Journal of

Fisheries and Aquatic Science

ISSN 1816-4927

Academic Journals Inc.

www.academicjournals.com

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_∞, K and t_0 were estimated through the appropriate routines of the FiSAT II software. The optimized values for K and L_∞ 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

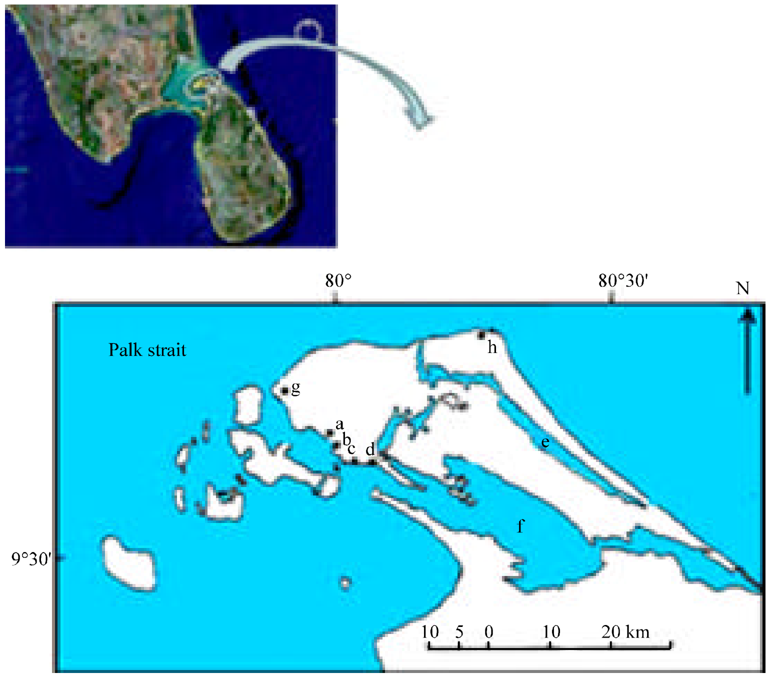

Fig. 1: Sampling sites (a, c, d, g and h) of *Sepioteuthis lessoniana* form the northern coast of Sri Lanka (a) Kakkaithevu, (b) Navanthurai, (c) Kurunagar, (d) Pasaioor, (e) Thodaimannar lagoon, (f) Jaffna lagoon, (g) Ponnalai and (h) Point pedro

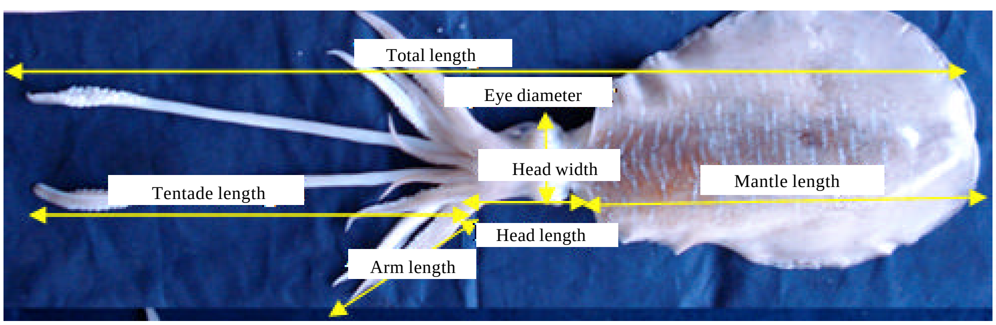

Fig. 2: Photograph showing length measurements of *S. lessoniana*

stepwise procedures were adopted to estimate $L\infty$ 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 ($L\infty$) and growth coefficient (K) using the initial estimates of $L\infty$ estimated by Powell Wetherall method
- Estimation of an initial value for asymptotic length ($L\infty$) and Z/K (Z = total mortality and K = growth coefficient) using the Powell-Wetherall method (Powell, 1979; Whetherall, 1986)
- Preliminary estimation of asymptotic length ($L\infty$) and growth coefficient (K) using the initial estimates of $L\infty$ 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:

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

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):

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

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):

$$\log(-t_0) \tilde{}\ -0.3922 - 0.2752 \log L\infty - 1.038 \log K \tag{3}$$

Longevity was obtained from the following Eq. 4:

$$t_{max} = t_0 + 3/K \tag{4}$$

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):

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

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 $L_c/L\infty$ (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.

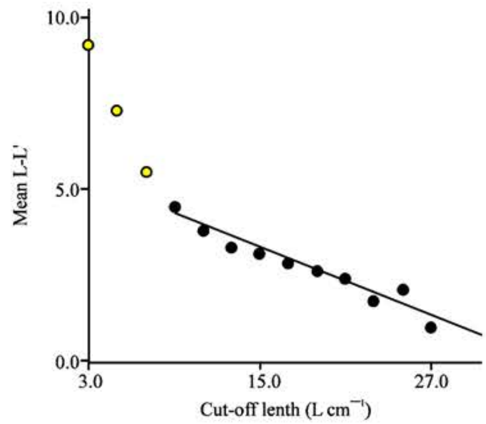

Fig. 3: Powell Wetherall plot of *Sepioteuthis lessoniana*

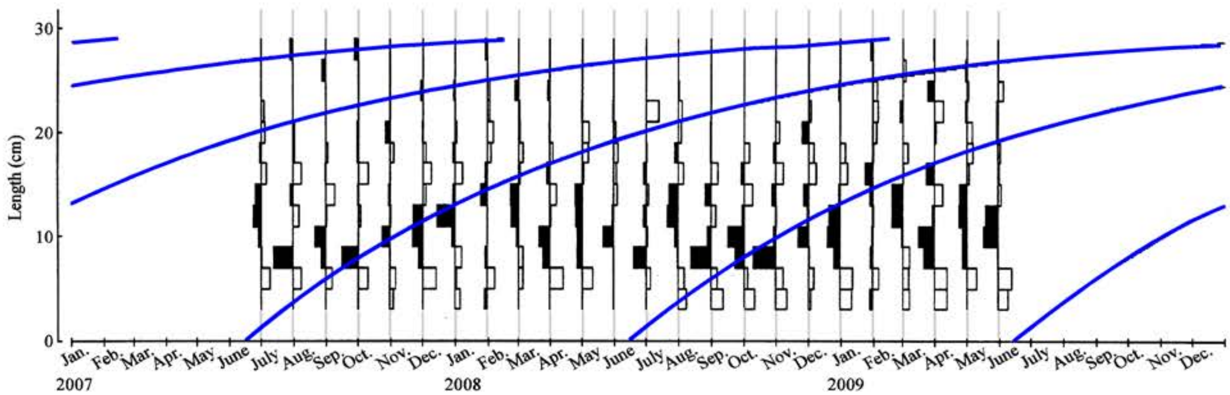

Fig. 4: Growth curve of *Sepioteuthis lessoniana* drawn using ELEFAN I programme

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

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

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

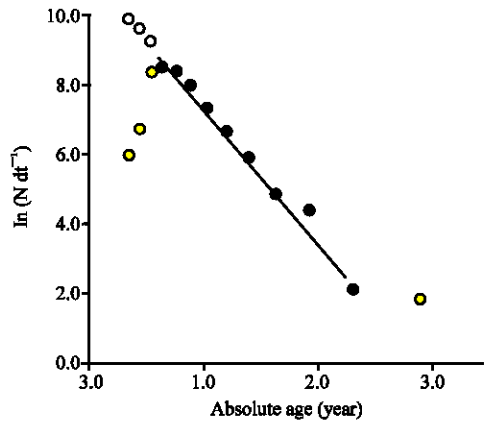

Fig. 5: Length converted catch curve of *Sepioteuthis lessoniana* (Z = 3.75; M (at 30°C) = 1.64; F = 2.11; E = 0.56)

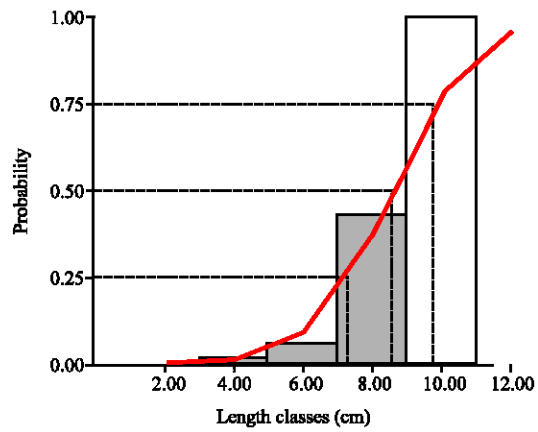

Fig. 6: Probability plot of *Sepioteuthis lessoniana*

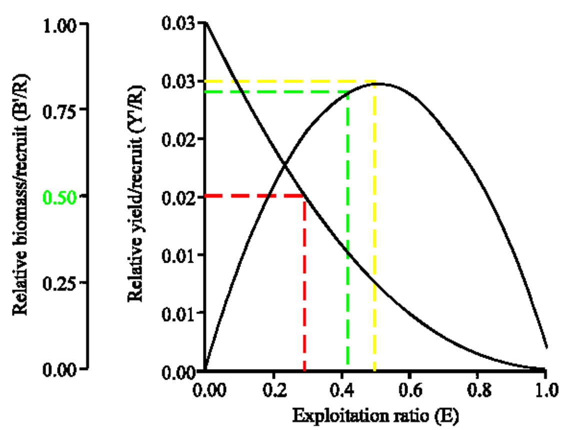

Fig. 7: Relative yield per recruit using selective ogive for *Sepioteuthis lessoniana*

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.