FINAL REPORT OF THE RESEARCH PROJECT TITLED

SYSTEMATIC AND POPULATION DYNAMICS OF SQUIDS IN THE NORTHERN COASTAL WATERS OF SRI LANKA FROM THE COMMERCIAL CATCHES

SANCTIONED BY

NATIONAL SCIENCE FOUNDATION, SRI LANKA

RESEARCH GRANT NUMBER: RG/2006/MS/01

PRINCIPAL INVESTIGATOR

DR. MRS. S. KUGANATHAN, B.SC. (HONS.), MSC, PHD

RESEARCH STUDENT

GNANAMUTHU ANTON CHARLES, B.SC. (HONS.)

FINAL REPORT

OF THE RESEARCH PROJECT TITLED

SYSTEMATIC AND POPULATION DYNAMICS OF SQUIDS IN THE NORTHERN COASTAL WATERS OF SRI LANKA FROM THE COMMERCIAL CATCHES

SANCTIONED BY NATIONAL SCIENCE FOUNDATION

RESEARCH GRANT NUMBER: RG/2006/MS/01

PRINCIPAL INVESTIGATOR

DR. MRS. S. KUGANATHAN

RESEARCH STUDENT

GNANAMUTHU ANTON CHARLES, B.SC. (HONS.)

DATE OF SUBMISSION OF MPHIL THESIS: 14.08.2010

SUBMITTED TO: FACULTY OF GRADUATE STUDIES, UNIVERSITY OF JAFFNA

RESEARCH INSTITUTE

DEPARTMENT OF ZOOLOGY

FACULTY OF SCEINCE

UNIVERSITY OF JAFFNA

THIRUNELVELY, JAFFNA

SRI LANKA

2010

Department of Zoology,
University of Jaffna,
Jaffna,
30.11.2010

FORWARDED
K. Kandasamy
30.11.2010 Dean Science
Date. University of Jaffna

The Director,
National Science Foundation,
47/5, Maitland Place,
Colombo-07

Through: The Vice-Chancellor / University of Jaffna,
Dean/ Faculty of Science & Head/ Zoology

Forwarded
VICE CHANCELLOR
UNIVERSITY OF JAFFNA
DATE: 30/11/2010

Dear Sir,

Submission of Final Report: RG/2006/MS/01

Please find the enclosed three bound copies of the final report for the research project titled **"Systematic and population dynamics of squids in the northern coastal waters of Sri Lanka from the commercial catches" (Grant No. RG/2006/MS/01)** funded by the National Science Foundation of Sri Lanka.

I greatly acknowledge the funds awarded for me by the NSF, Sri Lanka and the overwhelming, magnanimous support at each and every step for the successful completion of the above research project.

Thank you.

Yours Sincerely,

30/11/2010

Dr. Mrs. S. Kuganathan
Senior Lecturer in Zoology &
Principal Investigator

FORWARDED
Head / Zoology
Date 30.11.2010

Contents

List of Tables

List of Figures

List of Plates

Section 1

Information regarding Project/Project Personnel:

i) Contract Number
RG/MS/2006/01

ii) Title of the Project
Systematic and Population dynamics *of* squids in the northern coastal waters of Sri Lanka from the commercial catches

iii) Principal Investigator
Dr. (Ms) S. Kuganathan

iv) Co-Investigators
N/A

v) Institute(s) where research was being carried out
Department of Zoology, University of Jaffna.

vi) Date of award
14.11.2007

vii) Date of completion of Project
14.08.2010

viii) Total allocation of funds (Rs)
1,430,553.34/=

ix) Total spent (Rs)
1,424,094.47/=

x) Number of Research Students employed
01

xi) Post graduate degree completed with dates
14.08.2010

xii) Number of Technical Assistants and/or labourers employed and period of service
N/A

xiii) Publications/Communications arising from the project during the reporting period

Charles, G. A. and **Kuganathan. S.** (2008). Preliminary studies on length - weight parameters of *Sepioteuthis lessoniana* (Cephalopoda:Teuthida) from the Jaffna lagoon, Sri Lanka. **Proceedings of Jaffna Science Association**. Fifteenth Annual Session (07-09 May 08), Vol 15(1): 20 (Abstract). (ISSN 1800-1289).

Thevarulrajah. T and Kuganathan. S. (2008). Preliminary studies on reproductive biology of squid *Sepioteuthis lessoniana* (Lesson, 1830). P***roceedings of Jaffna Science Association***. Seventh Annual Session (07-09 May 08): 22 (Abstract).

Kuganathan, S. and Charles, G.A. [2008]. The squid body. pp 44. Printed by Computer World. ISBN: 978-955-9194-15-6

Sivashanthini, K., Charles, G. A. and Thulasitha, W. S. (2009). Length-weight relationship and growth pattern of *Sepioteuthis lessoniaana* Lesson 1830 (Cephalopoda: Teuthida) from the Jaffna lagoon. Journal of Biological Sciences. Vol. 9(4): 357-361. DOI: 10.3923/jbs.2009.357.361

Sivashanthini, K., Thulasitha, W. S. and Charles, G. A. (2010). Reproductive characteristics of *Sepioteuthis lessoniana* from the Northern coast of Sri Lanka. Journal of Fisheries and Aquatic Science, 5(1): 12-22. ISSN 1816-4927. DOI: 10.3923/jfas.2010.12.22

Charles, G. A. and **Sivashanthini, K.** (2011). Population Dynamics of Squid *Sepioteuthis lessoniana* (Lesson, 1830) from the Northern Coast of Sri Lanka. Journal of Fisheries and Aquatic Science, 6(1): 74-84. ISSN 1816-4927. DOI: 10.3923/jfas.2011.74.84

Section 2

Executive Summary of the Project:
This should be limited to 200-250 words and include the scientific background and objectives, methodology and major findings

The present investigation was carried out from June 2007 to May 2009 to understand the systematic and population dynamics of squids in the northern coastal waters of Sri Lanka. Among the three species of squids recorded *Sepioteuthis lessoniana* is the most abundant squids found throughout the year and therefore the present investigation was continued with *S. lessoniana*. Regression analysis of length weight relationship revealed that the squid follows cube law. Histological analysis of gonads showed male and female were categorized into immature, maturing, fully maturing and matured. High occurrence of spawning stage in squids observed in August 2007, November 2007, April 2008 and October 2008 suggests that the peak spawning period is in those months even though it spawns throughout the year. Presence of all stages of macroscopic eggs in the same ovaries confirms that it spawns more than once and said to be asynchronous. Fecundity varied from 20 to 852 but a weak correlation was obtained with mantle length. Size at maturity curves indicated male reached maturity at 15 cm mantle length while female reached maturity at 17.5 cm mantle length. The optimized values for K and L_∞ obtained by the ELEFAN I was 0.83 year^{-1} and 31.10 cm. The estimated t_0 value was -0.191. The length-converted catch curve gave a Z value of 3.75 year^{-1}. The natural mortality coefficient (M) obtained through Pauly's empirical model was 1.64 year^{-1}. The computed instantaneous fishing mortality coefficient (F) is 2.11. The predicted exploitation rate is 0.501. The computed exploitation rate of 0.56 is slightly above the predicted E_{max} express that the stock is slightly overexploited. Thus, the fishing pressure on the stock has to be reduced. More capture should be prohibited by a reasonable decrease in the effort or by modifying the mesh size of the net for *S. lessoniana* species.

Section 3

Report in detail: should contain the following (not less than 2000 words excluding Tables and Figures)

(i) Introduction/background

Squids are among the fastest-growing short lived commercial species and as opposed to most finfish resources world wide their contribution to the total world fish production has been increasing at a high rate in the past two decades. Once a year class is overfished there will be no resources of genetic diversity. Thus, detailed understanding of diversity, stock structure and highly variable recruitment dynamics is essential to ensure conservation of the resource base and to achieve sustainability of directed fisheries. *Sepiotuethis lessoniana* is the most abundant commercially important species in the northern region of Sri Lanka. As they provide a livelihood and income for millions of the poorest people and also contribute to the overall economic well being of the country, detailed research on squids can make a positive contribution to every socio-economic resource or environmental issue. There exists a need for studying the biology and population dynamics to promote productivity, sustainable exploitation and to implement proper management measures.

Being a short lived species no studies have been perfomed in the northern region of Sri Lanka to identify the squid resources, its pattern of growth, age and growth parameters, reproductive season, reproductive pattern, fecundity, mortality and stock assessment which will enhance for proper managment and sustainability of squids and therefore the present investigation was carried out from June 2007 and May 2009 in the northern coastal waters of Sri Lanka. During the study period the fishermen from the Northern coast of Sri Lanka were allowed only for coastal fishing that is up to 2 – 3 km distance from the coastal egde. Deep sea fishery was not performed at all due to security reasons. Several restrictions imposed on fishermen, fishing with mechanized boats was prohibited due to security reasons, fishing allowed only with traditional crafts and wooden canoes.

World fishery

Cephalopods are considerably important as a food resource as well as in scientific investigations (Ngoile 1987). Issues of squid growth and population dynamics are increasing in prominence and importance. Increased fishing pressure is changing the trophic structure in many marine environments around the world (Pauly *et al.* 1998). As a result of this phenomenon, a greater emphasis is being placed on new fisheries and on cephalopod stocks in many parts of the world (Rodhouse 1997). The over-fishing of longer lived finfish has resulted in a shift to squid fishing (O'Dor *et al.* 1997). There is a significant worldwide commercial interest in cephalopods for human consumption.

Of the 16.4 kg of fish per capita available for consumption in 2005, about 74 percent came from finfish. Shellfish supplied 26 percent (or about 4.1 kg per capita), subdivided into 1.6 kg of crustaceans, 0.5 kg of cephalopods and 2.0 kg of other molluscs. Freshwater and diadromous species accounted for about 32 million tonnes of the total supply (about 4.9 kg per capita). Marine finfish species provided more than 47 million tonnes, of which 20.0 million tonnes were demersal fish, 19.9 million tonnes were pelagic species and 7.6 million tonnes were unidentified marine fish. The remaining share of the total food supply consisted of shellfish, of which 10.5 million tonnes were crustaceans, 3.5 million tonnes cephalopods and 12.9 million tonnes other mollusks (Anonymous 2007).

Sepioteuthis lessoniana (big fin reef squid) is a commercially important squid throughout the Indo-West Pacific region. It has now been cultured through seven successive generations in closed, recirculating seawater systems (Walsh et al. 2002). World catches of cephalopods have increased steadily throughout the last 50 years with annual landings increasing from 0.5 million tonnes in 1950 to over 3.3 million tonnes in 2001 (FAO 2003). Squids play an important role not only as human food equipped with protein and fat but also used as animal feeds, particularly as fishmeal. Another emerging application of squids is as a source of bioactive molecules for the pharmaceutical industry.

Fishery in Sri Lanka

Sri Lanka is a coastal state located in the Indian Ocean to the south of India, between latitudes 6 – 10 degrees north and longitudes 80 - 82 degrees east. The fishing industry of the island has a long history. According to the Mahawamsa (the historical record of the island), a coastal fishery existed even prior to 190 B.C. The fishery plays an important role in the island's economy. Catches of cephalopods, mainly octopus (*Octopus vulgaris* Cuvier, 1797), cuttlefish (*Sepia officinalis hierredda* Linnaeus, 1758) and squid (*Sepioteuthis lessoniana*, *Loligo vulgaris* Lamarck, 1798), were very small until the 1960s when a spectacular increase was observed in their landings, inducing boats already operating in the area to shift their fishing strategy (Anonymous 2007).

Though, the share of fisheries sector in Gross Domestic Production (GDP) is less than 2%, the sector provides about 600,000 employment opportunities directly and indirectly in Sri Lanka, in 2006 (Anonymous 2006). Food security is the availability of food primarily carbohydrates for human consumption without shortage. Fish is also an essential food item providing high nutritional value. Medical Research Institute (MRI) recommends increasing the per capita consumption of fish to 21 kilograms. However, the per capita availability of fish was about 15.7 kg in 2006. This dropped to 11.38 kg in 2005 due to decline in local production. About 18.9 per cent of per capita availability of fish is provided by imports. Although, per capita availability of fish was 15.7 kg, the per capita net availability for consumption was 12.03 kg after adjustment is made for wastages. There is no separate statistics for squid production in Sri Lanka.

Fishery in Jaffna

In addition to agriculture and livestock, fishery sector is the most important industry in Jaffna provides major source of food and income for society. Jaffna district alone contributed 26% of the total fish production and 57% of the total dry fish production of Sri Lanka, in 1983. Fisheries in Jaffna district started to decline with the war in 1985. In 1983, one third of the country's fisheries exports were from Jaffna totalling 49,000 metric tones (Anonymous 2007).

Specifically, *Sepioteuthis lessoniana* (big fin reef squid) is an important species for human consumption in Jaffna, Sri Lanka. It is captured by sirahu valai made up of 12 mm mesh size net wing, trawls, pots, traps, lures, hook-and-lines etc. Usually they are captured along with other fish and fish related organisms. Due to the significance of the common squid fishery and the declining trend in landings during the last decades, there is increasing interest in managing and conserving common squid stocks. Currently, squid stocks in Northern region of Sri Lanka are not assessed and managed. Despite the present study, population dynamics for *Sepioteuthis lessoniana* remain largely unknown. The dynamics of a population are described from life-history parameters such as natural mortality, fishing mortality, maturity, life-span, recruitment and growth. The scientific literature presents different viewpoints regarding squid growth and suggests that squid have long life spans and asymptotic growth. This viewpoint exists primarily as a direct consequence of researchers fitting asymptotic growth curves to squid length-frequency data. By using the model, several life cycle parameters, necessary for developing a conservation policy were estimated and compared with the earlier more or less similar studies wherever applicable.

Mainly sirahu valai (Fig. 1; Plate 1) is the major gear used to catch the cephalopods like squids, cuttle fish and octopi in the study area. But these types of fish were also caught along with the other food fish in trawl nets, cast net and seines.

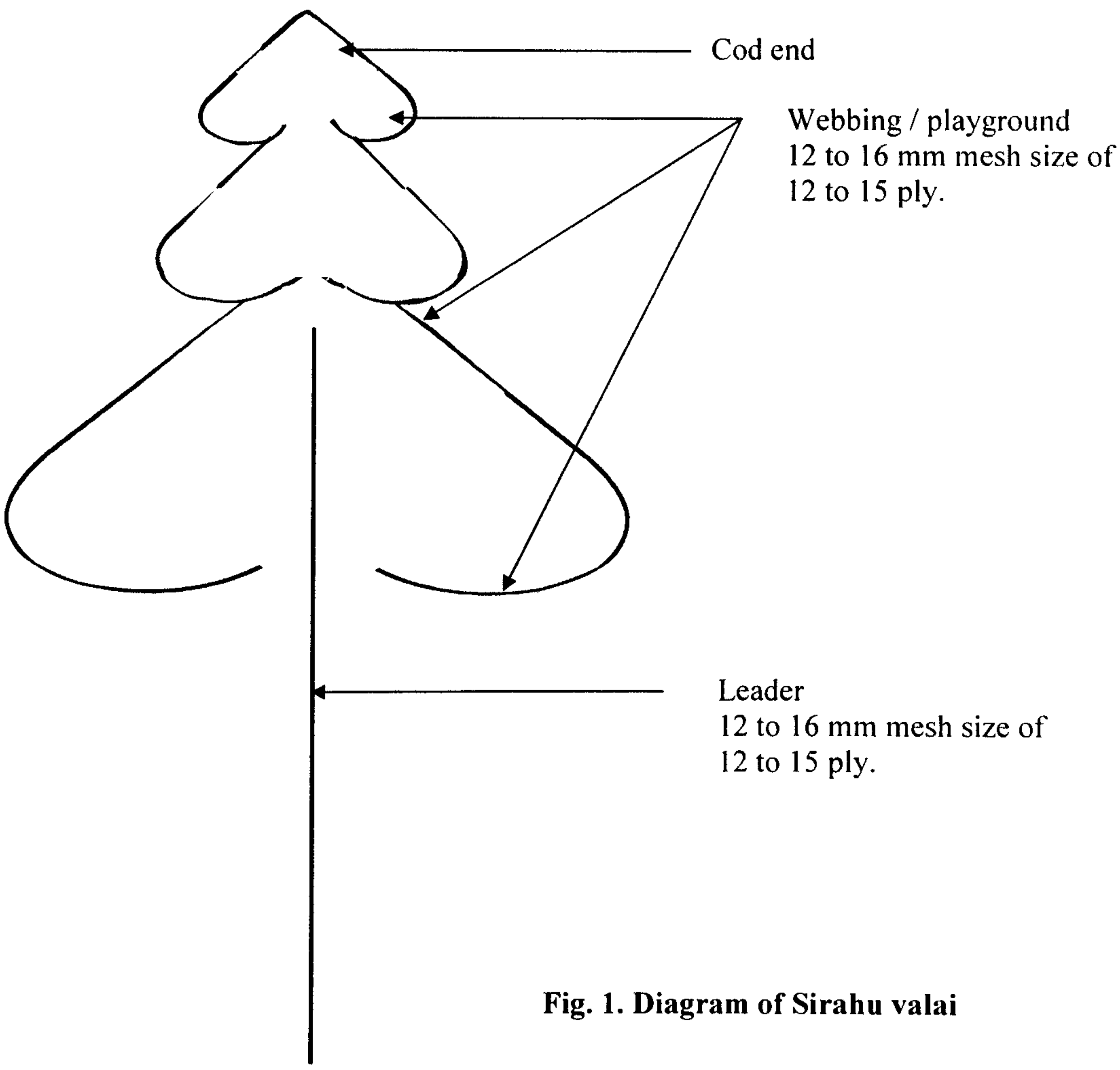


Fig. 1. Diagram of Sirahu valai

Plate 1. Sirahu valai installed in the northern coast of Sri Lanka

This species available throughout the year, the major season is November to March. Huge amount of squids were obtained in the fog season.

Study Area

The present study was carried out in the Northern coastal waters of Sri Lanka that is the coastal waters surrounding Jaffna peninsula. Jaffna peninsula is surrounded by sea water but connected to mainland via an isthmus called Elephant pass. Jaffna is situated within ten degrees of latitude to the north of the equator. It is in close proximity to the sub-continent of India and separated from it by the Palk Strait and the Bay of Bengal. The Jaffna lagoon is a shallow water body located in the northern province of Sri Lanka. It lies between approximately 79° 52'E longitude and 9° 26'N latitude and has an area of about 412 km^2 (160 square miles) and the depth does not exceed 4 m (Chitravadivelu 1987).

None of the waterways in the Jaffna lagoon has any significant freshwater input except during heavy rains when salinity gradients develop and the stream assumes estuarine characteristics. On the seaward side, immediately adjacent to the mangrove vegetation, the lagoon opens up to less intertidal flats which are covered by a mixed assemblage of sea grasses and algae. A coral reef, which is part of the extensive reef that fringes the coast of the northern waters. Fishing activities are conducted near the reef.

The local climate in Northern waters is dominated by monsoons, which prevails from north-east monsoon rains occur in the northern and eastern regions in December and January. The climate is cool from November to March with average temperature of 28.5ºC and hot from May to August with average temperature of 31.2ºC (data from meteorological station, Thirunelvely). Heavy rains (long rains) coupled with thunderstorms, occur from November to January and light rains (short rains) occur from April to June. Samples for research were collected from fishermen at fish landing stations at Paasaiyoor, Gurunagar, Kakkaitivu, Ponnalai and Point Pedro (Fig. 2) between June 2007 and May 2009.

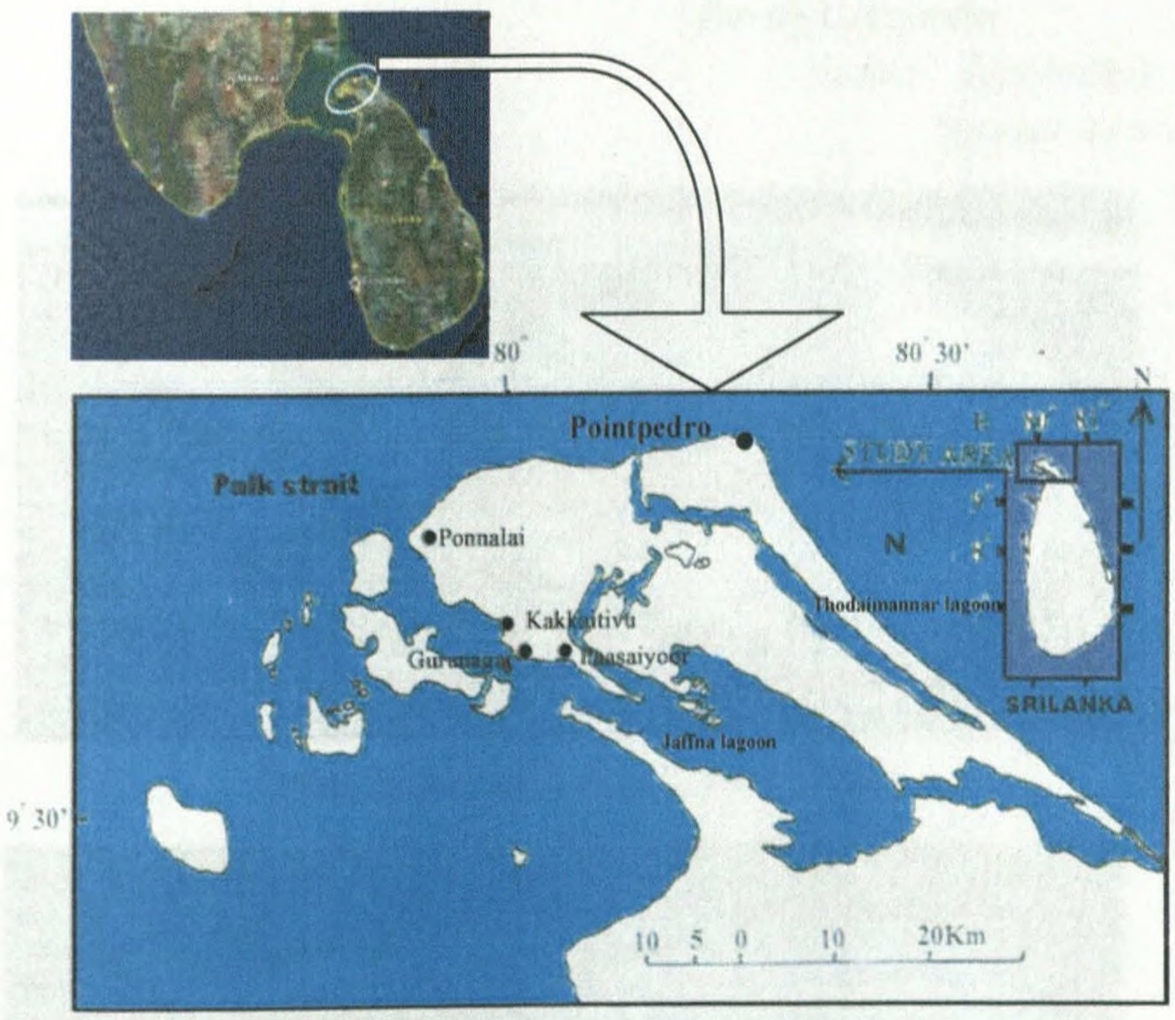


Fig. 2. Diagram showing sampling sites

Systematic

During the study period three speccies of squids were recorded. Moderate numbers of Bobtail squids *Euprymna berryi* of order sepiolida, family sepiolidae and subfamily sepiolinae were collected only during October to February. Few numbers of *Loligo duvauceli* included under order Teuthida, family Loliginidae was recorded intermittently during the study period. The most abundant species available throughout the year was *S. lessoniana* included under order Teuthida, family Loliginidae. The population dynamics studies were undertaken only for *S. lessoniana* as it is the most abundant species throughout the year.

Sepioteuthis lessoniana **(Plate 2 and 3)**

Kingdom: Animalia
Phylum: Mollusca
Class: Cephalopoda
Subclass: Coleoidea
Superorder: Decapodiformes
Order: Teuthida
Suborder: Myopsina
Family:Loliginidae
Genus: *Sepioteuthis*
Species: *lessoniana*

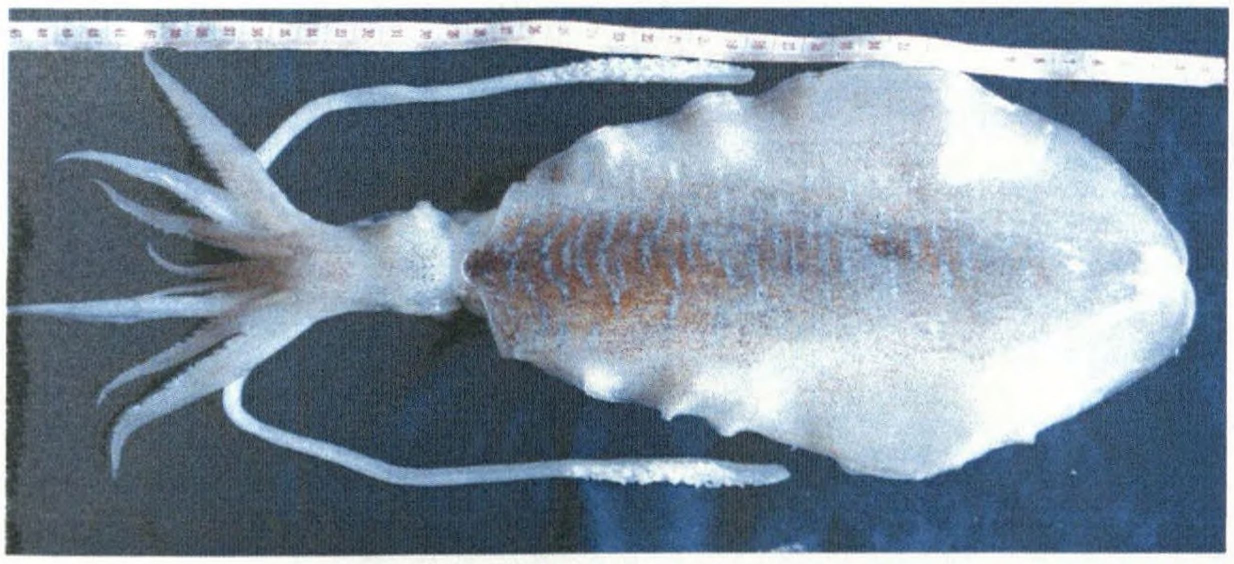


Plate 2. Dorsal view of *S. lessoniana*

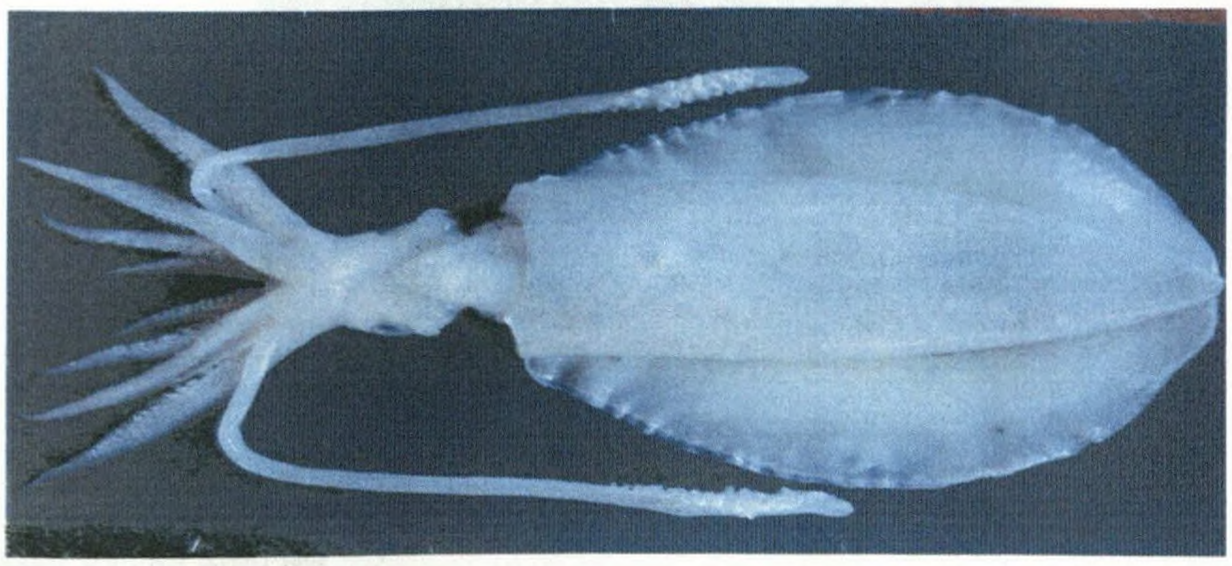


Plate 3. Ventral view of *S. lessoniana*

Description of the species

Shell internal, usually thin, but well developed gladius - Order: Teuthidea. Marginal fin and extends about 1-2 mm from the lateral margin of the mantle - *Sepioteuthis lessoniana.* The photograph of dorsal and ventral view of *Sepioteuthis lessoniana* is shown in (Plate 2 and 3). Mantle is long and tubular, rounded posteriorly. Head is broad and stout wider than the mantle, with prominent eyes, small olfactory crest below and ventral to the eyes. There are eight arms and two non retractile tentacles. The order of the arms 3, 4, 2, 1 and all the arms are somewhat flattened and keeled for at least part of their length. The sessile suckers are bordered on either side on all arms by protective membrane being largest and deepest on 3rd arm where the dorsal membrane is much wider than the ventral one. In the males left ventral arm is hectocotylized by a modification of the distal 4th of the arm. The tentacles are long and stout, with slightly expanded clubs and well developed protective membranes. The tentacular suckers are in four rows. The suckers of the dorsal and ventral marginal rows are two-third of the size of the median suckers. The horney rings are present in the suckers consist of 14-15 teeth. Colour variable, chromatophores are large and very numerous dorsally in the mantle, fin, headed arm but absent ventrally. Internal shell chitinous, flexible and pen shaped (De Bruin et al., 1995).

***Loligo duvauceli* (Plate 4)**

Kingdom : Animalia

Phylum: Mollusca

Class: Cephalopoda

Subclass: Coleoidea

Infraclass : Decapodiformes

Order: Myopsidae

Family : Loliginidae

Genus : *Loligo*

Species: *duvauceli*

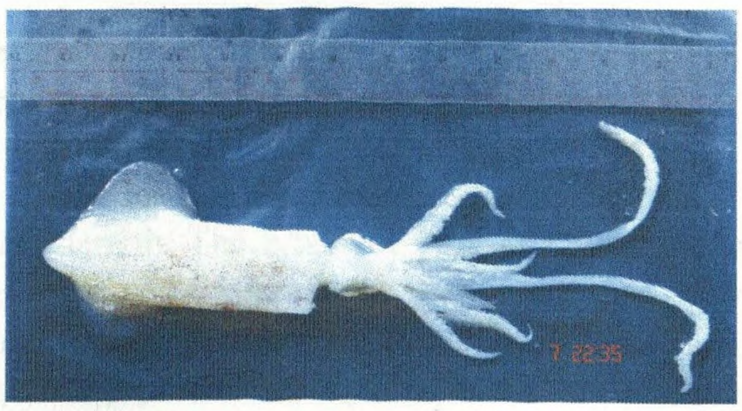


Plate 4. Dorsal view of *Loligo duvauceli*

Description of the species

Total length 150-155 mm; Mantle length 100-108 mm; Head length 30-37.6 mm; Tentacular length 37-40 mm Color: Reddish with brown chromatophores with pale white back grow, which dark and the head region. Mantle long, slender, tubular, tapering from middle and blunt posterior end; fins rhomboidal. Left ventral arm hectocotylised, distal half possessing pedicle flattened into conical papillae.

***Euprymna berryi* (Plate 5)**

Kingdom: Animalia

Phylum: Mollusca

Class: Cephalopoda

Order: Sepiolida

Family: Nematocarcinoidea

Subfamily: Sepiolinae

Genus: *Euprymna*

Species: *berryi*

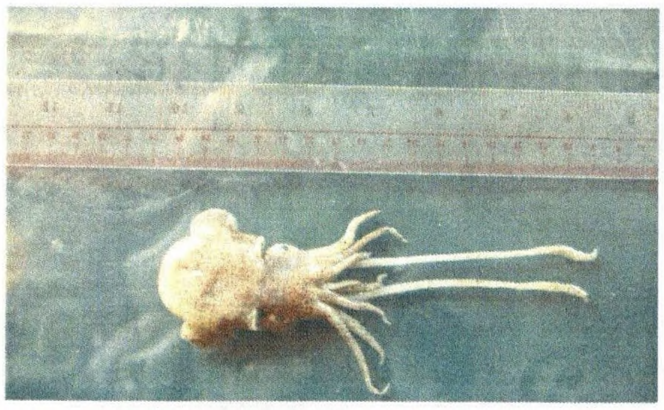


Plate 5. Dorsal view of *Euprymna berryi*

Description of the species

The body and head are united by a broad dorsal commissure in the nuchal region and except for this connective commissure the head is free from the mantle opening. The fins are semi-circular in outline and inserted at mid length of the mantle. The fin length from the point of intersection is about 33.3% of mantle length. The funnel is long and reaching the base of the ventral arms and the funnel valve is short and triangular in shape. The arm formula is usually 3:2:1:4. The arm suckers are arranged in four longitudinal rows and large suckers are present on the lateral rows of II and IV arms. The protective membrane is not well developed on arms and the web is present between III and IV arms. In males the left arm I is hectocotylised. This arm is shorter and thicker with the proximal half possessing normal suckers and two prominent suckerless nipple like papillae and the distal half is closely packed with modified papillae and rudimentary suckers. The tentacles are stout and the stem is rounded. The tentacular clubs are short with swimming keel extending proximally along stalk and the suckers are extremely numerous, inute, elongated and goblet shaped giving it a 'swab' like appearance. The gladius is absent. Light organs or photophores are present and they are bean-shaped and placed on lateral lobes of ink sac. The body is transparent when fresh and the mantle is whitish with numerous dark brown chromatophores both on dorsal and ventral sides. The fins have few chromatophores at the base where they are united with the mantle.

Distribution

Most widely distributed loliginids in the Indo Pacific region and also reported in Eastern Indian Ocean, Japanese Islands to Australia and New Zealand. Worldwide distribution of *S. lessoniana* is shown in (Fig. 3).

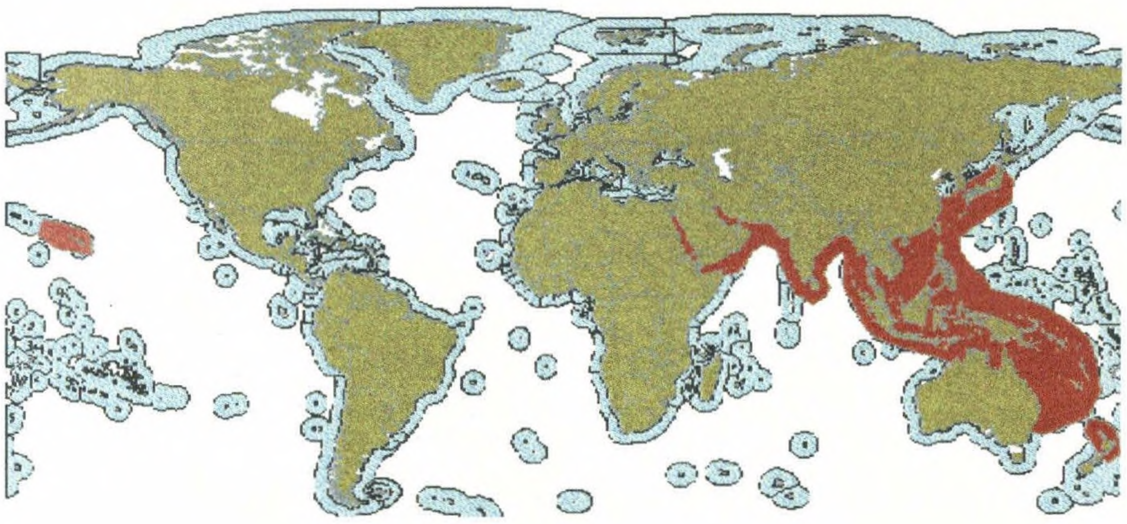


Fig. 3. Worldwide distribution of *S. lessoniana* (Red patches indicates the distribution areas of *S. lessoniana*) – Source: http://www.cephbase.utmb.edu/biogeo/biogeo.cfm

Habitat

Squids are the euryhaline, which can tolerate the water salinity, temperature and p^H ranges were from 28 ppm - 34 ppm, 28°- 30° and 6.8 - 7.1 respectively. These are the quick moving predacious creatures which feed on crustaceans, fishes and worms.

Common names

Tamil: Oosikanavai / Oolaikanavai
Sinhala: Thalilla
English: Big fin reef squid

(ii) Scientific scope of the project (overall and specific objectives)

(ii) Scientific scope of the project (overall and specific objectives)

1. Identification of all species of squids found in the northern region which will enhance documentation and systematics of diversity of squid resources in the northern region of Sri Lanka.
2. To make a detailed picture on the length-weight biology, reproductive biology, growth parameters, mortality parameters, virtual population analysis, exploitation and relative yield per recruit models of squid will emphasize a detail understanding of their spawning pattern, spwning frequency, spawning month, growth pattern, exploitation level and lipid dynamics of squids form the northern region of Sri Lanka.
3. To emphasize whether the fishing pressure on squid population in the northern part of Sri Lanka could be increased or not.
4. To suggest some recommendations for the fishery society to formulate management measures in the northern region of Sri Lanka.
5. As a whole the present study leads towards conservation and management of squid fishery.

(iii) Materials and methods (including statistical methods)

Squid samples for the present study were collected from the commercial catches of Ponnalai, Kakkaitivu, Paasaiyoor, Gurunagar and Point Pedro landing centres at weekly intervals during June 2007 and May 2009. Sample size from different stations were simply tested for homogenety by student t- test. As there were no significant ($P>0.05$) difference between samples the data collected from different stations were pooled togethr for further analysis.

Squid samples caught by sirahuvalai were identified into species and mantle length measurements were taken for all possible squids to the nearest 1 mm at the landing centres itself in order to arrange in to length frequency data. Random samples were also collected from the commercial catches of the said landing centres and brought to the laboratory for further analysis.

Age and growth and stock assessment

The length frequency data were grouped sex wise into 2 cm class intervals, sequentally arranged for two years and used for estimation of growth. Length frequency analysis were done with FiSAT II (Gayanilo and Pauly, 1997) soft ware.

The length frequency data of *S. lessoniana* from the commercial sirahu valai catches were analyzed using ELEFAN I routine of FISAT II software (Gayanilo and Pauly, 1997). The following stepwise procedures were adopted to estimate L_∞ and K and for correction of length frequency data for mesh selection as per literature (Sparre and Venema, 1992; Amarasinghe and De Silva 1992; Amarasinghe, 2002).

- 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).

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

- 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 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 optimized estimates of L_∞ and K through ELEFAN I routine (Gayanilo and Pauly, 1997) from the corrected length frequency data.

L_∞ and K values were obtaind through the four options such as, curve fitting by eye, response surface analysis, scan of K values and automatic searh routine. In this method the growth parameters L_∞ and K were estimated following the von Bertalanffy growth equation. The equation for growth in length is given by,

$$L_t = L_\infty (1-\exp^{-K(t-t_0)})$$

Where L_t is the length at age t, L_∞ the asymptotic length, K the growth oeefficient and t_0 theoritical age at which fish would have had zero length if they had grown according to the above equation. The most optimized L_∞ and K values were obtained by ELEFAN I – automatic search routine and the restructured length frequency histograms were also obtained.

As ELEFAN cannot estimate the t_0 value from the length frequency data, a very aproximate value of 't_0' was estimated by substituting the L_∞ (in cm) and K (year $^{-1}$) in the following equation (Pauly, 1983):

$\log(-t_0) \approx -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$

Longevity was obtained from the following equation.

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

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

A multi-stage stratified sampling design (Bal and Rao 1984) developed by the Central Marine Fisheries Research Institute (CMFRI), Cochin was adopted to make a record of the catch at size data from the north coast.

The total mortality coefficient (Z) was estimated using length converted catch curve analysis (Gayanilo an Pauly, 1997) in the FiAt II program using the input parameters L_∞, K and t_0. The histogram showing probability of capture for each size class was obtained by backward extrapolation of the straight portion of the right descending part of the catch curve. The length at first capture L_c was obtined from the plot of cumulative probability of capture against mid-length of class interval, through detailed analysis of ascending part of catch curve.

Estimation of natural mortaliy rate was obtained thorugh Pauly's empirical model (Pauly, 1980),

$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T)$

Where M is the natural mortality, L_∞ is in cm, K is annual and T is the mean annual emperature (in ^{0}C) which is taken as 30^0 C.

Fishing mortality was calculated using using the formula,

$Z = M + F$

Exploitation rate E was determined from the relationship,

E (exploitation rate) = F/Z

The relative yield per recruit (Y/R) was predicted by considering Y'/R as a function of U and E and M/K by employing Beverton and Holt Y'/R analysis (selection ogive) in the FiSAT package. The relative yield per recruit equation which gives a quantity proportional to Y'/ R was derived from the method of Beveron and Holt (1959) through a number of algebric manipulations. The prdicted values were obtained by substituting the input parameters of L_c/L_∞ (L_c is the minimum length captured; obtained from the extrapolation of length converted catch curve) and M/ K in the FiSAT II package (Gayanilo and Pauly 1997). The assumptions considered in this model being fishing aand natural mortalities are constant from the moment of entry to the exploited phase recruitment is constant and the length weight relationship has the expoent 3.

The samples brought to the laboratory were analyzed for length weight relationship and reproductive parameters.

Length weight relationship

Mantle length and total body weight measurements were taken to formulate regression analysis of length-weight relationship. The parameters 'a' (proportional constant or intercept) and 'b' (exponent) were estimated for male and female separately by using the logarithmic transformation. The regression line was computed by the method of simple least square regression analysis.

The 'b' values obtained for male and female *S. lessoniana* were tested by Students' t-test to see whether the 'b' values differ significantly from '3' or not. Students' t-test was employed by dividing the difference between 'b' and '3' by standard error of 'b'. The regression lines of male and female *S. lessoniana* were then analyzed further for significant differences by General Linear Model Analysis of Covariance (GLMANCOVA) using MINITAB (Version 14) statistical software in the computer.

Reproduction

Sexes were confirmed after dissecting the squid specimens; for each specimen maturity stage was categorized by macroscopic observation of the gonads.

Various morphometric measurements were taken for males and females. For males, the Weight of Testis (TEW) and Spermatophoric Complex Weight (SCW) were measured; then the spermatophoric complex was dissected to separate the spermatophores and the total numbers of macroscopic spermatophores were counted. Various reproductive indices such as the Gonado Somatic Index (GSI), Spermatophoric Complex Index (SCI) and Maturity Coefficient (MCO) for males were computed using the standard equations (Gabr *et al.*, 1998).

Formulations of various reproductive indices for males.

(BW is the body weight, TEW is the testis weight and SCW is the spermatophoric complex weight. The spermatophoric complex includes the spermatophoric organ, vas deference, spermatophoric sac or Needam's sac, sperm duct and penis).

Indices	**Formula**
Gonado Somatic Index GSI	TEW/BW x 100
Spermatophoric Complex Index SCI	SCW/BW x 100
Maturity Co-efficient MCO	(TEW + SCW)/BW x100

For females, the total Weight of Ovary (OW), Weight of OViducal gland (OVW), Nidamental Gland Weight (NGW) and colour of accessory nidamental gland were recorded. Various reproductive indices such as the Gonado Somatic Index (GSI), Nidamental Gland Index (NGI) and Maturity COefficient (MCO) for females were computed using the standard equations (Gabr *et al.*, 1998).

Formulations of various reproductive indices for females

(BW is the body weight, OW is the ovary weight, NGW is the nidamental gland weight and OVW is the oviducal complex weight).

Indices	Formula
Gonado Somatic Index GSI	OW/BW x 100
Nidamental Gland Index NGI	NGW/BW x 100
Maturity Co-efficient MCO	(OW + OVW)/BW x100

Sex ratio was determined from the number of specimens of each sex sampled every month to test the significant deviations from an expected 1:1 sex ratio for all male and female fishes. Histological sectioning was also continued in order to categorize the maturity stages.

The percentage occurrence of various maturity stages of ovaries in different months was computed. Fecundity was defined as the total number of maturing ova (with striation) and mature ova (large smooth ova) in the ovary and the number of ova in the oviducal glands, proximal and distal gland (Gabr et al., 1998). Length at maturity was also analyzed.

Lipid analysis

Information on quantitative variation in lipid is lacking for squids and therefore lipid extraction was carried out to quantify changes in lipid deposition during ovarian maturation. Variation in total lipid content of gonad, liver and muscle of different maturity stages was analyzed to understand the variation during maturation and reproduction.

Total lipids in tissue sample were extracted according to the AOAC method (1995). One hundred gram muscle tissue was cut from the fresh fish, rinsed with distilled water and dried to constant weight in a drying oven (60^0 C, 24 hr). Dried samples were minced in a glass coffee grinder and made as homogenized powder. Exactly 20 grams of sample was introduced into cellulose extraction thimble in a soxlet extractor. The lipids were extracted with 150 to 200 ml of hexane at the boiling point (-69°C) for 7 to 12 hours. The flat bottom extraction flask of the soxlet extractor was pre dried and weighed with a few boiling chips or glass beads. Sample was left to cool. The solvent in the extract was removed in a rotary evaporator (IKA RV 10 basic) at 40°C under reduced pressure. The amount of lipid was then computed in percentage.

Total lipid was extracted randomly in ninety different sizes *S. lessoniana* muscle tissue. The percentage of total lipid was computed. Correlation between percentage of total lipid and mantle length of *S. lessoniana* was tested by MINITAB 14 software in the computer.

Total lipid content of muscle, ovary and liver of six immature, maturing and spawning individuals were also computed. The average total lipid content in immature, maturing and spawning, muscle, ovary and liver was plotted as a histogram to analyze the fluctuations in the lipid concentration. Different maturity stages of gonads were visually examined, grouped together macroscopically and then subjected to estimation of total lipid. For the sake of convenience, three categories of gonads such as immature, maturing and spawning were considered. Stages III and IV of female squids were considered as spawning.

Changes in lipid content during various maturity stages were first analyzed by one way analysis of variance (ANOVA). When a single factor ANOVA rejects the null hypothesis i.e. when the mean of the samples was significantly different, ANOVA was followed by Post hoc comparison of means: Duncan's multiple range test (DMRT) using a computer. The level of statistical significance was set at $P<0.05$.

iv) Results / outputs

A total of 4856 specimens of *Sepioteuthis lessoniana* ranging from 3.8 to 27.8 cm were subjected for the age and growth and stock assessment studies.

Collected samples of *Sepioteuthis lessoniana* were brought to the laboratory for further analysis kept in a deep freezer and analyzed. About two thousand two hundred and ninety seven adult samples were brought to the laboratory and subjected to analysis.

Age and growth and stock assessment

The analysis of length frequency data by the Powell-Wetherall method (Fig. 4) gave an initial estimate of L_∞ value of 33.2 cm and Z/K value of 4.093. The optimized values for K and L_∞ obtained by the ELEFAN I was 0.85 $year^{-1}$ and 31.13 cm.

The goodness of fit index (R_n) for the obtained K and L_∞ value was 0.175.

Usually, the R_n value ranges between 0 and 1 in the ELEFAN-FiSAT package. The oscillation parameter (C) and winter point were assumed to be 0 as it is a tropical species.

The non seasonalized restructured length frequency histograms with growth curve is shown in Fig. 5. The estimated t_0 value was -0.18627.

The von Bertalnaffy's growth equation for *S. lessoniana* can be expressed as:

Male: $L_t = 31.13\ [1 - \exp\{-0.85(t+0.18627)\}]$

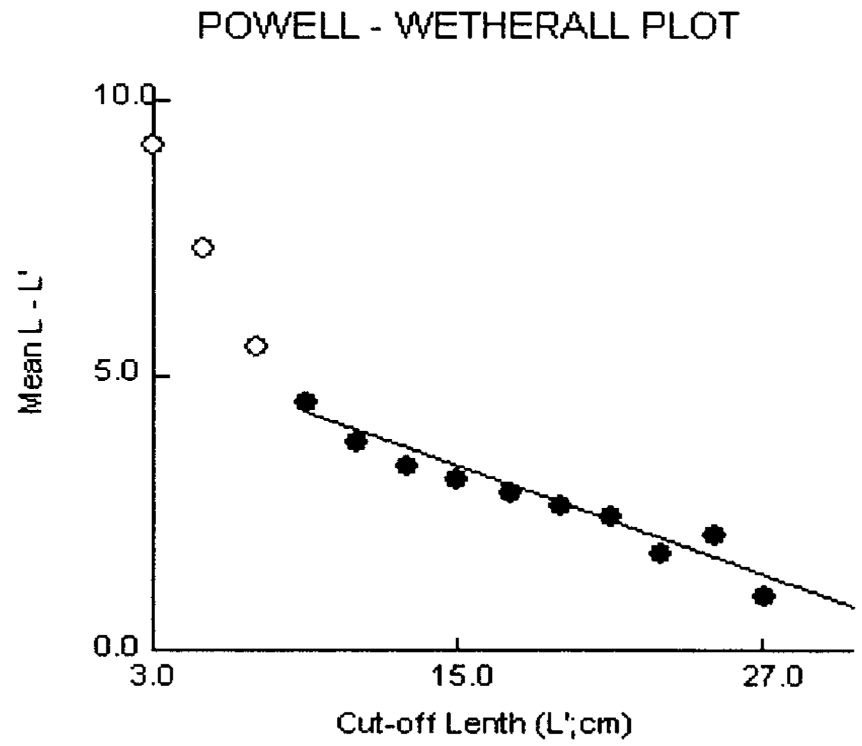


Fig. 4. Powell Wetherall plot of *Sepioteuthis lessoniana*

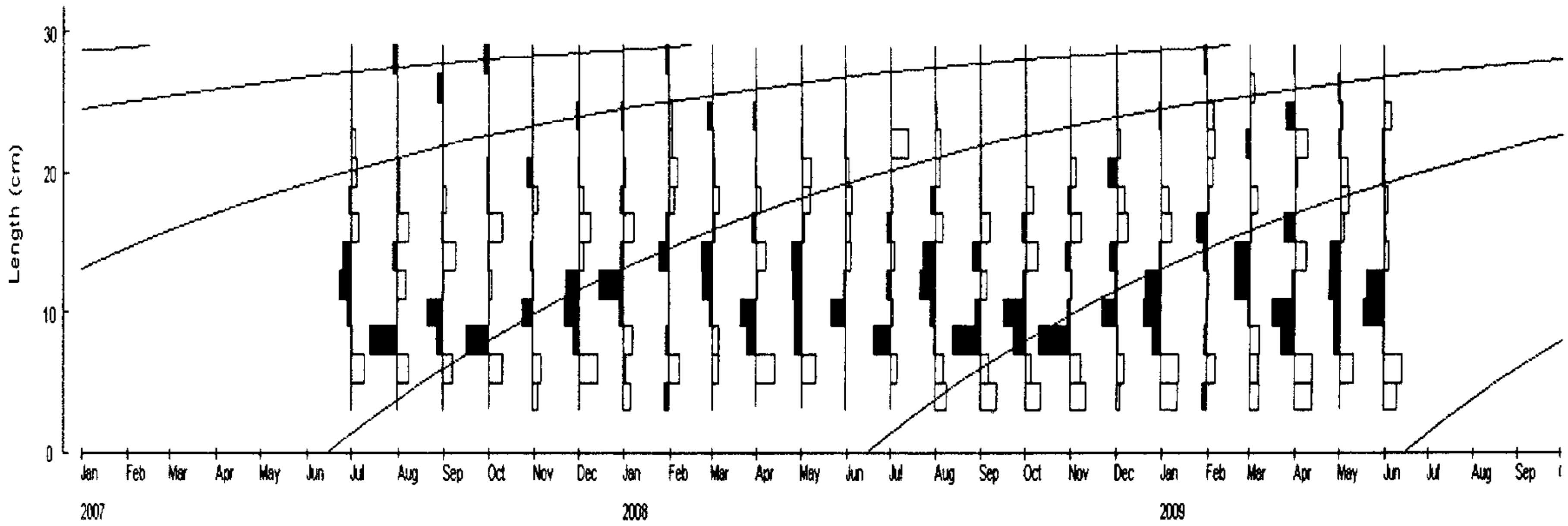


Fig. 5. Growth curve of *Sepioteuthis lessoniana* drawn using ELEFAN I programme

Estimated longevity for *S. lessoniana* calculated from Pauly's equation is 3.34.

The length-converted catch curve for *S. lessoniana* is shown in Fig. 6. The length-converted catch curve gave a Z value of 3.75 year^{-1} (confidence interval of Z = 3.368 – 4.127; standard deviation of the slope = 0.55; r = 0.98). The lengths at first capture L_c (length at 50% capture) estimated by backward extrapolation of the straight portion of the right descending part (Fig. 7) of the catch curve was 8.57 cm.

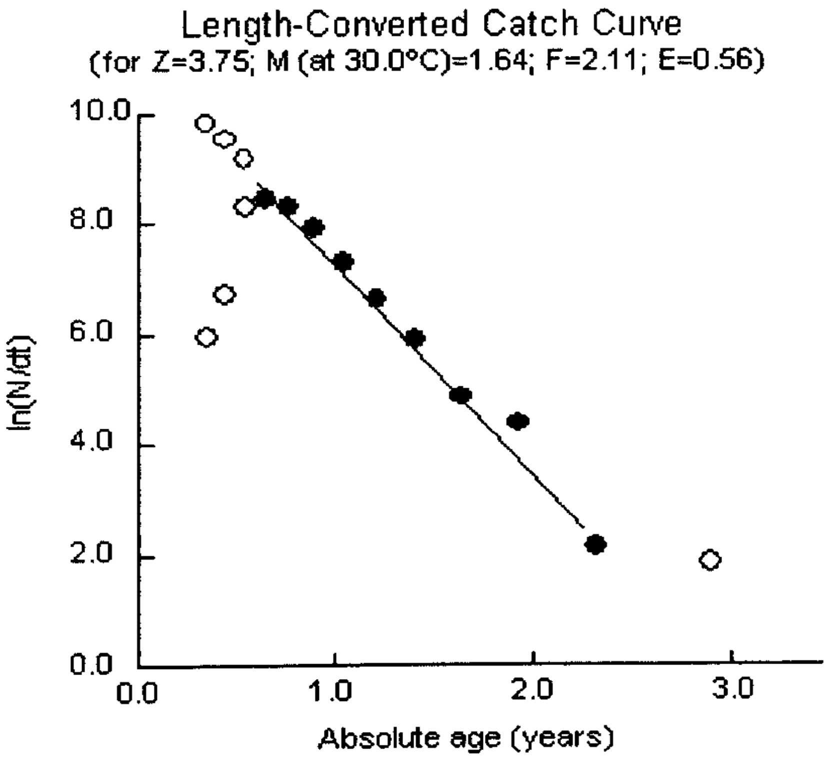


Fig. 6. Length converted catch curve of *Sepioteuthis lessoniana*

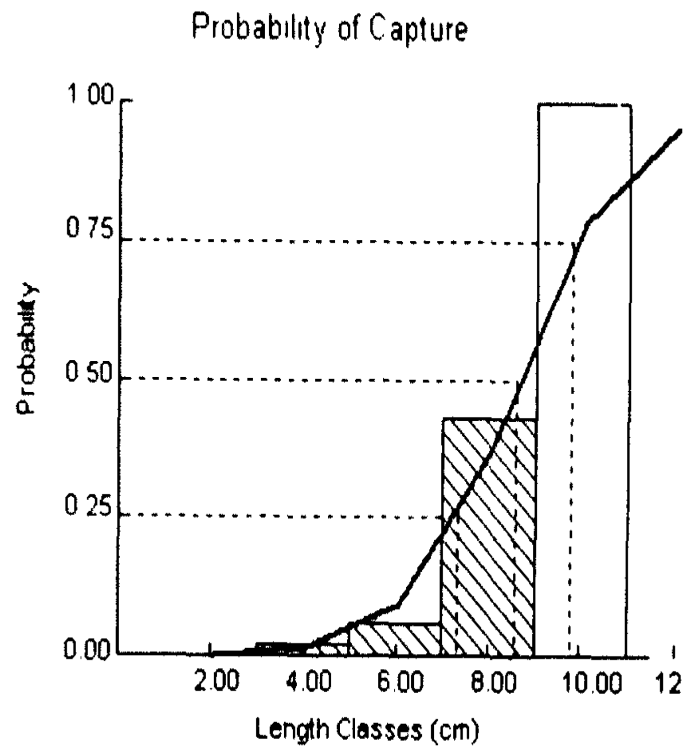


Fig. 7. Probability plot of *Sepioteuthis lessoniana*

The natural mortality coefficient (M) obtained through Pauly's empirical model at 30°C surface temperature was 1.64 $year^{-1}$. Therefore, the computed instantaneous fishing mortality coefficient (F) for *S. lessoniana* is 2.11. The respective current exploitation ratio (E) for *S. lessoniana* is 0.56.

Two dimensional relative yield per recruit prediction model incorporating probabilities of capture is given in Fig. 8. The selective ogive procedure for the analysis of relative yield-per-recruit gave predicted values of 0.501 for E_{max} for *S. lessoniana*. The computed current exploitation rates (E) of 0.56 for *S. lessoniana* is slightly above the predicted E_{max} for *S. lessoniana*. The implication is that the stock is slightly overexploited. Thus, the fishing pressure on the stock has to be reduced. More capture should be prohibited by a reasonable decrease in the effort or by modifying the mesh size of the net for *S. lessoniana* species.

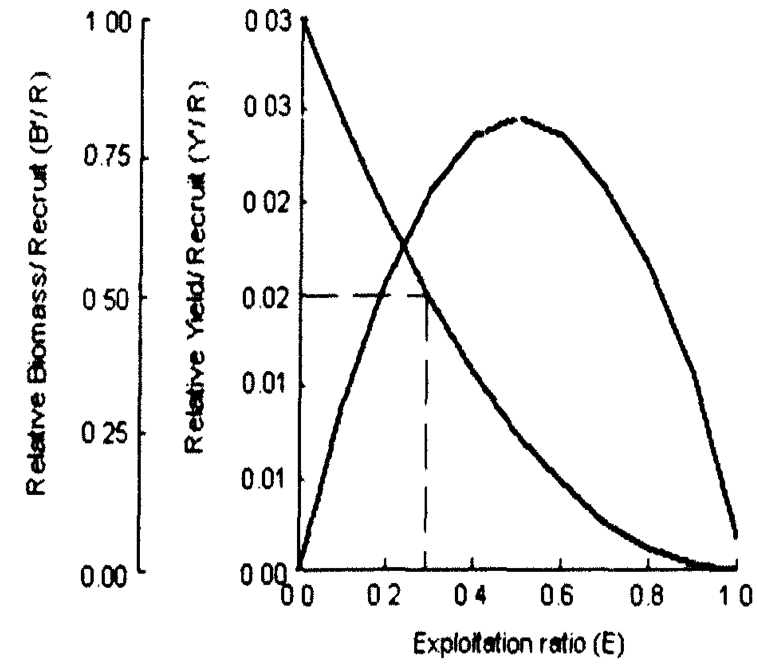


Fig. 8. Relative yield per recruit using selective ogive for *Sepioteuthis lessoniana*

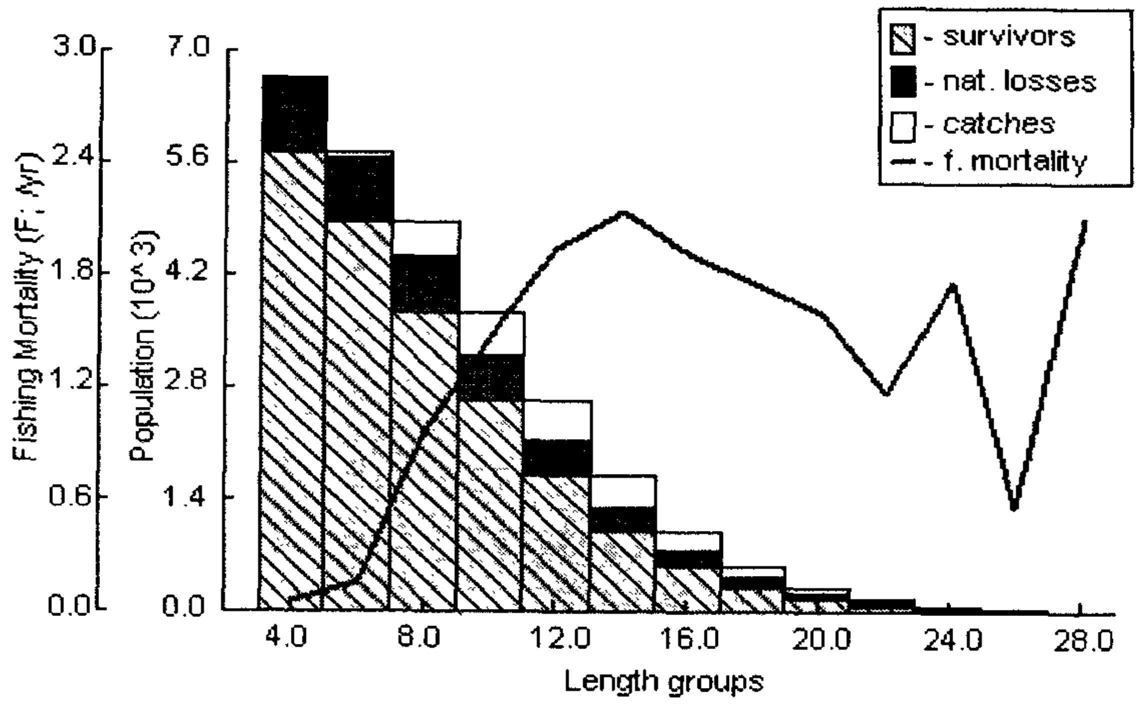


Fig. 9. Virtual population analysis for *Sepioteuthis lessoniana*

The results of the virtual population analysis are shown in (Fig. 9). In *S. lessoniana*, specimens below 140 mm were found less vulnerable to exploitation. The fishing mortality increased up to 140 mm length group and attained a maximum F of 2.13. Again it decreased gradually fluctuated and reached maximum of 1.77 at 240 mm length groups. Then it decreased and increased to attain the F_t of 2.11 at 280 mm length group.

Higher fishing mortality for *S. lessoniana* may be due to its higher growth rate. It is evident from the present study that the stress exerted by fishing mortality to the *S. lessoniana* stock peaks at 140 mm and 280 mm and therefore this is the most vulnerable size range at the Northern coast of Sri Lanka.

Length weight relationship

A total of 2529 specimens (232 indeterminate, 1189 males and 1108 females) of *S. lessoniana* were analyzed.

The size (Mantle Length-ML) of *S. lessoniana* ranged from 2.4 to 30.2 cm (mean ± SD = 15.03 ± 4.26 cm). Males ranged from 3.8 to 29.7 cm ML (mean ± SD = 14.53 ± 4.38 cm), females ranged from 3.5 to 30.2 cm ML (mean ± SD = 15.56 ± 4.05 cm) while indeterminate ranged from 2.4 to 12.5 cm ML (mean ± SD = 5.58 ± 1.36 cm).

The results of two – sample t – test (Table 1) for weight data of male and female show that females were larger than males but there is no significant difference (P>0.05) between males and females.

The estimates of the regression parameters of mantle length-weight relationship for male, female and indeterminate obtained by regression analysis are shown in Table 2. The equations of mantle length - weight relationship and their logarithmic transformation are given in Table 3. The 'b' values 2.2205, 2.1137 and 2.396 obtained for male, female and indeterminate respectively indicate that the fish more or less follows the cube law, its growth is proportionally three-dimensional (n = 1188, r^2 = 0.878, 95% CL a = 0.298 to 0.382, 95% CL b = 2.173 to 2.268 and coefficient of variation = 0.00329 for males; n = 1107, r^2 = 0.8471, 95% CL a = 0.191 to 0.274, 95% CL b = 2.060 to 2.166 and coefficient of variation = 0.00333 for females; n = 232, r^2 = 0.7574, 95% CL a = 0.1348 to 0.3311, 95% CL b = 2.137 to 2.654 and coefficient of variation = 0.01755 for Indeterminate). That is, with increasing age, rate of growth in terms of weight in this squid becomes slower than that of its length. Correlation coefficients(r) 0.937 for male, 0.920 for female and 0.8703 for indeterminate were found to be significant ($p<0.01$) in all instances indicate good correlation between mantle length and weight.

Table 1. Two – sample t – test for weight data of male and female *S. lessoniana*

	Weight of body male	Weight of body female
Mean	150.15	152.36
Variance	13760.50	9120.85
Observations	1189	1108
Hypothesized mean difference	0	
Df	2255	
t stat	-0.4980	
P (T<=t) one tail	0.3092	
t critical one tail	1.6455	
P (T<=t) two tail	0.6185	
t critical two tail	1.9610	

Table 2. Mantle Length-weight relationship parameters of *S. lessoniana* (N=Number of observation, df=Degrees of freedom, b=Regression exponent, a=Constant, SS=Sum of squares, r=Correlation coefficient, M=Male, F=Female, I = Indeterminate and T=Total).

Sex	N	Df	b	a	Errors of estimation		r
					df (residual)	SS (residual)	
M	1189	1187	2.2205	0.3370	1186	15.3358	0.9372
F	1108	1106	2.1137	0.4137	1105	13.5349	0.9204
I	232	230	2.3960	0.2098	229	16.3603	0.8703
T	2529	1132	-	-	2291	-	-

Table 3. Relationship between mantle length and weight of male and female of *S. lessoniana* (M=Male, F=Female, I = Indeterminate, W=Weight and ML= Mantle length)

Sex	Mantle Length-weight relationship	Logarithmic transformation
M	$W= 0.3370 * TL^{2.2205}$	Log W= -0.4723 + 2.2205 * Log ML
F	$W= 0.4137 * TL^{2.1137}$	Log W= -0.3833 + 2.1137 * Log ML
I	$W= 0.2098 * TL^{2.3960}$	Log W= -0.6780 + 2.3960 * Log ML

The significance of variation in the estimates of 'b' for *S. lessoniana* from the expected value for the ideal fish (3.0) was tested by Students' t test (Snedecor and Cochran 1967; Jayaprakash 2001).

Students' t test was employed by dividing the difference between 'b' and '3' by standard error of 'b' (Zar 1996). The results are as follows:

Male: (2.2205~3.0)/0.0239 = 32.615 Significant
(computed $t_{\alpha(2),0.05,1187} > 1.960$)

Female: (2.1137~3.0)/0.02701 = 32.814 Significant
(computed $t_{\alpha(2),0.05,1106} > 1.960$)

Pooled: (2.3960~3.0)/0.1310 = 4.610 Significant
(computed $t_{\alpha(2),0.05,231} > 1.970$)

The above result shows that the 'b' values of male, female and indeterminate *S. lessoniana* significantly differ (P<0.05) from the ideal value 3 and exhibit significant negative allometric growth in all instances.

The GLMANCOVA results for the comparison of regression coefficients (b) of the length-weight relationship of male, female and indeterminate is presented in Table 4. In GLMANCOVA a full rank design matrix was formed from the factors and covariates and each response variable was regressed on the columns of the design matrix.

The GLMANCOVA showed the slopes (b) of male, female and indeterminate exhibit significant interaction (computed $F_{2,\ 2528} < 3.69$ P<0.05). Further, comparison of regression co-efficient of male and female using GLMANCOVA for the regression of log weight on log mantle length of male and female showed the 'b' values show significant differences (P>0.05). The confidence intervals of 'a' for male and female does not overlap with each other and therefore there is significant difference between the intercepts, too. Interestingly, comparison of regression co-efficient of indeterminate with that of male and female using GLMANCOVA showed the 'b' values not to show significant differences (P>0.05).

The scatter diagrams of weight versus length of male and female samples of *S. lessoniana* are illustrated in Fig. 10 and 11.

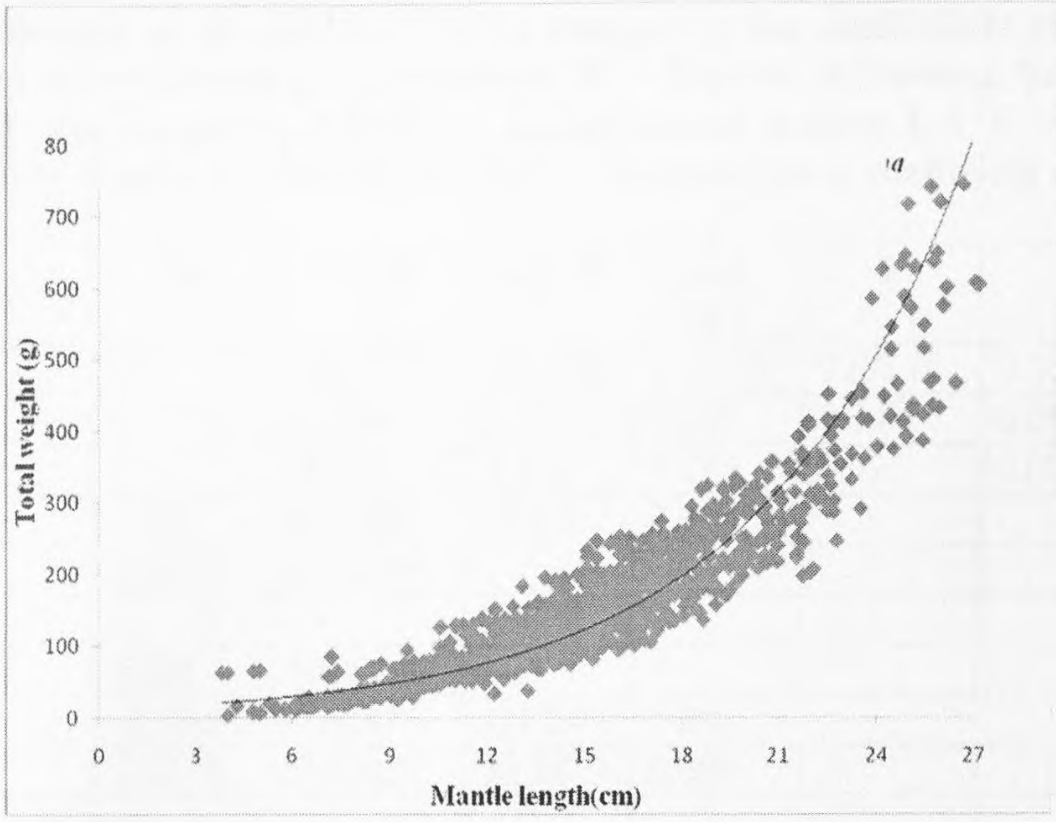


Fig. 10. Total weight versus mantle length of male *S. lessoniana*

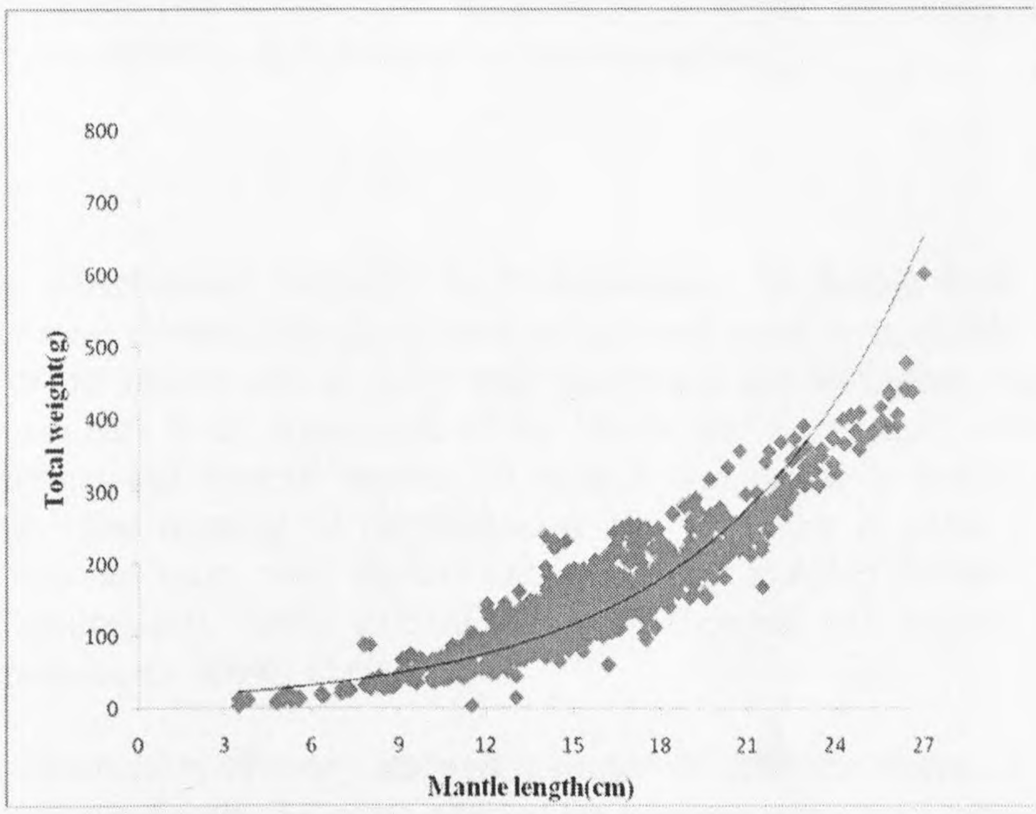


Fig. 11. Total weight versus mantle length of female *S. lessoniana*

Table 4. Results of the GLMANCOVA comparing the coefficients of male, female and indeterminate of *S. lessoniana* (df = Degrees of freedom, Seq SS = Sequential sum of squares, Adj SS = Adjacent sum of squares, F = 'F' value, P = Probability, Coef = Coefficient, SE Coef = Standard error coefficient and t = 't' value).

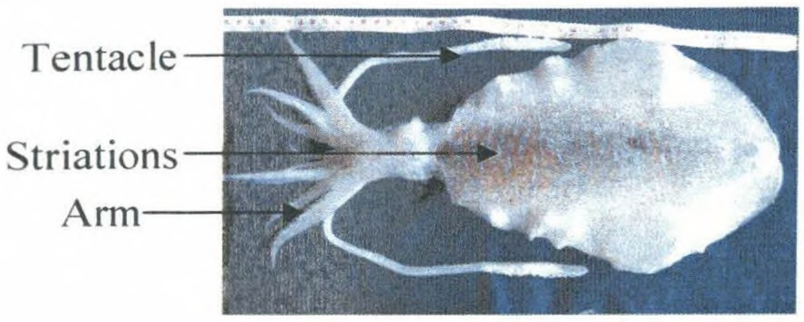
Source	df	Seq SS	Adj SS	Adj MS	F	P
All	1	406.198	131.103	131.103	7238.01	0.000
sex	2	1.321	0.335	0.167	9.24	0.000
sex*all	2	0.251	0.251	0.125	6.92	0.001
Error	2523	45.699	45.699	0.018		
Total	2528	453.469				
Term	**Coef**	**SE Coef**	**t**	**P**		
Constant	-0.50393	0.02372	-21.24	0.000		
all	2.23481	0.02627	85.08	0.000		
all*sex						
Male	-0.01422	0.03096	-0.46	0.646		
Female	-0.12032	0.03239	-3.71	0.000		
Indeterminate	0.13454	0.04617	2.91	0.004		

Interpretation: F-value for "all" showed significant differences; F-value for "sex*all" (interaction) did not show significant difference in slopes (length-weight relationship); Slope of the mean line is 2.23481, differences in slopes for male, female and indeterminate are -0.01422, -0.12032 and 0.13454 respectively.

Reproduction

Sexes can be differentiated externally in *S. lessoniana.* In female fresh specimens, whitish colour mass (Nidamental gland), and pale colored ovary were visible through the ventral side of the mantle and in fresh male specimens chromatophore arrangements create transverse bars in the dorsal side of the mantle and hectocotyle arms were also observed. External and internal features of male *S. lessoniana* is shown in plate 6. Photograph and line drawing of hectocotilized arm is shown in plate 7 and 8. In comparison, matured males were narrow and longer than matured females. Dissection through mid ventral axis clearly defined the sexes. External and internal features of female *S. lessoniana* are shown in plate 9.

Macroscopic observation of ovary showed presence of different stages of ova in the ovary (plate 10). In freshly dissected ovaries the matured eggs were observed in the peripheral region whereas immature and maturing eggs were observed as the central mass. Extrusion of matured eggs to the exterior through the oviduct and sperms through the penis was also observed in females and males and it is shown in plate 11 and 12 respectively. Interestingly some females had bunches of spermatophores at the buccal funnel region and a photograph of it is shown in plate 13.



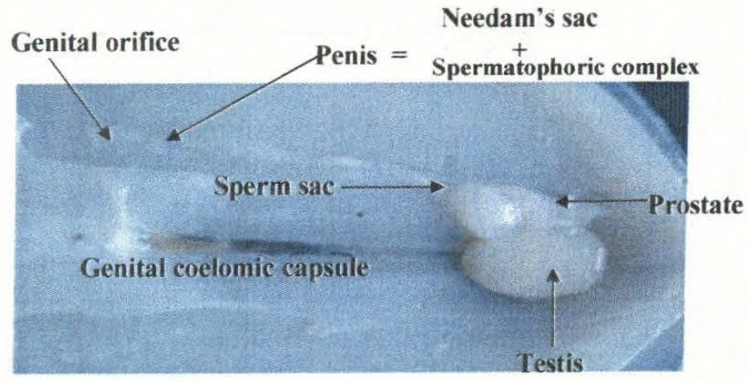


Plate 6. External and Internal features of male *S. lessoniana*

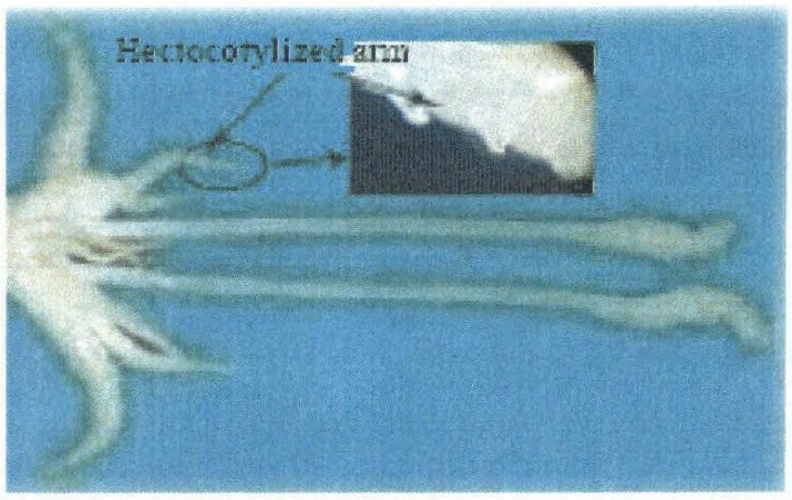


Plate 7. Detailed photograph of hectocotyli arm of male *S. lessoniana*

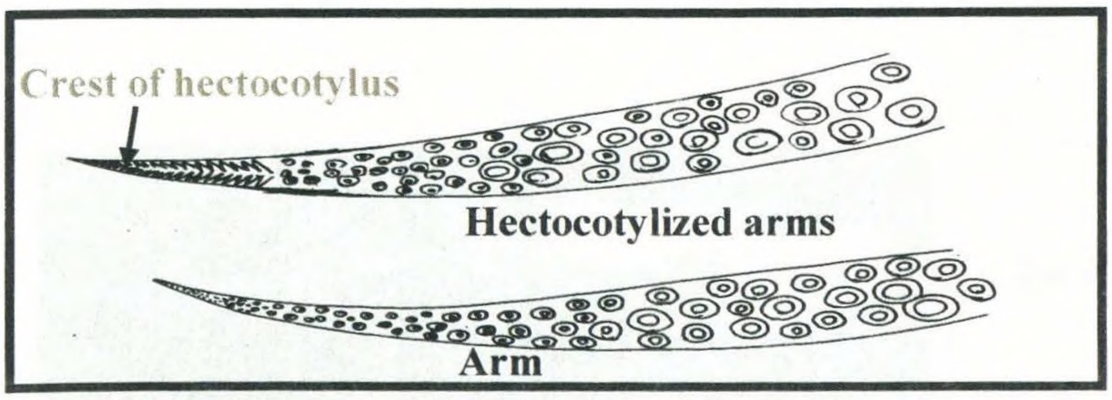
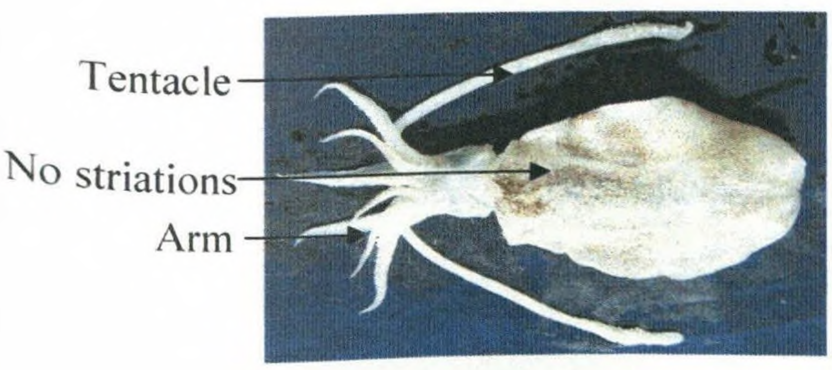


Plate 8. Detailed drawing of hectocotyli arm of male *S. lessoniana*



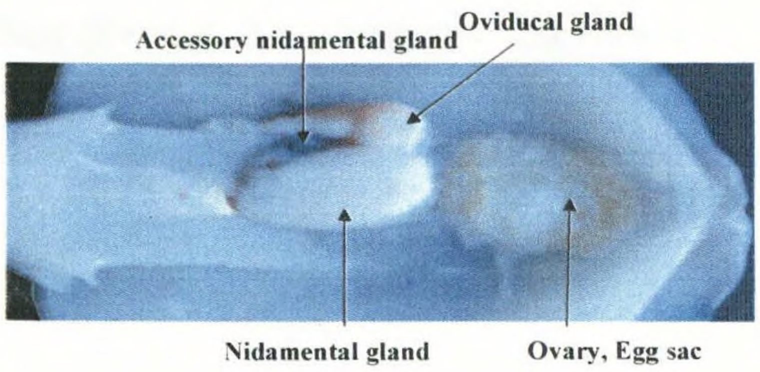


Plate 9. External and Internal features of female *S. lessoniana*

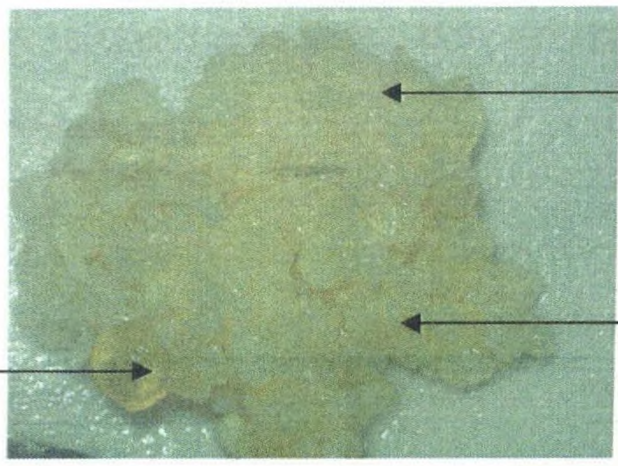


Plate 10. Different sizes of eggs *S. lessoniana*

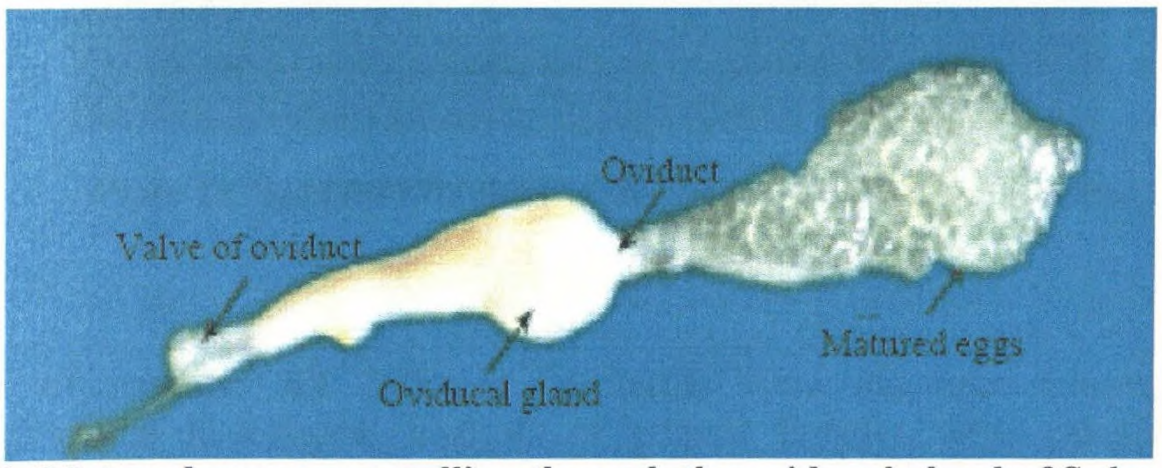


Plate 11. Matured eggs are expelling through the oviducal gland of S. *lessoniana*

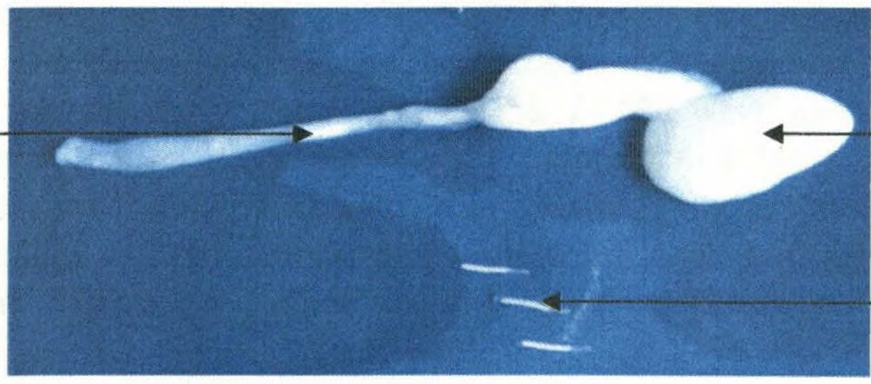


Plate 12. Matured sperms expelling through the penis of S. *lessoniana*

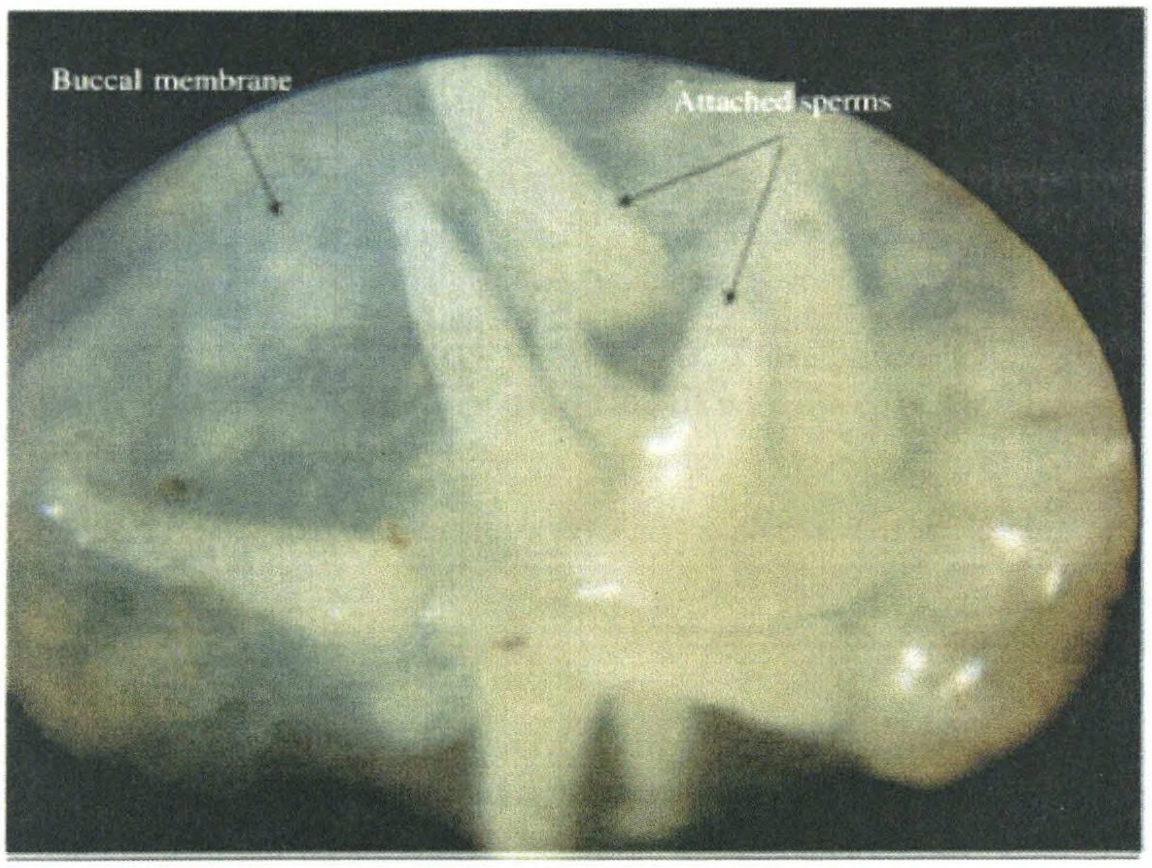


Plate 13. Sperms attached to the females buccal membrane

Histology of gonads: All collected specimens were examined macroscopically. According to the histological analysis of gonads females were categorized into immature, maturing, fully maturing / pre spawn and matured / spawn as described in Table 5 while males were categorized into immature, maturing, fully maturing / pre spawn and matured / spawn as described in Table 6. Images of the various stages of *S. lessoniana* ovary are shown in plate 14 and testis in plate 15.

Among the specimens analyzed 305 ovaries and 269 testes were subjected to histological analysis. Of these, 11.0% were in pre spawning condition (stage III) and 5.0% were in spawn (stage IV). Of the other remaining 84.0%, 24.0% were immature (stage I) and 60.0% were maturing (stage II). Females with maturing ova (stages II) were apparent throughout the year, but the main occurrence of spawning and spent females was during April, August, October and November. Some spawning and spent females were evident throughout the year. Similar occurrence was also observed for males.

Table 5. Female maturity stages of *S. lessoniana*			
Identified maturity stage	**Size of oocyte**	**Morphological observations of the reproductive combine organs**	**Histological observation**
Stage I Immature	All oocytes below 1 mm	Very small ovary. Transparent NG. No OG	Cluster of developing oocytes surrounded by the follicular cells
Stage II Maturing	All oocytes below 1 mm and uniform	Clearly visible NG. Transparent OG. Visibly granular like uniformly sized oocytes.	More oocytes surrounded by the follicular cells. Follicles initiate to penetrate the developing oocytes
Stage III Fully maturing/ pre spawn	All stages below 1mm, 1-2 mm and 2-6mm	White NG.OG begins from yellow to brown. Large number of 1-2 mm striated oocytes. Chromatophores create transverse bars in the dorsal side of the mantle.	More follicular epithelium initiates to enter the oocytes and forms the folds.
Stage IV Matured/ Spawn	All stages Less Number below 1mm, 1-2 mm and 2-6mm in more Number	Large ovary smooth oocytes surrounded the periphery of the maturing oocytes. Swallowed white NG. Full of smooth transparent oocyte in proximal end of the brownish OG	Degeneration of follicular epithelium.

Table 6. Male maturity stages of *S. lessoniana*			
Identified maturity stage	**Size of Sperm**	**Morphological observations of the reproductive combine organs**	**Histological observation**
Stage I Immature	No sperm	Small transparent testis, thin developing spermatophoric organ	Considerable numbers of spermatogonia mass along insides the wall of semniferous tubule
Stage II Maturing	No sperm	Enlarged thickened testis, poor developing lees number of sperm within the Needham's sac, chromatophores create transverse bars in the dorsal side of the mantle. Left ventral arm begins to hectocotyli by a modification of the distal 4^{th} of the arm.	Spermatogonia with large numbers of spermatocytes present
Stage III Fully maturing/ pre spawn	Below 6 mm	Transparent thread like bundle of poorly developed full of sperms within the Needham's sac. Left ventral arm is hectocotyli by a modification of the distal 4^{th} of the arm.	Spermatozoa in abundance
Stage IV Matured/ Spawn	6-7 mm	White needle like bundle of developed full of sperms within the Needham's sac.	

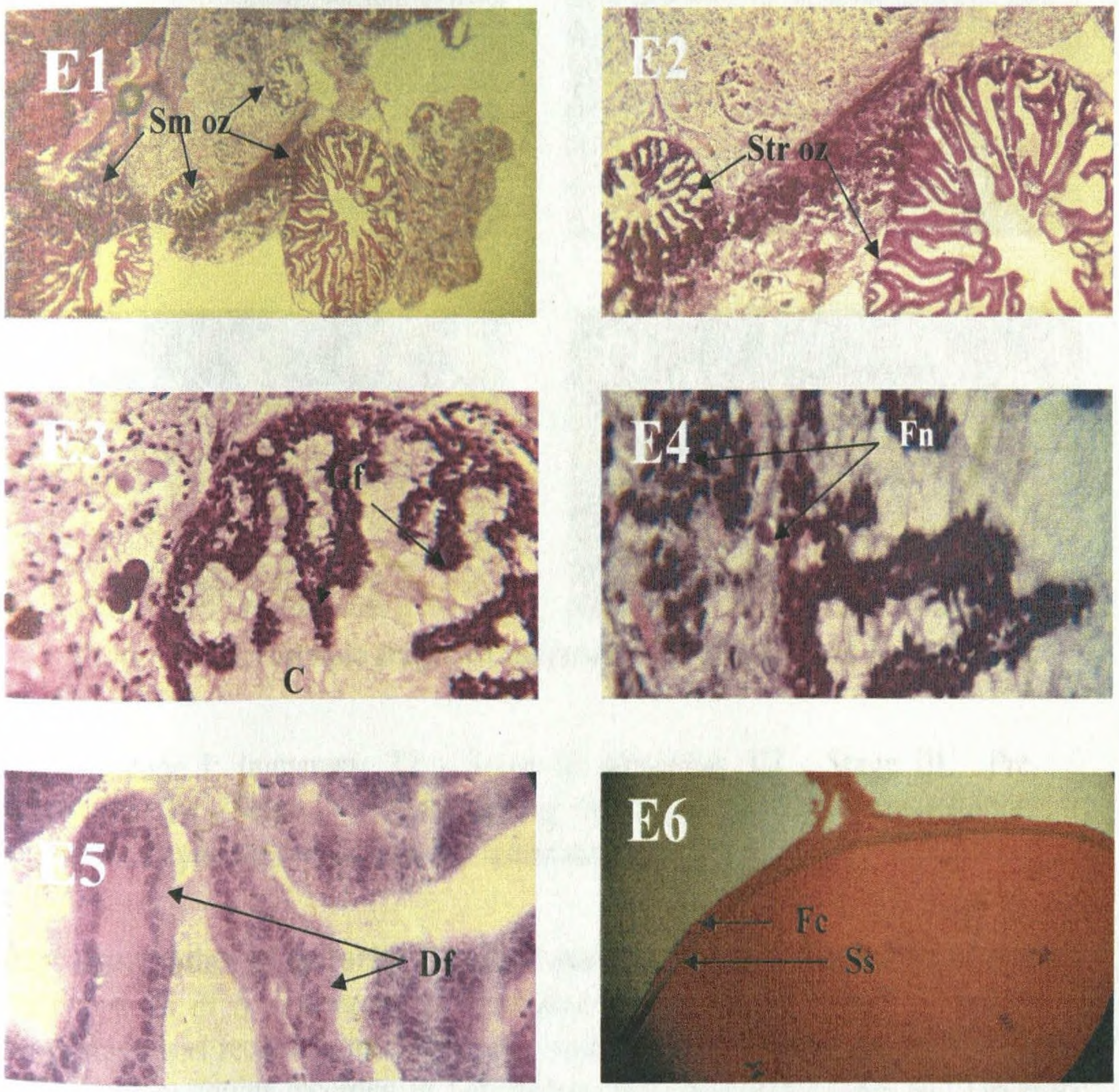


Plate 14. Microscopic stages of oocyte development of *S. lessoniana*

E1 - Stage I: Immature; **E2** - Stage II: Maturing; **E3**- Stage III: Pre spawning; **E4** - Pre spawning (enlarged); **E5** – degenerating stage; **E6** - Stage IV: Spawning; C: cytoplasm; Fc: follicle cell; Fn: follicle nucleus; Df: degenerating fold; Gf: generating fold; Sm oz: small oocyte; Ss: smooth surface; Str: striated oocyte.

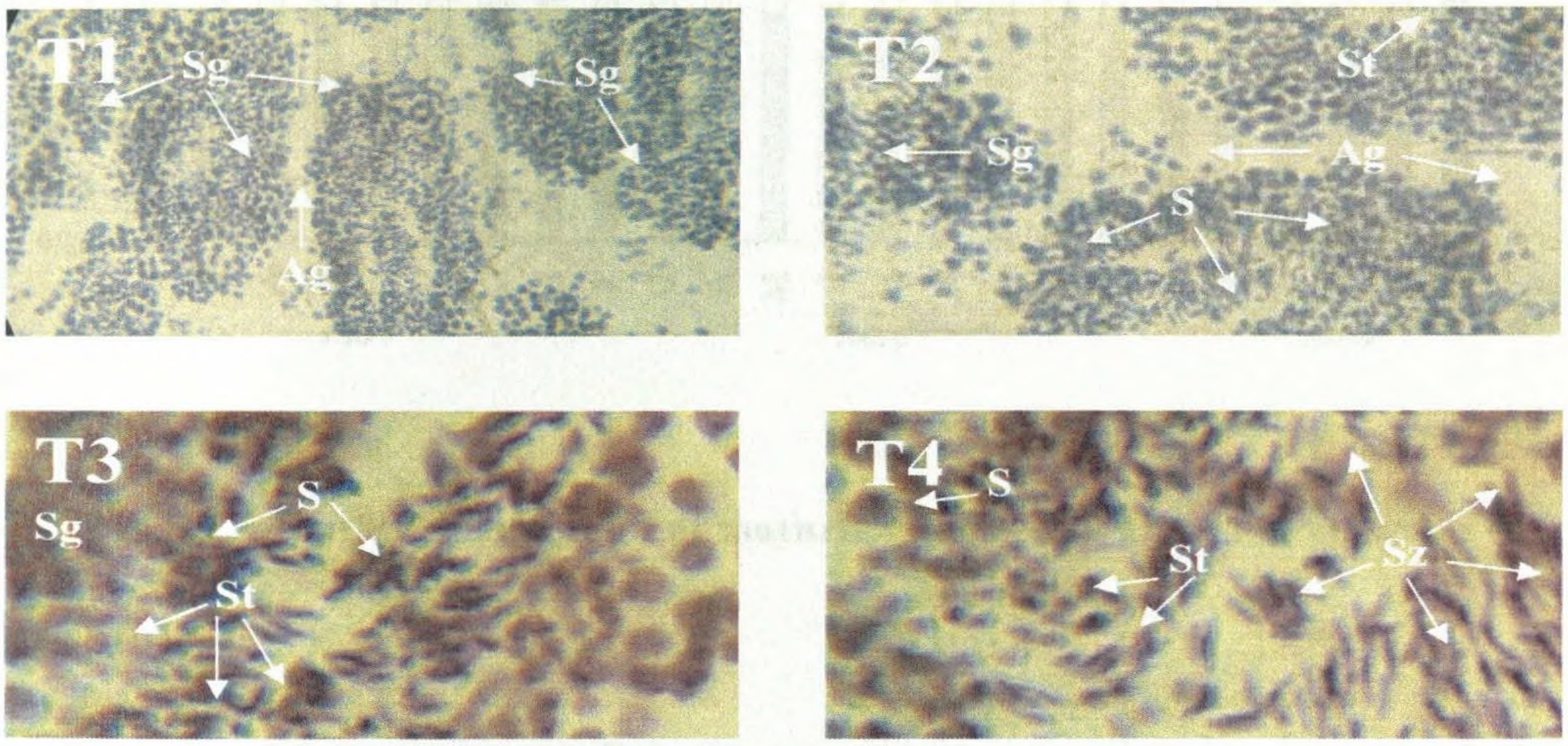


Plate 15. Microscopic stages of spermatid development of *S. lessoniana*

T1 - Stage I: Immature; **T2** - Stage II: Maturing; **T3** - Stage III: Pre spawning; **T4** - Stage IV: Spawning. Ag: artifactual gap Sg: spermatogonia; S:spermatocyte; St: spermatids; Sz: spermatozoa.

Monthly distribution of maturity stages of ovaries: Monthly distribution of maturity stages of ovaries of *S. lessoniana* is illustrated in Fig. 12. In female *S. lessoniana*, spawning stage was recorded throughout the year. High percentages i.e. 64%, 62% and 60% of immature squids recorded in September 2007, November 2008 and December 2007 & March 2009 respectively. No immature squids were recorded in August 2007. Maturing squids were recorded throughout the year; very low percentage in August 2007. High occurrence of spawning stage in squids was observed in August 2007, November 2007, April 2008 and October 2008. This suggests that the peak spawning period of *S. lessoniana* is in April, August, October and November even though it spawns throughout the year. Presence of all stages of macroscopic eggs in the same ovaries confirms that the spawning of *S. lessoniana* in the northern coastal waters should be more than once and said to be asynchronous or group synchronous. Monthly distribution of maturity stages of testis of *S. lessoniana* is illustrated in Fig. 13. In male *S. lessoniana*, spawning stage was recorded throughout the year. High occurrence of spawning stage for males was observed in September 2007, March 2008, November 2008 and April 2009.

Maturity indices: Monthly variation of various maturity indices of male and female are shown in Fig. 14 and 15. For males, the MCO values varied from 0.956 to 4.022 with an average of 1.67 ± 0.605; GSI values varied from 0.648 to 1.5 with an average of 1.004 ± 0.256; SCI values varied from 0.443 to 3.357 with an average of 0.832 ± 0.565. For females, the MCO values varied from 8.235 to 12.879 with an average of 10.568 ± 1.311; GSI values varied from 3.440 to 8.670 with an average of 6.393 ± 1.216; NGI values varied from 2.092 to 5.849 with an average of 4.241 ± 0.911.

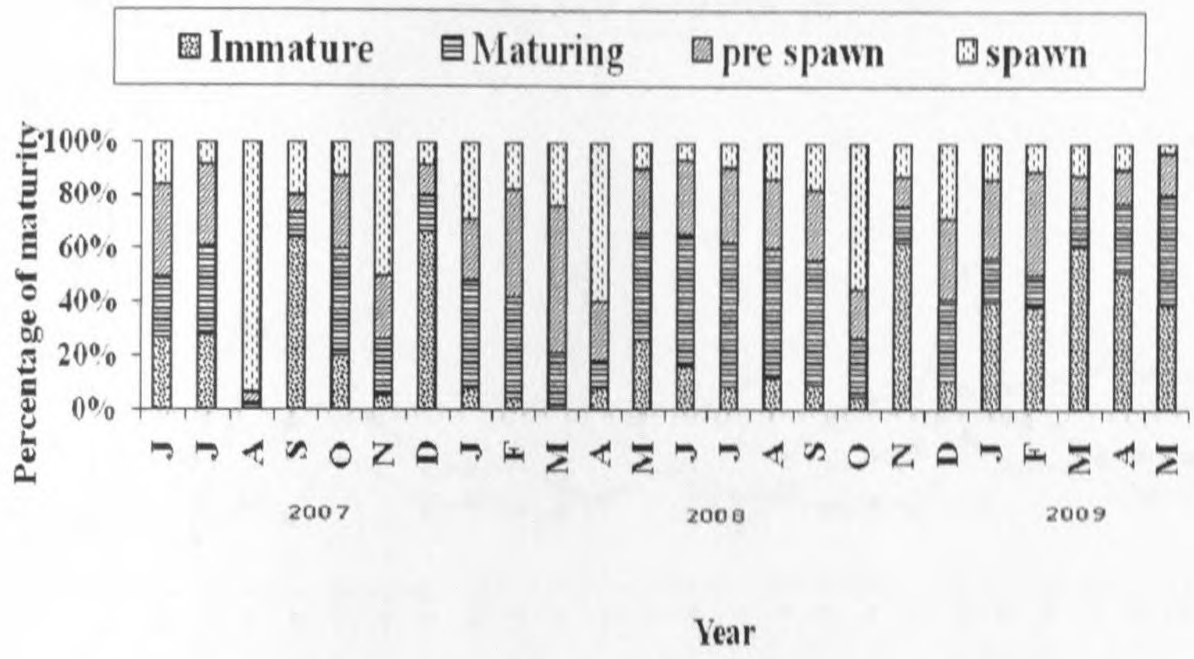


Fig. 12. Monthly distribution of maturity stages of female *S. lessoniana*

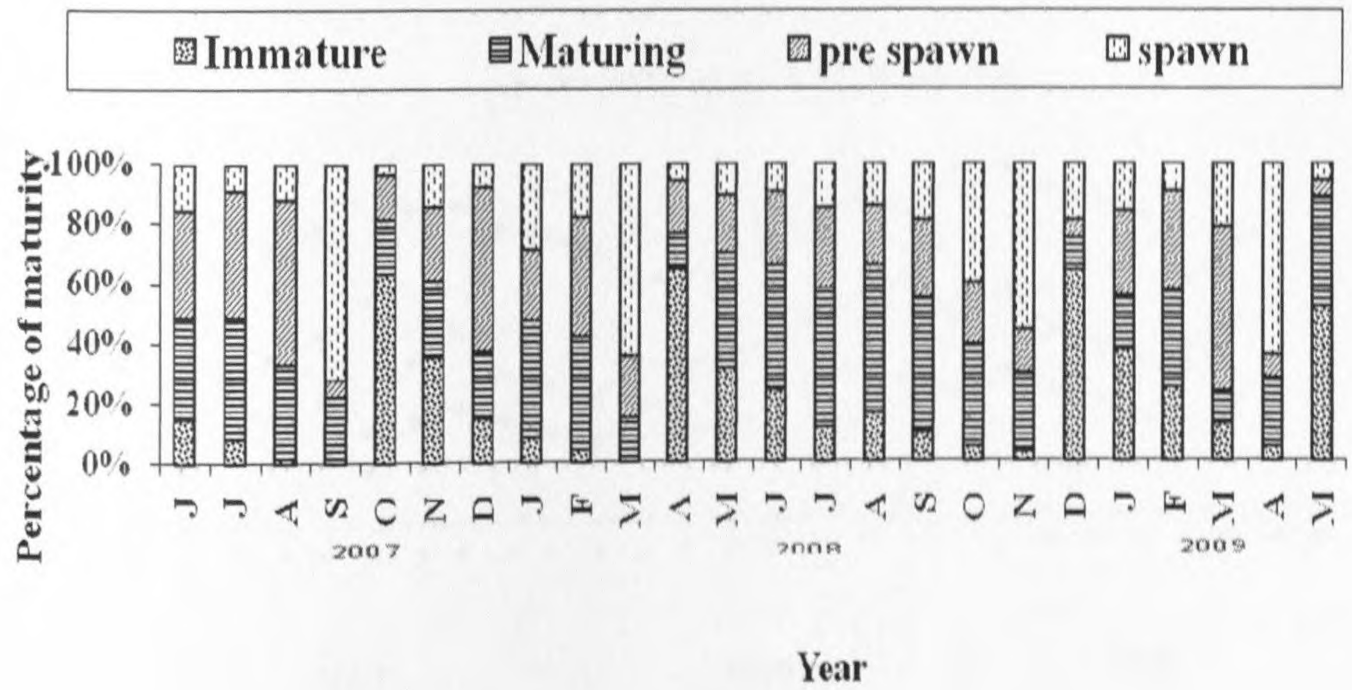


Fig. 13. Monthly distribution of maturity stages of male *S.lessoniana*

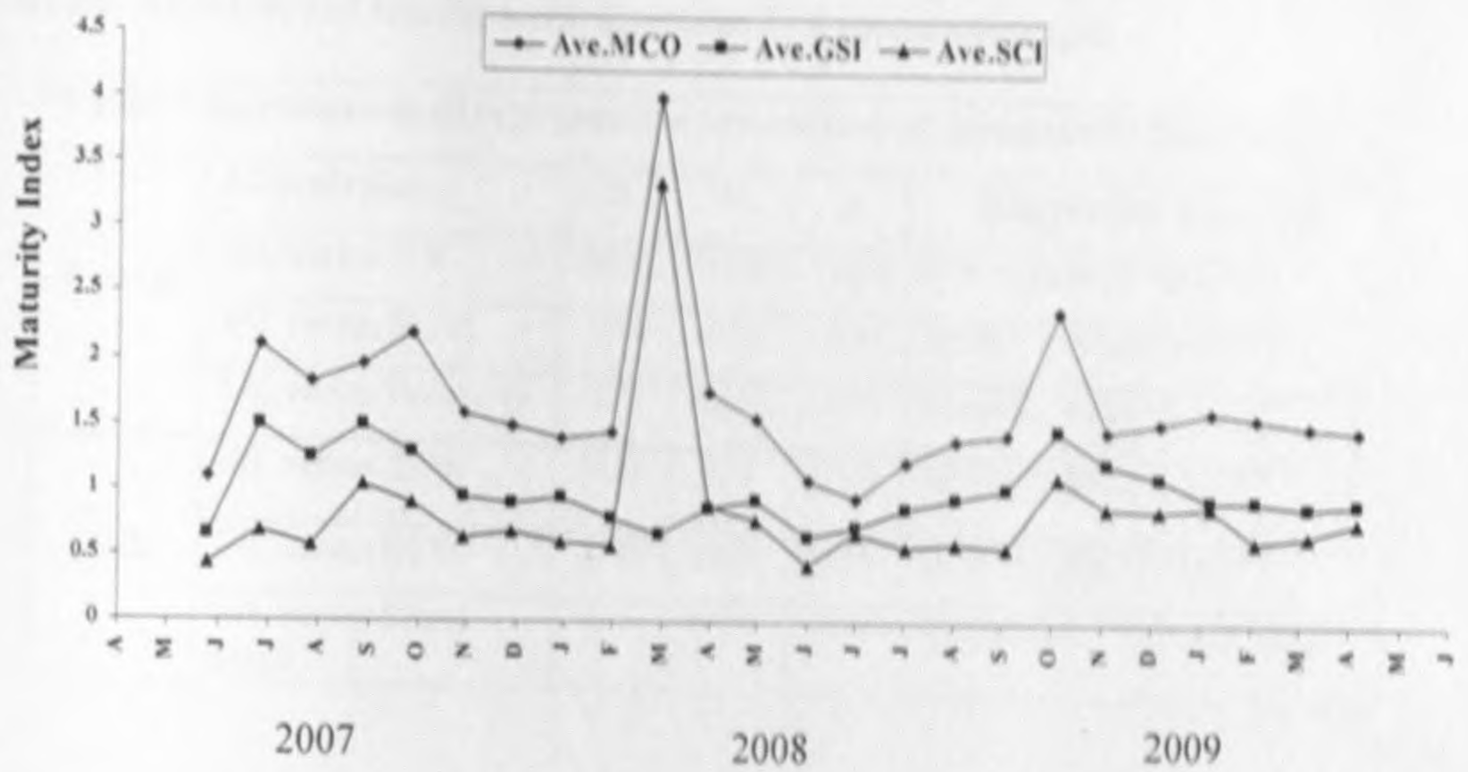


Fig. 14. Maturity indices of male *S.lessoniana*

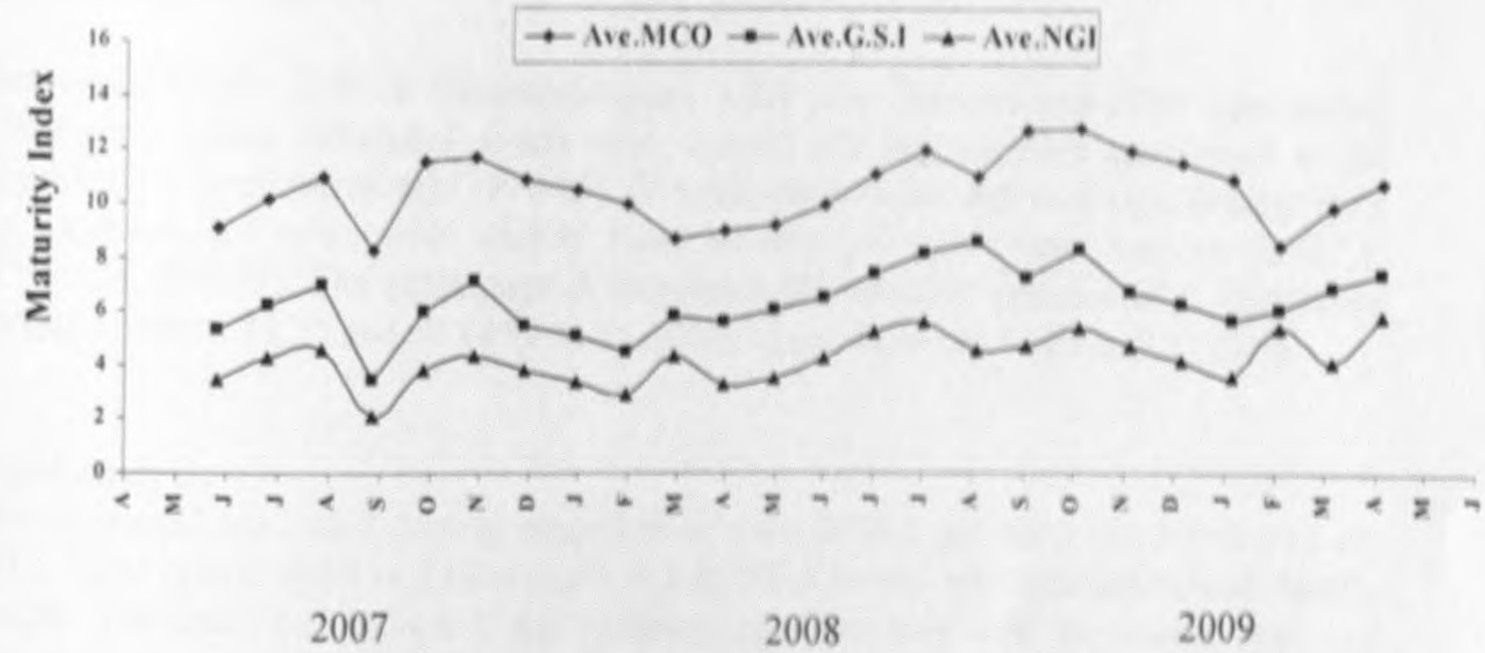


Fig. 15. Maturity indices of female *S.lessoniana*

Fecundity: Fecundity increased exponentially with mantle length (ML) from 20 (7 cm) to 852 (30.2 cm ML) but a weak correlation was obtained with mantle length ($r = 0.535$, $P<0.01$). Linear regression equation for fecundity versus mantle length is given in Table 7. In males number of sperm varies from 5 to 568 for individuals of 9.8 to 29.7 cm dorsal mantle length.

Size at maturity: Plots obtained for percentage occurrence of mature squids (Fig. 13 and 14) against mantle length class interval indicates that *S. lessoniana* male reached maturity at 15 cm mantle length while female reached maturity at 17.5 cm mantle length. All males and females were matured at 22.0 cm mantle length.

Table 7. Correlations of reproductive parameters of *Sepioteuthis lessoniana*

	Correlation	N	R	p	Regression equation
Female	ML versus OW	1108	0.767	<0.01	$OW = (2.24x10^{-7})\ ML^{6\,46}$
	ML versus NGW	1108	0.879	<0.01	$NGW = (4.57x10^{-7})\ ML^{6\,12}$
	ML versus Fecundity	233	0.616	<0.01	$Fecundity = (0.056)\ ML^{3\,22}$
Male	ML versus TEW	1189	0.78	<0.01	$TEW = (5.62x10^{-4})\ ML^{2\,95}$
	ML versus SCW	1189	0.854	<0.01	$SCW = (5.89x10^{-5})\ ML^{3\,65}$
	ML versus Sperm count	217	0.767	<0.01	$Sperm\ count = (6.76x10^{-3})\ ML^{3\,44}$

Relationship between mantle length and other parameters: The least square linear regression analysis expressed that there are highly significant (P<0.001) relationships for OW and NGW with the mantle length in females. That is OW and NGW proportionately increased with increasing mantle length in females. Similarly highly significant (P<0.001) relationships for TEW, SCW and sperm count with mantle length obtained for males. Parabolic equations for relationships of various morphometric measurements versus mantle length, R^2 and P values of above relationships for both male and female squids are presented in Table 7.

Sex ratio: Of the 2297 *S. lessoniana* sexed, 1108 were females and 1189 were males. Chi-square values calculated month wise showed that the sex ratio conformed to the expected 1:1 in all the months (P>0.05). Overall, sex ratio did not vary significantly from an expected 1:1 ratio, with slightly more number of males than females (0.932:1, X^2=0.124, P>0.05). The percentage of females in the monthly samples of *S. lessoniana* ranged between 42.35 and 57.14 % while males ranged between 42.85 and 57.65 %.

Lipid analysis

The estimated total lipid content ranged from 0.043% (6.1 cm ML) to 15.75% (12 cm ML). Total lipid content in different size squids did not show any correlation with mantle length. The total lipid content is not increasing exponentially with the mantle length of the *S. lessoniana*. Regression analysis between total lipid and mantle length of *S. lessoniana* gave a 'r' value of 1.89 and P<0.01. It confirms that there is no significant correlation between the two said parameters.

The average total lipid content of muscle, ovary and liver of immature, maturing and matured individuals are shown in Fig. 16 and Table 8. ANOVA showed that the lipid content of liver, gonad and muscle of *S. Lessoniana* in different maturity stages is significantly different (Table 8).

Liver and gonad lipid increased significantly (P<0.05; DMRT; Table 8) from immature to spawning stage. It declined from maturing to spawning stage due to breakdown of lipid as energy for ovarian maturation, in the muscle. A significant increase (P<0.05; DMRT; Table 8) in liver and gonad lipid in spawning stages could be attributed to accumulation of lipids at this stage. Muscle lipid increased significantly (P<0.05; DMRT; Table 8) from immature to maturing stage indicating considerable lipid storage while maturing. It declined in spawning not significantly as that of immature (P>0.05; DMRT; Table 8) due to liberation of gametes. Liver tissue contained relatively high percentages of lipids in all analyzed stages compared to gonad and muscle.

Table 8. Lipid content of liver, gonad and muscle in different maturity stages of female *S. lessoniana*

Stages	Liver	Gonad	Muscle
Immature	1.96 ± 0.08^{a} (6)	0.00 ± 0.00^{a} (6)	0.53 ± 0.13^{a} (6)
Maturing	4.05 ± 0.22^{b} (6)	8.31 ± 0.31^{b} (6)	1.21 ± 0.29^{b} (6)
Spawning	11.99 ± 0.70^{c} (6)	6.31 ± 0.42^{c} (6)	0.59 ± 0.24^{a} (6)

Values are mean±SD from six replicates. $^{a-c}$Values not sharing a common superscript differ significantly at P<0.05 (DMRT). Values in parenthesis are number of observations.

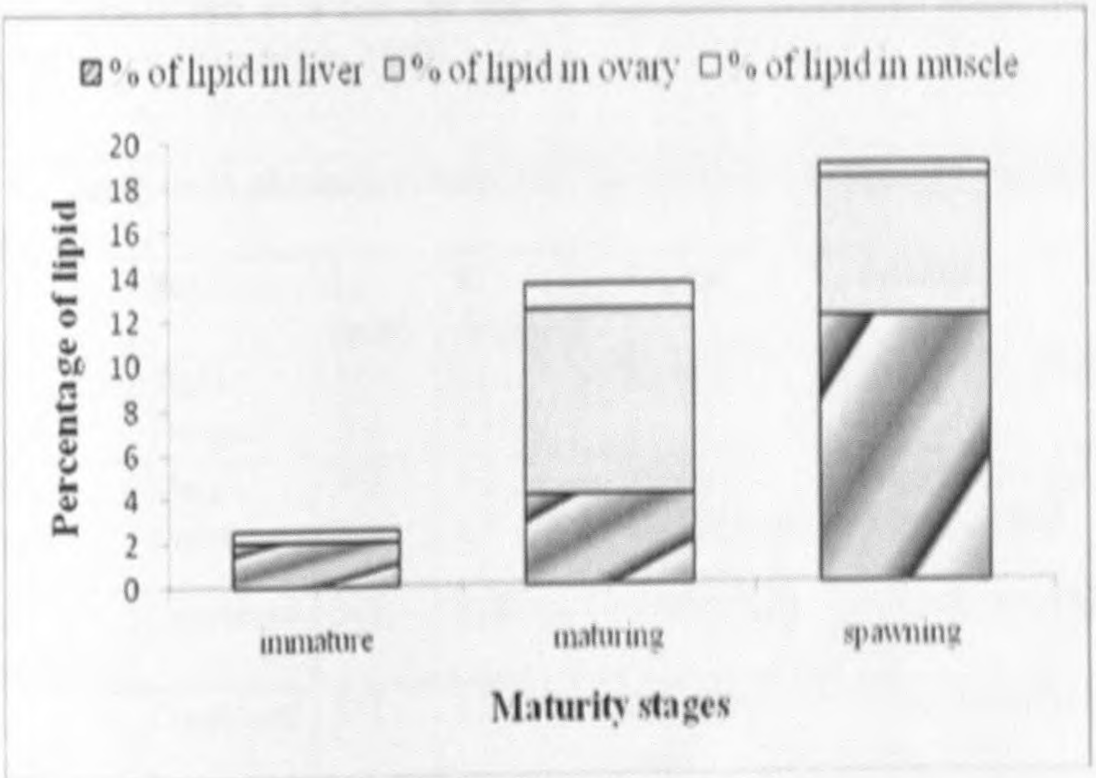


Fig. 16. Fluctuations in lipid during ovarian cycle in gonad, liver and muscle tissues of female *S. lessoniana*

v) Discussion

Age and growth and stock assessment

Age and growth parameters of the squid *S. lessoniana* were not reported in Sri Lanka and this is the first study to estimate those parameters. One related preliminary study was performed for *S. lessoniana* and it is the study by Balgos and Pauly (1998) in Philippine waters. However growth and mortality parameters were not clearly defined in that study. Few other studies were performed on *Loligo duvauceli* in Indian waters (Chakraborty et al., 1997; Karnik et al., 2003; Meiyappan and Srinath, 1989; Mohammed and Rao, 1997; Neethiselvan and Venkataramani, 2002 and Silas et al., 1986). The L_∞ and K values estimated for congeners of *S. lessoniana* are given in Table 9. The estimated values of L_∞ for *L. duvauceli* differ at all instances from that of *S. lessoniana*. It clearly expresses the variation of maximum length for different species of squids as well as in different geographical location. The K value obtained is also extremely differing with that of *L. duvauceli* and consistent at only one instance that is with the *L. duvauceli* found in Mumbai coast.

The estimated growth performance (Ø) index for *S. lessoniana* shows the growth performance index is 2.904. Higher estimated growth performance index for both species is due to high growth rate constants and it clearly shows how fast these squids approaches their asymptotic length. This clearly shows the reliability of the estimates of K and L_∞ in the present study. Such estimation for growth performance index was not computed for *S. lessoniana* or the conveners of this species and therefore a comparison cannot be made at this juncture. The growth performance index 2.9 calculated for *Doryteuthis sibogae* by Neethiselvan and Venkataramani (2002) from Tuticurin waters is same as that of the result obtained for growth performance index in the present study. High annual growth rate of a fish can lead to high turnover rates or production per biomass (P:B) ratios (Gunderson, 1997).

Table 9. The growth parameters estimated for squids from different regions of the world

Species	Sex	L_∞ (mm)	K (annual)	Region	Source
Loligo duvauceli	Male Female	327 205	0.61 1.19	Cochin	Silas et al., 1986
Loligo duvauceli	Male Female	372 238	1.1 1.7	Cochin (Kerala coast)	Meiyappan and Srinath, 1989
Loligo duvauceli	Combined	343	0.49	Mumbai coast	Charaborty et al., 1997
Loligo duvauceli	Combined	371	1.4	Karnataka coast	Mohammad and Rao, 1997
Doryteuthis sibogae	Combined	395	0.4	Thoothukudi coast	Neethiselvan and Venkataramani, 2002
Loligo duvauceli	Combined	385	0.85	Mumbai coast	Karnik et al., 2003
Sepioteuthis lessoniana	Combined	311	0.85	Northern coast, Sri Lanka	Present study

Fast growth rate and small asymptotic length indicate that the fish species in these waters mature early in life and has a short life span (Sparre & Venema 1992). Hendrickson (2004) found the lifespan of winter cohort of *Illex illecebrosus* in United State waters ranges from 115 to 215 days. It is not consistent with the present study for *S. lessoniana*. Moreover, the allometric relationships for the *Illex illecebrosus* were studied by Staudinger et al., 2009 in North Carolina.

Karnik et al., (2003) computed total, natural and fishing mortality coefficients of 4.29, 1.82 and 2.47 respectively for *L. duvauceli* in Mumbai waters. The computed total, natural and fishing mortality for *S. lessoniana* differs from the earlier study for *L. duvauceli*. In a study with siboga squid *Doryteuthis sibogae*, Neethiselvan and Venkataramani (2002) estimated total, natural and fishing mortality coefficients of 2.27, 0.91 and 1.36 respectively in Tuticorin waters. Again the obtained results are not in consistent with the present study. This may be due to varied environmental conditions, fishing methods and topography of the studied regions.

Generally M/K is used as an index for checking the validity of M and K values estimated by different methods and it is known to range from 1 to 2.5 (Beverton and Holt, 1959). The M/K ratios obtained in the present study (1.92) was well within this range. Instantaneous total mortality computed by length converted catch curve for *Loligo duvauceli* in the previous study was 4.29 (Karnik et al., 2003) and the values obtained in the present study is lower than that. Only one earlier report is available for *S. lessoniana* for growth parameter estimates (Balgos and Pauly, 1998) which lacks information about mortality and virtual population analysis.

In the relative yield per recruit and biomass per recruit prediction models the descending curves showed decrease in biomass / recruits (B'/R) as exploitation ratio increased. The other curve showed increase in yield / recruit (Y'/R) with increase in exploitation ratio (E) up to E_{max}. The E_{max} is the value of E with the highest Y'/R value that is possible with a given value of L_c i.e. exploitation rate which produces maximum sustainable yield (E_{MSY}) which represents the mean maximum catch that can be taken from the fishery without affecting the biology of the stock or the balance of the system. E_{50} is the value of E associated with a 50% reduction of the biomass (per recruit) in the unexploited stock. When harvesting at the MSY level, fishing mortality (F) is roughly equal to the natural mortality (M) and harvesting above MSY denotes over fishing. The present computed yield per recruit analysis showed exploitation rate (E) of 0.56 which is 0.059 above the predicted maximum value of 0.501 for *S. lessoniana*.

Neethiselvan and Venkataramani (2002) found a slightly lower value of exploitation rate (0.53) for *Doryteuthis sibogae* from Tuticurin waters whereas Karnik et al., (2003) also estimated a very close value of 0.57 for *L. duvauceli* from Mumbai waters. In both instance a slightly higher exploitation was observed and a reduction of fishing effort was recommended. Further size selectivity of trammel net for oval squid *S. lessoniana* in Tateyama Bay, Chiba prefecture was studied by Akiyama et al. in 2004. Akiyama et al., (2004) further studied the capture characteristics of a trammel net for oval squid *S. lessoniana* in Tateyama Bay, Chiba prefecture.

In the present study, the implication is that the stock is over exploited to a small degree. Thus, the fishing pressure on the stock has to be reduced. More yields could be obtained by a reasonable increase in size at first capture without necessarily leading to over exploitation.

Length weight relationship

The values of 'a' and 'b' differ not only in different species but in the same species depending on sex, maturity stage, feeding intensity etc. according to Hile (1936) and Martin (1949) the value of exponent 'b' usually range between 2.5 and 4.0. The reasons for this variation are said to be due to seasonal fluctuations in environmental parameters, physiological conditions of the fish at the time of collection, sex, gonadal development and nutritive conditions of the environment of the fishes (Froese 2006).

The length weight relationship parameters estimated for this species by previous studies expressed 'a' = 0.0005 and 'b' = 2.255 (Mhitu et al. 2001). The 'b' value obtained for *S. lessoniana* in the present study is almost consistent with the recorded value for this species. The growth pattern also remains the same as that of previous studies.

Comparison of the relationship between mantle length - ML (mm) and total weight - TW (g) in different regions of the Mediterranean and eastern Atlantic, as well as comparison of different years indicated an allometric length-weight relationship which is positive in males ($b>3$) and negative in females ($b<3$) (Ragonese and Jereb 1992; Gonzalez et al. 1992).

Length – weight relationship and morphometric study for squids from Mumbai waters, west coast of India was studied by Karnik and Chakraborty (2001). Chojnacki (1972) described the length – weight relationship for squids *Illex illecebrosus* and *Loligo pealei* from Georges Bank. It was observed that the 'b' values obtained for these species exhibit negative allometry with high correlation coefficient value. This result is in consistent with the reported values for 'b' in the present study. In a study on *Illex coindetii* in Galician waters, Gonzalez et al. (1992) reported mature males had a greater body weight at the same length than the rest of the animals and the regression coefficient was significantly higher than '3' and mature females showed a negative allometry. This result slightly differs from the present study in that negative allometry was observed in all cases, i.e. male, female and indeterminate. Some of the earlier results on length-weight relationship for squids in world waters are summarized in Table 10. Deviation in growth pattern i.e. allometric growth, in the present study could be attributed to variations in ecology of the geographical locations, food availability and different environmental conditions.

The present study reveals important parameters which are useful in understanding the growth pattern of this species that would definitely lead to a successful management and information for successful culture of *S. lesoniana* in Sri Lankan waters.

Table 10. The parameters of length-weight relationship of squids from different regions of the world (ML – Mantle Length; TL – Total Length; Wt – Weight)

Species	Place	Type of relation ship	Sex	a	b	Author
Illex illecebrosus	Georges bank.	ML-Wt	M+F	0.2192	1.782	Chojnacki (1972)
Loligo pealei	Georges bank	Ml-Wt	M+F	0.5144	2.056	Chojnacki (1972)
Sepia officinalis (Linnaeus, 1758)	Baltic Sea	ML-Wt	M+F	0.2204	2.773	Manfrin Piccinetti and Giovanardi 1984
Loligo vulgaris	Gulf of Guinea	TL-Wt	M+F	0.4703	2.788	Flamigni and Giovanardi (1984)
			M+F	0.113	2.511	Marano (ed.) (1993)
			M	0.008	2.3501	Krstulović Šifner S (2000)
Eledone cirrhosa (Lamarck, 1798)	Adriatic Sea	ML-Wt	M+F	0.394	2.713	Marano (ed.) (1993)
Eledone moschata (Lamarck, 1798)	Atlantic	ML-Wt	M+F	0.858	2.389	Marano (ed.) (1993)
Illex coindetii	Galician waters	ML-Wt	M	1.496×10^{-5}	3.163	Gonzalez *et al.* (1992)
			F	3.901×10^{-5}	2.910	Gonzalez *et al.* (1992)
Sepioteuthis lessoniana	Jaffna lagoon	ML-Wt	M	0.20	2.477	Sivashanthini *et al.* 2009
			F	0.229	2.4347	Sivashanthini *et al.* 2009

Reproduction

Some females had bunches of spermatophores on both sides of the mantle wall at the base of the gill near the opening of the oviduct suggesting that the fertilization in this species occurs at the buccal funnel region. Sometimes more than two bunches of spermatophores were observed indicating the possibility of females mating more than once. Egg clusters of *S. lessoniana* were frequently found attached to hard substrate from August to January near the coasts further confirms the spawning period.

Fecundity of *S. lessoniana* found to be lesser than that of *S. pharaonis* for example, number of ova in 14 cm ML *S. dollfusi* and *S. lessoniana* was 730 (Gabr *et al.* 1998) and 700, respectively. Fecundity of *S. pharaonis* ranged between 517 and 1525 ova for females of 11 – 24 cm ML (Gabr *et al.* 1998) whereas for *S. lessoniana* ranged between 20 and 793 for females of 7 – 26 cm ML. Fecundity for *S. lessoniana* in the Zanzibar coastal waters ranged from 180 to 1180 eggs for individuals of size range 14.0 24.9 cm ML (Mhitu *et al.* 2001) which is higher than the present value. The variation in fecundity for *S. lessoniana* may have been attributed due to varying environmental factors and food availability in different habitats.

The weak correlation between fecundity and mantle length may have been resulted as some females of similar size have already been spawned different number of eggs. Therefore all these individuals appeared to be in spawning condition, and it is an evidence of continuous egg production throughout the adult life confirming the multiple spawning. A similar result was also observed in *S. lessoniana* and *S. australis* of Australian waters by Peel (2001). Multiple spawning strategy can also be explained by the fact that large eggs in the ovary causing the oviduct volume to be insufficient to accommodate all eggs. Therefore, number of egg masses must be spawned in several batches (Rocha *et al.* 2001).

Maturation in female *S. lessoniana* individuals was a size-related process, because weight of ovary, nidamental gland, and oviducal gland were all correlated highly with mantle length. Maturation in male *S. lessoniana* individuals was also a size-related process, because testis weight was correlated highly with mantle length.

Finally, it can be concluded that squid *S. lessoniana* exhibits reproductive pattern of spawning more than once, group-synchronous ovulation and reproductive strategy of intermittent terminal spawning. Peak or intense spawning of this squid in the Northern coast is in March, August and October to November. In a squid population an exploited stock can be renewed through recruitment. If overexploitation occurs, matured squids could be reduced and subsequently reproductive capacity of the population diminished. Such situation can be managed by imposing restrictions on mesh sizes of the gears used to catch squids. Further, breeding females should be protected during the peak spawning period in order to maintain sustainability. It may also be protected by imposing size restriction during the specified spawning months. Findings of the present study would definitely lead to formulate a management strategy and ensure a long term sustainability of *S. lessoniana* in the Northern coast.

Lipid analysis

Large differences in the levels of lipid have been observed among fish of the same size in the collection. The reasons for such variation may be difficult to resolve, since it is not possible to know the history of individuals collected in the field. However, tracing the variations in lipid in relation to gonadal cycles is quite meaningful and is of use in understanding the function of lipid storage in squids. The initial hypothesis was that stored lipid would be used in reproduction, based on Roberts' (1979) observations. Lipid and gonad cycles are highly correlated. The present study clearly showed that the energy for gonadal growth is probably derived from lipid deposits. It was apparent from the present study that lipid reserves are used for the maturation of additional ova in multiple spawners.

Further the present study provides preliminary ideas for future study in terms of other components of lipids i.e. phospholipids, triglycerides and cholesterol. Studies on seasonal fat deposition and reproductive cycles, categorized by size and sex, would be useful in evaluating the hypothesis. The present study will provide good information for future culture trials of *Sepioteuthis* sp. Incorporation of lipid at the optimum level in the diet will be of help in improving the performance of broodstock through successful maturation.

vi) Conclusions

Three species of squids such as *Sepioteuthis lessoniana, Loligo duvauceli* and *Euprymna berryi* included under two families are found in northern coast of Sri Lanka among them the most abundant species available throughout the year is *S. lessoniana*.

Length frequency analysis shows that the exploitation rate at the northern coastal waters is 0.56 which is higher than the predicted exploitation rate of 0.501. It could be mentioned that the stock is slightly overexploited. Thus, the fishing pressure on the stock has to be reduced. More capture should be prohibited by a reasonable decrease in the effort or by modifying the mesh size of the net used to capture *S. lessoniana* species.

Regression analysis of length weight relationship shows that the squid grows negative allometrically in all instance, i.e. in male, female and immature.

The squid *S. lessoniana* exhibits a group-synchronous reproductive pattern and intermittent terminal spawning. Peak or intense spawning of this squid in the Northern coast is in March, August and October to November. In a squid population an exploited stock can be renewed through recruitment. If overexploitation occurs, matured squids could be reduced and subsequently reproductive capacity of the population diminished. Such situation can be managed by imposing restrictions on mesh sizes of the gears used to catch squids. Further, breeding females should be protected during the peak spawning period in order to maintain sustainability. It may also be protected by imposing size restriction during specified spawning months.

Findings of the present study would definitely lead to formulate a management strategy and ensure a long term sustainability of *S. lessoniana* in the Northern coast.

vii) References

Akiyama, S., Kaihara, S. and T. Arimoto., 2004. Capture characteristics of a trammel net for oval squid *Sepioteuthis lessoniana* in Tateyama bay, Chiba prefecture. Bulletin of the Japanese Society of Scientific Fisheries, 70(6), pp. 865-871.

Amarasinghe, U. S, and S. S. De Silva., 1992. Population dynamics of *Oreochromis mossambicus* and *O. niloticus* (Cichlidae) in two reservoirs of Sri Lanka. *Asian Fisheries Science*, 5, pp. 37-61.

Amarasinghe, U.S., 2002. The Fishery and Population Dynamics of *Oreochromis mossambicus* and *Oreochromis niloticus* (Osteichthyes, Cichlidae) in a Shallow Irrigation Reservoir in Sri Lanka. *Asian Fisheries Science*, 15(1), 7-20.

Anonymous., 2006. The state of world fisheries and aquaculture. FAO Rome, Italy.

Anonymous., 2007. Sri Lanka fisheries yearbook. NARA, Colombo, Sri Lanka.

Anonymous., 2008. The state of world fisheries and aquaculture. FAO Rome, Italy.

AOAC 1995. Official Methods of Analysis, 16th Edition, AOAC International, Gaithersburg, MD.

Bal, D. V. and K. V. Rao., 1984. Marine Fisheries. (New Delhi: Tata McGraw Hill Publishing company. pp. 470.

Balgos M. C. and D. Pauly., 1998. Age and growth of the squid *Sepioteuthis lessoniana* in N. W. Luson, Philippines. *South African Journal of Marine Science*. 20, pp. 449-452.

Beverton, R. J. H. and S. J. Holt. 1959. A review of the life spans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics, 142-180. In: G. E. W. Wolstenholme and M. O'Connor (eds), Colloquia on aging, Vol. 5. The Lifespan of Animals, CIBA Foundation, London, Churchill, Vol.5.

Chakraborty, S. K., et al 1997. Growth, mortality and yield-per-recruit of bearded croaker *Johnius dussumieri* (Val.) from Mumbai waters. *Indian Journal of fisheries*, 44 (1), pp. 45-49.

Chitravadivelu, K 1987, 'Observations on the biology of three siganids *Siganus lineatus*, *Siganus javus* and *Siganus canaliculatus* from waters around Jaffna', *Vingnanam Journal of Science*, vol. 2, pp. 1-13.

Chojnacki, F., 1972. Length – weight relationship for squids *Illex illecebrosus* Le Sueur and *Loligo paelei* (Le Sueur). *Acta Ichthyologica et piscatorial*, Vol. II, Fasc.2. 99-103.

De Bruin, G. H. P., B. C. Russell and A. Bogusch, 1995. FAO Species Identification Field Guide for Fishery Purposes. The Marine Fishery Resources of Sri Lanka. FAO, Rome, Italy, pp. 400.

FAO. (2003) Fisheries Global Information System (FIGIS). World Wide Web electronic database (http://www.fao.org/fi/figis/index.jsp) November 2003.

Flamigni, C, and O. Giovanardi., 1984. Biological data collected during the Pipeta expeditions, on the squid *Loligo vulgaris* Lam. FAO *Fishery Report*, 290, pp. 143-146.

Froese, R., 2006. Cube law, condition factor and weight-length relationships: History, meta analysis and recommendations. *Journal of Applied Ichthyology*, 22, pp. 241-253.

Gabr, H. R., R. T. Hanlon., M. H. Hanafy and S.G. El-Etreby., 1998. Maturation, fecundity and seasonality of reproduction of two commercially valuable cuttlefish. *Sepia pharaonis* and *Sepia dollfusi* in the Suez Canal. *Fisheries Research*, 36, pp. 99-115.

Gayanilo, F.C. Jr., and Pauly, D. (Eds.)., 1997. FAO-ICLARM stock assessment tools (FiSAT). Reference manual. *FAO Computerized Information Series (Fisheries)*. No. 8, FAO Fisheries technical Paper, 384/1, FAO, Rome, pp. 262.

Gonzalez, A.F., G.C. Bernardino and A. Guerra, 1992. Age and growth of the short-finned squid *Illex coindetii* in Galician waters (NW Spain) based on statolith analysis. ICES. *Journal of Marine Sciences*, 53, pp. 802-810.

Gunderson, D. R. 1997. Trade off between reproductive effort and adult survival in oviparous and viviparous fishes. *Canadian Journal of Fisheries and Aquatic Science*, 54(5), pp. 990-998..

Hendrickson, L.C., 2004. Population biology of northern shortfin squid (*Illex illecebrosus*) in the northwest Atlantic ocean and initial documentation of a spawning siite in the Mid-Atlantic Bight (USA). ICES J. Marine Sci., 61: 252-266.

Hile, R., 1936. Age and growth of the cisco, *Leucichthys ardeti* (Le Sueur), in the lakes of the North-Eastern Highlands. Wisconsin. *Bulletin of U.S. Bureau of Fisheries*, 48, pp. 211-317.

Jayaprakash, A., 2001. Length weight relationship and relative condition in *Cynoglossus macrostomus* Norman and *C. arel* (Schneider). *Journal of Marrine Biological Association of India*, vol. 43, pp. 148-154.

Karnik, N. and K. Chakraborty, 2001. Length-weight relationship and morphometric study on the squid *Loligo duvauceli* (d'Orbigny) (Mollusca: Cephalopoda) off Mumbai (Bombay) waters, West Coast of India. *Indian Journal of Marine Sciences*, 30, pp. 261-263.

Karnik, N. S., Chakraborty, S. K., Jaiswar, A. K., Swamy, R. P., Rajaprasad, R., Boomireddy, S. and A. F. Rizvi. 2003. Growth and mortality if Indian squid, Loligo duvauceli (Mollusca/ Cephalopoda/ Teuthoidea) from Mumbai waters, India. Indian Journal of Marine Sciences, 32(1): 67-70.

Krstulović Šifner, S., 2000. Prilog poznavanju biologije i ekologije lignje, *Loligo vulgaris* (Lamarck, 1798) u Jadranu. Master Thesis, Sveučilište u Zagrebu, pp: 98.

Manfrin Piccinetti, G, and O. Giovanardi., 1984. Donnees sur la biologie de *Sepia officinalis* L. dans l'Adriatique obtenues lors de expeditions pipeta. FAO Fishery Report, 290, pp. 135-138.

Marano, G., 1993. Valutazione delle risorse demersali dell-Adriatico meridionale dal promotorio del Gargano al capo d'Otranto: Relazione finale triennio 90-93. Min. Mar. Mer., Roma.

Martin, W. R., 1949. The mechanics of environmental control of body forms in fishes. University of Toronto Studies Biological Series, 70, pp. 1-91.

Meiyappan, M. M., and Srinath, M. 1989. Growth and mortality of Indian squid (*Loligo duvauceli*) off Cochin, India, in: Contribution to tropical fish stock assessment in India, edited by Venema S.C.and van Zalinge, N. P. (eds.) FAO, Rome, pp 14.

Mhitu, H., Y. Mgaya and M. Ngoile, 2001. Western Indian Ocean Marine Science Association, Zanzibar (Tanzania), and Institute of Marine Sciences, Zanzibar (Tanzania) University of Dar es Salaam. In: Growth and Reproduction of the Big Fin Squid, *Sepioteuthis lessoniana*, in the Coastal Waters Of Zanzibar, Richmond M.D. and J. Francis (Eds.). IMS/WIOMSA, Zanzibar, pp: 289-300.

Mohamed, K .S, and G. S. Rao., 1997. Seasonal growth, stock-recruitment relationship and predictive yield of the Indian squid *Loligo duvauceli* exploited off Karnataka coast. *Indian Journal of Fisheries*, 44(4), pp. 319-329.

Neethiselvan and Venkataramani., 2002. *Sepia prabahari. Indian Journal of Marine Sciences*, 31(1), pp. 45-51.

Ngoile, M. A. K., 1987. Fishery biology of the squids *Loligo forbesi* Steenstrup (Cephalopoda: Loliginidae) in Scottish waters. PhD thesis, University of Aberdeen. pp, 218.

O'Dor, R. K., Rodhouse, P. G., and Dawe, E. G., 1997. Squid recruitment in the genus *Illex*. *In* Developing and Sustaining World Fisheries Resources: the State of Science and Management: *2nd World Fisheries Congress Proceedings*, pp. 116–121. (Eds). by D. A. Hancock, D. C. Smith, A. Grant, and J. P. Beumer. CSIRO Publishing, Collingwood.

Pauly, D., 1980. A new methodology for rapidly acquiring basic information on tropical fish stocks: growth, mortality and stock-recruitment relationships, pp. 154-72 In S. B. Saila and P. Roedel (Eds.) Stock assessment for tropical small-scale fisheries. Proceedings of an International Workshop held 19-21 September 1979, Kingston, University of Rhode Island, International Center for Marine Resource Development.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks. FAO *Fisheries Technical Paper*, 234, pp. 52.

Pauly, D. 1986a. On improving operation and use of the ELEFAN programmes. Part II. Improving the estimation of L_{∞}. Fishbyte 4: 18-20

Pauly, D. 1986b. On improving operation and use of the ELEFAN programmes. Part III. Correcting length-frequency data for effects of gear selection and for incomplete recruitment. Fishbyte 4: 11-13.

Pauly, D. 1986c. On improving operation and use of the ELEFAN programmes. Part IV. Conclusions. Fishbyte 4: 14.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., and Torres, F. C. Jr, 1998. Fishing down marine food webs. *Science*, 279, pp. 860–863.

Pecl, G.T, Moltschaniwskyj, N.A., 1997. Changes in muscle structure associated with somatic growth in Idiosepius pygmaeus, a small tropical cephalopod. *London Journal of Zoology,* 242, pp. 751-764.

Powell, D. G. 1979. Estimation of mortality and growth parameters from the length frequency of a catch. Rapp.P.-v.Réun.CIEM,. 175, pp. 167-169

Ragonese, S. and P. Jereb, 1992. Length-weight relationships of *Illex coindetii* Veranv, 1839 (Mollusca: Cephalopoda) in the Sicilian Channel. *Obelia*, 28, pp. 17-24.

Roberts, D. A. 1979. Food habits as an ecological partitioning mechanism in the nearshore rockfishes (*Sebastes*) of Carmel Bay, California. MA Thesis, San Francisco State Univ., San Francisco: 74pp.

Rocha, F., Guerra, A, and Gonazalez, A. F. 2001. A review of reproductive strategies in cephalopods. *Biological reviews*, 76, 291-304.

Rodhouse, P. G., 1997. Precautionary measures for a new fishery on *Martialia hyadesi* (Cephalopoda: Ommastrephidae) in the Scotia Sea: an ecological approach. CCAMLR *Science*, 4, pp. 125–139.

Silas, E. G., Sarvesan, R., Nair, K. P., Sastri, Y. A., Sreenivasan, P. V., Meiyappan, M. M., Vidyasagar, K., Rao, K. S., Rao, B. N., 1986. Some aspects of the biology of cuttlefishes. Cephalopod bionomics, fisheries and resources of the exclusive economic zone of India. CMFRI. *Bulletin*, 7, pp. 49-70.

Sivashanthini, K., G. A. Charles, and W. S. Thulasitha., 2009. Length-weight relationship and growth pattern of *Sepioteuthis lessoniana* lesson 1830 (Cephalopoda: Teuthida) from the Jaffna Lagoon, Sri Lanka. *Journal of Biological Sciences*, 9, pp. 357-361.

Snedecor, G. W. and W. G. Cochran, 1967. Statistical Methods. 6th Edn., Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India, pp. 593.

Sparre, P., and S. C. Venama. 1992. Introduction to Tropical Fish Stock Assessment. Part I. Manual, FAO. *Fisheries Technical Paper* No. 306/1, pp. 376.

Staudinger, M.D., F. Juanes and S. Carlsn, 2009. Reconstruction of original body size and estimation of allometric relationships for the longfin inshore squid (*Loligo pealeii*) and northern shortfin squid (*Illex illecebrosus*). Fishery Bull., 107: 101-105.

Walsh, L. S., Turk, P. E., Forsythe, J. W, and Lee, P. G., 2002. Mariculture of the loliginid squid *Sepioteuthis lessoniana* through seven successive generations. *Aquaculture*, 212, pp. 245-262.

Wetherall, J. A., 1986. A new method for estimating growth and mortality parameters from length frequency data. *Fishbyte*, 4(2), pp. 12–14.

Zar, J.H., 1996. Biostatistical Analysis. 3rd Edn., Prentice Hall Inc., Englewood Cliffs, New Jersey, USA, pp 717.

viii) Problems if any, encountered during the implementation of the project

Purchasing of equipments, glasswares and chemicals took a long time and a tedious tight procedure which is not suitable for a researcher. If the NSF may think about providing certain percentage of the grant to the researcher and to purchase the items needed through NSF, it would be better and will give hands to the researcher to finish the research work as scheduled. Bringing the purchased items to Jaffna was a big problem at the early part of the study, incurred more expenditure to transport it by ship to Jaffna.

Section 4

Impact of Research results:

i) Relevance of results achieved to scientific advancement

The present investigation provides information on status of squid diversity, exploitation rate of squids in the northern coast, reproductive pattern, reproductive season, growth pattern and pattern of lipid changes of squids which are of valuable addition and documentation to the scientific knowledge for the first time in the northern region of Sri Lanka. The results provide valuable recommendations in formulating rules and regulations in order to manage squid fishery.

Method of fishing in the northern coast, feasibility status of the mesh size of the nets used to capture squids is also an interesting message to the scientific community whoever is keen in developing sustainable fisheries.

The knowledge gained by this project could also be applied in culture practices of squids to maintain sustainability.

ii) Relevance of results achieved to national/socio-economic development

The results obtained will deliver a good lesson to the national scientist in the relevant field to maintain sustainable stock. Findings in the present study could be applied in developing fishery management strategy in the study area and therefore indirectly contribute to socioeconomic development of the country.

Based on the present results the recovery measures of stock could be addressed to the grass hood level through the respective authorities such as Department of Fisheries and Aquatic Sciences, Federation, Fishermen Co-operative Society Union and Fishermen Co-operative Societies. Implementing such measures will lead to a sustainable fishery of our country, satisfy the FAO's "FISH FOR ALL" statement and improve socio economics of the country.

iii) Dissemination/application of research output

The output of the present study has already been published through different Journals and annual session proceedings by which researchers and students gain knowledge about it.

The output has been discussed several times with the officials of the Department of Fisheries and Aquatic Sciences, Federation, Fishermen Co-operative Society Union and Fishermen Co-operative Societies. Necessity to increase the mesh size of the fishing gear has been theoretically accepted. Detrimental effects of capturing small squids have also been discussed.

Section 5

Miscellaneous

i) List of major equipment acquired during the project period and their functionality

	Type or model	Quantity	Functionality
1.	Vortex mix	1	Functioning
2.	Soxlet apparatus (Soxhlet Extraction Systems – P-99036-00/ Cole parmer)	1	Functioning
3.	Deep freezer	1	Functioning

ii) List of publications/communications arising from the project and/or presentations made at seminars, workshops etc. (Please attach copies)

a. Charles, G. A. and **Kuganathan. S.** (2008). Preliminary studies on length - weight parameters of *Sepioteuthis lessoniana* (Cephalopoda:Teuthida) from the Jaffna lagoon, Sri Lanka. **Proceedings of Jaffna Science Association**. Fifteenth Annual Session (07-09 May 08), Vol 15(1): 20 (Abstract). (ISSN 1800-1289).

b. **Thevarulrajah. T and Kuganathan. S.** (2008). Preliminary studies on reproductive biology of squid *Sepioteuthis lessoniana* (Lesson, 1830). ***Proceedings of Jaffna Science Association***. Seventh Annual Session (07-09 May 08): 22 (Abstract).

c. **Kuganathan, S. and Charles, G.A.** [2008]. The squid body. pp 44. Printed by Computer World. ISBN: 978-955-9194-15-6

d. **Sivashanthini, K.,** Charles, G. A. and Thulasitha, W. S. (2009). Length-weight relationship and growth pattern of *Sepioteuthis lessoniaana* Lesson 1830 (Cephalopoda: Teuthida) from the Jaffna lagoon. Journal of Biological Sciences. Vol. 9(4): 357-361. DOI: 10.3923/jbs.2009.357.361

e. **Sivashanthini, K.,** Thulasitha, W. S. and Charles, G. A. (2010). Reproductive characteristics of *Sepioteuthis lessoniana* from the Northern coast of Sri Lanka. Journal of Fisheries and Aquatic Science, 5(1): 12-22. ISSN 1816-4927. DOI: 10.3923/jfas.2010.12.22

f. Charles, G. A. and **Sivashanthini, K.** (2011). Population Dynamics of Squid *Sepioteuthis lessoniana* (Lesson, 1830) from the Northern Coast of Sri Lanka. Journal of Fisheries and Aquatic Science, 6(1): 74-84. ISSN 1816-4927. DOI: 10.3923/jfas.2011.74.84

Preliminary Studies on Length - Weight Parameters of *Sepioteuthis lessoniana* (Cephalopoda:Teuthida) From the Jaffna Lagoon, Sri Lanka

Charles, G.A. and Kuganathan, S.

Department of Zoology, Faculty of Science, University of Jaffna

Sepioteuthis lessoniana (Lesson ,1830) known as big fin reef squid is one of the two important species of squid recorded along the costal areas in the northern part of Sri Lanka. It lies between approximately 79° 52′ E to 80° 38′ E longitude and 9° 26′ N to 9° 46′ N latitude and has an area of about 412 km^2 and depth doesn't exceed 4m. The study was conducted by collecting random samples of squids from three landing centers namely Kurunagar, Pasaiyoor and Kakkaitivu from June 2007 to December 2007. A total of 190 specimens were analyzed. The values obtained for the mean weight of female is 127 g (+ 6.5697 SE) and for male is 108g (+ 9.011SE). Two sample 't' test show that females were not significantly (P>0.05) heavier than males. Covariance analysis for length-weight relationships of male and female squids reveals that there was no significant variation between male and female squids (P>0.05). The calculated length-weight relationships of $W = 0.0165 * TL^{2.5098}$ and $W = 0.0093 * TL^{2.6387}$ obtained for males and females respectively. The exponent value, b=2.5098 for males and b=2.6387 for females, significantly different from 3 (P<0.05) reflect a negative allometric growth in both instances. The results obtained from the present study helps in establishing yield and also in converting one variable into the other as is often required during monitoring field measurements.

Preliminary Studies on Reproductive Biology of Squid *Sepioteuthis lessoniana* (Lesson, 1830)

Thevarulrajah, T. and Kuganathan, S.

Department of Zoology, Faculty of Science, University of Jaffna

The big fin reef squid *Sepioteuthis lessoniana* is a commercially important species in cephalopod fishery. The knowledge on reproductive biology of this species is essential for proper management and its conservation. The present study was carried with weekly samples collected from the Jaffna lagoon from March to November 2007 (79º 52′ E to 80º 38′ E longitude and 9º 26′ N to 9º 46′ N latitude) aims to examine some important aspects of its reproductive biology. A total of 148 squids were analyzed. A range of reproductive indices were estimated to provide information on different reproductive parameters. Fecundity was estimated by counting the number of mature and maturing ova. It varies from 90 to 676 for individuals of 9.7 to15.9 cm dorsal mantle length. The computer based linear regression statistical analysis of dorsal Mantle Length (ML) versus Ovary Weight (OW), Nidamental Gland Weight (NGW) and Oviducal gland weight (OvW) were $OW = (1.8301x10^{-7})\ ML^{6.5836}$ ($r = 0.87$, r^2 adj = 0.75, n = 71), $NGW = (3.0158x10^{-7})\ ML^{6.2778}$ ($r = 0.9$, r^2 adj = 0.87, n = 71) and $OvW = (1.2703x10^{-6})\ ML^{5.3909}$ ($r = 0.91$, r^2 adj = 0.87, n = 71) respectively. The regression equations expressed that OW, NGW and OvW were highly correlated ($P<0.05$) with the mantle length. The correlation of fecundity against dorsal mantle length is $(1.01x10^{-1})\ ML^{2.9763}$ ($r = 0.63$, r^2adj = 0.37, n = 28). The histology of ova clearly indicates the presence of transparent, striated as well as small oocytes without striation in a single ovary which varies from 0.03 mm to 6.1 mm in diameter. From the histological observations it has been inferred that this species exhibit group-synchronous ovulation pattern. It spawns more then once a year and peak spawning was observed during August and November.

Page 52 (ii) c.

(BOOK ENCLOSED)

Page 52(ii) - d

Journal of Biological Sciences 9 (4): 357-361, 2009
ISSN 1727-3048

Length-Weight Relationship and Growth Pattern of *Sepioteuthis lessoniana* Lesson 1830 (Cephalopoda:Teuthida) from the Jaffna Lagoon, Sri Lanka

K. Sivashanthini, G.A. Charles and W.S. Thulasitha
Department of Zoology, University of Jaffna, Jaffna, Sri Lanka

Abstract: In the present study, length-weight regression equations were derived for male and female *S. lessoniana* collected from the Jaffna lagoon, Sri Lanka in order to find out the regression parameters and growth pattern of this species. *Sepioteuthis lessoniana* (Lesson 1830) are one of the commercially important group of cuttlefishes and becoming an important model system for neurobiological and behavioral research. It appears to be the most adaptable species to the laboratory environment and there exist a need for detail study on length-weight relationship for this species. Such a mathematical equation enables conversion of one parameter in to another as is often required during monitoring field measurements. Regression coefficients were estimated by using the logarithms of the mantle lengths and the corresponding weights and the growth pattern of the species was also noticed. The curvilinear relationships of mantle length-weight relationships for male and female were $TW = 0.200*ML^{2.477}$ and $TW = 0.229*ML^{2.437}$, respectively. Covariance analysis for mantle length-weight relationships of males and females revealed that there is no significant difference ($p>0.05$) between male and female and hence a common formulae of $TW = 0.213*TL^{2.459}$ was derived for *S. lessoniana*. The 'b' values 2.477 and 2.4347 obtained for male and female, respectively indicate that the growth rate significantly differ from the ideal value '3' and its growth said to be negative allometry.

Key words: Length-weight relationship, big fin reef squid, *Sepioteuthis lessoniana*, allometric growth, cube law

INTRODUCTION

Sepioteuthis lessoniana (Lesson 1830) known as big fin reef squids is one of the important species of squid recorded along the coastal areas in the northern part of Sri Lanka (Varoopa and Sivashanthini, 2006). These are one of the commercially important groups of squids inhabiting the Jaffna lagoon (Fig. 1). It is also becoming an important model system for neurobiological and behavioral research (Ikeda *et al.*, 2003). *Sepioteuthis lessoniana* is classified under family Loliginidae of the order Teuthoidea (De Bruin *et al.*, 1994). In a study on diversity of commercially important species of cephalopods from the Jaffna lagoon ten species belonging to four families and seven genera were recorded (Varoopa and Sivashanthini, 2006). The recorded species are *Sepia aculeata*, *Sepia latimanus*, *Sepia pharaonis* and *Sepiella inermis* (Family: Sepiidae), *Euprymna berryi* (Family: Sepiolidae), *Loligo duvauceli* and *Sepioteuthis lessoniana* (Family: Loliginidae), *Cistopus indicus*, *Octopus aegina* and *Octopus vulgaris* (Family: Octopodidae) (Varoopa and Sivashanthini, 2006). Among the recorded species *Sepioteuthis lessoniana* is the most abundant commercially important species and therefore the present study was concentrated on *S. lessoniana*.

The Jaffna lagoon is one of the largest shallow water body of Western region located in the peninsular Northern province of Sri Lanka with an area of 412.8 km^2 and extends from the fort Hammenhill in the East to the elephant pass and extends in the West as a narrow body of water and separating the Jaffna peninsula from the main land and a few neighboring islands (Somasekaram, 1997). The Jaffna lagoon lies between 79° 52' to 80° 38' E longitude 9° 26' to 9° 46' N latitude. Length of the coast is 140 km and generally 1 to 1.5 m in depth, where there are more fishery resources and thus fishing villages are found all along the coast line (Somasundarampillai, 2002).

Squids are captured by various means; mainly caught by sirahu valai. Some fishermen use jiggers and pots to capture these species as small scale fisheries. In general they are caught incidentally along with other food fishes in trawl nets, boat seines and cast nets. During the peak season special squid jiggers with light attracters were used to catch squids and larger species of cuttlefish at night. A Y-shaped pole, long jigger consisting 5 to 6 hooks arranged in granell fashion and baited hooks are commonly used in this method. Even though, these

Corresponding Author: K. Sivashanthini, Department of Zoology, University of Jaffna, Jaffna, Sri Lanka
Tel: 00 94 21 2225925 Fax: 00 94 21 2222685

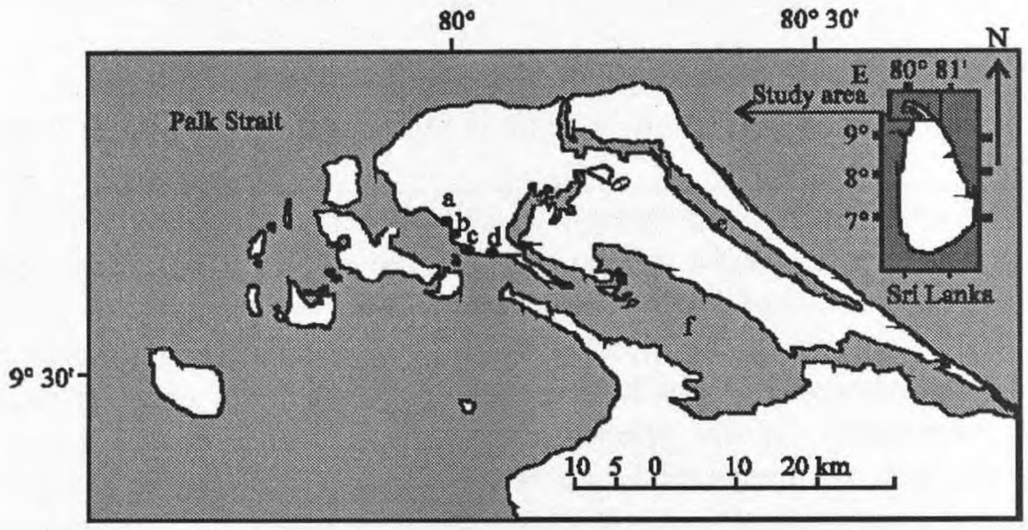


Fig. 1: Map showing the collection sites (a-d) of Jaffna lagoon, Sri Lanka. (a) Kakkaithevu, (b) Navanthrai, (c) Kurunagar, (d) Pasaioor, (e) Thondaimannar logoon and (f) Jaffna lagoon

species are available throughout the year, the major fishing season is from December to March. While, investigating it was observed that *Sepioteuthis lessoniana* and other cuttlefishes are caught in large numbers during full moon days and fog season.

The knowledge of length-weight relationship plays a vital role in the fisheries biology and population dynamics. It helps in estimating the standing stock or biomass and thereby establishing the yield by converting one variable into the other as is often done during field studies (Petrakis and Stergiou, 1995). Length-weight relationship parameters are useful to the fish farmers and farm managers in predicting the yield of the cultured fish from the equation. In the field it is easier to measure the length of fish than the weight and therefore the biomass or the stock could be computed only by measuring the length of the fishes. Compared to other loliginid squid species, *Sepioteuthis lessoniana* appears to be the most adaptable species to the laboratory environment (Hanlon *et al.*, 1991) and there exist a need for detail study on length weight relationship for on these species. Various studies on length weight relationship of squids were studied by different authors in world water (Flamigni and Giovanardi, 1984; Gonzalez *et al.*, 1992; Karnik and Chakraborty, 2001; Krstuloviæ Šifner, 2000; Manfrin Piccinetti and Giovanardi, 1984; Marano, 1993).

No studies have been performed on mantle length-weight relationship of *Sepioteuthis lessoniana* from the Jaffna lagoon, so far. Therefore, the present study is an attempt to understand information on size distribution, mantle length-weight relationship parameters, a comparison between regression lines of male and female mantle length-weight relationships and growth pattern of *S. lessoniana* from the Jaffna lagoon.

MATERIALS AND METHODS

Random weekly samples of squids were obtained from different landing centers from the commercial squid fishery from Pasaiyoor, Kurunagar, Kakkaiteevu and Navanthurai from May 2007 to April 2008. Twelve field visits were made to each landing centers in the mornings between 7 a.m. and 11 a.m. A total of 413 specimens were analyzed, among those 125 specimens were collected from Pasaiyoor, 101 specimens from Kuruagar, 77 from Kakkaiteevu and 110 from Navanthurai. Mantle Length (ML) was measured to the nearest 5 mm with the measuring board. The specimens were cleaned with tap water and plant parts or fish scales attached with suckers were removed. Then it was mopped with blotting sheet to remove the external moisture and weighed to the nearest 0.01 g on a top loading electrical balance (AND FY 300) and recorded. Measured mantle length data for all male and female *S. lessoniana* were classified in to 5 cm class interval and the mantle length frequency distribution was calculated for each length group.

According to Bagenal and Tesch (1978) and Ricker (1975), the relationship between total body weight (TW) and Mantle Length (ML) typically takes the form:

$$TW = a\ Ml^b$$

or in the liner form:

$$\text{Log TW} = \log a + b * \text{Log ML}$$

where, 'a' and 'b' are constants. The parameters 'a' (proportional constant or intercept) and 'b' (exponent) were estimated for male and female separately by using the logarithmic transformation. The regression line was computed by the method of simple least square regression analysis.

The 'b' values obtained for male and female *S. lessoniana* were tested by Students' t-test to see whether the 'b' values differ significantly from '3' or not (Zar, 1996). Students' t-test was employed by dividing the difference between 'b' and '3' by standard error of 'b'. The regression lines of male and female *S. lessoniana* were then analyzed further for significant differences by General Linear Model Analysis of Covariance (GLMANCOVA) using MINITAB (Version 14) statistical software in the computer.

RESULTS AND DISCUSSION

The size Mantle Length (ML) of *S. lessoniana* ranged from 3.8 to 25.5 cm (mean±SD = 13.73±3.98 cm). Males ranged from 5.5 to 25.5 cm ML (mean±SD = 13.89±4.51 cm) while females ranged from 3.8 to 24.8 cm ML (Mean±SD = 13.58±3.32 cm). The values for mean weight by sex were simply compared by two-sample t-test. The results show that females were larger than males but there is no significant difference (p>0.05) between males and females (Table 1). The mantle length (size) frequency distribution of male and female *S. lessoniana* individuals is shown in Fig. 2. Highest percentage of frequency (i.e., 54%) was observed for *S. lessoniana* individuals of 11-15 cm mantle length class interval.

The estimates of the regression parameters of mantle length-weight relationship for male and female, obtained by regression analysis are shown in Table 2. The equations of mantle length-weight relationship and their logarithmic transformation are given in Table 3. The 'b' values 2.477 and 2.437 obtained for male and female, respectively indicate that the fish follows the cube law, its growth is proportionally three-dimensional (n = 194, r^2 = 0.931, 95% CL a = 0.1561 to 0.2576, 95% CL b = 2.380 to 2.573 and CV = 0.00237 for males; n = 219, r^2 = 0.957, 95% CL a = 0.191 to 0.274, 95% CL b = 2.368 to 2.506 and CV = 0.00223 for females). That is, with increasing age, rate of growth in terms of weight in this squid becomes slower than that of its length. Correlation coefficients (r) 0.965 for male and 0.978 for female were found to be significant (p<0.01) in both instances indicate good correlation bet ween mantle length and weight.

The significance of variation in the estimates of 'b' for *S. lessoniana* from the expected value for the ideal fish (3.0) was tested by Students' t-test (Snedecor, 1963; Jayaprakash, 2001). Students' t-test was employed by dividing the difference between 'b' and '3' by standard error of 'b' (Zar, 1996). The results are as follows:

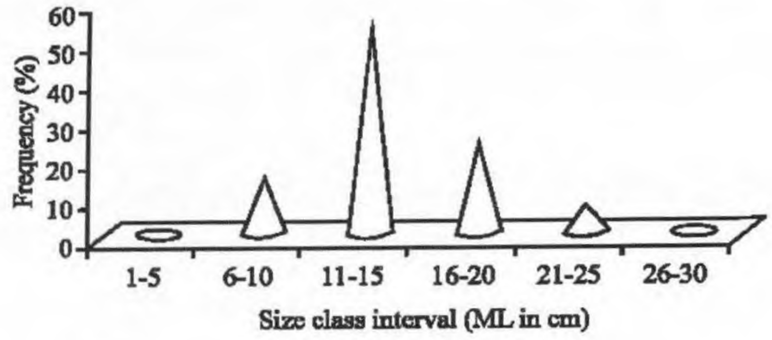


Fig. 2: Percentage frequency of size Mantle Length distribution of male and female *S. lessoniana*

Table 1: Parameters obtained from two-sample t-test for mean weight of male and female *S. lessoniana* collected from the Jaffna lagoon, Sri Lanka

Statistical parameters	Female	Male
Mean	166.10	147.33
Variance	20613.33	9058.57
Observations	194	219
Hypothesized Mean Difference	0	
df	328	
t-statistic	1.545	
P (T≤t) (one-tail)	0.062	
t-critical (one-tail)	1.65	
P (T≤t) (two-tail)	0.12	
t-critical value (two-tail)	1.97	

Table 2: Length-weight relationship parameters of *S. lessoniana* collected from Jaffna lagoon, Sri Lanka

Sex	R	N
Male	0.965	194
Female	0.978	219
Pooled	0.970	413

Table 3: Relationship between total length and weight of male, female and pooled sexes of *S. lessoniana*

Sex	Length-weight relationship	Logarithmic transformation
Male	$W = 0.200*L^{2.477}$	Log W = -0.698+2.477*LogL
Female	$W = 0.229*L^{2.437}$	Log W = -0.641+2.437*LogL
Pooled	$W = 0.213*L^{2.459}$	Log W = -0.672+2.459*LogL

Male: (2.477~3.0)/0.0488 = 10.717 Significant (computed $t_{\alpha(2),0.05,193}$>1.960)

Female: (2.437-3.0)/0.0351 = 16.039 Significant (computed $t_{\alpha(2),0.05,218}$>1.970)

Pooled: (2.459-3.0)/0.0303 = 17.854 Significant (computed $t_{\alpha(2),0.05,412}$>1.965)

The above result shows that the 'b' values of male, female and pooled *S. lessoniana* significantly differ (p<0.05) from the ideal value '3' and exhibit negative allometric growth in all instances.

The GLMANCOVA showed the slopes 'b' of males and females not to exhibit significant interaction (computed F_{412}<3.86, p>0.05). Further, comparison of

Table 4: The parameters of length-weight relationship of squids from different regions of the world

Species	Place	Type of relation ship	Sex	a	b	Author
Illex illecebrosus	Georges bank.	ML-Wt	M+F	0.2192	1.782	Chojnacki (1973)
Loligo pealei	Georges bank	Ml-Wt	M+F	0.5144	2.056	Chojnacki (1973)
Sepia officinalis (Linnaeus, 1758)	Baltic Sea	ML-Wt	M+F	0.2204	2.773	Manfrin Piccinetti and Giovanardi (1984)
Loligo vulgaris	Gulf of Guinea	TL-Wt	M+F	0.4703	2.788	Flamigni and Giovanardi (1984)
			M+F	0.113	2.511	Marano (1993)
			M	0.008	2.3501	Krstuloviæ Šifner (2000)
Eledone cirrhosa (Lamarck, 1798)	Adriatic Sea	ML-Wt	M+F	0.394	2.713	Marano (1993)
Eledone moschata (Lamarck, 1798)	Atlantic	ML-Wt	M+F	0.858	2.389	Marano (1993)
Illex coindetii	Galician waters	ML-Wt	M	1.496×10^{-5}	3.163	Gonzalez *et al.* (1992)
			F	3.901×10^{-5}	2.910	Gonzalez *et al.* (1992)

ML: Mantle Length; TL: Total Length; Wt: Weight

regression co-efficient of males and females using GLMANCOVA for the regression of log weight on log mantle length of males and females showed the 'b' values not to show significant differences ($p>0.05$). The confidence intervals of 'a' for male and female overlap with each other and therefore there is no significant differences between the intercepts, too. Hence, the following common formulae were derived for males and females:

Parabolic equation: $TW = 0.213 * ML^{2.459}$

Logarithmic equation: $\text{Log } TW = -0.672 + 2.459 * \log ML$

The values of 'a' and 'b' differ not only in different species but also in the same species depending on sex, maturity stage, feeding intensity etc. According to Hile (1936) and Martin (1949) the value of exponent 'b' usually range between 2.5 and 4.0. The reasons for this variation are said to be due to seasonal fluctuations in environmental parameters, physiological conditions of the fish at the time of collection, sex, gonadal development and nutritive conditions of the environment of the fishes (Froese, 2006).

The length weight relationship parameters estimated for this species by previous studies expressed 'a' = 0.0005 and 'b' = 2.255 (Mhitu *et al.*, 2001). The 'b' value obtained for *S. lessoniana* in the present study is slightly higher than the recorded value for this species. However, the growth pattern remains the same as that of previous studies.

Comparison of the relationship between mantle length-ML (mm) and total weight-TW (g) in different regions of the Mediterranean and Eastern Atlantic, as well as comparison of different years indicated an allometric length-weight relationship which is positive in males ($b>3$) and negative in females ($b<3$) (Ragonese and Jereb, 1992; Gonzalez *et al.*, 1992).

Length-weight relationship and morphometric study for squids from Mumbai water, West coast of India was studied by Karnik and Chakraborty (2001). Chojnacki (1973) described the length-weight relationship for squids *Illex illecebrosus* and *Loligo pealei* from Georges Bank. It was observed that the 'b' values obtained for these species exhibit negative allometry with high correlation coefficient value. This result is in consistent with the reported values for 'b' in the present study. In a study on *Illex coindetii* in Galician waters, Gonzalez *et al.* (1992) reported mature males had a greater body weight at the same length than the rest of the animals and the regression coefficient was significantly higher than 3 and mature females showed a negative allometry. This result slightly differs from the present study in that negative allometry was observed in both cases, i.e., males and females. Some of the earlier results on length-weight relationship for squids in world waters are summarized in Table 4. Deviation in growth pattern i.e., allometric growth, in the present study may be the due to variations in ecology of the geographical locations, food availability and different environmental conditions. The present study reveals important parameters which are useful in the culture systems as well as in understanding the growth pattern of this species that would definitely lead to successful management and information for successful culture of *S. lesoniana* in Sri Lankan waters.

ACKNOWLEDGMENTS

Authors are grateful to the authorities of National Science Foundation for the financial assistance (Research grant No. RG/MS/2006/01). Authorities of University of Jaffna, Sri Lanka deserve grateful thanks for the facilities during this study.

REFERENCES

Bagenal, T.E. and F.W. Tesch, 1978. Age and Growth. In: Methods for Assessment of Fish Production in Freshwater. IBP Handbook No. 3, Bagenal, T. (Ed.). Blackwell Scientific Publications, Oxford and Edinburgh, pp: 101-136.

Chojnacki, J., 1973. Length weight relationship for squids-*Illex illecebrosus* Lesueur and *Loligo paelei* (Lesueur). Acta Ichthyol. Pisca., 2: 99-103.

De Bruin, G.H.P., B.C. Russell and A. Bogusch, 1994. FAO Species Identification Field Guide for Fishery Purposes. The Marine Fishery Resources of Sri Lanka. FAO, Rome, Italy, pp: 440.

Flamigni, C. and O. Giovanardi, 1984. Biological data collected during the Pipeta expeditions, on the squid *Loligo vulgaris* Lam. FAO Fish. Rep., 290: 143-146.

Froese, R., 2006. Cube law, condition factor and weight-length relationships: History, meta analysis and recommendations. J Applied Ichthyol., 22: 241-253.

Gonzalez, A.F., G.C. Bernardino and A. Guerra, 1992. Age and growth of the short-finned squid *Illex coindetii* in Galician waters (NW Spain) based on statolith analysis. ICES J. Mar. Sci., 53: 802-810.

Hanlon, R.T., P.E. Turk and P.G. Lee, 1991. Squid and cuttlefish mariculture: An updated perspective. J. Ceph. Biol., 2: 31-40.

Hile, R., 1936. Age and growth of the cisco, *Leucichthys ardeti* (Le Sueur), in the lakes of the north-eastern highlands. Wisconsin. Bull. US. Bur. Fish., 48: 211-317.

Ikeda, Y., I. Sakurazawa, Y. Sakurai and G. Matsumoto, 2003. Initial trials on squid rearing, maintenance and experimentation at the Brain Science Institute of RIKEN. Suisanzoshoku, 51: 391-400.

Jayaprakash, A., 2001. Length weight relationship and relative condition in *Cynoglossus macrostomus* Norman and *C. arel* (Schneider). J. Mar. Biol. Assoc. Ind., 43: 148-154.

Karnik, N. and Kr. Chakraborty, 2001. Length-weight relationship and morphometric study on the squid *Loligo duvauceli* (d'Orbigny) (Mollusca: Cephalopoda) off Mumbai (Bombay) waters, west coast of India. Ind. J. Mar. Sci., 30: 261-263.

Krstuloviæ Šifner, S., 2000. Prilog poznavanju biologije i ekologije lignje, *Loligo vulgaris* (Lamarck, 1798) u Jadranu. Master Thesis, Sveuèilište u Zagrebu. pp: 98.

Manfrin Piccinetti, G. and O. Giovanardi, 1984. Données sur la biologie de *Sepia officinalis* L. dans l'Adriatique obtenues lors de expéditions pipeta. FAO Fish. Rep., 290: 135-138.

Marano, G., 1993. Valutazione delle risorse demersali dell'Adriatico meridionale dal promotorio del Gargano al capo d'Otranto: Relazione finale triennio '90-'93. Min. Mar. Mer., Roma.

Martin, W.R., 1949. The mechanics of environmental control of body forms in fishes. Univ. Toronto Stud. Biol. 58. Publ. Ont. Fish. Res. Lab., 70: 1-91.

Mhitu, H., Y. Mgaya and M. Ngoile, 2001. Western Indian Ocean Marine Science Association, Zanzibar (Tanzania) and Institute of Marine Sciences, Zanzibar (Tanzania) University of Dar es Salaam. In: Growth and Reproduction of the Big Fin Squid, *Sepioteuthis lessoniana*, in the Coastal Waters Of Zanzibar, Richmond M.D. and J. Francis (Eds.). IMS/WIOMSA, Zanzibar, pp: 289-300.

Petrakis, G. and K.I. Stergiou, 1995. Weight-length relationships for 33 species in Greek water. Fish. Res., 21: 456-469.

Ragonese, S. and P. Jereb, 1992. Length-weight relationships of *Illex coindetii* Veranv, 1839 (Mollusca: Cephalopoda) in the Sicilian Channel. Obelia, 28: 17-24.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board. Can., 191: 1-382.

Snedecor, G.W., 1963. The Comparison of Two Groups. In: Statistical Methods. Chapter 4, The IOWA State College Press, Ames, IOWA, USA., pp: 534.

Somasekaram, T., 1997. Arjuna's Atlas of Sri Lanka. Arjuna Consulting Company Ltd., Dehiwela, Sri Lanka, pp: 220.

Somasundarampillai, A., 2002. Introduction of Sri Lanka Fisheries Exploitation and Development. Ampalam Publications, Wattala, pp: 1-2.

Varoopa, P. and K. Sivashanthini, 2006. Taxonomy and species diversity of cephalopodos (Phylum: *mollusca*) from the jaffna lagoon, Sri Lanka. Proceedings of International Symposium of Sabaragamuwa, Jul. 4-8, University of Sri Lanka, pp: 291-291.

Zar, J.H., 1996. Biostatistical Analysis. 3rd Edn., Prentice-Hall, Inc., USA., ISBN: 0-13-084542-6, pp: 662.

Journal of Fisheries and Aquatic Science 5 (1): 12-22, 2010
ISSN 1816-4927

Reproductive Characteristics of Squid *Sepioteuthis lessoniana* (Lesson, 1830) from the Northern Coast of Sri Lanka

K. Sivashanthini, W.S. Thulasitha and G.A. Charles
Department of Zoology, University of Jaffna, Jaffna, Sri Lanka

Abstract: The present study was carried out to understand some reproductive characteristics such as spawning season, variation in maturation indices with months, fecundity, sperm count and relationships between various measurements and mantle length of tropical *Sepioteuthis lessoniana* from the Northern coastal waters of Sri Lanka. A total of 797 specimens of *S. lessoniana* (404 males and 394 females) were collected from commercial catches of squid fishery and analyzed. The dorsal mantle length of male *S. lessoniana* ranged from 4 to 26 cm while females ranged from 3.8 to 24.3 cm. According to the morphological appearance of gonads males were categorized into immature, maturing and fully mature whereas females were categorized into immature, maturing and spawning. High occurrence of spawning stage in squids was observed in August, October, November and March. Fecundity increased exponentially with mantle length from 20 (7 cm mantle length) to 793 (26 cm mantle length). The least square linear regression analysis expressed that there are positive, significant ($p<0.001$) relationships for ovary weight, nidamental gland weight and oviducal gland weight with the mantle length in females and for total weight, testis weight and spermatophoric complex weight with mantle length in males. It was concluded that *S. lessoniana* spawns more than once, exhibits group-synchronous ovulation and intermittent terminal spawning. Peak or intense spawning of this squid in Northern coast of Sri Lanka is during March, August and October to November.

Key words: Fecundity, spawning, group-synchronous, *Sepioteuthis lessoniana*, nidamental gland weight

INTRODUCTION

Sepioteuthis lessoniana is a neritic species most widely distributed throughout the Indo-west pacific (Lee *et al.*, 1994) and it has a major commercial value in Northwestern, Northern and Northeastern waters around Sri Lanka. Squids are important components of food webs in most marine ecosystems, too (O'Dor *et al.*, 2005; Clarke, 1996). They are organism with a fast metabolic rate and growth and they play an important role in the transfer of energy to higher trophic levels (Jackson and Domeier, 2003).

The squid giant axon is a valuable preparation in biomedical research. Squids have been used as research models not only for neuroscience, but also for physiology (cardiac, circulatory, sensory and muscle), immunology, molecular biochemistry, nutritional biochemistry, oncology, aging and ethology (Gilbert *et al.*, 1990). Squids also have commercial importance since they are eaten regularly in many regions of the world, especially in the orient and Southern Europe (Asian Development Bank/Infofish, 1991).

Corresponding Author: K. Sivashanthini, Department of Zoology, University of Jaffna, Jaffna, Sri Lanka Tel: 00 94 21 2225925 Fax: 00 94 21 2222685

The knowledge on reproductive biology of this species is essential for proper management and its conservation. Ovulation may be distinguished as synchronous, group-synchronous and asynchronous ovulation according to oocyte formation and development in cephalopods (Rocha *et al.*, 2001).

Mode of reproduction in fishes can be expressed as two major types, iteroparous and semelparous. Iteroparous organisms have more than one reproductive event in their life-time whereas, semelparous organisms reproduce only once (Rocha *et al.*, 2001; Stearns, 1992). The present study attempts to identify the mode of reproduction in *S. lessoniana* from the Northern waters of Sri Lanka.

Little is known about the spawning seasonality of tropical and subtropical squid and cuttlefish (Jackson and Moltschaniwskyj, 2001). In several loliginids mature females and eggs are found year-round. In the Gulf of Mexico *Loligo peali* spawns throughout the year. *Sepioteuthis sepioidea* in the Western tropical Atlantic and *S. lessoniana* in the Western Pacific also spawn year-around (Costa and Fernandes, 1993). However, the greater abundance of recruits during certain periods of the year suggests that some seasonality exists.

The present study was carried out to understand some reproductive characteristics such as spawning season, variation in maturation indices with months, fecundity, sperm count and relationships between various measurements and mantle length of tropical *S. lessoniana* from the Northern coastal waters of Sri Lanka. Such information provides detailed understanding about *S. lessoniana* and knowledge to formulate management measurements in the squid fishery in order to maintain sustainable squid fishery in Sri Lanka.

MATERIALS AND METHODS

Random samples of *Sepioteuthis lessoniana* were collected weekly from Kurunagar, Ponnalai, Navanthurai and Point pedro coast (Fig. 1) from June 2007 to May 2008. Jaffna lagoon is one of the largest shallow water body located in the Northern Province of Sri Lanka with an area of 412.8 km^2 (Somasekaram, 1997). It is situated between 79° 52' E to 80° 38' E longitude and 9° 26' N to 9° 46' N latitudes (Somasundarampillai, 2002).

In Jaffna, fishermen use various techniques to capture squids. Mainly they capture squids by Sirahu valai. Being a small scale fishery, some fishermen use jiggers and pots to capture squids. Usually, they are caught incidentally along with other food fishes in trawl nets, boat seines and cast nets (Sivashanthini *et al.*, 2009).

A total number of 797 squids, covering a size range of 2.1 to 26.0 cm dorsal mantle length were analyzed. Measurements of dorsal Mantle Length (ML) and total Body Weight (BW) were recorded. Length measurements were measured to the nearest cm using measuring board and vernier caliper and weight was measured to the nearest 0.001 g by using top loading electronic balance (AND FY 300). Sexes were confirmed after dissecting the squid specimens; for each specimen maturity stage was categorized by macroscopic observation of the gonads.

Various morphometric measurements were taken for males and females. For males, the Weight of Testis (TEW) and Spermatophoric Complex Weight (SCW) were measured; then the spermatophoric complex was dissected to separate the spermatophores and the total numbers of macroscopic spermatophores were counted. Various reproductive indices such as the Gonado Somatic Index (GSI), Spermatophoric Complex Index (SCI) and Maturity Coefficient (MCO) for males were computed using the following equations (Durward *et al.*, 1979; Lipinski, 1979; Juanico, 1983; Gabr *et al.*, 1998):

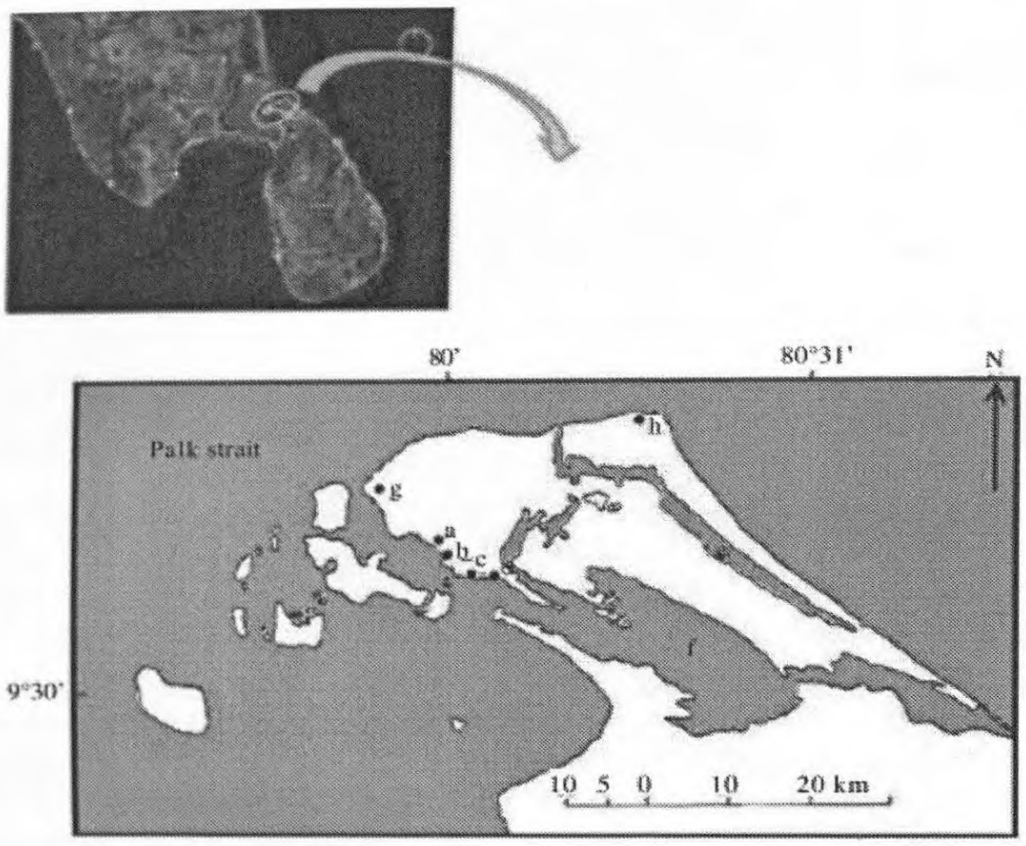


Fig. 1: Sampling sites (b, c, g and h) of *Sepioteuthis lessoniana* form the Northern coast of Sri Lanka; a: Kakkaithevu, b: Navanthurai, c: Kurunagar, d: Pasaioor, e: Thodaimannar lagoon, f: Jaffna lagoon, g: Ponnalai and h: Point pedro

$$\text{Gonado Somatic Index (GSI)} = \frac{\text{TEW}}{\text{BW}} \times 100$$

$$\text{Spermatophoric Complex Index (SCI)} = \frac{\text{SCW}}{\text{BW}} \times 100$$

$$\text{Maturity COefficient (MCO)} = \frac{\text{TEW} + \text{SCW}}{\text{BW}} \times 100$$

where, BW is the body weight. The spermatophoric complex includes the spermatophoric organ, vas deference, spermatophoric sac or Needam's sac, sperm duct and penis.

For females, the total Weight of Ovary (OW), Weight of OVviducal gland (OVW), Nidamental Gland Weight (NGW) and colour of accessory nidamental gland were recorded. Various reproductive indices such as the Gonado Somatic Index (GSI), Nidamental Gland Index (NGI) and Maturity COefficient (MCO) for females were computed using the following equations (Durward *et al*., 1979; Lipinski, 1979; Juanico, 1983; Gabr *et al*., 1998):

$$\text{Gonado Somatic Index (GSI)} = \frac{\text{OW}}{\text{BW}} \times 100$$

$$\text{Nidamental Gland Index (NGI)} = \frac{\text{NGW}}{\text{BW}} \times 100$$

$$\text{Maturity COefficient (MCO)} = \frac{OW + OVW}{BW} \times 100$$

where, BW is the body weight.

The percentage occurrence of various maturity stages of ovaries in different months was computed by pooling the data for one year and represented graphically. Maturity stages recognized macroscopically were categorized in to different stages.

Fecundity was defined as the total number of maturing ova (with striation) and mature ova (large smooth ova) in the ovary and the number of ova in the oviducal glands, proximal and distal gland (Gabr *et al.*, 1998). Collected eggs were preserved in Gilson's fluid for at least 48 h in order to count the total number of eggs, the fecundity. Fecundity was counted in 116 females ranged from 7.0 to 26.0 cm mantle length. In the ovaries, there were different stages of ova; striation was used to group ova into small (without striation and milky in appearance), maturing (with striation) or mature (large and smooth-transparent) (Gabr *et al.*, 1998).

Length at maturity were analyzed for squids collected from July to November to reduce the possibility of classifying resting, mature fish as immature. Length at maturity was based on 165 females and 159 males (9.7 to 26.0 cm TL). The maturity data were grouped into 2.5 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 and by obtaining the length at 50% maturity (L_{50}).

For male squids, relationships of total Body Weight (BW)-Mantle Length (ML), Weight of TEstis (TEW)-Mantle Length (ML), Spermatophoric Complex Weight (SCW)-Mantle Length (ML) and Total Sperm Count (TSC)-Mantle Length (ML) were fitted by the logarithmic transformation of Log Y = log a + b log X (Bagenal and Tesch, 1978), where, Y is the dependant variable and X is the independent variable.

Similarly for females, relationships of total Body Weight (BW)-Mantle Length (ML), the total Weight of Ovary (OW)-Mantle Length (ML), Weight of OViducal gland (OVW)-Mantle Length (ML), Nidamental Gland Weight (NGW)-Mantle Length (ML), Fecundity (F)-Mantle Length (ML), Fecundity (F)-total Body Weight (BW) and the total Weight of Ovary (OW)-total Body Weight (BW) were fitted by the least square regression analysis.

Sex ratio was determined from the number of specimens of each sex sampled every month to test the significant deviations from an expected 1:1 sex ratio for all male and female fishes. The sex ratio values obtained every month were subjected to chi-square test (Sokal and Rohlf, 1981) employing the formula:

$$\chi^2 = \sum [(o-e)^2/e]$$

where, o is observed number and e is expected number.

RESULTS

A total of 797 specimens of *S. lessoniana* (404 males and 394 females) were collected from commercial catches of squid fishery from the Northern coast of Sri Lanka. The size (dorsal mantle length, ML) of male *S. lessoniana* ranged from 4 to 26 cm ML while females ranged from 3.8 to 24.3 cm ML. From the collected data it was apparent that males are heavier than the females. Eleven unsexed specimens which range from 2.1-4.3 cm ML were also collected.

Unlike most fin fishes, external sex differentiation is possible in *S. lessoniana*. In fresh female specimens, whitish colour mass (Nidamental gland) and pale colored ovary were able to observe through the ventral side of the transparent mantle. In fresh male *S. lessoniana* chromatophore arrangements create transverse bars in the dorsal side of the mantle and fourth left arm is hectocotylized. External appearance (dorsal view) of fresh female and male *S. lessoniana* is shown in Fig. 2a and b. In comparison, matured males were narrow and longer than matured females. Dissection through mid ventral axis clearly defined the sexes. Interestingly some females had bunches of spermatophores at the buccal funnel region and a photograph of it is shown in Fig. 3.

According to the morphological appearance of gonads males were categorized into immature, maturing and fully mature as described in Table 1 while females were categorized into immature, maturing and spawning as described in Table 2 and Fig 4a and b. In freshly dissected ovaries the matured eggs were observed in the peripheral region whereas immature and maturing eggs were observed as the central mass. Extrusion of matured eggs to the exterior through the oviduct was also observed in females and it is shown in Fig. 4c.

Monthly variation of various maturity indices of males and females are shown in Fig. 5 and 6. For males, the MCO values varied from 1.09 to 4.02 with an average of 1.87±0.21; GSI values varied from 0.65 to 1.5 with an average of 1.02±0.08; SCI values varied from 0.44 to 3.36 with an average of 1.00±0.23. For females, the MCO values varied from 7.70 to 11.70 with an average of 9.92±0.37; GSI values varied from 3.44 to 7.11 with an average of 5.39±0.31; NGI values varied from 1.52 to 4.55 with an average of 3.49±0.27.

Monthly distribution of maturity stages of ovaries of *S. lessoniana* is shown in Fig. 7. In female *S. lessoniana*, spawning stage was recorded throughout the year except in May (Fig. 8). High percentages i.e., 65 and 60% of immature squids recorded in September and May, respectively. Lowest percentage (20%) of immature squids was recorded in July. Maturing squids were recorded throughout the year except in August and September. High

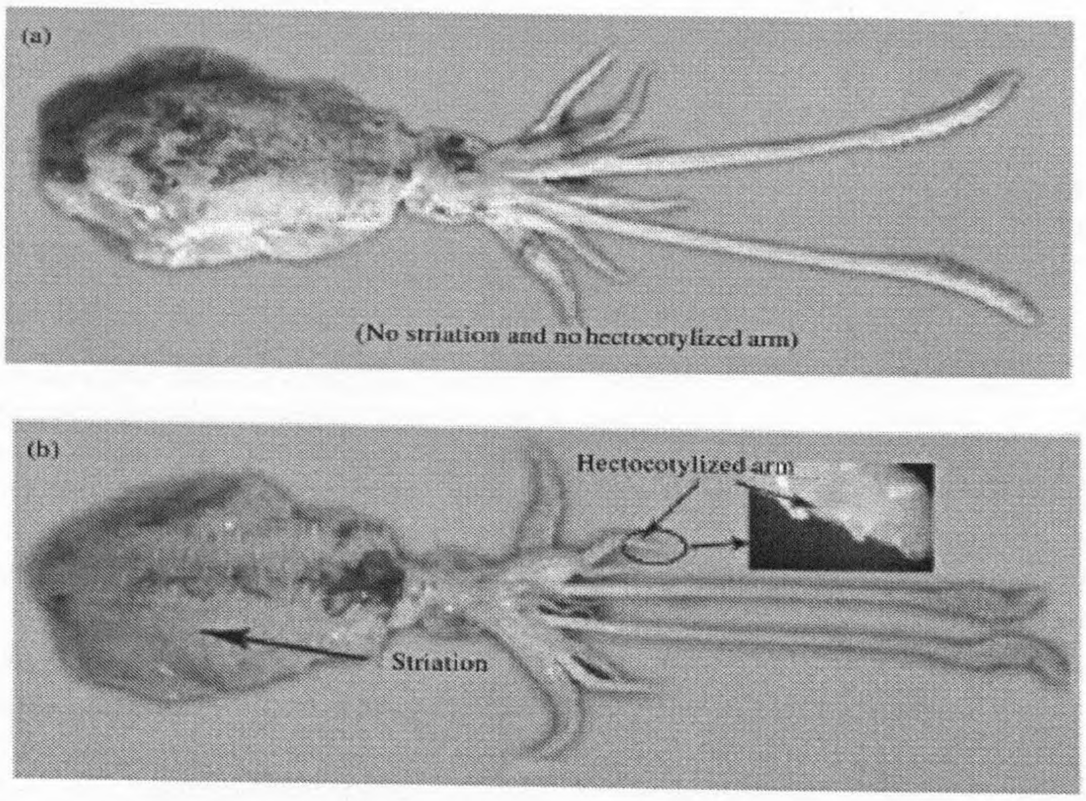


Fig. 2: (a) External appearance of fresh female *S. lessoniana*. (b) External appearance of fresh male *S. lessoniana*

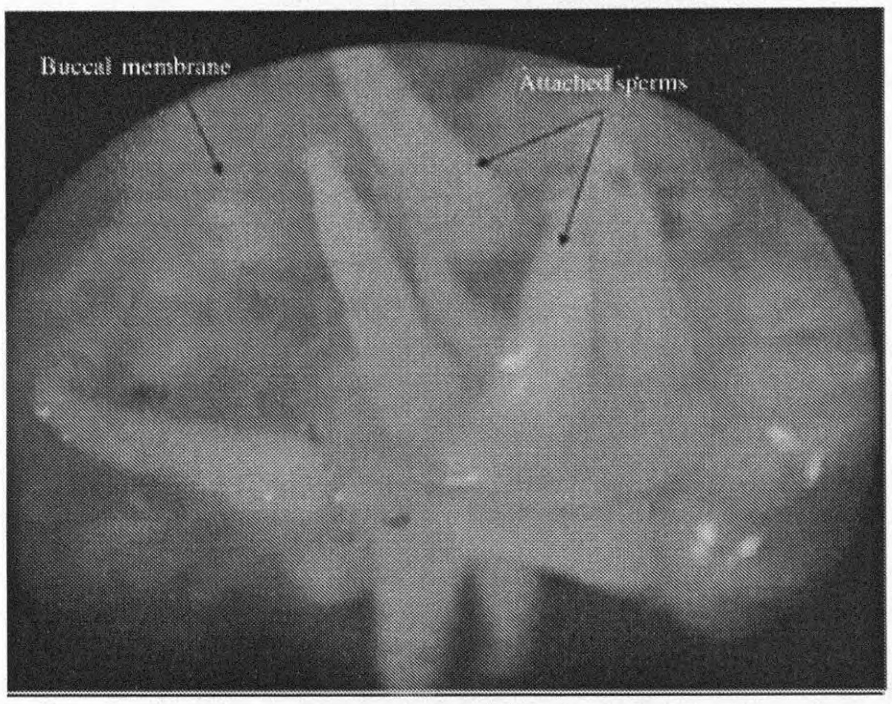


Fig. 3: Sperms attached to the female's buccal membrane

Table 1: Male maturation scale in *Sepioteuthis lessoniana*

Maturity stage	Morphological characters
Immature	Small, thin, transparent testis; very small, transparent spermatophoric complex; Needham's sac without sperms.
Maturing	Testis is white and large. Spermatophoric complex and Needham's sac clearly visible. Needham's sac contains few spermatophores.
Fully mature	Needham's sac is filled with tightly packed spermatophores, which are well developed with distinct spiral filament cement body

Table 2: Female maturation scale in *Sepioteuthis lessoniana*

Maturity stage	Morphological characters
Immature	Nidamental gland (NG) thin transparent or translucent, Accessory Nidamental (ANG) gland transparent or translucent with white or light brown patches. Ovary very small, no ova apparent
Maturing	NG thicker, creamy white and clearly visible, ANG translucent with light orange patches. Ovary with small to striated eggs
Spawning	NG swollen, thick and white colour in appearance, ANG pale yellow with dark orange patches. Ovary has small ova, medium ova, large yellow reticulated ova and large smooth transparent ova. Proximal oviduct is filled with mature eggs

occurrence of spawning stage in squids was observed in August, October, November and March. This suggests that the peak spawning period of *S. lessoniana* is in August, March, October and November even though it spawns throughout the year. Presence of all three stages of macroscopic eggs in the same ovaries confirms that the spawning of *S. lessoniana* in the Northern coastal waters should be more than once and said to be asynchronous or group synchronous.

Fecundity increased exponentially with Mantle Length (ML) from 20 (7 cm) to 793 (26 cm TL) but a weak correlation was obtained with mantle length ($r = 0.59$, $p<0.01$). A weak relationship ($r = 0.59$, $p<0.01$) was also obtained for fecundity with total body weight. However a correlation ($r = 0.77$, $p<0.01$) between ovary weight and total body weight was obtained in the present study. In males, number of sperm varies from 5 to 568 for individuals of 9.8 to 24.3 cm dorsal mantle length.

Plots obtained for percentage occurrence of mature squids against mantle length class interval indicates that *S. lessoniana* male reached maturity at 15 cm mantle length, while

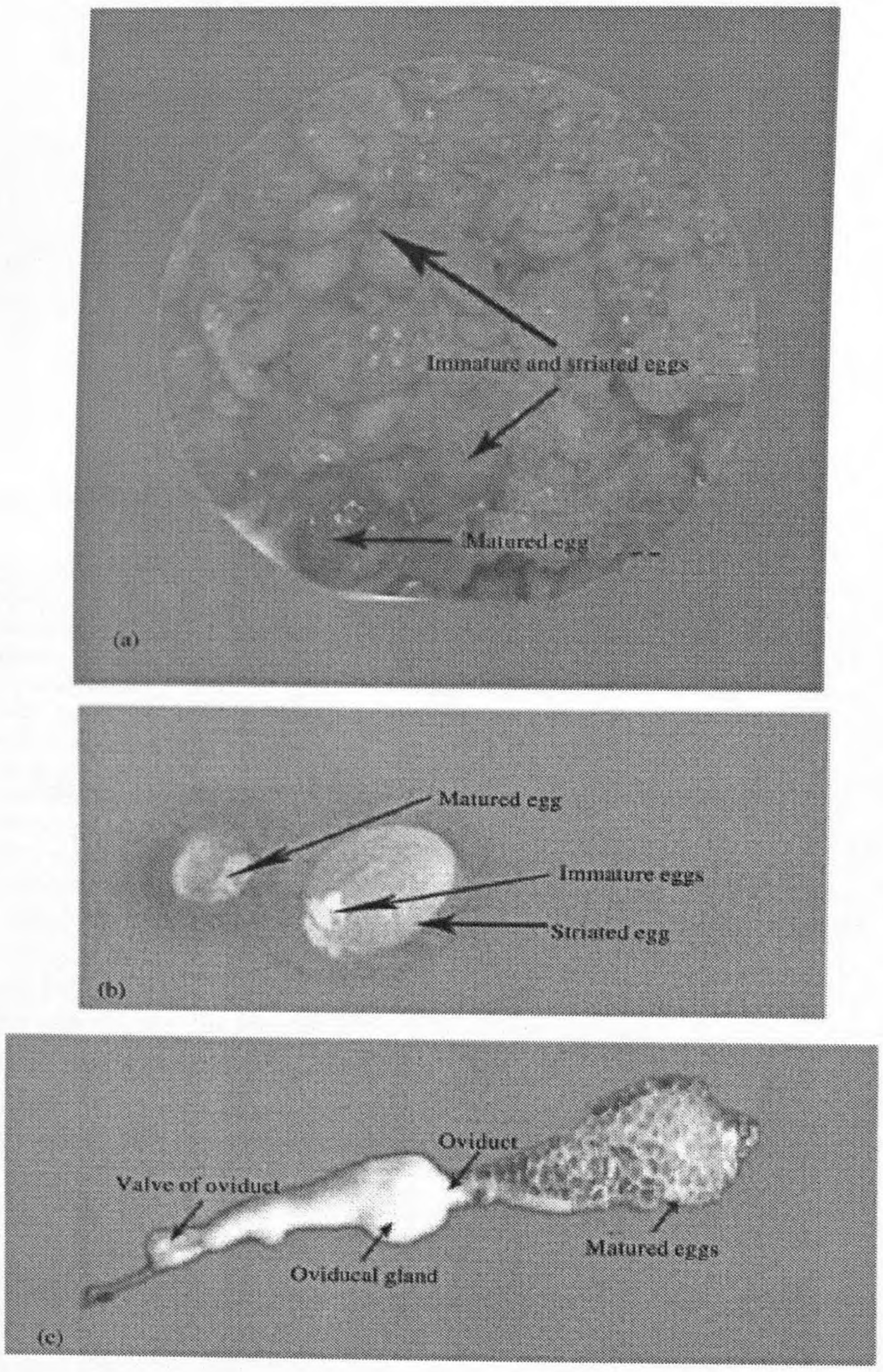


Fig. 4: (a, b) Immature, maturing and matured stages of ova in female *S. lessoniana* ovary. (c) Extrusion of matured eggs to the exterior through the oviduct in female *S. lessoniana*

female reached maturity at 17.5 cm mantle length. All males and females were matured at 20.0 cm mantle length.

The least square linear regression analysis expressed that there are highly significant ($p<0.001$) relationships for OW, NGW and OvW with the mantle length in females. That is OW, NGW and OvW proport

Similarly highly significant (p<

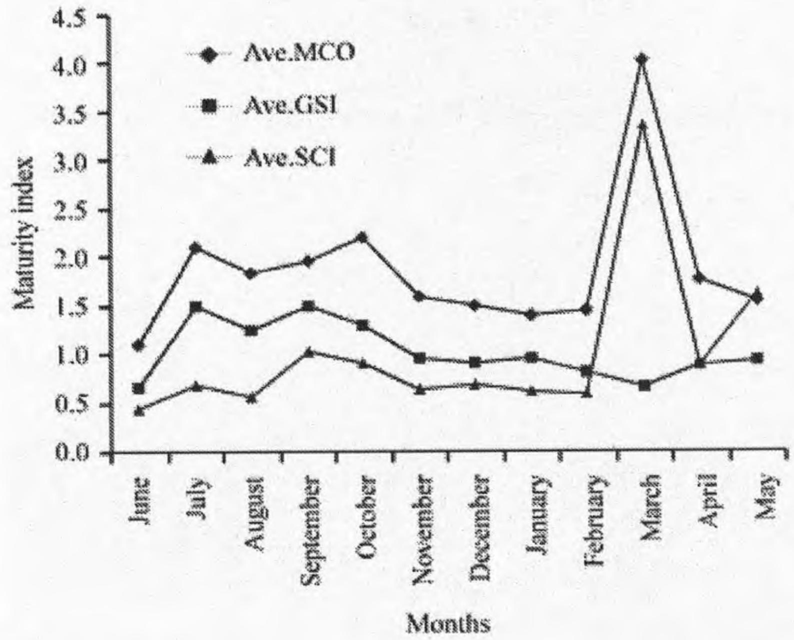


Fig. 5: Indices of reproductive status for male *S. lessoniana* against months

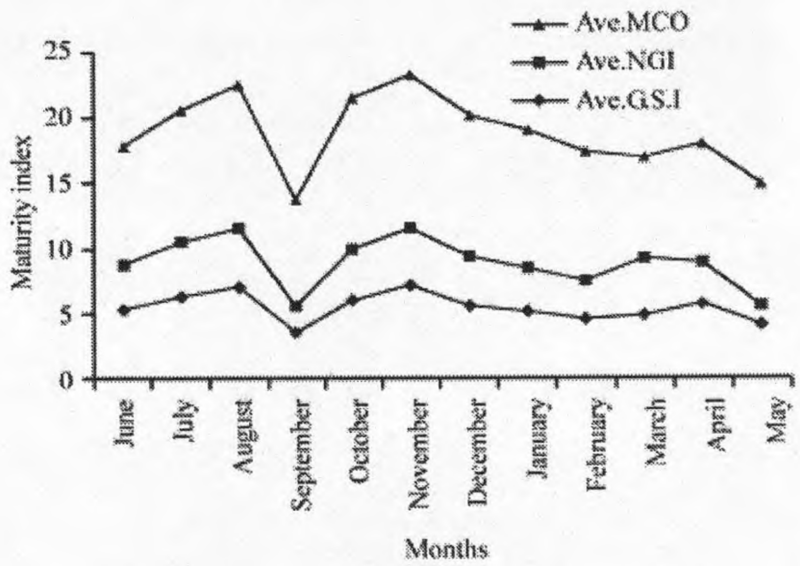


Fig. 6: Indices of reproductive status for female *S. lessoniana* against months

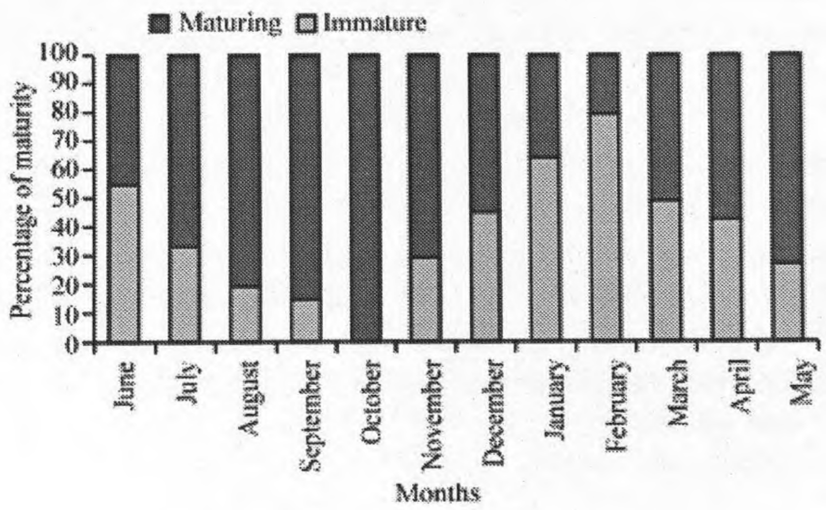


Fig. 7: Monthly distribution of maturity stages of male *S. lessoniana*

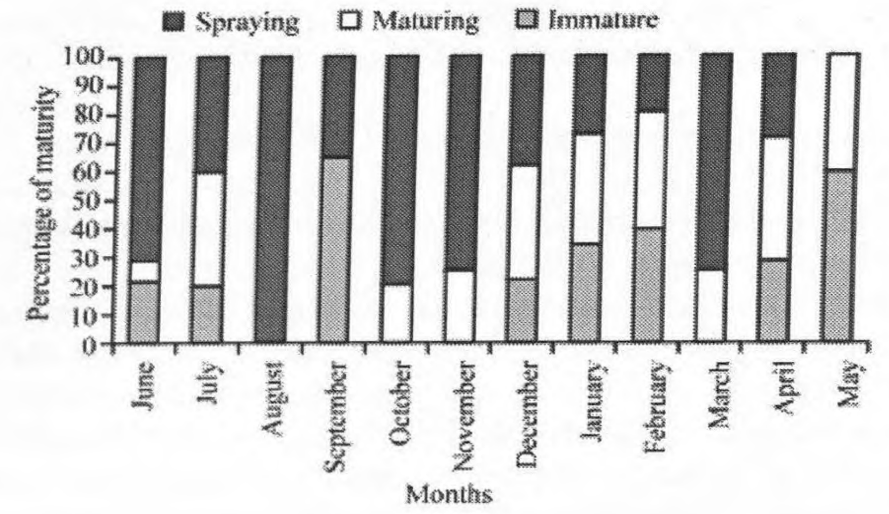


Fig. 8: Monthly distribution of maturity stages of female *S. lessoniana*

Table 3: Correlations of reproductive parameters of *Sepioteuthis lessoniana*

Sex	Correlation	N	R	p-value	Equations
Female	TW versus ML	404	0.98	<0.001	$TW = (0.18)\ ML^{2.491}$
	OW versus ML	404	0.77	<0.001	$OW = (2.38\times10^{-7})\ ML^{6.447}$
	NGW versus ML	404	0.88	<0.001	$NGW = (4.06\times10^{-7})\ ML^{6.162}$
	OvW versus ML	404	0.83	<0.001	$OvW = (1.00\times10^{-6})\ ML^{5.492}$
	Fecundity versus ML	116	0.59	<0.001	$Fecundity = (0.05)\times ML^{3.234}$
	Fecundity versus BW	116	0.59	<0.001	$Fecundity = (0.48)\times ML^{1.298}$
	OW versus BW	404	0.77	<0.001	$OW = (7.81)\times BW^{0.233}$
Male	TW versus ML	393	0.98	<0.001	$TW = (0.18)\times ML^{2.512}$
	TEW versus ML	393	0.77	<0.001	$TEW = (5.67\times10^{-4})\ ML^{2.947}$
	SCW versus ML	393	0.85	<0.001	$SCW= (6.06\times10^{-5})\ ML^{3.639}$
	Sperm count versus ML	108	0.76	<0.001	$Sperm\ count = (6.78\times10^{-3})\ ML^{3.437}$

were obtained for males. Parabolic equations for relationships of various morphometric measurements versus mantle length, R^2 and p-values of above relationships for both male and female squids are presented in Table 3.

Of the 797 *S. lessoniana* sexed, 404 were females and 393 were males. Chi-square value calculated for overall sex ratio conformed to the expected 1:1 ratio ($p>0.05$).

DISCUSSION

Sexual differences in length - weight relationship in *S. lessoniana* was not evident in the present study. It tallies with the earlier findings of the researchers. Comparison of length-weight regression lines for both sexes showed no significant difference ($p>0.05$) between males and females (Sivashanthini *et al.*, 2009). Length weight relationship of *S. arctipinnis* males were reported as $W = 0.0005\ L^{2.449}$ and females as $W = 0.0003\ L^{2.659}$ by Rao (1954). Segawa (1987) reported on the length-weight relationship of wild and cultured *S. lessoniana* and obtained the regression equations $W = 0.0003\ L^{2.675}$ and $W = 0.0004\ L^{2.553}$, respectively. The exponential value 'b' obtained for *S. lessoniana* male and female in the present study 2.5119 for males and 2.491 for females are in consistent with the earlier studies. The slight deviation may be due to food supply and water condition.

Some females had bunches of spermatophores on both sides of the mantle wall at the base of the gill near the opening of the oviduct suggests that the fertilization in this species occur at the buccal funnel region. Sometimes more than two bunches of spermatophores were observed and it infers that females may mate more than once. Egg clusters of

S. lessoniana were frequently found attached to hard substrate from August to January near the coasts further confirms the spawning period.

Fecundity of *S. lessoniana* found to be lesser than that of *S. pharaonis* for example, number of ova in 14 cm ML *S. dollfusi* and *S. lessoniana* was 730 (Gabr *et al.*, 1998) and 700, respectively. Fecundity of *S. pharaonis* ranged between 517 and 1525 ova for females of 11-24 cm ML (Gabr *et al.*, 1998) whereas for *S. lessoniana* ranged between 20 and 793 for females of 7-26 cm ML. Fecundity for *S. lessoniana* in the Zanzibar coastal waters ranged from 180 to 1180 eggs for individuals of size range 14.0-24.9 cm ML (Mhitu *et al.*, 2001) which is higher than the present results. The variation for the same species may have been attributed due to varying environmental factors, food availability and so on in different habitats.

The weak correlation between fecundity and mantle length may have been resulted as some females of similar size have already been laid different number of eggs. Therefore all these individuals appeared to be in spawning condition and it is an evidence of continuous egg production throughout the adult life confirming the multiple spawning. A similar result was also observed in *S. lessoniana* and *S. australis* of Australian waters by Peel (2001). Multiple spawning strategy can also be explained by the fact that large eggs in the ovary causing the oviduct volume to be insufficient to accommodate all eggs. Therefore, number of egg masses must be spawned in several batches (Rocha *et al.*, 2001).

Maturation in female *S. lessoniana* individuals was a size-related process, because weight of ovary, nidamental gland and oviducal gland were all highly correlated with mantle length. Maturation in male *S. lessoniana* individuals was also a size-related process, because testis weight was highly correlated with mantle length.

Finally, it can be concluded that squid *S. lessoniana* exhibits reproductive pattern of spawning more than once, group-synchronous ovulation and reproductive strategy of intermittent terminal spawning. Peak or intense spawning of this squid in Northern coast of Sri Lanka is in March, August and October to November. In a squid population an exploited stock can be renewed through recruitment. If overexploitation occurs, matured squids could be reduced and subsequently reproductive capacity of the population diminished. Such situation can be managed by setting restrictions on mesh sizes of the gears used to catch squids. Further, breeding females should be protected during the peak spawning period in order to maintain sustainability. Findings of the present study would definitely lead to formulate a management strategy and ensure a long term sustainability of *S. lessoniana* in coastal waters of Sri Lanka.

ACKNOWLEDGMENT

Authors are grateful to the authorities of National Science Foundation for the financial assistance (Research grant No. RG/MS/2006/01).

REFERENCES

Asian Development Bank/ Infofish, 1991. Cephalopods AOB infofish global industry update. Infofish, Kaula Lumpur, Malaysia, pp: 127.

Bagenal, T.E. and F.W. Tesch, 1978. Age and Growth. In: Methods for Assessment of Fish Production in Freshwater. IBP Handbook No. 3, Bagenal, T. (Ed.). Blackwell Scientific Publications, Oxford and Edinburgh, pp: 101-136.

Clarke, M.R., 1996. The role of cephalopods in the world's ceans. Phil. Trans. R. Soc. Lond., 351: 977-1112.

Costa, P.A.S. and F.C. Fernandes, 1993. Reproductive cycle of *Loligo sanpaulensis* (Cephalopoda: Loliginidae) in the Cabo Frio region, Brazil. Mar. Ecol. Prog. Ser., 101: 91-97.

Durward, R.D., T. Amaratunga and R.K. O'Dor, 1979. Maturity index and fecundity for female squid *Illex illecebrosus* (Le Sueur, 1821). ICNAF Res. Bull., 14: 67-72.

Gabr, H.R., R.T. Hanlon, M.H. Hanafy and S.G. Etreby, 1998. Maturation, fecundity and seasonality of reproduction of two commercially valuable cuttlefish. *Sepia pharaonis* and *Sepia dollfusi* in the Suez Canal. Fish. Res., 36: 99-115.

Gilbert, D.L., W.J. Jr. Adelman and J.M. Arnold, 1990. Squid as Experimental Animals. Plenum Press, New York, pp: 516.

Jackson, G.D. and N.A. Moltschaniwskyj, 2001. The influence of ration level on growth and statolith increment width of the tropical squid *Sepioteuthis lessoniana* (Cephalopoda: Loliginidae): An experimental approach. Mar. Biol., 138: 819-825.

Jackson, G. D. and M.L. Domeier, 2003. The effects of an extraordinary El Nino/ La nina event on the size and growth of the squid *Loligo opalescens* off Southern California. Mar. Biol., 142: 925-935.

Juanico, M., 1983. Squid Maturity Scale for Population Analysis. In: Advances in Assessment of World Cephalopod Resources, Caddy, J.F. (Ed.). FAO., Rome, Italy, pp: 341-378.

Lee, P.G., P.E. Turk, W.T. Yang and R.T. Hanlon, 1994. Biological characteristics and biomedical applications of the squid *Sepioteuthis lessoniauna* cultures through multiple generaions. Biol. Bull., 186: 328-341.

Lipinski, M., 1979. Universal maturity scale for the commercial important squids. The results of maturity classification of *Illex illecebrosus* (Lesueur, 1821) population for years 1973-1 977. Res. Doc. 79/11/38. Serial No.5364. Int. Comm. Northwest Atl. Fish., 40.

Mhitu, H., Y. Mgaya and M. Ngoile, 2001. Western Indian Ocean Marine Science Association, Zanzibar (Tanzania) and Institute of Marine Sciences, Zanzibar (Tanzania) University of Dar es Salaam. In: Growth and Reproduction of the Big Fin Squid, *Sepioteuthis lessoniana*, in the Coastal Waters of Zanzibar, Richmond M.D. and J. Francis (Eds.). IMS/WIOMSA, Zanzibar, pp: 289-300.

O'Dor, R., J. Aitken and G.D. Jackson, 2005. Energy balance growth models: Applications to cephalopods. Phuket mar. Biol. Cent. Res. Bull., 66: 329-336.

Peel, G., 2001. Flexible reproductive strategies in tropical and temperate *Sepioteuthis* squids. Marine Biol., 138: 93-101.

Rao, K.V., 1954. Biology and fishery of the Palk-bay squid, *Sepioteuthis arctipinnis* gould. Ind. J. Fish., 1: 37-67.

Rocha, F., A. Guerra and F.A. Gonzalez, 2001. A review of reproductive strategies in Cephalopods. Biol. Rev., 76: 291-304.

Segawa, S., 1987. *Sepioteuthis lessoniana* in Kominato and adjacent waters, Central Honshu, Japan. J. Tokyo. Univ. Fish., 74: 67-105.

Sivashanthini, K., G.A. Charles and W.S. Thulasitha, 2009. Length-weight relationship and growth pattern of *Sepioteuthis lessoniana* lesson 1830 (Cephalopoda: Teuthida) from the Jaffna Lagoon, Sri Lanka. J. Biol. Sci., 9: 357-361.

Sokal, R.R. and F.J. Rohlf, 1981. Biometry: The Principles and Practice of Statistics in Biological Research. W.H. Freeman and Company, San Francisco, pp: 706.

Somasekaram, T., 1997. Arjuna's Atlas of Sri Lanka. Arjuna Consulting Co. Ldt., Dehiwela, Sri Lanka, pp: 220.

Somasundarampillai, A., 2002.. Introduction of Sri Lanka Fisheries Exploitation and Development. Ampalam Publications, Wattala, pp: 1-2.

Stearns, S.C., 1992. The Evolution of Life History. Oxford University Press, Oxford.

Journal of Fisheries and Aquatic Science 6 (1): 74-84, 2011
ISSN 1816-4927 / DOI: 10.3923/jfas.2011.74-84

Population Dynamics of Squid *Sepioteuthis lessoniana* (Lesson, 1830) from the Northern Coast of Sri Lanka

G.A. Charles and K. Sivashanthini
Department of Zoology, University of Jaffna, Jaffna, Sri Lanka

Corresponding Author: K. Sivashanthini, Department of Zoology, University of Jaffna, Jaffna, Sri Lanka

ABSTRACT

The present study was carried out to understand the growth and mortality parameters and exploitation rate of the big fin squid *Sepioteuthis lessoniana*. Growth parameters of *S. lessoniana* such as $L\infty$, K and t_0 were estimated through the appropriate routines of the FiSAT II software. The optimized values for K and $L\infty$ obtained by the ELEFAN I was 0.85 $year^{-1}$ and 31.13 cm. The estimated t_0 value was -0.18627. The length-converted catch curve gave a Z value of 3.75 $year^{-1}$. The natural mortality coefficient (M) obtained through Pauly's empirical model was 1.64 $year^{-1}$. The computed instantaneous fishing mortality coefficient (F) for *S. lessoniana* is 2.11. The predicted exploitation ratio (E) for *S. lessoniana* is 0.501. The computed current exploitation rates (E) of 0.56 for *S. lessoniana* is slightly above the predicted E_{max} for *S. lessoniana*. The implication is that the stock is slightly overexploited. Thus, the fishing pressure on the stock has to be reduced. More capture should be prohibited by a reasonable decrease in the effort or by modifying the mesh size of the net for *S. lessoniana* species.

Key words: Population dynamics, growth, mortality, *Sepioteuthis lessoniana,* exploitation rate

INTRODUCTION

Cephalopods are becoming increasingly important in world fisheries (Boyle, 1990), cephalopod landings increasing at a faster rate than total landings of all marine resources for the past few decades (Pierce and Guerra, 1994). Increased fishing intensity, technological advances in catching and marketing and the growing demand for the non conventional resources has allowed the introduction and acceptance of cephalopods on expanded markets, where they were not previously appreciated (Amaratunga, 1987).

The cephalopoda which includes nautilus, cuttlefishes, squids and octopods is the most advanced class of the phylum mollusca adapted to a swimming existence. They are exclusively marine, diverse in form, size and nature (Mhitu *et al.*, 2001; Worms, 1983) and occupy littoral and benthic to pelagic environments of all world oceans. Cephalopods are considerably important as a food resource as well as in scientific investigations (Lefkaditou *et al.*, 2003; Mhitu *et al.*, 2001). Research on cephalopods is important for their conservation because relatively little is known about their life history, development and reproductive behavior, particularly of deep ocean species. Cephalopods constitute increasingly important resources for human consumption and a principal food for many top predators (Lefkaditou *et al.*, 2003). The knowledge of their abundance and distribution is fundamental, not only for fisheries, but also for the understanding of their significance in energy and material flow in marine ecosystems (Piatkowski *et al.*, 2001).

Cephalopods can be abundant predators that are large, active and voracious; conversely, they are important as prey for many marine mammals, birds and fishes, including economically important species (Clarke, 1996). Substantial squid fisheries have existed in Northern Sri Lanka almost to provide food for human and bait for other fisheries.

Cephalopods are important in biomedical research with direct application to man. Because of the highly developed brain and sensory organs, cephalopods are valuable in behavioural and comparative neuroanatomical studies (Hochner *et al.*, 2006).

The classification of recent taxa of the molluscan Class Cephalopoda includes the squids (Order Teuthoidea), the octopods (Order Octopoda) and the cuttlefishes and sepiolid or bobtailed squids (Order Sepioidea), as well as the bizarre vampire squid in the monotypic Order Vampyromorpha and the chambered nautilus in the separate subclass Nautiloidea. Teuthoid squids are further distinguished based on whether their eyes are covered by a transparent cornea (Suborder Myopsida) or are exposed (Suborder Oegopsida).

The squid of the genus *Sepioteuthis*, belonging to the family Loliginidae, are characterized by wide oval fins that extend almost the entire perimeter of the mantle. Only three species of squids *Euprymna berryi*, *Sepioteuthis lessoniana* and *Loligo duvauceli* were recorded from the northern coastal waters of Sri Lanka. Of these, *Sepioteuthis lessoniana* was collected throughout the year and therefore the population dynamics was studied in detail in the present investigation. Despite their importance to the people of northern coastal waters, very little attention has been paid in studying their population dynamics. Hence, the present study was carried out in order to investigate some aspects of the growth and mortality parameters and exploitation rate of the squid *Sepioteuthis lessoniana* in the northern coastal waters of Sri Lanka with a view to obtain basic scientific information relevant to management of its fishery.

MATERIALS AND METHODS

Squid samples for the present study were collected from the commercial catches of Ponnalai, Kakkaitivu, Pasaioor, Gurunagar and Point pedro landing centres (Fig. 1) at weekly intervals during June 2007 and May 2009. At least one landing centre was visited per week. Jaffna lagoon is one of the largest shallow water body located in the northern province of Sri Lanka with an area of 412.8 km^2 (Somasekaram, 1997). It is situated between 79° 52' E to 80° 38' E longitude and 9° 26' N to 9° 46' N latitudes (Somasundarampillai, 2002).

In Jaffna, fishermen use various techniques to capture squids. Mainly they capture squids by Sirahu valai. Being a small scale fishery, some fishermen use jiggers and pots to capture squids. Usually, they are caught incidentally along with other food fishes in trawl nets, boat seines and cast nets (Sivashanthini *et al.*, 2009).

Squid samples caught at depth of about 4-7 m, by sirahuvalai were identified into species and mantle length measurements (Fig. 2) were taken for all possible squids to the nearest 1 mm at the landing centres in order to arrange in to length frequency data. Random samples were also collected from the commercial catches of the said landing centres and brought to the laboratory for further analysis.

The length frequency data were grouped sex wise into 2 cm class intervals, sequentally arranged for two years and used for estimation of growth. Length frequency analysis were done with FiSAT II (Gayanilo and Pauly, 1997) soft ware.

The length frequency data of *S. lessoniana* from the commercial sirahu valai catches were analyzed using ELEFAN I routine of FISAT II software (Gayanilo and Pauly, 1997). The following

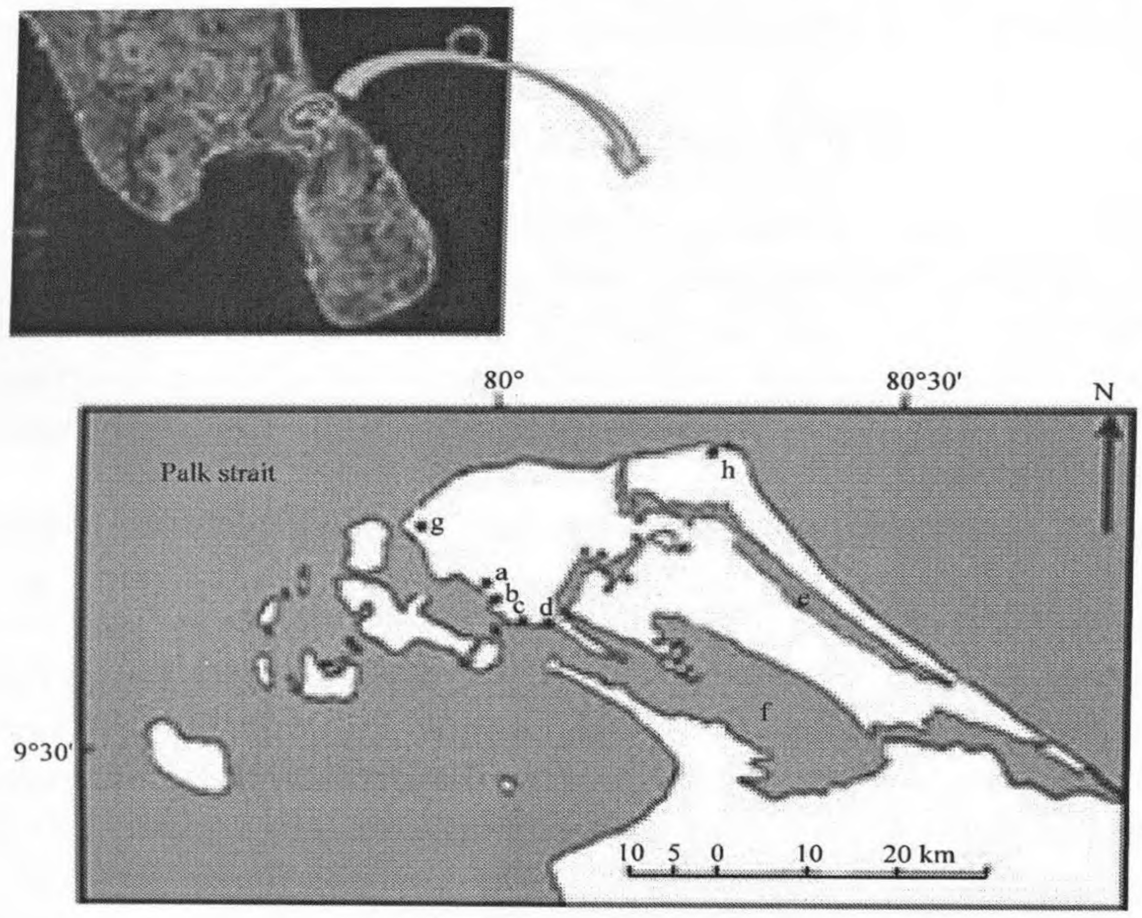


Fig. 1: Sampling sites (a, c, d, g and h) of *Sepioteuthis lessoniana* form the northern coast of Sri Lanka (a) Kakkaithevu, (b) Navanthurai, (c) Kurunagar, (d) Pasaioor, (e) Thodaimannar lagoon, (f) Jaffna lagoon, (g) Ponnalai and (h) Point pedro

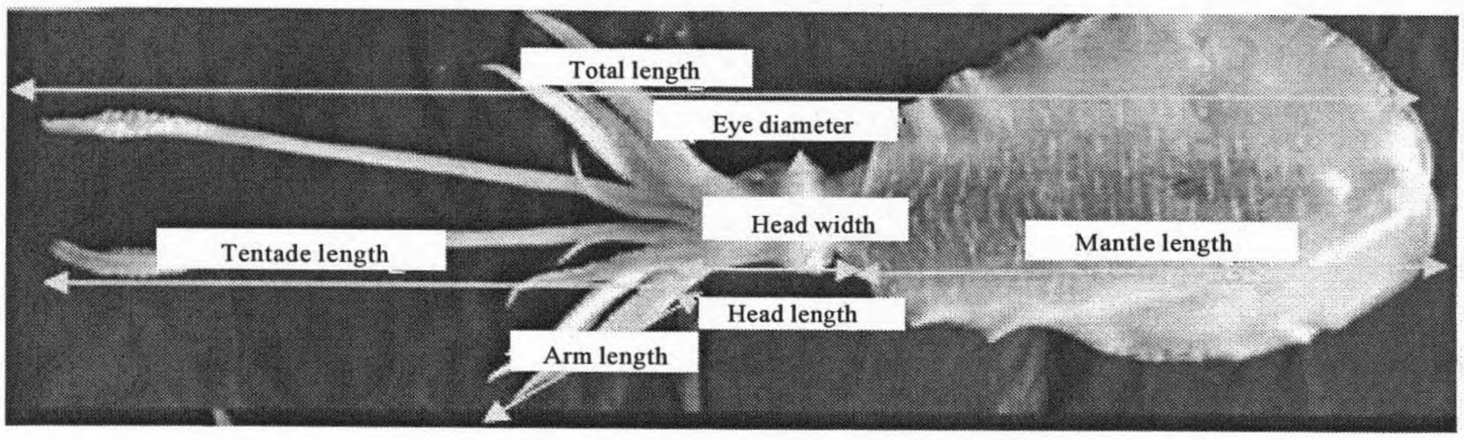


Fig. 2: Photograph showing length measurements of *S. lessoniana*

stepwise procedures were adopted to estimate L_∞ and K and for correction of length frequency data for mesh selection as per literature (Sparre and Venema, 1992; Amarasinghe and De Silva, 1992; Amarasinghe, 2002):

- 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; Whetherall, 1986)
- Preliminary estimation of asymptotic length (L_∞) and growth coefficient (K) using the initial estimates of L_∞ estimated by Powell Wetherall method

- 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 ($L\infty$) growth coefficient (K) and computed t_0
- Correction of the original length frequencies using probabilities of capture (Pauly, 1986a-c) for incomplete selection for length classes smaller than the first fully selected length through appropriate routine
- Estimation of best optimized estimates of $L\infty$ and K through ELEFAN I routine (Gayanilo and Pauly, 1997) from the corrected length frequency data.

$L\infty$ and K values were obtained through the four options such as, curve fitting by eye, response surface analysis, scan of K values and automatic search routine. In this method the growth parameters $L\infty$ and K were estimated following the von Bertalanffy growth equation. The equation for growth in length is given by:

$$L_t = L\infty\,(1\text{-}\exp^{-K(t-t_0)}) \quad (1)$$

where, L_t is the length at age t, $L\infty$ the asymptotic length, K the growth coefficient and t_0 theoritical age at which fish would have had zero length if they had grown according to the above equation. The most optimized $L\infty$ and K values were obtained by ELEFAN I - automatic search routine and the restructured length frequency histograms were also obtained. The growth performance index (Ø) was computed using the following equation (Pauly and Munro, 1984):

$$\varnothing = \log_{10} K + 2 \log_{10} L\infty \quad (2)$$

As ELEFAN cannot estimate the t_0 value from the length frequency data, a very aproximate value of t_0 was estimated by substituting the $L\infty$ (in cm) and K ($year^{-1}$) in the following equation (Pauly, 1983):

$$\log(-t_0) \approx -0.3922 - 0.2752 \log L\infty - 1.038 \log K \quad (3)$$

Longevity was obtained from the following Eq. 4:

$$t_{max} = t_0 + 3/K \quad (4)$$

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

The total mortality coefficient (Z) was estimated using length converted catch curve analysis (Gayanilo and Pauly, 1997) in the FiSAT II program using the input parameters $L\infty$, K and t_0. The histogram showing probability of capture for each size class was obtained by backward extrapolation of the straight portion of the right descending part of the catch curve. The length at first capture L_c was obtained from the plot of cumulative probability of capture against mid-length of class interval, through detailed analysis of ascending part of catch curve.

Natural mortality rate was obtained through Pauly's empirical model Pauly (1980):

$$\ln(M) = -0.0152 - 0.279 \ln(L\infty) + 0.6543 \ln(K) + 0.463 \ln(T) \quad (5)$$

where, M is the natural mortality, L_∞ is in cm, K is annual and T is the mean annual temperature (in °C) which is taken as 30°C.

Fishing mortality was calculated using the formula:

$$Z = M + F \tag{6}$$

Exploitation rate E was determined from the relationship:

$$E \text{ (exploitation rate)} = F/Z \tag{7}$$

The relative yield per recruit (Y/R) was predicted by considering Y'/R as a function of U and E and M/K by employing Beverton and Holt Y'/R analysis (selection ogive) in the FiSAT package. The relative yield per recruit equation which gives a quantity proportional to Y'/R was derived from the method of Beverton and Holt (1959) through a number of algebraic manipulations. The predicted values were obtained by substituting the input parameters of L_c/L_∞ (L_c is the minimum length captured; obtained from the extrapolation of length converted catch curve) and M/ K in the FiSAT II package (Gayanilo and Pauly, 1997). The assumptions considered in this model being fishing and natural mortalities are constant from the moment of entry to the exploited phase recruitment is constant and the length weight relationship has the exponent 3.

RESULTS

Squids are among the most important cephalopods caught in the Northern coastal waters of Sri Lanka. Among the total fish catch, cephalopods contribute 17.1% for the year 2007, 10.9% for the year 2008 and 26.4% for the year 2009 (Data gathered from statistical unit, Department of Fisheries, Jaffna, Sri Lanka) from the waters surrounding Jaffna peninsula.

A total of 4856 specimens of *S. lessoniana* ranging from 3.8 to 27.8 cm were analyzed for the age and growth studies. Among them 1416 suids were collected from Ponnalai, 256 from Kakkai teevu, 640 from Point pedro, 1160 from Pasaioor and 1340 from Kurunagar. During the study period three species of squids were recorded. Large numbers of Bobtail squids *Euprymna berryi* of order sepiolida, family sepiolidae and subfamily sepiolinae were collected only during October 2008 to February 2009. Very few numbers of *Loligo duvauceli* included under order Teuthida, family Loliginidae was recorded intermittently during the study period. The most abundant species available throughout the year was *S. lessoniana* included under order Teuthida, family Loliginidae. The population dynamics studies were continued only for *S. lessoniana* as it is the most abundant species.

The analysis of length frequency data by the Powell - Wetherall method (Fig. 3) gave an initial estimate of L_∞ value of 33.2 cm and Z/K value of 4.093. The optimized values for K and L_∞ obtained by the ELEFAN I was 0.85 year^{-1} and 31.13 cm. The goodness of fit index (R_n) for the obtained K and L_8 value was 0.175.

Usually, the R_n value ranges between 0 and 1 in the ELEFAN - FiSAT package. 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. 4. The estimated growth performance index (Ø) was 2.915. The estimated t_0 value was -0.18627.

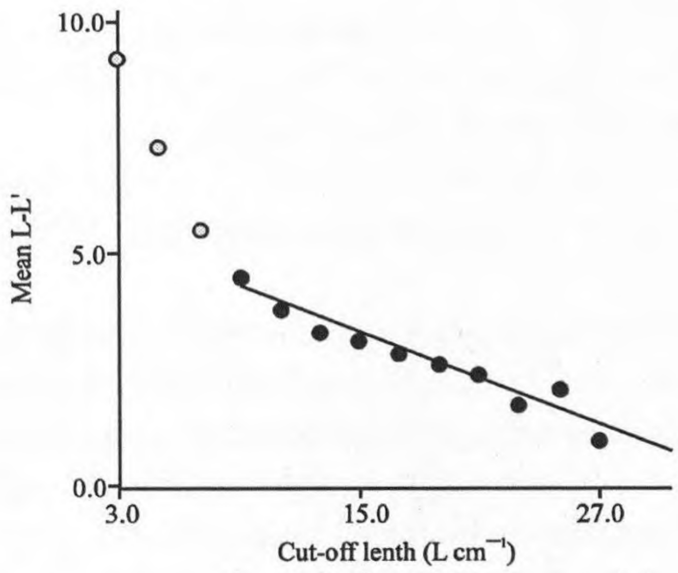


Fig. 3: Powell Wetherall plot of *Sepioteuthis lessoniana*

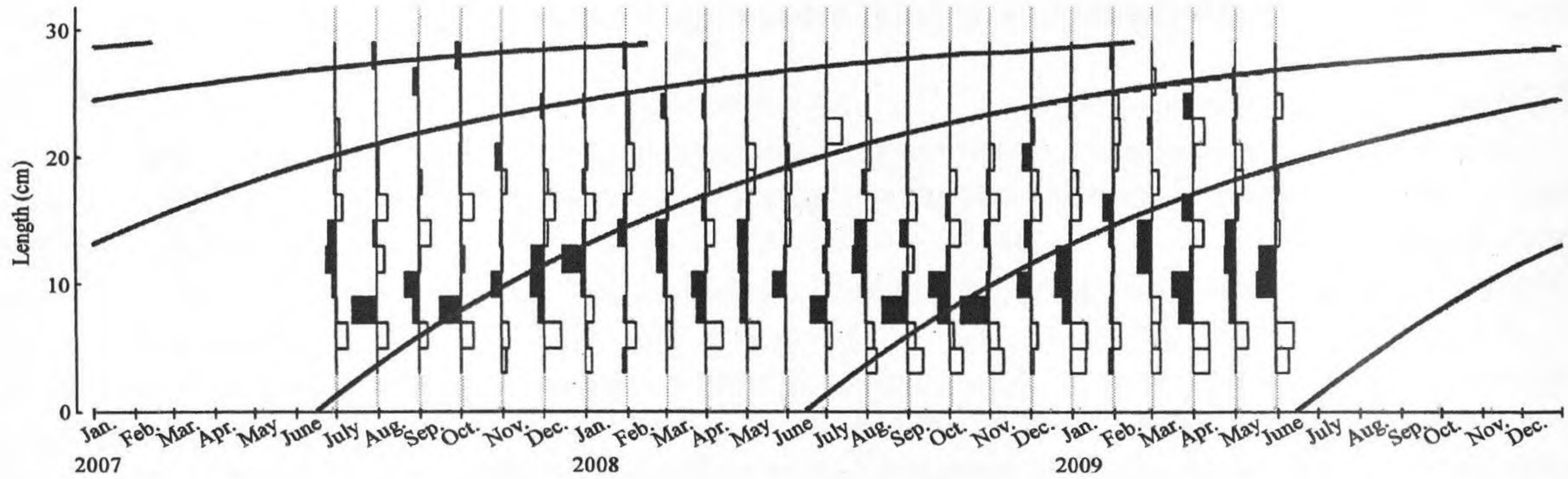


Fig. 4: Growth curve of *Sepioteuthis lessoniana* drawn using ELEFAN I programme

The von Bertalanffy's growth equation for *S. lessoniana* can be expressed as:

$$\text{Male: } L_t = 31.13\ [1\text{-exp}\ \{-0.85(t+0.18627)\}] \qquad (8)$$

Estimated longevity for *S. lessoniana* calculated from Pauly's equation is 3.34.

The length-converted catch curve for *S. lessoniana* is shown in Fig. 5. The length-converted catch curve gave a Z value of 3.75 year^{-1} (confidence interval of Z = 3.368-4.127; standard deviation of the slope = 0.55; r = 0.98). The lengths at first capture L_c (length at 50% capture) estimated by backward extrapolation of the straight portion of the right descending part (Fig. 6) of the catch curve was 8.57 cm.

The natural mortality coefficient (M) obtained through Pauly's empirical model at 30°C surface temperature was 1.64 year^{-1}. Therefore, the computed instantaneous fishing mortality coefficient (F) for *S. lessoniana* is 2.11. The respective current exploitation ratio (E) for *S. lessoniana* is 0.56.

The selective ogive procedure (Fig. 7) for the analysis of relative yield-per-recruit gave predicted values of 0.501 for E_{max} for *S. lessoniana*. The computed current exploitation rates (E) of 0.56 for *S. lessoniana* is slightly above the predicted E_{max} for *S. lessoniana*. The implication is that the stock is slightly overexploited. Thus, the fishing pressure on the stock has to be reduced. More capture

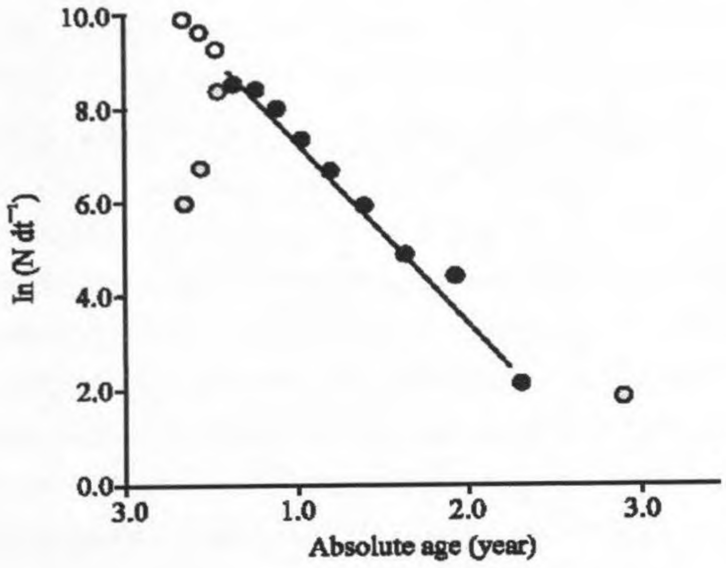


Fig. 5: Length converted catch curve of *Sepioteuthis lessoniana* (Z = 3.75; M (at 30°C) = 1.64; F = 2.11; E = 0.56)

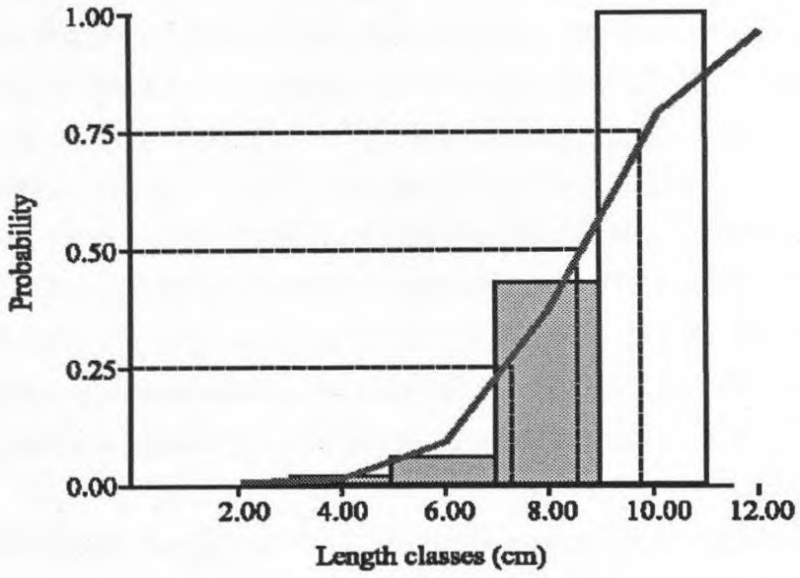


Fig. 6: Probability plot of *Sepioteuthis lessoniana*

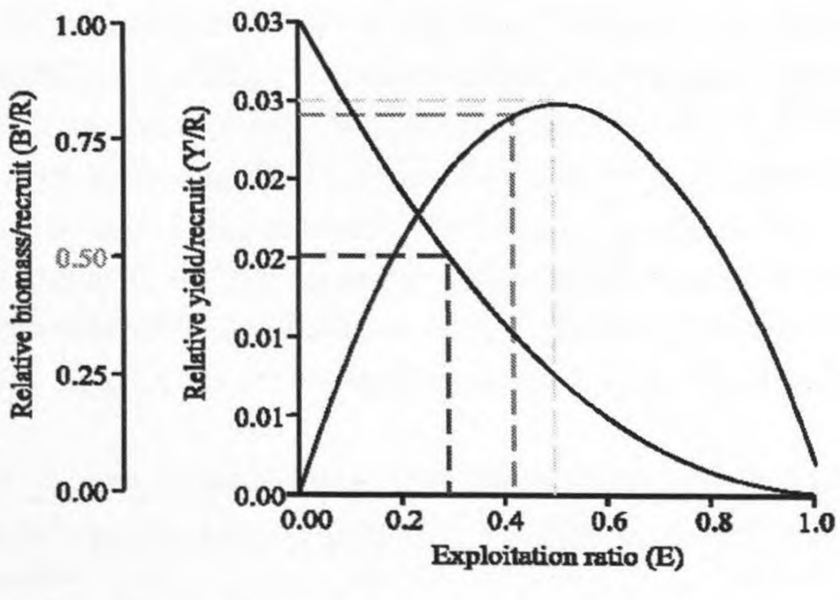


Fig. 7: Relative yield per recruit using selective ogive for *Sepioteuthis lessoniana*

should be prohibited by a reasonable decrease in the effort or by modifying the mesh size of the net for *S. lessoniana* species.

DISCUSSION

Population dynamics of the squid *S. lessoniana* were not studied either in Sri Lanka or in other parts of the world and this is the first study to estimate those parameters. One related preliminary study was performed for *S. lessoniana* and it is the study by Balgos and Pauly (1998) in Philippine waters. However growth and mortality parameters were not clearly defined in that study. Few other studies were performed on *Loligo duvauceli* in Indian waters (Chakraborty *et al.*, 1997; Karnik *et al.*, 2003; Meiyappan and Srinath, 1989; Mohamed and Rao, 1997; Neethiselvan and Venkataramani, 2002; Silas *et al.*, 1986).

The L_∞ and K values estimated for congeners of *S. lessoniana* are given in Table 1. The estimated values of L_8 for *L. duvauceli* differ at all instances from that of S. *lessoniana*. It clearly expresses the variation of maximum length for different species of squids as well as in different geographical location. The K value obtained is also extremely differing with that of *L. duvauceli* and consistent at only one instance that is with the *L. duvauceli* found in Mumbai coast.

Karnik *et al.* (2003) computed total, natural and fishing mortality coefficients of 4.29, 1.82 and 2.47, respectively for *L. duvauceli* in Mumbai waters. The computed total, natural and fishing mortality for *S. lessoniana* differs from the earlier study for *L. duvauceli*. This may be due to varied environmental conditions, fishing methods and topography of the studied regions. Neethiselvan and Venkataramani (2002) estimated total, natural and fishing mortality coefficients of 2.27, 0.91 and 1.36, respectively in Tuticorin for siboga squid *Doryteuthis sibogae*, Again the obtained results are not in consistent with the present study.

The estimated growth performance (Ø) index for *S. lessoniana* shows the growth performance index is 2.915. This clearly shows the reliability of the estimates of K and L_8 in the present study. Such estimation for growth performance index was not computed for *S. lessoniana* or the conveners of this species and therefore a comparison cannot be made at this juncture. The growth performance index 2.9 calculated for *Doryteuthis sibogae* by Neethiselvan and Venkataramani (2002) from Tuticorin waters is same as that of the result obtained for growth performance index in the present study. High annual growth rate of a fish can lead to high turnover rates or production per biomass (P:B) ratios (Gunderson, 1997).

Fast growth rate and small asymptotic length indicate that the fish species in these waters mature early in life and has a short life span (Sparre and Venema, 1992). Hendrickson (2004) found the lifespan of winter cohort of *Illex illecebrosus* in U.S. waters ranges from 115 to 215 days. It is not consistent with the present study for *S. lessoniana*. Moreover, the allometric relationships for the *Illex illecebrosus* was studied by Staudinger *et al.* (2009) in North Carolina.

Table 1: The growth parameters estimated for squids from different regions of the world

Species	Sex	L_∞ (mm)	K (annual)	Region	Source
Loligo duvauceli	Male	327	0.61	Cochin	Silas *et al.* (1986)
	Female	205	1.19		
Loligo duvauceli	Male	372	1.1.0	(Kerala coast)	Meiyappan and Srinath (1989)
	Female	238	1.70		
Loligo duvauceli	Combined	343	0.49	Mumbai coast	Chakraborty *et al.* (1997)
Loligo duvauceli	Combined	371	1.40	Karnataka coast	Mohamed and Rao (1997)
Doryteuthis sibogae	Combined	395	0.40	Thoothukudi coast	Neethiselvan and Venkataramani (2002)
Loligo duvauceli	Combined	385	0.85	Mumbai coast	Karnik *et al.* (2003)
Sepioteuthis lessoniana	Combined	311	0.85	Northern Sri Lanka coast	Present study

Generally M/K is used as an index for checking the validity of M and K values estimated by different methods and it is known to range from 1 to 2.5 (Beverton and Holt, 1959). The M/K ratios obtained in the present study (1.92) was well within this range. Instantaneous total mortality computed by length converted catch curve for *Loligo duvauceli* in the previous study was 4.29 (Karnik *et al.*, 2003) and the values obtained in the present study is lower than that. Only one earlier report is available for *S. lessoniana* for growth parameter estimates which lacks information about mortality (Balgos and Pauly, 1998).

In the relative yield per recruit and biomass per recruit prediction models the descending curves showed decrease in biomass/recruits (B'/R) as exploitation ratio increased. The other curve showed increase in yield/recruit (Y'/R) with increase in exploitation ratio (E) up to E_{max}. The E_{max} is the value of E with the highest Y'/R value that is possible with a given value of L_c i.e., exploitation rate which produces maximum sustainable yield (E_{MSY}) which represents the mean maximum catch that can be taken from the fishery without affecting the biology of the stock or the balance of the system. E_{50} is the value of E associated with a 50% reduction of the biomass (per recruit) in the unexploited stock. When harvesting at the MSY level, fishing mortality (F) is roughly equal to the natural mortality (M) and harvesting above MSY denotes over fishing. The present computed yield per recruit analysis showed exploitation rate (E) of 0.56 which is slightly above the predicted maximum value of 0.501 for *S. lessoniana*.

Neethiselvan and Venkataramani (2002) found a slightly lower value of exploitation rate (0.53) for *Doryteuthis sibogae* from Tuticorin waters whereas Karnik *et al.* (2003) also estimated a very close value of 0.57 for *L. duvauceli* from Mumbai waters. In both instance a slightly higher exploitation was observed and a reduction of fishing effort was recommended. Further size selectivity of trammel net for oval squid *S. lessoniana* in Tateyama Bay, Chiba prefecture was studied by Akiyama *et al.* (2004a). Akiyama *et al.* (2004b) further studied the capture characteristics of a trammel net for oval squid *S. lessoniana* in Tateyama Bay, Chiba prefecture.

In the present study, the implication is that the stock is slightly overexploited. Thus, the fishing pressure on the stock has to be reduced. More yields could be obtained by a reasonable increase in size at first capture without necessarily leading to over exploitation. However, increasing the stretched mesh size according to the minimum L_c is not a good recommendation to increase the yield. As this may perhaps result in unsustainable fishery at one instance, the suggested recommendation is that decreasing fishing efforts mainly by reducing the number of boats to lower the fishery in northern coastal waters of Sri Lanka.

ACKNOWLEDGMENT

Authors are grateful to the authorities of National Science Foundation for the financial assistance (Research grant No. RG/MS/2006/01).

REFERENCES

Akiyama, S., S. Kaihara and T. Arimoto, 2004a. Capture characteristics of a trammel net for oval squid *Sepioteuthis lessoniana* in Tateyama bay, Chiba prefecture. Bull. Jap. Soc. Sci. Fish., 70: 865-871.

Akiyama, S., S. Kaihara, T. Arimoto and T. Toaki, 2004b. Size selectivity of a trammel net for oval squid *Sepioteuthis lessoniana*. Fish. Sci., 70: 945-951.

Amarasinghe, U.S. and S.S. De Silva, 1992. Population dynamics of *Oreochromis mossambicus* and *Oreochromis niloticus* (Cichlidae) in two reservoirs of Sri Lanka. Asian Fish. Sci., 5: 37-61.

Amarasinghe, U.S., 2002. The fishery and population dynamics of *Oreochromis mossambicus* and *Oreochromis niloticus* (Osteichthyes, Cichlidae) in a shallow Irrigation Reservoir in Sri Lanka. Asian Fish. Sci., 15: 7-20.

Amaratunga, T., 1987. Population Biology. In: Cephalopod life cycle, Boyle, P.R. (Ed.). Vol. II, Academic press Inc. Ltd., London, pp: 239–252.

Balgos, M.C. and D. Pauly, 1998. Age and growth of the squid *Sepioteuthis lessoniana* in N. W. Luzon, Philippines. South Afr. J. Mar. Sci., 20: 449-452.

Beverton, R.J.H. and S.J. Holt, 1959. A review of the life spans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. Ciba Foundation Colloquia Ageing, 5: 142-180.

Boyle, P.R., 1990. Cephalopod biology in the fisheries context. Fish. Res., 8: 303-321.

Chakraborty, S.K., V.D. Deshmukh, M.Z. Khan, K. Vidyasagar and S.G. Raje, 1997. Estimation of growth, mortality, recruitment pattern and maximum sustainable yield of important fishery resources of Maharashtra coast. Indian J. Mar. Sci., 26: 53-56.

Clarke, M.R., 1996. The role of cephalopods in the world's ceans. Phil. Trans. R. Soc. Lond., 351: 977-1112.

Gayanilo, Jr., F.C. and D. Pauly, 1997. FAO-ICLARM Stock Assessment Tools (FiSAT) Reference Manual. FAO, Rome, ISBN: 9251040478, pp: 262.

Gunderson, D.R., 1997. Trade off between reproductive effort and adult survival in oviparous and viviparous fishes. Can. J. Fish. Aquat. Sci., 54: 990-998.

Hendrickson, L.C., 2004. Population biology of northern shortfin squid (*Illex illecebrosus*) in the northwest Atlantic ocean and initial documentation of a spawning siite in the Mid-Atlantic Bight (USA). ICES J. Marine Sci., 61: 252-266.

Hochner, B., T. Shomrat and G. Fiorito, 2006. The octopus: A model for a comparative analysis of the evolution of learning and memory mechanisms. Biol. Bull., 210: 308-317.

Karnik, N.S., S.K. Chakraborty, A.K. Jaiswar, R.P. Swamy, R. Rajaprasad, S. Boomireddy and A.F. Rizvi, 2003. Growth and mortality if Indian squid, *Loligo duvauceli* (Mollusca/ Cephalopoda/ Teuthoidea) from Mumbai waters, India. Indian J. Mar. Sci., 32: 67-70.

Lefkaditou, E., P. Peristeraki, P. Bekas, G. Tserpes, C.Y. Politou and G. Petrakis, 2003. Cephalopods distribution in the Southern Aegean sea. Meditteranean Marine Sci., 4/1: 79-86.

Meiyappan, M.M. and M. Srinath, 1989. Growth and Mortality of Indian Squid (*Loligo duvauceli*) off Cochin, India, In: Contribution to Tropical Fish Stock Assessment in India, Venema, S.C. and N.P. van Zalinge (Eds.). FAO, Rome, pp: 14.

Mhitu, H., Y. Mgaya and M. Ngoile, 2001. Western Indian Ocean Marine Science Association, Zanzibar (Tanzania) and Institute of Marine Sciences, Zanzibar (Tanzania) University of Dar es Salaam. In: Richmond, M.D. and J. Francis (Eds.). Growth and Reproduction of the Big Fin Squid, *Sepioteuthis lessoniana* in the Coastal Waters of Zanzibar, IMS/WIOMSA, Zanzibar, Tanzania.

Mohamed, S.K. and G.S. Rao, 1997. Seasonal growth, stock recruitment and prediction of yield of Indian squid *Loligo duvauceli* exploited from Karnataka coast. Indian J. Fish., 44: 319-329.

Neethiselvan, N. and V.K. Venkataramani, 2002. Population dynamics of siboga squid *Doryteuthis sibogae* (Cephalopoda/Teuthoidea) in Thoothukkudi (Tuticorin) coast, southeast coast of India. Indian J. Marine Sci., 31: 213-217.

Pauly, D., 1980. A selection of simple methods for the assessment of tropical fish stocks. FAO Fish. Circ., 729: 54-54.

Pauly, D. and J.L. Munro, 1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2: 21-21.

Pauly, D., 1986a. On improving operation and use of the ELEFAN programmes. Part II. Improving the estimation of L. ICLARM. Fishbyte, 4: 18-20.

Pauly, D., 1986b. On improving operation and use of the ELEFAN programmes. Part III. Correcting length-frequency data for effects of gear selection and for incomplete recruitment. Fishbyte, 4: 11-13.

Pauly, D., 1986c. On improving operation and use of the ELEFAN programmes. Part IV. Conclusions. Fishbyte, 4: 14-14.

Pauly, D., 1983. Some simple methods for the assessment of tropical fish stocks. FAO. Fish. Tech. Pap., 234: 52-52.

Piatkowski, U., G.J. Pierce and M.M. Cunha, 2001. Impacts of cephalopods in the food chain and their interaction with the environment and fisheries: An overview. Fish. Res., 52: 5-10.

Pierce, G.I. and A. Guerra, 1994. Stock assessment methods used for cephalopod fisheries. Fish. Res., 21: 255-285.

Powell, D.C., 1979. Estimation of mortality and growth parameters from the length frequency in catch. J. Cons. Int. Explor. Mer., 175: 167-169.

Silas, E.G., R. Sarvesan, K.P. Nair, M. Srinath and K.S. Rao, 1986. Stock assessment of squids and cuttlefish at selected centres. Bull. Central Mar. Fis. Res. Inst., 37: 71-79.

Sivashanthini, K., G.A. Charles and W.S. Thulasitha, 2009. Length-weight relationship and growth pattern of *Sepioteuthis lessoniana* lesson 1830 (Cephalopoda: Teuthida) from the Jaffna Lagoon, Sri Lanka. J. Biol. Sci., 9: 357-361.

Somasekaram, T., 1997. Arjuna's Atlas of Sri Lanka. Arjuna Consulting Company Ltd., Dehiwela, Sri Lanka.

Somasundarampillai, A., 2002. Introduction of Sri Lanka Fisheries Exploitation and Development. Ampalam Publications, Wattala, pp: 1-2.

Sparre, P. and S.C. Venema, 1992. Introduction to tropical Fish Stock Assessment. Manual. FAO Fisheries Technical Paper 306/1, Rev. 1, Rome, pp: 376.

Staudinger, M.D., F. Juanes and S. Carlsn, 2009. Reconstruction of original body size and estimation of allometric relationships for the longfin inshore squid (*Loligo pealeii*) and northern shortfin squid (*Illex illecebrosus*). Fishery Bull., 107: 101-105.

Whetherall, J.A., 1986. A new method for estimating growth and mortality parameters from length-frequency data. Fishbyte, 4: 12-14.

Worms, J., 1983. World Fisheries for Cephalopods. A Synoptic Overview. In: Advances in Assessment of World Cephalopod Resources, Caddy, J.F. (Ed.). Food and Agriculture Organization, Rome, ISBN-10: 9250014317, pp: 452.

Section 6

Summary Statement of Expenditure (indicate under Personnel, Equipment, Consumables, Travel and Subsistence and Miscellaneous)

Please see overleaf

University of Jaffna, Sri Lanka
National Science Foundation

Statement of Accounts

The financial position of the Grant No : RG/2006/MS/01 for the period from 13/07/2010 to ~~30~~ 31/10/2010.

Nature of Expenditure & Income	Expenditure			Income			Balance Available
	Expenditure up to 13/07/2010	Expenditure from 13/07/2010 to 30/10/2010	Total Expenditure	Grant Recd. Upto 13/07/2010	Grant Recd.from 13/07/2010 to 30/10/2010	Total Grant Recd.	
Personals	851,333.34	----------	851,333.34	851,333.34	---------	851,333.34	Nil
Equipments	345,456.13	----------	345,456.13	345,840.00	---------	345,840.00	383.87
Consumable	27,472.00 10752.00 *17,250.00	---------- ---------- ----------	27,472.00 10752.00 *17,250.00	57,000.00	---------	57,000.00	1526.00
Travel & Sub	103,470.00	----------	103,470.00	107,880.00	---------	107,880.00	4410.00
Misc.	68,361.00	----------	68,361.00	68,500.00	---------	68,500.00	139.00
Total	1,424,094.47	---------	1,424,094.47	1,430,553.34	---------	1,430,553.34	6458.87

Balance as at 10/07/2010 is Rs.6458.87

.... (signature)
Bursar.

* Order placed but not paid and delivered.

Section 7

i) Grantees' signatures

[signature] 30/11/2010

ii) Comments of the Head of the Department/signature

The research student done a verygood research work. The study of this research work has not been performed in the Northern region.
The out-come of this research project is veryuseful to Researchers, Public, as well as fishing community in the Northern part of Sri Lanka.

[signature] 30/11/20

Mrs. Nithiyagowry Rajan
Head & Senior Lecturer
Department of Zoology
University of Jaffna
Jaffna, Sri Lanka

iii) Head of the Institution's signature

[signature] 2010/11/30

Prof. N. Shanmugalingam Ph.D
Professor of Sociology
Vice Chancellor
University of Jaffna
Jaffna, Sri Lanka.