BIOLOGY AND FISHERY OF CEPHALOPODS (MOLLUSCA: CEPHALOPODA) ALONG THE MALABAR COAST

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By

P.K. Asokan

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Department of Zoology, University of Calicut, Kerala, 673 638 INDIA

Department of zoology,
University of Calicut.

Phone: 044-401144* 419 (Off.)
0494-400026
Calicut University P.O.
Kerala, INDIA, 673 635
Date: 29, December 2000

Dr.U.C.Abdurahiman
M.Sc., Ph.D., F.E.S.I.
Professor of Zoology

CERTIFICATE

This is to certify that this thesis is an authentic record of the work carried out by Shri.P.K.Asokan from November 1995 to November 1998 under my supervision and guidance in partial fulfillment of the requirements of the degree of **Doctor of Philosophy** under the faculty of Sciences of the University of Calicut. No part of this thesis has been presented for any other degree. I also certify that Shri.P.K.Asokan has passed the Ph.D preliminary qualifying examination held in 1998.

U.C.Abdurahiman

DECLARATION

I do hereby declare that the present work is original and has not been published or submitted in part or full for any degree or prize.

C.U.Campus
27, December 2000

P.K.Asokan

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CHAPTER - 1

INTRODUCTION

Cephalopoda - the octopuses, squids and cuttlefishes - comprise one of the most significant components of marine life. All are large, fast-growing, and active predators with highly evolved and specialized qualities of great inherent interest. There are approximately 650 recognized species of cephalopods alive today and more than 10,000 fossil forms. Cephalopod translates literally into "head footed" which explains why squid, as well as the nautilus, cuttlefish and octopus among others, with their arms and tentacles attached directly to their heads, is so named. Cephalopods are found in all of the world's oceans, from the warm water of the tropics to the near freezing water at the poles. They are found from the wave swept intertidal region to the dark, cold abyss. All species are marine, and with a few exceptions which tolerate brackish water.

Large populations of cephalopods are found in all the world's oceans from the surface to the deep sea. They are major food resources for many top predators such as whales, dolphins, seals, birds and large fish. Worldwide, between 1990 and 1997, cephalopod landings increased steadily from 2.4

million tonnes to 3.3 million tonnes. Japan accounted for 20% of the world cephalopod landings in 1997 (Globefish, 1997).

Squids are by far the main cephalopod species caught in the world representing 73% of the cephalopod world catches. During 1997, the world total squid landings were 2.4 million tonnes. Squids represent a major fishery resource widely distributed throughout the oceans of the world. Of the several hundred species harvested around the world, only the Indian squid (*Loligo duvauceli*) has been of major commercial importance to the Malabar area. This species is common throughout the East and West Coast of India. The needle squid *(Doryteuthis sibogae)* also occurs, but only in very low abundance. The other squid is the big fin squid *Sepioteuthis lessoniana* found in the Palk Bay area where a fishery exists.

Distribution and Migration

The Indian squid, *Loligo duvauceli* forms fishery all along the coast from Gujarat to Orissa. Abundance and distribution vary greatly, both seasonally and annually.

Distribution of the squids is believed to be strongly influenced by environmental conditions, with water temperature being a major factor. Evidence suggests that highest concentrations occur in the inshore areas during the post-monsoon period when spawning congregations have been noticed. There seems little doubt that thermocline at intermediate depths as well as other biological factors such as predator and prey abundance and their distribution also plays an important role in this migration.

Life History

The Indian squid *Loligo duvauceli* lays egg capsules and these form egg mops consisting of gelatinous fingers. Each capsule contains 125 to 150 eggs (Asokan and Kakati, 1991). The egg measures 2mm in length and 1.75 mm in width. The young squids on emergence measure on an average 1.8-mm in DML and 3.17 mm in total length including arms. The hatching takes about 13 days to emerge. Large-scale destruction by the shore seines during the breeding season is noticed. The study of the ova diameter shows that *Loligo duvauceli* is a continuous spawner.

The food of *Loligo duvauceli* consists of prawns, crabs, stomatopods and euphasids and a variety of finfishes (Kore and Joshi, 1975). Smaller squids tend to feed more heavily on small crustaceans such as euphasids, turning more to fish and fellow squid as they mature. Squids are also a food source for a variety of fish, marine mammals and birds. Some of the better-known predators of squids in Indian waters are skipjacks, *Katsuwonus pelamis* (Raju, 1964), *Euthynnus affinis affinis*, *Auxis thazard*, *A.thynnoides* (Kumaran, 1964). Many other species of deep-sea sharks, eels, flatfishes and catfishes have been reported to feed on a variety of cephalopods. The squid *Loligo duvauceli* show sexual difference in growth rate.

The Fishery and Resource Management

The success of the fishery depends critically on the state of the fish stocks (Gulland, 1983). The squids and cuttlefish have fewer eggs production compared to the finfishes and prawns. Nabhitabhata (1996) found that there are 1000 egg clusters in *Sepioteuthis lessoniana* and 1500 egg clusters in *Sepia pharaonis*. The squids have spawning congregation and mating behavior also. With the increasing trawling activity and targeting the cephalopod, the cephalopods need regular monitoring to avoid a possible collapse of the fishery as observed in the case of catfishes of Malabar.

The rapid rise in catch the late 1970s were mainly due to the emergence of export market. Before that it was used as baits and formed a sustenance fishery. During 1995-96, India exported 8,1139 tonnes of cephalopods valued at Rs.592 crores (MPEDA, 1996). In Karnataka, the stocks of *Loligo duvauceli* has been found to be marginally over exploited (Mohammed and Rao, 1997) while the stock of cuttlefishes are under exploited or at optimum level of exploitation.

Unlike other large commercially viable species of fish, each generation of squid generally appears only once in the fishery because of their rapid growth and short life span, making it difficult to evaluate and project the likely size of subsequent populations. Consequently, management of the squid resource has to be directed primarily at ensuring that exploitation does not reach levels that would unduly jeopardize the reproductive capacity of the stock. In general, this has meant application of conservative Total Allowable Catches (TACs), which do not reflect annual changes in available stock. In many parts of the world, the highly cyclical nature of this resource, with its large fisheries impact, has quickly brought the biological and management problems into focus.

In the Malabar area, squid resources came to limelight with the opening of the export market in 1970's. It soon became a target species of highly ambitious trawl fishery. The total catches of cephalopods in India quickly shot from 1,505 tonnes in 1971 to 1,13,855 tonnes by 1997. Soon the strains of the pressure of exploitation were evident. The fecundity of the species is low. Overfishing can easily affect the natural resilience of the species. At present the exploitation of the species is uncontrolled. It is high time we studied the dynamics of the major species of squid for managing their exploitation and protecting the population from destruction.

Loligo duvauceli is the most important constituent of the cephalopod catches of the Malabar area. Detailed studies were made on the biology and population dynamics of the species in relation to the present fishery to recommend measures for management to protect the sustainability of the resource. A study on the growth and population dynamics of the important cuttlefish *Sepia aculeata* was also carried out.

MATERIAL AND METHODS

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CHAPTER-2

MATERIAL AND METHODS

The area of study included the four districts of Kasaragod, Cannanore, Calicut and Malappuram. As the bulk of the trawl catches were landed at Puthiappa and Beypore, regular landing data were taken from Nov 1995 to Dec 1997. The positions of the major and minor fish landing centres are shown in the Fig 2.1.

2.1.Catch and Effort:

Catch and effort data were collected on a regular basis by the sampling design adopted by the CMFRI, which is based on the stratified multi-stage random sampling technique, the stratification being over space and time.

From the landings of the observed fishing units, the landings for all the units landed during the observation period are estimated. By adding the quantities landed during the two six hour periods and during the night (12 hours), the quantity landed for the day at a centre, is the landings for each centre day included in the sample is estimated. From these, the monthly zonal landings are obtained.

$$YiJk = \frac{NiJk}{N} \sum_{i=1}^{n} YiJkl$$

Fig 2.1. Area of the present study

Districts

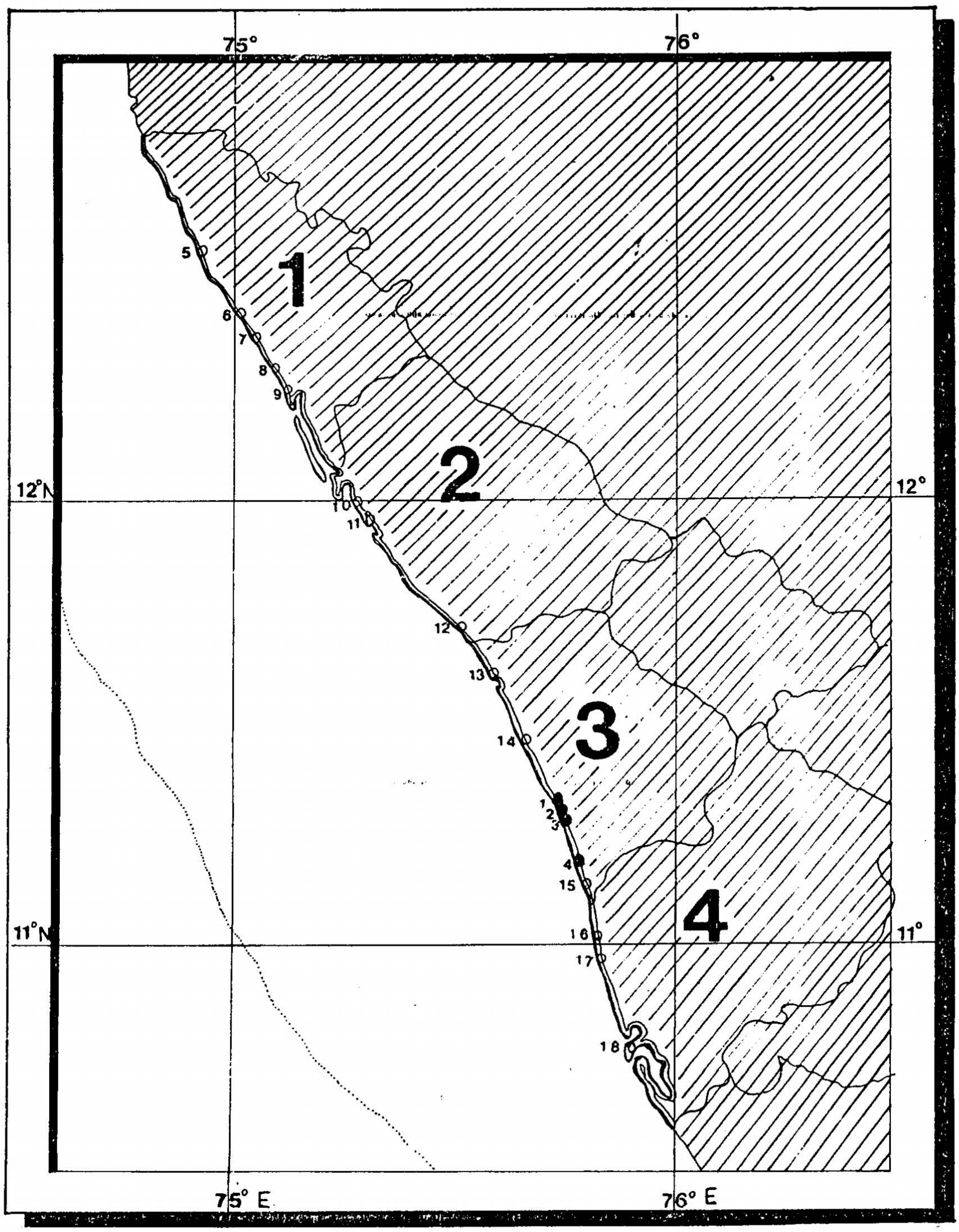
1. Kasaragod
2. Kannur
3. Kozhikode
4. Malappuram

Landing centres of regular observation

1. Puthiappa
2. Puthiangadi
3. Vellayil
4. Beypore

Landing centres observed occassionally.

5. Adakathibail
6. Kottikulam
7. Pallikere
8. Hosdur
9. Kanjangad
10. Puthiangadi
11. Ayikere
12. Thalasseri
13. Vadakara
14. Quilandi
15. Parappanangadi
16. Tanur
17. Ponnani



75°
76°
12°N
12°
11°N
11°
75° E
76° E
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Where YiJk is the estimated landings for the k th month in the j^{th} zone . NiJk is the number of landings centre days in the k th month for the respective zone, n is the corresponding number of centre days actually sampled and YiJkl is the estimated yield for the l th landing centre-day in the sample for the respective space time stratum.

2.2. Length frequency distribution:

Data for the estimation of population parameters is obtained by sampling the commercial landings. The samples were taken before sorting is done to get an unbiased sample. The samples were collected once in a week, depending upon the availability of the samples. A minimum of 50 samples was measured for the dorsal mantle length (DML). The biological data were collected and recorded. The gonads were weighed for estimating the fecundity. Individual length and weight were estimated to find the length-weight relationship. The length measurements were arranged in length groups.of 5mm intervals and the frequencies were recorded.

The relationship between the length (L) and the weight (W) of the fish can be expressed by the equation:

$$W = aL^n$$

Where 'a' is the multiplicative factor and 'b' lies between 2.5 and 3.5. In most of the squids the value of b $\neq$ 3 and hence weight growth is allometric.

When pairs of length-weight data are available, the value of a and b in the length-weight relationship can be computed by means of linearised form of the equation, namely

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

2.3. Age and Growth

Growth is the change of size of a living organism with age. The fishes differ from higher animals like mammals in that they appear to continue to grow throughout their lives. Mammals and birds tend to grow to the adult size and then retain their size for the large part of their adult lives.

Age and growth was estimated by using FiSAT (FAO-ICLARM Stock Assessment Tools) programme. The von Bertalanff's growth model expresses body length as a function of age. The equation is expressed as:

$$Lt = L\alpha\,[1 - \exp(-k.\,(t-t_0))\,]$$

Where $L\alpha$ is the asymptotic length or the mean length the fish would reach if allowed to grow indefinitely. K is the rate at which $L\alpha$ is approached and t_0 is the age of the fish at zero length.

It has been shown by various workers that seasonal oscillating features like temperature, food availability etc cause seasonal oscillating growth of fishes. Somers (1988) has given the modified VBGF as:

$$L_t = L_\alpha \left[1 - e^{-k(t-t_o) - (CK/2\pi)[\sin 2\pi(t-t_s) - \sin 2\pi(t_o-t_s)]} \right]$$

Where the additional parameters C and ts are the intensity of growth oscillations of growth curve and the onset of the first oscillation relative to t=0, respectively.

ELEFAN I (Electronic Length Frequency Analysis) programme estimates the growth parameters from sequential length-frequency data. The parameter ts is replaced by WP (winter point) when the growth is the slowest.

$$WP = ts + 0.5$$

The parameter t_0 is replaced by parameter ts, expressing the origin of the growth curve as fraction of a year as 'starting point' through which the growth curve passes.

Identifying the peaks and trough and separating the peaks attains the best fit or optimum fit for a growth curve in ELEFAN. ELEFAN I calculates the maximum sum of points available in the length frequency data called ASP or the available sum of peaks for a given set of $L\alpha$ and K values.

The points by each growth curves when passing through peak (positive points) or trough (negative points) are accumulated. The curve that passes through most peaks and avoids most trough is selected as it accumulates the largest number of points. The new sum is the ESP or the explained sum of peak.

The criterion for the best fit is the Rn factor, the range being 0 to 1.

$$Rn\ (= 10^{ESP/ASP/10}) \quad \text{where } 0 < Rn < 1$$

2.4. Mortality:

The reduction in number s in a cohort is caused by fishing activity and due to all other causes like predation, disease and death due to old age. The latter is called together as natural mortality and the former as fishing mortality. The combination of both the factors gives the total mortality.

2.4.1. Fishing mortality

The length converted catch curves are commonly used as they are functionally equivalent to age and age data are difficult to obtain. It consists of a plot of the natural logarithm of the number of fish caught in various age groups (Ci) against the corresponding age or age groups (ti):

$$Ln(Ci) = a + b.ti$$

Z is estimated from the slope b.

As the fish growth in length is not linear, but slows down as length and age increase. This slowing down has the effect that older size groups contain more age groups than do younger size groups or they "pile up" (Baranov, 1918) in the size classes pertaining to the old, large, slow-growing fish.

Ricker (1975) and van Sickle (1977) appraoches this problem by multiplying the number in each length classes by the growth rate of the fish in that class. This result in a catch curve equation of the form:

$$Ln(Ci) . (\Delta L_i/\Delta t) = a + b . ti$$

Where $\Delta L_i/\Delta t$ is the growth rate and ti the relative age corresponding to the length class i.

2.4.2. Natural mortality

Natural mortality is the mortality created by all other causes than fishing, e.g., predation, cannibalism, disease, old age etc. An idea of the value of the natural mortality can be gauged from the growth pattern of the species concerned. A fish that approaches its ultimate length quickly (high value of K) is likely to have a high natural mortality (M), whereas a fish that grows slowly (low value of K) is likely to have a low M. Natural mortality can also be demonstrated to be correlated with mean environmental temperature (Pauly,1980).

2.4.1.1. Pauly's M emperical equation:

Based on the data from 175 different fish stocks, the estimated emperical linear relationship established was:

$$\text{Log}_{10} M = -0.0066 - 0.279 \text{ Log}_{10} L\infty + 0.6543 \text{ Log}_{10} K + 0.463 \text{ Log}_{10} T$$

Where M is the natural mortality, $L\infty$ is the total length in cm, K is the curvature parameter of the VBGF and is expressed on an annual basis and the value of T s the annual mean habitat temperature (°C) of the water in which the stock in question lives.

2.5. Yield per recruit:

2.5.1. Beverton and Holt's method:

Beverton and Holt (1957) developed the yield per recruit model describing the state of the stock and the expected yield in a situation where a given fishing pattern has been operating for a long time or under steady-state conditions. The formula for estimating the yield per recruit (Y/R) is:

$$Y/R = F.e^{-Mr2}\ W\alpha \left(\frac{1}{Z}\right) - \left(\frac{3e^{-Kr1}}{Z+K}\right) + \left(\frac{3e^{-2Kr1}}{Z+2K}\right) - \left(\frac{3e^{-3Kr1}}{Z+3K}\right)$$

Where Z +F+M,

$r_1 = t_c - t_0$ and

$r_2 = t_c - t_r$

with $W\alpha$, K and t_0 being the VBGF growth parameters, t_c the mean age at first capture, t_r the mean age at recruitment.

The recruits was estimated by the equation

$$Re = \frac{Y}{Y/Rp}$$

Where Yrp is the yield per recruit at the present F

Yield at F id estimated by:

$$Y = Re.\ Y/R_F$$

Where Y/R_F is the yield per recruit at corresponding F value.

Maximum sustainable yield (MSY) was estimated by:

$$MSY = Re.\ Y/R_{max}$$

Where Y/R_{max} is the maximum value of Y/R.

F_{max} is the maximum value of F necessary to produce maximum Y/R

2.5.2. Thompson and Bell yield and stock prediction:

This model is used to predict the catches and stock size under given assumptions on further exploitation levels and mesh sizes. The analysis takes the fishing mortalities by length groups as input and calculates the numbers caught as well as the stock numbers. It requires the number of fish in the smallest length group and the natural mortality as input. The yield (catch in weight) in length group is:

Yield (Li,Li+1) = C(Li,Li+1) * W(Li,Li+1)

Where W(Li,Li+1) is the mean weight of fish of length between Li and Li+1 which is calculated from:

$W(Li,Li+1) = q * (Li^b + Li+1^b)/2$

Where q and b are the parameters in the Length- weight relationship.

The mean number of survivors times Δt, where Δt is the time it takes to grow from length Li to Li+1 in length group I and is given by:

Nmean (Li,Li+1) * Δt = (N(Li) – N(Li + 1)) / Z(Li,Li+1)

And the corresponding mean biomass times Δt is:

Biom (Li,Li+1) * Δt = Nmean (Li,Li+1) * Δt *W(Li,Li+1)

2.6. Sea-water analysis

Sea water samples collected from the near shore area of Calicut was analysed following the standard procedures given in Strickland and Parsons (1968):

Salinity: Argentometric method wherin the precipitable halide halogen in a 10 ml volume of sea water are determined by titration with a silver nitrate solution using a chronate end point. The silver solution is standardised against 10 ml of standard seawater.

Oxygen: Modified Winkler procedure was followed. By the addition of divalent manganese solution and followed by strong alkali, manganous hydroxide is precipitated and dispersed in the stoppered glass bottle. The dissolved oxygen oxidises an equivalent amount of divalent manganese to basic hydroxides of higher valency states. When the solution is acidified in the presence of iodide, the oxidised manganese again reverts to the divalent state and iodine, equivalent to the original dissolved oxygen content of the water, is liberated. This iodine is titrated with standard thiosulphate solution.

Phosphate: The sea water sample is allowed to react with a composite reagent containig molybdic acid, ascorbic acid, and trivalent antimony. The resulting complex heteropoly acid is reduced *in situ* to give a blue solution the extinction of which is measured at 8850 Å.

Silicate: The seawater is allowed to react with molybdate under conditions, which result in the formatiom of complexes. A reducing solution containing metol and oxalic acid is then added which reduces the silicomolybdate complex to give a blue reduction compound, the extinction of which is measured.

Nitrate: The nitrate in the seawater is reduced to nitrite when a sample is run through a column containing cadmium filing loosely coated with copper. The nitrite so produced is measured as given for nitrite.

Nitrite: The nitrite in the seawater is allowed to react with sulphanilamide in an acid solution. The resulting diazo compound reacts with N- (1-naphthyl)-ethylenediamine and forms a highly coloured azo dye, the extinction of which is measured.

2.7. Histology

The ovaries for histological studies were taken fresh, cut into convenient size to allow proper infiltration of fixative and then transferred to the fixative (10% Neutral buffered formalin) overnight. The ovaries were then passed through series of grades of alcohol for dehydration. After complete dehydration, the tissue was put in xylene and then finally embedded in paraffin wax. The tissue was sectioned in 7 μ section. The sections were spread on a slide smeared with Mayer's albumin and carefully heated so that the stretching of the wax section is complete.

The dried slides were cleared in xylene, passed through alcohol grades and finally through distilled water and stained with haematoxylin. The slides were dehydrated using series of alcohol grades and stained with alcoholic eosin at 80% alcohol grade. After finally dehydrating, the slides were cleared in xylene and finally mounted in DPX.

REVIEW OF LITERATURE

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CHAPTER-3

REVIEW OF LITERATURE

In the oceanic waters, cephalopods are second only to the scrombroides. The world production of cephalopods stands around 2.78 million tons. In many areas of the world they were part of the by-catch of shrimp trawling. But of late, due to the export potential and the development of new markets, a large number of countries have given importance to cephalopod fisheries.

In the Malabar area, the squid *Loligo duvauceli* and to a smaller extent *Doryteuthis sibogae* are of commercial importance. The cuttlefishes of commercial importance are *Sepia pharaonis* and *S.aculeata.*

Earliest work on cephalopods of the Indian waters were on systematics by Goodrich (1896), Massy (1916), Adams (1939) and Adam and Rees (1966). Hornell (1911) was the first to describe the fishing of squids in the Palk Bay. Rao (1954) gave a detailed account of the fishery and biology of the Palk-Bay squid *Sepioteuthis lessoniana.* Silas (1968) gave details of the distribution of the 201 species of cephalopods in Indian waters. Most of the information on the biology and distribution of the cephalopod resources of Indian waters were the result of the researches by Central Marine Fisheries Research Institute and the Fishery Survey of India.

3.1 Size at first maturity

In all the areas studied along the Indian coast, the males of *Loligo duvauceli* mature earlier than females. Along the East Coast of India, the length at first maturity is 76mm for males and 86 mm for females, whereas along the West Coast it is about 110 mm in males and 120 mm in females (Silas *et.al,* 1982). However, Rao (1988) in his study at Mangalore found that mature males occurred from a length of 70 mm and above and 50% reached maturity at 124 mm (120-129 mm length group). In the case of females, the size at first maturity was found to be the same at 70 mm but the 50 % level was at 108 mm (100-109 mm group).

Studies conducted by Silas *et.al.* (1985a), on the maturity of *Doryteuthis sibogae* at Vizhinjam showed that the males attain maturity in about the size range of 70-170 mm and 50 % at a length of 97 mm. The females mature at a size range of 70 – 130 mm and 50 % mature at 84 mm.

3.2 Sexuality and Sex-ratio

Many maturity scales for cephalopods are available that are species specific. Juanico (1983) has exhaustively reviewed the published descriptions of maturity scale of male and female squids. Lipinski (1979) proposed a universal scale.

Loligo duvauceli is heterosexual and hectocotylization of the left ventral arm is distinguishable. The males grow larger than the females. At Vizhinjam, on the West Coast, females were dominant (F58:M42). Only in 1-3 months especially during July, August and September, males were the dominant sex (Silas *et.al.*, 1985a). Along the Cochin coast, males were dominant during February to March and September to October. However, along the Bombay coast, sex ratio did not show any particular pattern of seasonal change. Rao (1988) found that at Mangalore females were significantly dominant in February, April, May and November. In general, a dominance of females was observed at lengths below 150 mm and after that there was a sudden decline. The dominance of males beyond the length of 150 mm was found to be significant. Along the East Coast, at Waltair, females were generally the dominant sex. However, in some years during certain months the males were dominant. At Kakinada and Madras coast, males were the dominant sex (Silas *et.al,* 1985a).

In *Doryteuthis sibogae*, the species is heterosexual and apart from hectocotylisation of the left ventral arm, the males grow larger and are slender with concentration of chromatophores on the ventro-medial region of its slender body. At Vizhinjam, females of *D. sibogae* were generally the dominant sex when the annual ratios were compared. Males dominate especially during the months of December to March (Silas *et.al,* 1985a).

3.3 Spawning congregation, mating and egg laying

Vecchione (1988) using remote controlled submersible off Charlotte harbour in Florida found large clusters of egg capsules (possibly that of *Loligo plei*) in the sandy bottom. Such spawning pattern may result in large numbers of squids being concentrated over patches of suitable substratum.

Spawning congregation of *Loligo duvauceli* has been noticed along the West Coast of India. Meiyappan and Srinath (1989) had recorded the congregation along the Alleppey coast during September-October 1978. Asokan and Kakati (1991) observed the spawning congregation of *Loligo duvauceli* along the Karwar coast during September-October period and the availability of egg mops in large quantities in the shore seines. Mohammed (1993) observed spawning congregation in Mangalore and Malpe area during September-October and based on the low gonadosomatic index and slow growth after attaining sexual maturity highlighted the non-semelparous nature of *Loligo duvauceli*.

Arnold and Arnold (1977) observed that in *Loligo pealei* mate selection and copulation can be initiated with visual stimulus of an egg mass, either real or artificial or even occur spontaenously in animals held in captivity over a period of time. Mating behaviour occurs after dark or dawn when they can be easily stimulated.

In *Loligo pealei* the male protects the mate against the advances of other males to maintain a social hierarchy based on their size, aggressiveness and persistance. Copulation occurs in head to head and by side to side position. During copulation, the hectocotylus puts up a bundle of spermatophore and deposits them in her buccal pouch. This whole process takes only a few seconds (Arnold and Arnold, 1977).

In cephalopods, the gametes are highly protected by specific structures. The male spermatozoa are enclosed in spermatophore and females produce protective envelope for the eggs secreted by the nidamental glands during spawning. In *Ilex illecerebrosus*, upto 1000 spermatophores are seen stored in the Needham's sac (Mangold, 1987).

Ikeda *et.al.* (1993) studied the fertilizing capacity in spermatozoa taken from different areas in the male and female squid *Todarodes pacificus*, by inseminating the eggs in the presence and absence of the gelatinous substance of oviducal gland. Spermatozoa collected from female's seminal receptacle showed 95-99% rate of fertilization. The spermatozoa collected from male's accessory gland could fertilize 89 to 98 % of the ovum and the spermatozoa collected from the male's vas deferens could fertilize only 30 –

50 %. This shows that the spermatozoa become fertile long before they are transferred to the female's seminal receptacle.

Maturing takes place throughout the year with mature males and females recorded along both the coasts. In *Loligo duvauceli*, spawning is reported throughout the year, but usually attains its peak when water temperature increases i.e., February and June to September off Madras; from February to March, from May throughout July and from September to October off Cochin. At Vizhinjam, spawning females were not observed, spawning males were observed in small numbers during August-October. Along Cochin coast, spawning females were recorded in small numbers except during July-August and spawning males were seen in all the months except for February-March and July-August forming good percentage during June and October-December (Silas *et.al,* 1985a). Along Bombay coast, mature females were common from January to May and in September. Spawning females occurred during May-June and October to November. The studies showed that along both the coasts the spawning season of *Loligo duvauceli* is rather a prolonged one with peaks at varying months. In *Doryteuthis sibogae*, mature females were recorded in October, December and January to April with dominance in December, January and February. Mature males occur from October to April (Silas *et.al,* 1985a). The occurrence of mature squids during October-April suggests that the spawning season of the species is protracted (Silas *et.al,* 1985a).

3.4 Fecundity

The spawning behaviour, timing and place of the laying of the egg masses are of considerable importance from the fisheries management perspective. No throughly systematic study of fecundity is available with which to evaluate factors affecting fecundity within the population or seasonal and temporal trends. It is known that mean fecundity can differ significantly at differnet localities (Boyle *et.al.*, 1988). Since the coleoids are gererally supposed to breed only once, egg counts from a mature individual egg mass can potentially give the lifetime fecundity. The position is complicated, as there is differences in the duration of spawning (Boyle, 1990).

The number of eggs in *Loligo vulgaris* from southern Portugal varied from 1441 to 14,886 and the fecundity was correlated with mantle length, body weight and length and weight of the nidamental gland (Coelho *et.al*, 1994).

Rao (1988) estimated the fecundity in *Loligo duvauceli* to range from 1500 to 13,156 with an average of 5284. A significant correlation between length and fecundity and ovary weight and fecundity was found.

The relative fecundity of *Loligo duvauceli* was found to range between 60 to 86. The values peaked between 110 mm and 140 mm, indicating the size at which the most spawning takes place. A sharp decline in the relative frequency beyond 140 mm was observed.

The Order Teuthoidea has two suborders, Myopsida and Oegopsida. The former is the open eyed and is found in deeper waters and the latter is the covered eyed found in shallower areas. Loliginidae is the major family of Myopsids and this covered eye is believed to be an adaptation to the sediment rich waters of the coastal areas (Morton and Young, 1964). The Myopsids produce egg mops of gelatinous materials fixed to hard substratum in the inshore waters where they come to breed. In contrast the Oegopsids produce eggs in large amorphous gelatinous massess, which are neutrally bouyant or floating (Durward *et.al.,* 1980 and O'Dor and Balch, 1985) and released in offshore surface waters. The number of eggs produced by the Oegopsids is much higher when compared to that of the Myopsids. Sepioids and octopods have relatively small number of large eggs, well protected with various coasts and firmly fixed to a hard surface (Boyle, 1990).

Maxwell and Hanlon (2000) reared the squid *Loligo pealeii* and found that it can lay multipe clutches of eggs. 28 out of 47 females produced 5 or more egg capsules per clutch. The number of ova laid in capsules

(11,800 to 15,293) far exceeds the combined number of ova and oocytes remaining at death which are about 4500. Thus counting the remaining oocytes and ova can grossly underestimate the fecundity. Thus the spawning strategy of *Loligo pealeii* involves multiple oviposition over weeks or months with oocytes being developed continually.

The estimated fecundity of various squids and cuttlefishes are tabulated below:

Sl.No	Name	Fecundity range	Author
A) Oegopsids:			
1.	*Dosidiscus gigas*	1,00,000 – 6,00,000	Nesis (1970)
2.	*Todarodes pacificus*	3,20,000 – 4,70,000	Soeda(1956)
3.	*Illex illicebrosus*	1,00,000	Durward *et.al.*, (1980)
4.	*Gonatus fabricii*	10,000	Kristensen (1981)
5.	*Ornithoteuthis antillarum*	50,000 – 2,20,000	Arkhipkin *et.al.*., (1999)
B) Myopsids:			
6.	*Loligo vulgaris*	3500 - 6000	Mangold(1963)
7.	*L.pealei*	3500 - 6000	Summers(1971)
8.	*L.pealei*	2500 – 15,900	Vovk(1972)
9.	*L. pealei*	21,315 – 55,308	Hixon (1980)
10.	*L.duvauceli*	1500 - 13,156	Rao (1988)

C) Sepioids:			
11.	*Sepia officinalis*	500 - 1000	Mangold-Wirz (1963)
12.	*Sepiola robusta*	54	Boletzky (1987)
13.	*Sepiella inermis*	69 - 71	Unnithan (1982)

3.5 Embryonic development, Larvae and young ones

Cephalopods do not have a larval form in the strict sense. Hatchings resemble the adult body form in most essential features. In Ommastrephid squids, the rhynchoteuthion stage is distinctive as the tentacles are fused to form a median proboscis-like appendage (Boyle, 1990). Asokan and Kakati (1991) collected the egg mops of *Loligo duvauceli* from the shore seines operated in Karwar. The egg capsules were highly structured with a central spiral fold of jelly. It was found that the same egg mop had capsules of different stages of development. This indicated that the egg capsules in one mop may be contributed by different individuals in the same population to form a community pile (Morton, 1979).

The egg mass or mop consists of a gelatinous finger like capsule, containing about 125-150 eggs in them. The proximal end of the capsule formed an elongated gelatinous strand, and the end of the strand of each capsule entwines to form the egg mass (Asokan and Kakati, 1991).

The eggs are large and yolky, measuring on an average 2mm in length and 1.75 mm in width. It is encased in a chorion surrounded by a perivitelline space. The first embryonic organs appeared as thickening of the outer cell layer forming the mantle. The mantle increases in size and spread towards the animal pole. The mantle formed a prominent ring, which grows over the developing visceral organs forming the mantle cavity. The eyes, appear as thickening palcodes on either side of the embryo and the arms as thickened buds slightly above the equatorial constriction. The mantle grows downwards and covers almost upto the funnel. The hatching of *Loligo duvauceli* measured on an average 1.83-mm in DML and 3.17 mm in total length including the arms with a mantle width of 1.55-mm (Asokan and Kakati, 1991).

3.6 Distribution of juvenile and adult

Hatfield and Rodhouse (1994) found that the greatest abundance of the juveniles of *Loligo gahi* in Falkland waters were observed of <100 meters in the south and east of east Falkland. These juveniles aggregate close to the sea floor and are more available by night than by day. The distribution suggested that the austral winter/spring spawning ground of *L.gahi* be probably situated to the south and east of the Falkland Island. Near bottom collection of the euryhaline squid, *Loliginicula brevis* was made by

Vecchione (1991). The paralarvae were observed in the coastal waters of Lousiana from April through January, but in eustuarine waters only in May, July and August. The abundance of the paralarvae was greatest in the salinity of about 26 ‰. Unlike in the case of *L.gahi*, the abundance of paralarvae was found to be greater during daytime. Vecchione and Roper (1986) found that the larvae of *Illex illecebrosus* concentrate in waters where density (σ t) is approximately 26.7, indicating that spawning occurs in the subsurface interface where slope waters mixes with the Gulf stream.

In India, larvae of cephalopods have not been observed, but along both the coasts, juveniles of *Loligo duvauceli* (measuring 45 mm) have been recorded at Waltair, Kakinada, Madras and Cochin throughout the year. Adults of *Loligo duvauceli* were observed from knee deep waters upto a depth of about 80 meters on the continental shelf on both the coasts. At Madras, the size range of males and females, caught in trawls were 50-150 mm and 70-155mm respectively. At Waltair, the size range is slightly higher at 50-175 mm for males and 70-155 for females. In the West Coast at Bombay, the adult males upto 285 mm and females measuring 80-165 mm were caught in the trawl nets and down south at Cochin and Vizhinjam the size range were 90-255mm for males and 90-190 mm for females (Silas *et.al*, 1985a).

At Vizhinjam, juveniles of the squid *Doryteuthis sibogae* measuring 20-60 mm are caught during January to February and sometimes upto June in shore seines and adults measuring 70-205 mm are caught in shore seines, boat seines and hooks and lines (Silas *et.al*. 1985a).

The commercial fishery for the loliginid squid, *Loligo gahi*, operates over a realtively narrow part of the species lifetime depth range. *L.gahi* is known to migrate from shallow coastal waters down to the restricted depths at whch the fishery operatesinto the deeper waters of the shelf and slope as it grows and matures (Hatfield *et.al.*, 1990). Hatfield and Rodhouse (1994) found that this migratory behaviour could introduce bias in sampling. The effects of migration on the interpretation of modal progression analyses have been demonstrsted in *Illex illecebrosus* by Dawe *et.al.*, (1985). Two populations of these squids observed, one offshore and the other inshore. The discrepancy in the offshore population was likely to be due to the immigration of younger individual to the offshore areas (Hatfield and Rodhouse, 1994).

3.7 Feeding and Predation

Cephalopods, especially the squids are an important member of the marine food chain (Amaratunga, 1983). They seek the prey, feeding on crustaceans, fishes and cephalopods (Boucher-Rodin *et.al.*, 1987; Nixon, 1987). The cephalopods form the diets of marine mammals, fish and seabirds (Summers, 1983). Based on the diet of the black-browed albatross (*Diomedea melanophris*) chick fed by adults around Falkland Island, Thompson (1989) estimated that 500 – 1000 tonnes of *Loligo gahi* is consumed during one month period. Clarke (1977) estimated that in 1972, the sperm whales alone consumed 100 million tonnes of squids. Squids macerate the prey making identification of stomach contents difficult and the digestion is also rapid at about 4-6 hours (Bidder, 1966). Prey items lacking hard parts are also likely to be ignored (Nixon, 1987). The stomach comtents of *Loligo forbesi* showed crustaceans and cephalopods occurring in 26.4% and 7.5% respectively. The diets changed with size. Crustaceans were the main prey item in squids of less than 100-mm mantle length, together with clupeids and gobies. The medium sized squids (100 – 220 mm) were found to feed on gadiods and clupeid fishes while the largre squids (>220 mm) preyed on gadiods and other cephalopods (Collins *et.al.*, 1994). Cannibalism and predation on other cephalopods are usually restricted to squids of size greater than 100 mm in *L.forbesi* (Collins *et.al.* 1994). The feeding in the population of *Loligo gahi* was found to commence from afernoon (Hatfield *et.al.*, 1990) which has also been observed in the case of *L.forbesi* on the Faroe Bank (Gaard, 1987) and *L.pealei* in the north-west Atlantic (Vovk, 1985). It has been estimated that the annual squid consumption by seabirds as 40,000 tonnes in the NE North Atlantic, 63,000 tonnes in the SE North Atlantic and 3000 tonnes in the Mediterranean (Furness, 1994).

Kore and Joshi (1975) reported that at Ratnagiri the food of *Loligo duvauceli* consists of crustaceans, fishes and squids. The crustaceans included the mysids, euphausids and ostracods. A decrease in feeding intensity during spawning period was observed. Oommen (1972) found that crustaceans and fishes was the important diet of the squids. Prawns, crabs and squilla were the most common crustaceans and sardines, anchovies, mackerel, *Synagris* and *Lactarius* the most common food fishes.

The biology of *Doryteuthis sibogae*, is very poorly known as it was being taken as bycatch and also for restricted period in the fishery in most part of its area of distribution. The stomach contents of this species include fishes, cephalopods and crustaceans Silas *et.al.* (1985a).

Scrombroides like *Euthynus affnis affinis*; large sized *Auxis thazard* and *A.thynnoides* have been found to feed on *Loligo* sp at Vizhinjam. Silas *et.al.*, (1985a).

3.8 Growth and Maximum size

There is no general agreement as to a typical growth model for loliginid squids (Boyle, 1990). There has been extensive application of Von Bertalanffy growth function (Caddy, 1983) and a seasonally oscllating version advocated by Pauly (1985). In cephalopods, growth is slowed or becomes erratic at the onset of seasonal maturity (Boyle, 1990). Recently statolith has been used for ageing the squids. The markings are interpreted as 'daily' and 'monthly' in deposition (Spratt, 1978) or 'daily' and 'fortnightly' (in *Gonatus fabricii*; Kristensen, 1980).

In Vizhinjam, *Loligo duvauceli* grows to 69 mm at the end of 6 months, 122.2 mm in one year, 167 mm in 1 ½ year and 209 mm in 2 years. Along the Bombay coast a growth of 68.6 mm in 6 months, 124.4 in one year and 170.5-in 1 ½ year, 208.4 mm in 2 years was observed (Silas *et.al,* 1985a).

Along the east and west coasts, the growth difference is observed after one year of growth. While a growth of 149 mm is reached at the end of 1 ½ year along the East Coast, a higher growth of 167-176 mm is attained in West Coast. Again, along the East Coast, *Loligo duvauceli* grows to 209-220 mm in two years and 233-255 mm in 2 ½ years and 263 mm in three years. The largest size of male *Loligo duvauceli* recorded at Bombay and Cochin were 285 mm and 190 mm respectively. The largest adult male recorded along the East Coast were 170 mm at Madras and 184 mm at Kakinada. The largest female along both the coasts measured 190 mm (Silas *et.al,* 1985a).

Doryteuthis sibogae attained an average size of 113 mm and 182 mm at the end of first and second year. The longevity of the species is estimated to exceed over two years. The largest size of *Doryteuthis sibogae* recorded for males and females is 205 mm and 165 mm respectively (Silas *et.al*, 1985a).

3.9 Fishery

Squids and cuttlefish had been a part of the by-catch of indigenous fishery for a long time forming localised fishing in certain areas like the Palk-bay. In the twenty-three year period (1971-93), the lowest catch of cephalopod was 1026 tonnes in 1972 forming 0.104 % of the total marine catch and the highest was 96,889 tonnes in 1993 forming 14.31 % of the total marine catch of India. Barely 20 % of the production comes from East Coast and the rest from West Coast. Kerala, Maharastra, Gujrat and Tamil Nadu rank high in abundance of the species, with moderate catch from Karnataka and Andhra Pradesh Silas *et.al.* (1985b).

In Kerala, the area between Trivandrum and Neendakara contributed on an average about 94.5% of the total catch of the state in the years 1968-76. During the same period, the area between Ponnani and Kasargod showed poor landing of cephalopod with annual catches of 1.3 – 3 tonnes. Of the state's total cephalopod production, 48.9 % comes from trawl nets, 19.7% from hooks and lines, 16.8 % from boat seines and 14.6% from shore seines. The cpue of trawl nets was higher (6.2 – 22.8 Kg.) in July, September and October (Silas *et.al,* 1985).

In Kerala, the landing of cephalopods during the period 1975-81 was 11.9% of the total all India production of cephalopods. The annual cephalopod production varied from 17 tonnes and 714 tonnes during 1960-67 and increased to 1122 tonnes in 1968 followed by a decrease in 1970-73. During 1974 and 1975, the production was again higher at 2175 tonnes and 3342 tonnes respectively. The period 1977-81 was characterised by large fluctuations in annual landings between 2376 tonnes (1981) and 6516 tonnes (1978). The cephalopods constitute upto 1.8% of the annual marine fish production of Kerala and the state's contribution to the annual cephalopod production of the country varied from 7.3 % in 1970 to 90.3 % in 1960 (Silas *et.al,* 1985b).

3.10 Environmental factors and fisheries

Araya (1983) described the relationship between the Kuroshio currents and the fishery of the oceanic squid *Ommastrephes bartrami*. Pierce (1995) discussed the importance of sea surface temperature and salinity. The cpue of the squid *Loligo forbesi* in the UK waters have showed a positive correlation with both mean sea surface temperature and mean salinity in various months during the year and a negative correlation with the hydrographic variables for the summer squid fishery at Rockall. This in turn relates to the interannual variation in the strength of the North Atlantic drift. A reduction in squid production of 60 – 80% of the average catch along the California coast was observed when the *El nino* condition occurred in the equatorial Pacific during 1983 (Rathyen and Voss, 1987).

In squids, an upward migration is observed during darkness and this behaviour is exploited in the light fishery using jigs and gillnets when they are more distributed on the surface and bottom trawl fishery is more successful during daytime (Serchuk and Rathyen, 1974).

3.11 Stock assessment and management.

The cephalopods are short-lived and this poses difficulty in stock assessment, as the future catches are entirely dependent upon the recruitment, which is rather unpredictable. The management measures require being rapid, as changing the fishery strategies are few once the cohort enters the fishery. The biological characteristics like the occurrence of post spawning mortality, change in catchability due to spawning behaviour, effects of competition with fish species should be considered (Bravo de Laguna, 1989).

Two general categories of assessment are known: in season assessment and post-spawning assessment. The former makes use of data as they are collected to be used to adjust levels of fishing activity during the season, while in the latter based on complete dataset for a season to establish management goals for the following season (Basson *et.al.*, 1994).

The Japanese squid jigging fishery began as a "free fishery" in which anyone could participate without restriction. With the increase in effort in the late 1960's, a 'ministry approval system' was established to regulate the operation of large and midium sized squid jigging vessels. Further, fishery was permitted in specified approved fishering grounds and dring the period March to April no fishery was allowed. These measures were more of management of fishing operation rather than resource management (Murata, 1989). Squid jigging is species specific and there is normally little or no bycatch of protected or unwanted species (Rathyen and Voss, 1987).

Doi and Kawakami (1979) found that the decline in the winter spawning stock during the late 1960's and 1970's was due to an increase in fishing effort of 2.5 times during the period by examining the relationship between fishing mortality coefficient and reproduction. Araya (1985) reported that an upper limit to fishing intensity was attained during late 1960's. Based on the relationship between yiels per recruit and fishing mortality coefficient, Shimyu *et.al.*, (1983) recommended that the fishing sesaon for the winter spawning group should be moved to August – September. Hasagawa (1982) calculated that the MEY (Maximum sustainable economic yeild) occurred around 1965 level of effort when 6,00,000 tonnes were landed which is about half the fishing effort during 1979 and 1980. Murata (1989) suggested three ways to improve the management of the fishing of the common squid: a) reduction of total fishing effort by jigging vessels to half of the present level b) prohibition of fishing in the fishing ground for 1 or 2 years and c) extension of the fishing ban from December to June period.

The Saharan trawl fishery for cephalopods in the western African coast consists of Western Sahara, Maurtania, Senegal, Gambia, Guinea-Bissau and Guinea. FAO (1986) adhoc working group on cephalopod stock advocated reduction in fishing effort. This advice has been based on the result of production modelling, suggesting reduction in fishing effort applied in 1984 by 49% for octopus, 38% for cuttlefish and 60% for squids. This reduction in effort on cephalopod stocks would have increasing yields and spawning stocksizes and should maintain near previous levels. Other measures included the enforcement of 60-mm mesh size and a closed zone of 12 nautical miles from the coast.

Sanders (1979) studying the resource of the cuttlefish *Sepia pharaonis* in the People's Democratic Republic of Yemen found that substaintial gains are likely to accrue from raising the Lc, the length at first capture. To attain the increase in Lc, a minimum mesh size was annual stock and standing stock of the three major species have been estimated as 1800 tonnes (*Loligo duvauceli*), 1961 tonnes (*S.aculeata*) and 2352 tonnes (*S.pharaonis*) totaling to 5513 tonnes (Silas *et.al.*, 1985c).

Rao *et.al,* (1994) studied the stock of *S.aculeata* from different centres along both the coast of India for 1979-89 indicating that the production has increased many times in recent years, with bulk (88%) of the catches coming from trawl catches. On the West Coast of India the MSY of males varied from 3687 t to 7652 t and that of females from 4735 t to 11424 tonnes. To reach the MSY, the effort has to be increased by many times. On the East Coast, the MSY for males varied from 685 tonnes to 859 tonnes and for females from 1381 tonnes to 1750 tonnes.

Mohammed (1996) estimated the stock of *Loligo duvauceli* from Mangalore area and estimated the total average annual stock to be 1088 t and the maximum sustainable yield (MSY) was estimated as 877 tons.

ENVIRONMENTAL FACTORS

P.K. Asokan “Biology and fishery of cephalopods (mollusca: cephalopoda) along the malabar coast ” Thesis. Department of Zoology , University of Calicut, 2000

CHAPTER 4

ENVIRONMENTAL FACTORS

The fluctuations in the environmental conditions have a profound influence on the seasonal migration and occurrence of cephalopods and fishes. Furthermore, the coditions in the aquatic environment and their changes influence the recruitment, survival and growth. Thus, the survival, abundance and spawning success depend on the prevailing environmental conditions.

4.1.1. Rainfall:

Rainfall affects the physical and chemical characteristics of the inshore waters. Fig 4.1 gives the monthly rainfall from Nov'1995 to Nov'1997. The maximum rainfall for the period was during the month of July when 863 mm and 1456 mm rainfall was observed during 1996 and 1997 respectively. The peak period during southwest mosoon is during the months of June and July. A secondary peak is observed in October indicating the northwest monsoon (Fig.4.1).

4.1.2. Salinity:

The salinity increases from November after the monsoon and reaches its maximum around April –May in summer when it attains

Fig 4.1. Monthly rainfall from Nov'95 to Nov'97.

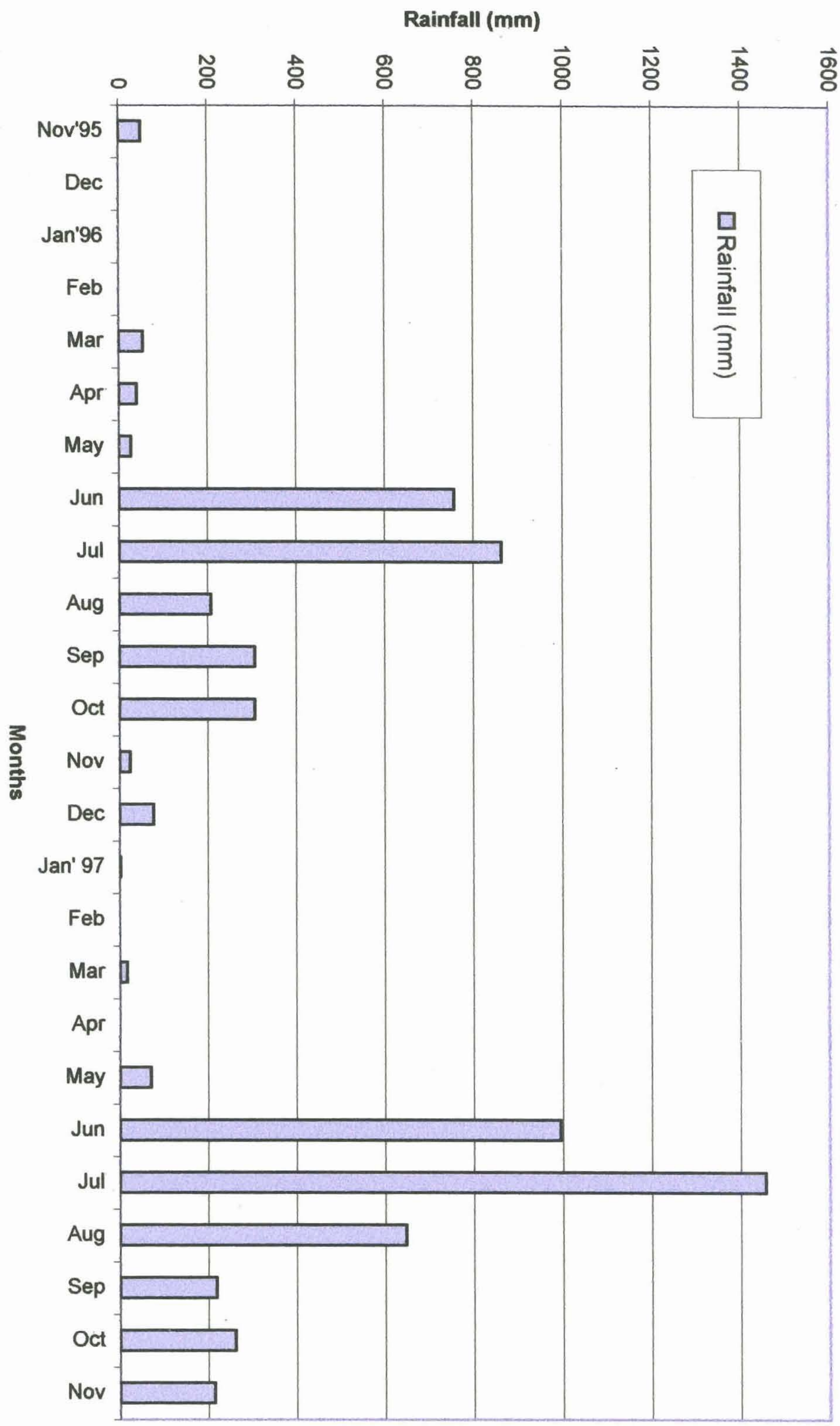
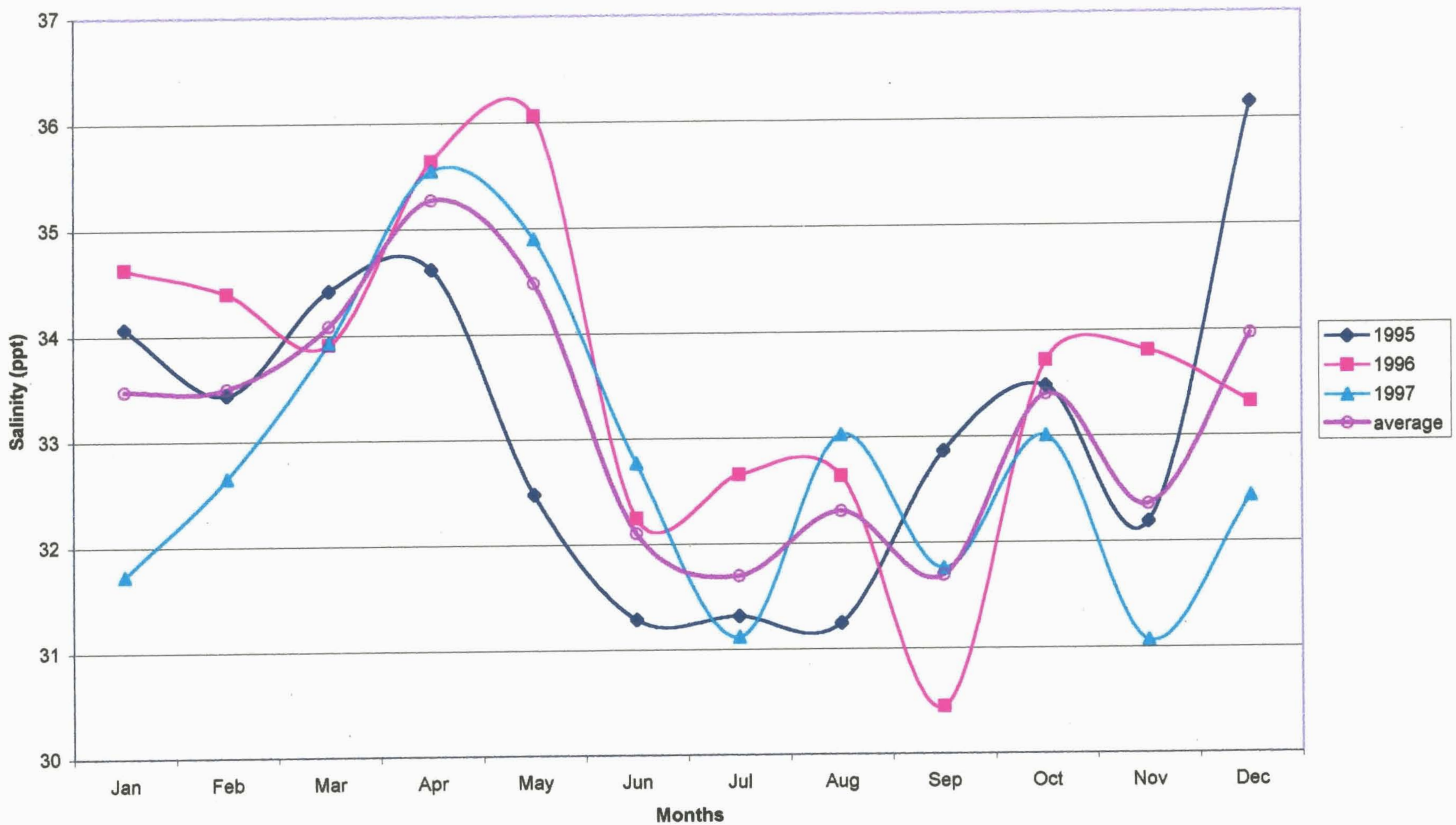

Rainfall (mm)
0
200
400
600
800
1000
1200
1400
1600
Rainfall (mm)
Months
Nov'95
Dec
Jan'96
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan' 97
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

Fig. 4.2. Average monthly values of salinity at Calicut from 1995 – 1997.

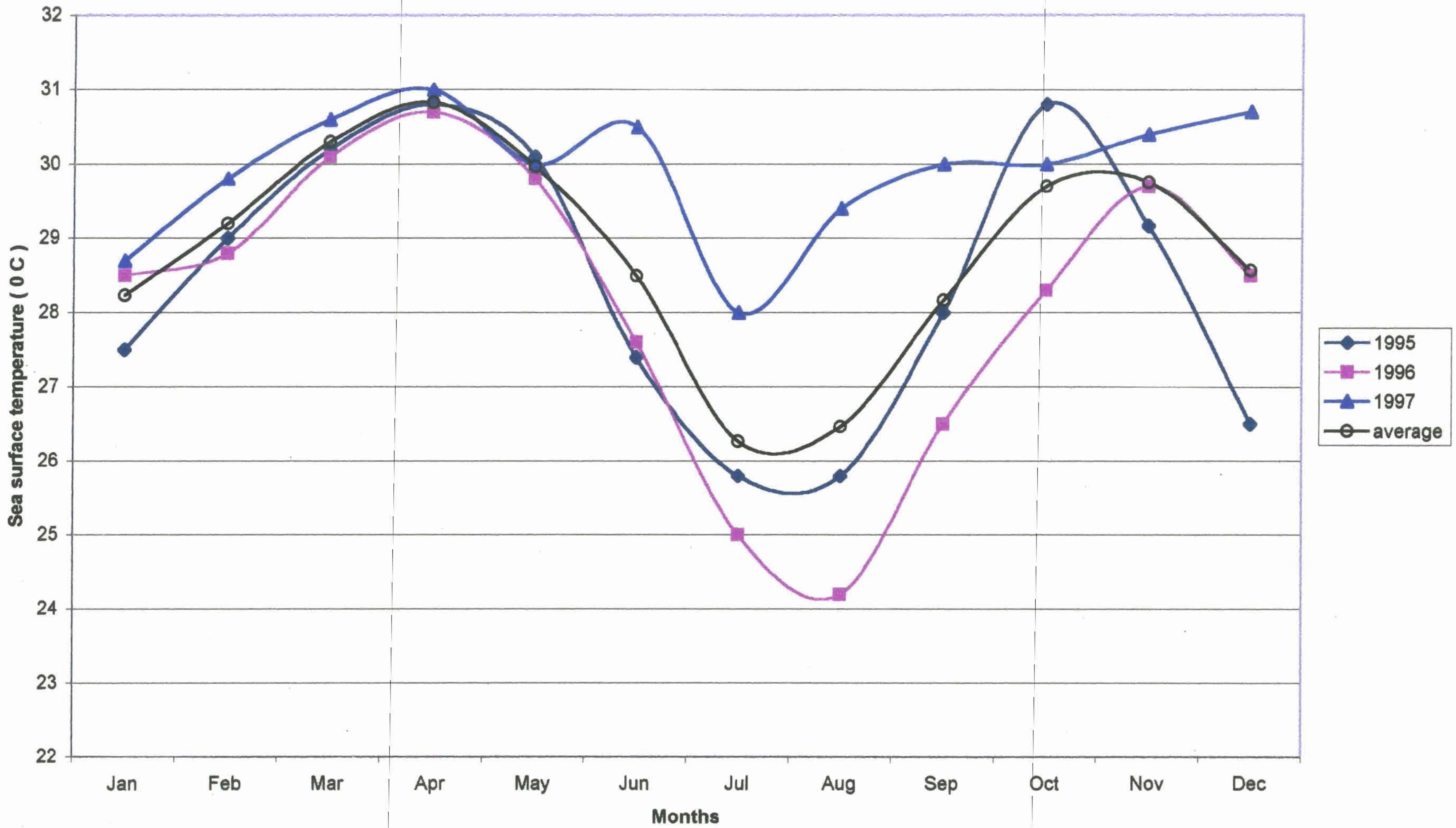
13

4x2D



Salinity (ppt)
37
36
35
34
33
32
31
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

Fig. 4.3. Average monthly values of sea surface temperature at Calicut from 1995 – 1997.



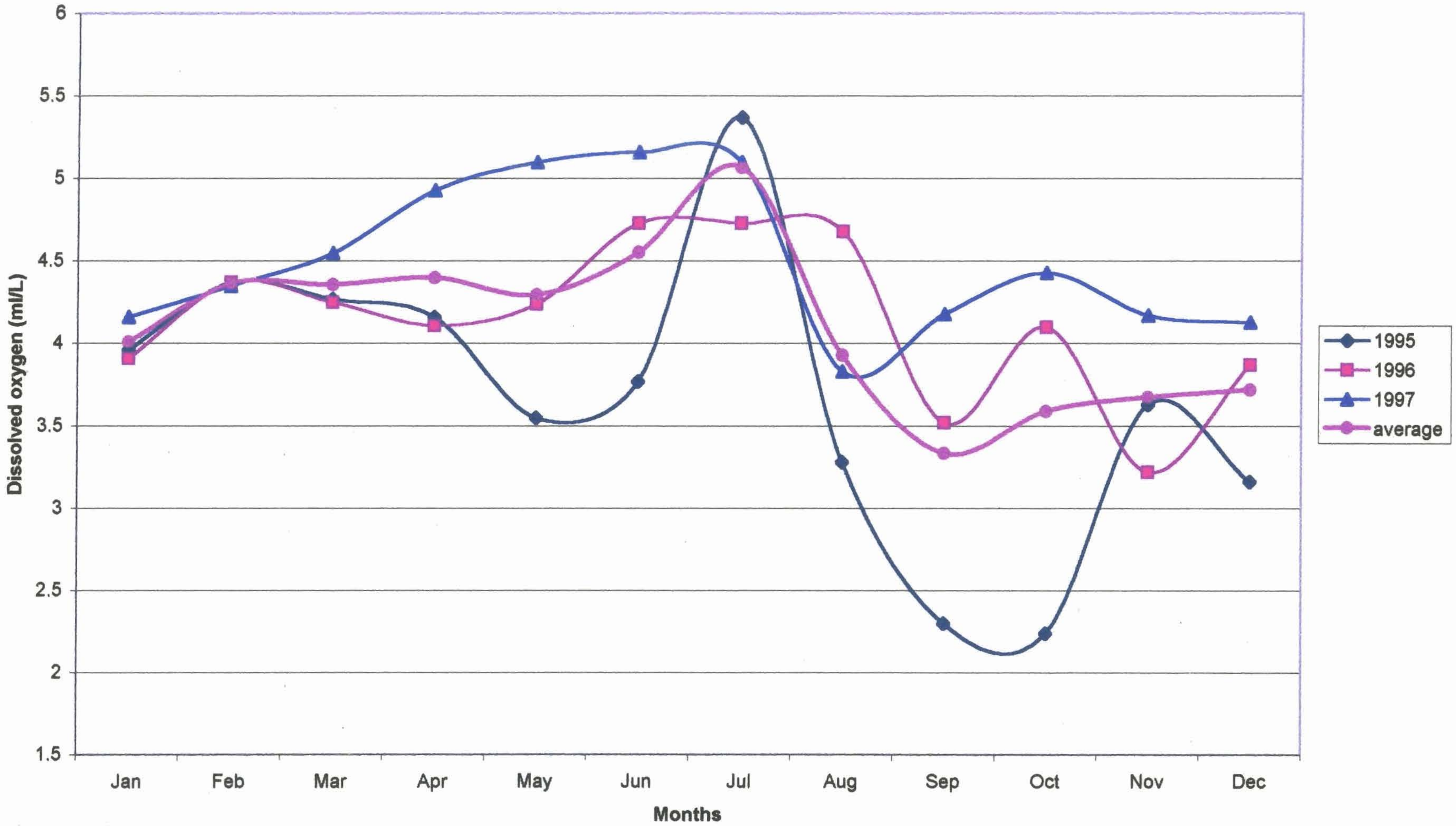
Sea surface temperature (0 C)
32
31
30
29
28
27
26
25
24
23
22
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

slightly above 35 ‰. During the month of July, the lowest salinity is recorded, as it is the month of peak monsoon activity. Again after an increase during August-September, a decline is noted during the Northeast monsoon during the month of October. This trend shifts every year slightly but by and large the pattern remains the same. Fig. 4.2 shows the values of salinity from 1995 to 1997 with the averages plotted. During 1996, the lowest salinity was recorded during September (30.45 ‰) and the highest was recorded during April (35.45 ‰). During 1997, the highest was again recorded during the month of April (35.55 ‰) and the lowest during November. More depression in the surface salinity was noticed in the Southwest monsoon period.

4.1.3. Temperature:

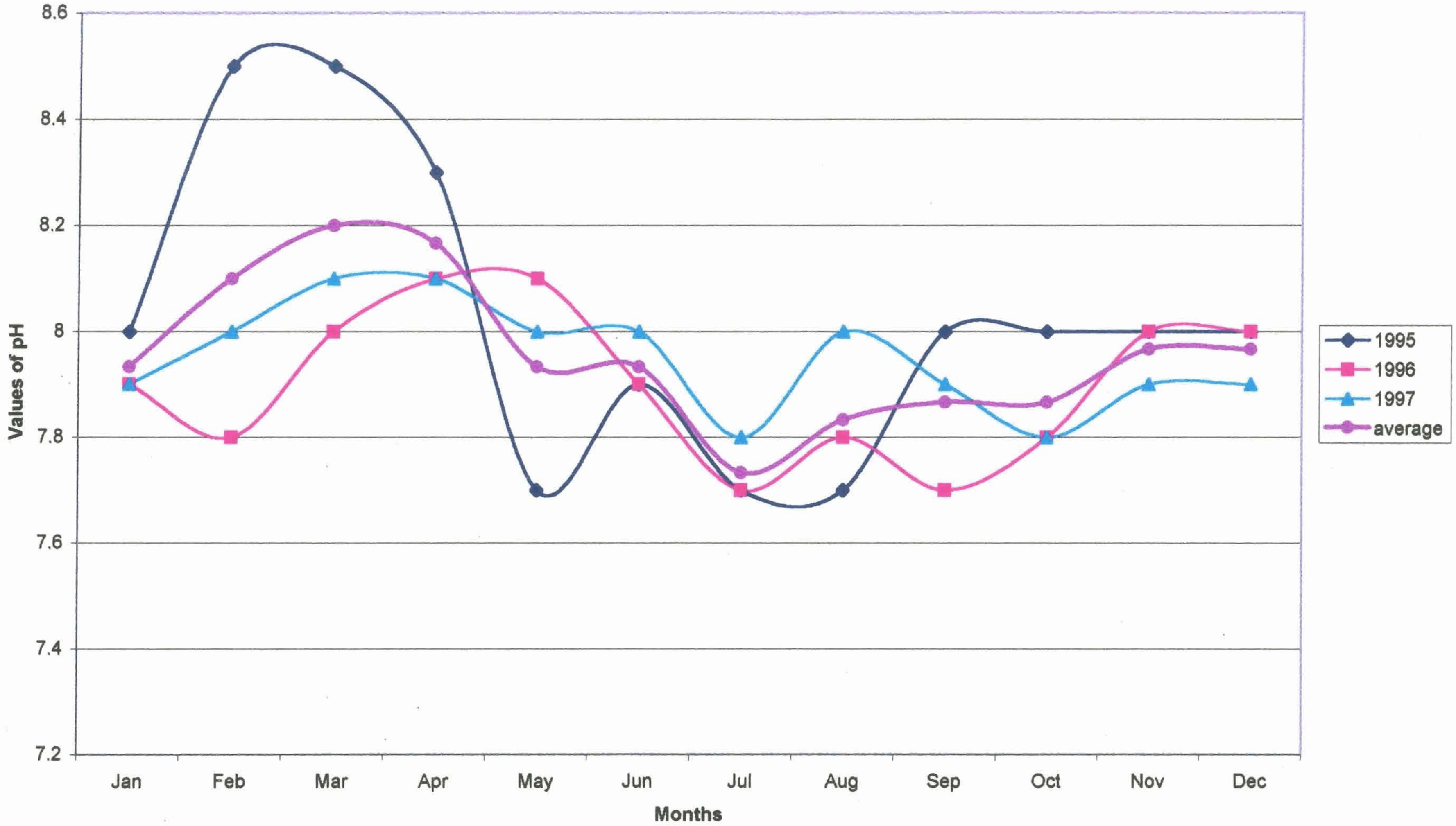
The temperature of the sea-surface shows the minimum during July – August when the Southwest monsoon is most active and due to the effect of upwelling. There is another decline in temperature during December/January due to winter cooling. The two maxima recorded are during the summer month of March-April and also during the month of October. The peak was observed during the month of April (30.9 ^{0}C) of the pre monsoon period and again during October-November period (29 ^{0}C) of the post-monsoon period. In 1995, during the post monsoon period the

Fig. 4.4. Average monthly values of dissolved oxygen at Calicut from 1995 – 1997.



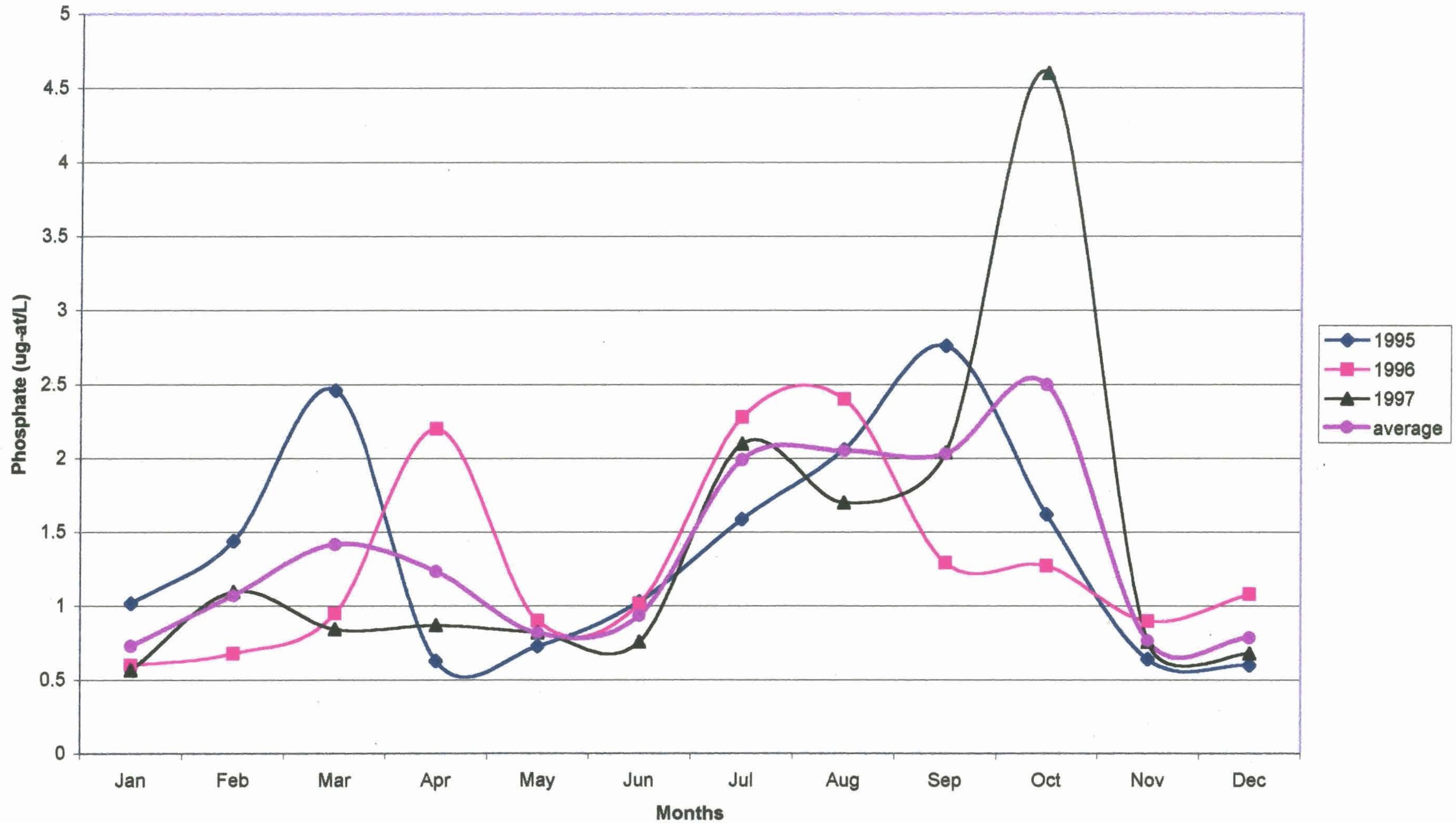
Dissolved oxygen (ml/L)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

Fig. 4.5. Average monthly values of pH at Calicut from 1995 – 1997.


8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
Values of pH
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

430

Fig. 4.6. Average monthly values of Phosphate (µg-at/L) at Calicut from 1995 – 1997.


5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Phosphate (ug-at/L)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

43F

21

temperature was higher than that observed during the pre monsoon period. (Fig.4.3).

4.1.4. Oxygen:

The oxygen content in the surface waters of the inshore area show a maximum during June and July (5.16 ml/L) when the monsoon activity and lowering salinity causes increase in dissolved oxygen. It again reduces (4.1 ml/L) during September and then stabalises till the next monsoon. It is during this month, the phytoplankton bloom is observed which causes oxygen depletion. During the same period, blooms of toxic flagellates are observed causing mortality of fishes at times (Fig.4.4).

4.1.5. pH:

The pH value is high during the month of March-April at 8.1. This value reduces during the monsoon period (July) and slowly rises subsequently to 7.8 (Fig.4.5). Higher pH values have been associated with higher temperature and higher oxygen content (Rao and Madhavan, 1964)

4.1.6. Phosphate:

Two peaks are observed – one during the post monsoon period (July to October) and again during the month of May to July – the pre-monsoon period. From 1995 to 1997, the value ranged from 0.567 to 4.6 ug

Fig. 4.7. Average monthly values of Nitrate (μg-at/L) at Calicut from 1995 – 1997.

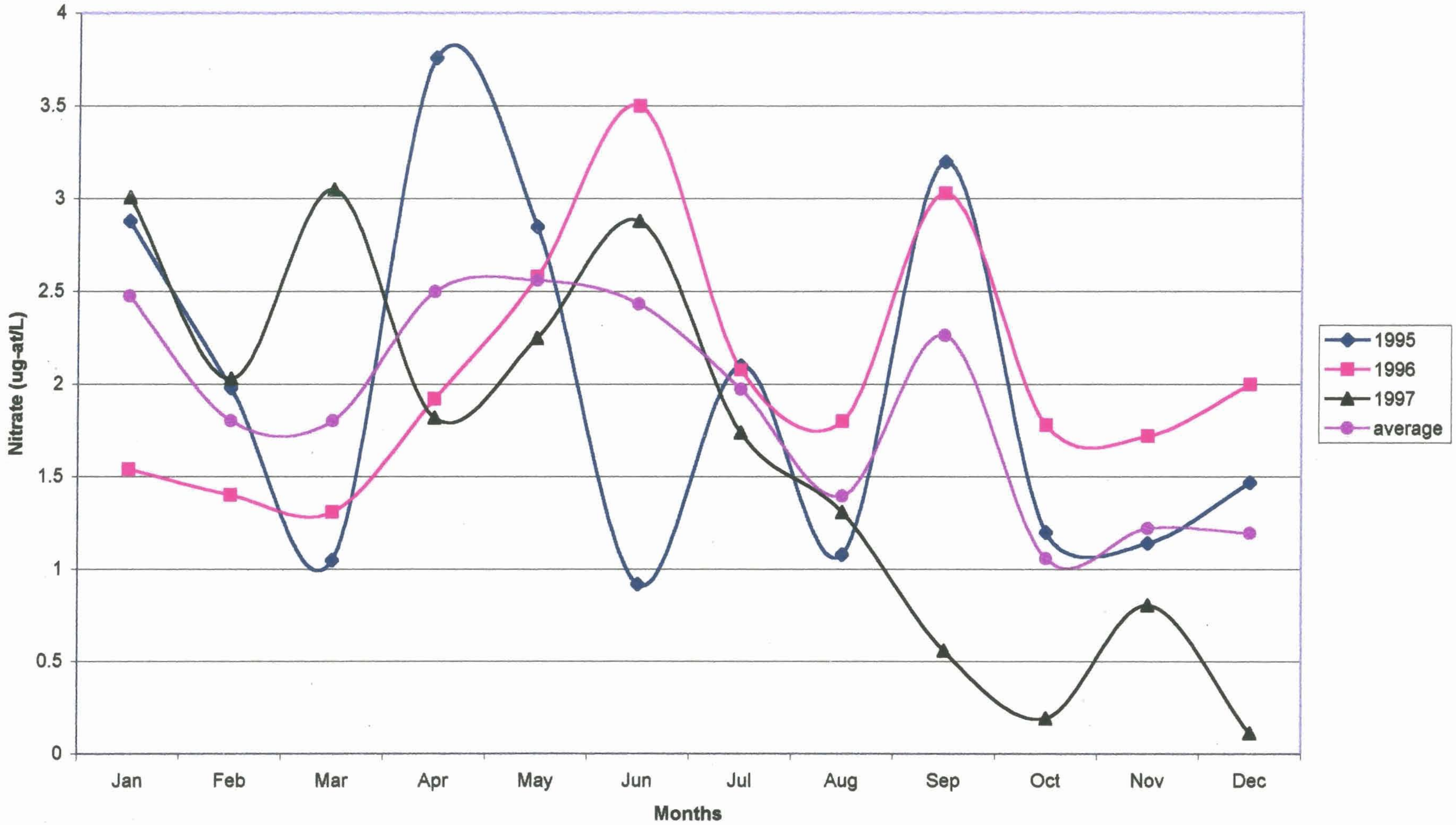
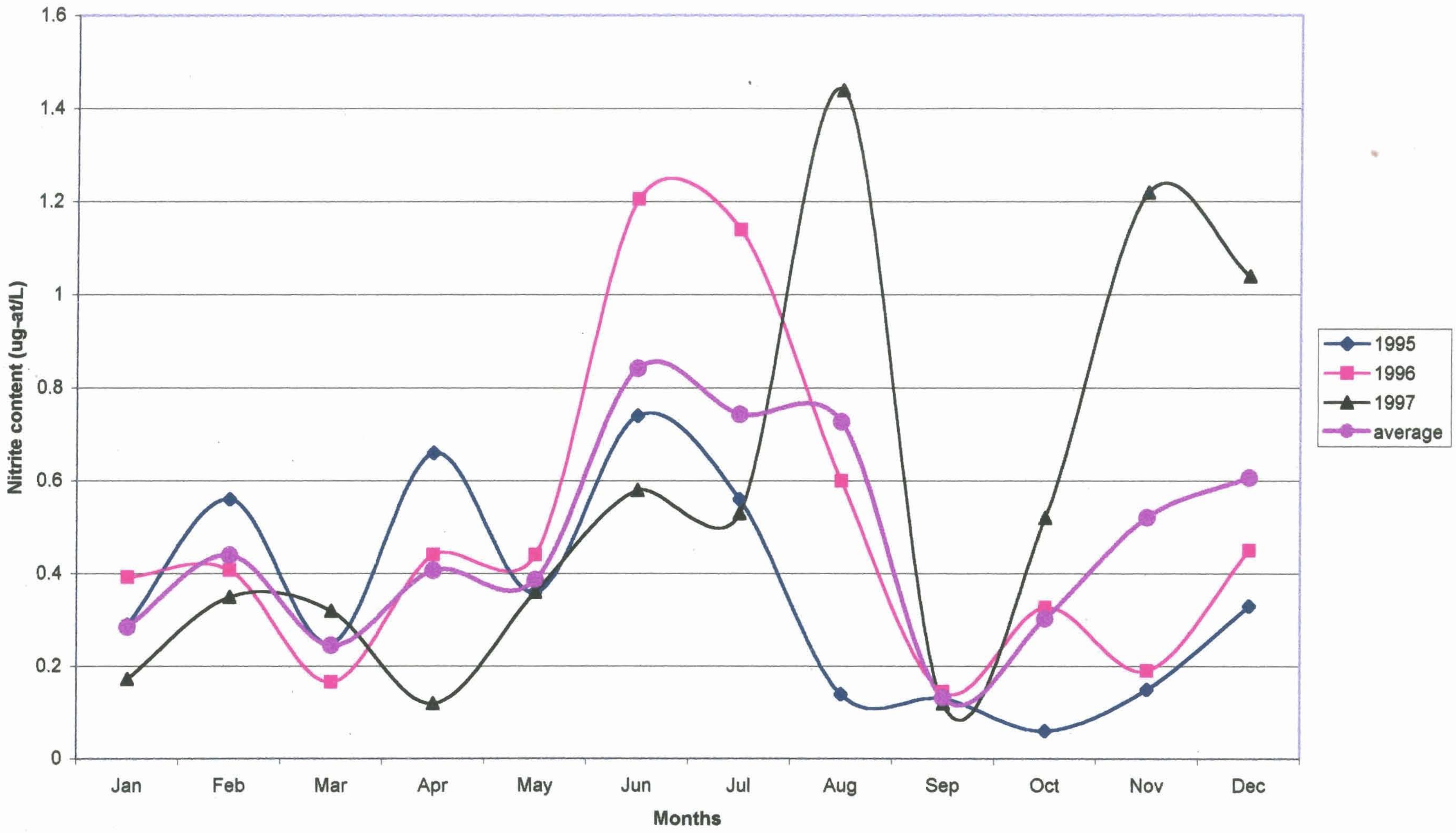

4
3.5
3
2.5
2
1.5
1
0.5
0
Nitrate (ug-at/L)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

Fig. 4.8. Average monthly values of Nitrite (μg-at/L) at Calicut from 1995 – 1997.


Nitrite content (ug-at/L)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

at/L. The peaks in the values were observed during monsoon and post monsoon periods (Fig.4.6).

Seshappa (1953) mentions that the possible source of phosphate mud as the run off during the monsoon months bringing with it fine particles of laterite containing a lot of absorbed phosphate. Seshappa and Jayaraman (1956) have suggested that the monsoon increase in phosphate be due to the agitation of the bottom deposits releasing the interstitial phosphates.

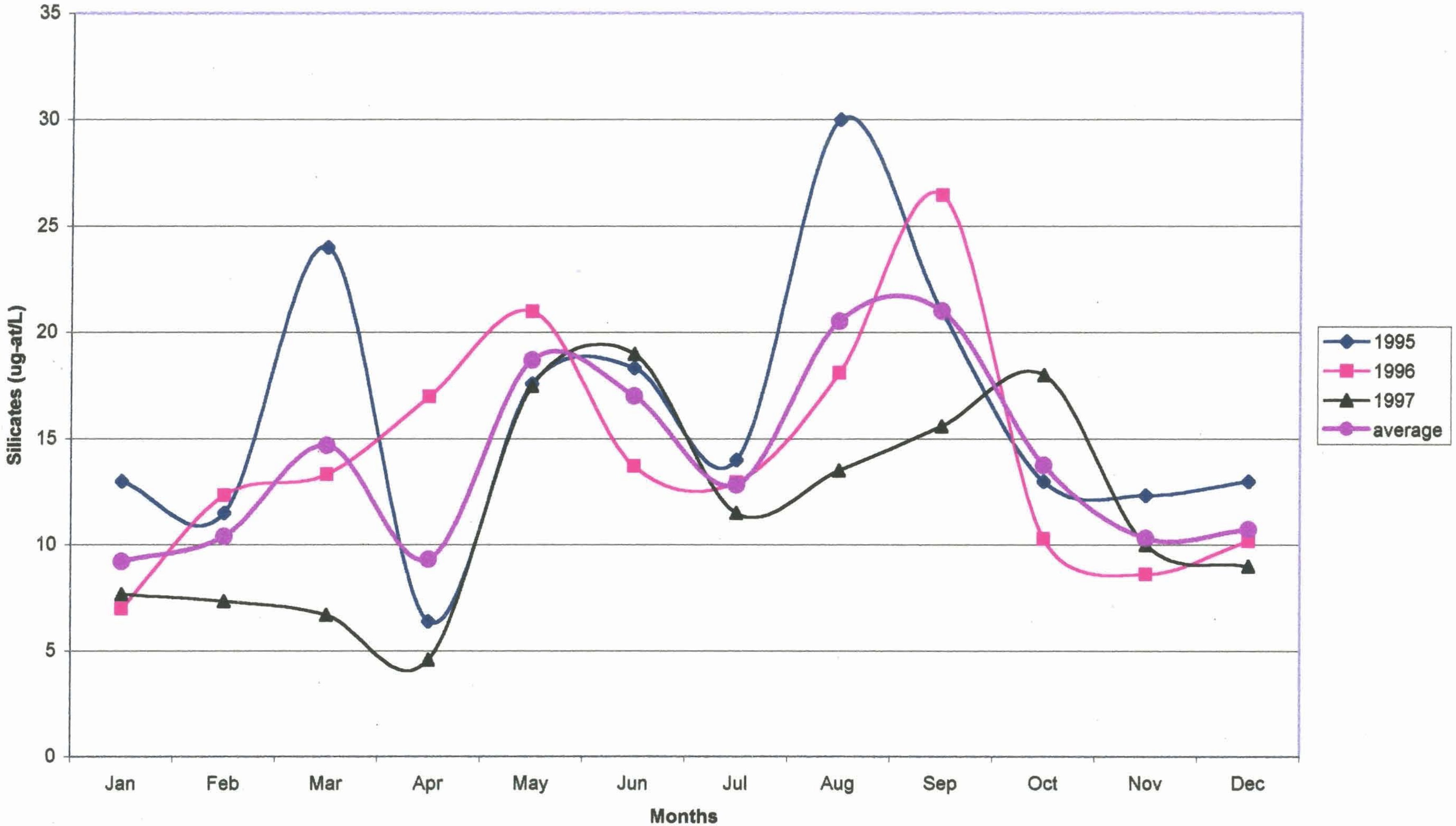
4.1.7. Nitrate:

The nitrate content shows variations from year to year with wide variations. The values varied from 0.113 to 3.5 ug at/L. The values during postmonsoon period were lower compared to the values recorded during the monsoon and just prior to it (Fig.4.7).

4.1.8. Nitrite:

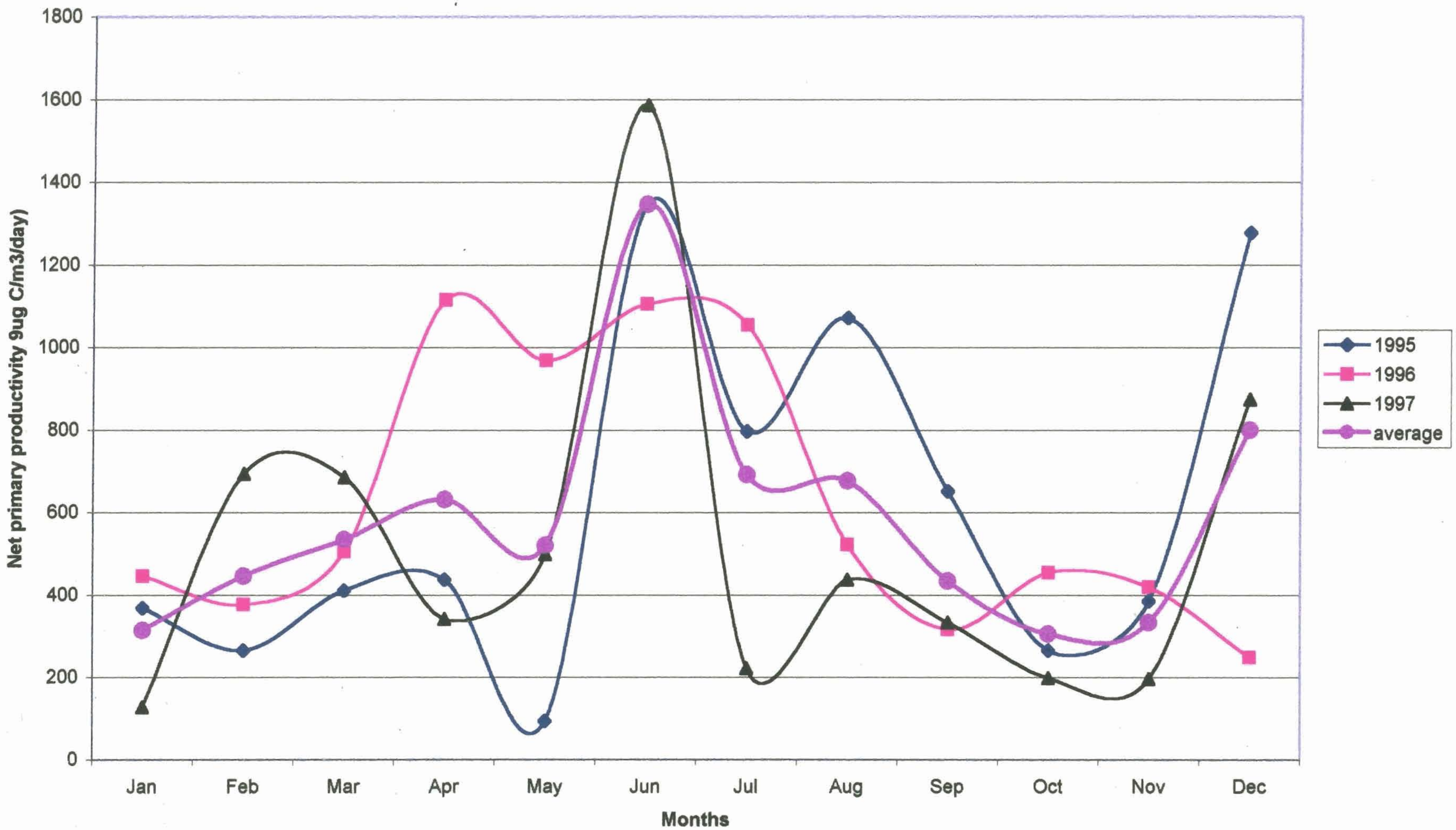
The values of nitrite show maxima during the months of June to August, the active monsoon period and declined during the month of September. The value ranged from from 0.06 to 1.44 ug at/L (Fig.4.8).

Fig. 4.9. Average monthly values of Silicates (μg-at/L) at Calicut from 1995 – 1997.


Silicates (ug-at/L)
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

45B 27

Fig. 4.10. Average monthly variations in net primary production ($\mu g\ C/m^3/day$) at Calicut from 1995 – 1997.


Net primary productivity 9ug C/m3/day)
1800
1600
1400
1200
1000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
1995
1996
1997
average

4.1.9. Silicate:

The silicate shows an increase during the pre-monsoon period (May) and during July the value is lowered and again during August to September, the value goes higher, suggesting that the silicates were not fully utilized for diatom production during this period. The value ranged from 4.57-to 30-µg at/L (Fig.4.9).

4.1.10. Primary productivity:

The net primary productivity is the highest during the months of June and again during the months of November – December (Fig.4.10). Among the nutrients, phosphate content and the primary productivity show an inverse relationship.

4.2. Upwelling and cephalopod fishery:

Upwelling ecosystems are some of the most productive systems in the oceans. Ryther (1969) stated that 50% of the world's fish catch comes from the 0.1% of the ocean's area where coastal upwelling occurs. Though the vertical motion in the sea is much less than that of horizontal currents, it has got significant influence on the oceanic environment. Upwelling is the process by which subsurface waters are brought to the surface layers. The reverse process is called sinking. Upwelling occurs mainly near the coast where the prevailing wind transport surface waters offshore and also in regions of divergence. Thus the large-scale wind system provides the driving force and the large-scale circulation pattern determines the water properties for upwelling and hence coastal upwelling is a mesoscale ocean response to large-scale wind driving (Barber and Smith, 1981). Strong upwelling occurs in regions of eastern boundary currents, i.e., along the west coast of continents where the wind systems produces offshore transport. A secondary reason for the upwelling may be the local topography of the coast and the continental shelf in relation to the permanent ocean currents (Laevastu and Hela, 1970). When the wind direction is parallel to the coast on to the left relative to the wind direction in the north hemisphere, one may expect some coastal upwelling but it is along the eastern ocean boundary that the wind is persistantly in a climatological sense favourable for coastal upwelling for enough time and over a sufficiently large length of coastline that a distinct coastal upwelling ecosystem can develop (Barber and Smith, 1981). The Indian Ocean is unique in that it is limited in the north by the Asian continent. One consequence of this is that the Arabian Sea is forced by intense, anually reversing monsoon winds. In South West Coast of India, the phenomenon of upwelling is noticed from Karwar to Quilon. Upwelling brings the subsurface cold, nutrient rich, low oxygen and dense waters to the surface layers. This favours high biological productivity and these regions of upwelling are rich in fishery resources.

Data collected by George (1953) shows that the fall in the sea surface temperature during May/June occurrs suddenly and this is not related to the onset of the monsoon rain. So the sudden decrease in the temperature is related to upwelling. Johannesson et.al (1987) has opined that upwelling is not only associated with the local winds, but also with the large scale monsoonal conditions which drive the anti cyclonic Arabian sea monsoon gyre.

The earliest record of the surface conditions and pattern of circulation in the Laccadive Sea and Indian Ocean is that of Sewell (1929). The double seasonal oscillation of the sea-surface temperature of the Laccadive Sea was related to the monsoon. Maxima were observed before and after southwest monsoon and lowest during southwest monsoon. Sewell (1929) estimated the yearly variation of sea surface temperature in Laccadive sea to be 1.88 ^{0}C, but near Calicut the seasurface temperature variation was 4-5 ^{0}C.

Later studies conducted by Chidmbaram (1950), George (1953); Seshappa and Jayaraman (1956) and Kasturirangan (1957) have shown a distinct pattern in sea surface temperature variation around Calicut. During the peak southwest monsoon period the minimum sea surface temperature of about 25 ^{0}C is recorded. The annual maximum of the inshore water temperature of above 30 ^{0}C is observed during April/May – the pre-monsoon period. A secondary annual maxima of about 29 ^{0}C is recorded during October/November – the post-monsoon period.

Ueta (1999) found a strong correlation between the year class and abundance and water temperature during the spawning of the oval squid *Sepioteuthis lessoniana.* Rearing experiments have shown that the incubation period to hatching becomes shorter at higher water temperature with periods estimated to be 54-56, 33-36, 24-27 and 19-23 days at water temperatures of 15, 20, 25 and 30 ^{0}C respectively. Being a tropical species, higher temperature during spawning season and early stages appear to result not only in early hatching and higher growth rate but also successful feeding in higher metabolic activity and greater predator avoidance ultimately leading to higher spawning success.

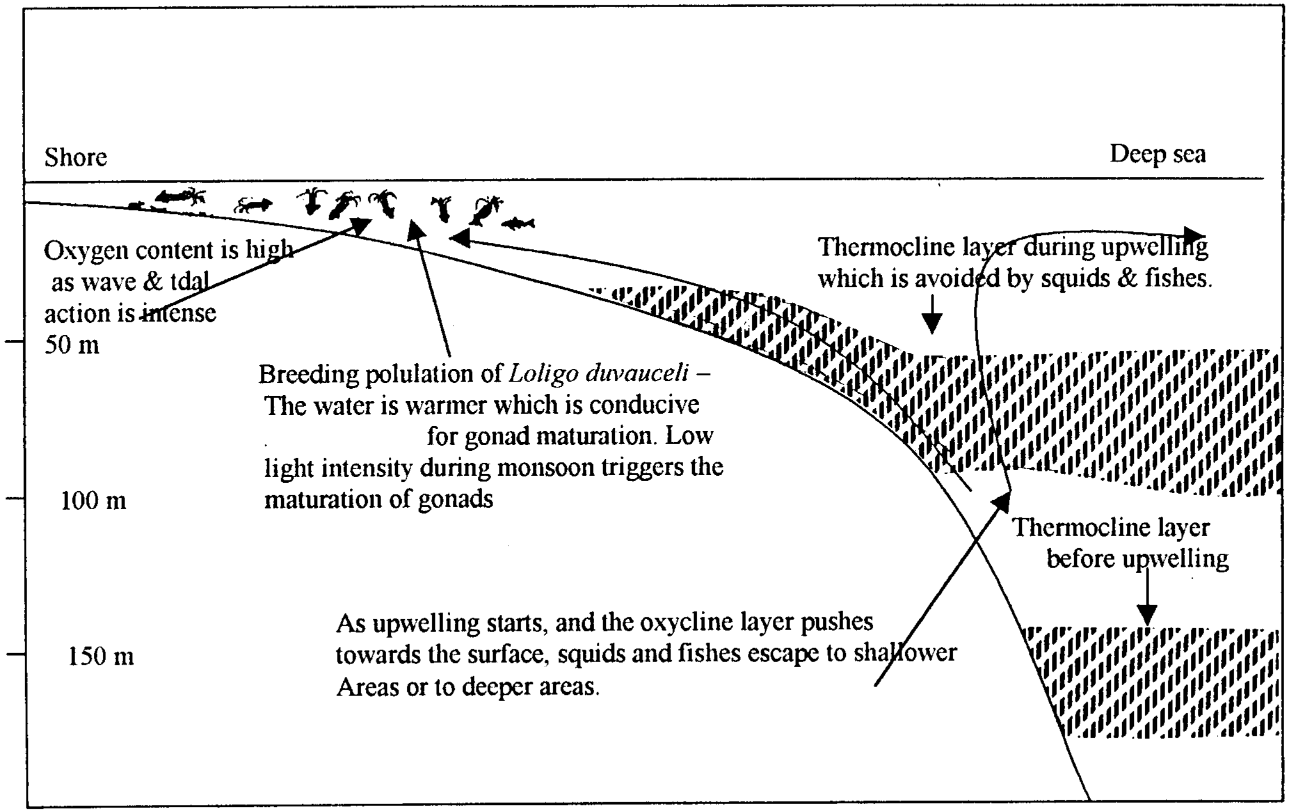
Anon (1996) reported that in the South African chokka squid, *Loligo vulgaris reynaudii* change in turbidity rather than temperature is important in spawning activity during upwelling. This is because squids rely on visual communication for mating and are therefore likely to move inshore to spawn at the start of upwelling events when the water column is relatively clear as recorded in the underwater video monitoring programme.

Nair *et.al.*, (1992) mentioned that the total cephalopod fishery at Vizhinjam during 1985 was 532 tonnes, but during the next year it was a record catch at 1752 tonnes, while during 1987 it recorded an all time low of only 37 tonnes. The reason may be the intensity of upwelling during the period, which can be indicated by the temperature recorded during the monsoon period. Rajagopal et.al (1992) recorded the difference in temperature between the seasons during 1984-85 to be 2.7 and 0.3 ^{0}C. This was less than the average of 4.0 and 2.2 ^{0}C and during 1987-88, it was above average and only during the month of June, 24 ^{0}C was recorded which then rose to 26.5 ^{0}C during July, and during August it was at 27 ^{0}C showing a weak upwelling season.

Unlike the other landing centres, the Vizhinjam cephalopod fishery is entirely landed by hooks and lines and boat seines (Nair *et al.*, 1992). The catch in these gears is very much dependent on the success of the upwelling as it pushes the cephalopods into the pelagic areas.

In the squid *Loligo duvauceli* spawning is observed during the post monsoon period in the coastal waters when the temperature is high and the availability of plankton is also high. This ensures the higher survival rate and reduces the larval period. This strategy is observed in many tropical species of the Malabar Coast.

Fig. 4.11. Diagrammatic representation of the migration and breeding population of *Loligo duvauceli* during upwelling season along the Malabar Coast.


Shore
Deep sea
Oxygen content is high as wave & tdal action is intense
50 m
100 m
150 m
Breeding polulation of *Loligo duvauceli* – The water is warmer which is conducive for gonad maturation. Low light intensity during monsoon triggers the maturation of gonads
Thermocline layer during upwelling which is avoided by squids & fishes.
Thermocline layer before upwelling
As upwelling starts, and the oxycline layer pushes towards the surface, squids and fishes escape to shallower Areas or to deeper areas.

Higher values of pH are associated with higher temperature. This is attributed to the amount of photosynthesis by phytoplankton and the subsequent assimilation of carbon-di-oxide (Rao and Madhavan, 1964).

Maturation process:

In cephalopods the factors that can cause early maturation and spawning are short day length, low light intensity, high temperature and restricted feeding. It is during the post monsoon period these parameters are optimally observed and that a large population of *Loligo duvauceli* is seen to migrate to the shore for spawning. This is depicted in the Fig.4.11.

4.3. Upwelling and spawning:

During the monsoon periods, the thermocline with its low oxygen content slowly rises to the surface, due to upwelling. During this period, *Loligo duvauceli* starts the annual migration to the shallow coastal waters for spawning. This zone in the shallow waters does not suffer the oxygen depletion due to the strong action of the tidal currents and waves. The primary and secondary productions are also increased and this is the best time for the hatchings of the squids to survive. Large collection of the spawning squids and egg mops are littered on the shores discarded by the shore seines in the spawning areas of *Loligo duvauceli* (Asokan and Kakati, 1991).

Anon (1996) reported that in the South African chokka squid, *Loligo vulgaris reynaudii,* the change in turbidity rather than temperature is important in spawning activity during upwelling. This is because squids rely on visual communication for mating and are therefore likely to move inshore to spawn at the start of upwelling events when the water column is relatively clear as recorded in the underwater video monitoring programme.

Another trend observed is that the cuttlefishes peak during the winter months (post monsoon period) and the squids in the pre monsoon period. This is because the area of trawling is upto 60 meters depth, which is dominated by squids. But during the monsoon periods due to upwelling, the cuttlefishes that are present in the deeper waters are forced to shallower areas and are vulnerable to fishing. During monsoon and post monsoon periods the cuttlefishes and squids are also found in the column waters. In Malabar area squids are observed in the ring seines used for catching the pelagic fishes like mackerel and sardines.

Data collected by Silas *et.al.* (1984) show that at Vizhinjam the landings of cephalopods in shore seines attain peak during Sept-Oct when the upwelling is observed. At Waltair the shore seine land cephalopods from Dec to May. Mojumdar (1967) found that during January to April the dissolved oxygen had a minimum value and sea surface temperature was lowest and the values of phosphates and silicates were also higher indicating the features of upwelling at Waltair. Ganapati and Murthy (1954) observed a general upwelling along the Waltair coast during the month of March.

Studies on the availability of the market squid *L.opalescens* and ocenographic conditions was studied by McInnis and Bwenkov (1978). Upwelling begins by February and continues through early summer. The onset of upwelling coincides with the cool water temperature of March, April and May when the prevailing northwestern winds drives California current offshore by Ekman transport and thus allowing deeper, cool nutrient rich water to surface along the coast. The peak squid catch follow the minimum temperature by approximately two months. Spawning is believed to be triggered by this warming trend, which follow by the cessation of upwelling.

As in most short-lived species, annual fluctuations of the resource can be attributed to both environmental factors and fishing pressure. In order to manage the resource efficiently it is important to be able to predict squid recruitment for any given year, requiring research into all the factors affecting recruitment.

CATCH AND EFFORT

P.K. Asokan "Biology and fishery of cephalopods (mollusca: cephalopoda) along the malabar coast " Thesis. Department of Zoology , University of Calicut, 2000

CHAPTER – 5

CATCH AND EFFORT

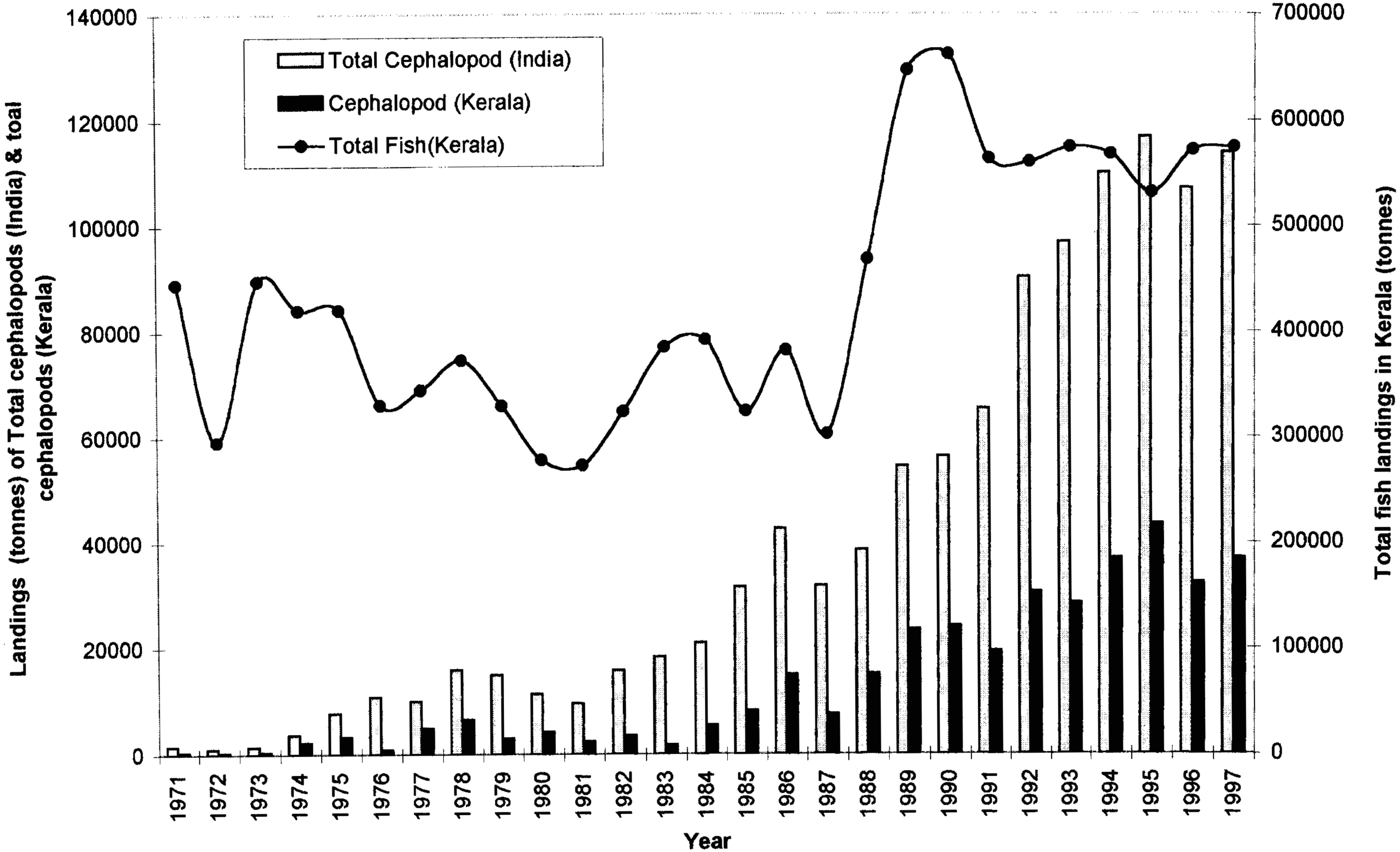
Globally, the cephalopods catch increased from 1990 when 2.4 million tonnes was landed to 3.3 million tonnes in 1997. During 1998, the total landings were only 2.60 million tonnes. Japan with 20% of the world cephalopod landing is the leading country. The landing in Japan in 1997 was 685,000 tonnes. South Korea and Argentina rank second and third, catching 15% and 12% respectively of the world cephalopods (Globefish, 1997).

Areawise, 35% of the cephalopods are landed in the NW Pacific. The SW Atlantic landed 997,000 tonnes in 1997. Cephalopod caught in the Western Indian Ocean recorded a negative trend (-87,000 tonnes) between 1990-1997 (Globefish, 1997). Squids form about 73% of the total cephalopod catch with 2.4 million tonnes landings in 1997. This is followed by cuttlefish landings of 5,00,000 tonnes in 1997. Octopus is in third position with 2,90,000 tonnes in 1997 (Globefish, 1997).

In India, cephalopods were obtained as by-catch in the traditional gears like shore seines, hooks and line and forming localised fishery in places like Palk Bay. With the demand for export increasing, the catch increased to 3677 tonnes in 1974 from 1394 tonnes the previous year. In 1975, the production more than doubled compared to the previous year to 7889 tonnes. It was in 1976 that the production reached 10,825 tonnes and increased to 15,931 tonnes in 1978. After that there was reduction in the production till 1981 when it reached 9538 tonnes. From 1982 onwards there was steady increase till 1986 when it reached 42,590 tonnes. There was a fall in the catch during 1987 when 31,875 tonnes were landed. From 1988 there has been a steady increase from 38,526 tonnes to 1,16,841 tonnes in 1995 when the highest landing was recorded. During 1996 there was a slight reduction in the production but in 1997 it again increased to 1,13,855 tonnes.

Among the maritime states of India, Kerala is the major cephalopod producing states of India. Kerala, Gujarat, Maharastra and Tamil Nadu contribute the bulk of the landings of India. The landing in the state of Kerala varied from 8.05% during 1976 to 59.15% during 1974. During 1974 and 1975 the landings were high at 2175 tonnes and 3342 tonnes respectively. After a fall in 1976, the production reached 6516 tonnes during 1978. With fluctuations in the production till 1983, there was a sharper increase till 1986 when 14,987 tonnes were landed. Again after a fall in production during 1987, the production reached 24,206 tonnes during

Fig. 5.1. Graph showing total fish catches (Kerala), total cephalopod landings in India and Kerala's contribution (1971 – 1997).


Total Cephalopod (India)
Cephalopod (Kerala)
Total Fish(Kerala)
Landings (tonnes) of Total cephalopods (India) & toal cephalopods (Kerala)
Total fish landings in Kerala (tonnes)
Year
0
20000
40000
60000
80000
100000
120000
140000
0
100000
200000
300000
400000
500000
600000
700000
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

1990. The ninties saw the production rise in Kerala attaining 43,472 tonnes in 1995. During 1996, the production decreased to 32,445 tonnes and again increased to 37,058 tonnes during 1997. During 1998, the production reached the 1996 level of 32,311 tonnes. During the past decade, the cephalopod production from Kerala contributed on an average 35.22 % of the total production of India. This ranged from 29.38 % during 1993 to 43.11 % during 1989. The landings in Kerala and India are shown in Fig.5.1.

5.1. Catch and Effort in the Malabar area:

There is no comprehensive information on the catch, effort and cpue from the Malabar area. Hence an attempt has been made to study the production and abundance of commercially exploited cephalopods of Malabar area. The average total catch in Malabar area for the period 1995-1997 was 13,452 tonnes. In 1995 it was 14,370 tonnes but during the next year it decreased to 8868 tonnes. In 1997, there was improvement in the production and reached 16,291 tonnes. The total landings of cephalopods in the four districts of Malabar are depicted in Table 5.1. Bulk of the catches (88%) are landed at Kozhikode district. This is followed by Malappuram (6.5%), Kasaragod (3%) and Cannanore district (2.36%). The cpue is also higher in Calicut district (181 Kg.). The cpue of Malappuram and Kasragod

Fig. 5.2. Average monthly catch of cephalopods by mechanical trawlers at Kasaragod district (1995-97).

Fig. 5.3. Average monthly catch of cephalopods by mechanical trawlers at Kannur district (1995-97).

Fig.5.2

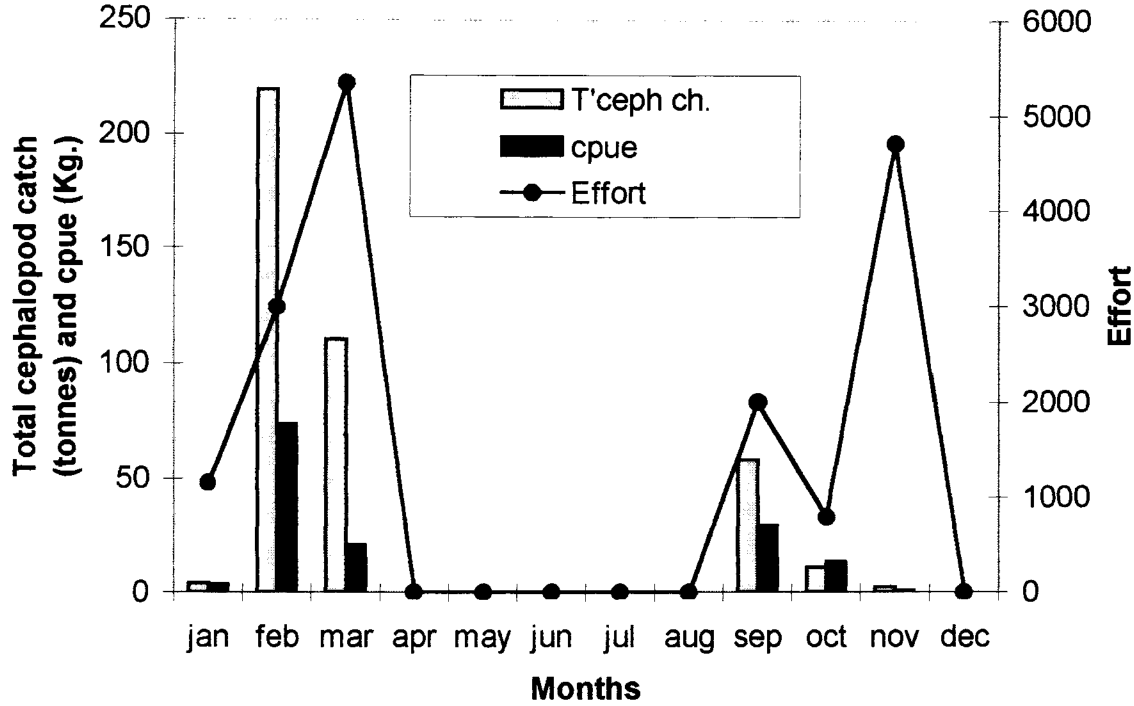

T'ceph ch.
cpue
Effort
Total cephalopod catch (tonnes) and cpue (Kg.)
Effort
250
200
150
100
50
0
6000
5000
4000
3000
2000
1000
0
jan feb mar apr may jun jul aug sep oct nov dec
Months

Fig.5.3

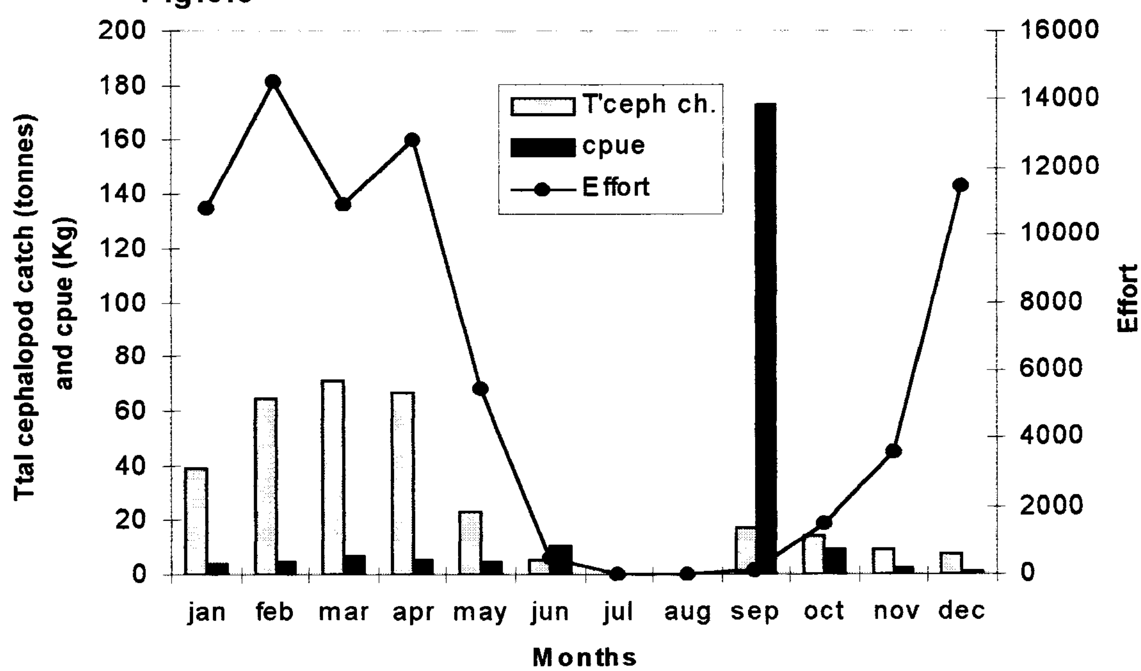

T'ceph ch.
cpue
Effort
Ttal cephalopod catch (tonnes) and cpue (Kg)
Effort
200
180
160
140
120
100
80
60
40
20
0
16000
14000
12000
10000
8000
6000
4000
2000
0
jan feb mar apr may jun jul aug sep oct nov dec
Months

Fig. 5.4. Average monthly catch of cephalopods by mechanical trawlers at Kozhikode district (1995-97).

Fig. 5.5. Average monthly catch of cephalopods by mechanical trawlers at Malappuram district (1995-97).

Fig.5.4

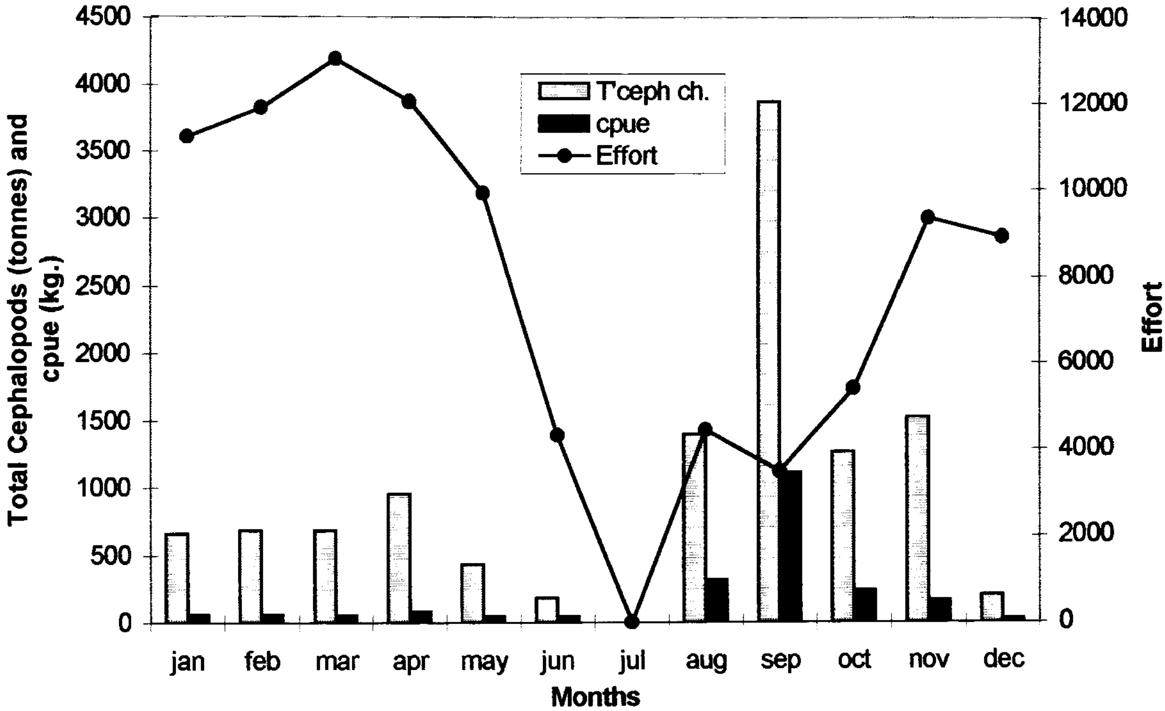

T'ceph ch.
cpue
Effort
Total Cephalopods (tonnes) and cpue (kg.)
Effort
4500
4000
3500
3000
2500
2000
1500
1000
500
0
14000
12000
10000
8000
6000
4000
2000
0
jan feb mar apr may jun jul aug sep oct nov dec
Months

Fig. 5.5

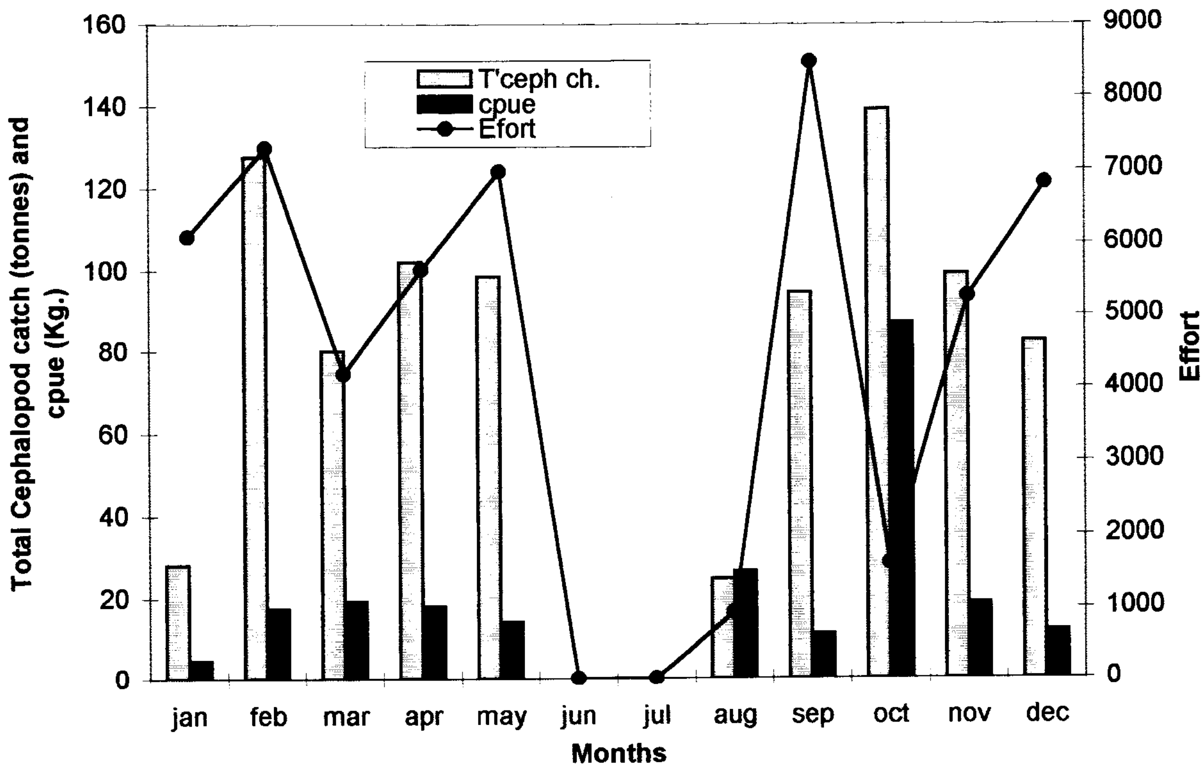
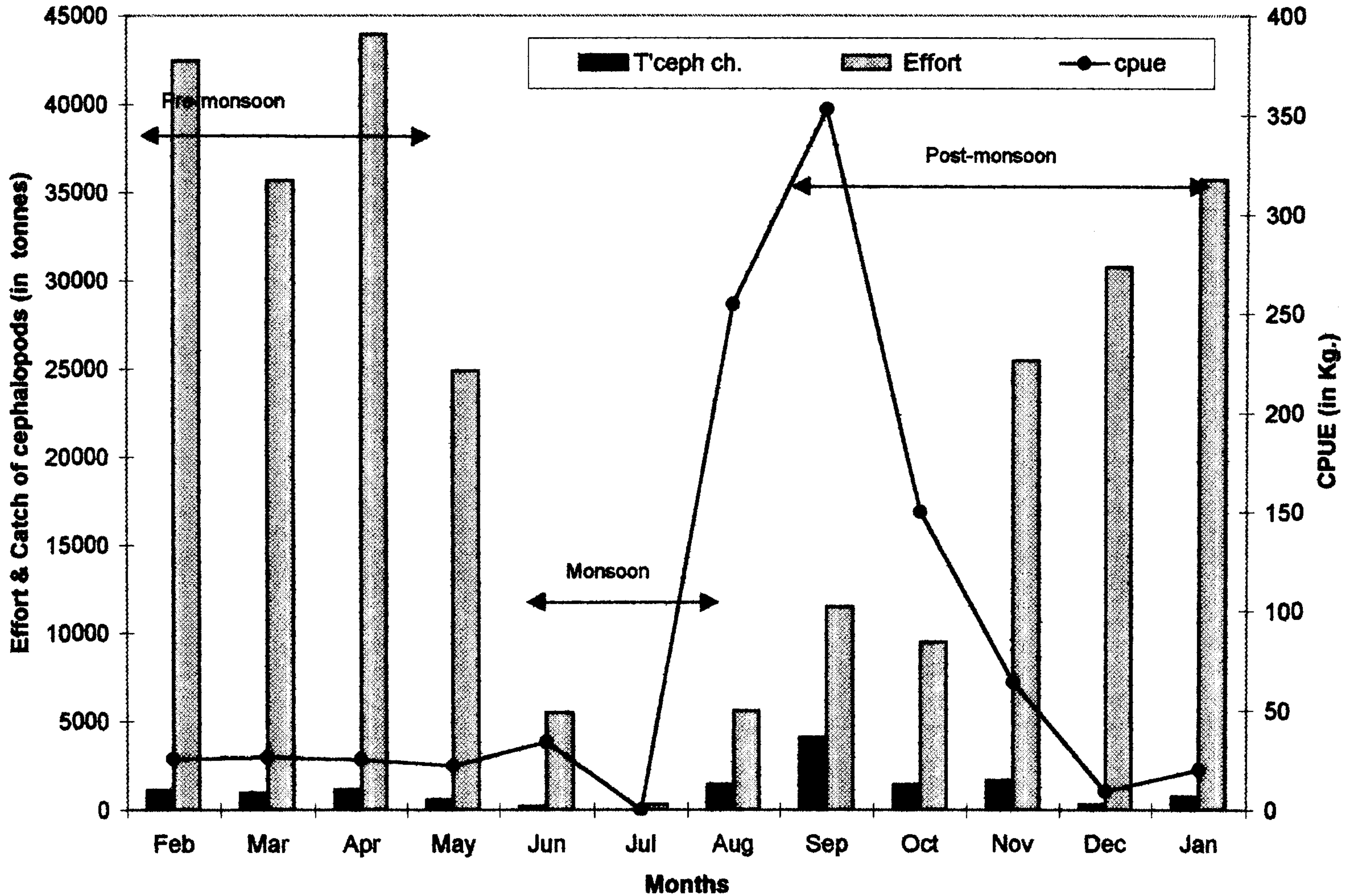

T'ceph ch.
cpue
Efort
Total Cephalopod catch (tonnes) and cpue (Kg.)
Effort
160
140
120
100
80
60
40
20
0
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
jan feb mar apr may jun jul aug sep oct nov dec
Months

Fig. 5.6. Average monthly effort, catches and catch per unit effort (cpue) of cephalopods by mechanical trawlers of Malabar area (Pooled for 1995 – 1997).



T'ceph ch.
Effort
cpue
Pre-monsoon
Monsoon
Post-monsoon
Effort & Catch of cephalopods (in tonnes)
CPUE (in Kg.)
Months
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
400
350
300
250
200
150
100
50
0
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

and Kasragod districts are comparable. However, the cpue of Cannanore district is the lowest with 18.37 Kg.

The average annual catches of cephalopods in the Malabar area during the study period amounted to 13,452 tonnes. Kozhikode district contributed 88.11% of the catch followed by Malappuram (6.50%), Kasaragod (3.01%) and Kannur (2.36%) (Table 5.1).

The major gear operated for cephalopods was trawl, which contributed almost 99.68 % of the total cephalopod catches. Hooks and lines are also operated for cephalopods in Kozhikode but the catches were negligible. The monthwise distribution of catches in the Malabar area is given in Fig 5.6. It shows that the peak catches and cpue is obtained in September, the best season being August to November. There is a decline in the fishery in December followed by a minor increase till April. There is an indication of an increase in cpue in June. July is the closed season for trawls. When trawling re-starts in August, the cpue is high which increase to a peak in September. The effort shows a gradual increase from August and goes to a peak by February – April and then declines. Effort is generally very poor during monsoon. Though the effort is low during August – October, the cpue of cephalopods are comparatively very high (Fig.5.6).

In Kasargod district the peak catches and cpue is obtained in February with a minor peak in September (Fig.5.2). The higher effort is shown during the months of March and November but highest catch and cpue is recorded during the month of March. During 1995-97, the best catches were landed in 1995 when 1120 tonnes was recorded with a cpue of 59.27 Kg forming 8.97 % of the total fish catch. But during subsequent years poor landing of cephalopods were recorded – 20 tonnes during 1996 and 76 tonnes during 1997 forming 0.96 % and 2.22 % of the total fish catch. Almost the entire catch was landed by trawlers except during 1997 when 3 tonnes were landed by ring seines.

In Kannur, the peak catches are made in February – April (Fig.5.3). But peak cpue is obtained in September when the fishery starts after the monsoon. The effort during the month of September is very low but the cpue is the highest during this month. The maximum catches of cephalopods were recorded during 1995 with a landing of 566 tonnes and a cpue of 9.47 Kg. This formed 6.2 % of the total fish catch. During 1996 the landings were 177 tonnes and the cpue 3.22-kg but during 1997, 310 tonnes were recorded with a cpue of 2.09 Kg.

The average picture of Malabar area is influenced by the situation in Kozhikode district where bulk of the catches is made. Peak catches and cpue is obtained in Kozhikode district is in September, the season being August to November (Fig.5.4). After a decline in Decemeber. the catches increase to a minor peak in April. The effort during August – November period is lower compared to the pre-monsoon period and hence the higher cpue is recorded. During 1995, the landing recorded 13,213 tonnes with a cpue of 172.13 Kg forming 20 % of the total fish catch. During 1996, the landings reeduced to 8161 tonnes forming 11.9 % of the total fish catch with a cpue of 111.3 Kg. During 1997, the catches improved to 14186 tonnes but with a reduced cpue of 107.44-Kg forming 14.71 % of the total catch. In Calicut district, the drift gill nets landed 2 tonnes of cephalopods during 1995 and the Hooks and line landed 58 tonnes during 1996 and 50 tonnes during 1997. The species landed by this gear were mainly the cuttlefish *Sepia pharaonis*.

The seasonality of the fishery is not so distinct in Malappuram district (Fig 5.5.) Here the peak catches are made in October with a secondary but almost equal peak cathes in February and a decline in January. However, peak cpue is obtained in August and October, as the effort during these months is low. During 1995-97, the cephalopod landings were modest at 302 tonnes with a cpue of 8.44 Kg forming 4.26 % of the total fish catch. During 1996, the catch improved to 510 tonnes with a cpue of 19.42 Kg and during 1997, 1814 tonnes was landed with a cpue of 28.17 Kg forming 15.8 % of the total catch. Only 5 tonnes of cephalopods were landed in drift gill nets during 1995.

Table 5.1. Districtwise, average annual landings of Cephalopods in Malabar (1995-1997) – Catches in tonnes.

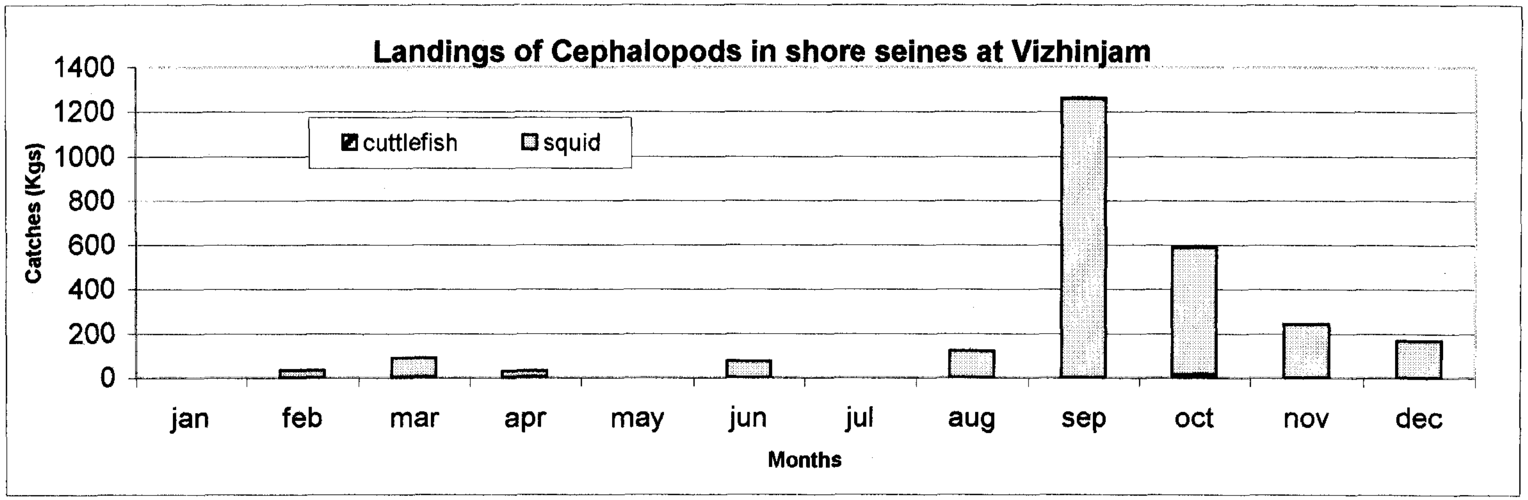
Districts	Effort Trawl	Total av. Cephalopod Catch (tonnes)	Cpue of Cephalopods in trawl (Kg)	Percentage of cephalopods	T.fish (tonnes)
Kasaragod	16,974	405	23.8	3.01%	5,994
Cannanore	71,700	318	4.43	2.36%	11,399
Kozhikode	94,042	11,853	126	88.11%	76,891
Malappuram	42,146	875	120.7	6.50%	9,780

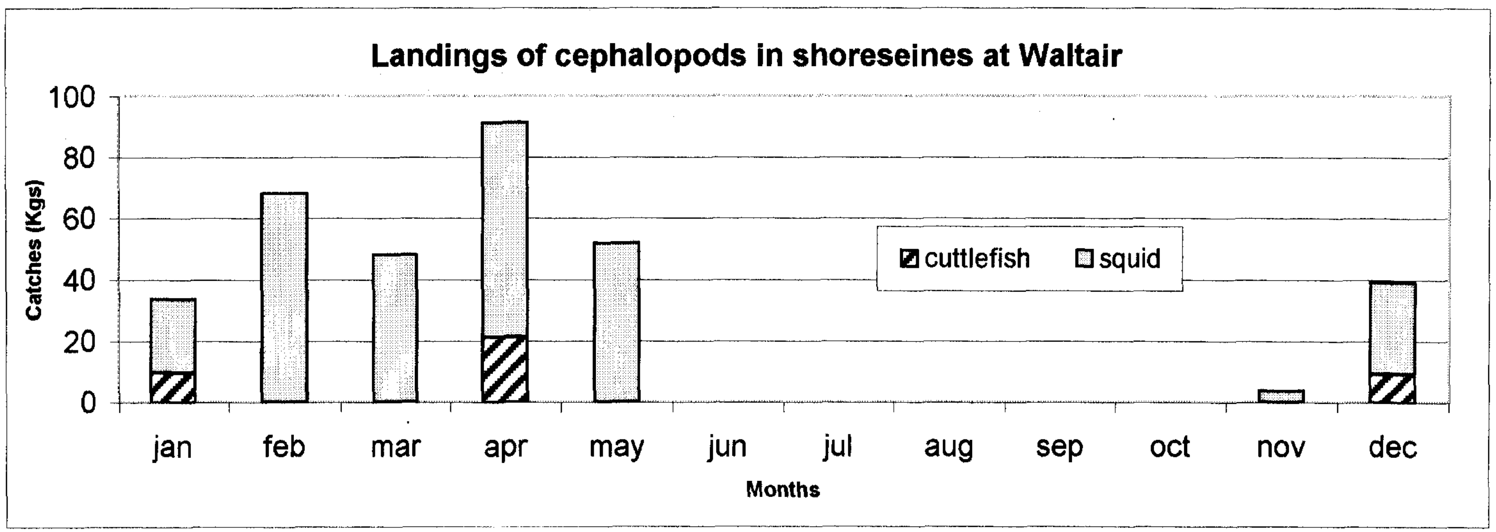
5.2. Gearwise seasonal catch trends:

5.2.1.Shore seines:

Of the 2683 units operated in 1996, only in Cannanore district this gear had catches of 2 tonnes of cephalopods during the month of October with a cpue of 3.58-Kg (Table 5.7). From the data presented by Silas (1985) for the shore seines at Vizhinjam, it is interesting to note that the landings peaked during September-October period when upwelling is observed. The same trend of shore seine landing is observed in Malabar area also.

Fig. 5.7. Average landings of cephalopods in shore seines at Vizhinjam and Waltair (1977 – 1980).


Landings of Cephalopods in shore seines at Vizhinjam
1400
1200
1000
800
600
400
200
0
Catches (Kgs)
cuttlefish
squid
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Months


Landings of cephalopods in shoreseines at Waltair
100
80
60
40
20
0
Catches (Kgs)
cuttlefish
squid
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Months

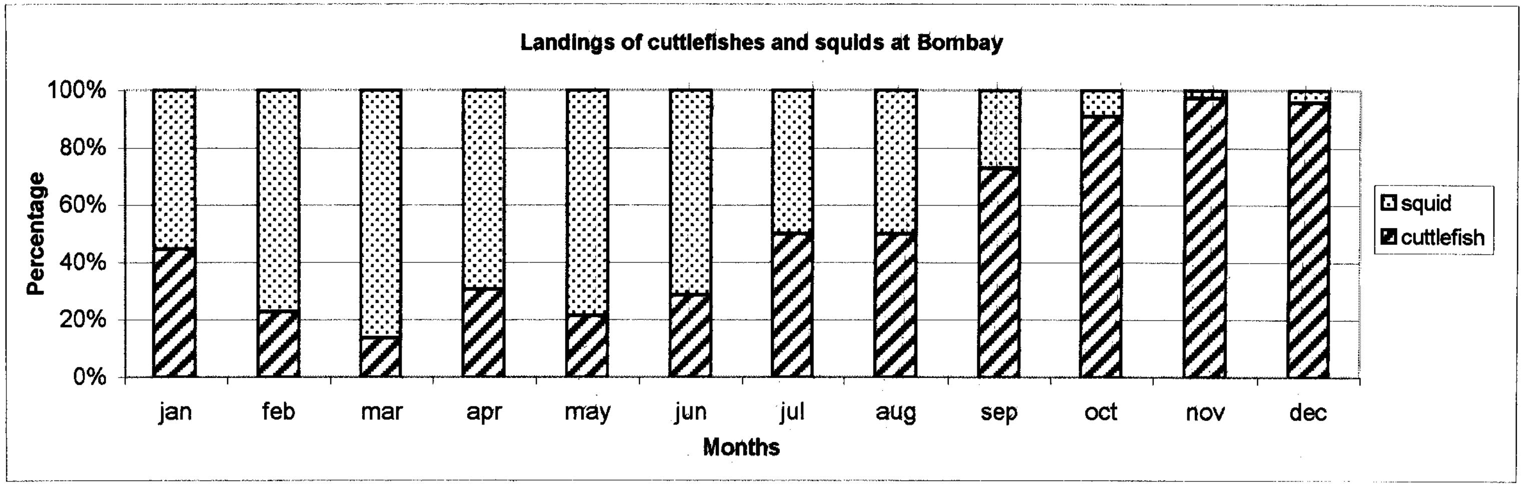
Similarly, at Waltiar, the cephalopods appear during December to May (Silas et.al, 1985). This again coincides with the upwelling in the East Coast. Mojumdar (1967) found th at during January to April the dissolved oxygen had a minimum value and sea surface temperature was lowest and the value of phosphate and silicate were also high indicating the features of upwelling at Waltair (Fig 5.7).

5.2.2. Hooks and line:

The entire hook and line fishery for cephalopods is observed in Kozhikode district. The migrant fishermen mainly from Colachel and Vizhinjam are engaged in hook and line fishery during the post-monsoon period. (Table 5.6). Hooks and line is operated mainly in boats with outboard engines (OBHL), non-mechanised boats (NMHL) and also mechanised boats. The OBHL gets maximum catch followed by NMHL. The total percentage of cephalopods caught by these gears is negligible. During 1996, the percentage was 0.71, which is the highest during 1995-'97. This gear mainly lands the cuttlefish *Sepia pharaonis*. The cpue for OBHL is 7.76 Kg and that of NMHL is 3.64 Kg.

It is interesting to note that the entire catch of traditional gears is realised during the post-monsoon period (Table 5.7) and when compared with earlier data of 1931-'32 to 1937-'38 the trend remains the same

Fig. 5.8. Monthly percentage composition of cuttlefishes and squids at Bombay (1977 – 80) and Malabar area (1995 – 1997).


Landings of cuttlefishes and squids at Bombay
Percentage
100%
80%
60%
40%
20%
0%
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Months
squid
cuttlefish

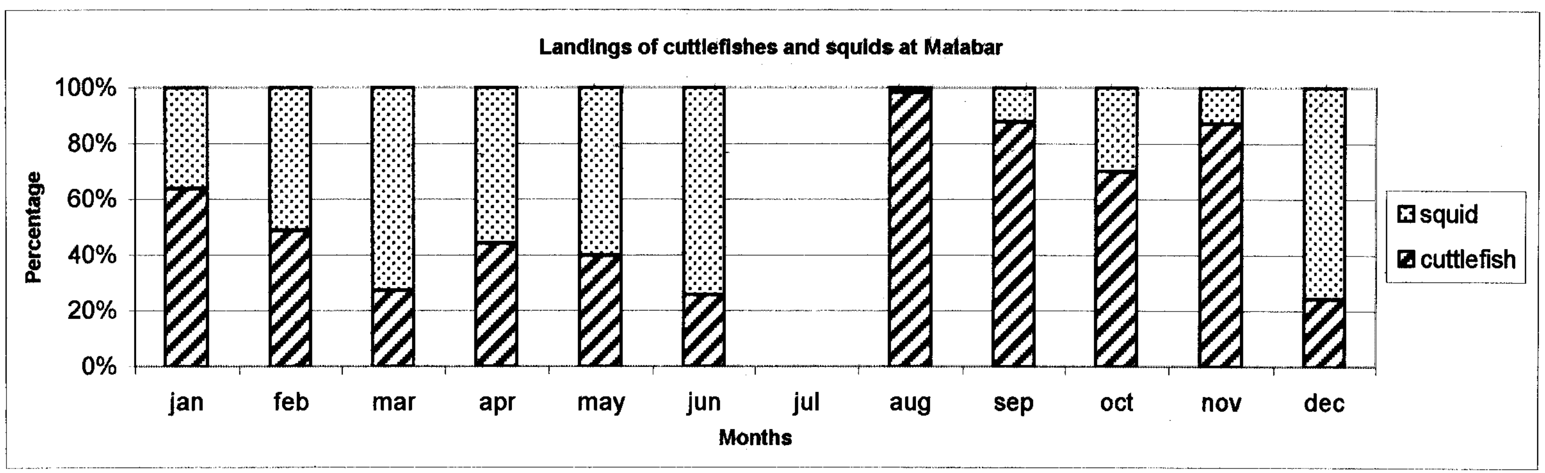

Landings of cuttlefishes and squids at Malabar
Percentage
100%
80%
60%
40%
20%
0%
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Months
squid
cuttlefish

Table 5.2. Total fish catch (in tonnes), Total Cephalopod catch (in tonnes), Total effort and Average cpue (cephalopods in Kg.) of Mechanised trawlers of Kasaragod district from 1995-1997.

Months	Total Ceph.catch	Total Fish Catch	Effort	cpue (Kg.)
Jan'95	0	0	0	0.00
Feb	659	6407	8932	73.78
Mar	294	5895	7564	38.87
Apr	0	0	0	0.00
May	0	0	0	0.00
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	0	0	0	0.00
Sep	167	184	2400	69.58
Oct	0	0	0	0.00
Nov	0	0	0	0.00
Dec	0	0	0	0.00
Total	**1120**	**12486**	**18896**	**59.27**

Months	Total Ceph.catch	Total Fish Catch	Effort	cpue (Kg.)
Jan'96	12	412	3462	3.47
Feb	0	0	0	0.00
Mar	0	0	0	0.00
Apr	0	0	0	0.00
May	0	0	0	0.00
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	0	0	0	0.00
Sep	3	30	960	3.13
Oct	0	0	0	0.00
Nov	5	1634	4400	1.14
Dec	0	0	0	0.00
Total	**20**	**2076**	**8822**	**2.27**

Months	Total Ceph.catch	Total Fish Catch	Effort	cpue (Kg.)
Jan'97	0	0	0	0.00
Feb	0	0	0	0.00
Mar	37	1737	8473	4.37
Apr	0	0	0	0.00
May	0	0	0	0.00
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	0	0	0	0.00
Sep	5	52	2640	1.89
Oct	32	324	2372	13.49
Nov	2	1307	9720	0.21
Dec	0	0	0	0.00
Total	**76**	**3420**	**23205**	**3.28**

Table 5.3. Total fish catch (in tonnes), Total Cephalopod catch (in tonnes), Total effort and Average cpue (cephalopods in Kg.) of Mechanised trawlers of Kannur district from 1995-1997.

Months	Total Ceph.catch	T.catch	Effort	cpue (kg.)
Jan'95	89	1263	7667	11.61
Feb	172	2824	19045	9.03
Mar	165	2389	14467	11.41
Apr	121	1129	5082	23.81
May	0	0	0	0.00
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	0	0	0	0.00
Sep	0	0	0	0.00
Oct	0	0	0	0.00
Nov	5	659	4515	1.11
Dec	14	871	8971	1.56
Total	**566**	**9135**	**59747**	**9.47**
Months	**Total Ceph.catch**	**T.catch**	**Effort**	**cpue (Kg.)**
Jan'96	27	1423	8337	3.24
Feb	17	1232	7076	2.40
Mar	24	761	5966	4.02
Apr	15	1135	12795	1.17
May	5	353	3679	1.36
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	0	0	0	0.00
Sep	52	139	300	173.33
Oct	8	296	682	11.73
Nov	22	1424	6315	3.48
Dec	7	1485	9889	0.71
Total	**177**	**8248**	**55039**	**3.22**
Months	**Total Ceph.catch**	**T.catch**	**Effort**	**cpue (Kg.)**
Jan'97	1	1819	16394	0.06
Feb	5	2600	17453	0.29
Mar	24	1665	12338	1.95
Apr	63	3285	20670	3.05
May	65	2447	12689	5.12
Jun	16	228	1500	10.67
Jul	0	0	0	0.00
Aug	0	0	0	0.00
Sep	0	0	0	0.00
Oct	34	1695	3854	8.82
Nov	0	0	0	0.00
Dec	2	3074	15417	0.13
Total	**210**	**16813**	**100315**	**2.09**

Table 5.4. Total fish catch (in tonnes), Total Cephalopod catch (in tonnes), Total effort and Average cpue (cephalopods in Kg.) of Mechanised trawlers of Kozhikode district from 1995-1997.

Months	Total Ceph.catch	T.catch	Effort	cpue (Kg.)
Jan'95	1028	9068	11029	93.21
Feb	659	6407	8932	73.78
Mar	294	5895	7564	38.87
Apr	356	7615	9618	37.01
May	253	5934	12067	20.97
Jun	102	2050	3170	32.18
Jul	0	0	0	0.00
Aug	1755	3632	5142	341.31
Sep	6341	12858	3690	1718.43
Oct	1764	5613	4222	417.81
Nov	546	3383	5543	98.50
Dec	115	3141	5786	19.88
Total	**13213**	**65596**	**76763**	**172**

Months	Total Ceph.catch	T.catch	Effort	cpue (Kg.)
Jan'96	354	5185	9170	38.60
Feb	382	5810	9185	41.59
Mar	454	4792	7230	62.79
Apr	42	4969	8270	5.08
May	192	8322	8470	22.67
Jun	140	3040	2944	47.55
Jul	0	0	0	0.00
Aug	1985	12799	4650	426.88
Sep	2450	8343	3308	740.63
Oct	1244	6432	5371	231.61
Nov	738	4978	7160	103.07
Dec	180	3988	7570	23.78
Total	**8161**	**68658**	**73328**	**111.29**

Months	Total Ceph.catch	T.catch	Effort	cpue (Kg.)
Jan'97	600	5668	13487	44.49
Feb	1020	17038	17598	57.96
Mar	1311	14196	24355	53.83
Apr	2466	13391	18285	134.86
May	852	7051	9199	92.62
Jun	301	6487	6855	43.91
Jul	0	0	0	0.00
Aug	441	3968	3555	124.05
Sep	2819	8467	3461	814.50
Oct	783	5652	6614	118.39
Nov	3284	6467	15290	214.78
Dec	309	8035	13336	23.17
Total	**14186**	**96420**	**132035**	**107.44**

Table 5.5. Total fish catch (in tonnes), Total Cephalopod catch (in tonnes), Total effort and Average cpue (cephalopods in Kg.) of Mechanised trawlers of Malappuram district from 1995-1997.

Months	Total Ceph.catch	T.catch	Effort	cpue (Kg.)
Jan'95	84	1567	9988	8.41
Feb	26	2224	12180	2.13
Mar	0	0	0	0.00
Apr	118	2465	11934	9.89
May	0	0	0	0.00
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	74	827	1674	44.21
Sep	0	0	0	0.00
Oct	0	0	0	0.00
Nov	0	0	0	0.00
Dec	0	0	0	0.00
Total	**302**	**7083**	**35776**	**8.44**
Months	**Total Ceph.catch**	**T.catch**	**Effort**	**cpue (Kg.)**
Jan'96	0	0	0	0.00
Feb	0	0	0	0.00
Mar	0	0	0	0.00
Apr	0	0	0	0.00
May	0	0	0	0.00
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	0	43	558	0.00
Sep	279	8803	13500	20.67
Oct	0	0	0	0.00
Nov	170	662	6000	28.33
Dec	61	1260	6200	9.84
Total	**510**	**10768**	**26258**	**19.42**
Months	**Total Ceph.catch**	**T.catch**	**Effort**	**cpue (Kg.)**
Jan'97		215	8277	0.00
Feb	357	1693	9720	36.73
Mar	240	1796	8370	28.67
Apr	188	922	4950	37.98
May	295	4214	13950	21.15
Jun	0	0	0	0.00
Jul	0	0	0	0.00
Aug	0	43	558	0.00
Sep	4	44	3438	1.16
Oct	417	724	3203	130.19
Nov	127	896	4500	28.22
Dec	186	941	7440	25.00
Total	**1814**	**11488**	**64406**	**28.17**

Table 5.6 Cephalopod catch (tonnes) by different gears in Malabar area from 1995 to 1997.

Districts	Year	OBRN	OBRS	OBTN	MTN	NMDGN	NMHL	OBHL	MHL	NMSS	TOTAL	MTN %age	%age indegenous
Kasaragod	1995				1120						1120	100	0
	1996				20						20	100	0
	1997		3		76						79	96.20	3.80
Cannanore	1995	1			566						567	99.82	0.18
	1996			1	177					2	180	98.33	1.67
	1997				210						210	100	0
Kozhikode	1995				13213	2		4			13219	99.95	0.05
	1996				8161		6	49	3		8219	99.29	0.71
	1997				14186		31	16	3		14236	99.65	0.35
Malappuram	1995				302	5					307	98.37	1.63
	1996				510						510	100	0
	1997				1814						1814	100	0

Abbreviations:

OBRN Out board Ring net
OBRS Out board ring seine
OBTN Out board trawl net
MTN Mech. Trawl net
NMDGN Non-mech drift gillnet
NMHL Non-mech.hooks and line
OBHL Out board Hooks and line
MHL Mech. Hooks and line
NMSS Non-mech Shore seine

Table 5.7. Gearwise catch per unit effort (Kg.) of cephalopods during pre-mosoon, monsoon and post-monsoon seasons of 1995-'97 in the districts of Malabar

		Pre-Monsoon		Monsoon	Post-Monsoon										
Districts	Year	MTN	OBHL	MTN	MTN	OBRS	NMHL	MHL	OBHL	NMDGN	OBRN	OBTN	NMSS	OBDGN	OBHL
Kasaragod	1995	37.16		0	17.14										
	1996	0		0	1.53										
	1997	0.97		0	0.89	0.29									
Cannanore	1995	11.87		0	5.06						0.23				
	1996	2.07		0	4.55							3.33	3.58		
	1997	2.49		10.67	0.82										
Kozhikode	1995	40.91		223.4	323.55									1.29	0.91
	1996	32.27		279.86	152.43		2.13	375	8.04						
	1997	81.35	0.48	71.95	149.36		5.15	375	7.49						
Malappuram	1995	4.56		44.21	8.41					3.47					
	1996	0		0	19.8										
	1997	29.2		0	27.33										

Abbreviations:

OBRN	Out board ring net	NMHL	Non-mech. hooks and line
OBRS	Out board ring seine	OBHL	Out board hooks and line
OBTN	Out board Mech. Trawl net	MHL	Mech. Hooks and line
MTN	Mech. Trawl net	NMSS	Non-mech shore seine
OBDGN	Out board drift gillnet	NMDGN	Non-mech drift gillnet

5.2.3. Mechanised trawlers:

The average monthly catch data of total cephalopods, total fish catch, effort and cpue of cephalopods for the 3 years from1995-1997 for the four districts of Malabar are give in Table 5.2 to 5.5. The cephalopods are landed throughout the year except during the monsoon month of July (Fig.5.6). The catch per unit effort is high during the post-monsoon period and also during the month of August. This trend can be observed in all the districts in varying degrees (Fig. 5.2 to 5.5). In Kasaragod district higher cpue was observed durig February-March period and in Malappuram district the differnece between the cpue of post monsoon and pre-monsoon catches were less compared to Kozhikode district. The landings of cuttlefish and squids s how a seasonal trend. The squids dominate during the premonsoon period and the early monsoon period upto June. During the late monsoon and post monsoon period upto November it is the cuttlefish that dominates (Fig.5.8). Similar trend is observed in Bombay (Silas *et.al*, 1985). This again can be correlated with the upwelling phenomenon as cuttlefishes are found in the outer regions of the contenental shelf area and upwelling brings them towards the shore where they are vulnerable to the trawlers.

Plate 5.1. Catch of the Pharaoh cuttlefish *Sepia pharaonis* and the needle cuttlefish *Sepia aculeata* at Puthiappa Fishing Harbour.

Plate 5.2. Mixed catch of the siboga squid, *Doryteuthis sibogae* and the Indian squid, *Loligo duvauceli* at Puthiappa Fishing Harbour.

5.3. Species composition:

In Malabar, the cephalopod fishery was mainly constituted by the cuttlefishes *Sepia aculeata* and *Sepia pharoanis* and the squid *Loligo duvauceli*. The species wise catch during the months (Pooled data from 1996 to 1997) for the four districts of Malabar are given in Table 5.8 to 5.11. The landings of Malabar are given in Table 5.12.

During the pre-monsoon period, 3941.8 tonnes of cephalopod were landed in Malabar during the period forming 31.43 % of the total landings. The cpue varied from 18.91 to 43 Kg. The squid *Loligo duvauceli* was the dominant species forming 42% of the total cephalopod catch. The cuttlefish *Sepia aculeata* and *Sepia pharaonis* form 16.4 % and 17.6% of the catch respectively. The octopus formed 16.9 % and *Sepiella inermis* contributed only 0.55%.

During the monsoon period, the total cephalopod catch is only 1435 tonnes as the fishery stops completely by July. By August, the cuttlefish are caught in larger percentage than the squids. The cuttlefish *Sepia aculeata* and *Sepia pharaonis* form 28.1% and 57.7% of the total catch whereas the squids form only 11.3%.

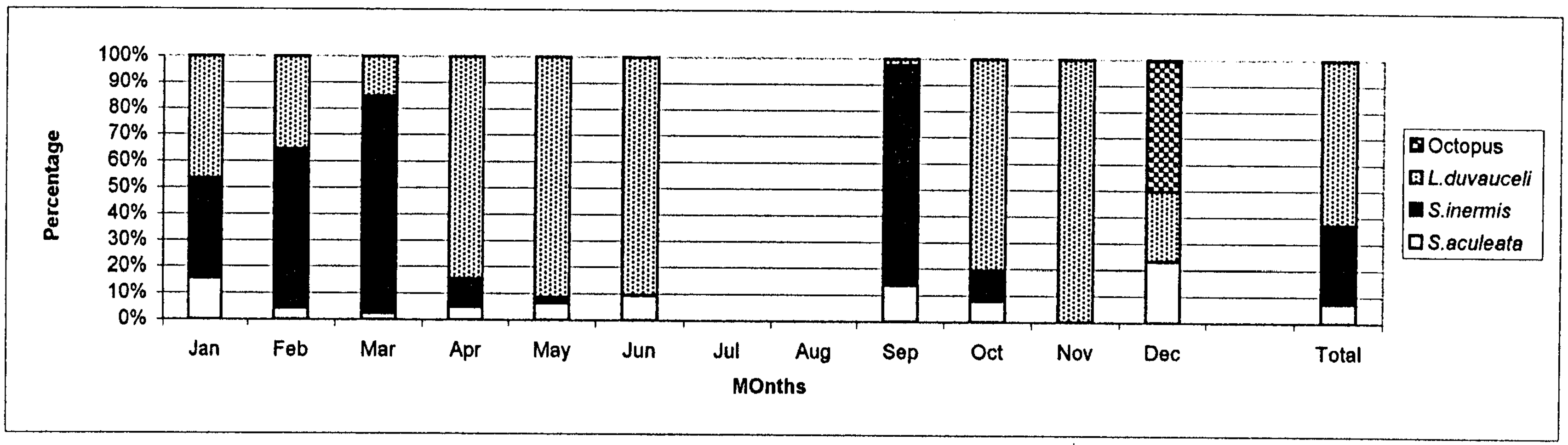
During the post-monsoon period, 7161.6 tonnes of cephalopod is landed. The cuttlefish *Sepia aculeata* and *Sepia pharaonis* dominate the catch forming 45% and 27% respectively. The squid *Loligo*

Table 5.8. Estimated landings (tonnes), fishing effort, CPUE (Kg) and species composition of cephalopods at Kasargod dist. in trawl catches for the year 1996–'97.

Table 5.9. Estimated landings (tonnes), fishing effort, CPUE (Kg) and Species composition of cephalopods at Kannur dist. in trawl catches for the year 1996–'97.

Table 5.9.

Month	*S.aculeata*	*S.inermis*	*.duvaucel*	Octopus	Total squid	Octopus	Total cuttlefish	Fishing effort	Tot.C'pods	CPUE
Jan	0.99	2.36	2.93		2.93		3.35	12366	6.28	0.51
Feb	0.30	4.03	2.39		2.39		4.33	12265	6.72	0.55
Mar	0.36	12.63	2.35		2.35		13.00	9152	15.34	1.68
Apr	1.88	4.15	32.75		32.75		6.03	16733	38.78	2.32
May	2.20	0.73	31.39		31.39		2.94	8184	34.32	4.19
Jun	0.74	0.00	7.02		7.02		0.74	750	7.76	10.34
Jul	0.00	0.00	0.00		0.00		0.00	0	0.00	0.00
Aug	0.00	0.00	0.00		0.00		0.00	0	0.00	0.00
Sep	3.40	20.59	0.62		0.62		23.99	150	24.61	164.06
Oct	1.58	2.29	16.14		16.14		3.86	2268	20.00	8.82
Nov	0.00	0.00	3.90		3.90		0.00	3158	3.90	1.23
Dec	0.21	0.00	0.24	0.45	0.24	0.45	0.21	12653	0.89	0.07
Total	**11.6485**	**46.7865**	**99.715**	**0.45**	**99.715**	**0.45**	**58.435**	**77679**	**158.6**	**2.04**



duvauceli forms only 19.5%. The octopus form 8.14% of the total catch during the period (Table 5.12).

It is interesting to note that the cuttlefish which are normally found in the deeper waters compared to the squids are more available during the post-mosoon period and during the late monsoon period when the effect of upwelling starts. Also during the pre-monsoon periods, the squids are caught in larger percentages.

In Kasaragod district, the total cephalopod catch is only 87.78 tonnes. Almost the entire catch is composed of *Loligo duvauceli* forming 93% of the total catch. The cuttlefish *S.inermis* formed 6.7 % and *Sepia aculeata* formed only negligible catch and were observed during the post monsoon period (Table 5.8).

In Cannanore district, the total cephalopod caught is about 158.6 tonnes. About 63% of the catch are of *Loligo duvauceli.* The cuttlefishes *S.inermis* (29.5 %) and *Sepia aculeata* (7.35 %) are landed. The cpue was highest during the month of October at 164 Kg. The squids dominated during the month of April and May and the cuttlefishes during September (Table 5.9).

In Kozhikode district, about 10,466 tonnes of cephalopod is landed mainly in the two major fishing harbours of Puthiappa and Beypore. The cuttlefish forms about 70% of the total cephalopod catch, the squids form about 22% and the octopus forms about 8.76%. The average

Table 5.10. Estimated landings (tonnes), fishing effort, CPUE (Kg) and species composition of cephalopods at Kozhikode dist. in trawl catches for the year 1996–'97.

Table 5.10.

Month	*S.aculeata*	*L.duvauceli*	Octopus	*S.pharaonis*	*D.sibogae*	Tot.squid	Tot.cuttlefish	Tot.octopus	Fishing effort	Tot.C'pods	CPUE
Jan	183.0	159.1	28.0	101.3	0	159.1	284.3	28.0	11329	471.5	41.62
Feb	206.8	223.0	153.6	115.1	0	223.0	321.9	153.6	13392	698.5	52.16
Mar	64.5	144.1	70.1	59.6	0	144.1	124.2	70.1	15793	338.3	21.42
Apr	245.0	277.9	205.0	266.5	177.0	454.9	511.5	205.0	13278	1171.4	88.22
May	106.4	113.3	96.1	123.8	82.5	195.8	230.3	96.1	8835	522.2	59.11
Jun	48.3	136.3	35.8	0.0	0	136.3	48.3	35.8	4900	220.4	44.97
Jul	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.00
Aug	354.0	18.9	5.2	829.4	0	18.9	1183.4	5.2	4103	1207.4	294.28
Sep	1166.7	293.0	160.9	1014.0	0	293.0	2180.7	160.9	3385	2634.6	778.32
Oct	198.3	271.5	106.5	436.7	0	271.5	635.0	106.5	5993	1013.0	169.03
Nov	1580.8	160.9	0.0	108.7	0	160.9	1689.5	0.0	1123	1850.4	1647.69
Dec	16.9	238.9	55.2	27.5	0	238.9	44.3	55.2	10453	338.5	32.38
Total	**4170.8**	**2036.9**	**916.4**	**3082.6**	**259.5**	**2296.4**	**7253.4**	**916.4**	**92584.0**	**10466.2**	**113.05**

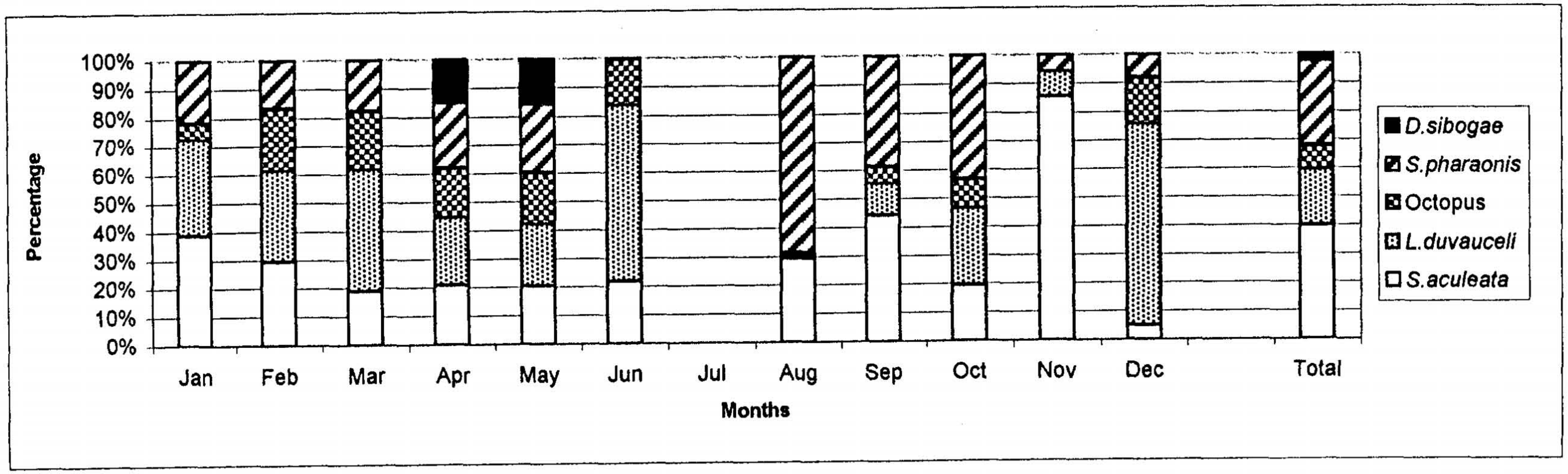


Table 5.11. Estimated landings (tonnes), fishing effort, CPUE (Kg) and species composition of cephalopods at Malappuram dist. in trawl catches for the year 1996–'97.

Table 5.11.

Month	*S.aculeata*	*S.pharaonis*	*L.duvauceli*	Octopus	Total squid	Total cuttlefish	Fishing effort	Tot.C'pods	CPUE
Jan	0.00	0.00	0.00	0	0.00	0.00	4139	0.00	0.00
Feb	0.00	66.06	189.00	100.98	189.00	66.06	4860	255.06	52.48
Mar	0.00	3.99	197.69	38.661	197.69	3.99	4185	201.68	48.19
Apr	0.00	7.65	180.00	0	180.00	7.65	2475	187.65	75.82
May	18.60	49.29	227.39	0	227.39	67.89	6975	295.28	42.33
Jun	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Jul	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Aug	0.00	0.00	0.00	0	0.00	0.00	558	0.00	0.00
Sep	0.00	0.00	3.60	0	3.60	0.00	8469	3.60	0.43
Oct	5.48	210.97	50.82	99.2	50.82	216.44	1602	267.27	166.83
Nov	47.70	19.20	92.78	25.65	92.78	66.90	5250	159.68	30.41
Dec	27.90	16.31	39.49	107.973	39.49	44.21	6820	83.70	12.27
Total	**99.68**	**373.47**	**980.762**	**372.464**	**980.76**	**473.14**	**45333**	**1453.90**	**4.38**

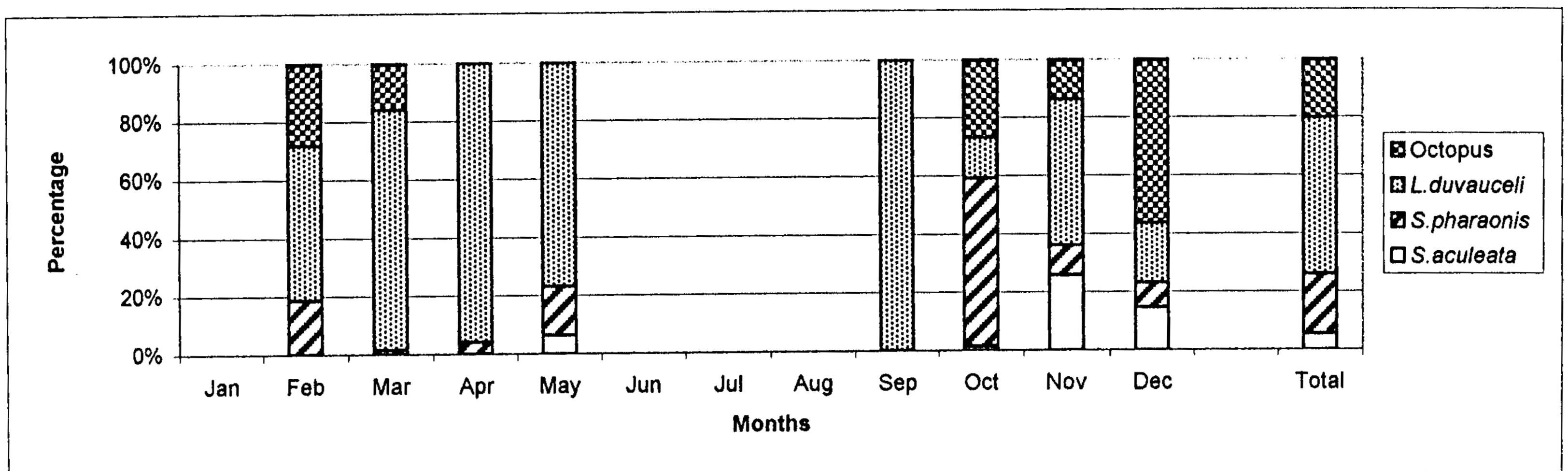
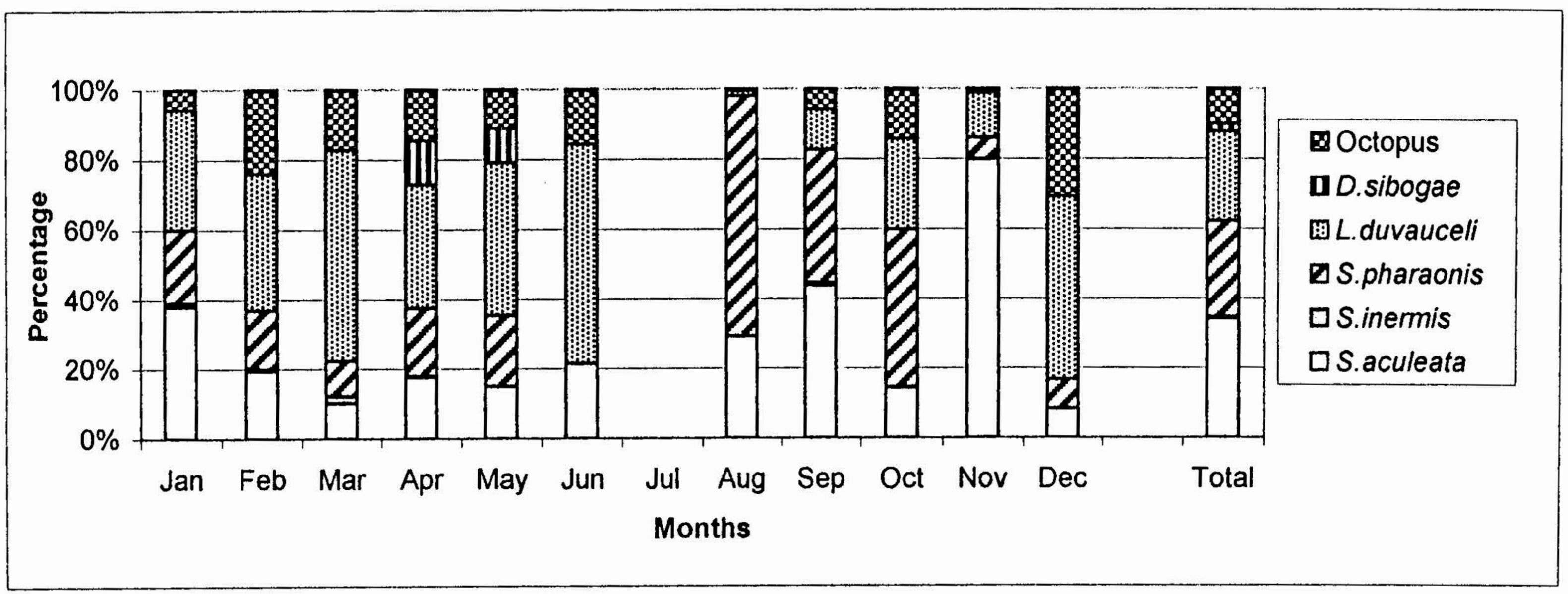


Table 5.12. Estimated landings (tonnes), fishing effort, CPUE (Kg) and species composition of cephalopods at Malabar area in trawl catches for the year 1996–'97.

Table 5.12.

Month	*S.aculeata*	*S.inermis*	*.pharaoni*	*L.duvauceli*	*D.sibogae*	Octopus	Tot.squid	Tot.octopus	Tot.cuttlefish	Effort	T.C'pods	CPUE
Jan	184.03	5.15	101.31	165.48	0.00	28.00	165.5	28.0	290.5	29565	484.0	16.37
Feb	207.13	4.03	181.16	414.35	0.00	254.55	414.3	254.6	392.3	30517	1061.2	34.77
Mar	64.90	12.63	63.63	380.99	0.00	108.75	381.0	108.8	141.2	33367	630.9	18.91
Apr	246.90	4.15	274.13	490.66	176.99	205.04	667.7	205.0	525.2	32486	1397.9	43.03
May	127.23	0.73	173.13	372.09	82.51	96.09	454.6	96.1	301.1	23994	851.8	35.50
Jun	49.02	0.00	0.00	143.30	0.00	35.81	143.3	35.8	49.0	5650	228.1	40.38
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0	0.0	0.00
Aug	354.03	0.00	829.37	18.86	0.00	5.17	18.9	5.2	1183.4	4661	1207.4	259.05
Sep	1170.46	22.15	1013.97	304.63	0.00	160.90	304.6	160.9	2206.6	13804	2672.1	193.57
Oct	205.36	3.82	647.65	369.02	0.00	205.74	369.0	205.7	856.8	11049	1431.6	129.57
Nov	1628.46	0.00	127.89	260.89	0.00	25.65	260.9	25.7	1756.4	16591	2042.9	123.13
Dec	44.97	0.00	43.79	278.64	0.00	163.61	278.6	163.6	88.8	29926	531.0	17.74
Total	**4282.48**	**52.67**	**3456.03**	**3198.92**	**259.50**	**1289.32**	**3458.4**	**1289.3**	**7791.2**	**231610**	**12538.9**	**54.14**



cpue for cephalopod is about 113 Kg., which again is also the highest in the Malabar region. The cuttlefish *Sepia aculeata* formed 39.8% of the total cephalopod catch at 4170.8 tonnes. *Sepia pharaonis* fromed 29.45 % of the total cephalopod catches at 3083.6 tonnes. Among the squids *Loligo duvauceli* formed 19.46 % of the catch at 2036.9 tonnes and *Doryteuthis sibogae* formed 2.48 % of the catch at 259.5 tonnes (Table 5.10).

In Malappuram district, the squid Loligo duvauceli dominated the catch forming 67.45 % of the total cephalopod catch at 980.76 tonnes. The cuttlefish *Sepia pharaonis* formed 373.4 tonnes (25.68 %) and *Sepia aculeata* formed 99.68 tonnes (6.85 %). The cuttlefish landings were highest during the month of October and the squids dominated during the months of February to May (Table 5.11).

5.4. Distribution of cuttlefishes and squids

Fishery of the cephalopods in India from 1976 to 1980 (Silas *et.al.*, 1985b) and in Pakistan from 1985 to 1990 (Khaliluddin, 1995) show a trend in the distribution. The averages of the period are shown in percentages in Fig 9.13. In Pakistan, the cuttlefish *Sepia pharaonis* constitute 65% of the total cuttlefish catch. This is followed by *Sepia prashadi* and *Sepiella inermis*. The squid is mainly composed of *Loligo duvauceli*. The percentage of cuttlefishes to squid is 62: 38. Further south at Bombay, the percentage of cuttlefishes increases to 61 % and at

Table 5.9. Estimated landings (tonnes), fishing effort, CPUE (Kg) and Species composition of cephalopods at Kannur dist. in trawl catches for the year 1996–'97.

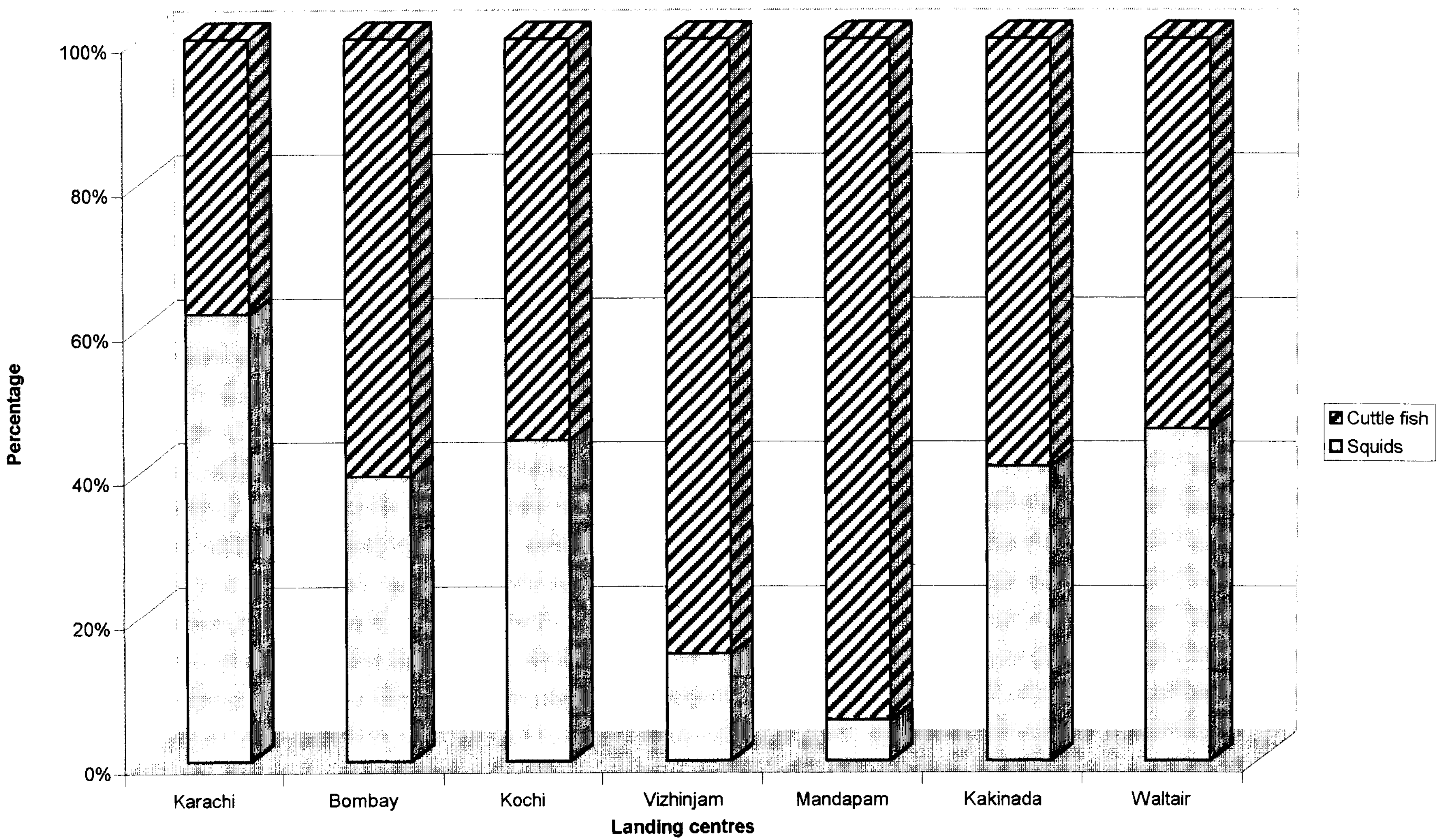
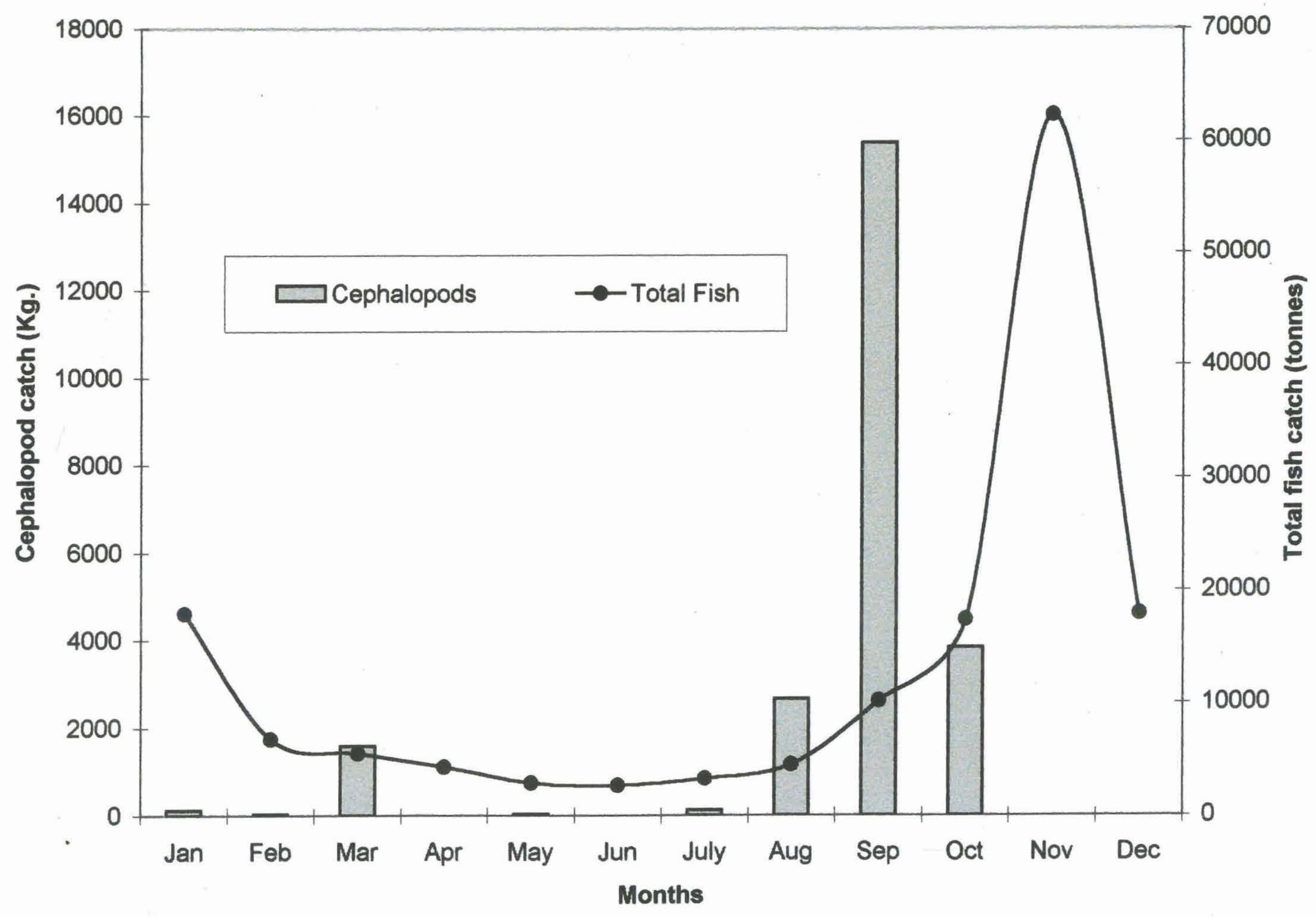

100%
80%
60%
40%
20%
0%
Percentage
Karachi
Bombay
Kochi
Vizhinjam
Mandapam
Kakinada
Waltair
Landing centres
Cuttle fish
Squids

Fig 5.10. Catch of cephalopods from Malabar area during 1931 –'32 to 1937 – '38. (Data pooled from fish statistics of Madras state 1932 – 1938).



Cephalopods
Total Fish
Cephalopod catch (Kg.)
Total fish catch (tonnes)
Months
Jan Feb Mar Apr May Jun July Aug Sep Oct Nov Dec
0 2000 4000 6000 8000 10000 12000 14000 16000 18000
0 10000 20000 30000 40000 50000 60000 70000

Vizhinjam it is 85 %. Along the East Coast at Mandapam the ratio of cuttlefish to squids is 94:6. Further north at Kakinada, again the percentage of cuttlefish's decreases with a ratio of 58:40. At Waltair, the ratio of cuttlefish to squid is 54:45. In the West Coast at higher latitudes, the squids dominate and at lower latitute the cuttlefishes dominate. In the East Coast also the percentage of squids increases with the increase in latitude. But during the recent years, due to the large-scale multiday fishing targeting the cuttlefishes in deeeper waters in many areas, this ratio has changed (Fig.5.9).

Philip and Somvanshi (1991) studying the resource of cephalopods along the contenental shelf and slope of India observed that the cuttlefish in relatively good density were found even beyond 200-meter depth. The squids were found in highest density of 331 Kg/Sq. Km in 0–50 meters depth.

5.5. Comparison with the past:

The catch data for the Malabar area in the year 1931-'32 to 1937-'38 is pooled in Fig.5.10. It is interesting to note that there is a distinct season of August to October and another during March. The present catch of cephalopods is almost throughout the year and is mainly due to the mechanised trawlers, which can reach the demersal grounds inaccessible in the earlier years. During the period from July to October, the upewelling is very active and these demersal cephalopods come to the surface waters and are thus vulnerable to the surface gears employed. It is during the post monsoon period that the large congregation is observed and is more exposed to exploitation. The catch during the earlier period was very low (Average 23.77 tonnes). The other reason is that cephalopods had the lowest price ranging fron ½ to 1 ½ rupees per maund compared to sharks which fetched 1-11 rupees per maund in 1931-'32.

5.6. Exports:

Worldwide the export of fresh and frozen cephalopods almost doubled between 1990 and 1996. The increase went up from 5,00,000 tonnes to almost 1 million tonnes. The main exporter of fresh and frozen cephalopod is Spain. From 51,700 tonnes in 1990 it doubled its export to 1,04,000 t in 1996. But Morocco remains the top fresh and frozen cephalopod exporter in value terms at US$430 million in 1996 although its export in quantity decreased from 54,700 tonnes in 1990. Second position is that of Spain with US$ 302 million and India with US$ 165 million (FAO, 1997).

Among the seafood items exported from India, cephalopod form the third largest component after prawn and Tuna. During the year 1973, the figure was 46 tonnes valued at Rs.4 lakhs. By 1975 the figure increased to 1,072 tonnes at Rs.2.94 crores. The export gradually increased and by 1980, India was exporting 3,818 tonnes valued at 5.58 crores. After showing a decline for couple of years, export picked up and by 1983, reached 4050 tonnes. There has been a spectacular increase in cephalopod export and by 1991-92, the quantity exported was 38,579 tonnes valued at 171.83 crores. This growth steadily increased and during 1995-96, a total of 81139 tonnes valued at 591.61 crores was exported (MPEDA, 1998).

Cuttlefish are exported in various forms like whole, whole cleaned, fillets, stripes, tentacles, roes, ink and in Individually Quick Frozen (IQF) form. The most preferred form of product is whole cleaned, followed by whole frozen while in case of squids whole, whole cleaned, tubes and rings are the preferred forms.

The major market for cuttlefish is Spain, followed by China, Japan, HongKong and Italy. For squids, the major market is Thialand, followed by Greece, Spain, Italy, USA, France and Japan. For octopus, the major markets are Italy and Spain.

Lately, the Asian markets have emerged. Countries like Hong Kong, South Korea, Malaysia, Singapore, Taiwan and Thailand are the major consumers after Japan. These countries among themselves share

32% of the global consumption against 45 % for Japan and 15% for Mediterrainian countries (Nambiar, 1995).

In India after shrimps and tunas, cephalopods are the largest seafood export item (MPEDA, 1996). In recent times, this group has emerged as our important seafood export item.

Squids: During 1996-97, Thialand was the largest importer with 16.18%, followed by Greece (11.72%), Italy (9.95%) and USA (8.74%). Other important counttries are France, Spain and Japan.

Cuttlefish: China has emerged as the biggest market in terms of qantity forming 21.27%, followed by Spain (16.58%), HongKong (15.32%). Other important importers are Italy, Japan, Portugal and Thailand.

Octopus: During 1996-97,more than a quarter (26.42%) of the octopus was exported to Italy. Spain with 17.41% is the second biggest importer. S.Korea, Netherlands, Thailand, Cyprus, Greece and China are other markets.

Recently, export of dried cephalopod products has started. During 1994-95, 77 tonnes of dried squid and 2 tonnes of cuttlefish valued at Rs.46.6 lakhs were exported. This increased to 237 tonnes valued at Rs.141.3 lakhs in 1995-96 but declined during 1996-97 to just 22 tonnes valued at Rs.17.9 lakhs.

Table 5.13 depicts the quantity and value wise export of major cephalopod groups from India from 1994-95 to 1996-97.

Table 5. 13: Export of cephalopods from India.

Quantity in tonnes and Value in Crore rupees

Year	Squid	Cuttlefish	Octopus
1994-95 Quantity	37,197	28,145	1956
Value	245.1	224.01	9.38
1995-96 Quantity	45,924	33,845	1981
Value	319.58	260.86	9.32
1996-97 Quantity	40.924	31,778	2952
Value	290.45	272.37	13.35

AGE AND GROWTH

P.K. Asokan "Biology and fishery of cephalopods (mollusca: cephalopoda) along the malabar coast " Thesis. Department of Zoology , University of Calicut, 2000

CHAPTER – 6

AGE AND GROWTH

Growth is the change of size and weight of a living organism with age. This is very important parameter in the estimation of yield per recruit from exploitation. Growth can be recorded by making measurements of the length or weight of an individual and relating them to age. Growth in length does not quite ceases, but tend towards an asymptotic size. At any age, the slope of the curve can then estimate the growth rate at that age. The growth rate is rapid at young stage and decreases successively as it becomes older.

Some studies on the age and growth of cephalopods in India have been made by Rao (1953), Silas *et.al.*, (1985a), Kasim (1985), Meiyappan and Srinath (1987), Meiyappan *et.al.*, (1993), Nair *et.al.*, (1993), Mohammed (1996) and Mohammed and Rao (1997).

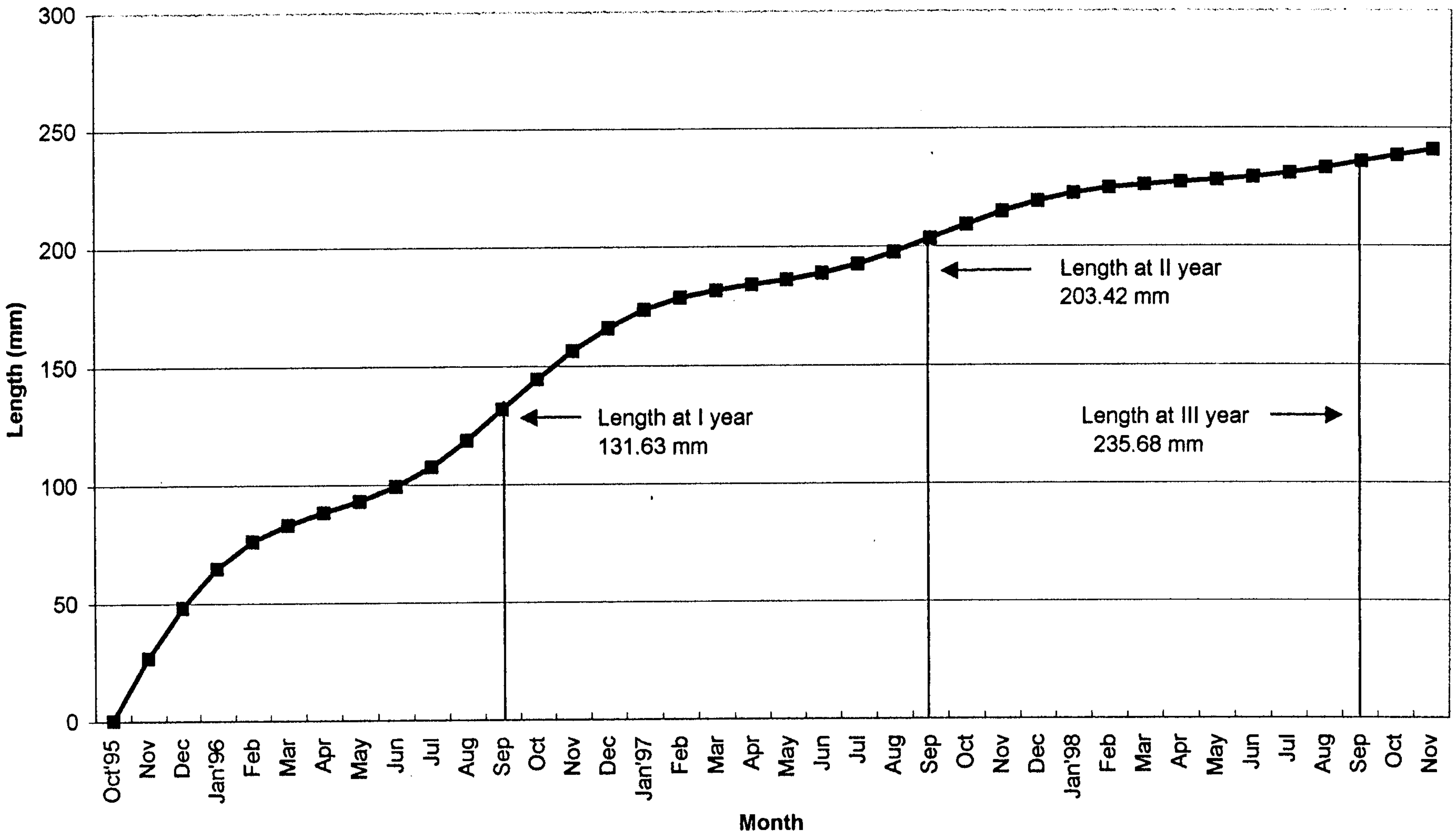
Recently the ageing of the squids using the statoliths have been attempted. This is similar to the otoliths and other hard parts used in finfishes. This requires speciaslised equipments and processing. But for easy and practical purposes, studies on the length frequency distribution are most suitable.

6.1. GROWTH PARAMETERS OF *L.DUVAUCELI*

The data for males and females were treated separately for the estimation of growth parameters. For estimation of growth parameters, the length frequencies were grouped in 5mm intervals. The samples for each day were raised to the catch of the day. The raised frequencies for all samples in a month were pooled and raised again to the catch of the month to get the monthly length frequency distribution. The monthly length frequency distribution for the whole period of observations were fed to FiSAT (FAO-ICLARM Stock assessment Tools) programmes to extract the best fitting growth line.

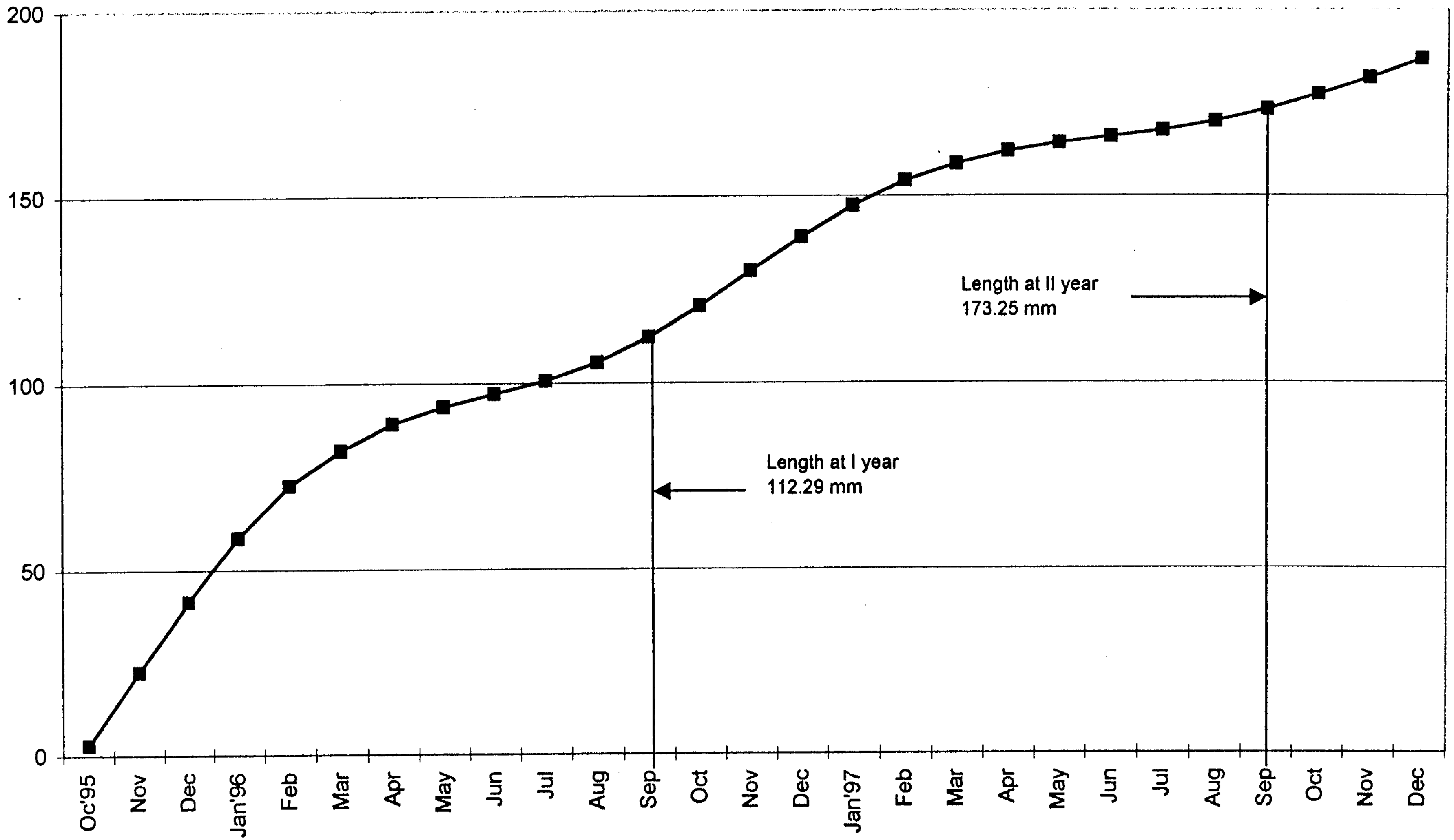
The length frequency distribution in 5mm length groups produced multiplicity of modes making the extraction of growth parameters very difficult. Hence the length frequency interval was increased to 10 mm and the best fitting growth line was extracted using seasonalised von Bertalanffy's growth curve (Pauly and Gaschütz, 1979). The best fitting growth line had the following parameters:

Fig.6.1. Monthly growth of *Loligo duvauceli* (male)
$L\alpha$ = 262, K = 0.80, C = 0.6 and Wp = 0.3



300
250
200
150
100
50
0
Length (mm)
Length at I year
131.63 mm
Length at II year
203.42 mm
Length at III year
235.68 mm
Oct'95
Nov
Dec
Jan'96
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan'97
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan'98
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Month

Fig.6.2. Monthly growth of *Loligo duvauceli* (female)
$L\alpha$ = 230, K = 0.73, C = 0.6 and Wp = 0.44


200
150
100
50
0
Oc'95
Nov
Dec
Jan'96
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan'97
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Length at I year
112.29 mm
Length at II year
173.25 mm

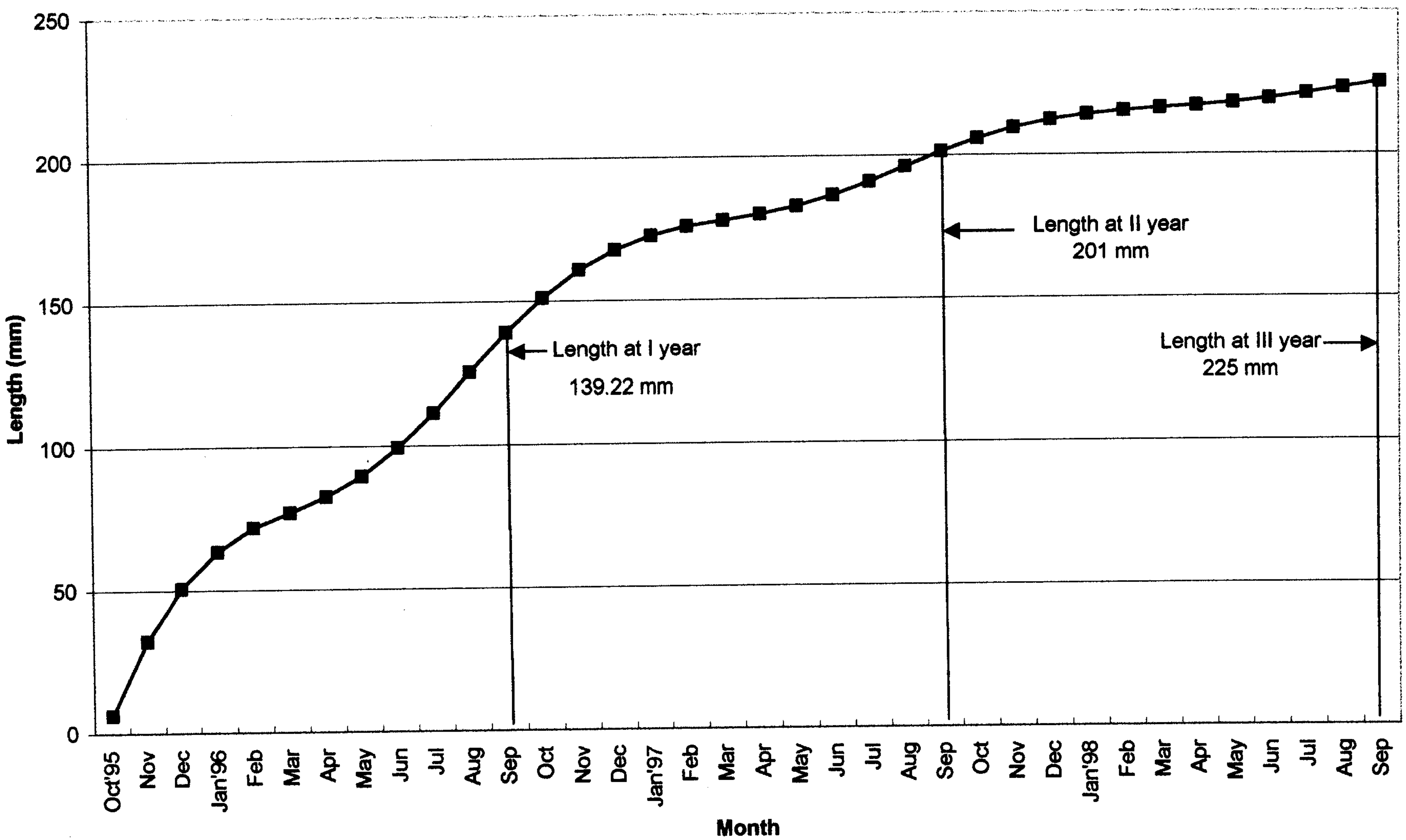
	Male	Female
L α	262 mm	230 mm
K	0.80	0.73
C	0.60	0.60
Wp	0.30	0.44
Rn value	0.150	0.207

Accordingly, the males reach a size of 131.63 mm by first year and 203.42 mm by second year and by the end of third year they reach a size of 235.42 mm. The resultant growth curves are given in Fig 6.1. The effective life span estimated as the age to reach 0.95 of L α is only 3.8 years.

In the case of females, the size attained at the end of first year is 112.29 mm and by second year reaches a size of 173.25 mm. The resultant growth curves are given in Fig 6.2.

It can be seen that the Lα of males is considerably larger than females and K value also is slightly more indicating that the males grow a little faster than the females. Perhaps the strains of maturation and spawning are experienced more by the females. The seasonality factors C

Fig.6.3. Monthly growth of *Loligo duvauceli* (pooled)
$L\alpha$ = 239, K = 0.97, C = 0.6 and Wp = 0.21



Length (mm)
250
200
150
100
50
0
Length at I year
139.22 mm
Length at II year
201 mm
Length at III year
225 mm
Oct'95
Nov
Dec
Jan'96
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan'97
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan'98
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month

and Wp indicated that the growth rate decrease considerably after April till August. Best growth rate is observed during August to February producing amplitude in growth rate.

However, management measures cannot be evolved separately for males and females as they are exploited together by the same gears. For the yield per recruit studies on the resource, common growth parameters were estimated using similar method. The best fitting growth line gave the following parameters:

$L\alpha = 239.4$ mm

$K = 0.97$

$C = 0.6$

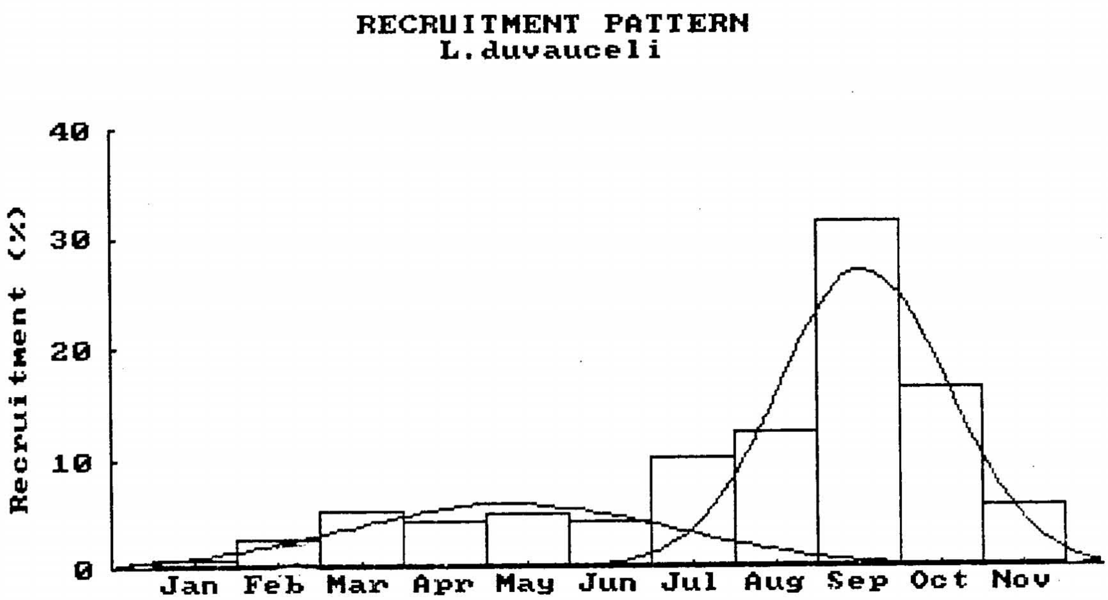
$Wp = 0.210$

with a Rn value of 0.154.

The average size reached by the species (male and female) at the end of 1,2 and 3 years is 139.22 mm, 201 mm and 225 mm, the effective life span being 3 years. The resultant growth curves are given in Fig 6.3.

The Fig 6.1, 6.2 and 6.3 indicates that the major brood that supports the fishery was born in September. The length frequency data

Fig.6.4.



Lα = 239 mm, K = 0.97, C = 0.6, Wp = 0.21

Recruitment percentage for each month:

January	0.93	July	10.24
February	2.73	August	12.79
March	5.32	September	31.71
April	4.41	October	16.48
May	5.05	November	5.82
June	4.51	December	0.0

was subjected to analysis of recruitment pattern using FiSAT. The result is given in Fig. 6.4. The figure shows a major spawning in September and a minor one around May.

6.2. GROWTH PARAMETERS OF *SEPIA ACULEATA*:

The seasonalised Von Bertallanfy's growth equation was used with the FiSAT programme and the following parameters were estimated:

$$L\alpha = 200 \text{ cm}$$

$$K = 0.83$$

$$C = 0.50$$

$$Wp = 0.40$$

with a Rn value of 0.277.

The growth in length at the end of 6 month, one year and 1½ and 2 years are 45.83cm, 110 cm, 132.78 and 161.17 cm respectively. To attain an asymptotic length it takes 5 years. This is shown in Fig 6.5. The major brood that supports the fishery is born in March. The recruitment pattern of *Sepia aculeata* was calculated using FiSAT. The result given in Fig.6.6 shows the major recruitment during the months of February to June with peak during March to April period.

Fig.6.5. Monthly growth of *Sepia aculeata* (pooled)
$L\alpha$ = 200, K = 0.83, C = 0.5 and Wp = 0.40

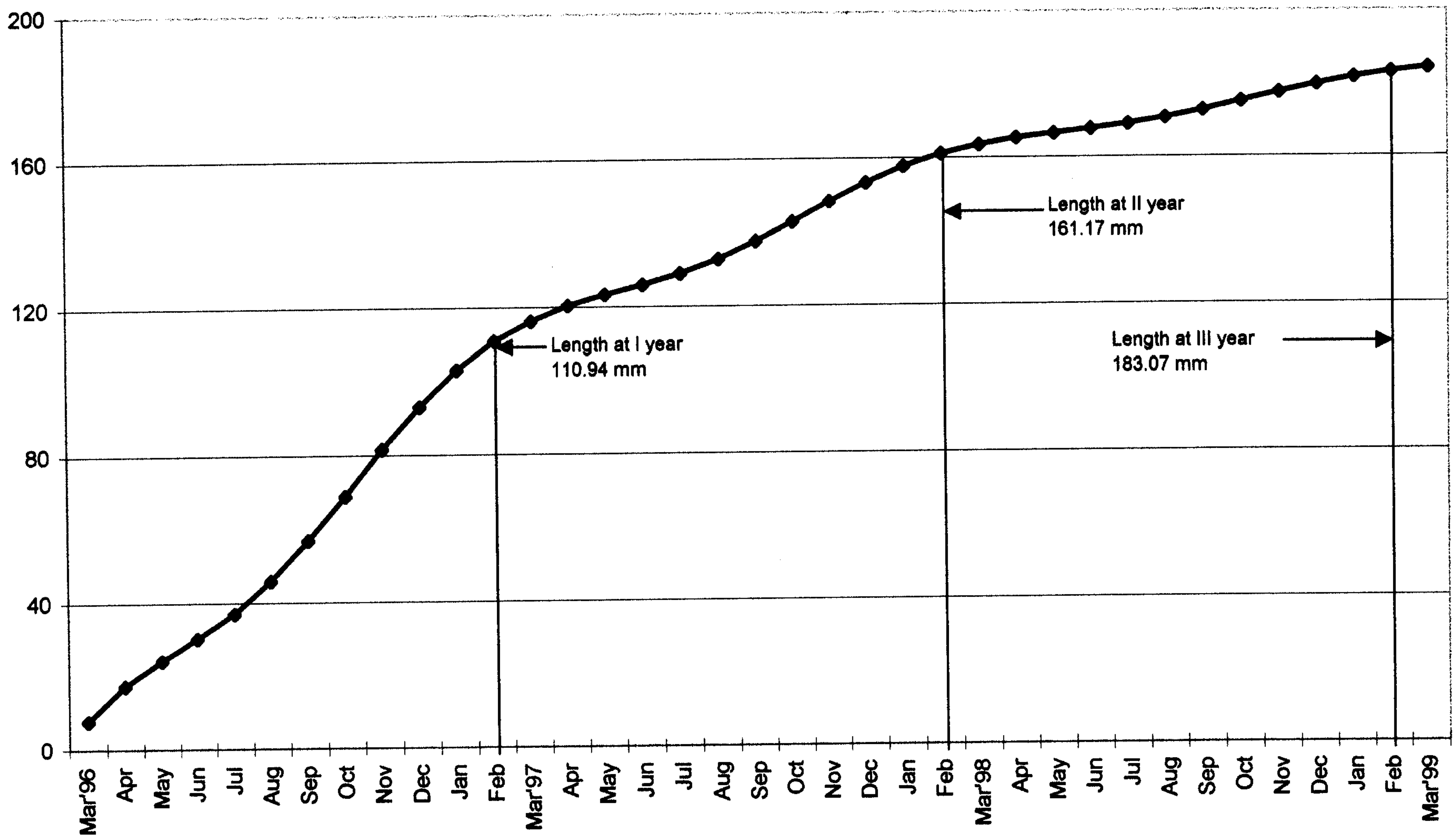
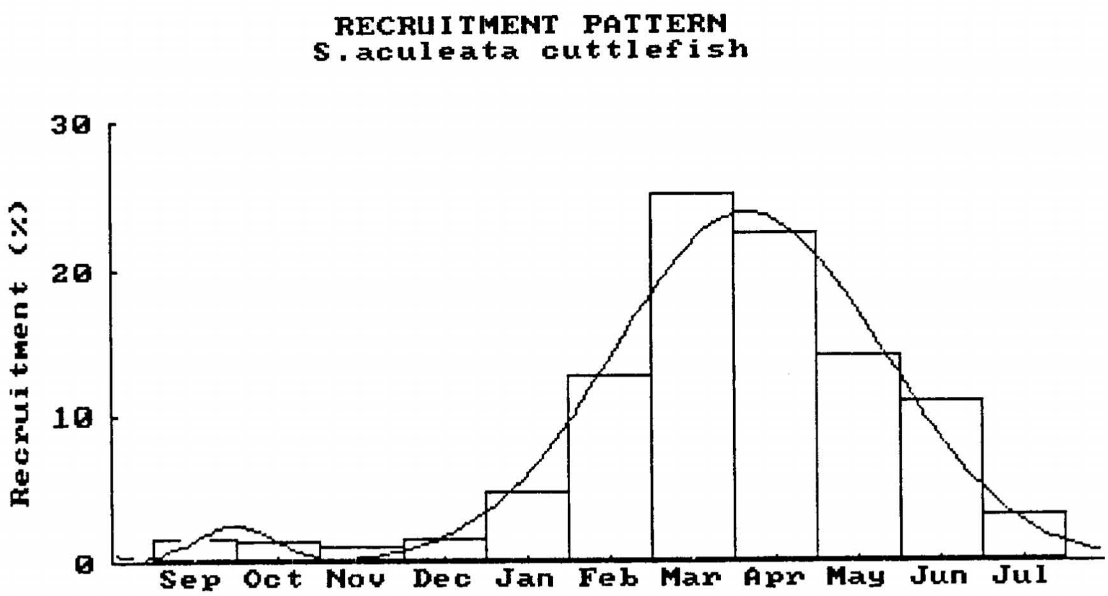

200
160
120
80
40
0
Length at I year
110.94 mm
Length at II year
161.17 mm
Length at III year
183.07 mm
Mar'96
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar'97
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar'98
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar'99

Fig.6.6.



Lα = 200 mm, K = 0.83, C = 0.5, Wp = 0.40

Recruitment percentage for each month:

January	4.86	July	3.29
February	12.69	August	0.0
March	25.46	September	1.64
April	22.80	October	1.47
May	14.14	November	1.10
June	10.93	December	1.61

The growth of squids has been variously described as linear, exponential, asymptotic or oscillating. Pauly (1995) mentions that these conflicting growth patterns could be resolved in a basic growth pattern of the asymptotic type with superimposed seasonal growth oscillations. What appear as differences in growth characteristics within the populations are considered artifacts due to changes in birth date.

The growth parameters of *Loligo duvauceli* estimated by different studies are tabulated below in Table 6.1.

Table 6.1. Growth parameters of *Loligo duvauceli* estimated by different workers

Sl.No.	Place	Sex	L α (cm)	K	C	Reference
1.	Madras	Male	20	0.94		Silas (1985)
	Madras	Female	20	0.94		
2.	Cochin	Male	32.7	0.61		Silas (1985)
	Cochin	Female	20.5	1.19		
3.	Veraval	Pooled	33.4	0.5		Kasim (1985)
4.	Cochin	Male	37.9	1.1		Meiyappan and Srinath (1987)
	Cochin	Female	23.8	1.7		
5.	E.coast	Male	22.0	0.9		Meiyappan *et.al.* (1993)
		Female	20.5	1.3		

6.	W.coast	Male	36	0.8		Meiyappan *et.al.* (1993)
		Female	23.2	1.1		
7.	Mangalore	Male	41.5	1.1		Mohammed (1996)
		Female	24.5	0.9		
8.	Karnataka	Pooled	37.1	1.4	0.5	Mohammed and Rao (1997)
9.	Calicut	Male	26.2	0.8	0.6	Present study
		Female	23.0	0.73	0.6	
		Pooled	23.9	0.97	0.6	

The growth characteristics obtained for *Sepia aculeata* is in agreement with Rao *et.al.*, (1993) than that obtained by Rao (1997), which has a higher value of K and L α. For estimating the growth parameters, the sexes were pooled, as the analysis of covariance indicated no significant variation between the sexes. The results obtained by Rao *et.al.*,(1993) also show not much difference between sexes in the parameters calculated from both the coast of India. The growth parameters calculated by different workers for *Sepia aculeata* is given in Table 6.2.

Table 6.2. Growth parameters of *Sepia aculeata* estimated by different workers.

Sl.No.	Place	Sex	L α (cm)	K	C	Reference
1.	E.Coast	Male	20.3	0.9		Rao *et.al.*(1993)
	E.Coast	Female	20.3	0.9		
2.	W.coast	Male	20.6	1.1		Rao *et.al.*(1993)
	W.coast	Female	20.5	1.0		
3.	Mangalore	Pooled	23.1	1.49		Rao, G.S. (1997)
4.	Calicut	Pooled	20.0	0.83	0.5	Present study

POPULATION DYNAMICS AND MANAGEMENT

P.K. Asokan "Biology and fishery of cephalopods (mollusca: cephalopoda) along the malabar coast " Thesis. Department of Zoology , University of Calicut, 2000

CHAPTER – 7

POPULATION DYNAMICS AND MANAGEMENT

Estimation of population parameters and the study of the dynamics give the basic input data for the estimation of stock and understanding its changes with variation in exploitation and the optimum time of capture.

7.1. POPULATION PARAMETERS (*L.DUVAUCELI*)

7.1.1. Length-weight relation:

Length and weight was estimated separately for male and female as well as the pooled data of both the sexes. A total number of 275 males were used for the study and the curvilinear relation was:

$$W = 0.0058014 \, L^{1.90369}$$

Where W is the weight of the males in grams and L, the dorsal matle length (DML) in mm. The correlation coefficient was 0.91270 (Fig7.1).

355 numbers of females were used for a similar study and the estimated relation was:

Fig. 7.1. Length-weight relationship of *Loligo duvauceli* (male).
(Curvilinear relation of the form: $W = aL^b$
with a = 0.0058014
b = 1.903)

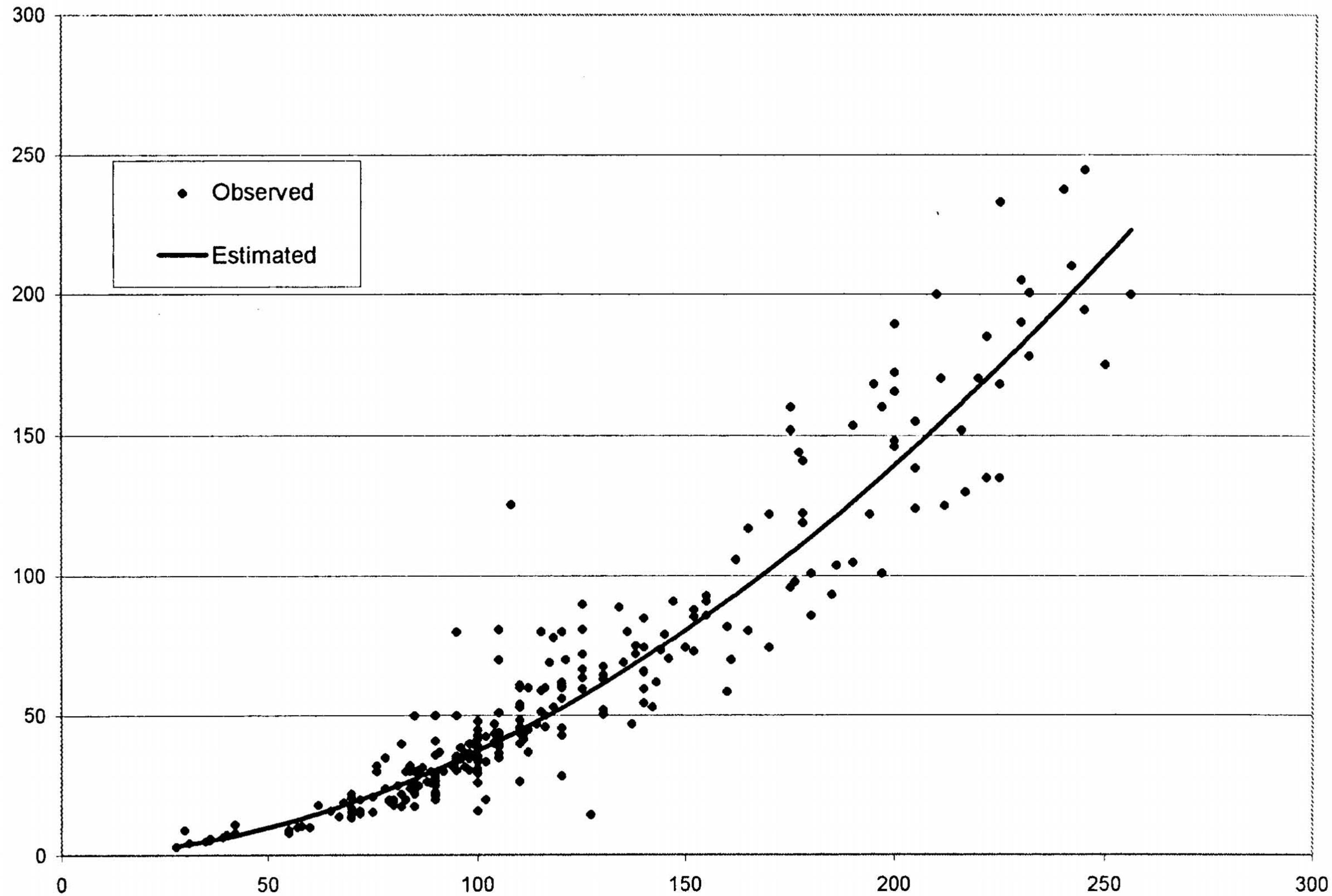
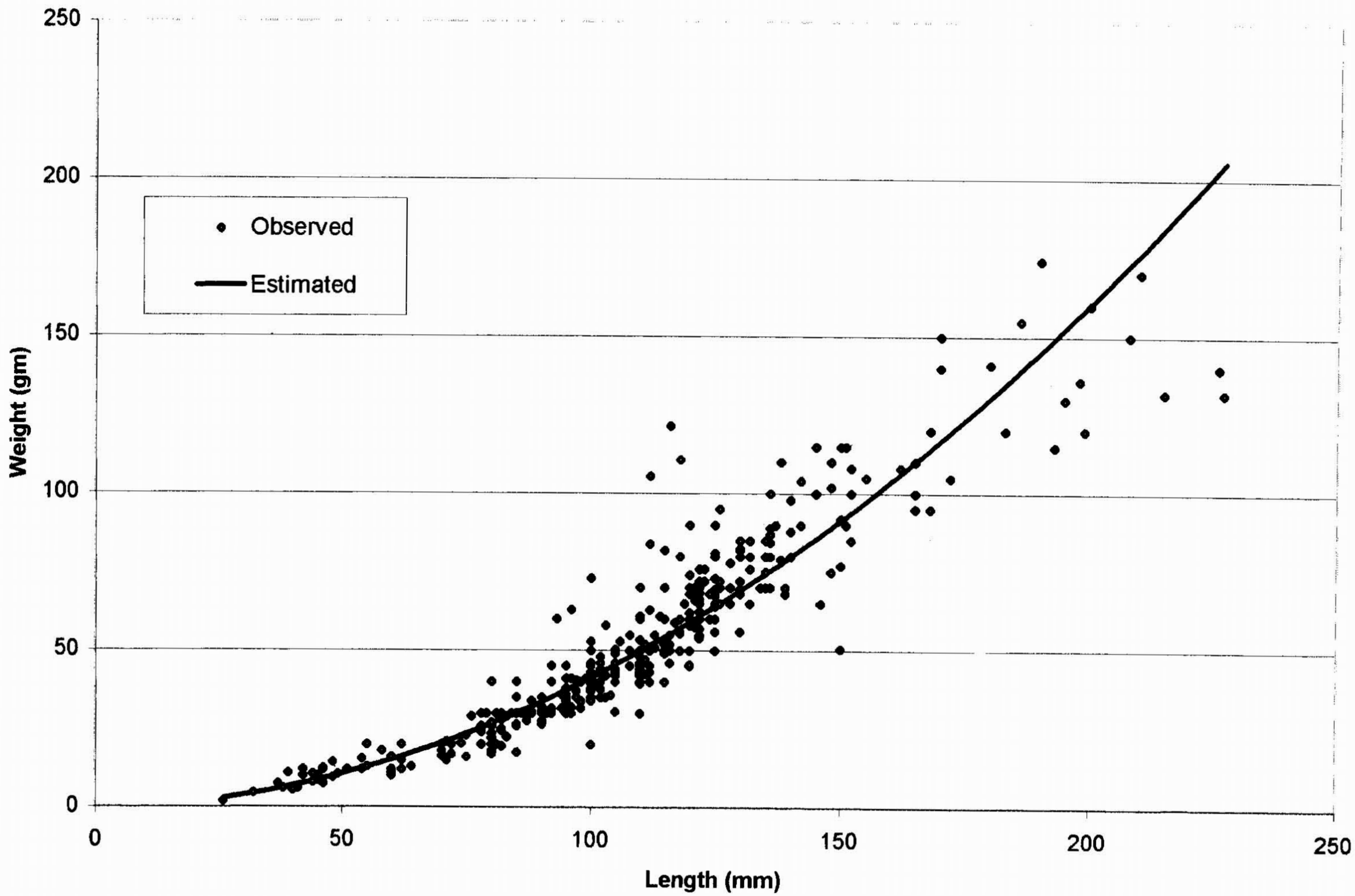
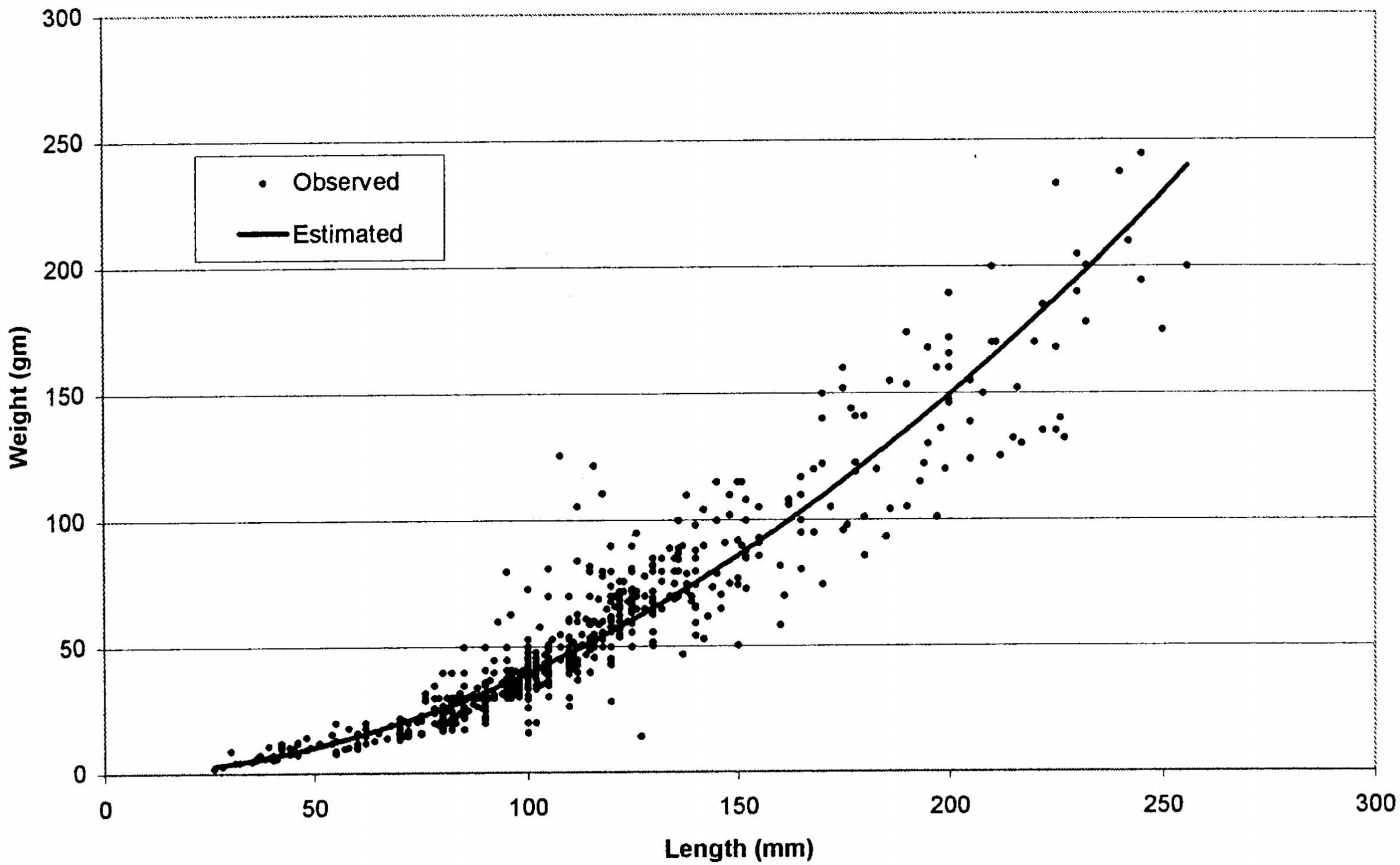

300
250
200
150
100
50
0
Observed
Estimated
0
50
100
150
200
250
300

Fig. 7.2. Length-weight relationship of *Loligo duvauceli* (female).
(Curvilinear relation of the form: $W = aL^b$
with $a = 0.00502384$
$b = 1.9568$)



250
200
150
100
50
0
Weight (gm)
0
50
100
150
200
250
Length (mm)
Observed
Estimated

Fig. 7.3. Length-weight relationship of *Loligo duvauceli* (pooled).
(Curvilinear relation of the form: $W = aL^b$
with a = 0.0057387
b = 1.91887)



Observed
Estimated
Weight (gm)
300
250
200
150
100
50
0
0
50
100
150
200
250
300
Length (mm)

$$W = .00502384 \, L^{1.956822}$$

with a regression coefficient of 0.916581 (Fig7.2)

The pooled data of 630 numbers of observations gave the relation as:

$$W = .0057387 \, L^{1.91887}$$

with a regression coefficient as 0.90956. (Fig7.3).

The Wα was estimated using the Length-weight relation. The relation estimated with the following values:

Combined Wα = 210.21 gm

Male Wα = 232.93 gm

Female Wα = 210.92 gm

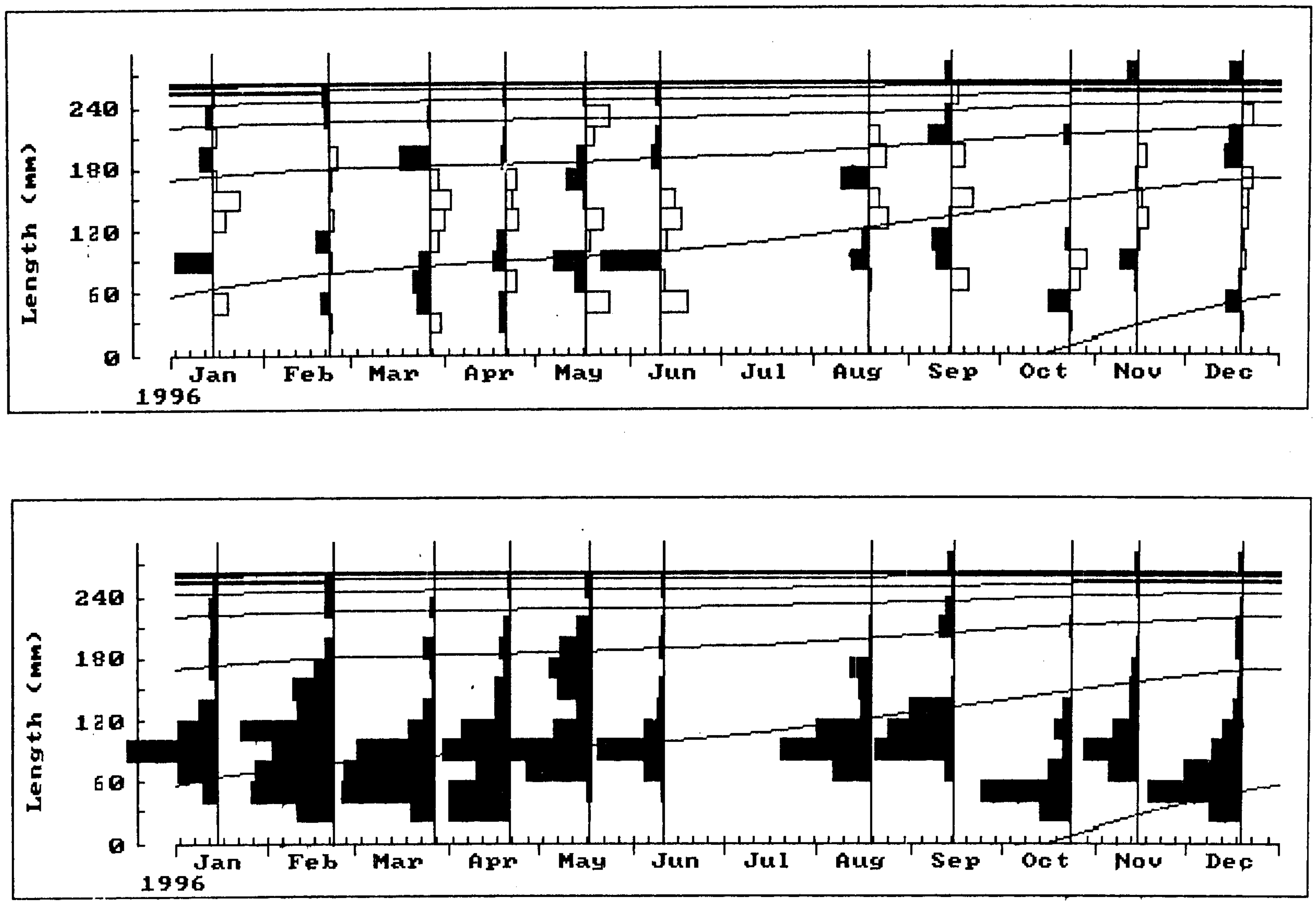
7.1.2. Total mortality (Z) :

The total mortality (Z) was estimated separately for males and females and the values are given in Table 7.1 and Fig. 7.4 and 7.5.Hence, the Z was estimated from the pooled data of males and females to be used for further studies (Fig.7.6). The estimated Z was 6.08. Other details of

Fig. 7.4. Restructured (A) and percentage (B) length frequency (1996 – 1997 Pooled) of male *Loligo duvauceli* fitted with seasonally oscillating version of VBGF.

A

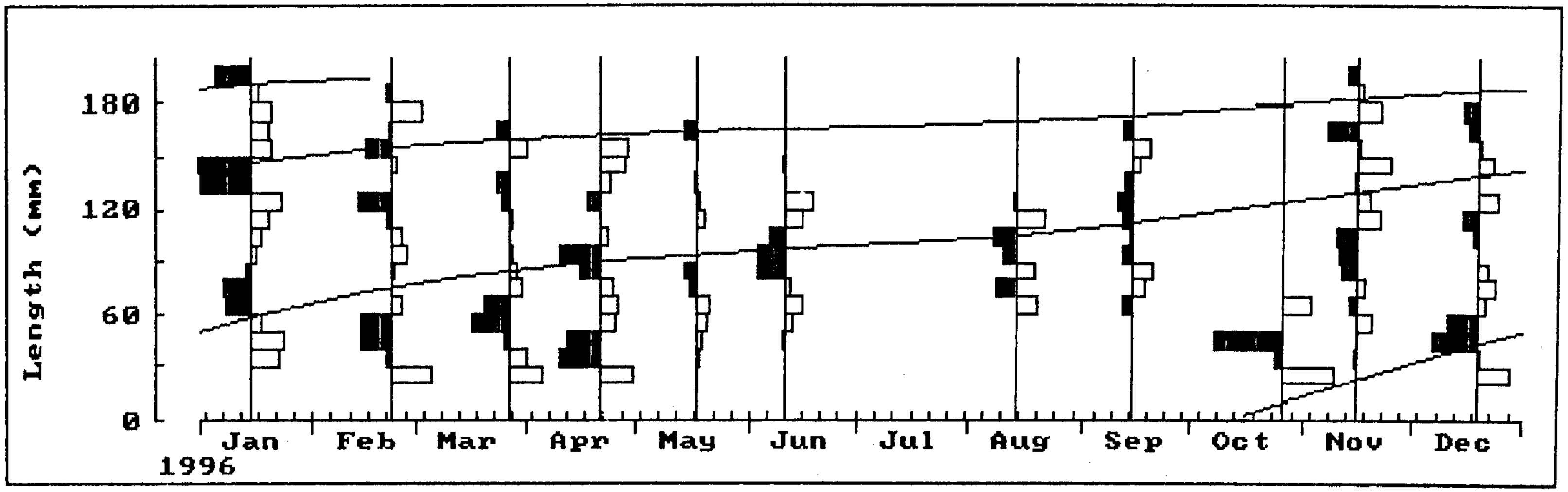
B



Length (mm)
0
60
120
180
240
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1996

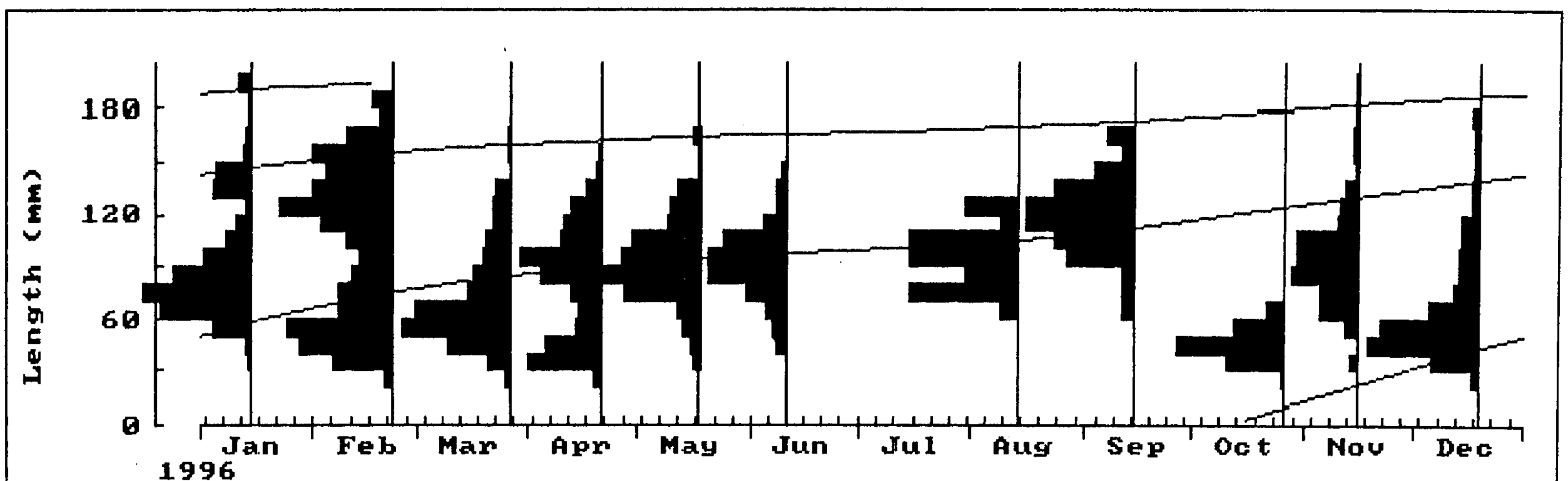
Fig. 7.5. Restructured (A) and percentage (B) length frequency (1996 – 1997 Pooled) of female *Loligo duvauceli* fitted with seasonally oscillating version of VBGF.

A



Length (mm)
180
120
60
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1996

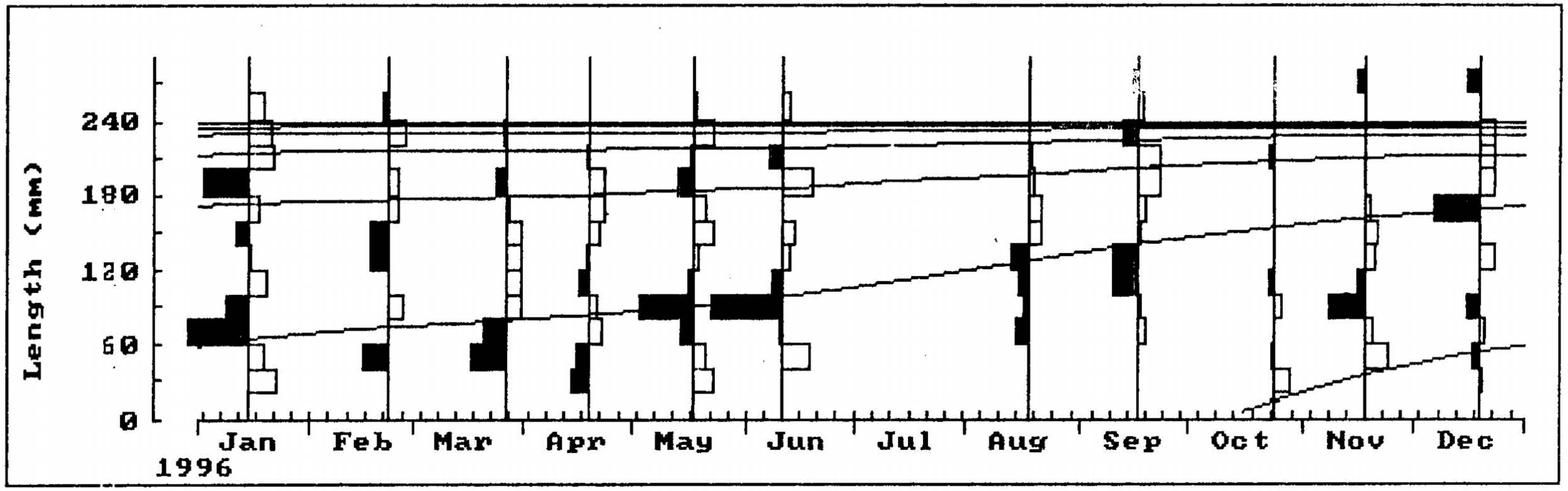
B



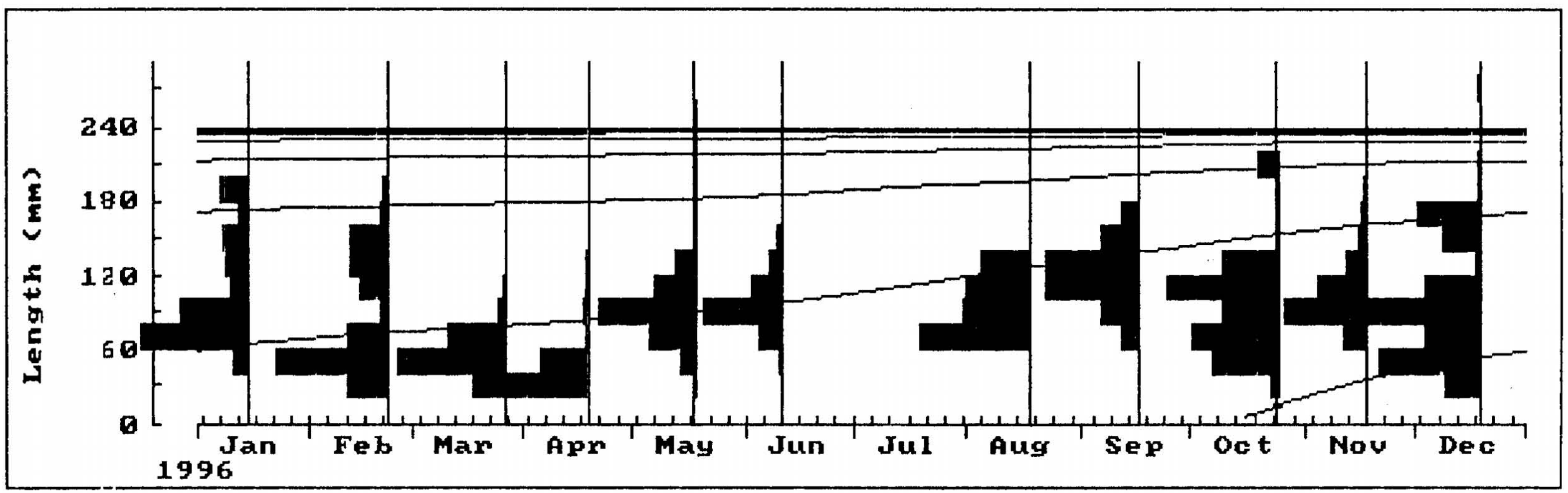
Length (mm)
180
120
60
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1996

Fig. 7.6. Restructured (A) and percentage (B) length frequency (1996 – 1997 Pooled) of *Loligo duvauceli* fitted with seasonally oscillating version of VBGF.

A


240
180
120
60
0
Length (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1996

B


240
180
120
60
0
Length (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1996

estimation are given in Table 7.1. The estimation of mortality separately for males and females will serve no purpose in managing the fishery in which the males and females are exploited together.

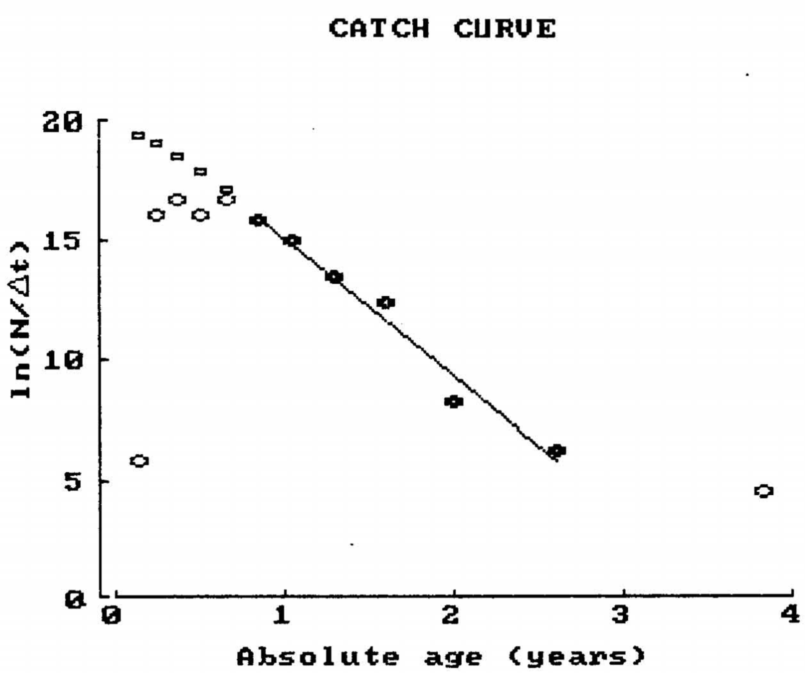
Table 7.1

	Males	**Females**	**Pooled**
Lα	262.0	230	239
K	0.8	0.73	0.97
C	0.6	0.6	0.6
Wp	0.3	0.44	0.21
Z	5.78	3.15	6.08
Cutt of length (mm)	120	100	80

7.1.3. Natural mortality (M) and fishing mortality (F) :

M was estimated using the equation given by Pauly (1980) for an average temperature of 28 ^{0}C. The linearised catch curve based on length composition of males, females and pooled data is shown in Fig.7.7, Fig.7.8 and Fig.7.9. The estimates for males, females and pooled data are given below:

Fig.7.7. Linearised catch curve based on length composition of male *Loligo duvauceli*.

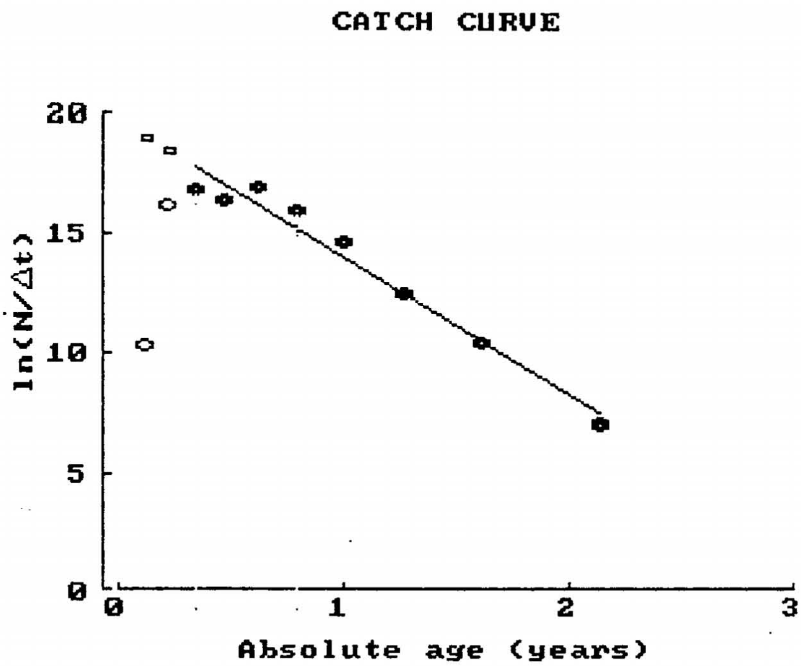


Growth parameters:

Lα : 262 mm K : 0.80

Cutoff length (L')	= 120.0
Mean length (from L')	= 141.15
Z from catch curve	= 5.78
Natural mortality (M)	= 1.60
Fishing mortality (F = Z – M)	= 4.18
Exploit. Rate (E = F/Z)	= 0.72

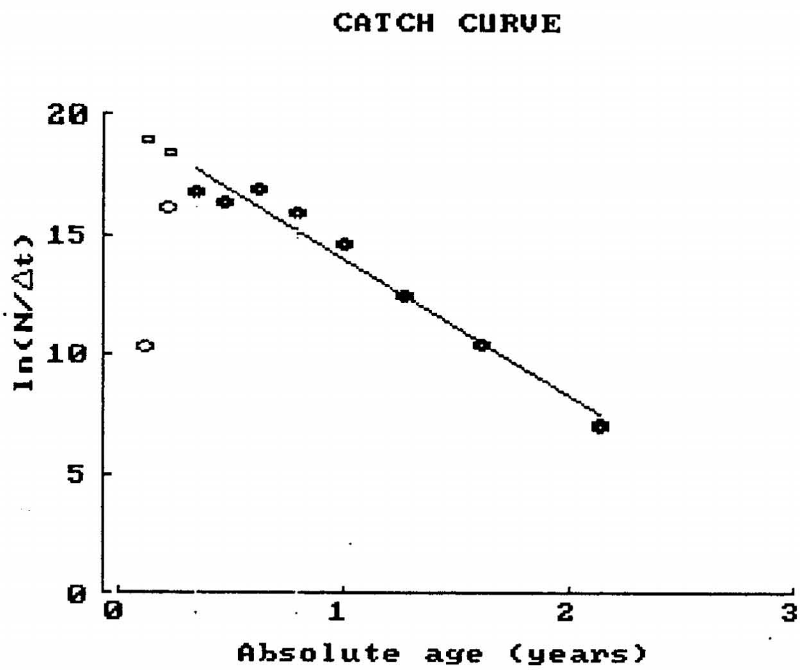
Fig.7.8. Linearised catch curve based on length composition of female *Loligo duvauceli*.



Growth parameters:
Lα : 239 mm K : 0.97

Cutoff length (L')	= 60.0
Mean length (from L')	= 102.6
Z from catch curve	= 5.74
Natural mortality (M)	= 1.86
Fishing mortality	
(F = Z – M)	= 3.88
Exploit. Rate (E = F/Z)	= 0.68

Fig.7.9. Linearised catch curve based on length composition of pooled (male and female) *Loligo duvauceli*.



Growth parameters:

Lα : 239 mm K : 0.97

Cutoff length (L')	= 60.0
Mean length (from L')	= 102.6
Z from catch curve	= 5.74
Natural mortality (M)	= 1.86
Fishing mortality (F = Z – M)	= 3.88
Exploit. Rate (E = F/Z)	= 0.68

Table 7.2

	Males	Females	Pooled
M	1.6	1.57	1.86
F	4.18	1.58	3.88
M/K	2.0	2.15	1.917
E	0.72	0.50	0.68

7.1.4. Stock estimates:

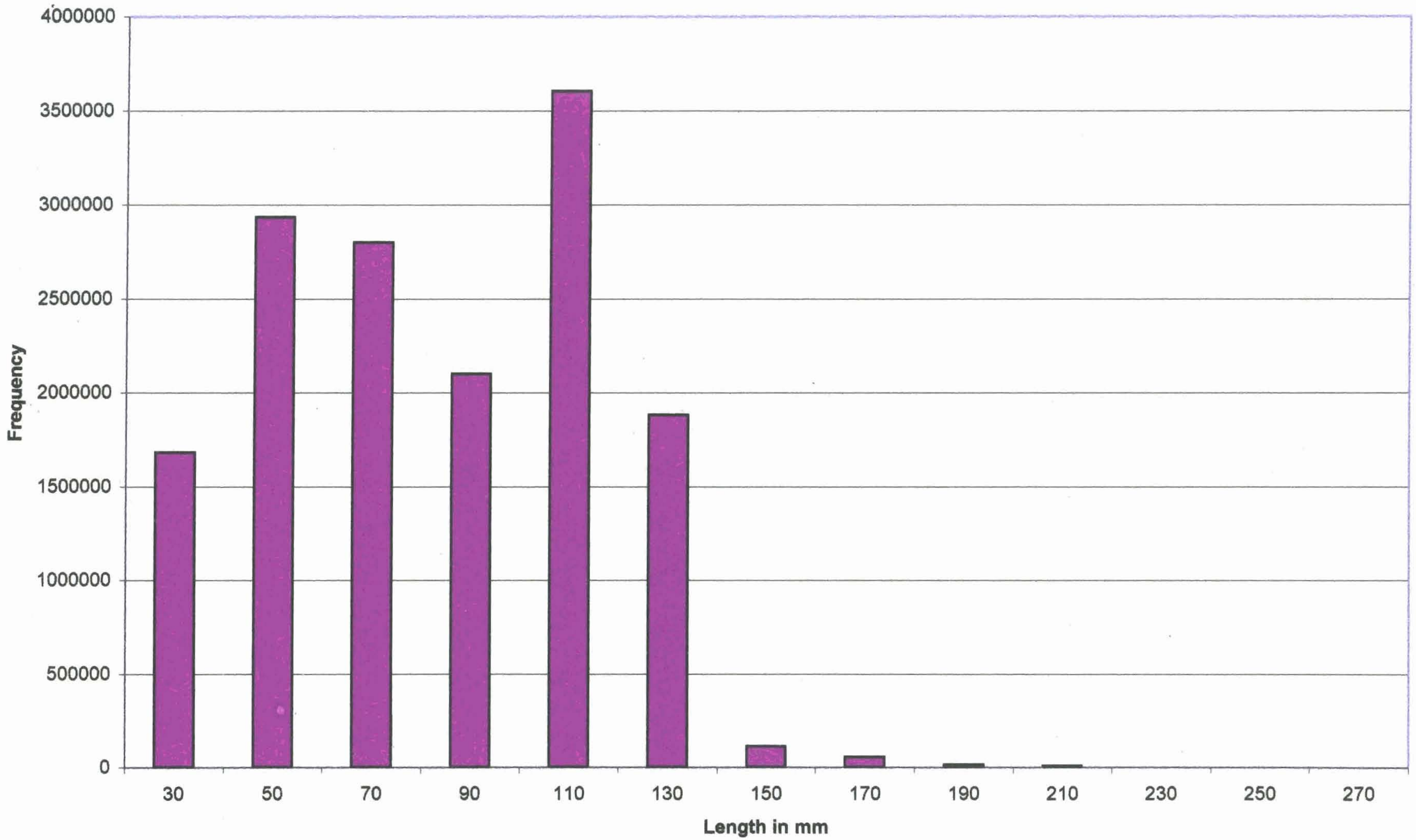
The average annual catch (Y) from the fishery of Malabar area is 3458.4 tonnes. The exploitation rate (U) was estimated by the formula:

$$U = \frac{F\,(1 - e^{-Z})}{Z}$$

Where F and Z are the mortality values estimated from the pooled data of males and females. The estimated U was 0.6925.

Total annual stock (Y/U) and average annual standing stock (Y/F) of the species in the Malabar area estimated from the pooled data are given below:

Fig. 7.10. Total length frequency distribution of *Loligo duvauceli*.


4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
Frequency
30
50
70
90
110
130
150
170
190
210
230
250
270
Length in mm

$Y/U = 4994.2$ tonnes

$Y/F = 819.526$ tonnes

7.1.5. Age at recruitment (T_c) and the age at first capture (T_r):

Fig 7.10 gives the length frequency distribution of males and females pooled for the year 1996 and 1997. From the figure it can be seen that the fishes enter the fishery at a size of 30 mm. Their corresponding age is 0.17 years, which is taken as the age at recruitment. The first peak in the length frequency distribution was observed at a mid length of 50 mm which corresponds to the age 0.25 years which is taken as the age at first capture.

7.1.6. Yield per recruit:

Yield per recruit studies was made using the population parameters estimated from the pooled data. The result is given in Table 7.3. The table shows that the present yield per recruit against the present fishing mortality of 3.88 is near 5.9762 g. The maximum yield per recruit of 7.1381 is obtained at an F value of 1.6, which has to be considered the F_{max}. This indicates that the present fishing is above the optimum levels and the declining limb of the yield curve. The yield is on the decline and further increase in effort will be detrimental to the resource. The fishing mortality has to be brought down to the level of 1.6.

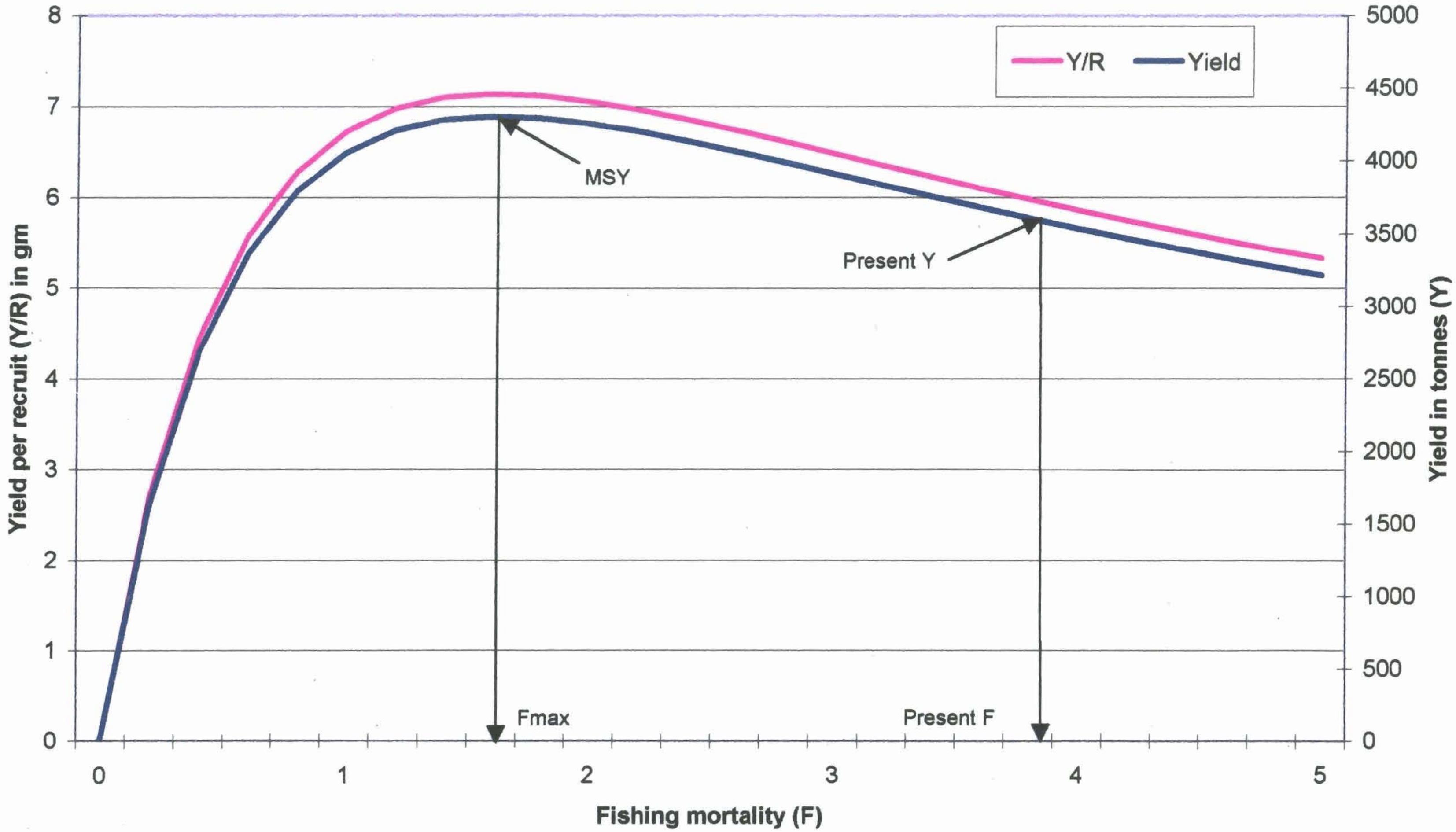
Table 7.3

F	Y/R	F	Y/R
0	0.0	2.6	6.73
.2	2.7045	2.8	6.6093
.4	4.4486	3.0	6.4808
.6	5.5717	3.2	6.3518
.8	6.2850	3.4	6.2239
1.0	6.7235	3.6	6.0985
1.2	6.9758	**3.8**	**5.9762**
1.4	7.1006	4.0	5.8575
1.6	**7.1381**	4.2	5.7428
1.8	7.1158	4.4	5.6324
2.0	7.0527	4.6	5.5261
2.2	6.9623	4.8	5.4241
2.4	68542	5.0	5.3262

7.1.7. Management options:

The possible management options to controll the present fishing were investigated. One option is to reduce the fishing intensity. The present age at first capture is very low at 0.25 years. The effect of changing

Fig. 7.11. Yield and Y/R with changing F



Y/R
Yield
MSY
Present Y
Fmax
Present F
Yield per recruit (Y/R) in gm
Yield in tonnes (Y)
Fishing mortality (F)

Fig. 7.12. Yield per recruit with the changing Fishing mortality.
The present F and the F_{max} are also indicated.

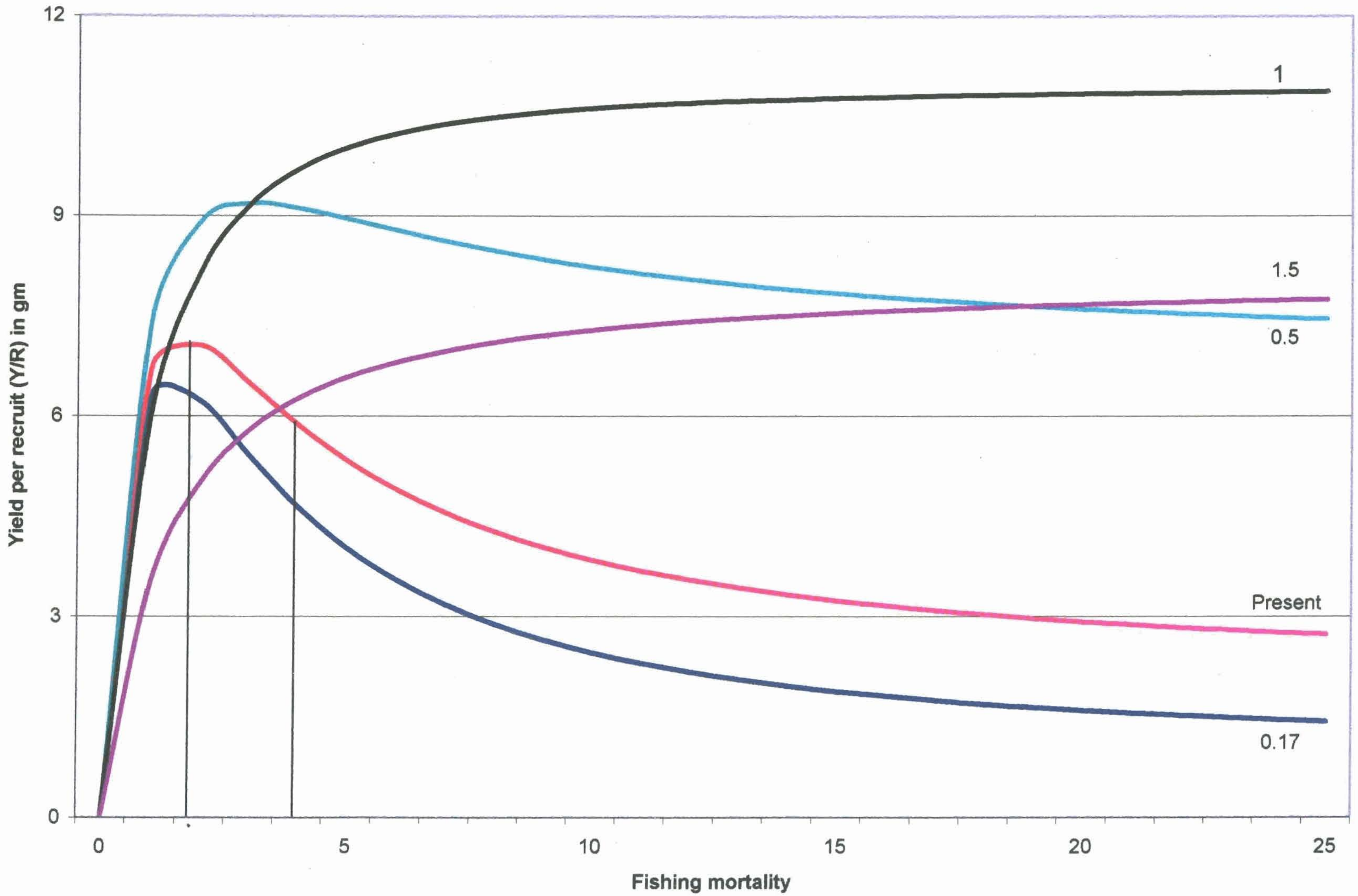

Yield per recruit (Y/R) in gm
0
3
6
9
12
0
5
10
15
20
25
Fishing mortality
1
1.5
0.5
Present
0.17

Fig. 7.13. Yield in tonnes with the changing Fishing mortality.
The present F and the F_{max} are also indicated.

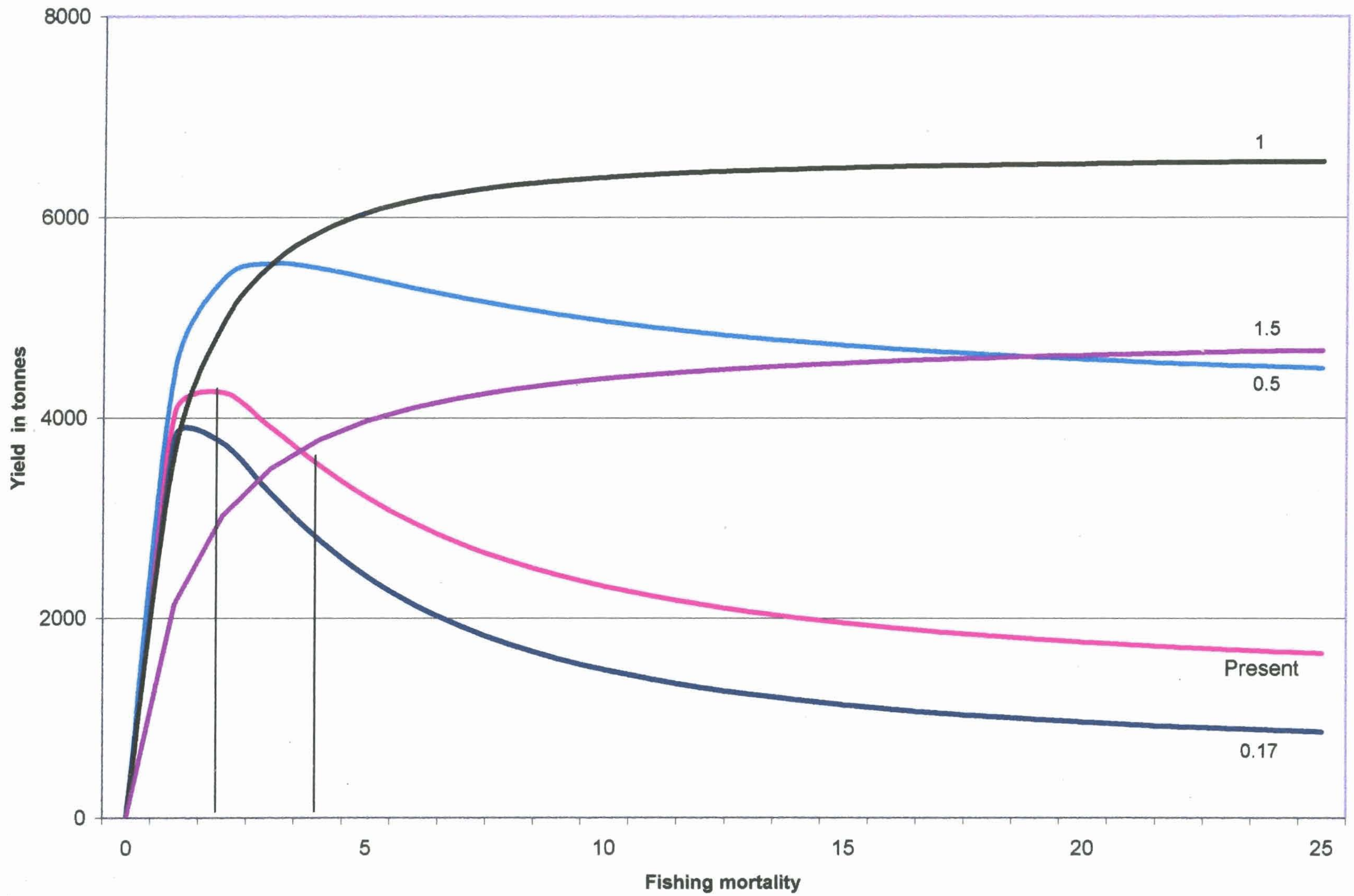

8000
6000
4000
2000
0
Yield in tonnes
0
5
10
15
20
25
Fishing mortality
1
1.5
0.5
Present
0.17

Plate 7.1. Catch of the undersized *Loligo duvauceli*, known in the trade circles as 'nipple'.

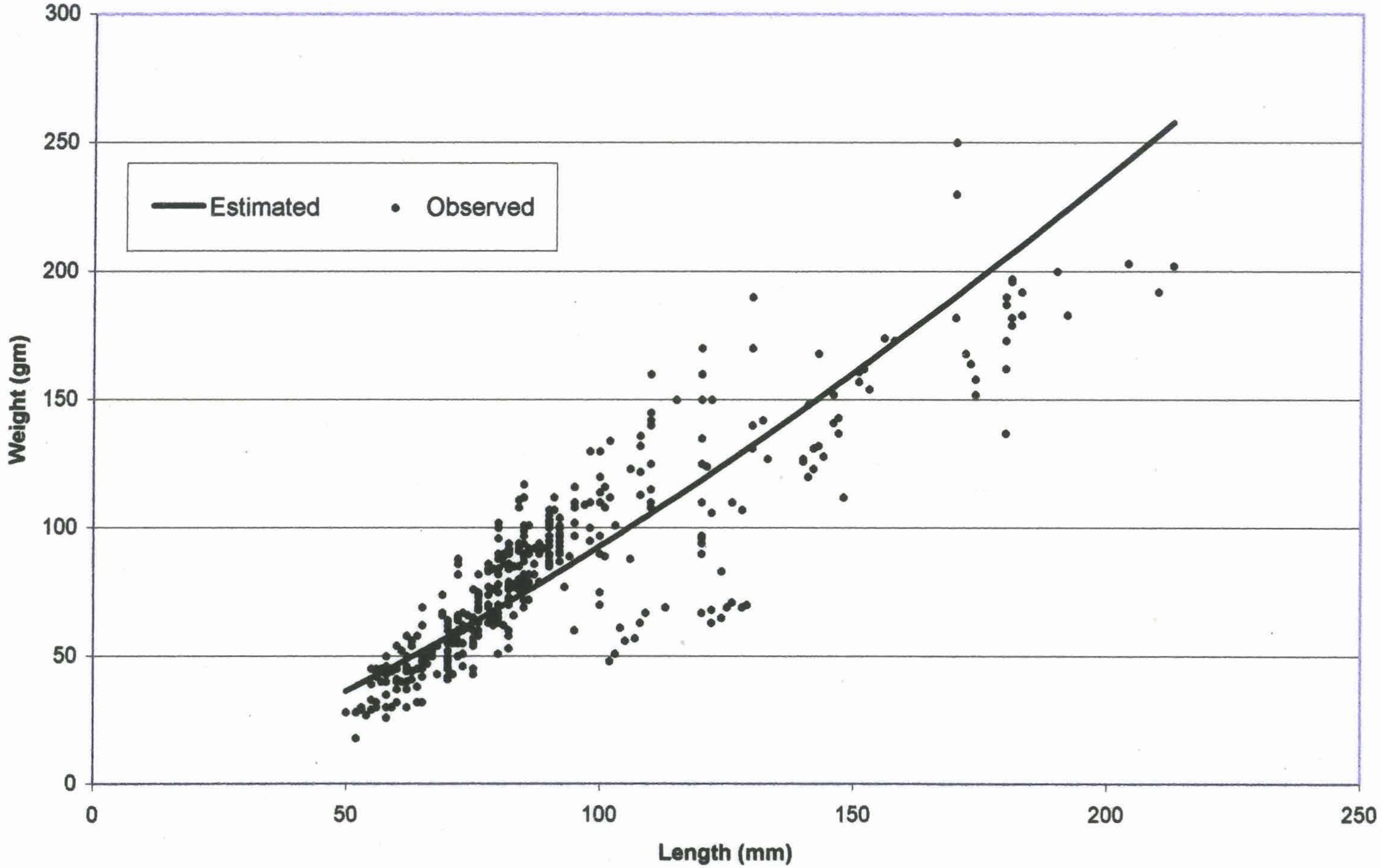
64H

F on Yield and Y/R is given in Fig 7.11. To know how the changing of age at first capture will affect the fishery, the yield per recruit at different values of T_c was estimated. The result is given in Fig 7.12. The figure 7.13 also gives the catch in tonnes. The figure indicates that the best yield per recruit and the yield are obtained at a T_c value of 1. This value is a guarantee for the safety of the fishery even if the fishing mortality increases to 25, which has to be considered as a far cry.

Fig 7.10 indicates that the juveniles are caught abundantly from an age of 2 months. Naturally they are abundant than the larger squids and the mesh size of the gear (trawl) operated for the species is very small (22-mm). The practical difficulty in controlling the exploitation of juveniles and increasing the T_c is that trawl is a multipurpose gear to catch all sizes of demersal resources, especially prawns. With the introduction of high opening trawl, the gear has become efficient even to catch columnar fishes. Hence, for any meaningful management of the fishery, the mesh size will have to be increasesd to avoid the catch of juveniles, which will reduce the efficiency of the gear to catch other fishes.

The present F should be brought down from 3.88 to 1.6 which is the maximum allowed F (F_{max}) and the optimum F should be considered as much less, probably at 1 to keep a safe distance from from F_{max} in which case the yield will be 4051 tonnes. The present fishing pressure is giving great strain to the stocks, which is moving fast to collapse. Another

Fig. 7.14. Length-weight relationship of *Sepia aculeata* (pooled).
(Curvilinear relation of the form: $W = aL^b$
with a = 0.183477
b = 1.351893)

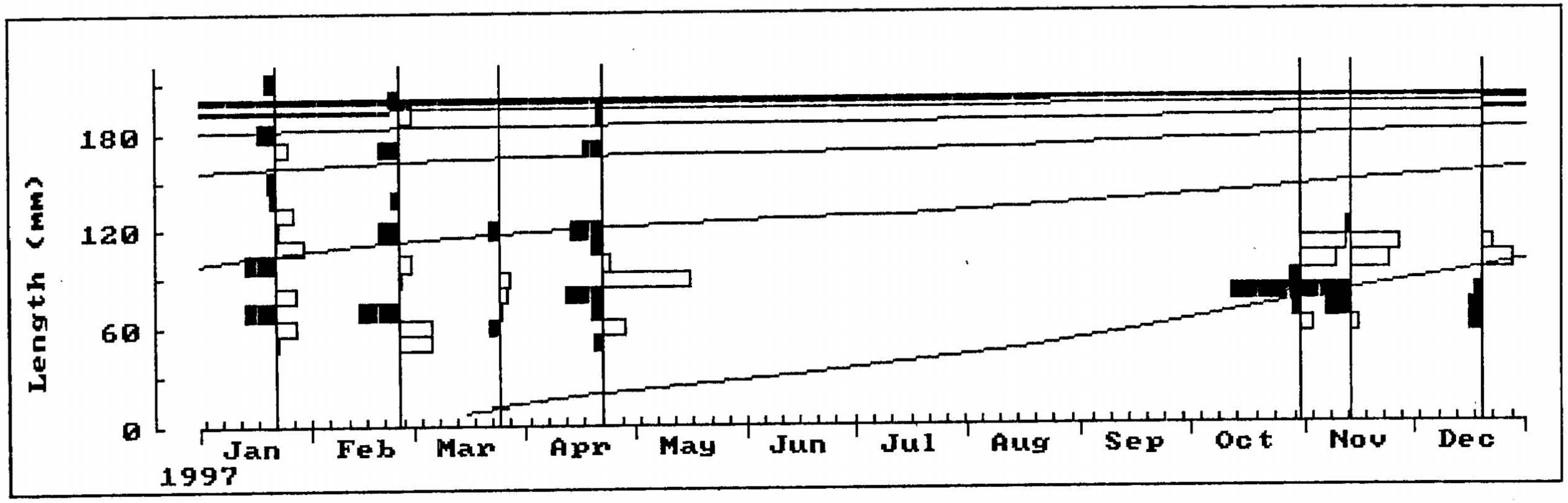

300
250
200
150
100
50
0
Weight (gm)
Estimated
Observed
0
50
100
150
200
250
Length (mm)

105

858

Fig. 7.15. Restructured (A) and percentage (B) length frequency (Pooled) of *Sepia aculeata* fitted with seasonally oscillating version of VBGF.

A


Length (mm)
0
60
120
180
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1997

B

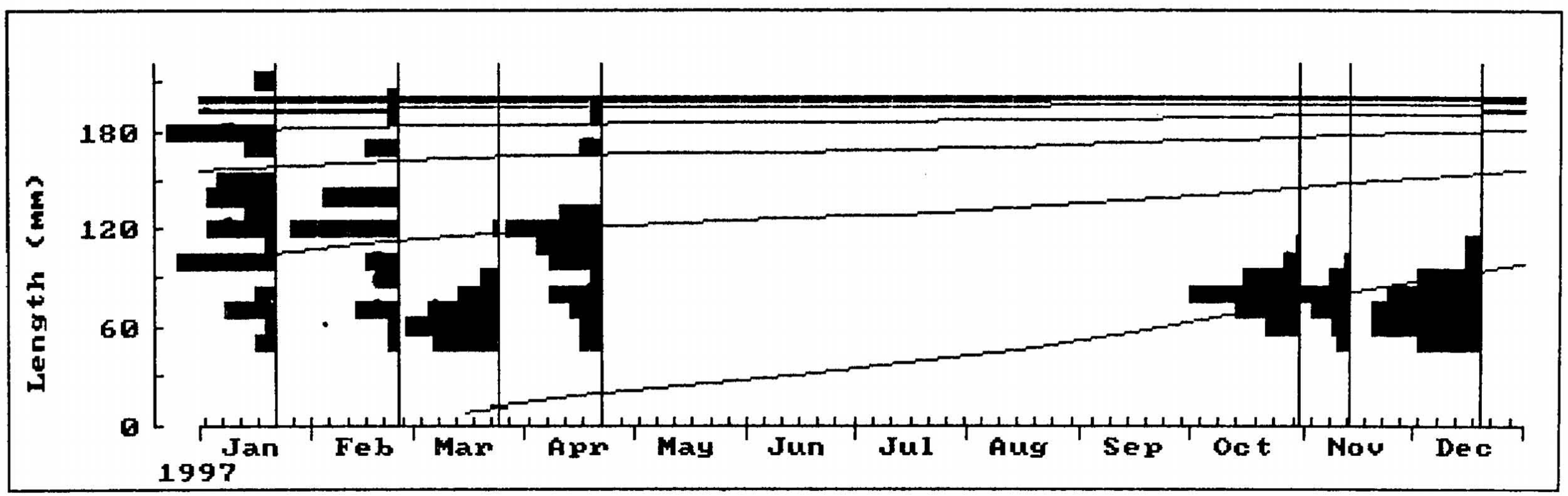
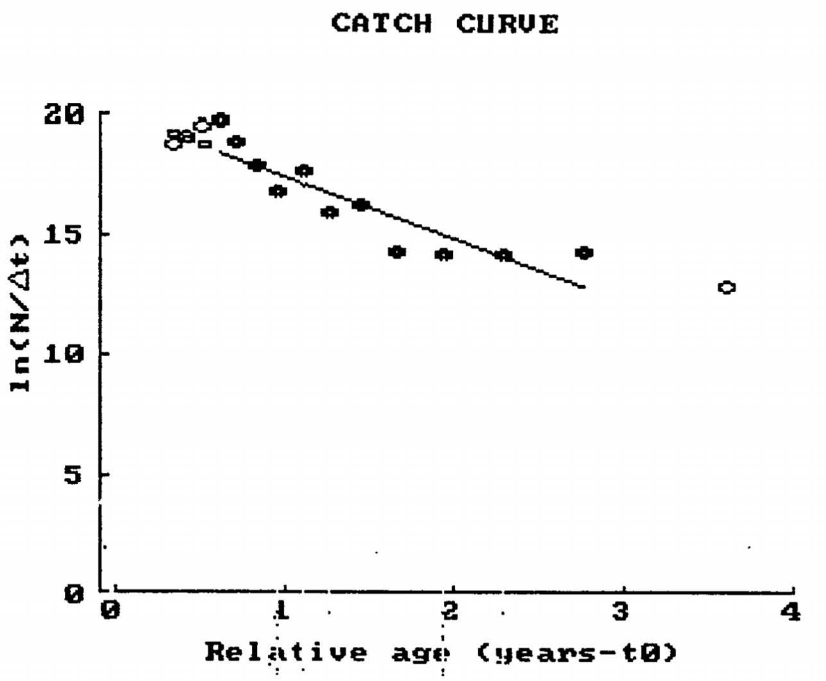

Length (mm)
0
60
120
180
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1997

Fig.7.16. Linearised catch curve based on length composition of *Sepia aculeata* .



Growth parameters:

Lα : 200 mm K : 0.83

Cutoff length (L')	= 75.0
Mean length (from L')	= 95.84
Z from catch curve	= 2.53
Natural mortality (M)	= 0.93
Fishing mortality (F = Z – M)	= 1.60
Exploit. Rate (E = F/Z)	= 0.63

method of bringing the stock back to equilibrium condition is raising the preset age at capture to 1 in which case the F_{max} will be attained only at a very high increase of F probably beyond 30. The exploitation cannot reach this level in the near future. This will be the safest guard againt over exploitation of the stocks of *Loligo duvauceli*.

7.2 POPULATION PARAMETERS (*S.ACULEATA*)

7.2.1. Length weight relation:

Length weight was estimated by pooling the samples of males and females. A total number of 275 males were used for the study and the straight line was:

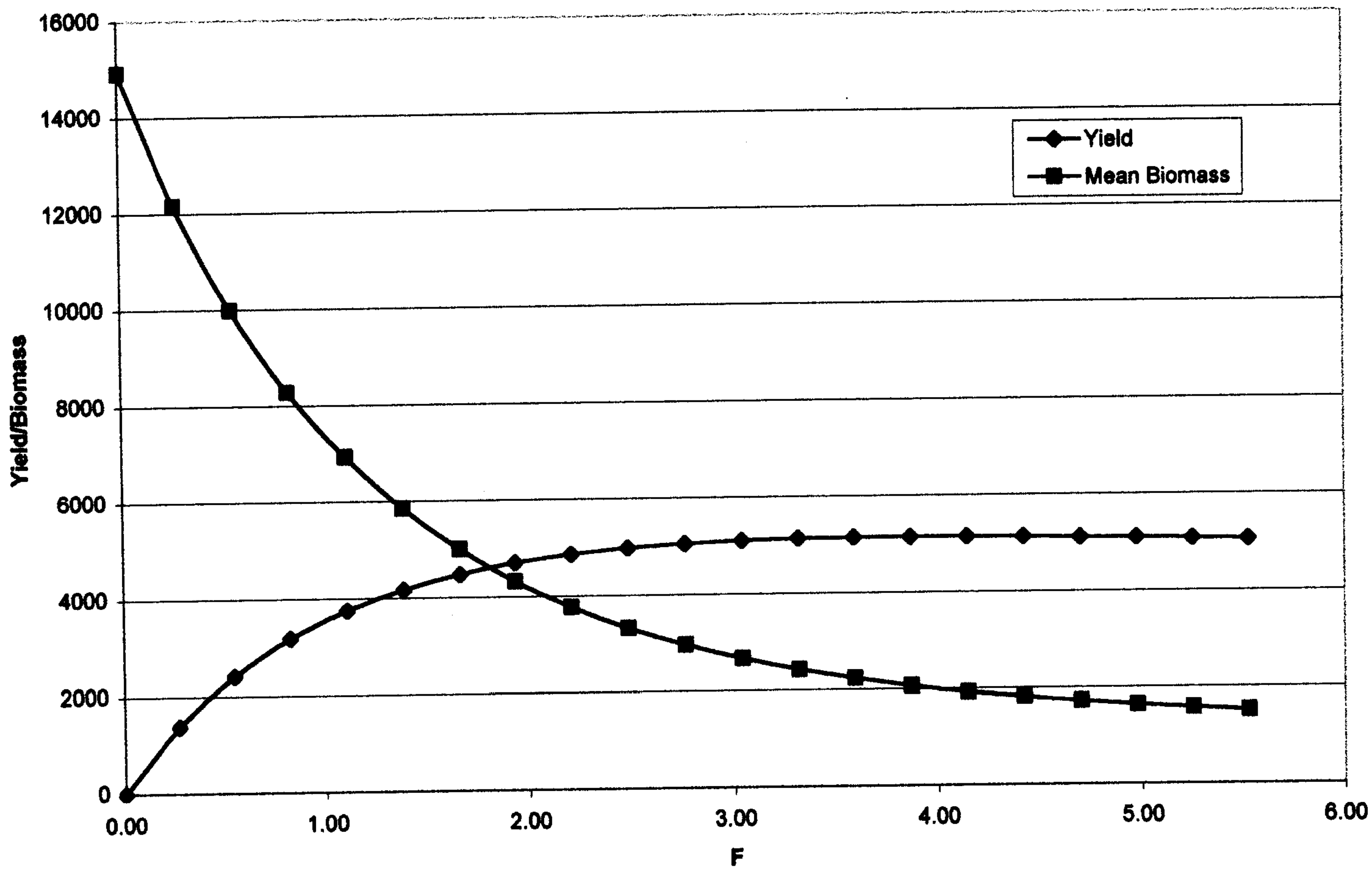
$$W = 0.183477\, L^{1.351893}$$

Where W is the weight of the males in grams and L, the dorsal mantle length (DML) in mm. The correlation coefficient was 0.772 (Fig7.14).

7.2.2. Mortality:

Natural mortality was estimated by Pauly's emperical formula for the temperature of 28^0C and was estimated at 0.93. The linearised catch curve based on length composition data is shown in Fig.7.16. The mortality rates were estimated by length cohort analysis

Fig.7.17. Yield and biomass of *Sepia aculeata* plotted against different values of F (Thompson and Bell model)



Yield
Mean Biomass
Yield/Biomass
16000
14000
12000
10000
8000
6000
4000
2000
0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
F

Table 7.4. Results of length based cohort analysis and Thompson and Bell's analysis.

S. aculeata cuttlefish

Interval	C	X*)	N	F/Z	F	Z
15.00- 25.00	0.000	1.0316	6972E+08.00	0.0000	0.0000	0.9300
25.00- 35.00	0.000	1.0335	4453E+08.00	0.0000	0.0000	0.9300
35.00- 45.00	0.000	1.0356	2501E+08.00	0.0000	0.0000	0.9300
45.00- 55.00	4892262.000	1.0381	1145E+08.00	0.3826	0.5764	1.5064
55.00- 65.00	7047516.000	1.0408	2906E+07.00	0.4889	0.8897	1.8197
65.00- 75.00	29442E+07.000	1.0441	1508E+07.00	0.6668	1.8608	2.7908
75.00- 85.00	91096E+07.000	1.0478	0145E+07.00	0.7693	3.1016	4.0316
85.00- 95.00	7574129.000	1.0523	1983E+07.00	0.6635	1.8338	2.7638
95.00-105.00	2744564.000	1.0577	0459E+07.00	0.4574	0.7839	1.7139
105.00-115.00	999905.875	1.0643	0395E+07.00	0.2501	0.3101	1.2401
115.00-125.00	2545406.000	1.0726	0576E+07.00	0.4834	0.8702	1.8002
125.00-135.00	503147.313	1.0835	4012E+07.00	0.1700	0.1905	1.1205
135.00-145.00	843355.625	1.0981	8092E+07.00	0.2688	0.3419	1.2719
145.00-155.00	219570.000	1.1190	4335E+07.00	0.0931	0.0954	1.0254
155.00-165.00	0.000	1.1512	8383824.50	0.0000	0.0000	0.9300
165.00-175.00	558119.188	1.2074	6326271.00	0.2279	0.2745	1.2045
175.00-185.00	402545.000	1.3313	3877011.50	0.2021	0.2355	1.1655
185.00 plus	339299.281	0.0000	1884995.88	0.1800	0.2041	1.1341
		Total	9.330231E+08			

*) X = ((L8-L(i))/(L8-L(i+1)))^(M/2K)

Interval	W +)	meanN *)	meanN*W	C*W
15.00- 25.00	10.6876	8872989.0000	3086E+07.0000	0.0000
25.00- 35.00	18.3383	8812069.0000	5982E+08.0000	0.0000
35.00- 45.00	26.9779	8747940.0000	0013E+08.0000	0.0000
45.00- 55.00	36.4284	8487245.0000	1767E+08.0000	2172E+08.0000
55.00- 65.00	46.5767	7920942.5000	9315E+08.0000	2502E+08.0000
65.00- 75.00	57.3434	6956374.0000	9023E+08.0000	2646E+08.0000
75.00- 85.00	68.6687	5452315.0000	4036E+08.0000	1254E+09.0000
85.00- 95.00	80.5058	4130235.5000	5079E+08.0000	7611E+08.0000
95.00-105.00	92.8166	3501157.0000	9655E+08.0000	7411E+08.0000
105.00-115.00	105.5697	3223952.7500	3518E+08.0000	5598E+08.0000
115.00-125.00	118.7384	2924980.5000	3076E+08.0000	2375E+08.0000
125.00-135.00	132.2999	2640922.2500	3937E+08.0000	6632E+07.0000
135.00-145.00	146.2341	2466895.0000	7443E+08.0000	3274E+08.0000
145.00-155.00	160.5235	2301028.5000	3692E+08.0000	4615E+07.0000
155.00-165.00	175.1526	2212423.0000	5117E+08.0000	0.0000
165.00-175.00	190.1074	2033484.2500	5805E+08.0000	1026E+08.0000
175.00-185.00	205.3753	1702932.7500	7404E+08.0000	7282E+07.0000
185.00 plus	220.9085	1662039.3750	1586E+08.0000	9541E+07.0000
	Total	9476E+09.0000	1155E+09.0000	

) meanN(i) = (N(i)-N(i+1))/Z(i). +) W(i) = q(L(i)^b+L(i+1)^b)/2

Mean F (L >= 75) : 1.3828 (weighted by stock number)

These results were obtained using the parameters :

L8 (L-infinity)	200	M/2K	.56
K (curvature parameter)	.83	q in W = q L^b (grammes,cm)	.183477
M (natural mortality)	.93	b in W = q L^b	1.351893
Terminal exploitation rate	.18		

(Jones, 1984). Thompson and Bell model analysis (Sparre, 1987) was employed to analyse the yeild and biomass. The parameters used for the estimation were Lα=200cm, K=0.83 and M=0.93 with a terminal exponential rate (F/Z) of 0.18. The mean F estimated by length cohort analysis was 1.3828 (Table 7.4). Using these estimates, MSY was calculated. Different values of F were used to estimate the yield and biomass and plotted (Fig.7.17). Based on Thompson and Bell long-term prediction model, yield and biomass was calculated for values of F ranging from 0 to 6 (Table 7.5).

Table 7.5.

S. aculeata

THOMPSON AND BELL LONG TERM FORECAST

x	Yield	Mean Biomass	F	Yield	Mean Biomass
0.0	0	14928	0.00	0	14928
0.2	1383	12159	0.28	1383	12159
0.4	2412	9989	0.55	2412	9989
0.6	3179	8279	0.83	3179	8279
0.8	3747	6927	1.11	3747	6927
1.0	4167	5854	1.38	4167	5854
1.2	4476	4998	1.66	4476	4998
1.4	4700	4313	1.94	4700	4313
1.6	4861	3762	2.21	4861	3762
1.8	4974	3317	2.49	4974	3317
2.0	5051	2957	2.77	5051	2957
2.2	5101	2664	3.04	5101	2664
2.4	5130	2424	3.32	5130	2424
2.6	5144	2227	3.60	5144	2227
2.8	5147	2065	3.87	5147	2065
3.0	5142	1930	4.15	5142	1930
3.2	5131	1817	4.42	5131	1817
3.4	5115	1723	4.70	5115	1723
3.6	5097	1643	4.98	5097	1643
3.8	5076	1576	5.25	5076	1576
4.0	5055	1518	5.53	5055	1518
Present F =1.3828			Present M = 0.93		
MSY = 5147.089		X = 2.812501	Biom.msy = 2039.282		
F-MSY = 3.889125					

The MSY was calculated as 5147 tonnes corresponding to a F_{max} of 3.89. Biomass MSY was estimated to be 2039 tonnes. To attain the MSY level, the present level has to be increased to 2.8 times. By this increase, the expected increase in catches will be only 23%. This may not be economically workable.

In the cephalopod fishery of India, the exploitation is considered to be optimal along the East Coast but on the west coast there is scope for increase with regards to the needle cuttlefish *Sepia aculeata* (Nair *et.al.*, 1993; Rao *et.al.*, 1993). In the case of the squid *Loligo duvauceli*, the fishery is at the optimum level on both the coasts (Meiyappan *et.al.*, 1993)

MATURATION AND SPAWNING

P.K. Asokan “Biology and fishery of cephalopods (mollusca: cephalopoda) along the malabar coast ” Thesis. Department of Zoology , University of Calicut, 2000

CHAPTER 8

MATURATION AND SPAWNING

Oogenesis in cephalopod molluscs involves a highly coordinated differentiation of the oocyte and follicular epithelium. (Selman & Arnold, 1977). Recent studies in cephalopods by Dhainaut and Richard, 1972; O'Dor & Wells, 1973; Bottke, 1974; Richard and Dhainaut, 1972; Arnold and William-Arnold 1976, have revealed that during oogenesis the follicular cells become highly differentiated secretory cells, but the exact nature and product have not been fully known.

8.1. Relation between body length and ovary weight.

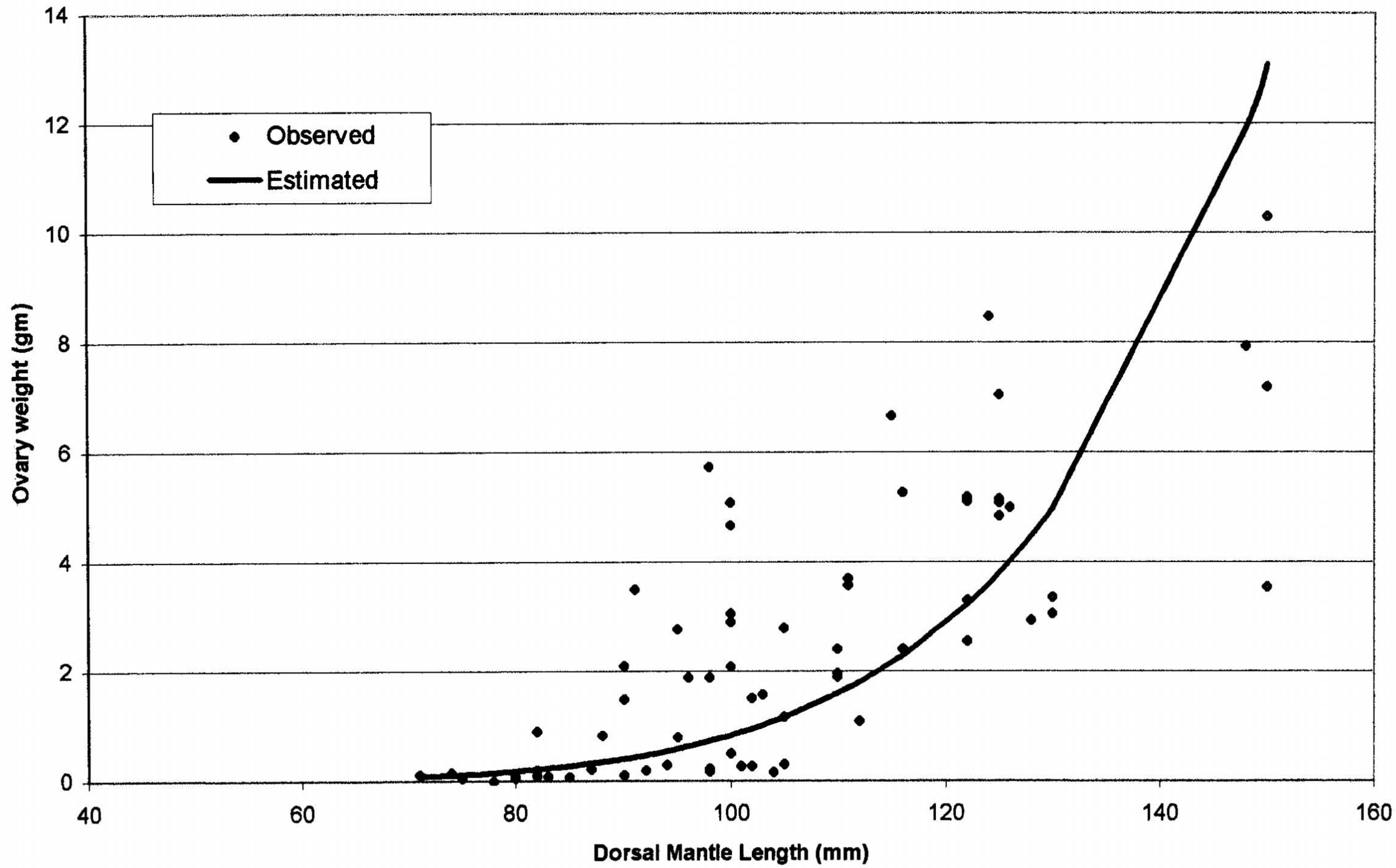
The relation between the length of the squid and the weight of ovary was curvilinear. Hence the Log_{10} values were used to estimate the regression of the ovary weight on total length of the squid. The regression parameters are:

a= -13.6131

b= 6.76

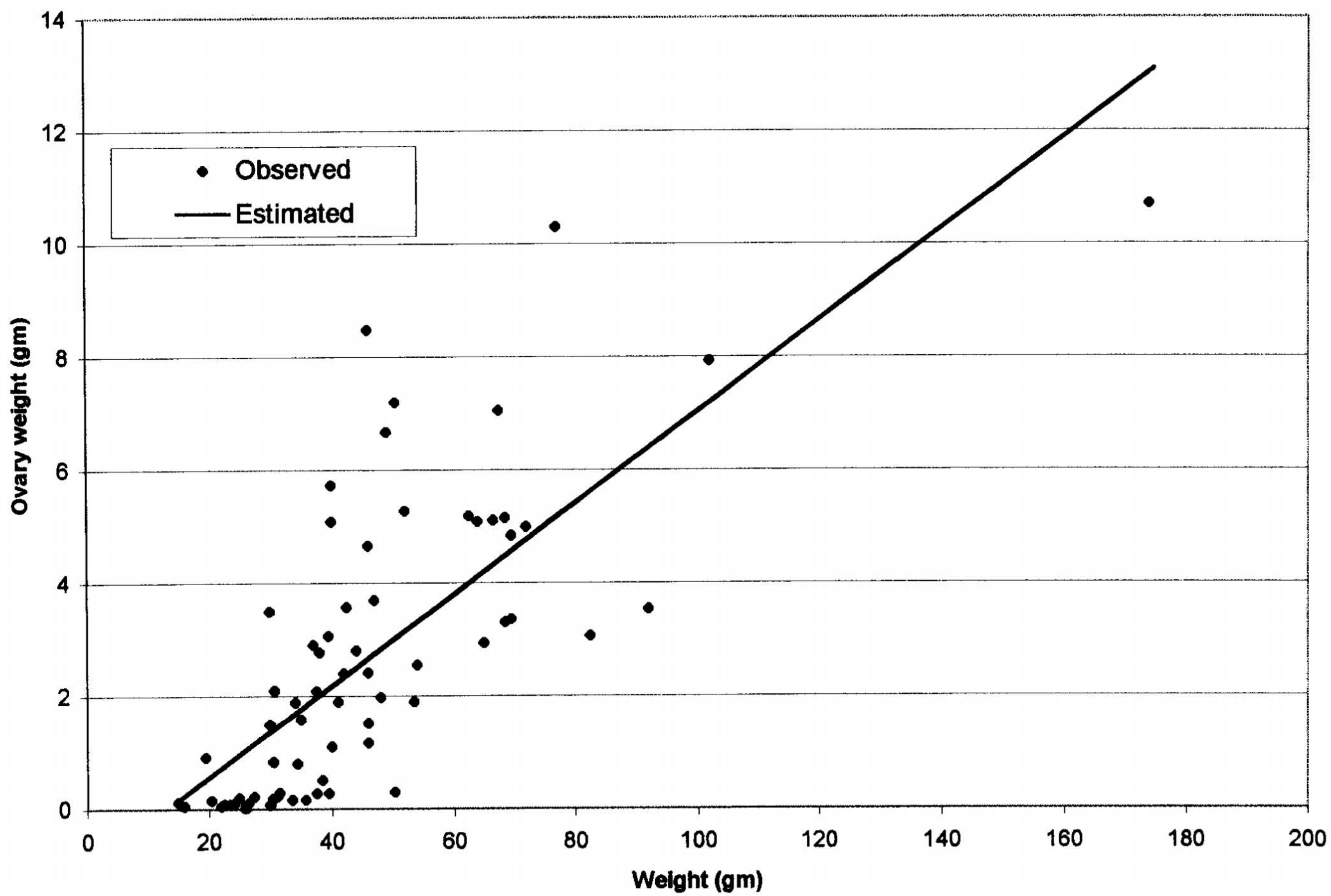
This straight line was transferred to the curvilinear equation of $W=aL^n$, which gives the value as:

Fig. 8.1. *Loligo duvauceli* . Relation between body length (DML in mm) and ovary weight (gm).



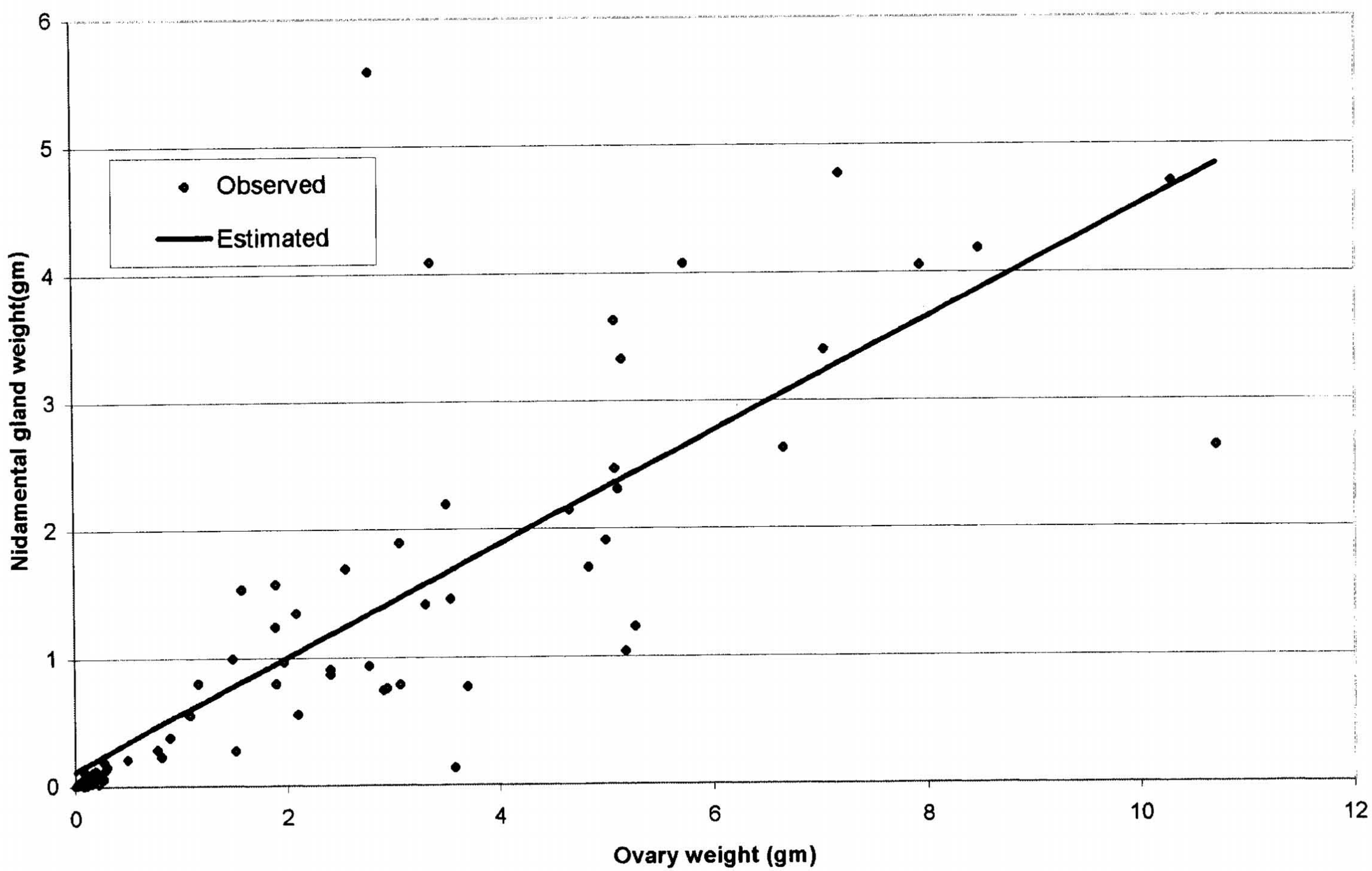
14
12
10
8
6
4
2
0
40
60
80
100
120
140
160
Observed
Estimated
Ovary weight (gm)
Dorsal Mantle Length (mm)

Fig.8.2. *Loligo duvauceli* . Relation between body weight (gm) and ovary weight (gm).



Observed
Estimated
Ovary weight (gm)
Weight (gm)
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140
160
180
200

Fig. 8.3. *Loligo duvauceli*. Relation between ovary weight (gm) and nidamental gland weight (gm).



Observed
Estimated
Nidamental gland weight(gm)
Ovary weight (gm)
0
1
2
3
4
5
6
0
2
4
6
8
10
12

$$W = 2.4369 * 10^{-15} L^{6.76}$$

Where W is the weight of the gonad in grammes and L is the total length of the squid in mm. The correlation coefficient was 0.60. The relation is shown in Fig. 8.1.

8.2. Relation between weight of the squid and ovary weight

The relation between weight of the squid and ovary weight was found to be straight and direct with the estimated relation:

$$W= -1.06356 + 0.80967 X$$

Where W = is weight of the gonad in gms and

X = is weight of the squid in gms.

The correlation coefficient estimated was 0. 55. The relation is showed in Fig. 8.2.

8.3 Relation between ovary weight and nidamental gland weight

In the mature *Loligo duvauceli*, the nidamental gland becomes larger, white and the accessory nidamental gland become red in colour. The size increases with the onset of maturation. The relation between mature ovary weight and nidamental gland weight is found to be linear with the relation:

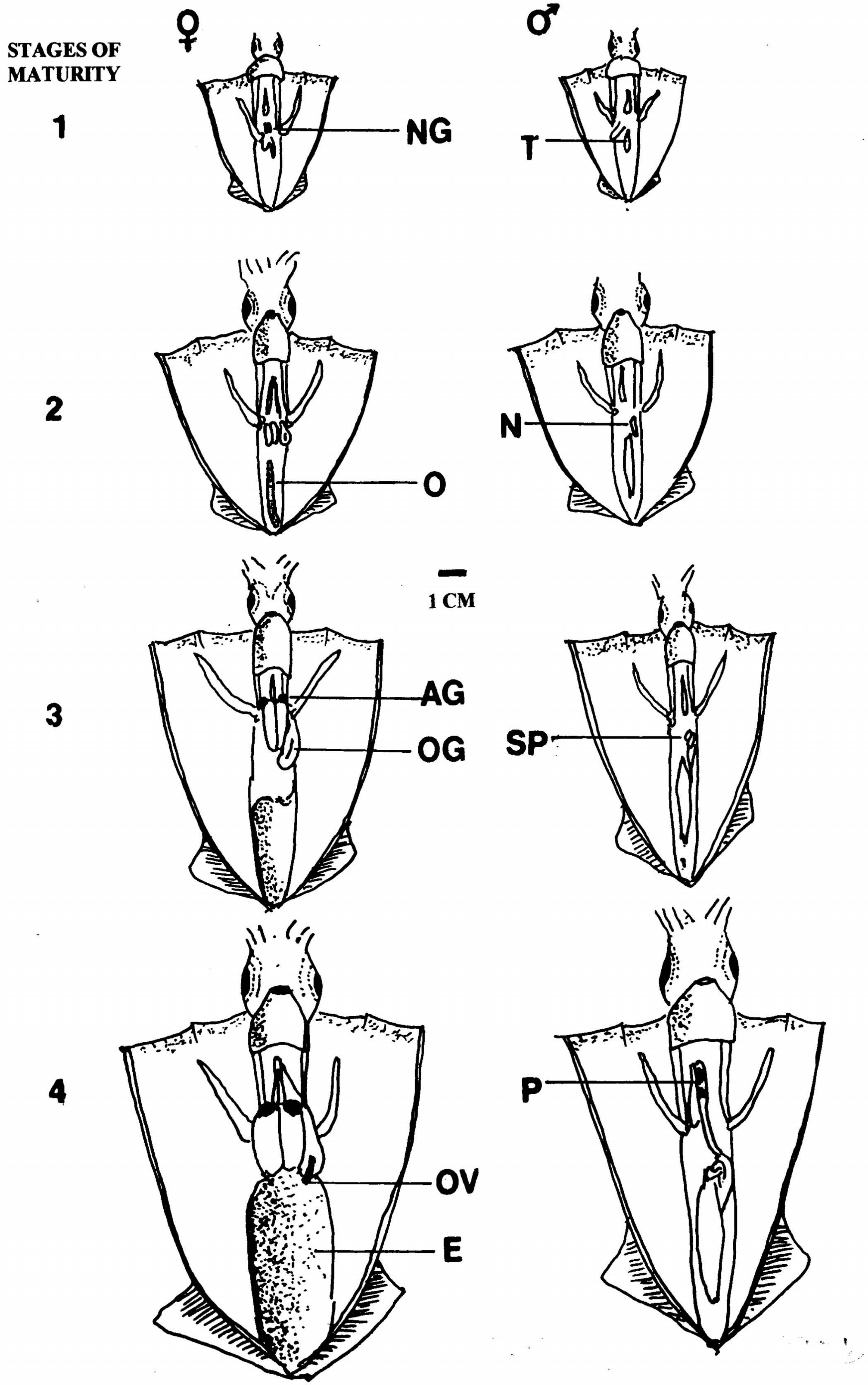
$$W= 0.11752 + 0.44155 X$$

Where W= weight of ovary in gm and

X = weight of nidamental gland.

The coefficient of regression is 0.66. The relation is shown in Fig.8.3.

Fig. 8.4. *Loligo duvauceli* . Sketches of the morphological changes during the maturity stages of both the sexes. NG = Nidamental gland; T = Testes; N =Needham's sac; O = Ovary; AG = Accessory gland; OG = Oviducal gland; SP = Spermatophores; OV = Oviduct; P = Penis; E = Egg mass. The bar denotes approx.1cm.



STAGES OF MATURITY
♀
♂
1
NG
T
2
N
O
1 CM
3
AG
OG
SP
4
P
OV
E

8.4. Maturity stages in *Loligo duvauceli*:

The squids were classified into four maturity stages for both the sexes. Diagrammatic sketch of the changes in the morphology of both the sexes is given in Fig 8.4. A brief description of the general morphological characters is given below:

Stage 1. In females, the nidamental gland appears as a thin and transluscent. In males, the testis appears as a pale oval body.

Stage 2. The nidamental glands have doubled in length. The oviducal gland and the accessory nidamental gland appear. The ovary shows the characteristic granulate structure. In males, the testis double in size and the spermatophoric organ complex becomes evident.

Stage 3. The opaque ovary is whitish in colour. Immature spermatophore may be visible as small white specks in the Needham's sac. However, no gamete can be seen in the penis.

Stage 4. The posterior half of the mantle cavity is completely occupied by the bulging ovary and oviduct. Ripe eggs fill the ovary and the oviduct. The nidamental gland is turgid and rigid. In males the spermatophores are visible in the Needham's sac and in the penis. The testis occupies a larger area of the mantle cavity.

Very small *Loligo duvauceli* in which ovary, testis or nidamental gland cannot be seen is classified as indeterminates (ID).

Plate 8.1. Ovary of immature female showing oocytes in early stages of development. Primordial germ cells (oogonia) pgc can be seen measuring about 15-20 μm. Bar denotes 50 μm.

Plate 8.2. Enlarged secondary oogonia (stage Ic) showing nucleolii and cytoplasm. Bar denotes 20μm. Cytoplasm(C), nucleolii (Ni) and nucleus (N).


50μ
pgc

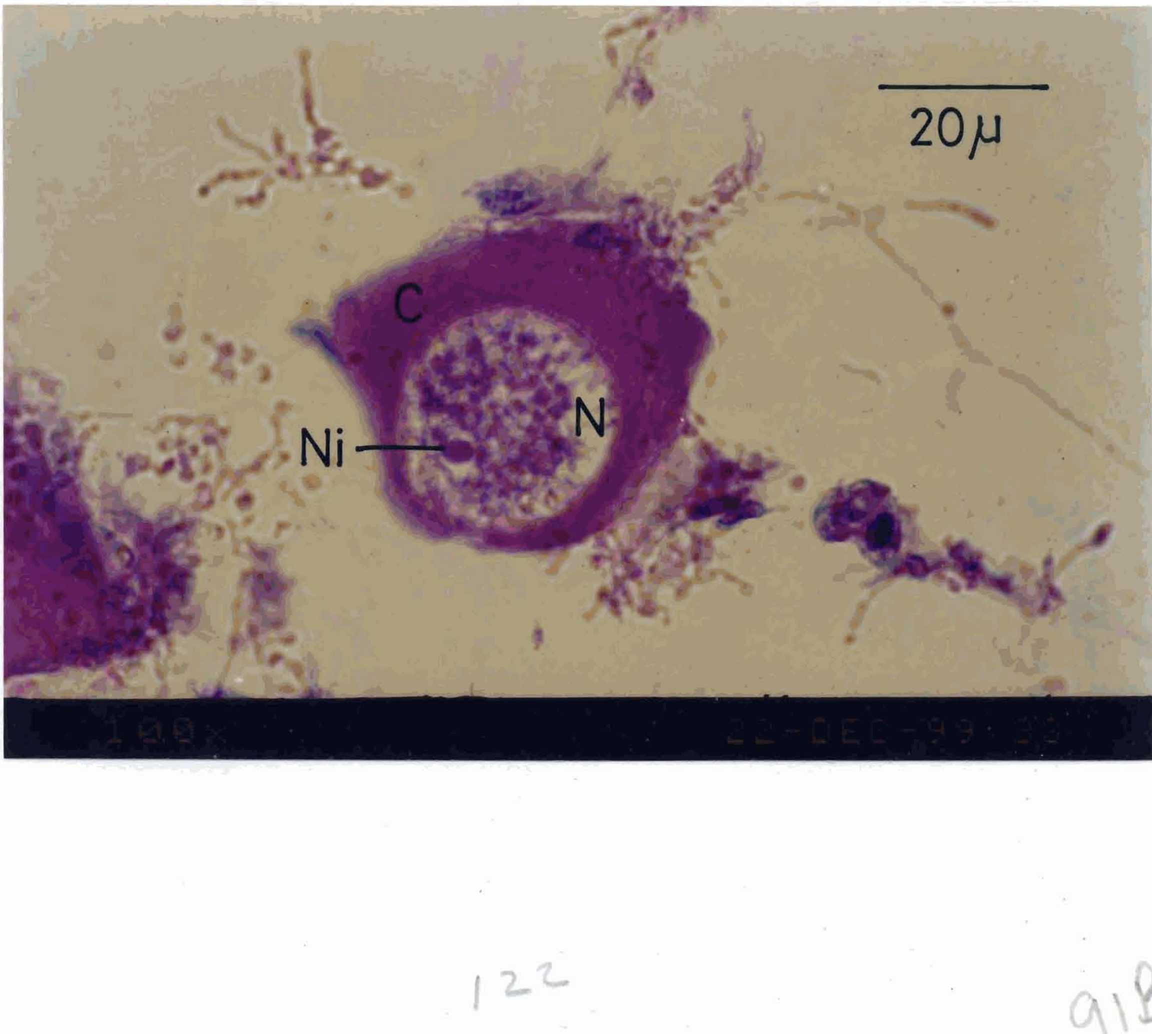
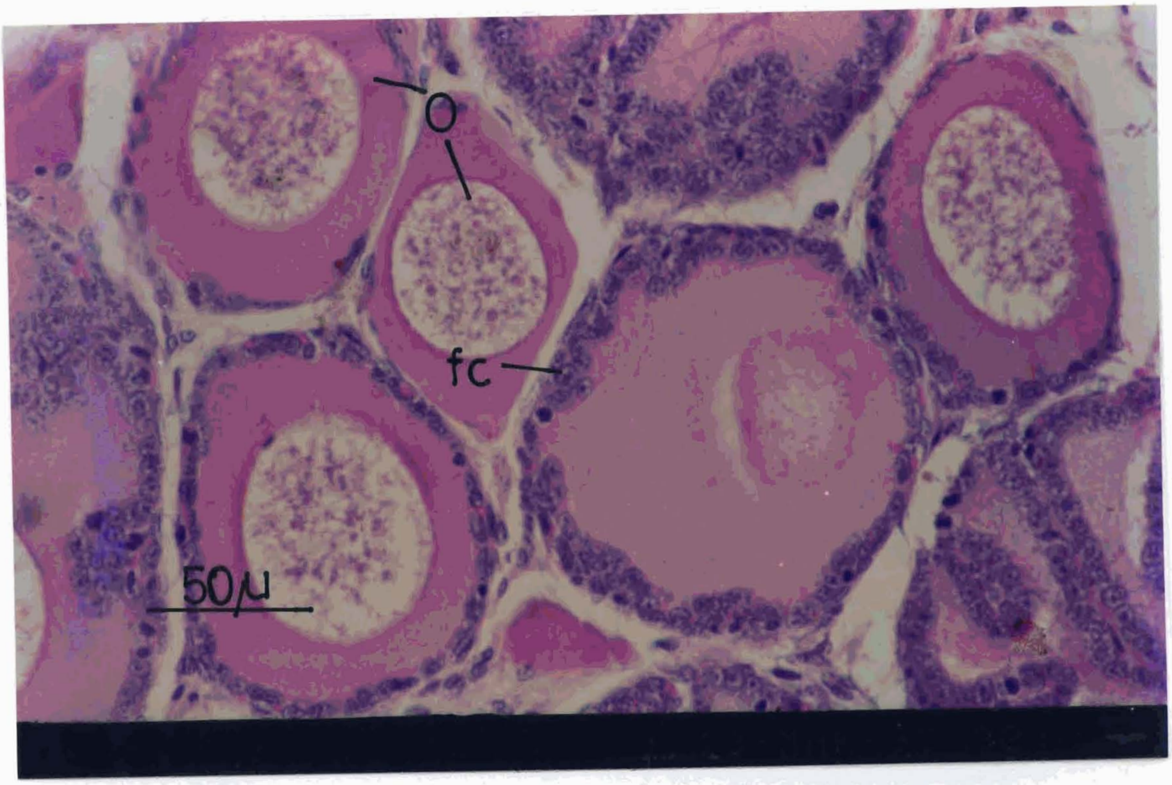

20μ
C
N
Ni

Plate 8.3. Stage II oocytes. The follicle cells (fc) proliferate on the surface of the oocyte. Follicle cell (fc), oocyte (o). Bar denotes 50 µm.

Plate 8.4. Stage II oocyte with follicle cell cap (fcp) on vegetative pole. Bar denotes 20µm. The oocyte measures about 120 µm.


O
fc
50μ

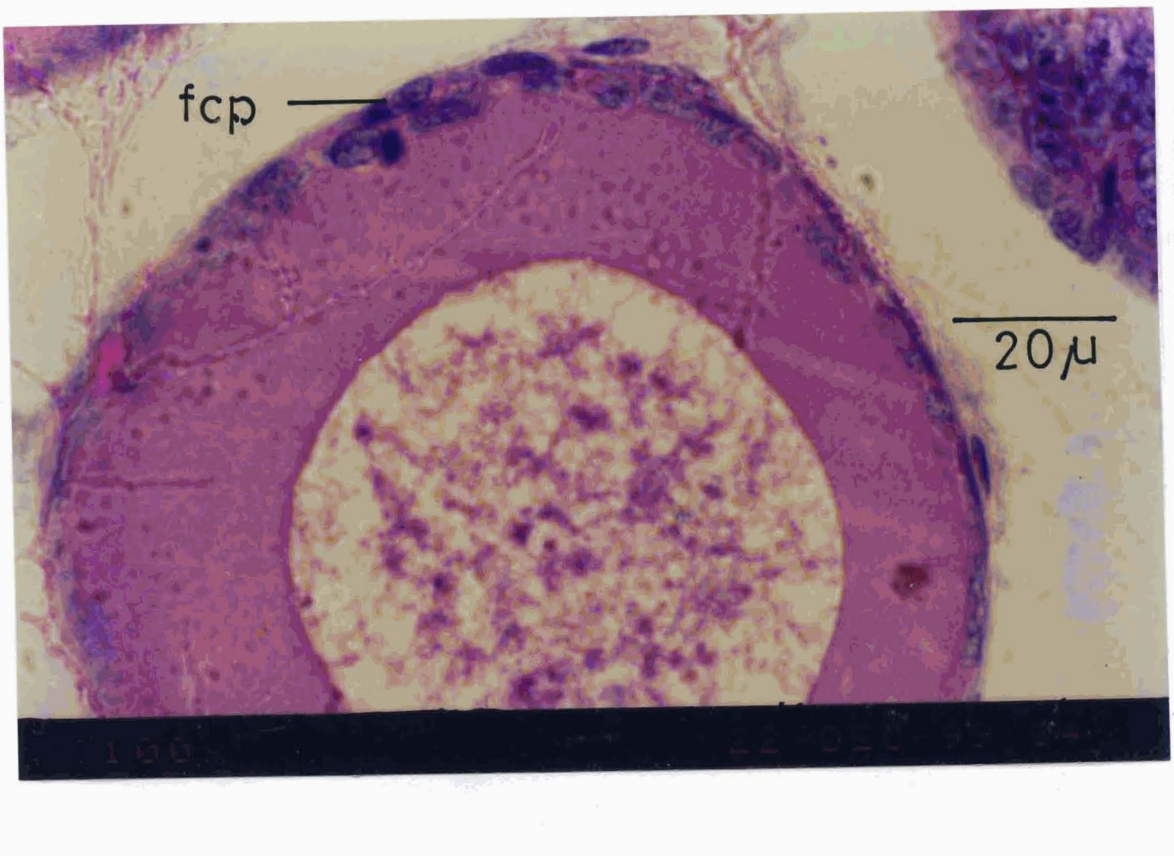
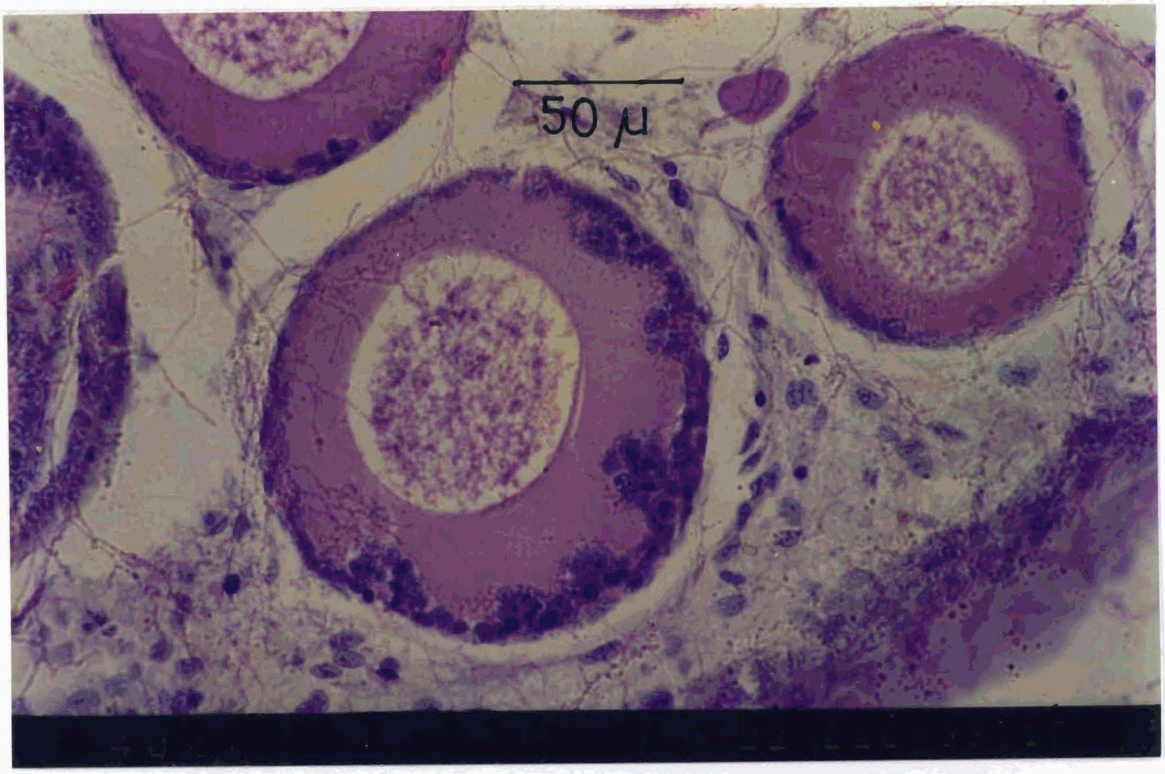
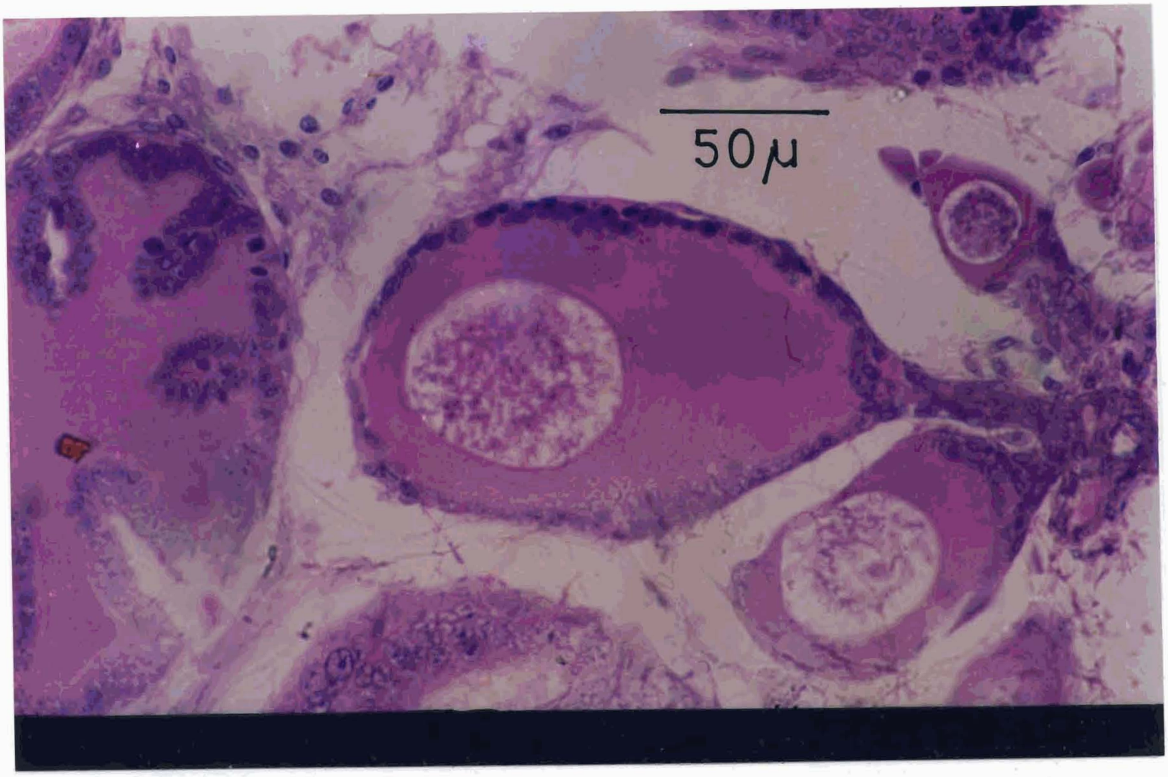

fcp
20μ

Plate 8.5. The oocyte in stage III. Cuboidal follicle cells (cfc). The oocyte measure about 140 μm. Bar denotes 50 μm.

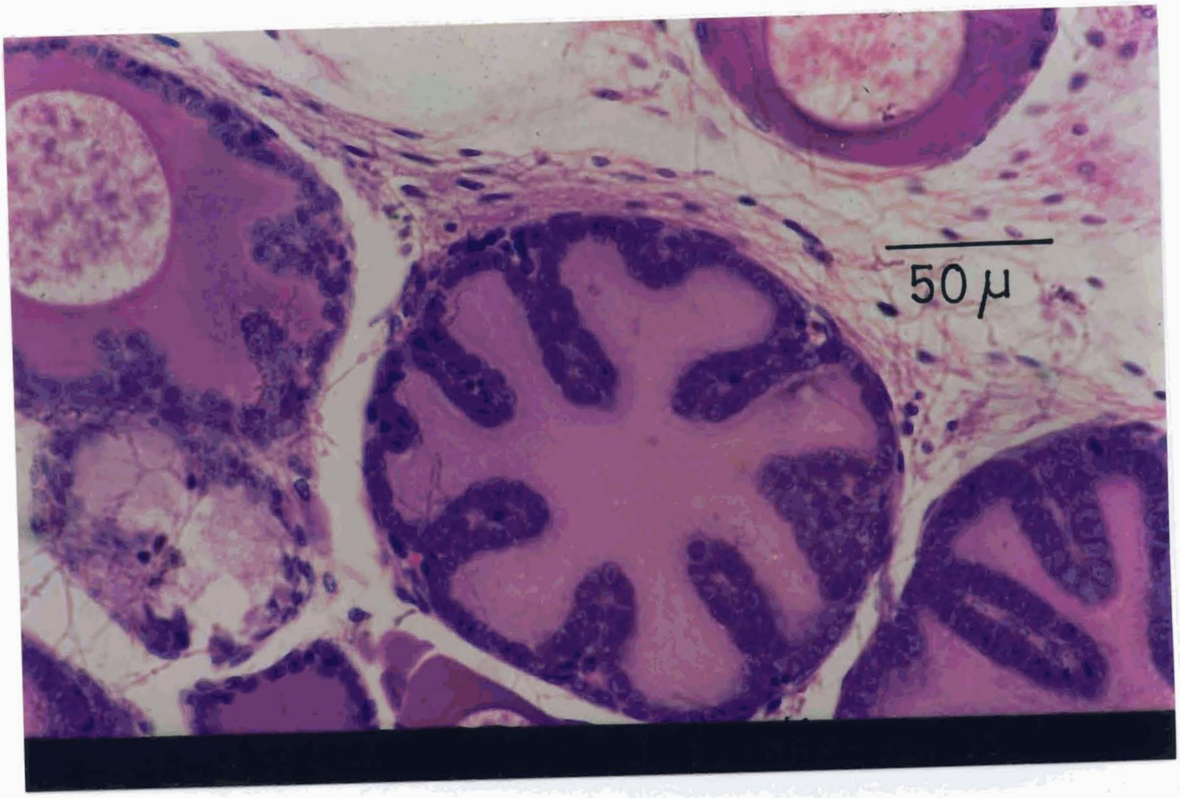
Plate 8.6. The oocytes in stage III. Differnet stage of maturation of oocytes can be observed. Bar denotes 50 μm.

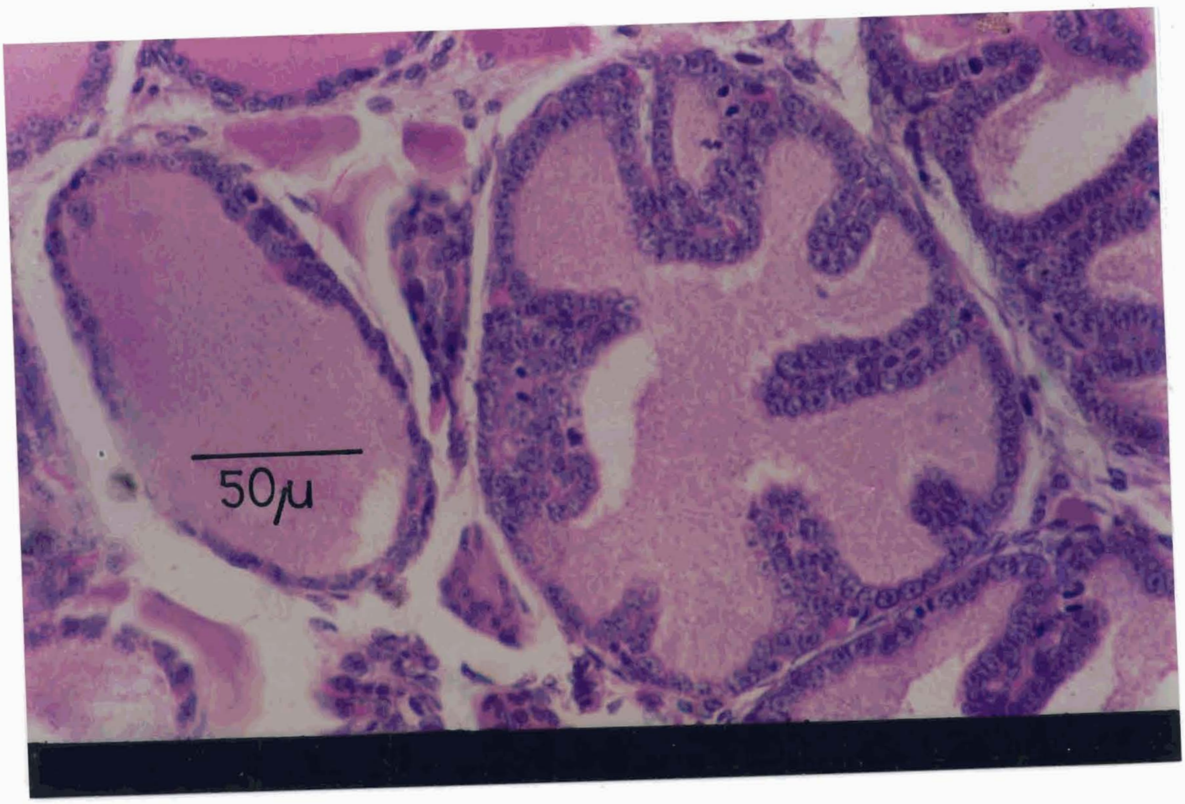




91F

Plate 8.7 and Plate 8.8. The follicle cells penetrate into the oocyte and proliferation starts. During stage IV the follicle cells transforms from cuboidal to columnar. The bar denotes 50 µm. The oocyte measure 160 – 170 µm.


50μ


50μ

8.5. Stages of Oogenesis:

Oogenesis begins when the primordial germ cells differentiate and become primary oogonia. Primary oogonia enlarge and become secondary oogonia, which in turn become oocytes.

Oogenesis can be divided into six stages depending upon the degree of follicular cell development in association with oogonia and oocyte.

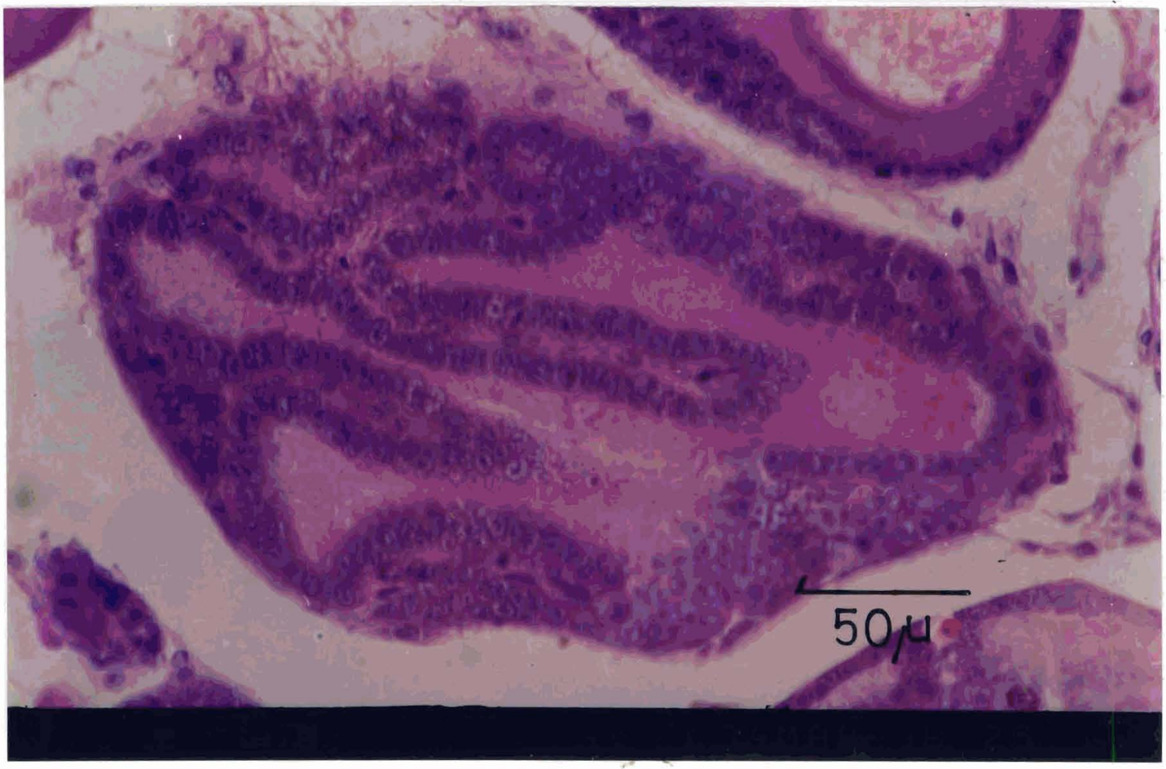
During the stage I, the primary oogonia transfers to the secondary oogonia by forming a well-defined nucleus with one or more nucleoli which increasingly show a cytoplasmic to nuclear volume. The secondary oogonia have well defined nucleus with one or more nucleoli. The nucleus is surrounded by a thin cytoplasm (Plate 8.1 and 8.2).

During the stage II, the oocyte contains a large germinal vesicle, which is surrounded by an irregular corona. The follicular cells attach to the oocyte and begin to proliferate on its surface. The follicle cells can be clearly seen on the surface of the oocyte and the formation of the follicle cell cap can also be seen (Plate 8.3 and 8.4). During the stage III, the follicle cells completely surround the oocyte and change from the earlier squamous to cuboidal shaped cells (Plate 8.5 and 8.6). During the stage IV, the follicular cells continue to proliferate and begin to penetrate the oocyte. The morphological changes from cuboidal to columnar (Plate 8.7 and 8.8).

During the stage V (Plate 8.9, 8.10 and 8.11), the syncytium formed by the follicle cells disperses the member from the animal pole and

Plate 8.9. Oocyte stage V. The follicle disperses the nucleus to the animal pole. The oocyte measure about 250 µm. Bar measures 50 µm.

Pllate 8.10. Enlarged view. Bar measures 20 µm.


50µ

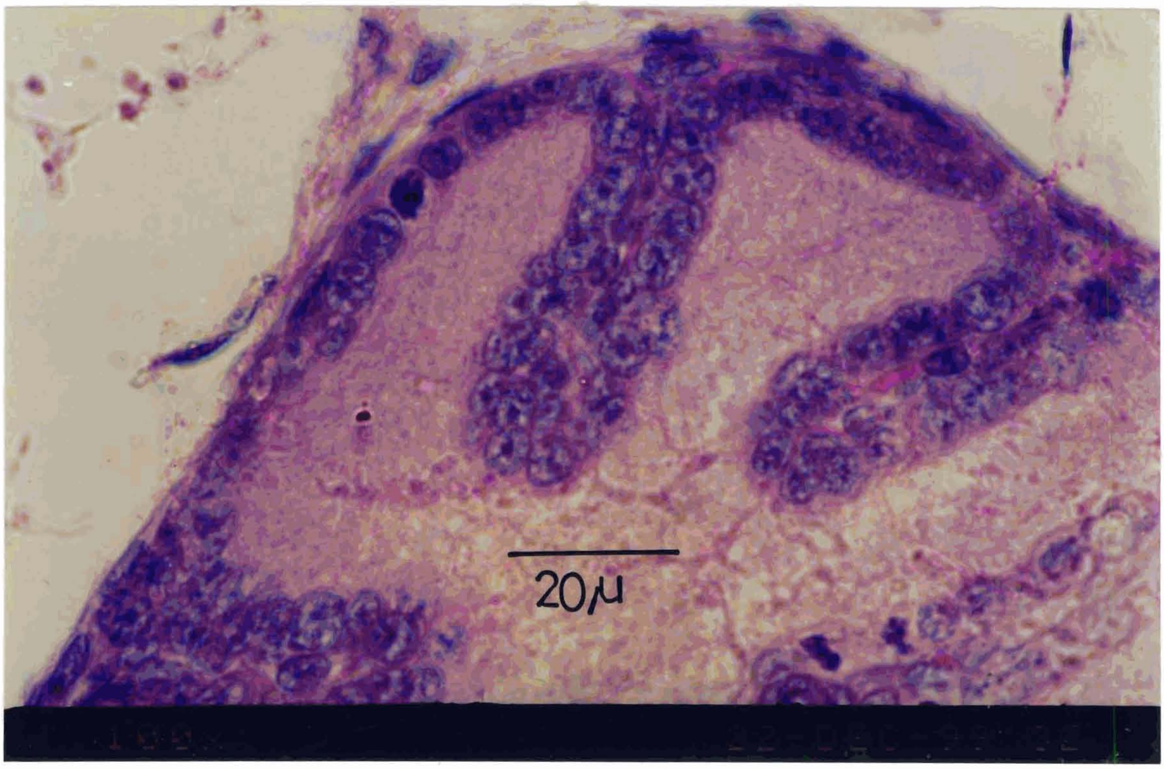
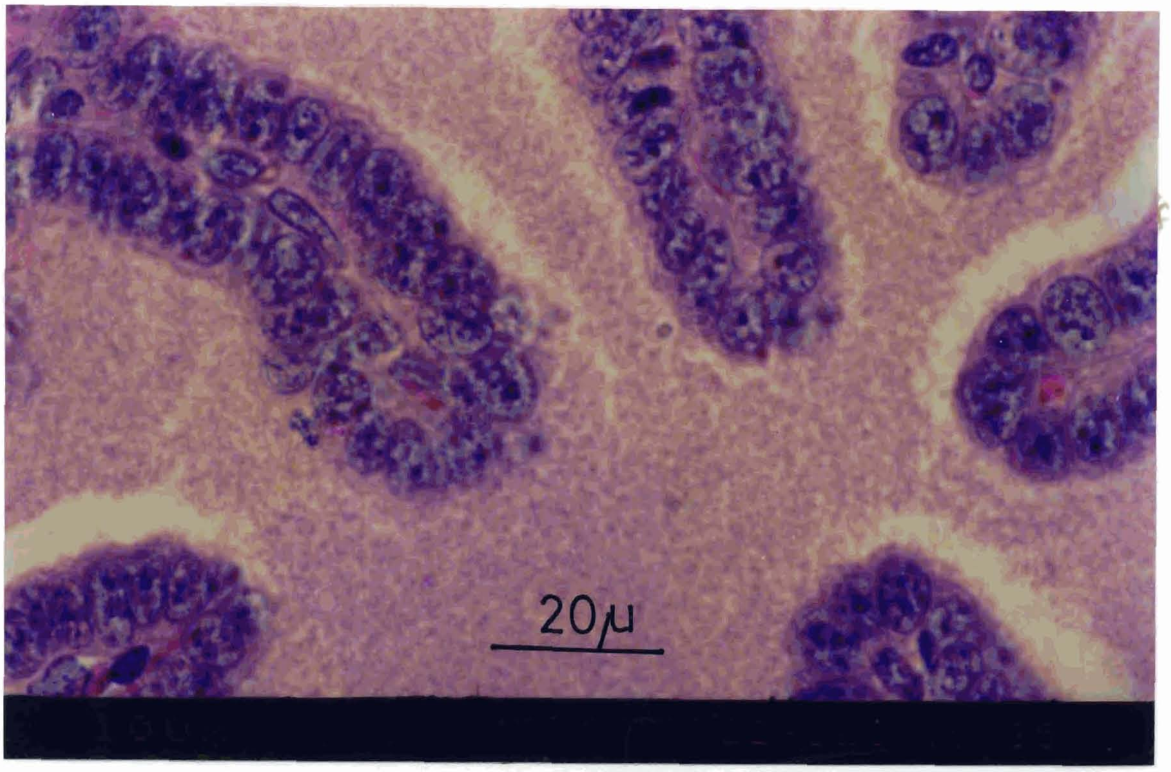

20µ

Plate 8.11. The follicle cells proliferate from the surface of the oocyte and meet towards the centre. Bar denotes 20 µm.

Plate 8.12. Section of an ovary showing atretic oocyte at differenrt stages of degeneration. Bar denotes 50 µm.


20μ

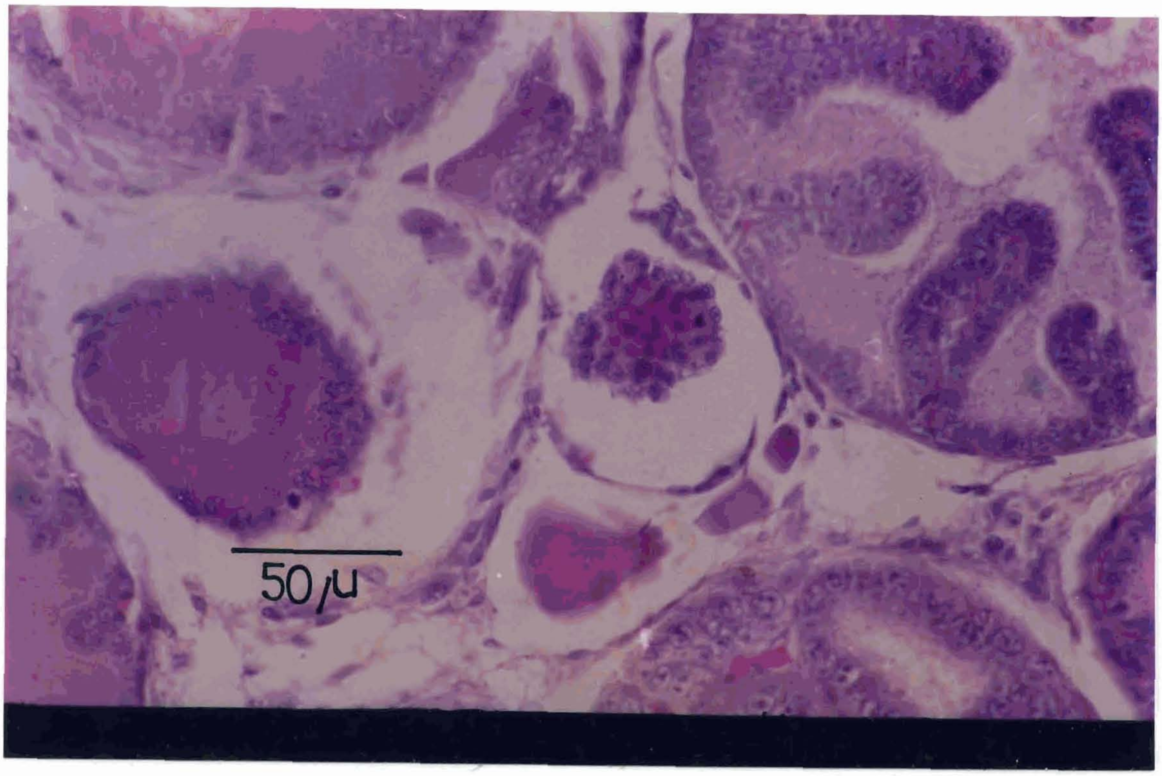
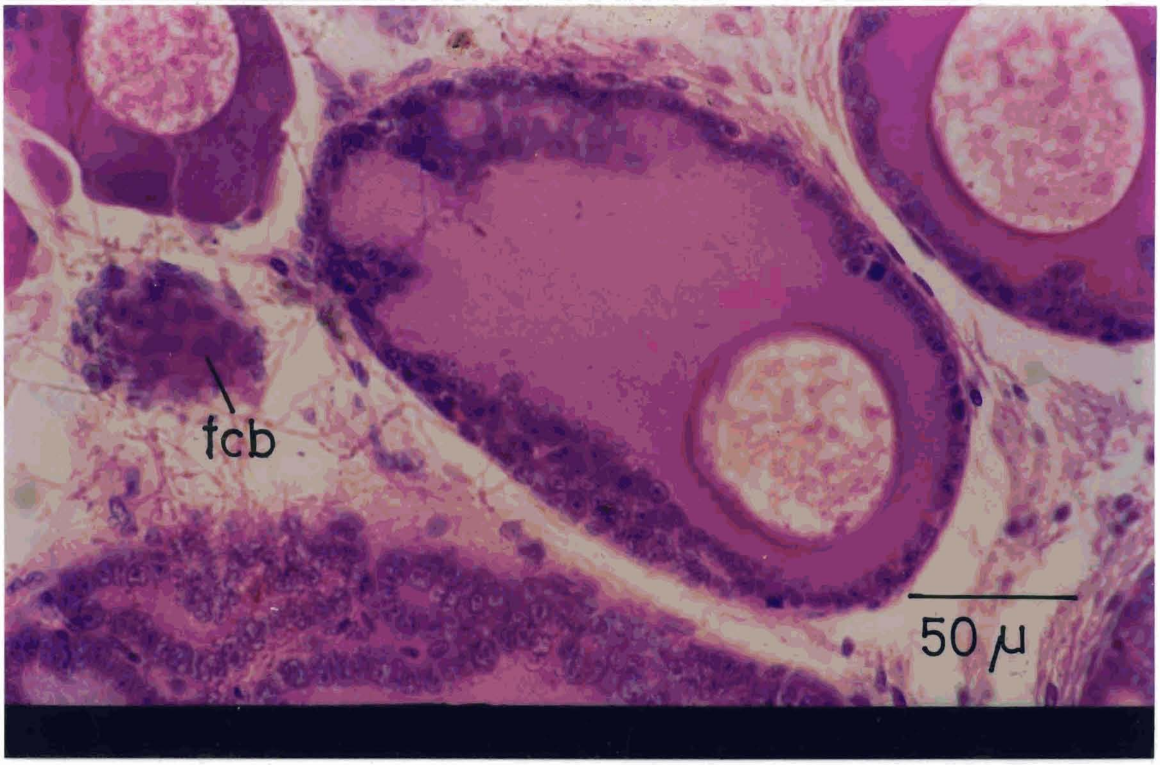

50μ

Plate 8.13. Bundle of follicle cells (fcb) seen in the interspaces of oocytes. at differenet. Bar denotes 50 µm.

Plate 8.14. Enlarged view of the follicle cell bundle (fcb). Bar denotes 20 µm.


fcb
50 µ

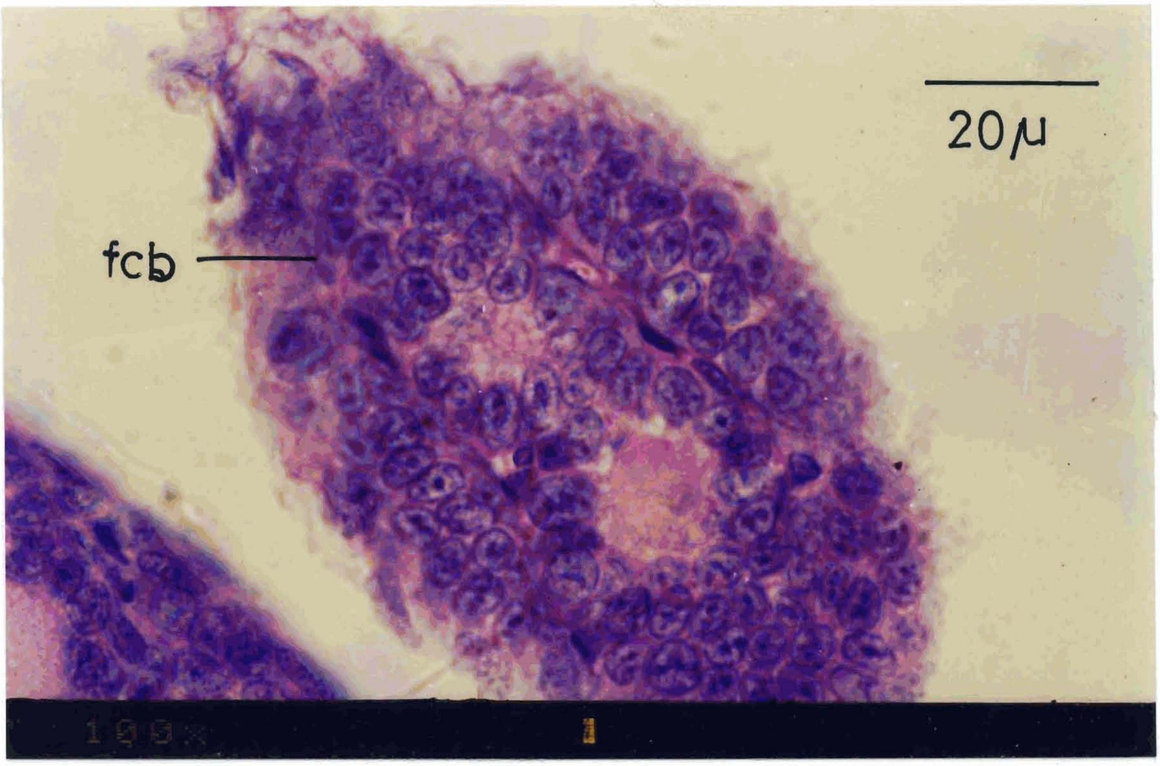
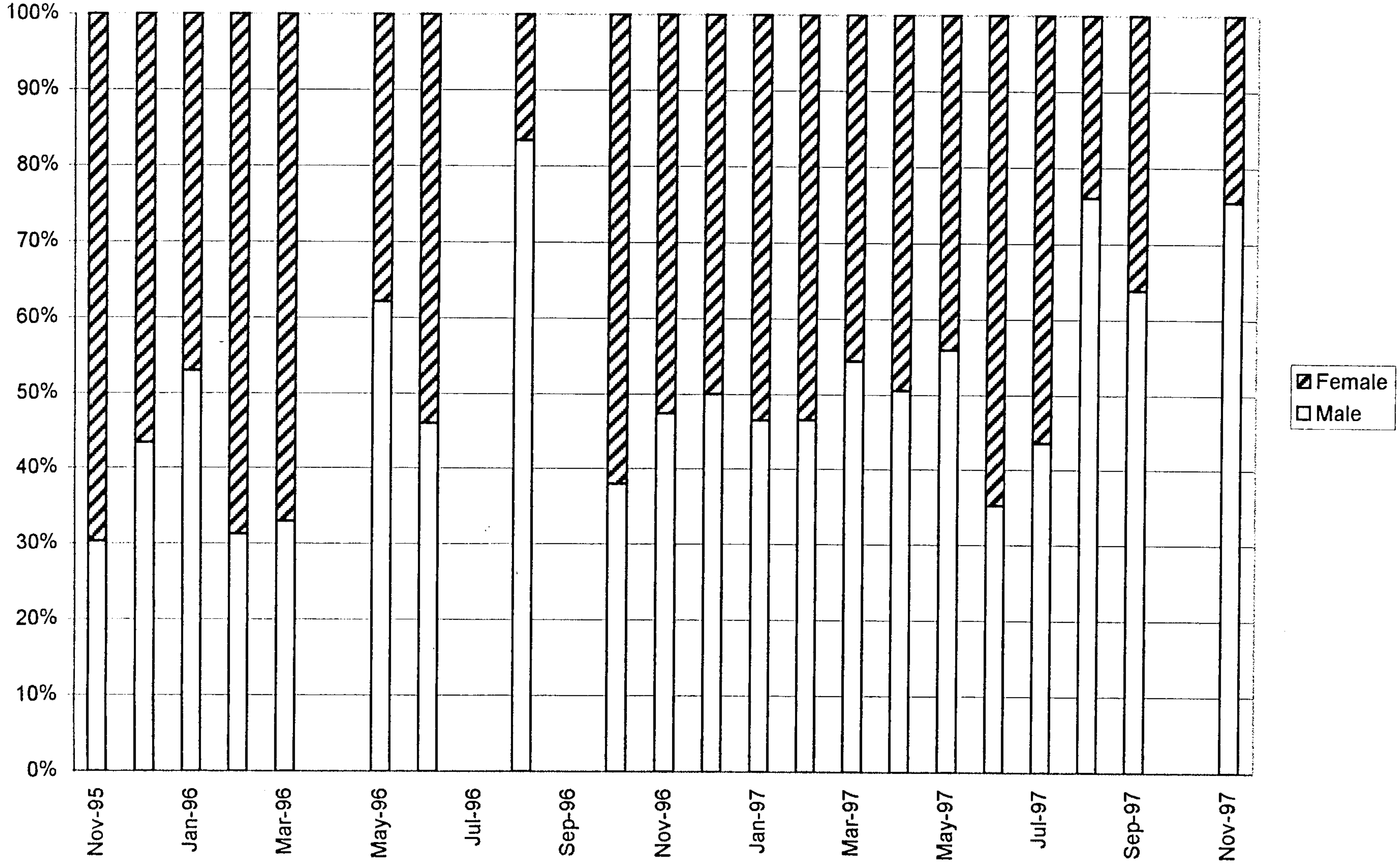

20µ
fcb
100×

Fig.8.5. Monthly sex ratio of *Loligo duvauceli* at Calicut.



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Nov-95
Jan-96
Mar-96
May-96
Jul-96
Sep-96
Nov-96
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Nov-97
Female
Male

finally the mature oocyte is ovulated with the degeneration of the follicular syncytium. The Plate 8.12 shows the atretic oocytes at different stages of degeneration. Atresia marks the end of spawning. It also indicates that *Loligo duvauceli* may live after spawning. The follicle cells sometimes form small bundles and are seen in the spaces between the oocytes but the specific function is not fully known (Plate 8.13 and 8.14).

8.6. Sex ratio:

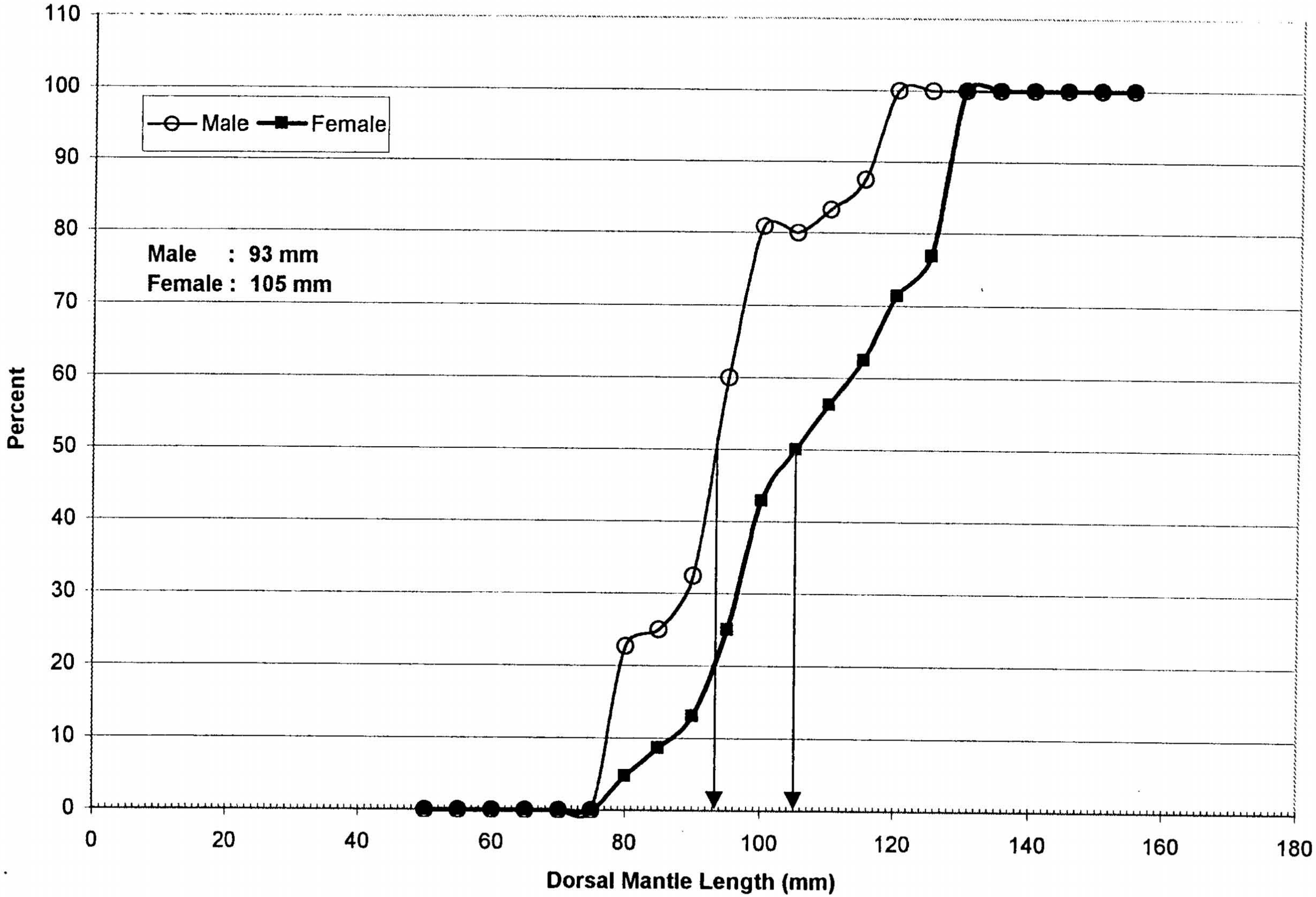
Along Calicut coast, females were generally the dominant sex with the average sex ratio during Nov'1995 to Nov'1997 being F 56: M 44. But during certain months of the year, the males dominated the females, which differed from year to year. As *Loligo duvauceli* congregates during the breeding period of September to November, the ratio is more pronounced (Fig.8.5). However Fields (1965) found in the case of *L.opalescens*, the ratio to be 1:1.

8.7 Maturity:

Females attain maturity when they range in size from 75 and 120 mm. They were found to attain maturity at a larger size as compared with males. The size at first sexual maturity for females is 105 mm. All the females mature by the time they attain the size of 130 mm.

Males get mature from 75 to 120 mm size. The size at sexual maturity is 93 mm and all the males attain maturity on reaching 120-mm size.

Fig.8.6. Size at first maturity of *Loligo duvauceli* of males and females of Calicut.



Male
Female
Male : 93 mm
Female : 105 mm
Percent
Dorsal Mantle Length (mm)
0
10
20
30
40
50
60
70
80
90
100
110
0
20
40
60
80
100
120
140
160
180

Fig.8.7. Monthly stages of maturity of females of *Loligo duvauceli* at Calicut.

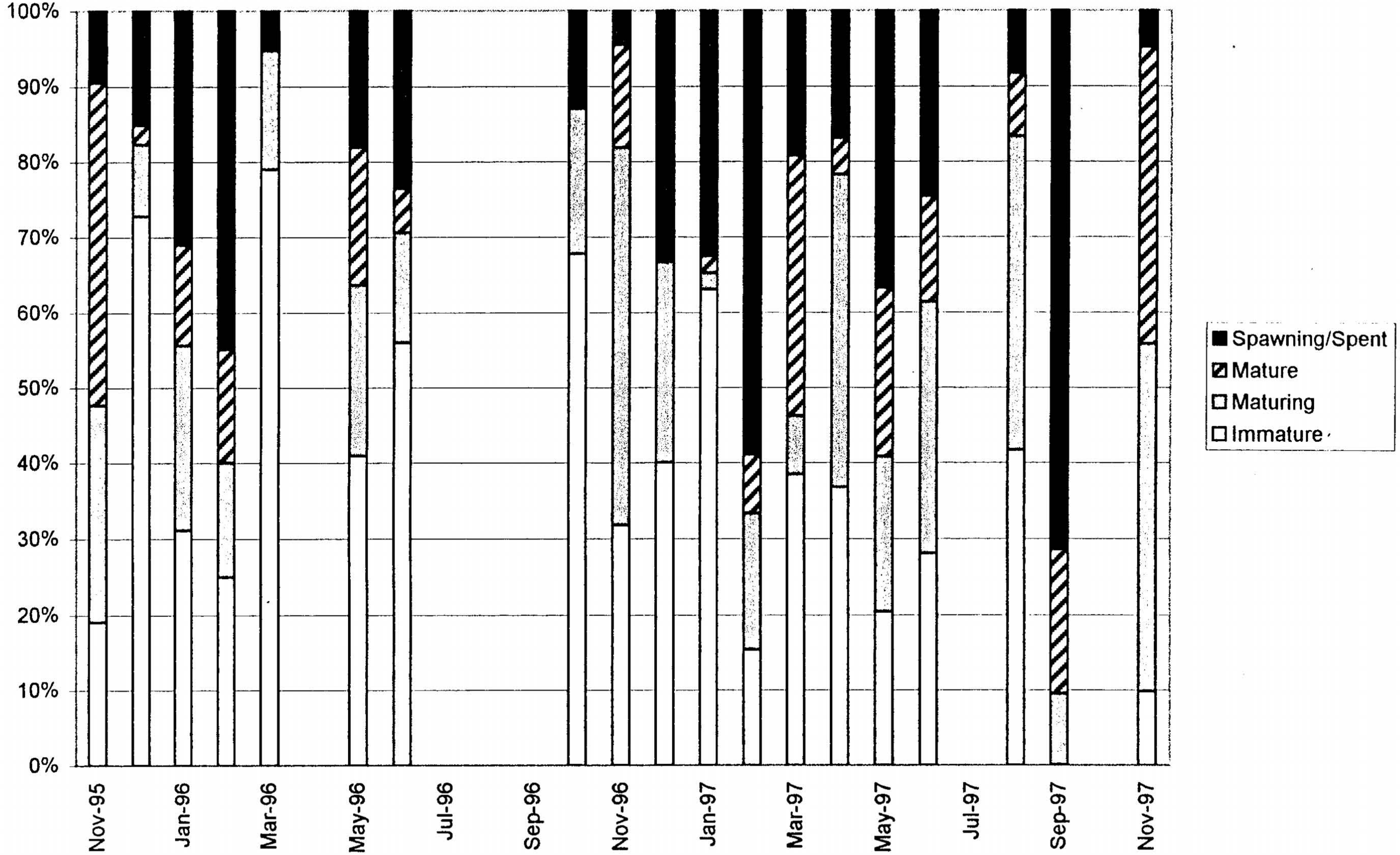

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Nov-95
Jan-96
Mar-96
May-96
Jul-96
Sep-96
Nov-96
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Nov-97
Spawning/Spent
Mature
Maturing
Immature

Fig.8.8. Monthly stages of maturity of males of *Loligo duvauceli* at Calicut.

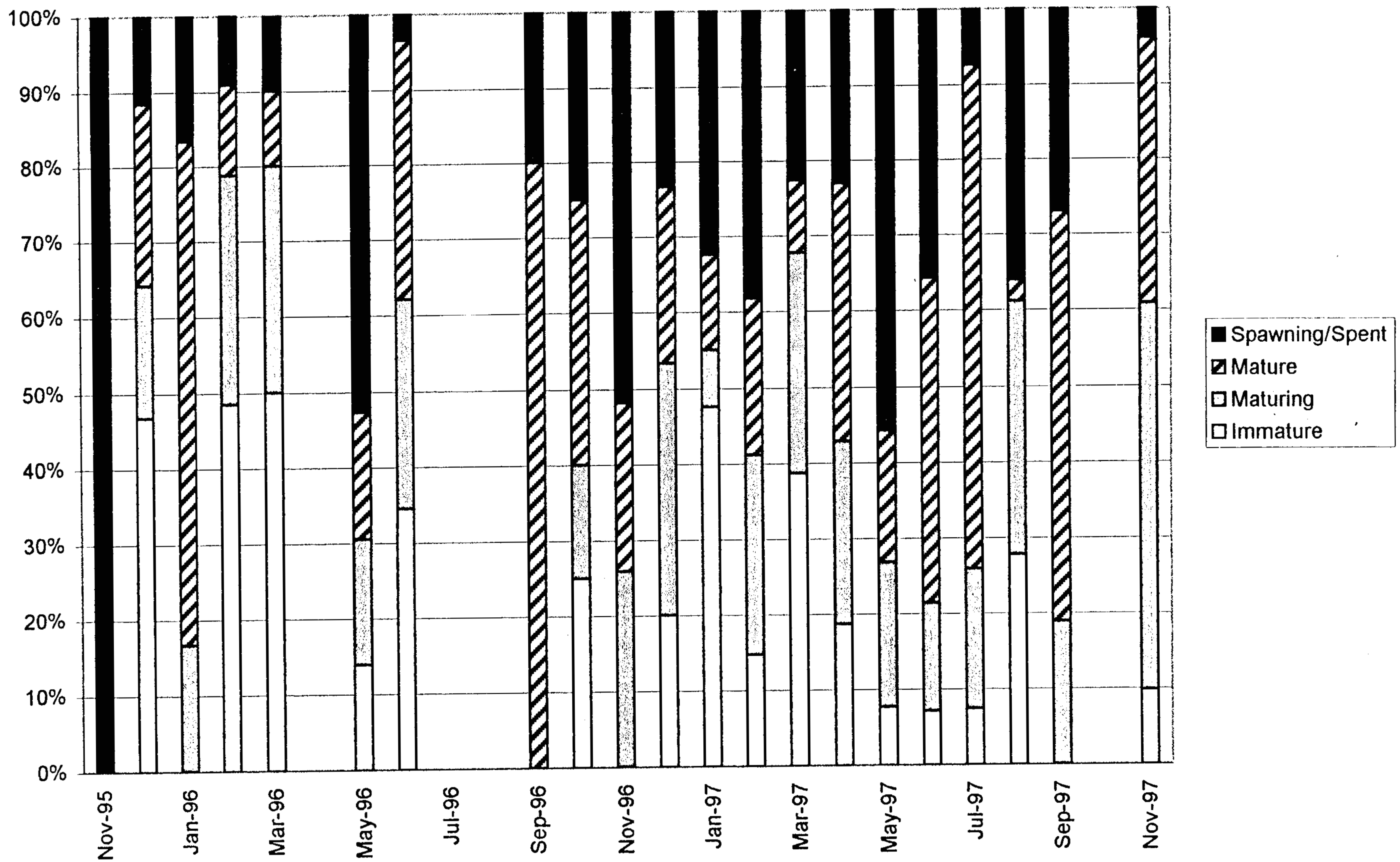
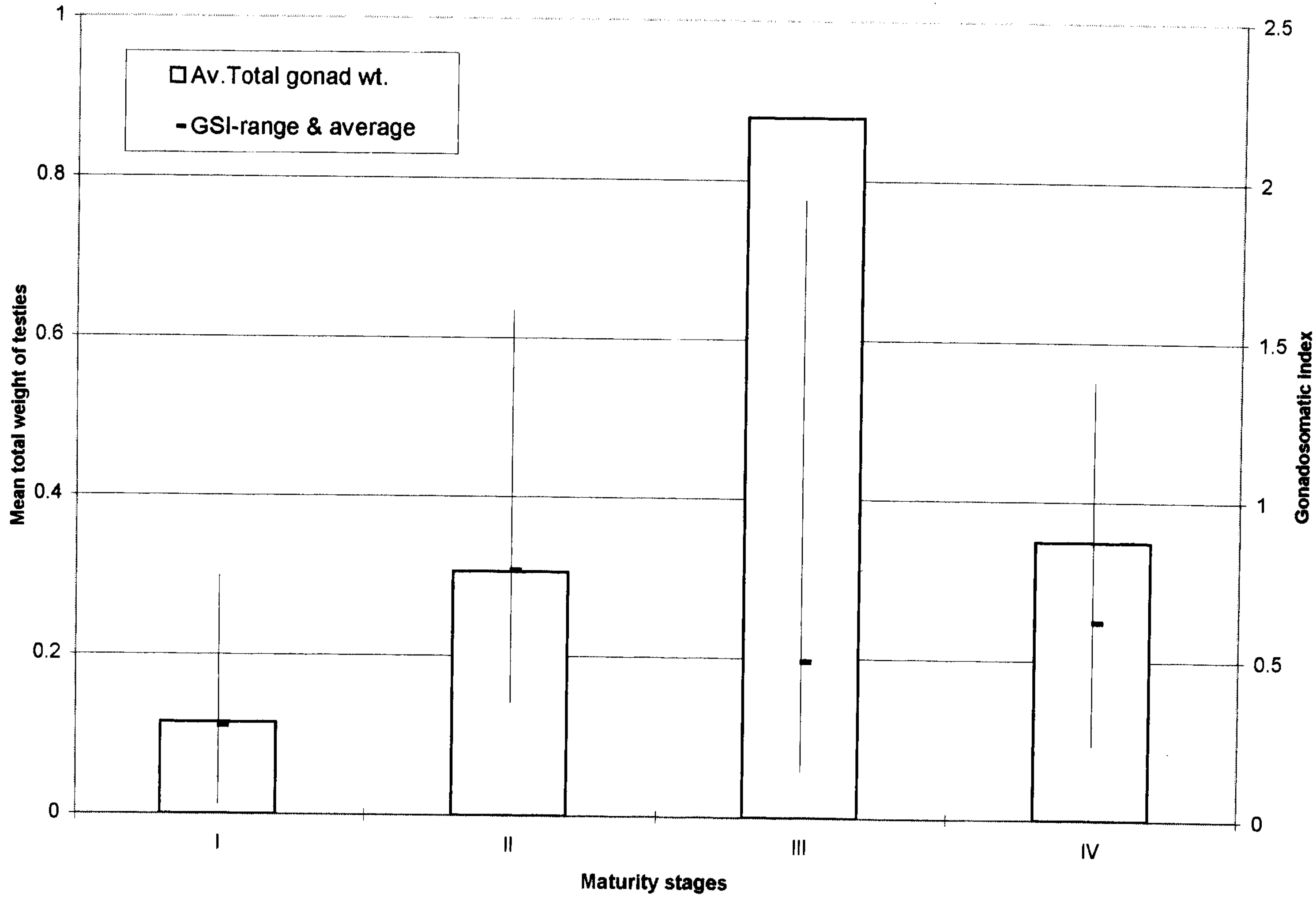
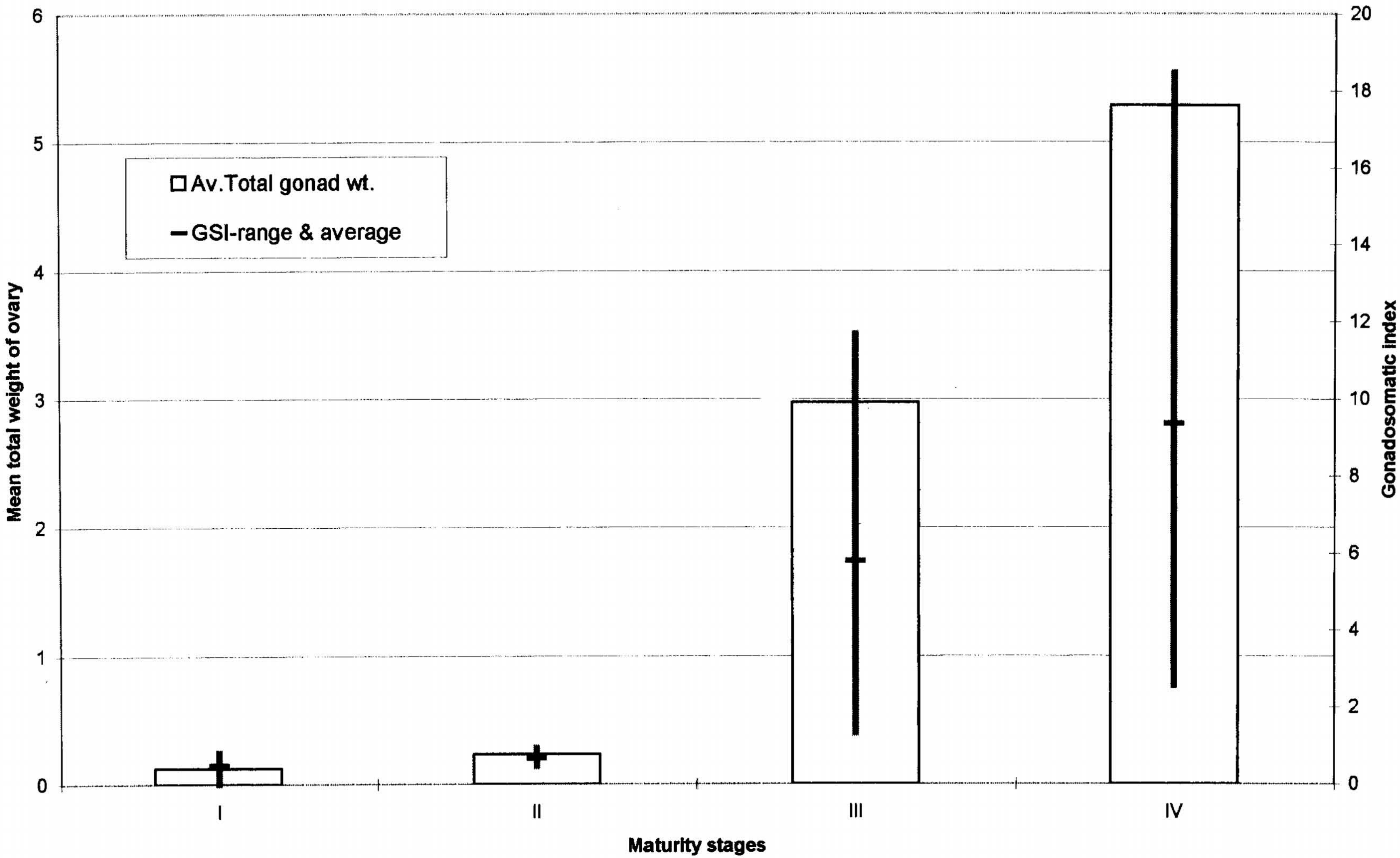

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Nov-95
Jan-96
Mar-96
May-96
Jul-96
Sep-96
Nov-96
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Nov-97
Spawning/Spent
Mature
Maturing
Immature

Fig.8.9. Gonadosomatic index (GSI) and mean total weight (gonad) of male *L.duvauceli*.



Av.Total gonad wt.
GSI-range & average
Mean total weight of testies
Gonadosomatic index
Maturity stages
I
II
III
IV
0
0.2
0.4
0.6
0.8
1
0.5
1.5
2
2.5

Fig.8.10. Gonadosomatic index (GSI) and mean total weight (gonad) of female *L.duvauceli.*



Av.Total gonad wt.
GSI-range & average
Mean total weight of ovary
Gonadosomatic index
Maturity stages
I
II
III
IV
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
18
20

The plot of the size of squid and the 50% sexual maturity for both the sexes is shown in Fig 8.6.

8.8. Spawning:

In *Loligo duvauceli*, the spawning activity was recorded throughout the year in males and females. All the stages of maturity could be observed in both the sexes. However the abundance of mature individuals show a pattern. During the period, October to February, spawning activity is at its peak. After this period, smaller sized immature individuals are seen in more numbers. A secondary peak during the pre-monsoon month period of April-May can be observed. The Fig.8.7 and Fig.8.8 depict the plot over a period of two years for males and females respectively.

8.9. Gonadosomatic index:

The Gonadosomatic index (GSI) values of male and female *Loligo duvauceli* are shown in Fig.8.9 and Fig.8.10. The GSI of female *Loligo duvauceli* is very low in stage 1 and 2. There is a rapid rise in the total as well as in the mean values in the subsequent stages.

In the males, the GSI is low compared to the females as the testis donot show the dramatic changes. In stage 3 the the GSI average is lower than the stage 2 as the body weight of stage 3 increases considerably and hence lower than stage 2. However, the total gonad weight increases

Fig.8.11.1. Size frequency of oocytes in 100mm DML *L.duvauceli.*

Fig.8.11.2. Size frequency of oocytes in 105 mm DML *L.duvauceli.*

Fig.8.11.1

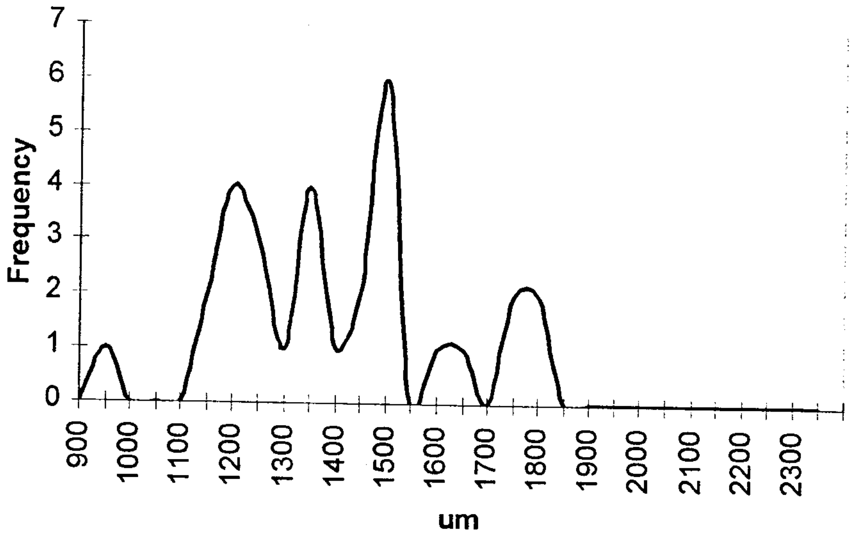


Fig.8.11.2

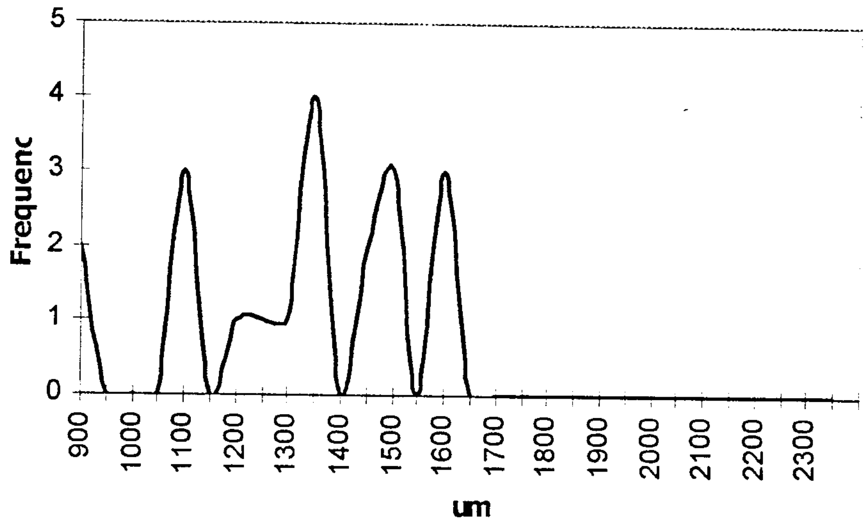


Fig.8.11.3. Size frequency of oocytes in 110mm DML *L.duvauceli.*

Fig.8.11.4. Size frequency of oocytes in 122 mm DML *L.duvauceli.*

Fig.8.11.3

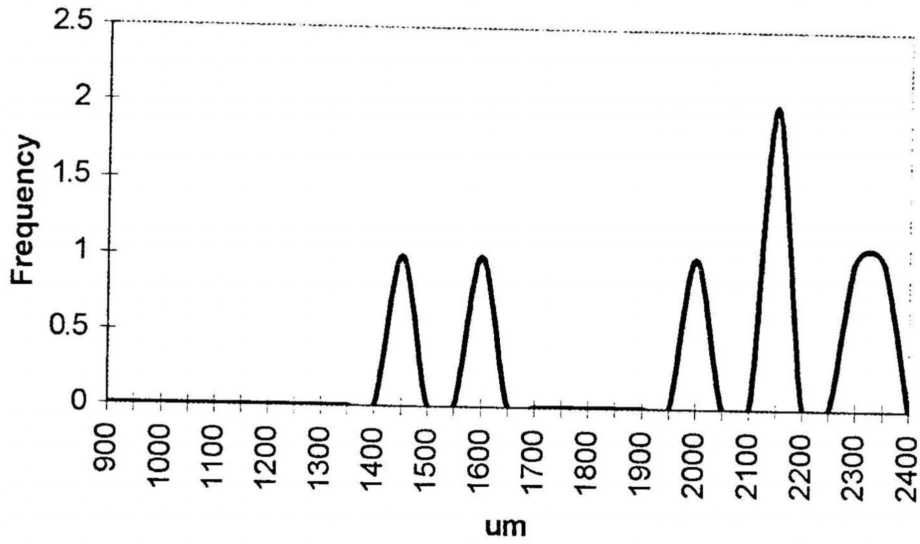


Fig.8.11.4

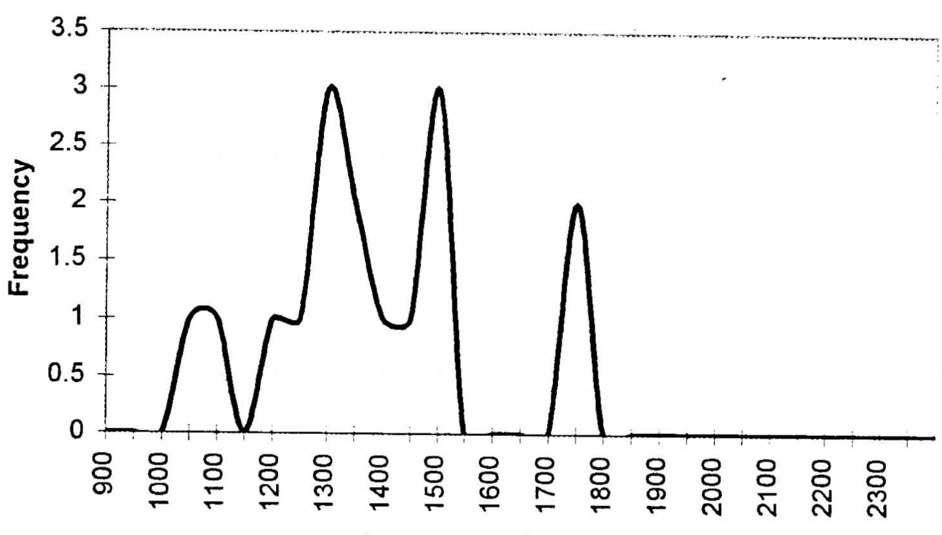


Fig.8.11.5. Size frequency of oocytes in 128mm DML *L.duvauceli.*

Fig.8.11.6. Size frequency of oocytes in 150 mm DML *L.duvauceli.*

Fig.8.11.5

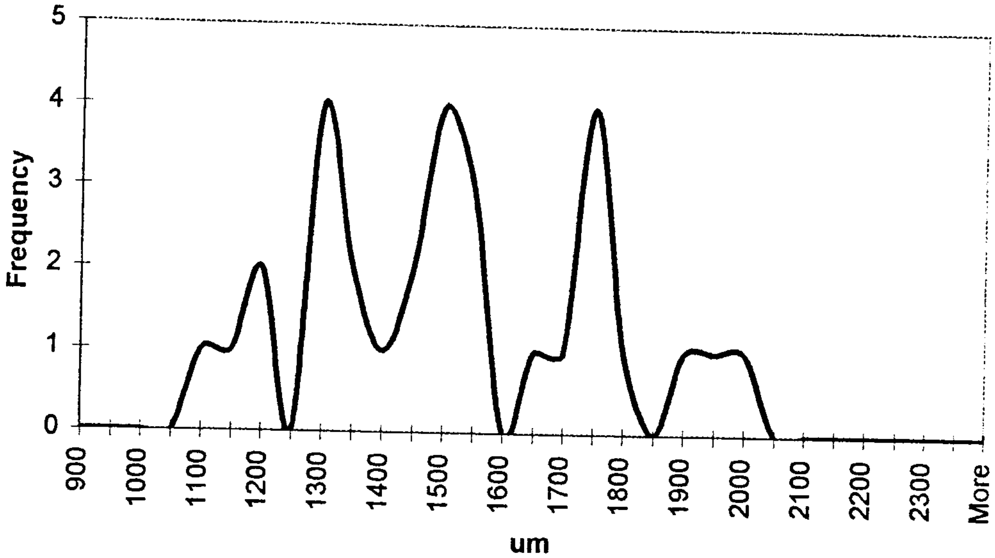
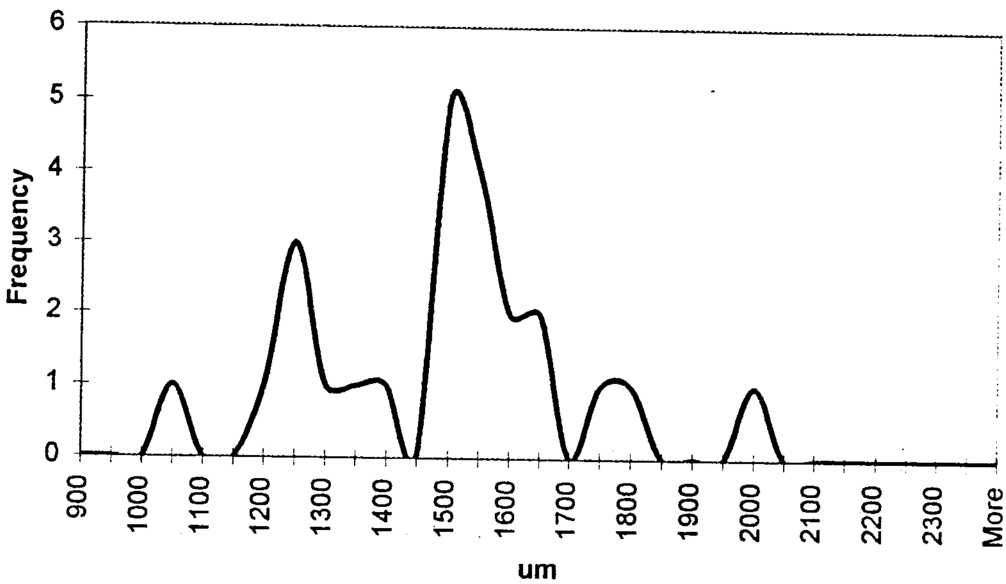


Fig.8.11.6



considerably. There is again a reduction in the gonad weight after the spawning activity.

8.10. Ovadiameter studies:

The spawning population, which comes to the knee deep inshore waters, was caught in the shore seines and was used for ova diameter studies. All the sqiuids were in the final stage of maturation i.e., the spawning/spent stage. Six different size groups ranging from 100 to 150 mm DML were studied. The ova diameters were recorded using an ocular micrometer standardised with a stage micrometer. The ovadiameter were grouped into 50 μm intervals and the frequencies plotted. The spawning population showed 5-7 different modal values in the ova of size groups. The plots are shown in Fig. 8.11.1 to Fig.8.11.6.

8.11. Fecundity

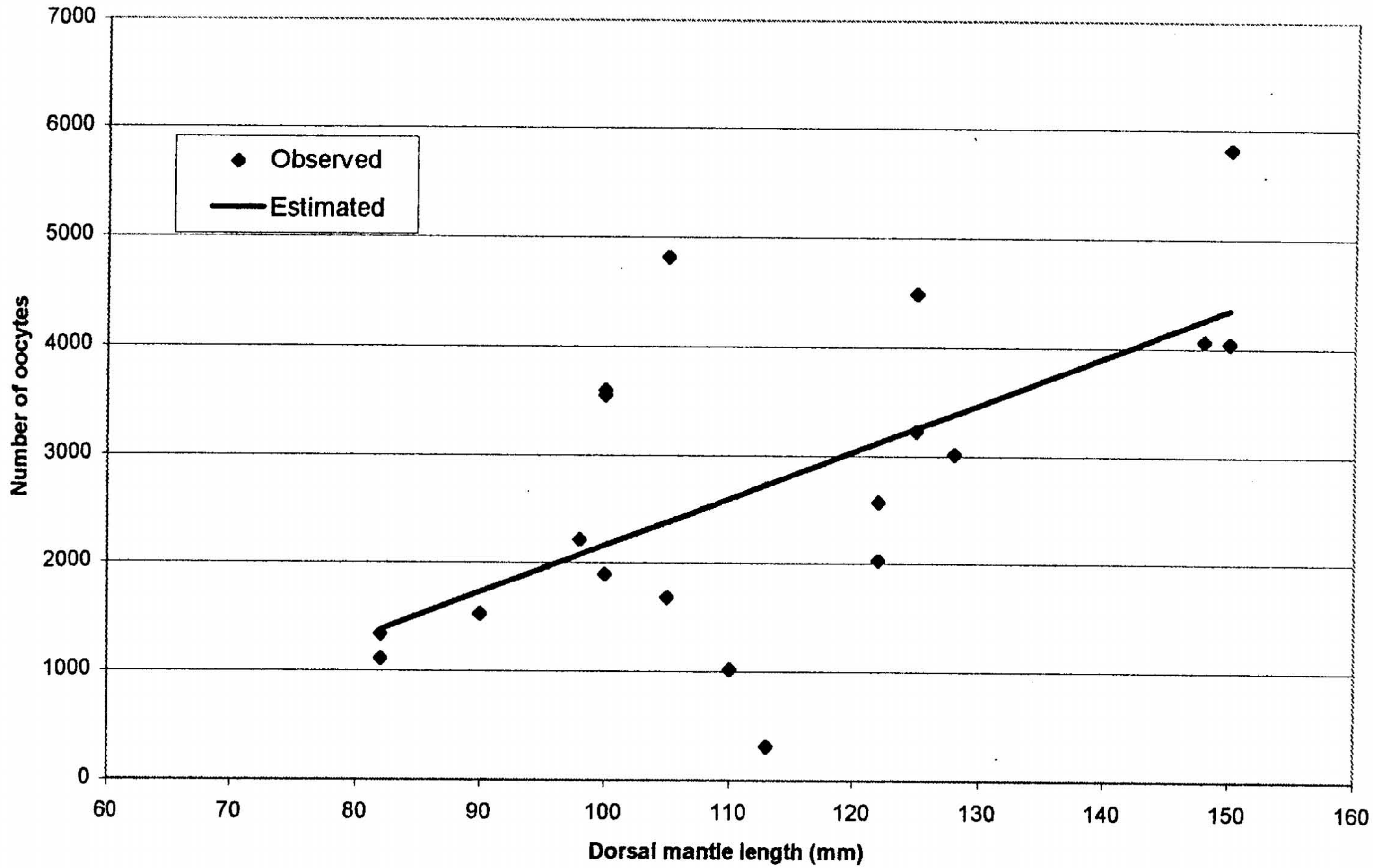
Fecundity in *Loligo duvauceli* ranged from 309 to 5815. The size of the sample ranged from 82 mm to 150 mm DML. The relation between the dorsal mantle length and number of oocytes is found to be linear with the relation:

$$N= -2194 + 43.64 X$$

Where N= Number of oocytes and

X = Length (DML) of the squid in mm.

Fig. 8.12. *Loligo duvauceli*. Relation between Dorsal Mantle Length and number of oocytes.



7000
6000
5000
4000
3000
2000
1000
0
Observed
Estimated
Number of oocytes
60
70
80
90
100
110
120
130
140
150
160
Dorsal mantle length (mm)

The coefficient of regression is 0. 38. The relation is shown in Fig.8.12. The specimens were collected from shore seines where the squids come for spawning.

8.12. Conclusion:

From the above account it is clear that *Loligo duvauceli* is a continuous spawner. But during the months September to February the percentage of maturing and spawning squids are more. This may be due to the fact that in the cephalopods, light acts as a limiting factor in the maturation of the gonad. Wells and Wells (1959) were able to show that the sexual maturation in octopus is under the hormonal control produced by the optic gland, seen as small subpedunculate lobes at the back of the supra-opthalmic veins (Frosch, 1974). Since blind animals (by cutting the optic nerves) also lead to early maturation, light is thought to be the stimulus acting on the nervous inhibitory centres (Wells and Wells, 1959). During monsoon and post monsoon conditions, the light intensity is low and the maturation process may be hastened. It is during the post-monsoon period the mass migration of the spawning population of the squid is observed towards shallow waters for mating and spawning (Fig. 4.11). It is during this period that large numbers of *Loligo duvauceli* are caught in the shore seines (Asokan and Kakati, 1991) and also in the purse seines (Mohammed, 1993).

The results suggest that *Loligo duvauceli* is a multiple spawner, developing and spawning more than one batch of eggs in a lifetime. There is lack of strong correlation in mature females between body size and quantity of mature eggs. There is also indication of continuous egg production throughout the adult life history. In the case of *Loligo duvauceli* the gonadosomatic index is low (9.35) compared to the known semelparous squids like *Illex illecerebrosus* which is 23% (O'Dor, 1983). This suggests that the *Loligo duvauceli* puts less energy at any time during ovarian development.

The ovarian oocyte size frequency plot shows continuous egg development in all mature females from 100 to 150 mm DML. In the case of the known semelparous squids such as *Illex illecerebrosus* and *Teuthowenia megalops*, the oocyte distribution show only a single mode. (O'Dor 1983, Nixon, 1983).

The histological studies have revealed that the squid oocytes undergo atresia. Atresia involves degeneration and resorption of oocytes, the processes that are not only important in the reproductive cycle of squid but also in declining the reproductive capability of the population on the spawning grounds. In terms of estimating reproductive capability in squid, atresia certainly lowers the number of maturing eggs in the ovaries, so decreasing effective fecundity. An inference of this study is that previous calculations of fecundity of cephalopods may have been too high.

CONCLUSIONS

CHAPTER 9

CONCLUSIONS

The cephalopod fishery of the Malabar area that was at a low key prior to 1987 came to limelight with the opening of export market for them in 1988. They suddenly became economically important and became the target species of the ambitious trawl fishery along with prawns. As the prawn fishery had already reached a saturation point and the demand for cephalopods were on the increase, the exploitation pressure on this comparatively new resource mounted. Trawl fishery quickly underwent changes to meet the challenges. Larger and powerful boats with facilities for stay-over fishing in the deeper waters for 3 – 5 days were introduced. Consequently, annual catches in Kerala increased from 437 tonnes in 1971to 43,472 tonnes in 1995. The growth of the fishery was uncontrolled as usual. The strains of over-exploitation started becoming evident warranting a study to understand the natural resilience of the resource to withstand the exploitaion pressure and the changed status of their stocks.

The gear that was instrumental to this increase in exploitation was trawl net operated from mechanised boats with a cod end mesh size of 22 mm. The gear was exploiting all size groups of cephalopods. The fishery did not show any restraint in exploiting any size group of cephalopods. The construction of a series of fishing harbours helped the trawl fishery operators to increase fishing trips even during rough weather exploiting cephalopods from any changing area of distribution.

Cephalopods like many other fishery resource of this area are highly influenced by the prevailing environmental conditions of the coastal waters of the Malabar area. Intensive spawning takes place to exploit the bloom of primary productivity followed by upwelling. The upwelling pushes them to the coastal waters. New recruits enter the fishery by December. Another recruitment by April is also observed. Larger groups are caught in December – February period.

The management of the fishery in India is restricted to the fishery ban for one and half months from 15 th of June till July end. There is no restriction for entering the fishing operation. During the upwelling period, the resources of *Loligo duvauceli* is pushed to the coastal waters when smaller boats fishing in one-day trips can catch the resource abundantly. With the sinking of the thermocline they move towards deeper waters and are caught mainly by larger boats going for multi-day fishing. This introduction of multi-day fishing was the major reason for the increase in the catch in recent years.

During the peak upwelling period in September, the catch rates are very high because it is the period when the squids move towards the coastal waters. Subsequently, though the effort increases because of better weather conditions, the catch rates decline fast and reach the minimum by December with the retreate of thermocline from the coastal area. It is observed that the juveniles of *Loligo duvauceli* of size below 50 mm are abundant in the catches during October-December and February to April. October, a month of good catch rates result in overexploitation of juveniles. February – April is another important period of recruitment when juveniles are caught abundantly.

The peak perod of spawning of *Loligo duvauceli* is in September when catch rates are very high. *Loligo duvauceli* move towards coastal waters for spawning. The exploitions of spawners are very high during this period. The spawners are caught abundantly during February. The fecundity of *Loligo duvauceli* is not very high. They lay limited number of eggs. Trawling during spawning can effect the egg production.

The estimated value of the present fishing mortality is very high at 3.88. The studies on the yield per recruit revealed that an F value beyond 1.6 would push down the yield. No responsible manager will allow the F value to reach even the F_{max}. Hence the F should not be allowed to go beyond even 1.4. This indicates that in the Malabar area, the resource of

Loligo duvauceli is presently over exploited and is on the decline. It is time we have started controlling exploitation. The question is how?

Trawl, which is the main gear used in the exploitation of *Loligo duvauceli*, is a multipurpose gear. The use of this can not be controlled only for *Loligo duvauceli*. The gear has a mesh size of 22 mm to exploit all sizes of different varieties of demersal resources. The studies have revealed that the best age at capture for *Loligo duvauceli* is 1 year, which will take care of the present fishing mortality and will safeguard the resources even in the event of increased fishing mortality. To attain this Tc value the mesh size of the trawl net will have to be increased even beyonf 35 mm, perhaps 40 mm. This is the safest option. Another option will be controlling trawling by closed seasons at least to protect the recruits from growth overfishing and protect the spawning population. For such an option, the trawling will have to be restricted to January to June period to protect the products of spawning in September from over-exploiting. Controlled fishing during July to September will be beneficial to the spawning population and successful spawning. Controlling fishing during October – December will restrict growth overfishing during the periof of their high vulnerability to the trawling in the coastal waters.

None of these options are easy considering the present scenario of the exploitation of the precious resource of *Loligo duvauceli*. But, it is time we have taken some hard decisions to protect it before it is too late.

For *Loligo duvauceli* the management option of changing the age at first capture was considered. The results indicate that the best yield per recrut and yield can be obtained at a Tc value of 1. This value is a safe value as even if the fishing mortality increases to 25, which is a far cry.

The present fishing pressure is giving great strain to the stock, which is moving towards a collapse. The present F should be brought from 4.22 to 1.6 which is the maximum allowed F and the optimum should be considered much less. An F of 1.6 will yield a catch of 4051 tonnes.

The stock assessment of *Sepia aculeata* was made based on the Thompson and Bell long-term prediction model. Yield and biomass was calculated for values of F ranging from 0 to 6. The maximum sustainable yield (MSY) was calculated as 547 tonnes corresponding to a F_{msy} of 3.89. Biomass MSY was estimated to be 2039 tonnes. To attain the MSY level, the present level has to be increased to 2.8 times the present value. But this increase will only increase the catch by 23%, which may not be econimically workable. As the cuttlefish is available in the outer edge of the continental shelf, fishing pressure on this resource is restricted unlike the *Loligo duvauceli*, which is available in the inshore areas and more vulnerable to the trawl operations.

Unlike the pelagic fishes and oceanic squids, the cuttlefish *Sepia aculeata* and the coastal squid *Loligo duvauceli* produces lesser number of eggs and these eggs are deposited on the hard substratum. So we cannot depend upon the resilence of these resources as already the fishing of the undersized *Loligo duvauceli* is going on in a very large scale and the trawling operation also disturbs the spawning areas.

Studies on the maturity stages show that *Loligo duvauceli* is a continous spawner. During the months of September to February the percentage of spawners are more and spawning migration is also seen during this period. The post monsoon period is also the period of zooplankton blooming and this seems to be a strategy for better survival rate. During the same period, the water temperature is also higher which helps in earlier hatching of the eggs.

The histological studies of the ovaries have revealed that *Loligo duvauceli* is a multiple spawner. Many batches of eggs can be seen in the ovaries at the same time. It is difficult to estimate the fecundity of batch spawners like *Loligo duvauceli,* as it may be an underestimate.

SUMMARY

P.K. Asokan "Biology and fishery of cephalopods (mollusca: cephalopoda) along the malabar coast " Thesis. Department of Zoology , University of Calicut, 2000

CHAPTER – 10

SUMMARY

Understanding the dynamics of a population is central to management of the fish stocks. With the advent of export market, there has been a tremendous increase in the effort for catching the cephalopods. The highest catch in India was recorded in 1995 and after that it had declined. This important resource has not been studied in Malabar area where it is of considerable economic importance. The present study is an attempt to understand the stock position and the management options available for effective stock management.

The chapter 2 deals with the materials and methods used in the study. Details of the methods for seawater analysis and the procedures for histology are mentioned. Details of the catch and effort in the four districts of Malabar area were collected and analysed. Data was collected on the length frequency distribution, to get a clear picture on the recruitment, growth, and mortality of *Loligo duvauceli* and *Sepia aculeata*.

The study on the environmental factors is given in chapter 4. The environmental factors play an important role in the fishery and the

biology of *Loligo duvauceli*. The upwelling brings the cephalopods from the deeper area towards the shore and thus become vulnerable to trawl catches. The cathes in the shore seines and boat seines appear during this season. Simailarly in the East Coast, the cephalopods appear in the upwelling period of January to May.

The changing pattern of the catch and effort is detailed in the chapter 5. The data collected from Malabar area during the thirties were analysed to know the seasonal availbility during the period. The cephalopods were available only during March and August to October period, as the craft and gear were not available to exploit the resource. The cephalopods were also not of commercial importance and were mainly used as bait fishes.

With the introduction of trawlers, the cephalopods are available almost throughout the year. The trawling operation is spreading to deeper areas to exploit the cuttlefish resource, as the export market is remunerative.

The contribution from Kerala during the past decade is o the average 35 % of the total production from India. In Malabar area, Kozhikode district produces about 88 % of the total catch. At Kozhikode district, the major fishing harbour and the infrastructure like marketing is better and has multiday fishing for cephalopods operating mainly from Puthiappa and Beypore fishing harbours. The major fishing gear for cephalopods is trawl. Other gears like hook and lineis very seasonal and the availability in purse seine is very low. The hook and line fishery exists for *Sepia pharaonis*, which fetches good, price for the fishermen.

Undersized *Loligo duvauceli* known to the industry as 'nipple' is fished in large numbers. This is of great concern as they are very small and some size restriction is warranted.

The age and growth is discussed in chapter 6. The males of *Loligo duvauceli* grow to larger size than females. The growth rate of male is also different than females. The K value of females was found to be slightly lower than the males. The seasonalised von Bertalanffy' s growth equation was used as it gave better estimation of the parameters.

The recruitment pattern in *Loligo duvauceli* shows maximum recruitment during August/October period. This coincides with with the post monsoon period when the spawning of *Loligo duvauceli* is observed along the West Coast of India. A minor recruitment during the summer months of March - May is also observed. In *Sepia aculeata* the maximum recruitment is observed during the summer months of March – April.

Study of the population dynamics and management with recommendations for management is made in Chapter 7. The present fishing *Loligo duvauceli* is beyond the F_{max} as the optimum F is much lower. The strains in the stocks of *Loligo duvauceli* are high. The age at first capture is very low at 0.25 years. The best yield per recruit ad yiels is obtained at a Tc value of 1. So the present age at capture should be raised at 1 and by doing so the Fmax will be at a very high level of F which can be considered as a safe level.

A discussion on the maturity and spawning in *Loligo duvauceli* is given in Chapter 8. Gonadial studies on *Loligo duvauceli* was conducted to know the fecundity and the ova diameter of various sizes in the population. The relation between body weight/length and ovary weight is established. The relation between ovary weight and nidamental gland is also shown. The stages of maturity and the various stages of oogenesis are also given in detail with diagrams and photomicrography. Ova diameter studies indicate the different batches of ova in mature gonads. The *Loligo duvauceli* appears to spawn in differnet batches and hence the true fecundity is rather difficult to estimate.

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APPENDIX -

Publications.

Indian Journal of Fisheries 38 (4) : 201 -206 December 1991

Embryonic development and hatching of *Loligo duvaucelii* Orbigny (Loliginidae, Cephalopoda) in the laboratory

P K ASOKAN[1] and V S KAKATI[2]

Karwar Research Centre, Central Marine Fisheries Research Institute, Karwar, Karnataka 581 301

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ABSTRACT

The egg masses and adults of common squid *Loligo duvaucelii* were collected on the shore seine and from the intertidal sandy shore at Karwar. The embryonic development and hatching of the squid was observed in the laboratory. Each egg mop consisted of many egg capsules, each of which, in turn, consisted of 125–150 eggs. Eggs were 2 mm long and 1.75 mm wide and very yolky. The young ones hatched in 5 days measuring 1.83 mm in DML and 3.17 mm in total length including the arms. Mantle width was 1.55 mm. The young ones survived for 5 days in the aquarium.

The bulk of the cephalopod production in Indian waters comprises cuttlefishes (60%) and the rest consists of squids and a negligible quantity of octopods (Silas 1986). The biology and fishery of cephalopods have attracted the attention of many workers in India (Rao 1954, Alagarswami 1966, Silas 1968, 1986, Sarvesan 1969, Silas *et al.* 1982, Sivalingam and Pillai 1983). However, the embryonic development and hatching of the common squid *Loligo duvaucelii* Orbigny has not been studied so far. This squid is a neritic, shallow water species distributed throughout the Indian coast. It is commonly known as the Indian squid though distributed widely in the Indo-Pacific region. The recent appearance and landings of unusually large quantities of this squid at Tadri in Karnataka amounting to 12 tonnes in a single trawl net haul, and at Karwar by trawlers and shore seines, promp-ted this study. The present account deals with the embryonic development and hatching of the squid based on laboratory observations.

Present address: [1]Scientist, [2]Senior Scientist.

MATERIALS AND METHODS

The egg masses of *Loligo duvaucelii* were collected along with adults in the shore seines and also from intertidal sandy shore at Karwar (Lat. 14°50′N, Long. 74°03′E) at low tide on 21 September 1989. Since this squid aggregated very close to the shore for spawning, collection of egg masses that came along with adult squids in shore seines was very easy. Apart from this, egg masses noticed in the intertidal areas during low tides were also collected. These egg masses were maintained in the laboratory where the hatching took place.

The egg masses or mops were maintained in seawater in 10-litre glass trough under continuous aeration. The water was changed daily. The temperature of the rearing medium was maintained at $28^\circ \pm 2^\circ$C and salinity at 33 ± 2‰. The first batch of young ones emerged from some egg capsules on 26 September at

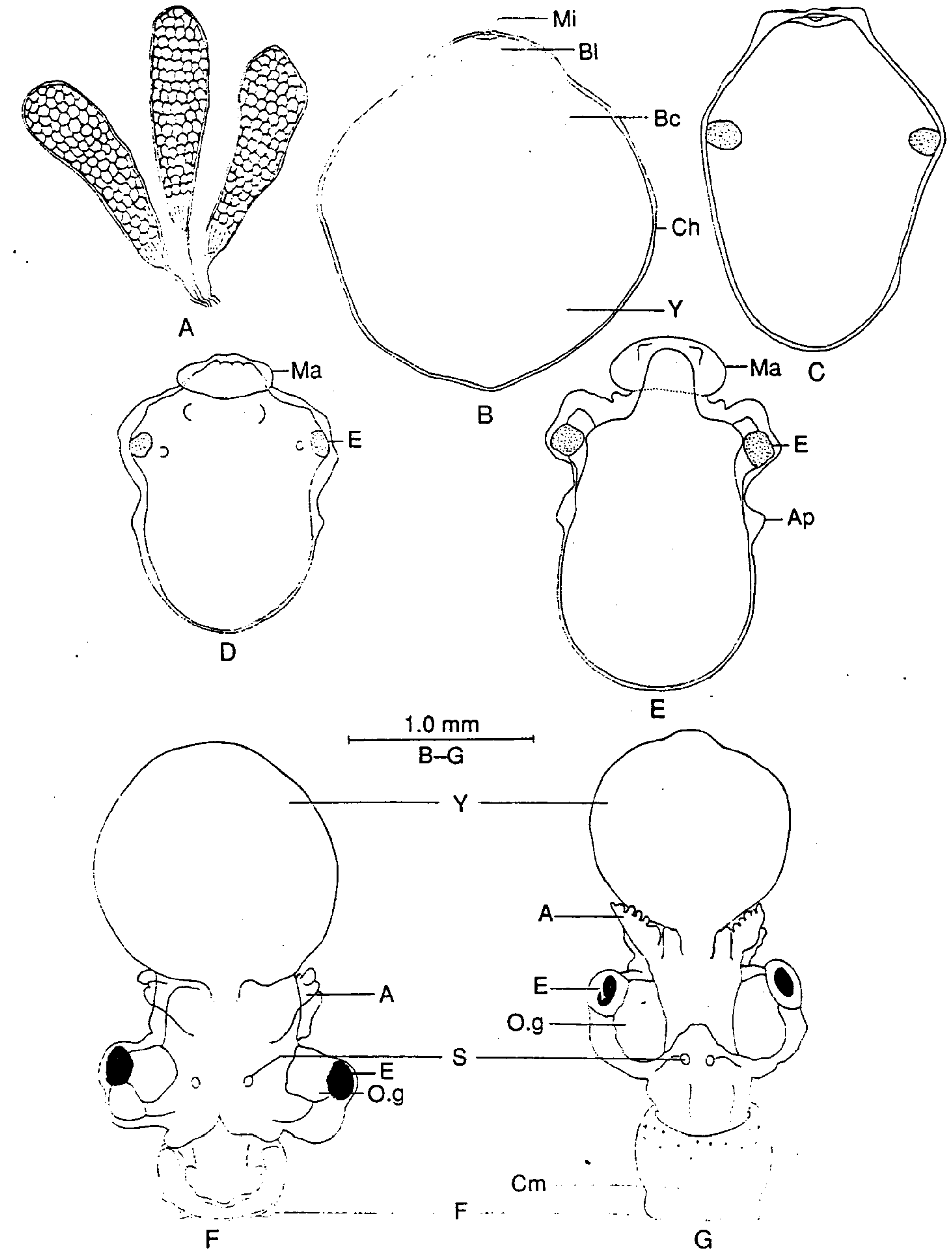

Fig. 1. Embryonic development of *Loligo duvaucelii*. **A.** Egg capsules. **B.** Formation of the blastodisc with the micropyle. **C, D, E, F** and **G.** Developmental stages.
A, Arm; Ap, Arm primordia; Bc, blastocones; Bl, blastoderm; Ch, chorion; Cm, chromatophore; E, eye; Ma, mantle; Mi, micropyle; O.g, optic ganglion; S, statocyst; Y, yolk.

1030 hrs while other embryos were still in the process of development. The hatching process continued till 29 September in different capsules. Healthy young ones were segregated for further rearing. The hatched young ones were positively phototactic. A few young ones were narcotized by adding magnesium sulphate heptahydrate ($MgSO_4.7H_2O$) so as to get uncontracted specimens for sketching. The specimens were preserved in 5% formalin. Sketches were drawn to scale with a Camera lucida. Embryonic stages were studied from the developing egg capsules.

RESULTS

When the egg capsules were collected the eggs were with apical body and still in the process of development.

Egg mass

The egg mass or egg mop used in the laboratory consisted of gelatinous finger like capsules. The proximal end of the capsule formed an elongated gelatinous strand, and the end of the strand of each capsule was entwined with one another to form the egg mass (Fig. 1A) which was attached to the substratum. The egg mass sways and dangles in the water during wave action. There were 64 egg capsules in the present egg mop, and each of the capsules contained 125–150 eggs. It was observed that all the egg capsules of the mop were not in the same stage of development.

Egg

The egg was large and very yolky. It was telolecithal as in other cepahalopods. The egg measured on an average 2 mm in length, and 1.75 mm in width. It was encased in the chorion surrounded by perivitelline space in between and had a micropyle at the animal pole (Fig. 1B).

Organogenesis

The first embryonic organs appeared as a thickening of the outer cell layers forming mantle. The mantle increased in size and spread towards the animal pole and towards the equator of the embryo with the shell gland gradually disappearing. The mantle then formed a prominent ring which grew outwards and over the developing visceral organs forming the mantle cavity (Fig. 1C, D, E). The

Fig. 2. About-to-emerge hatchling of *Loligo duvaucelii* with dwindling yolksac.

eyes, arms and the funnel folds appeared later (Fig. 1 F, G). The eyes appeared as a thickened placode on either side of the embryo which on invagination formed the optical vesicle, the inner wall of which forming the retina. The arms first appeared as thickened buds of cells slightly above the equatorial constriction. These arm primordia grew outwards and differentiated with small sucker buds on their inner surface. The mantle then grew out downwards and covered almost the funnel leaving only the distal portion beyond its cavity (Fig. 2).

Squid hatching

Before liberating from the egg capsule, the young ones were seen making jerky movements inside the chorion. In some, the yolksacs were seen inside the capsule as they got detached from the young ones. In some cases, the yolksac was retained even as the young hatched out (Fig. 3) but subsequently it was dropped.

The young squid led an independent life. It measured on an average 1.83 mm in DML (dorsal mantle length) and 3.17 mm in total length including the arms. The specimens was

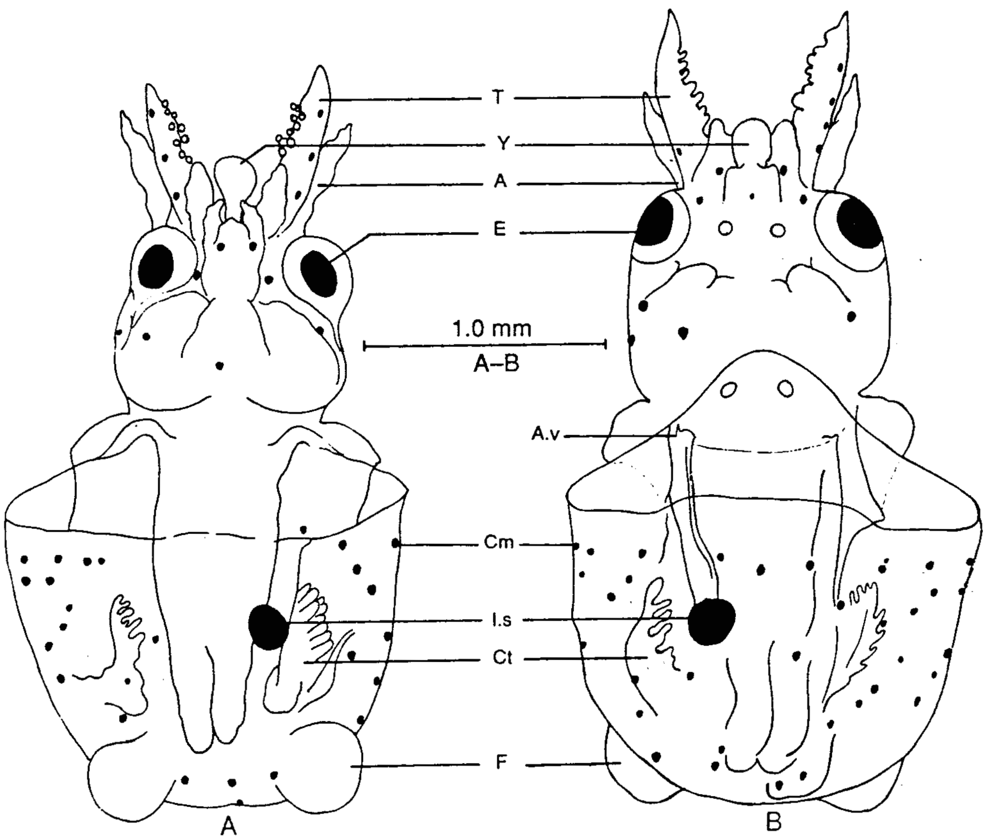

Fig. 3. Hatchling in *Loligo duvaucelii*: Yolk is still in a reduced form. **A.** Ventral view. **B.** Dorsal view. A.v, anal valve; Ct, ctenidium; F, fin; I.s, Ink sac; T, tentacle (for other abbreviations *see* Fig. 1).

1.55 mm in mantle width. The mantle being transparent, much of the internal organs could be seen under the microscope. The chromatophores were expanding and contracting. The fins were seen as 2 separate flaps without fusing posteriorly. The suckers on the arms, the funnel and the nuchal cartilage were well developed. The ink gland was seen as a dark patch as were the eyes. During the observation of the live young ones under microscope, one hatchling ejected ink from the ink gland on to the slide. The ctenidia, anal valve and branchial heart were also seen.

All the young ones survived for 5 days in the aquarium after which they all perished due to non-availability of proper food. They did not feed upon live *Artemia salina* nauplii. There was no death in intervening days.

DISCUSSION

The egg capsules were highly structured as observed in *Loligo pealei* (Arnold and Arnold 1977) with a central spiral fold of jelly (Fig. 1A). It was found that the same mop had capsules of different stages of development which indicated that the egg capsules in one mop might have been contributed by different individuals in the same population to form a community pile (Morton 1979).

The incubation in loliginids differs from species to species, and in the same species temperature of water seems to determine the duration as reported by Hamabe (1960) in *Loligo bleekeri*. Fields (1965) and McGowan (1954) also found different hatching periods for the same species at different temperatures. Alagarswami (1966) observed an incubation period of 15 days in *Sepioteuthis lessoniana* (= *arctipinnis*) at 27°–29°C at Mandapam. In the present species hatching was observed on the 13th day at 28°C.

The egg being very yolky, the embryonic development did not follow the typical molluscan pattern of spiral cleavage. There was no larval form. The hatching was direct to a minature adult as is the case in other decapod molluscs. The young one was small as compared to the hatchling of the Palk Bay squid *Sepioteuthis lessoniana* (= *arctipinnis*) which was much larger, measuring 7.5 mm in total length and 3.11 mm in width. The flaps were also fused posteriorly unlike in *L. duvaucelii*.

Since the occurrence of egg masses during September–October is a regular feature on the Karwar coast due to swarming of the adult squids, there is scope for rearing and ranching of young squids along this coast. This may increase the production of the squid which is at present sold up to Rs 45/kg. Therefore, attempts should be made to rear these 'easy to rear' egg masses of this squid on a large scale for sea ranching purpose.

ACKNOWLEDGEMENTS

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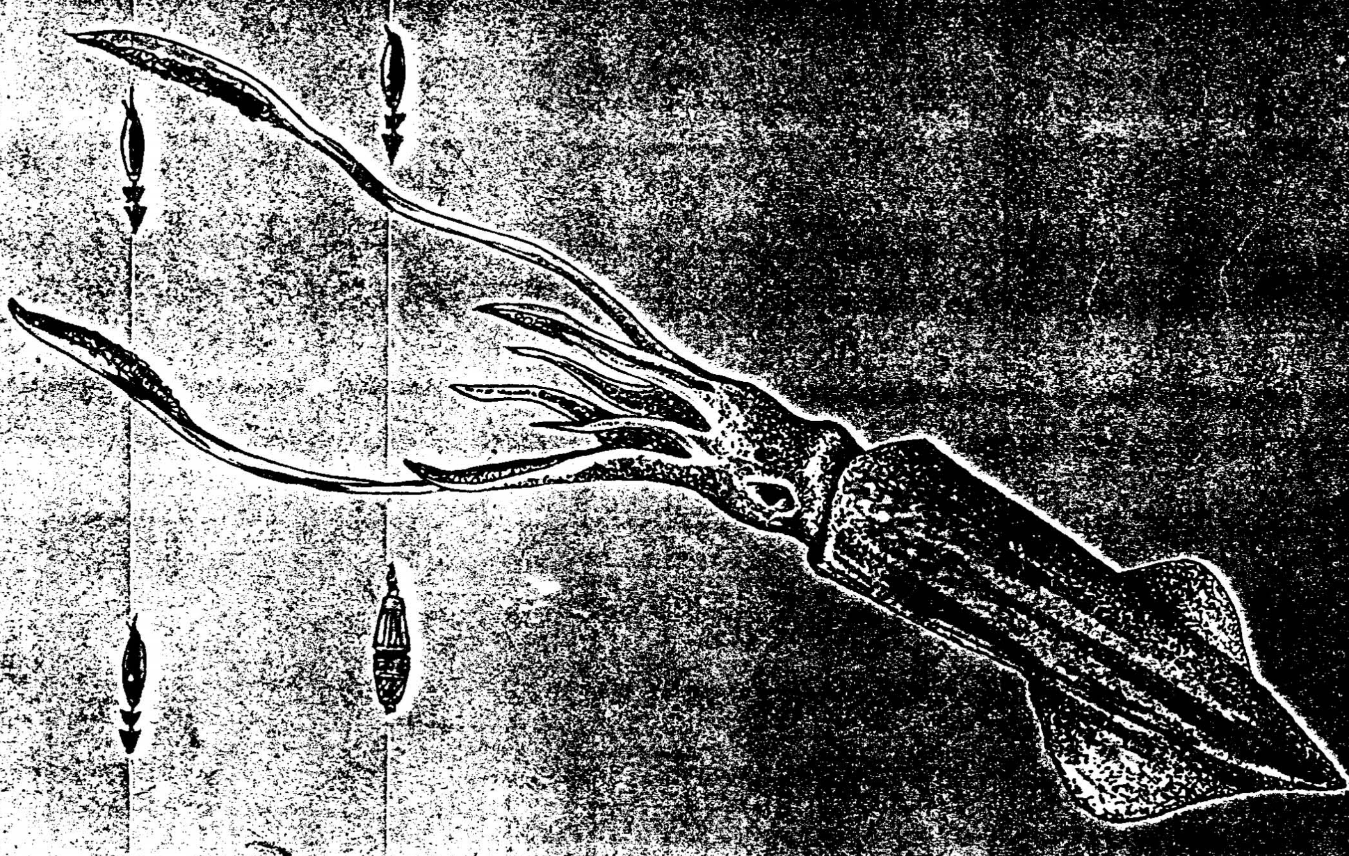
Bulletin 23

EXPLORATORY SQUID JIGGING IN INDIA WITH NOTES ON BIOLOGY OF SQUIDS



FISHERY SURVEY OF INDIA
Government of India
(Ministry of Food Processing Industries)
Bombay

July 1992

BIOLOGY OF SQUIDS

K. PRABHAKARAN NAIR, M.M. MEIYAPPAN, P.S. KURIAKOSE,
R. SARVESAN, A.P. LIPTON, SUNILKUMAR MOHAMED,
P.K. ASOKAN, MATHEW JOSEPH and D. NAGARAJA
Central Marine Fisheries Research Institute, Cochin

This section is based on the data collected in the squid jigging survey made by two vessels, **M.F.V. Matsya Sugandhi** and **M.V. Blue Fin** on the southwest coast of India during the 9-month period from June 1988 to February 1989. The data were collected onboard by the scientists of CMFRI who participated in the survey.

Three species of squids were jigged during the survey, and to understand some aspects of the biology of each of these species a general idea about their distribution and relative abundance in space and time is necessary. For this purpose, a one-degree square where jigging was done during the period is taken as a unit area.

Areas of operation

Sixteen one-degree were covered for jigging operations within 8-76 and 8-77 off Muttom-Colachel in the south and 16-72 and 16-73 off Ratnagiri in the north (Fig.1). These squares are so identified only to indicate the geographical location of jigging operations, and not related to the estimation of the resource potential of squids (which is not the aim of this section). The bottom depths ranged from 20 m to 80 m at areas near the coast; the squares 12-72 and 13-72 are in the oceanic region where the depth is very high, upto about 2,500 m.

Species composition

The squids taken in the jigging survey belong to three genera: **Loligo** (one species), **Doryteuthis** (two species) and **Symplectoteuthis** (one species). The relative abundance of these squids by number as well as by weight is shown in Fig.2. The squid belonging to the first neritic genus is **Loligo duvauceli** which accounted for 64% by number and 57% by weight of the total quantity of squids taken by jigging. Two species **(Doryteuthis singhalensis** and **D. sibogae)** belonging to the second neritic genus together constituted 12% by number and 13% by weight. The second in importance by number as well as by weight was the oceanic squid **Symplectoteuthis oualaniensis** contributing 24% and 30% respectively.

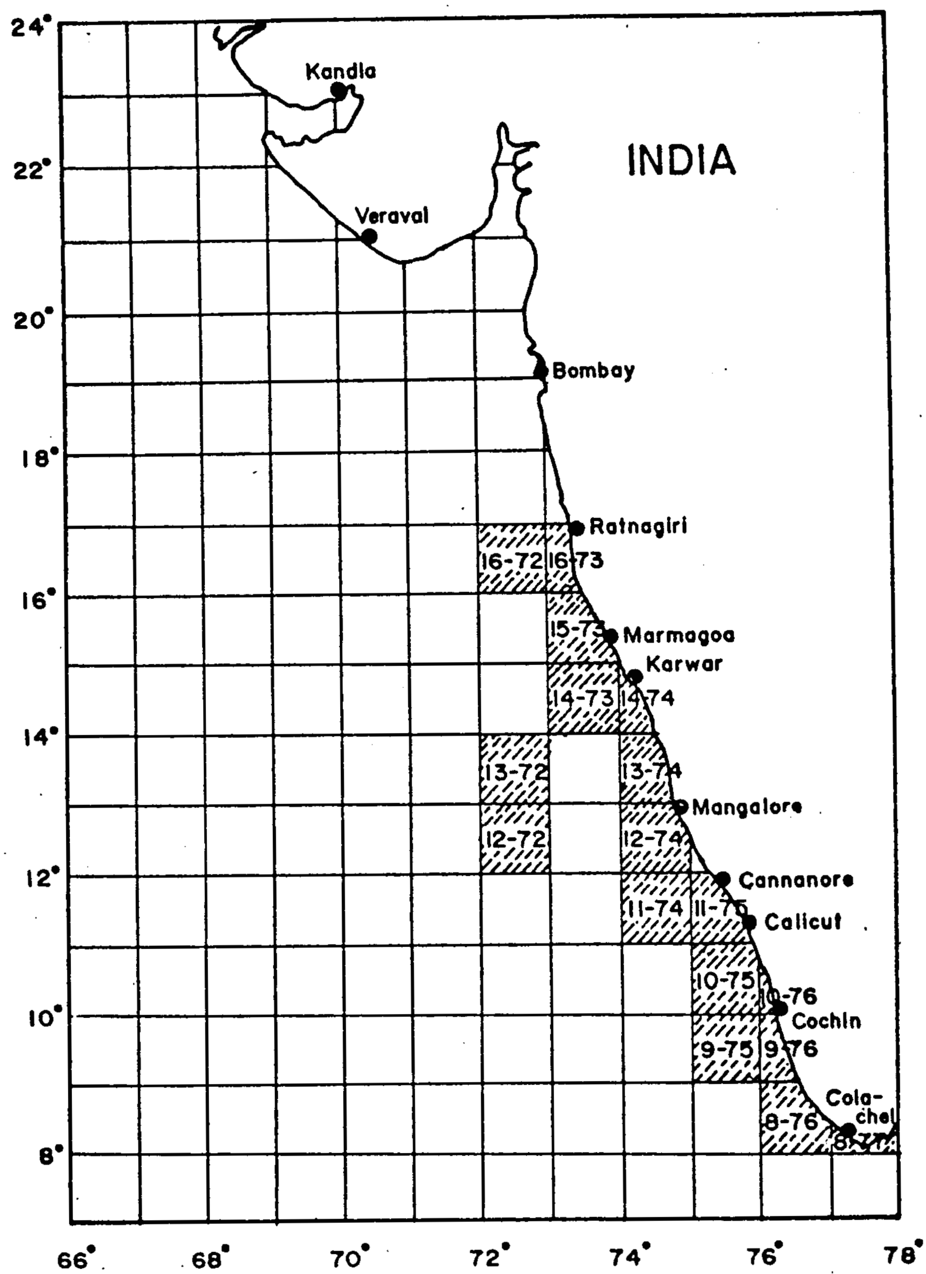


Fig.1 Areas (one-degree squares) of squid jigging operations on the west coast of India.

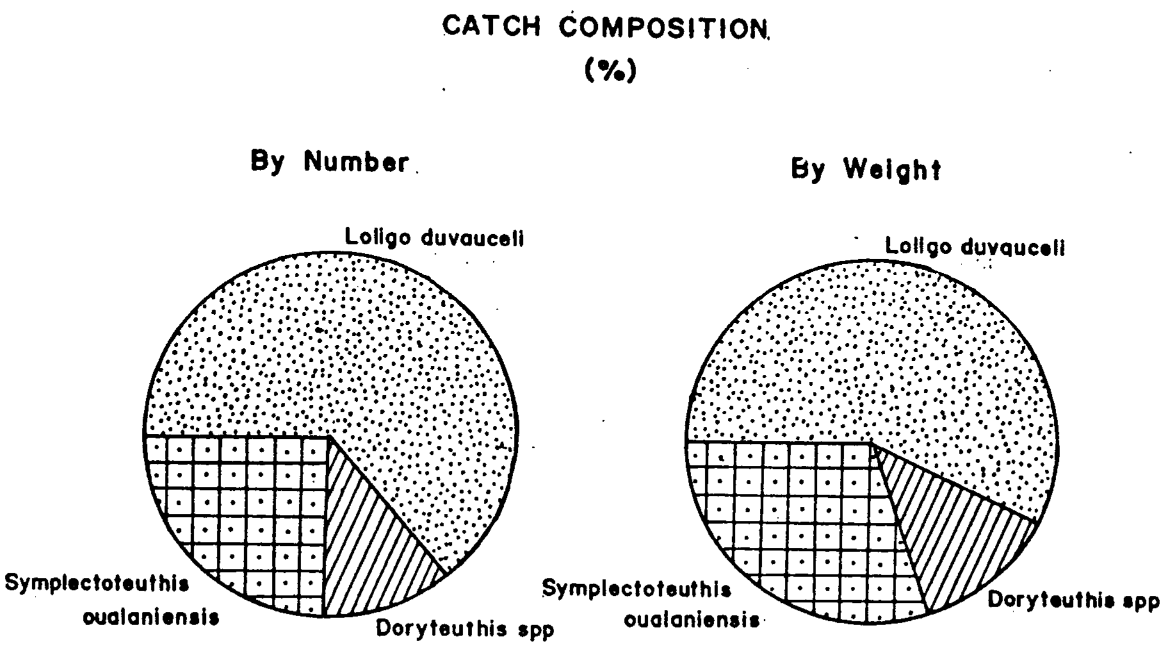


Fig.2 Species composition of squid catches by number and weight.

Species distribution by area

Fig.3 shows the distribution of different species of squids, based on their occurrence during the course of the jigging operations. The most widely distributed squid is **Loligo duvauceli** which occurred in 13 out of 17 squares off Muttom to Ratnagiri (Fig.3 A), mostly restricted to the coastal region within 100 m depth with abundant occurrence within 60 m. The maximum number of squids were taken from 8-76. Over 1000 squids each were obtained from 8-77, 9-76, 10-75, 11-75 & 12-74. While the catch was generally poor from 14 to 16 degree latitude squares, this squid did not occur in the oceanic areas of 12-72 and 13-72. Temporal distribution shows that the squid was obtained in almost all months when there was jigging operation. The maximum number (over 16,000) was caught in July 1988, mostly from the square 8-76.

The distribution of **Doryteuthis** spp is shown in Fig.3 B. These species occurred in six areas but abundantly (3,445 numbers) in 8-76, north of which their distribution was continuous but in lesser numbers. The data show that beyond 14 degree latitude these species are not distributed. Another significant observation was that the outer distributional limit of **Doryteuthis** is closer to the shore when compared to that of **Loligo duvauceli.** Most of these squids were taken from areas with bottom depths upto 62 m, particularly within 45 m and in the months of June to December.

Fig.3 C shows the distribution of the oceanic squid **Symplectoteuthis oualaniensis.** This species occurred in 6 out of 17 squares, confined to deeper areas. The southern limit was 9-75 with depth more than 1,200 m. Over 1,000 squids were obtained from 10-75 but the maximum numbers, above 4,000 each, were caught from 12-72 and 13-72 where the bottom depth range was 200-2,000 m. The northern limit for this squid was 16-72 from where only one squid was recorded. Since jigging operations in deeper areas were very limited, the occurrence of this species was recorded only in November, January and February.

Information collected on the biological aspects such as size composition, sex ratio, maturation, food and length-weight relationship of the squids is presented below:

1. LOLIGO DUVAUCELI

Size Composition

The size (dorsal mantle length) of male **Loligo duvauceli** jigged during the entire period ranged from 50 mm to 310 mm. Females were smaller in length, ranging between 50 mm and 230 mm. Fig.4 shows the length-frequency distribution by sex and by area (square) of occurrence.

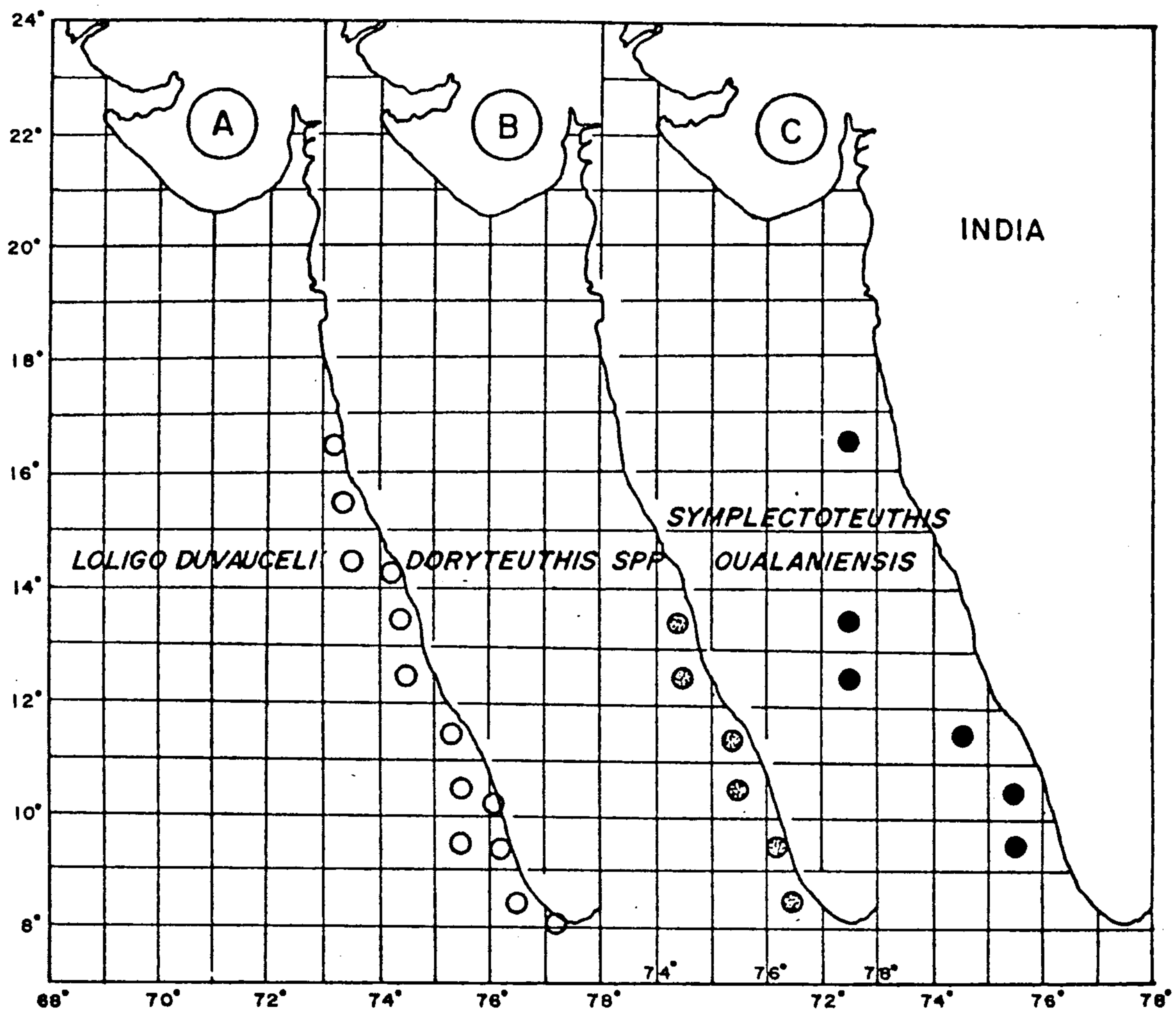


Fig.3 Areas of occurrence of different species of squids taken in jigging operations. A. *Loligo duvauceli* ; B. *Doryteuthis* spp.; C. *Symplectoteuthis oualaniensis*.

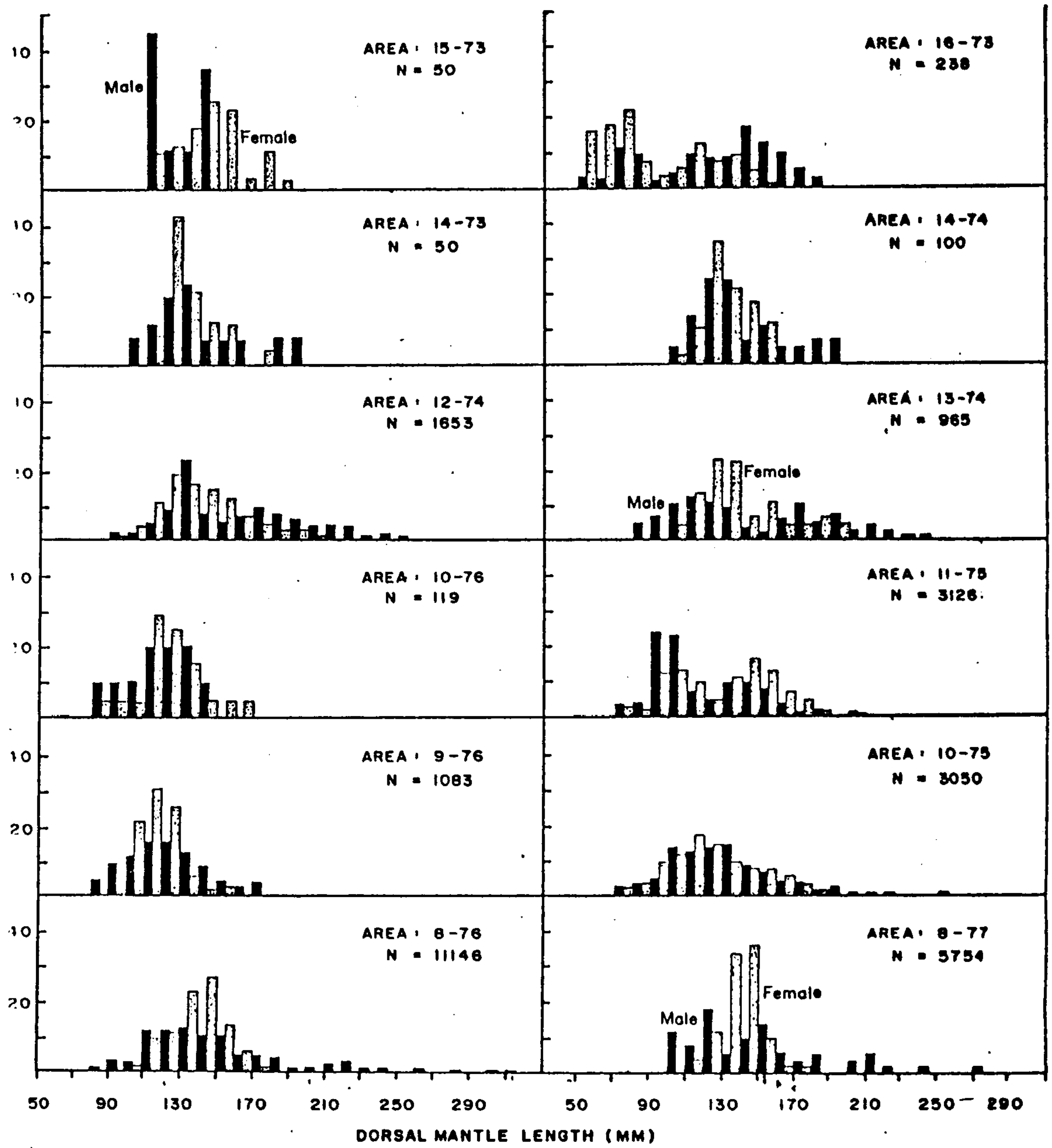


Fig.4 Length-frequency distribution of *Loligo duvauceli* by sex in 12 out of 13 areas for which data are available.

Males

The males had multimodal distribution in all the squares with the highest modal sizes ranging from 95 mm (mid-point of length class) to 175 mm. In the area 8-76 from where the maximum numbers of squids were caught, they had five modes, with the main mode at 135 mm and subsidiary modes at 95 mm, 155 mm, 225 mm and 265 mm. In most other squares also the highest modal size was the same or very close to it (125 mm and 145 mm).

Taking the males caught from all the squares as a whole, the maximum frequency was that of squids having the modal size of 125 mm, with secondary modes at 105mm, 155mm, 215mm, 245 mm & 275mm. Bulk of the quantity of male squids, about 83%, was composed of those having sizes within 100 mm and 200 mm, with small-sized squids below 100 mm contributed 8% and those above 200 mm, 9%.

Females

The females, which had a smaller size range than the males, also showed multimodal or bimodal distribution except in some squares where there was only a single mode. The main modes of females were in the range of 115 mm and 145 mm, except in the northern square 16-73 where there was a shift towards smaller size of 75 mm. As in the case of males, the maximum number of females were taken from 8-76 but the distribution was unimodal with the maximum frequency at 145 mm.

When the female squids jigged from all the squares are pooled, the distribution was trimodal, with the main mode at 145 mm and smaller modes at 75 mm and 115 mm. Squids within the size range of 100-200 mm constituted about 94% of the total number, with smaller squids forming 5%; those above 200 mm were negligible.

In the southern sector (8°-10°) which accounted for the bulk of the catch taken by jigging, squids below 100 mm belonging to both the sexes accounted for only 10% of the total catch from this sector, whereas in the middle (11°-13°) and northern (14°-16°) sectors they accounted for 26% and 28% respectively. This shows that larger squids above 100 mm are more concentrated in the southern parts of the west coast.

Sex Ratio

There was always differential numerical distribution between sexes, except in a very few cases. The equal or near-equal distribution of males and females was noticed only in squares 8-77, 10-75, 12-74, 13-74, 14-73, 14-74 and 16-73. In other squares the male-female ratio ranged from 61:39 to as much as 18:82. In general, when all the data for the period from June 1988 to February 1989 are pooled, the average sex ratio was 45:55 (Fig. 5A).

Fig.5 A also shows the sex ratio of **Loligo duvauceli** by size groups. Among small squids below 100 mm, males were slightly more than females in the ratio 53:43 but in the group between 100 mm and 200 mm which accounted for the bulk of the number of squids caught in jigging operations, females outnumbered the males in the ratio 42:58. As females above the size of 200 mm were only a very few, among the squids above this length the males almost constituted the bulk in the ratio 94:6.

Maturation Stages

Majority of squids belonging to either sex were found to be mature. The largest immature male observed was 120 mm while the smallest mature male was 90 mm, indicating that there is slight overlapping of sizes. The same was the case with the females also in which the largest immature squid was 120 mm and the smallest mature squid 90 mm. The size at first maturity, which, as is generally followed, is the size at which 50% of the individuals attain maturity, was found to be 134 mm for the males and 130 mm for the females.

Length weight Relationship

A study of the length-weight relationship of 225 males and 310 females showed that the rate of increase in weight in relation to length differed in the two sexes. The allometric growth formula for males and females are given below:

Males : $W = 0.00125 \times L^{2.167553}$

Females : $W = 0.000652 \times L^{2.360356}$

Food

Most of the squids caught by jigs had empty stomachs. In others the stomach contents were in varying stages of digestion. The stomach content was always observed as mascerated pieces of the prey animals beyond recognition, but from the component fragments it could be deduced that the squids have preyed upon fish, crustaceans and also on cephalopods exhibiting canniballistic tendency.

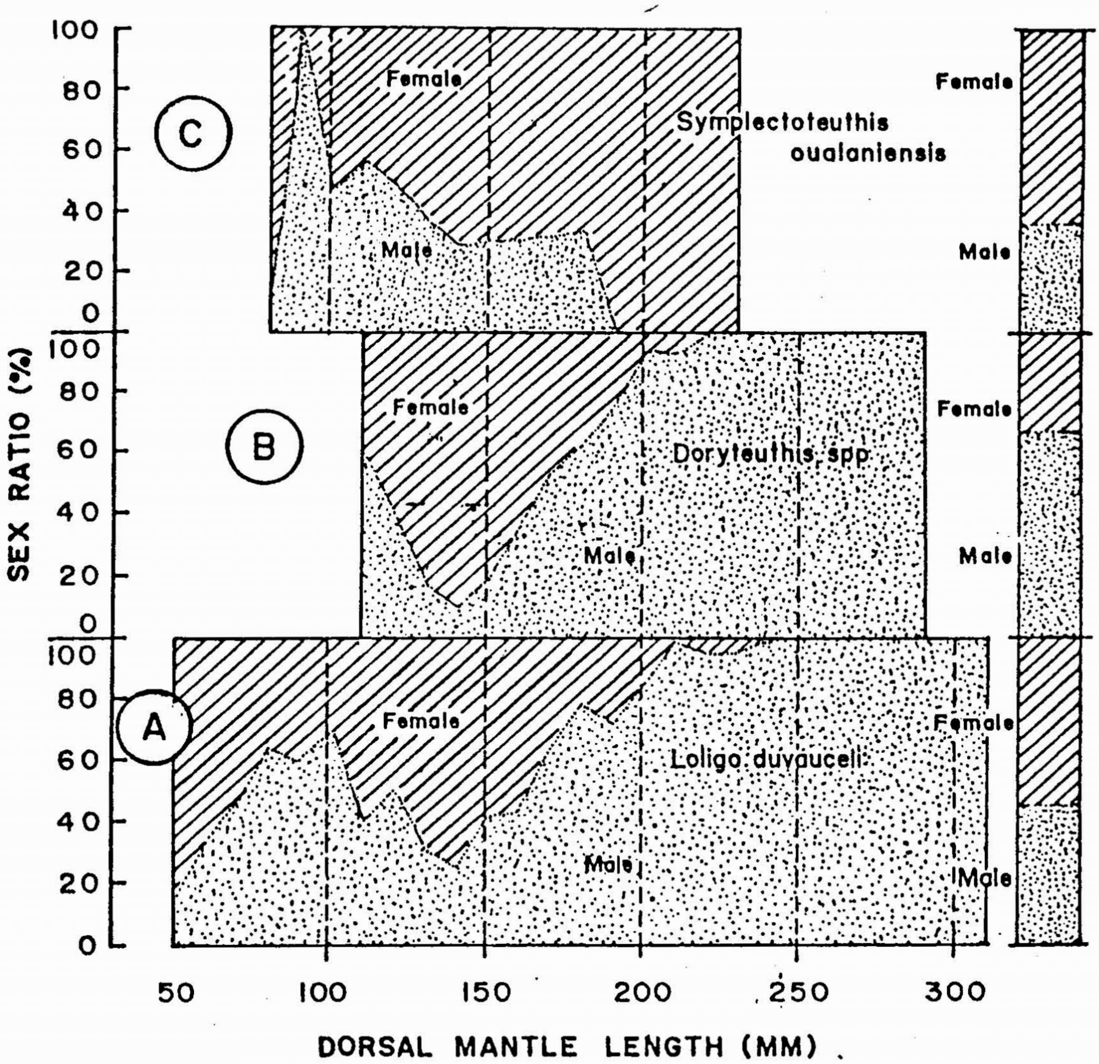


Fig.5 Sex ratio of three species of squids by size groups and by all sizes combined. A. *Loligo duvauceli* , B. *Doryteuthis spp*, C. *Symplectoteuthis oualaniensis*.

2. DORYTEUTHIS SPP

The two species of **Doryteuthis, (sibogae** and **singhalensis),** were taken together in squid jigging, and often they could not be sorted separately onboard because of their close resemblences in many morphological characters. Therefore separate data on each species are not available and hence they are treated here as a single group denoted as **Doryteuthis** spp.

Size Composition

The size of **Doryteuthis** spp ranged from 110 mm to 300 mm for males, and from 110 mm to 260 mm for females, which indicate that males were larger, as in the case of **Loligo duvauceli.** Fig.6 A shows the length-frequency distribution of **Doryteuthis** spp by sex and area (square) of occurrence. The males had multimodal distribution in all the areas. In the square 8-76 from where the maximum numbers of squids were taken, the main mode was at 205 mm with secondary modes at 175 mm and 255 mm. In other areas the main modes were within 155-245 mm. In the case of females, in four areas (8-76, 10-75, 11-75 and 13-74) they had bimodal distribution with modes in the close range of 145-165 mm; in one area (12-74) the number of female squids obtained was too small to show any modal size.

Among male squids caught from all the areas together, the maximum frequency was that of squids having the modal size of 205 mm with subsidiary modes at 115 mm, 175 mm and 255 mm. Bulk of the quantity of male squids (67%) was composed of those above 200 mm, while those below this size formed 33%.

The maximum number of females had a modal length of 155 mm with smaller modes at 115 mm and 195 mm. Almost the entire quantity (98%) of female squids were less than 200 mm, while those above this length accounted for only 2%.

Sex Ratio

The difference in sex ratio of this squid was very pronounced in most of the areas, with the minimum male-female ratio of 57:43 in 8-76; in other areas the ratio varied from 86:14 in 13-74 to 93:7 in 12-74. In general the average ratio for the entire catch was 66:34 (Fig.5 B), indicating that the males numerically outnumbered the females by about 94%.

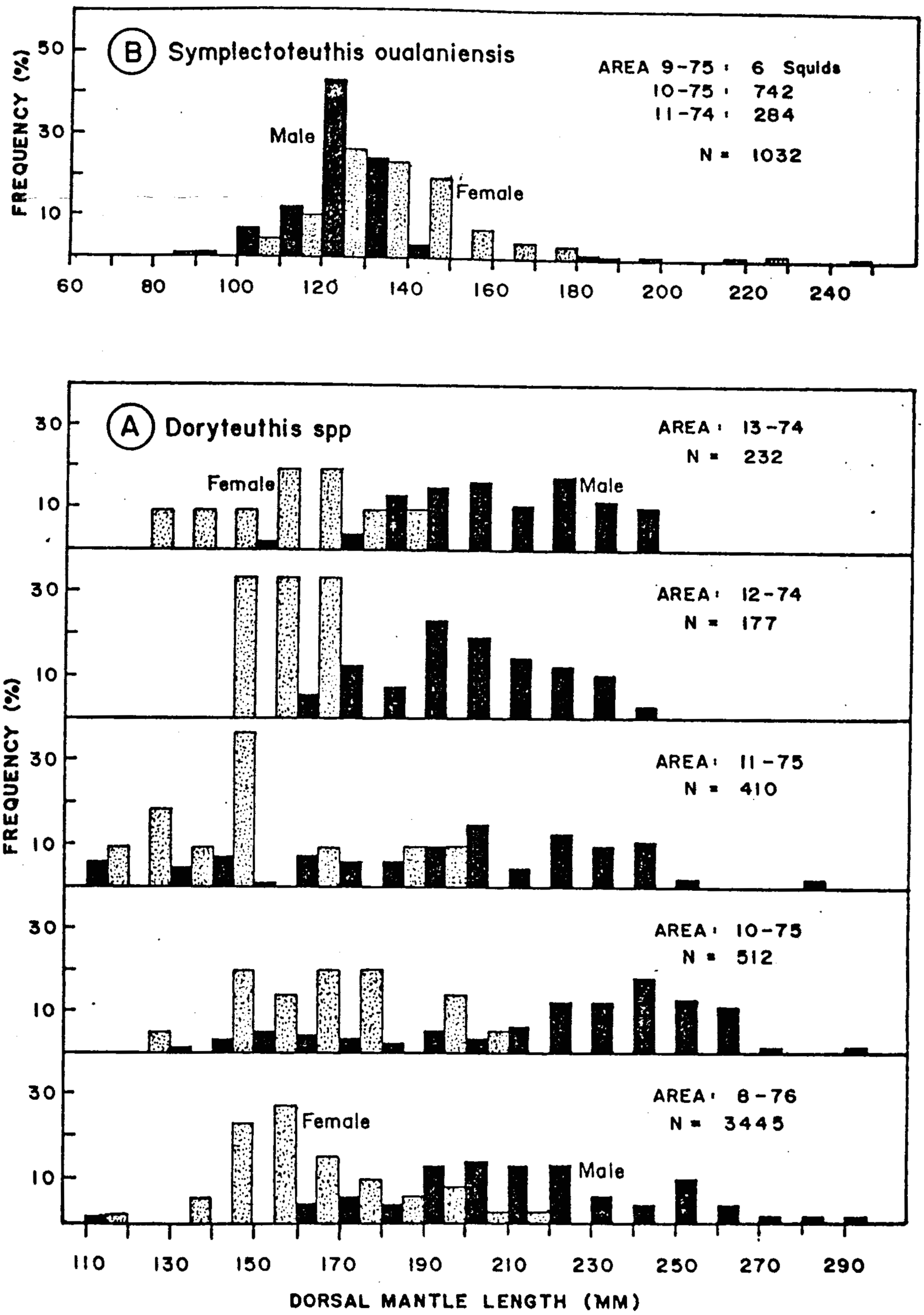


Fig. 6 Length frequency distribution of A. *Doryteuthis* spp., B. *Symplecteuthis oualaniensis*

Fig.5 B also shows the sex ratio of **Doryteuthis** spp by size. There were no squids below the size of 110 mm. From this length upto 200 mm, the females outnumbered the males in the ratio 39:61, while among those above 200 mm which accounted for 45% of the catch the females were very few, in the ratio 99:1.

Though some data are available, aspects of maturation stages and length-weight relationship are not attempted here as more than one species are involved and their data are mixed.

3. SYMPLECTOTEUTHIS OUALANIENSIS

Size Composition

This oceanic squid was taken from six squares but the great majority was from squares 12-72 and 13-72 (4,150 and 4,757 respectively). The male squids had a size range of 80-190 mm. The females were larger than the males, unlike the neritic squids, and the length ranged between 80 mm and 250 mm. The length data of this squid by sex are available only from three squares; the frequency distribution of male and female squids caught from these areas together is shown in Fig.6 B. Both the sexes showed unimodal distribution with the modal size of 125 mm. Almost 99% of the total number of squids of both the sexes were constituted by those within the length range 100-200 mm.

Sex Ratio

In all the three squares for which data of squids by sex are available, the females outnumbered the males in the ratio ranging from 38:62 to 33:67. When all the squids are pooled, the sex ratio was found to be 36:64 (Fig.5 C). The Figure also shows the sex ratio of **Symplectoteuthis** by size. Except in the length class 110-120 mm, females were dominant over males in all the length classes. From 150mm onwards all were females with the exception of 180-190mm length class in which there were males in the ratio 33:67. Among squids within the length range of 100-200mm which contributed 99% of the total number of species, the male-female ratio was 36:64.

Maturation Stages

Most of the squids examined for stages of maturation (98% of the males and 97% of the females) were mature. The smallest size of the mature male was 90 mm and that of the mature female 100 mm.

Based on 30 mature males in the size range of 90-150 mm and 70 females of 100-160 mm, it was observed that 50% attain sexual maturity at about the length of 112 mm, and 50% of the females at 120 mm; these lengths are considered as the size at first maturity for the respective sexes.

DISCUSSION

Squids are well-known for their strong positive phototaxis, and this makes them aggregate near the surface of the sea at night when attracted by artificial light. The world's largest squid fishery of **Todarodes pacificus** and **Ommastraphes bartrami** by the Japanese exists on this behavioural aspect of the squid. In our waters many species of squids have been found to be attracted bv artificial light, and these include the neritic squids **Loligo duvauceli**, **Doryteuthis sibogae** and **Sepioteuthis lessoniana,** and the oceanic squid **Symplectoteuthis oualaniensis** (Chellappa, 1959; Yamanaka **et al.,** 1976; Silas, 1969; Nair, 1986; Nair and Omana, 1986; Nair **et al.,** 1990). Among these the first mentioned two neritic squids and the oceanic squid were obtained in the present squid jigging operations but **Sepioteuthis lessoniana** was never caught even once though it is distributed on the southern part of the southwest coast of India, besides from its normal occurrence in the Palk Bay and the Gulf of Mannar. It has been obtained in small numbers during the light-fishing experiments with lift-net near the shore at Vizhinjam (Nair and Omana, 1986) and the **Kelong** fishery in the Gulf of Mannar (Chellappa, 1959), and this indicates that the squid shows positive phototaxis. Another species that was caught by jigging is **Doryteuthis singhalensis** along with **D. sibogae.** All these show that the important squids of the Indian waters are attracted by artificial light and can be jigged.

The size composition of **Loligo duvauceli**, **Doryteuthis** spp. and **Symplectoteuthis oualaniensis** indicated that medium and large-sized mature squids (74-98%) were the mainstay of jigging operations. The small and immature squids were extremely rare, and therefore jigging seems to be more or less selective for larger sizes.

The differential sex ratio of squids is as expected from previous observations. The ideal 1:1 male-female ratio does not exist in nature as seen from many earlier findings. In the case of **Loligo duvauceli** the average sex ratio observed off Vizhinjam was 42:58, but off Cochin the males were slightly more (Silas, **et al.,** 1986) and off Mangalore also the females dominated (Rao, 1988). The average sex ratio of the species taken during the present squid jigging was 45:55 which is more or less similar to the earlier observation. In the case of **Doryteuthis sibogae** also the female was found to be the dominant sex (Silas **et al.,** 1986) but there is no information on this aspect for **Doryteuthis singhalensis.** As regards the oceanic squid **Symplectoteuthis oualaniensis,** the earlier observation based on data collected in pelagic trawling shows that the male had numerical dominance over the female (Nair, **et al.,** 1990) but in the present study the females outnumbered the males in the ratio 36:64.

All the above observations show that the sex ratio varies from area to area, month to month and size to size. It is not evident whether a particular sex is more attracted towards artificial light and more often jigged than the other.

The size at first maturity (taken here as the size at which 50% of the individuals are found mature) for males of **Loligo duvauceli** is observed to be 134 mm, which is higher than 108 mm recorded for male squids off Vizhinjam, but closer to the value of 122 mm at Cochin (Silas **et al.,** 1986) and 124 mm at Mangalore (Rao, 1988). In the case of females this size is 130 mm as against 110 mm observed at Vizhinjam and very close to 128 mm at Cochin but higher than 108 mm obtained for females at Mangalore. These variations are within a reasonable range and not quite unexpected, since the comparison is based on data collected from different areas over a number of years. From the above values it can be taken that the size at first maturity for males is between 105 mm and 135 mm, and for females it lies between 110 mm and 130 mm.

The size at first maturity for **Doryteuthis sibogae** observed by Silas **et al.** (1986) is 97 mm for males and 84 mm for females. In the present study this aspect was not considered as separate data were not available for this species alone.

For **Symplectoteuthis oualaniensis,** Nair **et al.** (1990) have observed that the size at first maturity is 100 mm for males and 110 mm for females. The values obtained in the present investigation were closely identical, 112 mm for males and 120 mm for females, confirming that both the sexes become mature at more or less the same length.

The length-weight relationship of **Loligo duvauceli** obtained in the present investigation is almost similar to the values derived earlier for the same species (Silas **et al.,** 1986; Rao, 1988). In all the cases the allometric growth formulae show that the rate of increase in weight in relation to length differes in males and females. Rao (1988) has observed that in this species there is good correlation between length and weight at different stages of maturity, and that the weight increment in females seems to be more than in males.

The length-weight relationship in **Doryteuthis** and **Symplectoteuthis** was not studied.

In conclusion, the above observations drive home certain points:

1. Jigging is aimed fishing, targeted exclusively for squids, so that no other groups of finfish or shellfish are caught.

2. Four species of squids, **Loligo duvauceli**, **Doryteuthis sibogae**, **Doryteuthis singhalensis** (all neritic) and **Symplectoteuthis oualaniensis** (oceanic) in our waters are attracted by artificial light and can be jigged.

3. Mostly the medium and large-sized squids are jigged, indicating that this is a selective gear, without exploiting juveniles.

4. Both the sexes are attracted by lights and are jigged, the sex ratio showing no regular trend.

5. Larger squids are concentrated in the southern part (Vizhinjam-Muttom) than in the central (Mangalore) and northern (Ratnagiri) parts.

6. The biological aspects studied are in close agreement with earlier observations.

7. The squids taken in jigging are sea-fresh, unmutilated and practically uncontaminated with their own ink, as against those taken in trawling which are often flabby, highly pressed with the weight of other fish and discoloured with ink.

The economics of squid jigging is not discussed in this section but if this method is found economically feasible, it will be the most ideal of fishing for squids, especially oceanic squids. Since the gear is highly selective for medium and larger sizes without affecting juvenile populations, the management and conservation problems are expected to be far less than in other modes of fishing. Moreover, the freshness of squid is a prime prerequisite in export trade and for this, jigging is the most suited fishing method.

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Oceanic squids - their distribution, abundance and potential in the EEZ of India and contiguous seas

K. Prabhakaran Nair, M.M.Meiyappan, R. Sarvesan, Kuber Vidyasagar, G. Syda Rao, K. Sunilkumar Mohamed, P.K.Asokan, A.P. Lipton, K.Ramadoss, V.G. Surendranathan, D.Nagaraja & K. Jayabalan

Central Marine Fisheries Research Institute, P.B. No. 1603, Cochin - 682 014

ABSTRACT

FORV Sagar Sampada collected a good number of oceanic squids belonging to several families from the Indian EEZ and contiguous seas. Of these, the most important species was the purpleback flying squid *Symplectoteuthis oualaniensis* which forms a potential oceanic squid resource. This species was caught in pelagic trawl at depths up to.200-250 m from surface in the oceanic areas. Though the squid is known to be distributed throughout India's oceanic waters, it frequently occurred in comparatively more abundance, up to 318 squids per haul, in the northneastern Arabian Sea. There was wide variation in the size of this squid (from 20 mm to 472 mm), the largest individual weighing 4.5 kg. The diamondback squid *Thysanoteuthis rhombus*, the largest specimen of which measured 585 mm in length and 5.3 kg in weight, was also caught from a few stations. Besides these large species, several others belonging to families such as Onychoteuthidae, Histioteuthidae, Enoploteuthidae and Cranchiidae are also distributed in the EEZ. A large number of oceanic squids were collected at night, which is indicative of their diel vertical migration towards surface layers during night hours.

INTRODUCTION

The importance of oceanic squids as a potential resource in the Indian waters has been well recognised. The occurrence and distribution of different species of oceanic squids have been recorded by many workers since late 60's (Filippova, 1968; Silas, 1968, 1969; Okutani, 1973; Yamanaka *et al.* 1976, 1977; Roper *et al.* 1984). Some of these authors indicated that a few species, especially the purpleback flying squid *Symplectoteuthis oualaniensis*, are potential resources which offer vast scope for exploitation. Initial studies by *Sagar Sampada* since 1985 provided additional information on the distribution, behaviour and biology of this squid, and on the distribution of other oceanic squids and mesopelagic cephalopods (Meiyappan & Nair, 1990; Meiyappan *et al.* 1990; Nair *et al.* 1990; Sarvesan & Meiyappan, 1990; Sreenivasan & Sarvesan, 1990). Nair *et al.* (1992) gave an account of the experimental squid jigging operations on the west coast of India, in which the purpleback flying squid was one of the components of the catch. Nair *et al.* (1992) provided some information on the biology of this squid based on the samples collected in the same experimental fishing. One of the objectives of the cruises of *FORV Sagar Sampada* was to locate and identify the stocks of exploitable resource of oceanic squids (as well as other resources) in the EEZ.

MATERIALS AND METHODS

The oceanic squids collected in pelagic trawl operations onboard *FORV Sagar Sampada* in the Exclusive Economic Zone and its contiguous seas during 1985-1992 formed the data base for this study. Pelagic trawl was used in 40 cruises, mostly in oceanic waters beyond the continental shelf but occasionally in shallow waters of <100 m depth. The gears used were the German-type rectangular midwater trawls of CIFT design. These nets were operated for about 30-60 minutes duration for each haul in depths up to 420 m. The cephalopods collected in each haul were sorted for qualitative studies with regard to temporal distribution of different species of oceanic squids. Whenever direct observations onboard were not possible, log data of the cruise reports were consulted and preserved samples were studied. The length of squid always refers to the dorsal mantle length (DML). Since the catches of oceanic squids taken in each haul were very poor or insignificant, often a few grams in weight, quantitative estimation was not possible. Therefore the present study is limited to the distribution of component species and their relative abundance in different regions of the EEZ. In the absence of sufficient data, the earlier estimates of potential oceanic squid resources have been discussed in the light of the new information gathered by *Sagar Sampada* cruises.

RESULTS

Sufficiently wide coverage was given to different regions on the east and the west coasts, including the Andaman-Nicobar waters, Lakshadweep waters and the central equatorial waters. The geographic regions, number of positive stations for oceanic squids in each of the regions, bottom depths and depths of operation of gear are given in Table 1. The maximum coverage was on the west coast, of which the centralwest region had the highest number of stations positive for cephalopods, followed by the southwest region, including the Lakshadweep waters. On the east coast, the southeast region and the centraleast region had almost equal number of cephalopod stations. The Andaman-Nicobar waters were rich in oceanic squids, with as many as 31 positive stations. In the central equatorial region 6 stations were positive for oceanic squids. In all, there were 169 positive stations.

Table 1— Number of stations positive for oceanic squids by region, based on pelagic trawl operation by *FORV Sagar Sampada*

Region	Latitude	No. of squid stations	Bottom depth (m)	Depth of gear operation (m)
Southwest	6° - 12°N	35	145-4500	20-400
Centralwest	12° - 18°N	42	62-4150	25-225
Northwest	18° to North	14	87-3444	40-1590
Southeast	6° - 12°N	18	244-3816	20-380
Centraleast	12° - 18°N	19	2578-3452	25-350
Northeast	18° to North	4	250-2100	70-100
Andaman-Nicobar	4° -15°N, 89° -95°E	31	447-4057	18-350

Most of these stations, situated within the EEZ and slightly beyond, were in the oceanic areas with depths up to 4500 m but some stations, especially on the west coast, had shallower depths up to 62 m. The gear was operated mostly within 100 m from sea surface but occasionally at deeper depths up to 420 m; at one station (21°N, 67°15'E) in the northwest region the gear was operated at a depth of 1590 m.

The geographic positions of stations from where oceanic squids were obtained are shown in Fig.1. The centralwest region and the southwest region including the Lakshadweep waters abound in oceanic squids as judged from the frequency of their occurrence. In the northwest region they are also obtained from contiguous areas beyond the EEZ. The coverage in the northeast region was poor, since there were only 16 stations where pelagic trawl was operated, out of which four were positive for oceanic squids. In the centraleast region and the southeast region there was fairly good distribution of oceanic squids, but in the Andaman-Nicobar waters their occurrence was much more frequent. In the central equatorial region, out of 12 pelagic trawl stations six were positive for oceanic squids. In general, oceanic squids are distributed in the entire EEZ and its contiguous waters, with more concentration in some areas like the northeastern Arabian Sea, southeastern Arabian Sea, Lakshadweep waters, southwestern and centralwestern Bay of Bengal and the Andaman-Nicobar waters.

Quantitywise, the catches of oceanic squids obtained in pelagic trawl from almost all stations were very poor or negligible, often 1 kg and very rarely 10 kg. In most hauls the squids occurred in very few numbers and weighed a few grams only.

A number of species of oceanic squids belonging to several oegopsid families occur but at present most of them are not used for human consumption due to their small size, unfavourable body consistency and insufficient quantity, eventhough they con-

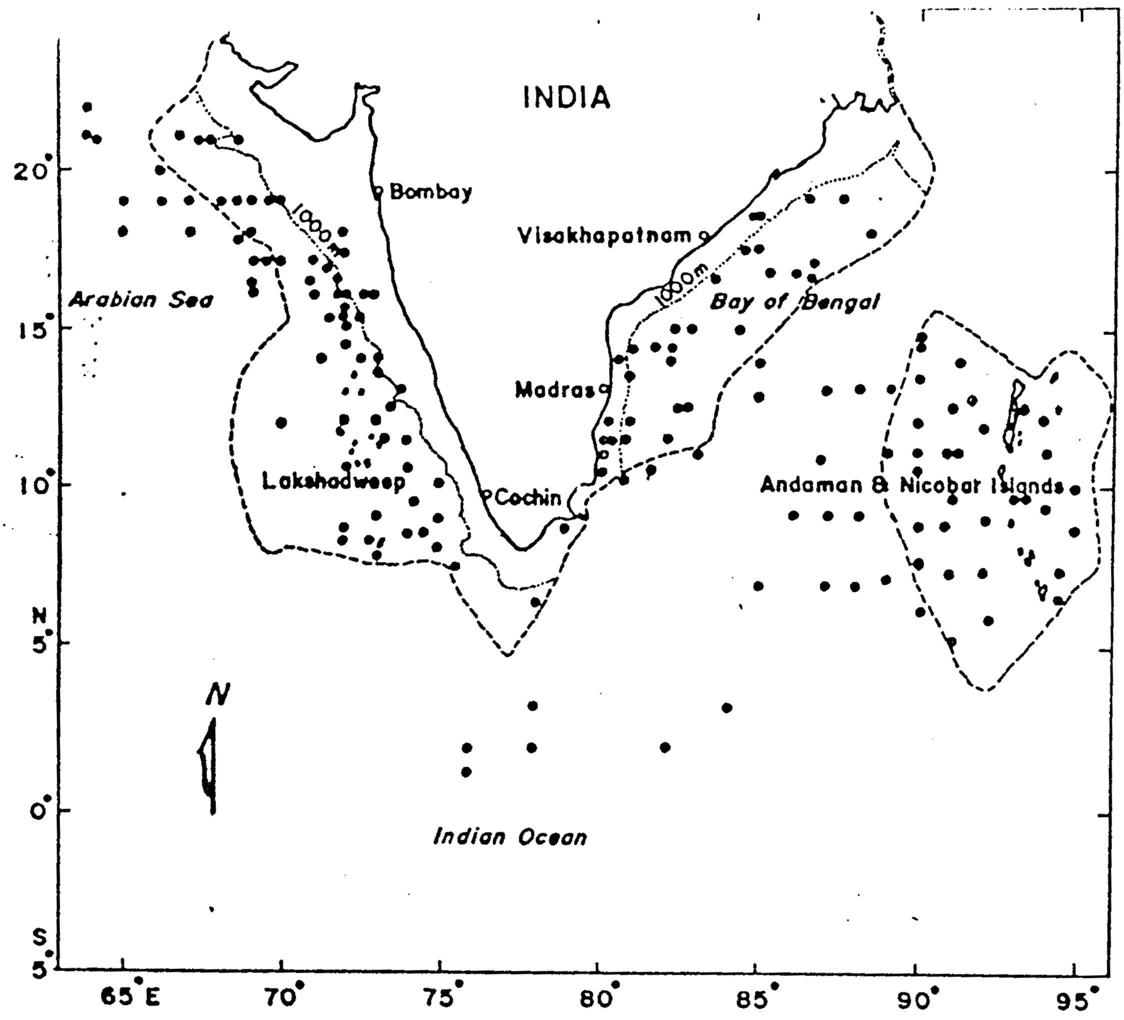

Fig. 1- Distribution of oceanic squids (dots) in the EEZ of India and contiguous areas, based on pelagic trawling by *FORV Sagar Sampada* (broken line is the outer boundary of EEZ)

stitute an important forage item to many fishes in the oceanic areas. The most important among the oceanic squids is the purpleback flying squid *Symplectoteuthis oualaniensis* which belongs to the commercially significant oceanic squid family of the world, Ommastrephidae. It is a large-sized squid occurring in commercial quantities in the Gulf of Aden, northern Arabian Sea, Japan, Taiwan and Hawaian Islands where it is collected in moderate to heavy quantities by jigging and dipnet fishing. Earlier surveys indicated the occurrence of this squid in many parts of the Indian waters with concentration in some areas, especially in the northern Arabian Sea. The cruises of *Sagar Sampada* further confirmed this and provided additional information on the distribution of this in many other areas.

The pelagic trawl operations did not reveal any fishable concentration of medium and large-sized *S.oualaniensis* at most of the stations, as the maximum number obtained from a single station was only 318 squids of <200 mm length with 115 mm modal size, weighing 20 kg; the next highest number from another station was 74 with the same modal size. In all other stations the squids collected were few in number and smaller in size, with some exceptions. From station 517, situated northeast of Car-

Nicobar Island, 3537 juvenile squids of 13-26 mm were obtained in one hour of pelagic trawling. The largest squid, measuring 472 mm in length and 4.7 kg in weight, was collected from station 774 in the northwest region. Five more squids measured >400 mm from the same station, all caught at depths of 110-250 m. A large squid of 425 mm weighing 4.5 kg was obtained from station 1225 in the northwest region.

Another large species of oceanic squid rarely obtained in *Sagar Sampada* cruises is the diamondback squid *Thysanoteuthis rhombus* of the family Thysanoteuthidae. Most of the specimens of this species collected were small in size and stray in occurrence and on no occasion any fishable concentration of this squid was observed. The largest squid obtained was a female measuring 585 mm in length and weighing 5.3 kg, caught from Andaman-Nicobar waters. All other specimens collected from different parts of the EEZ were small in size, measuring 40-105 mm in length.

Most other oceanic squids collected by *Sagar Sampada* were small species, except for some species such as the common clubhook squid *Onychoteuthis banksii.* Small and medium-sized squids of this species measuring 28-100 mm length occurred at some stations on the west coast, while in the Bay of Bengal its occurrence was sparse. In the Andaman-Nicobar waters its distribution was more frequent and as many as 82 squids of 32-195 mm length were taken in pelagic trawl from 9 stations in a single cruise. Young squids (85-100 mm) of another large species, *Ancistrocheirus lesueri,* were collected in stray numbers from the west coast and from Andaman-Nicobar waters.

Smaller species recorded were *Abralia andamanica, Abraliopsis gilchristii, Cranchia* spp, *Liocranchia* spp, *Leachia* spp, *Enoploteuthis* sp., *Chiroteuthis* sp., *Octopoteuthis* sp., *Histioteuthis* sp, *Ctenopteryx* sp., and *Japatella* sp. Among squids *Abralia, Abraliopsis* and *Cranchia* occurred more frequently in maximum number of stations. Apart from squids, some octopods (*Octopus* spp and *Argonauta* sp.) were also obtained.

The number of squids obtained during night were much higher than during day, and about 65% of the oceanic squids were collected at night, indicative of their diel vertical migration towards surface layers during night hours.

DISCUSSION

The pelagic trawling operations conducted by *Sagar Sampada* in the Indian EEZ and in some areas contiguous to it have corroborated earlier observations on the distribution of oceanic squids in general, and the purpleback flying squid *Symplectoteuthis oualaniensis* in particular (Filippova, 1968; Silas, 1968; Zuev, 1971; Okutani, 1973; Yamanaka *et al.* 1976, 1977). Dense concentrations were observed in exploratory surveys in the north Arabian Sea, and medium and large-sized squids up to a size of 500 mm were caught in jigging operations. Though a few large- sized squids were taken in pelagic trawl by *Sagar Sampada,* the occurrence of such large squids was extremely rare. Even the smaller squids were few in number except the instance of over 3500 juveniles caught at a station in Andaman-Nicobar waters. In the exploratory squid jigging operations with light-attraction system off the southwest and centralwest coasts, purpleback flying squid was observed at a rate of 33 kg (576 squids) per night (Nair *et al.* 1992); the highest areawise catch recorded was 1438 squids (75 kg) per night. This shows that squids are present in Indian waters and can be fished by jigging. Jigging was not possible from *Sagar Sampada,* and the only one available was pelagic trawling, the performance of which was very poor throughout the cruises. Therefore, pelagic trawling operations did not give much information about the stock position or potential of not only oceanic squids but also any other pelagic fishery resources.

Though the picture of the extent of the oceanic squid resource and its potential has not emerged, the cruises provided new information on the distribution of *Symplectoteuthis oualaniensis* in Indian waters. Earlier studies have indicated the occurrence in some areas, especially in the northern Arabian Sea (Yamanaka *et al.* 1976, 1977) and off the southwest coast of India (Silas, 1968). The occurrence of jeveniles in the pelagic trawl collections, the observation on many occasions of shoals of medium and large-sized squids aggregating near the ship attracted by its light, and the exploratory squid jigging operations on the southwest coast of India (Nair *et al.* 1992) have further confirmed this. The *Sagar Sampada* cruises have revealed the distribution of this squid in the Bay of Bengal, especially off the southeast coast and the centraleast coast. The occurrence of juvenile squids, particularly that of over 3500 numbers at a single station in the Andaman-Nicobar waters (Sreenivasan & Saevesan, 1990) indicates that this region is rich in oceanic squid resource, and that this may be one of its breeding and nursery grounds.

All these point towards the importance of the purpleback flying squid as a potential resource in the Indian waters, and there is need for exploiting the resource in the light of the high unit price of squids in the export trade. Chikuni (1983) indicated the possibility of commercial fishery for this squid in the eastern Arabian Sea. Realising the scope for exploitation of this squid, Silas (1986) gave the projection that about 2500 t could be harvested by 1990, and somewhere between 25000 t and 50000 t would be the exploitation by the year AD 2000. However, there is still no fishery for this squid in India, nor there is any information on the fishery in Indian waters by other countries under any charter agreement. The main reason for this is probably the lack of suitable catching technique to fish in distant waters away from the conventional neritic region. Pelagic trawling has proved ineffective, but jigging seems to be the ideal method in the absence of any other suitable technique. Jigging takes advantage of the squid behaviour of getting attracted towards artificial light. Another advantage of jigging is that only the medium and large-sized squids are jigged, and the juvenile population is not affected. However, the economics of jigging operations in Indian waters is yet to be proved.

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Physiological and cellular responses to copper and mercury in the green mussel *Perna viridis* (Linnaeus)

P.K. Krishnakumar, P.K. Asokan and V.K. Pillai

Central Marine Fisheries Research Institute, Cochin, India

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The purpose of the study was to measure the physiological and cellular responses of *Perna viridis* after 1 and 2 weeks chronic exposure to copper (25 μg l^{-1}) and mercury (25 μg l^{-1}). Filtration rate, O:N ratio, scope for growth and growth efficiency of metal exposed mussels decreased significantly in comparison to controls. Digestive cells and tissues of metal-exposed mussels had severe pathological changes such as increased lipofuscin accumulation, digestive tubule dilation, tubule breakdown and cilia loss in the digestive diverticula. Compared to mercury, copper accumulated more in the tissues of exposed mussels. The physiological and cellular responses of mussels to copper and mercury were generally in the same direction, although mercury exposed mussels were comparatively less affected. Toxic effects of copper and mercury observed at cellular and tissue levels were found to be in agreement with those observed at the organismic level.

Key words: Physiological effect; Copper; Mercury; *Perna viridis*; Digestive tubule; Lipofuscin

INTRODUCTION

The suspension feeding bivalve molluscs accumulate and concentrate most of the pollutants within their tissues to concentrations significantly above ambient levels in the environment thus facilitating accurate chemical analysis and assessment. The use of bivalve molluscs and in particular, mussels, as sentinel organisms for indicating levels of pollutants in coastal marine waters has been established in various mussel watch programmes. The term 'pollution' implies a biological effect and if levels of pollution are to be determined, biological techniques must be deployed, preferably in concert with chemical measurements (Bayne, 1989).

A wide range of techniques have been proposed for monitoring biological effects, based on physiological (O:N ratio, scope for growth and growth efficiency) and cellular responses (lysosomal membrane stability, neutral lipid and lipofuscin accumula-

Correspondence to: P.K. Krishnakumar, Research Centre of C.M.F.R.I., PB No. 5, Karwar-581 301, India.

tion, tubule dilation and degeneration in the digestive cells) of bivalve molluscs to stress (Bayne et al., 1985; Bayne, 1989). Physiological and cellular responses are indicative of the overall fitness of the individual organism and they contribute to our understanding of possible consequences of pollution to the population (Bayne et al., 1988a). In mussels, digestive cells of digestive tubules appear to be sensitive to environmental pollutants (Moore, 1988b). It has been recently demonstrated that lipofuscin, besides being a significant marker of the aging process, can also be used as an indicator of environmental stress (Aloj Totaro and Pisanti, 1987; Moore, 1988a). Recent marine pollution studies, using physiological and cellular stress tests on temperate mussels have been conducted with xenobiotics (Lowe et al., 1981; Poulsen et al., 1982; Stickle et al., 1984; Martin et al., 1984; Calabrese et al., 1984; Moore et al., 1984, 1985; Widdows et al., 1985; Bayne et al., 1988a). However, very little is known about the physiological responses of the green mussel *Perna viridis* to pollutants (Menon, 1986; Krishnakumar, 1987) and studies are not reported on cellular responses. *P. viridis* have a widespread distribution along the east and west coast of India and other tropical areas of the world, and this species has been proposed as a biomonitor for trace metals in tropical waters (Phillips 1985; Krishnakumar and Pillai, 1990). The objectives of these studies were to assess the physiological and cellular responses of *P. viridis* to copper and mercury at sublethal levels and to compare the toxic effects of these metals.

MATERIALS AND METHODS

Mussels were collected from a natural population of a small, uninhabited, rocky island (Kurmagad Is.) north of Karwar on 6 July 1989. Mussels (70–75 mm) were brought to the laboratory, cleaned of epibiotic growths and acclimated for 2 days in experimental seawater (Salinity, 33.5‰; temp., 28 ± 1.0°C; pH, 8.1 ± 0.1 and dissolved oxygen >90% saturation).

The experimental concentration of 25 $\mu g \cdot l^{-1}$ was selected both for copper (as $CuSO_4 \cdot 5H_2O$) and mercury (as $HgCl_2$) after the acute toxicity (96 h LC_{50} for copper, 86 $\mu g \cdot l^{-1}$; mercury, 155 $\mu g \cdot l^{-1}$) experiments (Krishnakumar et al., 1987). Fourty mussels were placed 20 to a plastic basin, containing 20 litres of seawater for studies with each metal. Control and treatment basins were maintained in duplicate. Water was changed daily to replenish metal concentrations and optimal conditions were maintained throughout the experiment (salinity, 33.5‰; temp., 28 ± 1.0°C; pH, 8.1 ± 0.1 and dissolved oxygen >90% saturation). Concentrations of copper (Cu^{2+}) and mercury (Hg^{2+}) in the treatment basins were determined daily and the mean concentrations were 24.95 and 24.9 $\mu g \cdot l^{-1}$, respectively. Algal culture (*Synechocystis* sp.) was added to the control and treatment basins and a concentration of 3×10^3 cells ml^{-1} was maintained.

Physiological measurements

Ten mussels were removed for measurement from both the control and treatment basins after a 2-wk exposure. The same mussels were used individually for all the physiological measurements. Filtered seawater (Whatman 42) with respective metal concentrations (25 $\mu g \cdot l^{-1}$) were used. A glass respiratory chamber of 1-litre capacity was used for oxygen consumption estimation following the static method (Widdows, 1985). The decline in the oxygen level in the chamber was measured every 30 minutes, employing the Winkler method (Strickland and Parson, 1968), until the value reached just below 90% saturation. Mussels were taken individually in beakers containing 300 ml seawater and incubated for 3 h for ammonia excretion estimations (Widdows, 1985).

Filtration rate

The filtration rates of mussels were determined using neutral red (Abel, 1976). Some variations in the experimental procedures were tested using healthy mussels and the following method was found to give comparable values with similar species. Mussels were placed individually in 400 ml seawater containing 1 mg l^{-1} neutral red. Allowing 10 minutes for recovery, the first sample of 10 ml was removed. After 20 min a second sample of 10 ml was removed. Dye concentration in the samples was determined spectrophotometrically and the filtration rates were calculated.

Calculation of scope for growth

After the completion of physiological measurements, soft tissues of mussels were removed and dried at 80°C for 24 h. Physiological rates were converted to mass specific rates for mussels of 1 g dry tissue weight using appropriate weight exponents (b) in the allometric equation (oxygen consumption b= 0.7; ammonia excretion b= 0.42; filtration b= 0.5). From the oxygen consumption (ml $O_2 \cdot h^{-1}$) and ammonia excretion rates (μg NH_4-$N \cdot h^{-1}$), O:N ratio, energy expired (R) and energy excreted (U) were calculated (Widdows, 1985). Using the neutral red method, absorption efficiency cannot be determined. So the energy absorbed from the seston (A) is calculated indirectly, assuming that absorption efficiency is 0.58 (value reported for *Mytilus edulis*, Widdows et al., 1981), particulate organic matter (POM) is 1.3 $mg \cdot l^{-1}$ and the energy content of the POM is 23.5 $J \cdot mg^{-1}$ (Widdows, 1985).

A ($J \cdot h^{-1}$) = Filtration rate ($l\,h^{-1}$) $\times$ $1.3 \times 23.5 \times 0.58$. From the above energy equations, scope for growth (SFG) and the net growth efficiency (K_2) were calculated (Widdows, 1985).

$$\text{SFG}\ (\text{J h}^{-1}) = A - (R + U)$$

$$K_2 = \frac{A - (R + U)}{A}$$

Preparation of tissue sections

Ten mussels each were removed from the treatment and the respective control basins after 1 and 2 weeks of exposure. The digestive gland was dissected and sliced across into four portions and fixed in Baker's formal calcium. Paraffin sections (7 μ) were prepared and lipofuscin content was detected using the Schmorl reaction (Pearse, 1972). The intensity of the blue reaction product was rated microscopically, on a scale 1–7, based on graded micrographs (Moore, personal communication). Sections for histopathological examinations were processed into slides using Harri's hematoxylin and eosin stains (Yevich and Barszcz, 1981). The percentage incidence of digestive tubule conditions such as tubule breakdown, tubule dilation (Lowe, 1988) and cilia loss in the digestive diverticula was assessed. One slide each, consisting of 10 duplicate sections from 10 mussels, was used for quantification of each histochemical and histopathological condition.

Metal analysis

For determination of copper and mercury in the tissue, mussels were removed from the treatment and control basins after 1 and 2 weeks exposure. The whole soft tissue and the digestive glands were pooled from 5 animals and wet digested with a HNO_3 and H_2O_2 mixture (Dalziel and Baker, 1983). Digested samples were analysed for mercury in a mercury analyser (ECIL), using the cold vapour absorption technique and copper in a Perkin-Elmer atomic absorption spectrophotometer (model 2380). Samples for chemical, physiological and pathological analysis were coded and measured 'blind'. Data on physiological and cellular responses were statistically tested using the t-test and the Mann Whitney U-test, respectively.

TABLE I

PHYSIOLOGICAL RESPONSES OF *PERNA VIRIDIS* (1 g DRY TISSUE WEIGHT) AFTER 2 WEEKS EXPOSURE TO COPPER AND MERCURY ($\bar{x} \pm SD$, N = 10)

Experiment	Oxygen uptake (ml O_2 h^{-1})	NH_4-N excretion (μg NH_4-N·h^{-1})	Filtration rate (l·h^{-1})	O:N ratio (atomic equivalent)	Scope for growth (J·h^{-1})	Growth efficiency (K_2)
Control	0.43±0.17	7.8± 2.8	2.3 ±0.49	68.6±15.6	31.8±6.4	0.78±0.06
Mercury (25 $\mu g \cdot l^{-1}$)	0.46±0.13	55.8± 6.7**	1.2 ±0.3**	10.1± 2.5**	9.9±6.3**	0.45±0.2*
Copper (25 $\mu g \cdot l^{-1}$)	0.72±0.39	193.9±75.8**	0.25±0.18**	4.6± 2.0**	−15.0±7.5**	−4.7 ±3.6*

*$P < 0.01$; **$P < 0.001$.

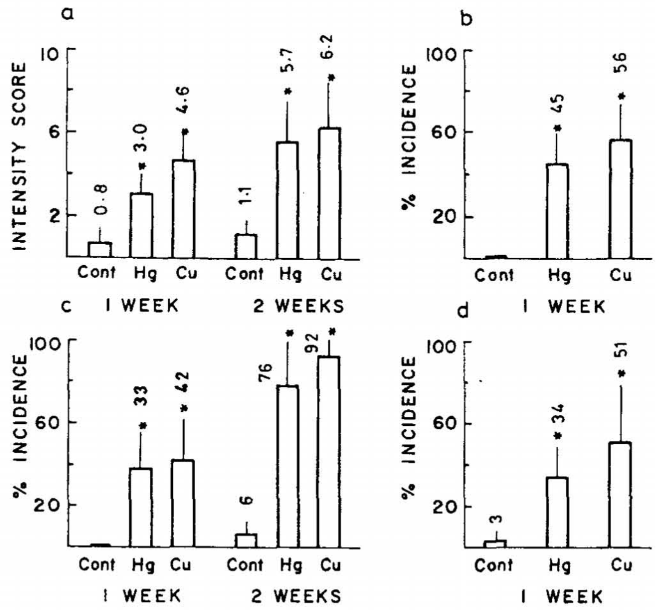

Fig. 1. Responses of the digestive cells and tissues of *Perna viridis* to copper (Cu) and mercury (Hg) after 1 and 2 weeks exposure (25 $\mu g \cdot l^{-1}$). (a) Lysosomal lipofuscin content (intensity score), (b) Digestive tubule dilation (% incidence). (c) Tubule breakdown (% incidence) and (d) Cilia loss in the digestive diverticula (% incidence). Difference from control (Cont) indicated by $^{*}P<0.001$. (Mean values above bars.)

RESULTS

Physiological responses

Measurements of physiological responses are summarised in Table I. After 2 wk exposure to copper and mercury, both oxygen consumption and ammonia excretion rates increased. Filtration rates, O:N ratio, scope for growth and growth efficiency were significantly ($P<0.001$) reduced. Toxic effects of copper on physiological responses were more than those for mercury (Table I).

Cellular responses

Microscopic assessments of digestive cells revealed an increase in lysosomal lipofuscin content in copper and mercury exposed animals, both after 1 and 2 wk exposure (Fig. 1a). Lipofuscin content showed a significant ($P<0.001$) increase after 2 wk exposure in comparison to the control and 1 wk-exposed mussels. Lipofuscin accumulation was greater under copper stress than under mercury stress (Fig. 1a).

Percentage incidence of tubule dilation was found to be significantly ($P<0.001$) high in both copper- and mercury-exposed mussels in comparison to the control (Fig.

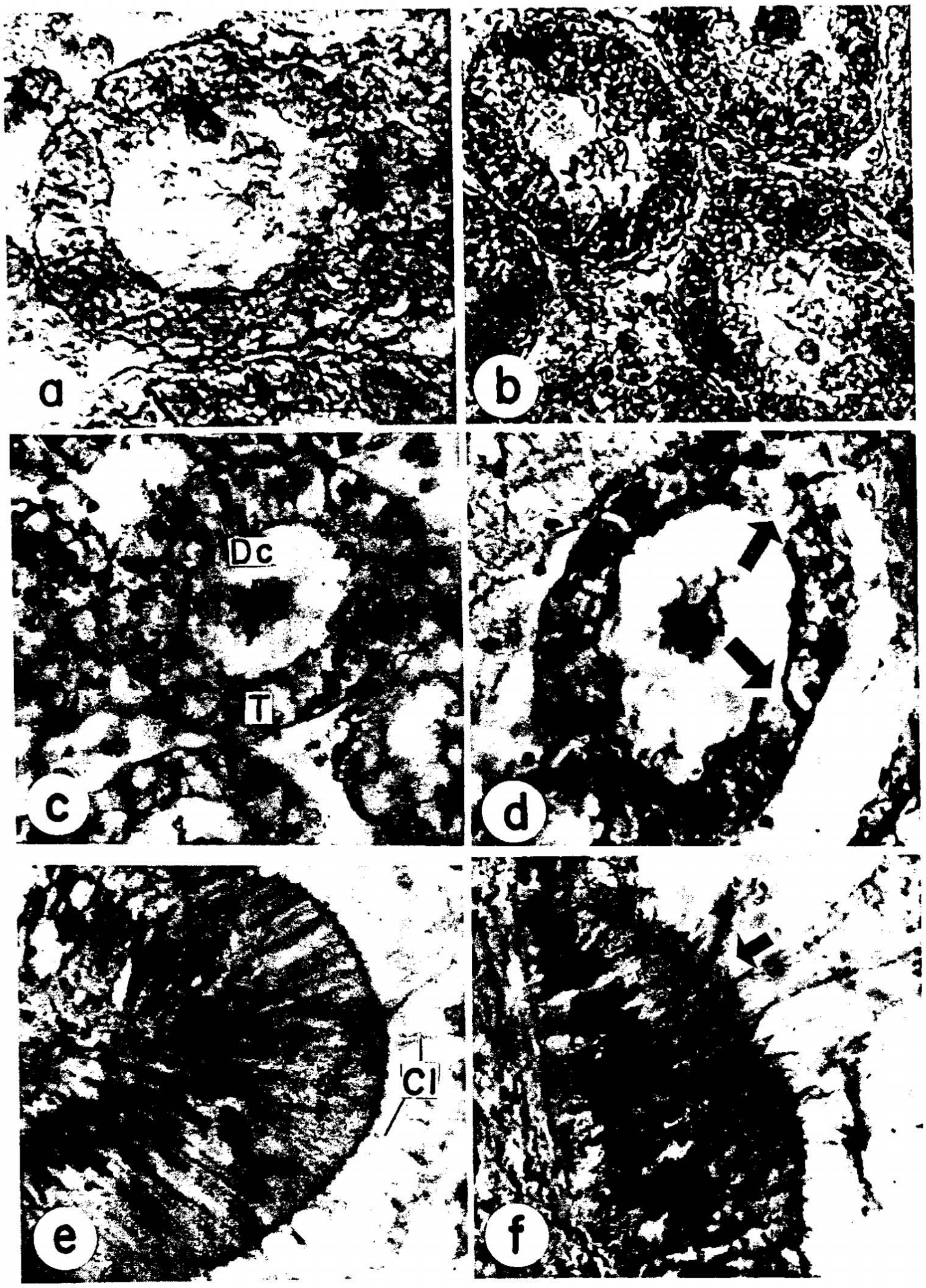
a
b
Dc
T
c
d
Cl
e
f

TABLE II

TISSUE CONCENTRATION OF COPPER AND MERCURY ($\mu g\ g^{-1}$ WET WEIGHT) IN *PERNA VIRIDIS* AFTER 1 AND 2 WEEKS EXPOSURE TO COPPER AND MERCURY

Exposure time	Whole body		Digestive gland	
	Copper	Mercury	Copper	Mercury
Control[a]	1.35	0.026	2.65	0.043
One week[a]	13.20	2.89	18.81	0.370
Two weeks[a]	24.70	3.76	38.20	1.04

[a]Samples pooled from 5 mussels.

1b). Similarly the percent incidence of tubule breakdown and loss of cilia in the digestive diverticula were high in exposed mussels in comparison to the control (Fig. 1c and d). Toxic effects of copper on the digestive tubule condition and on the cilia of digestive diverticula were more severe than the effects of mercury (Fig. 1b–d). As compared with controls, digestive cells showed extensive vacuolation of the cytoplasm. In metal exposed mussels there was loss of cilia and erosion of the cytoplasm of the ciliated columnar cells (Fig. 2f). After 2 wk exposure to copper and mercury, almost 100% cilia loss and tubule dilation was observed.

Metal accumulation

Total mercury and copper levels ($\mu g\ g^{-1}$ wet weight) in the whole tissue and digestive glands of mussels after 1 and 2 wk exposure are given in Table II. After 2 weeks exposure, more copper was accumulated in the digestive gland than in the whole tissue of the copper exposed mussels. The reverse was observed in mercury exposed mussels. Compared to mercury, copper accumulated more in the tissues of exposed mussels. Tissue copper in mussels was elevated above controls by factors of 10 to 20, whereas mercury levels were elevated by more than 100-fold above controls (Table II).

←

Fig. 2. Histochemical and histopathological responses of the digestive cells and tissues of *Perna viridis* to copper and mercury (25 $\mu g\ l^{-1}$). (a) Lipofuscin in the lysosomes localized by Schmorl reaction; control. (b) Enhanced lipofuscin content in mussel after 1 week exposure to copper. (c) Control digestive tubule (T) and digestive cells (Dc). (d) Degeneration and dilation of digestive tubule after 1 week exposure to copper. Arrows point to tubule breakdown. (e) Digestive diverticula of control mussels showing cilia (Cl). (f) Digestive diverticula of mussel after 1 week exposure to mercury. Arrow points to erosion of cytoplasm of columnar cells and loss of cilia. Magnification: a–f, × 1 000.

DISCUSSION

As proposed by Bayne et al. (1988b), simplified procedures have been tried, in the absence of sophisticated equipments to study the physiological responses of mussels. Oxygen consumption and filtration rates of mussels were measured using the Winkler method and neutral red method, respectively, and were found to give comparable results (Davenport, 1983; Hawkins et al., 1987).

Copper- and mercury-exposed mussels showed increased oxygen consumption and ammonia excretion rates. The increased oxygen consumption is indicative of an increased energy requirement, while increased ammonia excretion is indicative of increased protein catabolism. In agreement with that, O:N ratio and scope for growth of the exposed animals decreased significantly ($P < 0.001$), compared with the control. Previous field and laboratory studies have shown that the O:N ratio and scope for growth of mussels are very responsive to pollutants, including trace metals (Poulsen et al., 1982; Martin et al., 1984; Martin, 1985; Widdows et al., 1981, 1985; Widdows and Johnson, 1988).

The lysosomal system in the digestive cells of molluscs is sensitive to environmental perturbations including those that are pollutant-related (Moore, 1988b). Lipofuscin content in the digestive cells of mussels exposed to copper and mercury was found to be significantly high (Fig. 2b). Digestive cells of *M. edulis* and *Littorina littorea* exposed to copper and hydrocarbons, showed increased formation of lipofuscin (Pipe and Moore, 1986; Moore, 1988a). Lipofuscin buildup in the digestive cells is evidence of lysosomal pathology (Moore, 1988a). Lipofuscin accumulation is casually associated with oxygen-free radical reactions (Marzabadi et al., 1988). Elevated intracellular or intralysosomal concentrations of metals such as copper and iron may contribute to the enhanced lipofuscin content, as metals are important in mediating the toxic effects of oxygen (Moore, 1988a; Pisanti et al., 1988; Marzabadi et al., 1988).

Mussels exposed to copper and mercury had severe degenerative changes such as tubule dilation, breakdown and cilia loss in the digestive diverticula of digestive gland (Fig. 2d and f). Similar changes were reported in the digestive glands of *M. edulis* exposed to trace metals and hydrocarbons (Calabrese et al., 1984; Lowe, 1988; Auffret, 1988). These changes may be due to the autolytic processes as a consequence of lysosomal destabilization. Dysfunction of the lysosomal system would lead to increased autophagocytosis and increased vacuolar fusion as evidenced by accumulation of lipofuscin (Moore, 1988a; Auffret, 1988). This would in turn lead to atrophy of the digestive cells, resulting in the observed dilation and degeneration of the digestive tubules (Lowe et al., 1981; Calabrese et al., 1984; Lowe, 1988). Alterations in the lysosomal vacuolar system and a reduction in the volume density of the digestive epithelium, combined with an increase in its specific surface was reported in the digestive cells of *M. edulis* exposed to a mixture of copper and hydrocarbons (Lowe and Clarke, 1989).

Physiological and cellular responses of mussels show that copper is generally more toxic than mercury. Previous acute toxicity studies have shown similar trends (Krishnakumar et al., 1987). This may be due to the comparatively higher levels of copper accumulated in the tissue and due to the differences between the kinetics of copper and mercury accumulation from the medium (Table II). The rate of accumulation of mercury was found to be less than that of copper in *P. viridis* (Krishnakumar, 1987; Krishnakumar et al., 1990a). However, in the present study tissue copper in mussels was elevated above controls by factors of 10 to 20, whereas mercury levels were elevated by more than 100.

Mussels exposed to copper have shown reduced O:N ratios and negative scope for growth (Table I). Previous physiological effect studies have shown that copper is highly toxic to bivalve molluscs (Scott and Major, 1972; Manley, 1983; Moore et al., 1984; Grace and Gainey, 1987; Widdows and Johnson, 1988). Mussels exposed to copper displayed severe pathological changes in the digestive cells and tissues in comparison with the mercury-exposed animals. This may be again due to the higher levels of copper accumulated in the digestive gland than in the whole tissue. A higher concentration of copper was observed in the digestive gland, in comparison to gill, kidney, and the whole tissue of *P. viridis* collected from the field (Krishnakumar et al., 1990b). The physiological and cellular responses of mussels to copper and mercury were generally in the same direction, although mercury exposed mussels were comparatively less affected. Toxic effects of copper and mercury observed at lower levels – cellular and tissue – were found to be in agreement with those observed at higher levels – organismic – in the present study.

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