STUDIES ON THE FISHERY, BIOLOGY AND POPULATION DYNAMICS OF THE WHITEFISH *Lactarius lactarius* (BLOCH & SCHNEIDER, 1801) ALONG THE KARNATAKA COAST

THESIS SUBMITTED

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY IN BIOSCIENCES

BY

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Dedicated to

My beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON THE FISHERY, BIOLOGY AND POPULATION DYNAMICS OF THE WHITEFISH *Lactarius lactarius* (BLOCH & SCHNEIDER, 1801) ALONG THE KARNATAKA COAST" submitted by Shri. P.U. Zacharia for the award of Degree of Doctor of Philosophy in Biosciences is based on results of experiments carried out by him under my supervision. The thesis or part thereof has not previously been presented for any Diploma or Degree.

(N. Jayabalan)

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DECLARATION

I do hereby declare that the thesis entitled "STUDIES ON THE FISHERY, BIOLOGY AND POPULATION DYNAMICS OF THE WHITEFISH *Lactarius lactarius* (BLOCH & SCHNEIDER, 1801) ALONG THE KARNATAKA COAST" is the work carried out by me in the Department of Biosciences, Mangalore University, Mangalagangothri, Dakshina Kannada, Karnataka, under the guidance of Dr. N. Jayabalan, Professor and Head, Department of Fisheries Resources and Management, University of Agricultural Sciences, College of Fisheries, Mangalore. Further, I declare that the work has not previously been used as a basis for the award of any degree, diploma, fellowship or other similar titles.

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Chapter 1

General Introduction

INTRODUCTION

Fisheries in India, of late have grown as a major industry with an annual turnover of Rs. 220 billion accounting for 1.4% of the GDP of the country (Ayyappan and Biradar, 2000) and employing about 10 million people directly or indirectly. Among the Asian countries, India ranks second in fish production through aquaculture and third in capture fisheries. The area available for fish production in the country is vast with 2.02 million km^2 of EEZ for marine capture fisheries and 1.2 million ha for coastal aquaculture. The present total fish production of the country is 5.6 million metric tonnes (mmt) with a per capita fish availability of 8 kg (world average is 12 kg) against 11 kg recommended by WHO (Sugunan and Sinha, 2001). Realising the importance of fisheries in national development, the Government of India has identified fisheries as a priority sector in the national five-year plans. As the result, the marine fish production of the country has increased from 0.534 mmt in 1951 to the present yield of 2.72 mmt in 2000 (CMFRI, 2001) with an export of fish and fishery products valued about Rs.69.97 billions during 2000 (Anon., 2000 a).

India with a coastline of about 8,129 km and continental shelf area of about 0.5 million km^2 possesses rich and diverse marine fish and shellfish fishery resources. Due to the complex problems related to multi-species and multi-gear, besides changing climatic and oceanographic conditions, it is a challenge to manage the fishery resources effectively. The potential yield of the Indian EEZ has been estimated to be 3.9 mmt annually, comprising 2.2 mmt from 0-50 m depth zone and 1.7 mmt from beyond this region (MOA, 1991).

However, the Indian marine fisheries presently are confronted with serious problems of declining yields in certain areas and increasing conflict among different resource users warranting urgent need for management of the fisheries (Devaraj and Vivekanandan, 1999). As the present marine fish production of India stands at 2.72 mmt and catches of fishes from the inshore waters have reached the catchable potential (2.2 mmt) by 1997, scope for further increase in production is limited (Vivekanandan, 2001). Hence, for the management of the marine fishery resources of India within the presently exploited grounds, constant monitoring of fishery-dependant and independent factors are needed for. In this context, studies on the fishery, biology and population dynamics of the component species are essential pre-requisites.

The whitefish (also known as false trevally or big-jawed jumper) belonging to the Family Lactariidae is represented by the single species *Lactarius lactarius* (Bloch and Schneider, 1801) and is widely distributed in Indian waters forming local fisheries of considerable importance in different regions along the coast. *L. lactarius* is a small sized fish that moves in small shoals in inshore waters, occurs up to a depth of about 100 m and is exploited mainly by trawl net.

The average annual yield of whitefish in the country was 7,640 t during 1960-69 which increased to 13,704 t in 1980-89 but fell to 6,997 t in 1990-99. The all-India whitefish production that reached an all-time high of 25,337 t in 1985, started to decline thereafter and reached a low of 4,189 t in 1993. During the years 1996-2000, the annual catch fluctuated between 4,945 t (1999) and 8,983 t (1998) with an average annual catch of 6,797 t.

Among the coastal states of India, Karnataka contributes substantially to the marine fish production of the country. While the marine fish production of the state increased from 18,113 t in 1960 to 1,82,914 in 2000, whitefish landing increased from 1,083 t in 1960 to 2,930 t in 1988 which was the highest annual catch and the landing now stands at 1,256 t in 2000. The lowest annual catch (34 t) was recorded in 1964. Nevertheless, the annual percentage contribution of *Lactarius* from Karnataka to the all-India *Lactarius* production had increased from 4.2% during 1960-69 to 15% in 1990-99 with an average contribution of 8.8%. The catch from Karnataka formed 11.1% of total *Lactarius* catch of west coast during 1960-69, which increased to 17.2% in 1990-99. During 1990-99, *Lactarius* formed 1.2 % of the total marine fish production and 7.3 % of the demersal fish production from Karnataka.

Several studies on fishery and biology of *L. lactarius* from both east and west coasts of India are available (Details are provided under review of literature). However, investigations on the population dynamics of the species is lacking from any part of the Indian coast. From Karnataka state, though the biology and fishery of whitefish has been studied by James *et al.* (1974), Kartha (1975) and Neelakantan (1981), there is a gap in our knowledge on the stock and population dynamics of whitefish. Further, the fishery of whitefish has undergone drastic changes during the few decades. Realising the lacuna, the present study was undertaken on the fishery, biological characteristics and population dynamics of the whitefish *L. lactarius* from the Karnataka coast covering all the three coastal Districts (Dakshina Kannada, Udupi and Uttara Kannada) to help evolve management strategies for the judicious exploitation of whitefish resources.

1.1. REVIEW OF LITERATURE

1.1.1. From Outside India

Though several studies have been carried out on the fishery aspects of *L. lactarius* from various countries, reports on the biological and population characteristics of *L. lactarius* are scanty. The available information on various aspects is presented below.

Occurrence

Though, *L. lactarius* does not contribute to any exclusive fishery, its occurrence in the commercial catches from various countries has been reported. It forms as a component in the fishery of Philippines (Herre and Umali, 1948; Herre, 1953; Rau and Rau, 1980; Aprieto and Villoso, 1982; Cinco *et al.*, 1992, Dioneda *et al.*, 1995; Ganaden and Lavapie-Gonzales, 1999), Indonesia and southern Australia (Schuster and Djajadiredja, 1952; Gloerfelt-Tarp and Kailola, 1984), Tanzania and Pakistan (Bianchi, 1985a and b), eastern Africa (Rass, 1965), Taiwan (Shen, 1993), Burma (U Hla Vin, 1987), Malaysia (Mohsin *et al.*, 1993), Sri Lanka (De Bruin *et al.*, 1995), South China Sea (Kyushin *et al.*, 1982), Fiji (Lewis and Pring, 1986), Papua New Guinea (Kailola, 1987, Hermes, 1993), Chagos Archipelago-Mauritius (Winterbottom and Anderson, 1997, Fricke, 1999), Somalia (Sommer *et al.*, 1996), and from Hong Kong (Ni and Kwok, 1999).

Length-Weight Relationship

Pauly *et al.* (1996) described the length weight relationship of *L. lactarius* from Indonesian waters.

Taxonomy

Leis (1994) described the larvae of *L. lactarius* from Australia and reviewed the taxonomic position based on the external morphology and osteology.

1.1.2. From India

Studies on the fishery, biology and other miscellaneous aspects of whitefish along the Indian coasts have been made. They are presented under different aspects of study.

Taxonomy and Distribution

Choudhary and Dwivedi (1980) studied the meristic and morphometric characters of *L. lactarius* from Bombay waters. Shanmughavelu (1973) and Kunjipalu (1975) described the largest specimens of *L. lactarius*. Kaikini (1974) discussed the distribution and seasonal abundance of *L. lactarius* in the trawling grounds off Bombay and Saurashtra coasts. Alam *et al.* (1989) described the anchorage of air bladder with the interspinous bone of the anal fin and discussed the taxonomic significance of the bone in *L. lactarius*.

Commercial and Experimental Fishing

Bhimachar and Venkataraman (1952) described the fishery of *L. lactarius* from the Malabar Coast. Satyanarayana *et al.* (1972) carried out comparative fishing experiments with a four-seam trawl and a two-seam trawl along the east coast, which caught good quantity of *L. lactarius*. Kaikini (1974) described the regional and seasonal abundance of the fish in the trawling grounds off Bombay-Saurashtra coasts. Muthu *et al.* (1975) gave an account on commercial trawl fisheries of the species during 1967-70 from Kakinada coast. Neelakantan and Kusuma (1991) described the exploitation of whitefish resources in Uttar Kannada waters. Kunjipalu *et al.* (1990,

1992) and Vijayan *et al.* (1992) studied the efficiency of large mid-water trawl in capturing *L. lactarius*. Manohardoss *et al.* (1993) reported on the effect of heavy bridles for the capture of *L. lactarius*.

Length-Weight Relationship

Rao (1966) and Reuben *et al.* (1993) studied the length-weight relationship in *L. lactarius* from Andhra-Orissa waters along the east coast and Neelakantan (1981) from Uttara Kannada waters along the west coast

Food and Feeding

Chidambaram and Venkataraman (1946) and Devanesan and Chidambaram (1953) studied the food and feeding of *L. lactarius* from the Madras waters, Chacko (1949) from the Gulf of Mannar region and Venkataraman (1960) from the Malabar Coast. Basheeruddin and Nayar (1961) reported on the food and feeding of juvenile *L. lactarius* caught by the shore-seine along the Madras coast. Rao (1966) gave a brief account on the food and feeding of whitefish from Waltair. George *et al.* (1968) studied the food and feeding of the species caught from the trawling grounds off Cochin. James *et al.* (1974) described the feeding habits of *L. lactarius* from Mangalore waters. Neelakantan (1981) gave a detailed account on the food and feeding of *L. lactarius* from Karwar waters.

Reproduction

Rao (1966) studied the maturation and spawning of *L. lactarius* from Waltair. James *et al.* (1974) made a similar study on the species from Mangalore. The sex ratio and fecundity of *L. lactarius* along the Karwar coast were studied by Neelakantan *et al.* (1980, 1986). Neelakantan and Pai (1985) described the relative condition factor of *L. lactarius* from Karwar waters. Reuben *et al.* (1993) described the maturation in *L. lactarius* from Andhra Pradesh-Orissa coast.

Age and Growth

Rao (1966) described the growth of whitefish from Waltair. Kartha (1975) determined the growth rate of the species from Karwar waters. Reuben *et al.* (1993) studied the growth and mortality of the species from Andhra-Orissa waters. The growth of juvenile *L. lactarius* was described by Basheeruddin and Nayar (1961) from Madras waters.

Proximate Composition

Jacob and Rajagopal (1980) estimated the relationship between calorific values of the stomach contents (food) and protein, fat and carbohydrates of body tissues of *L. lactarius*. Edward *et al.* (1989) studied the trace metals in *L. lactarius* collected by FORV Sagar Sampada from the Bay of Bengal and Manganese was found to be the prime one. Gopakumar (1997) studied the biochemical composition of *L. lactarius* from Cochin waters.

Processing

Balachandran (1969) described the accelerated method of hot air drying of *L. lactarius*. Balachandran and Madhavan (1976) proposed a technique for canning of *Lactarius* by which the flavour as well as the lustrous skin can be retained. Devadasan and Nair (1977) carried out studies on changes in protein fractions of whitefish muscle during storage in ice. Narayanaswamy *et al.* (1980) studied the penetration of sodium chloride during prolonged salting of *L. lactarius*. Agarwal *et al.* (1986) worked on the frozen storage of composite fish mince prepared from sciaenid and *L. lactarius*.

Others

Ramamurthy (1973) and Jayabalan *et al.* (1986) described the luminescent bacteria from *L. lactarius* from Porto Novo waters of southeast coast of India and Mangalore waters respectively. Kusuma and Neelakantan (1981) reported an abnormal specimen of *L. lactarius* without a pelvic fin caught off Karwar. Chandra and Rao (1984) reported on the cestode parasite *Prochristianella bengalense sp. nov.* from *L. lactarius* of Waltair coast.

1. 2. DESCRIPTION OF THE STUDY AREA

Geographically, Karnataka state is wedged between the Western Ghats in the east and the Arabian Sea in the west. The state is situated between 11° 31' and 18° 45' N latitude and 74° 12' and 78° 40' E longitude and lies in the west-central part of the peninsular India. More than a dozen rivers originating in the Western Ghats open into the Arabian Sea in these three districts, rendering the inshore waters rich in nutrients and plankton. Netravati, Gurupur, Gangoli, Sitanadi, Aghanasini, Kali and Sharavati are the important rivers. The estuaries formed by these rivers are important from the ecological and biological points of view. The state is well forested and characterised by rich floral and faunal diversity. The weather is hot and humid most part of the year. The average annual rainfall is about 4000 mm with 80% being received during June-September.

Karnataka state has a 300 km long coastline and is a frontline state in marine fisheries development. Historically known as the 'mackerel coast', it has a continental shelf area of 25,000 km^2. About 80% of the shelf area lies between 0 and 72 m depth (Anon., 1978). Its contribution to the total marine fish production of the country has varied from 6 to 14 % annually. The state has three coastal districts, Dakshina Kannada (D.K), Udupi and Uttara Kannada (U.K). Pelagic species like mackerel and sardines and demersal finfishes, prawns and cephalopods are exploited along the coast. There are 5 medium harbours and 4 minor harbours in the region. More than 90% of the state's marine fish catches are landed in the fisheries harbours of Mangalore in Dakshina Kannada District, Malpe in Udupi District and Tadri and Karwar in Uttara Kannada District. The state has 151 ice plants, 40 cold storages, 22 freezing plants, 7 canning plants, 18 fish meal plants (Anon., 2000 b). The large number of ice plants and their production capacity of 1296 t/day are primarily because of the substantial intake of ice by the multi-day trawlers for their voyages. Besides, there are 82 primary fisheries co-operative societies and 2 co-operative fish marketing federations in the three coastal districts.

Karnataka state has been a pioneer in the introduction of new mechanized fishing technologies, development of fishing harbours and improvement in the living standards of fishermen in the country. Consequently, the state has the largest purse-seine fleet in the country (327 nos.) and its trawl fleet is very modern and dynamic which had resulted in steep increase in marine fish production in the state during the 1970s and 1980s. However, in the 1990s, the catches and catch rates have fallen/stabilized for major gears like purse-seine and trawl resulting in reduction of profit for the fishermen and revenue for the state (Mohamed *et al.*, 1998). The production rate (marine fish production/km coastline) of the state is almost double the national average right from the 1950s.

There are 28 fish landing centers, of which Mangalore, Malpe and Karwar are the major ones, while Honavar and Tadri are minor landing centres. For the present study, three major centres (Mangalore, Malpe and Karwar) were selected for observation of whitefish landings and collection of samples for biological and other related studies. Fig.1 shows the major fish landing centers of Karnataka.

The general hydrographical features along west coast of India including Karnataka state in general were given by Madhupratap *et al.* (2001). During spring inter-monsoon period (March-May) the entire Arabian Sea has very low primary productivity (14-21 $mgC/m^{-2}/d^{-1}$). During this period, the Arabian Sea attains typical tropical structure. Similar scenario prevails during September-October when transition of summer to winter monsoon occurs. These periods have higher sea surface temperature (=28 ^0C), shallow mixed layer depth at 20-30 m depth and strong stratification. Nutrients especially nitrates are at undetectable levels in the surface waters. With the onset of summer monsoon (June-September) the situation changes considerably under the influence of southwesterly winds along the west coast, surface water moves away from the coast and is replaced by colder nutrient rich oxygen depleted water from sub-surface. This leads to phytoplankton blooms and increased primary productivity. Upwelling starts at southern tip of west coast by May/early June and progresses to northwest with time. This phenomenon lasts up to end of August/early September. During this period, a low level jet current flows across Arabian Sea from north of Africa to northern India.

While high biological productivity, both primary and secondary is reported in these waters during and after upwelling (Devassy, 1983), high benthic production is noticed during the late post-monsoon (Harkantra and Parulekar, 1981). About 40 to 60% of total annual fish production in Karnataka is realised during October-December, which consists mainly of planktivorus fishes like clupeids, mackerel and anchovies. The coastal upwelling of nutrients occurring during the southwest monsoon supports the rich fisheries in this region during post-monsoon season (De Sousa *et al.*, 1996).

1.3. DESCRIPTION OF THE SPECIES

Species : *Lactarius lactarius* (Bloch and Schneider, 1801)

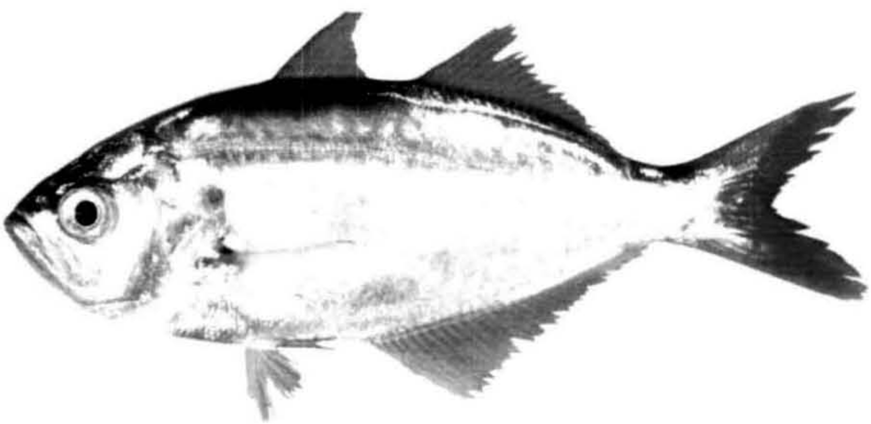
The earliest description of whitefish from Indian waters is by Day (1878). Later Weber and Beaufort (1931) and Munro (1955) described the taxonomy of *Lactarius*. For describing the species in the present study, works of Day (1878), Weber and Beaufort (1931) and Munro (1955) were consulted.

Systematic Position

Phylum	Chordata
Sub-Phylum	Vertebrata
Super-class	Gnathostomata
Class	Teleostomi
Sub-class	Actinopterygii
Order	Perciformes
Sub-order	Percoidei
Family	Lactariidae
Genus	*Lactarius*

Characters of the Family Lactariidae

Body oblong, strongly compressed, branchiostegals seven, pseudobranchiae present. Eyes lateral. Cleft of mouth deep, with the lower



Lactarius lactarius (Bloch & Schneider, 1801) jaw prominent, pre-opercular margins entire, teeth in jaws small, with one or two pairs of strong canine. Two dorsal fins, first with 7 or 8 feeble spines, second with 1 spine and 20-22 rays, no finlets. Ventral fin with 1 spine and 5 rays. Anal fin with 3 spines, joined to the remainder of the fin. Scales cycloid, moderate sized, some cover the second dorsal and anal fins. Lateral line continuous, unarmed. Air bladder bifurcate both anteriorly and posteriorly. Pyloric appendages present.

Single Genus *Lactarius* Cuvier & Valenciennes, 1833.

Characters of the Genus

As described for the family Lactariidae.

Single species: *Lactarius lactarius* (Bloch & Schneider, 1801)

Scomber lactarius Bloch and Schneider, *Syst. Ichth*, 1801, p.31.

Seriola lactaria Cuvier, *Regne Anim*. 2nd ed. II. 1829.p.206.

Seriola lactarius Cuvier and Valenceiennes, *Hist. nat. Poiss*. IX.1833. p.238

Lactarius delicatulus, Bleeker, Nat.& Geneesk, *Arch. Ned. Indie* (3)II.1845, p.518.

Lactarius delicatulus Canton *Journ. Asiat. Soc. Bengal* XVIII, 1850, p.1120.

Lactarius delicatulus Gunther, *Cat. Brit. Mus*.II.1860, p.507.

Lactarius delicatulus Day, *Fish India*, 1878-88, Pl. liii, fig 2 (plate 23).

Lactarius delicatulus Mcleay, *Proc. Linn. Soc. N.S. Wales* IX, 1844. p.26.

? *Lactarius burmanicus* Lloyd, *Records Indian Mus*. I. 1907. p.63.

Lactarius lactarius Seale, *Philippines J. Sc*.V.1910, p.270.

Distribution

Whitefish is distributed in the Indo-West Pacific consisting of East Africa and Eastern Indian Ocean extending eastward to Southeast Asia, northwest to Japan, and southeastward to Queensland, Australia. Countries where *Lactarius* is reported are Mozambique, Tanzania, Somalia, Mauritius (Chagos Islands), Pakistan, India, Sri Lanka, Myanmar, Malaysia, Indonesia, Philippines, Vietnam, Taiwan, Japan, Australia, Fiji and Papua New Guinea. Found in coastal waters up to a depth of 100 m.

Description

For the study of morphology, morphometrics and meristics of the species, specimens were collected from trawl catches from Mangalore and Malpe. Colour and pigmentation of fresh specimens were noted and measurements were taken from fresh specimens. Morphometric and meristic data were recorded following Hubbs and Lagler (1958). Total length (TL) was measured from tip of snout to the tip of the upper caudal lobe. A total of 15 morphometric characters were recorded (Fig.2).

Material

50 specimens of length range 83-224 mm total length (62 –170 mm standard length).

D^1. VII-VIII, D^2. I, 20-22; P.17; V.I, 5; A. III, 25-28, C.17.

L.I.74-80; Ceac. pyl. 6.

Colour: A black spot exists on the upper and posterior part of opercle. Fins diaphanous, marginal halves of dorsals and caudal minutely dotted with black, sometimes the base is also dark. Irish silvery, upper portion darkish.

1.4. SCOPE OF THE STUDY

From the review of literature, it is evident that in spite of its commercial importance and wide distribution, there is considerable lacuna in our knowledge on various aspects of biology of *Lactarius lactarius* from Indian waters. As the catch of *L. lactarius* has fallen in many parts of the coasts in recent years, scientists have expressed their concern and listed the species as vulnerable. The present study was therefore undertaken to give a comprehensive account on the status of the fishery and the biological characteristics such as food and feeding, length-weight relationship, reproduction, age and growth and population dynamics of the species covering mortality, yield-per-recruit and stock assessment along the Karnataka coast. Besides better understanding of the biological characteristics of the species, the information gathered on population parameters and maximum sustainable yield (MSY) will be useful to evolve suitable strategies for management and rational exploitation of the whitefish resource in Indian waters in general and along Karnataka coast in particular.

1.5. PRESENTATION OF RESULTS

The results of the present study are presented in seven chapters. The **first chapter** includes the general introduction, review of literature, descriptions of study area and species and the scope of the present study.

The **second chapter** deals with the fishery of *L. lactarius* that includes a review of whitefish fishery on all-India basis and Karnataka state during 1960-1999. Also the fishery data of whitefish collected along the Karnataka coast during 1997-98 and 1998-99 (September-August) are described in detail which include information on fishing area, depth, major gears for exploitation, annual catch trends and seasonal fluctuations at important fish landing centres *viz*. Mangalore, Malpe, Gangoli, Bhatkal, Tadri and Karwar.

The **third chapter** pertains to the food and feeding habits of whitefish. The results of qualitative and quantitative analyses of stomach contents with reference to month and sex, size and maturity condition and feeding habit of the fish are presented.

The **fourth chapter** deals with the total length-body weight relationships of both the sexes and juveniles of the fish and the results were statistically tested and compared.

Information on maturation and spawning of the fishes such as maturity stages of males and females, size at first maturity, gonado-somatic index, development of ova to maturity, spawning season, frequency of spawning, sex-ratio and fecundity is presented in **chapter 5**. This chapter also includes the relative condition factor of the fish during different months and size.

The **sixth chapter** deals with the age and growth estimated separately for males and females as well as sexes pooled using different methods and includes aspects such as growth parameters, comparison of growth parameters, life span and recruitment pattern. The growth characteristics are compared and discussed with studies from other regions.

The **seventh chapter** relates to the population dynamics of the species covering the stock assessment with facts on mortality, length at first capture, exploitation rate (U), exploitation ratio (E), standing stock, annual average stock, maximum sustainable yield (MSY), relative yield per recruit and optimum age of exploitation with suggestions for keeping the whitefish fishery at sustainable level.

The salient findings of the present study are given in the summary, which is followed by a list of references. Tables and figures are provided together in the text under each chapter at appropriate places.

The list of publications of the candidate relevant to the above subject is given in **Appendix**.

Table 1. Body proportion of *L. lactarius* in % of total length (No. of specimens: 50)

Sl. No	As percentage of Total length	Range		Mean	Standard Deviation
		min	max		
1	Fork length	85.84	94.53	88.64	1.90
2	Standard length	70.71	88.64	76.31	3.79
3	Snout length	4.03	5.82	4.89	0.40
4	Head length	25.25	28.57	27.08	0.74
5	Eye diameter	4.99	7.46	5.95	0.51
6	Post orbital distance	10.68	14.58	12.28	0.69
7	Inter orbital distance	2.49	6.23	3.27	0.71
8	Snout to insertion of first dorsal	18.32	34.05	32.20	2.53
9	Snout to insertion of second dorsal	25.25	49.41	45.43	3.16
10	Snout to insertion of pectoral	22.83	28.25	24.69	1.06
11	Snout to insertion of pelvic	22.68	30.89	29.40	1.19
12	Snout to insertion of anal	28.26	46.24	42.03	2.55
13	First dorsal to anal	19.77	30.51	28.39	1.60
14	Second dorsal to anal	18.93	28.15	26.33	1.37
15	Breadth	7.77	9.16	8.44	0.33
Sl. No	**As Percentage of Head length**				
1	Snout length	14.98	21.61	18.05	1.47
2	Eye diameter	18.18	27.15	21.99	1.95
3	Post orbital distance	41.16	51.94	45.35	2.43
4	Inter orbital distance	9.09	22.98	12.08	2.66

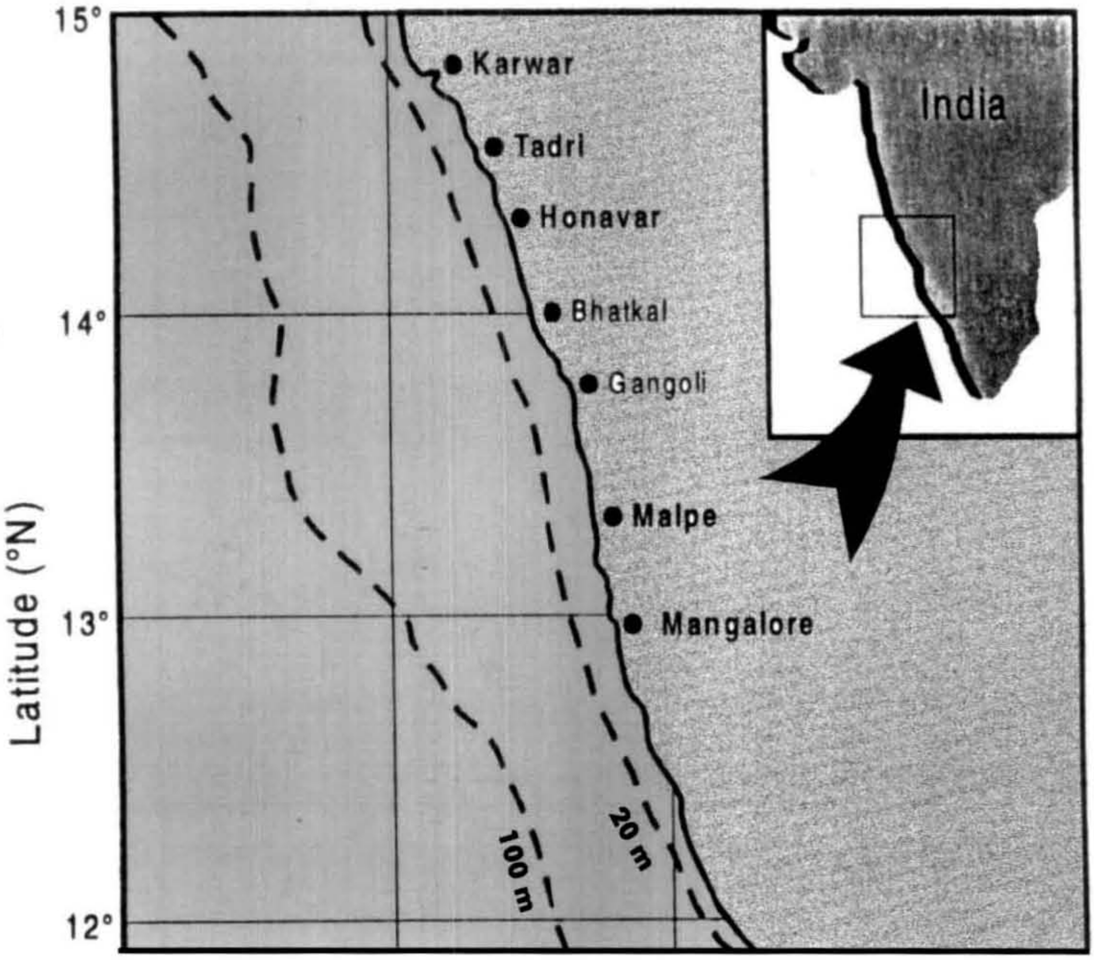


Fig. 1. Map showing the important fish landing centres along Karnataka Coast.

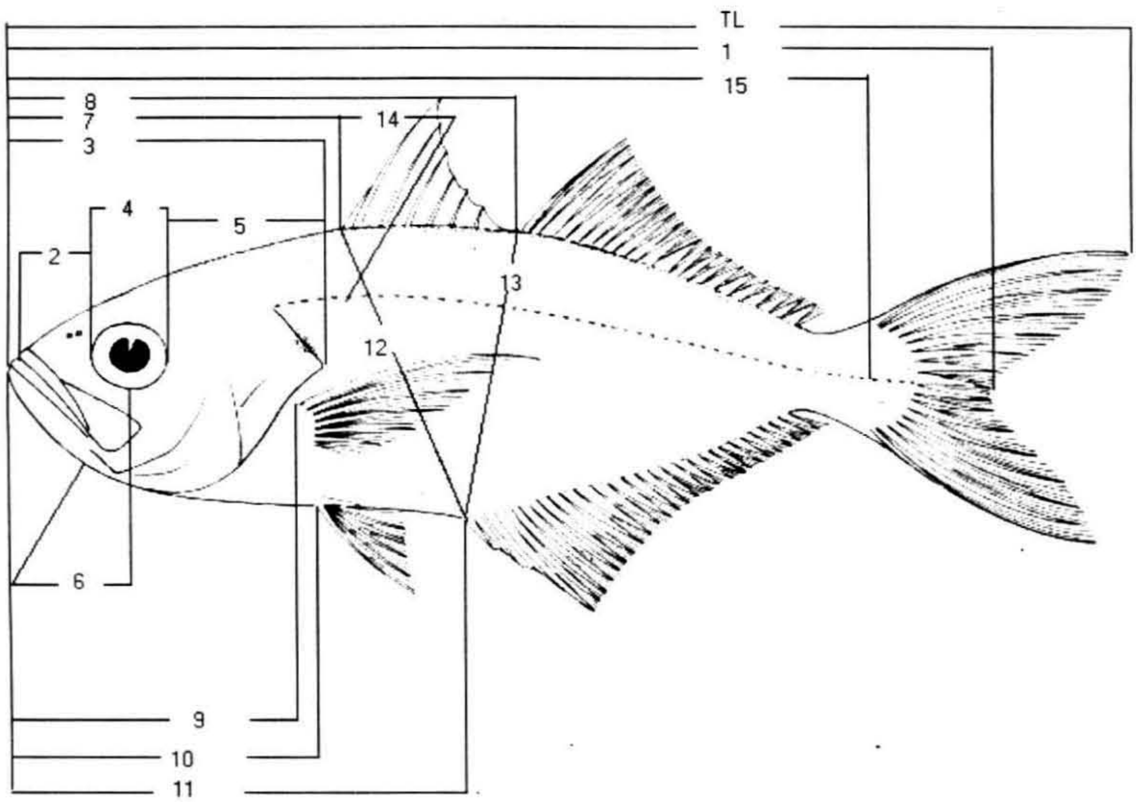


Fig. 2. Outline drawing of *L. lactarius* showing various morphometric measurements

TL. Total length
1. Fork length
2. Snout length
3. Head length
4. Eye diameter
5. Post-orbital distance
6. Inter-orbital distance
7. Snout to insertion of first dorsal
8. Snout to insertion of second dorsal
9. Snout to insertion of pectoral (pre-pectoral lengtl
10. Snout to insertion of pelvic (pre-pelvic length)
11. Snout to insertion of anal (pre-anal)
12. First dorsal to anal
13. Second dorsal to anal
14. Breath
15. Standard length

Chapter 2

Fishery

2.1. INTRODUCTION

India has a long coastline of 8,129 km and 2.02 million km^2 of EEZ. The fishery resources are supported by multi-species and harvested by multi-gear. There are about 3,651 fishing villages and 2,271 fish landing centres all along the coast (Devaraj and Vivekanandan, 1999). The fish production increased from 0.88 million metric tonnes (mmt) in 1960 to 2.72 mmt in 2000 (CMFRI, 2001). The marine fish production during the last 40 years fluctuated between a minimum of 0.644 mmt in 1962 and the maximum of 2.73 mmt in 1997. The decadal change in marine fish production shows that the production has increased from 0.812 mmt in 1960-69 to 1.13 mmt in 1970-79, 1.61 mmt in 1980-89 and 2.37 mmt in 1990-99. The rate of increase was rapid from 1980-89 to 1990-99 and this was mainly due to the diversification of fishing operations to deeper waters by mechanised trawlers.

The major fishery resources of India comprise pelagic fishery resources such as, oil sardine, mackerel, whitebait, Bombay-duck, seerfish, tunas and carangids and demersal resources, such as, perches, catfish, pomfrets, sharks, flatfish, ribbonfishes, lizardfishes, flatheads, silverbellies, whitefish, cephalopods, shrimps and crabs. The marine fisheries have witnessed rapid changes over the years, due to the advancement in fisheries research and technologies.

Karnataka state with a coastline of 300 km along the southwest coast of India is one of the frontline states of the country in marine fisheries development (Mohamed *et al.*, 1998). The principal gears used in the state are trawl net, purse seine and gillnet in addition to a few small long-liners, which are based in the fishing harbours and a variety of artisanal gears. The trawl fleet in the State is distinctly of two types, a single day fishing fleet (SDF) consisting of small (30'-32') coastal trawlers and the multi-day fishing fleet (MDF) consisting of larger (36'-52') trawlers operating in the 30-150 m depth zones (Zacharia *et al.*, 1996). The purse-seine fleet is mainly concentrated in the major harbours and some of them are functioning as combination vessels (purse-seining during the peak pelagic fisheries season and multi-day trawling during rest of the season). The largest fleet in all the fishing harbours is the small coastal trawlers. Indigenous gears like *matabale*, *beenibale*, and *jeppubale* are operated mainly during the monsoon season but a few like *kairampani* and *yendi* are operated throughout the year. In 1986, the Government of Karnataka has passed the Marine Fisheries Regulation Act to regulate fishing activities by scientific means to ensure fishing wealth and to de-limit fishing zones for different types of fishing vessels. Fishing by mechanised vessels is banned during the southwest monsoon months (June-August) along the entire Karnataka coast.

The coastal waters of Karnataka are known for the two major pelagic resources of the country, the Indian mackerel and the oil sardine. The success or failure of the fishery in the state is determined by the landing of these two species (Muthiah, 1994). The other important resources include carangids, anchovies, threadfin breams, flatfishes, lizardfishes, catfishes, tunas, seerfishes, cephalopods, shrimps, squilla and crabs. The marine fish production in the state is characterised by wide fluctuations.

The annual marine fish production of Karnataka steadily increased from 18,113 tonnes (t) in 1961 to 1, 82,914 t in 2000 with an average annual production of 1,17,858 t. The average decadal marine fish production in the state steadily increased from 57,400 in 1950s to 1, 65, 400 in 1980s, but dropped to 1, 57,500 in 1990s. The production rate (marine fish production/km coastline) of the state is almost double the national average, right from the 1960s. The rate of increase has been steep during 1970s and 1980s, mainly due to the very efficient exploitation of the pelagic resources by the purse-seine fleet (Mohamed *et al.*, 1998).

Mechanised gears accounted for more than 95% of the annual average catch in Karnataka. Of the mechanised gears, purse-seiners (44.8%) and trawlers (43.5%) together form 88% of the total catch. The last two decades have witnessed remarkable development in the mechanised sector. The trawl fishery has been intensified with the introduction of more number boats of varying sizes and horse-power (HP), coupled with the extension of fishing grounds up to 150 m depth, and a change in the pattern of fishing from single-day to multi-day fishing for shrimps and fishes for domestic use and export. The increased exploitation by the mechanised units has resulted in substantial increase in all demersal finfishes and shellfishes in the state.

The world annual *L. lactarius* catch, which stood at 500 t in 1950 has reached 8,156 t in 2000 (Froese and Pauly, 2002) with wide fluctuations. The minimum catch (200 t) was recorded during 1953-1957 and maximum production (14,927 t) was observed in 1982. Maximum contribution was by India forming up to 92% in some years. In India, the production varied from 4,474 t in 1979 to 25,357 t in 1985 and the production stood at 6,179 t in 2000. The other country with substantial production of *Lactarius* is Malaysia where the production varied from 500 t in 1950 to 422 t in 2000. In Pakistan, *Lactarius* was not recorded till 1980, but, in 1981 and 1982, 326 t and 650 t have been landed and while the landing was almost nil during subsequent years and it stood at 4 t in 1997. In the Philippines, whitefish was first recorded in 1970 with a production of 300 t, but thereafter it declined to 25 t in 1996 and improved to 253 t in 2000. *Lactarius* forms a fishery of some magnitude in Thailand. It was first landed in 1973 (800 t) and thereafter declined to 6 t in 1988 and, there is no report of any catch after 1988. An analysis of the decline of Gulf of Thailand trawl fishery indicated that the rate of decrease of *L. lactarius* was the most significant and ranked first among all demersal fishes (Pauly, 1979).

The present fisheries scenario points to the fact that *Lactarius* catch has declined worldwide and in some countries (Pakistan, Thailand and

Philippines), the catch has almost vanished. This alarming situation had prompted a few to categorize the species as vulnerable and called for conservation measures (Bensam and Menon, 1994).

Information on the whitefish fishery and fishing methods from different parts of Indian coasts (Bhimachar and Venkataraman, 1952; Satyanarayana *et al.*, 1972; Kaikini, 1974; Muthu *et al.*, 1975; Kunjipalu *et al.*, 1990, 1992 and Vijayan *et al.*, 1992) and from Karnataka coast (Neelakantan, 1981; Neelakantan and Kusuma, 1991) is available.

Whitefish is a commercially important resource in Karnataka forming 0.7% of all marine fish production and 7.3% of demersal fish catch. For better understanding of the magnitude of exploitation and to evolve management strategies for judicious use of this resource, estimation of catch and effort assumes great significance. As there is no comprehensive information on catch and effort, and catch rate from different centres of Karnataka state, an attempt has been made to study the abundance and production of whitefish from major fish landing centres of Karnataka. The information gathered would help the development and management of the whitefish fishery of the region.

2.2. MATERIAL AND METHODS

Data on fish catch and effort were collected on an average of 8 days (2 days a week) in a calendar month at Mangalore and Malpe, and 4 days (once a week) at Karwar from September 1997 to August 1999. On each observation day, catch and effort data were collected at random from approximately 10 % of the fishing units landed at that centre. Whitefish catch data for other mechanised centres and for the entire Karnataka coast were obtained from the National Marine Living Resource Data Centre (NMLRDC) of Central Marine Fisheries Research Institute (CMFRI), Kochi.

Two categories of mechanised trawl boats (SDF and MDF) are in operation. The first category consists of small boats (<9.75 m OAL) making daily trips (SDF) and fishing up to a depth of 30 m. The second category comprising medium sized boats (9.75-15.0 m OAL) makes multi-day fishing cruises (MDF) fishing at depths beyond 30 m. The number of days of absence of the observed boat from the landing centre was ascertained by enquiry and the catch details were noted at the landing centre by eye estimate. The multi-day boats were grouped 2 nights, 3 nights, 4 nights etc. for facilitating the estimation of effort in actual fishing hours. On an average, 6.6 hours were spent on actual fishing out of each 12-hour absence from the harbour by these units. Accordingly, the effort in actual fishing hours for 1 night, 2 nights (2 nights + 1day), 3 nights (3 nights + 2 days) and 4 nights (4 night + 3 day) was 6.6 hours (6.6 hour x 1 unit of 12 hours), 19.8

hours (6.6 hour x 3 units of 12 hours), 33 hours (6.6 hours x 5 units of 12 hours), 46.2 hours (6.6 hours x 7 units of 12 hours) respectively. The number of units landed under each category was recorded on the observation days. For units, which make daily cruises (SDF), an average of 5 hour was taken as the effort in fishing hours. The mean catch and effort for the observed units under different categories on each observation day were raised to the total units of the respective type landed on that day to get the estimate for the day. Pooling the estimates for different observation days and raising to the total number of fishing days in that month gave catch and effort data for the month.

Data on state-wise and all-India marine fish production and whitefish landings were extracted from the publications of CMFRI and NMLRDC of CMFRI, Kochi. In addition to the trawl net, as whitefish is occasionally caught by various indigenous gears, for presentation of results, the data on catch were categorized into trawl (SDF, MDF and bull trawl), seines (purse-seine and all boat-seines), gill net (drift gill net and bottom set gill nets operated from boat) and other gears (shore-seines, hook and lines, hand trawl etc.). To estimate the seasonal abundance of whitefish, the catch and effort data were pooled under different seasons such as monsoon (June-August), post-monsoon (September-January) and pre-monsoon (February-May).

2.3. RESULTS

2.3.1. Whitefish Production in India

The annual production of whitefish from India shows wide fluctuations (Fig.1). The annual landings showed a steady fall from 1960 (14, 506 t) to reach 4, 546 t in 1969, which decreased further to 4,474 t in 1979, and to an all time low of 4,189 t in 1993. Barring the spurt in landings in 1983 (20,233 t) and 1985 (25,337 t), the annual landings fluctuated between 4,189 t and 15,805 t during these years. The production level was 6,179 t in 2000.

The decadal average production of *Lactarius* during 1960-69, 1970-79, 1980-89, and 1990-99 is shown in Table 1. The percentage of *Lactarius* in all-marine fish production of the country was 0.94 % in the first decade of 1960-69, fell to 0.70 % in the second decade, rose to 0.85 % in the third decade but fell drastically to 0.29 % in the last decade. Fig.2 represents the decadal annual average production of whitefish from west and east coasts of India. The production from east coast shows a steady decline from 4,738 t in 1960-69 to 888 t in 1990-99; whereas, the production from west coast increased from 2,901 t in the former period to reach a peak of 12,354 t in 1980-89 from where it declined drastically to 6,109 t in 1990-99.

The average contribution of *Lactarius* to Indian marine fish production during 1960-2000 was 0.64%. The coast-wise decadal contribution to the Indian whitefish production shows that the west coast contribution was 37.8%

in 1960-69 that increased to 90.2% in 1980-89 and decreased to 87.3% during 1990-99 (Table 1). The average percentage contribution of west coast was 74.2% for the 4 decades and the rest from east coast.

The whitefish landings along the northwest coast was less than 750 t till 1972 and increased to an all-time peak of 20,180 t in 1985 (Fig 3). It decreased thereafter to 1,963 t in 1988 and further to 1,847 t in 2000. The decadal average production shows that the catch has increased from 163 t in 1960-69 to 8,778 t in 1980-89 and fell to 3,313 t in 1990-99. The landing was contributed mainly by Gujarat coast, where, it increased from nil catch t in 1960 to 18,195 t in 1985 but subsequently decreased to 541 t in 1999. The percentage contribution of northwest coast increased from 0.6% in 1960 to 79.6% in 1985 but decreased to 29.9 % in 2000.

The landings along the southwest coast varied between 977 t in 1979 and 8,573 t in 1973 (Fig.3). The decadal contribution of southwest coast to all-India production was 35.6 % in 1960-69 and 32.6% in 1990-99. In southwest coast, 68.6% of catch was contributed by Kerala, which showed a steady decline from 2,398 t in 1960-69 to 1,156 t in 1980-89 but increased to 1,490 t in 1990-99 (Fig.4). The catch from Karnataka showed a steady increase from 323 t in 1960-69 to 1,231 t in 1980-89, but declined to 1,048 t in 1990-99. The catch from Goa increased from almost nil to 231 t in 1970-79 and to 1,190 t in 1980-89 but declined drastically to 257 t in 1990-99.

The whitefish landing along the southeast coast decreased from 6,392 t in 1960 to 771 t in 1999. The contribution of southeast coast to all-India *Lactarius* production decreased from 62% in 1960-69 to 10.5 % in 1990-99. The catch from all the states in southeast coast decreased uniformly. In Tamil Nadu, the catch decreased from 6,175 t in 1961 to 164 t in 1997 and in Andhra Pradesh it fell from 1,044 t in 1961 to 607 t in 1999. The contribution from northeast coast to the whitefish landings was very meagre ranging from 0.2% to 0.3 % during 1960s, 1970s and 1980s, which increased to 2.2% in 1990s.

2.3.2. Whitefish Production in Karnataka

2.3.2.1. Production During 1960-1999

The whitefish production from Karnataka fluctuated between a lowest of 37 t in 1964 and highest of 2,930 t in 1988. The percentage contribution of *Lactarius* from Karnataka to the all-India *Lactarius* production increased from 4.2% in 1960s to 15% in 1990s with an average contribution of 8.8%. There were two peaks in the catch, the first one during 1973 (1,740 t) and the second one during 1988 (2,930 t) (Fig.1). The catch from Karnataka formed 11.1% of *Lactarius* catch from west coast during 1960-69 and increased to 17.2% during 1990-99. *Lactarius* formed 0.67 % of the marine fish production from Karnataka.

The decadal average production of whitefish from Karnataka shows a similar trend to all-India production (Fig.5). It increased from 323 t in 1960s to 668 t in 1970s and reached the highest of 1,231 t in 1980s. However, it fell marginally in the nineties to 1,048 t.

2.3.2.2. Whitefish Fishery During the Study Period

The total whitefish landings by all gears from Karnataka were 1,552 t during 1997-98 and 1,386 t in 1998-99 forming 0.90% and 0.78% of all-fish production during these years respectively (Table 2). During 1997-98 an amount of 1,166 t (75.1%) was landed by trawl, 252 t (16.3%) by seines, 98 t (6.3%) by gill nets and 36 t (2.3 %) by other gears. In 1998-99, trawlers landed 957 t (69 %), seines 227 t (16.4%), gill nets 131 t (9.5%) and other gears 71 t (5.1%). The pooled data for two years showed the trawlers to be the major gear contributing to 72% of whitefish and the rest was by seine nets (16%), gillnets (8%) and other gears (4%) (Fig.6). Seines, operated by mechanised and non-mechanised crafts contributed 441 t and 38 t respectively forming 15% and 1.3 % of total whitefish landings by all gears (Table 2). Mechanised and non-mechanised gill nets landed 84 t and 145 t respectively forming 2.9% and 5% of the total whitefish landings.

The total whitefish landing by all gears from the six major landing centres in Karnataka was 1,154 t in 1997-98 and 988 t in 1998-99 contributing 73% to the Karnataka catch (Table 3). The rest of the catch came from minor landing centres (Hungarcutta, Thengingundi, Kesarkodi, Gorate, Belke etc.) where, few trawlers and other non-mechanised artisanal gears are under operation. The important centres for *Lactarius* landing are Mangalore in Dakshina Kannada and Malpe in Udupi District (44.7% and 29% respectively), which together contributed to 73.7% of the state's whitefish catch. Karwar contributed to 9%, Gangoli 7%, Tadri 6% and Bhatkal 4%. The District-wise figures of landing were: Dakshina Kannada 45%, Udupi 36%, and Uttara Kannada 19%.

2.3.3. Fishing Ground

Trawl fishing is done from 10 m to 75-100 m depth during September-May. The fishing ground is generally characterised by muddy or sandy bottom. The fishing ground for indigenous gears is mostly restricted to shallow water regions of the coast within 30 m. During monsoon season, fishing is generally carried out close to the shore. Fig.7 gives the area of fishing for whitefish along Karnataka coast.

2.3.4. Crafts and Gears Employed

2.3.4.1. Trawl

Whitefish are caught mainly by trawl nets operated by mechanised vessels along with other fishes. The boats are wooden measuring an over all length (OAL) of 6.75 to 15 m fitted with 37-102 hp engines to operate otter trawl nets. These are grouped into two categories as (1) single-day trawlers of 6.75-9.75 m (30-32 footer) long fitted with 37-68 hp engine that makes daily fishing trips using shrimp net with cod-end mesh-size of 14-20 mm at a depth of 10-25 m. (2) Multi-day fleet of trawlers of 9.75-15 m OAL (36-52 footer) fitted with engines of 53-102 hp make trips lasting up to 7 days and have fish hold of varying capacity to store the catch in ice. They operate in 30-100 m depths but recently they extended their operation to still deeper depths (150 m) targeting non-conventional shrimp and finfish resources. The MDF use two types of nets: shrimp net during night and relatively bigger fish trawl during day. The cod-end mesh size of shrimp net is 18-20 mm and fish net 18-22 mm. The fishing area lies between 10 and 60 km from shore. Peak season of trawling is between December and March.

2.3.4.2. Seines

The seine nets operated are the mechanised purse-seines, during September-May with peak operation during September-December. Whitefish is caught in this gear as incidental catches. The other seine nets are the *matabale* and *ranibale* operated from motorised canoes.

Matabale a boat seine (a small version of purse-seine) operated from two plank- built canoes fitted with out-board engine of 8-15 hp. The net made of 8-10 pieces is of size 240 m in length and 30 m in width and is operated at 8-20 m depth. The mesh size of the net varies from 12 mm to18 mm. About 16-20 people operate the net during calm days in monsoon season.

Ranibale a boat seine similar to Matabale is bigger in size and made of 25-30 pieces. The mesh size of the net is 18-20 mm and is operated from plank built boats at 8-20 m depth.

2.3.4.3. Gillnets

Different types of gill nets operated are the drift gill net, *jeppubale*, *kanthabale*, *pattabale* and *beenibale*. The drift gill net is operated either by mechanised boats or by motorised canoes. The peak period of operation is during September-March. The depth of operation is 30-100 m and whitefish is seldom caught in this gear. The mesh size of the net is 65-135 mm.

Jeppubale is a bottom set gill net without any floats. It is of 80-120 m long and 1 m in height. The mesh size varies from 50mm to 56 mm. The net is set at a depth of 6-10 m in the previous evening and hauled up by next day morning. The catches mainly include crabs, mullets, sciaenids, flatheads and carangids. It is generally operated by 2-3 persons in the coastal inshore waters during monsoon months using dug out canoes (5-6 m length) without outboard engines.

Kanthabale is a bottom-set gill net. The length of the net is 200-300 m and depth is 3.6-4 m with a mesh size of 52-56 mm. It is operated by 4-5 fishermen with wooden canoes (7.6-9.2 m length) fitted with outboard engines in the inshore waters at 4-18 m depths throughout the year for the capture of sciaenids, mackerel, carangids and scomberoids. This gear is operated from Panambur harbour (near Mangalore) during monsoon months and small sized whitefish is caught in appreciable quantities.

Pattabale is a drift gill net of size 20x23 m with mesh size of 60-65 mm. The net is made of 12 to 18 pieces. The depth of operation varies from 11 to 30 m. The net is operated from a plank-built boat (9 m) with outboard engines.

Beenibale is mainly operated at non-mechanised landing centres like Kesarkodi, Gorate and Belke near Bhatkal. This is a set gillnet operated by a single person from a plank built canoe locally known as *marigi* or *pathi* of 3-3.5 m length and using oars for propulsion. The net is made of monofilament and is 275 m in length and 3.7 m in height, joined by 3 pieces and weighs 3 kg. The mesh size is 36-45 mm. The net is set in the middle of the water column and the sinkers used are stones weighing 150-200 g. Plastic floats are set at every 11 m. The pieces are joined by nylon rope of 2.5 mm thickness. The canoes leave at 040-050 h in the morning and return by 07.30-08.0 h. *Lactarius* forms around 30-50 % of the catch in *Beenibale* and the other species caught are *Opisthopterus tardoore*, *Scoliodon* sp., sciaenids, silverbellies and *Penaeus indicus*.

2.3.4.4. Shore Seine

Kai-rampani/Yendi is a small shore seine made up of 50-60 pieces. The total length of the net ranges from 400 m to 500 m with a depth of 7-8

m. The mesh size is 5-6 mm in the middle. It is a popular gear at Karwar and is employed throughout the year in the near-shore waters (up to a depth of 6 m) for shoaling fishes, shrimps and crabs. Depending on the size of the net, 8-20 persons are employed in operating the net.

2.3.5. Gear-wise Landings

Fig.5 shows contribution of whitefish landings by various gears during 1997-98 and 1998-99 pooled. The major gear for whitefish production was trawl net, accounting for 72% of the landings from Karnataka. The catches in 1997-98 and 1998-99 were 1,166 t and 957 t respectively (Table 4). Out of these, the SDF trawlers landed 621 t (53.3%) in 1997-98 whereas in 1998-99 the catch was 341 t (35.6%). The total effort expended by both SDF and MDF together were 22.814 million fishing hours in 1997-98 and 21.61 million fishing hours in 1998-99 at average catch rate (catch per fishing hour) of 0.746 kg/h and 0.382 kg/h respectively. The catch rates were better in SDF compared to MDF.

Seine nets (purse-seine, encircling nets like *matabale*, *ranibale* etc.) accounted for 16% of the landings (252 t in 1997-98 and 227 t in 1998-99) (Table 2). Mechanised gill nets like *pattabale*, *kanthabale* and *jeppubale* as well as non-mechanised gill nets like *beenibale* landed 8% of total whitefish (98 t and 131 t). Gears like shore seine, kairampani, yendi, hand trawl, and hook and line landed the rest of 4% (36 t and 71 t).

About, 65% of the whitefish was obtained by trawl during pre-monsoon (February-May), 34% in post-monsoon (September-January) and less than 1% during monsoon (June-August) period (Fig.8). Seines landed peak catches (about 62%) during monsoon and the rest in post-monsoon. Gill-netters caught maximum catches during monsoon (45%) and post-monsoon (43%). Maximum production by other gears was during post-monsoon (58%) and the rest during monsoon and pre-monsoon.

In trawl, maximum production was in May followed by March, February and April. The catch rate, however, was maximum during June, followed by August, and July (Fig.9).

2.3.6. Season-wise and Month-wise Catches

The peak period of whitefish landing was pre-monsoon months (February-May) recording 60% of the catch. Post-monsoon months (September-January) recorded 33% and monsoon period (June-August), 7%. The month-wise catch analysis shows maximum landings during May followed by March, April and February (Fig.10). During August and September, seines were the major gears followed by trawl (Fig.11). During October trawlers became the dominant gear followed by seine nets and other gears.

2.3.7. Depth-wise Occurrence

For analysing depth-wise occurrence of whitefish, data on catch by different gears were pooled (Fig.12). About 60% of the landing was obtained from 5-30 m depth, wherein the single-day trawl, indigenous gears, purse-seine, shore-seine and hook and line were operated and 40% was from 30-100 m depth where the multi-day trawl boats operated.

2.3.8. Whitefish Fishery at Selected Centres

2.3.8.1. Whitefish Fishery at Mangalore

The estimated whitefish production by all gears at this centre was 452 t in 1997-98 and 506 t in 1998-99. Whitefish formed 1% of the all fish production during 1997-98 (Table 5) and trawlers contributed 443 t (98%), and seines 9 t (2%). During 1997-98 the trawl effort expended was 37,125 fishing trips or 10.4 lakh fishing hours by both multi-day and single day trawlers at a catch rate of 0.42 kg/h. In 1998-99, the production increased to 506 t with 99.6% of the catch by trawlers at catch rate of 0.47 kg/h. Maximum catch (132 t) and catch rate (0.75 kg/h) in trawl were recorded during May 1999.

When the data pooled for both the years (Table 5), it is seen that trawlers landed 947 t (98.9%) and seine nets 7 t (1.1%). Whitefish formed 1.6% of the all-fish catch at a catch rate of 0.44 kg/h. Month-wise analysis of catch by trawl shows that maximum production as well as catch rate (0.69 kg/h) was in May.

Maximum production was recorded during pre-monsoon period (60.6%) followed by post-monsoon months (37.5%) and the minimum in monsoon (1.9%).

2.3.8.2. Whitefish Fishery at Malpe

The total whitefish production by all gears was 388 t in 1997-98, and 233 t in 1998-99 forming 0.9 % and 0.7% of all-fish production respectively (Table 6). In the pooled data for 2 years, trawl contribution was 72%, seines 25.6%; indigenous gillnets 0.5% and other gears (hand trawl) 2%. Whitefish production by trawl was 307 t in 1997-98, which reduced to almost half in 1998-99 (152 t). The trawling effort expended was 7.1 lakh fishing hours in 1997-98 and 5.2 lakh fishing hours in 1998-99 and catch rates were 0.43 kg/h and 0.29 kg/h respectively. Month-wise landing data showed maximum production during March and the maximum catch rate (kg/h) during June (1.14 kg/h). In the landing data by trawl pooled for two years whitefish formed 1% of all-fish landed by trawl with a catch rate of 0.37 kg/h. Among trawlers, the multi-day trawlers accounted for 67% and single-day trawlers 33 %.

Purse-seiners landed 2 t in 1997-98 and 59 t in 1998-99. Maximum catch was landed during September-October in 1998. Other indigenous seine nets (*matabale* and *pattabale*) landed 79 t during July-August in 1997-

98 and 19 t during August in 1998-99. The production during the post-monsoon period was 27.5%, pre-monsoon 54% and monsoon 18.5%.

2.3.8.3. Whitefish Fishery at Karwar

The landing of whitefish by all gears was 130 t in 1997-98, which drastically decreased to 55 t in 1998-99 (Table 7). The major gears in use at this centre were purse-seines, out-board ring seines, trawl nets, gill nets operated by motorised and non-motorised canoes, and hook and line used by motorised canoes. Trawlers landed the entire whitefish catch in 1997-98 expending an effort of 20,266 fishing trips/1.25 lakh fishing hours at a catch rate of 1.04 kg/h. In 1998-99, the catch fell to 21 t with 0.69 lakh fishing hours and 9,257 boat trips. The catch rate of whitefish also reduced to 0.30 kg/h. Purse-seiners with an effort of 3,965 boat trips landed the rest of the catch in 1998-99. In the pooled data, the percentage contribution was 81.6% by the former and 18.4% by the latter gears. At this centre whitefish formed 0.81% of the all-fish catch. In trawl 151 t was estimated to have landed forming 1.4% of the all-fish catch at catch rate of 0.78 kg/h. SDF trawlers contributed maximum catch (94%). The post-monsoon period contributed 39.4%, pre-monsoon period 58.4% and monsoon period 2.2%.

2.3.9. Whitefish Fishery at Other Mechanised Centres

2.3.9.1. Whitefish Fishery at Gangoli

The whitefish landing at Gangoli amounted to 69 t in 1997-98, which increased to 88 t in 1998-99 (Table 8). Mostly SDF trawlers carry out the operation at this centre. Trawlers obtained the entire catch in 1997-98 whereas, in 1998-99, about 92% (81 t) of the catch was landed by trawl, 5.7% (5 t) by seine nets and 2.3% (2 t) by gill nets. In trawl, maximum catch was observed during April 1998 but catch rate was maximum in May 1998. Whitefish formed 1.1% of all-fish catch by trawl at a catch rate of 0.64 kg/h. In 1998-99, maximum catch was recorded in May 1999 at a catch rate of 3.34 kg/h. Pooled data for two years showed (Table 8) that trawlers contributed 95.5%, gill-netters 1.3% and indigenous gears 3.2%. Whitefish formed 1% of the total trawl fish catch for an effort of 33,212 fishing trips or 1.9 lakh fishing hours at a catch rate of 0.75 kg/h. Post-monsoon months recorded 43% of the catch and rest during pre-monsoon months

2.3.9.2. Whitefish Fishery at Bhatkal

The major gears operated at this centre were purse-seine, trawl (SDF), hook and line and seine net (Table 9). Whitefish was landed only by trawl and *matabale* with 23 t in 1997-98 and 67 t in 1998-99. Trawl contributed 18 t of whitefish forming 1% of the total trawl catch in 1997-98 and 23 t in 1998-99. The increase in 1998-99 was mainly due to the landing of 43 t by *matabale* in August 1999. The percentage contribution was 54.4% by trawl and 45.6% by seine nets. Overall, whitefish formed only 0.33% of all-fish catch at this centre. In trawl, whitefish formed 1.41% of all-fish landed at a catch rate of 0.64 kg/h. While the post-monsoon period contributed to 23.3% of whitefish production, pre-monsoon and monsoon periods contributed to 28.9% and 47.8% respectively.

2.3.9.3. Whitefish Fishery at Tadri

The principal gears employed were purse seine, trawl (SDF and MDF) and the indigenous gears like gill net and *disco net* (Table 10). *Disco nets* (canoe fitted with outboard engine operating encircling net) and SDF and MDF trawlers landed whitefish. The landing of whitefish by all gears was 92 t in 1997-98, which fell to 39 t in 1998-99. Trawl obtained the entire catch in 1997-98 and in 1998-99, 11 t was obtained by seine and the rest by trawl. The pooled data (Table 10) showed that trawl nets landed 120 t at a catch rate of 0.42 kg/h. The percentage contribution was 91.6% by trawlers and 8.4% by *disco nets*. Whitefish formed 0.82% of the all-fish catch. While post-monsoon period contributed 40% to the annual whitefish landings, pre-monsoon period recorded 58% and monsoon period 2%.

2.3.10. Marketing and Disposal

Whitefish is considered as an esteemed table fish among the coastal population of Karnataka. It is locally called *Ademeenu* in Dakshina Kannada, *Saundale* in Bhatkal and *Saundale* or *Adabanagu* in Uttara Kannada. While majority of the whitefish catch is consumed in fresh condition, it is also transported to interior places in iced or cured condition. During peak periods of production, excess catch is salt cured or sun dried after applying salt and marketed in distant places. Neelakantan (1981) has described the various methods of processing of whitefish. The first one is the wet process or *Ratnagiri* method in which the salt is applied in three stages and the fish is stacked and kept for three days. A loss of weight of 25% is reported in this process. The final product can be kept for 5-6 months but the quality depends upon the humidity and air temperature of the season and place. In the second process the fish are sun-dried after applying salt over the gutted fish and kept in cement tanks with intermittent layers of salt for 2 days.

The price of big sized fish varies from Rs. 60 to100 kg^{-1} and small ones fetch Rs.40-60 kg^{-1}. The price of dried fish varies from Rs. 120-160 kg^{-1}.

2.4. DISCUSSION

The annual average production of whitefish in India increased from 7,640 t in 1960-69, to 8,765 t in 1970-79 and further to 13,705 t in 1980-89 but fell to 6,997 t in 1990-99 (Table 1). The record production during 1980-89 was due to the expansion of fishing grounds and introduction of multi-day trawl fishing (Zacharia *et al.*, 1996). While production of whitefish from east coast of India declined from 4,738 t in 1960-69 to 888 t in 1990-99, west coast recorded a sharp increase from 2,901 t in 1960-69 to reach the peak of 12,354 t in 1980-89 and however, the white fish catch declined drastically to reach 6,109 t in 1990-99. The average contribution of whitefish from the west coast was 74.2% for the 4 decades (1960s, 1970s, 1980s and 1990s) and the east coast was 25.9%. The northwest coast has emerged as the major contributor of whitefish during 1980s and 1990s and the fall in catch has reflected in the all-India landings. The landing was mainly contributed by Gujarat, which rose to play a deterministic role in

India's whitefish production during 1971-1999 (Vivekanandan *et al.*, 2000). The production was maximum during 1980s but decreased in 1990s.

Along the southwest coast, though the production declined in Kerala it was compensated by the increase in catch in Karnataka (Fig 4). The landings along southeast coast has declined drastically whereas, the catch has not decreased along northeast coast. Though *L. lactarius* has been suggested as a vulnerable species (James, 1994) it is viewed that conclusion on vulnerability should be based on decline in biomass rather than mere reduction in catches (Vivekanandan *et al.*, 2000). Nonetheless, the consistency in the decline in the landing of *L. lactarius* in the southeast coast is a cause of concern. As whitefish perform vertical migration for feeding their favourite food anchovies, introduction of high opening trawls have effectively caught these resources. The absence of seasonal ban on fishing in southeast coast could be one of the reasons for the decline. In Karnataka currently the whitefish production has stabilised around 1,100 t though, the all-fish production has increased from 0.18-lakh t to 1.83 t. However, the decadal production shows an increasing trend up to 1990 and thereafter the catch has fallen. The decadal average production of whitefish from Karnataka is similar to the trend of all India whitefish production.

During 1978-79 the major gears for *Lactarius* capture along Uttara Kannada coast were shore-seines (Rampani) and cast nets and trawl net was third important gear (Neelakantan, 1981). The present investigation revealed a shift in that the trawl has become the dominant gear and seines and gill nets caught only about 16% of whitefish, mainly during the monsoon season. Purse-seine occasionally catches whitefish while the fish ascend in the water column for feeding. Individuals of *Lactarius* congregate between 20 m and 45 m and 30-35 m depth being the optimum (Kaikini, 1974). During the present study, 60% of landing was obtained from 5-30 m depth and the rest from above 30 m depths indicating that the depth range of maximum occurrence of *L. lactarius* is between 5 and 30 m.

Though the benthic production in the North Karnataka coast is high during late post-monsoon (Harkantra and Parulekar, 1981) and rich fishery is related to up welling during southwest monsoon along the southwest coast, the present study indicates that *L. lactarius* was abundant during pre-monsoon than during monsoon and post-monsoon seasons (Fig.8). This finding corroborates well with an earlier study from the region (Neelakantan, 1981).

Along the Karnataka coast, Mangalore appears to be the most productive centre (44.7%) for *Lactarius* followed by Malpe (29%) (Fig.13). These two principal landing centres in Karnataka record about 40 % of marine fish production of the state (Zacharia *et al.*, 1996). Also about 73% of the whitefish is landed from these two centres. It is also evident from the catch statistics that the production of whitefish decreases gradually from Mangalore to Karwar i.e., south to north. Trawl net is the most efficient gear for harvesting *Lactarius* in all the centres and single-day units landed 957 t (45%) and multi-day units landed 1,161 t (55%) of the whitefish catch. The multi-day units introduced in the 1980's was responsible for increased whitefish production. This may be mainly due to the MDF trawlers venturing into deeper waters for shrimps and squids. Though *Lactarius* is found to occur up to 100 m (FAO, 1974) the optimum depth appears to be 10 to 30 m depths.

The decline of *L. lactarius* catches along the southwest coast of India is attributed to the habitat damage (James, 1994) and irrational bottom trawling along the coastal waters that have severely trampled the benthic communities (Bensam and Menon, 1994). As the shallow coastal waters serve as nursery grounds for a number of finfish and shellfish species, large scale trawling along these regions might be responsible for mass removal of juveniles and sub-adults of this species, which ultimately has led to growth over-fishing.

Though the introduction of medium sized trawlers for exploiting marine fishery resource is a positive step towards diversification of fishing activity, the long term effect of this on the demersal fishes needs a critical study as the bottom trawling is known to adversely affect the benthos which forms the food of demersal fishes ((Jennings and Kaiser, 1998). As *L. lactarius* feeds mainly on small crustaceans (*Acetes*) and the diet spectrum of this species was found to be narrow (see chapter 3 on food and feeding), even small changes in the abundance of food item brought out by bottom disturbances due to trawling would affect abundance and fishery of *Lactarius*. Further, a decrease in cod-end mesh-size of 10 mm for shrimp nets and 12 mm for fishnets is observed at Mangalore from what was reported in a 1989-90 study (Rao *et al.*, 1990), which is a matter of serious concern. Since whitefish forms a component in the multi-species trawl fisheries, it may not be possible to evolve management options exclusively for one species. However, effective regulation of fishing effort, coupled with regulation in mesh size and uniform period of closed seasons is required for sustainability of whitefish resource along Karnataka and other Indian coasts.

Table 1. Decadal average landings (t) of whitefish along Indian coast.

	1960-69	*%*	*1970-79*	*%*	*1980-89*	*%*	*1990-99*	*%*	*Average*	*%*
North-West coast	163	2.13	3178	36.26	8777	64.05	3313	47.35	15431	41.59
South-West coast	2722	35.63	3008	34.32	3577	26.10	2795	39.95	12103	32.62
West coast	*2885*	*37.76*	*6186*	*70.58*	*12354*	*90.15*	*6108*	*87.31*	*27534*	*74.20*
North-East coast	20	0.27	17	0.19	37	0.27	151	2.16	226	0.61
South-East coast	4736	61.98	2561	29.22	1313	9.58	736	10.53	9347	25.19
East coast	*4756*	*62.24*	*2578*	*29.42*	*1350*	*9.85*	*888*	*12.69*	*9573*	*25.80*
Total	**7641**	**20.59**	**8764**	**23.62**	**13704**	**36.93**	**6996**	**18.86**	**37107**	**100**

Table 2. Whitefish catch (t) by different gears in Karnataka during 1997-98 and 1998-99.

	Trawl Net	Mech. Seine nets	Non-mech. Seine nets	Mech. Gill nets	Non-mech. Gill nets	Other Gears	Total All gears	All Fish Catch	% in all fish catch
1997-98									
September	38	55	0	7	0	0	100	32447	0.31
October	124	1	0	0	0	16	141	36071	0.39
November	104	0	0	0	0	5	109	15471	0.70
December	76	1	0	0	0	0	77	16050	0.48
January	85	0	4	1	0	0	90	13730	0.66
February	139	0	2	1	1	0	143	11788	1.21
March	242	3	0	9	4	0	258	17438	1.48
April	149	0	0	4	6	0	159	9154	1.74
May	203	0	0	3	41	0	247	11149	2.22
June	0	0	0	2	4	0	6	172	3.49
July	3	37	0	0	0	12	52	2882	1.80
August	3	141	8	0	15	3	170	5679	2.99
Total	**1166**	**238**	**14**	**27**	**71**	**36**	**1552**	**172031**	**0.90**
1998-99									
September	10	57	15	0	0	0	82	30602	0.27
October	36	40	0	0	0	18	94	21287	0.44
November	62	5	0	16	0	23	106	24754	0.43
December	70	0	0	0	0	0	70	14552	0.48
January	104	0	1	0	4	0	109	16625	0.66
February	145	0	0	3	0	2	150	14367	1.04
March	193	0	0	1	0	9	203	19884	1.02
April	133	0	0	1	0	0	134	10173	1.32
May	197	0	0	10	14	12	233	6268	3.72
June	2	25	4	26	36	2	95	2147	4.42
July	1	0	2	0	18	0	21	1326	1.58
August	4	76	2	0	2	5	89	15612	0.57
Total	**957**	**203**	**24**	**57**	**74**	**71**	**1386**	**177597**	**0.78**
POOLED									
September	48	112	15	7	0	0	182	63049	0.29
October	160	41	0	0	0	34	235	57358	0.41
November	166	5	0	16	0	28	215	40225	0.53
December	146	1	0	0	0	0	147	30602	0.48
January	189	0	5	1	4	0	199	30355	0.66
February	284	0	2	4	1	2	293	26155	1.12
March	435	3	0	10	4	9	461	37322	1.24
April	282	0	0	5	6	0	293	19327	1.52
May	400	0	0	13	55	12	480	17417	2.76
June	2	25	4	28	40	2	101	2319	4.36
July	4	37	2	0	18	12	73	4208	1.73
August	7	217	10	0	17	8	259	21291	1.22
Total	**2123**	**441**	**38**	**84**	**145**	**107**	**2938**	**349628**	**0.84**

Table 3. Month-wise estimated effort, catch and catch rate of *L. lactarius* in different gears pooled for all mechanised landing centers in Karnataka during 1997-98 and 1998-99.

	TRAWL					SEINES					GILL NET				OTHER GEARS				TOTAL			
	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)
1997-88																						
September	5178	149342	8173	38	0.25	12180	31778	20242	4	0.01	1681	12393	219	0	0	0	0	0	19039	193513	28634	42
October	11944	235416	9193	120	0.51	13373	38651	20056	0	0	2528	20525	268	0	0	0	0	0	27845	294592	29517	120
November	13708	210905	6454	94	0.45	6173	14220	6769	0	0	1856	13346	122	0	0	0	0	0	21737	238471	13345	94
December	14948	227310	8884	66	0.29	5136	10449	4931	0	0	774	6883	30	0	171	383	48	0	21029	245025	13893	66
January	14601	226761	9365	81	0.36	4130	8808	2420	0	0	1254	7544	49	0	0	0	0	0	19985	243113	11834	81
February	13377	236637	9319	125	0.53	2431	10809	996	0	0	620	2345	30	0	23	186	3	0	16451	249977	10348	125
March	17220	321569	13526	199	0.62	2910	7223	1784	3	0.04	1738	6109	48	0	0	0	0	0	21868	334901	15358	202
April	16102	230684	6974	128	0.55	1355	2699	573	0	0	333	1710	18	0	0	0	0	0	17790	235093	7565	128
May	15972	285592	8661	190	0.67	1717	2220	827	0	0	1064	8525	111	0	0	0	0	0	18753	296337	9599	190
June	445	879	12	0	0	0	0	0	0	0	173	1928	1	0	0	0	0	0	618	2807	13	0
July	1489	7031	161	3	0.43	1545	3483	1803	37	1.06	1487	3667	581	0	2327	6153	92	12	3658.4	20334	2637	52
August	1038	3456	46	3	0.87	3388	8747	3146	51	0.58	269	821	115	0	64	106	2	0	4759	13130	3309	54
Total	**126022**	**2135582**	**80768**	**1047**	**0.49**	**54338**	**139087**	**63547**	**95**	**0.07**	**13777**	**85796**	**1592**	**0**	**2585**	**6828**	**145**	**12**	**193532**	**2367293**	**146052**	**1154**
1998-99																						
September	4903	142492	2375	10	0.43	10177	15618	16854	57	0.36	2806	19761	667	0	10	40	1	0	17294	175551	18333	67
October	4379	111896	3814	36	3.58	8757	35454	14130	40	0.11	3046	23836	320	0	0	0	0	0	16182	171186	18264	76
November	8085	209821	7218	58	6.46	7052	15681	13350	2	0.01	2870	20881	307	0	30	106	3	0	18037	246489	20878	60
December	9730	165892	4727	65	3.35	6503	13618	7377	0	0	2835	21554	246	0	16	43	1	0	19084	201107	12351	65
January	15494	226822	8972	103	1.20	4927	11082	3632	0	0	2173	17428	125	0	0	0	0	0	22594	255332	12729	103
February	14338	239043	9437	86	1.40	2332	5571	1814	0	0	596	4754	33	3	0	0	0	0	17266	249368	11284	89
March	15581	279702	12228	118	1.80	3202	10616	1853	0	0	2294	14947	148	1	8	16	1	0	21085	305281	14230	119
April	16424	302536	11812	133	4.48	1154	2510	523	0	0	850	7358	66	1	0	0	0	0	18428	312404	12401	134
May	9096	265569	4505	194	9.76	1555	10542	847	11	0.10	1197	5530	176	0	0	0	0	0	11848	281641	5528	205
June	630	1618	24	2	1.24	500	900	565	0	0	260	455	64	0	192	1003	8	0	0	3976	661	2
July	218	1113	8	0	0	545	1837	476	0	0	0	0	0	0	0	0	0	0	763	2950	484	0
August	1699	10511	144	4	0.78	5569	13743	5900	64	0.47	98	613	6	0	0	0	0	0	7366	24867	6050	68
Total	**100577**	**1957015**	**65264**	**809**	**0.41**	**52273**	**137172**	**67321**	**174**	**0.13**	**19025**	**137117**	**2158**	**5**	**256**	**1208**	**14**	**0**	**169947**	**2230152**	**133193**	**988**
Pooled																						
September	10081	291834	10548	48	0.16	22357	47396	37096	61	1.29	4487	32154	886	0	10	40	1	0	36333	369064	46967	109
October	16323	347312	13007	156	0.45	22130	74105	34186	40	0.54	5574	44361	588	0	0	0	0	0	44027	465778	47781	196
November	21793	420726	13672	152	0.36	13225	29901	20119	2	0.07	4726	34227	429	0	30	106	3	0	39774	484960	34223	154
December	24678	393202	13611	131	0.33	11639	24067	12308	0	0	3609	28437	276	0	187	426	49	0	40113	446132	26244	131
January	30095	453583	18337	184	0.41	9057	19890	6052	0	0	3427	24972	174	0	0	0	0	0	42579	498445	24563	184
February	27715	475680	18756	211	0.44	4763	16380	2810	0	0	1216	7099	63	3	23	186	3	0	33717	499345	21632	214
March	32801	601271	25754	317	0.53	6112	17839	3637	3	0.17	4032	21056	196	1	8	16	1	0	42953	640182	29588	321
April	32526	533220	18786	261	0.49	2509	5209	1096	0	0	1183	9068	84	1	0	0	0	0	36218	547497	19966	262
May	25068	551161	13166	384	0.70	3272	12762	1674	11	0.86	2261	14055	287	0	0	0	0	0	30601	577978	15127	395
June	1075	2497	36	2	0.80	500	900	565	0	0	433	2383	65	0	192	1003	8	0	618	6783	674	2
July	1707	8144	169	3	0.37	2090	5320	2279	37	6.95	1487	3667	581	0	2327	6153	92	12	4421.4	23284	3121	52
August	2737	13967	190	7	0.50	8957	22490	9046	115	5.11	367	1434	121	0	64	106	2	0	12125	37997	9359	122
Total	**226599**	**4092597**	**146032**	**1856**	**0.45**	**106611**	**276259**	**130868**	**269**	**0.97**	**32802**	**222913**	**3750**	**5**	**2841**	**8036**	**159**	**12**	**363479**	**4597445**	**279245**	**2142**

TC=Total catch; LC=*Lactarius* catch;C/E= Catch per unit effort; F.hrs=Fishing hours

Table 4. Month-wise catch of *L. lactarius* (t) in trawl in Karnataka during 1997-98 and 1998-99.

	Single Day Fishing Fleet				**Multi-Day Fishing Fleet**				**Total**			
	Effort (Fish.hrs)	Total Catch (t)	Lact catch (t)	Catch rate (kg/hr)	Effort (Fish.hrs)	Total Catch (t)	Lact catch (t)	Catch rate (kg/hr)	Effort (Fish.hrs)	Total Catch (t)	Lact catch (t)	Catch rate (kg/hr)
1997-98												
September	64781	2883	31	0.479	97542	5452	7	0.072	162323	8335	38	0.234
October	79670	3318	68	0.854	180908	7119	56	0.310	260578	10437	124	0.476
November	16898	4366	44	2.604	125574	2850	60	0.478	142472	7216	104	0.730
December	40941	5669	28	0.684	142204	4659	48	0.338	183145	10328	76	0.415
January	141611	5503	42	0.297	125529	4593	43	0.343	267140	10096	85	0.318
February	113525	4272	67	0.590	185729	5750	72	0.388	299254	10022	139	0.464
March	136384	6045	115	0.843	241831	8865	127	0.525	378215	14910	242	0.640
April	109702	4406	113	1.030	147109	3631	36	0.245	256811	8037	149	0.580
May	120074	3783	107	0.891	202922	5619	96	0.473	322996	9402	203	0.628
June	341	6	0	0.000	0	0	0	0.000	341	6	0	0.000
July	7031	161	3	0.427	0	0	0	0.000	7031	161	3	0.427
August	1112	18	3	2.698	0	0	0	0.000	1112	18	3	2.698
Total	**832070**	**40430**	**621**	0.746	**1449348**	**48538**	**545**	0.376	**2281418**	**88968**	**1166**	**0.511**
1998-99												
September	14377	1101	10	0.696	128284	6786	0	0	142661	7887	10	0.070
October	75685	1394	15	0.198	46991	2635	21	0.447	122676	4029	36	0.293
November	57142	1995	34	0.595	161480	5343	28	0.173	218622	7338	62	0.284
December	71271	2858	28	0.393	113806	2721	42	0.369	185077	5579	70	0.378
January	163295	6659	2	0.012	148109	5056	102	0.689	311404	11715	104	0.334
February	140587	6053	37	0.263	153051	5741	108	0.706	293638	11794	145	0.494
March	210827	7672	82	0.389	161715	8135	111	0.686	372542	15807	193	0.518
April	78408	3181	64	0.816	120897	6341	69	0.571	199305	9522	133	0.667
May	57518	1305	62	1.078	235257	3668	135	0.574	292775	4973	197	0.673
June	1025	36	2	1.951	0	0	0	0.000	1025	36	2	1.951
July	4635	153	1	0.216	0	0	0	0.000	4635	153	1	0.216
August	17097	359	4	0.234	0	0	0	0.000	17097	359	4	0.234
Total	891867	32766	341	0.382	1269590	46426	616	0.485	2161457	79192	957	0.443
Average	**861969**	**36598**	**481**	**0.558**	**1359469**	**47482**	**580.5**	**0.427**	**2221438**	**84080**	**1061.5**	**0.477**

Table 5. Month-wise estimated effort, catch and catch rate of *L. lactarius* in different gears at Mangalore during 1997-98 and 1998-99.

	TRAWL					SEINES					GILL NET				OTHER GEARS				TOTAL			
	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)
1997-88																						
September	2290	95086	5546	24	0.25	2465	6063	4951	0	0	965	7336	166	0					5720	108485	10663	24
October	3791	130418	4764	66	0.51	2094	2094	4752	0	0	930	7440	86	0					6815	139952	9602	66
November	4380	124040	2793	68	0.55	1140	2484	1058	0	0	356	2850	11	0					5876	129374	3862	68
December	5217	125961	3854	46	0.37	1218	2712	1855	0	0	248	2077	14	0					6683	130750	5723	46
January	5105	109772	3505	28	0.26	821	1792	858	0	0	336	3449	17	0					6262	115013	4380	28
February	4047	98259	2605	42	0.43	606	2381	474	0	0	256		12	0					4909	100640	3091	42
March	4535	126501	3424	55	0.43	850	1870	788	0	0	430		21	0					5815	128371	4233	55
April	2952	87788	1540	23	0.26	416	759	186	0	0	60	480	4	0					3428	89027	1730	23
May	4395	145837	3066	91	0.62	441	776	438	0	0	417	3475	62	0					5253	150088	3566	91
June	413	568	6	0	0.00														413	568	6	0
July	0	0	0	0	0.00	599	1139	409	3	2.63	475	1248	96	0	289	529	2	0	1363	2916	507	3
August	0	0	0	0	0.00	299	546	188	6	10.99	160	569	5		32	53	1	0	491	1168	194	6
Total	**37125**	**1044230**	**31103**	**443**	**0.42**	**10949**	**22616**	**15957**	**9**	**0.40**	**4633**	**28924**	**494**	**0**	**321**	**582**	**3**	**0**	**53028**	**1096352**	**47557**	**452**
1998-99																						
September	1876	115724	169	1	0.01	2535	2124	5014	0	0	1260	7577	428	0					5671	125425	5611	1
October	1690	49936	2828	25	0.50	1407	1910	3164	0	0	860	6883	84	0					3957	58729	6076	25
November	3340	129565	3813	28	0.22	2557	4677	5125	0	0	747	5973	52	0					6644	140215	8990	28
December	3019	106184	2584	40	0.38	1903	4239	3330	0	0	980	7843	91	0					5902	118266	6005	40
January	4629	116291	4430	75	0.64	909	2181	458	0	0	1018	8538	61	0					6556	127010	4949	75
February	5020	129568	4713	57	0.44	630	1511	444	0	0	0	0	0	0					5650	131079	5157	57
March	5162	135836	6529	93	0.68	728	1815	431	0	0	832	7037	47	0					6722	144688	7007	93
April	5055	124058	3267	53	0.43	64	160	41	0	0	0	0	0	0					5119	124218	3308	53
May	3503	176512	2652	132	0.75	0	0	0	0	0	303	2580	9	0					3806	179092	2661	132
June	0	0	0	0	0.00	0	0	0	0	0									0	0	0	0
July	0	0	0	0	0.00	0	0	0	0	0									0	0	0	0
August	0	0	0	0	0.00	364	730	206	2	0.27									364	730	206	2
Total	**33294**	**1083674**	**30985**	**504**	**0.47**	**11097**	**19347**	**18213**	**2**	**0.01**	**6000**	**46431**	**772**	**0**	**0**	**0**	**0**	**0**	**50391**	**1149452**	**49970**	**506**
Pooled																						
September	4166	210810	5715	25	0.119	5000	8187	9965	0	0	2225	14913	594	0	0	0	0	0	11391	233910	16274	25
October	5481	180354	7592	91	0.505	3501	4004	7916	0	0	1790	14323	170	0	0	0	0	0	10772	198681	15678	91
November	7720	253605	6606	96	0.379	3697	7161	6183	0	0	1103	8823	63	0	0	0	0	0	12520	269589	12852	96
December	8236	232145	6438	86	0.370	3121	6951	5185	0	0	1228	9920	105	0	0	0	0	0	12585	249016	11728	86
January	9734	226063	7935	103	0.456	1730	3973	1316	0	0	1354	11987	78	0	0	0	0	0	12818	242023	9329	103
February	9067	227827	7318	99	0.435	1236	3892	918	0	0	256	0	12	0	0	0	0	0	10559	231719	8248	99
March	9697	262337	9953	148	0.564	1578	3685	1219	0	0	1262	7037	68	0	0	0	0	0	12537	273059	11240	148
April	8007	211846	4807	76	0.359	480	919	227	0	0	60	480	4	0	0	0	0	0	8547	213245	5038	76
May	7898	322349	5718	223	0.692	441	776	438	0	0	720	6055	71	0	0	0	0	0	9059	329180	6227	223
June	413	568	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	413	568	6	0
July	0	0	0	0	0	599	1139	409	3	2.63	475	1248	96	0	289	529	2	0	1363	2916	507	3
August	0	0	0	0	0	663	1276	394	8	6.27	160	569	5	0	32	53	1	0	855	1898	400	8
Total	**70419**	**2127904**	**62088**	**947**	**0.45**	**22046**	**41963**	**34170**	**11**	**0.26**	**10633**	**75355**	**1266**	**0**	**321**	**582**	**3**	**0**	**103419**	**2245804**	**97527**	**958**

TC=Total catch; LC=*Lactarius* catch;C/E= Catch per unit effort; F.hrs=Fishing hours

Table 6. Month-wise estimated effort, catch and catch rate of *L. lactarius* in different gears at Malpe during 1997-98 and 1998-99.

	TRAWL					SEINES					GILL NET				OTHERS				TOTAL			
	Unit	Effort (F hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F hrs)	TC (t)	LC (t)	Unit	Effort (F hrs)	TC (t)	LC (t)	Unit	Effort (F hrs)	TC (t)	LC (t)
1997-88																						
September	1374	47511	2410	11	0.23	2232	3400	2987	0	0	186	1451	26	0					3792	52362	5423	11
October	3052	71827	2892	13	0.18	3541	6323	5574	0	0	792	7166	87	0					7385	85316	8553	13
November	3765	51845	1812	7	0.14	1000	1749	805	0	0	765	6697	37	0					5530	60291	2654	7
December	3155	57933	2353	5	0.09	696	1511	653	0	0	262	2945	13	0					4113	62389	3019	5
January	2846	76521	2918	25	0.33	583	1611	528	0	0	608	2384	25	0					4037	80516	3471	25
February	3125	98553	3789	36	0.37	264	632	168	0	0					23	186	3	0	3412	99371	3960	36
March	4185	137244	6049	80	0.58	412	1135	340	2	1.76	859	3417	0						5456	141796	6389	82
April	3521	70943	2437	45	0.63	214	451	122	0	0.00	83	660	5	0					3818	72054	2564	45
May	4379	90837	3892	70	0.77	132	380	127	0	0.00	616	4929	46						5127	96146	4065	70
June	2	131	1	0	0.00					0.00									2	131	1	0
July						850	2056	1358	34	16.54	593	1652	481	0	1749	5095	88	12	2.36	8803	1927	46
August	903	3084	35	3	0.97	1151	2856	1365	45	15.76	109	252	110	0					2163	6192	1510	48
Total	**30307**	**706429**	**28588**	**295**	**0.42**	**11075**	**22104**	**14027**	**81**	**3.66**	**4873**	**31553**	**830**	**0**	**1772**	**5281**	**91**	**12**	**44837**	**765367**	**43536**	**388**
1998-99																						
September	1761	21388	1567	9	0.42	3746	5052	5915	55	10.887	896	7991	72	0					6403	34431	7554	64
October	1345	15101	570	3	0.20	1705	10229	2748	4	0.391	1054	8504	109	0					4104	33834	3427	7
November	2389	68154	2563	8	0.12	473	458	817	0	0	210	1680	25	0					3072	70292	3405	8
December	1358	24491	505	3	0.12	431	626	391	0	0	978	7723	74	0					2767	32840	970	3
January	3696	68135	1892	26	0.38	118	293	175	0	0	434	4678	19	0					4248	73106	2086	26
February	3382	53405	2253	25	0.47	196	507	138	0	0	498	4523	29	3					4076	58435	2420	28
March	4030	69797	3127	20	0.29	553	1429	688	0	0	346	2845	21	0					4929	74071	3836	20
April	4650	126456	6359	40	0.32	90	135	47	0	0	690	5520	32	0					5430	132111	6438	40
May	1911	68384	1188	16	0.23	165	248	106	0	0	206	1653	5	0					2282	70285	1299	16
June	630	1618	24	2	1.24	500	900	565	0	0	260	455	64	0	192	1003	8	0	0.00	3976	661	2
July						545	1837	476	0	0									737	2840	484	0
August	165	833	8	0	0.00	1218	2387	925	19	7.960	93	557	5	0					1476	3777	938	19
Total	**25317**	**517762**	**20056**	**152**	**0.29**	**9740**	**24101**	**12991**	**78**	**3.236**	**5665**	**46129**	**455**	**3**	**192**	**1003**	**8**	**0**	**39524**	**589998**	**33518**	**233**
Pooled																						
September	3135	68899	3977	20	0.29	5978	8452	8902	55	6.507	1082	9442	98	0	0	0	0	0	10195	86793	12977	75
October	4397	86928	3462	16	0.18	5246	16552	8322	4	0.242	1846	15670	196	0	0	0	0	0	11489	119150	11980	20
November	6154	119999	4375	15	0.13	1473	2207	1622	0	0.0	975	8377	62	0	0	0	0	0	8602	130583	6059	15
December	4513	82424	2858	8	0.10	1127	2137	1044	0	0.0	1240	10668	87	0	0	0	0	0	6880	95229	3989	8
January	6542	144656	4810	51	0.35	701	1904	703	0	0.0	1042	7062	44	0	0	0	0	0	8285	153622	5557	51
February	6507	151958	6042	61	0.40	460	1139	306	0	0.0	498	4523	29	3	23	186	3	0	7488	157806	6380	64
March	8215	207041	9176	100	0.48	965	2564	1028	2	0.8	1205	6262	21	0	0	0	0	0	10385	215867	10225	102
April	8171	197399	8796	85	0.43	304	586	169	0	0.0	773	6180	37	0	0	0	0	0	9248	204165	9002	85
May	6290	159221	5080	86	0.54	297	628	233	0	0.0	822	6582	51	0	0	0	0	0	7409	166431	5364	86
June	632	1749	25	2	1.14	500	900	565	0	0.0	260	455	64	0	192	1003	8	0	2	4107	662	2
July	0	6098	96	0	0.00	1395	3893	1834	34	8.734	593	1652	481	0	1749	5095	88	12	739.36	11643	2411	46
August	1068	3917	43	3	0.77	2369	5243	2290	64	12.207	202	809	115	0	0	0	0	0	3639	9969	2448	67
Total	**55624**	**1230289**	**48740**	**447**	**0.36**	**20815**	**46205**	**27018**	**159**	**3.441**	**10538**	**77682**	**1285**	**3**	**1964**	**6284**	**99**	**12**	**84361**	**1355365**	**77054**	**621**

TC=Total catch; LC=*Lactarius* catch;C/E= Catch per unit effort; F hrs=Fishing hours

Table 8. Month-wise estimated effort, catch and catch rate of *L. lactarius* in different gears at Gangoli during 1997-98 and 1998-99.

	TRAWL					SEINES					GILL NET				OTHER GEARS				TOTAL			
	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)
1997-98																						
September	510	2267	56	0	0	3270	6340	3260	0	0	530	3606	27	0					4310	12213	3343	0
October	2457	16532	742	14	0.85	3542	6769	4904	0		806	5919	95	0					6805	29220	5741	14
November	2955	16908	1114	4	0.24	2168	4468	3270	0		735	3799	74	0					5858	25175	4458	4
December	2511	17469	1206	5	0.29	1085	1167	284	0		264	1861	3	0	171	383	48		4031	20880	1541	5
January	2333	15066	718	3	0.20	1489	2522	441	0		310	1711	7	0					4132	19299	1166	3
February	1519	9660	467	5	0.52	791	2233	150	0		364	2345	18						2674	14238	635	5
March	1728	10061	663	9	0.89	682	1429	248	0		449	2692	27	0					2859	14182	938	9
April	2290	13591	928	20	1.47	580	1171	195	0		190	570	9	0					3060	15332	1132	20
May	982	5762	279	9	1.56	733	855	208	0		31	121	3	0					1746	6738	490	9
June																			0	0	0	0
July																			0	0	0	0
August																			0	0	0	0
Total	**17285**	**107316**	**6173**	**69**	**0.643**	**14340**	**26954**	**12960**	**0**	**0**	**3679**	**22624**	**263**	**0**	**171**	**383**	**48**	**0**	**35475**	**157277**	**19444**	**69**
1998-99																						
September	1230	5242	612	0	0	3330	6220	4388	2	0.03	650	4193	167	0	10	40	1	0	5220	15695	5168	2
October	729	3341	234	7	2.10	2426	8408	2441	2	0.02	1132	8449	127	0					4287	20198	2802	9
November	1643	8424	509	15	1.78	1448	885	1749	1	0.11	1905	13205	228	0	30	106	3	0	5026	22620	2489	16
December	2364	12373	754	5	0.40	1977	3694	1903	0	0.00	861	5945	80	0	16	43	1	0	5218	22055	2738	5
January	2093	12173	679	0	0.00	1442	2571	1250	0	0.00	713	4189	44	0					4248	18933	1973	0
February	1218	7568	512	3	0.40	406	751	128	0	0.00	98	231	4	0					1722	8550	644	3
March	2573	16096	626	1	0.06	971	5012	487	0	0.00	1116	5065	80	1					4660	26173	1193	2
April	2527	15307	931	26	1.70	682	806	71	0	0.00	160	1838	34	1					3369	17951	1036	27
May	1550	7182	271	24	3.34	302	451	82	0	0.00	688	1297	162	0					2540	8930	515	24
June																			0	0	0	0
July																			0	0	0	0
August																						
Total	**15927**	**87706**	**5128**	**81**	**0.92**	**12984**	**28798**	**12499**	**5**	**0.02**	**7323**	**44412**	**926**	**2**	**56**	**189**	**5**	**0**	**36290**	**161105**	**18558**	**88**
Pooled																						
September	1740	7509	668	0	0	6600	12560	7648	2	0.159	1180	7799	194	0	10	40	1	0	9530	27908	8511	2
October	3186	19873	976	21	1.06	5968	15177	7345	2	0.132	1938	14368	222	0	0	0	0	0	11092	49418	8543	23
November	4598	25332	1623	19	0.75	3616	5353	5019	1	0.187	2640	17004	302	0	30	106	3	0	10884	47795	6947	20
December	4875	29842	1960	10	0.34	3062	4861	2187	0	0	1125	7806	83	0	187	426	49	0	9249	42935	4279	10
January	4426	27239	1397	3	0.11	2931	5093	1691	0	0	1023	5900	51	0	0	0	0	0	8380	38232	3139	3
February	2737	17228	979	8	0.46	1197	2984	278	0	0	462	2576	22	0	0	0	0	0	4396	22788	1279	8
March	4301	26157	1289	10	0.38	1653	6441	735	0	0	1565	7757	107	1	0	0	0	0	7519	40355	2131	11
April	4817	28898	1859	46	1.59	1262	1977	266	0	0	350	2408	43	1	0	0	0	0	6429	33283	2168	47
May	2532	12944	550	33	2.55	1035	1306	290	0	0	719	1418	165	0	0	0	0	0	4286	15668	1005	33
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	33212	195022	11301	150	0.77	27324	55752	25459	5	0.02	11002	67036	1189	2	227	572	53	0	71765	318382	38002	157

TC=Total catch; LC=*Lactarius* catch;C/E= Catch per unit effort; F.hrs=Fishing hours

Table 9. Month-wise estimated effort, catch and catch rate of *L.lactarius* in different gears at Bhatkal during 1997-98 and 1998-99.

	TRAWL					SEINES					GILL NET				OTHER GEARS				TOTAL			
	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)
1997-98																						
September	270	811	2	0	0	3150	6942	7127	4	0.06									3420	7753	7129	4
October	791	4230	363	4	0.95	3000	17505	1569	0	0									3791	21735	1932	4
November	405	2390	81	3	1.26	1118	2386	488	0	0									1523	4776	569	3
December	581	3541	219	0	0	1294	1372	1086	0	0									1875	4913	1305	0
January	543	3957	144	0	0	1027	1754	303	0	0									1570	5711	447	0
February	483	3054	91	0	0	630	1664	67	0	0									1113	4718	158	0
March	1093	7556	347	4	0.53	822	1849	262	1	0.05									1915	9405	609	5
April	1200	8070	357	6	0.74	130	213	42		0									1330	8283	399	6
May	744	4899	190	1	0.20	403	162	43	0	0									1147	5061	233	1
June																			0	0	0	0
July											248	333	3	0					248	333	3	0
August						1380	2733	819	0	0									1380	2733	819	0
Total	**6110**	**38508**	**1794**	**18**	**0.47**	**12954**	**36580**	**11806**	**5**	**0.01**	**248**	**333**	**3**	**0**	**0**	**0**	**0**	**0**	**19312**	**75421**	**13603**	**23**
1998-99																						
September																						
October	233	1275	65	1	0.78	2202	8082	3643	1	0.01									2435	9357	3708	2
November	173	787	19	2	2.54	1688	3539	3594	0	0	8	23	2	0					1869	4349	3615	2
December	643	4120	159	6	1.46	1720	3239	787	0	0	16	43	1	0					2379	7402	947	6
January	512	3070	155	0	0	1597	3211	756	0	0	8	23	1	0					2117	6304	912	0
February	1050	5752	344	0	0	546	868	278		0									1596	6620	622	0
March	736	4732	144	3	0.63	767	1718	136	0	0					8	16	1	0	1511	6466	281	3
April	510	2856	156	4	1.40	105	210	107	0	0									615	3066	263	4
May	542	2972	64	7	2.36	728	1450	373	0	0									1270	4422	437	7
June																			0	0	0	0
July																			0	0	0	0
August						2676	5031	2735	43	0.85									2676	5031	2735	43
Total	**4399**	**25564**	**1106**	**23**	**0.90**	**12029**	**27348**	**12409**	**44**	**0.16**	**32**	**89**	**4**	**0**	**8**	**16**	**1**	**0**	**16468**	**53017**	**13520**	**67**
Pooled																						
September	270	811	2	0	0	3150	6942	7127	4	0.06	0	0	0	0	0	0	0	0	3420	7753	7129	4
October	1024	5505	428	5	0.91	5202	25587	5212	1	0.01	0	0	0	0	0	0	0	0	6226	31092	5640	6
November	578	3177	100	5	1.57	2806	5925	4082	0	0	8	23	2	0	0	0	0	0	3392	9125	4184	5
December	1224	7661	378	6	0.78	3014	4611	1873	0	0	16	43	1	0	0	0	0	0	4254	12315	2252	6
January	1055	7027	299	0	0	2624	4965	1059	0	0	8	23	1	0	0	0	0	0	3687	12015	1359	0
February	1533	8806	435	0	0	1176	2532	345	0	0	0	0	0	0	0	0	0	0	2709	11338	780	0
March	1829	12288	491	7	0.57	1589	3567	398	1	0.054	0	0	0	0	8	16	1	0	3426	15871	890	8
April	1710	10926	513	10	0.92	235	423	149	0	0	0	0	0	0	0	0	0	0	1945	11349	662	10
May	1286	7871	254	8	1.02	1131	1612	416	0	0	0	0	0	0	0	0	0	0	2417	9483	670	8
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	248	333	3	0	0	0	0	0	248	333	3	0
August	0	0	0	0	0	4056	7764	3554	43	0.85	0	0	0	0	0	0	0	0	4056	7764	3554	43
Total	**10509**	**64072**	**2900**	**41**	**0.64**	**24983**	**63928**	**24215**	**49**	**0.08**	**280**	**422**	**7**	**0**	**8**	**16**	**1**	**0**	**35780**	**128438**	**27123**	**90**

TC=Total catch; LC=*Lactarius* catch;C/E= Catch per unit effort; F.hrs=Fishing hours

Table 10. Month-wise estimated effort, catch and catch rate of *L. lactarius* in different gears at Tadri during 1997-98 and 1998-99.

	TRAWL					SEINES					GILL NET				OTHER GEARS				TOTAL			
	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	C/E (kg/hr)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)	Unit	Effort (F.hrs)	TC (t)	LC (t)
1987-88																						
September	214	1069	22	3	2.81	493	7133	845	0	0									707	8202	867	3
October	1705	11481	407	23	2.00	517	3580	871	0	0									2222	15061	1278	23
November	1946	14239	622	12	0.84	396	2094	603	0	0									2342	16333	1225	12
December	2108	14660	789	9	0.61	372	2289	554	0	0									2480	16949	1343	9
January	1581	7432	801	3	0.40	101	480	181	0	0									1682	7912	982	3
February	1375	7740	807	14	1.81	115	3690	121	0	0									1490	11430	928	14
March	1677	10043	886	9	0.90	48	289	50	0	0									1725	10332	936	9
April	2205	26900	1077	13	0.48	15	105	28	0	0									2220	27005	1105	13
May	2038	20118	907	6	0.30	8	47	11	0	0									2046	20165	918	6
June	30	180	5	0	0					0									30	180	5	0
July										0	171	434	1	0					171	434	1	0
August	50	155	2	0	0					0									50	155	2	0
Total	**14929**	**114017**	**6325**	**92**	**0.81**	**2065**	**19707**	**3264**	**0**	**0**	**171**	**434**	**1**	**0**	**0**	**0**	**0**	**0**	**17165**	**134158**	**9590**	**92**
1998-99																						
September	36	138	27	0	0	336	992	914	0	0												
October	382	42243	117	0	0	238	865	168	0	0									620	43108	285	0
November	27	113	1	0	0	193	2272	555	0	0									220	2385	556	0
December	1216	6849	298	1	0.15	110	411	173	0	0									1326	7260	471	1
January	2995	19199	821	1	0.05	388	1117	401	0	0									3383	20316	1222	1
February	2184	31909	705	0	0	213	703	269	0	0									2397	32612	974	0
March	1626	45439	925	0	0	28	153	32	0	0									1654	45592	957	0
April	1673	15320	711	9	0.59	206	1171	254	0	0									1879	16491	965	9
May	988	4826	269	14	2.90	354	8368	279	11	0.131									1342	13194	548	25
June										0									0	0	0	0
July										0									0	0	0	0
August	1064	5552	93	3	0.54	392	2078	568	0	0									1456	7630	661	3
Total	**12191**	**171588**	**3967**	**28**	**0.16**	**2458**	**18130**	**3613**	**11**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**14277**	**188588**	**6639**	**39**
Pooled																						
September	250	1207	49	3	2.81	829	8125	1759	0	0	0	0	0	0	0	0	0	0	707	8202	867	3
October	2087	53724	524	23	2.00	755	4445	1039	0	0	0	0	0	0	0	0	0	0	2842	58169	1563	23
November	1973	14352	623	12	0.84	589	4366	1158	0	0	0	0	0	0	0	0	0	0	2562	18718	1781	12
December	3324	21509	1087	10	0.76	482	2700	727	0	0	0	0	0	0	0	0	0	0	3806	24209	1814	10
January	4576	26631	1622	4	0.46	489	1597	582	0	0	0	0	0	0	0	0	0	0	5065	28228	2204	4
February	3559	39649	1512	14	1.81	328	4393	390	0	0	0	0	0	0	0	0	0	0	3887	44042	1902	14
March	3303	55482	1811	9	0.90	76	442	82	0	0	0	0	0	0	0	0	0	0	3379	55924	1893	9
April	3878	42220	1788	22	1.07	221	1276	282	0	0	0	0	0	0	0	0	0	0	4099	43496	2070	22
May	3026	24944	1176	20	3.20	362	8415	290	11	0.13	0	0	0	0	0	0	0	0	3388	33359	1466	31
June	30	180	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	180	5	0
July	0	0	0	0	0	0	0	0	0	0	171	434	1	0	0	0	0	0	171	434	1	0
August	1114	5707	95	3	0.54	392	2078	568	0	0	0	0	0	0	0	0	0	0	1506	7785	663	3
Total	**27120**	**285605**	**10292**	**120**	**0.42**	**4523**	**37837**	**6877**	**11**	**0**	**171**	**434**	**1**	**0**	**0**	**0**	**0**	**0**	**31442**	**322746**	**16229**	**131**

TC=Total catch; LC=*Lactarius* catch;C/E= Catch per unit effort; F.hrs=Fishing hours

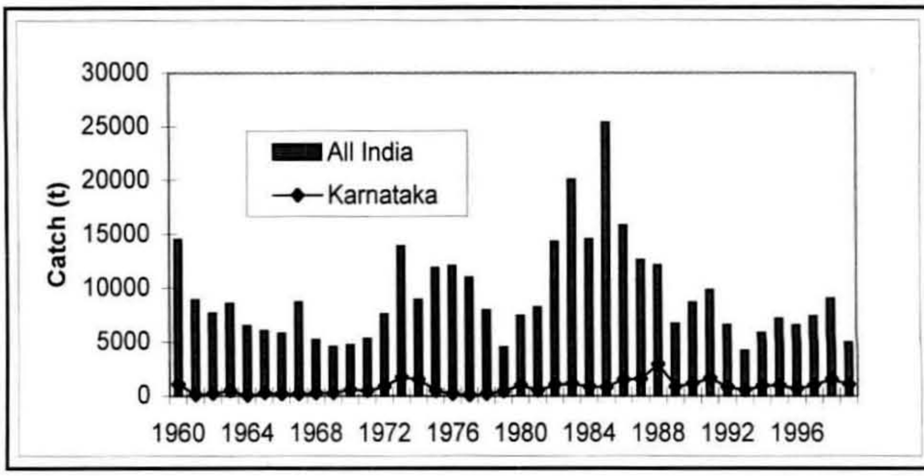


Fig.1. All-India and Karnataka whitefish landing during 1960-1999.

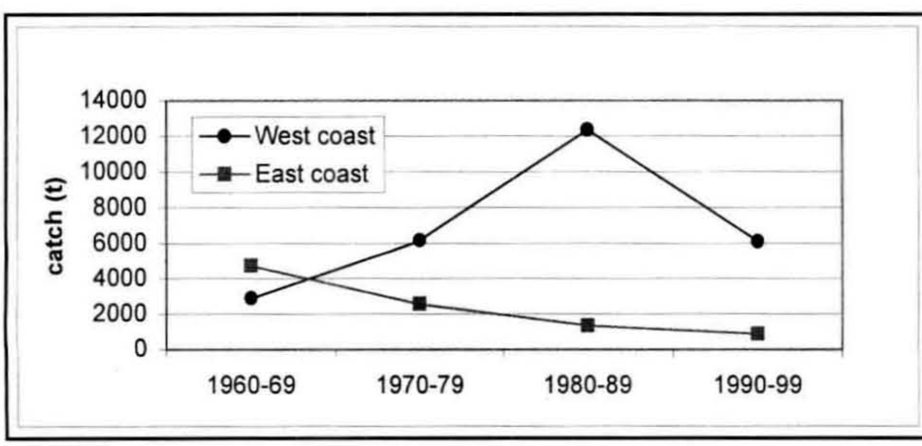


Fig.2. Decadal average production of whitefish along the east and west coasts of India.

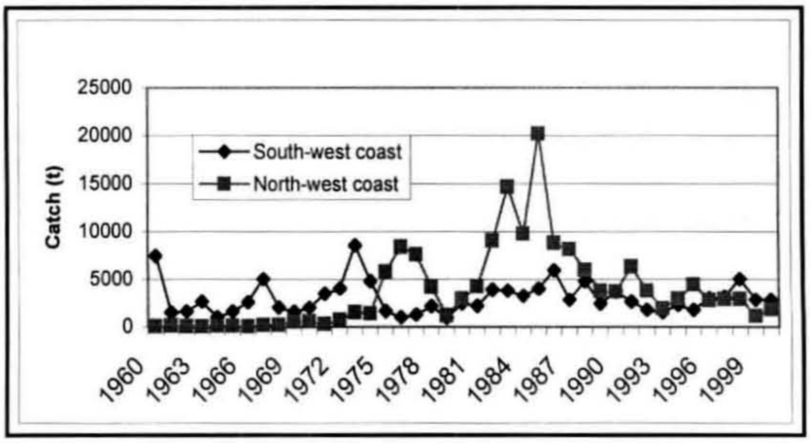


Fig.3. Whitefish landing along west coast during 1960-2000.

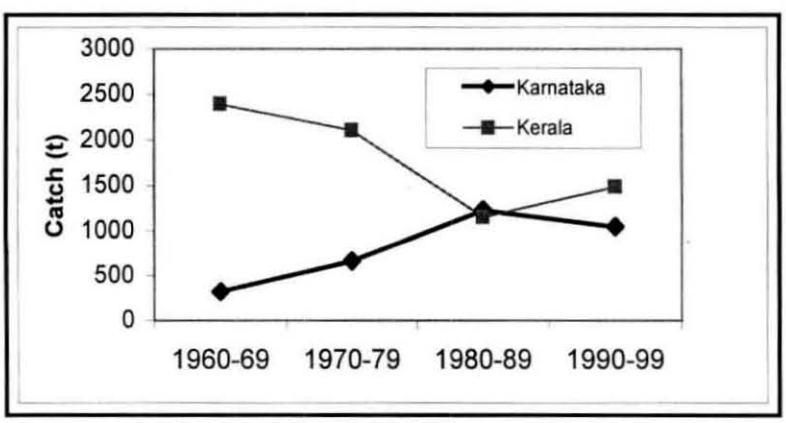


Fig.4. Decadal whitefish catch in Karnataka compared to Kerala.

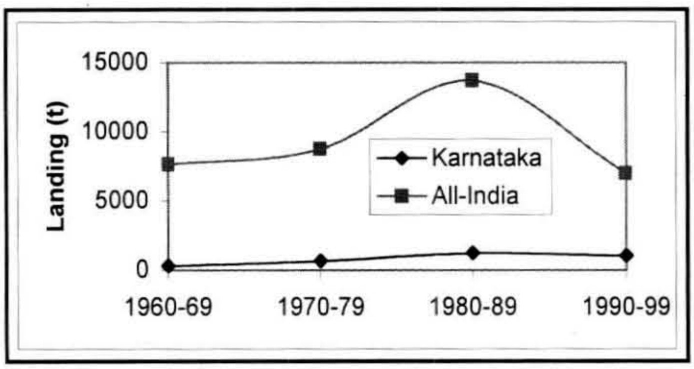


Fig.5. Decadal average landing of *L. lactarius* along Karnataka as compared with all-India production.

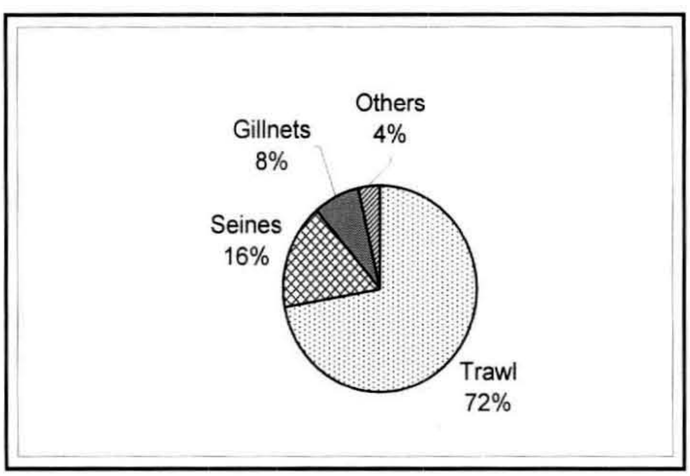


Fig.6. Gear-wise landing of *L. lactarius* for 1997-98 and 1988-99 from Karnataka pooled.

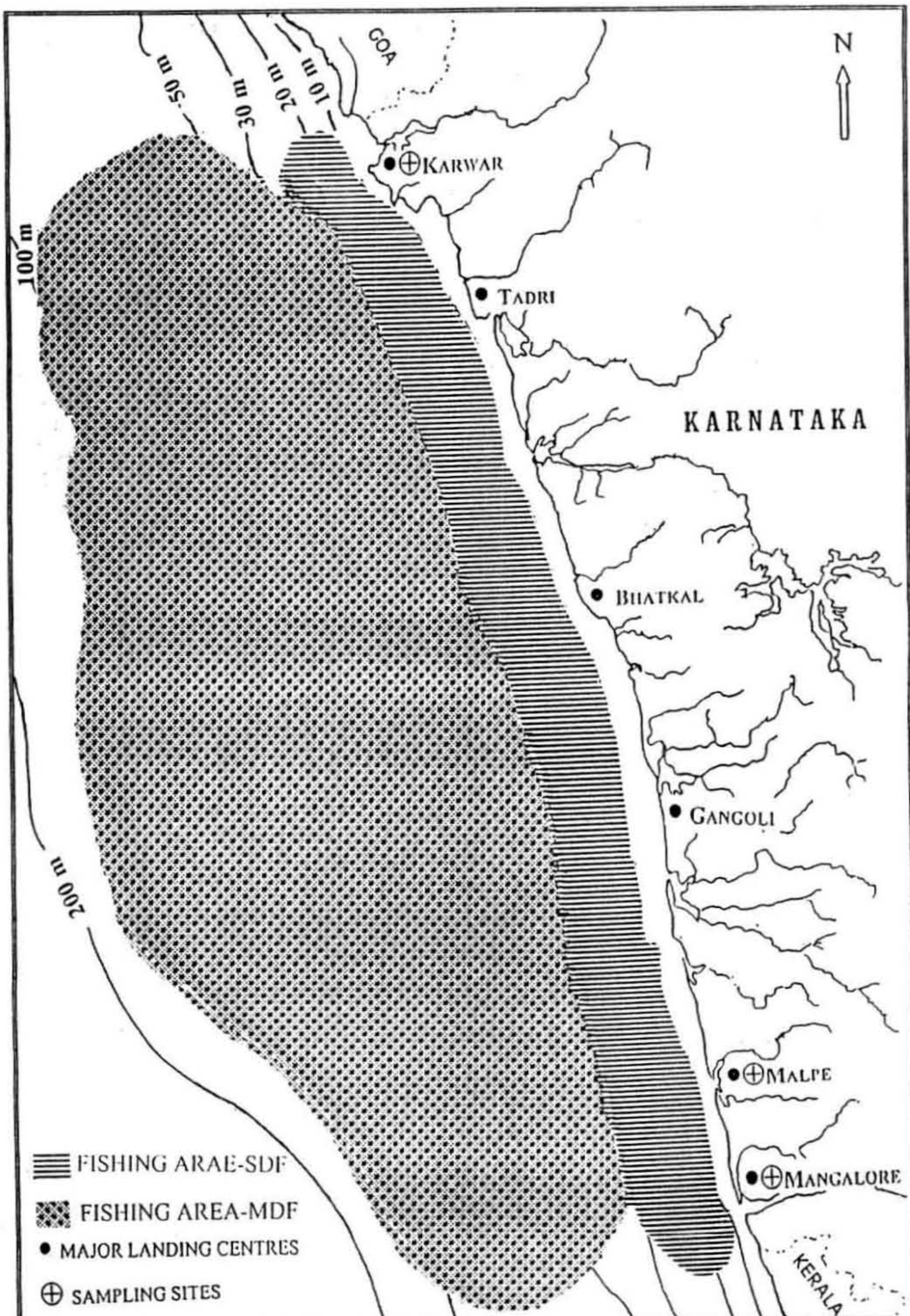


Fig. 7. Map showing area of fishing for whitefish along Karnataka coast by Multi-Day Fishing (MDF) and Single-Day Fishing (SDF) trawlers with major landing centres and sampling location.

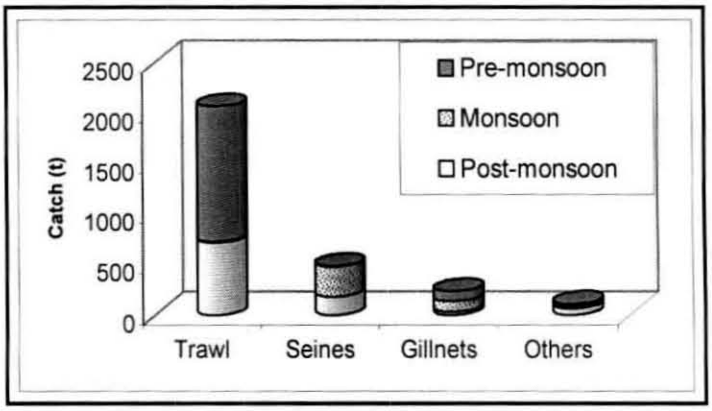


Fig.8. Seasonal variations in catch of whitefish in different gears pooled for 1997-98 and 1998-99.

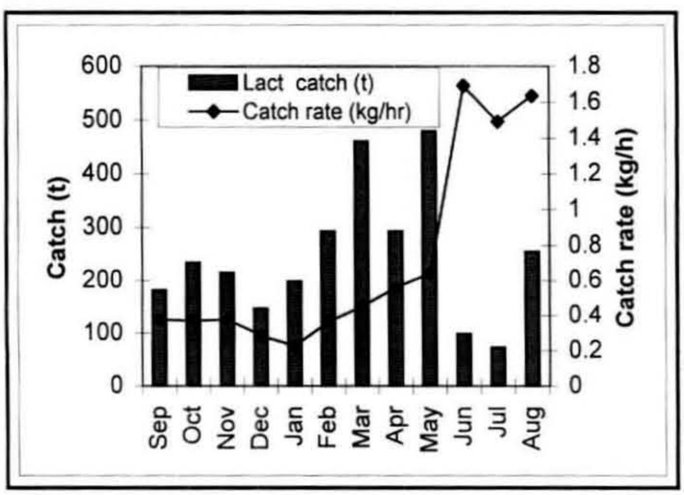


Fig.9. Month-wise catch and catch rate of *L. lactarius* in (pooled from all centres) in Karnataka.

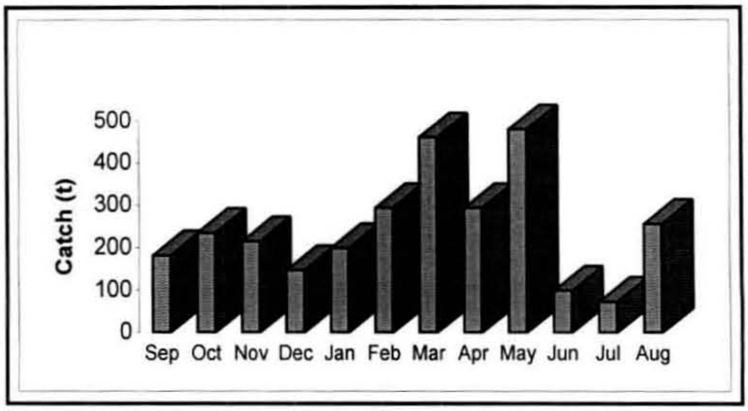


Fig.10. Month-wise variation in the catches of whitefish pooled for all gears during 1997-98 and 1998-99

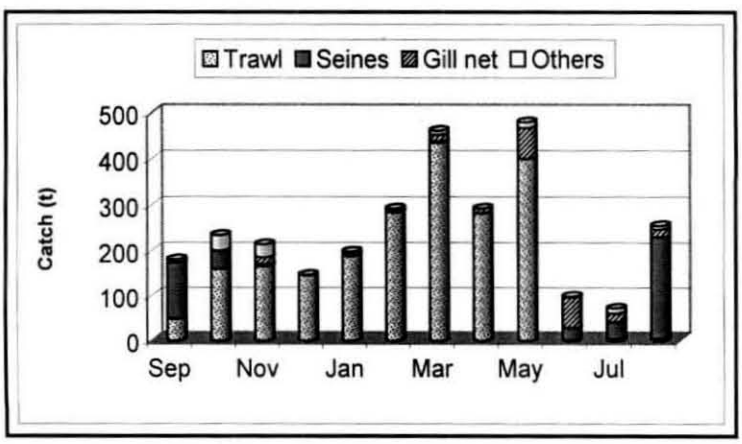


Fig.11. Month-wise variation in catch of whitefish in different gears during 1997-1999

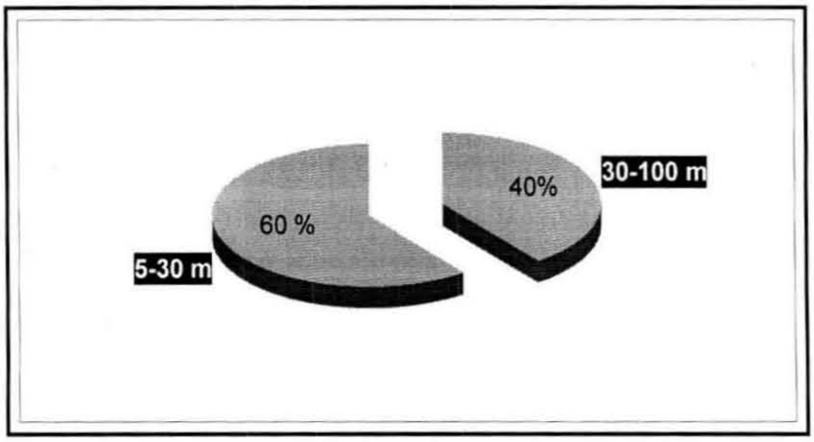


Fig.12. Depth-wise catch of whitefish pooled for all gears from Karnataka

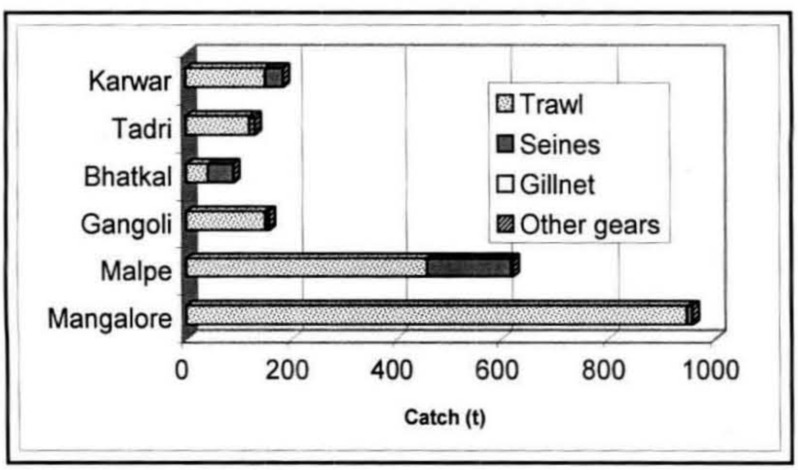


Fig.13. Catch of whitefish landed at various mechanised fishing vessel landing centres by different gears.

Chapter

3

Food and Feeding Habits

3.1. INTRODUCTION

Information on food and feeding habits of fishes is essential for better understanding of their growth, breeding and migration and also for improving the harvest from the commercially important fisheries resources. Further, knowledge on natural diet of an animal is required for the study of its nutritional requirements, its interaction with other organisms and its potential for culture (Royce, 1987). The spectrum of prey consumed by a species helps to define its fundamental niche (Hutchinson, 1957) and its realized niche in terms of interaction with co-habitating species (Greenberg, 1991).

As food being the most important factor regulating or influencing the abundance, growth and migration of fishes, any information in this regard will add to the existing knowledge needed for better management of fish stock. Many authors have discussed the food of fishes in relation to sexual cycle, condition of feed, selectivity in feeding and drawn conclusions that bear upon the biology of the species concerned (Green, 1919; Lovern and Wood, 1937; Nikolsky, 1950; Radhakrishnan, 1957; Venkataraman, 1960; Popova, 1963; Jayabalan, 1991; Molinero and Flos, 1992 and Link and Burnett, 2001). Diet of a population is examined first with a view to assessing the species' nutritional standing in the fish community which considers seasonal variation in diet or dietary comparison either between different sub-groups of the species, e.g., year-class or different species living in the same or comparable habitat to discern whether there is competition for food.

The first work on food of marine fishes from India was on *Sardinella longiceps* by Hornell and Nayudu (1924). Subsequently, several workers have carried out investigations on the food and feeding habits of many species of marine fishes from Indian waters (Devanesan, 1932; Job, 1940; Chidambaram and Venkataraman, 1946; Chacko, 1949; Bapat and Bal, 1950; Bhimachar and George, 1952; Vijayaraghavan, 1953; Sarojini, 1957; Kuthalingam, 1955; Prabhu, 1955; Karekar and Bal, 1958; Venkataraman, 1960; Natarajan and Jhingran, 1961; Dhulkhed 1962; James, 1967; Reuben, 1969; Suseelan and Nair, 1969; Qasim, 1972; Sreenivasn, 1974; Chatterji, 1976; Pati, 1982; Jayabalan and Ramamoorthi, 1985; Kurup and Samuel, 1988; Sivakami, 1996; Devaraj, 1998; Kingston *et al.*, 1998 and Philip, 1998).

Studies on the food and feeding habits of *L. lactarius* from Indian waters are available from Madras (Chidambaram and Venkataraman, 1946, Basheeruddin and Nayar, 1961), Gulf of Mannar (Chacko, 1949), Malabar coast (Devanesan and Chidambaram, 1953; Venkataraman, 1960), Waltair (Rao, 1966) and Cochin (George *et al.*, 1968).

From Karnataka State, though studies on food and feeding habits of *L. lactarius* have been carried out from Mangalore in Dakshina Kannada District (James *et al.*, 1974) and Karwar in Uttara Kannada District (Neelakantan, 1981), no information is available from Udupi District. The present study was undertaken on the food and feeding habits of *L. lactarius* collected from Malpe coast in the Udupi District in addition to the fish samples collected from Mangalore and Karwar.

For analysing fish stomach contents, occurrence method, numerical method, points method, volumetric method and gravimetric method are widely used (Hynes, 1950; Borutsky *et al.*, 1952; Pillay, 1952; Lagler, 1956; Windell, 1968; Windell and Bowen, 1978). Hence, to study the food and feeding habits of fishes, choice of the method should suit the diet of the fish to be investigated. For studying the dynamics of food and feeding habits of marine fishes a combination of numerical and volumetric methods would give better picture of food than when each of these methods is applied in isolation (Qasim, 1972). The best measure of dietary importance is the one where both the amount and bulk of a food category are recorded (Hyslop, 1980). The index of pre-ponderance method (Natarajan and Jhingran, 1961) takes into account both the frequency of occurrence as well as bulk of the food item (volume) providing a definite and measurable basis for grading different food items. As this method is suitable for carnivorus fishes and many workers from India have adopted this in their investigations.

3.2. MATERIAL AND METHODS

Samples of *L. lactarius* were collected once a week from trawl landings at Mangalore, Malpe and Karwar fish landing centres between September 1997 and August 1999. In the laboratory after washing, each fish was measured to its total length (TL) and weight to the nearest mm and g respectively. After cutting open the fish, the sex, maturity stage and degree of fullness of stomachs were recorded. The variations in the fullness of fish stomachs were classified as 'gorged', 'full', '¾ full', '½ full', '¼ full', trace and 'empty'. The stomachs of fishes were removed, weighed and preserved in 7% buffered formalin for further analysis.

The index of preponderance method (Natarajan and Jhingran, 1961) suitable for carnivorus fishes was adopted in this study. The index of preponderance was worked out by the following formula:

$$I = \frac{V_i O_i}{\Sigma V_i O_i} \times 100$$

where V_i and O_i represent the percentage of volume and percentage of occurrence indices of each food item respectively and *I* the index.

Food items of fish were identified up to the generic level wherever possible and counted and measured volumetrically. All unidentifiable and partially digested fishes were grouped under digested fish remains. For the analysis of fullness of stomachs, they were grouped into actively fed (gorged, full and ¾ full stomachs), moderately fed (½ full stomachs), poorly fed (¼ full stomachs and stomachs with traces of food) and empty. A total of 7,115 specimens comprising of 2,998 males measuring between 90 and 215 mm, 3,467 females measuring between 90 and 265 mm TL and 650 juveniles measuring between 50 and 90 mm were used for the present study. Food analysis was done in relation to months, sexes, maturity stages and size-groups. The fishes were classified into groups with a class interval of 10 mm length. For maturity stage-wise analysis, the stages I and II were classified as 'immature', stages III and IV as 'early mature', stages V and VI as 'mature' or 'ripe' and stage VIIa as 'partially spent' and VIIb as 'spent'. The data from all the centres were pooled for the analysis.

Monthly feeding index (Kow, 1950) was calculated which is the ratio of the number of specimens whose feeding were either active or moderate to the total number of specimens examined during that month x 100.

3.3. RESULTS

3.3. 1. General Diet Composition of *L. lactarius*

The list of food items occurred in the stomachs of *L. lactarius* is given in Table 1. Analysis of stomach contents showed that the food of *L. lactarius* consisted of two major groups, teleosts and crustaceans. These two groups together formed 95.8% of the food in 1997-98 and 96.03 % in 1998-99

(Table 2). Fishes formed 71.39% in 1997-98, whereas, it was 50.03% in 1998-99. Crustacean diet increased from 24.42 % in 1997-98 to 46.01% in 1998-99. Analysis of pooled data for 2 years showed that, fish was the major food item forming 61%, crustaceans constituted 36% and miscellaneous items (gastropods, cephalopods, unidentifiable digested matter, echinoderms, detritus etc.) formed the rest of the 3% (Fig.1).

Among fish food items, major group was anchovies (*Stolephorus bataviensis, Stolephorus devisi)* forming 69% of the diet. Unidentified digested fish remains were an important component forming 25% of fish diet. Other fish species found occasionally in the stomach of *L. lactarius* are given in Table 2. The presence of young *L. lactarius* in the stomach in certain months is an indication of the cannibalistic nature of the species.

Among crustaceans, *Acetes* was the dominant item (76.2%) followed by prawns (13.4%) comprising *Metapenaeus dobsoni, Parapenaeopsis stylifera, Solenocera* sp., *Trachypenaeus* sp., Squilla (*Oratosquilla nepa*) (7.5%), small benthic crabs (0.54%), decapod larvae (0.2%), and mysids and copepods the rest.

Among miscellaneous items *Loligo duvauceli*, gastropods, sea urchin, and detritus were seen.

3.3.2. Monthly Variation in the Percentage Composition of Diet

Anchovies (*Stolephorus* spp.) were the most preferred food item in most of the months (except in June and September) and they formed up to 98.3 (July) (Table 3). Good landing of anchovies was noticed in trawl during January-May along Karnataka coast. *Acetes indicus* was the dominant food item in August (30.34), October (86.91) and November (88.93) and *Acetes* was landed by trawl in considerable quantities during these months. Unidentified fish remains (fish in semi-digested state) were found aplenty in June (94.29), September (74.8) and January (32.27). In December, shrimps formed as an important diet with an index value of 8.42. Among shrimps, *Metapenaeus dobsoni* was found in all months except June, July and September. *Parapenaeopsis stylifera* occurred as minor food component in February, March, April, October, November and December. *Solenocera* sp. was recorded only during April (0.014) and *Trachypenaeus* during January (0.06), April (0.019), May (0.023) and December (0.019).

Squilla formed as minor component in the diet of *L. lactarius* in October (2.95), November (3.88) and was absent during most of the months. Benthic crabs were found in the diet in appreciable numbers during January (1.35), and August (2.50) and in negligible quantities during April (0.019), July (0.079), November (0.071) and December (0.11).

Fishes other than anchovies were found only occasionally in the stomachs. While *Trichiurus* sp. was observed in January (0.145), September

(1.44) and October (0.07), silverbellies were recorded during February (0.85), April (0.04), May (0.05) and July (0.16); *Coilia dussumieri* during February (0.08); *Therapon* sp. during April (0.02); *Nemipterus japonicus* during March (0.01); *Platycephalus* sp. during February (0.13) and March (0.03); *Decapterus russelli* during December (0.08); *Saurida* spp. in April (0.08); *Bregmaceros* sp. in February (0.38), March (0.10) and December (0.05); *Cynoglossus macrostomus* in October (0.14) and *Ambassis* sp. during August (1.25). Young ones of *L. lactarius* were found in the stomach during February (0.702), November (1.5) and December (0.02).

Molluscan food items were represented by *Loligo* sp. and gastropods. *Loligo* sp. was consumed during March (0.015), May (0.01) and December (0.02) and gastropod only in March (0.01). Decapod larvae were recorded in January (0.01), April (0.01), September (0.14) and October (0.02).

Mud and detritus were found in the food during February (0.01), November (0.01) and December (0.01). Copepod was found only during April (0.01). Echinoderms represented by sea urchin were ingested in September (0.6).

3.3.3. Diet Composition of Juveniles and Adults

The diet composition in males, females and juveniles of *L. lactarius* is given in Fig.2. Juveniles preferred crustaceans as the major food item with an index value of 83 whereas in males and females, the values were 29 and

22 respectively. The index value for fish food items in juvenile was 13 while, in males and females which formed major component had index values of 69 and 74 respectively. Pooled data for both sexes, showed fish food item to be dominant (71.5) followed by crustaceans (25.5) and miscellaneous items (3).

3.3.4. Diet Composition in Relation to Size

The diet composition of *L. lactarius* in relation to size in respect of the major components of food is depicted in Fig.3.

Acetes alone was consumed by *L. lactarius* up to the size of 69 mm (Table 4) and dominated in the food up to 139 mm. From 140 mm onwards, fishes like anchovies became dominant. Up to 89 mm the food items were limited to *Acetes*, digested fish and unidentified digested matter; while, shrimps were found in 90-189 mm fish, squilla from 90-179 mm, benthic crabs in 120-139 mm and 160-169 mm size groups were found. Young ones of *Lactarius* figured in the food of fish in 130-159 mm. Fishes were the only food item occurred above 190 mm of *L. lactarius*.

3.3.4.1. Diet Composition in Relation to Size in Males

The major diet composition of male *L. lactarius* in relation to size is depicted in Fig.4.

Acetes sp. was the most favoured food item in males of 90-129 mm length (Table 5). The index of preponderance values were 98.7, 69.4, 52.1

and 36.05 for 90-99, 100-109, 110-119 and 120-129 mm size groups respectively. The index values for all crustaceans together respectively were 99.8, 67.4, 53.6 and 39.5. From 120 mm onwards, male *L. lactarius* fed on fishes, mainly anchovies, the favoured food item. Young ones of *L. lactarius* were observed in the stomachs of 130-149 mm size. Squilla was recorded in the stomachs in 110-169 mm fish and benthic crabs in 90-99 mm and 120-139 mm length groups. Decapod larvae were seen in 100-109 mm and detritus in 100-129 mm size fishes.

3.3.4.2. Diet Composition in Relation to Size in Females

The major food items of female *L. lactarius* in different sizes are provided in Fig.5.

Small-sized females preferred *Acetes* and with growth, the preference shifted to anchovies (Table 6). Up to the size of 130-139 mm, *Acetes* was the most dominant item with index values varying from 51.65 to 86.04. Squilla was an important diet in the size group of 90-99 (29.2). From 140 mm onwards anchovy was the dominant food item. Fish formed the principal food item in the size group from 150-159 mm (92) to 230-239 mm. Shrimps were recorded up to 150-159 mm length fishes and benthic crabs in length groups 130-139 mm and 160-169 mm. The results show that while smaller sized fishes prefer *Acetes* as the diet, larger ones feed exclusively on fishes.

3.3.5. Seasonal Variation in the Diet

3.3.5.1. Monthly Variation in the Diet of Males

Anchovies formed the major food item of male *L. lactarius* during February- May and July-August (Table 7). *Acetes* was the dominant food item in October and November and was found in good percentage in April, May, August and December. Partially digested unidentifiable fish remains formed as an important item in the diet during most part of the year and were abundant during January, June and September. In December, shrimps accounted for substantial portion of food. *M. dobsoni* was present in the diet in January (0.1), February (1.03), March (0.64), April (1.7), May (0.15), October (0.3), November (2.53) and in December it formed the third largest food item in the stomach with index value of 27.8. *P. stylifera* was present in the diet during February- April and October-December; *Trachypenaeus* sp. in January and April and *Solenocera* sp. in April. Among fishes, while young *L. lactarius* was seen in February and November; *Bregmaceros* sp. occurred in March and December; *Trichiurus* sp. in September and October; leiognathids in February, April and July. Benthic crabs were seen during October-December and copepods in April (0.04), *Loligo* sp. in March and Squilla (*Oratosquilla nepa*) in October and November.

3.3.5.2. Monthly Variation in the Diet of Females

Anchovies formed the major diet in females (Table 8). *Stolephorus* sp. was the chief food in February (92.4), March (92), April (63.95), May (42.43) July (98.7) and December (55.13). The other fishes were represented by

Trichiurus sp. in January (0.9); *Platycephalus* sp. (0.16), *Leiognathus* sp. (0.9) and *L. lactarius* (0.82) in February and *Bregmaceros* sp. in February (0.66) and March (0.4). *Acetes* was preferred during October-November. Digested fish remains were dominant during January (33.45), June (91.7) and September (83.5). Shrimps formed an important diet in December (22.7) and August (9.7). *M. dobsoni* was recorded in January, March, May, August and October-December; *P. stylifera* during October-December and *Trachypenaeus* sp. during May. Mysids were ingested in lesser proportions in January and March. Squilla was an important component in the diet during October (14.5) that decreased during November and December. *Loligo* sp. formed a minor component in the food in May and December. Detritus was found in the stomach in considerable quantities in August and February.

3.3.6. Diet Composition in Relation to Maturity Stages

3.3.6.1. Diet Composition in Relation to Maturity Stages in Males

Among immature male fishes, *Acetes* was the dominant (51.6) food item. In early mature stage, ripe and spent conditions, anchovies formed the preferred diet with index values of 71.5, 92.2 and 85.6 respectively (Table 9). Squilla was not observed in spent fish. Benthic crabs were seen in immature and early mature stages of fish. While, more number of food items was seen in immature and early maturing stages, it was less in spent stage.

3.3.6.2. Diet Composition in Relation to Maturity Stages in Females

Acetes was dominant over anchovies in immature females (44.34). Other crustaceans such as shrimps (0.01%), crab (0.28%) and squilla (0.53%), detritus and fish were also ingested (Table 9). In early mature females, anchovies were the dominant food item (43.5) followed by *Acetes* (11.04%), and other shrimps (10.2%). Crustaceans altogether formed 22.42%. In ripe females, anchovies formed the dominant item with an index value of 75.8. In spent fishes anchovies were the major food (58.6) followed by *Acetes* (10.4), squilla (0.12) and shrimps (0.37).

3.3.7. Feeding Condition

3.3.7.1. Feeding Condition in Males

3.3.7.1.1. Feeding Condition in Relation to Months

Higher percentages of empty stomachs were encountered during June-September and January. However, their number was higher than 45% during rest of the months (Fig.6). The feeding indices calculated for different months are shown in Table 10. Better feeding index was seen in March (22), April (20) and May (24), October (23) and December (19). Poor index values were seen in June, August and September and moderate feeding index was observed in January-February.

3.3.7.1.2. Feeding Condition in Relation to Size

Empty stomachs were more in the size groups 110-119 mm, 120-129 mm, 170-179 mm and 210-219 mm. Active feeding was noticed in 90-99 mm with a feeding index of 15.7 (Table 11). Feeding index was less in fishes up to 159 mm TL, but better index values were seen in 180-189 mm (30.4%), 190-199 mm (66.7%) and 200-209 mm (Fig.7) whereas in fishes of 210-219 mm TL the stomachs were empty.

3.3.7.1.3. Feeding Condition in Relation to Maturity Stages

The occurrence of empty stomachs dominated in males of different maturity stages *viz.*, immature fish (70.4 %), early mature (69.5 %), mature (65.76 %) and spent fishes (66.7%) (Fig.8). Feeding index was higher in mature (21.9) and spent fishes (21.2) compared to immature and early mature fishes (Table 12).

3.3.7.2. Feeding Condition in Females

3.3.7.2.1. Feeding Condition in Relation to Months

Empty stomachs were dominant during June, August and September than in the other months (Fig.9). Higher values of feeding index were noticed in March-May, July and October-December (Table 13); while, lower values were seen during August and September. Active/moderate feeding was more during March, April, May and July.

3.3.7.2.2. Feeding Condition in Relation to Size

Incidence of empty stomachs was less in fishes of 90-99 mm size group (Fig.10). Active feeding was observed in more number of fishes measuring 80-89 mm. In 130-139 mm, 140-149 mm and 150-159 mm fishes, active/moderate feeding was recorded. Occurrence of empty stomachs was more in 195 mm mid-size group. In 200-209 mm fishes moderate/active feeding was recorded. In fishes of 210-219 mm size groups, moderate feeding was high. Compared to males, the feeding index values in females were high in all size groups and the values showed decreasing trend in fishes of 85 mm to 145 mm but showed increase in 215 mm size group. Beyond 235 mm size group (Table 14) only empty stomachs were met with.

3.3.7.2.3. Feeding Condition in Relation to Maturity Stages

Almost 60.4% of females had empty stomachs. The occurrence of empty stomachs was 59.7 % in immature fish, 63 % in early mature fish and 69.3 % in mature fish and 69.3 % in spent fish (Table 15). Overall, mature (21.9) and spent (21.2) fish fed better. In immature fish, occurrence of empty stomachs varied from 48.85 % in 1998-99 to 65.7 % in 1997-98. In mature and ripe fish empty stomachs varied from 57.3% in 1997-98 to 70.0 % in 1998-99. In spent fishes, empty stomachs varied from 66.5% in 1997-98 to 68.5% in 1998-99 (Fig.11).

3.3.8. Feeding Habits

L. lactarius very often preyed upon entire organisms and stomachs exclusively contained certain items like *Stolephorus* sp. and *Acetes* sp., indicating abundance of the prey organisms and selectivity by the fish. The stomachs often were gorged with 2 to 3 anchovies and where *Acetes* was encountered its number was up to 80.

3.4. DISCUSSION

Analysis of the stomach contents has shown that food of *L. lactarius* consisted of two major groups *viz.*, teleosts and crustaceans. These two groups together formed 95.8 % of the food of *L. lactarius* in 1997-98 and 94.9 % in 1998-99. The third group consisting of molluscs, detritus and other miscellaneous food items formed 4.2 % and 5.1% in 1997-98 and 1998-99 respectively. More than 50% of the food items in both years consisted of teleosts, thus indicating *L. lactarius* a piscivorus predator and the same view has been expressed by a number of workers (Chidambaram and Venkataraman, 1946; Chacko, 1949; Devanesan and Chidambaram, 1953; Venkataraman, 1960; Rao, 1966 and Neelakantan, 1981). Crustacean diet represented by *Acetes*, shrimps, alima larva, *Cypris, Eucalanus*, isopods, amphipods and *Lucifer* was found as the dominant food item followed by teleosts (42.2%) and polychaetes (0.7%) in the fish (Rao, 1966). Besides, teleost fishes and their juveniles, *Acetes* and other food items were found in meager quantities (James *et al.*, 1974). The present study indicates that no relationship could be established with the reproductive cycle and food preference. Occurrence of empty stomachs was fairly high in all the months. No seasonal variation in diet could be observed. It is apparent that when *L. lactarius* grow older the number of food items in their stomach also reduces. This may be due to the restricted mobility in older fishes.

Smaller fish had limited items as food compared to bigger ones and with increase in age, the diet changed. In juveniles, crustaceans formed the bulk of food. Along the Madras coast, juvenile *L. lactarius* (20-90 mm) obtained during March, April and June in 1954 and 1955 had fed on *Acetes indicus* and other crustaceans like prawn larvae as the major food (Basheeruddin and Nayar, 1961).

Rao (1966) noticed slackness of feeding during February-March when spawning was intense. The percentage occurrence of crustaceans was high during June-September but very low during December-February. However, the occurrence of teleosts as food showed an inverse relationship between the crustacean food item and fish food item along Andhra-Orissa coast (Rao, 1966). James *et al.* (1974) observed in Mangalore waters; the fish to feed more often on juvenile of teleost fishes and crustacean *Acetes* sp. The present study corroborates with the above observation that *L. lactarius* is a selective feeder feeding mainly on anchovies and *Acetes* sp.

Stolephorus spp. formed one of the main elements of food and formed 91% of the teleostean prey. Their percentage composition varied from 1.65 % to 98.3 %. They occurred in most of the months. In October and November, the index values for *Stolephorus* were less when *Acetes* was the major food. The largest specimen of *Stolephorus* sp. measuring 53 mm was found in the gut of *L. lactarius* of 173 mm TL. Young *Lactarius* was found in the stomach contents in February and November and December indicating the cannibalistic nature of the species. The other fish species found occasionally in the stomach were *Decapterus russelli* (December), *Nemipterus mesoprion* (March), *Coilia dussumieri* (February), *Saurida tumbil* (April), *Platycephalus* sp. (February and March), *Therapon* sp. (April) and *Cynoglossus macrostomus* (October).

Qasim (1972) based on the study of Venkataraman (1960) has stated that *L. lactarius* is a true carnivore and feeds in different trophic levels and at all depths. The present study from Karnataka supports the above view as the variety of organisms found in the stomach ranged from pelagic groups like anchovies to mid-water organisms like *Acetes*, mid-water fishes and benthic organisms such as gastropods, echinoderms and crabs representing various ecological niches within the vertical section of the inshore water column. It is opined that fishes that fed on benthic infauna and epifauna and fish generally show a seasonal variation in the feeding intensity (Longhurst, 1957). However, feeding intensity in fishes could be correlated with the abundance of plankton in the environment and also with the maturity stages of fishes (Venkataraman, 1960).

Similar to other piscivorus fishes, *L. lactarius* possess streamlined and laterally compressed body for rapid propulsion, large eyes, very wide and protrusible mouth with canine teeth and elongated lower jaw which gives a large gape and high buccal volume while the caecum of the cardiac stomach is highly distensible giving all prerequisites for devouring prey of considerable size. In the present study, the largest prey (anchovy) obtained was 33% of the body length of the whitefish.

The presence of anchovies in large quantities in the Arabian Sea may be a factor for feeding of *L. lactarius* extensively on them along the Karnataka coast. Scarcity of forage fishes usually lead to cannibalism as an adaptation for a greater utilization of the food base in a water body (Nikolsky, 1963). However, sporadic feeding irrespective of the scarcity of forage fishes may be due to the abundance of juveniles during most part of the year as reported in tropical predators like *Trichiurus haumela* (Prabhu, 1955) and *Harpodon nehereus* (Bapat *et al.,* 1952). In the present study, the cannibalism may be due to combination of all the above facts.

The feeding intensity studies showed that occurrence of empty stomachs was high in all the months. Similar observation has been made from Mangalore in an earlier study (James *et al.,* 1974). The frequent occurrence of empty stomachs may be due to the faster digestion rate due to strong gastric juices in carnivorus fishes (Qasim, 1972) or may be due to regurgitation while removing from deeper waters (Job, 1940).

In the present study active feeding in *L. lactarius* was common during October-December and March-May in both the sexes and July in females. Along Karwar coast, the active feeding of *L. lactarius* during June-September, moderate feeding during October-November and low feeding from

December-April could be correlated to the reproductive cycle of the fish *i.e.*, higher feeding intensity during earlier stages of maturity and vice versa (Neelakantan, 1981). In several other species of fishes also, the feeding intensity was correlated with the maturity stages of individuals (Venkataraman, 1960). In the present study, the feeding intensity was moderate in January and February when spawning activity was high and active feeding was seen in March-May when more individuals were in spent and spent recovering conditions. Similarly, low feeding intensity during spawning was noticed in herrings (Jesperson, 1928) and in haddock (Ritchie, 1937). Several species of fishes feed low in pre-spawning, moderate during spawning and high during post-spawning periods (Radhakrishnan, 1957). The low feeding in pre-spawning and spawning periods have been attributed to less space in the abdominal cavity due to fully developed gonads affecting the food intake (Green, 1919; Lovern and Wood, 1937 and Chidambaram *et al.*, 1952). However, no relation between feeding and spawning of fishes could be observed in several species of fishes from Indian waters (Pillay, 1953; Kuthalingam, 1955; Tandon, 1961; Jayabalan, 1986; Kalita and Jayabalan, 1990). In *L. lactarius* also no relation could be found between feeding and breeding (James *et al.*, 1974). However slackness of feeding was observed during intense spawning in *L. lactarius* (Basheeruddin and Nayar, 1961).

In the present study, high feeding index was recorded in small sized fish of both the sexes. There was gradual fall in the feeding intensity up to

129 mm in males and 149 mm in females and thereafter, the intensity increased and above 210 mm in males and 230 mm in females all the stomachs were empty. Low feeding activity in the length groups 150-159, 160-169 and 170-179 mm size group may be attributed to the physiological strain associated with spawning.

As in *L. lactarius* of present study, the feeding indices were better in mature and spent fishes of both sexes, it may be inferred that there is no relation between feeding intensity and maturity stages of fish. Similarly along the Karnataka coast feeding index values for different months indicate that there in no relation between feeding intensity and season either. This inference corroborates with the findings of James *et al.* (1974) on *L. lactarius* from Mangalore.

From the present study, it may be concluded that:

i. *L. lactarius* is a selective feeder feeding mainly on *Stolephorus* sp. and *Acetes* sp.

ii. There is a shift in the food item from juvenile to adult. Smaller sized fish prefer *Acetes* as the food item; whereas, larger ones, prefer anchovies as the favourite food item.

iii. There is no definite relationship between feeding intensity/index and maturity stage of fish as well as size of fish and season.

iv. The occurrence of empty stomachs was high in all months.

Table 1. List of food items in the stomach of *L. lactarius*.

A. FINFISHES

Stolephorus bataviensis
Stolephorus devisi
Bregmaceros sp.
Leioganthus sp.
Lactarius lactarius
Trichiurus sp.
Platycephalus sp.
Decapterus russelli
Saurida tumbil
Cynoglossus macrostomus
Caranx kalla
Coilia sp.
Nemipterus mesoprion
Saurida sp.
Ambassis sp.
Therapon sp.

B. CRUSTACEANS

Shrimps
Acetes indicus
Metapenaeus dobsoni
Parapenaeopsis stylifera
Solenocera spp.
Trachypenaeus sp.

Stomatopods
Oratosquilla nepa

Benthic crabs
Mysids
Copepods
Decapod larvae

C. MISCELLANEOUS

Echinoderms
Loligo spp.
Gastropods
Detritus

Table 2. Index of pre-ponderance values of different food items in the stomach of *L. lactarius*.

Sl. No	Food item	INDEX VALUE		
		1997-98	**1998-99**	**Pooled**
1	*Stolephorus* spp.	46.112	36.720	41.416
2	Digested fish remains	20.779	10.408	15.594
3	Unidentifiable dig.matter	3.722	5.436	4.579
4	*Acetes*	18.551	36.279	27.415
5	Shrimps	0.696	8.986	4.841
6	*Oratosquilla nepa*	4.926	0.472	2.699
7	Benthic crabs	0.218	0.161	0.190
8	Mysids	0.001	0.000	0.001
9	*Leiognathus* spp.	0.192	0.008	0.100
10	*Bregmaceros* sp.	0.270	0.455	0.362
11	*Lactarius lactarius*	0.035	0.150	0.092
12	*Trichiurus* sp.	0.000	0.633	0.317
13	Other fishes	4.001	0.062	2.032
14	Gastropods	0.001	0.000	0.000
15	*Loligo* spp.	0.048	0.121	0.084
16	Decapod larvae	0.020	0.107	0.063
17	Detritus	0.418	0.000	0.209
18	Echinoderms	0.015	0.000	0.008

Table 3. Monthly Index of preponderance of different food items of *L. lactarius* pooled for 1997-98 and 1998-99.

Sl. No	Food Items	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Pooled
1	*Stoleophorus* spp.	0	8.874	1.651	80.563	51.18	87.742	95.159	69.436	54.790	0	98.290	47.94	63.067
2	Digested fish remains	74.820	0.286	3.021	0.908	32.27	3.361	2.804	6.106	10.150	94.286	0.714	9.738	19.928
3	Digested matter	6.475	0.080	0.196	0.152	10.71	2.804	0.093	1.337	8.559	0	0.500	7.491	3.937
4	*Acetes* sp.	16.691	86.912	88.932	9.662	3.86	3.511	1.179	22.616	26.330	1.143	0.254	30.337	11.153
5	*Metapenaeus dobsoni*	0	0.463	0.618	7.216	0.261	0.358	0.556	0.315	0.045	0	0	0.749	0.286
6	*Parapenaeopsis stylifera*	0	0.229	0.119	1.207	0	0.032	0.039	0.006	0	0	0	0	0.010
7	*Solenocera* sp.	0	0.692	0.737	0	0.319	0.39	0.595	0.014	0	0	0	0	0.165
8	*Trachypenaeus* sp.	0	0	0	0.019	0.058	0	0	0.019	0.023	0	0	0	0.013
9	*Oratosquilla nepa*	0	2.950	3.884	0.023	0.014	0	0	0.351	0	0	0	0	0.046
10	Benthic crab	0	0.000	0.071	0.113	1.348	0	0	0.019	0	0	0.079	2.497	0.493
11	*Mysids*	0	0	0	0	0.213	0.155	0.015	0	0	4.571	0	0	0.619
12	*Trichiurus* sp.	1.439	0.069	0	0	0.145	0	0	0	0	0	0	0	0.018
13	Leiognathids	0	0	0	0	0	0.846	0	0.037	0.05	0	0.159	0	0.137
14	*L. lactarius*	0	0	1.4960	0.015	0	0.702	0	0	0	0	0	0	0.088
15	*Platycephalus* sp.	0	0	0	0	0	0.128	0.031	0	0	0	0	0	0.020
16	*Coilia dussumieri*	0	0	0	0	0	0.008	0	0	0	0	0	0	0.001
17	*Therapon* sp.	0	0	0	0	0	0	0	0.019	0	0	0	0	0.002
18	*Nemipterus* sp.	0	0	0	0	0	0	0.008	0	0	0	0	0	0.001
19	*Decapterus russelli*	0	0	0	0.083	0	0	0	0	0	0	0	0	0.000
20	*Bregmaceros* sp.	0	0	0	0.052	0	0.383	0.1030	0	0	0	0	0	0.061
21	*Saurida* sp	0	0	0	0	0	0	0	0.074	0	0	0	0	0.009
22	*Cynoglosssus macrostomus*	0	0.137	0	0	0	0	0	0.000	0	0	0	0	0.000
23	*Ambassis* sp.	0	0	0	0	0	0	0	0.000	0	0	0	1.248	0.156
24	Gastropds	0	0	0	0	0	0	0.006	0	0	0	0	0	0.001
25	*Loligo* sp	0	0	0	0.019	0	0	0.015	0	0.009	0	0	0	0.003
26	Detritus	0	0	0.012	0.008	0	0.010	0	0	0	0	0	2.717	0.341
27	Copepod	0	0	0	0	0	0.000	0	0.007		0	0	0.000	0.001
28	Echinoderms	0.576	0	0	0	0	0.000	0	0	0	0	0	0.000	0.000
29	Decapod larva	0	0	0	0	0	0	0	0.007	0	0	0	0	0.001

Table 4. Size-wise Index of pre-pondernance of different food items of *L. lactarius (pooled for 1997-98 and 1998-99).*

Food item	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199	200-209	210-219	220-229	230-239
Stoleophorus spp.	0	0	10	12.71	11.14	14.87	25.74	33.50	35.43	75.20	76.83	62.11	89.04	91.25	90.44	63.69	71.43	72.81	100
Digested fish remains	0	0	0	0	0.44	3.70	1.47	10.99	3.87	11.82	16.78	31.95	8.84	6.52	9.23	24.20	0	27.19	0
Digested matter	0	0	0	12.71	0.59	2.19	0.68	2.79	3.93	2.18	4.08	5.25	1.15	0.68	0.33	12.10	28.57	0	0
Acetes sp.	100	100	90	74.58	86.37	78.48	71.36	50.63	52.91	9.06	1.14	0.52	0.85	1.36	0	0		0	0
Bregmaceros sp.	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0
Shrimps	0	0	0	0	0.27	0.77	0.43	0.73	3.33	1.23	0.92	0.07	0	0.204	0	0	0	0	0
Gastropods	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0
Oratosquilla nepa	0	0	0	0	1.19	0	0.32	0.91	0.20	0.181	0.16	0.06	0.11	0	0	0	0	0	0
Crab	0	0	0	0	0	0	0	0.40	0.29	0	0	0.03	0	0	0	0	0	0	0
Silverbellies	0	0	0	0	0	0	0	0.05	0	0.10	0	0	0	0	0	0	0	0	0
Other fishes	0	0	0	0	0	0	0	0	0	0.01	0.02	0	0	0	0	0	0	0	0
Detritus	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
Young whitefish	0	0	0	0	0	0	0	0	0.05	0.19	0.07	0	0	0	0	0	0	0	0

Table 5. Index of pre-ponderance of different food items in different size groups of male *L. lactarius* (pooled for 1997-98 and 1998-99).

	Length groups (mm)											
Food items	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199	200-209
Stolephorus spp.	0.12	28.16	44.67	46	59.19	84.656	87.008	74.885	90.428	64	97.06	100
Other fishes	0	0.61	0.16	14.14	10.77	4.752	5.313	18.143	5.288	32	2.941	0
Unidentified dig.matter	0	1.84	0.21	0.69	3.80	0.125	0.885	4.32	0.317	0	0	0
Acetes sp.	97.58	69.08	52.07	36.05	19.82	9.888	3.365	0.216	3.966	1.6	0	0
Shrimps	1.17	0	0	0	5.92	0.428	1.535	1.189	0	2.4	0	0
Oratosquilla nepa	0	0	1.59	1.04	0.04	0.145	0.354	1.08	0	0	0	0
Benthic crabs	1.15	0	0	1.39	0.29	0	0	0	0	0	0	0
Mysids	0	0	0	0.17	0	0	0	0	0	0	0	0
Cephalopods	0	0	1.28	0	0.18	0	1.58	0	0	0	0	0
Gastropods	0	0	0	0	0	0	0	0.18	0	0	0	0
Detritus	0	0.26	0	0.57	0	0	0	0	0	0	0	0
Decapod larvae	0	0.06	0	0	0	0	0	0	0	0	0	0

Table 6. Index of pre-ponderance of different food items in different size groups of female *L. lactarius* (pooled for 1997-98 and 1998-99)

	Length groups (mm)														
Food items	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180-189	190-199	200-209	210-219	220-229	230-239
Stolephorus spp.	6.69	3.60	47.10	23.22	9.18	64.72	66.71	58.77	87.89	97.99	86.20	30.49	71.45	72.81	100
Other fishes	0	4.86	0.33	6.93	0.05	22.05	25.53	34.79	9.68	0.62	13.07	46.34	0	27.19	0
Unidentified dig.matter	0	1.80	0.79	7.50	3.23	8.39	6.66	4.78	1.01	0.78	0.726	23.17	28.57	0	0
Acets sp.	63.1	85.39	51.65	61.49	86.04	0.91	0.38	0.609	0.37	0.62	0	0	0	0	0
Shrimps	0	3.96	0	0	0.86	3.37	0.64	0	0	0	0	0	0	0	0
Oratosquilla nepa	29.2	0	0.13	0.86	0.43	0.49	0.08	0	0.21	0	0	0	0	0	0
Benthic crabs	0	0	0	0	0.22	0	0	0.05	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	1.02	0.85	0	0	0	0	0	0
Detritus	0.98	0.42	0	0	0	0.12	0	0	0	0	0	0	0	0	0
Decapod larvae	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0

Table 7. Month-wise distribution of Index of preponderance of different food items of male *L. lactarius* (pooled for 1997-98 and 1998-99).

Sl.No	Food item	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
1	*Stoleophorus* spp.	0	2.65	7.66	33.14	33.80	83.67	89.63	63.10	57.44	0	85.88	57.97
2	Digested fish remains	73.33	0.12	5.15	2.39	61.35	5.64	6.62	6.17	13.11	100	7.63	0
3	Unidentified dig.matter	6.67	0.18	0.42	0.17	4.41	6.27	0.34	0.81	0.95	0	1.53	3.13
4	*Acetes* sp.	8.89	92.52	80.78	29.58	0.09	0.05	2.30	27.34	28.35	0	1.15	37.58
5	*Metapenaeus dobsoni*	0	0.30	2.53	27.83	0.09	1.03	0.64	1.67	0.15	0	0	0
6	*Parapenaeopsis stylifera*	0	0.10	0.26	4.39	0	0.23	0.14	0.03	0	0	0	0
7	*Solenocera* sp.	0	0	0	0	0	0	0	0.06	0	0	0	0
8	*Trachypenaeus* sp.	0	0	0	0	0.25	0	0	0.10	0	0	0	0
9	*Oratosquilla nepa*	0	3.64	3.56	0	0	0	0	0	0	0	0	0
10	Benthic crab	0	0.24	0.05	1.35	0	0	0	0	0	0	0	0
11	Mysids	0	0	0	0	0	0.23	0	0	0	0	0	0
12	*Leiognathus* sp.	0	0	0	0	0	1.64	0	0.20	0	0	3.82	0
13	*L. lactarius*	0	0	0.53	0	0	1.41	0	0	0	0	0	0
14	*Platycephalus* sp.	0	0	0	0	0	0	0.11	0	0	0	0	0
15	*Coilia* sp.	0	0	0	0	0	0.06	0	0	0	0	0	0
16	*Trichiurus* sp.	11.11	0.24	0	0	0	0	0	0	0	0	0	0
17	*Therapon* sp.	0	0	0	0	0	0	0	0.10	0	0	0	0
18	*Nemipterus mesoprion*	0	0	0	0	0	0	0	0	0	0	0	0
19	*Decapterus russelli*	0	0	0	1.10	0	0	0	0	0	0	0	0
20	*Bregmaceros* sp.	0	0	0	0.05	0	0	0.141	0	0	0	0	0
21	*Saurida* sp.	0	0	0	0	0	0	0	0.39	0	0	0	0
22	*Cynoglossus macrostomus*	0	0	0	0	0	0	0	0	0	0	0	0
23	*Ambassis* sp.	0	0	0	0	0	0	0	0	0	0	0	1.33
24	Gastropd	0	0	0	0	0	0	0.02	0	0	0	0	0
25	*Loligo* sp.	0	0	0	0	0	0	0.06	0	0	0	0	0
26	Detritus	0	0	0	0	0	0	0	0	0	0	0	0
27	Copepod	0	0	0	0	0	0	0	0.04	0	0	0	0
28	Echinoderms	0	0	0.01	0	0	0	0	0	0	0	0	0
29	Decapod larvae	0	0	0	0	0	0	0	0.02	0	0	0	0

Table 9. Stage-wise Index of pre-ponderance of different food items of male and female *L. lactarius* (pooled for 1997-98 and 1998-99).

	MALE				FEMALE			
Food item	*Immature*	*Early mature*	*Ripe*	*Spent*	*Immature*	*Early mature*	*Ripe*	*Spent*
Stolephorus spp.	37.41	71.49	92.24	85.58	42.88	43.54	75.8	58.66
Other fishes	5.94	6.35	4.332	10.43	6.76	24.579	19.775	24.88
Acetes sp.	51.6	18.18	0.88	0.68	44.34	11.04	3.04	10.4
Unidentified dig.matter	1.54	0.73	1.84	2.16	5.14	9.26	0.55	5.57
Shrimps	2.685	3.127	0.172	0.933	0.013	10.196	0.554	0.371
Oratosquilla nepa	0.194	0.054	0.345	0	0.535	1.161	0.092	0.124
Benthic crabs	0.594	0.002	0	0	0.283	0.283	0	0
Mysids	0	0.03	0	0	0	0	0.02	0
Cephalopods	0.01	0	0.192	0	0.01	0	0.185	0
Detritus	0.02	0.04	0	0	0.008	0	0	0
Gastropods	0	0	0	0.212	0	0	0	0
Decapod larvae	0	0.01			0.05	0	0	0

Table 10. Feeding intensity of males in different months (pooled for 1997-98 and 1998-99).

Month	**Condition of stomach (%)**					**Feeding**
	Empty	Poor	Moderate	Active	Total %	index
September	80.3	16.9	0.0	2.8	100	3
October	46.8	30.4	11.6	11.2	100	23
November	47.5	29.6	13.2	9.6	100	13
December	59.6	21.4	11.1	7.9	100	19
January	73.2	11.1	8.9	6.8	100	16
February	54.4	27.9	8.7	9.1	100	18
March	60.4	16.8	13.3	9.5	100	22
April	62.2	18.5	10.6	8.8	100	20
May	57.2	19.3	16.9	6.6	100	24
June	86.7	10.0	3.3	0.0	100	3
July	72.1	10.5	12.8	4.7	100	18
August	91.0	6.7	1.1	1.1	100	2

Table 11. Size-wise feeding intensity of males, pooled for all months (pooled for 1997-98 and 1998-99).

Mid-size (mm)	Condition of stomach (%)									Feeding Index
	Empty		Poor		Moderate		Active		Total	
	No	%	No	%	No	%	No	%	No	
95	60	49.6	33	27.3	9	7.4	19	15.7	121	23.1
105	162	57.2	51	18.0	38	13.4	32	11.3	283	24.7
115	288	63.2	79	17.3	49	10.7	40	8.8	456	19.5
125	408	64.5	133	21.0	50	7.9	42	6.6	633	14.5
135	286	57.3	119	23.8	62	12.4	32	6.4	499	18.8
145	254	55.0	115	24.9	55	11.9	38	8.2	462	20.1
155	193	61.5	59	18.8	35	11.1	27	8.6	314	19.7
165	85	55.9	29	19.1	26	17.1	12	7.9	152	25.0
175	36	70.6	9	17.6	5	9.8	1	2.0	51	11.8
185	11	47.8	2	8.7	7	30.4	3	13.0	23	43.5
195	1	33.3	0	0	2	66.7	0	0.0	3	66.7
205	1	50	0	0	1	50.0	0	0.0	2	50.0
215	1	100	0	0	0	0.0	0	0.0	1	0.0
Total	1786	59.5	629	21.0	339	11.3	246	8.2	3000	19.5

Table 12. Maturity stage-wise feeding intensity in males pooled for 1997-98 and 1998-99.

Stage	Empty		Poor		Moderate		Active		Total Nos	Feeding Index
	No	%	No	%	No	%	No	%		
Immature	919	70.4	198	15.2	110	8.4	78	6.0	1305	14.4
Early mature	1119	69.5	257	16.0	134	8.3	100	6.2	1610	14.5
Mature	267	65.8	50	12.3	63	15.5	26	6.4	406	21.9
Spent	132	66.7	24	12.1	26	13.1	16	8.1	198	21.2
Total	2437	69.3	529	15.0	333	9.5	220	6.3	3519	

Table 13. Feeding intensity of females in different months (pooled for 1997-98 and 1998-99)

Month	Condition of stomach (%)					Feeding index
	Empty	Poor	Moderate	Active	Total %	
September	80.8	15.2	0.0	4.0	100	4
October	42.6	31.1	14.3	11.9	100	26.2
November	45.5	32.3	11.1	11.1	100	22.2
December	58.2	20.7	7.5	13.6	100	21.1
January	60.7	21.4	8.0	10.0	100	18
February	58.4	23.0	7.1	11.5	100	18.6
March	59.8	14.5	15.7	10.0	100	25.7
April	52.2	22.2	15.2	10.4	100	25.6
May	57.9	17.9	15.2	8.9	100	24.1
June	75.7	10.8	10.8	2.7	100	13.5
July	55.0	12.5	7.5	25.0	100	32
August	80.1	10.4	7.0	2.5	100	9.5

Table 14. Size-wise feeding intensity of females of *L. lactarius* (pooled for all months).

Mid-size (mm)	Condition of stomach (%)									Feeding Index
	Empty		Poor		Moderate		Active		Total	
	No	%	No	%	No	%	No	%		
95	32	33.0	34	35.1	10	10.3	21	21.6	97	32.0
105	116	41.6	83	29.7	43	15.4	37	13.3	279	28.7
115	186	39.3	141	29.8	81	17.1	65	13.7	473	30.9
125	221	47.0	113	24.0	74	15.7	62	13.2	470	28.9
135	205	41.7	146	29.7	81	16.5	60	12.2	492	28.7
145	228	41.5	149	27.1	94	17.1	79	14.4	550	31.5
155	181	37.3	124	25.6	90	18.6	90	18.6	485	37.1
165	126	40.0	89	28.3	42	13.3	58	18.4	315	31.7
175	66	41.3	30	18.8	39	24.4	25	15.6	160	40.0
185	32	43.2	17	23.0	11	14.9	14	18.9	74	33.8
195	22	43.1	9	17.6	12	23.5	8	15.7	51	39.2
205	8	72.7	0	0	2	18.2	1	9.1	11	27.3
215	2	40	0	0	2	40	1	20	5	60.0
225	0	0	1	50	1	50	0	0	2	50.0
235	1	50	0	0	1	50	0	0	2	50.0
245	0	0	0	0	0	0	0	0	0	0.0
255	1	100	0	0	0	0	0	0	1	0.0
265	1	100	0	0	0	0	0	0	1	0.0
Total	1428		936		583		521		3468	

Table 15. Maturity stage-wise feeding intensity in females pooled for 1997-98 and 1998-99.

stages	Empty		Poor		Moderate		Active		Total Nos	Feeding Index
	No	%	No	%	No	%	No	%		
Immature	518	59.7	165	19.0	107	12.3	78	9.0	868	14.4
Early mature	613	63.0	157	16.1	103	10.6	100	10.3	973	14.5
Mature	145	46.6	64	20.6	76	24.4	26	8.4	311	21.9
Spent	190	69.3	32	11.7	36	13.1	16	5.8	274	21.2
Total	1466	60.4	418	17.2	322	13.3	220	9.1	2426	

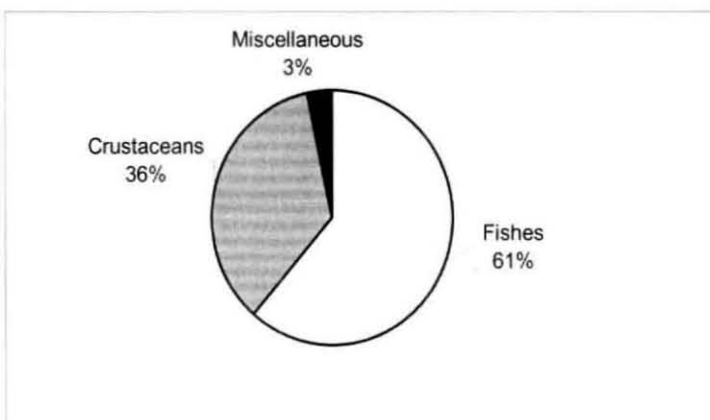


Fig.1. General diet composition of *L. lactarius*

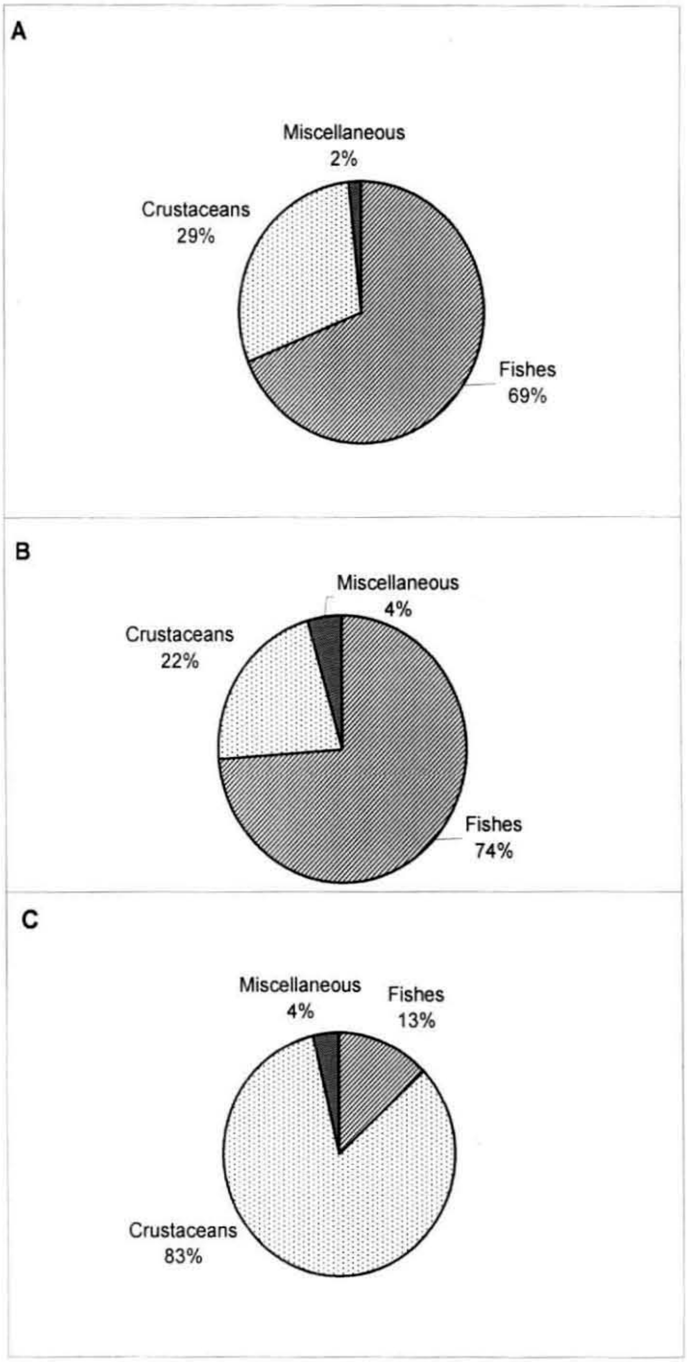


Fig.2. Diet composition of male (A), female (B) and juvenile (C) of *L.lactarius*

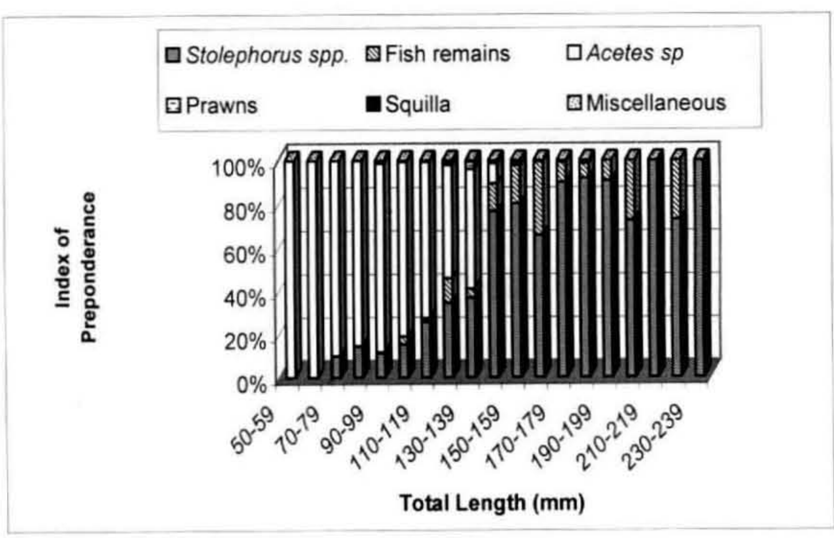


Fig.3. Diet composition of *L. lactarius* in relation to size in respect of major components of food.

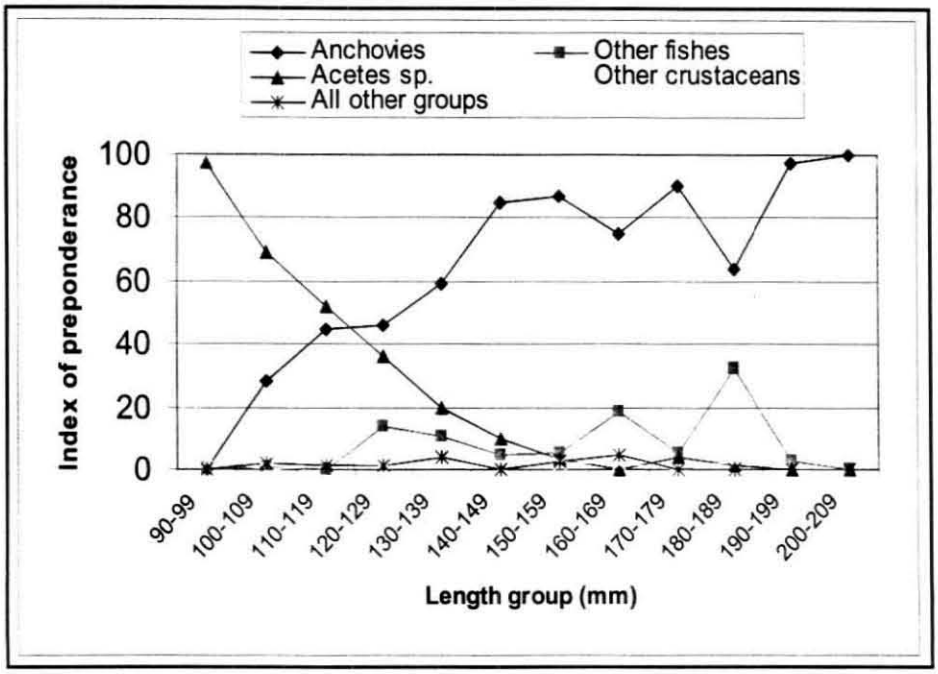


Fig.4. Diet composition in males of *L. lactarius* in different size in respect of major components of food.

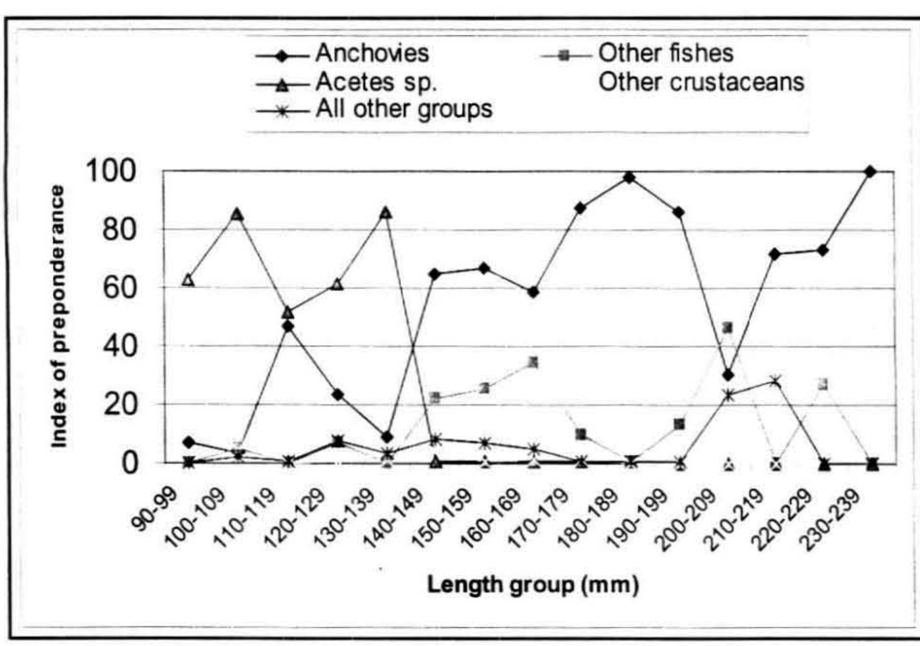


Fig.5. Diet composition in females of *L. lactarius* in relation to size in respect of major components of food.

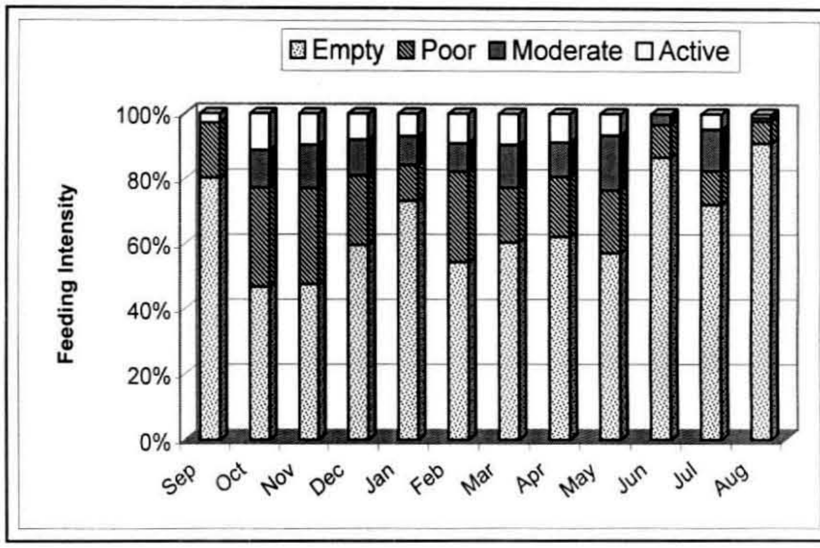


Fig.6. Feeding intensity in males of *L. lactarius* in different months.

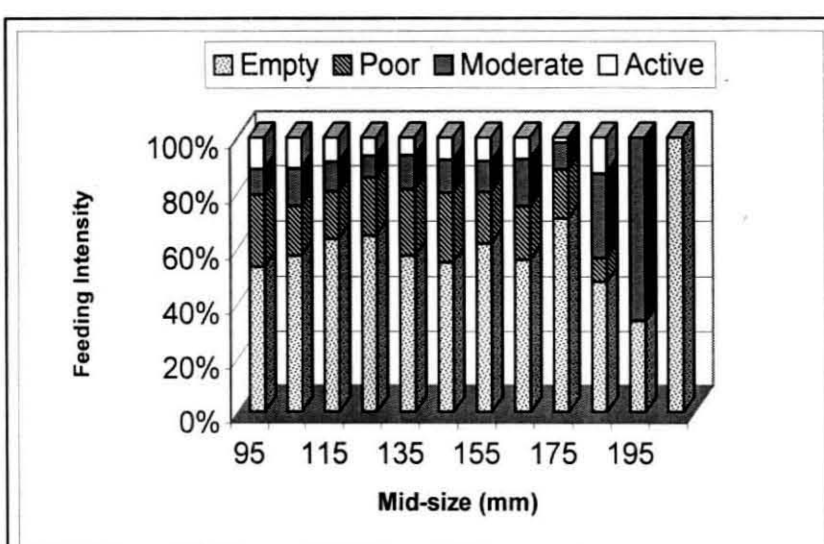


Fig.7. Feeding intensity in males of *L. lactarius* in relation to size.

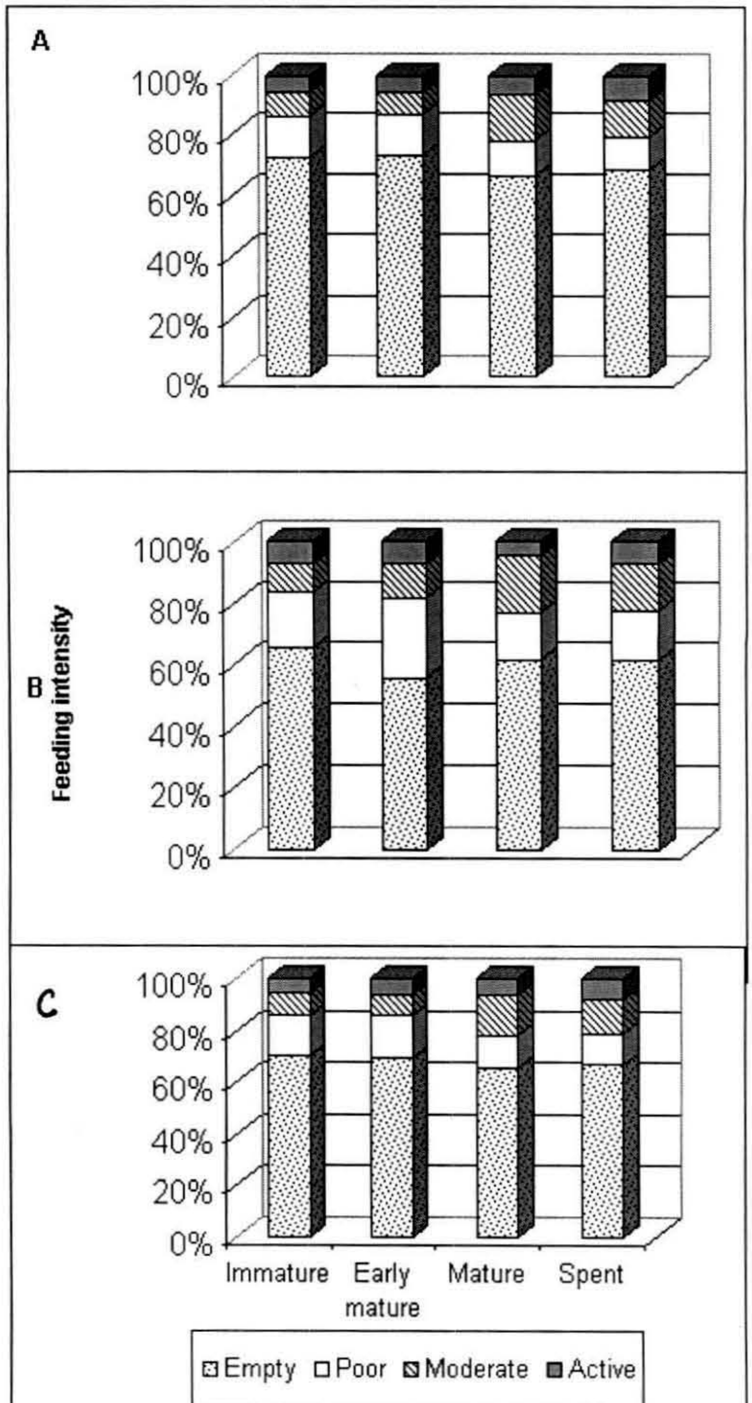


Fig.8. Maturity stage-wise feeding intensity of male *L. lactarius* during 1997-98 (A), 1998-99 (B) and 1997-99 Pooled (C)

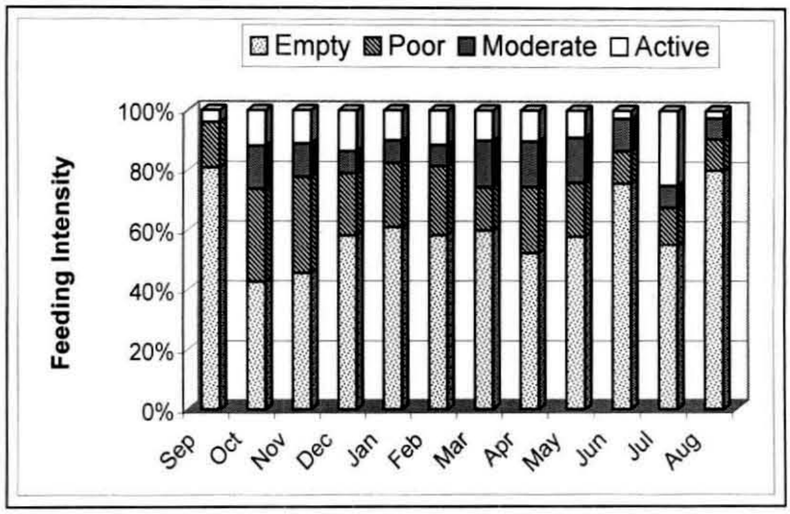


Fig.9. Feeding intensity of females *L. lactarius* in different months.

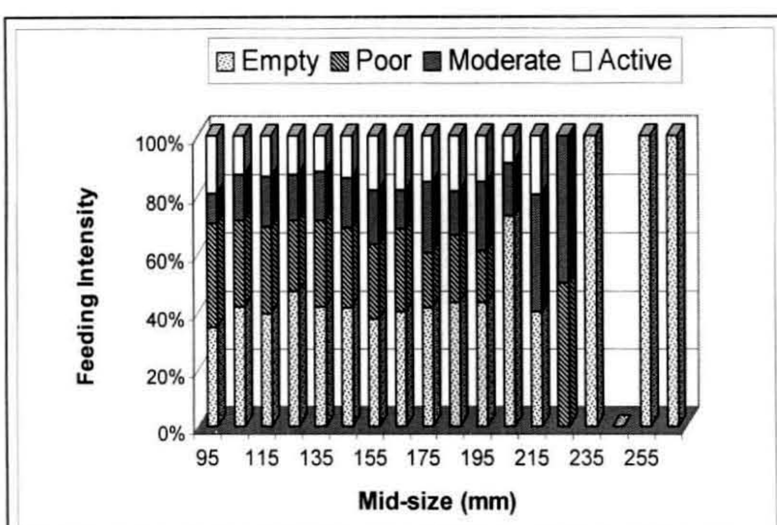


Fig.10. Size-wise feeding intensity in females of *L. lactarius*.

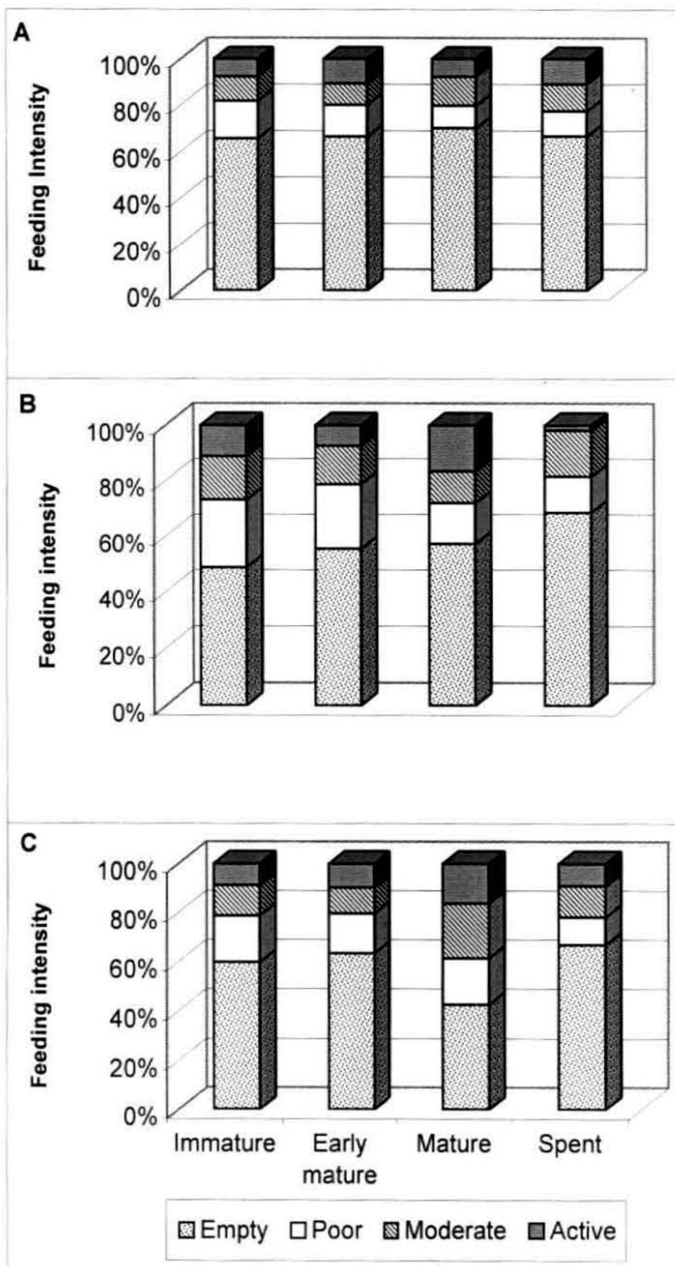


Fig.11. Maturity stage-wise feeding intensity of female during 1997-98 (A), 1998-99 (B) and 1997-99 pooled (C).

Chapter 4

Length-Weight Relationship

4.1. INTRODUCTION

Every animal in its life grows both in length and weight, the relationship between these two is of both theoretical and practical importance. Comparison of the relationship in different phases of its development indicates changes in body shape or in the condition of the animal. Study of length-weight relationship is of vital importance in fishery biological investigations. It helps to establish a direct mathematical relationship between the two variables, namely, length and weight, so that, if one is known, the other could be easily computed. This also helps to know the variations from the expected weight for the known length, which in turn reflects its fatness, general well being of the fish, gonadal development, rate of feeding and the suitability of the environment of the fish (Le Cren, 1951). It can further be used to indicate some important events in the life history of fishes such as metamorphosis, maturity and condition (Hoda, 1976).

The weight of the animal is considered a function of length and since length is a linear measure and weight is a measure of volume, the relationship between the length and weight of an animal could be expressed by the hypothetical cube law, $W = CL^3$, where W and L are the weight and length respectively and C a constant. This expression holds well only when the specific gravity and the form of the animal remain constant. However in fish the growth is not always isometric and therefore does not exactly follow the cube law. Le Cren (1951) modified the equation in to a non-linear type equation as $W = aL^b$, where *a* and *b* are constants to be derived empirically. This equation explains the relationship between length and weight of a fish better than the cube law. The exponent value of *b* in the equation is found to vary from 2.5 to 4 (Hile, 1936) depending on the shape of the fish. However, significant variation from the isometric growth (*b* = 3) is not always common in fishes (Beverton and Holt, 1957) and *b* will be equal to 3 in an ideal situation where the animal maintains its body proportions throughout (Allen, 1938).

This non-linear equation can be transformed into a linear equation of the form, $Y = a + bX$ by taking logarithms on both sides as,

$$LogW = Loga + bLogL$$

i.e., $Y = A + BX$ where A = *log a*, Y = *log* W and X = *Log L*

Log a represents the point at which the regression line intercepts the *log* W axis and *b* represents the slope of the line.

Several studies have been made on the length-weight relationship of marine fishes from India. Some of the important works are of Jhingran (1952), Pillay (1954), Prabhu (1955) and Antony Raja (1967) on *Sardinella longiceps,* Pradhan (1956) on *R. kanagurta,* Krishnamoorthi (1971) and Sophy and Hameed (1994) on *Nemipterus japonicus,* Kagwade (1964) on

Polynemus heptadactylus; Mojumder (1971) on *Tachysurus thalassinus,* Sreenivasan (1981) on *Decapterus russelli*, Muthiah (1982) on *Euthynnus affinis,* Murty (1983) on *Leiognathus bindus*, Jayasankar (1991) on *Sillago sihama*, Swain (1993) on *Trichiurus lepturus,* Kalita and Jayabalan (1997) on *Caranx kalla,* Varghese (1998) on *Priacanthus hamrur* and Jayaprakash (2000) on *Cynoglossus macrostomus* and *C. arel*.

Studies on the length-weight relationship of *L. lactarius* from Indian waters are very few. Rao (1966) studied the length-weight relationship of *L. lactarius* from Waltair. While Neelakantan (1981) reported the length-weight relationship in the fish from Uttara Kannada waters, Reuben *et al.* (1993) studied the length-weight relationship from Andhra Pradesh-Orissa coast. The only study from outside India is that of Pauly *et al.* (1996) from Indonesian waters.

4.2. MATERIAL AND METHODS

Samples of *L. lactarius* were collected from trawl and indigenous gear landings from Mangalore, Malpe, and Tadri landing centers. Altogether 1,611 fish comprising 179 juveniles (29-89 mm), 811 males (90-215 mm) and 621 females (90-265 mm) were analysed in the laboratory for estimating the length-weight relationship. All the fish were analysed in fresh condition.

The fish were washed thoroughly to remove all mud, sand and epizootic forms. After removing the excess water from the body using a blotting paper, the total length (from tip of the snout to tip of upper caudal lobe) of individual fish was measured to the nearest 1 mm and the individual weight was recorded to an accuracy of 0.001 g using an electronic balance.

The linear equation (*log W = log a +b log L*) was fitted for juveniles, males and females separately with the log-transformed values of length and weight. Regression analysis was performed to determine the constants A and *b* and relationship between length and weight using the Data Analysis package in EXCEL software. The correlation coefficient (r) was determined to know the strength and pattern of association between the two variables.

Analysis of covariance (Snedecor and Cochran, 1967) technique was used to test for significant difference in the relationship between the sexes and that between sexes and juveniles at 5% level. The Student's *t* test was carried out to find out whether the b values for males, females and juveniles were significantly different from 3 using the formula.

$$t = \frac{b - \beta}{S_b}$$ where β is equal to 3.

4.3. RESULTS

The regression equations for the length-weight relationship of males, females and juveniles were calculated as under:

Juveniles : Log W = -5.0339 + 3.07314 Log L (r = 0.98350; R^2=0.9672)

Males : Log W= -5.07633 + 3.0631 Log L (r = 0.98018; R^2=0.9607)

Females : Log W= -5.03713 + 3.04844 Log L (r = 0.98428; R^2=0.9688)

The length-weight relationship for various categories of fish of the form $W=aL^b$ is as follows:

Juveniles : $W = 0.000009247\ L^{3.07314}$

Males : $W = 0.000008388\ L^{3.063107}$

Females : $W = 0.000009180\ L^{3.04844}$

The 95% confidence interval of *b* values were:

Juveniles : 2.989296, 3.156991

Males : 3.02395, 3.105826

Females : 3.005269, 3.091615

Pooled : 2.942971, 2.971043

Results of the length-weight relationship in different categories of fish are given in Table 1. The regression equations between male and female, male and juveniles and female and juveniles were tested for equality through analysis of covariance (ANACOVA). Tables 2, 3 & 4 show that the values of slope do not differ significantly at 5% level; but, the elevation differ significantly at 5% level. However, for using in stock assessment studies, a common equation for the species was found out after pooling data for adults and juveniles.

$$\text{Log W} = -4.84509 + 2.9570 \ \text{Log L}; \ (r = 0.99532; R^2=0.990)$$

$$\text{i.e., W} = 0.000014286 \ L^{2.9570}$$

The relationship of lengths against weights are presented for juveniles (Fig.1 A and B), males (Fig.2 A and B), females (Fig.3 A and B) and adults and juveniles pooled (Fig.4 A and B). The value of *b* was highest in juveniles (3.07) and for males and females the values were 3.06 and 3.04 respectively.

The *t* test was conducted to test isometry and the values of *t* calculated were 1.6285 for males, 1.2966 for females, 1.2936 for juveniles and -1.0228 for sexes pooled which did not show significant difference at 5% level from the expected value of 3 indicating isometric growth in the species right from juvenile to adult state.

4.4. DISCUSSION

The length-weight relationship in fish can be explained by cube law $W=aL^3$ in an ideal fish wherein the fish maintains a constant shape, n = 3

(Allen, 1938). If there is a change in density and form as a result of growth, then there will be a significant deviation from the isometric growth. Hence the formula $W = aL^b$ will be more useful in describing the length-weight relationships of fishes.

The values of exponent for males and females of *L. lactarius* in the present study were very close to 3 indicating that the growth followed an isometric pattern. The value of *b* was highest in juveniles indicating that with every increase in unit length the cubic increase in weight was 3.07, and for males and females it was 3.063 and 3.04 respectively.

The regression coefficient of both sexes as well as juveniles was very close to 3, indicating isometric growth throughout the life span. The length-weight relationships of *L. lactarius* from earlier studies and the present investigations have been provided for comparison in Table 5. The values of *b* for males range from 2.958 (Reuben *et al.*, 1993) to 3.06 (Neelakantan, 1981 and the present study). The *b* values for females range from 2.9742 (Neelakantan, 1981) to 3.0484 (the present value being the highest). The *b* value in the present study indicates a slightly faster rate of increase in weight in juveniles than in females or males. However, there is no significant change in the rate of increase in weight corresponding to length between the sexes. This is in conformity with results of earlier studies (Rao, 1966 and Neelakantan, 1981). The regression coefficient for sexes pooled range from 2.861 (Rao, 1966) to 3.047 (Pauly *et al.*, 1996) and the value calculated presently (2.957) lies within the range between. The correlation coefficients (r) in all cases were found to be highly significant.

Table 1. Results of the length-weight relationship analyses for juveniles, males, females and all categories of *L. lactarius* pooled.

Group	N	*a*	*b*	r
Juveniles	179	0.00000924	3.07314	0.983
Male	811	0.00000838	3.06310	0.980
Female	621	0.00000918	3.04844	0.984
All Pooled	1611	0.00001428	2.95700	0.995

Table 2. Comparison of regression lines of male and female *L. lactarius* by ANACOVA.

	df	Regression coefficient	Deviation from regression		
			df	SS	MSS
Males	810	3.063	809	6.424	0.00794
Females	620	3.048	619	4.567	0.00738
Total			1428	10.891	0.00770
Pooled	1430		1429	10.993	0.00769
Difference			1	0.002	0.00172
Total	1431		1430	11.106	0.00777
Between adjusted means			1	0.113	0.11348

Comparison of slope: (df 1, 1430) F= 1.42 (Not significant at 5% level)

Comparison of elevation: (df, 1431) F= 14.75 (Significant at 5% level)

Table 3. Comparison of regression lines of male and juvenile *L. lactarius* by ANACOVA

	df	Regression coefficient	Deviation from regression		
			df	SS	MSS
Males	810	3.063	809	6.424	0.00794
Juveniles	178	3.073	177	2.987	0.01688
Total			986	9.411	0.00954
Pooled	988		987	9.412	0.00954
Difference			1	0.011	0.00060
Total	989		988	9.927	0.01005
Between adjusted means			1	0.515	0.51530

Comparison of slope: (df 1, 1502) F= 0.06 (Not significant at 5% level)

Comparison of elevation: (df, 1503) F= 54.04 (Significant at 5% level

Table 4. Comparison of regression lines of female and juvenile *L. lactarius* by ANACOVA.

	df	Regression coefficient	Deviation from regression		
			df	SS	MSS
Females	620	3.048	619	4.567	0.00738
Juveniles	178	3.073	177	2.987	0.01688
Total			796	7.554	0.00949
Pooled	798		797	7.558	0.00948
Difference			1	0.004	0.00354
Total	799		798	7.855	0.00984
Between adjusted means			1	0.297	0.29698

Comparison of slope: (df 1, 798) F= 0.37 (Not significant at 5% level)

Comparison of elevation: (df, 799) F= 31.32 (Significant at 5% level

Table 5. Comparison of Length-weight relationships of *L. lactarius* with the results available from literature.

Group	*a*	*b*	Length Range (mm)	N	*r*	Area of study	Reference
Male	0.014	2.958	114-230	247	0.981	India	Reuben, *et al.*
Female	0.031	2.808	123-245	220	0.969	-do-	1993
Unsexed	0.0098	3.047	55-315	-	0.997	Indonesia	Pauly *et al.* 1996
Unsexed	0.01608	2.86186	30-250	-	-	India	Rao, 1966
Male	0.0000110	3.0549	91-210	1212		India	Neelakantan,
Female	0.0000139	2.9742	91-260	943			1981
Juveniles	0.0000153	2.9385	56-90	554			
Sexes pooled	0.00001143	3.0072	56-260	2155			
Male	0.000008388	3.06310	90-215	811	0.980	India	Present study
Female	0.000009180	3.04844	90-265	621	0.984		
Juveniles	0.000009247	3.073143	30-89	179	0.983		
Juveniles and sexes pooled	0.000014286	2.9570	30-265	1610	0.995		

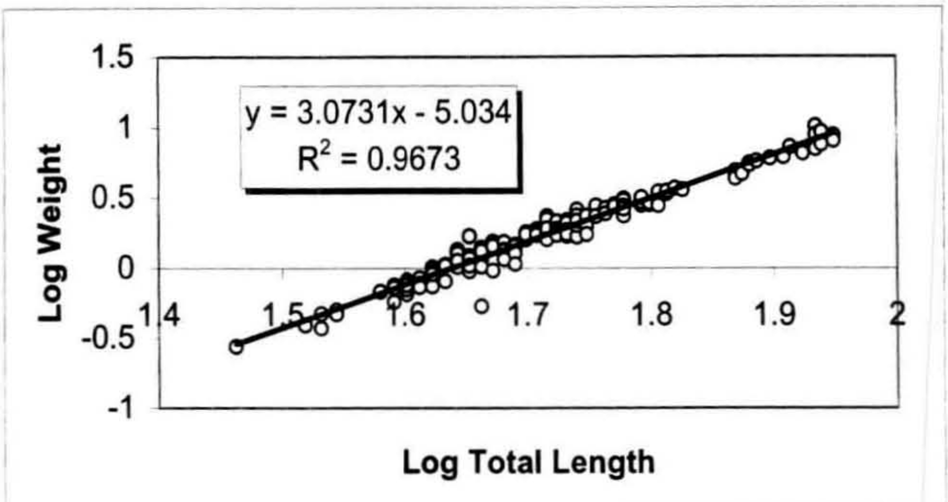


Fig. 1A. Logarithmic relationship between length and weight of juveniles of *L. lactarius*.

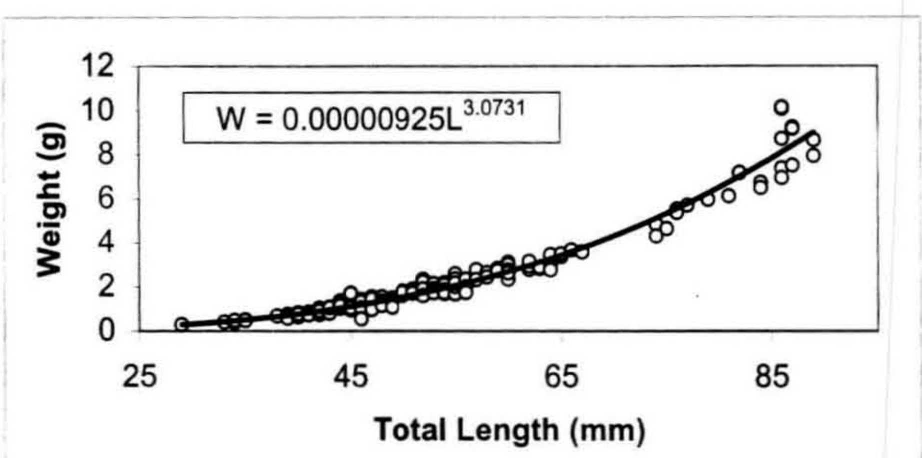


Fig.1B. Scatter diagram of relationship between length and weight of juveniles of *L. lactarius*

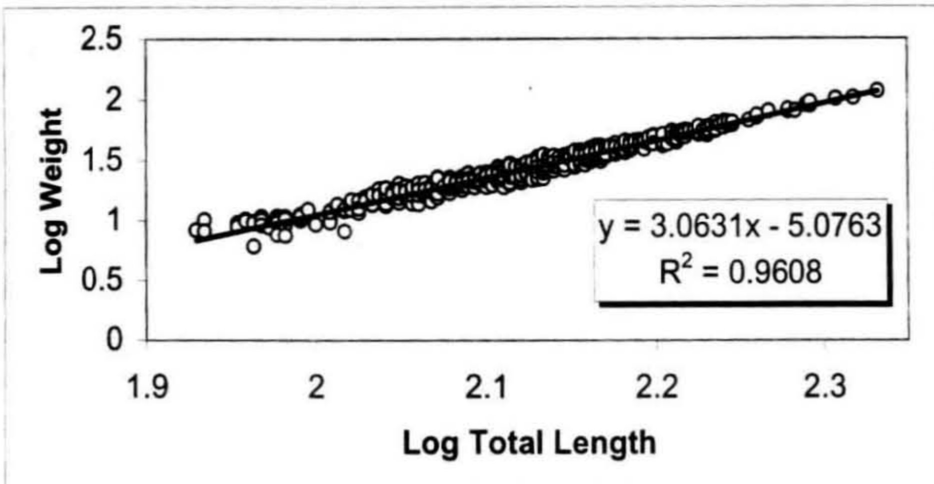


Fig.2A. Logarithmic relationship between length and weight for males of *L. lactarius*.

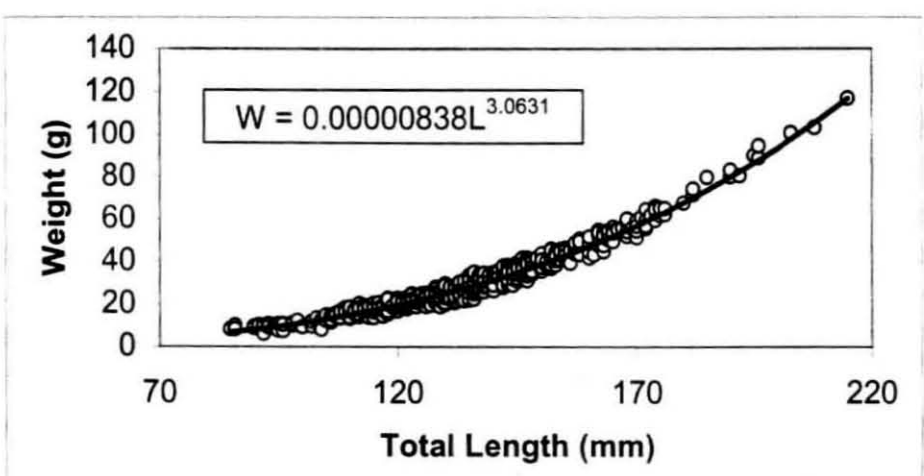


Fig.2B. Scatter diagram of relationship between length and weight for males of *L. lactarius*.

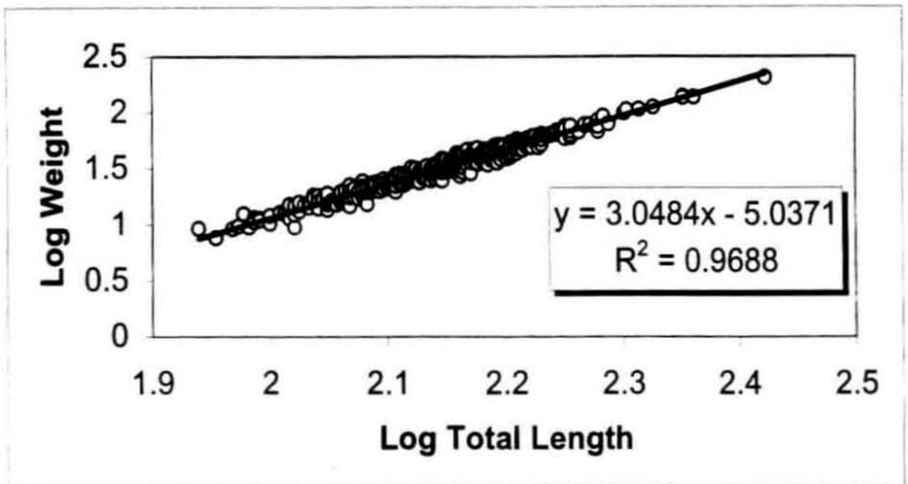


Fig.3A. Logarithmic relationship between length and weight for females of *L. lactarius*.

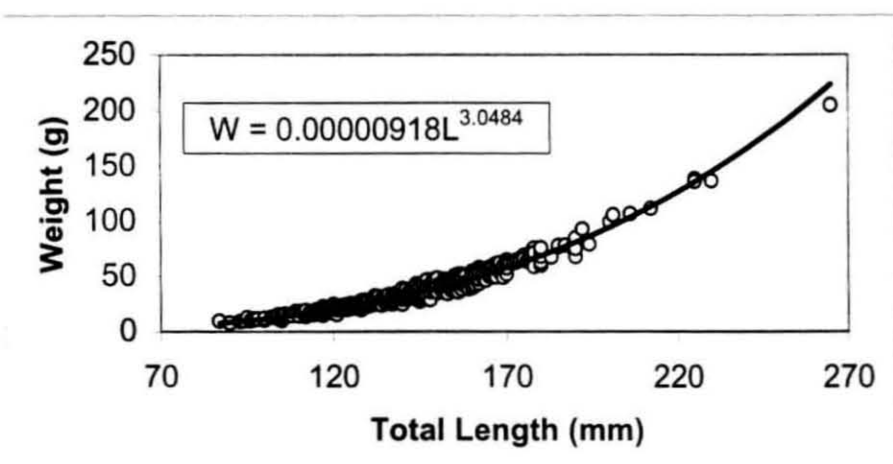


Fig.3B. Scatter diagram of relationship between length and weight for females of *L. lactarius*

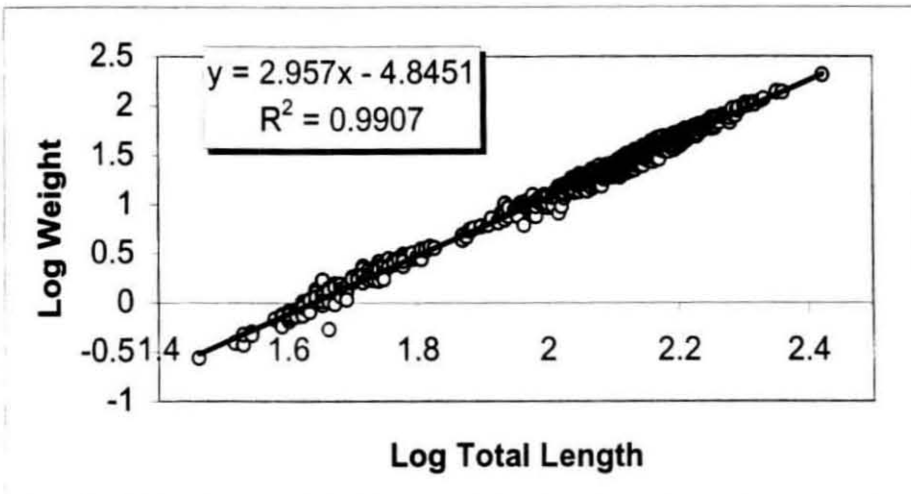


Fig.4A. Logarithmic relationship between length and weight of juveniles and sexes pooled of *L. lactarius*.

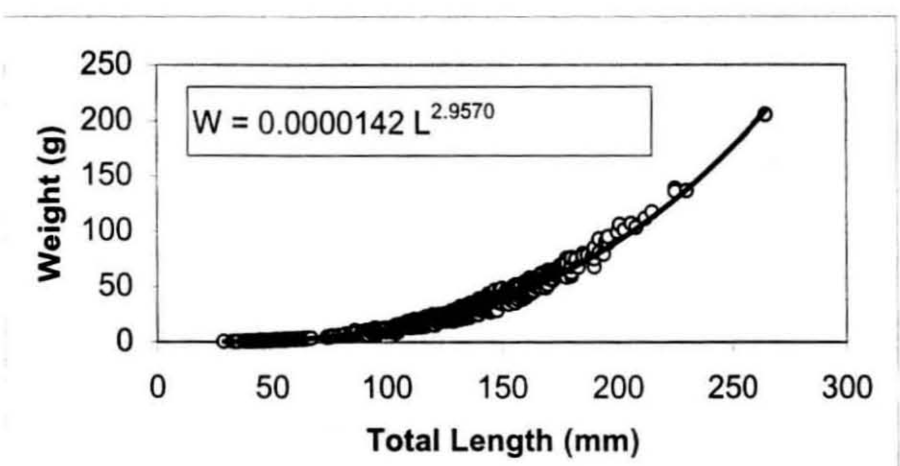


Fig.4B. Scatter diagram of relationship between length and weight of juveniles and sexes pooled of *L. lactarius*.

Chapter 5

Reproduction

5.1. INTRODUCTION

The aim of studying reproduction in fishes is to understand and predict biological changes in the population. An understanding of the age and size at which the fish attains sexual maturity, the time and duration of spawning and the rate of regeneration of the stocks is important for judicious exploitation and management of the stocks. Also knowledge of the total number of eggs produced by a fish during a year is important in determining the spawning potential of the fish.

Reproductive studies of fishes, such as assessment of size at first maturity, duration of spawning season and fecundity require knowledge of the stages of gonad development in individual fish (West, 1990). The methods for such studies range from histology to visual staging based on the external appearance of the gonad and also these are staging based on appearance of oocytes and gonad indices. Macroscopic staging based on changes in the appearance and size of the ovary is one of the most widely used techniques in fish reproductive studies. However, the accuracy of field staging has been questioned (Clark, 1934). As male fishes do not show much large change in their gonad weight (Otsu and Uchida, 1959; Crossland, 1977), the size of oocyte was used as a measure of development (Clark, 1934). The size of the largest ova can be used to assess the stages of maturation (Mac Gregor, 1957; Williams and Clarke, 1982). Hickling and

Rutenberg (1936) investigated the relationship between the oocyte size of ovary and duration of spawning season. On the basis of distribution of the sizes of intra-ovarian eggs, ovaries in fishes have been classified into 3 basic types (Wallace and Selmen, 1981).

1) Synchronous, total or isochronal ovaries in which the whole batch of developed oocytes will be shed over a short period.
2) Group synchronous ovaries in which two size groups of ova are present at some time.
3) Asynchronous ovaries in which the ova size distribution are continuous except in ripe ovaries where there may be a clear separation between the ripe and immature eggs.

Studies on the various aspects of reproductive characteristics of fishes have been made from different parts of the world. The important contributions are of Fulton (1899), Wallace (1903), Graham (1924), Clark (1934), Hickling and Rutenberg (1936), de Jong (1939), June (1953), Bagenal (1957), McGregor (1957), Howard and Landa (1958), Parrish *et al.* (1959), Orange (1961), Crossland (1977), Houde (1977), Fox (1978), Lenanton (1978), William and Clark (1982), de Vlaming *et al.* (1982), Davis (1985), Hoda and Qureshi (1989), Shoesmith (1990), West (1990), Jons and Miranda (1997), Beckmann *et al.* (1998), Glenn *et al.* (1998), Abdul-Fatah and El-Sayed (1999), Nancy *et al.* (2000) and Yondeda *et al.* (2000).

From Indian waters, notable contributions on the reproductive biology of Indian fishes include Hornell (1910), Khan (1924), Panikkar and Aiyar (1939), Job (1940), Devanesan and John (1940), Karandikar and Palekar (1950), Jones (1953), James (1967), Pillay (1954), Prabhu (1956), Pradhan and Palekar (1956), Krishnamoorthi (1958), Palekar and Bal (1961), Kurian (1966), Talwar (1967), Eggleston (1972), Qasim (1973a), Dan, (1977), Devaraj (1977, 1983a, 1986), James and Baragi (1980), Murty (1981), Pati (1982), Rao (1985), Jayabalan (1986), Muthiah (1986), Fernandez and Devaraj (1989), Menon *et al.* (1990), Jayasankar (1991), Vivekanandan (1991), Yohannan (1993), Tamahne and Somvanshi (1998), Jayaparakash (1999) and Jayabalan and Ramakrishnamurthy (1999).

Information on the maturation and spawning of *L. lactarius* is available from Mangalore (James *et al.*, 1974) and Karwar (Neelakantan, 1981; Neelakantan *et al.*, 1980; Neelakantan and Pai, 1985; Neelakantan *et al.*, 1986) along the west coast and from Waltair (Rao, 1966) and Andhra Pradesh-Orissa coast (Reuben *et al.*, 1993) along the east coast of India. The present study was undertaken on the reproductive biology of *L. lactarius* distributed along the entire coast of Karnataka covering Malpe for the first time and the Mangalore coast after a lapse of about three decades (James *et al.*, 1974) with a reconsideration of the species from Karwar for an in-depth knowledge on the fish.

5.2. MATERIAL AND METHODS

Samples of *L. lactarius* caught by different fishing gears were collected from the fisheries harbours at Mangalore, Malpe and Karwar on weekly basis for a period of two years (September 1997 to August 1999). The fish were brought to the laboratory, washed thoroughly to remove mud, sand and other attached forms and surface moisture was removed by blotting paper. The length and weight of individual fish were taken to an accuracy of 1 mm and 1 mg respectively. After cutting open the body cavity of the fish, the sex, colour, size and stage of maturity and weight of the gonad were recorded. The stages of maturity adopted were based on the ICES scale (Lovern and Wood, 1937) with suitable modifications as stage I - immature, stage II- developing immature and spent recovering, stage III - maturing (early mature), stage IV - mature, stage V - advanced mature, stage VI - fully ripe, stage VII a - partially spent and stage VII b - fully spent.

The different stages of ovaries were preserved in modified Gilson's fluid (Bagenal and Brawn, 1971) for the measurement of ova diameter and fecundity studies. Measurement of ova diameter was carried out following the methods of Clark (1934), Hickling and Rutenberg (1936) and Prabhu (1956). Ova diameters were measured using an ocular micrometer and 1 ocular micrometer division (omd) was equal to 15µ. Samples of ova from anterior, middle and posterior regions of both the lobes of ovary were examined. As there was no difference in the size of ova from different parts of the ovary, ova were sampled from middle region of the ovary. Ova measuring less than 3 omd (45 μm) were measured only from immature ovaries (Stages I and II) as they were found in large numbers in ovaries of all stages.

5.2.1. Gonado-somatic Index (GSI)

The gonado-somatic index (GSI), which is useful for determining the reproductive cycle and for separating the spawning and non-spawning fishes, was estimated month-wise. For this purpose, males and females were weighed individually to the nearest g after wiping it dry. The gonad was dissected out carefully and weighed to the nearest mg by using an electronic balance. The GSI was calculated by the methods described by June (1953) and Yuen (1955) using the formula:

$$\mathrm{GSI} = \frac{\text{Weight of the gonad}}{\text{Weight of the fish}} \times 100$$

A total of 705 males (355 from Mangalore, 236 from Malpe and 114 from Karwar) and 596 females (293 from Mangalore, 211 from Malpe and 92 from Karwar) collected during September 1997 to August 1999 were considered separately to calculate monthly mean GSI values.

5.2.2. Relative Condition Factor (K_n)

The term 'condition' was applied by Le Cren (1951) for the analysis of length-weight relationship with the aim of finding out the variation from the expected weight for length of individual fish or groups of individuals as an indication of fatness, general well being or gonad development. The variations of weight for length are not because of the changes in specific gravity of fish, but due to the changes of volume or form since the fish always maintain the density as that of the surrounding water. These changes are determined through the study of coefficient of condition or condition factor or ponderal index with the aim of expressing the condition of the fish in numerical terms such as degree of well-being, relative robustness, plumpness or fatness (Hile, 1936; Thompson, 1943 and Lagler, 1956).

The condition factor K is calculated based on the cube law using the expression:

$K = \frac{W}{L^3} \times 100$ (Hile, 1936).

This formula holds good only if the exponent b of the length-weight relationship is 3. As this formula does not function adequately independent of length and other variables, Le Cren (1951) formulated the relative condition factor K_n as:

$$K_n = \frac{W}{aL^n}$$

or,

$$K_n = \frac{W}{\overline{W}}$$

where W = observed weight, aL^n or $\overline{W}$ = calculated weight obtained from the length-weight relationship.

The mean monthly values of K_n were compiled for samples collected from September 1997 to August 1999. The K_n values were estimated for 831 males and 607 females separately. The K_n value was also calculated in relation to size of the fish by grouping them in to 10 mm class interval.

5.2.3. Maturity Stages

The classification of maturity stages is aimed to study the spawning period and to calculate the size/age at sexual maturity. The stages of gonad developmental were ascertained by the following methods:

5.2.3.1. Gross Examination of Gonads

The International Council for the Exploration of Sea (ICES) scale was used to recognize the different stages of the gonads (Lovern and Wood, 1937). The ovaries and testes were categorized into seven stages accordingly. The fresh ovaries were examined macroscopically for studying the general external characteristics and microscopic examinations of the ovary were made on preserved material. In males, maturity stages were classified on the basis of macroscopic examination only.

5.2.3.2. Study of the Ova Diameter Frequency Distribution.

In order to bring out the natural sequence of maturity stages which the ova pass through before becoming fully mature, ova diameter measurements taken from individual ovaries were classified according to the size-frequency distribution of ova and the position of the mode of the most mature groups of ova. For this purpose, about 300 ova were measured each from 103 ovaries in various stages maturity were utilised. From each ovary the diameters of about 300 ova were measured. The ova diameter from different ovaries of identical stage was pooled and grouped into 3 ocular micrometer divisions (omd) intervals for plotting the graph.

5.2.4. Length at First Maturity

The average length at first maturity (L_m) was determined by tabulating the percentage of fishes in stage III and above against their length. Maturity curves were drawn to the scatter plots so as to estimate the length at which 50% of fish mature.

5.2.5. Spawning Season

The percentage occurrence of various stages of maturity during different months was plotted to find the spawning period.

5.2.6. Sex-Ratio

To test the monthly difference in numbers between males and females, the sex ratio was tested using the chi square formula:

$$\chi^2 = \frac{\sum(O-E)^2}{E}$$

where,

O =observed number of males and females in each month/length group,

E = expected number of males and females in each month/length group.

For the present sex-ratio analysis 4,827 males (90-215 mm TL) and 3,795 females (90-265 mm TL) of *L. lactarius* were examined.

5.2.7. Fecundity

Fecundity was estimated using ovaries of stages V preserved in modified Gilson's fluid. The excess moisture was removed from the ovaries using blotting paper and weighed in an electronic balance to an accuracy of 0.001g. A small portion of the ovary was removed and weighed for counting the mature ova in the samples after placing in a counting chamber under a microscope. All the mature eggs in the piece of ovary were counted and fecundity was estimated using the formula,

$$\text{Fecundity} = \frac{\text{total weight of the ovary}}{\text{weight of the sample}} \times \text{number of ova in the sample}$$

Altogether 71 ovaries from fish ranging in length from 137 to 230 mm in TL, 30.5 - 136.35 g body weight and 0.68-5.03 g gonad weight were utilised. The relationship between fecundity and different variables like total length, fish weight and gonad weight was worked out by the least square method,

$$F = aX^b$$

where,

F = Fecundity, a = constant, X = variable (fish length, fish weight or ovary weight) and b = correlation coefficient. The exponential relationship was transformed into a straight line logarithmic form based on the equation,

$$LogF = \log a + bLogX$$

5.3. RESULTS

5.3.1. Reproductive Organs

The gonads lie in the posterior part of the abdominal cavity attached to the dorsal wall by a membranous meso-ovarium or meso-archium. Peritoneal folds in the intervening and posterior parts though free anteriorly, closely connect the two lobes. A common genital opening leads the gonads to the exterior.

5.3.2. Structure of Ovary

The ovary is situated in the lower abdominal cavity as a pair of sac like structure. The left lobe of the ovary is always shorter than the right one indicating the asymmetry of the organ. Both the lobes are free at the anterior while a connecting membrane holds them at the posterior. Both the ovaries join together and open directly to the exterior by a common genital aperture.

The inner wall of the ovary is lined by germinal epithelium, which proliferates the ova. (For details refer section **5.3.4.1**)

5.3.3. Structure of Testis

Testis is paired, elongated, laterally compressed and grows anteriorly with advancement of maturation. The testis, which is thread-like and reddish in the initial phases, becomes thick, fleshy and milky white on maturation. (For details refer section 5.3.4.2).

5.3.4. Maturation

5.3.4.1. Maturity Stages in Females

5.3.4.1.1. By Gross Examination of Ovary

Stage I: Immature

Ovary thin, transparent, occupies 1/3 of body cavity. Ova irregularly shaped and fully transparent with prominent nucleus.

Stage II: Developing immature and recovering spent

Ovary slightly larger than the previous stage, flat, transparent and occupies about half of body cavity. Ova invisible to naked eye.

Stage III: Maturing (Early mature)

Ovary yellowish, occupying half of body cavity, ovarian wall semi-transparent. Ova spherical, opaque with full deposition of granular yolk, visible to naked eye.

Stage IV: Mature

Ovary occupies about three-fourth of body cavity, yellowish with prominent blood vessels, fully packed with ova.

Stage V: Advanced mature

Ovary greatly enlarged, dark yellow, occupies more than three-fourth of body cavity. Ovarian wall thin. Ova spherical, semi transparent, yolk vacuolated and yellowish.

Stage VI: Fully Ripe

Ovary orange in colour, fully occupies body cavity, ovarian wall very thin. Ova spherical, separate from each other, oozes out under slight pressure.

Stage VII a: Partially spent

In this stage, ovary occupies nearly 3/4 the body cavity, appears yellowish, partly empty and in distorted shape. Ovary appears reddish in posterior part.

Stage VII b: Fully spent

Ovary shrunken and flaccid, blood shot, occasionally with blood vessels loosely hanging in lumen of ovaries. Ova small and transparent.

5.3.4.1.2. Microscopic Studies of Ova

Development of ova to maturity was studied by recording ova diameter from ovaries of all stages (Fig.1). In stage I, majority of ova were in the size range of 1-3 omd. This may be considered as the general egg stock. Few large ova measuring 7-9 and 10-12 omd were also seen. In stage II, besides the ova of 1-3 omd, a batch of ova forming a mode at 13-15 omd got separated from the general egg stock. Some large ova measured up to 19-21 omd. After stage II, the development of ova for maturity was rapid. In stage III, the batch of ova forming a mode at 13-15 omd in the stage II grew further to form a mode at 25-27 omd and a few ova measuring up to 31-33 omd was also seen. Another small mode was seen at 7-9 omd. In stage IV, the maturing mode (25-27 omd) shifted to 31-33 omd and the largest ova measured up to 37-39 omd. Another mode at 19-21 omd was also present. In stage V, the mature ova measuring 37-39 omd formed a prominent mode and also one maturing group of ova forming a mode at 22-24 was evident. The larger ova measured 43-45 omd. In stage VI, there was a clear separation of a group of ova measuring 37-57 omd with a mode at 46-48 omd. This was the batch of ripe ova with an oil globule measuring 13-14 omd. The mode seen at 22-24 omd in stage V was stationary. In partially spent condition (stage VII a), majority of the ripe ova were already shed and lesser number of ova measuring 37-57 were present. A mode of ova measuring 22-24 omd was seen in this stage.

The photomicrographs of immature, maturing and mature ova are given in Figs 2a, 2b and 2c. Fig 2d shows a fish with mature ovary.

5.3.4.2. Maturity Stages in Males (Gross Examination)

Stage I: Immature

Testis thread like and occupying less than quarter of the body cavity.

Stage II: Developing

Testis increased in size and translucent, occupies about quarter of body cavity.

Stage III: Maturing (Early mature)

Testis whitish, enlarged in size, occupies about half of body cavity

Stage IV: Mature

Testis white or creamy in colour, occupies more than half and less than three-fourth of the length of body cavity.

Stage V: Advanced mature

Testis greatly enlarged in size, convoluted in appearance and milky white, occupying about three-fourth of the length of body cavity.

Stage VI: Fully Ripe

Testis greatly enlarged, occupies full length of the body cavity, milky white and exudes milt on slight pressure.

Stage VII a: Partially spent

Testis partially collapsed, reddish, transparent along the margin due to partial release of milt at spawning.

Stage VII b: Fully spent

Testis reddish brown, flabby and shrunken occupying about one-fourth the length of body cavity.

5.3.5. Gonado-Somatic Index (GSI)

The monthly mean values of GSI for males and females are given in Table 1 and graphically represented in Fig.3. The values increased rapidly from August to January and reached a peak in February. The highest GSI values for males and females were 0.8116 and 3.6199 respectively during February. Thereafter, the values declined to reach the lowest during June-August. The appearance of individuals with high GSI indicates breeding activities during October-March. The fall in GSI values during April-June was mainly due to presence of spent gonads.

5.3.6. Relative Condition Factor (K_n)

5.3.6.1. Seasonal Variation in Relative Condition Factor

In the present study, the K_n values in females showed two peaks, a minor in February and a major one in May. In males, the minor peak was during April and a major one in June (Table 2 and Fig.4). During January-June, the K_n values stood above 1 for females and during the rest of the months the values were less than 1. Lower K_n values (less than 1) were seen in males during July-October and thereafter an increasing trend was observed and attained a minor peak during February, which is the period for peak spawning in *L. lactarius*. The value showed a fall in March and reached a trough in May, thereafter started to rise to reach the highest peak in June.

5.3.6.2. Relative Condition Factor in Relation to Size

Variation in K_n values at 10 mm length groups of males and females showed that the relative condition was high in younger groups (Table 3 and Fig.5). The K_n value was lowest in the size class 130-139 mm for both males and females. The K_n values oscillated at more or less regular intervals between 120 and 235 mm indicating the factors other than spawning for the oscillation.

5.3.7. Size at First Maturity

The percentage occurrence of ovaries and testes in different stages of maturity in relation to size is provided in Fig.6. All the males were immature up to 99 mm. Mature males were first met (9.68%) in 100-109 mm size group and continue to occur up to 215 mm. Fifty percentages of them matured at 131 mm in length. In the case of females, the smallest fish with mature ovary (6.8%) was seen in 105 mm and the first spent female was recorded at 115 mm. The size at first maturity (50%) for females was 133 mm.

5.3.8. Spawning

5.3.8.1. Spawning Season

The percentage occurrence of various stages of maturity of gonads during different months of the year was recorded to find out the spawning period (Tables 4 and 5 and Figs. 7 and 8). Higher percentages of fully mature testes and ovaries (stages V& VI) occurred during November-April indicating peak spawning activities during this period. This was further confirmed by the presence of spent specimens in March and small sized (35-60 mm) fish during February and May in the commercial landings as trash fish.

5.3.8.2. Spawning Frequency

The ripe ovaries of *L. lactarius* are characterized by transparent ova with distinct oil globule and oocytes of different maturity stages. In ripe ovaries besides a batch of ripe ova, a second largest group of yolked eggs is half way through the maturation process to become ripe (Fig.1). This batch may require some more time to become ripe and to spawn in the next spawning season.

5.3.9. Fecundity

The relationships between fecundity and body length, fecundity and body weight, fecundity and ovary weight were considered in the present study. The data were transformed to log base and regression lines were fitted using the method of least squares. The fecundity estimates varied from 7,042 eggs to 53,275 eggs (Table 6).

5.3.9.1. Relationship Between Fecundity and Total Length

The logarithmic relationship between fecundity (F) and total length (L) of fish is linear (Fig.9). The calculated relationship is:

$$\text{Log } F = -5.32277 + 4.30955 \log L$$

The correlation coefficient (r) was 0.8889 indicating was significant ($P<0.01$) relationship.

5.3.9.2. Relationship Between Fecundity and Body Weight

The fecundity and body weight also showed a linear relationship (Fig.10). The regression equation of fecundity (F) on bodyweight (W) is expressed by the formula:

$$\text{Log } F = 1.76815 + 1.42008 \log W$$

The correlation coefficient (r) was 0.881 indicating a significant relationship ($P<0.01$).

5.3.9.3. Relationship Between Fecundity and Ovary Weight

The logarithmic relationship between fecundity and ovary weight (OW) (Fig.11) can be expressed by the equation:

$$\text{Log } F = 3.8463 + 1.28995 \log OW.$$

The correlation coefficient value (r) was 0.9481 indicating highly significant ($P<0.01$) relationship between the two variables.

5.3.10. Sex-Ratio

Since sexual dimorphism is absent, the sexes of *L. lactarius* could not be distinguished externally. Specimens were examined with a view to determine the incidence of males and females of all sizes in the commercial catches collected from Mangalore, Malpe and Karwar. In specimens below 90 mm sexes could not be differentiated and they were grouped as juveniles (indeterminate). The results during the study period are given in Table 7 and Fig.12. Males were dominant during September 1997 to April 1998; whereas, females dominated in October 1997 and May-August 1998. Again during October 1998-April 1999 males were dominant. The males were dominant during the spawning period. The overall sex ratio indicated significant dominance of males.

Table 8 summarises the sex ratio for different length groups. Males were dominant in the fishery up to 155 mm and thereafter females became dominant. After 215 mm only females were present in the fishery. Chi square values were significant in length groups.

5.4. DISCUSSION

Most of the tropical marine fishes mature fairly early and spawn at the age of first or second year of their life (Qasim, 1973a). The size at first maturity of males and females of *L. lactarius* were 131 and 133 mm respectively and age at first maturity in the present study is less than one year as evidenced from age and growth studies (Chapter 6). In earlier studies from Mangalore and Karwar waters of the west coast the sizes at first maturity of *L. lactarius* were estimated as 131 and 122-130 mm respectively (James *et al.*, 1974 and Neelakantan, 1981) whereas from the east coast the size at first maturity was estimated as 167.5 mm (Reuben *et al.*, 1993). This shows that fish along the Karnataka coast matures at an earlier length.

The progression of ova from immature to ripe stages indicates that individual fish spawns more than once (Fig.1). As the size range of ripe ova is not very large, it may be inferred that the fishes may spawn for a shorter duration. The presence of yolked oocytes of different sizes in the mature ovary is a criterion for the existence of multiple spawning (Clark, 1934 and De Silva, 1937). However, regarding the question of whether the advanced group of yolked oocytes alone or all the yolked oocytes are spawned during the spawning season is not clear. It is believed that all the yolked oocytes are capable of development for eventual spawning (De Silva, 1937). In the present study, the distribution of ova in the mature/ripe ovaries indicates that the spawning in individual *L. lactarius* is more than once, but for shorter duration. Up to stage III, there is only a single mode of maturing ova and after which a group of ova separates from the maturing group and grows fast for spawning.

The mean monthly GSI values in *L. lactarius* of Karnataka coast followed a similar trend in males and females except that the change in weight of testes was small (Fig 3). The fluctuations in the indices during various months indicate asynchronous maturation of gonads in the population and an extended spawning season. This is evident from the occurrence of stages V, VI and VIIa gonads during most part of the year in the commercial catches. During the peak spawning period (November-March) higher values of GSI coincided with spawning in the species along the Karnataka coast.

The monthly fluctuations in K_n values of fishes are influenced either by the factors closely related to sexual cycles of the fish *i.e.*, the weight of gonads before and after spawning (Hickling, 1930; Thompson, 1943; Hart, 1946; Le Cren, 1951; Pillay, 1953; Sarojini, 1957 and Pantulu, 1961) or to the feeding condition irrespective of gonadal maturation (Hile, 1948; Qasim, 1957; Bal and Jones, 1960; Blackburn, 1960; Jayabalan and Ramamoorthi, 1985; Jayabalan, 1986; Jayabalan and Ramakrishnamurthy, 1999). In the Australian barru, *Thyrsites atun* there could be several alien factors responsible for temporal variations other than sexual and feeding cycles (Blackburn, 1960). The same trend could be observed from Indian waters in ribbonfishes (James, 1967), leiognathids (Jayabalan, 1986) and lesser sardines (Jayabalan and Ramamoorthi, 1985)

The gonadal maturation and feeding habits of fishes are inversely related to each other (Hoda, 1991). However, James (1967), Jayabalan (1986) and Jayabalan and Ramakrishnamurthy (1999) did not find any relation between gonadal maturation and feeding intensity In the present study also, as the rate of feeding during spawning months fluctuated, it appears that there is no relation between feeding intensity and maturation cycle. Similarly higher K_n values observed during November-July, which include peak spawning reveals that K_n are not influenced by maturity cycle of the fish. Hence, it may be stated that the changes in K_n values are not related to maturation and spawning, but may be due to feeding or due to some unknown factors.

The rise in K_n value at the time of spawning was observed in Indian fishes such as *L. lactarius* by Neelakantan (1981), *Nemipterus japonicus* by Murty (1981), *Sillago sihama* by Jayasankar (1991), *Saurida tumbil* and *S. undosquamis* by Muthiah (1994) and *C. macrostomus* by Jayaprakash (1999). High and low K_n was observed before and after spawning in certain

Pleuronectiformes (Thompson, 1943). The increasing and decreasing condition in *Blennius pholis* were probably due to the general building up and losing of biochemical reserves respectively (Qasim, 1957).

The point of inflexion in the curve of K_n values plotted against length is indicative of the length at which sexual maturity starts (Hart, 1946 and Pillay, 1954). The present investigation supports this observation as the point of inflexion was seen in the size group 130-139 mm for both the sexes and the size at first maturity of male and female was estimated at 131 mm and 133 mm respectively.

In the present study, the occurrence of more number of fully mature testes and ovaries in *L. lactarius* during November-April indicates that peak spawning occurs generally during these months along the Karnataka coast. However, in the east coast of India, while *L. lactarius* spawns during February-April along the Waltair coast, (Rao, 1966) and during February-July along Andhra-Orissa coast (Reuben *et al.*, 1993), the species spawns during December-March along Karwar, west coast of India (Neelakantan, 1981). This shows that along the Karnataka coast while the species spawns for a shorter duration (December-March) along the northern part of the coast, it spawns for slightly longer duration (November-April) in the southern part of the coast.

While *L. lactarius* is a fractional spawner along the Waltair coast (Rao, 1966), along the Karwar coast the male *L. lactarius* spawns thrice a year and female spawns 2-3 times a year (Neelakantan, 1981) and a protracted spawning was observed along Andhra Pradesh-Orissa coast (Reuben *et al.*, 1993). The pattern of occurrence of mature gonads and ova-diameter distribution in the present study shows that while the individual females spawns for more than once a year, the population spawns during most part of the year.

Fecundity is defined as the 'egg potential' or the number of eggs/ova in an organism, which has the potential to give rise to the offspring. The estimation of fecundity is difficult in fishes which spawn in batches (Qasim and Qayyum, 1963) and is affected by environmental conditions (Hickling, 1930 and Nikolsky, 1965). Fecundity has been shown to increase as square (Clark, 1934) or cube of length (Simpson, 1951; Bagenal, 1957; Pillay, 1958) or a fourth power of length (Farran, 1938) or more than a fourth power of length (Varghese, 1980). In the present study, the exponential value was 4.30 indicating that fecundity increases at a rate above the fourth power of length. This value was higher than the *b* in length-weight relationship suggesting that the fecundity increased at a higher rate than the rate of increase of body weight in relation to length. However, along the Karwar coast the estimated value for *L. lactarius* stood at 3.9 (Neelakantan, 1981).

While the fecundity of *L. lactarius* ranged from 9,000 to 79,000 in fish of size 163-214 mm from Mangalore (James *et al.*, 1974), the fecundity of the species from Karwar waters ranged from 17,972 to 63,121 eggs in fishes of total length from 156 to 232 mm (Neelakantan, 1981). In the present study, the smallest fish measuring 139 mm had a fecundity of 9,733 eggs. However, lowest number of eggs of 7,042 was recorded from a fish measuring 154 mm and highest of 53,275 eggs from a fish measuring 188 mm.

A straight-line relation between fecundity and body weight has been reported by Bagenal (1957), Sarojini (1957), Parulekar and Bal (1971) and Muthiah (1994). A comparison of correlation coefficient values with length, weight and ovary weight indicated that ovary weight and body weight were linearly related and the rate of increase in fecundity was 1.3675 times that of body weight of *L. lactarius* along the Karnataka coast. In an earlier study, Neelakantan (1981) estimated the rate of increase of fecundity 1.9626 times the weight of fish.

Along the Karwar coast males of *L. lactarius* were dominant during 1978-80 (Neelakantan, 1981). It is suggested that males dominate in place where spawning occurs (De Martine and Fountain, 1981) and during courtship a single female was followed by a group of males showing dominance of males (Magnuson and Prescott, 1966; Hunter and Goldberg, 1980). The deviation from normal 1:1 sex ratio might be due to the partial segregation of mature forms through their habitat preference (Parrish *et al.*,

1986) and behavioural differences between sexes (Baglin, 1982). Further, Sex ratio in fishes may be due to differential fishing (Kesteven, 1942) and also due to differences in growth rate between sexes (Qasim, 1973a), differences in age and size at maturity (Reynolds, 1974), differences in morphology and physiological activity (Baglin, 1982). The higher percentage of males in the present study throughout the year especially during spawning season may be related either to any one or to a combination of several factors stated above.

Table 1. Monthly mean GSI values of males and females of *L. lactarius* pooled from Mangalore, Malpe and Karwar for 1997-98 and 1998-99

Months	MALE				FEMALE			
	Minimum length (mm)	Maximum length (mm)	Numbers	Mean GSI	Minimum length (mm)	Maximum length (mm)	Numbers	Mean GSI
September	106	165	28	0.2738	108	149	24	0.9532
October	105	153	58	0.5477	103	154	46	1.7597
November	114	180	89	0.5272	115	154	102	1.9597
December	114	180	73	0.5390	118	200	60	2.5414
January	111	198	65	0.7221	133	201	47	3.0272
February	126	205	102	0.8116	130	206	94	3.6199
March	115	195	111	0.6059	130	267	45	2.5014
April	102	173	87	0.4210	136	212	56	2.4095
May	108	172	67	0.3837	109	175	77	1.9074
June	120	120	1	0.0770	115	153	7	0.4818
July	140	174	14	0.2583	122	180	25	0.3951
August	126	140	10	0.0677	118	154	13	0.3188
POOLED	102	205	705		103	267	596	

Table 2. Monthly K_n value of *L. lactarius* (pooled for 1997-98 and 1998-99).

Sex/Month	MALE		FEMALE	
	K_n	Number	K_n	Number
September	0.941	21	0.921	12
October	0.924	140	0.914	92
November	0.989	111	0.990	105
December	0.992	157	0.993	98
January	1.008	61	1.012	41
February	1.050	86	1.042	60
March	1.046	65	1.025	24
April	1.053	41	1.029	14
May	1.012	110	1.093	106
June	1.145	11	1.087	15
July	1.010	14	0.998	25
August	0.958	14	0.928	15
Total		831		607

Table 3. K_n values in different length groups of *L. lactarius* (pooled for 1997-98 and 1998-99).

Length group	Male	Female
90-99	1.011	1.0347
100-109	1.0124	1.0299
110-119	1.0314	1.0121
120-129	0.9994	0.9998
130-139	0.9808	0.9951
140-149	1.0003	0.9967
150-159	1.0208	1.0139
160-169	1.0314	0.9981
170-179	1.007	1.0352
180-189	1.0297	1.0037
190-199	1.007	1.0104
200-209	1.0106	1.0207
210-219	0.988	0.9725
220-229		0.9975
230-239		0.9275
240-249		0.9456
250-259		0.9042
260-269		0.8816

Table 4. Monthly distribution of maturity stages in males of *L. lactarius* (1997-98 and 1998-99 pooled).

Stages/Month	I	%	II	%	III	%	IV	%	V	%	VI	%	VII	%	Total	%
September	72	29.8	106	43.8	53	21.9	11	4.5	0	0.0	0	0.0	0	0.0	242	100
October	130	28.3	133	29.0	138	30.1	48	10.5	6	1.3	2	0.4	2	0.4	459	100
November	76	10.3	238	32.1	207	27.9	122	16.5	53	7.2	28	3.8	17	2.3	741	100
December	56	8.1	141	20.3	275	39.6	116	16.7	59	8.5	29	4.2	19	2.7	695	100
January	18	4.2	47	11.1	120	28.3	132	31.1	69	16.3	21	5.0	17	4.0	424	100
February	33	6.3	70	13.4	104	19.9	149	28.5	85	16.3	57	10.9	25	4.8	523	100
March	39	6.0	151	23.3	186	28.7	144	22.2	50	7.7	45	6.9	34	5.2	649	100
April	50	10.2	132	26.9	151	30.8	88	18.0	35	7.1	21	4.3	13	2.7	490	100
May	92	20.1	123	26.9	106	23.2	72	15.8	39	8.5	14	3.1	11	2.4	457	100
June	10	35.7	7	25.0	2	7.1	2	7.1	3	10.7	2	7.1	2	7.1	28	100
July	26	52.0	18	36.0	4	8.0	2	4.0	0	0.0	0	0.0	0	0.0	50	100
August	20	29.4	37	54.4	11	16.2	0	0.0	0	0.0	0	0.0	0	0.0	68	100
Sum	622	12.9	1203	24.9	1357	28.1	886	18.4	399	8.3	79	1.6	280	5.8	4826	100

Table 5. Monthly distribution of maturity stages in femals of *L. lactarius* (1997-98 and 1998-99 pooled).

Stages/month	I	%	II	%	III	%	IV	%	V	%	VI	%	VII a	%	GT	%
September	37	20.8	64	36.0	50	28.1	21	11.8	3	1.7	2	1.1	1	0.6	178	100
October	92	22.3	88	21.4	78	18.9	78	18.9	34	8.3	31	7.5	11	2.7	412	100
November	47	7.3	125	19.3	158	24.4	146	22.5	73	11.3	77	11.9	22	3.4	648	100
December	36	7.7	50	10.6	72	15.3	139	29.6	55	11.7	90	19.1	28	6.0	470	100
January	7	2.7	13	5.0	28	10.8	92	35.3	51	19.6	49	18.6	21	8.1	260	100
February	26	7.1	20	5.4	36	9.8	76	20.7	80	21.7	99	26.9	31	8.4	368	100
March	22	5.8	57	15.1	60	15.9	69	18.3	44	11.7	91	24.1	34	9.0	377	100
April	70	18.5	69	18.3	80	21.2	64	17.0	26	6.9	47	12.3	22	5.8	378	100
May	96	19.1	174	34.6	75	14.9	64	12.7	49	9.7	30	5.9	16	3.2	503	100
June	5	14.7	16	47.1	7	20.6	1	2.9	0	0.0	4	10.3	1.5	4.4	34	100
July	31	50.8	22	36.1	7	11.5	0	0.0	1	1.6	0	0.0	0	0.0	61	100
August	24	22.6	45	42.5	30	28.3	7	6.6	0	0.0	0	0.0	0	0.0	106	100
Sum	493	13.0	743	19.6	681	17.9	757	19.9	416	11.0	518	13.6	188	4.9	3795	100

Table 6. Fecundity in relation to average length, body weight and ovary weight in *L. lactarius*.

Average length (mm)	Average weight (g)	Average ovary weight (g)	No.of mature ova	No. of specimens
137	30.5	1.032	9733	1
139	30.938	1.132	9848	1
141	34.496	1.82	11905	1
143	32.775	1.135	8952	1
145	36.95	1.176	7585	1
146	41.357	1.123	7373	1
148	42.109	1.414	10519	2
149	39.515	1.362	9561	2
150	37.361	1.714	14640	1
152	45.722	1.667	11724	2
153	44.522	1.296	8153	2
154	43.314	1.097	7042	2
155	45.924	1.795	14682	1
157	52.88	2.106	16645	1
158	48.823	1.329	8231	4
159	45.343	2.187	12879	3
162	53.012	1.758	21212	4
163	51.671	1.767	12519	3
164	46.238	1.978	25871	1
165	54.485	2.292	18146	4
167	53.5	1.805	20377	2
168	55.6	1.936	15840	1
169	57.642	2.905	22823	1
171	63	2.115	20731	1
175	67.5	2.167	24222	2
176	65.858	2.627	22642	4
177	71	1.891	14627	1
178	71.251	3.116	24679	2
180	71.996	2.746	28797	4
182	70	2.974	32793	1
184	79.276	2.846	28068	2
187	81.966	2.561	25444	1
188	91.467	5.301	53275	2
190	89	3.283	39213	1
193	87.23	3.693	41570	2
194	81.505	3.503	33191	2
201	105.75	3.861	49877	1
214	101.825	3.601	42624	2
230	136.35	5.032	46000	1

Table 7. Monthly distribution of sex-ratio and chi square test in *L. lactarius* during 1997-98, 1998-99 and pooled for 1997-99.

1997-98	No.of specimens	Males	Females	Sex ratio	Proportion of males	Chi-square	Significant (S) or not (NS) at 5% level	D.F.
Month								
September	275	193	82	1:0.42	0.702	44.804	S	1
October	376	178	198	1:1.11	0.473	1.064	N S	1
November	774	404	370	1:0.92	0.522	1.494	N S	1
December	562	356	206	1:0.58	0.633	40.036	S	1
January	356	231	125	1:0.54	0.649	31.562	S	1
February	388	235	153	1:0.65	0.606	17.330	S	1
March	440	268	172	1:0.64	0.609	20.945	S	1
April	341	202	139	1:0.69	0.592	11.639	S	1
May	351	170	181	1:1.06	0.484	0.345	N S	1
June	-	-	-	-	-	-	-	-
July	33	13	20	1:0.54	0.394	1.485	N S	1
August	107	36	71	1:1.97	0.336	11.449	S	1
Total	4003	2286	1717	1:0.75	0.571	80.880	S	1
1998-99								
September	145	49	96	1:0.96	0.338	15.234	S	1
October	495	281	214	1:0.76	0.568	9.069	S	1
November	615	337	278	1:0.82	0.548	5.660	S	1
December	603	339	264	1:0.78	0.562	9.328	S	1
January	328	193	135	1:0.70	0.588	10.256	S	1
February	503	288	215	1:0.75	0.573	10.594	S	1
March	586	381	205	1:0.54	0.650	52.860	S	1
April	527	288	239	1:0.83	0.546	4.556	S	1
May	609	287	322	1:1.12	0.471	2.011	N S	1
June	62	28	34	1:1.21	0.452	0.581	N S	1
July	78	37	41	1:1.11	0.474	0.205	N S	1
August	67	32	35	1:1.09	0.478	0.134	N S	1
Total	4618	2540	2078	1:0.82	0.550	46.220	S	1
POOLED								
September	420	242	178	1:0.74	0.576	9.752	S	1
October	871	459	412	1:0.89	0.527	2.536	N S	1
November	1389	741	648	1:0.87	0.533	6.227	S	1
December	1165	695	470	1:0.67	0.597	43.455	S	1
January	684	424	260	1:0.61	0.620	39.322	S	1
February	891	523	368	1:0.70	0.587	26.964	S	1
March	1026	649	377	1:0.58	0.633	72.109	S	1
April	868	490	378	1:0.77	0.565	14.452	S	1
May	960	457	503	1:1.10	0.476	2.204	N S	1
June	62	28	34	1:1.21	0.452	0.581	N S	1
July	111	50	61	1:1.22	0.450	1.090	N S	1
August	174	68	106	1:1.56	0.391	8.299	S	1
Total	8621	4826	3795	1:0.79	0.560	123.299	S	1

Table 8. Length-wise distribution of sex-ratio and chi-square test in *L. lactarius* (1997-98 and 1998-99 pooled)

Mid length	No.of specimens	Males	Females	Sex Ratio	Chi square	Significant or not at 5% level	D.F
85	22	11	11	1:1.0	0.000	N S	1
95	76	41	35	1:0.85	0.474	N S	1
105	273	155	118	1:0.76	5.015	S	1
115	675	421	254	1:0.60	41.317	S	1
125	1288	806	482	1:0.6	81.503	S	1
135	1568	1011	557	1:0.55	131.452	S	1
145	1505	898	607	1:0.67	56.266	S	1
155	1351	753	598	1:0.79	17.783	S	1
165	913	419	494	1:1.18	6.161	S	1
175	507	189	318	1:1.68	32.822	S	1
185	251	83	168	1:2.02	30.904	S	1
195	111	30	81	1:2.7	23.432	S	1
205	58	9	49	1:5.44	25.136	S	1
215	12	1	11	1:11.0	8.33	S	1
225	5	0	5				
235	2	0	2				
245	1	0	1				
255	2	0	2				
265	2	0	2				
Total	8622	4827	3795	0.786203	123.299	S	1

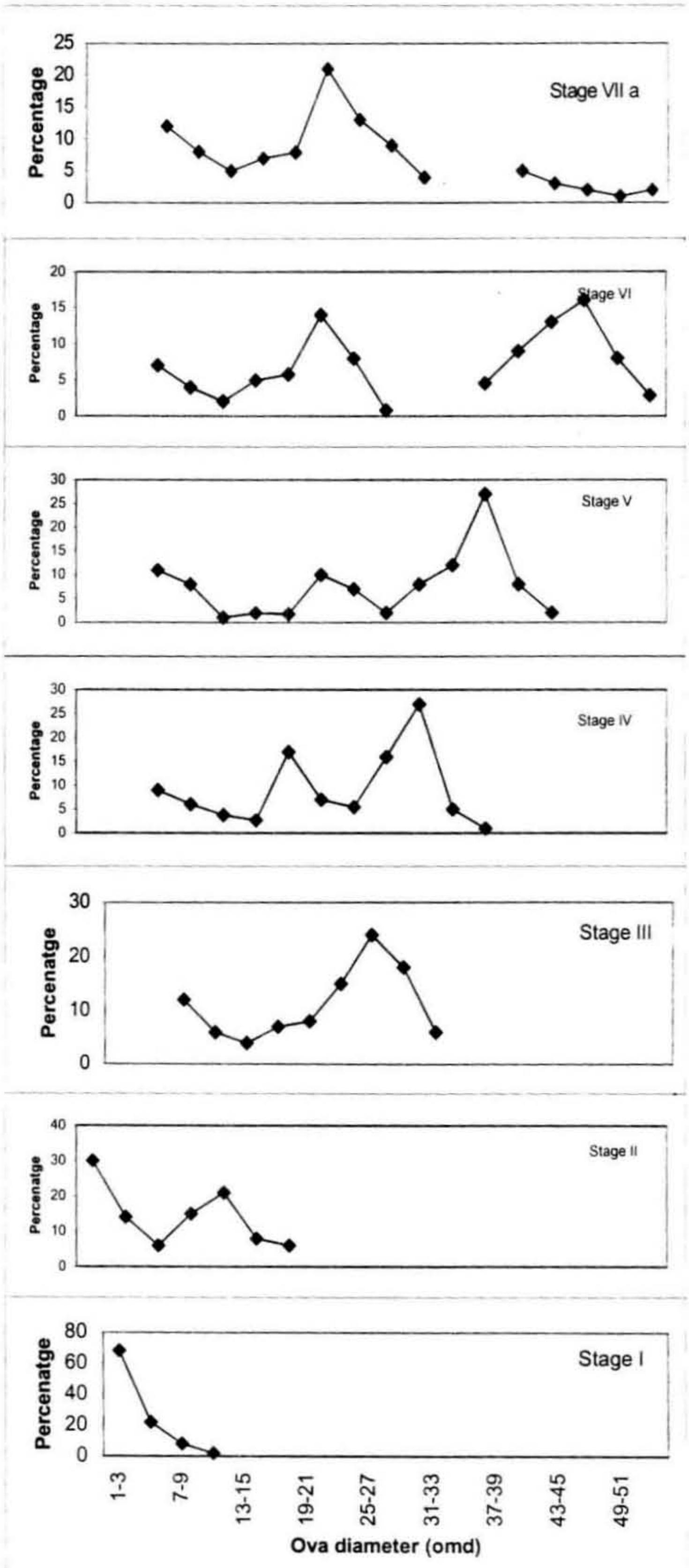
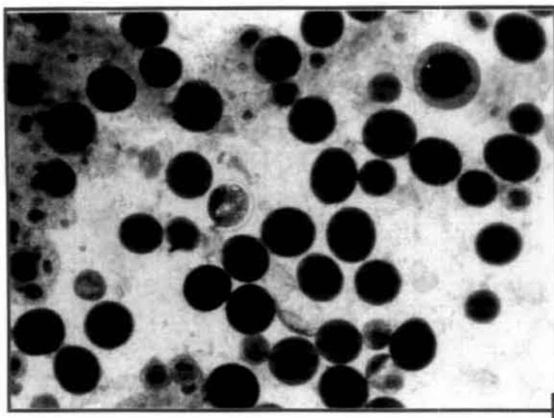
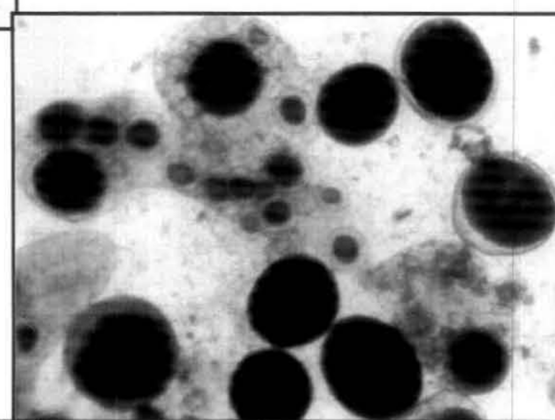


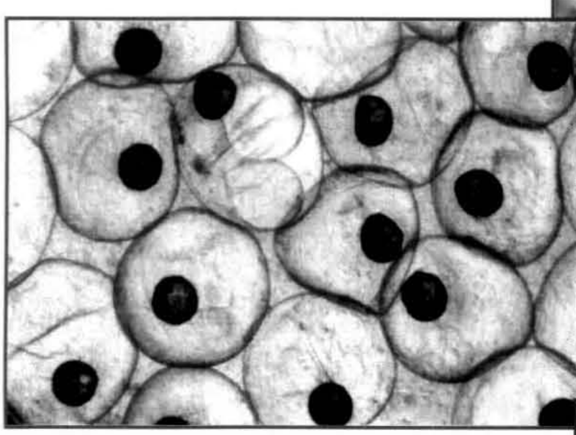
Fig.1. Ova diameter frequency polygons of *L. lactarius* showing growth of immature ova towards maturity



a. Photomicrograph of immature ovary (x 40)



b. Photomicrograph of maturing ovary (x 40)



c. Photomicrograph of fully ripe ovary (stage VI) x 40

d. Fish with mature ovary

Fig. 2. Photomicrograph of ova of *L. lactarius* in various stages of development (a-c) and fish with mature ovary (d)

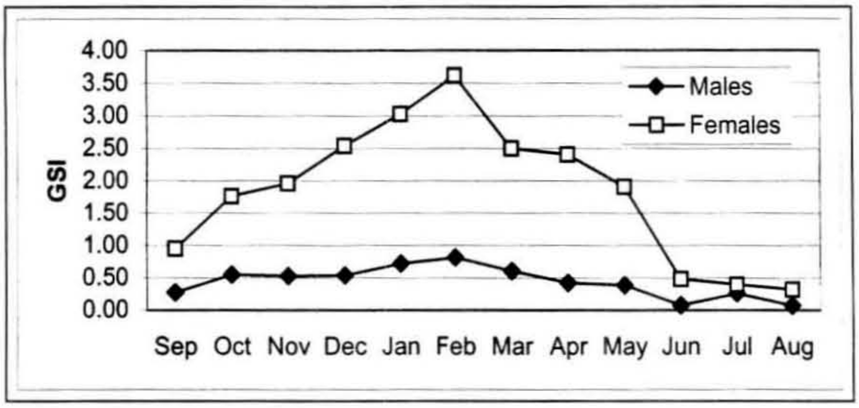


Fig.3. Monthly mean GSI values in *L. lactarius.*

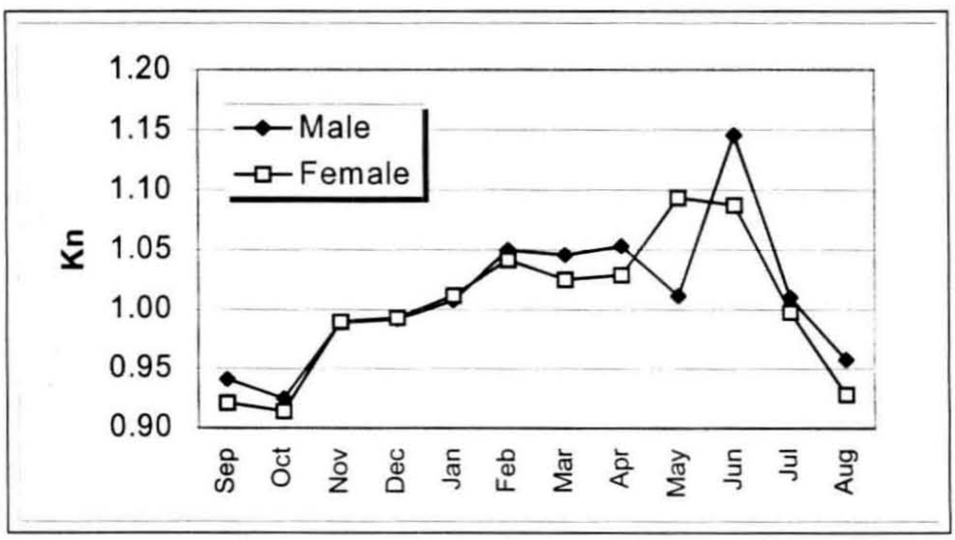


Fig.4. Monthly variation in K_n value in *L. lactarius.*

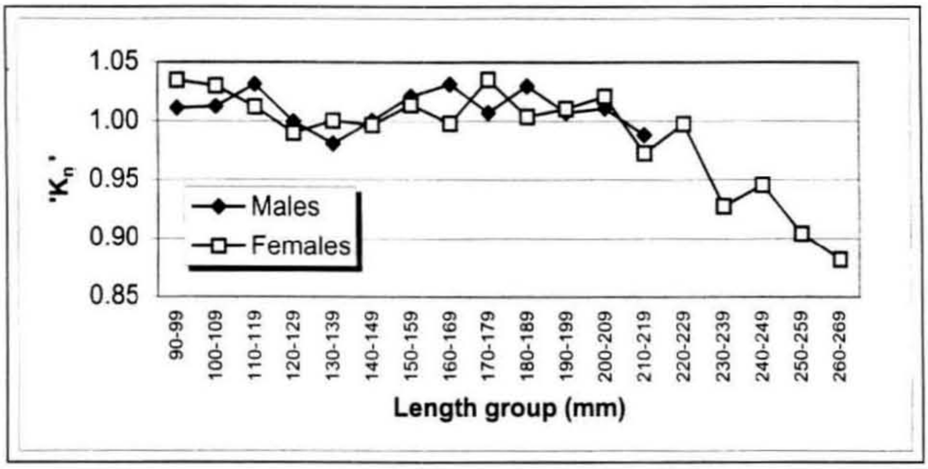


Fig.5. K_n values in different length groups in *L. lactarius*

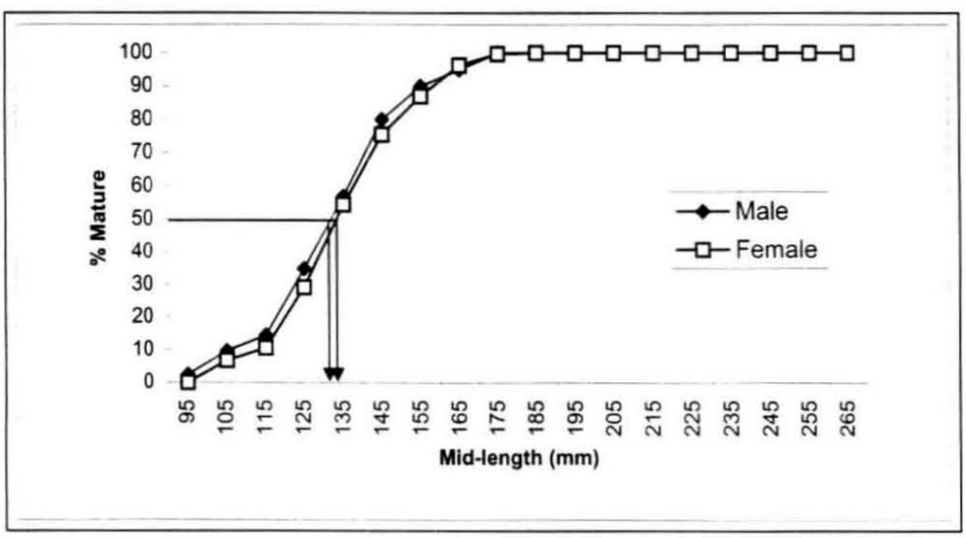


Fig.6. Maturity curve of *L. lactarius* showing size at first maturity.

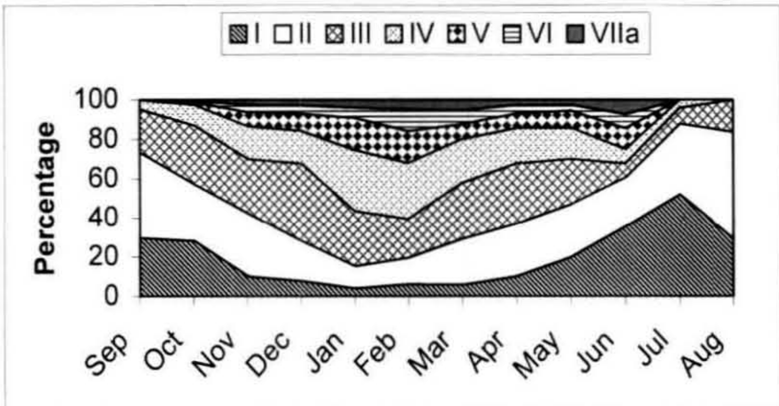


Fig.7. Month-wise distribution of different maturity stages in male *L. lactarius*.

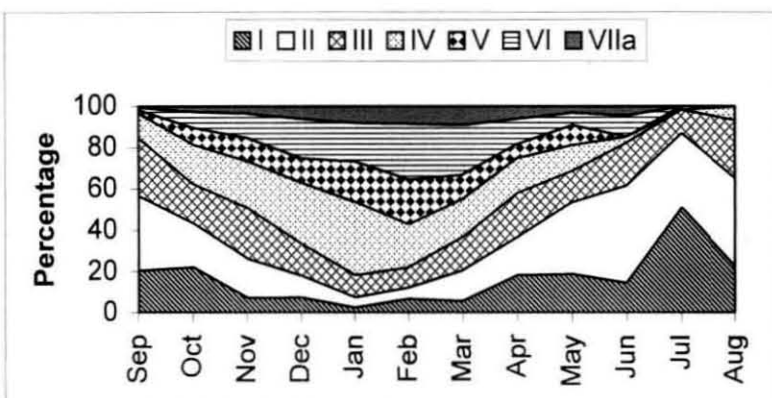


Fig.8. Month-wise distribution of different maturity stages in female *L .lactarius*.

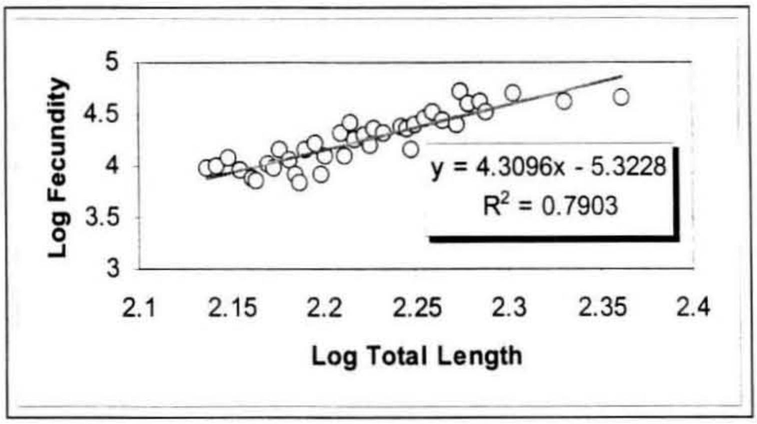


Fig.9. Relationship between total length and fecundity in *L. lactarius*

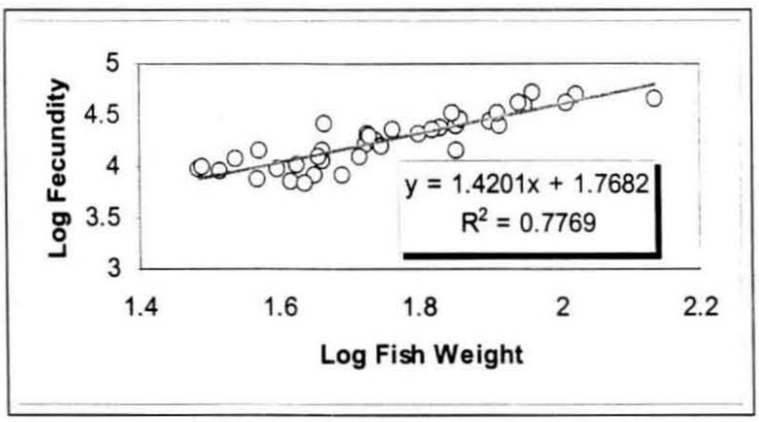


Fig.10. Relationship between body weight and fecundity in *L. lactarius*

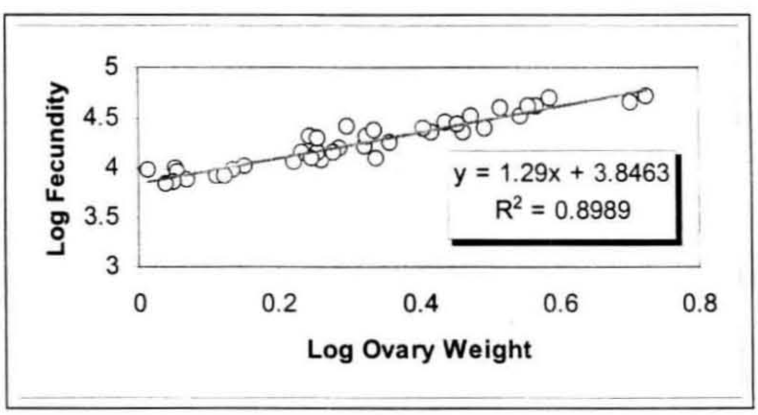


Fig.11. Relationship between ovary weight and fecundity in *L. lactarius*

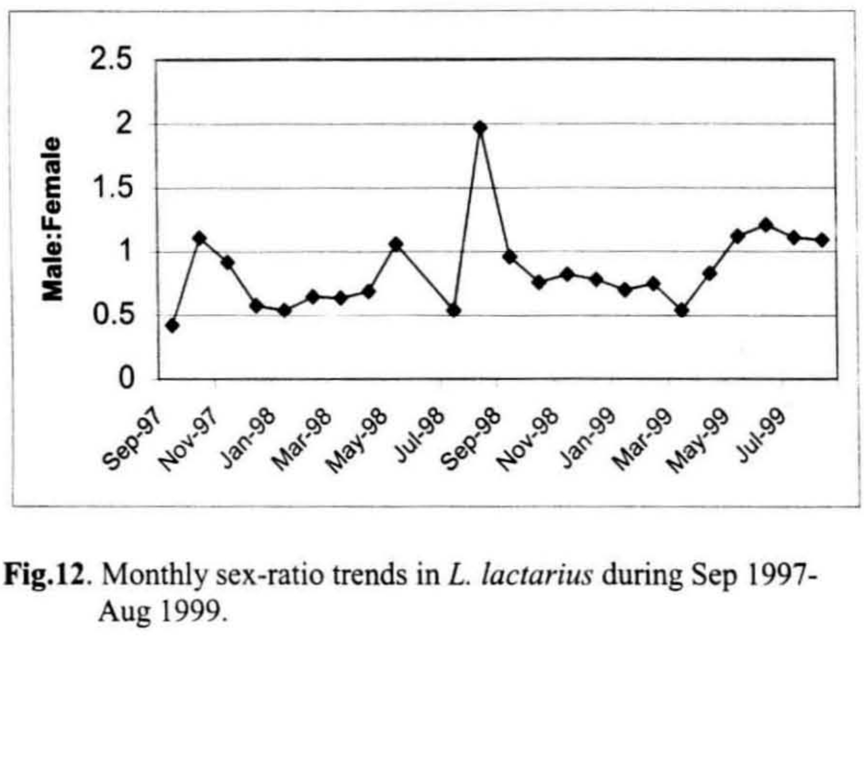


Fig.12. Monthly sex-ratio trends in *L. lactarius* during Sep 1997-Aug 1999.

Chapter

6

Age and Growth

6.1. INTRODUCTION

Growth is the most important factor that determines the dynamics of fish populations (Ricker, 1975). The growth of fish directly contributes to increases in stock biomass (Hilborn and Walters, 2001). Age and growth studies of fishes are directed to understand the age composition of the population, age at maturation, life span and pattern of growth of a species in different phases of its life history. All fish stock assessment methods work essentially with age composition data (Sparre and Venema, 1992). Growth studies form the basis for calculations leading to knowledge of mortality, recruitment and other fundamental parameters of the population. These parameters are the prerequisites for evolving effective management strategies for the development and judicious exploitation of the fish resources. Therefore, the main purpose of study of growth in any fish species is to determine the amount of fish that can be produced in terms of quantity with respect to time (Qasim, 1973b).

Growth can be expressed as an increase of length, volume or weight with time (Hartnoll, 1982). There are several methods available to determine the age and growth of fishes such as tagging experiments (capture and recapture methods), culturing the fish in cages and ponds and studying their growth in captivity, counting the seasonal markings on hard parts of body such as otoliths, scales, fin rays and other skeletal parts and analysing the length frequency of the population. The first two methods offer direct evidence, but appropriate infra-structural facilities are required to carry out the program. Of the other two methods which are indirect, first one is effectively used in temperate waters as slow growth during winter or spring leaves prominent rings on scales or vertebrae, which are closely spaced or opaque. Thompson (1902) was the first to use this method in marine fishes.

In tropical waters, the markings though found on hard parts are less pronounced and their annual nature is not authentically proved (Pauly and Morgan, 1987). Since there is no marked variation in environmental factors like temperature, the causative factor is attributed by various authors to spawning, monsoon and fluctuations in food supply. Nevertheless, there have been studies on age determination of fishes from Indian waters using hard parts (Chacko *et al.*, 1948; Menon, 1950; Raj, 1951; Seshappa and Bhimachar, 1951, 1954; Radhakrishnan, 1954, 1957; Kuttty, 1961; Pantulu, 1961, 1962; Qasim and Bhatt, 1964, 1966; Devaraj, 1977; Muthiah, 1982 and Rao and Rao, 1986). Qasim, (1973b) while critically reviewing the earlier work on age and growth by Indian workers, outlined the difficulties in determining age in tropical fish.

As the authenticity of markings on hard parts of fishes in depicting the annual nature is doubted, the method of analysing length frequency distribution has found wider application in the tropics. This method has the added advantage of requiring less equipment and facilities and has been the most popular technique for age determination all over the world since 19th century. It was first introduced by Petersen (Petersen, 1895, 1903) in which peaks in the length frequency of a given sample are assumed to represent different year classes or age groups. The main shortcoming in this technique is that the modes representing the older fishes may overlap as the growth rate slows down considerably with increasing age and thus making the fixation of age difficult. However, separation of the year classes was made possible by graphical methods (Harding, 1949; Cassie, 1954; Tanaka, 1956; Bhattacharya, 1967) or computer-based methods (Hasselblad, 1966; Abrahamson, 1971; Yong and Skillman, 1971). In the modal progression analysis technique, the peaks in the length frequency samples arranged sequentially in time are connected to follow the progression of modes (peaks) and the growth estimated. The problem in this method is the difficulty in interconnecting the several modes available in the length frequency, which may be the outcome of several broods arising from prolonged, or fractional spawning of fish as it happens in tropical waters. Hence, Josse *et al.* (1979) and Pauly (1981, 1982a) have stated that both methods are highly subjective and often lead to doubtful results.

Electronic Length Frequency Analysis (ELEFAN), a computer based method for length frequency data analysis was introduced as a rapid, reliable method to split the composite length frequency into peaks and troughs and the best growth curve passing through maximum number of peaks is selected using a goodness of fit ratio of ESP/ASP (R_n) (Pauly and David, 1981, Gayanilo *et al.*, 1988). The peaks are assumed to represent individual cohorts. This routine has been incorporated into the FiSAT (FAO-ICLARM Fish Stock Assessment Tools) software (Gayanilo and Pauly, 1997).

The notable works on age and growth of marine teleosts from Indian waters based on length frequency are of Hornell and Nayudu (1924), Devanesan (1943) and Chidambaram (1950) on *Sardinella longiceps*; Hora and Nair (1940), Jones and Menon (1951), Chidambaram and Krishnamurthy (1951), George and Banerji (1964), Sheshappa (1969) and Yohannan (1983) on *Rastrelliger kanagurta*; Kagwade (1971) on *Polynemus hexadactylus*; Devaraj (1977) and Annigeri (1989) on *Sardinella gibbosa*; Rao (1984), Muthiah (1994) on *Saurida* spp.; Vivekanandan (1991), Murty *et al.* (1992) on *Nemipterus* spp.; Yohannan *et al.* (1992) on *Scomberomorus commerson*; Chakaraborty (1996) on *Pennaiah macrophthalmus*; Philip and Mathew (1996) on *Priacanthus* spp.; Kalita and Jayabalan (1997) on *Alepes para* and Jayaprakash and Inasu (1998) on *Cynoglossus macrostomus*.

Studies on the age and growth of *L. lactarius* are very few from India and no published information is available from other parts of the world. James *et al.* (1974) studied the growth from Mangalore waters following the monthly modal progression. Pauly (1978) estimated the growth parameters of *L. lactarius* using the published length frequency data of Rao (1966) from Waltair. Kartha (1975) and Neelakantan (1981) studied the growth rate from Karwar waters by tracing the monthly progression of modes. Rueben *et al.* (1993) estimated the growth of *L. lactarius* from Andhra-Orissa coast using the length frequency data analysed with the ELEFAN method.

6.1.1. Growth equation

von Bertalanffy (1934) developed a mathematical model (von Bertalanffy Growth Formula-VBGF) for individual growth, which has been shown to conform to the observed growth of most fish species. The methods of fitting the formula have been given by Beverton and Holt (1957) and Ricker (1958). The VBGF equation is based on the concept of growth as a net result of the interaction of two opposite processes such as those tending to increase the mass (anabolism), and those tending to decrease it (catabolism), thus giving the growth curve fitting well with the growth rates of many species of organisms (Beverton, 1954; Beverton and Holt, 1957). This mathematical model expresses the length, *L* as a function of the age of the fish, *t*:

$$L_t = L_\infty \left[1 - e^{-K(t-t_0)}\right]$$

where,

L_t = length at age *t*

L_∞ = asymptotic length, or the maximum length that the fish can theoretically attain

e = base of the natural log

K = curvature parameter (other-wise known as coefficient of catabolism or growth coefficient) the rate at which the fish approaches asymptotic length,

t = age of fish

t_0 = age at which length of fish is theoretically zero

6.2. MATERIAL AND METHODS

Data on length frequency of *L. lactarius* were collected once a week from the commercial catches from Mangalore, Malpe and Karwar fish landing centers between September 1997 and August 1999. For getting the sex-wise length frequency data, 100-150 specimens were brought to the laboratory on each day of observation, fishes were sexed and length and weight measurements were taken. A total of 4,890 specimens of males (length range 80-215 mm TL) and 3,730 specimens of females (length range 80-265 mm TL) were used for the study. Total length from tip of snout to the tip of the upper caudal lobe was measured to the nearest mm. The length frequency data were grouped into 10 mm class interval. Growth was estimated separately for males, females and sexes pooled together. For determining the growth parameters for unsexed fishes, a total number of 9,627 specimens including the juveniles in the length range 50-265 mm TL were measured during 1997-99. The length measurements from the three landing centers were pooled and used for analysis.

The data were analysed using the ELEFAN I module of FiSAT software (Gayanilo and Pauly, 1997) without prior decomposition of data and also through modal progression analysis after decomposition of multi-cohort samples into their component distributions following the procedure adopted by Isa (1988) and detailed by Sparre and Venema (1992).

The step-wise details of the analysis are given below:

1. Estimate of L_∞ and Z/K was made using the Powell-Wetherall method (Wetherall, 1986; Pauly, 1986)
2. The growth parameters were estimated using the ELFAN I programme in the FiSAT software by identifying the best fit to the peaks.
3. L_∞ and K were used as input to the catch curve analysis and estimation of M using Pauly's empirical equation (Pauly, 1980b)
4. The resultant catch curve was estimated following the procedure recommended by Pauly (1986). This routine smoothens a set of probability of capture over different length classes so that a resultant length curve is established and the mean size at first capture is derived. The length frequency is corrected using the probability of capture and a new set of length frequency data was obtained.
5. Using the new (corrected) length-frequency data, procedure 2 was repeated and a new set of growth parameters were estimated.
6. From the corrected length-frequency data the decomposition of composite distribution into their components to identify means of

6.2.1. Powell-Wetherall Method

It is a simple method to estimate the asymptotic length and the ratio of the coefficients of growth (Z/K) using length-frequency data from the fish catch based on the equation of Beverton and Holt (1956).

$$Z = \left[\frac{L_\infty - L}{\overline{L} - L'}\right]$$

This estimates the total instantaneous mortality coefficient (Z) in a steady state population with constant exponential mortality and von-Bertalanffy growth, from the mean length (*L*) of a random sample of fish above length L'. It is shown that the mean length of the selected fish $(\overline{L})$ is a linear function of the knife-edge selection length L' given by:

$$\overline{L} = L_\infty \{1/[1+(Z/K)]\} + L'\{1/[1+(Z/K)]\}$$

If the intercept of the straight line is considered as *a* and its slope as *b*

$$a = L_\infty[(1+Z/K)]$$

and

$$b = (Z/K)/[1+(Z/K)]$$

from this L_∞ and *Z/K* can be computed

$$L_\infty = a/(1-b)$$

and

$$Z/K = b/(1-b)$$

In FiSAT the modified form of Wetherall method as proposed in Pauly (1986) is incorporated.

$$L_i' = a + bL_i$$

where,

$L_\infty = a + bL_i$ and $Z / K = (1+b)/-b$

6.2.2. ELEFAN I

The ELEFAN (Electronic Length Frequency Analysis) technique was developed at the International Council for Living Aquatic Resources Management (ICLARM) (Gayanilo *et al.*, 1988). ELEFAN-I is used to estimate the growth parameters of fish. It fits the growth curve to peaks defined independently without assuming any distribution and uses a five classes running average (a simple high pass filter) that leads to definition of peaks (those parts above the running average) and troughs (those below the running average) to identify them. The steps involved in fitting the growth curve are:

- Calculate the maximum number of points available in the set of length frequency samples. These are points that can possibly be accumulated by a single growth curve. This is termed as "available sum of peaks" (ASP).
- For the seed input of L_∞ and K start the growth curve from the base peak of a sample and project backward and forward to meet all other samples and trace sequentially arranged over time.

- Accumulate points when passing through peaks (+ve) and when passing through troughs (-ve).
- Select the curve which by passing through most peaks and avoiding most troughs best explains the peaks in the set and it accumulates large number of points called "explained sum of peaks" (ESP).
- Iterate through a range of values for L_∞ and K to get maximum for the ratio ESP/ASP.

6.2.3. Modal Progression Analysis

6.2.3.1. Decomposition of Modes by Bhattacharya Method

The modes in each sample were identified by separating the available length-frequency samples into their component distributions using the Bhattacharya (1967) method. By plotting the difference between consecutive logarithmic values of the number caught against length, a normal distribution is transformed into a straight line. In this manner, by visually inspecting the obtained plot, the first group can be separated and the number of fish belonging to this first group is calculated and subsequently subtracted from the sample. The process is repeated until the whole sample has been divided up into its component distributions.

Let *N* designates the number in a length frequency sample belonging to the length group: $[x - dL/2, x + dL/2]$

where *dL* is the interval size, x is the interval mid-point, x - *dL/2* is the lower and x + *dL/2* is the upper limit of the interval. If a certain length range in the sample contains only one cohort, this part of the frequency sample should conform to a normal distribution. In that case, the linear relationship,

$$\Delta \ln N = a + b * (\times dL/2)$$

would hold between the differences of the logarithms of the number in the preceding class.

$\Delta \ln N = \ln N(x + dL/2, x+3dL/2) - \ln N (x - dL/2, x + dL/2)$ as the dependent variable, y and the upper limit of the smallest length group:

$x + dL/2$ as the independent variable x. The standard deviation of the normal distribution and the mean are obtained by:

$$s = dl / b$$

and

$$x = -a / b$$

The means and standard deviation files saved are used as the input for analysis of growth increment by Gulland and Holt plot.

6.2.3. 2. Estimation of Growth Parameters by Gulland & Holt Plot

Gulland and Holt (1959) suggested the following equation for determining the growth parameters, L_∞ and K. This requires a plot of difference in length between consecutive means over difference in time $\left(\frac{\Delta L}{\Delta t}\right)$ against the mean length between the two corresponding mean lengths.

$$\Delta L/\Delta t = KL_{\infty} - KL_t$$

Using L_t as an independent variable and $\frac{\Delta L}{\Delta t}$ (growth increment) as the dependent variable, the equation becomes a linear regression:

$$\Delta L/\Delta t = a + bL_t$$

The parameters K and L_{∞} are obtained from the following equations:

$$K = -b$$

and

$$L_{\infty} = -a/b$$

Hence, through a regression analysis of the available data pairs, the growth parameters were estimated.

6.2.3.3. Comparison of Growth Parameters

The growth parameters were tested for their reliability by comparing them with the available growth studies of the same species or with related species in the same family. Since growth is not linear, growth comparisons in two fish populations using L_{∞} and K separately may be misleading (Pauly, 1979). Munroe and Pauly (1983) suggested an empirically derived growth performance index (Munroe's phi prime index, Φ') which is expressed by the equation:

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

where K is expressed on an annual basis and L_{∞} in cm. It is generally seen that the Φ' is approximately distributed around 3.

6.2.3.4. Recruitment Pattern

Since it is the pulsed nature of recruitment into a population that determines the structure of a set of length-frequency data, the converse also applies that one should be able to recover some information on the seasonality of recruitment from length-frequency data (Pauly, 1982b). This inverse approach is implemented in FiSAT, which allows identifying the number of recruitment pulses per year and evaluating the relative importance of these pulses when compared to each other. Recruitment patterns are obtained by backward projection onto the length axis, a set of length-frequency data by the following procedures:

1. projection onto the time axis of the frequencies after they have been divided by t, the time needed to grow through the length class;
2. summation for each month of the adjusted frequencies projected onto each month;
3. subtraction, from each monthly sum, of the lowest monthly sum to obtain a zero value where apparent recruitment is lowest;
4. output of monthly relative recruitment as a percentage of annual recruitment.

The monthly recruitment value pertains to months of the year when a precise estimate of t_0 is available. For this purpose, an approximate value of t_0 was estimated from Pauly's empirical equation (Pauly, 1979) for which the following equation was used.

$$Log(-t_0) = -0.392 - 0.275 \log L_\infty - 1.038K$$

6.3. RESULTS

6.3.1. Distribution of Length

The month-wise size frequency distribution of males and females of *L. lactarius* caught in different gears at Mangalore, Malpe and Karwar were pooled and given in Tables 1 and 2 respectively. The length composition of male ranged from 80 to 219 mm TL in 1997-98 and 1998-99. Maximum numbers were seen in the length class 140-149 mm during 1997-98 and 130-139 mm in 1998-99. In the case of females the length-frequency range was from 80 to 239 in 1997-98 and 80 to 269 mm in 1998-99. Maximum number was caught in the length class 135 mm in 1997-98 and 155 mm in 1998-99. The length frequency data of unsexed fishes raised to Karnataka catch for the year 1997-98 and 1998-99 are given in Table 3. The length of the smallest fish recorded was 50 mm in the commercial catch and maximum length class observed was 260-269 mm. In certain months (May 1998), up to three modes were seen in the length frequency data.

6.3.2. Estimation of Growth Parameters

6.3.2.1. Male

The data used for fitting regression for estimation of growth parameters using Powell-Wetherall method are shown in Table 4. The L_∞ obtained by Powell-Wetherall method was 240.3 mm and Z/K =5.265 (Fig.1). The L_∞ obtained from ELEFAN I with highest R_n value (0.242) was

245 mm and K =1.1 yr^{-1} (Fig.2). The selection parameters obtained by estimating the probabilities of capture were L_{50} = 131 mm and L_{75} = 141 mm and using these values, the data were corrected for selection. The modes in the length-frequency data were separated for each month using Bhattacharya's method and through modal progression analysis the means were grouped for each cohort. Table 5 represents the mean lengths obtained during different months. In certain months up to 3 cohorts were seen. The monthly modes were connected (Fig.3) and saved as growth increment file. The growth parameters estimated using the Gulland and Holt plot were L_∞ = 240 mm and K = 1.01 yr^{-1} (Fig.4). The growth parameters obtained by Gulland & Holt plot were taken to represent the growth in male *L. lactarius*.

The life span estimated for male was 3 years. From the equation, male *L. lactarius* attains length of 152 mm at the end of first year, 208 mm at the end of second year and 228 mm at the end of third year of life. Since the length at first maturity (l_m) has been estimated to be 131 mm (Chapter 5), the fish are able to spawn before they complete one year age.

6.3.2.2. Female

The data used for fitting regression for estimation of growth parameters using Powell-Wetherall method are shown in Table 6. The L_∞ obtained by Powell-Wetherall method was 283 mm and Z/K 6.0 (Fig.5). ELEFAN I showed L_∞ = 295 mm and K = 0.84 yr^{-1} (Fig.6) with an R_n value of

0.245. The selection parameters for the probability of capture were L_{50}=125 and L_{75}=136 mm. Table 7 shows the mean values obtained in different months employing Bhattacharya method. There were up to 3 cohorts in certain months. The monthly mean values of cohorts were connected (Fig.7) and saved as growth increment data files. Gulland and Holt plot indicated L_∞ to be 285 mm and 0.91yr^{-1} (Fig.8). The growth parameters obtained through Gulland and Holt plot method were taken to represent the growth in female *L. lactarius*.

The life span estimated for female was 3.3 years. From the growth equation estimated female *L. lactarius* attains length of 158.5 mm at the end of first year, 236 mm at the end of second year and 272 mm at the end of third year of life. Since the length at first maturity has been estimated at 133 mm, the fish is able to mature and spawn before they complete one year of its life.

6.3.2.3. Unsexed Fishes

The estimate growth parameters in pooled sample of *L. lactarius* using Powell-Wetherall method are shown in Table 8 and the calculated value of L_∞ was 280 mm and Z/K, 5.875 (Fig.9). Using the different options in ELEFAN I the best (R_n = 0.205) value of VBGF parameters obtained were L_∞ = 285 and K = 0.78 (Fig.10). Monthly mean values obtained in different months by the Bhattacharya analysis were shown in Table 9. The monthly mean values of cohorts were connected (Fig.11) and saved as growth increment data files.

The growth parameters, L_∞ and K estimated using the Gulland and Holt plot were 294 mm and 0.84 yr^{-1} respectively (Fig.12) and these values were considered for stock assessment of *L. lactarius* along Karnataka coasts (Chapter 7).

The life span estimated using the equation, $t_{max} = 3/K$ (Pauly, 1983b) is 3.57 years. VBGF equation indicated *L. lactarius* to attain a length of 166 mm at the end of first year, 239 mm at the end of second year and 270 mm at the end of third year of its life.

The results of the various analyses using length-frequency data of *L. lactarius* carried out for estimating growth parameters in males, female and pooled using FiSAT software are given in Table 10. The selected growth parameters and t_0 estimated using Pauly's empirical equation are given in Table 11. The von Bertalanffy growth curves drawn with the selected growth parameters are shown in Fig.13.

6.3.3. Comparison of Growth Parameters

Since sex-wise growth parameters were not available for *L. lactarius*, pooled parameters are compared with results available from literature. The results are given in Table. 12. The Φ' value ranged from 2.66 (Reuben *et al.*, 1993) to 2.94 (Pauly, 1980a). The values obtained in the present study were 2.78 for males, 2.85 for females and 2.87 for sexes pooled.

6.3.2.5. Recruitment Pattern

With the growth parameters L_∞ = 294 mm, K = 0.84 yr^{-1} and t_0 = -0.0215, the recruitment pattern obtained by FiSAT is given in Fig.14. Recruitment to the fishery takes place throughout the year. Nevertheless, two pulses are seen in the recruitment pattern every year. The major one corresponds to March (21.5%) and a minor one during June-August.

6.4. DISCUSSION

For determination of age and growth in *L. lactarius*, the methods recommended by Sparre and Venema (1992) were followed in the present study. The growth parameters were initially estimated by Powell-Wetherall technique, later by ELEFAN I and modal progression analysis using Beverton and Holt model with the corrected data. The results obtained by various methods were comparable.

The L_∞ values obtained for males by the above three methods were almost identical (240.3 mm by Powell-Wetherall method, 240 mm by ELEFAN I and Gulland & Holt plot), whereas, K values were 1.10 and 1.01 by the latter 2 methods respectively. In the case of females the growth parameters were L_∞ = 283 mm by Powell-Wetherall, 295 mm and K = 0.84 yr^{-1} by ELEFAN I and 285 mm and 0.91yr^{-1} by Gulland & Holt plot. However, the growth parameters estimated for the unsexed fishes show that the L_∞ and K

values were 285 mm and 0.78 by ELFAN I; whereas higher L_∞ and lower K values were evident by modal progression analysis. As the values obtained by modal progression and Gulland & Holt were found suitable to describe growth of *L. lactarius* from Karnataka the same were considered for stock assessment studies as described in Chapter 7.

Among the methods employed for growth estimates in fishes, Bhattacharya method is relatively less used (Chakraborty, 2001). Even though lot of subjectivity can creep in the Bhattacharya method, this is considered to be the best method (Pauly, 1983b). In the present study growth parameters were estimated using this method coupled with the method of ELFAN I and the results are compared and parameters were selected based on general agreement.

As there was no earlier attempt to estimate the sex-wise growth parameters for *L. lactarius*, in the present study growth parameters for males and females were calculated separately. The values show a slight difference in growth rate between sexes. While the values of L_∞ were 240 and 285 mm for males and females respectively, the growth coefficient (K) obtained were 1.01 and 0.91 respectively and the values of the t_0 were -0.0151 and -0.0183 respectively. The maximum size of males observed in the fishery was 215 mm whereas females measuring up to 265 mm size were encountered. From the VBGF equation, the length attained after the completion of 1, 2 and 3 years were 152 mm, 208 mm and 228 mm respectively for males and 169, 238 and 266 mm for females respectively.

The analysis of length-frequency data is not dependant technique if the sample size is small (Jones, 1981). In the present study more than 3,700 for females, and males and more than 9,600 individuals of both juveniles and adults were utilised. The growth parameters estimated for sexes pooled were L_{∞} = 294 mm, K = 0.84 yr^{-1} and t_0 =-0.0215. The maximum life span estimated by Pauly's equation was 3.57 years. By the inverse von Bertalanffy equation, the length attained after the completion of 1, 2 and 3 years were 166 mm, 239 mm and 270 mm respectively.

The length frequency analysis of *L. lactarius* from Waltair showed the fish to attain 160-180 mm at the end of 1st year of life and the commercial catches mainly consisted of 0-year class (Rao, 1966); whereas, *L. lactarius* from Mangalore waters had a growth rate of 12.0 mm per month in the first year reaching the size of about 150 mm at the end of 1 year and 270 mm at the end of second year. Though fish measuring above 270 mm were not represented in the commercial landings, the life span of the species is estimated to be 3 years and the commercial fishery was based on 0-year and 1-year old fish along the Mangalore coast (James *et al.*, 1974).

The growth of *L. lactarius* from Karwar waters estimated by tracing the modes in the commercial catches indicated 90 mm growth after 6 months as the juveniles had a growth rate of 15 mm per month till they attain size of 125 mm and thereafter with lesser growth rate of 6.9 mm per month (Kartha, 1975). Along the Karwar coast, *L. lactarius* attained a length of 150 mm at the end of first and 270 mm at the end of second year of its life (Neelakantan, 1981). It was also observed the fishery to consist mainly of individuals measuring less than 150 mm in length and was supported by 0-year class along Karwar coast.

Even though few authors have described the growth rate of *L. lactarius* from different parts of India by tracing the monthly progression of modes, the estimate of von-Bertalanffy growth parameters available are of Pauly (1978) from the published data of Rao (1966) from Waltair and Reuben *et al.* (1993) from Andhra Pradesh-Orissa coast. The growth parameters estimated by Pauly (1980b) were L_∞ = 320 mm, K=0.85 yr^{-1} and t_0 = -0.18. The L_∞, K and t_0 estimated and of Reuben *et al.* (1993) by modal progression analysis were 269.5 mm, 0.629 yr^{-1} and –0.2741 years respectively and the fishery was represented by fish of 1 to 3 years of age and the longevity was estimated as 4.8 years. Table 12 represents the growth parameters obtained from other workers compared with the present study.

The Φ' enables a comparison of estimates of growth parameter of one stock with the other and their compatibility. It is also possible to estimate K indirectly for a specific stock of given species from the mean value of Φ' estimated from other stocks of the same species used in conjunction with an estimate of L_∞ obtained through the method of Wetherall (1986) and is an index of growth performance. The Φ' value of *L. lactarius* ranged from 2.66 (Reuben *et al.,* 1993) to 2.94 (Pauly, 1978). The values obtained in the present study (2.78 for males, 2.85 for females and 2.87 for unsexed) lie well within this range. The growth estimates and Φ' index indicate that the growth parameters obtained by Gulland and Holt plot after separation of modes through Bhattacharya method are comparable with parameters obtained by other methods. The growth parameter estimates from the present study along the Karnataka coast when compared with the results from east coast show slightly faster growth rate.

Studies on the recruitment pattern show peak recruitment during March and minor one during July-August. This is in close agreement with the results of maturation and spawning (Chapter 5) which indicate peak season of spawning of *L. lactarius* during November-March. Small fishes which will grow at a growth rate of 20 mm in the initial months may attain 50 mm after 2-3 months and get recruited to the fishery. The length frequency data (Table 3) show occurrence of smaller fish (50-59 mm) in February and May, which further corroborates the present observation.

Table 1. Length-frequency data of male *L.lactarius* landed by different gears pooled for Mangalore Malpe and Karwar during 1997-98 and 1998-99.

1997-98 Length range/ (mm)	Sep-97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Total
70-79													0
80-89				3	1								4
90-99		2		1	5		2		3				13
100-109	1	13	8	4	6	3	3	1	15			3	57
110-119	9	37	54	13	1	10	15	20	16		2	2	179
120-129	21	61	123	59	10	17	40	44	16		8	16	415
130-139	33	32	103	110	30	12	53	40	28		3	10	454
140-149	54	20	63	97	69	63	41	33	36			5	481
150-159	54	12	33	41	67	55	61	33	30				386
160-169	16	1	33	16	33	49	24	14	15				201
170-179	3		11	5	6	16	17	15	6				79
180-189	2		6	3	3	5	8	1	2				30
190-199			1	3		4	2	1	3				14
200-209			1	1		1	2						5
210-219			1				1	1					3
220-229													0
Sum	**193**	**178**	**437**	**356**	**231**	**235**	**269**	**203**	**170**	**0**	**13**	**36**	**2321**
1998-99													
Length range/ (mm)	**Sep-98**	**Oct-98**	**Nov-98**	**Dec-98**	**Jan-99**	**Feb-99**	**Mar-99**	**Apr-99**	**May-99**	**Jun-99**	**Jul-99**	**Aug-99**	**Total**
70-79													0
80-89		5							2				7
90-99		21	4							1			26
100-109	1	46	6		2	2	7	2	14	5			85
110-119	13	63	30		15	7	24	10	30	5	6		203
120-129	9	50	84	15	18	25	33	33	54	1	4	11	337
130-139	10	41	108	92	31	52	93	59	52	1	7	16	562
140-149	10	24	46	97	36	44	85	49	48	3	12	4	458
150-159	5	13	34	74	48	46	70	71	44	3	5		413
160-169	1	10	11	35	29	57	47	28	28	3	32		281
170-179		6	8	15	10	34	13	24	5	1	1	1	118
180-189		2	4	9	4	14	4	9	10	3			59
190-199			1	2		6	3	1		2			15
200-209			1			1	2						4
210-219						1							1
220-229													0
Sum	**49**	**281**	**337**	**339**	**193**	**289**	**381**	**286**	**287**	**28**	**67**	**32**	**2569**

Table 2. Length-frequency data of female *L.lactarius* landed by different gears pooled for Mangalore Malpe and Karwar during 1997-98 and 1998-99.

1997-98 Length range (mm)	Sep-97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Total
70-79													0
80-89				1					7			2	10
90-99		1		0			1		19			3	24
100-109	1	14	4	0	1		4	2	29			8	63
110-119	7	18	21	5	1	1	6	10	20			14	103
120-129	27	54	65	34	6	6	13	15	19		10	19	268
130-139	15	48	91	34	13	6	9	20	16		6	13	271
140-149	7	17	62	35	42	19	12	29	19		3	9	254
150-159	10	8	39	32	22	33	24	13	10		0	3	194
160-169	13	11	12	18	17	34	41	25	20		1		192
170-179	0	8	14	11	18	24	31	9	12				127
180-189	2	17	7	5	0	17	22	6	4				80
190-199		1	12	3	4	7	4	4	3				38
200-209		1	3	1	1	6	3	4	3				22
210-219				0			2	1					3
220-229				1			0	1					2
230-239							1						1
240-249													0
Sum	**82**	**198**	**330**	**180**	**125**	**153**	**173**	**139**	**181**	**0**	**20**	**71**	**1652**
1998-99													
Length range (mm)	**Sep-98**	**Oct-98**	**Nov-98**	**Dec-98**	**Jan-99**	**Feb-99**	**Mar-99**	**Apr-99**	**May-99**	**Jun-99**	**Jul-99**	**Aug-99**	**Total**
70-79													0
80-89		1											1
90-99		10							1				11
100-109	3	26	4				2		14	5	1		55
110-119	32	41	24		5	5	3	9	20	5	7	1	152
120-129	28	28	48	7	1	14	8	29	40	4	7	4	218
130-139	13	22	58	41	8	20	34	38	28	0	9	8	279
140-149	8	23	64	54	17	20	44	41	44	4	5	10	334
150-159	8	27	27	69	38	32	31	46	92	4	4	4	382
160-169	4	13	29	52	36	39	27	39	39	5	7	4	294
170-179		14	11	15	18	44	29	11	32	3	0	4	181
180-189		5	5	14	6	13	14	15	9	3	1		85
190-199		3	3	6	3	16	7	2	1	0			41
200-209		1	3	5	2	8	3	4	0	1			27
210-219			2	0	0	4	1	1	0				8
220-229				1	0		2	0	0				3
230-239					0		1	0	0				1
240-249					0		1	0	0				1
250-259					1			0	1				2
260-269								2	1				3
Sum	**96**	**214**	**278**	**264**	**135**	**215**	**207**	**237**	**322**	**34**	**41**	**35**	**2078**

Table 3. Length-frequency data of *L. lactarius* (unsexed) for 1997-98 used for the estimation of growth parameters.

1997-98 Length range (mm)	Sep-97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Total
50-59						6			1				7
60-69				9		17			10				36
70-79		1		65		9			4				79
80-89		5		42	1				19			2	69
90-99	2	19		2	7		6		29			3	68
100-109	8	48	12	6	35	7	34	6	48			11	215
110-119	23	62	78	19	38	16	31	36	36		2	16	357
120-129	49	115	200	93	40	25	55	59	44		18	35	733
130-139	48	80	202	144	59	27	87	60	60		9	23	799
140-149	61	37	125	132	119	86	92	62	64		3	14	795
150-159	64	20	72	73	100	92	97	46	50			3	617
160-169	29	12	23	34	57	87	69	39	46		1		397
170-179	3	8	20	16	24	40	50	24	18				203
180-189	4	17	8	8	3	22	30	7	7				106
190-199		1	13	6	4	11	6	5	6				52
200-209		1	4	2	1	7	5	4	3				27
210-219							3	2					5
220-229				1				1					2
230-239							1						1
240-249													
250-259													
260-269													
Total	**291**	**426**	**757**	**652**	**488**	**446**	**566**	**351**	**444**	**0**	**33**	**107**	**4568**
1998-99 Length range (mm)	**Sep-98**	**Oct-98**	**Nov-98**	**Dec-98**	**Jan-99**	**Feb-99**	**Mar-99**	**Apr-99**	**May-99**	**Jun-99**	**Jul-99**	**Aug-99**	**Total**
50-59													
60-69													
70-79									9				9
80-89		7						5	23				35
90-99		31	4					14	32	3			84
100-109	5	72	12		2	2	10	34	45	12	1		195
110-119	61	106	57	2	20	12	31	37	74	13	13	1	427
120-129	49	90	137	22	19	39	50	66	114	5	11	15	617
130-139	34	74	169	133	40	72	138	97	92	1	16	24	890
140-149	23	54	111	151	55	64	133	90	107	7	17	14	826
150-159	17	43	63	143	94	78	108	117	142	7	9	4	825
160-169	5	24	44	87	73	96	79	67	78	8	9	4	574
170-179		20	19	30	30	78	45	35	41	4	1	5	308
180-189		7	9	23	14	27	21	24	21	6	1		153
190-199		3	4	8	4	22	12	3	2	2			60
200-209		1	4	5	4	9	6	4		1			34
210-219			2			5	1	1					9
220-229				1	2		2						5
230-239							1						1
240-249							1						1
250-259					1				1				2
260-269								3	1				4
Total	**194**	**532**	**635**	**605**	**358**	**504**	**638**	**597**	**782**	**69**	**78**	**67**	**5059**

Table 4. FiSAT output of the probabilities of capture of *L. lactarius* from Karnataka waters with raised length-frequency data.
Weighting mode : percentage sample total

Midlength (mm)	Prob. Selection	Smooth prob.
55	0.0024	0.0042
65	0.0103	0.0097
75	0.0165	0.0165
85	0.0228	0.0258
95	0.0382	0.0573
105	0.1112	0.1262
115	0.2293	0.02751
125	0.4849	0.4893
135	0.7538	0.7462
145	1	0.9179
155	1	1
165	1	1
175	1	1
185	1	1
195	1	1
205	1	1
215	1	1
225	1	1
235	1	1
345	1	1
255	1	1
265	1	1
L_{-25} = 113.314	L_{∞} = 294.000	
L_{-50} = 125.416	K = .84	
L_{-75} = 135.219		
slope = 0.000		

Table 5. Results of the Bhattacharya analsyis carried out for male *L. lactarius* and the monthly means obtained for males

Observation	Date	Mean length (mm)		
		1	2	3
1	9/15/1997	136.35	172.35	-
2	10/15/1997	112.54	156.1	-
3	11/15/1997	121.98	165.16	195.75
4	12/15/1997	84.01	130.27	192.88
5	1/15/1998	91.25	148.3	173.02
6	2/15/1998	115.37	154.11	199
7	3/15/1998	118.55	177.02	-
8	4/15/1998	126.05	160.41	207.1
9	5/15/1998	104.33	153.24	181
10	7/15/1998	122.05	-	-
11	8/15/1998	118.23	-	-
12	9/15/1998	118.03	152.41	-
13	10/15/1998	94.05	165.5	-
14	11/15/1998	115.01	183.94	-
15	12/15/1998	143.97	175.27	-
16	1/15/1999	121.19	154.36	-
17	2/15/1999	131.85	172.24	-
18	3/15/1999	122.12	153.72	203.41
19	4/15/1999	133.25	173.33	-
20	5/15/1999	90	151.27	-
21	6/15/1999	102.76	154.66	185.88
22	7/15/1999	119.16	151.63	-
23	8/15/1999	128.88	180.27	-

Table 6. Data for estimation of L_{∞} and Z/K for female *L. lactarius* using the method of Wetherall (1986 as modified by D. Pauly, 1986 both in Fish byte Vol. 4 (1) : 12-14 and 18-20)

L (mean)-L'	L'	N (cumulative)	
67.133	80.000	27901	
57.401	90.000	27781	
48.221	100.000	27353	
40.003	110.000	26269	
33.322	120.000	23994	
27.879	130.000	20669	
23.529	140.000	16576	
19.783	150.000	12392	***
16.95	160.000	8346	
14.942	170.000	5002	
13.937	180.000	2626	
13.214	190.000	1288	
13.166	200.000	583	
13.748	210.000	254	
17.921	220.000	97	
17.863	230.000	55	
14.728	240.000	36	
9.52	250.000	24	
5	260.000	11	
*** regression line is fitted from this point			
Y = 40.42 + (-0.143) *X, r = -0.876			
Estimate of Loo = 282.994 mm			
Estimate of Z/K = 6.002			

Table 7. Results of the Bhattacharya analsyis carried out and the monthly means obtained for female *L.lactarius*

Observation	Date	Mean (mm)			
		1	**2**	**3**	**4**
1	9/15/1997	123.93	162.5	--	-
2	10/15/1997	119.8	177.55	-	-
3	11/15/1997	132.55	193.86	-	-
4	12/15/1997	80	144.83	214.27	-
5	1/15/1998	146.17	207.1	-	-
6	2/15/1998	121.33	162.75	198.27	-
7	3/15/1998	109.25	169	218.91	-
8	4/15/1998		127.23	168.72	205.69
9	5/15/1998	80.16	126.9	169.77	205.89
10	7/15/1998	120.3	-	-	-
11	8/15/1998	107	178.64	-	-
12	9/15/1998	116.7	149.3	-	-
13	10/15/1998	95.19	160.08	211.25	--
14	11/15/1998	134.16	200.08	-	-
15	12/15/1998	151.97	200.21	-	-
16	1/15/1999	100	160.19	260	-
17	2/15/1999	128	170.5	213.35	-
18	3/15/1999	142.32	179.22	227.27	-
19	4/15/1999	128.07	161.71	208.05	-
20	5/15/1999	111.69	155.22	180.91	-
21	6/15/1999	93.44	163.22	195.83	-
22	7/15/1999	118.7	156.67	-	-
23	8/15/1999	134.03	168.21	-	-

Table 8. Data for estimation of L_{oo} and Z/K for sexes pooled of *L. lactarius* using the method of Wetherall (1986 as modified by D. Pauly, 1986 both in Fish byte Vol. 4 (1) : 12-14 and 18-20).

L (mean)-L'	L'	N (cumulative)	
91.432	50.000	326391	
81.511	60.000	326092	
71.859	70.000	324615	
62.382	80.000	322095	
53.011	90.000	318600	
43.873	100.000	312987	
35.806	110.000	298155	
28.801	120.000	271737	
23.62	130.000	225984	
19.613	140.000	170963	***
16.297	150.000	117304	
14.291	160.000	68692	
13.499	170.000	34500	
12.933	180.000	16351	
13.147	190.000	7148	
12.726	200.000	3285	
18.163	210.000	1096	
20.317	220.000	570	
22.951	230.000	312	
18.91	240.000	234	
11.293	250.000	200	
5	260.000	126	
*** regression line is fitted from this point			
Y = 38.98 + (-0.145) *X, r = -0.826			
Estiamte of Loo = 267.980 mm			
Estiamte of Z/K = 5.875			

Table 9. Results of the Bhattacharya analysis carried out for *L. lactarius* and the monthly means obtained for sexes pooled

Observation	Date	Mean legth (mm)			
		1	**2**	**3**	**4**
1	9/15/1997	125.47	157.5	-	-
2	10/15/1997	110.3	174.02	-	-
3	11/15/1997	127.75	159.83	198.57	-
4	12/15/1997	74.69	135.08	188.02	-
5	1/15/1998	109.5	156.67	201.11	-
6	2/15/1998	62.49	118.91	159.44	-
7	3/15/1998	112.12	152.49	192.61	-
8	4/15/1998	128.08	165.75	213.16	-
9	5/15/1998	63.93	155.72	199.55	-
10	7/15/1998	127.36	156.8	-	-
11	8/15/1998	108.76	-	-	-
12	9/15/1998	119.98	150.64		-
13	10/15/1998	107.3	155.75	188.11	-
14	11/15/1998	127.75	176	-	-
15	12/15/1998	151.69	190.25	-	-
16	1/15/1999	126.2	158.52	209.69	-
17	2/15/1999	132.8	168.91	210.97	-
18	3/15/1999	137.63	181.75	243.13	-
19	4/15/1999	107.05	157.35	214.74	-
20	5/15/1999	87.72	132.3	163.91	190.44
21	6/15/1999	107.16	168.5	191.38	-
22	7/15/1999	122.93	151.83	-	-
23	8/15/1999	135.47	169.25	-	-

Table 10. Results of the length-frequency analysis using various options in the FiSAT.

Method	Male		Female		Sexes Pooled	
	L_∞	K	L_∞	K	L_∞	K
	(mm)	yr-1	(mm)	yr-1	(mm)	yr-1
1. Powell-Wetherall method	240.3		283		268	
2.ELEFAN I after correction	240	1.1	295	0.84	285	0.78
3.Modal progression Analysis						
Analysis of growth increment						
G& Holt plot	240	1.01	285	0.91	294	0.84

Table 11. Selected VBGF growth parameters for *L. lactarius* and lengths calculated against age.

Parameters/ Sex	Male			Female			Sexes pooled		
L_∞ (mm)	240			285			294		
K yr^{-1}	1.01			0.91			0.84		
t_0	-0.0151			-0.0183			-0.0215		
	Age (years)								
Length attained (mm)	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
	154	209	229	172	240	267	168	240	271

Table 12. Comaparison of growth parameters of *L. lactarius* with the results available from literature.

L_∞ (mm)	K (yr^{-1})	t_0	Sex	Temp	L_{max}	L_m	L_m/L_∞	φ'	Area
270	0.629	-	P	27	270	168	0.62	2.66	India, AP-Orissa, 1976-79
320	0.854	-	P	28	280	167	0.52	2.94	India, Waltair, 1966 *
285	0.91	-0.015	F	29.5	265	134	0.47	2.87	India, Mangalore, 1997-99
240	1.01	-0.0183	M	29.5	215	132	0.56	2.76	India, Mangalore, 1997-99
294	0.84	-0.0215	P	29.5	265	133	0.45	2.86	India, Mangalore, 1997-99

M = Male; F = Female; P = Pooled

* Estimate made by Pauly (1978) based on published data of Rao (1966)

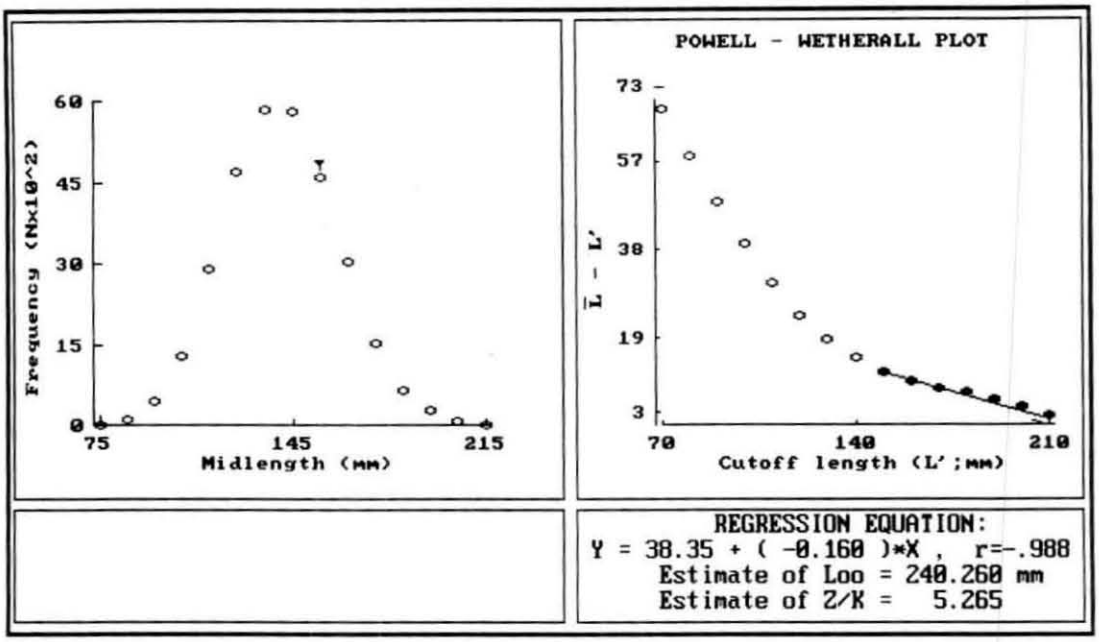


Fig.1. Estimation of L_∞ and *Z/K* of *L. lactarius* (male) using Powell-Wetherall Plot.

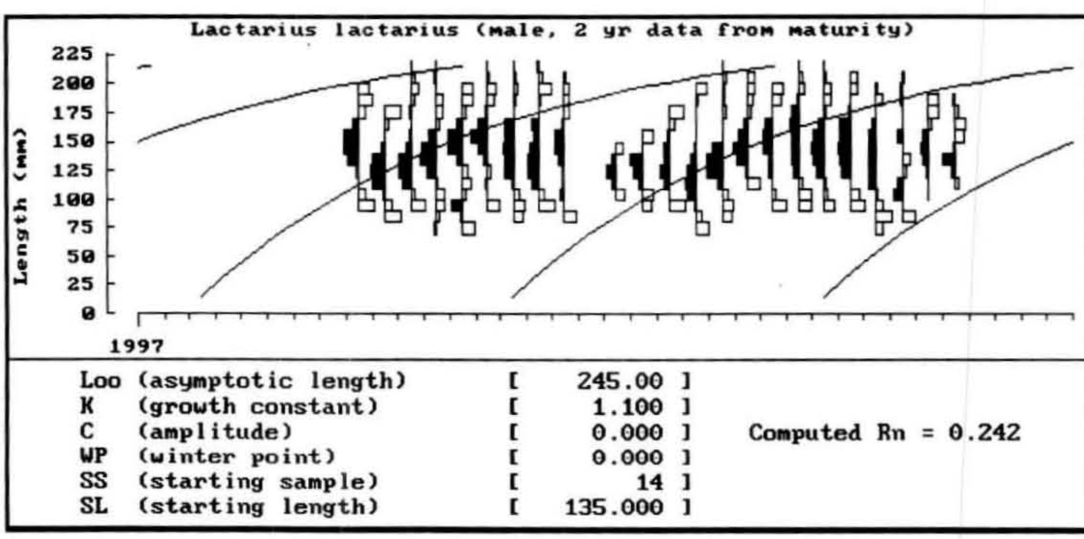


Fig.2. Estimation of L_∞ of *L. lactarius* (male) using ELEFAN I method.

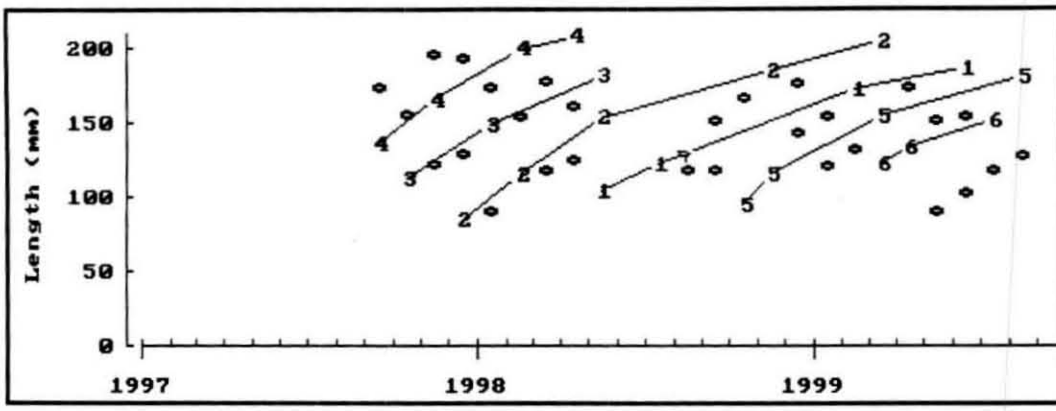


Fig.3. Linking of means in modal progression analysis of *L. lactarius* (male).

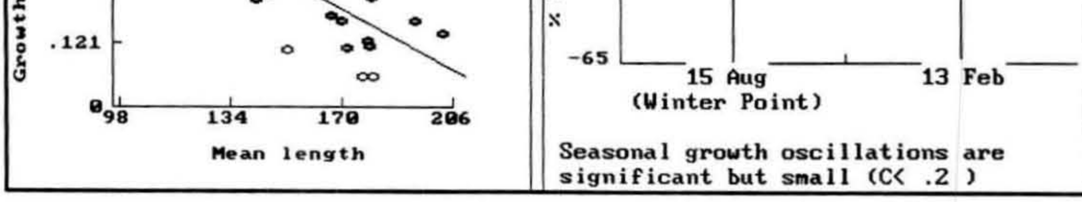


Fig.4. Estimation of growth parameters using G&H plot for *L. lactarius* (male).

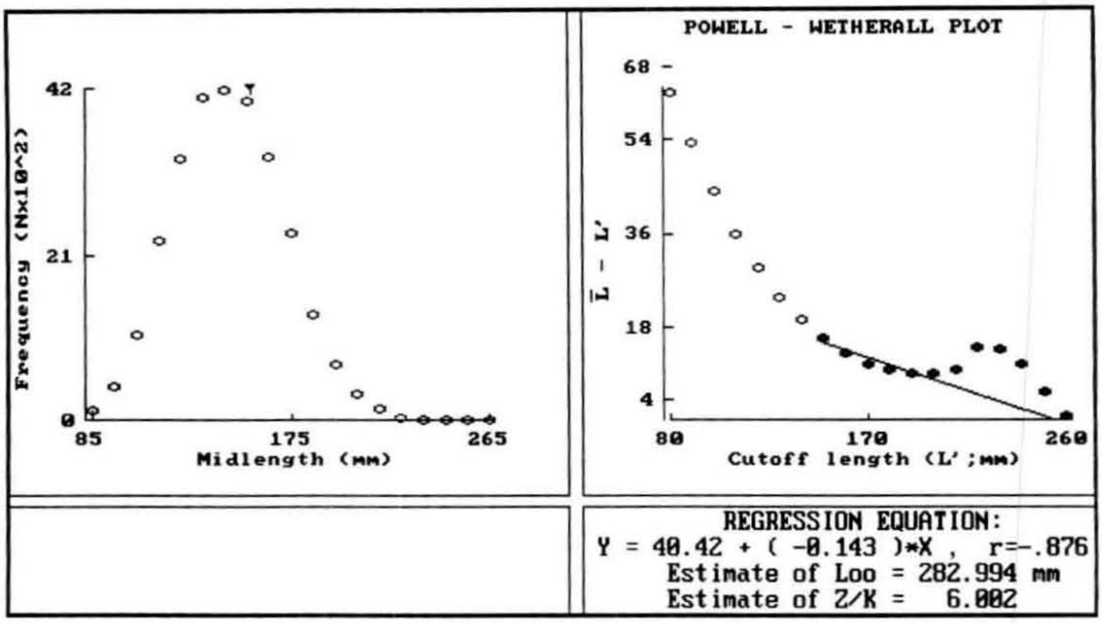


Fig.5. Estimation of L_∞ and Z/K of *L. lactarius* (female) using Powell-Wetherall Plot.

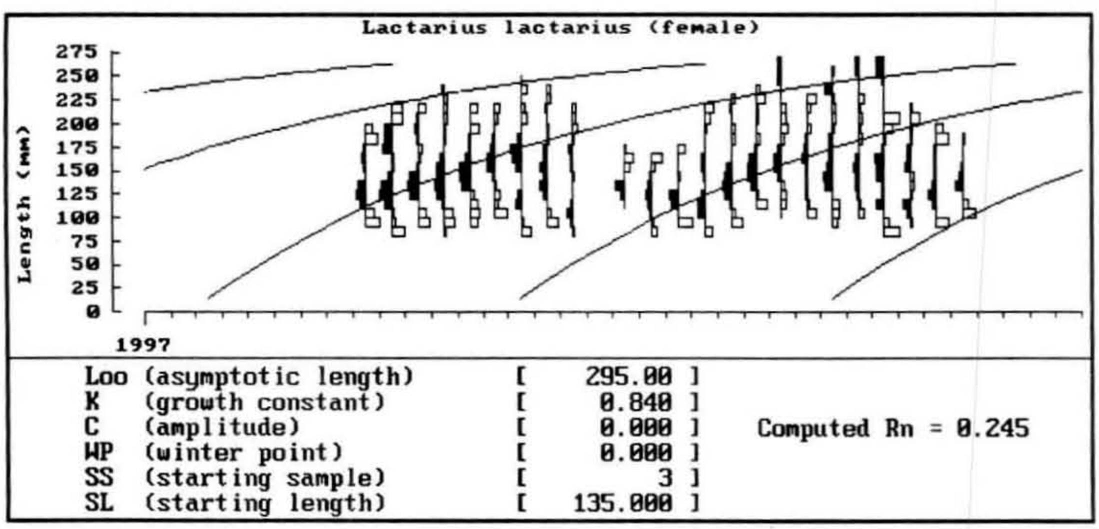


Fig.6. Estimation of L_∞ of *L. lactarius* (female) using ELEFAN I method.

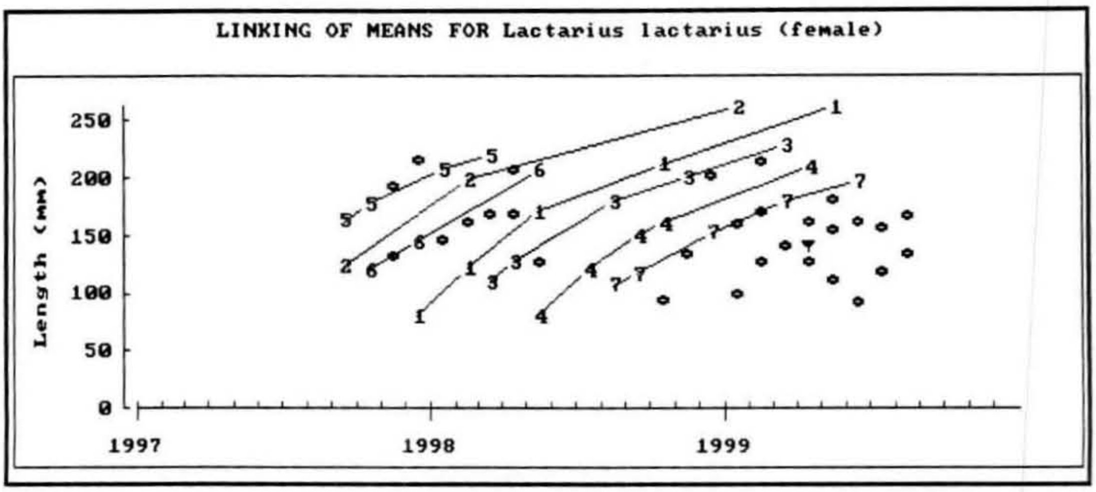


Fig.7. Linking of means in modal progression analysis of *L. lactarius* (female).

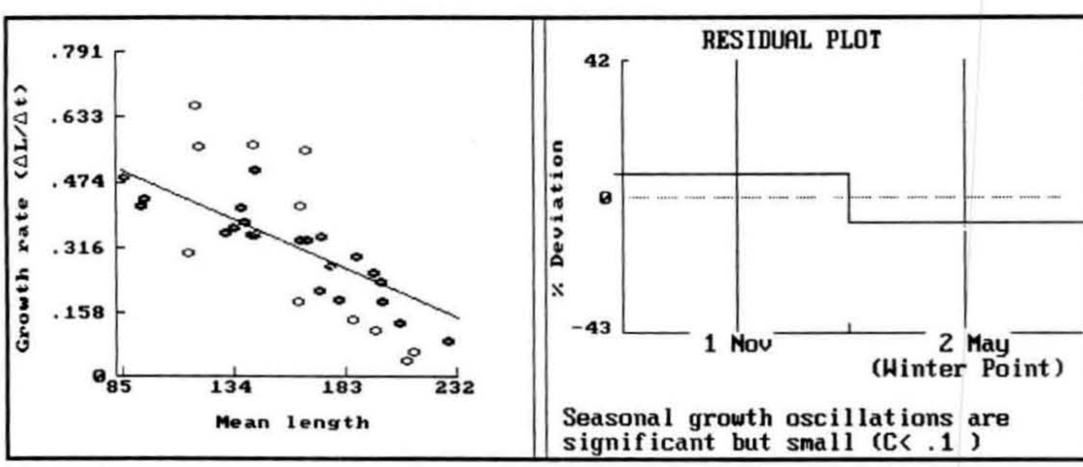


Fig.8. Estimation of growth parameters using G&H plot for *L. lactarius* (female).

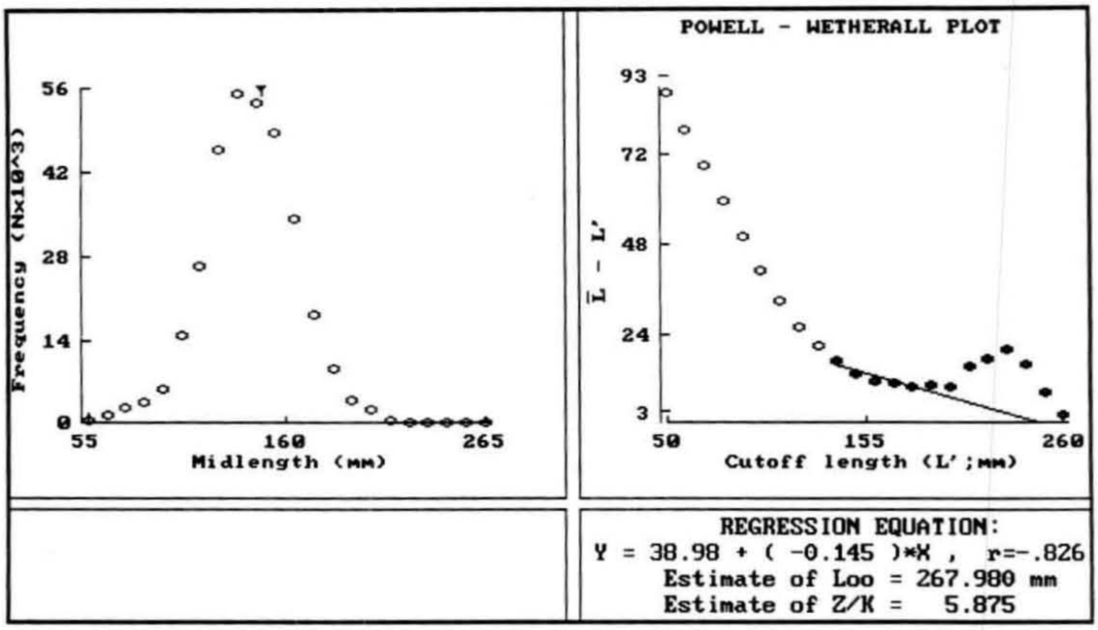


Fig.9. Estimation of L_∞ and *Z/K* of *L. lactarius* (sexes pooled) using Powell-Wetherall Plot

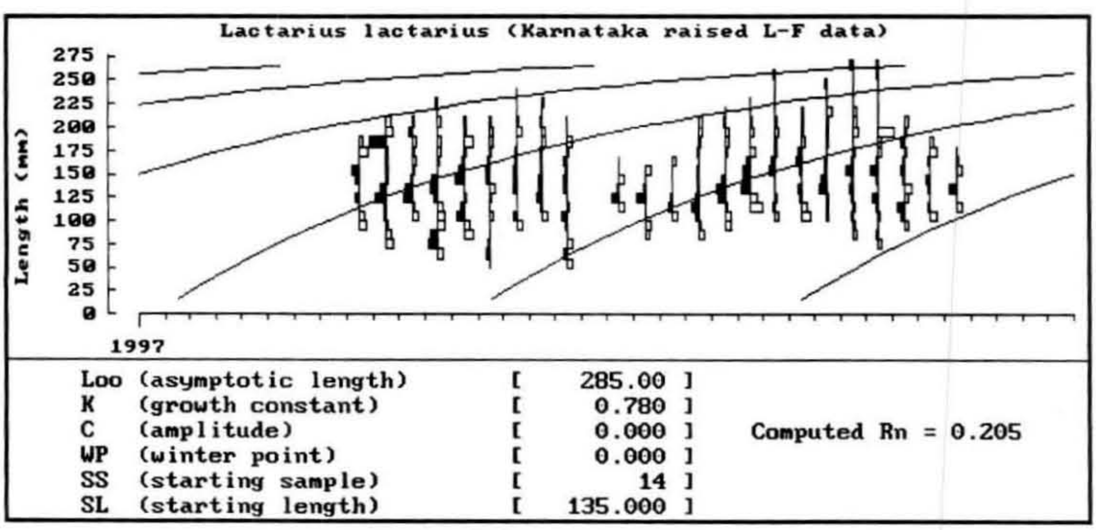


Fig.10. Estimation of L_∞ of *L. lactarius* (sexes pooled) using ELEFAN I method.

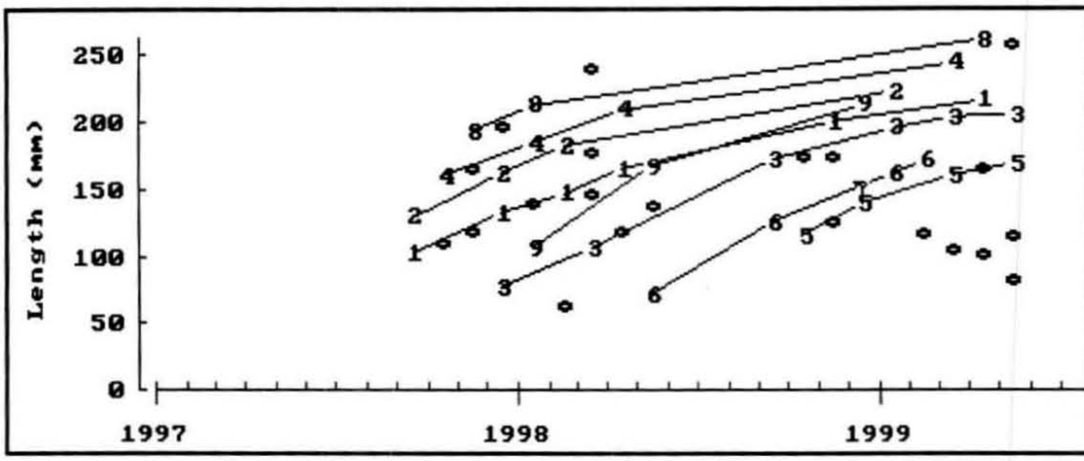


Fig.11. Linking of means in modal progression analysis of *L. lactarius* (sexes pooled).

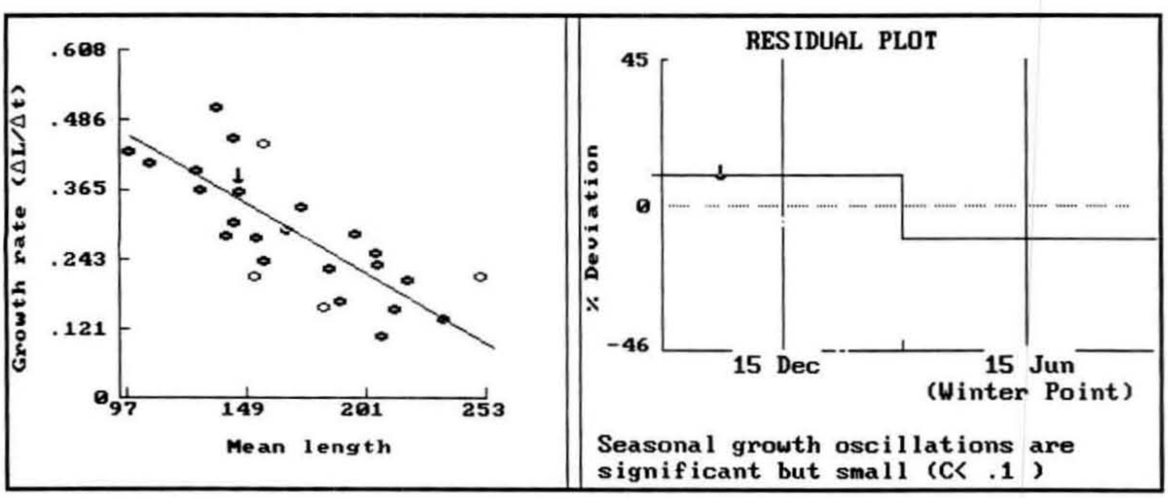


Fig.12. Estimation of growth parameters using G&H plot for *L. lactarius* (sexes pooled).

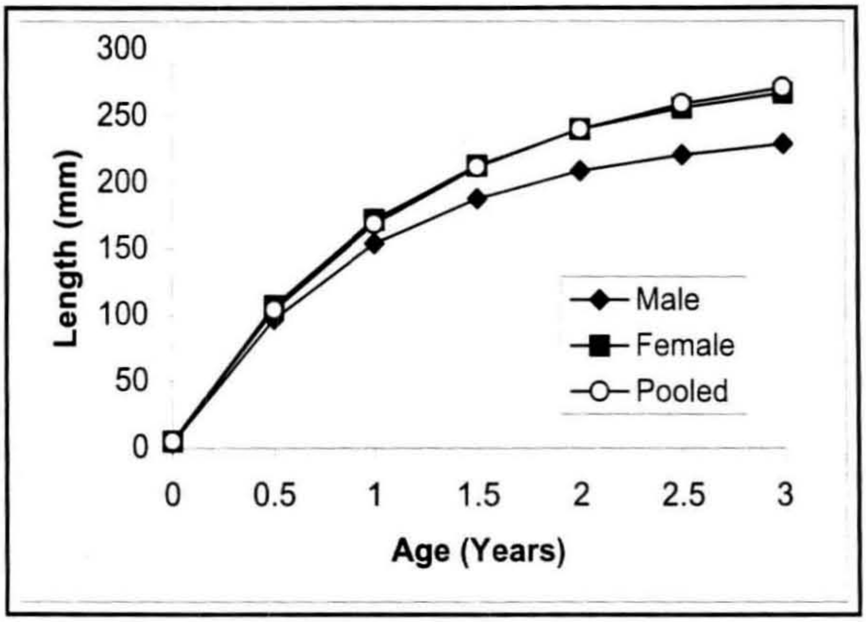


Fig.13. The VBGF curve of *L. lactarius* (sexes pooled) with selected growth parameters.

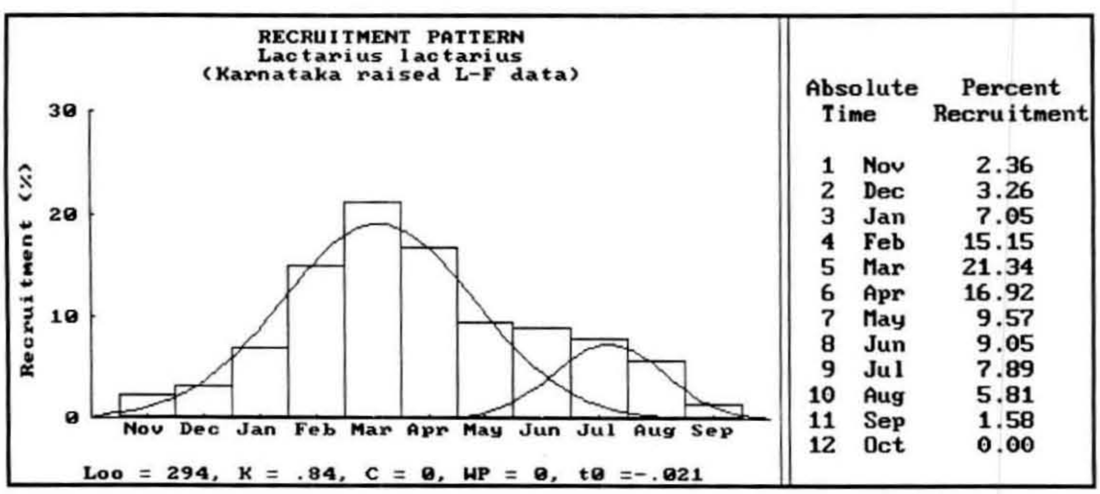


Fig.14. Recruitment pattern of *L. lactarius* (sexes pooled) with percentage recruitment during different months.

Chapter

7

Population Dynamics

7.1. INTRODUCTION

Aquatic living resources like fisheries are limited and renewable. In free access fisheries, competition for the resources leads to biological and economical over-fishing. Fish stocks of various oceans are in crisis. Nearly two thirds of world's fish stock are variously being fished to capacity, over fished or, are recovering from over fishing which is a slow process. Many fishery biologists believe that the current situation is the inevitable result or failures of adopting the suitable management strategies for conservation of fishery resources for rational use. In this context, studies on population dynamics of commercially important species are essential to help formulate fishing strategy to harvest the highest steady yield year after year.

The theory of fish population dynamics was formulated first by Ber (1854, 1860) followed by Danilevskii (1862, 1871, 1875), Hensen and Apstein (1897), Heincke (1898) and Petersen (1895, 1900, 1903). The reduction in catch from marine fish stocks was felt in the 19th century in North Sea and this paved the way for the establishment of the International Council for the Exploration of Sea (ICES) in 1902 for formulating facts and theories relating to fish population dynamics. Some of the notable contributions on the subject in the early 20th century were of Baranov (1918), Russel (1931, 1939), Chugunov (1935), Graham (1935, 1939), Thompson (1937) and Ricker (1940, 1944). Subsequent critical reviews on the subject by Nikolsky

(1950, 1953, 1965), Schaefer (1954) Beverton and Holt (1957), Thompson (1959), Lapin (1961) Paloheimo (1961) Gulland (1965, 1969, 1983), Ricker (1958), Holden (1974) and Powell (1979) have helped to popularise the subject world-wide. The recent and most important works on population dynamics were of Caddy (1980), Pope (1980), Munro (1980), Jones and van Zalinge (1981), Gulland (1983, 1988), Jones (1984), Garcia (1985), Cushing (1988), Hilborn and Walters (2001), Myers *et al.* (1995) and Froese and Binohlan (2000).

Important contributions on fish stock assessment in the tropics were of Pauly (1979, 1980a, 1980b, 1981, 1982a, 1982b, 1983a, 1983b, 1984a, 1984b, 1987), Banerji and Chakraborty (1973), Corten (1974), Tiews (1976), Pauly and David (1981), Garcia and Le Reste (1981), Devaraj (1982, 1983b), Sanders *et al.* (1984), Alagaraja (1984), Morgan (1985), Pauly and Morgan (1987), Sparre (1987, 1991), Sainsbury (1988), Sparre and Venema (1992), Silvester and Pauly (1997) and Gayanilo and Pauly (1997).

Prior to 1980s the studies on the population dynamics of marine fishes from Indian waters were very few, notable being the works of Rao (1971) on *Pseudosciaena diacanthus*, Annigeri (1972) and Sekharan (1974) on *Sardinella longiceps*, Banerji (1973) on *Rastrelliger kanagurta*, Krishnamoorthi (1976) on *Nemipterus japonicus* and Devaraj (1977) on seerfish. After 1980, several studies on fish population dynamics are available. Works of Venkataraman *et al.* (1981) and Yohannan (1983) on mackerel; Murty

(1983), Silas *et al.* (1986) on tunas; Khan (1986) on *Harpodon nehereus*; Alagaraja and Srinath (1987) on catfish; Vivekanandan and James (1986), Murty *et al.* (1992) and Zacharia (1998) on *Nemipterus spp.*; Biradar (1988) and Philip and Mathew (1996) on *Priacanthus hamrur*; Chakaraborty (1989) on *Otolithes cuvieri*; Murty (1990) on *Secutor insidiator*; Muthiah (1994) on lizardfishes; Chakraborty (1996) on *Pennahia macrophthalmus* and Devaraj *et al.* (1999) on seerfish are worth mentioning.

The dynamics of fish population are concerned with birth, growth and mortality of the stocks and these processes are governed by their adaptation to environment and reaction to fishing. Fishing not only reduces the population, but also interferes with the adaptive relation of the fish species to its environment.

Two types of models have been developed to determine the quantitative effects of fishing on the stocks and to maintain and get optimum yield. The surplus production model or logistic model is a holistic model proposed by Hjort *et al.* (1933) and later developed by Graham (1939, 1943) and improved by Schaefer (1954). The main drawback of this model is that it considers production/yield as a function of effort expended and the biological and fishery independent environment factors do not have a place in the model. To fit this model a fish stock was to be considered as a homogeneous mass without length or age composition of the individuals.

The analytical models were developed from the works of Baranov (1918), Russell (1931, 1939), Thompson and Bell (1934), Ricker (1948) and Beverton and Holt (1957). These models consider biological parameters of populations (age, growth, mortality etc.) and the yield information is obtained from a unit number or weight of recruits under a series of varying fishing conditions. These models are used for estimation of stock and for predicting future yields of a fishery employing mathematical models like Thompson and Bell (1934) and Beverton and Holt (1957) models. The first model, analyses the effect of fishing on a particular year class or cohort (Virtual population analysis or cohort analysis) and based on findings, the effect of fishing on the stocks in the future can be predicted. The second model, the yield-per-recruit model of Beverton and Holt (1957), assumes a steady state situation describing the state of stock and yield when the fishing pattern remains the same over a long period of time, so that all recruits are exposed to fishing.

Along the Karnataka coast, the heavy exploitation by mechanised trawlers, operated mainly in the narrow coastal waters, has resulted in wide fluctuations in abundance of several fishery resources as indicated by commercial catch statistics. This situation warrants better understanding of the magnitude and dynamics of exploitation of the individual fish species. The present study is directed to provide information on mortality, yield-per-recruit and stock assessment of one of the commercially important species, *L. lactarius* from the Karnataka coast. The results of the study would help to evolve management strategies for judicious exploitation of this resource having high economic value.

7.2. MATERIAL AND METHODS

For stock assessment, the data pertaining to trawl which is the major non-selective gear for the exploitation of *L. lactarius* in this region were used. Using the monthly length composition data collected from the trawl catches landed at Mangalore, Malpe and Karwar, catch estimates and length compositions were worked out for the entire State of Karnataka. For Karnataka the annual fishing effort (in actual fishing hours) was calculated as per the procedure mentioned in Chapter 2. The effort expended by both SDF and MDF trawlers during 1997-1999 was utilised for the study. The other necessary inputs for the analysis were the estimates of the parameters like the L_∞, K and t_0 of the von Bertalanffy growth model.

Assuming that the growth in length of *L. lactarius* follows von Bertalanffy Growth Formula (VBGF), the VBGF parameters, L_∞ and K and t_0 were estimated using the FiSAT software as mentioned in Chapter VI. The estimates of unsexed fishes (L_∞ =294 mm, K = 0.84 yr^{-1} and t_0 = -0.0215 yr^{-1}) were used.

The mortality in fishes are due to natural causes and fishing which are known as total mortality coefficient or instantaneous rate of total mortality and denoted by Z. Natural mortality due to predation including cannibalism and other factors such as disease, parasitic infection, starvation, old age and environmental conditions acting independently is expressed as instantaneous rate of natural mortality *M*. Fishing mortality caused by fishing activity is expressed as instantaneous rate of fishing mortality *F*.

7.2.1. Total Mortality Coefficient (*Z*)

The total mortality coefficient (Z) was estimated from the length-frequency data by Beverton and Holt (1957) method, length-converted catch curve method of Pauly (1983b) and the cumulative catch curve method of Jones and van Zalinge (1981) for 1997-98 and 1998-99 fishing seasons separately as well as pooled.

7.2.1.1. Beverton and Holt Method

In Beverton and Holt method (1956), *Z* is calculated from the mean length $\bar{L}$, L_∞ and *K* of the von Bertalanffy growth parameters. The number of fish in the fully exploited length group is used assuming that mortality is constant for all the length groups. It further considers that the size of the fish is related to mortality, the larger the mortality, the fewer the larger sized fish in the fishery which implies that higher the mean size, lesser is the mortality and vice versa. The relation between Z and $\bar{L}$ is:

$$Z = K\left(\frac{L_\infty - \bar{L}}{\bar{L} - L'}\right)$$

where,

L' is the lower limit of the size group from which length upwards all lengths are under full exploitation and $\bar{L}$ is the mean length of fish L' and larger.

7.2.1.2. Length-Converted Catch Curve Method

In the length-converted catch curve method of Pauly (1983b), the time taken for average fish to grow from length L_1 (lower limit) to L_2 (upper limit) and the age interval midpoints are derived from the inverse von Bertalanffy equation.

The catch curve equation is:

$$\ln\left[\frac{C(L_1,L_2)}{\Delta_t(L_{1.}L_2)}\right] = \text{C-Z}\left[\frac{\text{t}(\text{L}_1)+\text{t}(\text{L}_2)}{2}\right]$$

where $C(L_1,L_2)$ is the numbers caught in the length between L_1 and L_2, Δ_t is the time taken to grow from length L_1 to L_2. Then the equation becomes linear as:

$$Y = \ln\frac{C(L_1,L_2)}{\Delta_t(L_1,L_2)}$$

and

$$X = \frac{t(L_1)+t(L_2)}{2}$$

which is the form of $Y = a + bx$ where the slope $b = -Z$, with the sign changed Z is obtained. In the present study, the length-converted catch curve routine available in FiSAT was used to estimate Z.

7.2.1.3. Cumulative Plot Method of Jones and van Zalinge

Jones and van Zalinge (1981) found a linear relationship between catch and survivors. In the length-converted catch curve, when t_{i+1} takes a very high value (t_{i+1} tends to ∞), the term $e^{-Z(t_{i+1}-t_i)}$ will approach zero and $\ln(1-e^{-Z\Delta t})$ will therefore approach zero as well. Thus if, $C_{i,\infty}$ designates all fish caught at age t and older-

$$\ln(C_{i\infty}) = d - Z\left\{t_0 - \left(\frac{1}{K}\right)\ln\left[1 - \frac{L_i}{L_\infty}\right]\right\}$$

which can be reduced to the form

$$\ln(C_{i,\infty}) = a + \left(\frac{Z}{K}\right) \times \ln(L_\infty - L_i)$$

where,

$C_{i,\infty}$ is the cumulative catch corresponding to a given length, i is the lower limit of that length class, and the ∞ symbol indicates that the catch refers to a range from L_i to all larger sizes. The cumulative catch curve method is a variant of length-converted catch curve method but the assumptions are slightly different.

7.2.2. Natural Mortality Coefficient (*M*)

The natural mortality coefficient was calculated by the methods of Sekharan (1974), Rikhter and Efanov (1976), Pauly's empirical formula (Pauly, 1980b) and Cushing's method (Cushing, 1968).

7.2.2.1. The Sekharan's (1974) Method

Under this method, M is estimated assuming 99 % of fish by number would die if there was no exploitation by the time they attain t_{max} which corresponds to L_{max} in the catch, where L_{max} is the maximum observed length in catch and t_{max} is the corresponding age of the fish calculated from VBGF equation.

$$M = \frac{1}{t_{max}} \times \log e \frac{100}{1}$$

7.2.2.2. The Rikhter and Efanov (1976) Method

This method employs the following formula:

$$M = \frac{1.521}{t_m^{0.72}} - 0.155$$

where, t_m = age at which 50 % of the population matures. For *L. lactarius*, the L_m was estimated as 132 mm for sexes pooled (Chapter 5) and the corresponding t_m was estimated as 0.688 year.

7.2.2.3. The Pauly's (1980b) Method

M is derived using the following empirical formula:

$$\log_{10} M = 0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where,

L_∞ is the growth parameter expressed in cm and *T* is the mean annual surface water temperature in °C (29.5°C is taken as *T* in the present study as used by Zacharia, 1995 and Mohamed and Rao, 1997).

7.2.2.4. Cushing's (1968) Method

In the un-exploited state, if the number of one-year olds is taken as 100 and the number surviving to maximum age T_{max} as 1, then

$M = \frac{1}{T_{\max -1}} \log e \frac{100}{1}$ where T_{max} is the age of the largest fish.

7.2.3. Probabilities of Capture

The probability of capture by length (Pauly, 1984b) of *L. lactarius* was calculated by the ratio between the points of the extrapolated descending arm of the length-converted catch curve using the FiSAT software.

7.2.4. Fishing Mortality Coefficient (*F*)

The instantaneous fishing mortality coefficient (*F*) was computed from the following relationship:

$$F = Z - M$$

7.2.5. Exploitation Rate (*U*)

This is defined as the fraction of fish present at the start of a year that is caught during the year (Ricker, 1975). This is estimated by the equation given by Beverton and Holt (1957) and Ricker (1975) as:

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

7.2.6. Exploitation Ratio (*E*)

This refers to the ratio between fish caught and the total mortality (Ricker, 1975) or the exploitation rate or the fraction of deaths caused by fishing (Sparre and Venema, 1992). It is estimated by the equation:

$$E = \frac{F}{Z} = \frac{F}{M + F}$$

The *E* gives an indication of the state of exploitation of a stock under the assumption that the optimal value of exploitation is 0.5 or $E \approx 0.5$ which in turn is under the assumption that the sustainable yield is optimised when $F \approx M$ (Gulland, 1971).

7.2.7. Yield (*Y*)

Yield is the fraction of fish population by weight taken by the fishery and is denoted by Y.

7.2.8. Standing Stock (*Y/F*)

This term refers to a concentration of fish population for a given area at a given time. It is measured in terms of numbers or weight and is estimated from the relation Y/F.

7.2.9. Total Stock or Annual Stock or Biomass (*Y/U*)

This refers to the total weight or number of fish population available for a given area at a particular time. It is estimated from the relation *Y/U* where *Y* is the yield and *U* is the exploitation rate.

7.2.10. Maximum Sustainable Yield (*MSY*)

This refers to the weight of fish that can be taken by fishing without reducing the stock's biomass in a continuing basis. The MSY was calculated by the formula of Gulland (1965) as:

$MSY = Z(Y/F)*0.5$.

The *MSY* was also calculated from the length-based Thompson and Bell model as given under section 7.2.12.

7.2.11. Virtual Population Analysis -VPA (Gulland, 1965)

The term virtual population means the part, by number, of a fish stock that is alive at a given time and which will be caught in future. In Virtual Population Analysis (also known as Cohort Analysis), the annual catch obtained from a single cohort during the exploited phase is used to calculate the abundance and fishing mortality rates of the cohort in each year. Managing a fishery by limiting effort requires estimates of annual abundance and total catch at different levels of fishing effort. VPA is a suitable method in such situations.

The basic equations used in this analysis are:

1. $C(i,t,t+1) = N(i,t)\dfrac{F(i,t,t+1)}{M+F(i,t,t+1)}\exp[M+F(i,t,t+1)]$

2. $\dfrac{C(i,t,t+1)}{N(i+1,t+1)} = \dfrac{F(i,t,t+1)}{M+F(i,t,t+1)}\{\exp[M+F(i,t,t+1)]-1\}$

3. $N(i,t) = N(i+1,t+1)\exp[M+F(i,t,t+1)]$

(the notation *exp(x)* is used in place of e^x)

The terms used in these equations have the following meanings:

$C(i,t,t+1)$: Catch in number for year *i* with ages between *t* and *t+1*.

$N(i,t)$: Number of fish (survivors) of age *t* in the sea at the beginning of year *i*.

$F(i,t,t+1)$: Instantaneous rate of fishing mortality during the year *i* for those between ages *t* and *t+1*.

M : Instantaneous rate of natural mortality which is assumed to be the same for all age groups

$Z(i,t,t+1) = M + F(i,t,t+1)$: Instantaneous rate of total mortality during the year *i* for those between ages *t* and *t+1*.

The calculations for VPA are started from the bottom (highest age class in the catch, also known as the terminal class). With an initial guess of the fishing mortality for the terminal class (terminal F value), knowing the estimate of natural mortality M and catch for the terminal class, we can estimate the number of survivors at the beginning of the year for this class from the first equation as:

$$N(i,t) = \frac{M + F(i,t,t+1)}{F(i,t,t+1)} \frac{C(i,t,t+1)}{\exp[M + F(i,t,t+1)]}$$

Since the number of survivors at the beginning of a year is same as the number of survivors at the end of the previous year, we can estimate the fishing mortality for the immediate previous age class from the second equation in which the only unknown factor will be $F(i,t,t+1)$. The number of survivors for this class can be estimated using the third equation. This procedure can be repeated in this fashion starting from the last age class to estimate fishing mortality and number of survivors for each of the age classes.

7.2.12. Length-based Thompson and Bell Model

The Thompson and Bell model is the predictive version of VPA, which can predict the stock size and the catch for various assumptions on the future fishing pattern. The inputs are the same as that of the cohort analysis and the additional inputs required are the parameters of the length-weight relationship and the average price per kg by length group. The outputs are the number in each lower limit of the length group N (L1), the catch in numbers, the yield in weight, the biomass multiplied by Δt, *i.e.* the time required to grow from the lower limit to the upper limit of the length group and the value. Finally, the totals of the catch, yield, mean biomass x Δt and value are obtained. The calculations are repeated for a range of F values and the final results are plotted in graphs.

The equation to calculate F in length based VPA is rearranged as:

$$C(L_1,L_2)=[N(L_1)-N(L_2)]*\frac{F(L_1,L_2)}{Z(L_{1,}L_2)}$$

This gives the equation

$$N(L_1)=\left[N(L_2)*H(L_1,L_2)+\frac{N(L_1)-N(L_2)}{Z(L_1,L_2)}*F(L_1,L_2)\right]*H(L_1,L_2)$$

where,

$$H(L_1,L_2)=\left[\frac{L_\infty-L_1}{L_\infty-L_2}\right]^{M/2K}$$

with respect to N (L_2)

$$N(L_2)=N(L_1)*\frac{1/H(L_1,L_2)-F(L_1,L_2)/Z(L_1,L_2)}{H(L_1,L_2)-F(L_1,L_2)/Z(L_1-L_2)}$$

the catch in numbers has to be multiplied by the mean weight of the length group,

$$\bar{w}(L_{1,}L_2)=q*[L_1+L_2/2]^b$$

where *q* and *b* are the parameters of the length-weight relationship *a* and *b* respectively. The values of *a* and *b* in the length-weight relationship were 0.00001428 and 2.957 respectively. The yield of this group is given by

$$Y(L_1,L_2)=C(L_1,L_2)*\bar{w}[L_1,L_2]$$

and value given by

$$V(L_1,L_2)=Y(L_1,L_2)*\bar{v}(L_1,L_2)$$

where, $\bar{v}(L_1, L_2)$ are the average prices per kg of fish between lengths L_1 and L_2. The number of survivors of the length group decreases when a cohort grows from L_1 to L_2 and is calculated as:

$$\overline{N}(L_1, L_2) * \Delta t(L_1, L_2) = [N(L_1) - N(L_2)] / Z(L_1, L_2)$$

and the corresponding mean biomass * Δ_t is:

$$\overline{B}(L_1, L_2) * \Delta t(L_i, L_2) = [N(L_1) - N(L_2)] / Z(L_1, L_2)$$

The average biomass during the lifespan of a cohort or all cohorts during a year is given by $\overline{B} = \sum \overline{B_i} * \Delta t_i$

7.2.13. The Relative Y/R model (Y'/R)

Beverton and Holt (1966) based on the realisation that the absolute value of Y/R expressed for example in terms of grams per recruit per year, has no direct relation to fisheries management, proposed the relative yield-per-recruit based on the concept that what matters is the relative differences of Y/R for different values of F. The model requires fewer parameters and is especially suitable for assessing the effect of mesh size regulations.

$$\left(Y'/_R\right) = E\, U^{M/K}\, [1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}]$$

where,

$$m = \frac{1-E}{M/K} = \frac{K}{Z}$$

$$U = 1 - \frac{L_c}{L_\infty}$$

and

$E = \frac{F}{Z}$ is the exploitation rate which is the fraction of deaths due to fishing.

The relation between relative yield-per-recruit $\left(Y'/R\right)$ and the yield per recruit $\left(Y/R\right)$ is

$$\left(Y'/R\right) = \left(Y/R\right)\exp[-M(t_r - t_0)]/W_\infty$$

where, t_r is the age at recruitment and t_0 is the age corresponding to zero length, which is a parameter in VBGF.

Knowing the relative yield-per-recruitment, the corresponding yield-per-recruitment can be calculated using the following equation.

$$\left(Y/R\right) = \left(Y'/R\right)W_\infty \exp[M(t_r - t_0)]$$

The relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) were obtained from the estimated growth parameters and probabilities of capture by length (Pauly and Soriano, 1986). The estimates were made using the FiSAT software.

The concept of $F_{0.1}$ in the (Y'/R) model is to limit F to the values which correspond to 1/10th rate of increase of yield-per-recruit that can be obtained by increasing F at low levels of F (Gulland and Boerema, 1973). $E_{0.1}$ is defined as the exploitation rate at which the marginal increase of relative yield-per-recruit is 1/10th of its value at $E = 0$. The yield-per-recruit was calculated as a function of mesh size or age at first capture and of fishing effort or fishing mortality through a yield isopleth diagram.

7.2.14. Optimum Age of Exploitation and Potential Yield-per-Recruit

The optimum age of exploitation (t_y) is the age at which the brood attains maximum weight (Beverton and Holt, 1957) and the potential yield (Y') is the quantity corresponding to the weight as a function of infinite fishing intensity. The optimum catch (Herrington, 1943 and Ricker, 1945) which is none other than potential yield (Devaraj, 1983b) that could be obtained by allowing a year class to grow to its greatest total weight before being caught. Since, the potential yield is a theoretical estimate of asymptote fishing under ideal fishing conditions involving the optimum use of gear selectivity, the amount by which the actual catch falls short of potential yield is a measure of efficiency (Holt, 1958). Kutty and Qasim (1968) had stated that to increase the efficiency of fishing so as to bring the actual catch as nearer to the potential yield, it is imperative to know the t_y and Y'. These were estimated from the equation formulated by Kutty and Qasim (1968) and followed by Muthiah (1994):

$$Y' = ae^{-M}\left(t_y - t_r\right)\left\{L_\infty - \left(L_\infty - l_0\right)e^{-Kt_y}\right\}^b$$

where t_y is calculated from the relationship-

$$e^{Kt_y} = \frac{\left(L_\infty - l_0\right)\left(bK + M\right)}{ML_\infty}$$

where Y' is optimum yield per recruit, *a* and *b* are exponent and constant respectively from the length-weight relationship, M = natural mortality co-efficient, t_y is optimum age of exploitation in years; t_r is age at recruitment in years; L_∞ is the asymptotic length in cm; l_0 is the length in cm when age is 0 and K is the growth co-efficient. L_0 is calculated by inverse VBGF equation: $l_0 = L_\infty \left(1 - e^{-K(t-t_0)}\right)$.

The optimum length of exploitation (L_{opt}) was also estimated from the empirical equation of Froese and Binohlan (2000) using the relationship $L_{opt} = 3 * L_\infty / 3 + M / K$.

7.3. RESULTS

The monthly estimated numbers of the fish in different size groups for the years 1997-98 and 1998-99 using the length composition data collected from the trawl catches landed at Mangalore, Malpe and Karwar and raised to Karnataka State are given in Table 1. The growth parameters estimated with the unsexed data (Chapter 6) and used for stock assessment studies are L_∞ = 294 mm, K = 0.84 yr^{-1} and t_0 = -0.0215.

7.3.1. Total Mortality Coefficient (*Z*)

The total mortality coefficient (Z) estimated separately for 1997-98 and 1998-99 by different methods is given in Table 2. The Z values calculated by different methods varied from 3.14 to 8.95 for 1997-98, 3.45 to 6.83 for 1998-99 and 4.44 to 6.93 for 1997-1999 pooled. The estimates by Beverton and Holt method gave the lowest values while the estimates by Jones and van Zalinge were the highest. The averages of the estimates of various methods were 6.37 in 1997-98, 5.29 in 1998-99. For the pooled data of two years, the Z estimate calculated by taking the average of the 3 methods was 5.78 which was very close to the estimate by Pauly's catch curve method and hence this was taken for further analysis. The results of the catch curve analysis for 1997-98, 1998-99 as well as for pooled data for two years are shown in Figs. 1, 2 and 3 respectively.

7.3.2. Natural Mortality Coefficient (*M*)

The natural mortality coefficient values estimated by different methods are shown in Table 3. The values were 1.64 by Pauly's empirical formula, 1.67 by Sekharan's method, 1.38 by Rikhter and Efanov method and 2.62 by Cushing's formula. While the M values estimated by the first three methods were somewhat comparable, the estimate by Cushing's formula shows a high value. Since the estimate of *M* by Cushing's method was high, the average of the first three methods (1.56) was taken as the *M* estimate for *L. lactarius* from Karnataka.

7.3.3. Probabilities of Capture and Length at First Capture (l_c)

The results of the length-converted catch curve method were used for the estimation of probabilities of capture and l_c (Fig.4). The values obtained by the probability of capture were L_{25} =113.3 mm, L_{50} = 125.4 m and L_{75}= 135.2 mm (Table 4). These values were used as inputs in Thompson and Bell yield prediction analysis and relative *Y/R* of Beverton and Holt (Y'/R).

7.3.4. Fishing Mortality Coefficient (*F*)

The values of fishing mortality coefficient (*F*) estimated were 4.81 for 1997-98, 3.73 for 1998-99 and 4.22 for the two years pooled (Table 5).

7.3.5. Exploitation Rate (*U*) and Exploitation Ratio (*E*)

The exploitation rate (*U*) was 0.75 in 1997-98 and 0.70 in 1998-99 and for the pooled data U was 0.73. The exploitation ratio (*E*) was 0.748 and 0.698 during 1997-98 and 1998-99 respectively. The year-wise exploitation rate (*U*) and exploitation ratio (*E*) for the two years are given in Table 5.

7.3.6. Standing Stock and MSY

The yield (*Y*) of *L. lactarius* obtained from Karnataka by trawl was 1,116 t in 1997-98 and 957 t in 1998-99. The estimated total stock was 1,555 t in 1997-98, 1,367 t in 1998-99 and 1,453 t and for the two years pooled (Table 5). The standing stock was estimated as 242 t and 256 t respectively. Annual MSY was calculated as 725 t against the present average catch of 1,061 t.

7.3.7. Virtual Population Analysis (VPA)

Results of the VPA using the pooled length-frequency data for the two years show that *F* increases to a maximum of 4.84 at 170-179 mm (Table 6). Maximum numbers were caught in the size group 130-139 mm. The mean numbers, the length-wise catch and the steady state biomass pertaining to each length class (Table 7) show that maximum catch (337.9 t) was obtained in the size class 150-159 mm (Fig.5). Catch constituted mainly of 140-169 mm length class.

The biomass increased from 33 t in the size class 50-59 mm to the maximum (114.2 t) in the size class 130-139 mm and gradually reduced to 7.61 t in 260-269 mm. Year-wise analysis of the population shows that the numbers in the stock were high during 1997-98, than in 1998-99. The numbers caught as well as biomass (survivors) also showed similar trend. The mean *E* was 0.968 in 1997-98 and 0.773 in 1998-99.

7.3.8. Length-based Thompson and Bell Model

The size-wise average market rate of *L. lactarius* used for estimation of maximum sustainable economic yield (MSE) in Thompson and Bell routine is given in Table 8. The rate ranged from a minimum of Rs. 40 per kg (for 50-79 mm sized fishes) to the maximum rate of Rs. 100 (for fishes of length 220 mm and above). The results of the Thompson and Bell analysis show that the yield was maximum in the length class 150-199 mm whereas, biomass was maximum at 130-139 mm (Table 9). The maximum sustainable yield (MSY) of 1051.4 t can be obtained by decreasing the fishing effort to 80% of the present effort (Fig.6). The MSE of Rs. 72.55 million can be obtained by reducing the fishing effort to 80% of the present level (Table 10).

The average annual fishing effort during 1997-1999 in Karnataka by mechanised trawlers (Chapter 2) was 2.22 million fishing hours (m h) and the average catch was 1061.5 t. As per the Thompson and Bell model, the fishing effort required to harvest the whitefish resources at the MSY level of 1045 t along Karnataka coast is 1.78 million fishing hours.

7.3.9. The Relative Y/R Model (Y'/R)

The L_c/L_∞ and M/K used for the Y'/R analysis were 0.43 and 1.86 respectively. The relative yield-per-recruit and biomass-per-recruit determined as a function of L_c/L_∞ and M/K were 0.69351 g and 0.8153 g respectively (Table 11). The yield-per-recruit reaches a maximum at an exploitation rate of 0.539 and as the exploitation rate increases the Y'/R decreases. Fig.7 shows that the present exploitation rate, E (0.73) has exceeded the optimum exploitation rate (E_{max} = 0.549). The $E_{-0.1}$ was estimated as 0.5215 and $E_{-0.5}$ as 0.322.

The yield isopleth diagram shows that maximum Y'/R of 0.0244 g is obtained at various combinations of exploitation rate ranging from 0.322 to 0.76 and L_c/L_∞ from 0.21 to 0.62 (Fig.8). The present value of L_c/L_∞ was found to be 0.43.

7.3.10. Optimum Age of Exploitation and Potential Yield Per Recruit

The l_0 calculated was 8.337mm. The results of the analysis gave optimum age of exploitation of *L. lactarius* from Karnataka waters as 1.060

years (L_{opt}=172 mm) and the potential yield-recruit as 15.7195 g. The present l_c is 125 mm and t_c 0.638 years. Hence, l_c has to be increased by 38% from 125 to 172 mm. As the present *Y/R* is 12.1985 g and the potential yield calculated was 15.7195 g, the *Y/R* can be increased by 29% by increasing the length at first capture.

From the empirical equation of Froese and Binohlan (2000), the optimum length of exploitation (L_{opt}) was calculated as 182 mm.

7.4. DISCUSSION

Progress on studies on fish population dynamics in tropical waters has been slow even though great strides have been made in temperate region since 19th century. The main hindrance in the study of population dynamics of tropical fishes are the well known problems such as difficulty in the determination of age of fishes from their hard parts owing to the absence of clear cut annual markings on them and also due to the existence of large number of species supporting the fishery and variety of gears used for harvest. The stock assessment investigations from tropical waters gained momentum in the eighties due to the introduction of length based methods and models and also by the development of suitable computer softwares like ELEFAN, LFSA and FiSAT. In the present study, growth parameters were estimated using the modal progression routine available in FiSAT.

Excepting the study of Rueben *et al.* (1993) from Andhra-Orissa coast on the estimation of mortality, no attempt has been made to estimate the stock of *L. lactarius* from Indian waters. Present study is the first of its kind from Indian waters to estimate the stock of *L. lactarius*.

The total instantaneous mortality rate, Z was estimated by three methods, length- converted catch curve method, Beverton and Holt method and Jones and van Zalinge method using the length frequency distribution for the two years of study (1997-98 and 1998-99) separately as well as combined. The Z estimates obtained by these methods ranged from 3.14 to 7.99. The Beverton and Holt method gave lower estimates and of Jones and van Zalinge method gave higher estimates. The average estimate was 6.04 in 1997-98 and 5.52 in 1998-99 and 5.76 for the pooled data, which is very close to the estimate obtained from Pauly's catch curve method (Table 2).

For estimating natural mortality coefficient (M), several simple methods are available and the best and easy method is regressing Z against effort (Sparre and Venema 1992). However, in the tropical multi-species system, apportionment of effort for a single species is difficult. Hence, this method could not be attempted in this study. Moreover, as natural mortality is influenced by several biological and environmental factors, it is difficult to get an accurate estimate (Pauly, 1980b; Cushing, 1981; Liu and Cheng, 1999). Further it is also related to other growth parameters like L_∞ (Sparre and Venema, 1992) and maturity (Rikhter and Efanov, 1976) and gonad weight (Gunderson and Dygert, 1988). The empirical equation of Pauly (1980b), Sekharan's method (1974), Cushing's method (1968) and the method of Rikhter and Efanov (1976) were used to derive natural mortality in the present study. The *M* estimates by the above four methods varied from 1.38 to 2.62. Since the *M* estimate by Cushing method showed very high value (Table 3), it was excluded and the average of other three methods were taken as *M* estimate for *L. lactarius*.

The high natural mortality rate (1.56) in *L. lactarius* can be explained following Gulland (1969) who states that the fish which grow quickly (high *K*) are likely to attain higher natural mortality rate as compared to fishes which grow slow and consequently with lower *M*. The natural mortality (*M*) is closely related to age and size, as larger fishes generally would have less rate of predation. Since *M* is linked to longevity and the latter to growth coefficient *K*, *M/K* ratio is found constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959 and Banerji, 1973). *M/K* ratio usually ranges from 1 to 2.5 (Beverton and Holt, 1959). In the present study, the *M/K* ratio obtained for *L. lactarius* is 1.86. The *M/K* ratio obtained by three methods except the method of Cushing (3.11) falls within the range. The *M/K* ratios estimated by different authors for *L. lactarius* are shown in Table 12. The value ranged from 1.11 (Reuben *et al.*, 1993) to 1.86 (present study).

Accurate estimation of fishing mortality is possible by coefficient of catchability and fishing effort. However since, variation in fishing effort was less between years, reasonable estimate of F was difficult to obtain. Hence, *F* is obtained from the relation $Z=M+F$. The present exploitation rate (*E*) = 0.73 is higher than the optimum level of 0.6.

Along the Karnataka waters the average total stock (*Y/U*) appears to be at 1,453 t and average standing stock (*Y/F*) at about 251 t. From the present study as the estimate of MSY stands between 725 t (Gulland's formula) and 1, 051.4 t (Thompson and Bell model) against the present average catch of 1,061.5 t (Table 5), it is evident that the stock of *L. lactarius* is under stress of over-exploitation. The optimum age of exploitation was calculated as 1.060 years (l_c = 172 mm) against the present t_c of 0.638 years (l_c = 125.4 mm) indicating that the age at first capture also need to be increased. The optimum length of exploitation (l_{opt}) obtained from the empirical equation of Froese and Binohlan (182 mm) was very much close to this value.

The results of the stock assessment studies of *L. lactarius* in Karnataka waters by different methods are furnished in Table 13 which indicate the following:

1. The relative *Y/R* analysis shows that the E_{max} has to be maintained at 0.549 against the present *E* of 0.73 with a fishing effort

reduction of 25% from the present level of 2.221 m h to 1.6661 m h. However, Thompson and Bell model suggests a decrease in fishing effort by 20% (1.777 m h) from the present level to obtain *MSY* and *MSE*.

2. The exploitation rate of *L. lactarius* in Karnataka waters is high indicating levels above optimum exploitation.
3. The optimum length (L_{opt}) of exploitation works out to 172 mm by the methods of Kutty and Qasim (1968) and 182 mm by Froese and Binohlan (2000) respectively. These values indicate for the need to increase the length at first capture from the present 125 mm (increase of 37-45%) in other words the present cod-end mesh size of 20 mm of trawl net has to be increased 28-30 mm.
4. The calculated value of *Y/R* (12.1985 g) and the potential yield (15.7195g) show that by increasing the length at capture from 125 mm to 172 mm, an increase by 29% in yield can be obtained.
5. Further, it is evident from the stock estimates that the present level of annual catch has already exceeded the MSY.

Therefore, to keep the whitefish fishery of Karnataka waters at sustainable level in the years to come, reduction of the fishing effort by at least 20-25% from the current level coupled with increase in cod-end mesh size from 20 mm to 28-29 mm are urgently required.

Table 1. Raised length-frequency data of *L. lactarius* in trawl from Karnataka.

1997-98 Midlength (mm)	Sep-97	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98
55	0	0	0	0	0	43953	0	0	14533	0	0	0
65	0	0	0	35492	0	124532	0	0	145329	0	0	0
75	0	10550	0	256334	0	65929	0	0	58132	0	0	0
85	0	52750	0	165631	4872	0	0	0	276126	0	0	2356
95	7672	200452	0	7887	34106	0	64350	0	421455	0	0	3534
105	30688	506405	52369	23662	170529	51278	364649	68254	697582	0	0	12957
115	88229	654106	340397	74928	185146	117207	332474	409523	523186	0	6993	18847
125	187967	1213261	872812	366755	194891	183136	589874	671162	639450	0	62938	41228
135	184131	844008	881540	567879	287464	197786	933073	682538	871977	0	31469	27093
145	234000	390353	545508	520556	579800	629986	986698	705289	930109	0	10490	16491
155	245508	211002	314212	287883	487227	673939	1040323	523279	726647	0	0	3534
165	111246	126601	100373	134083	277719	637312	740023	443650	668516	0	3497	0
175	11508	84401	87281	63098	116934	293017	536249	273015	261593	0	0	0
185	15344	179352	34912	31549	14617	161159	321749	79629	101731	0	0	0
195	0	10550	56733	23662	19489	80580	64350	56878	87198	0	0	0
205	0	10550	17456	7887	4872	51278	53625	45503	43599	0	0	0
215	0	0	0	0	0	0	32175	22751	0	0	0	0
225	0	0	0	3944	0	0	0	11376	0	0	0	0
235	0	0	0	0	0	0	10725	0	0	0	0	0
245	0	0	0	0	0	0	0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0	0	0
265	0	0	0	0	0	0	0	0	0	0	0	0
1998-99												
Midlength (mm)	**Sep-98**	**Oct-98**	**Nov-98**	**Dec-98**	**Jan-99**	**Feb-99**	**Mar-99**	**Apr-99**	**May-99**	**Jun-99**	**Jul-99**	**Aug-99**
55	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	68592	0	0	0
85	0	17828	0	0	0	0	0	29750	175292	0	0	0
95	0	78951	11171	0	0	0	0	83301	243884	2455	0	0
105	9942	183371	33514	0	13219	12182	74987	202302	342962	9821	395	0
115	121291	269963	159190	5580	132193	73090	232460	220152	563982	10639	5130	1801
125	97431	229214	382614	61381	125583	237542	374935	392703	868837	4092	4341	27009
135	67605	188464	471984	371076	264386	438538	1034820	577154	701167	818	6314	43215
145	45733	137528	310001	421296	363530	389812	997327	535504	815488	5729	6709	25209
155	33802	109513	175947	398976	621306	475083	809859	696155	1082236	5729	3552	7202
165	9942	61124	122883	242734	482504	584718	592397	398653	594468	6547	3552	7202
175	0	50936	53063	83701	198289	475083	337441	208252	312477	3274	395	9003
185	0	17828	25135	64171	92535	164452	157473	142801	160049	4910	395	0
195	0	7640	11171	22320	26439	133998	89984	17850	15243	1637	0	0
205	0	2547	11171	13950	26439	54817	44992	23800	0	818	0	0
215	0	0	5586	0	0	30454	7499	5950	0	0	0	0
225	0	0	0	2790	13219	0	14997	0	0	0	0	0
235	0	0	0	0	0	0	7499	0	0	0	0	0
245	0	0	0	0	0	0	7499	0	0	0	0	0
255	0	0	0	0	6610	0	0	0	7621	0	0	0
265	0	0	0	0	0	0	0	17850	7621	0	0	0

Table 2. Estimates of total mortality coefficient (Z) by different methods for *L. lactarius* from Karnataka waters.

Sl. No	Method	1997-98	1998-99	Pooled
1	Pauly's catch curve method	7.01	5. 58	5.98
2	Beverton and Holt	3.14	3.45	4.44
3	Jones and van Zalinge	8.95	6.83	6.93
	Average	6.37	5.29	5.78

Table 3. Estimates of natural mortality coefficient (M) by different methods for *L. lactarius* of Karnataka waters.

Sl. No	Method	Estimate
1	Pauly's empirical formula	1.64
2	Sekharan's method	1.67
3	Rikhter and Effanov method	1.38
4	Cushing's formula	2.62
	Average of first three methods	1.56

Table 4. Data for estimation of Loo and Z/K for male *L. lactarius* using the method of Wetherall (1986 as modified by D. Pauly 1986 both in Fish byte vol. 4 (1) : 12-14 and 18-20)

L (mean)-L'	L'	N (cumulative)	
71.164	70.000	31266	
61.164	80.000	31266	
51.279	90.000	31201	
41.659	100.000	30947	
32.866	110.000	29961	
25.526	120.000	27350	
20.179	130.000	22296	
16.359	140.000	15845	***
13.235	150.000	9870	
11.746	160.000	4854	
10.872	170.000	2063	
9.429	180.000	840	
8.577	190.000	274	
8.207	200.000	74	
5.000	210.000	24	
*** regression line is fitted from this point			
Y= 42.25 + (-0.188) * X, r = -0.957			
Estimate of L_{oo} = 224.636 mm			
Estimate of Z/K = 4.316			

Table 5. Estimates of exploitation rate (U), exploitation ratio (E), total stock (Y/U) standing stock (Y/F) for 1997-98, 1998-99 and 1997-99 pooled.

Year	*Z*	*M*	*F*	*U*	*E*	Yield *Y* (t)	Total stock *Y/U* (t)	Standing stock *Y/F* (t)
1997-98	6.37	1.56	4.81	0.75	0.748	1166	1555	242
1998-99	5.29	1.56	3.73	0.7	0.698	957	1367	256
Pooled	5.78	1.56	4.22	0.73	0.726	1061	1453	251

Table 6. FiSAT output of results of the length-structured VPA results for *L. lactarius* of Karnataka waters for 1997-98 and 1998-99 (pooled).

Length class (mm)	Catches (N)		Population (N* 10^2)		Fishing Mortality	
50-59	58,486		1,647,777.13		0.0074	
60-69	305,353		1,517,942.75		0.0404	
70-79	459,537		1,390,947.00		0.0636	
80-89	724,605.01		1,267,898.00		0.1054	
90-99	1,159,217.99		1,147,887.63		0.1781	
100-109	2,861,067.98		1,029,563.69		0.4711	
110-119	4,546,506.97		901,344.56		0.822	
120-129	7,829,156.08		765,173.69		1.6256	
130-139	9,674,499.03		607,894.94		2.4685	
140-149	9,603,146.01		446,876.63		3.2479	
150-159	8,932,914.13		302,355.25		4.4205	
160-169	6,349,744.08		179,885.72		5.1447	
170-179	3,459,010.00		96,147.57		4.8973	
180-189	1,769,790.99		49,974.43		4.4338	
190-199	725,722.00		25,730.60		3.0701	
200-209	413,304.00		14,596.83		2.8061	
210-219	104,415.00		8,048.33		1.0457	
220-229	46,326.00		5,366.64		0.6025	
230-239	18,224.00		3,642.33		0.299	
240-249	7,499.00		2,460.66		0.1543	
250-259	14,231.00		1,588.78		0.3922	
260-269	25,471.00	(*Ct*)	851.46	(*Nt*)	0.7	(*Ft*)
Total catch : 59,088,236			Natural mort : 1.64			
Mean *E*: 0.359 (from L_{min}			L_{oo} : 294 mm			
Mean *F*: 0.917 to L_{max})			*K* : 0.84			

Table 7. FiSAT output of results of the length-structured VPA II results for *L. lactarius* of Karnataka waters for 1997-98 and 1998-99 (pooled)

ML (mm)	DELTA T (years)	MEAN N	CATCH (tonnes)	STEADY-STATE BIOMASS
55	0.05	7881070	0.12	15.89
65	0.052	7557449	1.01	24.91
75	0.054	7222785	2.31	36.29
85	0.057	6875875	5.27	49.98
95	0.06	6508033	11.7	65.68
105	0.063	6073686	38.8	82.37
115	0.067	5530843	80.66	98.13
125	0.07	4816293	177.7	109.31
135	0.075	3919106	275.63	111.66
145	0.08	2956711	337.91	104.04
155	0.086	2020779	382.8	86.6
165	0.092	1234225	327.32	63.62
175	0.1	706307	212.17	43.32
185	0.109	399157	127.93	28.85
195	0.12	236379	61.29	19.96
205	0.134	147287	40.47	14.42
215	0.151	99850	11.77	11.25
225	0.173	76893	5.97	9.91
235	0.202	60941	2.67	8.93
245	0.244	48591	1.24	8.06
255	0.307	36282	2.66	6.77
265	0.415	36387	5.33	7.61
Total		64444928	2112.72	1007.59

Table 8. FiSAT output of Thompson and Bell Data : Value array for *L. lactarius* during 1997/98-1998/99

Length class	Value (Rs/Kg)
50 - 59	40
60 - 69	40
70 - 79	40
80 - 89	50
90 - 99	50
100 - 109	50
110 - 119	60
120 - 129	60
130 - 139	60
140 - 149	60
150 - 159	70
160 - 169	70
170 - 179	70
180 - 189	80
190 - 199	80
200 - 209	80
210 - 219	80
220 - 229	100
230 - 239	100
240 - 249	100
250 - 259	100
260 - 269	100

Table 9. FiSAT output of Thompson and Bell Yield Stock Prediction for *L. lactarius* from Karnataka trawl fleet

Length group (mm)	Yield (10^9)	Biomass (10^9)	Value (10^11)
50-59	0.0001148	0.016396	0.000046
60-69	0.0009981	0.025591	0.000399
70-79	0.002305	0.037177	0.000922
80-89	0.005262	0.051088	0.002631
90-99	0.011732	0.06704	0.005866
100-109	0.0389797	0.084008	0.01949
110-119	0.0809755	0.100093	0.048585
120-129	0.1784666	0.111751	0.10708
130-139	0.2771232	0.114703	0.166274
140-149	0.3399857	0.107693	0.203991
150-159	0.3859845	0.090841	0.270189
160-169	0.3291826	0.067901	0.230428
170-179	0.2107516	0.047116	0.147526
180-189	0.1252946	0.032342	0.100236
190-199	0.058976	0.023182	0.047181
200-209	0.0387019	0.017648	0.030962
210-219	0.0111106	0.014281	0.008888
220-229	0.0056256	0.012785	0.005626
230-239	0.002513	0.011528	0.002513
240-249	0.0011661	0.010229	0.001166
250-259	0.0025016	0.008339	0.002502
260-269	0.0049942	0.007145	0.00005
Sum	2.112745	1.058878	1.40255

Table 10. Results of the Thompson and Bell Yield prediction for *L . lactarius* in Karnataka waters against variation in F

F	Yield (tonnes)	Biomass (tonnes)	Value (million Rs.)
0	0	2266.6	0
0.1	378.7	1765.6	27.46
0.2	629.5	1406.8	45.34
0.3	794.5	1147.3	56.89
0.4	901.8	957.5	64.15
0.5	901.8	957.5	64.15
0.6	1012.6	712.3	70.99
0.7	1012.6	712.3	70.99
0.8	1051.4	571.3	**72.55**
0.9	**1051.4**	571	72.55
1	1050.5	523.4	72.37
1.5	1032.2	390.5	68.56
2	992.1	350.2	64.33
2.5	956.5	330.4	60.87
3	926.5	269.1	58.04
3.5	901	250	55.85
4	878.8	234.8	53.68

Table 11. FiSAT output of relative yield/recruit from selection data for *L. lacatrius* from Karnataka trawl (Parameters : $L_{\infty} = 294$, $M/K = 1.86$)

E	*Y'/R*	*B'/R*
0.05	0.0051686	0.005186
0.1	0.0094956	0.009564
0.15	0.012991	0.01314
0.2	0.0156705	0.015925
0.25	0.0175571	0.017938
0.3	0.0186816	0.019205
0.35	0.0190842	0.019758
0.4	0.018816	0.019641
0.45	0.0179405	0.018911
0.5	0.0165354	0.017635
0.55	0.0146936	0.015896
0.6	0.0125248	0.013794
0.65	0.0101565	0.011445
0.7	0.0077325	0.008984
0.75	0.00541	0.006561
0.8	0.0033529	0.004335
0.85	0.0017163	0.002468
0.9	0.0006191	0.001099
0.95	0.0000948	0.000306
1	0.0000002	0
Optima :		
E_{max} = .549		
$E_{-.1}$ = .521		
E-.5 = .322		

Table 12. Comparison of some population parameters of *L. lactarius* from different parts of India.

Sl. No	Study area	L_c (mm)	*K* (yr^{-1})	*M*	*M/K*	Reference
1	Andhra-Orissa coast	269.5	0.629	0.703	1.11	Reuben *et al.* (1991)
2	Waltair, Andhra Pradesh	320	0.854	1.55	1.81	Pauly (1978) based on Rao (1966)
3	Karnataka	294	0.84	1.56	1.86	Present study

Table 13. Current scenario and the recommended strategies for sustainable fishery of *L. lactarius* along Karnataka coast.

Present				Recommended				Model
Effort (m. h)	Yield (t)	L_c (mm)	E	Effort (m.h)	MSY (t)	L_c/L_{opt} (mm)	E	
2.221	1061.5			1.777	1051.4	172		Thompson and Bell model
			0.73	1.666			0.549	Relative Y/R model
					725			Gulland's formula
		125.4				182		Empirical formula
						172		Kutty and Qasim

(m.h = Million fishing hours)

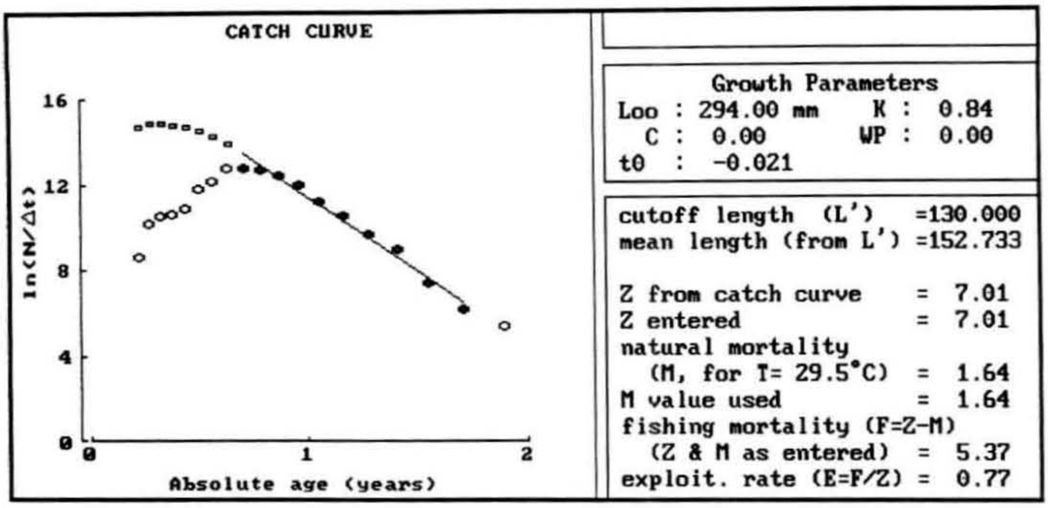


Fig.1. Estimation of *Z* for *L. lactarius* during 1997-98.

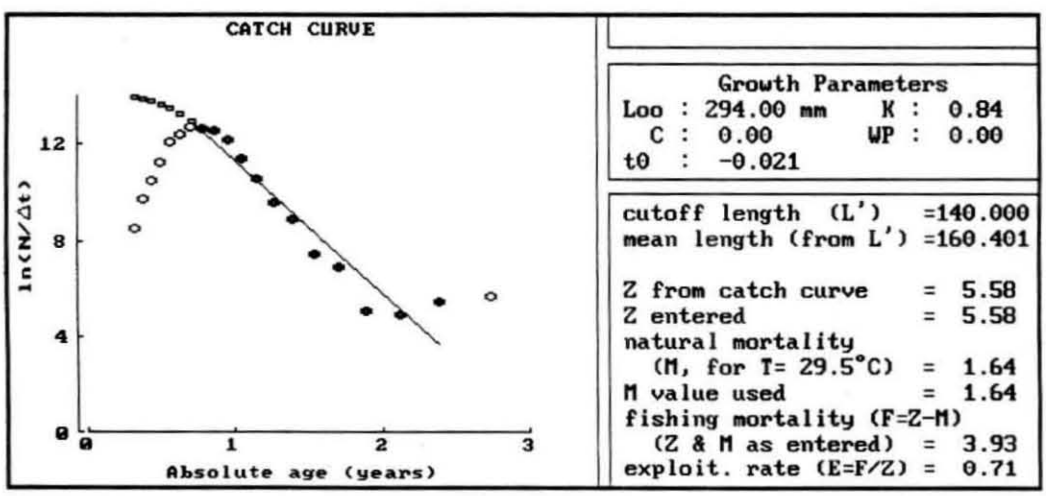


Fig.2. Estimation of *Z* for *L. lactarius* during 1998-99.

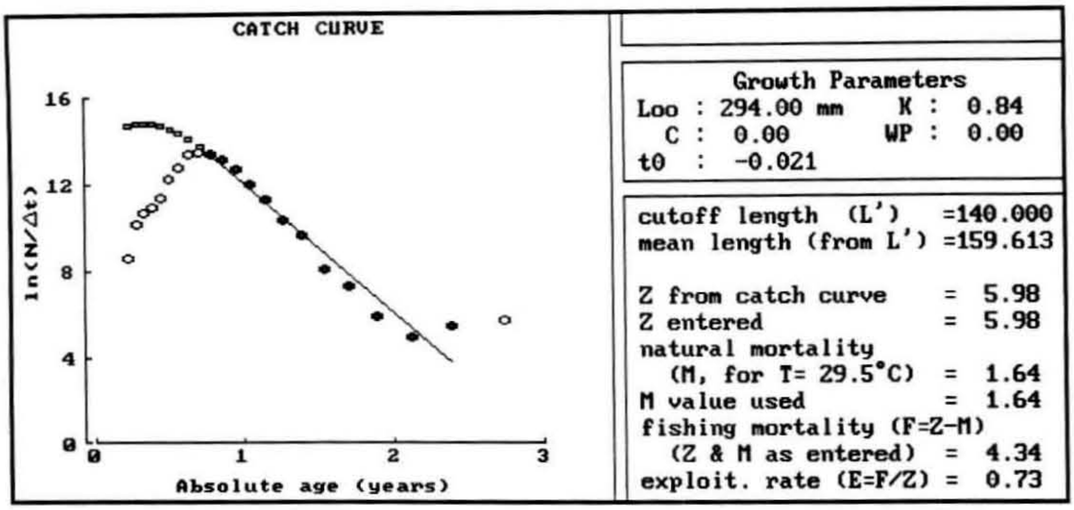


Fig.3. Estimation of *Z* for *L. lactarius* during 1997-99 (pooled data).

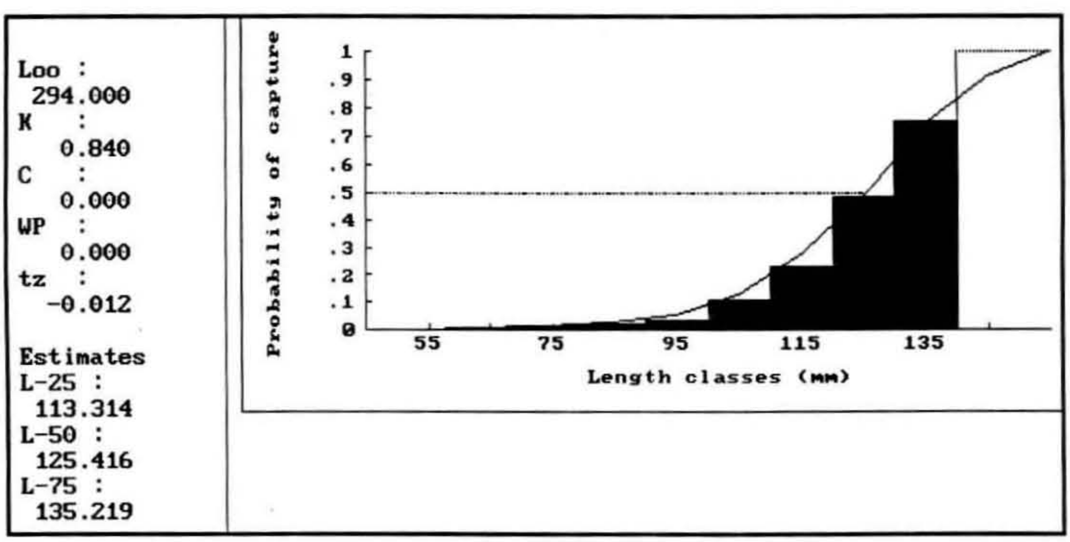


Fig.4. Analysis of probability of capture for *L. lactarius* with LF data pooled for 1997-99.

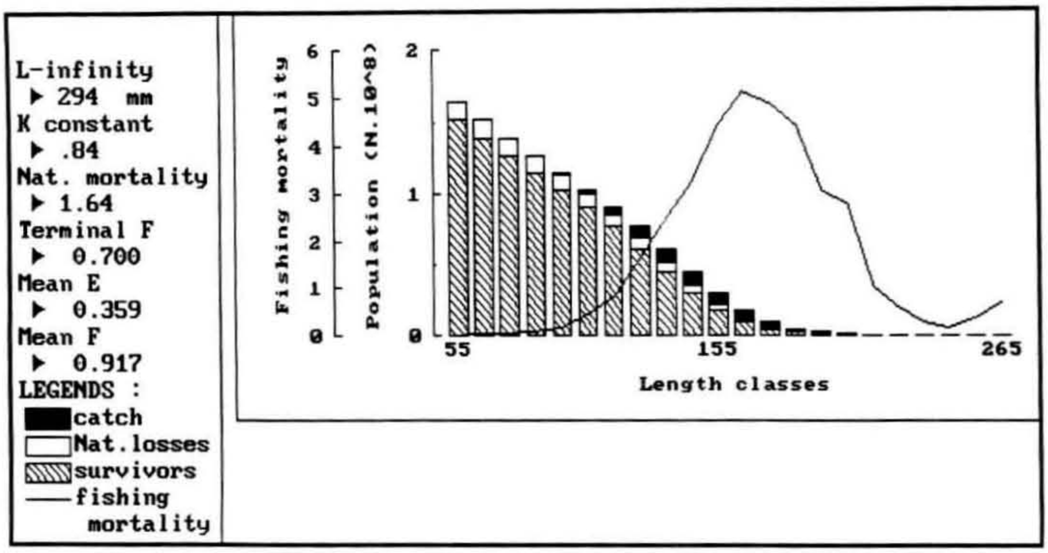


Fig.5. Results of length-structured virtual population analysis for *L. lactarius* with LF data pooled for 1997-99.

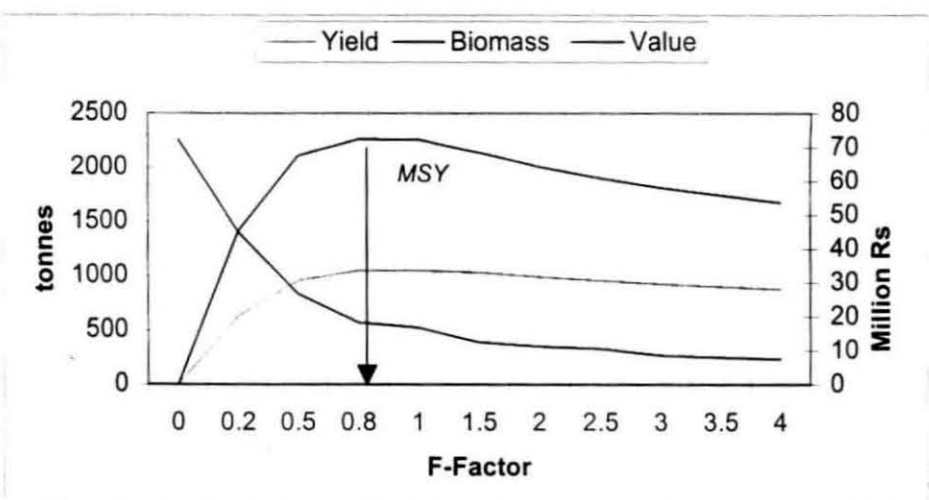


Fig.6. Results of Thompson and Bell analysis for *L. lactarius* indicating MSY and MSE with LF data pooled for 1997-99.

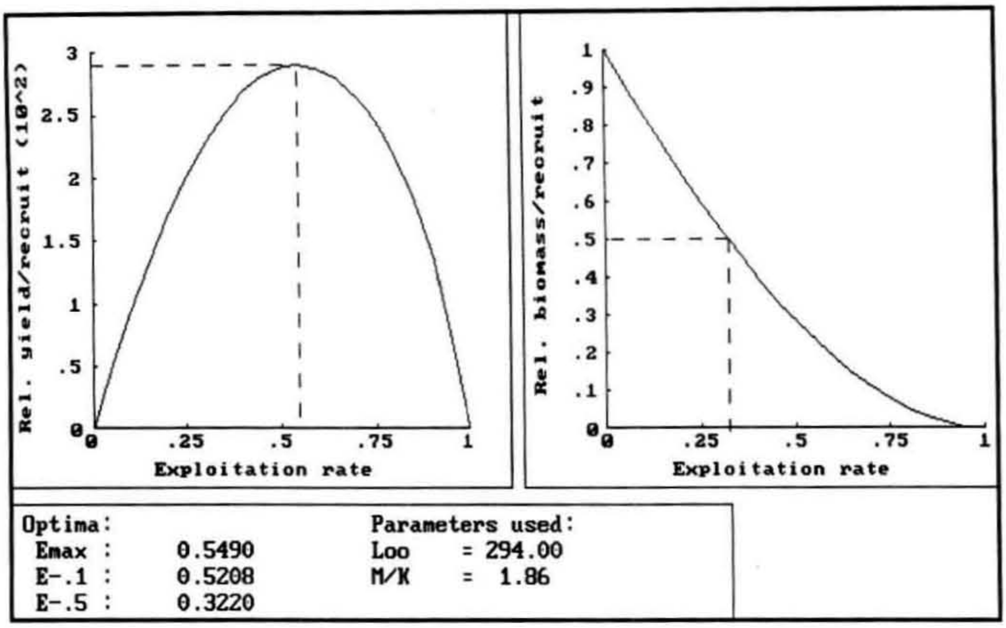


Fig.7. Results of relative yield-per-recruit and biomass-per-recruit analysis for *L. lactarius* indicating $E_{0.1}$ and $E_{0.5}$ (LF data pooled for 1997-99).

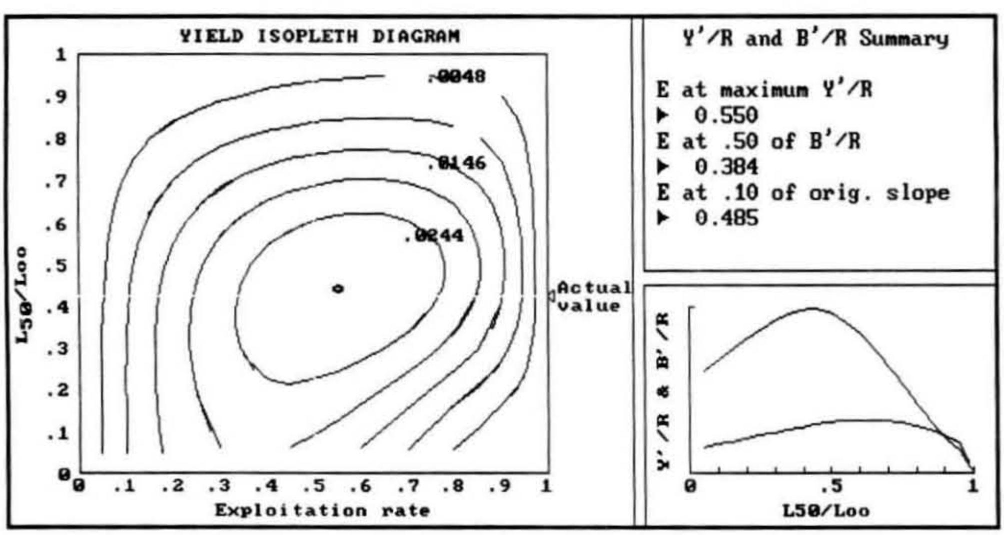


Fig.8. Yield isopleth diagram indicating isolines of relative yield-per-recruit for *L. lactarius.*

Summary

SUMMARY

The fish belonging to the Family Lactariidae commonly called whitefish/false trevally/big-jawed jumper is represented by a single species *Lactarius lactarius* (Bloch and Schneider, 1801) and is widely distributed in Indian waters. Though, *L. lactarius* has high demand in coastal markets, there is no concerted study on the stocks and population structure from any of the Indian coasts. Hence, the present investigation was undertaken to study its biology, stock and population characteristics from Karnataka waters. The findings would help to evolve suitable management measures for the rational exploitation of the white fish resources along the Karnataka coast.

Data for the present study were collected from three major fish landing centres of Karnataka state viz., Mangalore, Malpe and Karwar during September 1997-August 1999.

Besides the key characters of the family Lactariidae and the genus *Lactarius*, the species has been described in detail for easy identification based on the morphological, morphmetric and meristic characters.

The decadal trends of whitefish from different regions of the Indian coast in general and from Karnataka coast in particular for the period 1960-1999 are described. The decadal average production of whitefish from

Karnataka increased from 323 t in 1960s to 668 t in 1970s and reached the highest of 1,231 t in 1980s. However, the production fell marginally to 1,048 t in the 1990s.

The annual landing of whitefish in Karnataka fluctuated between 64 t (in 1964) and 2,930 t (in 1988) and the production stood at 988 t in 1998-99. The investigation revealed a shift from seine net to trawl net as the dominant gear and presently, only about 16% of whitefish is caught by seines and gill nets. During the study period, about 60% of whitefish landings were obtained from 5 to 30 m depth zone and the rest came from above 30 m depth zone, indicating that the preferable depth for the fish is between 5 and 30 m. The fish was abundant in the catches during pre-monsoon period (February-May). As over 73% of the landings were from Mangalore (44.7%) and Malpe (29%), the areas off these two centres appears to be the most productive belt for whitefish along Karnataka coast. The production decreased gradually from south to north, i.e., Mangalore to Karwar. Trawl net was the most efficient gear for harvesting *L. lactarius* in all the centres from Karnataka.

The food and feeding habits *L. lactarius* fish were studied by the method of index of pre-ponderance. The general diet of the fish in relation to seasons, size, and sex and maturity stages was analysed and it consisted of two major groups *viz.*, teleosts and crustaceans. These two groups together formed 95.8 % of the food in 1997-98 and 94.9 % in 1998-99 of the bulk of the food. Other minor food items were represented by molluscs, detritus and other miscellaneous food items. Occurrence of young ones of *L. lactarius* in the stomach of adults points to the cannibalistic tendency of the species. Smaller sized fish preferred *Acetes* as the food item; whereas, larger ones preferred fish especially anchovies as the diet. There was no relationship between the feeding intensity/index and maturity and size of the fish. The occurrence of empty stomachs was high in all the months.

L. lactarius is a true carnivore feeding at all the depths and organisms found in the stomach ranged from pelagic fish like anchovies to mid-water organisms like *Acetes*, other mid-water fishes and benthic organisms such as gastropods, echinoderms and crabs.

The length-weight relationship in the juveniles, males and females of *L. lactarius* were estimated. The values of exponent for males and females of *L. lactarius* in the present study were close to 3 indicating that the growth followed an isometric pattern. The value of *b* in juveniles was 3.07, and for males and females were 3.06 and 3.04 respectively.

The common length-weight relationship estimated for the pooled fish is:

$$\text{Log } W = -4.84509 + 2.9570 \text{ Log } L.$$

The description of gonads and maturity stages of males and females based on gross examination and ova diameter studies has been provided. Seven stages of maturity were recognised in females and males. Size at first maturity, sex ratio, gonado-somatic index (GSI) and relative condition factor (K_n) also were studied in detail Higher values of GSI coincided with the spawning season from October-May with peak spawning during November-March.

The progression of ova from immature to ripe stages of ovaries indicates that individual fish spawns more than once a year. As the size range of ripe ova was not very large, it may be inferred that the fish may spawn for a shorter duration. Up to stage III, there was only a single mode of maturing ova and after which a group of ova separated from the maturing group and grew fast for spawning. Occurrence of mature gonads almost throughout the year shows a prolonged spawning season in the population.

The average size at first maturity (50%) of males was 131 mm and females, 133 mm. The age at first maturity of the species worked out to less than one year as evidenced from age and growth studies. The monthly rise and fall in K_n could not be related to spawning period of *L. lactarius*. The development of gonads to advanced maturity stages in higher number of individuals was responsible for the higher values of gonado-somatic indices during the spawning months.

Fecundity estimate varied from 7,042 (154 mm TL) to 53,275 (188 mm TL) eggs. There were linear relationship between the fecundity and the length of the fish/weight of the fish/weight of the ovary. The overall sex ratio showed dominance of males in the population. Males were dominant in the fishery up to 155 mm and thereafter females were dominant.

The growth of *L. lactarius* was studied by ELEFAN I programme, modal progression analysis using Gulland and Holt model after separating the modes using Bhattacharya method. The growth parameters estimated for males were: L_∞ = 240 mm, K = 1.01yr^{-1} and t_0 = -0.0151; for females: L_∞ = 285 mm, K = 0.91 yr^{-1} and t_0 = -0.0183 and for all fish (juveniles, males and females pooled) were: L_∞ = 294 mm, K = 0.84 yr^{-1} and t_0 = -0.0215. The recruitment pattern showed two recruitment pulses every year, the major one during March and the minor one during June-August.

The von Bertalanffy growth formula fitted to *L. lactarius* indicated the fish to attain a length of 164 mm at the end of 1 year, 240 mm at the end of 2 year and 271 mm at the end of 3 year of its life. The estimated life span appears to be 3.57 years.

The total mortality coefficient (Z) estimated for the pooled data for 1997-98 and 1998-99 were 4.44 by Beverton and Holt model, 5.98 by length-converted catch curve method and 6.93 by cumulative plot method of Jones and van Zalinge. Natural mortality coefficient (M) estimated were by

1.38 by Rikhter and Efanov method, 1.64 by Pauly's empirical equation, 1.67 by Sekharan's method and 2.62 by Cushing's method. The average values obtained by different methods were: Z = 5.78 and M = 1.56. The fishing mortality (F) was calculated as 4.22. The exploitation rate (U) and exploitation ratio (E) of whitefish by trawlers during 1997-99 were 0.73 and 0.726 respectively. The estimated annual total stock of *L. lactarius* along Karnataka coast during the study period was 1,453 tonnes (t) and standing stock as 251 t. The length at first capture was calculated by probability of capture (FiSAT) as 125.4 mm.

The Beverton and Holt relative yield-per-recruit analysis and Thompson and Bell analysis were carried out to predict the stock and the catch for various assumptions on the future fishing pattern. The MSY estimates were 725 t by Gulland's formula and 1051.4 t by Thompson and Bell prediction model against the annual average catch of 1,061.5 t during 1997-1999. The optimum exploitation rate (E_{max}) for whitefish along Karnataka coast was estimated as 0.549 by Beverton and Holt's relative yield-per-recruit analysis and the exploitation rate (0.73) for the study period had exceeded this level. The $E_{-0.1}$ was estimated as 0.5215 and $E_{-0.5}$ as 0.322. The Thompson and Bell analysis showed that the maximum sustainable yield (MSY) and maximum sustainable economic yield (MSE) could have been obtained by decreasing the fishing effort to 80% (1.7772 million fishing hours.) of the annual average fishing effort of 2.2214 million fishing hours during 1997-99. The optimum length of exploitation calculated by the empirical equation of Froese and Binohlan was 182 mm, which agrees with the optimum length of exploitation derived from the optimum age (1.060 yr^{-1}=172 mm) calculated by the method of Kutty and Qasim. By increasing the length at first capture by 37% from the calculated l_c of 125.4 mm, the potential yield/recruit of 15.719 g can be achieved from the calculated Y/R of 12.1985 g (29%).

Based on the present study, for sustaining the fishery of *L. lactarius* along the Karnataka coast, the following viable management options are suggested:

(1) Reduction in the level of fishing effort by 20-25% of the 1997-1999 effort level.

(2) Increase of trawl cod-end mesh-size from 20 mm to 27-30 mm.

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