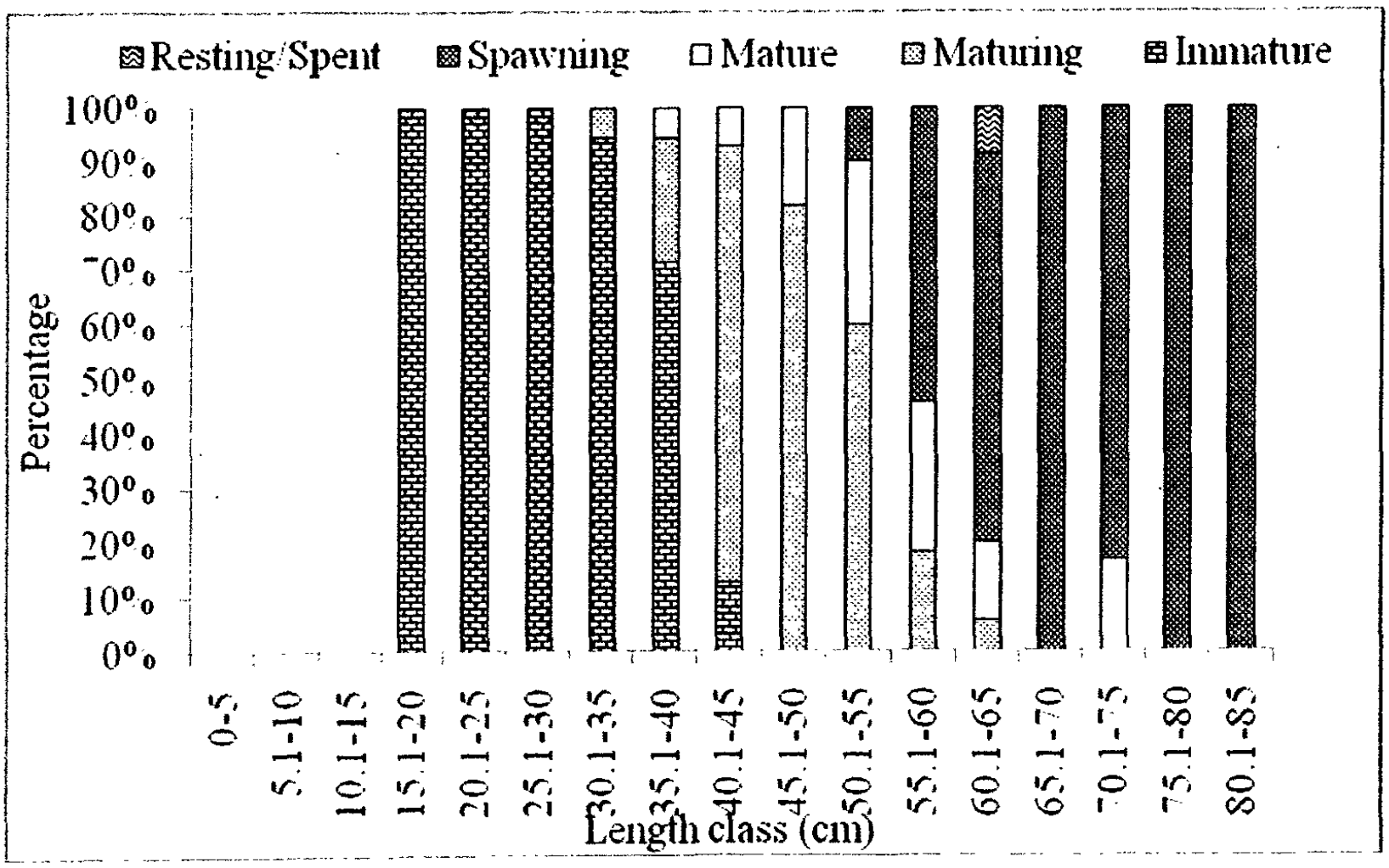


Fig.19. Length distribution of maturity stages of female *S. lysan*

4.9.Occurrence of maturity stages along the study area

Percentage occurrence of maturity stages of male and female with respect to different areas were shown in Fig.20 and 21.

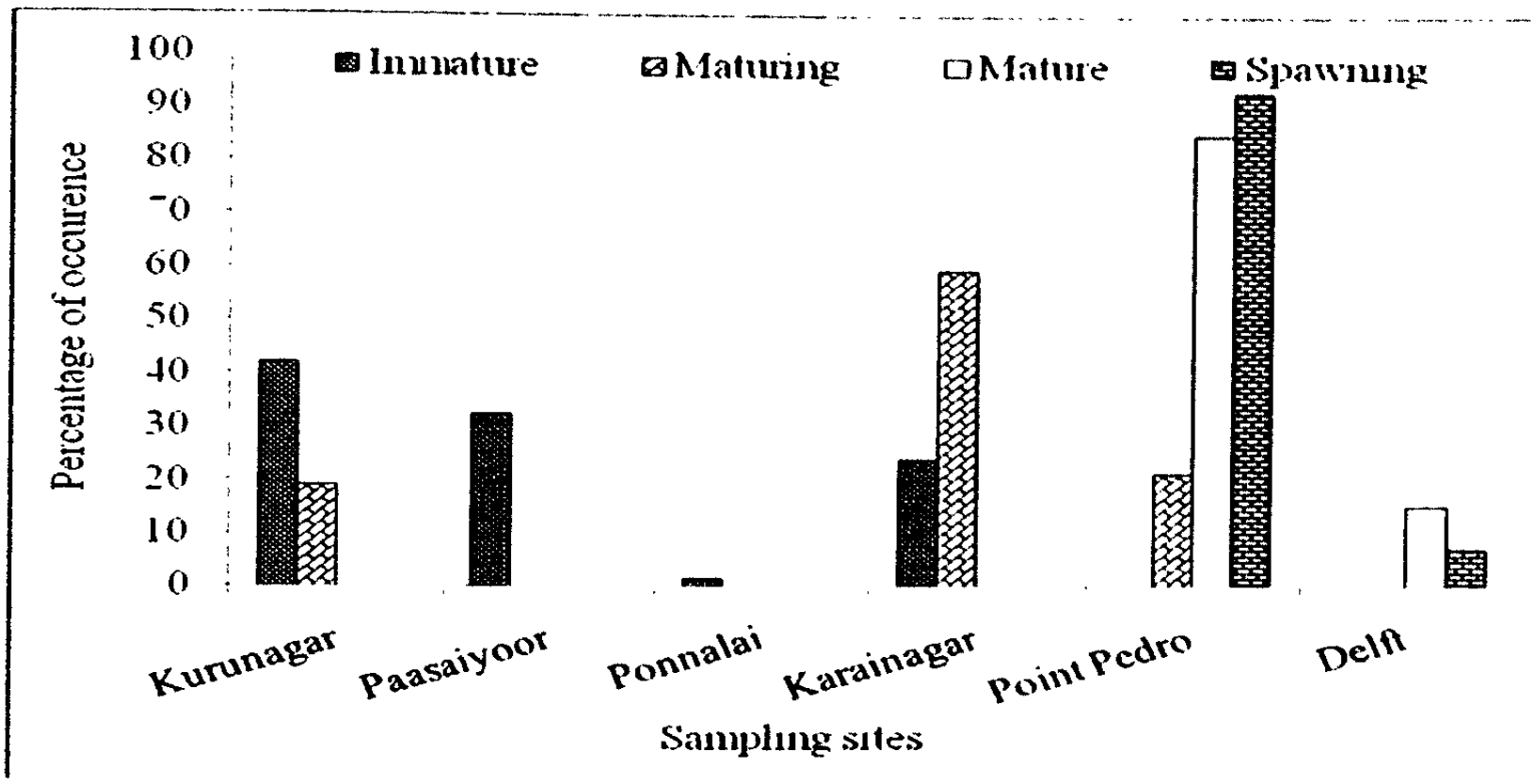


Fig.20. Percentage occurrence of male *S. lysan* in the waters around Jaffna Peninsula.

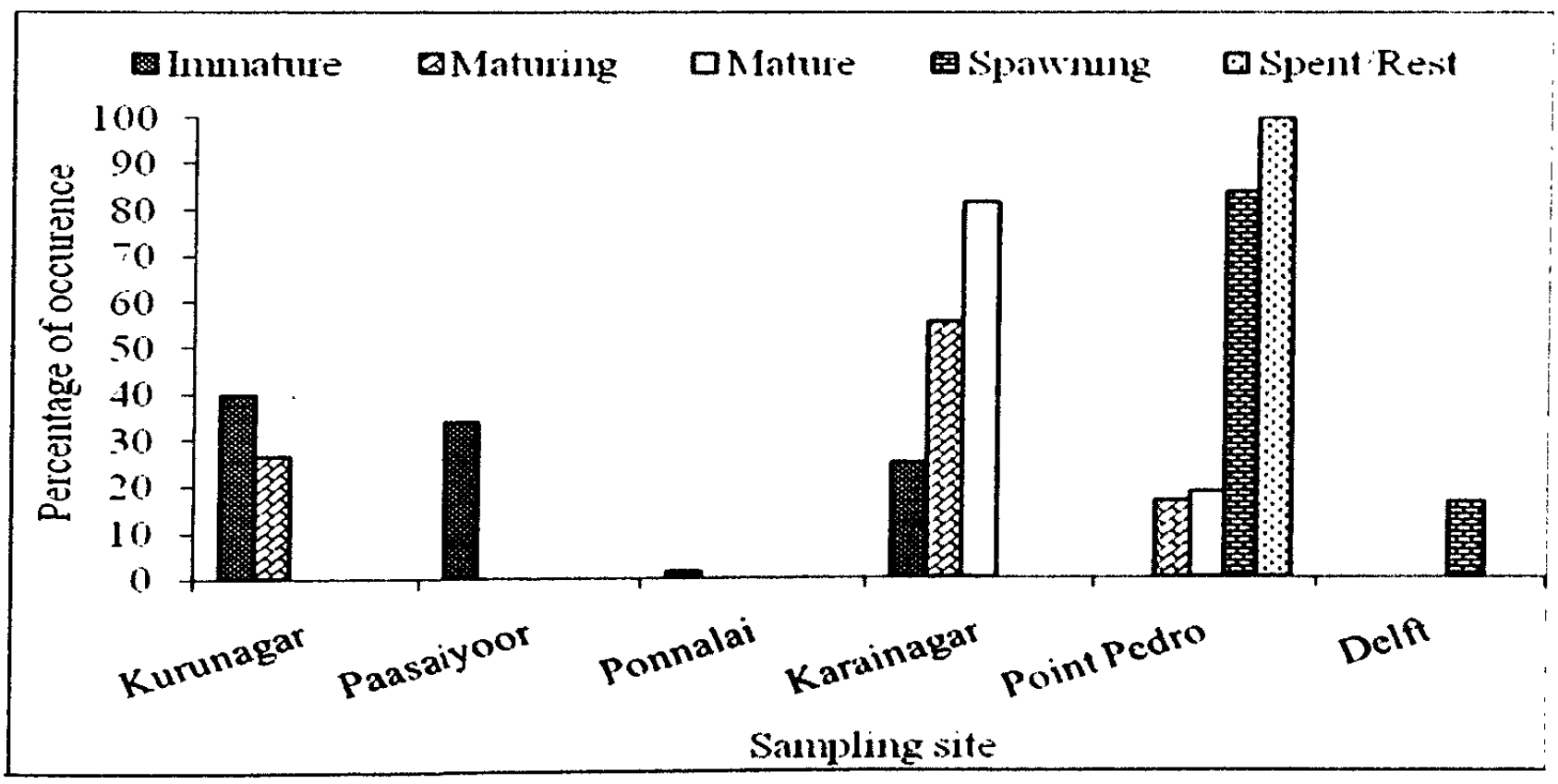


Fig.21. Percentage occurrence of female *S. lysan* in the waters around Jaffna Peninsula.

Within all immature individuals, highest percentage of immature stages of females were found in Kurunagar and Paasaiyoor followed by Karainagar and less than 5 % were found in Ponnalai waters. Paasaiyoor and Ponnalai waters had only the immature stages of both males and females. Maturing stages of both males and females were found in Kurunagar, Karainagar and Point Pedro; whereas mature males were observed in point Pedro and Delft waters and females were observed in Karainagar and Point Pedro waters. Spawning stages of both males and females only found in Point Pedro and Delft. Resting stages of few females were recorded in Point Pedro waters.

Length frequency distribution of maturity stages in different areas for both male and female are shown in Fig.22. Total length of less than 40 cm males and females were only available in the Jaffna lagoon. Fish with greater lengths (>50 cm in Total length) were available only in Point Pedro and Delft region.

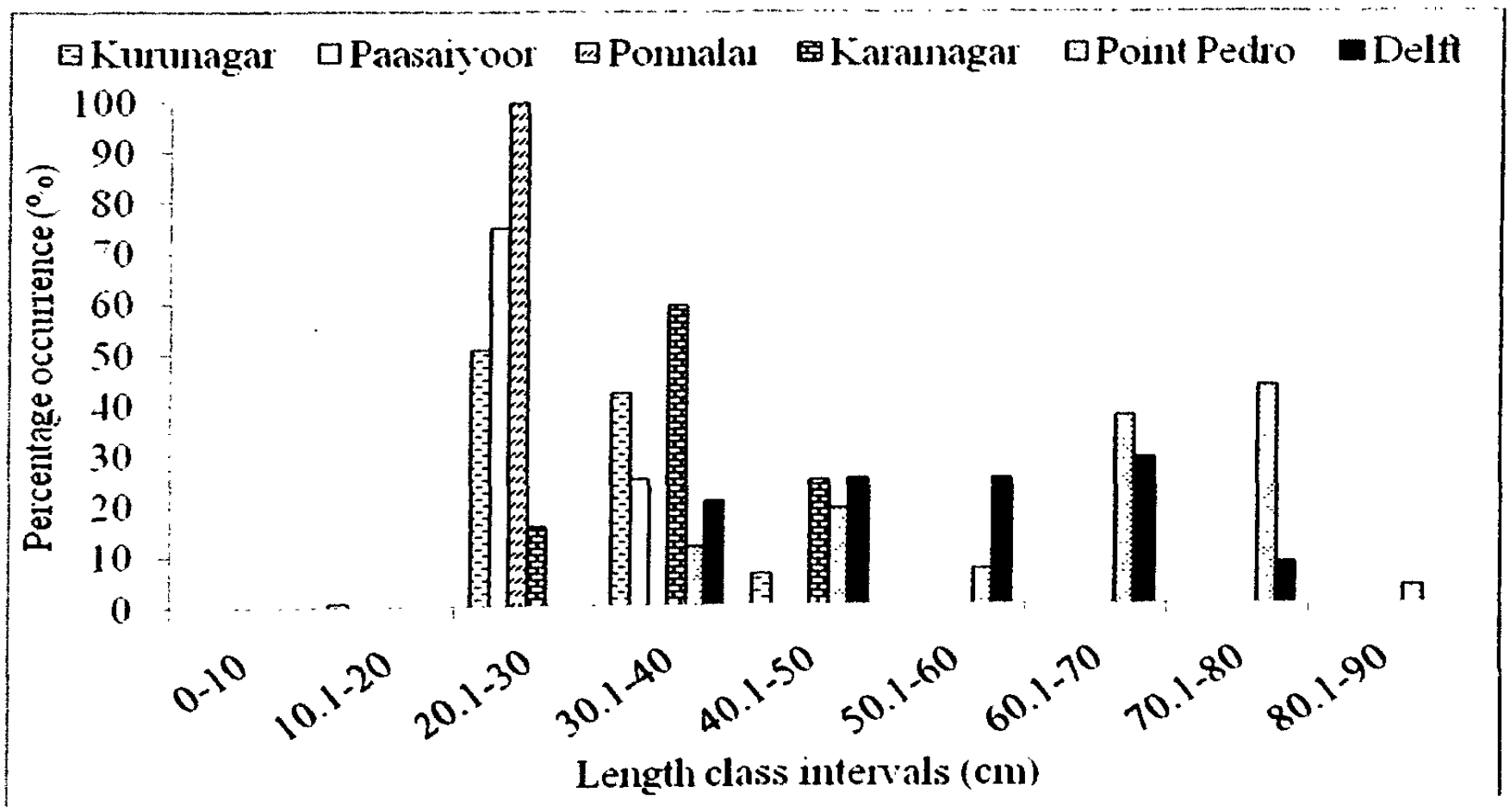


Fig. 22. Length distribution of male and female *S. lysan* present in the waters around Jaffna Peninsula.

4.10. Size at maturity

Probit analysis of proportion mature versus total length for male and female indicates that *S. lysan* male reached maturity at 55.4 cm total length while female reached maturity at 60.7 cm total length. All males and females were mature at 70 cm total length (Fig. 23).

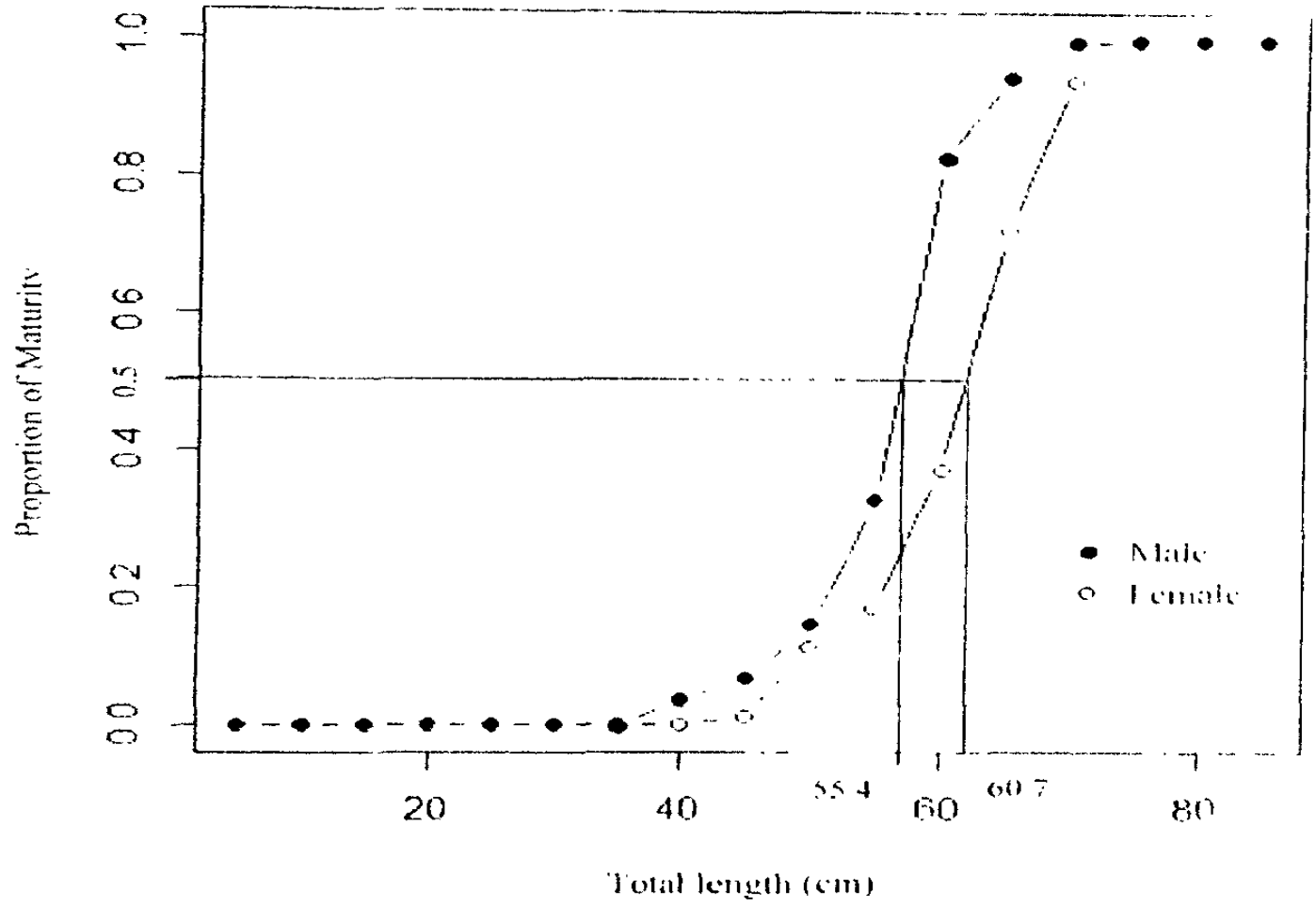


Fig.23. Proportion of sexually mature males and females of *S. lysan* by size class

4.11. Gonado somatic index (GSI)

Variation in GSI values throughout the study period (Fig.24) explained that GSI values of females were always higher than males and it fluctuated with season, attained a peak in September followed by December, March and June.

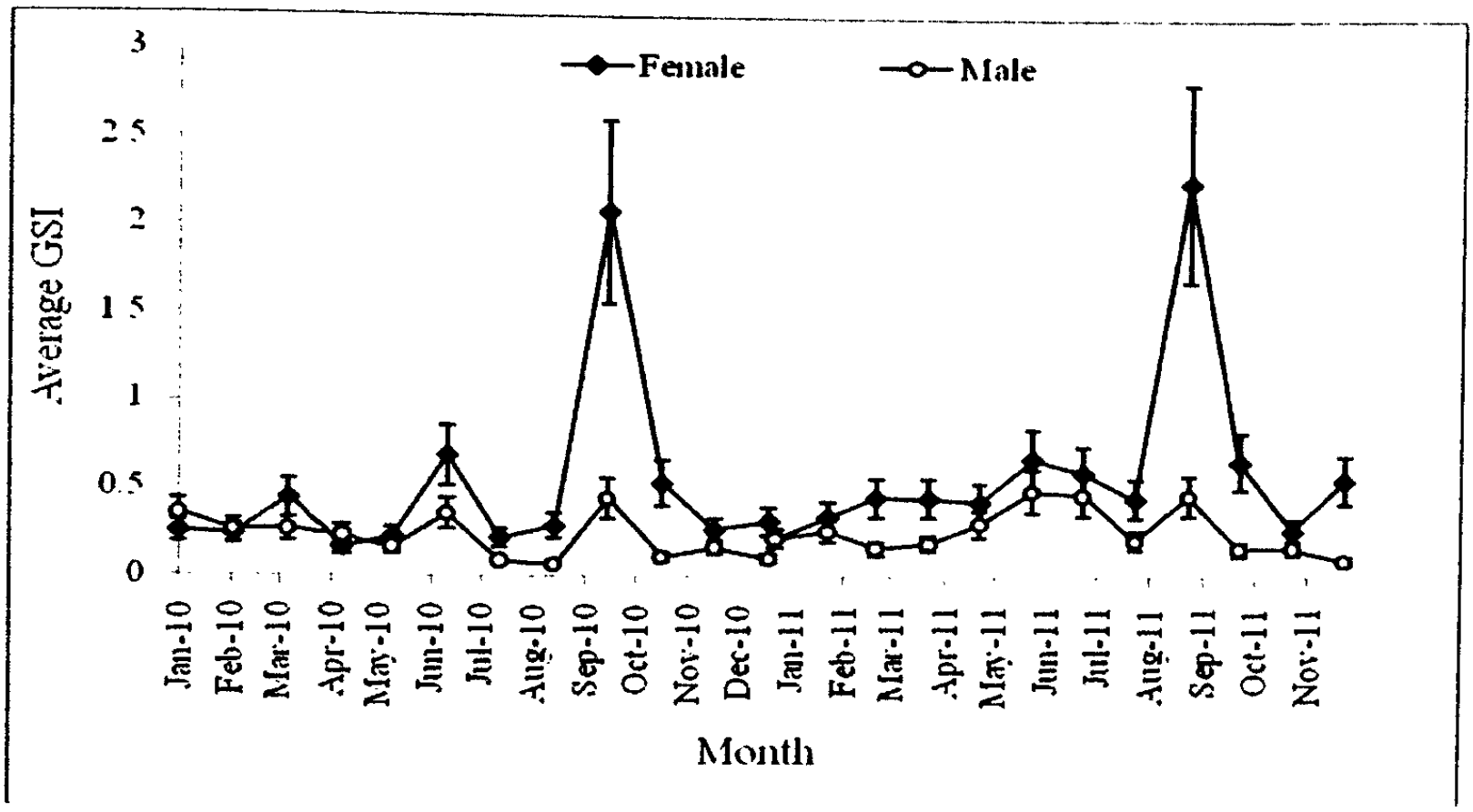


Fig.24. Monthly variation in Gonado somatic index (GSI) of male and female *S. lysan* from January 2010 to December 2011

4.12. Hepato somatic index (HSI)

Hepatosomatic index (HSI) measured in females (Fig. 25), showed similar seasonal patterns with the highest average of 2.05 % in December followed by September.

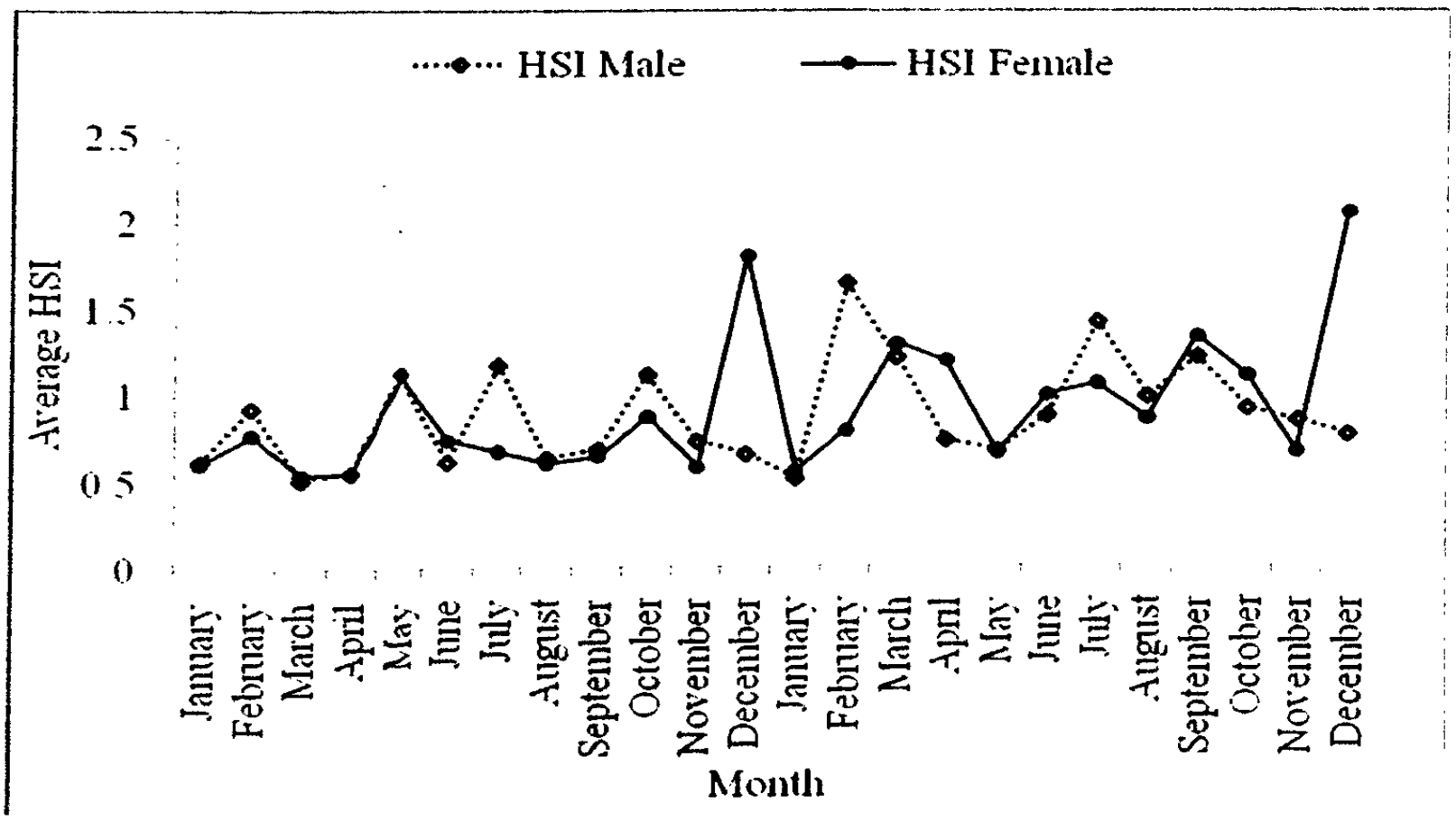


Fig.25. Monthly variation in Hepato somatic Index (HSI) of male and female *S. lysan* from January 2010 to December 2011.

4.13. Fecundity

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). The relationship between fecundity and total length of fish were shown in Fig.26.

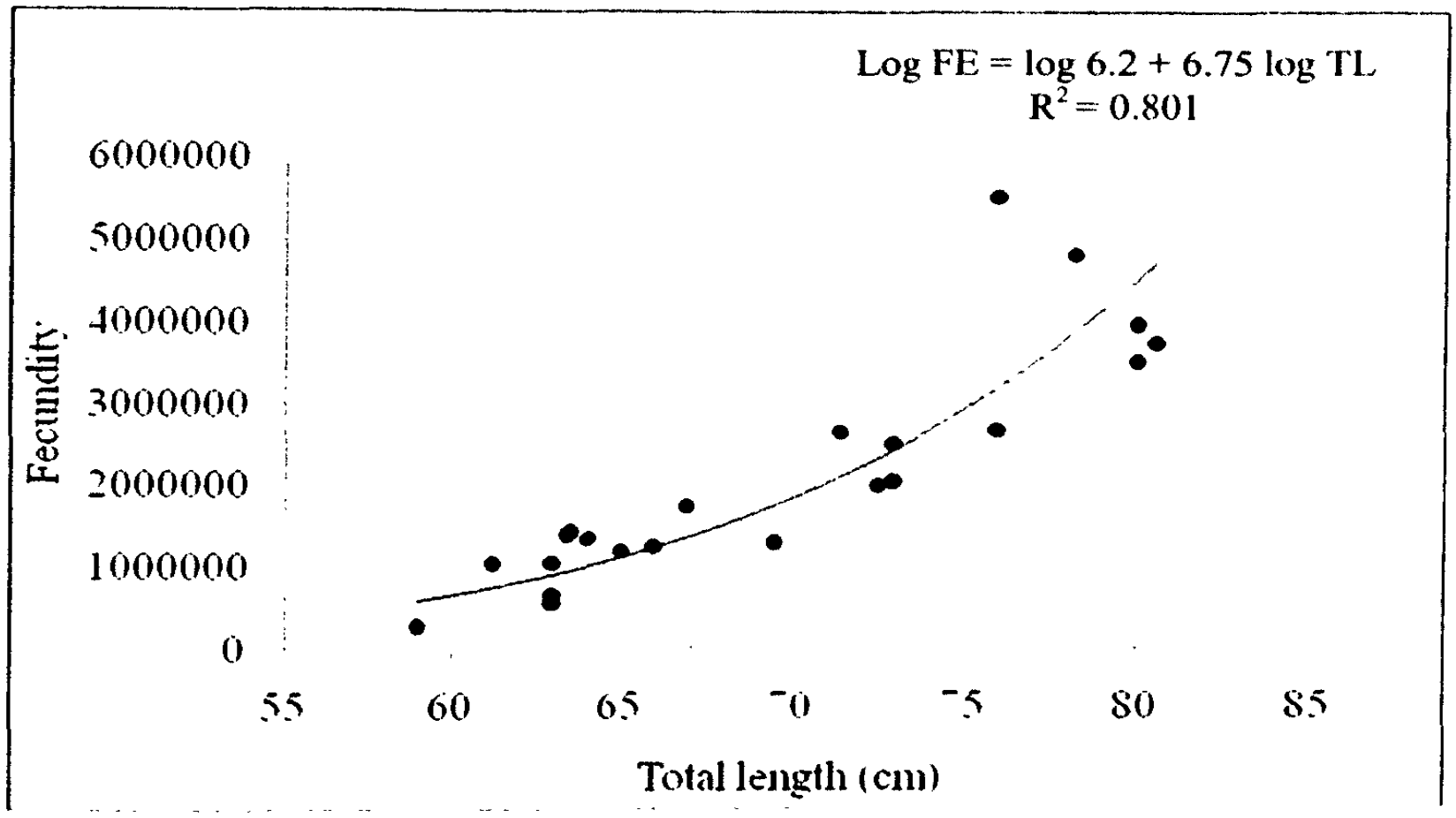


Fig. 26. Relationship between Fecundity and Total length of female *S. lysan*

4.14. Ova diameter distribution

For oocyte diameter distribution studies, ovarian developing stages V and VI were combined as spawning stage. Frequency distribution of various size oocytes in relation to maturity stages were shown in Fig. 27.

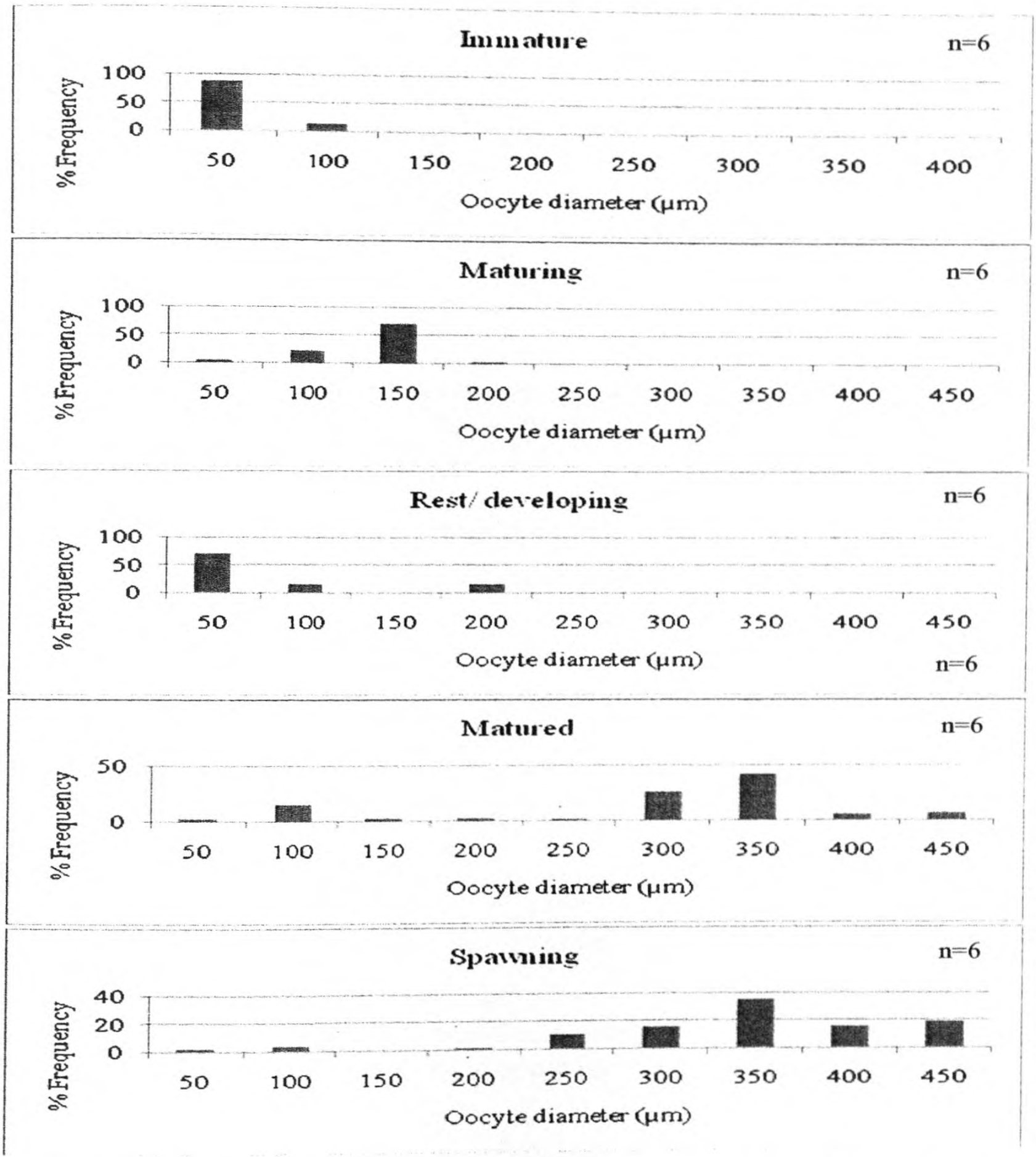


Fig. 27. Percentage frequency distribution of oocyte diameter of various maturity stages of *S. lysan* (n: sample size).

4.15. Linear relationship between testes weight versus fork length, liver weight versus fork length for males and ovary weights versus fork length, liver weight versus fork length for females.

Regression equations and regression parameters for relationships between testes weight versus fork length, testis weight versus total weight and liver weight versus fork length for males are given in Table.4.

Table 4.Relationship of testes weight-fork length, Total weight-testes weight, liver weight-fork length of male *S. lysan* (TEW - Testes weight, FL - Fork length, TW - Total weight, LW - Liver weight).

Parameters	Logarithmic relationship	n	R^2
TEW - FL	Log TEW= 0.246 x log FL + 0.246	668	0.9973
TEW - TW	Log TEW = 1.423 x log TW + 3.78	668	0.7328
LW - FL	Log LW = 2.924 x log FL + 4.023	668	0.6465

Regression equations and regression parameters for relationships between ovary weight versus fork length, fecundity versus ovary weight, fecundity versus total length and liver weight versus fork length for females are given in Table 5.

Table 5. Relationship of ovary weight - fork length, fecundity – ovary weight, fecundity – fork length of female *S. lysan* (OW-Ovary weight, FL- Fork length, FE-Fecundity, LW-Liver weight).

Parameters	Logarithmic relationship	n	R^2
OW-FL	Log OW= 4.5 x log FL + 6.73	760	0.7425
FE-OW	Log FE = 2.4 x log OW + 2.46	111	0.5581
FE-TL	Log FE = 6.75 x log TL + 6.2	22	0.8011
LW-FL	Log LW = 3.183 x log FL + 4.49	761	0.7465

4.16.Age and growth parameters

For age and growth studies, a total number of 1115 *Scomberoides lysan* (525 males and 590 females) were collected from commercial catches and analyzed.

4.16.1. Estimation of $L\infty$ and K

(a). Powell- Wetherall method

Powell- Wetherall plots for estimation of L_∞ and Z/K of male and female *Scomberoides lysan* were shown in Fig. 28a and b. The L_∞ and Z/K values obtained for male and female were 87.96 cm, 2.174 and 88.85 cm, 1.964 respectively.

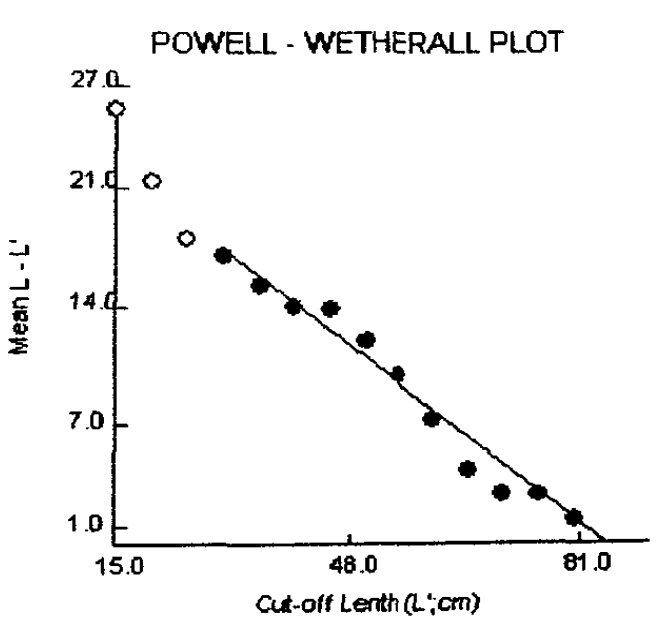


Fig. 28a . Powell Wetherall plot of male *S. lysan*

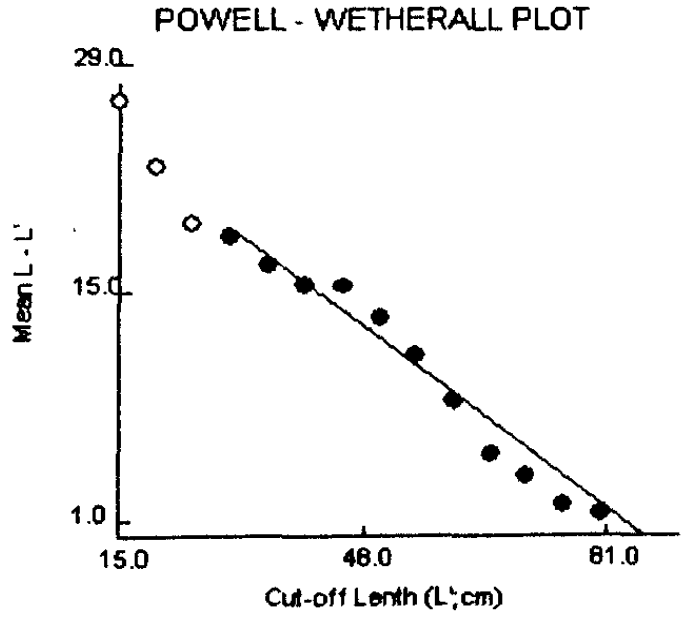


Fig. 28b. Powell Wetherall plot of female *S. lysan*

(b). ELEFAN I method

The optimized values for K obtained by ELEFAN I for male and female were 0.41 year^{-1} and 0.40 year $^{-1}$ respectively whereas L_∞ for male and female were

87.96 cm and 88.85 cm respectively. The oscillation parameter (C) and winter point were assumed to be 0 as it is a tropical species. The non seasonalized restructured length frequency histogram with growth curve is shown in Fig 29a and 29b

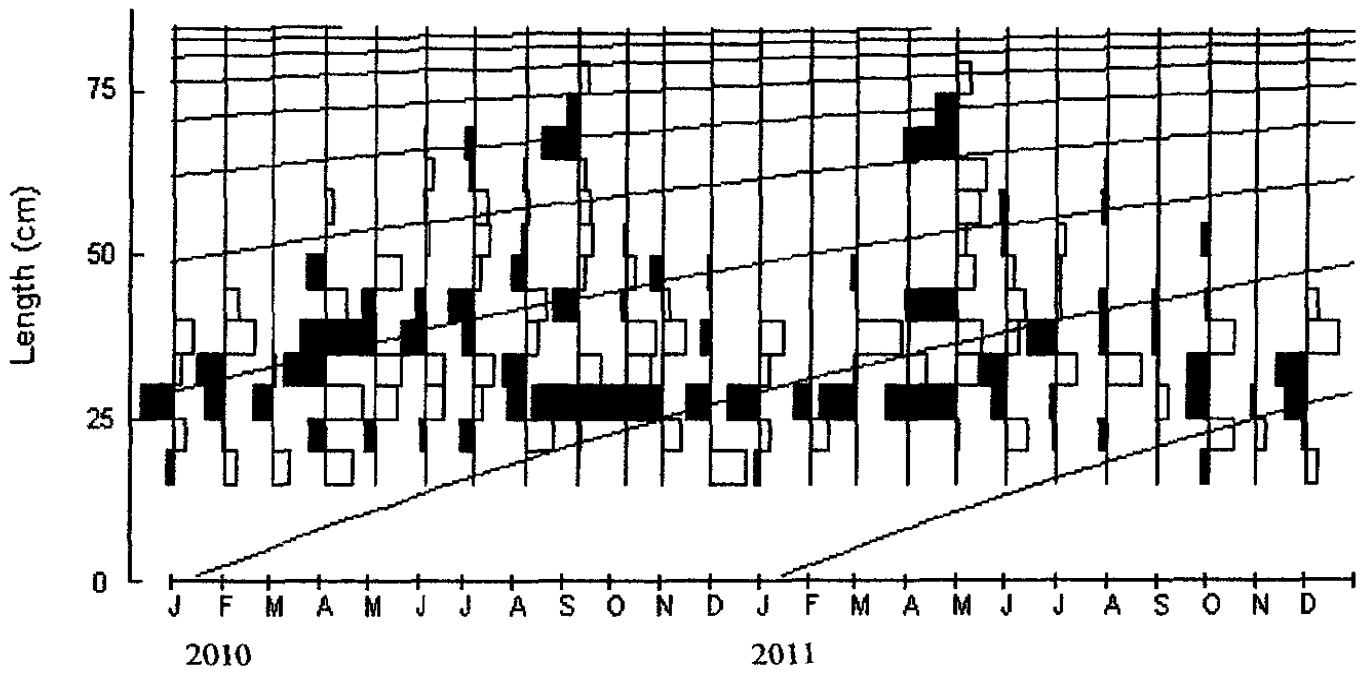


Fig 29a. Growth curve of male *S. lysan* drawn using ELEFAN I programme

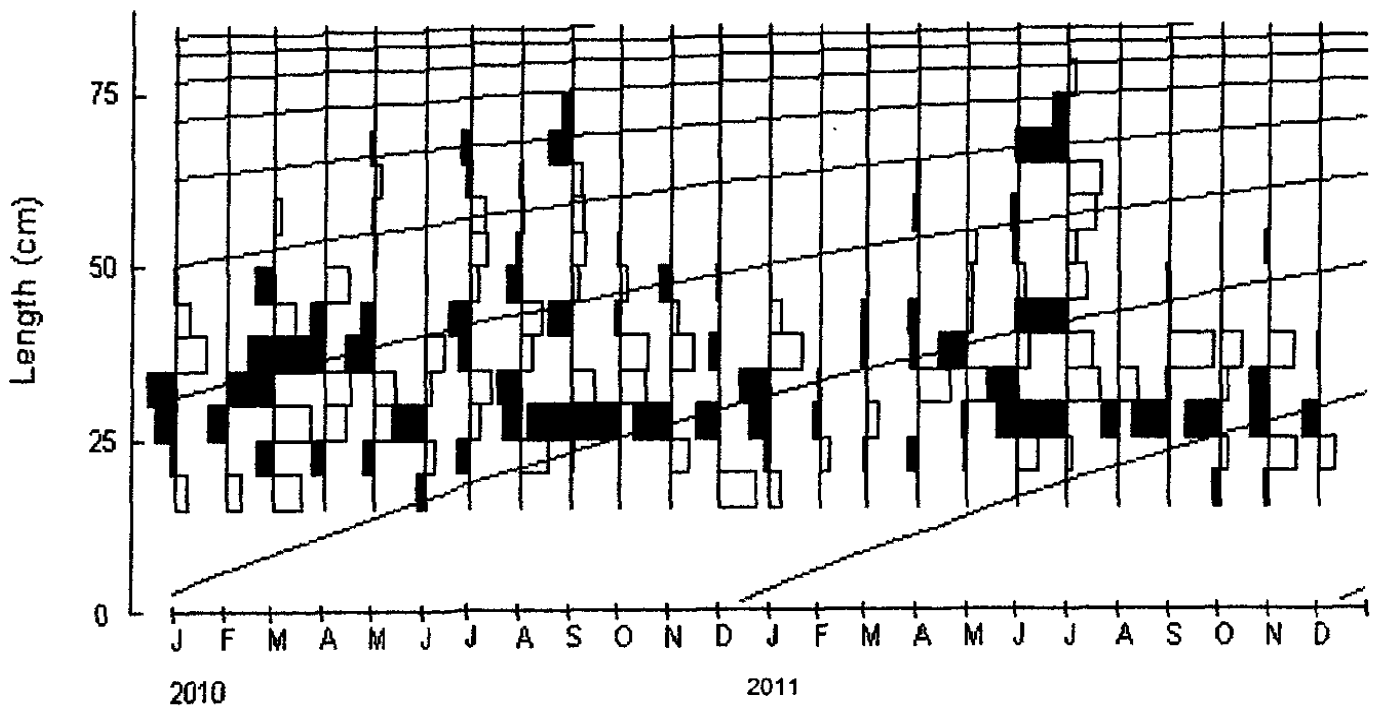


Fig 29b . Growth curve of female *S. lysan* drawn using ELEFAN I programme

4.16.2. Estimation of t_0

The estimated t_0 value for male and females were -0.15829 and -0.16195 respectively.

4.16.3. Age at maturity

The inverse von Bertalanffy equation shows that 50 % of males attained maturity at age 2.266 years (55.4 cm total length) and females at 2.712 years (60.7 cm Total length).

4.16.4. Estimation of longevity

Estimated longevity for male and female *S. lysan* calculated from Paul's equation was 7.317 years and 7.338 years respectively.

4.16.5. Growth performance index (Ø)

The estimated growth performance index for male and female were 3.5013 and 3.4993 respectively.

3.18.6. Reproductive load

The ratio of $L50/L_\infty$ for male and female *S. lysan* were 0.6928 and 0.6832, respectively.

5. Discussion

The presence of four species in the waters around Jaffna Peninsula shows that genus *Scombeoides* is well distributed in the Sri Lankan waters. The maximum total length for male (81.60 cm) and female (80.6 cm) were recorded for the first time in the present study. De B ruin *et al.*, (1994) stated that 75.0 cm total length is the maximum length in Sri Lankan waters and Fischer, W. and G. Bianchi. (1984) recorded 110.0 cm in Western Indian Ocean. Although, Froese and Pauly, (2012) stated that 110 cm in the maximum recorded length but 60 cm is the common length for *S. lysan*.

Different values for the exponent coefficient (b) for different fish have been recorded in different parts of the world. Earlier, Allen (1938) pointed out that the exponent coefficient (b) computed from the length-weight relationship of fishes is usually 3. Later, Carlander (1969) pointed out that the 'b' value is very close to 3.0 but varies between 2.5 and 3.5. Widely accepted concept is that if the exponent value is 3, the fish grows isometrically, if it is greater or less than 3 fish grows allometrically (Tesch 1968). The 'b' value depends on several factors such as age, body shape, and amount of fat present, sex, maturity stage, season, temperature, salinity and available nutrient food (Lagler *et al.*, 1977; Moutopoulos *et al.*, 2002).

Length – weight relationship (LWR) of *S. lysan* have not been studied in Sri Lanka, so far and this is the first study to compute such parameters. Some of the

earlier results on LWR of *Scomberoides* species from other parts of the world are shown in Table 6. In New Caledonia and South Africa respectively 'b' values of 2.896 and 2.685 were obtained for *S. lysan* (Letourneur *et al.*, 1998) whereas 2.937 were obtained for *S. tol* from Karnataka waters, India (Abdurahiman *et al.*, 2004). The 'b' value obtained in the present study for male (2.82) and female (2.89) is very close to the previously recorded values. At the same time *S. lysan* from the present study shows negative allometric growth. However the 'a' and 'b' values obtained for male and female *S. lysan* were superimposed in the plot of log 'a' versus 'b' available for *S. lysan*, Carangidae and 1300 miscellaneous species in FishBase 2012 (Froese and Pauly, 2012) and it is shown in Fig. 30a and 30b.

Table6. The parameters of length –weight relationships of genus *Scomberoides* from different regions of the world (SL= standard length, FL= Fork length, TL= Total length)

Species	Sex	N	Length type	a	b	Region	Source
S. lysan	all	68	SL	0.0579	2.685	South Africa	Letourneur *et al.*,1998
S. lysan	all	14	FL	0.0149	2.896	New Caledonia	Letourneur *et al.*, 1998
S. lysan	all	14	FL	0.0109	2.923	New Caledonia	Letourneur *et al.*, 1998
S. tol	male	59	TL	0.007	2.937	Karnadaka, India	Abdurahiman *et al.*, 2004
S. commersonnianus	all	306	TL	0.00004	2.792	Northern Australia	Griffiths *et al.*, 2005
S.lysan	male	525	TL	0.0112	2.82	Northern waters of Sri Lanka	Present study
S. lysan	female	590	TL	0.0087	2.89		

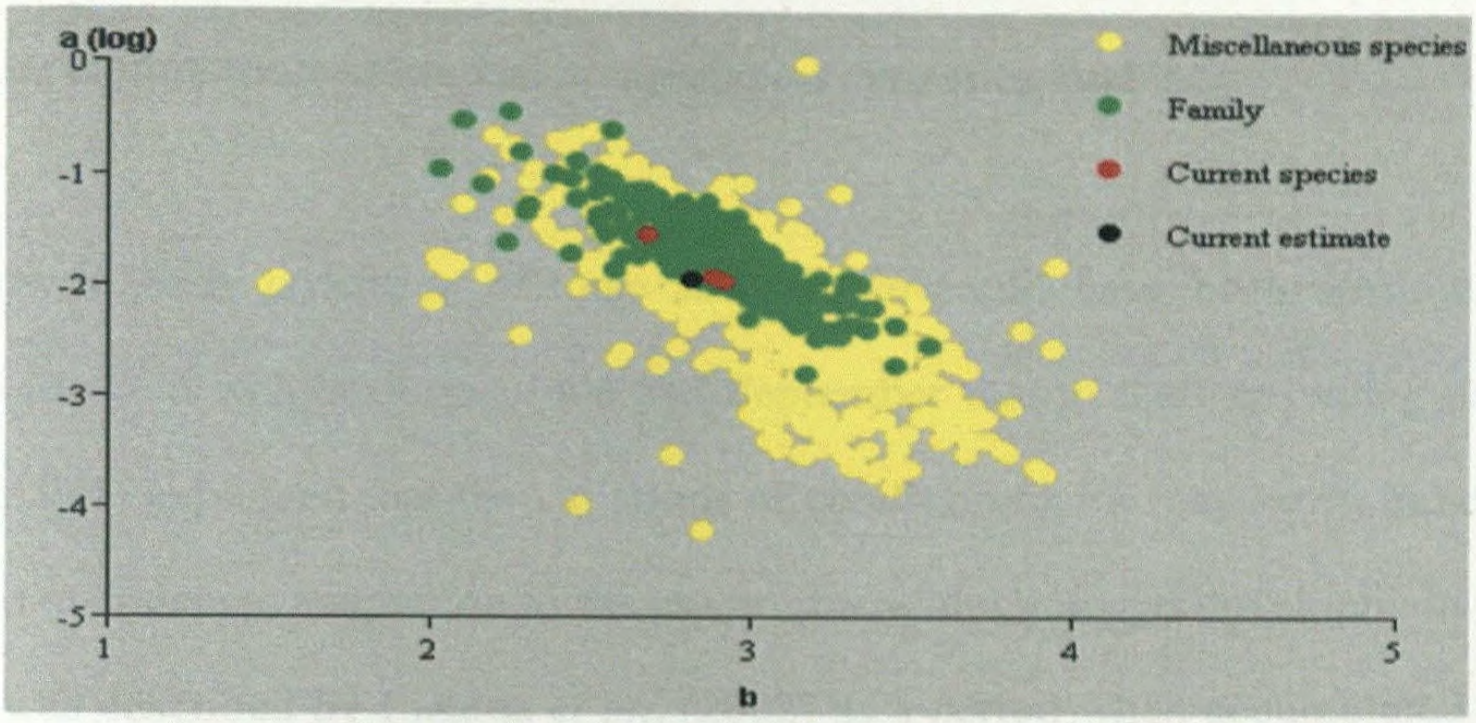


Fig. 30a. Plot of log 'a' versus 'b' for male *Scomberoides lysan*

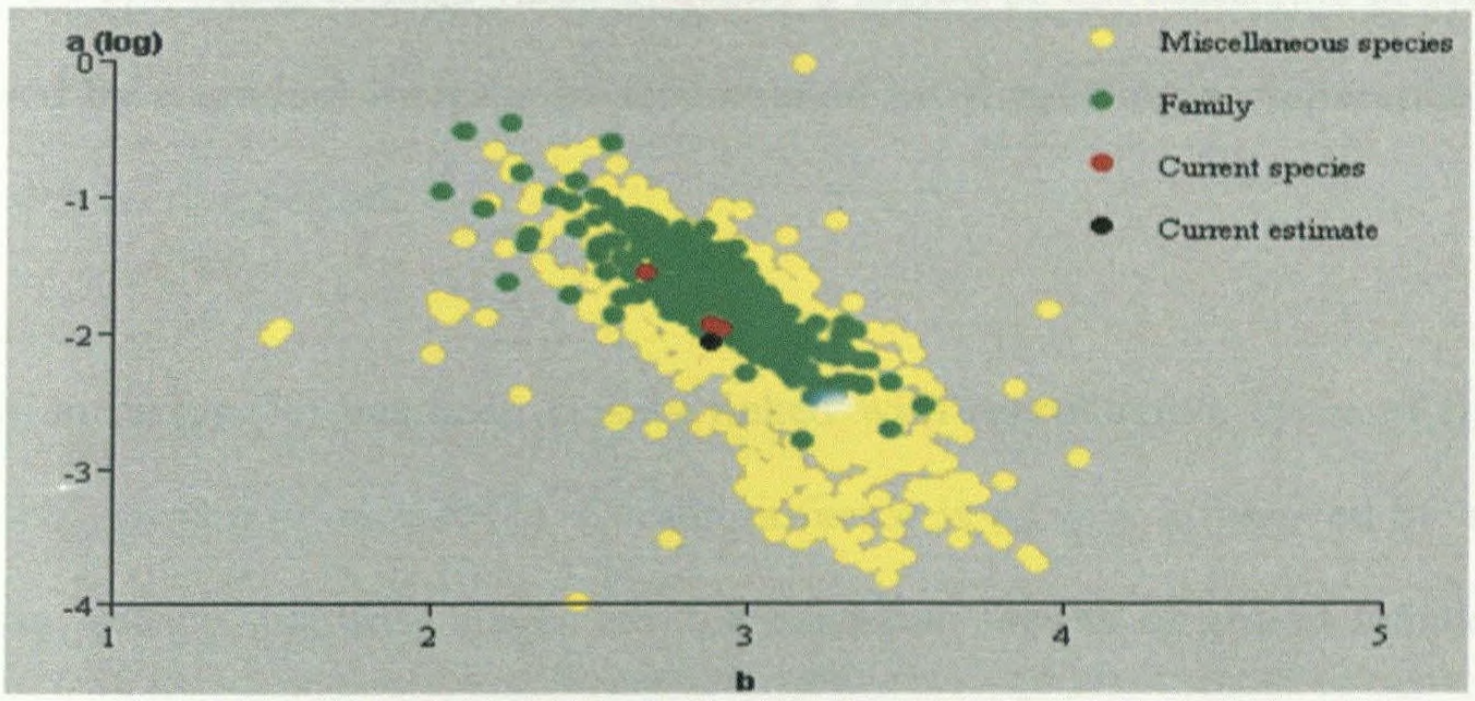


Fig. 30b. Plot of log 'a' versus 'b' for female *Scomberoides lysan*

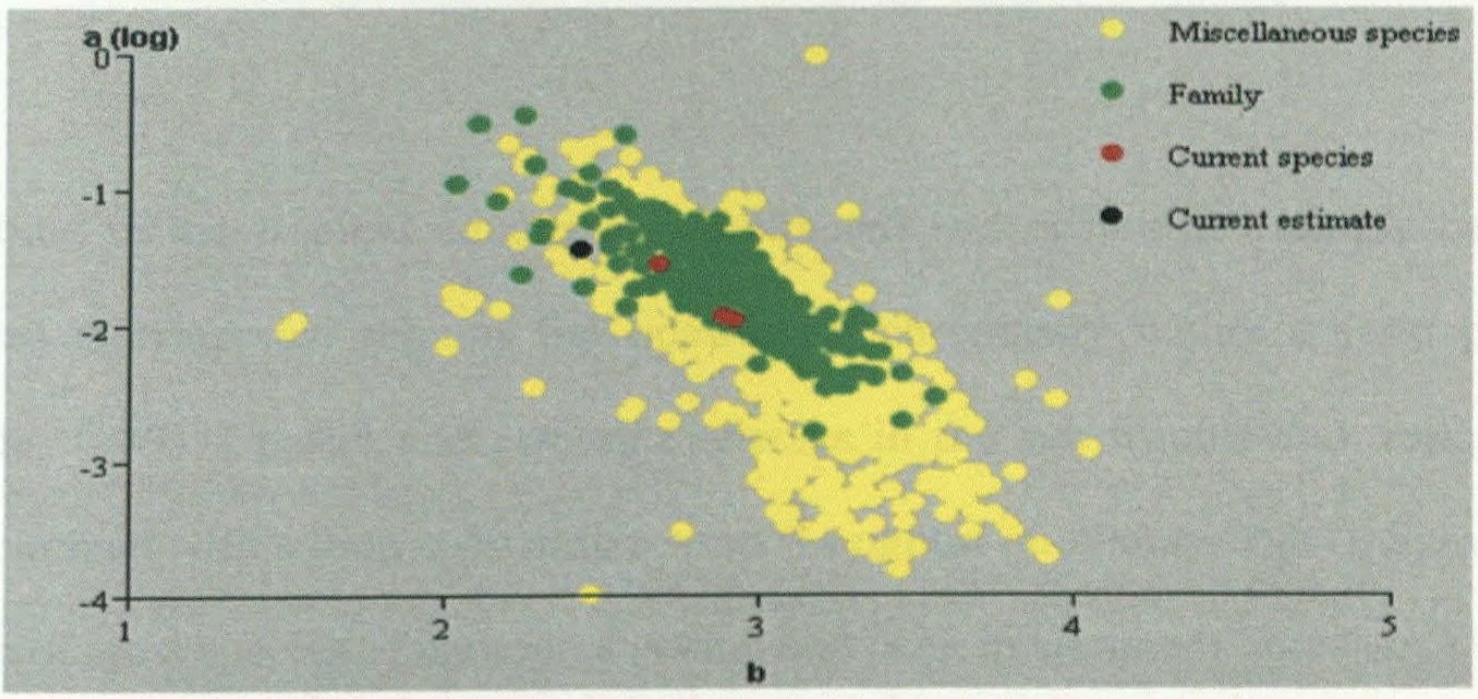


Fig. 30c. Plot of log 'a' versus 'b' for unsexed *Scomberoides lysan*

The parameters obtained from the study are useful fundamental factors applicable in future culture trials as well as in population dynamics studies.

The lowest body condition of male and female could have been attributed by sudden drop in weight during June and September due to their spawning nature. King (1995) explained that the variations of condition factor may be an indication of food abundance, adaptation to the environment and gonadal development. Low value was described by Lizama *et al.*, (2002) as a period when accumulated fat is in use for spawning. A high value indicates a period of increased rate of feeding, followed by a gradual increase in accumulated fat suggesting a preparation for a new reproductive period.

Condition factor (K) has been closely linked with reproductive cycle of fish, as stated by Lawson *et al.*, (2011). Condition factor is usually influenced by age of fish, sex, season, maturity stages etc. the condition factors of gravid females are usually higher but decrease after the eggs are shed (Anyanwu *et al.*, 2007; Lagler, 1997).

Spawning in the tropical countries is protracted and occurs in multiple batches whereas in temperate regions fish spawns synchronously within a short period (Houde, 1989). Coastal and estuarine teleosts in the sub tropics and tropics are characterized with a long spawning season (Longhurt and Pauly, 1987). Spawning season of most species of carangids is long and peak in summer (Thresher, 1984).

Macroscopic and microscopic structural changes on the ovaries of teleost were studied by various researches (Saeed *et al.*, 2010). Macroscopic staging system also revealed that it spawns more than once during its life span. At the same time macroscopic studies based on the colour and appearance is a cheaper and faster method (Mackie and Lewis, 2001).

In the present study, seven maturity stages of ovary were identified according to the macroscopic and microscopic analysis. Yamamoto and Yamazaki (1961) recorded ten developmental stages of ovary and Cerisola (1984), characterizes oocyte development into 8 stages of maturation. Histological studies on S. *lysan* explain the detailed developmental changes in the gonads during maturation. Rest / developing, pre spawning and partially spawned stages of ovary were clearly identified by microscopic staging only and it is the only way to identify commencement of reproductive activity by the proliferation of follicular cells in the peri nuclear stage of ovary.

The presence of spawning and spent stage ovaries with hydrated oocytes and post ovulatory follicles clearly explain the spawning season as June and September. Collection of rest / developing stage is a strong evident for the spawning pattern. Hunter and Macewicz (1980) suggested that the best indicator of the time of spawning was the occurrence of both hydrated eggs and post ovulatory follicles. The hydration stage is very short in duration and may not be commonly observed (Stahl and Kruse, 2008).

In the present study, GSI values of females and males indicate that *S. lysan* have an intense spawning season in September followed by less reproductive activity during June, December and March. It clearly explains that *S. lysan* spawns more than once a year in Sri Lankan waters. The small peaks during December and March may be due to the availability of few immature individuals. It was also observed on the studies of *S. commersonianaus* from the western Australian waters (Griffiths *et al.*, 2005).

Yamamato and Yamazaki. (1961) explained that some carangids are synchronous where all oocyte develop at the same time, spawn at once; others serial / batch spawners, ovary contain batches of oocyte at different stages of development leading to multiple spawning. The Talang queen fish, *Scomberoides commersonianus* from the Western Australian waters also shows two spawning peaks during November and February (Griffiths *et al.*, 2005). Pillay *et al.*, (1987) reported that *S. lysan* spawn at least twice during the spawning season.

Fecundity studies also support the spawning season as spent fish was available only during June and September. Honebrink (2000) stated that fecundity of *Caranx melampygus* 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 queen fish *S. commersonnianus* in Australian waters. Fecundity of *S. lysan* varies between 800 000 and 3500 000 in a study by Pillay *et al.*, 1987 along the Indian coast. In the present study, it varies from 24 655 to 82 562 542. Pre anal fin length, ovary free body mass and age were regressed against

fecundity to determine the strength and nature of the relationship (Rodveller *et al.* 2010). Statistically significant relations were found between the absolute fecundity and the body weight and gonad weight in *Cobitis* sp from the babolrud (Mousavi Sabet *et al.*, 2011).

The exponential value is usually reported as "3" when fecundity is related to length and "1" when fecundity is related to weight. However the values may vary from 2.3 to 5.3 for a great variety of fishes (Bagenal and Braum, 1978). In the present study exponential value of 6.75 (R^2 = 0.801) was obtained for *S. lysan* which is beyond the already reported value. This may have attributed due to changes in the environment such as temperature, salinity, oxygen, food supply and nutrients.

Fluctuations in Hepatosomatic index also explained the energy consumption and usage of stored energy in the liver. Female fishes cease their feeding activity during spawning. Therefore stored energy can be used during that period. Lowest value were observed during May to September for females; it should be an indicator for the preparation of spawning and peak during November to January may be due to the high feeding activity of immature and maturing individuals.

Distribution of maturity stages within the study period also explained that November, December and January months were dominated by immature individuals.

S. lysan females attained its maturity in larger length class 55-60 cm and males attained maturity within the length class 60-65 cm. Size at maturity reported for *S. lysan* in the present study showed that the capture of *S. lysan* less than 65 cm should be discouraged. Griffiths *et al.*, (2005) stated that *S. commersonnianus* from Northern Australia mature in larger lengths (60 - 70 cm fork length). Availability of immature stages throughout the year and size variation among maturity stages also explained that this species spawn more than once a year and could have long lifespan.

Among the sampling sites, Paasaiyoor, Kurunagar are located within the Jaffna lagoon; Ponnalai located in the entrance of Jaffna lagoon. Karainagar fishing area is directly connected to the Indian Ocean but it is found very close to the northern entrance of Jaffna lagoon. Delft Island is located in the Indian Ocean, southwest direction to the Jaffna Peninsula; Point Pedro located in the Northeast tip of Jaffna Peninsula. The fishing area for queen fishery in Delft and Point Pedro are directly connected to the Indian Ocean of which Point Pedro waters included into the Pedro bank.

Occurrence of maturity stages along the study area explained that only immature and maturing stages of both male and female *S. lysan* were found in lagoon shallow waters. It is also supported by previous records on Hawaii waters (Honebrink, 2000; Froese and Pauly, 2012): *S. lysan* fry entered the estuaries during the late summer, from January through April; at sizes of 20 to 30 mm. Juveniles tolerated salinity ranges of 6.5 to 35 ‰, and sub adults from 0.5 to 35

‰. All size classes were found in water of low turbidity. Gosline and Brock (1960) noted that in Hawaii, juveniles of one to four inches in length are often found in shallow brackish water.

Several researchers have reported that the juvenile stages of *Scomberoides lysan* inhabit in estuaries such as in Subtropical Queensland estuary, Australia by Morton (1992); in Sikao Creek mangrove estuary, Trang, Thailand by Tongnunui *et al.*, (2002); in South African estuary by Whitfield and Harrison (2003). Blaber and Cyrus (1983) reported that only juveniles and sub adults of *S. lysan* utilize the estuary. Juveniles of many members of the piscivorous fishes such as the carangids, sphyraenids and scombroids are commonly reported from estuaries in the tropical Indo- West Pacific (Blaber 1980, Blaber *et al.*,1985, 1989, Blaber & Milton 1990).

However individuals less than 14.10 cm in total length were not recorded during the study period. This may be due to the gear selectivity between the area of spawning (Point Pedro and Delft waters) and Jaffna lagoon or the migrating pathway may not be covered by sampling. The reason for the landings of immature and juvenile queen fishes is attributed mainly due to the selectivity of gear (Pillay *et al.*, 1987).

According to the presence of maturity stages along the sampling area, *S. lysan* in northern Sri Lankan waters could be a migratory species. Because there was no matured or spawning or spent *S. lysan* captured in the lagoon waters; and there

was no immature stage captured in Point Pedro or Delft region. Also it may have been influenced by the monsoons and water currents around Jaffna Peninsula. This is in confirmation with the findings of Sivasubramaniam (2001) that Sri Lankan fisheries were initially influenced by the two monsoon seasons, such as Northwest monsoon primarily from November to February and the Southwest monsoon primarily from May to August.

Sex ratios vary among different fish species, this variability may be due to true differences in the composition of local populations or it may be an artifact of sampling strategies rooted in seasons covered or gear biases. In the present study sex ratio not differ significantly differ from a 1:1 ratio during most of the months. However male *S. lysan* were more compared to females during the spawning period and such preponderance could be due to migration of females to relatively deeper waters for spawning or behavioral differences between the two sexes (Blaxter and Hunter, 1982).

Spent females collected were very rare in the present study, constituting only 2 % of the total sample analyzed microscopically. It appears that the coastal, offshore and deep sea fishing of the country may not be currently exploiting spent individuals because females retreat to deeper waters prior to spawning thus escaping from the capture fishery.

This is the first attempt to describe the age and growth parameters of *S. lysan.* Few studies were done on *S. commersonianus.* The von Bertalanffy growth

parameter L_∞ and K of *S. lysan* from the present study differ from *S. commersonianus* from the Australian waters (L_∞ = 140.4cm FL, K = 0.10 year $^{-1}$) reported by Griffiths *et al.*, 2006 and from the Iranian waters (L∞ =122 cm FL, K = 0.37 year -1) by Taghavi Motlagh *et al.*, 2005. This variation could be due to the different maximum length and different geographical region of *S. commersonianus*. High value of growth coefficient K of both male and female *S. lysan* from the present study indicate that this species grow faster than the *S. commersonianus*. The results from the present study gave fundamental data for the population dynamics and stock assessment studies of *S. lysan*.

An exploited stock is renewed by means of recruitment through reproduction. If indiscriminate harvesting of a population occurs the number of fishes that reach maturity is reduced to an extent at which the reproductive capacity of the population is diminished. One way of reducing this possibility 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 total length, fishes up to 60.7 cm should not be caught.

As the peak spawning season is September and June the breeding females of *S. lysan* shall be protected during this period in order to maintain 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 ocean. Disseminating these findings to the fishermen through fishermen co-operative societies and ministry of fisheries is an indispensable part of such management decision.

6. Concluding comments

The double spotted queen fish *Scomberoides lysan* in the waters around Jaffna Peninsula is a shows intense spawning during June and September months. The ovulation pattern is group synchronous. To protect the species in a sustainable level, *S. lysan* shall be protected during the peak spawning season such as September and June. The results obtained from the present study can be used in the management of *S. lysan* from the Sri Lankan waters to ensure the sustainable utilization and in mariculture of this species.

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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 commersonnianus* 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,

$$X^2 = \Sigma\ [|o-e| - 0.5]^2 \cdot e^{-1}$$

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):

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

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:

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

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-

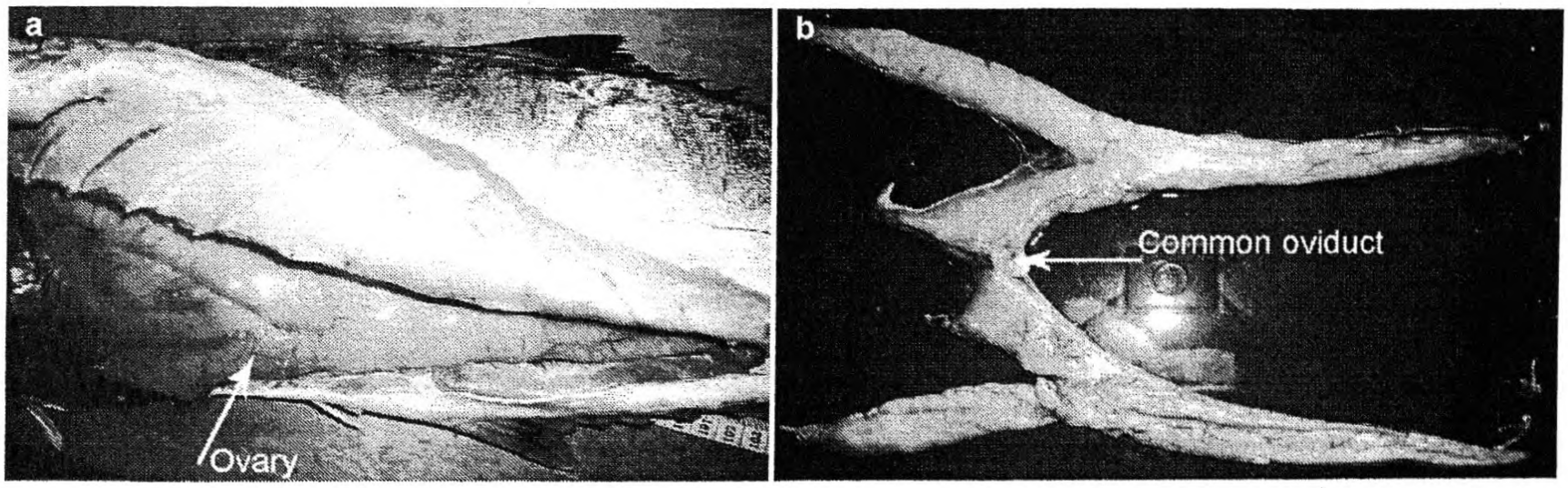

Fig. 1. Ovaries of *Scomberoides lysan*: right lobes (**a**) and whole ovary (**b**) with left and right lobes opens via common duct

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 lager 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

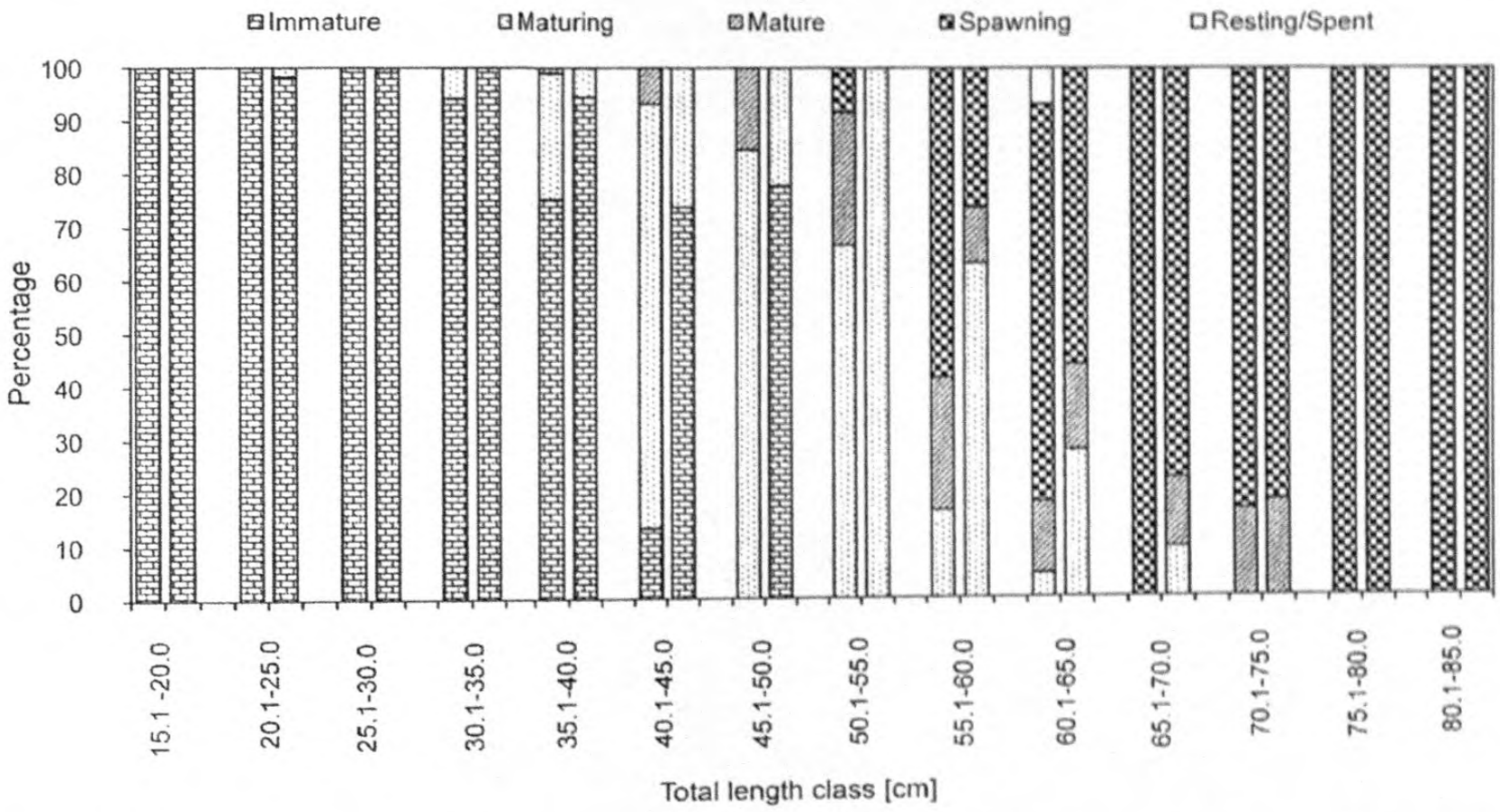

Fig. 2. Relative occurrence of respective gonad maturity stages in individual length classes of female and male *Scomberoides lysan* (F = female, M = male)

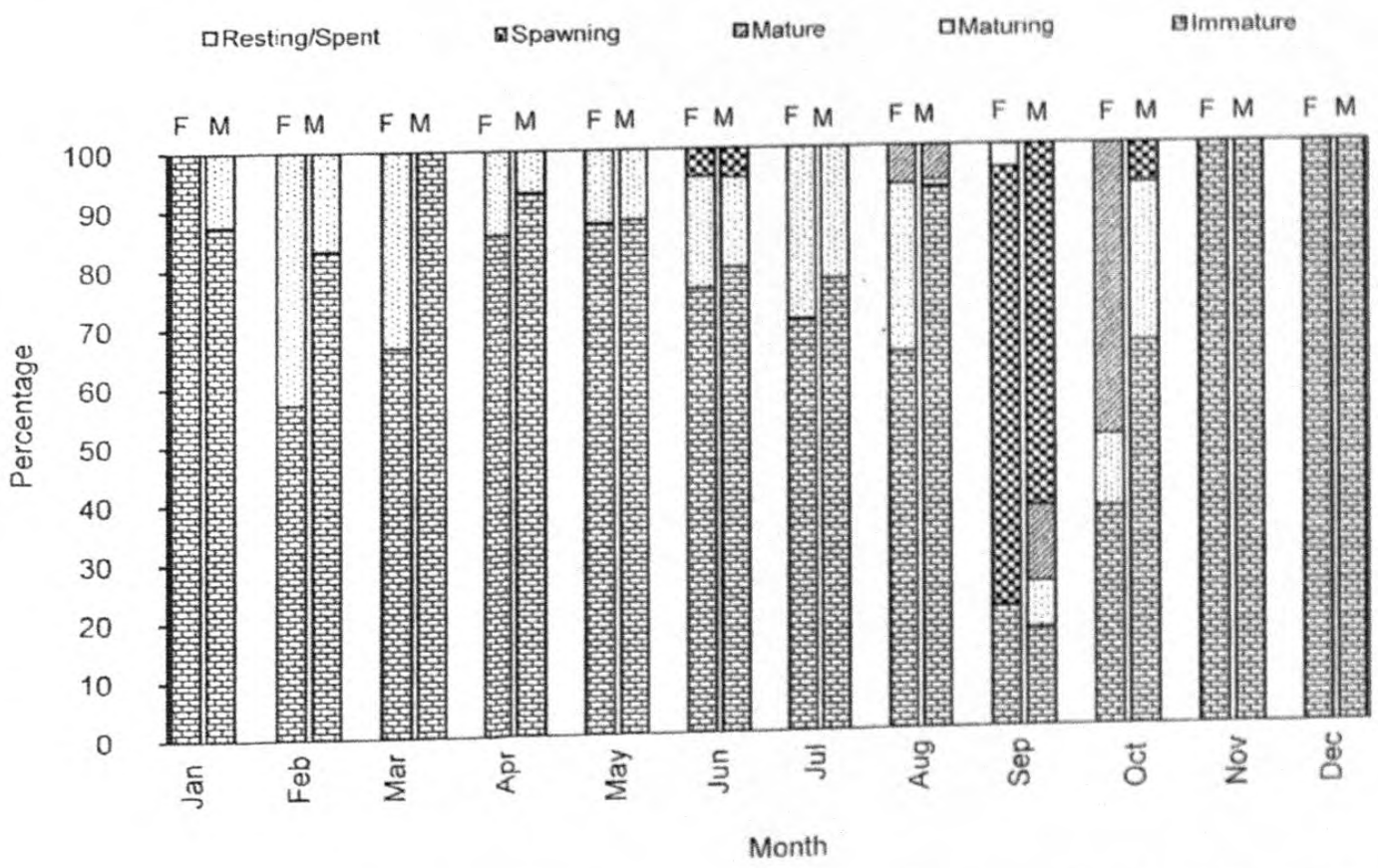

Fig. 3. Relative occurrence of respective gonad maturity stages in females and males of *Scomberoides lysan* sampled in consecutive months (F = female, M = male)

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

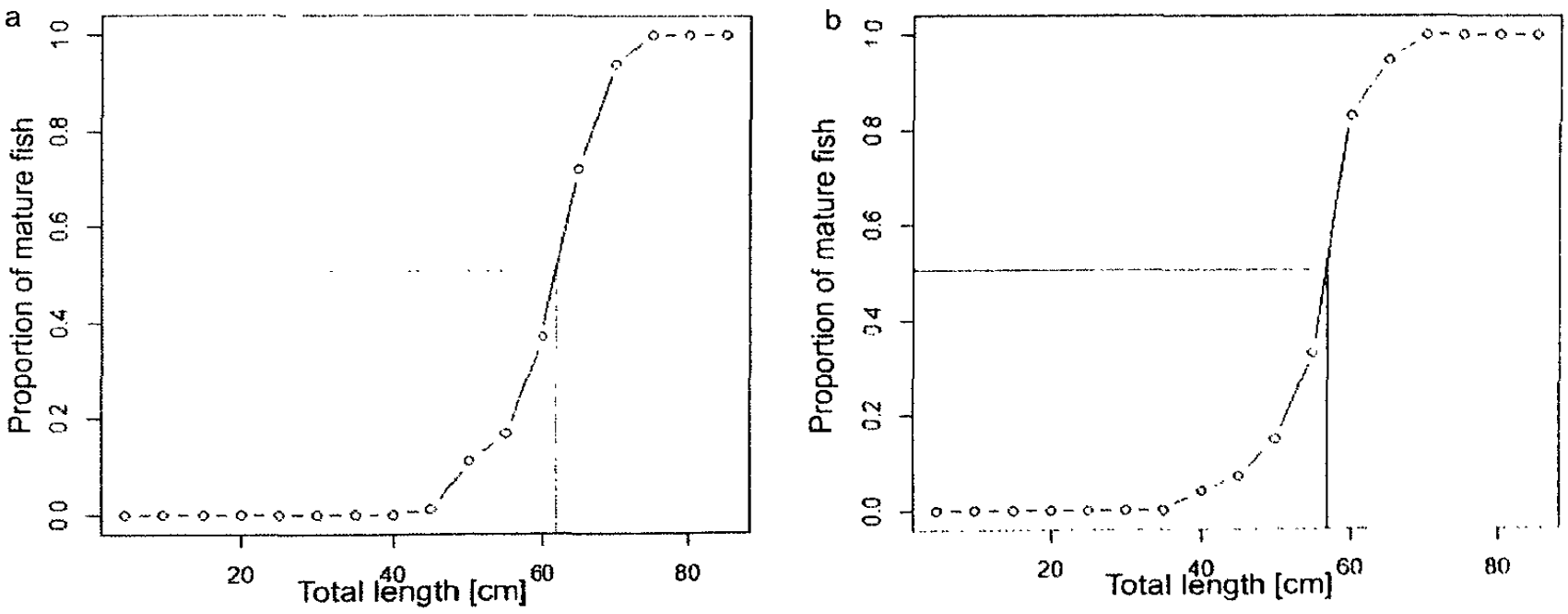

Fig. 4. The relation between the length of females (**a**) and males (**b**) of *Scomberoides lysan* and the proportion of sexually mature individuals

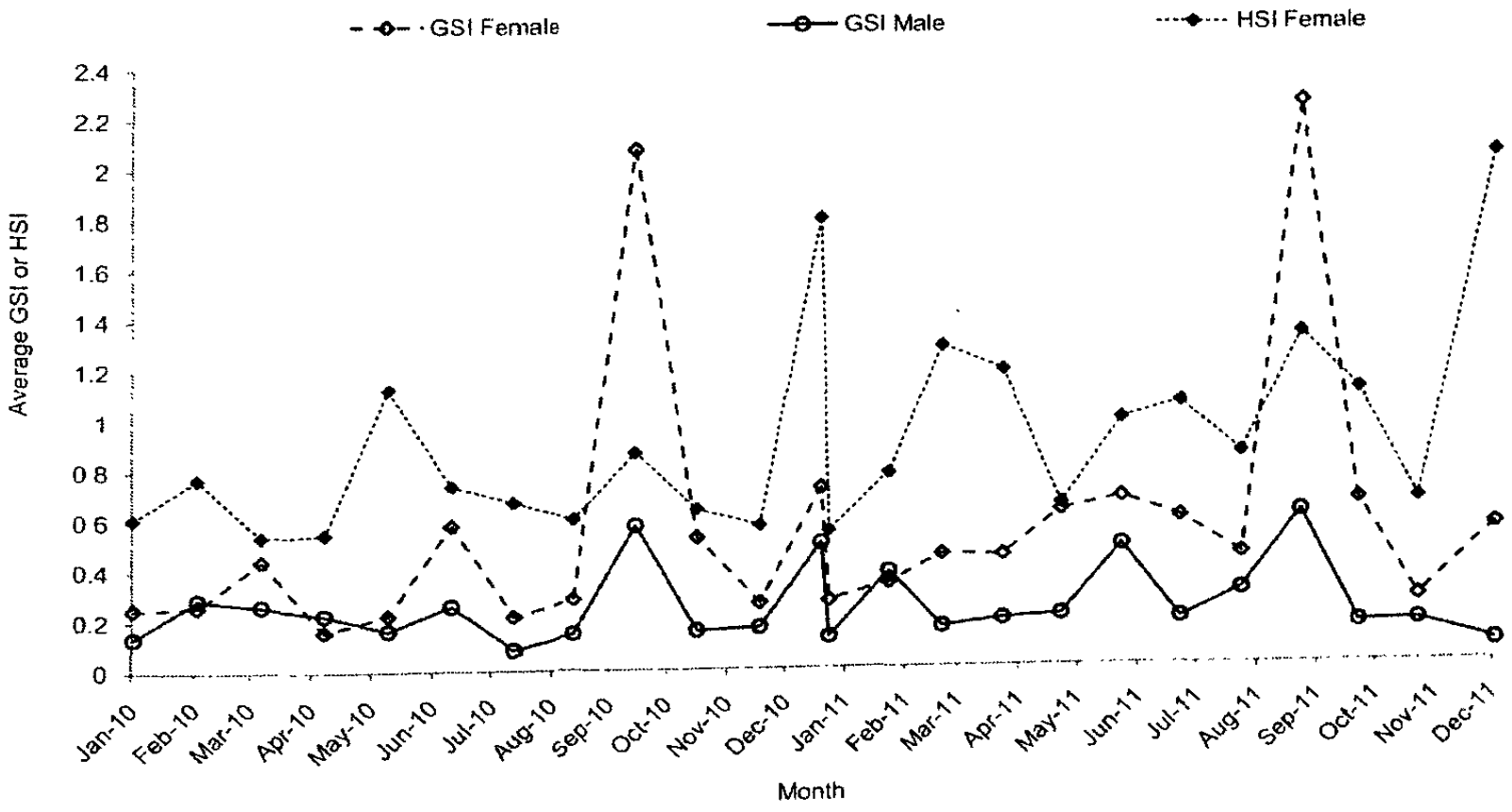

Fig. 5. Monthly average gonadosomatic index (GSI) of males and females and monthly average hepatosomatic index (HSI) of female *Scomberoides lysan*

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.

ACKNOWLEDEMENTS

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Table 3

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

Relation	Logarithmic equation	*n*	R^2
OW–FL	log OW = 4.5 × log FL + 6.73	760	0.7425
FE–OW	log FE = 2.4 × log OW + 2.46	111	0.5581
FE–TL	log FE = 6.75 × log TL + 6.2	22	0.8011
LW–FL	log LW = 3.183 × 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	*n*	R^2
TEW–FL	log TEW = 0.246 × log FL + 0.246	668	0.9973
TEW–TW	log TEW = 1.423 × log TW + 3.78	668	0.7328
LW–FL	log LW = 2.924 × 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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Microscopic Staging System used in the Identification of Gonad Developmental Stages of *Scomberoides lysan*

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ABSTRACT

The present study was carried out to identify the developmental changes in the gonads of *Scomberoides lysan* during maturation in order to determine the spawning pattern, ovulation pattern and spawning season. *S. lysan* is one of the most economically important Carangid food fish in Sri Lanka. Samples were obtained from June 2010 to May 2012 from the Sri Lankan waters and a total number of 570 ovaries and 525 testes were analyzed macroscopically and microscopically. Oocyte diameters of selected samples were measured in order to find out the ovulation pattern. Histologically ovaries were categorized in to seven stages by identifying chromatin nucleolus, peri nucleolus, cortical alveolar, yolk globular, late yolk, hydrated, atresia and post ovulatory follicle stage oocytes and testes were categorized in to four stages. Oocyte diameter range from 12.5-450.0 μm. Occurrence of several batches of oocytes at a time and the presence of different type of oocyte in an ovary revealed that this would be a multiple spawner with group synchronous ovulation pattern. Hydrated and post ovulatory follicle stage oocytes and spawning stage testes were only available during June and September. Immature stages of both gonads were available throughout the study period. Observations on seasonal maturity stages indicate that this species is a multiple spawner with two peak spawning season in June and September. The results obtained from the present study can be used in the management of *S. lysan* in the Sri Lankan waters to ensure the sustainable utilization of this species.

Key words: *Scomberoides lysan,* spawning pattern, ovulation pattern, histology, maturity stages

INTRODUCTION

Categorizing the ovaries into developmental stages and measuring the oocyte diameter distribution using histological staging system will provide detailed information on ovulation pattern, spawning season and abundance of maturity stages. Oocyte growth and development are the important issues in the reproductive biological studies of fishes (Tyler and Sumpter, 1996). Mackie and Lewis (2001) explained that the most accurate and detailed means of staging of gonads is by microscopic examination of histologically prepared sections of each specimen. Ovarian development usually defines the spawning season and number of offspring produced during spawning (De Martini and Fountain, 1981).

Histological studies are important to invent new and effective methods for increasing efficiency of brood stock, increasing fish production and ultimately increase efficiency and higher fish are predicted. Determining the peak period of spawning, exploitation level, understanding

the biological characteristics and life cycle of a species are important in the management and reconstruction of a fish species (Saeed *et al*., 2010). Stahl and Kruse (2008) stated that classification of ovaries into developmental stages is a prerequisite for setting annual catch quotas using a harvest rate strategy based on spawning biomass estimates. Information on maturation and spawning of species will contribute to the knowledge of their population dynamics and management of the stocks (Gabr *et al*., 1998).

Scomberoides lysan is commonly known as double spotted queen fish belongs to the family Carangidae, distributed through the Indo-West Pacific region (Froese and Pauly, 2012; De Bruin *et al*., 1994) and play a major role in the ecosystem as carnivore particularly piscivores in their adult stage and economically important as food fishes more popular as in the form of dried fish (Thulasitha and Sivashanthini, 2012; Anonymus, 2008) as well as popular game fishes (Honebrink, 2000).

Various studies have been made on reproductive biology of fish and fish related organisms from different parts of the world. Few examples for such reproductive biology studies are by Chelemal *et al*. (2009) for *Liza abu*, Karatas and Sezer (2005) for *Cyprinus carpio*, Sivashanthini *et al*. (2008) for *Gerres abbreviatus*, Azadi and Mamun (2004) for *Amblypharyngodon mola*, Ismen *et al*. (2004) for *Balistes capriscus*, Shinkafi and Daneji (2011) for *Synodontis eupterus* and Fernando *et al*. (2006) for *Amphiprion sebae*. From the literature survey it is apparent that the reproductive biology based on histological studies of *Scomberoides lysan* have not been studied, so far. The present study was carried out to identify the ovulation and spawning pattern through microscopic stages of gonads of *Scomberoides lysan* for the first time.

MATERIALS AND METHODS

Fish samples were collected weekly between June 2010 and May 2012 from commercial catches of Jaffna, Trincomalee, Mannar and Puttalam fish landing centers in Sri Lankan waters located in the Indian Ocean (between 79-80°E longitudes and 9-10°N latitudes). Fresh samples were brought to the laboratory and gonads were obtained by the dissection. Macroscopic staging of gonads were assigned as maturity stages according to Mackie and Lewis (2001) and West (1990).

Sub sample of four specimens (2 male and 2 female) from each 10 cm total length size range was taken from each monthly sample and gonads of each specimen were taken for histological inspection.

For histological examination different portions of ovaries and testis were fixed in formal saline (8.5 g of sodium chloride, 100 mL of 40% Formalin and 900 mL of distilled water). Clearing and paraffin embedding were performed using standard histological techniques (Clark, 1981; Ratcliffe, 1982) after one week they were dehydrated in graded alcohol series, exposed to Xylene and embedded in paraffin wax. Sections of 6 μm thickness were prepared and stained with Harris Haematoxylin and Eosin, then mounted with DPX. Photographs were taken from the OPTIKA binocular light microscope equipped with AIPTEK-AHD Z600 camera. Microscopic staging of gonads were assigned in to different maturity stages according to Mackie and Lewis (2001) and West (1990).

Oocyte diameter of all maturity stages were measured for key samples using ocular micrometer and the percentage occurrence were plotted against the oocyte diameter class interval in order to confirm the ovulation pattern.

RESULTS

A total number of 570 ovaries and 525 testes were examined. Developmental stages of ovaries were categorized into seven stages as immature, maturing, rest/developing, mature, pre spawning, spawning and spent and males were categorized in to four stages as immature, maturing, mature and spawning according to their macroscopic and microscopic features.

Among the total catches of females, immature stage ovaries (60%) were dominated and obtained throughout the study period. Maturing stages were obtained from February to August (15.5%) whereas mature stages (3%) during August and October. Pre spawning and spawning (20.5%) were only available during June and September. Only <1% of spent stages with post ovulatory follicles were collected during September. Less than 1% of rest developing or second time developing stages was available during September 2011, only.

Ovarian developmental stages

Stage I: Immature ovary

Macroscopic features: Small, thread like ovaries with pink and translucent colour; without visible oocytes (Fig. 1). It is difficult to determine the sex morphologically in the earlier stage.

Microscopic features: Two stages were identified such as chromatin nucleolar stage (Fig. 1, 2a) and perinucleolar stage (Fig. 2a, b). Chromatin Nucleolar Stage (CNS) is characterized by large spherical nucleus which occupies the greater portion of oocyte and strongly basophilic smooth cytoplasm appeared as dark purple in colour. CNS stage oocytes grow up to 50 μm. In the later stage they develop in to perinucleolus stage (PNS) which is characterized by the appearance of several nucleoli in the peripheral region of oval shaped nucleus. Cytoplasm is still strongly basophilic in nature and these stage oocytes reached to 100 μm. Small spindle shaped follicular cells starts to proliferate and surrounds the oocytes. Weakly eosinophilic layer (precursor of zona radiata) also starts to appear between the follicular cells and oocytes. But in the later stage, large PNS oocyte may develop small vacuoles in the cytoplasm, very close to the nucleus.

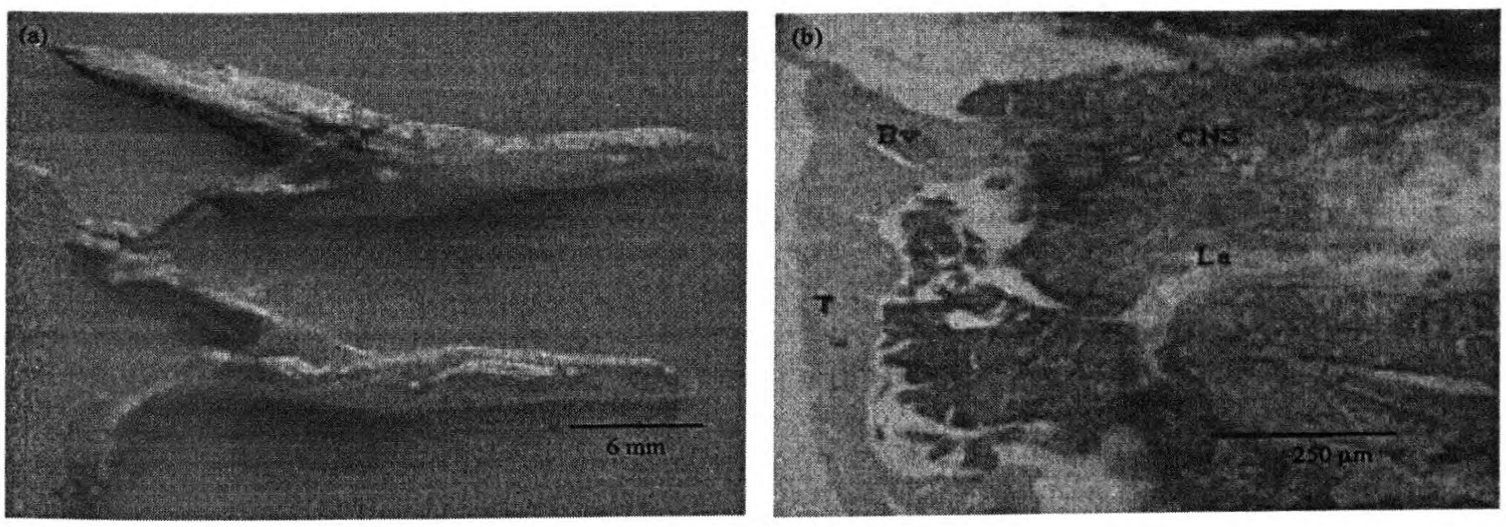

Fig. 1(a-b): Stage I: Immature ovary view; (a) Whole view and (b) Transverse section, CNS: Chromatin nucleolus, Bv: Blood vessel, T: Tunica, La: Lamella, Total length of fish is 24 cm

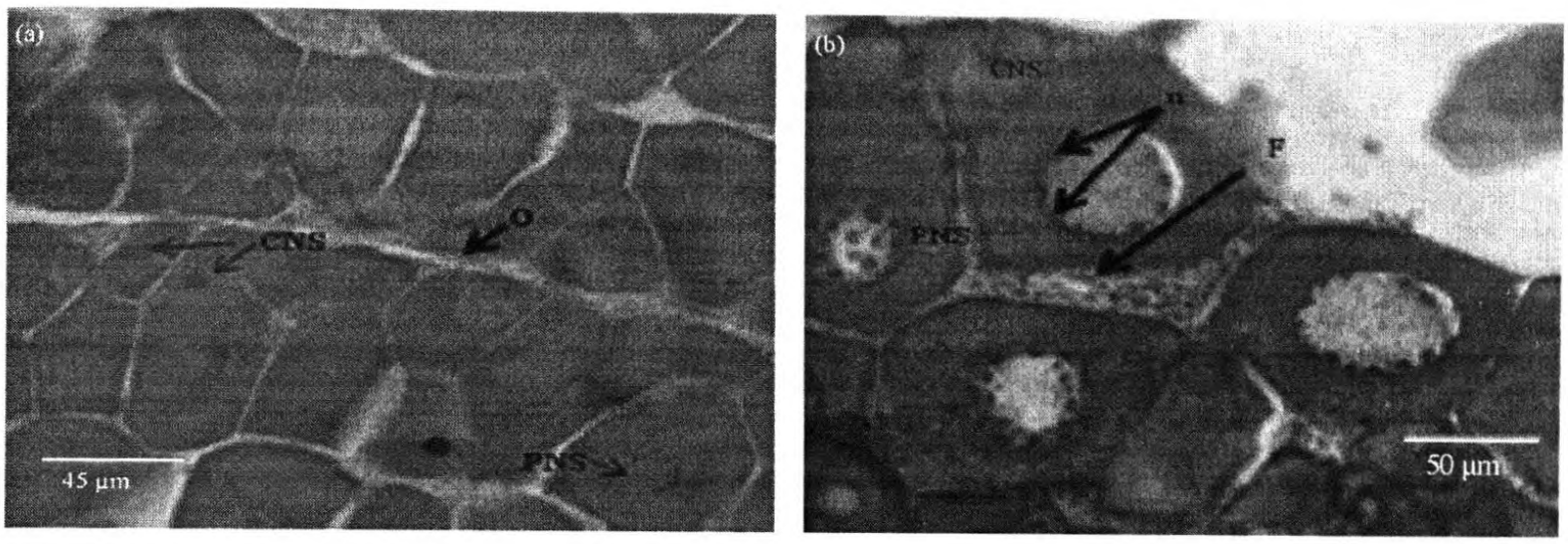

Fig. 2(a-b): Stage I: nucleolus stages in immature ovary, (a) Chromatin nucleolus and (b) Peri-nucleolus, CNS: Chromatin nucleolus stage, PNS: Peri-nucleolus stage, O: Oogonia, n: Nucleolus, F: Follicular cells

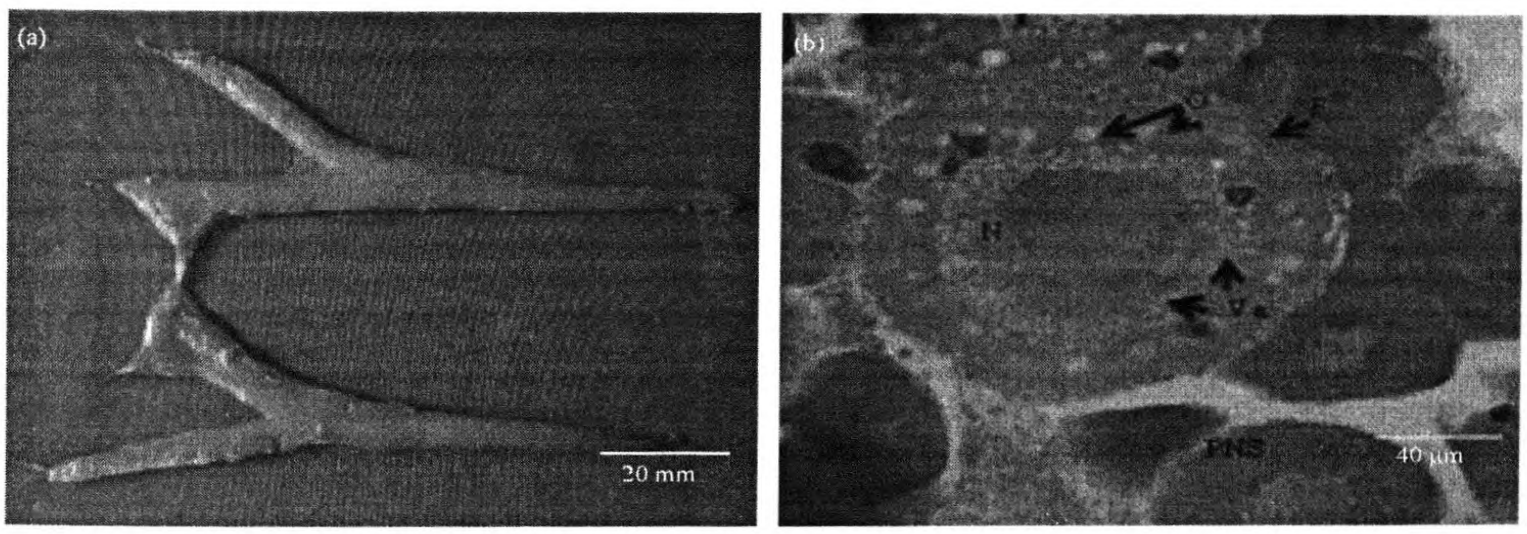

Fig. 3(a-b): Stage II: maturing ovary view; (a) Whole view and (b) Cortical alveoli stage, PNS: Peri-nucleolus stage, N: Nucleus, F: Follicular cells, O: Oil droplets, Va: Vacuoles, Total length of fish is 48

Stage II: Maturing ovary

Macroscopic features: Medium size ovaries usually appeared as translucent pink, flattened, flaccid and relatively inconspicuous. Oocytes are not visible through the ovarian wall. External surface is smooth and uniform in appearance (Fig. 3a).

Microscopic features: The Cortical Alveoli Stage (CAS) in which yolk deposition initiated. In this stage, cytoplasm becomes weekly basophilic nature and the nucleus is about half of the oocyte and still occupies a central position and it contains several nucleoli; Small clear staining yolk vesicles appear throughout the mid and outer regions of the cytoplasm and forming a narrow row (cortical alveoli) near the periphery of the cytoplasm and clear staining oil droplets also appear within the inner region of the cytoplasm, increasing in number and size around the central nucleus. Follicular

cells become enlarge and surrounds the oocytes. This stage of ovary also contains CNS and PNS oocytes. Large oocytes grow up to 150 μm (Fig. 3b).

Stage III: Rest/developing ovary

Macroscopic features: It is difficult to differentiate macroscopically with first time maturing stage. Colour is typically semi-translucent rose/purple; the ovarian wall and blood capillaries are thick. But the lumen is large when made a transverse section. Few oocytes can be seen in the late stage (Fig. 4a).

Microscopic features: Second time developing ovary with several stages of oocytes such as CNS, PNS and CAS but the dominating stage is depending on the season; Lamellae very thin; ovarian lumen is larger than fist time developing ovary. Some large oocytes reached to 200 μm (Fig. 4b).

Stage IV: Matured ovary

Macroscopic features: Large, rounded, yellow to orange coloured ovaries, occupying about 75% to almost filling body cavity. Ovarian wall is thin and transparent. Small opaque oocytes can be seen clearly through the ovarian wall. Prominent blood capillaries also formed (Fig. 5a).

Microscopic features: This stage starts with early YGS. In the early stage ovary is dominated by early YGS and Previtellogenic oocytes (PVO). YGS oocytes mature and grow, causing the lamellae to expand the lumen to decrease and the tunica to stretch and thin. Vascular tissue becomes more common. In the later stage (Yolk globule stage/advanced vitellogenic oocytes) yolk granules almost cover the cytoplasm; nucleus starts to migrate towards the periphery (also refereed as migratory nucleus stage-MNS) of the oocytes. In the ovary, 300-350 μm size oocytes dominate but few of them reached to 450 μm. This stage of ovary also consists of CNS, PNS and CAS oocytes (Fig. 5b).

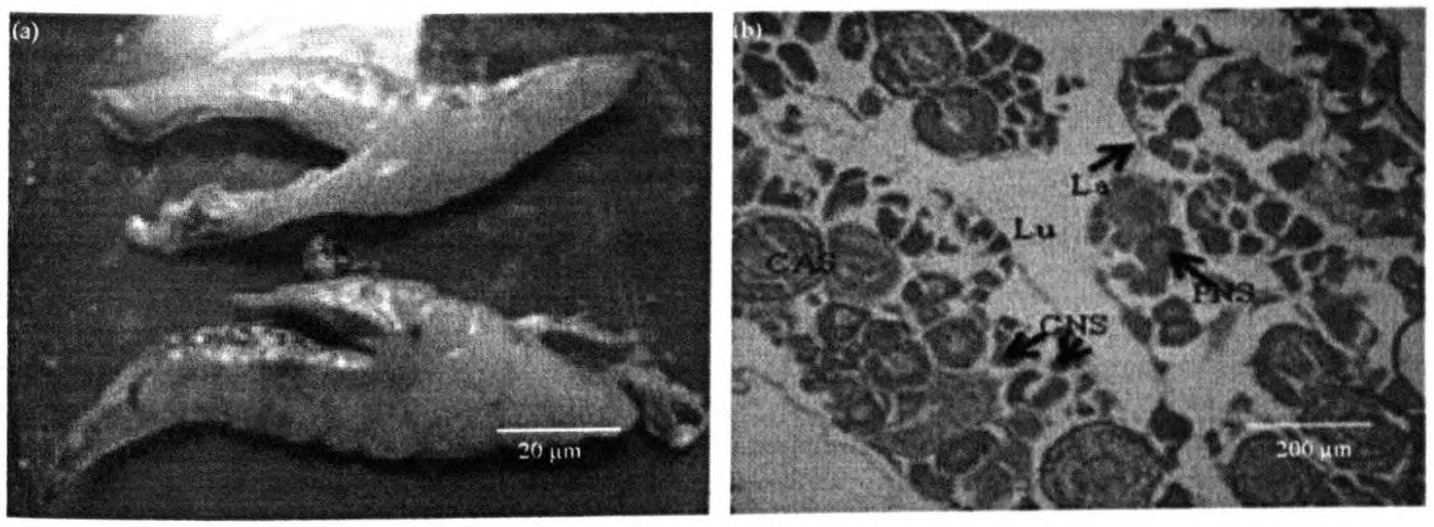

Fig. 4(a-b): Stage III: rest/developing (maturing) ovary view; (a) Whole view and (b) Cortical alveoli stage, CAS: Cortical alveoli stage, PNS: Peri-nucleolus stage, CNS: Chromatin nucleolus, Lu: Lumen, La: Lamella, Total length of fish is 71 cm

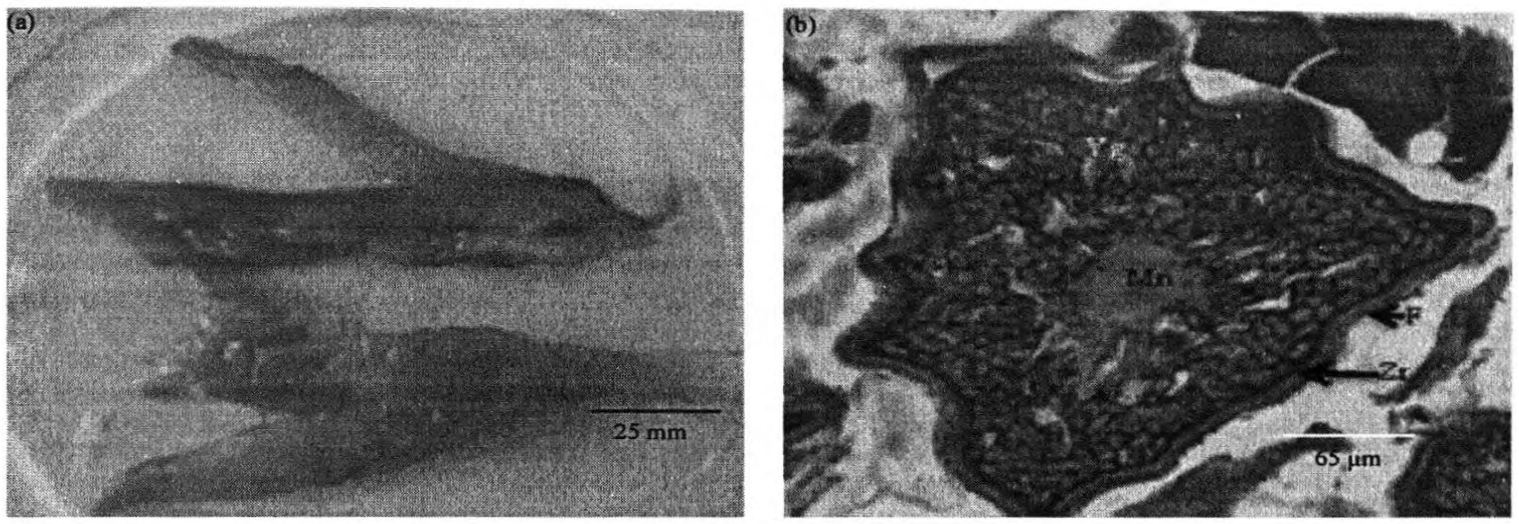

Fig. 5(a-b): Stage IV: matured ovary view; (a) Whole view and (b) Yolk globule stage oocyte, Yg: Yolk globule, Mn: Migratory nucleus, F: Follicular cells, Zr: Zona radiata, Total length of fish is 68 cm

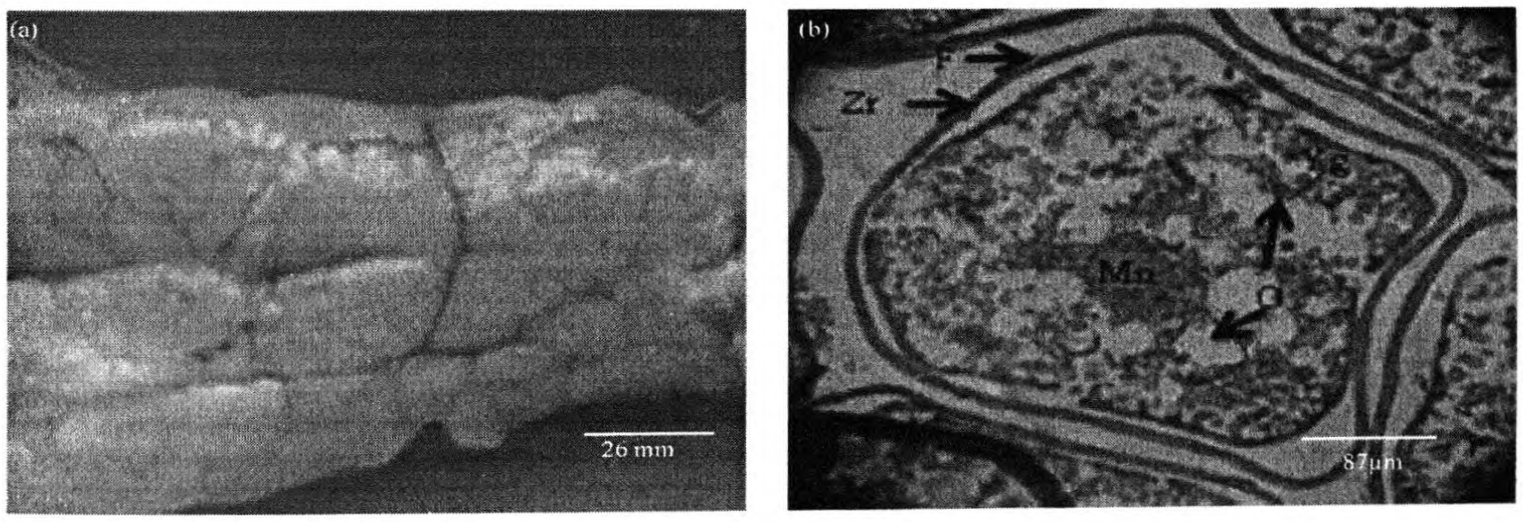

Fig. 6(a-b): Stage V: pre-spawning stage ovary, (a) A portion of pre spawning ovary and (b) Late yolk stage oocyte, Mn: Migratory nucleus, Yg: Yolk globules, O: Oil droplets, Zr: Zona radiata, F: Follicular cells, Total length of fish is 78 cm

Stage V: Pre spawning ovary

Macroscopic features: It is difficult to differentiate pre spawning stage from the stage VI-spawning stage ovary by macroscopic analysis (Fig. 6a).

Microscopic features: Large oil droplets increase in size and intermixed with the yolk globules. Nucleus starts to migrate towards the periphery of the oocyte. Hydrated oocytes and post ovulatory follicles can be seen if the spawning is started. Zona radiata becomes enlarged and can be seen clearly with surrounding follicular cells. Most of the oocytes in this stage are reached to 350 µm and considerable number of oocytes reached 400-450 µm (Fig. 6b).

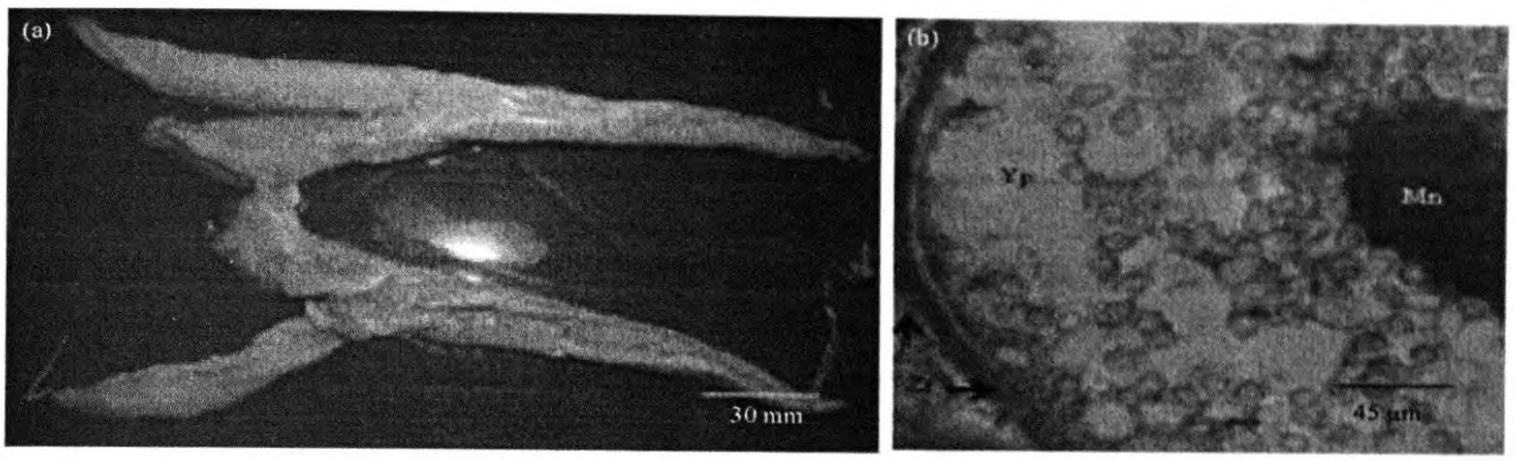

Fig. 7(a-b): Stage III: spawning stage ovary view; (a) Whole view and (b) A portion of hydrated oocyte, Yp: Yolk plate, Mn: Migratory nucleus, Zr: Zona radiata, F: Follicular cells, Total length of fish is 80 cm

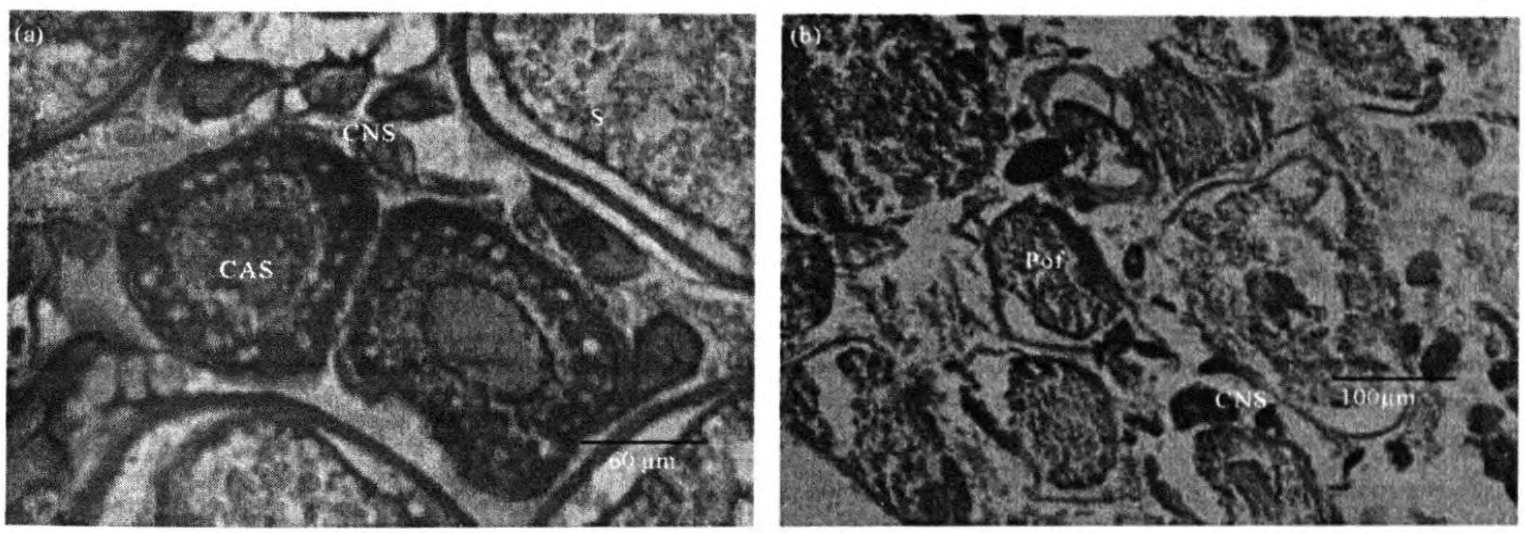

Fig. 8(a-b): (a) Spawning stage with different stages of oocytes and (b) Spent stage ovary Degenerating post ovulatory follicles, POF: Post ovulatory follicles, CNS: Chromatin nucleolus stage

Stage VI: Spawning ovary

Macroscopic features: Ovaries are very large and swollen. The translucent hydrated oocytes give the ovaries a distinctive speckled or granular appearance through the thin ovarian wall. Eggs may be released from the ovaries when pressure applied (Fig. 7a).

Microscopic features: Yolk granules become fused together and form yolk plates; nucleus migrates towards the periphery of the oocytes. Hydrated oocytes can be seen in the lumen. Yellow brown bodies and vascular tissue will become more prominent at this time and Post Ovulatory Follicle (POF) may be present if the fish has previously spawned. At the time of spawning ovulated eggs are found in the lumen and new POF are present in the periphery of the lamellae and few MNS, CNS, PNS may also present (Fig. 8a). Most of the oocytes in this stage are reached to 350 µm and considerable number of oocytes reached 400-450 µm (Fig. 7b).

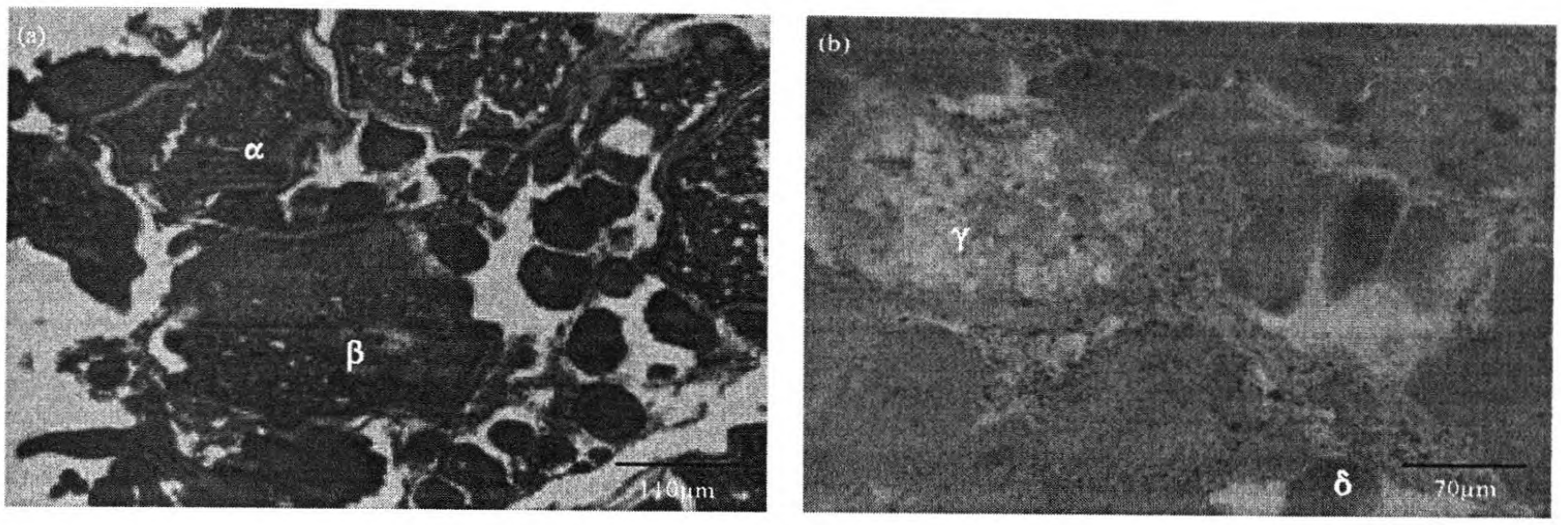

Fig. 9(a-b): Atretic oocytes histology (a) α and β and (b) γ and δ stage atresia

Stage VII: Spent ovary
Macroscopic features: Flaccid and large ovaries usually grayish in colour. Lumen is very large.

Microscopic features: Post ovulatory follicles dominate the space; few CNS also present (Fig. 8b).

Atresia stages of oocytes were recorded in matured, Pre spawning, spawning and spent stage ovaries (Fig. 9a, b).

Testicular developmental stages
Stage I: Immature testis
Macroscopic features: Small, strap/thread like opaque testis with smooth appearance (Fig. 10). No milt is present in the transverse section (Fig. 10a).

Microscopic features: Testis contains spermatogonia and isolated pockets of spermatocrypts. These mainly contain spermatocytes. The central sperm sinus is small and empty (Fig. 10e).

Stage II: Maturing testis
Macroscopic features: Larger than immature gonads and produce milt when squeezed (Fig. 10b).

Microscopic features: Spermatocytes are the prominent sperm tissues and spermatocrypts are larger than immature testis. Interstitial cells surround the spermatocrypts. Central sperm sinus is empty (Fig. 10f).

Stage III: Mature testis
Macroscopic features: Large, opaque and ivory or bone colour testis. Exterior dorsal blood vessels are present and prominent. Produce white milt when squeezed and milt should be visible in the outer areas of the transverse section (Fig. 10c).

Microscopic features: Spermatozoa and/or spermatids are the dominant stages. The central sperm sinus may be small with a thick muscular wall and may contain little or no sperm. However, the peripheral sperm sinuses are well developed, prominent and filled with spermatozoa (Fig. 10g, i).

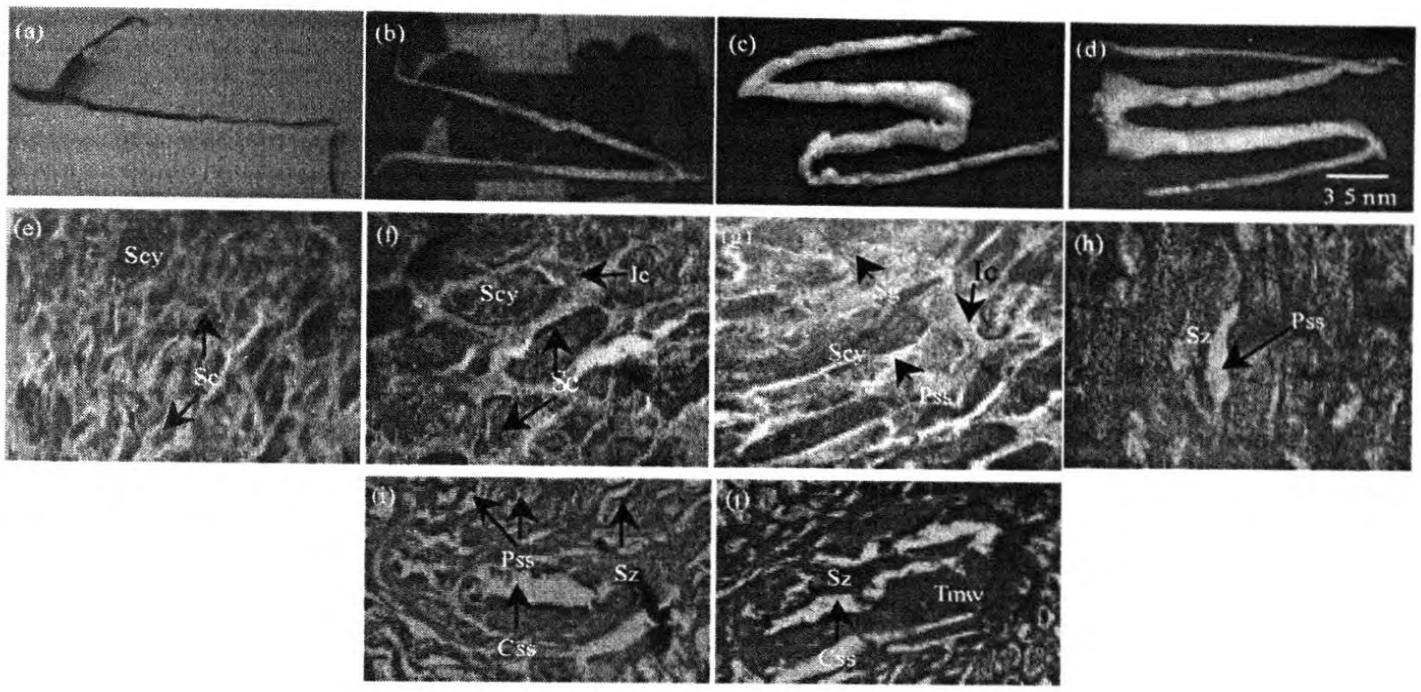

Fig. 10(a-j): Macroscopic and microscopic staging of testes; (a) Whole view of immature testis, (b) Maturing testis, (c) Mature testis, (d) Spawning testis and histology of; (e) Spermatocytes (Scy) in spermatocrypts (Sc) of testis; (f) Large spermatocrypts, (g) Spermatocytes in peripheral sperm sinus (Pss), (h) Spermatozoa (Sz) in Pss, (i) Empty central sperm sinus (Css) and spermatozoa present in Pss and (j) Spermatozoa present in the Css

Stage IV: Spawning testis

Macroscopic features: Running ripe stage. Testis is large in size similar to mature stage but more have swollen with lager exterior blood vessels. Milt is released with little or no pressure on the abdomen or when the testis is cut (Fig. 10d).

Microscopic features: Testis is dominated by spermatozoa in the large peripheral and central sperm sinuses. Crypts of spermatocytes are uncommon and in some testis they confined to the most outer region of each lobe (Fig. 10h, j).

For oocyte diameter distribution studies, ovarian developing stages V and VI are combined as spawning stage. Frequency distribution of various size oocytes in relation to maturity stages were shown in Fig. 11. It explained that the ovaries of *Scomberoides lysan* have several batches of oocytes at a time but their abundance varies with months.

DISCUSSION

Macroscopic and microscopic structural changes on the ovaries of teleost were done by various researches (Saeed *et al*., 2010). In the present study, seven maturity stages of ovary were identified according to the macroscopic and microscopic analysis. Although, Yamamoto and Yamazaki (1961) recorded ten developmental stages of ovary and Chen *et al*. (2006) characterizes *Thunnus orientalis* oocyte development into seven stages of maturation.

Macroscopic studies based on the colour and appearance is a cheaper and faster method (Mackie and Lewis, 2001) however, microscopic histological studies on the *S. lysan* explain the

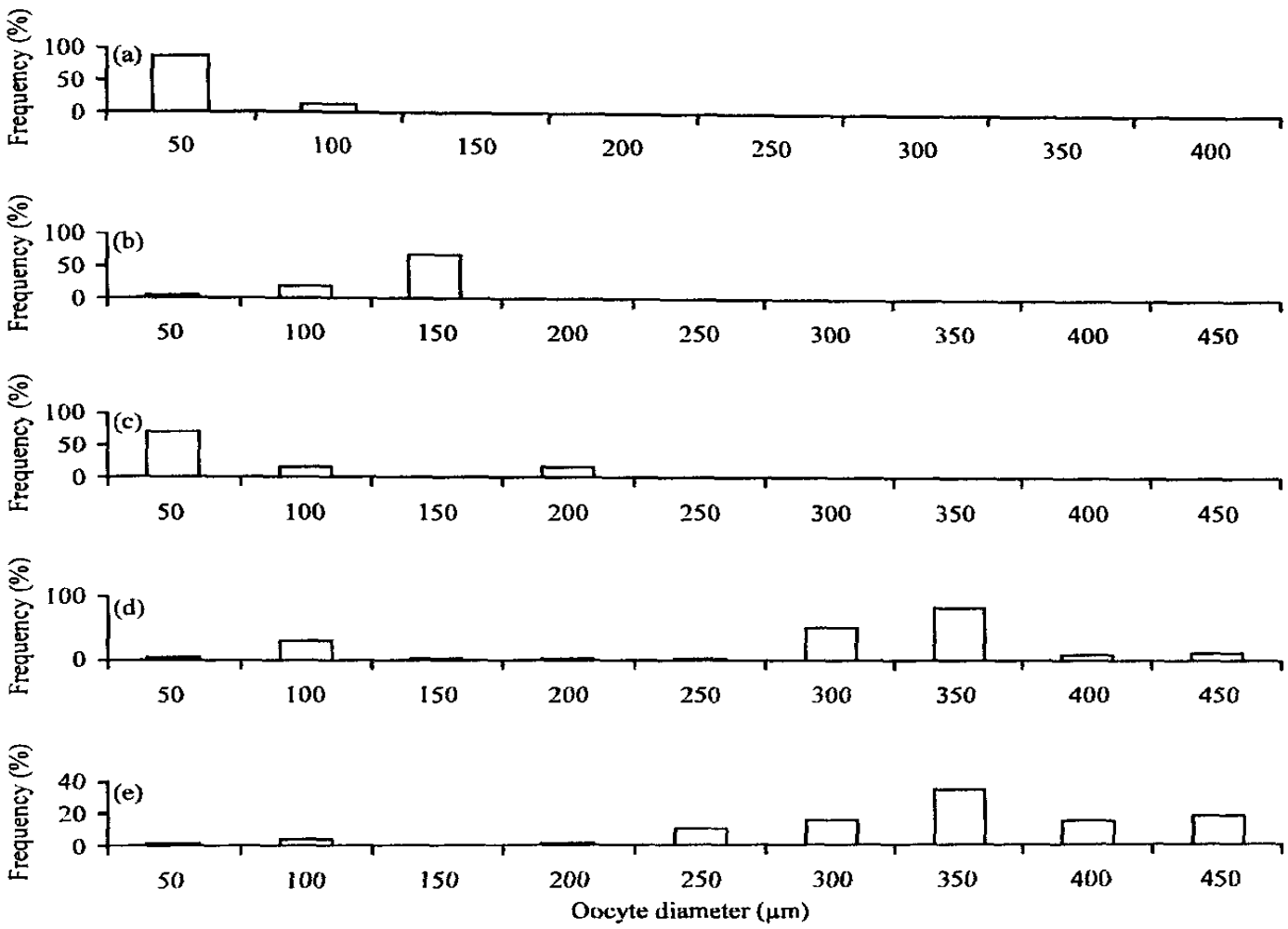

Fig. 11(a-e): Percentage frequency distribution of oocyte diameter at (a) Immature, (b) Maturing, (c) Rest/developing, (d) Matured and (e) Spawning stage of *S. lysan*, n = 6

detailed developmental changes in the gonads during maturation. In the *S. lysan* ovary, rest/developing and pre spawning stages were clearly identified by microscopic staging only. Proliferation of follicular cells in the peri nuclear stage of ovary explained the commencement of reproductive activity.

The presence of spawning and spent stage ovaries with hydrated oocytes and post ovulatory follicles clearly explain the spawning season as June and September. Hunter and Macewicz (1980) suggested that the best indicator of the time of spawning was the occurrence of both hydrated eggs and post ovulatory follicles. The hydration stage is very short in duration and may not be commonly observed (Stahl and Kruse, 2008; Hunter and Goldberg, 1980).

Occurrence of several stages present in an ovary at a time (Fig. 4b, 8a) revealed that the *S. lysan* spawns more than once. It is also supported by the studies on narrow-barred Spanish mackerel *Scomberomorus commerson* which has a prolonged spawning season during which eggs are spawned by females in multiple batches (McPherson, 1993) and oocytes of varying developmental stages are present within the ovary at the same time. Collection of rest/developing stage is a strong evident for the spawning pattern. That means *S. lysan* spawns more than once. Presence of spermatocytes in spermatocrypts of peripheral regions of spawning stage testis also explained that this species spawns more than once.

Presence of several batches of oocytes in an ovary at a time explain that *S. lysan* ovulated more than once termed as group synchronous ovulation pattern and it is a multiple spawner. Massut and Nin (1997) stated that the fish *Coryphaena hippurus* is a multiple spawner because their ovaries consist of various size distributions of oocytes with at least two groups of oocytes in the ovaries.

Mohamed (2010) also explained that the presence of oocytes at different stages of development belongs to the fish with prolonged and fractional spawning season. Griffiths *et al.* (2005) recorded two separate peak spawning seasons in February and November for *Scomberoides commersonnianus* from northern Australian waters. Sadeghi *et al.* (2009) studied the reproductive biology of *Scomberomorus commerson* in the coastal waters of Iran and reported *S. commerson* spawn from June to September.

CONCLUSION

From the present study it can be concluded that the *S. lysan* is a multiple spawner with group synchronous ovulation. The spawning time was determined as June and September by identifying the presence of pre spawning, spawning and post-ovulatory follicle stages. These findings could be used in formulating or suggesting management measures for this species.

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Lipid Changes in Relation to Maturation and Spawning of Tropical Double Spotted Queenfish, *Scomberoides lysan* (Forsskål, 1775)

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ABSTRACT

The present study was undertaken to understand the lipid changes in gonad, muscle and liver tissues of tropical double spotted queen fish, *Scomberoides lysan* (Family: Carangidae) in relation to sexual maturity and spawning. Cholesterol (CS), phospholipid (PL) and triacylgycerol (TAG) were determined in gonad, muscle and liver tissues with respect to maturity stages of both sexes as well as months. Fish were periodically caught from waters around Sri Lanka throughout the year 2010 to 2011. Fish length, weight, sex and maturation status were recorded. Content of CS, PL and TAG in gonad, muscle and liver tissues were determined at the laboratory. The values of CS, PL and TAG in the ovary increased to 2-5 fold throughout the ovarian maturation and decreased to 2-8 fold after spawning, whereas in liver and muscle tissue, increased up to maturation and decreased during spawning. Similar dynamics was recorded in males. The main lipid constituents in the liver and muscle of mature fish were TAG and PL, respectively. Lipid constituents in gonads showed higher value, whereas muscle and liver showed lower value in June and September, which represent the spawning time of *S. lysan*. It has been concluded that the values of lipid in tissues of *S. lysan* influence the cycle of maturation and time of spawning. This new information can be used for the determination of the fishing season for *S. lysan*, when it is not reproductively active and has high nutritional value in terms of lipid. The knowledge gained on CS, PL and TAG in different maturity stages of *S. lysan* can also be utilized in broodstock diet formulation in the future culture trials of *S. lysan*.

Key words: Cholesterol, phospholipid, *Scomberoides lysan*, triacylglycerol

INTRODUCTION

In fish, lipids are known to be an important energy source for reproduction, since large amounts of lipids are required both for female egg production and for male breeding activities, such as enhanced swimming activity, competition, courtship, parental care and nesting (Goda *et al*., 2007; Ebrahimnezhadarabi *et al*., 2011).

When a spawning migration is involved, the adult fish generally deplete all their reserves and die after spawning as in the case of Sockeye Salmon (*Oncorhynchus nerka*) (Hinch *et al*., 2006) and eel (*Anguillia anguillia*) (Fricke and Kaese, 1995). If no migration is involved, fish are capable of building their energy reserves completely after spawning.

The lipid storage tissue varies depending on the fish species; some species deposit in liver (most gadoids; Alonso-Fernandez and Saborido-Rey, 2012) while some in muscle (Antarctic fish; Clarke *et al*., 1984) and some in both liver and muscle (Jezierska *et al*., 1982; Hedayatifard and Yousefian, 2010).

Fluctuation of lipid classes in gonad, muscle and liver of adult fish is directly associated with sexual maturity and spawning of fish (Mourente *et al*., 2002; Huynh *et al*., 2007). Knowledge gained from lipid changes in different tissues of species would be helpful to understand the physiology and ecology of that species. Due to higher investment of resources for reproduction, lipid reserves in liver and muscle are mobilized and transferred to the gonad during maturation and spawning (Zaboukas *et al*., 2006; Sutharshiny and Sivashanthini, 2011a; Singh *et al*., 2012). Further, variations in lipid composition in fish tissues depend on environmental conditions (Lund *et al*., 2000) and seasonal variations (Kandemir, 2010).

The length of the spawning season and spawning frequencies varies greatly between species. Some species for example *Salmoniform, Atheriniform* and *Tetraodontiform* have a marked seasonal periodicity in gonadal maturation (Taylor, 1984), while species of *Blennius pholis* has ripe ovaries throughout the year (Qasim, 1957). Some fish spawn only once a year or once in their lifetime (e.g., most *Oncorhynchus* spp. and *Anguilla* spp., De Vlaming, 1983) while others spawn several times a year for example Black and White bream (Jacques and Patrick, 2003), *Latris lineate* (Bransden *et al*., 2007) and *Scombroides lysan* (Thulasitha and Sivashanthini, 2013).

Lipids are complex classes of compounds, can be broadly divided into two groups, one is polar lipids composed principally of phospholipids and the other one is non polar lipids composed principally of triacylglycerols and cholesterol (Tocher, 2003). These components affect the biochemical processes of organism at different level. Phospholipid is the main lipid of cellular membranes and important constituents of egg yolk in fish (Johnson, 2009). It can also be an important source of energy (fatty acids) in fish, particularly during embryonic and early larval development in species that produce phospholipid rich eggs (Tocher, 1995). Triacylglycerol is the major energy storage form in fish (Shulman, 1974) and stored in liver, muscle and mesenteric fat (Sheridan, 1994). Cholesterol is a precursor for the steroid hormones and bile acids (Scott, 1987) and used for additional cellular functions in the testis (Sharpe *et al*., 2006).

The Double spotted queenfish (*Scomberoides lysan*) is a tropical fish and broadly distributed throughout the Indo-Pacific region (Froese and Pauly, 2010; Varghese *et al*., 2011). It is an economically important food fish in Sri Lanka. The species is popular for dry fish production with export demands and especially consumed by mothers during pregnancy and immediately after delivery. Thus, it is highly prized, continues to maintain a high market demand and marketed preserved, dried or salted (Sutharshiny and Sivashanthini, 2011b; c) and hold an important position towards the economy of the fisheries of Sri Lanka.

Though there are several studies on lipid dynamics in different tissues related to reproduction were recorded for temperate fish species (Fiorin *et al*., 2007; Lloret *et al*., 2008) only few studies are available for tropical fish species (Arrington *et al*., 2006; Hiroaki, 2012; Ovie *et al*., 2007; Talat *et al*., 2006) especially for carangids (Ramadan, 2002; Assem *et al*., 2005). Few research works related to lipid composition of fish were carried out by different authors in Sri Lanka (Anas *et al*., 2009; Thilakarathne and Attygalle, 2009; Ubhayasekera *et al*., 2012). However no studies were performed on lipid changes in *S. lysan* and therefore the present study on variation in lipid classes of *S. lysan* is the first pilot study in Sri Lanka.

The knowledge gained from the present study on lipid changes of *S. lysan* based on lipid class constituents-cholesterol, triacylglycerol and phospholipids can be considered and applied in the future studies, contributing to economic and health development and sustainable management of *S. lysan* in Sri Lanka.

MATERIALS AND METHODS

Sample collection: Regular field visits were made once a month to the landing centers at Jaffna, Trincomalee, Mannar and Puttalam (Fig. 1). From the landed marketed fish, size selective samples were collected monthly from January 2010 to December 2011 with the assistance of fishermen co-operative society's Union of each landing site. The fish samples collected were actually caught mainly by 17.78 cm 21 ply mesh size, drift nets used particularly for queen fish (Katta valai). Fish samples were also collected from the by catch species caught using 6.35 and 8.89 cm mesh size drift net and seine net. Immediately after collection, fish were chilled before freezing (Graham *et al*., 1992) and brought to the laboratory in an ice box (Giostyle, Ole 25; Italy).

Morphometric analysis: Fish were allowed to thaw slowly and Standard Length (SL) was determined using measuring tape to the nearest 0.1 mm and Body Weight (BW) was measured using top loading balance to the nearest 0.01 g before conducting lipid analysis.

Sex determination: Sex and gonad maturity stages were determined for each specimen using macroscopic examination of gonad and recorded.

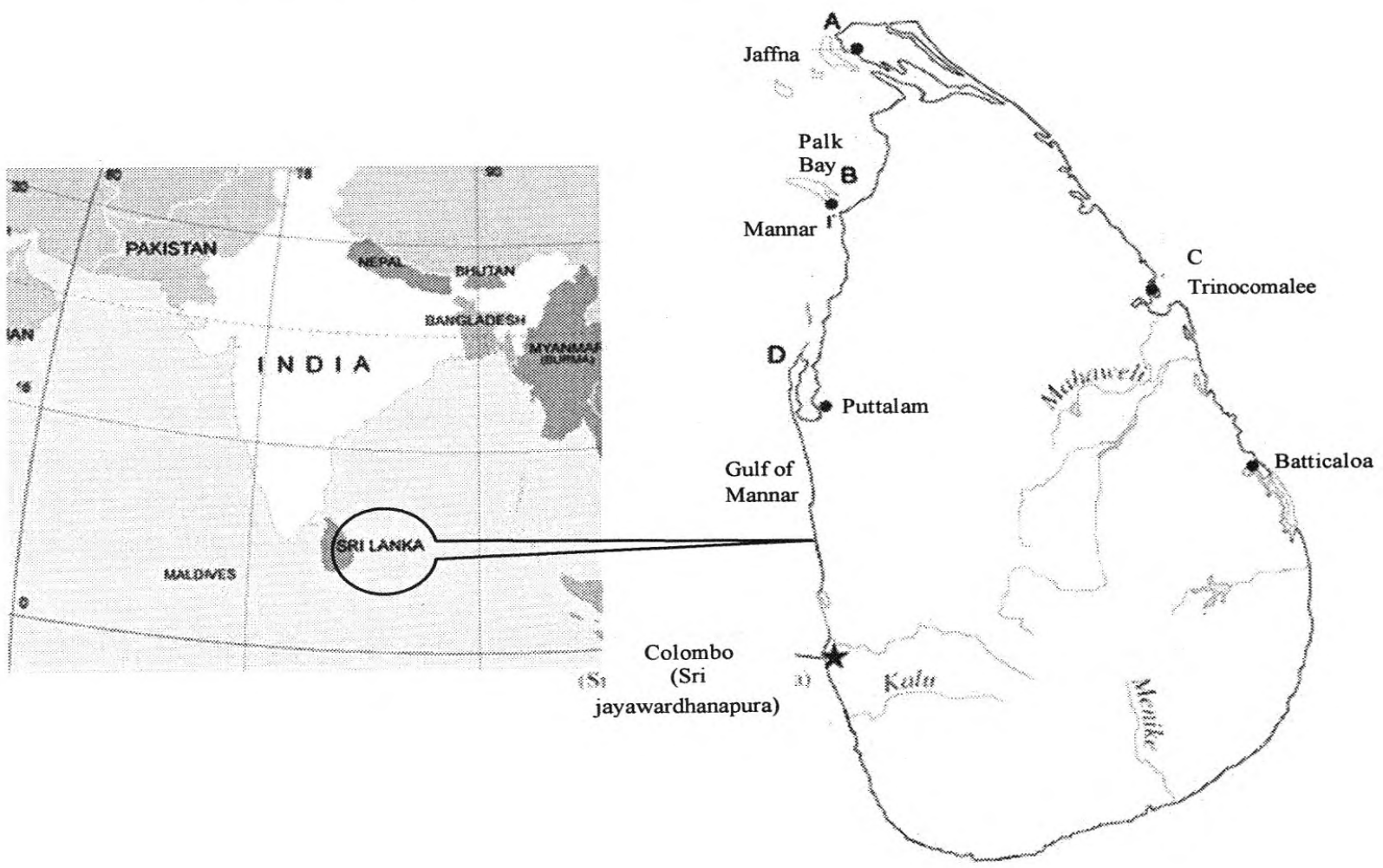


Fig. 1: Sampling stations of *S. lysan*. A: Jaffna, B: Mannar, C: Trincomalee and D: Puttalum

Tissues analysis: Fish were dissected and whole gonad and liver were removed and weighed using an electronic balance (OHAUS; USA) to the nearest 0.01 g. The muscle tissue from dorsal side that is directly under the dorsal fin and well above the lateral line was removed. Tissues were dried in an Oven (YCO-010; Germany) at 60°C for 24 h. The tissues were covered with filter paper to prevent accidental weight loss of lipid from tissues and to stop droplets erupting out of the container. The dried tissues were reweighed and ground twice in an electric grinder (Preett XT- 97; India).

Total lipid extraction: Total lipid in each tissue was analysed according to the Bligh and Dyer (1959) method. All chemicals were purchased from standard sources Sigma chemical company, USA. A weight of 10 g dried tissue powder was homogenized with 200 mL of chloroform/methanol mixture that prepared as in the ratio 2:1 (v/v). After dispersion, the whole mixture was agitated for 20 min at 2000 rpm in vortex mix (Karl Hecht KG; Germany) at room temperature. The whole mixture was filtered (funnel with a folded filter paper; Diameter-11 cm). The solids on filter paper were washed with 40 mL of distilled water, then the fluid mixture was vortexed for 1 min and centrifuged (Sigma; Germany) at low speed (2000 rpm) for 10 min to separate the two phases and allowed to stand. A biphasic system was obtained. The upper phase was siphoned, the lower chloroform phase containing lipids was filtered off and the water was removed from the extract by passing it through a folded filter paper containing anhydrous sodium sulphate. The interface was rinsed twice with methanol/chloroform (1:1 v/v). The lower phase containing individual lipids were recovered after evaporating under vacuum in a rotary evaporator (1 KA HB 10 basic; Germany). The dried lipid extracts with a small volume of chloroform-methanol mixture in Kjldhal flask were left to evaporate in the fume chamber. The resulting extract of total lipid was stored in a sealed vial at -20°C for further analysis.

Lipid class analysis: Cholesterol (CS) (Zlatkis *et al*., 1953), phospholipid (PL) (Zilversmit and Davis, 1950) and triacylglycerol (TAG) (Foster and Dunn, 1973) in different tissues were estimated. Standard curve for each lipid class constituents was plotted using the attached LABOMED, INC software in UV Visible spectrophotometer (LABOMED, UVD-3000). The concentrations of lipid classes in tissues were quantified.

Cholesterol analysis: A weight of 0.1 g extracted lipid was taken. Five milliliter of ferric chloride (in acetic acid) reagent was pipetted into lipid and mixed. Then 3 mL of concentrated sulphuric acid was pippetted into it, mixed again and allowed to stand for 20 min. 0.1 mL of glacial acetic acid was used for blank. The concentration of CS in tissues was read against the blank at 560 nm.

Phospholipid analysis: A weight of 0.1 g extracted lipid was taken into a 150 mL of kjeldhal flask and 1.0 mL of 5 N sulphuric acid was added to digest the lipid in a digestion rack (Sigma; Germany) till the appearance of light brown colour. Three drops of concentrated nitric acid were added to flask and continued the digestion till the brown colour changed into colourless. The Kjeldhal flask was cooled. 0.1 mL of distilled water was added to it and heated in a boiling water bath for 5 min. 1.0 mL of ammonium molybdate and 0.1 mL of amino-2-naphthol-4-sulphonic acid were added and it was transferred to 5 mL volumetric flask and total volume was made upto 5 mL with distilled water. Distilled water was used for blank. The concentration of PL in tissues was read against the blank at 660 nm within 10 min.

Triacylglycerol analysis: A weight of 0.1 g extracted lipid was taken. Four milliliter of isopropanol was added and mixed well. 400 mg of washed alumina was added. The mixture was placed in a mechanical rotator for 15 min and centrifuged. Two milliliter of supernatant was transferred into 15×100 mm of screw-capped tubes. A volume of 0.6 mL of potassium hydroxide was added into supernatant solutions, stoppered and incubated at 70°C for 15 min. Tubes were allowed to cool. 1 mL of metaperiodate solution and 0.5 mL of acetone reagent were added and mixed well; stoppered and incubated at 50°C for 30 min. Tubes were allowed to cool. One milliliter of distilled water was used for blank. The concentration of TAG in tissues was read against the blank at 405 nm.

Data analysis: All data were statistically analyzed by Micro soft Excel (Version 2007) and STATISTICA Soft ware (Version 6; Statsoft Inc.,Tulsa, USA). The data were checked for normal distribution by one-sample kolmogorov-smirno test and the variances were tested by the Levene's test for homogeneity. Lipid class concentrations in tissues were compared among gonad maturity stages as well as months. Lipid class contents in tissues were first analyzed by one way Analysis of Variance (ANOVA). When the results of the one way ANOVA show the mean values of the samples are significantly different, the ANOVA was followed by Post hoc comparison of means and Duncan's Multiple Range Test (DMRT) using STATISTICA 6.0 software. The level of statistical significance was set at $p<0.05$. Monthly analysis of lipid class content in different tissues was conducted only for adult fish (maturing stage to spent stage), which was collected throughout the year except January, November and December for female whereas March, November and December for male. Monthly lipid class data in different tissues for both years were pooled together and the average values for each month were computed.

RESULTS

One thousand four hundred and nineteen fish samples ranging from 10.7 to 67.8 cm in SL were examined and BW of individuals ranged from 21.10 to 2925.00 g. Reproductive status of individual fish was examined and the gonad developmental stages were classified as immature unsex (stage I), immature (stage II), maturing (stage III), mature (stage IV), spawning (stage V) and spent (stage VI) (Table 1).

Table 1: Macroscopic features of different gonad maturity stages (GMS) in *S. lysan*

Gonad maturity stages	Female	Male
Stage I	No differentiation of the gonad	No differentiation of the gonad
Stage II	Small ovaries, pinkish to translucent in colour with tapering ends. 25 to 35 mm in length	Small strap/thread like opaque testis with smooth appearance
Stage III	Flattened ovaries with pink colour. Oocytes are not visible externally and 30-100 mm in length	Larger than stage II, milt produced when squeezed
Stage IV	Rounded ovaries; yellow to orange in colour. Small oocytes can be visible through ovarian wall and 70-120 mm in length	Large opaque, bone colour testis. Exterior dorsal blood vessel are present and prominent
Stage V	Large, rounded and yellow colour ovaries with visible oocytes. Blood capillaries are also visible. Eggs may be released when pressure applied and 100-150 mm in length	Testis is large in size, but more have swollen with larger exterior blood vessels. Milt is released with little or no pressure on the abdomen or no pressure on the abdomen or when the tests is cut.
Stage VI	Ovaries are severely shrunken, flaccid, reddish yellow to grey in colour with large lumen and 100-130 mm in length	Testis is small and shrunken

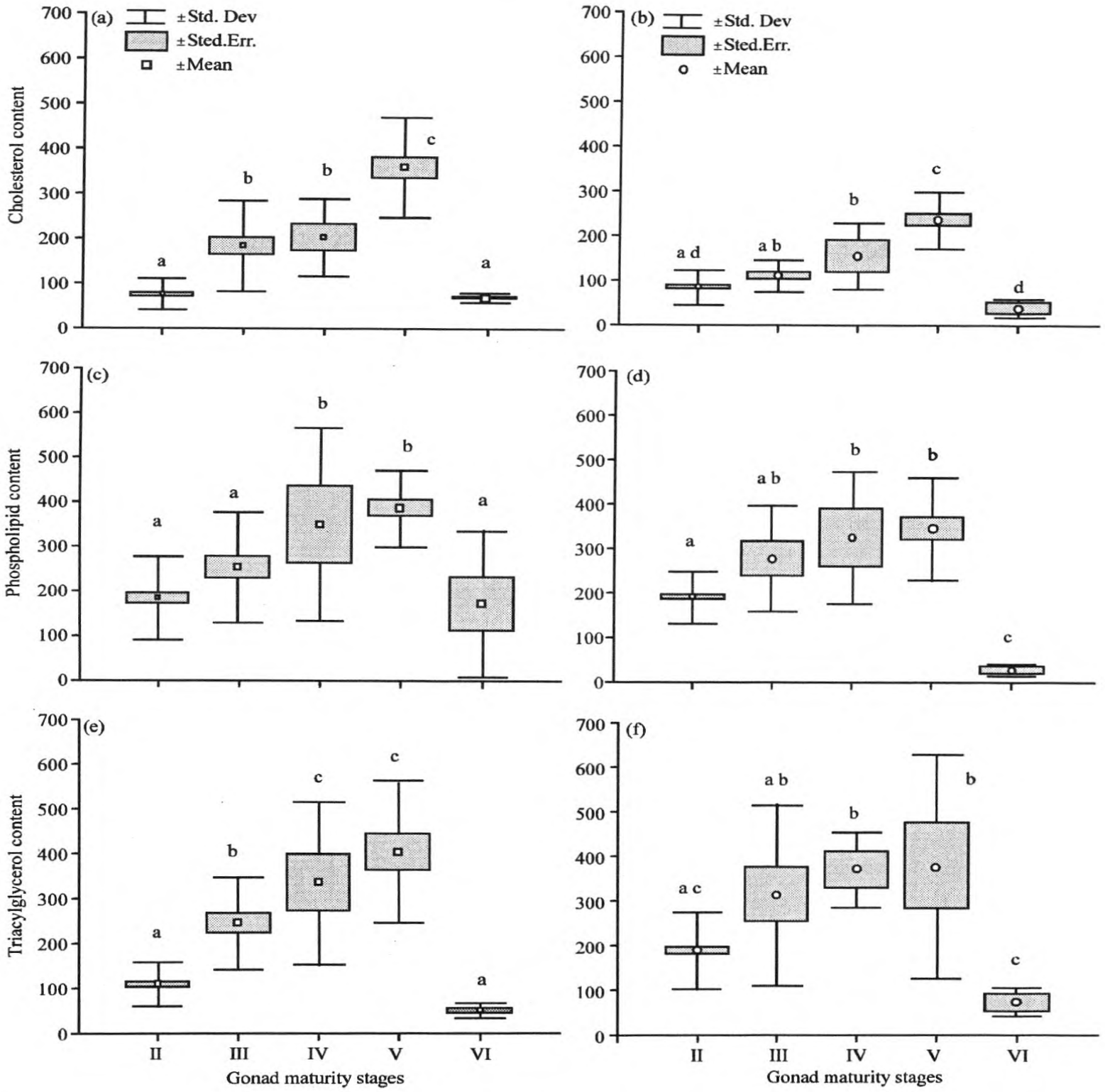


Fig. 2(a-f): Box and Whisker plot showing changes of lipid class content (mg.100g^{-1}) in gonad tissue of *S. lysan* in different gonad maturity stages, II: Immature; III: Maturing; IV: Mature; V: Spawning; VI: Spent. a, c and e-Gonad in female; b, d and f-Gonad in Male. Mean values for each gonad maturity stages with the common letters indicate not significantly difference (p>0.05)

Lipid changes in tissues with gonad maturity stages

Lipid class content in gonad tissues: The changes in lipid content of tissues for gonad maturity stages were analyzed for the entire data set (2010/2011). The amounts of CS, PL and TAG in the ovary increased throughout the ovarian maturation (stage I-V).

CS content in ovary showed 5 fold increase (p = 4.57E - 05) from stage II to stage V while 5 fold decrease (p = 2.86E-05) from stage V to VI (Fig. 2a). CS content in testis showed approximately

3 fold increase from stage II to V whereas a 6 fold decrease thereafter (Fig. 2b). The mean PL levels of both sexes showed 2 fold increases up to stage V and decreased thereafter (Fig. 2c, d). Content of TAG in ovary showed 4 fold increase ($p = 4.68E-05$) up to stage V whereas 8 fold decrease ($p = 2.94E-05$) from stage V to VI (Fig. 2e). Content of TAG in testis showed approximately 2 fold increase at stage V when compared to stage II while a 5 fold decrease from stage V to VI (Fig. 2f).

Lipid class content in muscle tissues: Lipid class concentration in immature unsex (stage I) of *S. lysan* was higher in muscle tissue compared with liver. PL content of muscle and liver tissues in stage I was higher than that of other lipid classes. The content of CS in muscle of female significantly ($p = 0.004$) increased from stage I to stage III and significantly ($p = 4.05E-06$) decreased beyond that (Fig. 3a). In the case of male, CS content in stage II is significantly ($p = 0.01$) increased from stage I and decreased therafter (Fig. 3b). The PL levels in the muscle of female were ($p = 0.008$) increased from stage I to IV (Fig. 3c). The content of PL was higher in females than males at stage IV. The highest contents of PL in male muscle tissue was observed at stage III and it was decreased ($p = 3.65E-05$) beyond stage IV (Fig. 3d). Content of TAG in muscle of females significantly ($p = 4.29E-06$) increased from stage I to stage IV and decreased ($p = 4.05E-06$) upto stage VI (Fig. 2e). In male, the content of TAG significantly ($p = 4.05E-06$) increased from stage I to III and decreased thereafter (Fig. 3f).

Lipid class content in liver: In female liver tissue, content of CS significantly ($p = 4.50E-06$) increased from stage I to III and significantly ($p = 4.3E-06$) decreased thereafter (Fig. 4a). Although the increase in CS content in male was moderately increased ($p = 4.05E-06$) from stage I to IV, it sharply decreased from stage IV to VI (Fig. 4b). PL content in female showed a slight fluctuation among maturity stages (Fig. 4c), significant ($p = 0.09$) difference was not observed from stage I to IV but a considerable ($p = 0.01$) drop was recorded at stage V. However, PL content in male increased from stage I to II and significantly ($p = 4.05E-06$) decreased from stage II to stage VI (Fig. 4d). Changes in the content of TAG was higher when compared to the moderate changes in PL and CS in the liver tissues of female (Fig. 4e). The mean TAG content of female liver tissues showed a 2 fold increase ($p = 1.09E-05$) from stage II to IV and then a 4 fold decrease ($p = 4.29E-06$) from stage IV to VI. A similar trend was also observed for TAG in male liver tissues (Fig. 4f) .

Monthly lipid changes in tissues: All three constituents of lipid class, CS, PL and TAG, showed higher and lower values corresponding to the maturation stage and annual spawning events (Table 2, 3). CS content of testis was significantly ($p = 0.003$) different from CS of ovary, whereas PL and TAG were not significantly different between male and female. Mean CS, PL and TAG content in ovary of females fluctuated throughout study and attained higher value in June and September (Table 2). Male gonads also followed a more or less similar pattern for CS, PL and TAG as that of female adult fish (Table 3).

The highest mean CS content in ovary of females collected in June and September months were 226.4 mg.100 g^{-1}±78.21 and 292.00 mg.100 g^{-1}±156.08, respectively (Table 2). Similar trend of CS content in male testis was observed (Table 3). CS content of testis significantly ($p = 0.046$) increased from July to September and attained a peak at September (226.3 mg.100 g^{-1}±69.92). The mean PL content in ovary of female reached the highest amount in June as 393.54 mg 100 g^{-1}±73.00

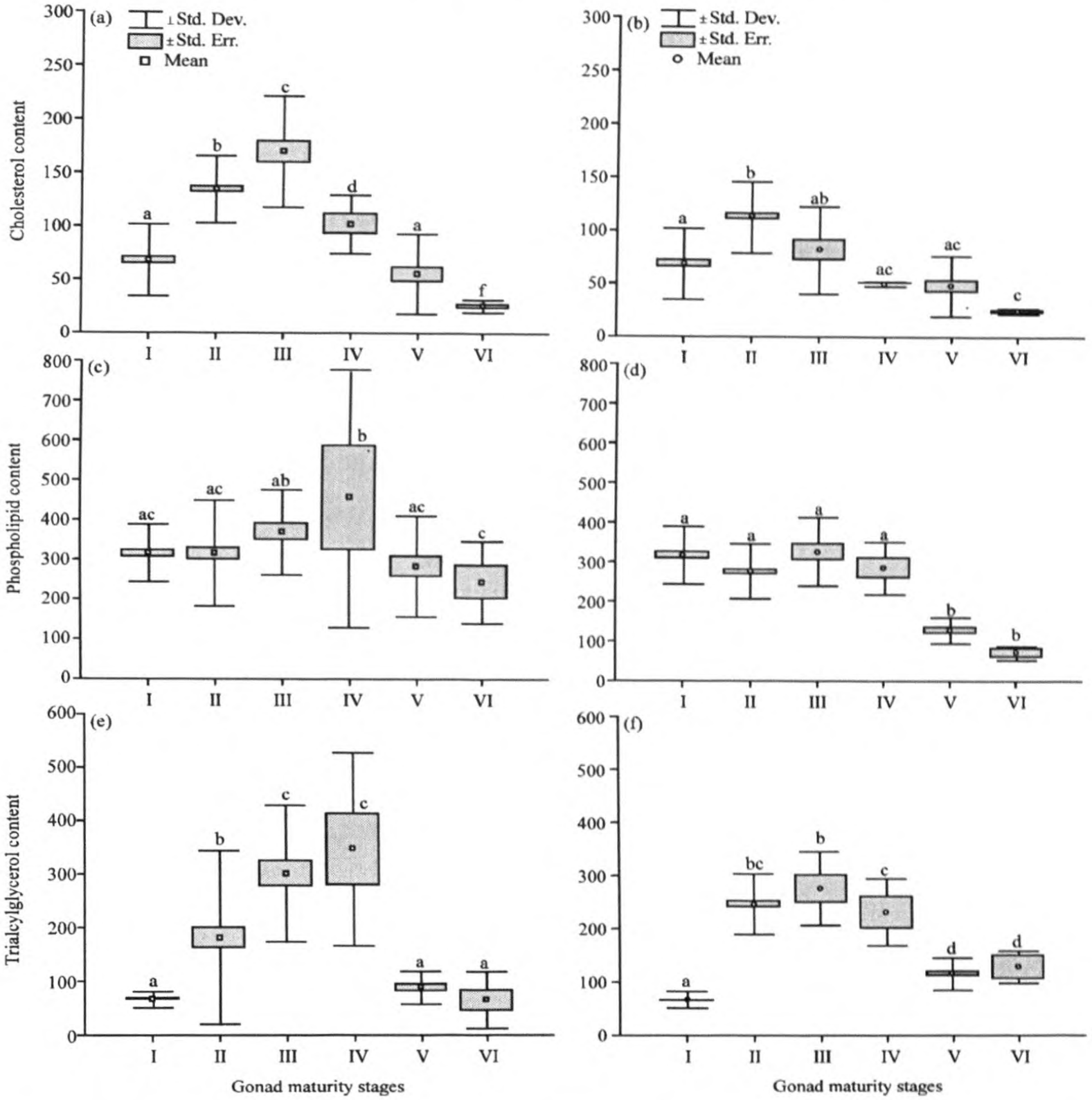
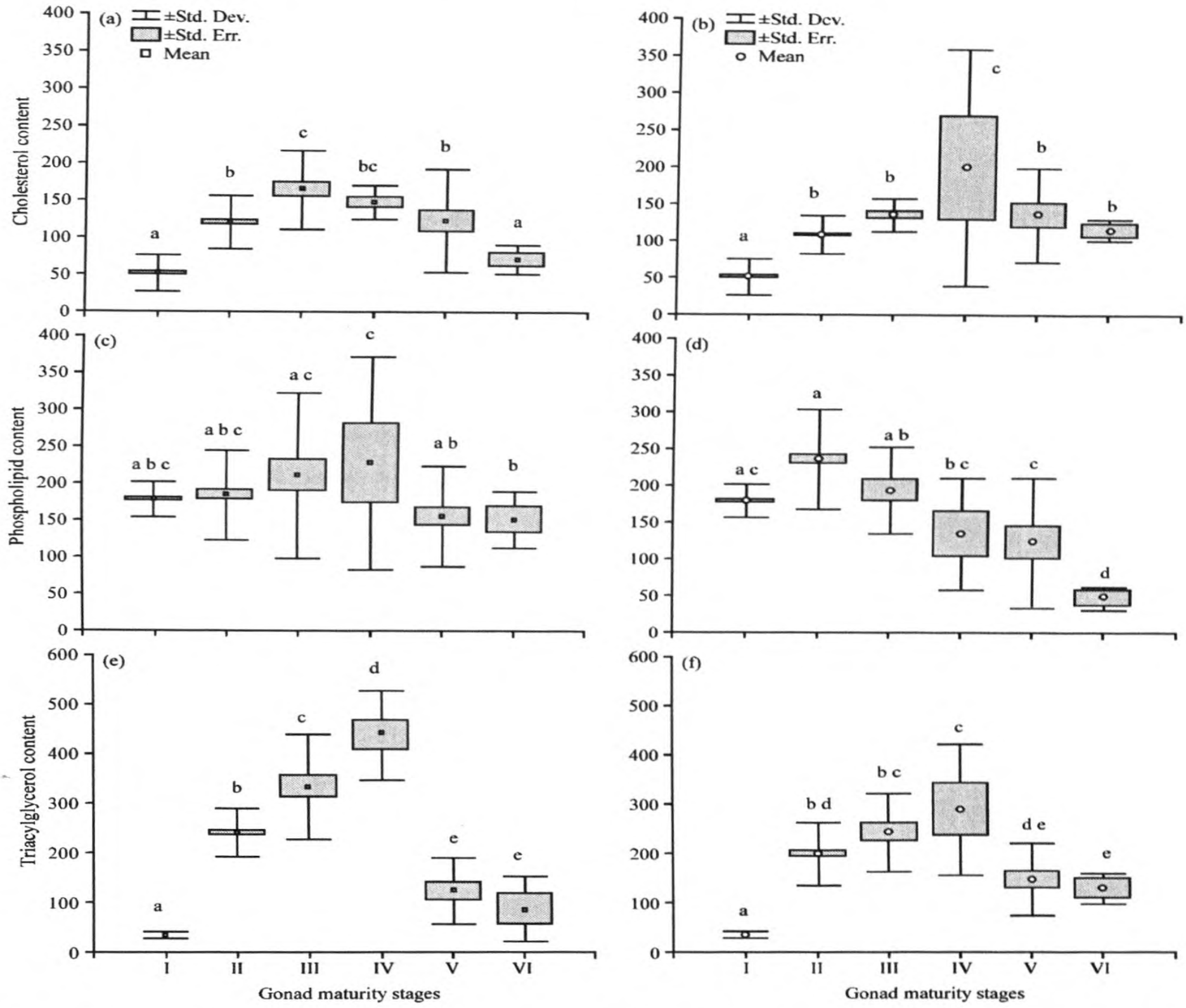


Fig. 3(a-f): Box and Whisker plot showing changes of lipid class content (mg.100g^{-1}) in muscle tissue of *S. lysan* in different gonad maturity stages, I: Immature unsex; II: Immature; III: Maturing; IV: Mature; V: Spawning; VI: Spent. a, c and e-in female; b, d and f-in Male. Mean values for each gonad maturity stages with the common letters indicate not significantly difference ($p>0.05$)

(Table 2). Similarly, mean PL content in testis of male significantly ($p = 0.040$) increased from April to June, attained the highest amount as 475.8 mg.100g^{-1}±153.6 and decreased in July (Table 3). Significantly ($p = 0.034$) highest TAG content in ovary of female was recorded in September (Table 2). The highest amount of TAG in testis of adult male fish was recorded in June as 453.1 mg.100g^{-1}±77.64 (Table 3).

Muscle tissue of both sexes contained low values of CS than the PL and TAG in all months (Table 2, 3). Fluctuations of CS content in muscle tissues of female were significantly lower in June



. 4(a-f): Box and Whisker plot showing changes of lipid class content (mg.100g^{-1}) in liver tissue of *S. lysan* in different gonad maturity stages, I: Immature unsex; II: Immature; III: Maturing; IV: Mature; V: Spawning; VI: Spent, a, c and e -in female; b, d and f -in Male. Mean values for each gonad maturity stages with the common letters indicate not significantly difference (p>0.05)

= 3.21E -05) and September (p = 1.8E-05) when compared to May. PL content in female muscle ue significantly (p = 0.004) decreased from April to June. TAG content in muscle tissues of ıale was significantly (p = 0.001) decreased from August to September (Table 2). But, monthly nges of CS, PL and TAG in male muscle tissue was not significantly fluctuated (Table 3).

Changes in liver CS and PL in both sexes was not significantly predictable (Table 2, 3). But ctuation of TAG content in liver was evident in both sexes. Female liver TAG significantly = 0.0017) declined from May to June and significantly (p = 0.0012) increased from June to

Table 2: Lipid class content of gonad, muscle and liver tissues in adult female *S. lysan* throughout the year 2010/2011

	Gonad			Liver			Muscle		
Month	Cholesterol	Phospholipid	Triacylglycerol	Cholesterol	Phospholipid	Triacylglycerol	Cholesterol	Phospholipid	Triacyl glycerol
January	ND	ND	ND	ND	ND	ND	ND	ND	ND
February	100.89±58.56^{a}	336.94±25.47$^{a c}$	152.01±53.87^{a}	133.32±15.91$^{a b}$	179.26±38.54^{a}	297.81±33.43$^{a d}$	171.66±8.79^{a}	368.16±96.75^{a}	267.93±153.75$^{a b c}$
March	141.19±43.82^{a}	355.48±90.03$^{a c}$	225.15±90.07$^{a b}$	154.17±2.02$^{a b}$	201.31±126.50^{a}	353.13±209.11$^{b d}$	175.01±8.37^{a}	467.98±94.51$^{a b}$	273.70±58.27$^{a b c}$
April	200.96±34.59^{a}	230.72±7.75$^{c b}$	205.27±72.18$^{a b}$	275.17±42.34^{c}	302.14±70.71$^{a b}$	307.02±7.77$^{a b d}$	273.74±11.99^{b}	616.20±35.35^{b}	234.37±30.90$^{a b c}$
May	220.30±7.20^{a}	383.23±82.00^{a}	292.23±73.56$^{a b}$	205.61±7.78$^{a c}$	350.68±0.79^{b}	456.50±62.93^{b}	283.50±1.95^{b}	464.71±28.97$^{a b}$	331.73±2.14$^{a b}$
June	226.38±78.21^{a}	393.54±72.98^{a}	327.19±81.41$^{a b}$	147.55±85.40$^{a b}$	154.70±52.76^{a}	190.02±116.69$^{a c}$	145.31±46.43^{a}	286.55±56.86$^{a c}$	153.84±130.90$^{a c}$
July	153.06±47.41^{a}	185.28±4.13^{b}	246.37±3.03$^{a b}$	140.74±7.75$^{a b}$	199.67±64.42^{a}	265.31±12.43$^{c d}$	134.44±11.18^{a}	345.35±56.56$^{a c}$	331.59±28.29$^{a b}$
August	267.78±117.76^{a}	349.34±131.54$^{a c}$	367.48±95.44$^{a b}$	167.42±24.38$^{a b}$	242.73±159.72$^{a b}$	451.86±100.23$^{b c}$	136.82±41.36^{a}	399.29±232.77$^{a b c}$	400.59±161.18^{b}
September	292.03±156.08^{a}	402.51±75.59^{a}	387.76±175.53^{b}	112.52±62.65^{b}	150.04±61.52^{a}	129.37±72.00^{c}	42.92±22.58^{c}	281.02±120.19$^{a c}$	97.78±61.03^{c}
October	135.18±53.28^{a}	218.40±100.53$^{c b}$	321.30±129.39$^{a b}$	134.89±15.55$^{a b}$	188.03±46.55^{a}	348.18±51.45$^{b d}$	87.77±25.15^{d}	185.67±79.80^{c}	263.04±64.86$^{a b c}$
November	ND	ND	ND	ND	ND	ND	ND	ND	ND
December	ND	ND	ND	ND	ND	ND	ND	ND	ND

Mean values for each month with the common letters indicate not significantly difference ($p>0.05$). ND: Not detected, Values are Means±SD

Table 3: Lipid class content of Gonad, Muscle and Liver tissues in adult male *S. lysan* throughout the year 2010/2011

	Gonad			Liver			Muscle		
Month	Cholesterol	Phospholipid	Triacylglycerol	Cholesterol	Phospholipid	Triacylglycerol	Cholesterol	Phospholipid	Triacyl glycerol
January	100.16±0.07^{a}	285.67±34.72$^{a b}$	147.16±6.99^{a}	110.12±14.14^{a}	123.36±1.49^{a}	169.71±26.16^{a}	163.66±11.96^{a}	305.10±7.06$^{a b}$	175.10±49.49^{a}
February	98.88±19.30^{a}	345.71±115.23$^{a b}$	190.94±108.48$^{a b}$	102.45±0.06^{a}	128.40±3.96^{a}	176.32±28.10^{a}	164.85±19.22^{a}	315.74±20.52$^{a b}$	182.26±58.35^{a}
March	ND	ND	ND	ND	ND	ND	ND	ND	ND
April	100.78±0.82^{a}	213.70±4.94^{a}	366.93±1.02$^{a b}$	151.26±1.49^{a}	310.35±14.34^{b}	354.90±6.63^{a}	41.37±1.63^{b}	342.65±3.59$^{a b}$	143.72±0.69^{a}
May	128.03±36.10$^{a b}$	384.55±148.42$^{a b}$	426.83±137.60$^{a b}$	99.36±66.69^{a}	214.21±66.77$^{a b}$	260.48±8.30^{a}	41.22±7.91^{b}	199.32±00.1$^{a b}$	163.43±30.82^{a}
June	133.42±28.84$^{a b}$	475.75±153.62^{b}	453.10±77.64^{b}	91.62±57.63^{a}	206.04±136.86$^{a b}$	218.31±39.48^{a}	38.96±10.62^{b}	202.09±34.90$^{a b}$	170.62±27.51^{a}
July	113.65±14.52^{a}	319.08±161.01$^{a b}$	367.73±105.00$^{a b}$	137.98±26.90^{a}	168.10±18.92$^{a b}$	259.60±00.2^{a}	57.01±7.68^{b}	304.87±117.29$^{a b}$	305.23±78.30^{a}
August	195.37±98.64$^{a b}$	229.00±96.50$^{a b}$	446.59±47.84^{b}	256.94±160.78^{a}	203.24±90.92$^{a b}$	339.20±178.65^{a}	50.62±0.70^{b}	275.16±38.65$^{a b}$	261.36±0.001^{a}
September	226.27±69.91^{b}	332.15±120.84$^{a b}$	424.13±225.51$^{a b}$	125.27±99.24^{a}	124.51±80.11^{a}	175.16±125.11^{a}	49.15±26.06^{b}	192.08±101.51^{a}	140.63±83.87^{a}
October	102.06±51.63^{a}	259.91±5.07$^{a b}$	412.96±115.53$^{a b}$	131.87±32.95^{a}	225.23±62.44$^{a b}$	220.88±65.37^{a}	97.60±29.24^{c}	376.71±63.83^{b}	222.04±76.17^{a}
November	ND	ND	ND	ND	ND	ND	ND	ND	ND
December	ND	ND	ND	ND	ND	ND	ND	ND	ND

Mean values for each month with the common letters indicate not significantly difference ($p>0.05$). ND: Not detected, Values are Means±SD

August and again significantly ($p = 0.0002$) decreased in September. Liver lipid in both sexes attained maximum value in August, whereas minimum values were obtained in June and September.

DISCUSSION

Analysis of lipid classes in gonad, muscle and liver tissues are a widely applied methodology in the study of reproduction (Shearer and Swanson, 2000; Das and Sahu, 2001).The results of the present study suggest that the *S. lysan* showed an important relationship between lipid classes and gonad maturity stages as well as with different months. It further shows that *S. lysan* undergoes major changes in lipid contents in gonad, muscle and liver tissue.

Lipid changes in tissues with gonad maturity stages: The findings of lipid classes in immature stages of *S. lysan* are in agreement with the observations made by Litvin *et al.* (2011), who reported that PL was the predominant lipid class in muscle of juvenile weakfish *Cynoscion regalis*, while TAG was in low concentrations. Yet, liver of juvenile fish contained low amount of TAG than that of muscle.

Total lipid content in ovary of *S. lysan* was higher in spawning stage while lowest in spent stage. Similar observation was shown in *Trachinotus ovatus,* where total lipid content of ovaries attained the highest value at spawning stage and lowest value at spent stage (Assem *et al.*, 2005).

The results of the present investigation reveal that the mean value of lipid class composition in ovary has relatively higher amount of TAG and PL than the CS. Ovary of red drum (Vetter *et al.*, 1983) and gilthead sea bream (Mourente and Odriozola, 1990) also contain highest amount of TAG and PL than the CS (proportions of total lipid content). Hilton *et al.* (2008) also noticed that the PL in the brood stock egg of yellowtail kingfish (*Seriola lalandi*) was higher whereas the triacylglycerol value was lower in egg of yellowtail kingfish. In contrast, sand eel has higher value of TAG than PL (proportions of total lipid content) (Tocher and Sargent, 1984).

Muscle lipid content of *S. lysan* attained a maximum value during mature stages and minimum value during spawning stage. Bransden *et al.* (2007) also identified a similar pattern, they specified that the fat content in muscle of male and female striped trumpeter *Latris lineate* were decreased by 25 and 40%, respectively during the spawning period. Contents of PL in muscle of *S. lysan* increased from immature stage to mature and decreased thereafter. Similar trend was demonstrated by Rao (1965), who recorded that concentration of inorganic phosphorous compounds in muscles of *Caranx sexfasciatus* increased with maturity. Yagana (1982) also reported that the value of phospholipid in muscle of catfish *Clarias bairachus* declined during spawning period and the low phosphorous content was observed in post-spawning period. In contrast, Thakur *et al.* (2009) reported that the polar lipid in muscle of yellowtail (*Seriola quinqueradiata*) was minor constituents throughout the maturation. Muscle tissues of mature *S. lysan* fish shows low CS content in the present study. Further the present study describes that *S. lysan* can be included under 'low fat fish' category (Sutharshiny and Sivashanthini, 2011a, c) Hence, consumption of *S. lysan* fish posses no risk to human health.

TAG content in liver tissues of mature *S. lysan* exhibited higher values. Seiichi *et al.* (1993) also identified that the major lipid component of the liver in amberjack and striped jack were triglyceride. Content of TAG in liver tissues of *S. lysan* was decreased after spawning. The observation is consistent with the findings by Phleger (1971), who found that the total liver lipid content of pink salmon *Onchorhychus gorbuscha* decreases in the spent fish. Phleger (1971)

further explained that the liver of fish do not to synthesize the triglyceride after spawning. The cholesterol content of the liver of *S. lysan* exhibited a low variation during the maturation cycle and highest value was recorded at mature stage, while the minimal value was recorded at spent stage. Findings of the present investigation on *S. lysan* is in agreement with the work of Idler and Bitners, 1960), who reported that the total cholesterol content in liver declined and deposited in ovary of migratory salmon, *Oncorhynchus nerka*, during the spawning phases. In contrast, Phleger (1987) identified that the CS content in liver of pink salmon (*Onchorhychus gorbuscha*) remain constant after spawning.

Lipid changes in tissues through out the year: From the present study, it is obvious that the lipid class constituents CS, PL and TAG of gonad, muscle and liver tissues of tropical *S. lysan* show a variation throughout the year, corresponding to the maturation stage and annual spawning events. Peak spawning of adult female *S. lysan* was reported in June and September months (Thulasitha and Sivashanthini, 2013).

The lipid class content in ovary of *S. lysan* fluctuated throughout the year and attained a noticeable peak value during the spawning period while, muscle and liver lipid content of *S. lysan* attained the lower amount. Arrington *et al.* (2006) also proposed similar pattern of seasonal changes in lipid content of muscle, liver and gonad of three neo tropical fish. Similarly, Bustamante (1989) recorded that the body fat accumulated before the spawning of bar jack (*Caranx ruber*) and decreased during the spawning period. At the same time, the lipid content in ovary increased during the spawning time.

Major fluctuations of PL and TAG content in muscle of *S. lysan* were noticed during the period of spawning. Likewise, Thakur *et al.* (2009) showed TAG content in muscle of amberjack (*Seriola dumerili*) varied considerably with season. Although, Polar Lipid (PL) content in muscle remained almost constant over the study period.

Fluctuation of liver TAG content was evident in both sexes of *S. lysan*. Similarly, liver lipid composition of red drum (*Sciaenops ocellatus*) varied throughout the year (Craig *et al.*, 2000). The mean TAG content in liver tissues of both sexes of *S. lysan* was higher during the maturation and declined thereafter. This is in confirmation with the findings of Craig *et al.* (2000).

CONCLUSION

From the present study it has been concluded that the variation in cholesterol (CS), phospholipid (PL) and triacylglycerol (TAG) in gonad, muscle and liver tissues in different gonad maturity stages, confirm a strong link between lipid profile and reproductive strategies of tropical *Scomberoides lysan*. Knowledge of the lipid dynamics of *S. lysan* throughout the year assist to determine the non spawning period and therefore it is the fishing season of *S. lysan*. Range of muscle CS, PL and TAG value obtained in the present study signifies that *S. lysan* recommended as one of the healthiest food fish for human consumption. Determination of CS, PL and TAG content in ovary, muscle and liver tissues of different maturity stages of *S. lysan* further provide information on nutrition of lipid in terms of diet formulation in future culture trails of *S. lysan*. The present study provides fundamental information to successful formulation and implementation of policies, strategies and plans in fisheries management and future aquaculture trials.

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Growth Pattern and Length-weight Relationship of *Scomberoides lysan* (Pisces: Carangidae) from the Northern Waters of Sri Lanka

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ABSTRACT

Estimating length-weight parameters for food fish is an important component in the population dynamics studies. The present study was carried out to find the length-weight relationship parameters of tropical *Scomberoides lysan* (Forsskal 1775) from the northern waters of Sri Lanka. Weekly samples were collected from the commercial catches during January 2010 to December 2010. A total of 892 specimens (299 males, 354 females and 239 unsexed) were analyzed. Curvilinear relationships of length-weight relationships for male, female and unsexed obtained were $W = 0.0037*L^{3.1319}$, $W = 0.0058*L^{3.0048}$ and $W = 0.0179*L^{2.6496}$, respectively. Comparison of regression co-efficient of male, female and unsexed using GLMANCOVA revealed that the 'b' values show significant differences ($p<0.05$) between each other. The exponent values 3.1319 for male and 2.6496 for unsexed were significantly different ($p<0.05$) from 3, whereas, the value 3.0048 for female did not deviate significantly ($p>0.05$) from 3. From the statistical analysis it can be concluded that males exhibit positive allometric growth, females exhibit isometric growth and unsexed exhibit negative allometric growth. The parameters obtained from the study are useful fundamental factors applicable in future culture trials as well as in population dynamics studies.

Key words: Length-weight relationship, double spotted queen fish, *Scomberoides lysan*, allometric growth, cube law, drift gill net, Indian ocean

INTRODUCTION

Understanding the length-weight relationship parameters plays a major role in fisheries biology and population dynamics (Sivashanthini, 2008). Studies on length-weight relationship provide information about their growth level (Okgerman, 2005). Measuring the weight of live fish in the field is very difficult and time consuming (Morato *et al*., 2001). Various authors revealed that information on length-weight relationship is required to determine the conversion of growth-in-length equations to growth-in-weight. These conversions can be used in stock assessment models. It can also be used in the estimation of biomass from length observations and estimation of the condition of the fish and this relationship is useful for comparison of life histories of certain species between regions (De La Cruz Aguero *et al*., 2011; Goncalves *et al*., 1996; Moutopoulos and Stergiou, 2002).

Using the length-weight relationships, the well-being of individuals can be assessed. Okgerman (2005) derived the condition factor form the length-weight relationship for

Scardinius erythrophthalmus from the Sapanca Lake. The 'b' values of 3.3731 and mean condition of 1.243 were recorded in his study. The differences between separate unit stocks of the same species can also be determined by these parameters (King, 2007). Moreover, estimating length-weight parameters is essential to compare the growth pattern in fisheries management (Moutopoulos and Stergiou, 2002).

Previous studies show that several researchers reported the length-weight parameters not only for finfish but also for fish related organisms from various parts of the world. Few examples for such research work on finfish are studies made by Ayoade (2011) for African carp *Labeo ogunensis*, Lawson *et al.* (2011) for frill fin goby, *Bathygobius soporator*, Elp *et al.* (2006) for Barbel, *Barbus plebejus ercisianus*, Hosseini *et al.* (2009) for *Sphyraena jello* and by Sivashanthini *et al.* (2009a) for *Sphyraena obtusata*. One related study available for fish related organism is the study made by Sivashanthini *et al.* (2009b) for squid, *Sepioteuthis lessoniana*. It is evident from the literature survey that the length-weight relationship of *Scomberoides lysan* have not been studied, so far and this is the first study for *S. lysan*.

The genus *Scomberoides* is classified under family Carangidae; and four species of *Scomberoides* have been recorded from the Sri Lankan waters, such as *S. lysan*, *S. commersonianus*, *S. tol* and *S. tala* (De Bruin *et al.*, 1995). No information is available on the biology or length-weight relationship of the above four species from the Sri Lankan waters. *S. lysan* is commonly known as double spotted queen fish found in the tropical areas of Indian and Pacific Ocean. These are one of the economically important large food fish found in coastal as well as offshore fisheries in Sri Lanka (De Bruin *et al.*, 1995). It is more popular for dry fish production and has high export value. Therefore, the present study has been carried out to find the length-weight relationship parameters of tropical *Scomberoides lysan* using morphometric measurements from the northern waters of Sri Lanka.

MATERIALS AND METHODS

Sample collection: Northern part of Sri Lanka is situated between 79°E to 80°E longitude and 9°N to 10°N latitudes in the Indian ocean. Samples were collected weekly from the commercial catches at Passaiyoor, Delft, Karainagar and Point Pedro landing centers during January 2010 to December 2010, using a specific drift gill net for Genus *Scomberoides* with the mesh size of 7", 21 ply (Katta valai). Beach seines and trap net (Kalankatti valai) fixed in shallow waters are also operated to caught *S. lysan* in waters around Jaffna peninsula.

Morphometric measurements: Total Length (TL) of each fish was measured from the anterior most edge of the lower lip (tip of snout) to the distal part of the caudal fin to the nearest mm with a measuring board and Total Weight (TW) was measured to the nearest 0.1 g by an electronic balance (AND, HF-1200G). All specimens were sorted by sex according to the morphological analysis of gonads as male, female or unsexed.

Regression analysis: The relationship between the length and weight of a fish is usually expressed by the equation $W = a L^b$ (Ricker, 1973); where, W is the weight of the fish, L is the total length, "a" is the intercept and "b" is the slope. If a fish is growing isometrically (increasing in all dimensions at the same rate) and doubles in length, its weight will increase in relation to the increase in volume; that is by 8 (or 2^3) times (King, 2007). Thus there is a cubic relationship between length (L) and weight (W) and 'b' is close to 3 in isometric growths and 'a' is a constant determined empirically.

Statistical analysis: Weights and lengths of male, female and unsexed were log transformed and the resulting linear relationship fitted by the computer based linear regression analysis. Significance of the regression was assessed by General Linear Model Analysis of Covariance (GLMANCOVA). The "b" values obtained for male, female and unsexed were tested by Student's t-test to see whether the 'b' values differ significantly from 3 or not (Zar, 1999). Two sample t-test was performed to compare the mean weight data of male and females to distinguish the significant difference between male and female. All statistical analysis was done by MINITAB (Version 14) statistical software and the significance level was tested at 95% confidence interval.

RESULTS AND DISCUSSION

A total number of 892 fish (299 males, 354 females and 239 unsexed) were analyzed. Length range of fish collected is 22.2-62.5 cm for males, 22.0-71.0 cm for females and 14.6-36.1 cm for unsexed. The estimates of the regression parameters for male, female and unsexed are given in Table 1. The r^2 values obtained while calculating the regression parameters are 0.9485 for males, 0.9490 for females and 0.9435 for unsexed. For male, female and unsexed *S. lysan* obtained residual degrees of freedom are 297, 352 and 237 whereas residual sum of squares are 1.505861, 1.348065 and 0.590727, respectively. Linear regression relationships between total length and weight of male, female and unsexed *S. lysan* are given in Table 2. Curvilinear relationships obtained for male, female and unsexed are $W = 0.0037\ L^{3.1319}$, $W = 0.0058\ L^{3.0048}$ and $W = 0.0179\ L^{2.6496}$, respectively.

The results of student's t-test to analyze the significance of variation in the estimates of 'b' for *S. lysan* from the expected value for the ideal fish (3.0) are as follows:

- Male (3.1319-3)/0.0424 = 3.1159 Significant (Computed $t_{a\ (2),0.05,\ 298} > 1.97$)
- Female (3.0048-3.0)/0.0371 = 0.1305 Not significant (Computed $t_{a\ (2)0.05,\ 353} < 1.97$)
- Unsexed (2.6496-3.0)/0.0421 = 8.3144 Significant (Computed $t_{a\ (2)0.05,\ 238} > 1.97$)

Student t-test showed that the 'b' values obtained for male and unsexed were significantly different ($p<0.05$) from 3 indicating positive allometric growth for male and negative allometric growth for unsexed whereas the 'b' value obtained for female very close to 3, did not deviate significantly ($p>0.05$) from 3 indicating isometric growth. Correlation coefficient (r^2) 0.9485 for

Table 1: Length-weight relationship parameters of *S. lysan*

			Error estimate					
Sex	N	df	df residual	SS residual	r^2	'a'	'b'	Length range in cm
Male	299	298	297	1.505861	0.9485	0.0037	3.1319	22.2-62.5
Female	354	353	352	1.348065	0.9490	0.0058	3.0048	22.0-71.0
Unsexed	239	238	237	0.590727	0.9435	0.0179	2.6496	14.6-36.1

N: No. of observations, df: Degrees of freedom, 'b': Regression exponent, 'a': Constant, SS: Sum of squares, r: Correlation coefficient

Table 2: Linear regression relationship between total length and weight of male, female and unsexed *S. lysan*

Sex	Length -weight relationship	Logarithmic transformation
Male	$W = 0.0037\ L^{3.1319}$	Log TW= -2.38+3.13 Log TL
Female	$W = 0.0058\ L^{3.0048}$	Log TW= -2.24+3.00 Log TL
Unsexed	$W = 0.0179\ L^{2.6496}$	Log TW= -1.75+2.65 Log TL

Table 3: Parameters obtained from two-sample t-test for mean weight of males and female of *S. lysan*

Parameters	Male	Female
Mean	303.23	263.53
Variance	54554.95	37996.08
Observations	299	354
Hypothesized mean difference	0	
Df	582	
T Stat	2.332	
P (T≤t) one-tail	0.010	
T Critical one-tail	1.647	
P (T≤t) two-tail	0.020	
T critical two-tail	1.964	

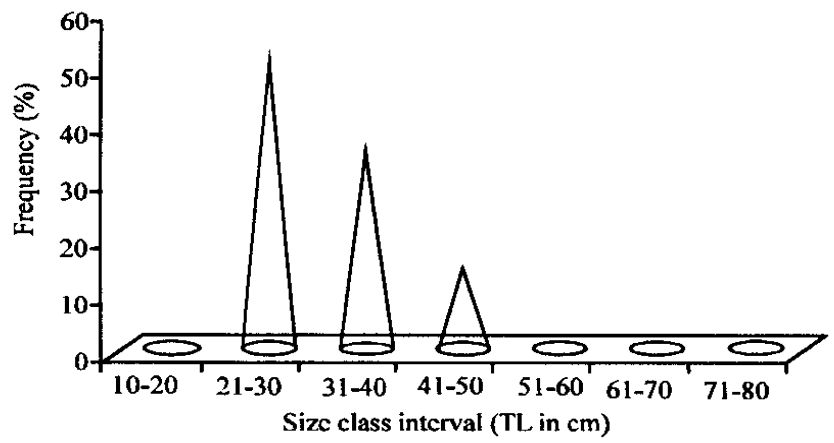

Fig. 1: Percentage frequency of total length distribution of male, female and unsexed *S. lysan*

males, 0.9490 for females and 0.9435 for unsexed found to be significant ($p<0.001$) in all instances indicating good correlation between length and weight of *S. lysan*.

Comparison of regression co-efficient of male, female and unsexed using GLMANCOVA for the regression of log weight on log total length for *S. lysan* male, female and unsexed revealed the b values show significant differences ($p<0.05$) between each other. The confidence intervals of 'a' value for male, female and unsexed do not overlap with each other and therefore there is a significant difference between the intercepts, too.

Results of the two sample t-test are given in Table 3. It showed that males were significantly ($p>0.05$) heavier than females. The frequency distribution of total length for male, female and unsexed *S. lysan* individuals is shown in Fig. 1. Highest percentage of frequency (50.4%) was observed for *S. lysan* individuals of 21-30 cm total length class interval.

Length-weight relationship of fish and fish related organisms have been studied widely in all parts of the world by several authors. Different values for the exponent coefficient (b) for different fish have been recorded in different parts of the world. Earlier, Allen (1938) pointed out that the exponent coefficient (b) computed from the length-weight relationship of fishes is usually 3. Later, Carlander (1969) pointed out that the 'b' value is very close to 3.0 but varies between 2.5 and 3.5. This statement could be supported by the previous work carried out for various fish species for example 3.171 for *Amblygaster sirm*, 3.24 for *Carcharhinus albimarginatus* (Kulbicki *et al*., 1993); 2.459 for *Sepioteuthis lessoniana* (Sivashanthini *et al*., 2009b); 3.359 for *Leuciscus cephalus* Karatas and Faith CAN (2005); 2.880 for *Tenualosa ilisha* (Ahmed *et al*., 2008) and 2.929 for *Atherina* sp. (Bouriga *et al*., 2011). These 'b' values cannot be simply compared for consistency as these are different species with different metabolic rate.

Widely accepted concept is that if the exponent value is 3, the fish grows isometrically, if it is greater or less than 3 fish grows allometrically (Tesch, 1968). The 'b' value depends on several factors such as age, body shape and amount of fat present, sex, maturity stage, season, temperature, salinity and available nutrient food (Moutopoulos and Stergiou, 2002). Taskavak and Bilecenoglu (2001) and Ozaydin and Taskavak (2006) stated that the parameter 'b' in the length-weight relationship vary seasonally, even daily and between habitats.

Length-weight relationship of *S. lysan* have not been studied in Sri Lanka, so far and this is the first study to compute such parameters. Some of the earlier results on length-weight relationship of *Scomberoides* species from other parts of the world are shown in Table 4. In New Caledonia and South Africa 'b' value of 2.896 and 2.685 was obtained, respectively for *S. lysan* (Letourneur *et al.*, 1998). But 'b' value of 2.937 was obtained for *S. tol* from Karnataka waters, India (Abdurahiman *et al.*, 2004). The 'b' value obtained in the present study for male (3.1319) and female (3.0048) is slightly higher than the previously recorded values. It may be due to the variations in ecology of the geographical locations, food availability and different environmental conditions. However the 'a' and 'b' values obtained for male and female *S. lysan* were superimposed in the plot of log 'a' versus 'b' available for *S. lysan*, Carangidae and 1300 miscellaneous species in FishBase 2011 (Froese and Pauly, 2011) and it is shown in Fig. 2a and b. The parameters obtained from the study are useful fundamental factors applicable in future culture trials as well as in population dynamics studies.

Table 4: The parameters of length-weight relationships of genus *Scomberoides* from different regions of the world (SL = standard length, FL = Fork length, TL = Total length)

Species	Sex	N	Length type	a	b	Region	Source
S. lysan	all	68	SL	0.0579	2.685	South Africa	Letourneur *et al.* (1998)
S. lysan	all	14	FL	0.0149	2.896	New Caledonia	Letourneur *et al.* (1998)
S. lysan	all	14	FL	0.0109	2.923	New Caledonia	Letourneur *et al.* (1998)
S. tol	M	59	TL	0.007	2.937	Karnataka, India	Abdurahiman *et al.* (2004)
S. commersonnianus	all	306	TL	0.00004	2.792	Northern Australia	Griffiths *et al.* (2005)

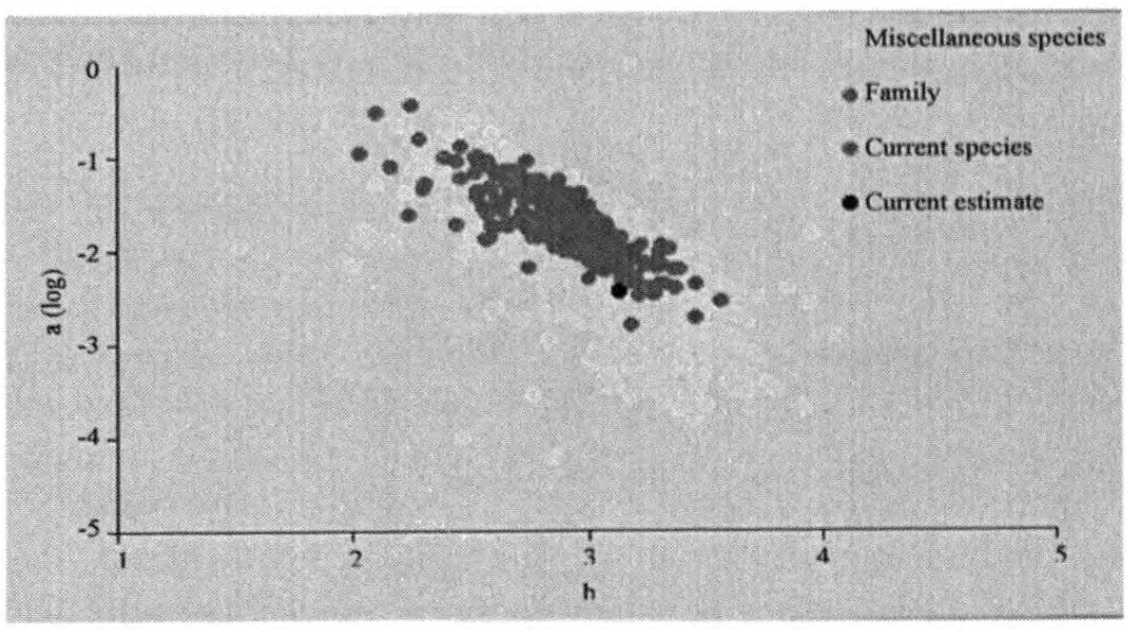

Fig. 2a: Plot of log 'a' versus 'b' for male *S. lysan* (Black dot indicates the current estimate; X axis denotes exponent coefficient 'b' and Y axis denotes constant 'log a'). Source: FishBase 2011

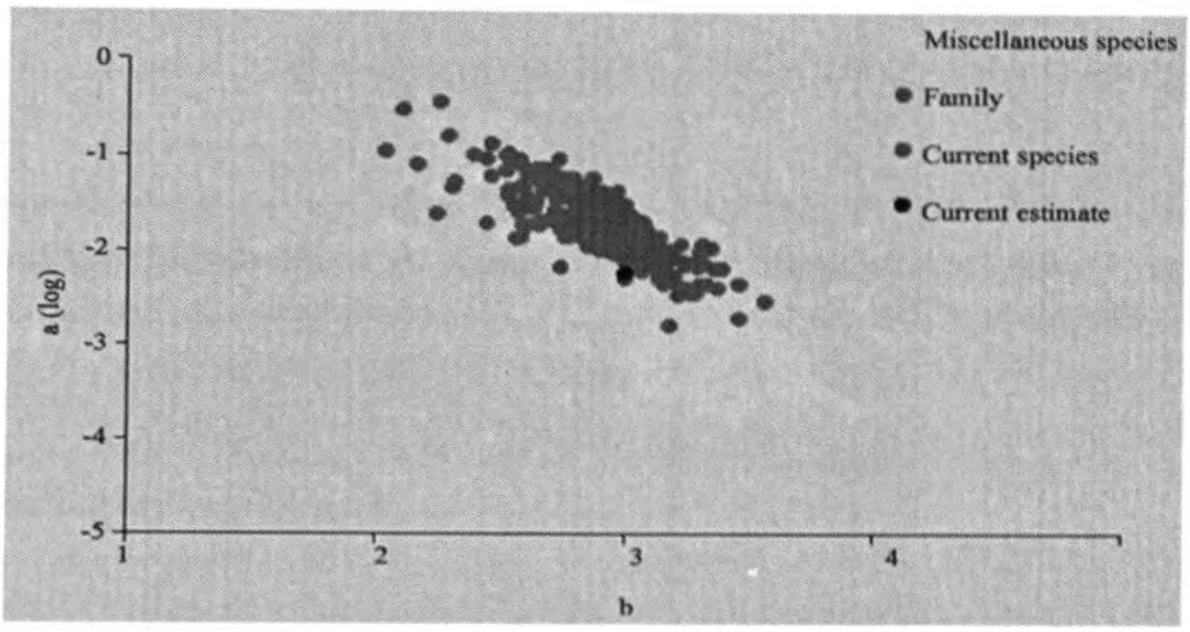

Fig. 2b: Plot of log 'a' versus 'b' for female *S. lysan* (Black dot indicates the current estimate; X axis denotes exponent coefficient 'b' and Y axis denotes constant 'log a'). Source: FishBase 2011

CONCLUSION

Length-weight relationships for male, female and unsexed *S. lysan* were $W = 0.0037*L^{3.1319}$, $W = 0.0058*L^{3.0048}$ and $W = 0.0179*L^{2.6496}$, respectively. Comparison of regression co-efficient of male, female and unsexed using GLMANCOVA revealed that the 'b' values show significant differences ($p<0.05$) between each other. The statistical analysis confirmed that males exhibit positive allometric growth, females exhibit isometric growth and unsexed exhibit negative allometric growth. The parameters obtained can be applied in future culture trials and in population dynamics studies.

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Estimation of growth parameters for tropical *Scomberoides lysan* (Carangidae)

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The present study was carried out to understand the growth parameters of the tropical double spotted queen fish, *Scomberoides lysan*. Growth parameters of *S. lysan* such as asymptotic length, growth coefficient and age at zero length were estimated based on length frequency data using FiSAT II software. A total number of 1115 samples were collected weekly from the commercial catches in the Northern waters of Sri Lanka during January 2010 to December 2011 and sexes were separated by observing the gonads. The von Bertalanffy growth parameters for male *S. lysan* were L_∞ = 87.96 cm, K= 0.41 year^{-1}, t_0 = -0.1582 year^{-1} and for females, L_∞ = 88.85 cm, K= 0.40 year^{-1}, t_0 = -0.16195 year^{-1}. The growth coefficient (K) of both male and female indicates that this species shows faster growth. The Powell-Wetherall plot gave a Z/K value of 2.174 for males and 1.964 for females, where Z is the total mortality. The estimated growth performance index (Ø) for male and female were 3.5013 and 3.4993. The inverse von Bertalanffy equation shows that 50 % of males attained maturity at age 2.266 years (55.4 cm total length) and females at 2.712 years (60.7 cm Total length). Estimated longevity (t_{max}) for *S. lysan* calculated from Pauly's equation was 7.317 for males and 7.338 for females. The results give fundamental data for the population dynamics and stock assessment studies of *S. lysan*.

Keywords: Age at maturity, growth coefficient, longevity, *Scomberoides lysan*, tropical fish

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The state of Malaysian marine capture fisheries and the world perspective

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The study analyzes the status of Malaysian marine and inshore capture fisheries status. The analysis was performed by using data and information related to world status and impacts from capture fisheries available in journals, reports and conference proceedings. The statistical database software *Fishstat Plus* (Food and Agricultural Organization) was also used to analyze fisheries production trend and comparison with world production. In last ten years Malaysian catches were increased from 1,255,968 metric tons in 1999 to 1,401,065 metric tons in 2008 which increased by 12 percent whereas world production was decreased by 2% at the same time. Malaysia contributes 1.5% of the world fisheries landing in average during last 10 years. More than half of the world fisheries production comes from Asian countries. Malaysia is the eleventh producer of capture fisheries in the Asian countries. Tunas, bonitos, billfishes are the highest catches in Malaysian landings. The number of fishing vessels and fishermen in Malaysia are increased as 19.01% and 14.45 respectively in 2009 from previous year, but total catches are not increased as same fashion. It seems fisheries stocks in Malaysian waters are declining. The reason might be overfishing in previous years or environmental factors rendering the fish stock declined.

Keywords: capture fisheries, world production, Malaysia

Variation in condition factor in relation to spawning season of double spotted queen fish *Scomberoides lysan* from the Sri Lankan waters

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Present study was carried out to understand the variation of condition of *Scomberoides lysan* (Frosskal, 1775) from the Sri Lankan waters. A total of 1429 *S. lysan* collected between January 2010 and December 2011 were analyzed. Total length of female *S. lysan* range from 19.5 cm to 80.6 cm and males range from 18.0 cm to 81.2 cm. Monthly variation of mean relative condition factor (Kn) expressed low values in June and September in both years. Males and females followed more or less similar pattern of variation in Kn. Males had relatively higher mean Kn values than females during February to July and females had relatively higher mean Kn values than male during July to February in both years. The lowest body condition of male and female could have been attributed by sudden drop in weight during June and September due to their spawning nature. Monthly distribution of Gonadosomatic index (GSI) of males and females showed significant peaks during June and September. It further confirms the spawning period of *S. lysan*. The present study forms a primary platform for the management of *S. lysan* fishery.

Key words: Condition factor, Gonado somatic index, Scomberoides lysan

Occurrence of *Scomberoides lysan* (Forsskal, 1775) (Pisces: Carangidae) in Relation to Ovarian Development

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Abstract: The present study was carried out to understand the occurrence of maturity stages of double spotted queen fish *Scomberoides lysan* in the waters around Jaffna Peninsula. These are economically important food fishes particularly used for dry fish production in Sri Lanka and also used in sport fishing. The knowledge on the reproductive biology by identifying the life stages in relation to the area of occurrence could be the most important parameter in the management of that species. A total number of 1072 weekly random samples were collected from the commercial catches at Point Pedro, Delft, Paasaiyoor, Kurunagar, Ponnalai and Karainagar during January 2010 to December 2011. Microscopic staging system used in the histological analysis of S. *lysan* ovary expressed seven ovarian stages such as chromatin nucleolus stage (I), perinucleolus stage (II), cortical alveolar stage (III), yolk globule stage (IV), previtellogenic stage (V), migratory nucleus stage (VI), and post ovulatory follicular stage (VII); and the developmental stage categorized as immature (I & II), maturing (III), mature (IV & V), spawning (VI & VII) and spent/resting stage (I & VII), macroscopically. Among all sampling sites Paasaiyoor (100%), Ponnalai (100%), and Kurunagar (90%) were dominated by immature stages. Maturing stages of females found in Kurunagar, Karainagar, Point Pedro and Delft. Mature stages of females only found in Point Pedro and Delft. Spawning stages of females found only in Point Pedro and Delft. Resting stage of few females was recorded in Point Pedro area. S. *lysan*, male and female less than 40cm in total length were available only in the Jaffna lagoon. Fish with greater lengths (>50 cm in Total length) were available only in Point Pedro and Delft region. These results express that the lagoon area are distributed only by immature and maturing stages meanwhile matured and spawning stages occurs in the open sea including Delft, Karainagar and Point Pedro. The knowledge gained from the present study would be a fundamental addition to ensure the sustainable fishery.

Keywords: Histological Analysis, Occurrence of Maturity Stages, Ovarian Developmental Stages, *Scomberoides lysan*, Total Length

A8

Preliminary studies on length - weight relationship of *Scomberoides lysan* (Forsskal, 1775) (Pisces: Carangidae) from the Point Pedro coastal waters, Sri Lanka.

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The present investigation was carried out to estimate the length weight relationship parameters and growth pattern of *Scomberoides lysan* (Forsskal, 1775) from the Point Pedro waters. *S. lysan* is commonly known as double spotted queen fish found in the tropical areas of Indian and Pacific Ocean. Random samples were collected monthly from January to September 2010 from Point Pedro landing centre, Northern part of Sri Lanka.

A total of 290 specimens were analyzed. Covariance analysis for length–weight relationships of male and female *S. lysan* reveals that there was no significant variation between male and female ($P>0.05$) but there is a difference between unsexed and male or female. The estimates of the regression parameters and equations for male, females and unsexed data of *S. lysan* obtained by regression analysis are $TW= 0.0302 * SL^{2.722}$ ($N = 94$, $r = 0.951$), $TW = 0.0240 * SL^{2.8475}$ ($N = 102$, $r = 0.877$) and $TW= 0.0371 * SL^{2.6631}$ ($N = 94$ $r = 0.956$) respectively. The exponent value, $b=2.722$ for males and $b=2.8475$ for females, significantly different from 3 ($P<0.05$) reflect a negative allometric growth in both instances. Two-sample T- Test show that females were not significantly ($P>0.05$) heavier than males.

The results obtained from the present study help in establishing yield and also in converting one variable into the other as is often required during monitoring field measurements.

Key words: Length-weight relationship, *Scomberoides lysan*, Regression analysis covariance analysis, allometric growth

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