

**SYSTEMATICS AND BIONOMICS OF
TETRAODONTIDS ALONG SOUTH WEST
COAST OF INDIA AND INLAND WATERS OF
KERALA**

**THESIS SUBMITTED
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
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**DOCTOR OF PHILOSOPHY
IN
ZOOLOGY
(FACULTY OF SCIENCE)**

**BY
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MARCH, 2004

Dedicated to the loving memory of late Dr. A.G.Govindankutty
Former Prof. & Head, Department of Zoology,
Christ College, Irinjalakuda.

DECLARATION

I hereby declare that the thesis entitled "Systematics and bionomics of tetraodontids along south west coast of India and inland waters of Kerala" is the result of investigation carried out by me in the Research and Postgraduate Department of Zoology, Christ college, Irinjalakuda, University of Calicut, under the supervision and guidance of Dr. N.D. Inasu, Professor and Head, Research and Postgraduate Department of Zoology, Christ college Irinjalakuda and has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

Irinjalakuda,

March, 2004.



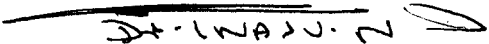
C.O. JOSHI.

CERTIFICATE

This is to certify that the thesis entitled "Systematics and bionomics of Tetraodontids along south west coast of India and inland waters of Kerala" is the bonafide record of the work carried out by Mr. Joshi, C.O. under my guidance and supervision in the Research Dept. of Zoology, Christ College, Irinjalakuda, University of Calicut and that no part thereof has been presented for any other degree.

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GENERAL INTRODUCTION

CHAPTER - I

GENERAL INTRODUCTION

Fishes constitute almost half the total number of vertebrates recognized world-over. The number of valid species is placed at 24,618 spreading under 4258 genera (Nelson, 1994). Wayt Gibbs (2001) has put the number of named fish species at 26,959 and expects an estimated number of about 35,000. In our Indian region alone there are about 2500 species of fish of which some 930 are freshwater inhabitants (Jayaram, 1999).

Fishes live in almost every conceivable aquatic habitat and occupy everything from Antarctic waters below freezing to hot springs of more than 100^o F and from soft, freshwater to water salty enough to float an egg. They are present in sunlit, torrential mountain streams to waters so quiet, deep and dark. Their vertical range goes above and beneath the sea level by three miles and seven miles respectively (Lagler *et al.*, 1962). Fishes also occupy estuaries where they face a difficult physical challenge surviving in a dynamic regime of tidal, daily and seasonal changes in depth, salinity, oxygen, temperature and turbidity (Blaber, 1997). Among the fishes, a remarkably wide range of biological adaptations showing impressive specializations of morphology, physiology and

behaviour can be seen . A general account on diversity in size, shape and habitats of fishes along with some aspects on physiological and anatomical modifications related to respiration and production of electricity is provided in the introductory chapter by Jayaram (2002).

Puffers belonging to the family Tetraodontidae (Order-Tetraodontiformes) are generally poisonous and hence hold relatively low value as food fish. The classification of puffers is given by a number of workers; to mention a few, Day (1994), Weber and de Beaufort (1962), Munro (1982), Talwar & Jhingran (1991) and Jayaram (1999) and they remarked that tetraodontids are all carnivorous. They are characterized by the absence of pelvic fins and presence of four heavy teeth. Tetraodontids are circumglobal in tropical and temperate waters, most of them are marine, but several enter estuaries and some live only in freshwater. They have the ability to inflate themselves with either air or water as a deterrent to predators. The presence of the neurotoxin, tetraodotoxin warrants careful preparation to render pufferfish flesh safe to eat ,and it is considered a delicacy in some countries like Japan.

Majority of fishes form human food and hence most of the research work in fishery studies has been oriented towards

economically important fishes, their taxonomy and biology, exploitation, culture, and topics related to craft and gears, catch/effort, nutritional value, processing etc. Being inedible, thanks to the presence of tetrodotoxin, puffers have been sidelined by fishery biologists and little is known about their biology like food & feeding, reproduction, age and growth etc. A systematic study is needed to reveal the food habits, spawning season, growth rate & sexual dimorphism, if any, in these fishes.

Literature available on tetraodontids is scanty except for their use in karyotyping, genome studies, cytological and immunological experiments, and for characterization of tetrodotoxin and its effects on mammals. The utility of the freshwater puffer fish, in the mosquito larva and molluscan control was reported from Kerala. Inasu (1996) worked out the predatory behaviour of *Tetraodon travancoricus* Hora & Nair on the culicine larva and based on the overall observation opined that *T.travancoricus* could be considered as one of the best candidates for the biocontrol of larval stages of *Culex quiquefasciatus*. Sheeba (1998) too worked on the same line studying the larvivorous propensity of *T.travancoricus* against the immature stages of the malarial vector. The advantage in using *T.travancoricus* as a predator in the biocontrol of mosquito larvae was also discussed in the same work. A

detailed study on the malacophagous efficacy of the same fish was carried out by Dalie *et al.* (2002) and hoped that the native predator might become a promising fish in controlling animal schistosomiasis. Apart from the larvivorous and molluscivorous aspects of the freshwater puffer fish, no significant work has been done on this line and biology of tetraodontids.

Papers on Tetraodontids were mainly centered around the distribution of different species with reference to the ichthyofauna studies in India. Majority of them are on the freshwater species *Tetraodon travancoricus* Hora and Nair, and a few on *Tetraodon cutcutia*, another freshwater puffer, found in North India. Natarajan *et al.* (1979) reported the regular catch of *Lagocephalus inermis* from the Vellar estuary, Porto Novo.

Ravish Chandra *et al.* (1990) observed the freshwater puffer *Tetraodon cutcutia* in the Dighali beel (flood plain lake), Kamrup district, Assam, which is connected with the river Sessa, a tributary of Brahmaputra. Pandey (1999) also recorded the presence of *T. cutcutia* from Faizabad district, Uttar Pradesh. Interestingly enough, he reported *Tetraodon fluviatilis* from the said region which is some 113m above mean sea level (MSL). *T. cutcutia* was also reported from the middle stretch of Yamuna (Delhi-Etawah) by Mishra and Usha Moza (2001).

During the ichthyological survey (1984–1987) in river Chaliyar, by Raghunathan (1995), *Tetraodon hispidus* was caught from the estuarine region, in the premonsoon and postmonsoon seasons. The collection site from where the fish was caught, designated as station 3, represented Kodampuzha near the Feroke road bridge, Calicut, Kerala. Finfish by-catch collected from the landings of small trawlers operated within a depth range of 50m, based at Visakhapatnam, Andhra Pradesh, during April 1989 to March 1990 provided eleven species of Tetraodontids – *Arothron hispidus*, *A. immaculatus*, *A. stellatus*, *Canthigaster solandri*, *Chelonodon fluviatilis*, *C. patoca*, *Lagocephalus lunaris*, *L. guentheri*, *L. inermis*, *L. scleratus* and *Torquigener hypselogenion* (Sujatha, 1995). Further, the author said that, of the above-mentioned tetraodontids *Lagocephalus guentheri* (Ribeiro) enjoyed the status of a new record from Indian waters. *Chelonodon patoca* was also reported by Bijukumar and Sushama (2000), while conducting a study on the ichthyofauna of Ponnani estuary, Kerala, along the south west coast.

The first description of *Tetraodon travancoricus*, in a collection from Pamba river (central Travancore) was made by Hora and Nair (1941). The sexual dimorphism of

T. travancoricus was reported for the first time by Inasu (1993). This species has been considered 'very rare' by Easa and Shaji (1997). According to the authors, *T. travancoricus* is endemic to Kerala and is seen in West-flowing rivers. Shaji and Easa (1998) reported the freshwater puffer 'vulnerable' while studying the status and distribution of freshwater fishes of Western Ghats, Kerala. Ajithkumar *et al.* (1999) described *T. travancoricus* 'rare' in their report on a study of fish fauna of Chalakudy river system, Biju *et al.* (1999) observed the occurrence of it in the Chalakudy, Periyar and Kechery rivers. Raju Thomas *et al.* (1999) could report *T. travancoricus* from Puzhakkal river, Thrissur district, Kerala. Daniels (2001) treated it as endemic to Western Ghats. Raju Thomas *et al.* (2002) gave the status 'common but vulnerable' to *T. travancoricus* after conducting a study on freshwater fishes of southern Kerala. Biju *et al.* (2002) treated this freshwater pufferfish endemic to Kerala while reviewing the freshwater fish fauna of Kerala. Contrary to the observations of the earlier workers who attributed endemicity to Kerala for *T. travancoricus*, Rema Devi *et al.* (2000) reported it from South Kanara, Karnataka, during a survey by ZSI-SRS from Dakshin Kannada at 50m above MSL. They opined that the report of a new species, *Carino-*

tetraodon imitator by Britz and Kottelat (1999) might be due to observation of slight variation in the colour distribution on the body of *Tetraodon travancoricus*, as no two specimen collected during the ZSI-SRS survey gave individuals with exactly identical colour pattern.

Of late, puffer fishes have been appearing in research publications related to projects on cytogenetics, especially genome studies. *Tetraodon nigroviridis* is unique among vertebrates by the possession of one of the smallest known vertebrate genomes. *Tetraodon fluviatilis*, *Tetraodon miurus* and *Fugu rubripes* are the other tetraodontids which have been used extensively in this field. The round-spotted puffer fish has been proposed as a model for genome studies because of the compactness of genome size with 380 mb. Yao *et al.* (1998) utilized this fish for cloning and characterizing the *snf* 5 and set genes. The same puffer fish was used for the isolation and identification of protein *kinase* genes, and of the 41 PK genes, three were new (Chou *et al.*, 1998). The Japanese puffer fish *Fugu rubripes* was subjected for a study involving analysis of puffer fish homologues of human APP β amyloid precursor protein gene. It was found that human APP gene is large, spanning approximately 300 kb whereas the *Fugu* APP gene is highly compacted with less than 10 kb

(Villard *et al.*, 1998). Tumour suppressor gene P53, whose mutation with genotoxic agents leads to tumourigenesis, is established in the puffer fish *Tetraodon miurus*. Bhaskaran *et al.* (1999) found that the full length P53 cDNA of *T. miurus* has 1834 bp encoding 367 amino acids. Karyotype study conducted by Grutzner *et al.* (1999) established the 2n chromosome number of the green spotted puffer fish as 42, of which ten pairs were metacentric or sub-metacentric and twenty-two chromosomes, sub-telocentric.

The presence of small introns and lack of large clusters of highly repetitive sequences attracted Mandrioli *et al.* (2000) to use *Tetraodon fluviatilis* as the animal for cytogenetic analysis. Karyotype studies revealed that this fish has 2n=42 with two metacentric, four sub-metacentric, two sub-telocentric and 34 acrocentric chromosomes. Compactness of puffer genome is exploited by Mandrioli *et al.* (2001) for deriving cytogenetic information and proposed *T. fluviatilis* as a model animal for the study of vertebrate genome. The same fish was subjected for cytochemical and ultrstructural study of clustered supramedullary neurons (Cuoghi, 2001). *T. fluviatilis* was used by Cuoghi *et al.* (2002) to bring forth the evidence that supramedullary neurons represent a distinct nitrenergic neuronal system in the vertebrate

central nervous system by demonstrating the presence of nitric-oxide converting enzyme, neuronal NOsynthase (nNOS).

As intergenic and intronic sequences are reduced in *Tetraodon nigroviridis*, as compared to other vertebrates, Crollius *et al.* (2000) used the aforesaid freshwater puffer fish for the structural analysis of its genome, which is an important pre-requisite to sequencing the *Tetraodon* genome. Neuroglobin, a recently discovered respiratory porphyrin-containing protein, expressed in the brain of mouse and man was reported by Awenius *et al.* (2001) in *Tetraodon nigroviridis*. The above mentioned fish, according to Dasilva (2002), represented an interesting model for studying genome architecture and evolution. The very same fish figured in the exploration of Grutzner *et al.* (2002) who mapped genes which are more or less evenly spaced on the human chromosomes 9 and X. Parrington and Coward (2002) proposed that with the completion of the human genome, data gathering would give way for interpretation. They felt that comparative genomics, using model organisms was likely to provide a powerful tool for such interpretation and concluded that perhaps the best known fish genome at present is that of *Takifugu rubripes*.

Tetradotoxin (TTX) is a potent neurotoxin named after the family of fish to which it is most commonly associated. Zaki *et al.* (2001) extracted crude TTX from the pufferfish *Lagocephalus scleratus* and found that the gonad TTX was more potent than the skin extract. The LD100 and LD50 of crude gonad TTX were found to be 8.33 and 6.26 mg/kg in rats subjected for the study. The first report on the occurrence of palytoxin (PTX) or PTX-like substance, as evidenced by the delayed haemolytic activity was given by Taniyama *et al.* (2001) who subjected the freshwater puffer in Bangladesh in order to elucidate its toxin composition. Presence of TTX in the skin of the puffer, *Tetraodon steindachneri* was described by Tanu *et al.* (2002) based on the immuno-histological studies. TTX was recognized in the undifferentiated basal cells and succiform cells in the skin. Interestingly enough, no glands were holding TTX in the skin. Recently, Shin Jung *et al.* (2002) conducted a detailed study in Taiwan with figure-eight puffer, *Tetraodon ocellatus* and *T. nigroviridis*, to estimate the amount of toxin in these species. It was found that *T. ocellatus* contained moderate amount of toxin in skin and viscera. *T. nigroviridis* had weak amounts of the toxin in the skin. Analyses by electrophoresis, thin layer chromatography and high performance liquid

chromatography showed that the toxin from both species was composed of tetrodotoxin and anhydro-tetraodotoxin.

Literature available on the systematics and biology of tetraodontids from Indian waters showed that except for a few studies related to larval control and malacophagous behaviour, the rest were all primarily meant for throwing light on the ichthyofauna of some economically important areas along south west coast, north east coast and major freshwater systems in Kerala and outside, as well. No attempt has been seriously made by any fishery biologist towards a comprehensive study on the biology of puffer fishes. It is not legitimate to overlook an entire family of fishes, merely because they happened to be inedible. The present work aims at a detailed investigation on the systematics of puffer fishes along the south west coast of India and inland waters of Kerala. Except for the contribution of Day, (1889 & 1994), Munro (1955), Weber and de Beaufort (1962), Talwar and Jhingran (1991) and Jayaram (1999), no serious endeavour has ever been made for the classification of puffer fishes. Preparation of a key, using the different species of puffer fishes collected from the aforesaid areas, for their easy identification is also attempted. Biology of puffer fishes attracted no fishery biologist because of their insignificance

as food fish. This may not be justified as each organism has its own significance in the ecosystem.

The second part of the present work is exclusively on the various biological aspects of the common freshwater puffer, *Tetraodon travancoricus* Hora and Nair and the marine form, *Lagocephalus inermis* (Temm. and Schleg.). Food and feeding of scores of freshwater fishes have been worked out by a number of workers, without a mention on the puffers. The age and growth studies were also undertaken by many a researcher, once again tetraodontids received neglect. Same is the fact with the length-weight relationship and relative condition factor. Yet another important aspect of biology of fishes is their reproduction. Fecundity, breeding period, maturity stages and sex-ratio were studied by researchers world over on thousands of fishes regardless of the habitat in which they live. But little investigation has been made either on the freshwater puffer or marine tetraodontids. The above-mentioned aspects, point towards the total neglect of puffers by fishery biologists.

It is imperative, at this stage, that deserving consideration be given to puffer fishes of our waters regardless of their unsuitability as food fish. The objectives of

the present study are there fore, to attempt a systematic grouping of puffers collected from south west coast of India and inland waters of Kerala and to learn about some very important biological aspects of two tetraodontids viz, *T.travancoricus* and *L.inermis*. The major collection centres of the freshwater puffer fish and *L.inermis* are shown in figure 1. In the light of the ever-increasing importance given to tetraodontids in genome studies, molecular biology and tetrodotoxin assay, every information about these fishes would be invaluable. The Malabar pufferfish, *Tetraodon travancoricus* presents itself as an efficient candidate in the advanced studies mentioned, for it is a freshwater inhabitant and is hardy in nature. Furthermore, the results of biological studies of these fishes would definitely delineate the position of puffers in their respective ecosystems.

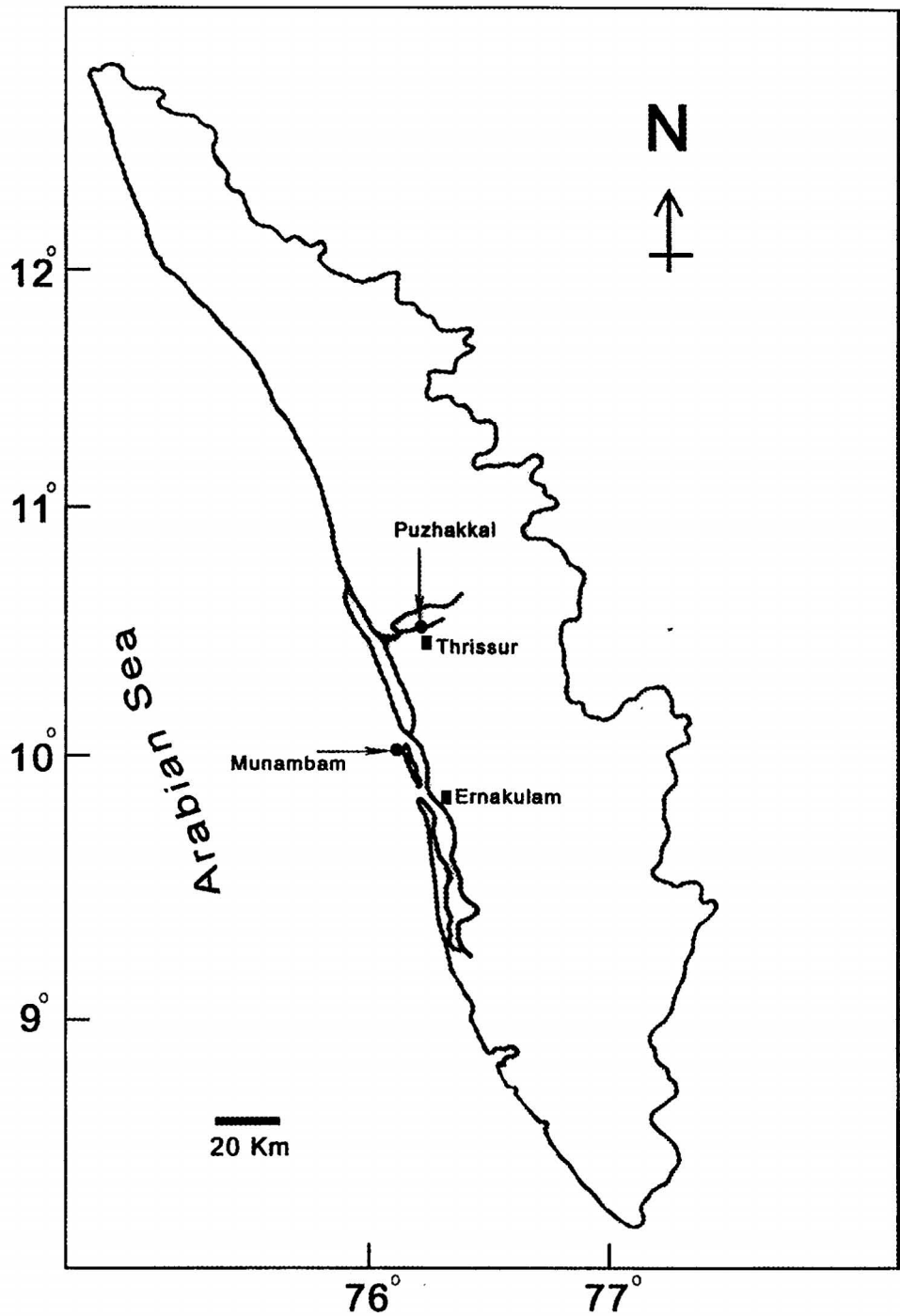


Figure 1. Map of Kerala showing the major collection sites of *Tetraodon travancoricus* (Puzhakkal) and *Lagocephalus inermis* (Munambam)

SYSTEMATICS

CHAPTER – II

TAXONOMY

INTRODUCTION

A review of literature showed that after the pioneer work of Day in the second half of the 19th century, only a few taxonomists had taken interest and involved in the classification of tetraodontids, all over the world. Many of them placed tetraodontids in taxa different from the original order Plectognathi and family-Gymnodontes of Day (1875-1878). Weber and de-Beaufort (1962) also treated Plectognathi as the order to which puffer fishes belonged, but placed them under family Tetraodontidae instead of Gymnodontes. Jordan (1963) adopted order Plectognathi and treated Gymnodontes as the suborder while placing tetraodontids under family Tetraodontidae whereas Jhingran (1975) followed Order Tetraodontiformes and family Tetraodontidae. Nelson (1976, 1984) also stuck on to Tetraodontiformes and Tetraodontidae as Order and family respectively.

Munro (1982) placed tetraodontids under families Lagocephalidae and Tetraodontidae, both belonging to the suborder Tetraodontoidei. Talwar and Jhingran (1991) also

followed Nelson's pattern of Order and family taxa. Jayaram (1999) provided information on the freshwater inhabitants of Tetraodontidae with classification.

The Order Plectognathi comprised of teleosts with an incompletely ossified skeleton (Day, 1889 & 1994.). They are a morphologically diverse and highly specialized group of fishes. Many of them are poisonous, and in some, stomach is modified to allow inflation. Regarding the distribution, they are circum-global, mostly oceanic; some are found in rivers and many in estuaries.

Day divided Order Plectognathi into families, Sclerodermi with distinct teeth in the jaws and Gymnodontes having jaws modified into beak. Weber and de Beaufort (1962) classified Order Plectognathi into the following nine families - Triacanthidae, Triacanthodidae, Balistidae, Monacanthidae, Ostraciontidae, Triodontidae, Tetraodontidae, Diodontidae and Molidae. Talwar and Jhingran (1991) picked up two families from the original Order Tetraodontiformes, as some representatives of the two families visit brackish and fresh waters: (1) Triacanthidae, in which jaws are with distinct teeth and pelvic fin with one strong spine and (2) Tetraodontidae, in which the jaws are with fused teeth. In the latter family, body is capable of rapid inflation by intake of

water (or air) as a deterrent to predators. Hence they are also called puffer fishes or blowfishes. To help inflation they are without pelvic bones. Puffer fishes are inhabitants of tropical and temperate seas, most frequent in shallow inshore waters, sometimes entering estuaries and some live only in freshwater. According to the same authors, of the sixteen genera world over, only six are seen in Indian waters, *viz.*, *Xenopterus*, *Tetraodon*, *Takifuku*, *Lagocephalus*, *Arothron* and *Chelonodon*. The genus *Tetraodon* is represented by two freshwater puffers, *Tetraodon travancoricus* and *T. cutcutia*. Genera *Xenopterus* and *Takifuku* are considered monotypic.

In spite of the studies done by the aforesaid authors, no systematic and conclusive attempt has been done on the taxonomy of puffer fishes from the south west coast of India. The present study is aimed at gathering information on the distribution of puffer fishes along the south west coast of India and inland waters of Kerala; and arranging the tertaodontids collected during the study period in a systematic way by observing the characters and preparing keys to genera and species.

MATERIALS AND METHOD

Puffer fishes belonging to different genera and species were collected from the Munambam harbour, Kodungallur backwaters, Laccadive coast, Mumbai shore and inland freshwater bodies in and around Thrissur district. Specimen collected except from Mumbai and Laccadives, were put in ice-box and carried to the laboratory. The fishes were washed and dried using blotting paper. Close observations regarding the colouration of the fishes in general and at various parts, if any, were done. Specimens were then kept on plywood board to spread out the dorsal, anal and caudal fins with the help of fine pins. To harden the fins, concentrated formalin was smeared over them using a small brush. After a few minutes, fishes thus treated were transferred to 5% formalin for preservation and later, studies on morphometric and meristic characters were carried out. Morphometric studies help to determine the degree of association of various characters and to establish proportions in total length facilitating the identification of fishes. The preserved fishes were used for taking the following measurements with the help of a pair of fine dividers and recorded in millimeters.

1. Total length: The greatest distance between the most anterior projecting part of the head to the posterior-most tip of the caudal fin (The measurement was taken in a straight line and was not taken over the curves of the body)
2. Standard length: The distance between the anterior-most part of the head and the end of the vertebral column or caudal fin base.
3. Body depth: The vertical measurement from a point in the body of the fish on its back where its height is greatest, by a straight line, to the ventral surface or profile.
4. Head length: The distance between the tip of the snout and the most distant point on the opercular membrane.
5. Snout length: The distance from the most anterior mid-point on the upper jaw to the front hard margin of the orbit.
6. Eye diameter: Distance from the front margin to the hind margin of the eye, along the long axis of the body.
7. Interorbital width: The least distance between the bony rims on the inner margin of eyes.
8. Post-orbital length: The greatest distance from the posterior edge of orbit to the posterior tip of operculum.

9. Pre-dorsal length: Measurement from the midpoint or tip of the snout or upper lip or the anterior-most part of the head to the structural base of the first dorsal fin ray or spine.
10. Post-dorsal length: Measurement from the structural base of the dorsal fin to the caudal fin base or the end of the vertebral column.
11. Pre-anal length: The distance from the tip of the snout to the insertion of anal fin.
12. Post-anal length: Measurement from the structural base of the anal fin to the caudal fin base.
13. Depth of caudal peduncle: the least vertical straight line distance from the dorsal to ventral profile at the narrowest part of caudal peduncle.
14. Caudal fin length: Distance between the base of caudal fin to tip of caudal fin, taken in a straight line.

The proportions of variables in percentage of total length were calculated by the formula $P = (Y/X) 100$ (Dutt, 1961), where 'X' represents the total length of the fish and 'Y', the variables like standard length, head length, pre-dorsal length, pre-anal length, caudal peduncle width, caudal fin length etc. Apart from that, proportions of variables like snout

length, eye diameter, inter-orbital space and post-orbital length, in percentage of head length were also found out.

The morphometric observations were followed by the accurate enumeration of meristic data or counts of fin rays to get the fin formula as it has great diagnostic importance.

Day (1889, 1994), Weber and de Beaufort (1962), Jayaram (1981, 1999), Munro (1982), FAO (1983), Talwar and Jhingran (1991) were referred to for the identification purpose of the tetraodontids collected during the study period. The classification followed by Talwar and Jhingran (1991) was adhered to for the taxonomy studies.

Outline classification of puffer fishes

| | | |
|-----------------|---|-------------------|
| Super class | - | Gnathostomata |
| Class | - | Osteichthyes |
| Sub class | - | Actinopterygii |
| Sub Division | - | Teleostei |
| [Infra Division | - | Euteleostei] |
| Order | - | Tetraodontiformes |
| Sub order | - | Tetraodontoidei |
| Family | - | Tetraodontidae |

Characters of the Order Tetraodontiformes

Head is often very large with varying snout lengths; Gill openings restricted to lateral slits in front of the pectoral fins. Opercular bones and branchiostegal rays covered by thick skin; Dorsal fin usually in the caudal portion of the vertebral column, opposite the anal. Pelvic fins absent or strongly reduced; No spines in the anal fin. Mouth small, Bones of the upper jaw mostly united, sometimes produced into a beak, strong teeth frequently coalesced into a biting plate. Skin is covered by rough scales, or bony plates or spines or partly or fully naked.

Characters of the family Tetraodontidae

Tetraodontids are with large and blunt head, jaws modified to form a beak of four heavy, powerful teeth (and hence the name), two above and two below. Nostrils distinct, single or sometimes with two solid tentacles having a common nasal sac or two nostrils on each side. Gill openings are simple slits, very close and anterior to the pectoral fins. Eyes are located high on the head, pelvic fins are absent, Dorsal and anal fins inserted far posterior; absence of fin spines, caudal fin truncate, rounded, emarginated or somewhat lunate. Lateral lines often indistinct, in some cases conspicuous and

in still others more than one. Body covered with numerous spinules on back and/or belly, sometimes on sides.

Keys and discription of species

Key to genera

1. (a) Two lateral lines on the body.....2
(b) Lateral line single.....5
2. (a) Caudal fin lunate to emarginate *Lagocephalus*
(b) Rounded or truncate caudal fin..... 3
3. (a) Nasal organ a raised papilla with two
sidewardly directed perforations *Takifugu*
(b) Nasal organ without sidewardly
directed openings.....4
4. (a) Nostril a short rounded tube with
terminal opening..... *Tetraodon*
(b) Nasal organ an upraised cup with
two fleshy flaps/lobes *Chelonodon*
5. Nasal organ divided into two solid
tentacles.....*Arothron*

Genus *Lagocephalus* Swainson

Lagocephalus Swainson 1839, Natural History of Fishes, 2:194, 328 (type-species *Tetraodon lagocephalus* Linnaeus).

Body rather elongate, two lateral lines, the upper lateral line curves down in front of the dorsal fin, the lower line on a low skin fold running along the ventro-lateral part. Nasal organ, a raised papilla with two openings. Spicules may be present or absent on the back. Caudal fin, emarginate to lunate. Pectoral fin with 16-19 rays and dorsal fin, 12-14 rays.

Key to species

1. Crowded spicules from the interorbital to the
Dorsal fin, caudal fin lunate *Lagocephalus lunaris*
- 2 Spicules absent on the back, caudal fin emarginate
Lagocephalus inermis

***LAGOCEPHALUS LUNARIS* (Bloch and Schneider)**

Plate 1

Tetraodon lunaris Bloch and Schneider, 1801, Syst. Ichth. p. 505.

Bleeker, 1865, Atlas Ichth. V, p.63.

Day, 1878, Fishes of India, Part IV, p. 701. pl. clxxxii, fig.2.

Day, 1889, Fauna Br. India, Fishes, 2: 491, fig.176.

Spheroides lunaris Herre, 1924. Philipp. Journ. Soc., 25(4): 482.

Lagocephalus lunaris Fowler, 1935, Proc. New England Zool. Club, XV, p.56.

Abe, 1949, Bull. Biogeogr. Soc. Japan, 14(1): p.13. ...

Talwar and Jhingran, 1991, Inland fishes of India and adjacent countries, Vol.II: p.1058.

Gastrophysus lunaris Smith, 1950, The sea fishes of S.Africa, 2nd impress. p.418.

Common names: moontail blassop / rough-backed blowfish

Body elongate with a rounded back. Head length only less than one-third the total length. Snout short and robust looking; eyes placed high, well above the corner of the mouth, somewhat flat inter-orbital space. Each nostril consists of short, lowly placed papilla, pierced by two openings. Two lateral lines, the upper one bends down in front of the dorsal fin and runs backwards along middle of caudal peduncle to the tip; lower lateral line forms a straight ridge from chin to caudal. Inter-orbital space and back up to dorsal fin with crowded short spines; belly to some distance before anus also spiny. Snout, sides and caudal peduncle smooth. Anterior rays are longest in dorsal and anal fins; pectorals with very long

upper rays, lower half concave, caudal fin lunate (emarginated).

Back greenish olive, up to the caudal fin, sides and abdomen satin white, a pale yellow line from eye to caudal along the sides, light yellow fins.

D-11, P-16, A-11, C-10

Based on 14 specimens ranging from 172 mm to 201 mm in TL, the following morphometric observations were made. Standard length, 79.35% TL; Head length, 29.57% TL; Snout length, 10.58% TL (36.37% HL); Eye diameter, 7.94% TL (27.27% HL); Inter-orbital space, 12.17% TL (41.82% HL); Post-orbital length, 10.58% TL (36.37% HL); Pre-dorsal length, 59.24% TL; Post-dorsal length, 20.11% TL; Pre-anal length, 57.14% TL; Post-anal length, 17.46% TL; Caudal peduncle width, 6.34% TL; Caudal fin, 20.65% TL; Body depth, 32.80% TL.

Distribution: Red sea, Coast of eastern Africa, Suez canal, Persian gulf, Coast of India, Ceylon, Andamans, China, Japan, Malay Peninsula. It is primarily marine, also found in estuaries.

Remarks: It is of no interest to fisheries. The specimens studied were all caught from trawling grounds of Mumbai coast. Grow up to 30 cm.

LAGOCEPHALUS INERMIS (Temmick and Schlegel)

Plate 2

Tetraodon inermis Temmick and Schlegel, 1844, Fauna Japon, p. 278, cxxii, fig.2.

Day, 1878, Fishes of India, Part IV, p. 701, pl. clxxx, fig. 1.

Day, 1889, Fauna Br. India, Fishes, 2: 490.

Lagocephalus inermis Munro, 1955, The marine and Freshwater fishes of Ceylon, p. 280, pl. 55, fig. 817.

Common names: smooth blassop / smooth-backed blowfish

Body elongate with an evenly arched back. Head very large and strong, snout occupying more than 40% of the length of head, mouth terminal, eyes placed very high and closer to the gill opening than the snout tip, broad and flat inter-orbital space. Nostril low and pierced with two openings on each side. Lateral lines distinct; the upper one curves down in front of the dorsal fin and runs along the caudal peduncle horizontally. Lower lateral line forms a ridge reaching up to the caudal fin. Dorsal part of the body without spines belly covered with prickles not reaching the vent, rest of the body smooth. Anterior 1/3rd of the dorsal and anal fins with longer rays than the posterior region. The upper part of the free end of pectoral fin is rounded. Caudal fin emarginated.

Greenish or dark grey above, silvery white below. Dark caudal fin with white margin at the extreme end. Gill opening black in colour internally.

D - 12, P - 18, A - 11, C - 10

The following morphometric observations were made on 26 fishes ranging from 92 mm to 320 mm. Standard length, 82.26% TL; Head length, 26.57% TL; Snout length, 10.11% TL (37.50% HL); Eye diameter, 7.87% TL (29.16% HL); Inter-orbital space, 10.71% TL (43.75% HL); Post-orbital length, 11.80% TL (43.75% HL); Pre-dorsal length, 52.26% TL; Post-dorsal length, 19.35% TL; Pre-anal length, 52.26% TL; Post-anal length, 21.46% TL; Caudal peduncle width, 3.93% TL; Caudal fin, 17.74 % TL; Body depth, 26.35% TL.

Distribution: Common along West and East coasts of India, South Africa to Southern Japan.

Remarks: Fishes were collected from Munambam, Vadanappilly, Chavakad and Cochin for the present study. Smooth blassop is poisonous to eat. It is of no interest to fisheries. Local fishery folk calls it 'motha' or 'kadal poocha'.



Plate 1. *Lagocephalus lunaris*



Plate 2. *Lagocephalus inermis*

10 27A

Genus *Takifugu* Abe

Takifugu Abe, 1949, Bull. Biogeogr. Soc. Jap., 14(13): 120
(type-species: *Tetraodon oblongus* Bloch).

Body elongate, top of head back and belly with spinules, dorsal side rounded, two nostrils on each side terminal mouth, eyes placed high, inter-orbital space relatively wide. Of the two lateral lines, lower line on a raised skin fold along tail. Dorsal and anal fins rounded respectively with 12 and 10 rays. Caudal truncate; narrow dark bands on sides, dorsal side ornamented with large spots. Genus *Takifugu* is monotypic.

TAKIFUGU OBLONGUS (Bloch)

Plate 3

Tetraodon oblongus Bloch, 1786, Ausland Fische II, p. 6.

(type-locality: Surate, East Indies).

Bloch- Schneider, 1801, Syst. Ichth., p. 504.

Day, 1878, Fishes of India, Part IV, p. 702, pl. clxxxii, fig. 3.

Day, 1889, Fauna Br. India, Fishes, 2: p. 492.

Spheroides oblongus Herre, 1924, Philipp. Journ. Sci. 25(4);
p. 484.

Hora, 1924, Mem. Asiat. Soc. Bengal, VI, p. 408.

Hora and Mukerji, 1936, Rec. Indian, Mus; 38(1); 39.

Lagocephalus oblongus 1937, Fowler, Proc. Acad. Nat. Sci. Philadelphia, LXXXIX, p. 264.

Torquigener oblongus Smith, 1950, The sea fishes of S. Africa, 2nd impress., p. 418.

Takifugu oblongus Whitley, 1953, Rec. Austr. Mus., XXIII, No. 3, p. 130. Talwar and Jhingran, 1991, Inland fishes of India and adjacement countries, Vol. II, p. 1059.

Common name: lattice blassop

Body oblong and head is broad. Mouth terminal, snout long occupying one-third of head length. Nasal organ on each side consists of a slightly raised papilla, perforated by two openings looking sideward. Eyes high, placed superior to the corner of the mouth opening. Inter-orbital space is slightly convex and relatively wide. Spines are distributed on back and belly and across body at the level of pectoral. Flanks are smooth, tail devoid of spinules. Rounded dorsal and anal fins, caudal truncate. Lower lateral line with a distinct fold or keel.

Dorsal surface is olive brown in colour and yellowish white on sides and beneath; upper part of the head and back with light creamy spots, from the back dark brown bars or

bands run down along the sides (9-10) reaching the horizontal mid-line interdigitating with the pale colour extending from below. Fins are slightly yellowish orange in life.

D – 12, P – 17, A – 10, C – 10

Based on observations on 18 specimens ranging from 96^{to} 105 mm in total length the following morphometric data were collected. Standard length – 82.29% TL; Head length 28.13%; Snout length, 9.38% TL (33.33% HL); Eye diameter, 6.25% TL (23.08% HL); Inter-orbital space, 14.58 % TL (51.89 % HL); Post-orbital length, 11.46% TL (40.74 % HL); Pre-dorsal length, 53.13% TL; Post-dorsal length, 16.67% TL; Pre-anal length, 56.25% TL; Post-anal length, 12.50% TL; Caudal peduncle width, 8.33% TL; Caudal fin, 17.71 % TL; Body depth, 23.94% TL.

Distribution: Indo-west Pacific, South Africa, Indonesia to Australia. Lives in shallow coastal waters, but enters brackish waters. Common along the west coast and east coast of India. Also reported from Chilka lake.

Remarks: Though it is considered as a harmless fish, it is of no interest to fisheries. Specimens were collected from shallow waters of Mumbai coast running to a depth of twenty meters.

Genus *Tetraodon* Linnaeus

Tetraodon Linnaeus, 1758, Systema Naturae, ed. 10:332 (type-species: *Tetraodon lineatus* Linnaeus)

Monotretus Troschel, 1856, Abh. Preuss. Akad. Wiss; Berlin, 88 (type - species: *Tetraodon cutcutia* Ham-Buch.)

Tetraodon Dekkers, 1975, Bijdr. Dierk., 45(1): 92-142 (Revision).

Laterally compressed body with inconspicuous spicules on the leathery skin, mouth forwardly directed and terminal, eyes large, inter-orbital space is flat, Nasal organ in the form of a short tube with terminal opening, slightly two-lipped in some, 7-13 rays in the dorsal fin, anal fin with 8-12 rays. Caudal fin rounded or truncate. Upper lateral line curves down and meets the lower one in the caudal peduncle. Relatively small-sized puffers, maximum total length attaining about 10 cm (*T. cutcutia*).

***TETRAODON TRAVANCORICUS* Hora and Nair**

Plate 4

Tetraodon travancoricus Hora and Nair, 1941 Rec. Indian Mus.43(3): 391, fig.3&4.(type locality: Pamba river, Kerala).

Talwar and Jhingran, 1991, Inland fishes of India and adjacent countries, Vol. II: p.1061, fig.301.

Jayaram, 1991, Freshwater fishes of the Indian region, p. 449, fig.320.

Remadevi, Indra and Raghunathan, 2000, J. Bombay nat. Hist. Soc. 97(3): 441.

Common name: freshwater Malabar puffer fish

Body is compressed laterally, still slightly oblong, dorsal profile arched; skin is rather leathery, forwardly directed terminal mouth. Head about $1/3^{\text{rd}}$ total length, eyes are large and prominent and placed almost mid length between gill slit and snout tip; flat inter-orbital space. Spinules on the body are inconspicuous. Dorsal and anal fins rounded, caudal truncate. Nasal organ an elevated, short, rounded tube with terminal opening.

Males with dark band running the entire belly along the mid-ventral line surrounded by yellow coloured zone. Fins are yellow in colour and tips of dorsal and anal fins are dark. Central rays of the caudal fin are also stained black in males, distinctly. In sexually mature females the ventral side is yellow without the prominent dark band in males. Belly in others are white in colour.

D- 8, P -16, A- 8, C- 8

Based on 38 specimens ranging in length from 10 mm-34 mm in total length, following morphometric studies were carried out. Standard length, 82.14% TL; Head length, 32.14% TL; Snout length 10.71% TL (33.33% HL); Eye diameter, 10.71% TL (33.33% HL); Inter-orbital space, 14.29 % TL (44.00 % HL); Post-orbital length, 10.71% TL (33.33 % HL); Pre-dorsal length, 60.71% TL; Post-dorsal length, 14.28% TL; Pre-anal length, 57.14% TL; Post-anal length, 10.71% TL; Caudal peduncle width, 10.71% TL; Caudal fin, 17.86 % TL; Body depth, 28.57% TL.

Distribution: Recorded for the first time in 1941 from Pamba river. Available in central Kerala in rivers, Kole fields and ponds and northern regions of the state, western ghats, south Kanara (Karnataka) etc. Also reported at a height of about 50-60m above MSL from Kerala and Dakshin[^] Kannada.

Remarks: Freshwater puffer fish, considered endemic to Kerala, prefers tropical climate. Many authors diversely designated it rare, very rare, endangered etc. It is very common in central Kerala and could be collected in hundreds from the kole fields (submerged paddyfields) and rivers. Duck keepers witness death of ducks brought to kole fields for feeding, by inflation of puffer fishes in their throats while



Plate 3. *Takifugu oblongus*

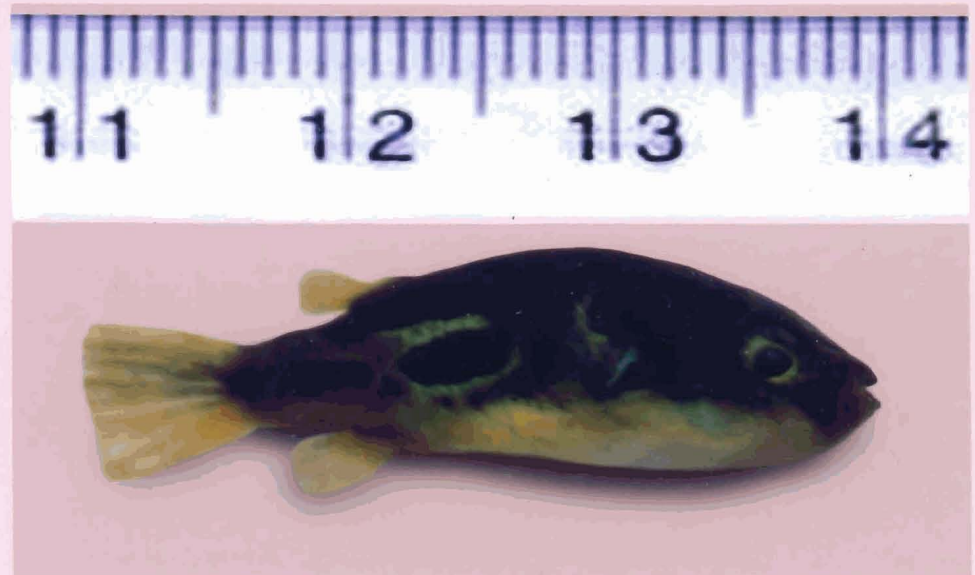


Plate 4. *Tetraodon travancoricus*

trying to swallow them. Commonly known as 'thavalapottil' in Malayalam meaning 'tadpole'.

Genus *Chelonodon* Muller

Chelonodon Muller, 1839, Abh. Preuss. Akad. Wiss., Berlin: 252 (type-species: *Tetraodon patoca* Hamilton-Buchnan)

Body fairly elongate, Nasal organ a depression surrounded by a slightly raised margin produced into a posterior and anterior flap or an upraised cup with two fleshy lobes; lateral lines two, the upper one joining the lower line in the caudal peduncle. Dorsal and anal fins rounded and caudal either truncate or rounded. Dark blotches or white spots on the body.

Key to species

1. Rim of the nostril produced into anterior and posterior flaps. Upper half of the body with numerous white spots.
Pectoral fin rays, 18 – D. 10 *Chelonodon patoca*
2. Nasal organ cup shaped with two fleshy lobes. Back, sides and tail with dark blotches
Pectoral fin rays, 22 – D. 14. *Chelonodon fluviatilis*

CHELONODON PATOCA (Hamilton-Buchanan)

Plate 5

Tetraodon patoca Hamilton-Buchanan, 1822, Fishes of Ganges, p. 7 (type-locality: estuaries of Ganges).

Leiodon patoca Bleeker, 1865, Atl. Ichth., V: p. 76.

Tetraodon Patoca Gunther, 1870, Cat. Brit. Mus. VIII: p. 288.

Day, 1878, Fishes of India, p. 703, pl. clxxxii, fig. 4.

Day, 1889, Fauna Br. India, Fishes, 2: p. 492.

Chelonodon patoca Herre, 1924, Philipp. Journ. Sci. 25(4): p. 487.

Smith, 1950, The sea fishes of S. Africa, 2nd impress. p. 419.

Common names: Gangetic blowfish / milk spotted puffer

Body elongate with the upper profile evenly arched from anterior margin of the orbit to the caudal. Skin naked except for the presence of small spines beginning from the posterior inter-orbital and not reaching the dorsal fin above and inferiorly another stretch not reaching the vent, on the sides coming up to the base of pectoral fin. Nasal organ a round depression in front of the eye, surrounded by a low rim which is produced into a short, more or less triangular flap

anteriorly and posteriorly. Eyes medium sized; a flat and broad inter-orbital space separating the eyes. Dorsal and anal fins are somewhat rounded but the caudal is truncate. Lateral lines are inconspicuous though a feeble ridge along the inferior half of the tail represents the lower lateral line.

In life, body is brownish in the upper half with a number of round or oval slightly yellowish or white spots not extending to the snout. Sides and abdomen are silvery with a yellow tinge on the ventro-lateral side below the pectoral fins. Dorsal and anal fins are slightly yellowish and the dorsal fin is with a dark base. Caudal fin stained black in the distal part.

D- 10, P- 17, A- 18, C- 10

12 Specimens ranging from 107 mm to 127 mm in total length were studied. Standard length, 80.99% TL; Head length, 29.75% TL; Snout length, 9.09% TL (30.56% HL); Eye diameter, 9.09% TL (30.56% HL); Inter-orbital space, 16.53% TL (55.56% HL); Post-orbital length, 11.57% TL (38.89% HL); Pre-dorsal length, 57.02% TL; Post-dorsal length, 16.53% TL; Pre-anal length, 58.68% TL; Post-anal length, 14.05% TL; Caudal peduncle width, 10.74% TL; Caudal fin length, 19.01% TL; Body depth, 28.10% TL.

Distribution: Seas of India, Ceylon, Andamans, Myanmar, Malaya, China, North Australia. Inhabits coastal waters, estuaries, lower reaches of rivers. Usually found around the mouths of rivers.

Remarks: The fishes were trapped in Chinese dip-net along the Kodungallur backwaters region during the summer period. The salinity was high, reaching 30‰. Not a single specimen was caught in the monsoon or post-monsoon season. It is known as 'motha' in Malayalam and is of no interest to fisheries.

***CHELONODON FLUVIATILIS* (Hamilton –Buchanan)**

Plate 6

Tetraodon fluviatilis Hamilton-Buchanan, 1822, Fishes of Ganges, p.6 (type- locality:Ganges river).

Tetraodon simulans Cantor, 1850, Journ. Asiat. Soc.Bengal, XVIII, Part II, p. 1356.

Crayracion fluviatilis Bleeker, 1865, Atlas Ichth., V: p.68.

Tetraodon fluviatilis Gunther, 1870,Cat. Brit. Mus, VIII: p. 209.

Day, 1878, Fishes of India, Part IV, p. 707, pl. clxxxiii,fig.1.

Day,1889, Fauna Br. India, Fishes, 2: p.496.

Herre, 1924, Philipp. Journ. Sci., 25 (4): p. 497.

Dichotomycter fluviatilis Fowler, 1937, Proc. Acad. Nat. Sci. Philadelphia. 89: p. 264.

Chelonodon fluviatilis Munro, 1955, The marine and freshwater fishes of Ceylon, p. 282, pl.55, fig.822.

Talwar and Jhingran, 1991, Inland fishes of India and adjacent countries, Vol. II: p.1061.

Common names: green puffer fish & potoka (West Bengal)

Body stout but fusiform rather than oblong. Mouth typically terminal, dorsal profile slightly arched. Spines short present on posterior sides of head, extending to dorsal fin, anterior part of sides of body and belly, the rest of the body naked. Two nasal tentacles on each side, snout short, eyes moderately sized, the inter-orbital space broad and convex. Dorsal anal and caudal rounded; indistinct lateral line.

Body colour green olive to light brown, belly yellowish white, upper side of head, back, superior part of sides of body entire tail with large, dark brown blotches; three of them large on the dorsal side between the eyes and the dorsal fin. Fins are slightly yellowish in colour.

D- 14, P- 22, A- 12, C- 11

15 specimens were subjected for study ranging from 76^{to} 118mm in total length. Standard length, 80.00% TL; Head length, 32.50% TL; Snout length, 11.25 % TL (34.62% HL);

Eye diameter, 7.50% TL (23.08% HL); Post-orbital length, 13.75% TL (41.31% HL) Pre-dorsal length 57.50% TL; Post-dorsal length, 12.50 % TL; Pre-anal length, 57.50 % TL; Post-anal length, 12.50 % TL; Caudal peduncle width, 11.25 % TL; Caudal fin, 20.00% TL; Body depth, 25.62% TL. ...

Distribution: India, Ceylon, Andamans, Myanmar, Malay Peninsula, the Philippines. In sea and estuaries, entering freshwater. Though the term 'fluviatilis' means river, this species is recorded from estuaries and coastal waters.

Remarks: Though this species of no interest to fisheries, the compactness of its genome has made it one of the best model animals for the study of vertebrate genome. The fish is poisonous for human consumption. The specimens studied were collected from coastal waters of Mumbai up to 20m. depth.

Genus *Arothron* Muller

Arothron Muller, 1841, Abh. Akad. Wiss., Berlin:252 (type-species: *Arothron testudinarius* Muller).

Kanduka Hora, 1924, Rec. Indian Mus., 26(6): 579. (type-species: *Kanduka michiei* Hora).

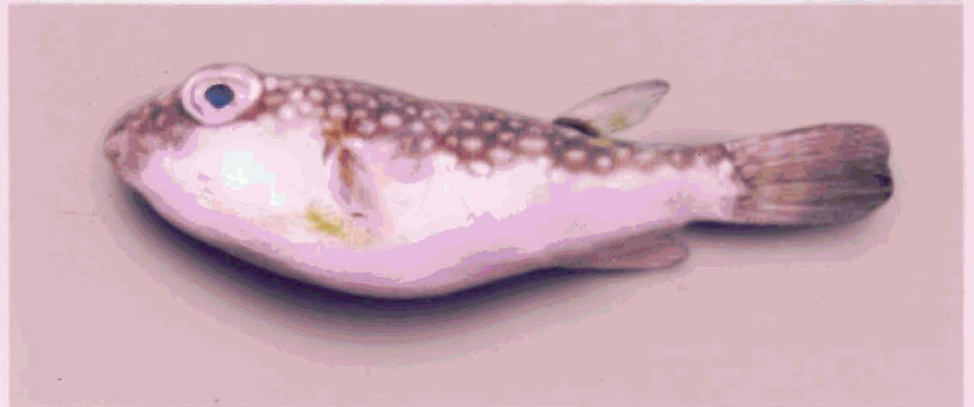


Plate 5. *Chelonodon patoca*

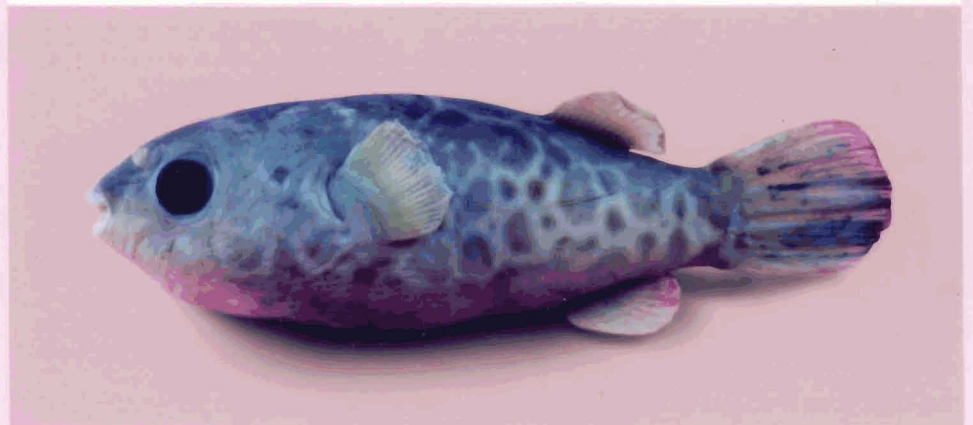


Plate 6. *Chelonodon fluviatilis*

12-3911

Body rather broad, covered over by spines, spicules on the abdomen conspicuous. Only one lateral line on each side, Nasal organ in the form of bifid tentacle. Dorsal, anal and caudal fins rounded. Vent in a black blotch; sometimes white or black specks all over the body, belly devoid of them in some.

Key to species

1. White rounded spots on snout back,
sides and caudal peduncle.

Caudal fin with 11 rays.....*Arothron hispidus*

2. Small black specks, moderately
distributed all over the body.

Caudal fin with 9 rays.....*Arothron nigropunctatus*

AROTHRON HISPIDUS (LACEPEDE)

Plate 7

Tetraodon hispidus Lacepede, 1802, Hist. Nat. Poiss. I: p.487.

Tetraodon implutus Jenyns, 1842, Zool. Voyage Beagle,
Fishes, p.152.

Tetraodon laterna Gunther, 1866, Fishes of Zanzibar, p 131.

Tetraodon hispidus Day, 1878, Fishes of India Part IV,
p.706, clxxiii,fig.2.

Day, 1889, Fauna Br. India, Fishes, 2: p. 492.

Arothron hispidus Smith, 1950, The Fishes of S. Africa, 2nd impress. p. 420.

Munro, 1955, The marine and freshwater fishes of Ceylon, p. 283, pl. 55, fig. 828.

Randall, 1955, Atoll Res. Bull. p. 234.

Weber and de Beaufort, 1962, The fishes of Indo-Australian Archipelago, XI, p. 402, fig. 87.

Common name: white spotted blowfish

Body oblong, small spines all over the body up to the dorsal fin. Spines large in the belly and very conspicuous when inflated; lateral line single and not conspicuous on the caudal peduncle. A pair of nasal tentacles on each side. Eyes very small, and are placed above the level of mouth opening, usually with two white circles around the orbit. Inter-orbital space wide and concave, fins are rounded.

Greenish brown above with dark bars on the belly. White spots on snout, back, sides, and caudal fin; more crowded in the caudal peduncle. Pectoral fin yellow, a yellow band encircling the base of pectoral fin and gillslit. Some are devoid of it.

D-10, P-17, A-10, C-11

Six specimens ranging from 156mm ^{to} 167mm were studied. Standard length, 76.97% TL; Head length, 33.94% TL; Snout length, 12.73% TL(37.50% HL); Eye diameter, 6.67% TL(19.64 HL); Post-orbital length, 13.94% TL (41.07% HL); Pre-dorsal length, 56.97% TL; Post-dorsal length, 12.50% TL; Pre-anal length, 57.50% TL; Post-anal length, 16.97% TL; Caudal peduncle width, 10.91 % TL; Caudal fin length, 23.03% TL; Body depth, 31.52% TL.

Distribution: East Coast of Africa, Coastal waters of India, Ceylon, China, Japan, Malay Archipelago and beyond, Red sea, West Australia.

Remarks: The specimens studied were all caught by Chinese dip-net along the bank of Kodungallur back waters area. Interestingly enough, the period of collection was monsoon and the salinity of the waters of the said region was less than 1‰. It is of no interest to fisheries but may be considered as a very good ornamental fish as it survives in waters of very low salinity.

***AROTHRON NIGROPUNCTATUS* (Bloch and Schneider)**

Plate 8

Tetradon nigropunctatus Bloch and Schneider, 1801, Syst. Ichth. p.507.

Arothron trichoderma Bleeker, 1856, *ibid*, XII, p. 218

Tetraodon nigropunctatus Gunther, 1870, *Cat. Brit. Mus.* VIII, p. 293.

Day, 1878, *Fishes of India*, Part IV, p. 704, pl. clxxx, fig. 4.

Day, 1889, *Fauna Br. India, Fishes*, 2: p. 494.

Arothron nigropunctatus Smith, 1950, *The sea fishes of S. Africa*, 2nd impress. p. 420

Munro, 1955, *The marine and freshwater fishes of Ceylon*, p. 283, pl. 55, fig. 825.

Common name: black spotted puffer

Body rounded rather than elongate and is covered over by small spines, mouth terminal and snout, especially the tip surrounding the mouth black. Eyes small, the inter-orbital space is somewhat flat. Dorsal, anal and caudal fins rounded. Two nasal tentacles are clearly seen on each side. Vent situated in a black blotch. Only one lateral line.

Dorsal side is brown in colour which fades along the sides. Ventral surface is pale. Scattered black spots all over the body without any specific pattern. Fins yellowish orange in colour.

D- 10, P -18, A -10, C- 9.

The morphometric studies were based on four specimens collected from Laccadives coast ranging in total length from

114/121 mm. Standard length, 79.20% TL; Head length, 31.20% TL; Snout length, 12.80% TL (41.03% HL); Eye diameter, 5.60% TL (17.95% HL); Post-orbital length, 12.80 TL (41.02% HL) Pre-dorsal length, 62.40% TL, Post-dorsal length, 10.40% TL; Pre-anal length, 62.40% TL; --Post-anal length, 10.40% TL; Caudal peduncle width, 12.00 % TL; Caudal fin length, 20.80% TL; Body depth, 36.00 % TL.

Distribution: East coast of Africa, Red sea, Madagascar, Mauritius, Coasts of India, Ceylon, Andamans, Japan, Australia.

Remarks: Reef associated, marine, depth range 3-25 m. The specimen studied were collected from the Laccadives coast. Though attractive, it doesn't hold any fisheries interest.

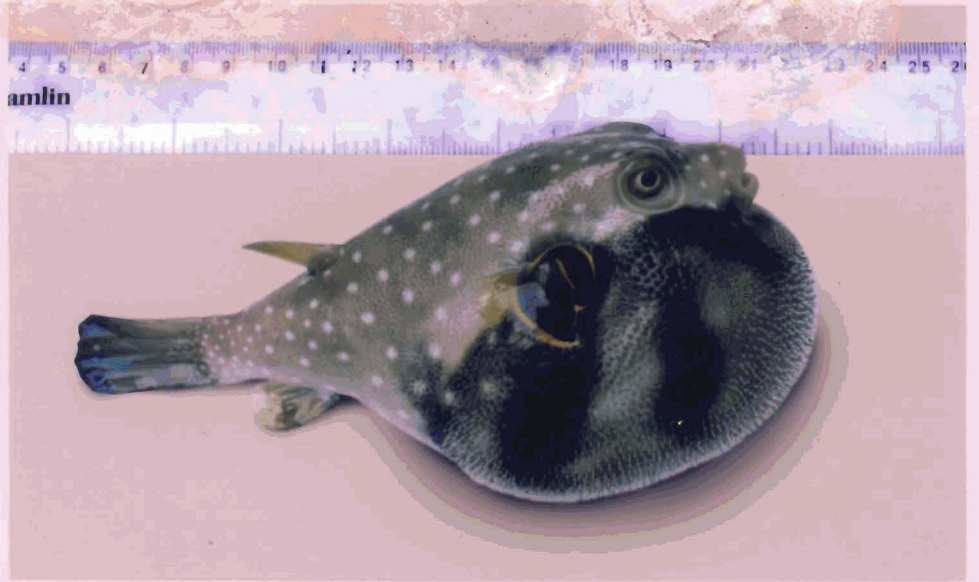


Plate 7. *Arothron hispidus*

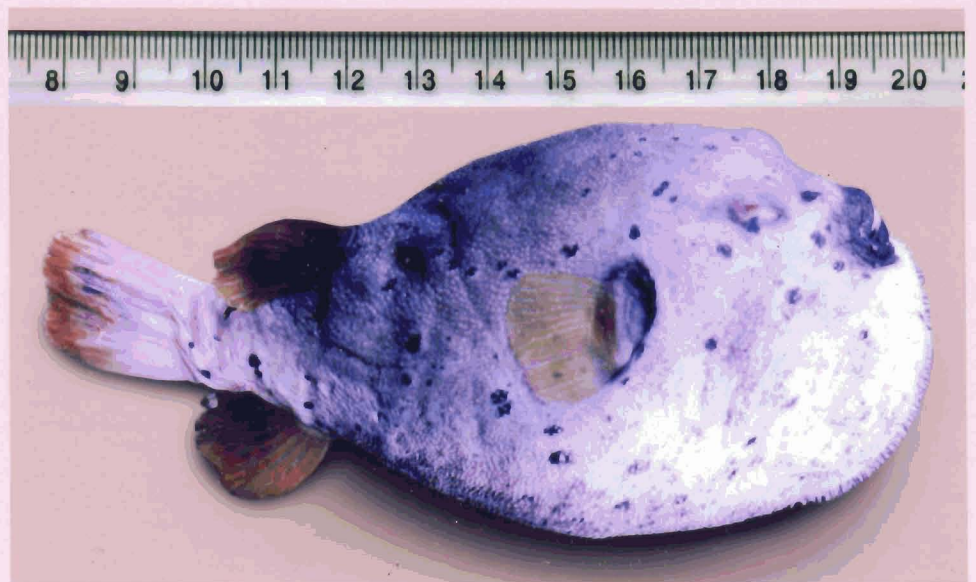


Plate 8. *Arothron nigropunctatus*

FOOD AND FEEDING HABIT

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CHAPTER - III

FOOD AND FEEDING HABIT

INTRODUCTION

Investigation on the food and feeding habits of fishes has, traditionally, been important in fishery biology studies. A detailed information on the food preferences of fishes is generally considered as an essential pre-requisite to understand the important aspects like growth, shoaling behaviour, breeding, migration and fishery. Trophic relationships of economic and uneconomic species of fishes will also be useful in understanding their role as prey, predator or competitor. It also provides information on the degree of competition the fish faces from other species. Furthermore, feeding habit is one of the primary criteria in deciding on transplantation of a species to new ecosystems with least possible damage to the native fauna. To sum up, knowledge of the diet of fishes is very important in community analyses like food webs, trophodynamics, resource partitioning etc. (Landenberger, 1968).

Seasonal abundance of favourable food organisms may be responsible for movement of fishes, providing a tool for the prediction and exploitation of the stocks. For instance, the

observation of peak fishery for plankton feeders like mackerel and sardines along the south west coast during September-December is related to the richness of inshore waters with phyto-and zooplankton in the said period(George, 1953). Seshappa and Bhimachar (1955) reported the abundance of *Cynoglossus semifasciatus* when its favourite polychaete appeared between October and May.

Fishes are grouped into herbivores, carnivores and omnivores depending on the percentage of animal and vegetable matter they consumed (Das and Moitra, 1956 and 1963). The same authors further classified fishes into three subgroups based on the feeding zones, that is, surface feeders, column feeders and bottom feeders. Schaperclaus (1961) categorized the natural food of fishes into (a) main or basic food which the fish prefers under favourable conditions and on which it thrives best, (b) occasional food, consumed in good quantities when available (c) emergency food, taken during the unavailability of preferred food and on which the fish is just able to survive and (d) incidental food which enters the gut along with other items.

Although most fishes feed on a limited range of prey types, dietary flexibility is a feature of many families. Such flexibility confers important advantages in terms of both

survival and mobility (Blaber, 1997). In field studies analysis of food contents is often the only available means of accessing information about feeding ecology and a vast number of publications considering stomach contents data exist.

Investigations on food and feeding habits have been conducted on a number of fishes belonging to freshwater, estuarine and marine environments. One of the earliest significant works pertaining to food and feeding of fishes was done by Day (1882). The other early workers were Scot (1902), Johnstone (1907), Hickling (1927), Allen (1935 and 1938), Neill (1938), Frost (1943), and Hynes (1950). A few prominent contributors in the second half of the 20th century were Jones (1952), Randall (1965), Roughgarden (1972), Berg (1979), Dewan (1979), Hyslop (1980), Martin and Blaber (1983), Davis (1985), Wijeyaratne and Costa (1987), Wijeyaratne and Costa (1988), Fraser *et al.* (1993) and Jobling *et al.* (1998).

Hornell and Naidu (1923) initiated the studies on food and feeding of fishes in India. Other prominent investigators were Devanesan (1932), Job (1940), Chacko (1949), Prabhu (1955), Alikunhi (1957), Venkataraman (1960), Natarajan & Jhingran (1961), Rao (1964), Qasim and Qayyum (1964), James (1967), George *et al.* (1968), Silas (1969), Qasim

(1972), Devaraj (1976) Sreenivasagam (1981), Appa Rao (1984), Prakash Nautiyal and Lal (1984), Ramkrishniah (1984 and 1986), Jayabalan and Ramamurthy (1985), Joseph (1986), Vincy (1986), Dasgupta (1988), Khan (1988), Devadoss (1989), Premalatha (1989), Dasgupta (1990), Rao and Sreenivasa Rao (1991), Vijayanand and Varghese (1992), Vasudevappa and James (1992), Appana Shastry (1993), Kurup (1993), Philip (1994), Sharma (1994), Tessy (1994), Badapanda (1996), Sivakami (1996), Pillai (1996), Gopal Raja and Sadasiv (1996), Das *et al.* (1997), Premalatha (1997) Vijayakumaran (1997), Devaraj (1998), Jayaprakash (1998), Kishore (1998), Philip (1998), Ramakrishna (1998) Rao *et al.* (1998), Basudha and Viswananth (1999), Rao and Padmag (1999), Mahapatra and Dutta (1999), Tessy (2001), Raje (2002) and Rao and Sankara Rao (2002).

The methods available and commonly used for the study of gut content analysis in fishes are occurrence method, gravimetric/ volumetric method, number method, points method, index of preponderance, and Costello method. The occurrence method is based on the presence or absence of the food item in the gut. The only one standard applied in this method is the physical presence of a food item. The number, volume or weight of the food content are not considered here.

In gravimetric/volumetric method, food contents in the stomach are measured either in weight or volume (displacement method). The method may not be suitable for fishes feeding on smaller items like unicellular algae, diatoms etc. Number method is relatively easy to carry out but is beset with distorted information on volume of the gut content components. Still, it is effective in deriving information on relative importance of various food items, for the relative error is less since the smaller items are generally encountered in large numbers. In points method, as in number method, the different food items in the stomach are counted and then points are allotted to each category against a standard unit. Each unit of food item present in the gut is weighed and points are allotted on eye estimation. Though there is some drawback owing to individual judgment in assigning points, this method is widely accepted among fishery biologists. Index of preponderance method grades the food elements as a combined picture of both occurrence and bulk (volume). Index of occurrence (O_1) and index of volume (V_1) of an item are calculated to find out its preponderance. The equation commonly used is, $IP = (O_1 * V_1)100 / \sum (O_1 * V_1)$.

Fishery biologists applied one method or the other for studying the gut content analysis of fishes considering the

suitability of the method for investigation. Swynnerton and Worthington (1940) pioneered the points method giving importance to the size and hence volume of the individual food items. It was subjected for slight modification by Frost (1943) and Hynes (1950), and the latter performed points method while studying the food contents of stickleback. Pillay (1952), made a critical assessment of various methods and concluded that the volumetric method was the most acceptable. During a study on the food of Indian mackerel, Bhimachar and George (1952) followed both points and number method. Occurrence method was adopted for the diet analysis of *Cynoglossus semifasciatus* by Seshappa and Bhimachar (1955). The method of index of preponderance was suggested for grading the food elements in the stomach analysis of fishes by Natarajan and Jhingran (1961). James (1967) suggested volumetric method for carnivorous fishes. Windell (1968) was of the view that, though a number of different methods were available, essentially, the outcome based on those techniques all gave almost the same comparative results. Bhatnagar and Karamchandini (1970) adopted the modified points method for diet analysis. According to Hyslop (1980), the best measure of stomach content is the one where both the frequency and bulk of a food category are recorded.

Recently Costello (1990), proposed the graphical method for analysis of predator feeding strategy, based on % occurrence and % abundance (volume, weight or number) of the prey. Costello's analysis is based on a two-dimensional representation, where each point on the graph represents the frequency of occurrence and abundance of the prey. The two diagonals of the plot represent prey importance: dominant (high % occurrence and high % abundance) and rare (low % O and low % A) and feeding strategy of the predator: specialized (high % A and low % O) and generalized (high % O and low % A). The diet analysis of the two-spot goby was carried out by Costello (1991) adopting the graphical method. Later, Amundsen *et al.* (1996) put forth a new approach to the graphical analysis of feeding strategy from stomach contents data as an attempt to overcome the problems inherent in the Costello method.

Although a number of freshwater fishes of Kerala were subjected for detailed studies on their biology, especially the food and feeding behaviour, none has attempted to access information on the food and feeding aspects of *Tetraodon travancoricus*. Same is the case with *Lagocephalus inermis*, one of the most common tetraodontids along the south west coast of the country. In the present study, the food and

feeding habits of the above mentioned fishes have been attempted with a view to gather information on the status (niche) of these fishes in their respective ecosystems and preferred food items.

MATERIALS AND METHOD

Fortnightly collections were made both for *T.travancoricus* and *L.inermis*, as far as possible for a period of two years, respectively, from October 1999 to September 2001 and January 2000 to December 2002. *T.travancoricus* was collected from Puzhakkal river, Thrissur district whereas *L.inermis* was brought to the laboratory from Munambam harbour and Vatanappilly. A total of 462 *T.travancoricus* and 287 *L. inermis* were utilized for the study. Of the 462 freshwater puffers, 178 were males, 185 were females and 99, indeterminates. The numbers of males, females and interminates were 135, 133, and 19, respectively for *L.inermis*. Fish samples brought to the laboratory were cleaned and made moisture free by blotting before measuring the length (in mm) and taking the weight (in mg for *T.travancoricus* and nearest gm for *L.inermis*). After recording the said parameters, fishes were dissected out to note the sex, maturity stage and degree

of distension of the stomach. Stomachs were removed and weighed for the calculation of gastrosomatic index.

By examining the distension of stomachs and food contents in them, stomachs were categorised into five groups to gather information about intensity of feeding. The five categories constructed according to the degree of fullness of stomach were 'full', '3/4 full', '1/2 full', '1/4 full' and 'empty'. Points 20,15,10,5 and 0 were allotted to the stomachs in the above mentioned order from full to empty.

In tropical regions, as the high temperature of water accelerates the process of digestion, food remains in the identifiable state more in the stomach than in the intestine. This fact, prompted Qasim (1972) to suggest that while performing diet analysis in fishes, observation had to be taken from stomach ignoring rest of the gut unless special reasons demanded it. During the present study, only the stomach contents were subjected for diet analysis.

Both qualitative and quantitative analyses were carried out. For the qualitative studies the food items placed in a petridish were separated and identified with the help of a binocular microscope. Simple microscope was sufficient on certain occasions for the identification of food in the stomach contents of *L.inermis*. Identification of food items was done

up to the lowest possible taxon depending on the extent of digestion. The food contents were assigned semi-digested matter status, when the process of digestion made identification difficult. The quantitative analyses were conducted by sticking on to the points method. The percentage occurrence of each item of food in different months was determined by finding the percentage of that item from the total number of occurrence of all items. The month wise data were pooled to arrive at a gross perspective of the diet. Feeding intensity was determined by dividing the percentage of fishes of different degrees of distension of stomach into two groups: actively fed (full, $\frac{3}{4}$ full and $\frac{1}{2}$ full) and poorly fed ($\frac{1}{4}$ full and empty). Month-wise, sex-wise and length group based determination of condition of feed was carried out. The monthly percentage occurrence of the stomachs in active and poor feeding conditions in males and females was utilized to find the seasonal fluctuations in feeding intensity. The average values were worked out separately for the two years (Oct. 1999 – Sept. 2001 in the case of *T.travancoricus* and Jan. 2000 – Dec. 2001 for *L.inermis*) of study. The pooled data on the two sexes were found out to get a gross picture on the overall condition of feed. Similarly, the

intensity of feeding was also estimated for diverse length groups.

In any biological investigation, feeding index holds great relevance. The points allotted to the stomachs of various degrees of distension were taken into account for finding the feeding index.

$$\text{Feeding index} = (P \cdot 100) / (X \cdot N),$$

where, P = total points allotted, X = point allotted to a full get (in the present study, 20) and N = number of guts observed. The denominator (X * N) actually represents to total points possible. The feeding index was calculated for both sexes in *T.travancoricus* and *L.inermis* month-wise and also based on length-groups.

Another very important parameter which expresses the extent of feeding is the gastro-somatic index (GSI).

$$\text{GSI} = 100 (\text{weight of stomach}) / \text{weight of fish.}$$

GSI during different months separately for males and females of both species, ie., *T.travancoricus* and *L.inermis* was studied. The pooled data were utilized to find maximum and minimum GSI values during the study period.

RESULTS

The detailed investigation on the diet of the freshwater puffer fish, *T.travancoricus* showed that the most preferred food item was composed of crustaceans. The percentage composition of various food items of males and females of *T.travancoricus* is shown in Table 3.1 (A,B & C) and Table 3.2(A,B&C) respectively. The pooled data for two years of study period for males from October 1999 to September 2001 gave a percentage of 48.77 (average) in favour of crustaceans which included whole organisms as well as crustacean fragments including appendages. The same food item was represented by an average of 42.80 percent in females. The organisms identified were the copepods (*Heliodyptomus* sp. and *Mesocyclops* sp.) and the cladoceran, *Moina* sp. During the period from October 1999 to September 2000, in males 65.22% crustacean food was observed in May. March also showed very high (62.50) percentage (Table 3.1A). But March (57.14%) and April (56.60) gave high percentage with reference to crustacean food (Table 3.1B) in males between October 2000 and September 2001. The pooled data on males for two years (Table 3.1C) provided the highest percentage of crustacean food in May (59.99%) followed by March (59.82%)

and April (54.66%). The lowest value was observed in September (33.57%).

In females of *T.travancoricus*, highest percentage of crustacean food was observed in January (56.82%) followed by December (52.78%), April (52.17%) and March (52.08%) during October 1999 to September 2000. The lowest on the same food item was 23.16%, in June (Table 3.2A). February (56.38%), December (54.55%), April (54%) and March (51.11%) were the months which had high percentages on crustacean food from October 2000 to September 2001 (Table 3.2 B). The crustacean and crustacean fragments had its lowest percentage in females during the months of June (21.58%) and July (31.18%). August (33.62%) and September (36.95%) were the other two months which showed low values.

The second largest food component both in males and females was the semi-digested tissue, 22.85% and 30.02% respectively, digested to such an extent that identification of the material was difficult. The food material ranked third was represented by algal filaments (Chlorophyceae) mainly *Spirogyra* sp., *Oedogonium* sp. and *Closterium* sp. (desmid). Stray occurrence of *Oscillatoria* (Cynophyceae) was also noticed. In males the percentage of the item was 9.56 whereas in females it was 8.74%. Next in the rank keeping aside

miscellaneous, was fish scale, which provided an average of 6.61% in males and 6.05% in females. Pieces of fish fin was seen in almost all months, but percentage for it was rather low. In males, it was only 3.85% whereas in females, the percentage was 3.46. Miscellaneous component of the food content was the most diverse with contribution from diatoms like *Pinnularia*, *Tabellaria* and *Navicula* (Bacillariophyceae), invertebrate eggs, cyst-like structures, rotifer (*Brachionus calyciflorus*), nematode worms, pieces of apodous larva, water mite (*Neumania nodosa*), fat droplets, etc. In males 8.37% was the miscellaneous component and slightly higher was the same item in females (8.93%). A comparison between the monthly percentage occurrence of various food items is shown in Fig. 3.1 (A-L).

The percentage occurrence of various food items in the stomachs of *L.inermis* is given in Tables 3.3 A, 3.3 B and 3.3 C (males) and Tables 3.4 A, 3.4 B and 3.4 C (females). The semi-digested food matter was the highest food component in both males (34%) and females (34.28). In 2000, February (42.86%) and August (41.27) had the highest values for the semi-digested food (Table 3.3 A). In the next year high values were observed (Table 3.3 B) in April (43.59%), June (41.09%), and February (40.62%). Pooled data for two years i.e., 2000

and 2001 (Table 3.3C) showed that February had the highest percentage (41.74%) for semi-digested tissue. Among females, during 2000 (Table 3.4A), high percentage on semi-digested food matter was observed in January (46.79%) and November (38.46%). In 2001, March (42.31%) and November (42.22%) had the highest percentage occurrence of semi-digested food (Table 3.4 B). The overall percentage composition of the said food item in various months pooled (Table 3.4 C), assigned highest percentage to November (40.34%) followed by March (38.29%).

The second highest food item recorded in both males (25.93%) and females (20.60%) of *L.inermis* was fishes and fish pieces. The prey fishes identified were *Stolephorus* sp. and *Secutor* sp., the former being the most preferred prey by the two sexes. The month of April showed a very high percentage (43.27%) for fish and fish pieces followed by August (31.74%) during 2000 (Table 3.3 A). The highest was only 38.33% in January 2001 with the lowest in March (9.30%). October (13.33%) was a month which also had a low value on fish and fish fragments (Table 3.3 B). The pooled data showed 38.30% in April for males (Table 3.3C). The lowest was calculated in November (17.63%). In females, during 2000 (Table 3.4A), the maximum predation was

observed in August (32.26%) followed by February (31.67%) and July (30.38%). The spawning period showed low percentage values on foraging (Table 3.4 A, 3.4 B and 3.4 C). July (29.56%), August (27.99%) and February (27.77%) had high overall predatory activity (Table 3.4C). Scales of fish constituted the third highest food component in males (10.42%) and females (11.57%). It was closely followed by fins of fish both in males and females with respective average percentages of 8.09 and 9.81. Another fish component, spines and vertebrae, encompassed an average of 5.72% in males and 6.38% in females. Crustaceans and crustacean appendages formed a food item, though not in all months. It was represented by fragmented *Acetes* sp., *Lucifer* sp., appendages and body parts of prawn, and stalked compound eyes. Sporadic and feeble occurrence of cephalopods and their tentacles was also noticed in males(3.09%) and females(2.77%). The first few months of the calendar year showed very high percentages compared to the second half of the year. *Sepia* sp. was the most common cephalopod obtained in the identifiable form. The miscellaneous component of the stomach content was moderate in all months and the overall average percentage values were 7.87 (males) and 10.23 (females). Body parts of crab, invertebrate/fish eggs, coelenterate fragments, annelid

bristles, algal filaments (Chlorophyceae), fat droplets, etc. constituted the miscellaneous lot. Many stomachs contained net knots. Variation in the occurrence of various food items in males and females (pooled) is shown in Fig. 3.2 (A-L).

Percentage of stomachs with various degrees of fullness (Empty, 1/4 Full, 1/2 Full, 3/4 Full and Full) in males and females of *T. travancoricus* is shown in Tables 3.5, 3.6, 3.7 and 3.8. The pooled data on males from October, 1999 to Sep. 2001 (Table 3.7) showed percentage occurrence of 28.22% 'empty' stomachs, 10.93% '1/4full', 35.09% '1/2full', 12.73% '3/4full' and 13.03% 'full'. 'Empty' stomachs were in plenty from May to November, the peak being in August (43.75%) followed by July (35.42%). Empty stomachs had low percentage occurrence from December to April with the lowest in January (14.59%). '1/2full' stomachs were more numerous in males and the highest percentage of occurrence for it was in October (52.08%). The lowest percentage for '1/2full' was in August (20.83%). stomachs with '3/4full' were relatively high from January to April. The lowest percentage occurrence of '3/4full' was in July (7.14%). Stomachs with the status of 'full' were in relatively good numbers in April (20.84%) and January (20.83%).

Percentage of stomachs with various degrees of fullness in females of *T.travancoricus* pooled for two years from October 1999 to September 2001 is given in Table 3.8. The highest average percentage was for 'empty' stomachs (33.31%) followed by '1/2full' (31.30%), '1/4full' (14.31%), '3/4full' (11.12) and 'full' (9.96%). Compared to the different stomachs obtained for males, females showed higher values for 'empty' (males - 28.22%) and '1/4 full' (males-10.93%). 'Full' stomachs were not reported in females in June, July, September and October. The same months gave high percentage for 'empty' stomachs. A comparison between percentage of stomachs in males in females is given in Figure 3.3.

The degree of distension and fullness of stomachs for *L.inermis* males and females separately for the two years of study (2000 and 2001) are shown in Tables 3.9 and 3.10 respectively. Table 3.11 represents the percentage of stomachs with various degree of fullness (pooled) in males. The percentages in the descending order were 31.04% (½ full), 28.9% (empty), 20.78% (¾ full), 10.06% (¼ full) and 9.18% (full). The highest number of empty stomach was observed in October (58.57%) followed by November and April. The lowest numbers were come across in January (7.14%) and

December 12.5%). $\frac{1}{4}$ full stomachs were in good numbers during January-April. The third category of stomachs maintained relatively high percentages in all months except December. The fourth group i.e., $\frac{3}{4}$ full had its highest percentage in December (62.5%) followed by May (50%) and January (35.72%). The least number of stomach in the same category was in September (5.56%). Regarding the 'full' group, the percentage values were relatively low and only in July (24.29%) and June (19.84%) moderately good number of stomachs existed in the fifth category.

Females of *L. inermis* also showed highest percentage occurrence of '1/2 full' stomachs. 'Empty' stomach maintained a very close percentage compared to that of males. Significant variation was seen in the '3/4 full' category in which females had only 13.67% (males-20.78%). 'Full' stomach also showed a lower value in females (7.41%) than in males (9.18%). The highest percentage occurrence of empty stomach was in the month of October (55.72%). March, April and September also showed relatively high percentage values (>40%). ' $\frac{1}{2}$ Full' stomachs were numerous in November (75%), May (66.67%) and December (53.34%). The occurrence of 'full' stomach was relatively low owing to the absence of such stomachs in March, April, May, September, October and November (Table 3.12).

Comparison between the occurrence of stomachs of different distension in males and females of *L. inermis* is presented in Figure 3.4

Percentage occurrence of stomachs of different degrees of fullness was also worked out based on 2 mm class intervals for *T.travancoricus* (Table 3.13). The average percentage values were 20.45, 23.38, 29.31, 16.94 and 9.93 respectively against 'empty', '1/4full', '1/2full', '3/4full' and 'full'. 'Empty' stomachs were moderately high in the 8-9, 10-11, 12-13, 14-15, 22-23, 24-25 millimeter length groups. '1/4 full' stomachs were in good numbers in the 14-15, 20-21 and 32-33mm categories. The highest percentage in almost all length groups was seen in '1/2full' column. The percentage occurrence of '3/4full' stomachs was high in 28-29 mm group (22.58) followed by 32-33 mm and 12-13 mm length groups. Except in two classes (8-9mm and 32-33mm) all had 'full' stomachs, but its percentage occurrence was relatively very low in many length groups, the lowest being 5.45% in the 24-25 mm group.

Percentage of stomachs with various degrees of fullness in each 20mm length groups of *L. inermis* is given in Table 3.14. The average percentage value of 'empty', '1/4 full', and '1/2 full' stomach was around twenty-five percent. The fourth

category ie, '1/4full' gave an average of 15.51% whereas 'full' stomach was constituted by only 8.28%. 60-79 mm, 80-99 mm, 220-239 mm, 280-299 mm and 300-319 mm length groups did not give 'full' stomachs.

Feeding intensity by grouping 'empty' and '1/4full' (poor feeding) and '1/2full', '3/4full' and 'full' (actively fed) for the two sexes in *T. travancoricus* and *L. inermis* was shown in Table 3.15 and Table 3.16 respectively. The average percentage values of poorly fed males and females were 39.14% and 47.62% respectively. Actively fed state was higher both for males and females with 60.86% (males) and 52.38% (females). Males showed a better condition of feed than the females. Poorly fed males were more numerous in the months of August (64.58%), September (56.25%) and June (50%). At the same time females of the same status were profuse in June, July, August, September and October. The highest percentage of 66.07 was observed in October. On the other hand, actively fed males were seen in December (73.22%), January (70.84%), February (74.60%), March (73.22%) and April (70.84%). Percentage values of actively fed fishes were low in August (35.42%) and September (43.75%). High feeding intensities were shown by females from November to May. The highest percentage was observed in April (75%). June to

October provided less than fifty percent in the number of actively fed females of *T.travancoricus*, the lowest being 33.04% in August. Figure 3.5 explicitly sketches the difference in the average percentage of males and females of poorly fed condition. A comparison between the percentage occurrence of males and females of *T.travancoricus* in the actively fed condition is drawn in Figure 3.6.

Condition of feed in *L.inermis* is given in Table 3.16. The average percentage values for males and females in the poorly fed condition were 39 and 44.11, respectively. In males and females April, May, September, October and November provided 50% or more in favour of poorly fed individuals. The highest percentage of poorly fed males was observed in October and April. The lowest values of 12.50% and 10% were observed respectively for males and females in the month of December. Actively fed males formed 61% during the whole study period whereas contribution from females was a shade below (58.89%), compared to males. January, May, June, July, August and December provided very high feeding intensity in males. Low average percentage values were obtained in March, April, September and October. Females of *L. inermis* also followed a pattern which was in agreement with that of males. The highest feeding intensity was recorded in

December (90%). On the other hand, the lowest average of 30.95% was observed in April. The difference between the males and females of poor condition is shown in Figure 3.7. A comparison of males and females of actively fed condition is sketched in Figure 3.8.

Feeding intensity with reference to length group classification of *T.travancoricus* showed that 56.19% of fish were in the actively fed condition (Table 3.17). Only in two length groups i.e., 14-15 mm and 24-25 mm, the condition of active feeding was lower than fifty percent. Of the twelve size classes, apart from the length groups already mentioned, nine were fluctuating from 50% to 60%. 12-13mm, 16-17 mm and 28-29 mm size groups were having 62.07%, 67.57% and 61.29% of feeding intensity in the said order. Figure 3.9 represents the comparison of poorly fed and actively fed individuals of *T.travancoricus* against length groups.

Condition of feed in different length groups of *L. inermis* from January 2000 to December 2001 is tabulated in Table 3.18. Poorly fed and actively fed individuals were almost equal when the overall average percentage was computed. Unlike that of *T.travancoricus*, feeding intensity fluctuated greatly from a moderate percentage of 30.77 (160-179 mm length group) to 68.42% in the 120-139 mm size class.

Actively fed fish were not numerous in the 220-239 mm and 240-259 mm length groups. A comparison of poorly fed and actively fed individuals belonging to the thirteen size classes is drawn in Figure 3.10.

Feeding index of males and females of *T.travancoricus* is presented in Table 3.19. Among males high feeding indices were observed in January (58.93%) February (53.13%), March (50%) and April (53.57%). June, July, August, September and October showed relatively low feeding index values with the least in August (28.57%). Feeding index in females presented a different pattern with high values in January (51.56%) and April (59.38%). July, August and September were the months in which the females showed low feeding indices. Variation in feeding index of males and females of *T.travancoricus* is shown in Figure 3.11.

Monthly fluctuation of feeding index in males and females of *L. inermis* is tabulated in Table 3.20. Feeding index was more than 50% in January (53.57%), May (62.50%), June (51.56%), July (56.25%) and December (62.50%). April and October were the months in which males had low feeding indices. In females January, July, November and December showed feeding indices from 50% onwards. The highest, as in males, was in December. The lowest feeding index observed

during the study period was 15% in October. March, April and September also had low feeding indices in females. The difference between the monthly variation of feeding index in males and females is shown in Figure 3.12.

Length group based observation on the feeding index of *T. travancoricus* showed highest value in the 33-34 mm category. 48.53%, 46.77% and 46.61% were the moderately high feeding indices in the descending order obtained for the 20-21 mm, 28-29 mm and 18-19mm size classes. The lowest ever value of 33.78% was observed in the 16-17 mm category. Feeding indices against different size groups are tabulated in Table 3.21. In *L. inermis*, 120-139mm length group had the highest feeding index (53.95%). 200-219 mm category only gave the second highest value (48.28%). The least index was observed in the 280-299 mm length group. The fluctuation of feeding index in various size classes of *L. inermis* is presented in Table 3.22.

Monthly average gastroscopic indices of males, females and pooled samples of *T. travancoricus* during the study period from October 1999 to September 2001 are tabulated in Table 3.23. The average values for the two years separately and pooled for males were 4.29, 4.08 and 4.18. A glance at the fluctuation of GSI for the pooled data of males showed a

steady increase from October to April, with a peak value in April (5.47). In females, the lowest gastroscopic index was obtained in September (1.91). Once again, as in males, GSI increased from October to April. The highest GSI for males during the whole study period was observed in March 2000. On the other hand females showed a maximum gastroscopic index in April 2001. The variation in the gastroscopic indices (average) of males and females of *T.travancoricus* is drawn in Figure 3.13.

Table 3.24 represents the variation in the gastroscopic indices of males and females of *L.inermis* during 2000, 2001 and average of the two years. The pooled data for males showed the highest GSI in July (7.69), followed by January (7.33). The lowest observed value for the same sex was 3.45 in October. In females, 8.31 was the highest gastroscopic index (July) observed. As in males January held the second position (7.7). October and May showed the two lowest indices respectively with 2.42 and 2.58. The highest ever GSI of males during the whole study period for *L. inermis* occurred in July 2000 (7.96). In females the same feature was observed in July 2001 (8.71). Fig. 3.14 represents the fluctuation in the average gastroscopic indices of males and females of *L.inermis*.

DISCUSSION

The food and feeding ecology of fishes has long been a favourite subject for study because information on diets, food availability and feeding behaviour of fishes is fundamental to an understanding of their community structure, distribution patterns and life history strategies (Blaber, 1997a).

A detailed analysis of the food content of *T.travancoricus* showed that crustaceans and crustacean fragments, digested animal tissue, fish scale and fish fin collectively constituted more than 80% of the food content in males and 82% in females even after leaving aside the miscellaneous component which included diatoms, rotifers, mites, insect wings etc. The occurrence of zooplankton represented by copepoda, cladocera, rotifera, aquatic mites as well as phytoplankton like chlorophyceae and diatoms indicated the surface feeding habit of fish. The sporadic occurrence of sand grains could be attributable to the stirring up of water especially during the monsoon months. The crustacean elements were noted in the food round the year. The onset of monsoon showed a decline in the number of mites and rotifers. It is in conformity with the findings of John (2001) and Francy (2003) respectively who could observe reduction in the density of those organisms owing mainly to

the inundation of the collection centre. Algal component was present in the food all through the year. The absence of organic detritus, mud and rooted plants indicated that *T. travancoricus* did not favour bottom-browsing habit. Lepidophagous inclination (pulling scales off other fishes) was shown by both the sexes irrespective of their size. Lepidophagy is known in a number of cichlid genera. It is quite common in freshwaters. According to Blaber (1997a) lepidophagy is advantageous since scales have a relatively high calorific value. Leim (1980) reported that to pull off scales and bite off fins from fishes required particular pattern of jaw muscle activity unlike the mechanism for plankton feeding. So it could be concluded that diverse jaw muscle activities exist in *T. travancoricus* to facilitate acquisition of food. There was no noticeable shift in the food component of fish belonging to the small size groups but for the presence of more number of minute organisms and near absence of fish scales and fin.

The qualitative and quantitative analyses of the stomach contents of males and females of *L. inermis* proved that the fish is highly carnivorous. The average percentage composition of animal matter (entire fish, fish pieces, semi-digested animal tissue, scales, fins, spines, crabs, crustaceans etc.) substantiated the conclusion. Furthermore, like many

other pelagic food seekers, *L.inermis* was also found to maintain a tremendous inclination for fish as its prey. Carnivory and piscivory are quite common in marine systems. Bone *et al.* (1995) opined that herbivorous fishes are very much in the minority in marine waters. Perhaps, it is because more energy has to be expended by herbivores for foraging. Furthermore, in carnivorous fishes, the energy absorption efficiency is very high. The absence of convoluted interstine and presence of large stomach also supported the carnivorous nature of *L.inermis*. Dasgupta (2002) conducted morphometric studies on the alimentary canal of some freshwater teleosts, only to conclude that large stomachs indicated carnivorous feeding.

L. inermis included a number of fishes in its menu. The worst hit was the whitebait, *Stolephorus* sp. The occurrence of small whole fish in the stomach of the predator was quite common during April, May, June, November and December. It coincided with the spawning periods of whitebaits along the south-west coast (Jayaprakash, 2003). The silverbellies, *Secutor* sp. and *Leiognathus* sp. were also seen in the stomachs in full and in part during the monsoon periods. The time of occurrence of youngones of silverbellies in the stomachs was in agreement with the report of Sriramachandra Murthy *et al.*

(2003). The powerful dentition is also used for cutting pieces of flesh off larger preys. The profuse occurrence of scales could not be attributed to lepidophagy but to the digestion of devoured fish. Whitebaits and silverbellies form prey for many a fish. *L. inermis* also shows immense inclination for the said items and joins the club of carangids, ribbon fishes, sciaenids, seerfishes, tunas, etc. (CMFRI, 2003) as a competitor for whitebaits and/or silverbellies. Darnell's (1961) suggestion that in a community only a few species suffer heavy loss from predatory fishes, holds good in the present study too.

Crustaceans, crustacean fragments and appendages were seen in the guts of small fishes and with increase in length and hence age, the food preponderance changed from crustacean dominated diet to predation on fishes, mainly. The percentage occurrence of the cuttlefish was high in the early months of the year, which goes in hand with the observation of Meiyappan and Mohamed (2003) that *Sepia aculeata* appeared on the west coast during the abovementioned time. The cuttle fish food component could be treated as an occasional food item of the predator.

When the percentage occurrence of stomachs at various degrees of fullness (full, 3/4 full, 1/2 full, 1/4 full and empty)

was studied it became evident that empty stomachs were more numerous from June onwards in males as well as females of *T.travancoricus*. Females showed considerable reluctance to feeding from June to October. It is reasonable to think that the drop in feeding was due to reproductive activity. Percentage of 'empty' stomachs was more in the 22-23mm, 24.-25 and 26-27 mm length group of *T.travancoricus*. This is the length range for the first time spawners of *T.travancoricus* (chapter VI) and hence good numbers of empty stomachs in the said size regime could be a manifestation of feeding quiescence during maturation of ova and spawning.

?
whether it
is agreeable
with the findings
on reproductive
period
which ?

Condition of feed in *T.travancoricus* could give a better picture when males and females were split into poorly fed and actively fed categories. Percentage of fish with poor feeding was high (more than 50%) from June to September in males except July. But females showed poor condition of feed from June to October. Size based studies on condition of feed provided the information that highest number of fish with poor condition belonged to the 24-25 mm size-group.

Feeding index is another measure to access information on feeding behaviour. When monthly variation in the feeding index of *T.travancoricus* was worked out, it became clear that feeding index started increasing from November and extended

up to May in males. In females, feeding indices were high in December, January, February, March and April. The length-group based observation of feeding index showed that 24-25 mm and 26-27 mm size classes of *T.travancoricus* exhibited moderately low indices. The said length range was the size of fish at first spawning.

Different authors were of diverse view on the variation in feeding. Natarajan and Jhingran (1963) observed that reduction in feeding intensity was due to gonad maturation and spawning. Qayyum and Qasim (1965) reported that the quality and quantity of food consumed by fish was influenced by physical factors (temperature, rainfall) and biological factors like gonad maturity and spawning. Thavamani (1969) supplemented food supply as a reason for variation in feeding but contradicted by suggesting that temperature had no bearing on feeding while the food and feeding of *Megalops cyprinoides* was discussed. Kesava *et al.* (1988) reported that apart from maturation of gonads and non-availability of food, ill-health might also influence feeding intensity. Shyam Sunder (1990) and Rao *et al.* (1998) too favoured the opinion that spawning had a bearing on rate of feeding.

The sum total of all observations on the feeding activity of *T.travancoricus*, sex-wise and length-wise proved that

feeding sluggishness did occur during the months of reproductive activity. Abundance of various food items could be designated as one of the factors for increased feeding activity in the hot months of the year, rather than temperature.

Percentage occurrence of stomachs at various degrees of fullness in *L.inermis* proved the information that March, April, September, October, November were the months in which very good numbers of 'empty' stomachs occurred in males. In females, no 'empty' stomach was observed in November probably due to the very small sample size. Both sexes had almost equal percentage of 'empty' stomachs when average for the two were considered (males, 28.50% and females, 28.11%). The average percentage of 'full' stomach was less than ten in males and females. It might be owing to the fast rate of digestion existing in carnivores, swelling the average percentage of '1/2 full' and '3/4full'. The absence of 'full' stomach in March, April, May, September, October and November in females could be attributable to the maturation of ova, spawning and post-spawning lethargy (May and November). Length-group based observation on the occurrence of various stomachs showed that there existed good numbers of 'empty' stomachs at ages one, two and three years (chapter IV) which in turn coincided with the spawning time.

Observation on the intensity of feeding showed that the overall percentage for actively fed males and females of *L.inermis* were 61% and 58.89% respectively. Poorly fed individuals were seen in March, April, September, October and November. Once again poor feeding intensity can be assigned to the inflation and deflation of ovaries. Higher number of fish in active feeding intensity is attributable to the post-spawning recovery. The high percentage of poorly fed fish in the 160-179 mm size-class is in agreement with the breeding activity as the said length range was found to be the time of first spawners (chapter VI). In *L.inermis*, the percentage occurrence of poorly fed and actively fed individuals was almost in equal proportion though fluctuation existed in various size categories and hence age. Such a type of discretion among individuals of different ages is advantageous, perhaps for the well-being and perpetuation of the species.

The measure of feeding index once again showed seasonal fluctuation in feeding. Indices fluctuated between 15% and 62.50%. Feeding index was also dependent on the breeding period and spawning. The high rate of feeding index in the months May, June, July, November, December and January indicated the recovery of both the sexes after intense spawning. The availability of the esteemed food items during

the monsoon months too, favoured increase in the rate of feeding. The first time breeders belonging to the 160-179 mm length-group showed only a moderate feeding index.

Variation in the gastroscopic index of *T.travancoricus* as well as *L.inermis* showed the same pattern of fluctuation observed for the other important measures of feeding like percentage occurrence of stomachs of diverse degrees of fullness, feeding intensity (poorly fed and actively fed) and feeding index. In *T.travancoricus* females were less active in feeding especially during the breeding season. This might be owing to the maturation of ova and spawning stress experienced by females. Higher values of gastroscopic index from December to May were indicative of intense feeding in the post-spawning period. Though temperature was attributed as one of the reasons for change in intensity of feeding (Qayyum and Qasim, 1965), an increase of gastroscopic index in *T.travancoricus* during the summer months was mainly due to the availability and abundance of various food items like rotifers, crustaceans, mites etc.

In *L.inermis* peak summer months (March, April and May) provided low gastroscopic indices, in sharp contrast with *T.travancoricus*. Once again, as in freshwater pufferfish, it was due to maturation, spawning stress. GSI plummeted

from 6.12 (August) to 3.06 (September) only to remain at a low level till December. This actually coincided with the second spawning time of the species. High gonadosomatic index values during the peak monsoon (south-west) months were primarily due to, fast recovery from the lean period of feeding and availability of fish fry as majority of fishes spawn in the aforesaid season. A sudden hike in the GSI from November to December could also be assigned to voracious eating after a feeding quiescence in the spawning period.

Table 3.1. Percentage composition of various food items of *Tetraodon travancoricus* (males)

A. October 1999-September 2000

| Month | I | II | III | IV | V | VI |
|-------|-------|-------|-------|------|-------|-------|
| Oct | 43.33 | 23.33 | 6.67 | 8.33 | 10.00 | 8.33 |
| Nov | 53.85 | 24.36 | 2.56 | 2.31 | 10.51 | 6.41 |
| Dec | 48.94 | 16.60 | 14.47 | 4.68 | 8.94 | 6.38 |
| Jan | 42.86 | 22.45 | -- | - | 14.28 | 20.41 |
| Feb | 42.55 | 23.40 | 10.64 | 6.38 | 12.76 | 4.26 |
| Mar | 62.5 | 16.07 | 4.46 | 4.46 | 7.59 | 4.91 |
| Apr | 52.73 | 17.27 | 7.64 | 6.91 | 11.82 | 5.45 |
| May | 65.22 | 20.11 | 1.63 | 1.09 | 4.35 | 7.61 |
| Jun | 42.10 | 31.05 | 3.16 | - | 13.86 | 9.87 |
| Jul | 39.06 | 29.69 | 7.81 | - | 10.94 | 12.50 |
| Aug | 45.71 | 23.43 | 5.14 | - | 12.86 | 12.86 |
| Sep | 33.82 | 30.88 | 6.47 | 5.29 | 13.24 | 10.29 |

B. October 2000-September 2001

| Month | I | II | III | IV | V | VI |
|-------|-------|-------|-------|------|-------|-------|
| Oct | 52.58 | 17.74 | 7.10 | 9.68 | 4.84 | 8.06 |
| Nov | 48.61 | 21.67 | 6.11 | 3.47 | 13.19 | 6.94 |
| Dec | 53.49 | 24.42 | 6.98 | 3.49 | 6.98 | 4.65 |
| Jan | 56.52 | 19.56 | 6.52 | - | 6.52 | 10.87 |
| Feb | 49.02 | 17.65 | 10.29 | 9.31 | 6.37 | 7.35 |
| Mar | 57.14 | 18.88 | 6.12 | 3.88 | 8.37 | 5.61 |
| Apr | 56.60 | 20.38 | 6.04 | 5.66 | 8.49 | 4.72 |
| May | 54.76 | 22.62 | 5.24 | 3.57 | 6.67 | 7.14 |
| Jun | 45.00 | 24.50 | 5.50 | 3.50 | 9.00 | 10.00 |
| Jul | 48.28 | 24.14 | 10.34 | - | 8.62 | 8.62 |
| Aug | 42.65 | 25.00 | 5.88 | 2.94 | 13.24 | 10.29 |
| Sep | 33.33 | 33.33 | 12.12 | 7.58 | 6.06 | 7.58 |

C. October 1999-September 2001

| Month | I | II | III | IV | V | VI |
|---------|-------|-------|-------|------|-------|-------|
| Oct | 47.95 | 20.53 | 6.88 | 9.00 | 7.42 | 8.19 |
| Nov | 51.23 | 23.01 | 4.33 | 2.89 | 11.85 | 6.67 |
| Dec | 51.21 | 20.51 | 10.72 | 4.08 | 7.96 | 5.51 |
| Jan | 49.69 | 21.00 | 3.26 | - | 10.40 | 15.64 |
| Feb | 45.78 | 20.52 | 10.46 | 7.84 | 9.56 | 5.80 |
| Mar | 59.82 | 17.47 | 5.29 | 4.17 | 7.98 | 5.26 |
| Apr | 54.66 | 18.82 | 6.84 | 6.28 | 10.15 | 5.08 |
| May | 59.99 | 21.36 | 3.43 | 2.33 | 5.51 | 7.37 |
| Jun | 43.55 | 27.77 | 4.33 | 1.75 | 11.43 | 9.93 |
| Jul | 43.67 | 26.91 | 9.07 | - | 9.78 | 10.56 |
| Aug | 44.18 | 24.21 | 5.51 | 1.47 | 13.05 | 11.57 |
| Sep | 33.57 | 32.10 | 9.29 | 6.43 | 9.65 | 8.93 |
| Average | 48.77 | 22.85 | 6.61 | 3.85 | 9.56 | 8.37 |

I crustaceans, II-semi-digested tissue, III-scales, IV-fin, V-algal filaments, VI-miscellaneous.

15
100%

Table 3.2. Percentage composition of various food items of *Tetraodon travancoricus* (females)

A. October 1999 – September 2000

| Month | I | II | III | IV | V | VI |
|-------|-------|-------|------|------|-------|-------|
| Oct | 44.44 | 29.67 | 9.72 | - | 8.33 | 8.33 |
| Nov | 38.21 | 27.86 | 6.25 | 4.46 | 14.29 | 8.93 |
| Dec | 52.78 | 18.06 | 9.72 | 6.11 | 7.78 | 5.56 |
| Jan | 56.82 | 20.45 | 7.95 | - | 6.82 | 7.95 |
| Feb | 47.78 | 28.33 | 7.72 | 5.56 | 6.11 | 5.00 |
| Mar | 52.08 | 23.44 | 7.81 | 6.25 | 5.21 | 5.21 |
| Apr | 52.17 | 24.56 | 5.87 | 3.91 | 6.96 | 6.52 |
| May | 47.58 | 29.84 | - | - | 10.48 | 12.10 |
| Jun | 23.16 | 39.47 | 6.32 | - | 8.95 | 22.10 |
| Jul | 30.00 | 47.50 | - | 5.00 | 7.50 | 10.00 |
| Aug | 34.62 | 38.46 | 7.70 | 3.85 | 7.70 | 7.70 |
| Sep | 35.00 | 27.50 | 8.50 | 6.50 | 7.50 | 15.00 |

B. October 2000 – September 2001

| Month | I | II | III | IV | V | VI |
|-------|-------|-------|------|------|-------|-------|
| Oct | 47.50 | 27.50 | 7.50 | 3.75 | 6.25 | 7.50 |
| Nov | 44.00 | 24.00 | 6.00 | 4.80 | 15.20 | 6.00 |
| Dec | 54.55 | 19.70 | 7.58 | 6.06 | 7.58 | 4.54 |
| Jan | 47.50 | 25.00 | 8.75 | 7.50 | 6.25 | 5.00 |
| Feb | 56.38 | 22.34 | 4.26 | 5.32 | 6.38 | 5.32 |
| Mar | 51.11 | 21.78 | 7.11 | 5.78 | 7.56 | 6.67 |
| Apr | 54.00 | 27.00 | 5.00 | 4.00 | 6.00 | 4.00 |
| May | 33.79 | 36.90 | 8.62 | - | 12.07 | 8.62 |
| Jun | 20.00 | 50.83 | 4.17 | - | 9.17 | 15.83 |
| Jul | 32.35 | 41.18 | - | - | 11.76 | 14.71 |
| Aug | 32.61 | 30.43 | 8.70 | 4.35 | 13.04 | 10.87 |
| Sep | 38.89 | 38.89 | - | - | 11.11 | 11.11 |

C. October 1999 – September 2001

| Month | I | II | III | IV | V | VI |
|---------|-------|-------|------|------|-------|-------|
| Oct | 45.97 | 28.58 | 8.61 | 1.87 | 7.29 | 7.91 |
| Nov | 41.11 | 25.93 | 6.12 | 4.63 | 14.74 | 7.46 |
| Dec | 53.67 | 18.88 | 8.65 | 6.08 | 7.68 | 5.05 |
| Jan | 52.16 | 22.72 | 8.35 | 3.75 | 6.53 | 6.47 |
| Feb | 52.08 | 25.33 | 5.99 | 5.44 | 6.24 | 5.16 |
| Mar | 51.60 | 22.61 | 7.46 | 6.01 | 6.38 | 5.94 |
| Apr | 53.09 | 25.78 | 5.43 | 3.95 | 6.48 | 5.26 |
| May | 40.69 | 33.37 | 4.31 | - | 11.27 | 10.36 |
| Jun | 21.58 | 45.15 | 5.24 | - | 9.06 | 18.96 |
| Jul | 31.18 | 44.34 | - | 2.50 | 9.63 | 12.35 |
| Aug | 33.62 | 34.44 | 8.20 | 4.10 | 10.37 | 9.28 |
| Sep | 36.95 | 33.19 | 4.25 | 3.25 | 9.30 | 13.05 |
| Average | 42.80 | 30.02 | 6.05 | 3.46 | 8.74 | 8.93 |

I crustaceans, II-semi-digested tissue, III-scales IV-fin, V-algal filaments, VI-miscellaneous.

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Table 3.3. Percentage composition of various food item of *Lagocephalus inermis* (males)

A January 2000 – December 2001

| Month | I | II | III | IV | V | VI | VII | VIII |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Jan | 30.43 | 26.09 | 10.14 | 5.79 | 7.25 | 17.39 | - | 2.90 |
| Feb | 25.71 | 42.86 | 12.86 | 7.14 | 5.71 | 2.86 | - | 2.86 |
| Mar | 26.12 | 28.57 | 12.24 | 14.28 | 6.33 | - | 6.33 | 6.12 |
| Apr | 43.27 | 34.21 | 13.16 | 4.10 | - | - | - | 5.26 |
| May | 27.59 | 24.14 | 8.62 | 1.72 | 3.45 | 3.45 | 24.14 | 6.89 |
| Jun | 25.76 | 34.85 | 12.12 | 13.64 | - | 7.57 | - | 6.06 |
| Jul | 22.78 | 39.97 | 12.66 | 10.12 | 11.39 | 1.27 | - | 3.80 |
| Aug | 31.74 | 41.27 | 11.11 | 6.35 | 3.17 | - | - | 6.35 |
| Sep | 17.78 | 33.33 | 11.11 | 13.33 | 4.44 | - | 2.22 | 17.78 |
| Oct | 25.00 | 25.00 | 12.81 | 9.06 | 6.25 | 9.38 | - | 12.50 |
| Nov | 18.60 | 37.21 | 11.63 | 9.30 | 11.63 | 2.33 | - | 9.30 |
| Dec | 22.22 | 31.48 | 9.26 | 7.41 | 3.70 | 16.67 | - | 9.56 |

B. January 2001 – December 2001

| Month | I | II | III | IV | V | VI | VII | VIII |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Jan | 34.21 | 25.00 | 3.95 | 7.89 | 6.58 | 19.74 | - | 2.63 |
| Feb | 26.56 | 40.62 | 9.37 | 4.69 | 4.69 | - | 9.38 | 4.69 |
| Mar | 9.30 | 30.23 | 16.28 | 9.30 | 9.30 | - | 11.63 | 13.95 |
| Apr | 38.33 | 43.59 | 7.69 | 5.13 | 5.13 | - | - | 5.13 |
| May | 32.73 | 29.09 | 7.27 | 3.64 | 5.45 | 5.45 | 10.91 | 5.45 |
| Jun | 27.40 | 41.09 | 4.11 | 5.48 | - | 13.70 | - | 8.22 |
| Jul | 27.03 | 37.84 | 6.76 | 10.81 | 10.81 | 1.35 | - | 5.41 |
| Aug | 29.23 | 35.38 | 9.23 | 10.78 | 6.15 | 1.54 | - | 7.69 |
| Sep | 26.19 | 33.33 | 9.52 | 9.52 | 4.76 | - | 2.38 | 11.90 |
| Oct | 13.33 | 26.67 | 20.00 | 10.33 | 9.67 | 6.67 | - | 13.33 |
| Nov | 16.67 | 39.58 | 10.42 | 8.33 | 6.25 | 4.17 | 2.08 | 12.50 |
| Dec | 29.31 | 34.48 | 7.76 | 6.03 | 5.17 | 3.45 | 5.17 | 8.62 |

C. January 2000 – December 2001

| Month | I | II | III | IV | V | VI | VII | VIII |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|
| Jan | 32.32 | 25.54 | 7.04 | 6.84 | 6.91 | 18.56 | - | 2.76 |
| Feb | 26.13 | 41.74 | 11.11 | 5.91 | 5.20 | 1.43 | 4.69 | 3.77 |
| Mar | 17.71 | 29.40 | 14.26 | 11.79 | 7.81 | - | 8.98 | 10.03 |
| Apr | 38.30 | 38.90 | 10.42 | 4.61 | 2.56 | - | - | 5.19 |
| May | 30.16 | 26.61 | 7.94 | 2.68 | 4.45 | 4.45 | 17.52 | 6.17 |
| Jun | 26.58 | 37.97 | 8.11 | 9.56 | - | 10.63 | - | 7.14 |
| Jul | 24.90 | 38.90 | 9.71 | 10.46 | 11.10 | 1.31 | - | 4.60 |
| Aug | 30.48 | 38.32 | 10.17 | 8.56 | 4.66 | 0.77 | - | 7.02 |
| Sep | 21.98 | 33.33 | 10.31 | 11.42 | 4.60 | - | 2.30 | 14.84 |
| Oct | 19.16 | 25.83 | 16.40 | 9.69 | 7.96 | 8.02 | - | 12.91 |
| Nov | 17.63 | 38.39 | 11.02 | 8.81 | 8.94 | 3.25 | 1.04 | 10.90 |
| Dec | 25.76 | 32.98 | 8.51 | 6.72 | 4.43 | 10.06 | 2.58 | 9.09 |
| Average | 25.93 | 34.00 | 10.42 | 8.09 | 5.72 | 4.87 | 3.09 | 7.87 |

I-Fish & fish pieces, II – Semi-digested tissue, III-scales, IV-Fins, V-Spines, VI-Crustacean, VII-Cephalopods, VIII-Miscellaneous.

Table 3.4. Percentage composition of various food items of *Lagocephalus inermis* (females)

A. January 2000 – December 2000

| Month | I | II | III | IV | V | VI | VII | VIII |
|-------|-------|-------|-------|-------|------|-------|-------|-------|
| Jan | 30.77 | 46.79 | 7.05 | 8.33 | 3.85 | - | - | 3.21 |
| Feb | 31.67 | 35.00 | 6.50 | 10.00 | 3.50 | - | 6.83 | 6.50 |
| Mar | 8.57 | 34.28 | 14.00 | 11.71 | 8.57 | - | 14.28 | 8.57 |
| Apr | 16.67 | 37.50 | 16.67 | 12.50 | 8.33 | - | - | 8.33 |
| May | 28.89 | 17.78 | 11.11 | 8.89 | 6.67 | 11.11 | 4.44 | 11.11 |
| Jun | 19.44 | 31.94 | 9.72 | 6.94 | 4.17 | 18.05 | - | 9.72 |
| Jul | 30.38 | 35.44 | 6.33 | 11.39 | 6.33 | 3.80 | - | 6.33 |
| Aug | 32.26 | 30.64 | 8.06 | 11.29 | 9.68 | - | - | 8.06 |
| Sep | 17.25 | 31.03 | 17.25 | 13.79 | 6.90 | - | - | 13.79 |
| Oct | 6.00 | 36.00 | 16.80 | 8.00 | 8.00 | 11.20 | - | 14.00 |
| Nov | 12.82 | 38.46 | 15.38 | 10.26 | 5.13 | 5.13 | - | 12.82 |
| Dec | 23.81 | 38.09 | 9.52 | 7.94 | 6.35 | 3.17 | 1.59 | 9.52 |

B. January 2001 – December 2001

| Month | I | II | III | IV | V | VI | VII | VIII |
|-------|-------|-------|-------|-------|------|-------|-------|-------|
| Jan | 20.00 | 26.67 | 9.33 | 10.67 | 8.00 | 4.00 | 13.33 | 8.00 |
| Feb | 23.88 | 34.33 | 6.87 | 10.45 | 8.06 | - | 9.25 | 7.16 |
| Mar | 11.54 | 42.31 | 15.38 | 11.54 | 7.69 | 3.85 | - | 7.69 |
| Apr | 19.64 | 35.71 | 16.07 | 8.93 | 7.14 | - | - | 12.50 |
| May | 24.49 | 28.57 | 10.20 | 6.12 | 6.12 | 8.16 | 8.16 | 8.16 |
| Jun | 25.00 | 33.82 | 8.82 | 5.88 | 2.94 | 14.70 | - | 8.82 |
| Jul | 28.73 | 36.78 | 4.60 | 9.19 | 6.90 | - | 4.60 | 9.19 |
| Aug | 23.73 | 30.51 | 13.56 | 11.86 | 5.08 | 3.39 | - | 11.86 |
| Sep | 14.52 | 29.03 | 12.90 | 16.13 | 9.68 | 3.22 | - | 14.52 |
| Oct | 6.52 | 34.78 | 21.74 | 4.35 | 4.35 | 8.69 | - | 19.56 |
| Nov | 13.33 | 42.22 | 11.11 | 8.89 | 4.44 | 2.22 | 2.22 | 15.56 |
| Dec | 24.56 | 35.09 | 8.77 | 10.53 | 5.26 | 3.51 | 1.75 | 10.53 |

C. January 2000 – December 2001

| Month | I | II | III | IV | V | VI | VII | VIII |
|---------|-------|-------|-------|-------|------|-------|------|-------|
| Jan | 25.38 | 36.73 | 8.19 | 9.50 | 5.93 | 2.00 | 6.67 | 5.60 |
| Feb | 27.77 | 34.66 | 6.68 | 10.22 | 5.78 | - | 8.04 | 6.83 |
| Mar | 10.05 | 38.29 | 14.69 | 11.62 | 8.13 | 1.92 | 7.14 | 8.13 |
| Apr | 18.15 | 36.60 | 16.37 | 10.71 | 7.73 | - | - | 10.41 |
| May | 26.69 | 23.17 | 10.65 | 7.50 | 6.39 | 9.63 | 6.30 | 9.63 |
| Jun | 22.22 | 32.88 | 9.27 | 6.41 | 3.55 | 16.37 | - | 9.27 |
| Jul | 29.56 | 36.11 | 5.47 | 10.29 | 6.61 | 1.90 | 2.30 | 7.76 |
| Aug | 27.99 | 30.57 | 10.81 | 11.57 | 7.38 | 1.69 | - | 9.96 |
| Sep | 15.89 | 30.03 | 15.08 | 14.96 | 8.29 | 1.61 | - | 14.16 |
| Oct | 6.26 | 35.39 | 19.27 | 6.17 | 6.17 | 9.94 | - | 16.78 |
| Nov | 13.07 | 40.34 | 13.24 | 9.57 | 4.78 | 3.67 | 1.11 | 14.19 |
| Dec | 24.18 | 36.59 | 9.14 | 9.23 | 5.80 | 3.34 | 1.67 | 10.02 |
| Average | 20.60 | 34.28 | 11.57 | 9.81 | 6.38 | 4.35 | 2.77 | 10.23 |

I-Fish & fish pieces, II – Semi-digested tissue, III-Scales, IV-Fins, V- Spines, VI-Crustacean, VII-Cephalopods, VIII-Miscellaneous

Table 3.5. Percentage of stomachs at various degrees of fullness in males of *Tetraodon travancoricus*

| Month | 1999-2000 | | | | | 2000-2001 | | | | |
|-------|-----------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|
| | I | II | III | IV | V | I | II | III | IV | V |
| Oct | 16.67 | 16.67 | 66.66 | - | - | 50.00 | - | 37.50 | - | 12.50 |
| Nov | 33.33 | - | 33.33 | 16.67 | 16.67 | 25.00 | 12.50 | 50.00 | - | 12.50 |
| Dec | 12.50 | 12.50 | 37.50 | 12.50 | 25.00 | 28.57 | - | 42.87 | 14.28 | 14.28 |
| Jan | 12.50 | 12.50 | 25.00 | 25.00 | 25.00 | 16.67 | 16.67 | 33.33 | 16.67 | 16.67 |
| Feb | 28.57 | - | 42.86 | 14.28 | 14.28 | 11.11 | 11.11 | 33.33 | 22.22 | 22.22 |
| Mar | 14.28 | 14.28 | 28.57 | 28.57 | 14.28 | 25.00 | - | 50.00 | 12.50 | 12.50 |
| Apr | 16.67 | 16.67 | 33.33 | 16.67 | 16.67 | 25.00 | - | 25.00 | 25.00 | 25.00 |
| May | 28.57 | 14.28 | 28.57 | 28.57 | - | 33.33 | - | 33.33 | - | 33.33 |
| Jun | 33.33 | 16.67 | 33.33 | 16.67 | - | 37.50 | 12.50 | 37.50 | - | 12.50 |
| Jul | 28.57 | 14.28 | 28.57 | 14.28 | 14.28 | 50.00 | - | 50.00 | - | - |
| Aug | 50.00 | 16.67 | 16.67 | 16.67 | - | 37.50 | 25.00 | 25.00 | - | 12.50 |
| Sep | 37.50 | 25.00 | 25.00 | 12.5 | - | 25.00 | 25.00 | 25.00 | 12.50 | 12.50 |

I-Empty, II- ¼ Full, III- ½ Full, IV- ¾ Full, V-Full

Table 3.6. Percentage of stomachs at various degrees of fullness in females of *Tetraodon travancoricus*

| Month | 1999-2000 | | | | | 2000-2001 | | | | |
|-------|-----------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|
| | I | II | III | IV | V | I | II | III | IV | V |
| Oct | 50.00 | 25.0 | 12.50 | 12.50 | - | 42.86 | 14.28 | 42.86 | - | - |
| Nov | 28.57 | 14.28 | 42.86 | 14.28 | - | 28.57 | - | 57.14 | - | 14.29 |
| Dec | 33.33 | 16.67 | 16.67 | 16.67 | 16.67 | 25.00 | 12.50 | 37.50 | 12.50 | 12.50 |
| Jan | 22.22 | 11.11 | 22.22 | 22.22 | 22.22 | 14.28 | 14.28 | 42.87 | 14.28 | 14.28 |
| Feb | 22.22 | 11.11 | 33.33 | 11.11 | 22.22 | 33.33 | - | 22.22 | 33.33 | 11.11 |
| Mar | 22.22 | 22.22 | 11.11 | 22.22 | 22.22 | 28.57 | 14.28 | 28.57 | 14.28 | 14.28 |
| Apr | 12.50 | 12.50 | 25.00 | 12.50 | 37.50 | 25.00 | - | 25.00 | 25.00 | 25.00 |
| May | 16.67 | 33.33 | 33.33 | 16.67 | - | 28.57 | 14.28 | 42.86 | - | 14.28 |
| Jun | 50.00 | 12.50 | 25.00 | 12.50 | - | 50.00 | - | 37.50 | 12.50 | - |
| Jul | 42.86 | 14.28 | 28.57 | 14.28 | - | 57.14 | 14.28 | 28.57 | - | - |
| Aug | 57.14 | 14.28 | 28.57 | - | - | 37.50 | 25.00 | 25.00 | - | 12.50 |
| Sep | 33.33 | 22.22 | 44.44 | - | - | 37.50 | 25.00 | 37.50 | - | - |

I-Empty, II- ¼ Full, III- ½ Full, IV- ¾ Full, V-Full

Table 3.7. Percentage of stomachs at various degree of fullness in males of *Tetraodon travancoricus* (pooled) from Oct. 1999 to Sep. 2001.

| Month | No. of fish | Empty | ¼ Full | ½ Full | ¾ Full | Full |
|---------|-------------|-------|--------|--------|--------|-------|
| Oct | 14 | 33.33 | 8.34 | 52.08 | - | 6.25 |
| Nov | 14 | 29.16 | 6.25 | 41.66 | 8.34 | 14.59 |
| Dec | 15 | 20.53 | 6.25 | 40.19 | 13.39 | 19.64 |
| Jan | 14 | 14.59 | 14.59 | 29.16 | 20.83 | 20.83 |
| Feb | 16 | 19.84 | 5.56 | 38.10 | 18.25 | 18.25 |
| Mar | 15 | 19.64 | 7.14 | 39.29 | 20.54 | 13.39 |
| Apr | 14 | 20.83 | 8.33 | 29.16 | 20.84 | 20.84 |
| May | 13 | 30.95 | 7.14 | 30.95 | 14.29 | 16.67 |
| Jun | 20 | 35.42 | 14.58 | 35.42 | 8.33 | 6.25 |
| Jul | 13 | 39.29 | 7.14 | 39.29 | 7.14 | 7.14 |
| Aug | 14 | 43.75 | 20.83 | 20.83 | 8.34 | 6.25 |
| Sep | 16 | 31.25 | 25.00 | 25.00 | 12.50 | 6.25 |
| Average | | 28.22 | 10.93 | 35.09 | 12.73 | 13.03 |

Table 3.8. Percentage of stomachs at various degree of fullness in females of *Tetraodon travancoricus* (pooled) from Oct. 1999 to Sep. 2001.

| Month | No. of fish | Empty | ¼ Full | ½ Full | ¾ Full | Full |
|---------|-------------|-------|--------|--------|--------|-------|
| Oct | 15 | 46.43 | 19.64 | 27.68 | 6.25 | - |
| Nov | 14 | 28.57 | 7.14 | 50.00 | 7.14 | 7.15 |
| Dec | 14 | 29.17 | 14.58 | 27.09 | 14.58 | 14.58 |
| Jan | 17 | 18.25 | 12.70 | 32.55 | 18.25 | 18.25 |
| Feb | 18 | 27.78 | 5.55 | 27.78 | 22.22 | 16.67 |
| Mar | 16 | 25.40 | 18.25 | 19.84 | 18.25 | 18.25 |
| Apr | 16 | 18.75 | 6.25 | 25.00 | 18.75 | 31.25 |
| May | 3 | 22.62 | 23.81 | 38.09 | 8.34 | 7.14 |
| Jun | 16 | 50.00 | 6.25 | 31.25 | 12.50 | - |
| Jul | 14 | 50.00 | 14.28 | 28.57 | 7.14 | - |
| Aug | 15 | 47.32 | 19.64 | 26.79 | - | 6.25 |
| Sep | 17 | 35.42 | 23.61 | 40.97 | - | - |
| Average | | 33.31 | 14.31 | 31.30 | 11.12 | 9.96 |

Table 3.9. Percentage of stomachs at various degrees of fullness in males of *Lagocephalus inermis*

| Month | 2000 | | | | | 2001 | | | | |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | I | II | III | IV | V | I | II | III | IV | V |
| Jan | 14.28 | 14.28 | 28.57 | 28.57 | 14.28 | - | 28.57 | 28.57 | 42.86 | - |
| Feb | 12.50 | 25.00 | 37.50 | 12.50 | 12.50 | 28.57 | 14.28 | 28.57 | 14.28 | 14.28 |
| Mar | 50.00 | 16.67 | 16.67 | 16.67 | - | 25.00 | 25.00 | 50.00 | - | - |
| Apr | 57.14 | 14.28 | 28.57 | - | - | 40.00 | 20.00 | 40.00 | - | - |
| May | - | - | - | 100.0 | - | - | - | 100.0 | - | - |
| Jun | 22.22 | 11.11 | 22.22 | 33.33 | 11.11 | 28.57 | - | 28.57 | 14.28 | 28.57 |
| Jul | 28.57 | - | 28.57 | 14.28 | 28.57 | - | 20.00 | 20.00 | 40.00 | 20.00 |
| Aug | 25.00 | 12.50 | 37.50 | 12.50 | 12.50 | 33.33 | - | 33.33 | 33.33 | - |
| Sep | 44.44 | 11.11 | 33.33 | 11.11 | - | 42.86 | 14.28 | 28.57 | - | 14.28 |
| Oct | 60.00 | - | 40.00 | - | - | 57.14 | 14.28 | 14.28 | - | 14.28 |
| Nov | 50.00 | - | 50.00 | - | - | 50.00 | - | 25.00 | - | 25.00 |
| Dec | 25.00 | - | 25.00 | 25.00 | 25.00 | - | - | - | 100.0 | - |

I-Empty, II- ¼ Full, III- ½ Full, IV- ¾ Full, V-Full

Table 3.10. Percentage of stomachs at various degrees of fullness in females of *Lagocephalus inermis*

| Month | 2000 | | | | | 2001 | | | | |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | I | II | III | IV | V | I | II | III | IV | V |
| Jan | 12.50 | 12.50 | 37.50 | 25.00 | 12.50 | 40.00 | - | 20.00 | 20.00 | 20.00 |
| Feb | 16.67 | 33.33 | 33.33 | 16.67 | - | 14.28 | 28.57 | 28.57 | 14.28 | 14.28 |
| Mar | 33.33 | 33.33 | 16.67 | 16.67 | - | 50.00 | 12.50 | 37.50 | - | - |
| Apr | 42.86 | 28.57 | 28.57 | - | - | 50.00 | 16.67 | 33.33 | - | - |
| May | - | - | 100.0 | - | - | 33.33 | - | 33.33 | 33.33 | - |
| Jun | 28.57 | 14.28 | 28.57 | 14.28 | 14.28 | 40.00 | - | 40.00 | 20.00 | - |
| Jul | 33.33 | - | 33.33 | 16.67 | 16.67 | 20.00 | - | 20.00 | 40.00 | 20.00 |
| Aug | 25.00 | 25.00 | 25.00 | 12.50 | 12.50 | 28.57 | 14.28 | 28.57 | 14.28 | 14.28 |
| Sep | 37.50 | 25.00 | 37.50 | - | - | 57.14 | - | 28.57 | 14.28 | - |
| Oct | 71.43 | - | 28.57 | - | - | 40.00 | 20.00 | 40.00 | - | - |
| Nov | - | - | 100.0 | - | - | - | - | 50.00 | 50.00 | - |
| Dec | - | - | 66.67 | - | 33.33 | - | 20.00 | 40.00 | 20.00 | 20.00 |

I-Empty, II- ¼ Full, III- ½ Full, IV- ¾ Full, V-Full

Table 3.11. Percentage of stomachs at various degrees of fullness in males of *Lagocephalus inermis* (pooled) from Jan. 2000 to Dec. 2001.

| Month | No. of fish | Empty | ¼ Full | ½ Full | ¾ Full | Full |
|---------|-------------|-------|--------|--------|--------|-------|
| Jan | 14 | 7.14 | 21.43 | 28.57 | 35.72 | 7.14 |
| Feb | 15 | 20.51 | 19.64 | 33.04 | 13.39 | 13.39 |
| Mar | 10 | 37.50 | 20.84 | 33.34 | 8.33 | - |
| Apr | 12 | 48.57 | 17.14 | 34.28 | - | - |
| May | 2 | - | - | 50.00 | 50.00 | - |
| Jun | 16 | 25.40 | 5.56 | 25.40 | 23.81 | 19.84 |
| Jul | 12 | 14.29 | 10.00 | 24.29 | 27.14 | 24.29 |
| Aug | 14 | 29.17 | 6.25 | 35.42 | 22.91 | 6.25 |
| Sep | 16 | 43.65 | 12.70 | 30.95 | 5.56 | 7.14 |
| Oct | 12 | 58.57 | 7.14 | 27.14 | - | 7.14 |
| Nov | 6 | 50.00 | - | 37.50 | - | 12.50 |
| Dec | 6 | 12.50 | - | 12.50 | 62.50 | 12.50 |
| Average | | 28.94 | 10.06 | 31.04 | 20.78 | 9.18 |

Table 3.12. Percentage of stomachs at various degrees of fullness in females of *Lagocephalus inermis* (pooled) from Jan. 2000 to Dec. 2001.

| Month | No. of fish | Empty | ¼ Full | ½ Full | ¾ Full | Full |
|---------|-------------|-------|--------|--------|--------|-------|
| Jan | 13 | 26.25 | 6.25 | 28.75 | 22.50 | 16.25 |
| Feb | 13 | 15.48 | 30.95 | 30.95 | 15.48 | 7.14 |
| Mar | 14 | 41.67 | 22.92 | 27.09 | 8.34 | - |
| Apr | 13 | 46.43 | 22.62 | 30.95 | - | - |
| May | 4 | 16.67 | - | 66.67 | 16.67 | - |
| Jun | 12 | 34.29 | 7.14 | 34.29 | 17.14 | 7.14 |
| Jul | 11 | 26.79 | - | 26.67 | 28.34 | 18.34 |
| Aug | 15 | 26.79 | 19.64 | 26.79 | 13.39 | 13.39 |
| Sep | 15 | 47.32 | 12.50 | 33.04 | 7.14 | - |
| Oct | 12 | 55.72 | 10.00 | 34.29 | - | - |
| Nov | 3 | - | - | 75.00 | 25.00 | - |
| Dec | 8 | - | 10.00 | 53.34 | 10.00 | 26.67 |
| Average | | 28.11 | 11.83 | 38.98 | 13.67 | 7.41 |

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Table 3.13. Percentage of stomachs at various degree of fullness in each 2 mm length groups of *Tetraodon travancoricus*.

| Length group (mm) | No. of fish | Empty | ¼ Full | ½ Full | ¾ Full | Full |
|-------------------|-------------|-------|--------|--------|--------|-------|
| 8-9 | 11 | 27.27 | 18.18 | 36.36 | 18.18 | - |
| 10-11 | 19 | 31.58 | 10.52 | 26.34 | 21.05 | 10.52 |
| 12-13 | 29 | 27.59 | 10.34 | 31.03 | 17.24 | 13.79 |
| 14-15 | 23 | 26.09 | 26.09 | 21.74 | 17.39 | 8.69 |
| 16-17 | 37 | 13.51 | 18.92 | 43.24 | 13.51 | 10.81 |
| 18-19 | 59 | 20.33 | 22.03 | 23.73 | 18.64 | 15.25 |
| 20-21 | 68 | 14.71 | 26.67 | 23.53 | 20.59 | 14.71 |
| 22-23 | 53 | 24.53 | 18.87 | 28.30 | 20.75 | 7.55 |
| 24-25 | 55 | 27.27 | 23.64 | 32.73 | 10.91 | 5.45 |
| 26-27 | 46 | 23.91 | 23.91 | 28.26 | 17.39 | 6.52 |
| 28-29 | 31 | 16.13 | 22.58 | 29.03 | 22.58 | 9.68 |
| 30-31 | 18 | 22.22 | 22.22 | 27.78 | 16.67 | 11.11 |
| 32-33 | 9 | 11.11 | 33.33 | 33.33 | 22.22 | - |
| 34-35 | 4 | - | 50.00 | 25.00 | - | 25.00 |
| Average | | 20.45 | 23.38 | 29.31 | 16.94 | 9.93 |

Table 3.14. Percentage of stomachs at various degree of fullness in each 20 mm length groups of *Lagocephalus inermis*.

| Length group (mm) | No. of fish | Empty | ¼ Full | ½ Full | ¾ Full | Full |
|-------------------|-------------|-------|--------|--------|--------|-------|
| 60-79 | 9 | 22.22 | 11.11 | 44.44 | 22.22 | - |
| 80-99 | 16 | 37.50 | 18.75 | 25.00 | 18.75 | - |
| 100-119 | 44 | 22.73 | 20.45 | 25.00 | 18.18 | 13.64 |
| 120-139 | 38 | 13.16 | 18.42 | 23.68 | 23.68 | 21.05 |
| 140-159 | 38 | 21.05 | 26.32 | 23.68 | 18.42 | 10.53 |
| 160-179 | 26 | 26.92 | 42.31 | 11.54 | 11.54 | 7.69 |
| 180-199 | 30 | 23.33 | 20.00 | 23.33 | 16.67 | 16.67 |
| 200-219 | 29 | 20.69 | 20.69 | 24.13 | 13.79 | 20.69 |
| 220-239 | 21 | 28.57 | 33.33 | 19.05 | 19.05 | - |
| 240-259 | 11 | 27.27 | 36.36 | 27.27 | - | 9.09 |
| 260-279 | 12 | 33.33 | 25.00 | 25.00 | 8.33 | 8.33 |
| 280-299 | 7 | 42.86 | 14.28 | 28.57 | 14.28 | - |
| 300-319 | 6 | 16.67 | 33.33 | 33.33 | 16.67 | - |
| Average | | 25.87 | 24.64 | 25.69 | 15.51 | 8.28 |

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Table 3.15 Percentages of fish at poorly fed and actively fed conditions in *Tetraodon travancoricus* pooled for two years (Oct. 1999- Sep. 2001)

| Month | Poorly fed | | Actively fed | |
|---------|------------|---------|--------------|---------|
| | Males | Females | Males | Females |
| Oct | 41.67 | 66.07 | 58.33 | 33.93 |
| Nov | 35.41 | 35.71 | 64.59 | 64.29 |
| Dec | 26.78 | 43.75 | 73.22 | 56.25 |
| Jan | 29.16 | 30.95 | 70.84 | 68.15 |
| Feb | 25.40 | 33.33 | 74.60 | 66.67 |
| Mar | 26.78 | 43.65 | 73.22 | 56.35 |
| Apr | 29.16 | 25.00 | 70.84 | 75.00 |
| May | 38.10 | 46.43 | 61.90 | 53.57 |
| Jun | 50.00 | 56.25 | 50.00 | 43.75 |
| Jul | 46.43 | 64.28 | 53.57 | 35.72 |
| Aug | 64.58 | 66.96 | 35.42 | 33.04 |
| Sep | 56.25 | 59.03 | 43.75 | 40.97 |
| Average | 39.14 | 47.62 | 60.86 | 52.38 |

Table 3.16 Condition of feed in *Lagocephalus inermis* in different months pooled for two years from Jan.2000 to Dec.2001

| Month | Poorly fed | | Actively fed | |
|---------|------------|---------|--------------|---------|
| | Males | Females | Males | Females |
| Jan | 28.57 | 32.50 | 71.43 | 67.50 |
| Feb | 40.18 | 46.43 | 59.82 | 53.57 |
| Mar | 58.33 | 64.58 | 41.67 | 35.42 |
| Apr | 65.72 | 69.05 | 34.28 | 30.95 |
| May | - | 16.67 | 100.00 | 83.33 |
| Jun | 30.95 | 41.43 | 69.05 | 58.57 |
| Jul | 24.28 | 26.67 | 75.72 | 73.33 |
| Aug | 35.42 | 46.43 | 64.58 | 53.57 |
| Sep | 56.35 | 59.82 | 43.65 | 40.18 |
| Oct | 65.72 | 65.72 | 34.28 | 34.28 |
| Nov | 50.00 | 50.00 | 50.00 | 50.00 |
| Dec | 12.50 | 10.00 | 87.50 | 90.00 |
| Average | 39.00 | 44.11 | 61.00 | 58.89 |

Table 3.17. Condition of feed in different length groups of *Tetraodon travancoricus* during Oct. 1999 – Sep. 2001.

| Length group (mm) | No. of fish | Feeding intensity | |
|-------------------|-------------|-------------------|--------------|
| | | Poorly fed | Actively fed |
| 8-9 | 11 | 45.45 | 54.55 |
| 10-11 | 19 | 42.11 | 57.89 |
| 12-13 | 29 | 37.93 | 62.07 |
| 14-15 | 23 | 52.17 | 47.83 |
| 16-17 | 37 | 32.43 | 67.57 |
| 18-19 | 59 | 42.37 | 57.63 |
| 20-21 | 68 | 41.18 | 58.82 |
| 22-23 | 53 | 43.40 | 56.60 |
| 24-25 | 55 | 50.91 | 49.09 |
| 26-27 | 46 | 47.83 | 52.17 |
| 28-29 | 31 | 38.71 | 61.29 |
| 30-31 | 18 | 44.44 | 55.56 |
| 32-33 | 9 | 44.44 | 55.56 |
| 34-35 | 4 | 50.00 | 50.00 |
| Average | | 43.81 | 56.19 |

Table 3.18. Condition of feed in different length groups of *Lagocephalus inermis* during Jan. 2000 – Dec 2001.

| Length group (mm) | No. of fish | Feeding intensity | |
|-------------------|-------------|-------------------|--------------|
| | | Poorly fed | Actively fed |
| 60-79 | 9 | 33.33 | 66.67 |
| 80-99 | 16 | 56.25 | 43.75 |
| 100-119 | 44 | 43.18 | 56.82 |
| 120-139 | 38 | 31.58 | 68.42 |
| 140-159 | 38 | 47.37 | 52.63 |
| 160-179 | 26 | 69.23 | 30.77 |
| 180-199 | 30 | 43.33 | 56.67 |
| 200-219 | 29 | 41.38 | 58.62 |
| 220-239 | 21 | 61.90 | 38.10 |
| 240-259 | 11 | 63.64 | 36.36 |
| 260-279 | 12 | 58.33 | 41.67 |
| 280-299 | 7 | 57.14 | 42.86 |
| 300-319 | 6 | 50.00 | 50.00 |
| Average | | 50.51 | 49.49 |

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Table 3.19. Monthly variation in feeding index of males and females of *Tetraodon travancoricus* during Oct. 1999 – Sep. 2001.

| Month | Males | | Females | |
|-------|-------------|---------------|-------------|---------------|
| | No. of fish | Feeding index | No. of fish | Feeding index |
| Oct | 14 | 33.93 | 15 | 36.67 |
| Nov | 14 | 42.86 | 14 | 39.29 |
| Dec | 15 | 45.00 | 14 | 42.86 |
| Jan | 14 | 58.93 | 17 | 51.56 |
| Feb | 16 | 53.13 | 18 | 48.61 |
| Mar | 15 | 50.00 | 16 | 43.75 |
| Apr | 14 | 53.57 | 16 | 59.38 |
| May | 13 | 44.23 | 13 | 34.61 |
| Jun | 20 | 33.75 | 16 | 39.00 |
| Jul | 13 | 34.61 | 14 | 23.21 |
| Aug | 14 | 28.57 | 15 | 25.00 |
| Sep | 16 | 34.38 | 17 | 26.47 |

Table 3.20. Monthly variation in feeding index of males and females of *Lagocephalus inermis* during Jan. 2000 – Dec. 2001.

| Month | Males | | Females | |
|-------|-------------|---------------|-------------|---------------|
| | No. of fish | Feeding index | No. of fish | Feeding index |
| Jan | 14 | 53.57 | 13 | 50.00 |
| Feb | 15 | 45.00 | 13 | 42.31 |
| Mar | 10 | 27.50 | 14 | 25.00 |
| Apr | 12 | 20.83 | 13 | 21.15 |
| May | 2 | 62.50 | 4 | 43.75 |
| Jun | 16 | 51.56 | 12 | 39.58 |
| Jul | 12 | 56.25 | 11 | 52.27 |
| Aug | 14 | 42.86 | 15 | 41.67 |
| Sep | 16 | 29.69 | 15 | 25.00 |
| Oct | 12 | 22.92 | 12 | 15.00 |
| Nov | 6 | 33.33 | 3 | 58.33 |
| Dec | 6 | 62.50 | 8 | 62.50 |

Table 3.21. Fluctuation of feeding index in different length groups of *Tetraodon travancoricus* (Oct. 1999 – Sep. 2001)

| Length group (mm) | No. of fish | Feeding index |
|-------------------|-------------|---------------|
| 08-09 | 11 | 36.36 |
| 10-11 | 19 | 42.11 |
| 12-13 | 29 | 44.83 |
| 14-15 | 23 | 39.13 |
| 16-17 | 37 | 33.78 |
| 18-19 | 59 | 46.61 |
| 20-21 | 68 | 48.53 |
| 22-23 | 53 | 41.98 |
| 24-25 | 55 | 35.91 |
| 26-27 | 46 | 39.67 |
| 28-29 | 31 | 46.77 |
| 30-31 | 18 | 43.06 |
| 32-33 | 9 | 41.67 |
| 34-35 | 4 | 50.00 |

Table 3.22. Fluctuation of feeding index in different length groups of *Lagocephalus inermis* (2000 & 2001)

| Length group (mm) | No. of fish | Feeding index |
|-------------------|-------------|---------------|
| 60-69 | 9 | 41.67 |
| 80-99 | 16 | 31.25 |
| 100-119 | 44 | 44.89 |
| 120-139 | 38 | 53.95 |
| 140-159 | 38 | 40.13 |
| 160-179 | 26 | 32.69 |
| 180-199 | 30 | 45.83 |
| 200-219 | 29 | 48.28 |
| 220-239 | 21 | 32.14 |
| 240-259 | 11 | 31.82 |
| 260-279 | 12 | 33.33 |
| 280-299 | 7 | 28.57 |
| 300-319 | 6 | 37.50 |

Table 3.23. Gastrostatic indices of males, females and pooled fishes of *Tetraodon travancoricus*.

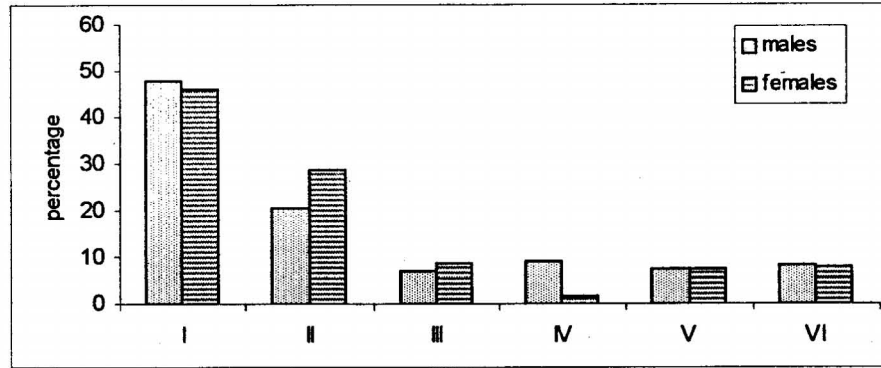
| Month | 1999-2000 | | 2000-2001 | | Pooled | |
|-------|-----------|---------|-----------|---------|--------|---------|
| | Males | Females | Males | Females | Males | Females |
| Oct | 3.22 | 1.88 | 2.78 | 2.15 | 3.00 | 2.01 |
| Nov | 3.94 | 2.85 | 3.67 | 2.51 | 3.80 | 2.68 |
| Dec | 4.72 | 3.63 | 4.38 | 3.38 | 4.55 | 3.50 |
| Jan | 4.98 | 4.41 | 4.65 | 4.03 | 4.81 | 4.22 |
| Feb | 4.79 | 4.56 | 5.19 | 4.72 | 4.99 | 4.64 |
| Mar | 5.61 | 4.92 | 4.96 | 4.56 | 5.28 | 4.74 |
| Apr | 5.55 | 4.61 | 5.39 | 5.09 | 5.47 | 4.85 |
| May | 4.63 | 3.12 | 4.26 | 2.97 | 4.44 | 3.04 |
| Jun | 3.86 | 1.97 | 4.03 | 2.41 | 3.94 | 2.19 |
| Jul | 3.25 | 2.07 | 2.99 | 1.72 | 3.12 | 1.89 |
| Aug | 3.51 | 2.68 | 3.42 | 2.34 | 3.46 | 2.51 |
| Sep | 3.41 | 2.05 | 3.21 | 1.78 | 3.34 | 1.91 |

Table 3.24. Gastrostatic index values of males, females and pooled fishes of *Lagocephalus inermis*.

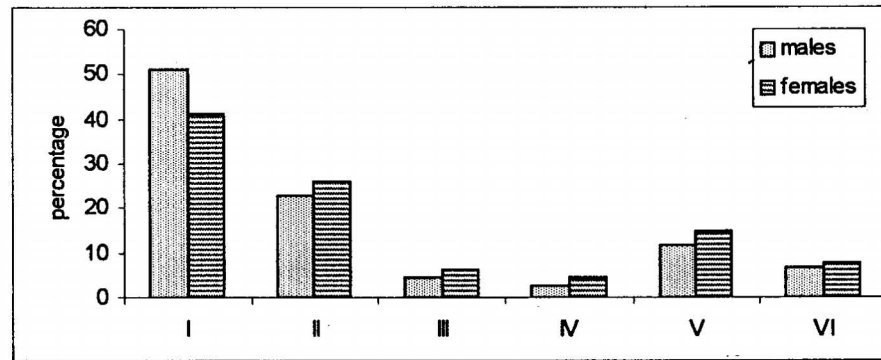
| Month | 2000 | | 2001 | | Pooled | |
|-------|-------|---------|-------|---------|--------|---------|
| | Males | Females | Males | Females | Males | Females |
| Jan | 6.98 | 7.86 | 7.69 | 7.54 | 7.33 | 7.7 |
| Feb | 7.01 | 6.08 | 6.48 | 6.73 | 6.74 | 6.40 |
| Mar | 4.94 | 3.57 | 4.36 | 2.85 | 4.65 | 3.21 |
| Apr | 3.87 | 2.45 | 3.99 | 2.71 | 3.93 | 2.58 |
| May | 5.83 | 4.59 | 5.44 | 4.97 | 5.63 | 4.78 |
| Jun | 6.65 | 7.21 | 7.38 | 6.85 | 7.01 | 7.03 |
| Jul | 7.96 | 7.92 | 7.42 | 8.71 | 7.69 | 8.31 |
| Aug | 6.38 | 6.26 | 6.51 | 5.98 | 6.44 | 6.12 |
| Sep | 4.54 | 2.94 | 4.22 | 3.19 | 4.38 | 3.06 |
| Oct | 3.28 | 2.54 | 3.62 | 2.30 | 3.45 | 2.42 |
| Nov | 4.36 | 3.92 | 4.86 | 4.57 | 4.61 | 4.24 |
| Dec | 5.46 | 6.32 | 5.86 | 5.75 | 5.66 | 6.03 |

Fig.3.1.(A-L). Comparison of various food items (pooled) in males and females of *Tetraodon travancoricus* in different months (Oct.1999-Sep.2001)

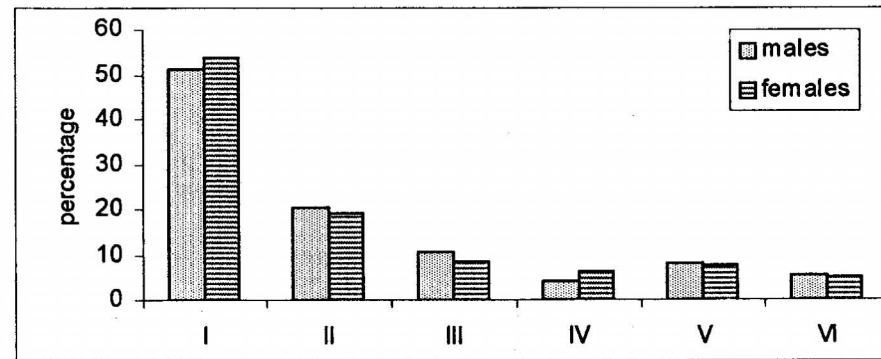
A.October



B.November



C.December

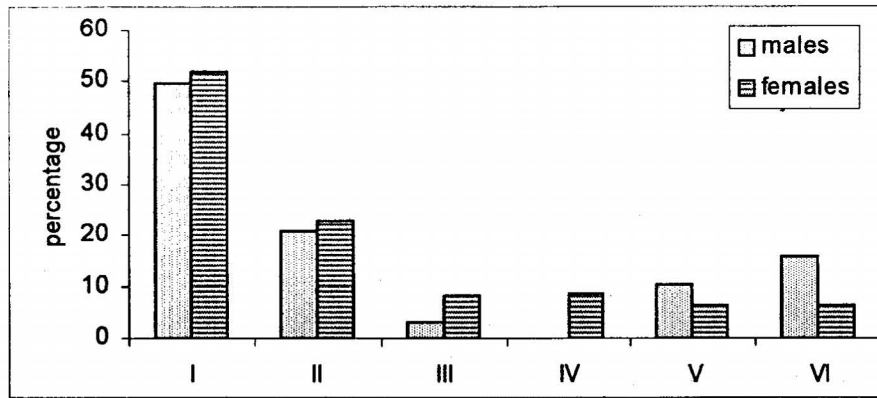


I-Crustaceans and crust. pieces II-Semi-digested tissue III-Fish scales IV-fin
 V-Algal filaments VI-Miscellaneous

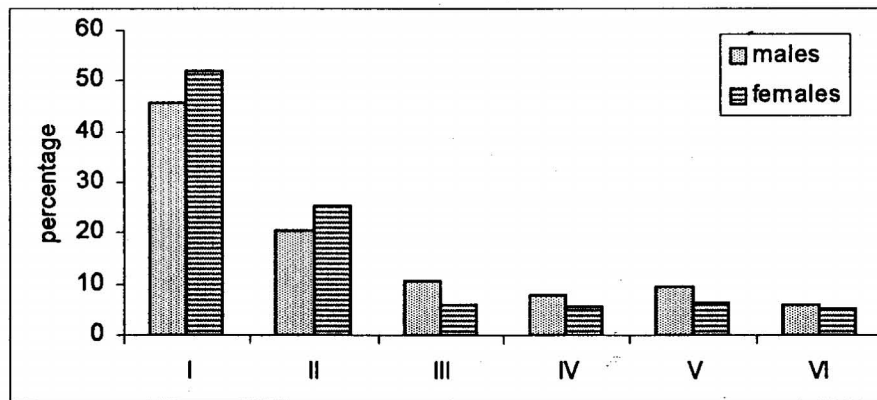
29 200

Fig.3.1. Cont.....

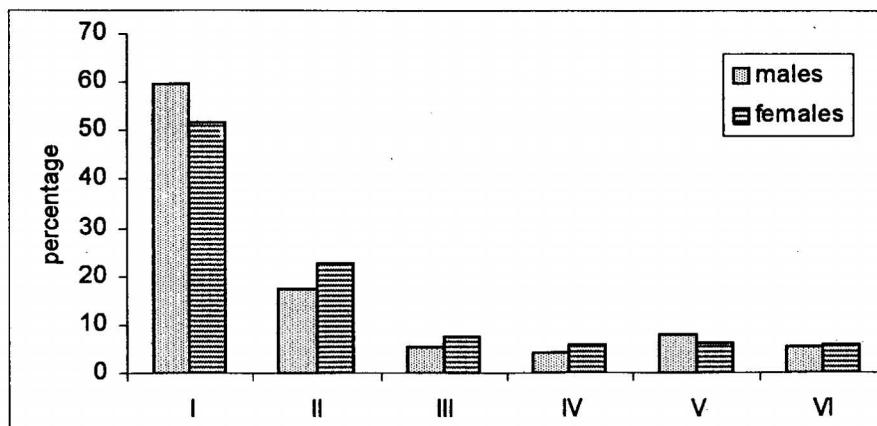
D. January



E. February



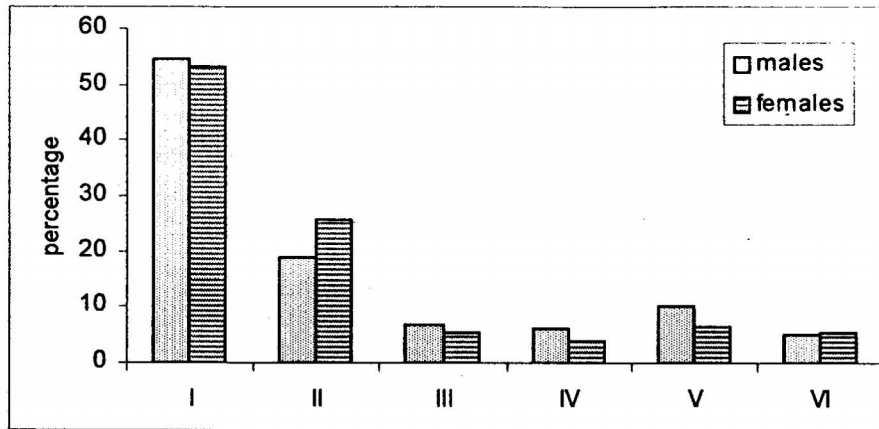
F. March



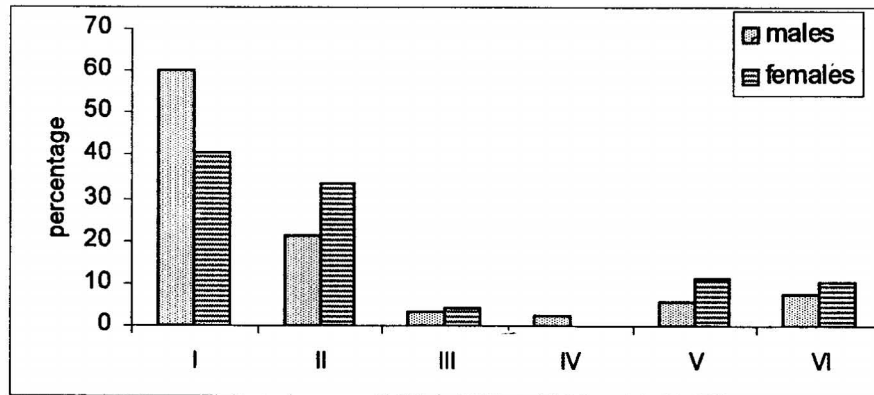
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Fig.3.1. Cont...

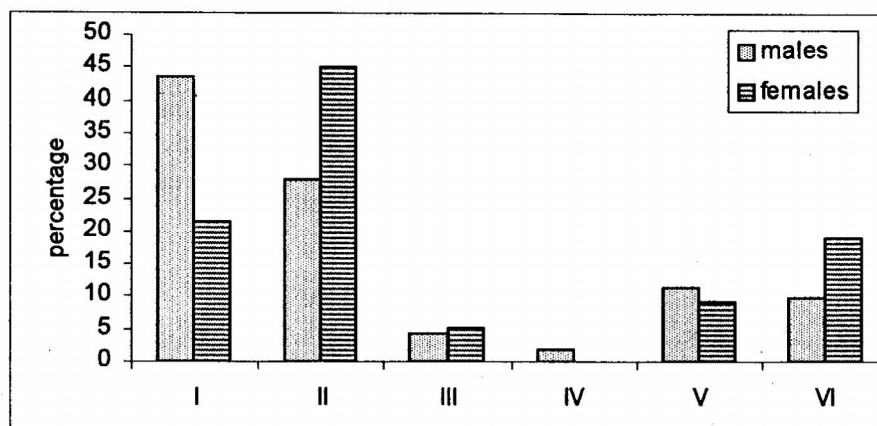
G. April



H. May



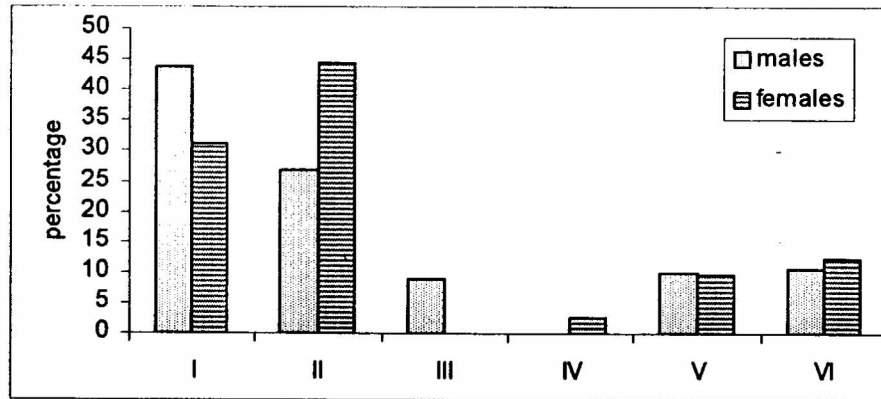
I. June



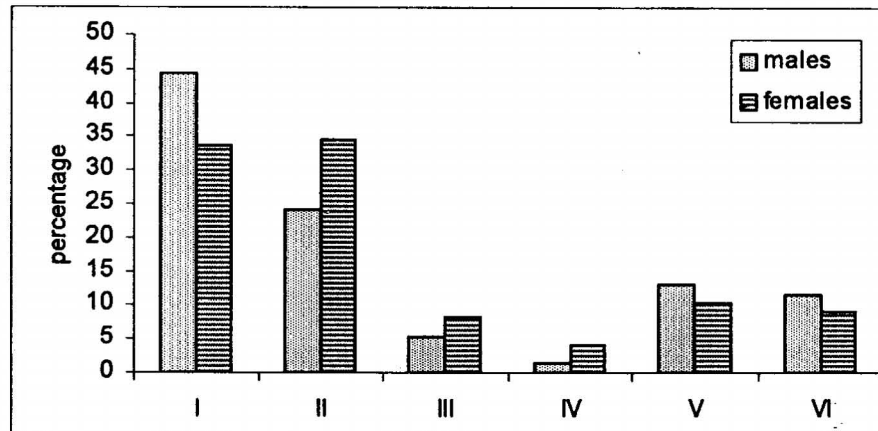
91

Fig.3.1. Cont...

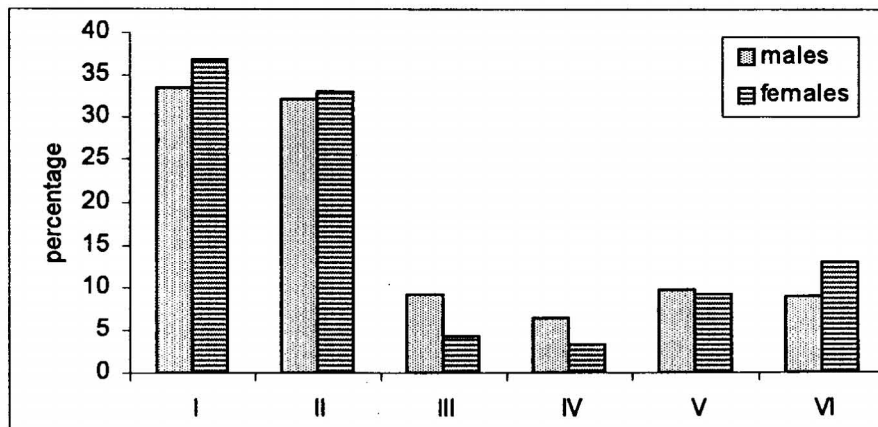
J. July



K. August

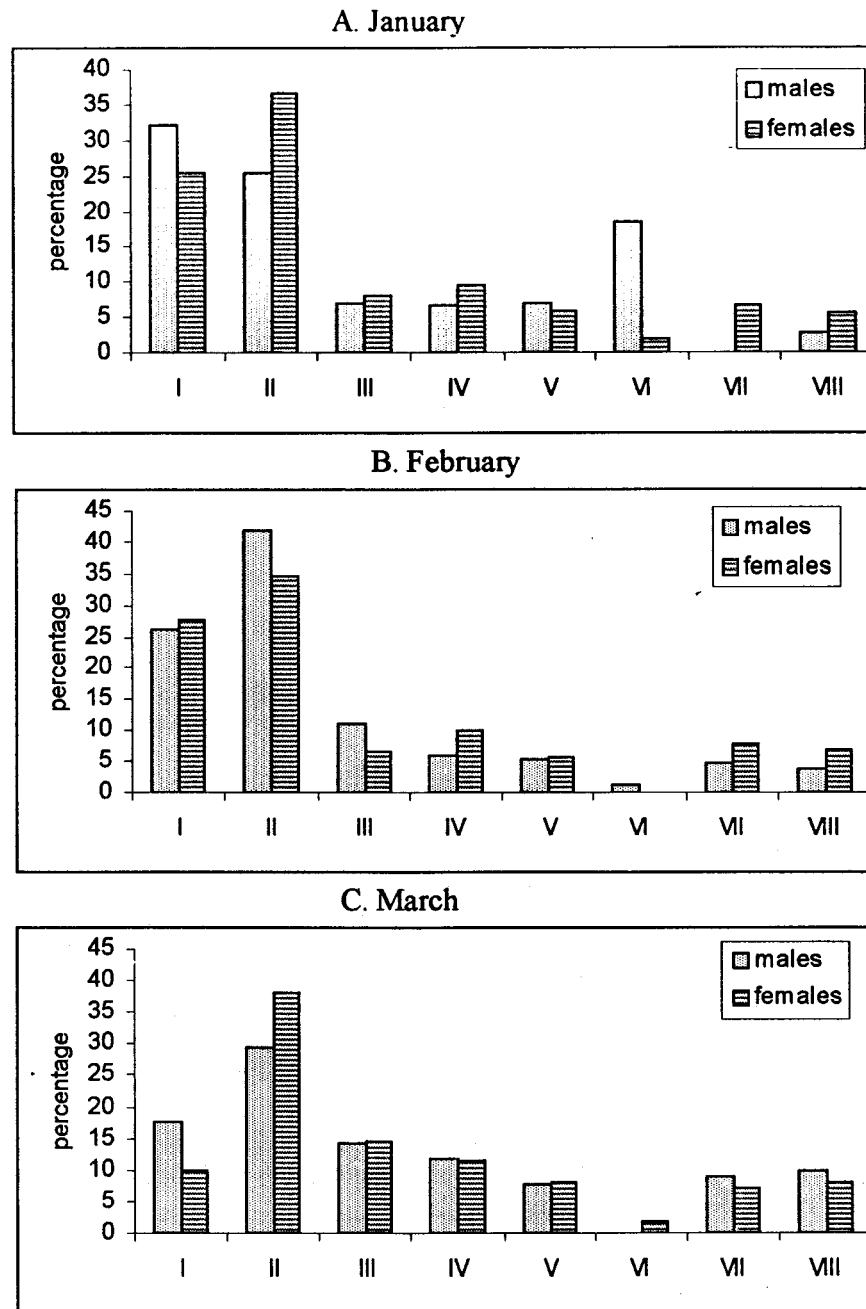


L. September



32 06

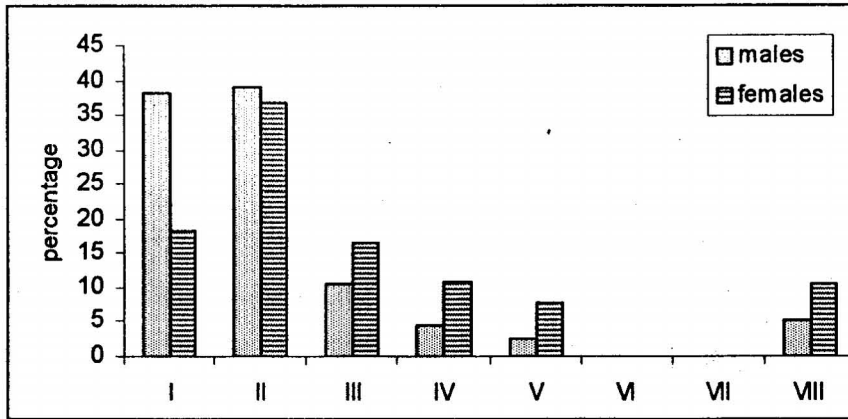
Fig. 3.2.(A-L) Comparison of percentage composition of food items (pooled) in males and females of *Lagocephalus inermis* (2000 & 2001)



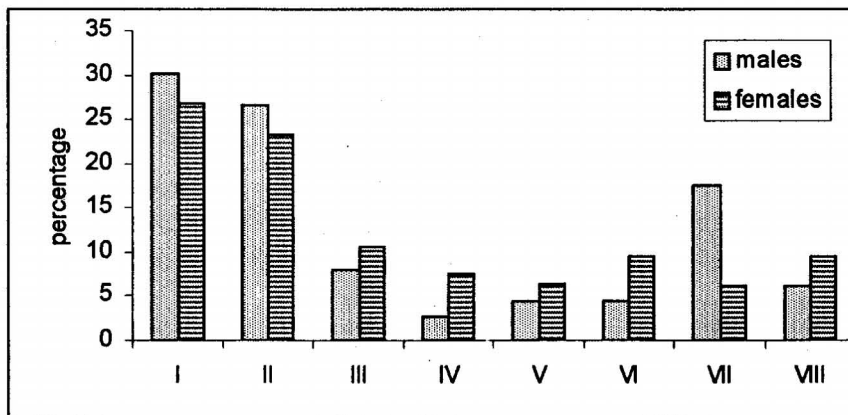
I-Fish & fish pieces II-Semi-digested tissue III-Fish scales
 IV-Fish fins V-Spines VI-Crustacean items VII-Cephalopod parts
 VII-Miscellaneous

Fig. 3.2. Cont...

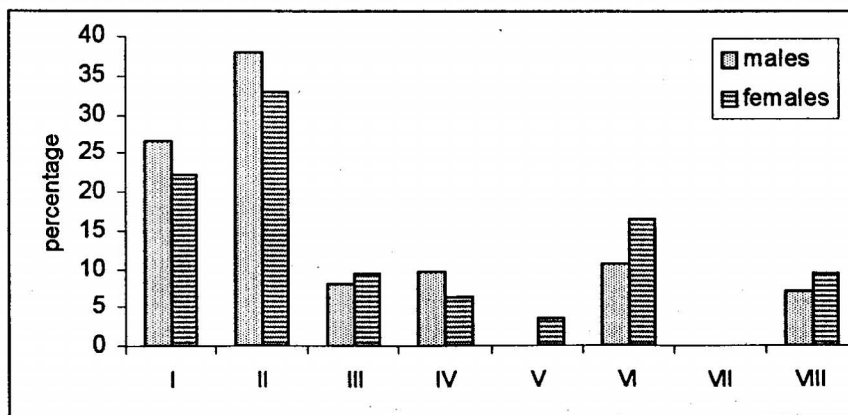
D. April



E. May



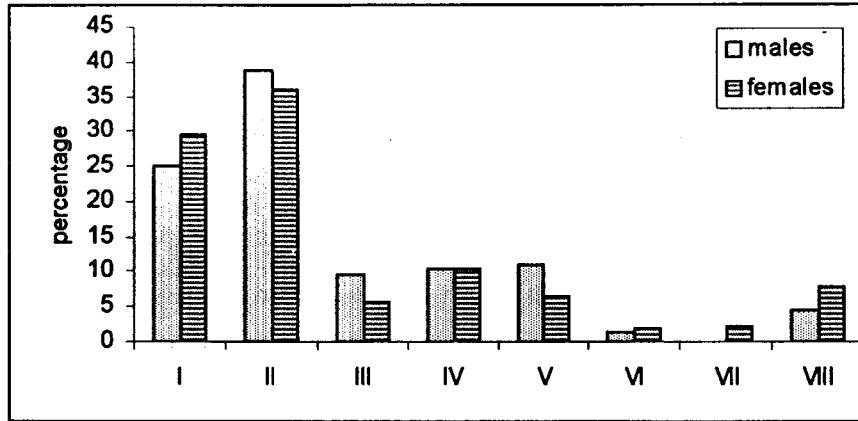
F. June



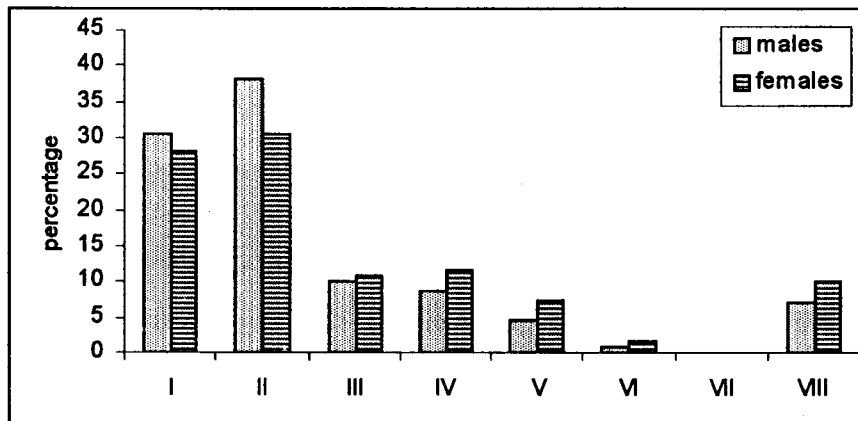
24
207

Fig. 3.2. Cont...

G. July



H. August



I. September

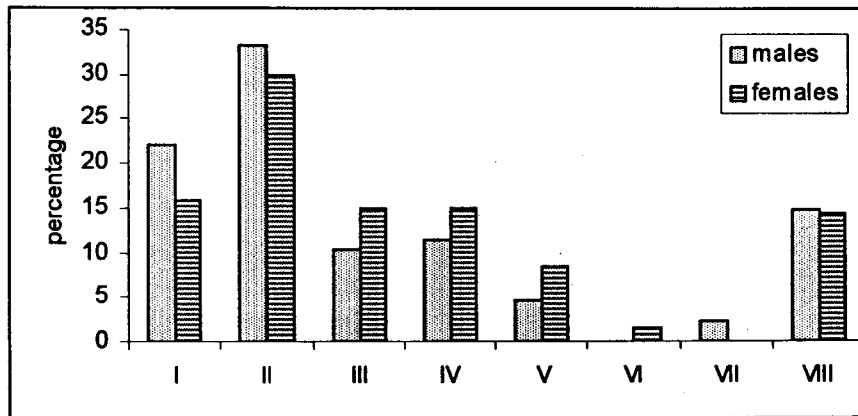
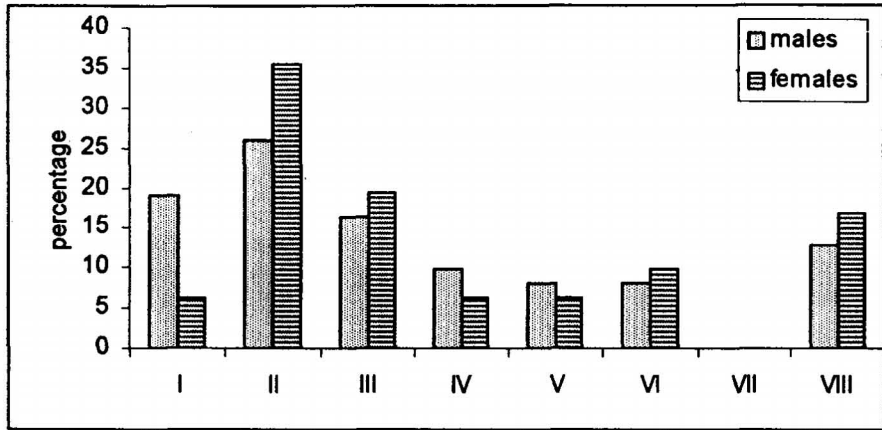
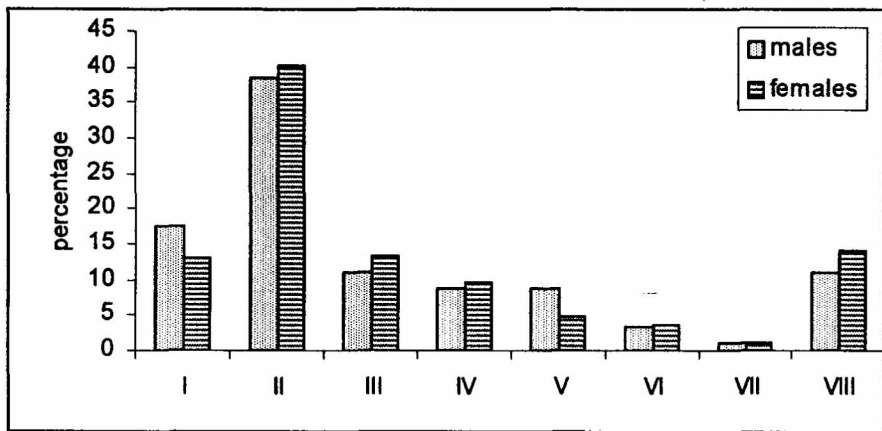


Fig.3.2. Cont...

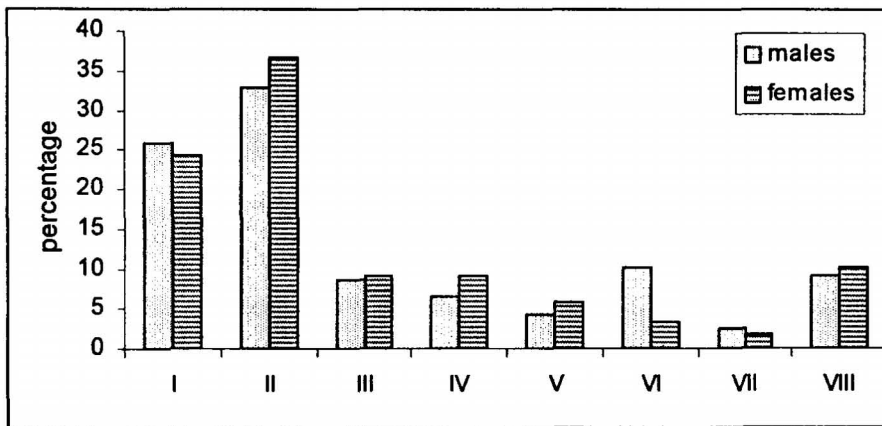
J. October



K. November



L. December



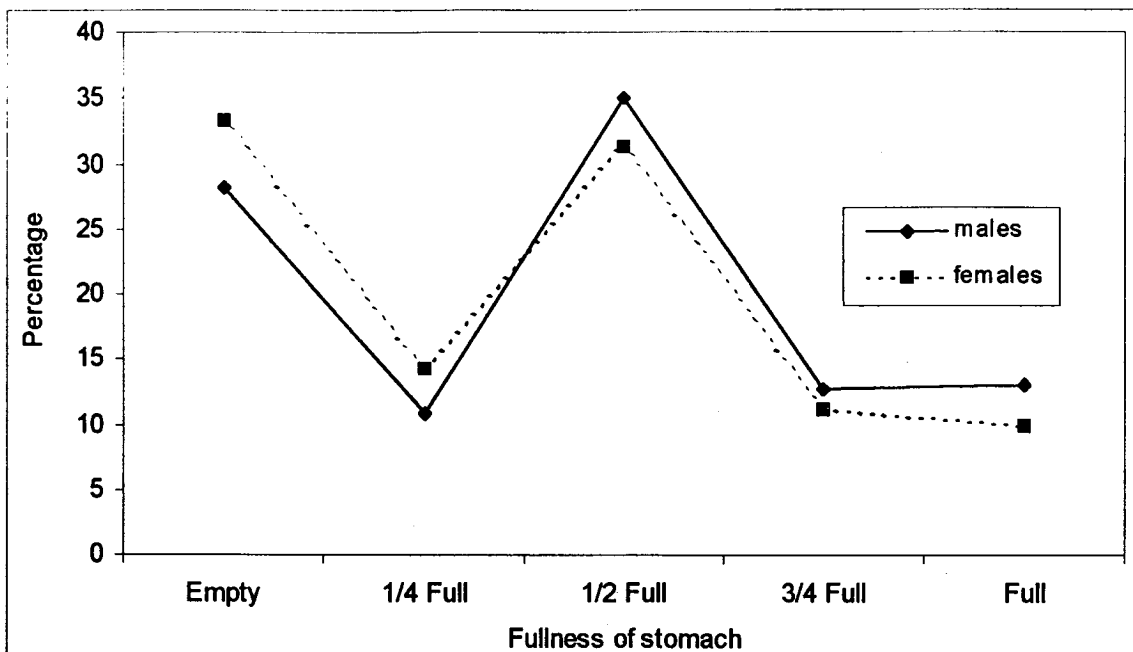


Fig. 3.3. Stomachs of various degrees of fullness in males and females of *Tetraodon travancoricus* (Oct. 1999 - Sep. 2001)

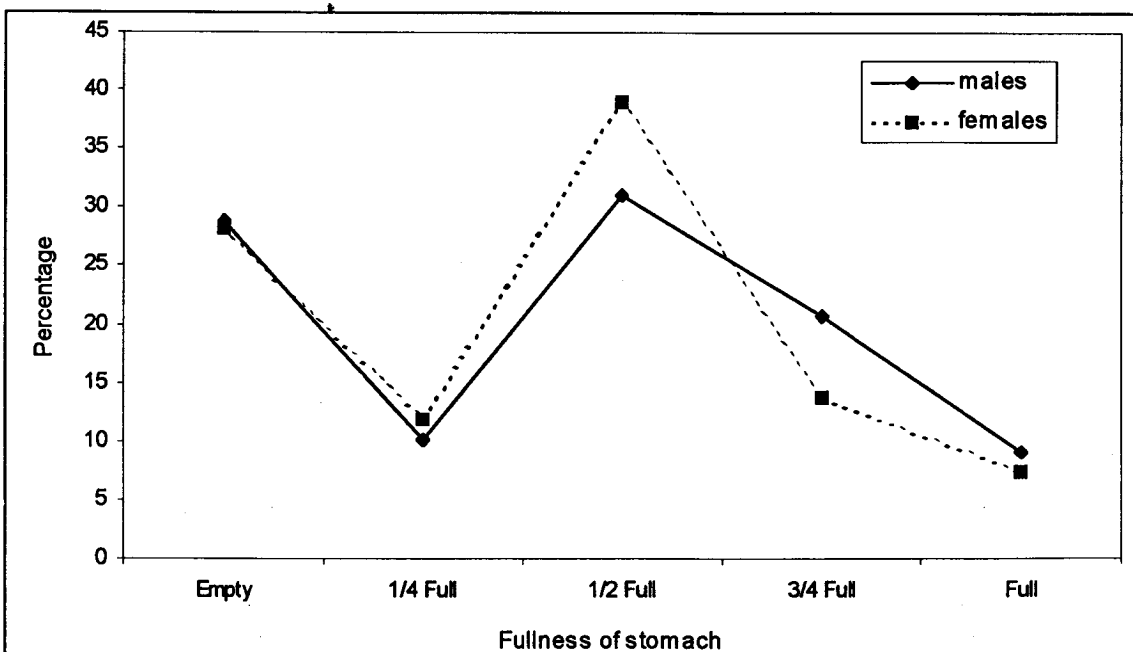
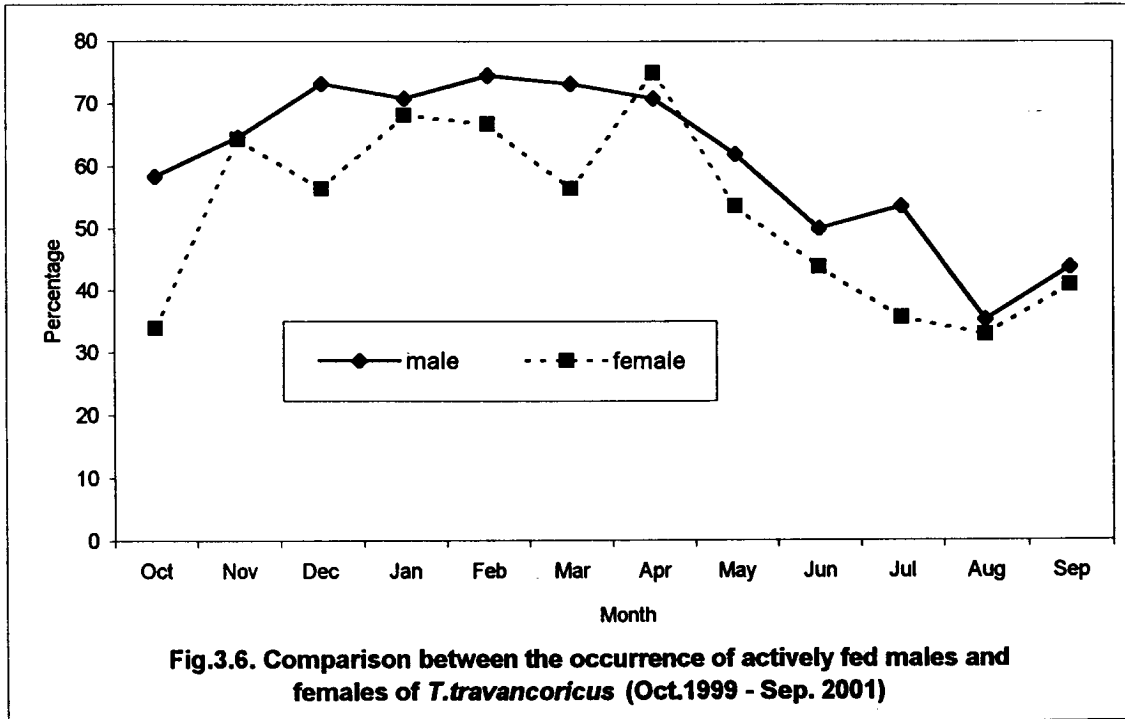
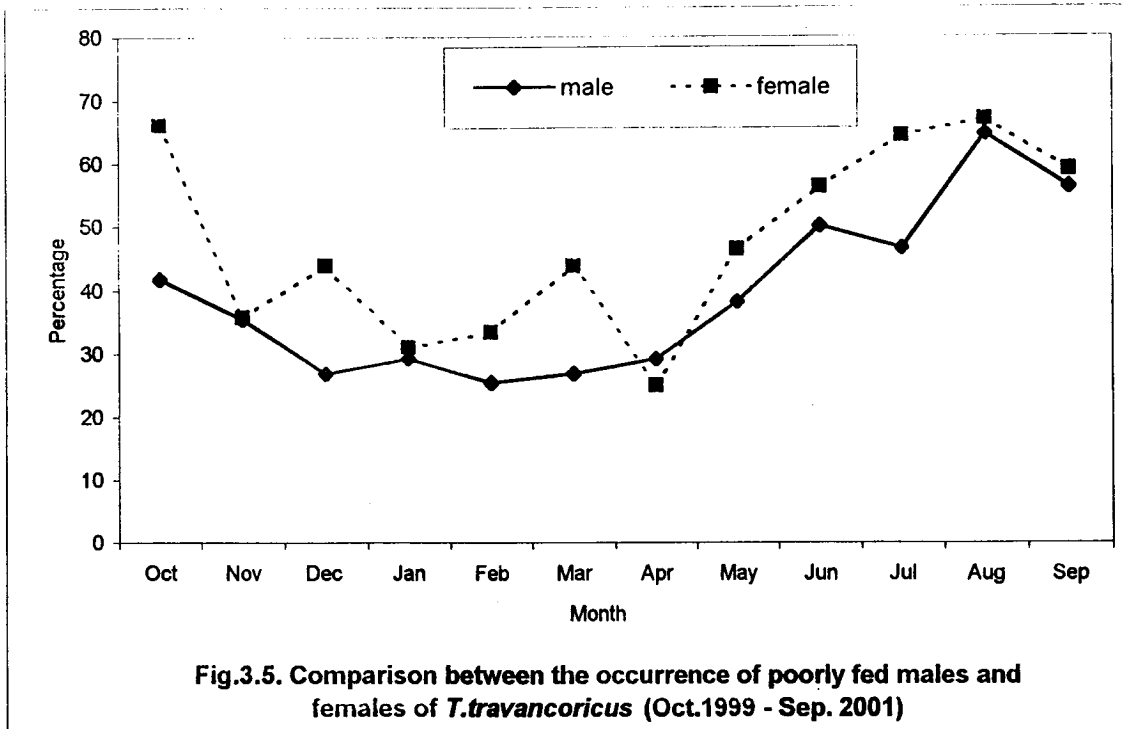
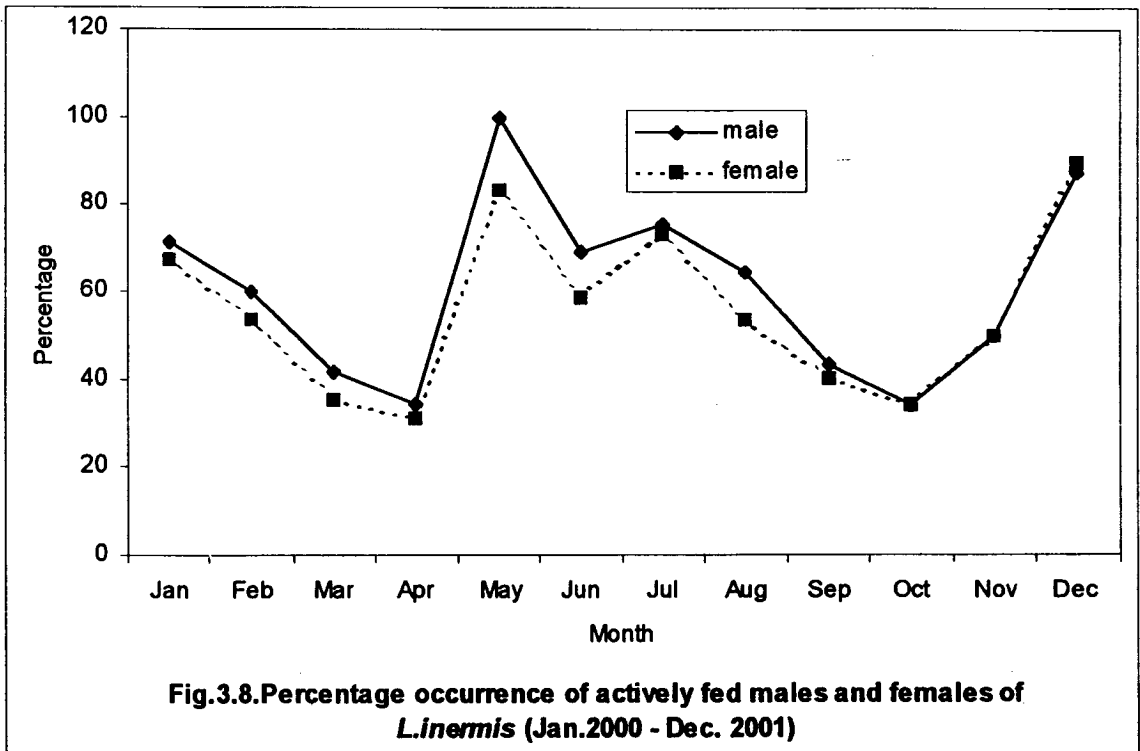
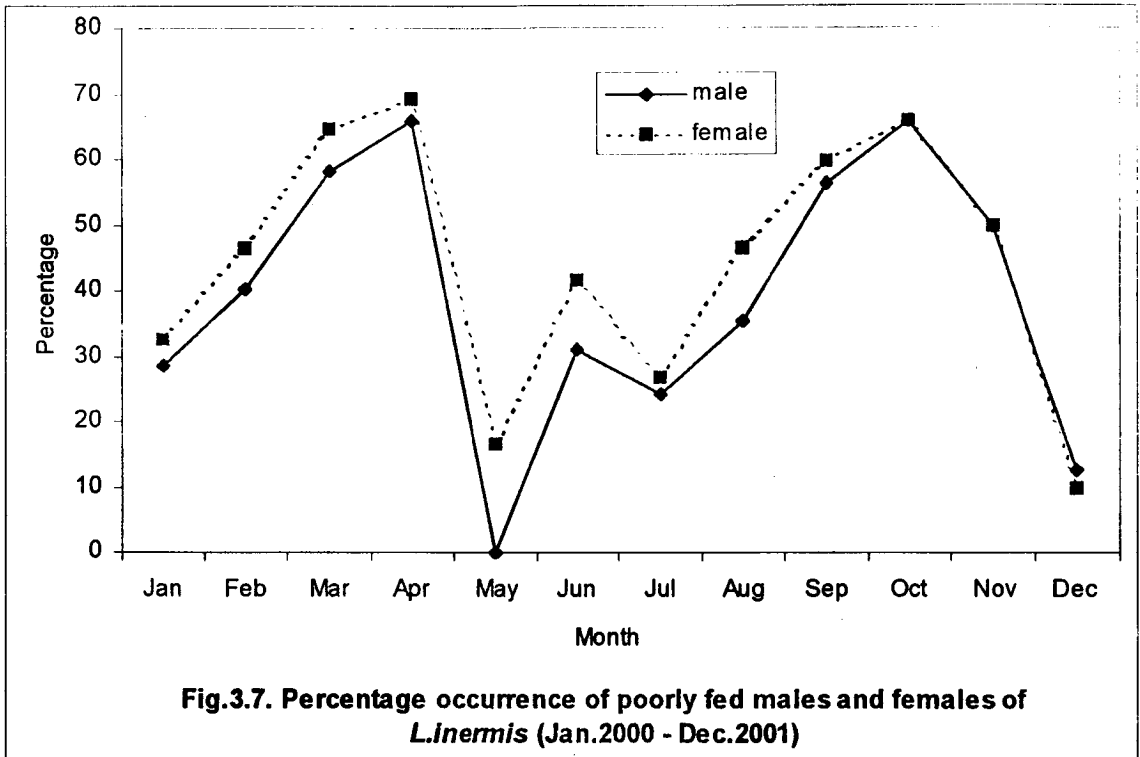


Fig.3.4. Stomachs of various degrees of fullness in males and females of *Lagocephalus inermis* (Jan.2000-Dec.2001)





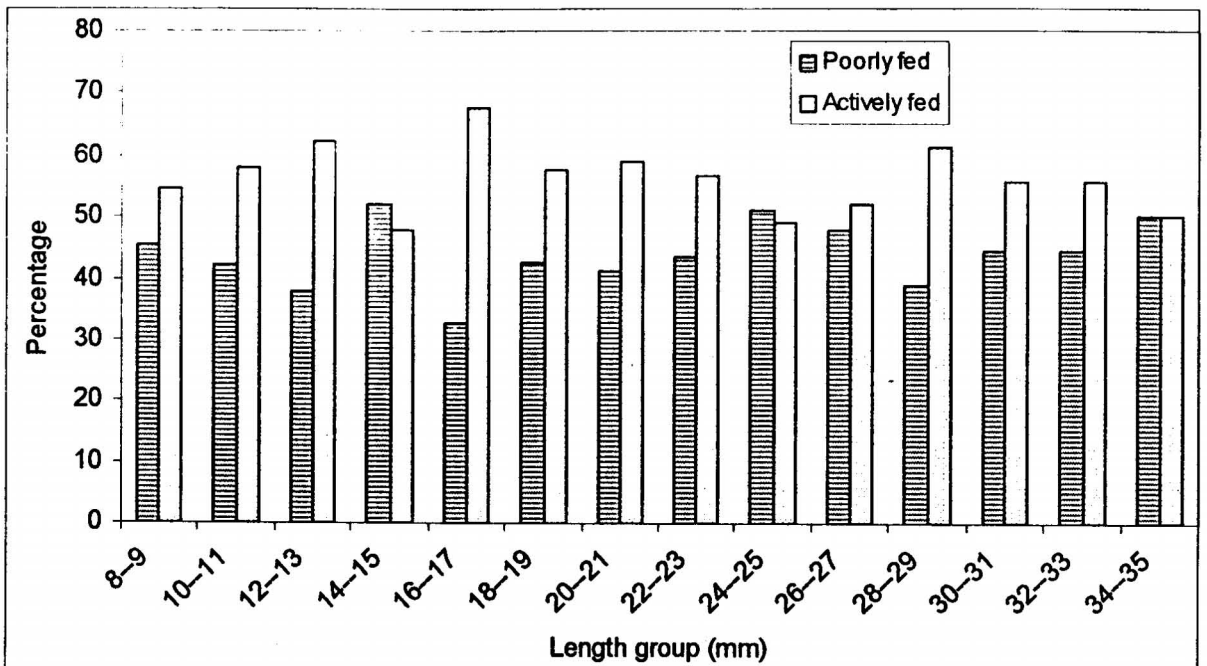


Fig.3.9. Feeding intensity in different length groups of *T. travancoricus* (Oct.1999 - Sep.2001)

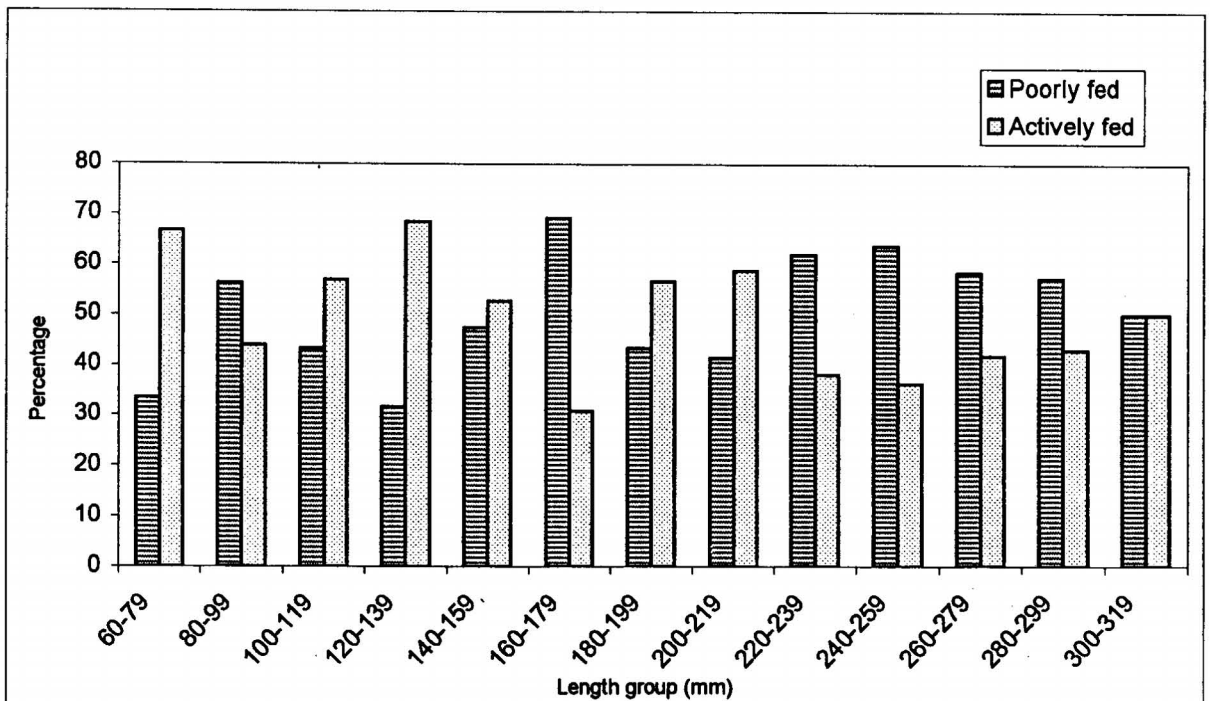
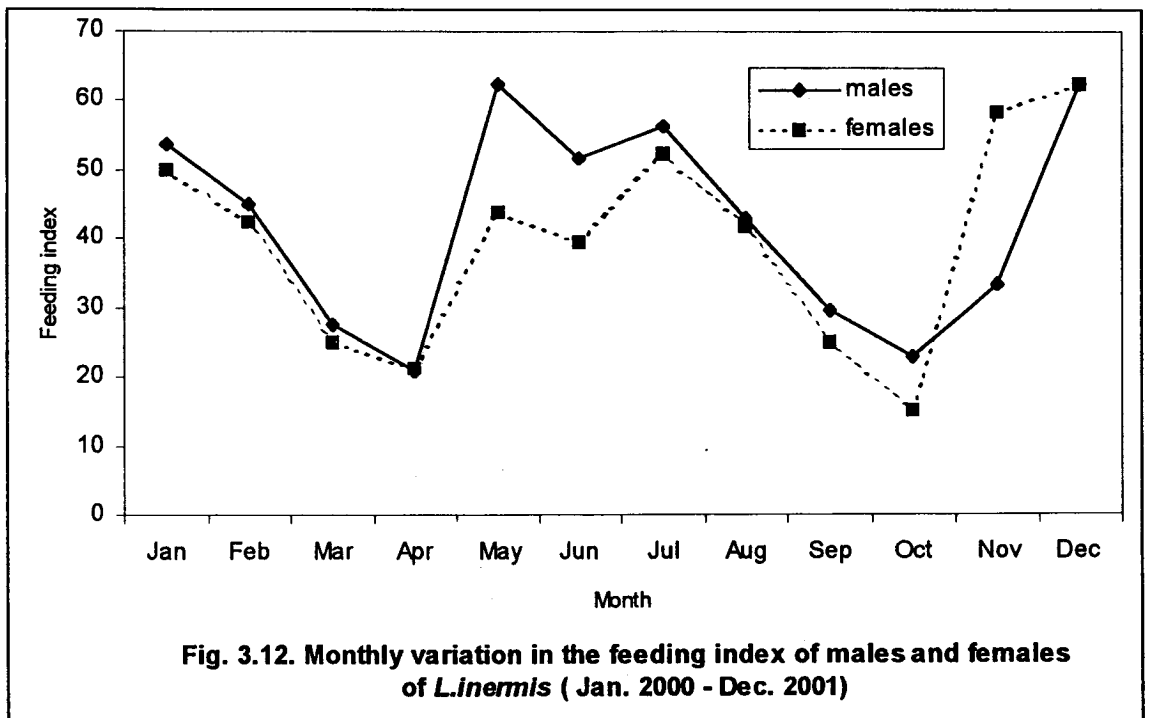
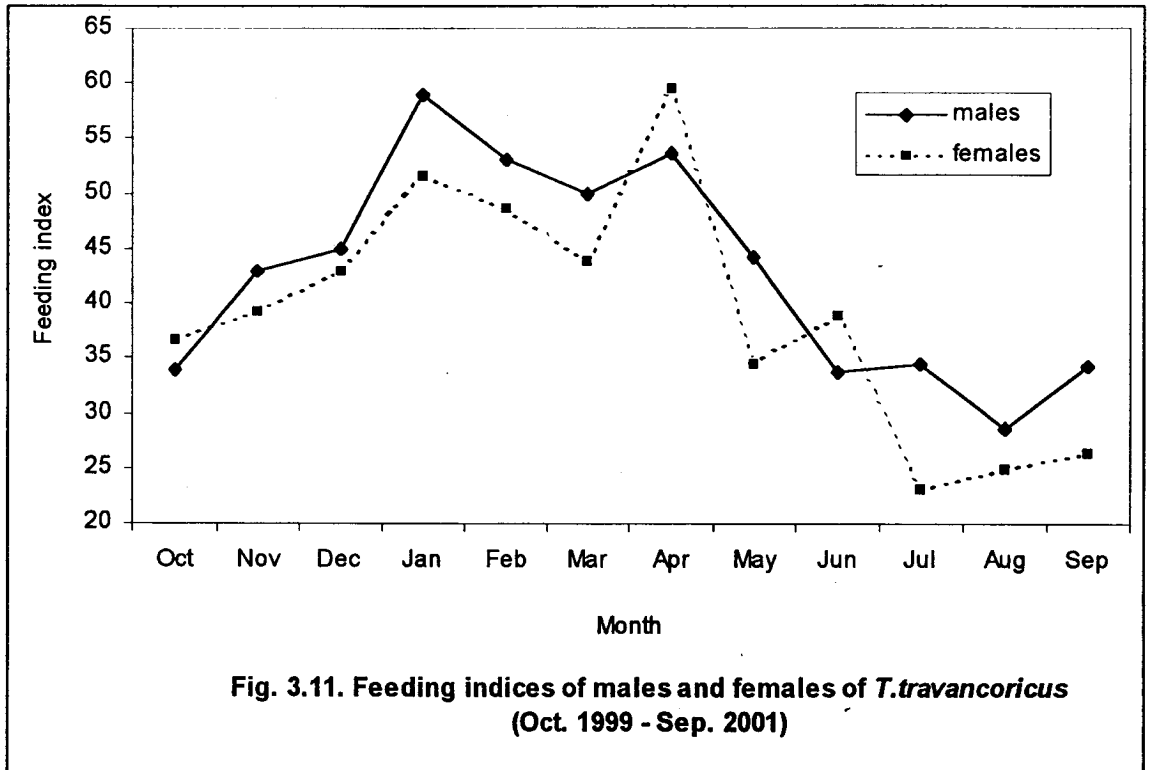
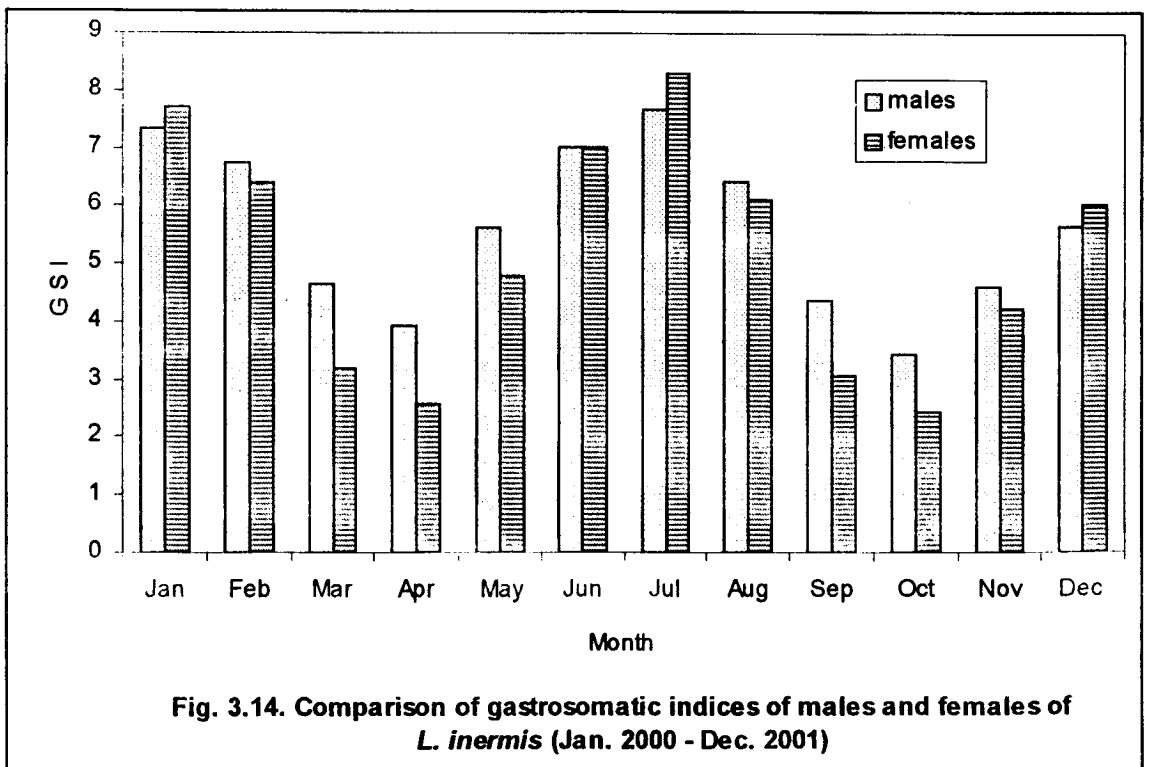
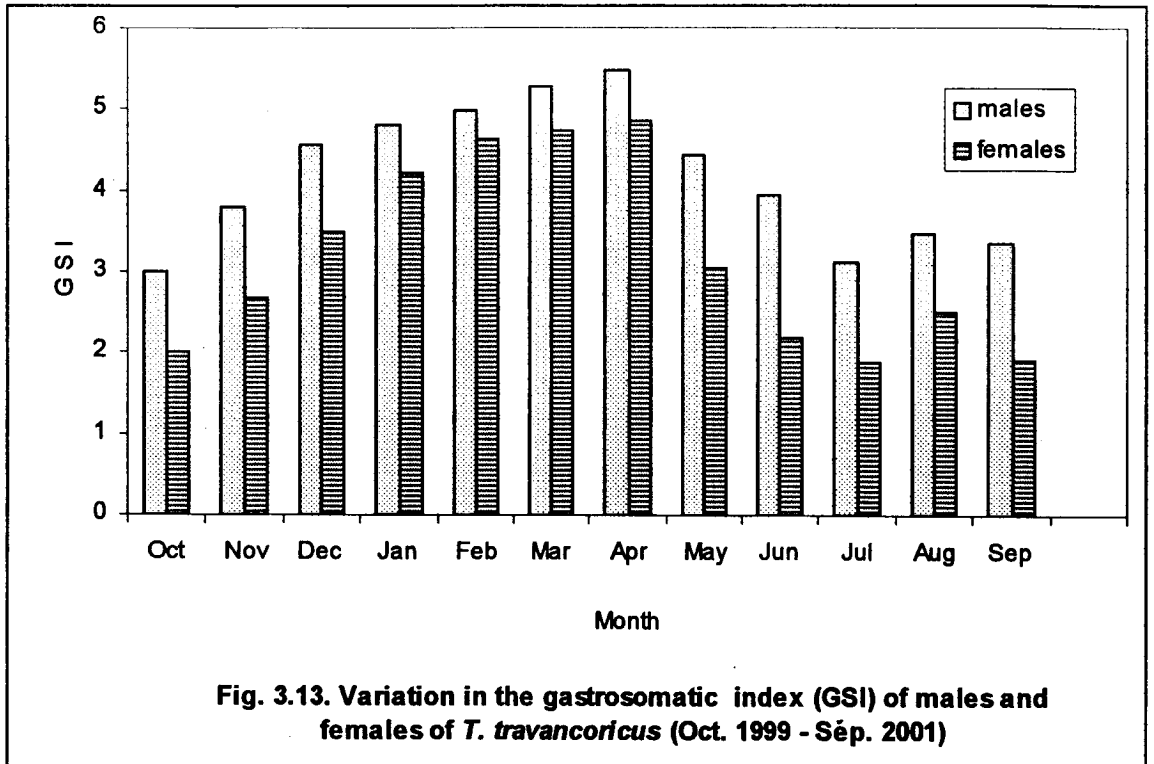


Fig. 3.10. Condition of feed in various length groups of *L. inermis* (Jan. 2000 - Dec. 2001)

40



41 A



42

AGE AND GROWTH

43

CHAPTER – IV

AGE AND GROWTH

INTRODUCTION

In fishery research, a knowledge of age and growth is very important because it is a necessary pre-requisite for answering many scientific questions related to management and conservation of fishes. Information on age and growth is essential to understand the dynamic features of population and helps in determining the quantity of fish that could be produced in a fish population against time. Once the addition of weight in a fish stock in relation to time is determined, the optimum size at age can be fixed for the rational exploitation. Thus, in the studies of biological profile of a species, age and growth form the most fundamental and important aspect. Knowledge of age data, in conjunction with length and weight can give valuable information on the stock composition, age and maturity, longevity, mortality, yield, etc. The age and growth study of fishes was first proposed by Petersen (1895) evolving a method to determine the age of fish from length frequency polygon.

Age and growth in fishes can be determined by both direct and indirect methods. Direct methods include tagging and recapture and culturing the fishes in cages, ponds or other

enclosed or semi-enclosed habitat providing congenial environment and suitable food substances. In the former technique, fishes are released back into water after properly tagging them and recaptured to note change in length against time. The direct methods are preferable as these approaches provide direct evidence, but are difficult to implement.

There are three commonly used indirect methods for the age and growth determination in fishes. The most frequently used method is the counting of growth zones or growth checks which appear in the hard parts of fishes such as scales, otoliths, fin-rays, vertebrae and interpreting the growth zones or growth checks. The second indirect method is simple and age is determined by analysis of length frequency distribution. The use of eye lens diameter and weight is also exploited in the age determination experiments, and this technique is relatively recent.

Growth determination from markings on hard parts of fishes has been successfully used in temperate waters. As fishes are poikilothermic, a characteristic periodicity is observed in their growth i.e., growth during summer and autumn is rapid and during the other seasons growth becomes slow due to food scarcity and unfavourable environmental conditions (Nikolskii, 1963). The unevenness in growth rate

is reflected on hard parts in the form of growth checks which are quite narrow and transparent. The fast growth is recorded as widely spaced or opaque zones. Some freshwater fishes of the tropics also show seasonal growth marks which correspond to the onset of dry season.

Age determination in fishes using hard parts (scales, otoliths, cleithra, opercular bones, vertebra, urohyal bone, etc) is two centuries old and a lot of literature is available on the use of hard parts in the study of fish growth. Maier (1906) made a review on the history of age determination from the 17th century to the end of 19th century. Lee (1920) also made a review of the methods of age and growth determination in fishes by means of scales. In the second half of the 20th century the main contributors were Menon (1950), Chugunova (1959), Bagenal (1974), Devraj (1981), Seshappa (1981), Campana and Neilson (1985), Lee and Yeh (1989), Secor and Dean (1989), Barger (1990), Campana (1990), Francis (1990), Pawson (1990), Fletcher (1991), Worthington *et al.*(1995), Sinis *et al.*(1999), Morales-Nin *et al.* (1999), Cardinale *et al.*(2000), Stevenson and Secor (2000), Fossen *et al.* (2003) and Pilling *et al.* (2003). Many of them concluded that otolith is one of the best objects for studying age of fish.

Age determination of fishes using hard parts has been done by many workers in India. The works of Seshappa and Bhimachar (1951, 1954), Muthiah (1982), Rao (1984), Gopinatha Menon (1986), Rao *et al.* (1986), Soni and George (1986), Ramakrishniah (1987), Maruthamuthu and Manickam (1988), Afser (1992), Rawat and Nautiyal (1996), Kurup (1997), Saha *et al.* (1997), Jayaprakash (1998), Johal *et al.* (2000) and Tessy (2001). Pectoral spines were used by Marzolf (1955) and Pantulu (1961) for the age determination of channel catfish and *Mystus gulio* respectively. Pantulu (1962) relied on the same structure for the age determination of *Pangasius pangasius*. Qasim (1973) and Murthy (1976) reviewed the work done on the age determination in Indian teleosts from 1952 to 1971 and 1954 to 1972 respectively and pointed out the diverse aspects regarding the contributive factors and the time of formation of the growth rings. Seshappa (1999) made a detailed review on the age determination of fishes in Indian waters from 1950 to 1994 and concluded that of the all methods available, the age ring method using scales, otoliths and other hard parts was the most satisfactory one.

The measurements on the hard parts are further validated by back-calculation. It is a technique that uses a set of

measurements made on a fish at one time to infer its length at an earlier time or times (Francis, 1990). Back-calculated lengths have been used for a variety of purposes, including estimation of lengths at age that are rarely observed, comparison of growth between sexes (Davis and West, 1992), cohorts (Beacham, 1981), populations of the same species (Gee, 1978), and different species (D'Onghia *et al.*, 2000).

Several back-calculation models have been proposed over the last 90 years including the direct proportional method (DPM) of Dahl-Lea (Dahl, 1907 and Lea, 1910), Fraser-Lee (Fraser, 1916 and Lee, 1920), scale proportional hypothesis, SPH (Whitney and Carlander, 1956), body proportional hypothesis, BPH (Francis, 1990), etc. Different workers have compared these methods to check their validity. Ricker (1992) supported the use of Fraser-Lee method while Pierce *et al.* (1996) found no significant difference between back-calculated lengths obtained using the Fraser-Lee, BPH and SPH methods.

In tropical waters, the markings on hard parts, though less pronounced, are found in marine and freshwater fishes, but no authentic evidence is available as to their annual nature. Various workers attribute the causative factors for such marking to spawning, fluctuations in food availability, monsoon, etc. Consequent upon the doubtful authority of

markings in fishes of the tropics, the method of length frequency distribution has found wider application for age determination. This technique known as 'Petersen's method' is easy to carry out and requires less equipment and facilities. Hence this method has become the most popular technique for the age determination of fishes all over the world. The peaks in the length frequency curve of a given sample are assumed to represent different age classes.

One of the major shortcomings of the method is that as there is overlapping of modes representing the older fishes due to the slowing down of growth in length, the determination of age at this stage becomes somewhat cumbersome. Harding (1949) and Bhattacharya (1967) with the aid of some graphical methods and Hasselblad (1966) by computer based methods solved the aforesaid problem to a certain extent.

George and Banerji (1964) followed the modal progression analysis for the estimation of age by sequentially arranging the peaks in the length frequency samples. Major drawback of this method is the judgement in interconnecting the resultant modes in the length frequency. Furthermore, the peaks in the length distribution may be the outcome of several broods arising from prolonged or fractional spawning. Pauly (1980) proposed an integrated method by combining the length

frequency method and the modal progression method. In this method a growth curve is drawn directly upon length frequency distribution arranged sequentially in time with a concept of length in fishes is fast in the early part of life and then slows down smoothly. Electronic length frequency analysis (ELEFAN) is a reliable and objective method of computer based length frequency analysis introduced by Pauly and David (1981) in which the composite length frequency is split into peaks and troughs. The growth curve passes through maximum number of peaks avoiding troughs.

Though a number of mathematical models are available for accessing information on age and growth of fishes, the most widely used model is the one proposed by von Bertalanffy (1938), the expression of which is as follows:

$$L_t = L_\alpha(1 - e^{-k(t-t_0)})$$

where, L_t = length at age 't', L_α = the maximum length the fish can attain theoretically, k =the growth coefficient, t_0 =age of fish at length zero, and e = the base of natural logarithm. The expression is based on the concept that growth is the net result of anabolism and catabolism. According to Beverton (1954) and Beverton and Holt (1957), von Bertalanffy's growth equation produces a growth curve with length that fits well the growth rate of many species.

A lot of literature is available on the application of length frequency distribution analysis (Petersen's method, modal progression, ELEFAN, etc) for the determination of age in many a fish from Indian waters, along with growth equation of von Bertalanffy. Chidambaram (1950), Dhulkhed (1977) Rengaswamy (1977) and Annigeri (1989) made detailed studies on the age and growth of oil sardines using the length frequency distribution method. Important workers on age and growth of Indian mackerels from various landing stations along South West coast of India were Pradhan (1956), Balakrishnan (1957), Sekharan (1958), George and Banerji (1964), and Yohannan (1979). Natarajan and Jhingran (1963) while studying the biology of *Catla catla* determined the age adopting length frequency method. Age determination of the catfish *Tachysurus thalassinus* by length frequency method was done by Mojumder (1977). Jayabalan and Krishnamoorthy (1986) made determination of age and growth in the toothed pony fish *Gazza minuta*; and using the same method, Jayabalan (1988) determined the age of *Leiognathus splendens*, Reuben *et al.* (1996) on *Ariomma indica*, Jayaprakash (1998) on flatfishes, Alam *et al.* (2000) on *Labeo calbasu*, Renukadevi (2002) on *Gerres filamentosus* and Sushantakumar Chakraborty

(2002) on *Nemipterus mesoprion* were the workers of the recent past who utilised length frequency distribution for studying age of fish.

Many workers tried the use of eye lens diameter and weight as age indicators in fishes. The ocular lens method was used previously for the estimation of age in mammals and birds (Friend, 1967). Later a number of workers concluded that the eye lens method could be used for the calculation of age of fishes. Calton and Jackson (1968), Burkett and Jackson (1971), Crivelli (1980) in the common carp, *Cyprinus carpio*, Boehlert (1985), Douglas (1987) in brown trout, *Salmo trutta*, Saleem *et al.* (1990), Al-Hassan *et al.* (1991) in *Mystus pelusius*, Al-Hassan *et al.* (1992) teleosts from Basrah waters, Iraq, Al-Hassan *et al.* (1994) in a catfish, *Siluris trigostegus* and Al-Hassan *et al.* (1999) in two sparid fishes off Benghazi coasts, Libya. More recently, Tessa (2001) used eye lens diameter and eye lens weight for determining the age of *Priacanthus hamrur* and *Pomadourys maculatus*. Udupa and Krishna Bhat (1986) suggested that even the eye diameter of a fish could be used as an indicator of age. They worked out the relationship between the total length and eye diameter of the Indian mackerel and determined the age of fishes belonging to different length groups.

A perusal of literature showed that no work has been done so far, for the determination of age in tetraodontids. The aim of the present study is to bring into light the various aspects of the age and growth of the freshwater puffer fish, *Tetraodon travancoricus* and *Lagocephalus inermis* from the South West coast of Kerala, as the information available on them regarding age and growth is scanty.

MATERIALS AND METHODS

The estimation of age and growth in the freshwater puffer fish *T.travancoricus* was carried out by adopting the length frequency distribution method in conjunction with the von Bertalanffy's growth equation fit. The samples were collected every month during the study period of twenty-four months from October 1999 to September 2001, in adequate numbers. The collections were done mainly from the Kechery puzha, the site being Puzhakkal. The total length of the fish was measured to the nearest millimeter and samples were divided into length groups of two millimeter class intervals, from the first length class of 9-10 mm to the last, 33-34 mm through 11-12, 13-14, 15-16, 17-18, 19-20, 21-22, 23-24, 25-26, 27-28, 29-30 and 31-32. A total of 1045 fishes were utilised for the present study. As the number of fish collected

was not the same in different months of collection, the length frequency distribution was made comparable by taking the percentage. A graph was plotted with length on X-axis and length frequency distribution on the vertical axis as percentage values. As the freshwater puffer fish is very small, (the highest observed length was 34 mm), the age was not considered in years 1,2 etc., but in quarter year increments.

Furthermore, the said age classification was also in somewhat good agreement with the observation made on fishes grown in captivity up to a period of one year.

Based on the results obtained from the length frequency analysis, length at ages was made which could be adequately expressed by von Bertalanffy growth equation,

$$L_t = L_\alpha(1 - e^{-k(t-t_0)}),$$

where, k =the growth coefficient, L_α maximum length the fish can attain theoretically, L_t =length at age, t and t_0 = age of fish at length zero.

The value of t_0 (age of fish at zero length) was estimated by plotting $\text{Log}_e(L_\alpha - L_t)$ against 't' as explained by Beverton (1954).

Growth parameters of the equation were solved by arithmetic method in the succeeding section.

von Bertalanffy's growth equation can be rewritten as:

$$L_{t+1} = L_{\alpha}(1 - e^{-k}) + L_t e^{-k}$$

It is the same as:

$$L_{t+1} = a + b * L_t$$

in which $a = L_{\alpha}(1 - e^{-k})$ and $b = e^{-k}$

$$\therefore L_{\alpha} = a / (1 - e^{-k})$$

The constant 'a' and 'b' can be solved by applying the least square method taking L_t (independent) and L_{t+1} (dependent) derived from the age length data.

The value of 'k' was determined by applying the formula,

$$k = \log_e 1/e^{-k}$$

$$\text{ie., } k = \log_e 1/b$$

The fit of von Bertalanffy's equation to length increments at successive quarters was compared with the results obtained from the length frequency method of age determination in the freshwater puffer fish.

Age determination in *Lagocephalus inermis* was done by observing the growth checks on the centra of vertebrae. Eye lens diameter and its weight were also made use of in the estimation of age. The fish brought from Munambam harbour, the main collection centre were measured to the nearest millimeter (total length) and after cleaning and blotting excess

moisture, weighed to the nearest gram. A total of 65 males ranging from 89 mm to 269 mm and 17 gm to 394 gm and 79 females ranging in length from 90 mm ~~to~~ 319 mm and 20 gm to 760 gm were utilised for the study. Both males and females were divided into 20 mm class intervals to mark the number of growth checks in the centra.

Vertebrae were collected from the fish after cooking it in boiling water and removing the flesh. The vertebrae were cleaned and dried before subjecting them for observing and counting the growth rings as explained by Tandon and Johal (1996). Vertebrae were then cleaved length-wise in the dorsoventral direction. Half of the vertebra was fixed on wax so that the growth checks could be identified and measured with ease. The distance between annular marks on either side (borne by the anterior and posterior centra) was measured using vernier calipers in millimeter. The total length of the vertebrae was also taken for facilitating back -calculation. Alternatively, the total lengths of the cleaved vertebrae and the distance between the growth check on oneside and its counterpart on the other were divided by two to get half the length of the vertebra and the distance between the origin and the various annuli. Making the centra dark using pencil tips produced better resolution of growth checks. The frequency

and number of annuli observed on vertebrae were recorded against the class intervals and the mean total length of fish was arrived at.

Back-calculation was performed using the following methods, though the equations were originally designed to study age of fish using scales. Still, Johal *et al.* (2001) employed the various back - calculation models for age determination using hard or bony structures (cleithrum and urohyal bone apart from scales) of silver carp; and as the BCLs were not significantly different from the observed length, DPM and SPH were adopted for the estimation of age using vertebrae.

1. Direct Proportional Method (DPM) of Dahl-Lea

$$L_i = (S_i S_c^{-1}) \cdot L_c$$

where, L_i = total length of fish at age i , L_c =total length of fish at the time of capture, S_i =distance between the i^{th} annulus on either side of the vertebra and S_c =total length of the vertebra.

2. Scale proportional hypothesis (SPH), which is based on the regression of vertebrae length on total length of fish

$$L_i = -(ab^{-1}) + (L_c + ab^{-1})(S_i S_c^{-1})$$

where L_i , L_c , S_i and S_c same as in DPM, 'a'=intercept and 'b'=slope of the regression line.

The percent difference of back-calculated lengths from observed lengths was calculated from;

$$\text{percent difference} = 100 [(L_b - L_o) L_o^{-1}]$$

where, L_b =back-calculated length and L_o = observed length (Klumb *et al.*,1999).

The method using eye lens in the determination of age was also done for *Lagocephalus inermis*. Ocular lenses were extracted from a total of 144 fishes ranging from 89 mm to 269 mm (males) and 90 mm to 319 mm (females). The eye lenses were removed from both left and right eye and kept separately after cleaning for further measurements. The diameter of the eye lens dried at room temperature was measured to the nearest millimeter using a screw gauge. The weight of the lens was recorded to 0.001 gm (1mg) using a digital electronic balance. The diameter and weight of the right and left eyes were taken and their mean was calculated for statistical analyses. The relationship between lens diameter and lens weight (dependent variables) against the total length of the fish for males and females separately was carried out using the formula,

$y=a + bx$, where y = eye lens diameter / eye lens weight, a =intercept, b =slope of the regression line and x =total length of fish.

RESULT

The length frequency distribution of the freshwater pufferfish for different months is shown in Table 4.1. The length frequency observed during the study period included specimens ranging from 9 mm to 34 mm. They were segmented into thirteen classes, each class mark with a width of only two millimeters. Four distinguishable modes emerged from the length frequency data (Fig. 4.1.) The first peak was observed in the 13-14 mm class mark. The second mode was in the 19-20 mm class mark which represented the fishes which acquired growth of 6 months. The next peak was rather a composite one encompassing both the eighth and ninth class marks. And hence the middle value of 24.5 mm was taken as the length attained by the fish at the end of ninth month. Another flattened out peak was observed between the 27-28 mm class width and 29-30 mm class width. Once again, the mean length (28.5 mm) was considered for fixing the age at one year completion. A fifth, but less pronounced value was obtained in the 31-32 mm length class. Considering the trend in growth pattern, it could be assumed that a mean length of 31.5 mm could be fixed as the length attained by the fish at the end of fifteen months.

The results of the length frequency analysis (age-length data) were utilised for fitting the von Bertalanffy's growth equation, $L_t = L_\alpha(1 - e^{-k(t-t_0)})$. Conversion of the said equation (explained elsewhere) required the regression of L_{t+1} on L_t . The constants 'a', the intercept value ($L_\alpha(1 - e^{-k})$) was found out to be 9.1335 and the regression coefficient 'b', (e^{-k}) provided a value of 0.7816.

Substituting the value of 'a' and 'b' in, $a = L_\alpha(1 - e^{-k})$

$$9.1335 = L_\alpha(1 - 0.7816)$$

$$L_\alpha = 9.1335 / 0.2184$$

$$= 41.82 \text{ mm}$$

The value of 'k' could be estimated by

$$k = \log_e 1/e^{-k}$$

$$= \log_e 1/0.7816$$

$$= \log_e 1.2794 = 0.2464 / \text{quarter}$$

$$= 0.9855 / \text{year}$$

The value of t_0 arrived at by graphical method was 0.1281/year (Fig. 4.2).

Thus, von Bertalanffy's fit for *Tetraodon travancoricus* could be read as:

$$L_t = 41.82(1 - e^{-0.9855(t-0.1281)})$$

Back-calculation was done to see the theoretical lengths attained by the fish at various ages and compared with the results obtained from age-length data (Table 4.2). The back-calculated lengths estimated were 13.01mm at age 0.25 year, 19.30 mm at 0.5 year, 24.22 at 0.75 year and 28.06 at the completion of one year of age. All these values provided overestimation of age by 3.36, 1.03, 1.14 and 1.54 percent compared to the observed lengths.

The number of growth checks in the centra of vertebrae and their frequency of distribution in different length classes in both the sexes of *Lagocephalus inermis* are consolidated and tabulated in Table 4.3. Of the 65 males, 26 showed no ring at all, 19 had one ring, 18 possessed two rings and only two were with the third ring in their vertebrae. In females (n=79), 21 had one ring, 17 were with two rings and eleven showed three rings in their vertebrae. Fishes up to a length of 139 mm showed no ring of growth. On the assumption that each ring is formed annually, the fishes were grouped into different age classes. The average length attained by the males at the completion of 1 year, 2 years and 3 years were respectively 148 mm, 212 mm and 269 mm. Females on the other hand showed a faster rate of growth and a mean length of 156 mm was reached within twelve months. The two-year old females

on the average showed a total length of 229 mm at the end of 24 months of life. The three-year old females attained a mean length of 292 mm, maintaining a difference of 26 mm from males.

Knowledge of the relationship between fish length and total length or half-the-length of the vertebrae is essential for the back-calculation of age. The mean length of vertebrae and total length of fishes ranging from 89mm-¹⁵269mm (males) and 90mm-319mm (females) segmented into length intervals of 20 mm class width were plotted in scatter respectively in Fig.4.3 and Fig.4.4. The spread of points showed that, there existed a linear relationship between the parameters both in males and females and the generalised relationship was $V_L = a + b \cdot TL$, where V_L represents the length of vertebra, 'a' and 'b' are constants and TL, the total length of fish. The regression equations calculated by the least square method in males and females were:

$$\text{Male : } V_L = 1.6038 + 0.0285 * TL$$

$$\text{Female } V_L = 2.1576 + 0.0280 * TL$$

Validation of the observed mean length at age was done by back-calculation. The direct proportional method (DPM) of Dahl-Lea and scale proportional hypothesis (SPH) were performed and the results are shown in Table 4.4 for males and

females of *L. inermis*. The back-calculated total lengths obtained by DPM for one-two-and three-year old males were 138.35 mm, 200.47 mm and 254.56 mm respectively.

The corresponding SPH values were 125.57 mm, 190.75 mm and 256.95 mm. The following were the back-calculated lengths obtained by DPM and SPH for females of one year old (DPM, 146.39 mm and SPH, 113.59 mm), two years old (DPM, 218.15 mm and SPH 200.88 mm) and three years old (DPM 287.04 mm and SPH 292.21 mm). The percent difference of back-calculated lengths from observed lengths both for males and females are presented in Table 4.5. The growth increments for observed length, DPM and SPH between age one and two were 64 mm, 62.12 mm and 65.18 mm for males and 73 mm, 71.76 mm and 87.29 mm for females. At the sametime the growth increments between age two and three were 54 mm (Obs. length), 54.09 mm (DPM) and 66.2 mm (SPH) in males and 63 mm (Obs.length), 68.89 mm (DPM) and 91.33 mm (SPH) in females. Comparison among observed length, DPM and SPH with respect to different years of age is shown in Fig. 4.5 (males) and Fig. 4.6 (females).

The relationship between the body length and eye lens diameter revealed that there existed a linear relationship in both the sexes of *Lagocephalus inermis*. The regression

equation of body length (TL) on lens diameter (Ed) of males based on a sample size of 65 fish ranging from 89 mm to 269 mm total length is given in Figure 4.7.

$$Ed = 0.5477 + 0.0184 TL \quad (r = 0.9939)$$

The regression equation of body length on eye lens diameter of females was, $Ed = 0.4570 + 0.0191 TL$ ($r = 0.9858$) based on a sample size of 79. The sample ranged in length from 90 mm to 319 mm. Figure 4.9 represents the relationship between the total length and eye lens diameter in females.

The average eye lens diameter attained by male *L. inermis* at the completion of one to three years were 3.2709 mm, 4.4485 mm and 5.4421 mm respectively. The corresponding average total lengths attained were 148 mm, 212 mm and 266 mm. diameter at different ages for males. The average total lengths reached by females at the completion of 1st, 2nd and 3rd years were 156 mm, 229 mm and 292 mm. The average total eye lens diameters during the aforesaid years were 3.4366 mm, 4.8309 mm and 6.0342 mm for females. The eye lens diameters at different completed years of growth for males and females are shown in Fig. 4.11.

The relationship between total length and eye lens weight of males and females of *L. inermis* is given in scatter diagrams (Fig. 4.8 & Fig. 4.10.) The regression equation of

total length (TL) on eye lens weight (Ew) based on a sample size of 65 fishes (males) ranging from 89 mm to 269 mm is given below.

$$Ew = -45.078 + 0.5476 TL (r= 0.9866)$$

The regression equation of body length on eye lens weight of females was,

$$Ew = -59.476 + 0.6512 TL (r= 0.9820)$$

The sample size was 79 and ranged in total length from 90 mm to 319 mm.

The average total lengths attained by the males in 1-3 years of completion were 148 mm, 212 mm and 266 mm, the corresponding values for the eye lens weight were 35.97 mg, 71.01 mg and 100.58 mg. In female *L.inermis*, the lengths attained at the completion of 1-3 years were 156 mm, 229 mm and 292 mm respectively and the corresponding average values of eye lens weight were 42.11 mg 89.65 mg and 130.67 mg. Fig 4.12 represents the mean weight of eye lens of males and females of *L. inermis* at various ages.

DISCUSSION

The length frequency method introduced by Petersen (1895) was the only reliable technique available for the determination of age in fishes for a long time. The polymodal

curve resulted from the length frequency distribution, explicitly proved that there existed individuals of various ages in the sample population subjected for the study. Towards the end of year one, the fish attained a mean total length of 28.5 mm showing a monthly growth rate of 2.4 mm. The average growth rate of 2.4 mm/month was appreciably lower than the rate of growth shown in the first quarter of growth ie 4.5 mm/month. The fast growth during the first three months was found slowing down and in the next six months the growth rate was only 2.33 mm/month. Further decrease in the growth rate in the fourth quarter (1.33 mm/month) could be attributable to the maturation and spawning stress because the attainment of size at maturity for *T. travancoricus* was observed to occur in the fourth quarter of its life. Flattening out of the polymodal curve in the region of 23 mm to 26 mm and 27 mm to 30 mm could be due to the differential growth between the sexes. Further, it might be the result of fractional spawning nature of the fish which provided individuals of insignificant length difference as there occurred slowing down of increase in length towards the reproductive maturity.

Age verification by calculating the growth parameters and fitting the von Bertalanffy growth equation also showed close agreement with the lengths-at-age derived by Petersen's

method. (Table 4.2). The value of growth parameter, K, was found to be high (0.9855/year). The growth coefficient values were observed to vary in different fish species. One of the lowest-ever 'K' values (0.2513/year) was found in *Hilsa ilisha* (Choudhury *et al.*, 1990). Natarajan and Jhingran (1963) worked out the 'K' value of *Catla catla* as 0.28/year. On the other hand, very high 'K' values were reported by Annigeri (1989) in *Sardinella gibbosa* (1.61/year) and Feroz Khan and Nandakumar (1993) in *Cynoglossus macrostomus* (1.6117/year). The growth parameter 'K' (per year) found in some other species of fish in the ascending order are, 0.4537 in *Scomberomorus commerson* (Naik *et al.*, 1998), 0.5034 in *Trichiurus lepturus* (Chakraborty, 1990), 0.5713 in *Ariomma indica* (Reuben *et al.*, 1996), 0.6092 in *Scomberomorus koreanus* (Naik *et al.*, 1998), 0.6117 in *Trichiurus lepturus* (Reuben *et al.*, 1997), 0.63 in *Labeo calbasu* (Alam *et al.*, 2000), 0.64 in *Labeo dussumeiri* (Madhusoodana Kurup, 1997), 0.66 in *Tenualosa ilisha* (Miah *et al.*, 1997), 0.71 in *Nemipterus mesoprion* (Chakraborty, 2002), 0.9317 in *Scomberomorus guttatus* (Naik *et al.*, 1998), and 1.44 in *Sardinella gibbosa* (Devaraj, 1983).

Pauly (1984) opined that species having shorter life have higher K values and reach their L_{α} very fast. On the other

hand, lower 'K' values show flat growth taking many years to reach L_{α} (Gulland, 1983). A high 'K' value found in *T.travancoricus* suggested that the fish reached its maximum growth in length in a few years. It was substantiated by the estimated length of the fish by von Bertalanffy's growth equation. The calculated length at the end of third year was approximately 40 mm ($L_{\alpha} = 41.82$ mm). It could be concluded that a slow and steady growth rate as the fish gets older, in species having moderately high growth coefficient, is applicable to *T.travancoricus*.

The discovery of regularly formed growth rings or annuli in scales, otoliths, vertebrae, urohyal bones, opercular bones, etc has provided a dependable additional and/or alternative method to assess the size of the fish at various ages. In *Lagocephalus inermis* the growth checks in the centra of vertebrae were identified and utilised for the determination of age. Ring formation is thought to be a result of the combined influence of biotic and abiotic factors ie; somatic growth, access to food, maturation, temperature and light (Rijnsdrop, 1993). The observation of Gauldie (1988) that, generally, the width of yearly growth zones in otoliths decreases with increasing age was also applicable to the growth checks in the centra of vertebrae of *L.inermis*. The rate of increase in length

in the first year of life for males was 12.33 mm per month, slightly lower than the growth in females (13 mm). The growth rates between age one and two respectively in males and females were 5.33 mm and 6.08 mm. It was further slowed down to 4.5mm/month in males and 5.25 mm in females in the third year of growth. The overall growth rate for males from 0-3 years was found to be 7.39mm/month whereas 8.11mm/month was the growth rate in females. Though the growth pattern was almost similar in both males and females, when average lengths for each year was taken, females showed higher lengths than males. The difference between growth rates of males and females was 5.41% in favour of females in the first year. During the second year and third year of growth, the percentage differences between males and females were 8.02% and 9.77% respectively, with females showing better length acquisition. This variation could be attributable to the sexual dimorphism as observed by Tessy and Inasu (1998) in *Priacanthus hamrur*.

Back-calculation is a technique that uses a set of measurements made on a fish at one time to infer its length at an earlier time or times (Francis, 1990). In the golden mahseer *Tor putitora*, Johal *et al.* (1999) employed three bony parts including vertebrae and found that there existed no significant

difference in the back-calculated lengths. The BCLs were providing overestimation of age when compared to the observed length. The overestimation in the early ages was greater than the back-calculated lengths in the older ages. The percentage difference between back-calculated lengths and observed lengths provided a range of -6.52% to -4.30% (males) and -6.16% to -1.70% (females) by DPM and -15.16% to -3.40% males and -27.16% to 0.07% (females) by SPH. With an increase in the size of the fish, the difference between the actual and back-calculated length decreased. Johal *et al.* (2001) traced the same pattern in the silver carp when back-calculated lengths were determined by different back-calculation models. The results demonstrated that, the back calculated length estimated by DPM was showing lengths close to the observed lengths. SPH provided lengths near the observed values at age three. The differences between the observed length and calculated lengths could be minimised if back-calculation lengths are based on a large sample size and the identification and measurements of annuli are highly precise.

Many workers concentrated on the whole structures like otolith and eye lens for the estimation of age in fishes. This goes in line with the opinion of Boehlert (1985) and Boehlert

and Yoklavich (1998) that inaccuracy might prop up owing to a certain degree of subjectivity in determining what constitutes a single growth check. Pawson (1990), Fletcher (1991), Worthington *et al.* (1995), Cardinale *et al.* (2000) and Pilling *et al.* (2003) were, but a few who related otolith weight to total length in age determination. Eye lens weight was considered by Crivelli (1980) for the age determination in the common carp, *Cyprinus carpio*. Douglas (1987) verified the age of the brown trout making use of the diameter of eye lens. Al Hassan *et al.* (1991), Al Hassan *et al.* (1992) and Al Hassan *et al.* (1994) published papers on the age determination of teleosts by considering eye lens diameter as age indicator. Eye lens studies of *Lagocephalus inermis* indicated that as the fish grows, the eye lens also enlarges in diameter and a corresponding change in weight of the ocular lens ensues. Udupa and Krishna Bhat (1986) found out a linear relationship between the eye diameter and total length in the Indian mackerel. The usual relationship between the eye lens diameter and fish length is isometric (Douglas, 1987). Same is the observation with eye lens weight and total length (Al Hassan *et al.*, 1999). The results of the present study also proved that the eye lens diameter and eye lens weight

increased with age in both sexes and showed isometric relationship.

However, in all these studies, although there was a general trend for an increase in average eye lens diameter and eye lens weight, certain amount of overlap was seen between different age groups. In *L. inermis*, the degree of overlap was greater in males at age one and age two. The absence of overlap at age three could be attributable to the number of fishes studied in that age group. Females showed overlapping in all age groups but the extent of it was rather reasonable and notwithstanding the overlap, fishes at different ages could be recognised considering either the eye lens diameter or eye lens weight.

The regression equations constructed separately for total length on eye lens diameter and total length on eye lens weight for males and females could be used as prediction lines, for estimating total length and hence age of fish using eye lens diameter and eye lens weight alone in the smooth blassop, *L. inermis*.

Table 4.1. Length frequency distribution of *Tetraodon travancoricus*

| Length (mm) | Jan. | | Feb. | | Mar. | | Apr. | | May | | Jun. | | Jul. | | Aug. | | Sep. | | Oct. | | Nov | | Dec. | |
|-------------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|
| | No | % | No | % | No | % | No | % | No | % | No | % | No | % | No | % | No | % | No | % | No | % | No | % |
| 9-10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 4.7 | - | - | 6 | 6.1 | 5 | 8.3 | - | - |
| 11-12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 9.4 | 6 | 6.5 | - | - | 13 | 21.7 | 3 | 2.9 |
| 13-14 | 9 | 8.5 | - | - | 14 | 13.0 | - | - | - | - | 7 | 9.2 | - | - | 11 | 12.9 | 20 | 21.7 | 12 | 12.2 | 7 | 11.7 | 15 | 14.4 |
| 15-16 | 12 | 11.3 | - | - | 12 | 11.1 | - | - | - | - | - | - | - | - | 13 | 15.3 | 8 | 8.7 | 11 | 11.2 | 5 | 8.3 | 9 | 8.7 |
| 17-18 | 6 | 5.7 | 3 | 3.7 | 8 | 7.4 | 13 | 14.8 | 15 | 22.1 | 6 | 7.9 | - | - | 10 | 11.8 | 4 | 4.3 | 5 | 5.1 | 5 | 8.3 | 9 | 8.7 |
| 19-20 | 15 | 14.2 | 19 | 23.2 | 20 | 18.5 | 34 | 38.6 | 24 | 35.3 | 12 | 15.8 | - | - | 3 | 3.5 | 5 | 5.4 | 3 | 3.1 | 2 | 3.3 | 31 | 29.8 |
| 21-22 | 12 | 11.3 | 4 | 4.9 | 15 | 13.9 | 7 | 8.0 | - | - | 7 | 9.2 | 35 | 44.9 | 8 | 9.4 | 11 | 11.9 | 19 | 19.4 | 11 | 18.3 | 3 | 2.9 |
| 23-24 | 12 | 11.3 | 16 | 19.5 | 11 | 10.2 | 13 | 14.8 | - | - | 12 | 15.8 | 21 | 26.9 | 11 | 12.9 | 10 | 10.9 | 25 | 25.5 | 3 | 5.0 | 14 | 13.5 |
| 25-26 | 27 | 25.5 | 37 | 45.1 | 9 | 8.3 | 17 | 19.3 | 29 | 42.6 | 13 | 17.1 | - | - | 6 | 7.1 | 3 | 3.3 | 2 | 2.0 | 1 | 1.7 | 6 | 5.8 |
| 27-28 | 7 | 6.6 | 3 | 3.7 | 11 | 10.2 | - | - | - | - | 5 | 6.6 | - | - | 5 | 5.9 | 14 | 15.2 | 13 | 13.3 | 8 | 13.3 | 4 | 3.8 |
| 29-30 | 6 | 5.7 | - | - | 6 | 5.6 | 4 | 4.5 | - | - | 14 | 18.4 | 9 | 11.5 | 6 | 7.1 | 10 | 10.9 | 2 | 2.0 | - | - | 10 | 9.6 |
| 31-32 | - | - | - | - | 2 | 1.9 | - | - | - | - | - | - | 9 | 11.5 | - | - | 1 | 1.1 | - | - | - | - | - | - |
| 33-34 | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 5.1 | - | - | - | - | - | - | - | - | - | - |

47

100

Table 4.2. Observed length and von Bertalanffy's growth estimated length of *Tetraodon travancoricus* along with percent difference

| Age in years | Observed length (mm) | Calculated length (mm) | Percent difference |
|--------------|----------------------|------------------------|--------------------|
| 0.25 | 13.50 | 13.01 | 3.63* |
| 0.50 | 19.50 | 19.30 | 1.03* |
| 0.75 | 24.50 | 24.22 | 1.14* |
| 1.00 | 28.50 | 28.06 | 1.54* |
| 2.00 | -- | 36.68 | - |
| 3.00 | -- | 39.90 | - |

* Overestimation of age

Table 4.3. Distribution of growth rings in the vertebrae of *Lagocephalus inermis* (males and females) against different length groups.

| Length group (mm) | Number of growth checks | | | | | | | |
|-------------------|-------------------------|--------|------|--------|------|--------|------|--------|
| | 0 | | 1 | | 2 | | 3 | |
| | Male | Female | Male | Female | Male | Female | Male | Female |
| 80-99 | 14 | 12 | | | | | | |
| 100-119 | 8 | 12 | | | | | | |
| 120-139 | 3 | 4 | 6 | 3 | | | | |
| 140-159 | 1 | 2 | 7 | 8 | | | | |
| 160-179 | | | 3 | 4 | 1 | - | | |
| 180-199 | | | 2 | 5 | 4 | - | | |
| 200-219 | | | 1 | 1 | 9 | 5 | | |
| 220-239 | | | | | 2 | 7 | | |
| 240-254 | | | | | 2 | 3 | | |
| 260-279 | | | | | - | 2 | 2 | 1 |
| 28--299 | | | | | | | - | 6 |
| 300-319 | | | | | | | - | 4 |
| Total | 26 | 30 | 19 | 21 | 18 | 17 | 2 | 11 |

Table 4.4. Validation of observed length of males and females at various ages of *Lagocephalus inermis* with back-calculated lengths by DPM and SPH.

| Age in years | Observed length (mm) | | Back-calculated length (mm) | | | |
|--------------|----------------------|---------|-----------------------------|--------|---------|--------|
| | males | females | males | | females | |
| | | | DPM | SPH | DPM | SPH |
| 1 | 148 | 156 | 138.35 | 125.57 | 146.39 | 113.59 |
| 2 | 212 | 229 | 200.47 | 190.75 | 218.15 | 200.88 |
| 3 | 266 | 292 | 254.56 | 256.95 | 287.04 | 292.21 |

DPM – Direct proportional method

SPH – Scale proportional method

Table 4.5. Comparison of the percent difference between observed length (Lo) and back-calculated lengths estimated by DPM and SPH for *Lagocephalus inermis*

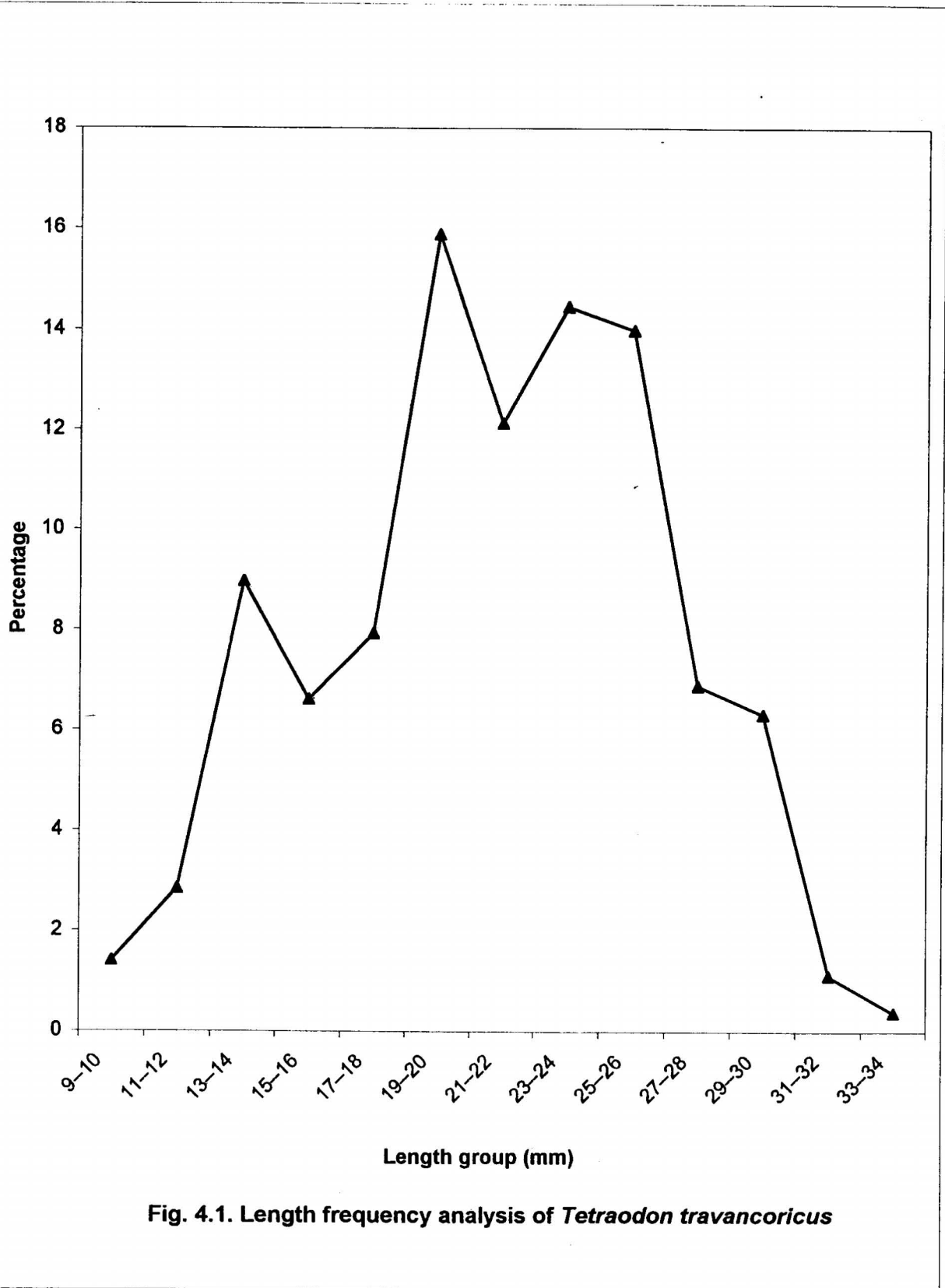
| Age in years | % difference between Lo & DPM | | % difference between Lo & SPH | |
|--------------|-------------------------------|--------|-------------------------------|---------|
| | male | Female | male | female |
| 1 | -6.52* | -6.16* | -15.16* | -27.16* |
| 2 | -5.44* | -4.74* | -10.02* | -12.28* |
| 3 | -4.30* | -1.70* | -3.40* | +0.07** |

* Overestimation of age

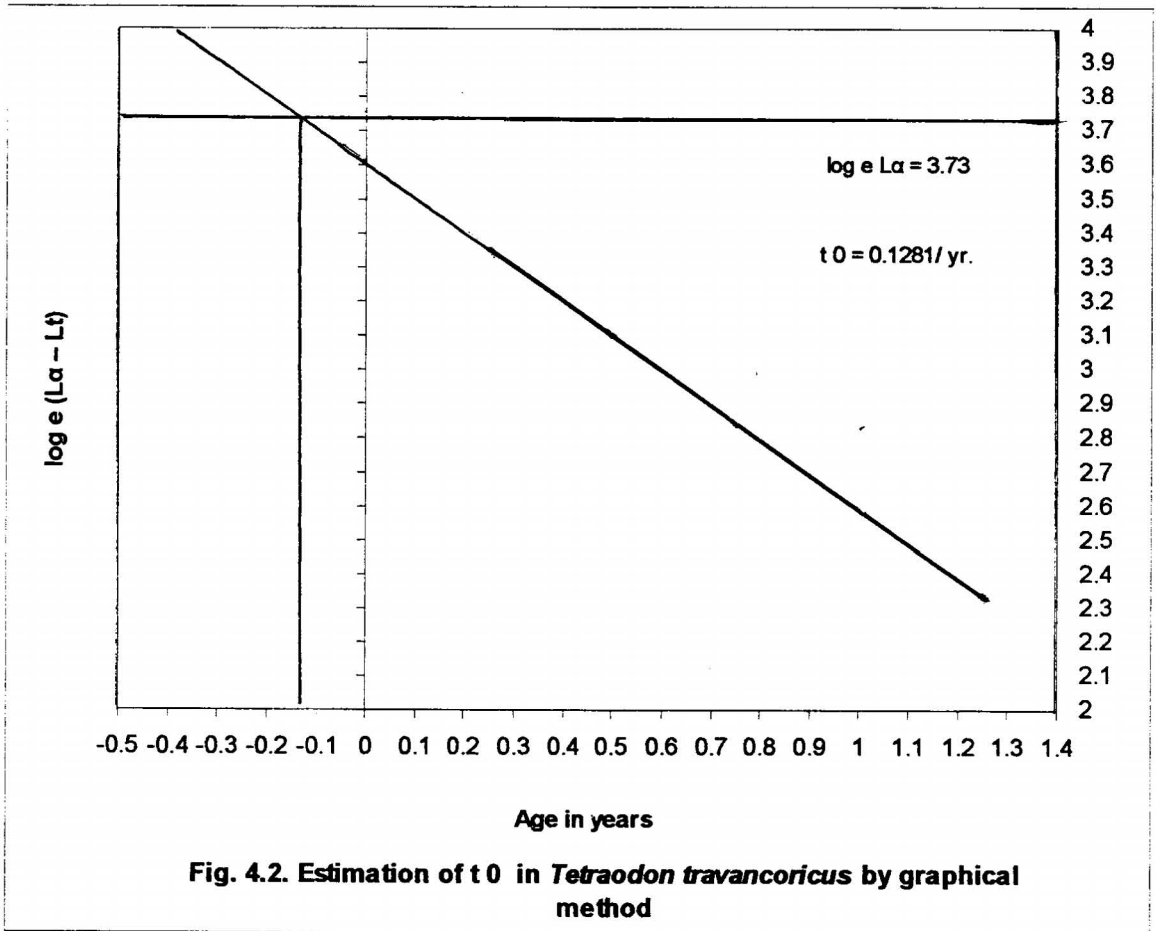
** Underestimation of age

Table 4.6 Relative range of eye lens diameter (Ed) and eye lens weight (Ew) in males and females of *Lagocephalus inermis* against age.

| Age in years | males | | females | |
|--------------|-----------|-------------|-----------|---------------|
| | Ed (mm) | Ew (mg) | Ed (mm) | Ew (mg) |
| 1 | 2.98-4.36 | 27.21-68.28 | 2.94-4.43 | 25.18-75.97 |
| 2 | 3.67-5.13 | 47.47-91.27 | 4.43-5.77 | 75.97-121.55 |
| 3 | 5.37- | 100.58- | 5.77-6.38 | 121.55-142.40 |



47 1090



48

1968

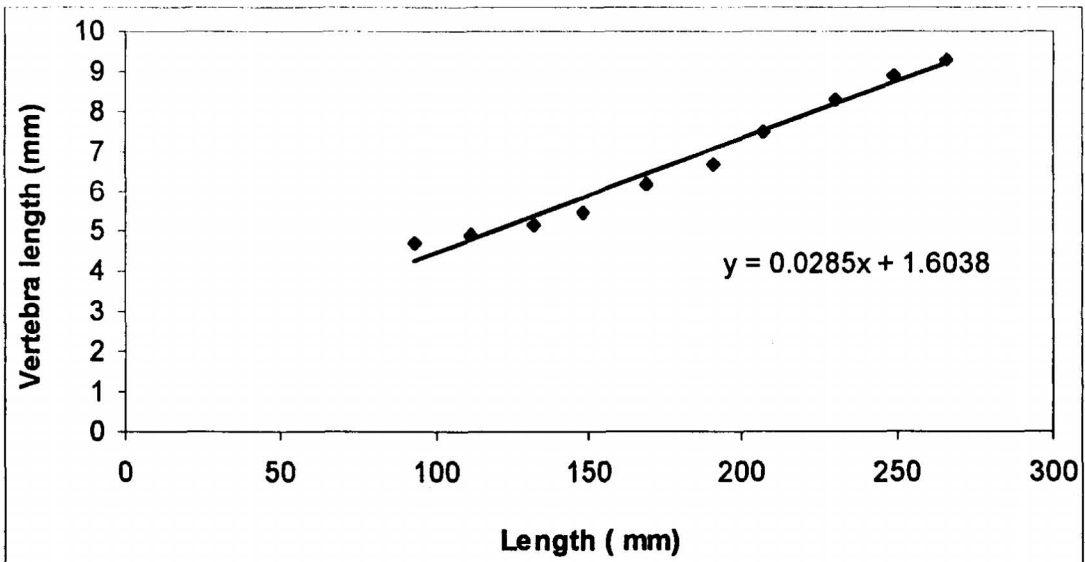


Fig. 4.3. Relationship between total length of fish and vertebra length in *Lagocephalus inermis* (males)

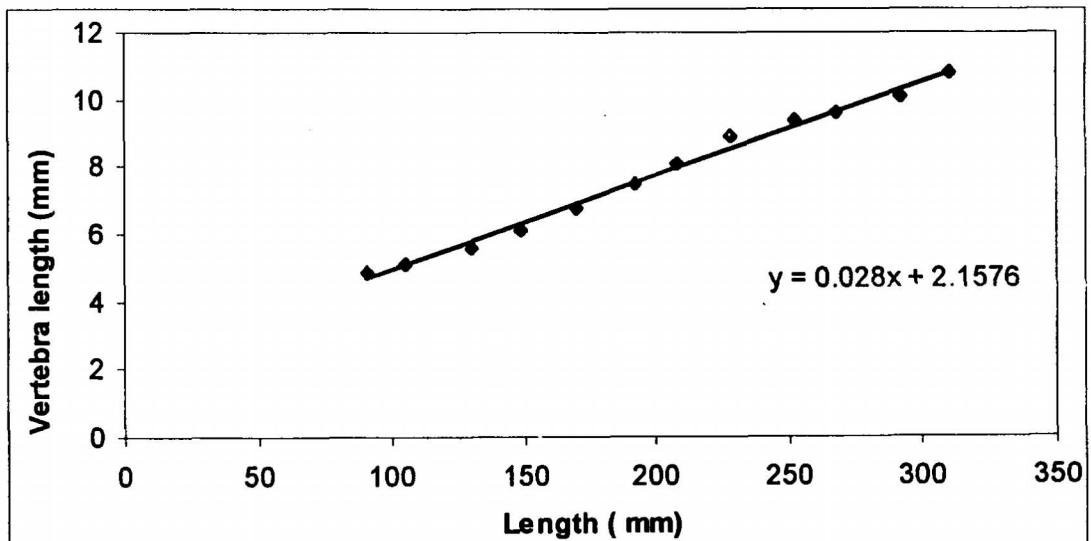
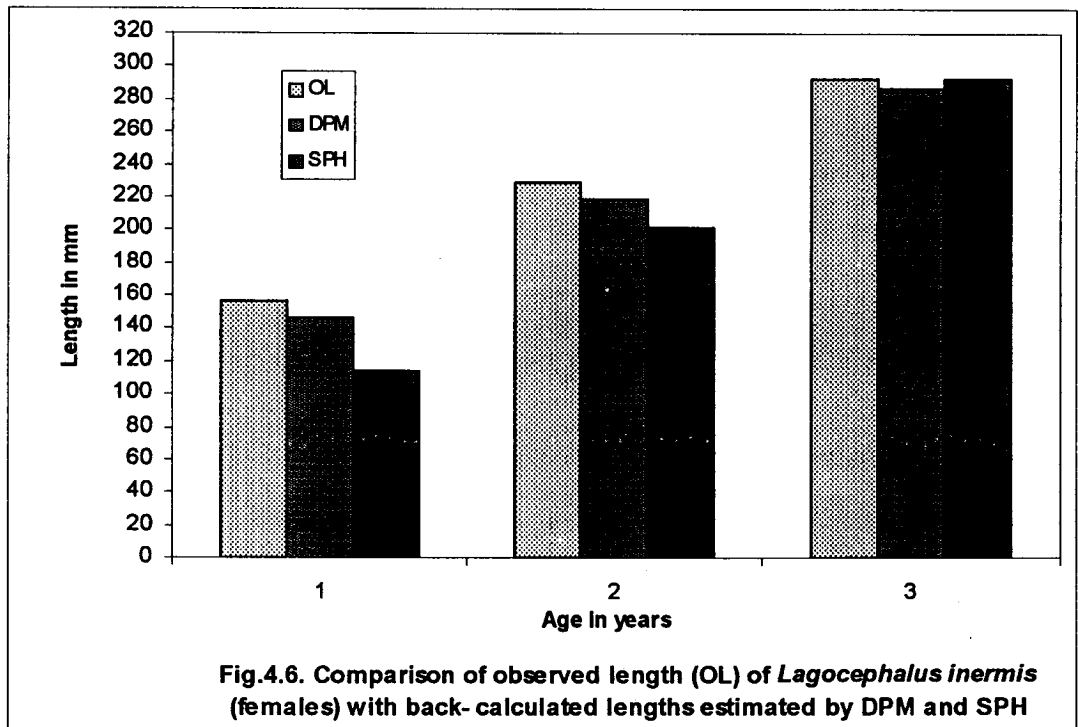
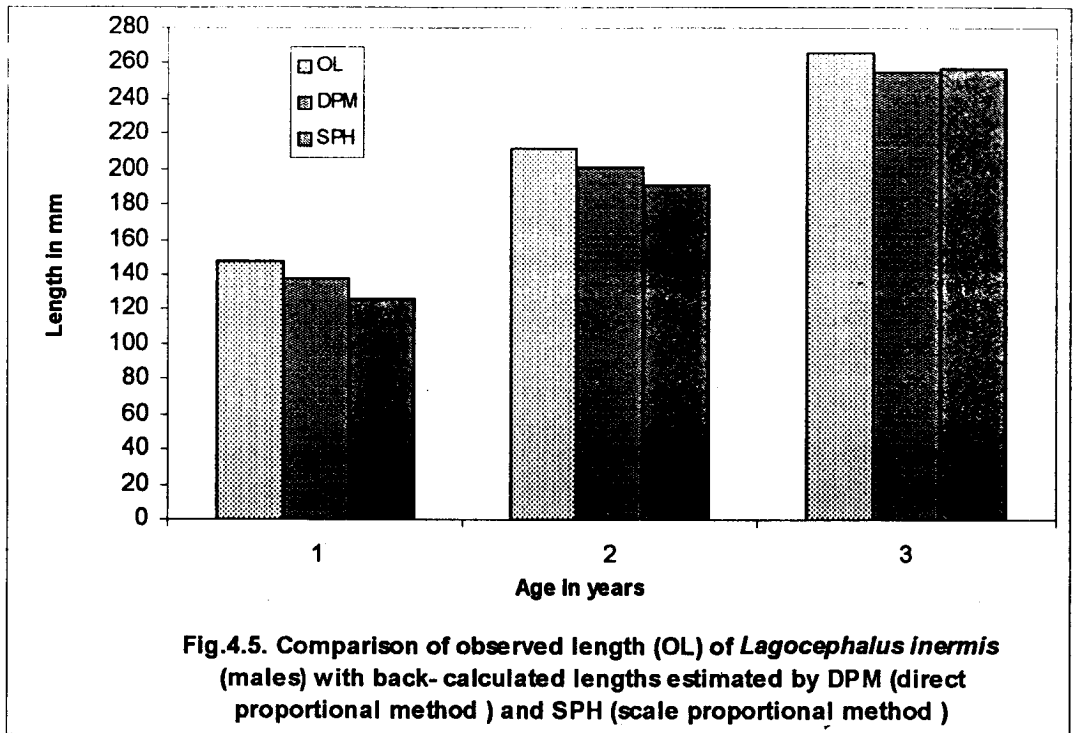


Fig.4.4. Relationship between total length of fish and vertebra length in *Lagocephalus inermis* (females)

45



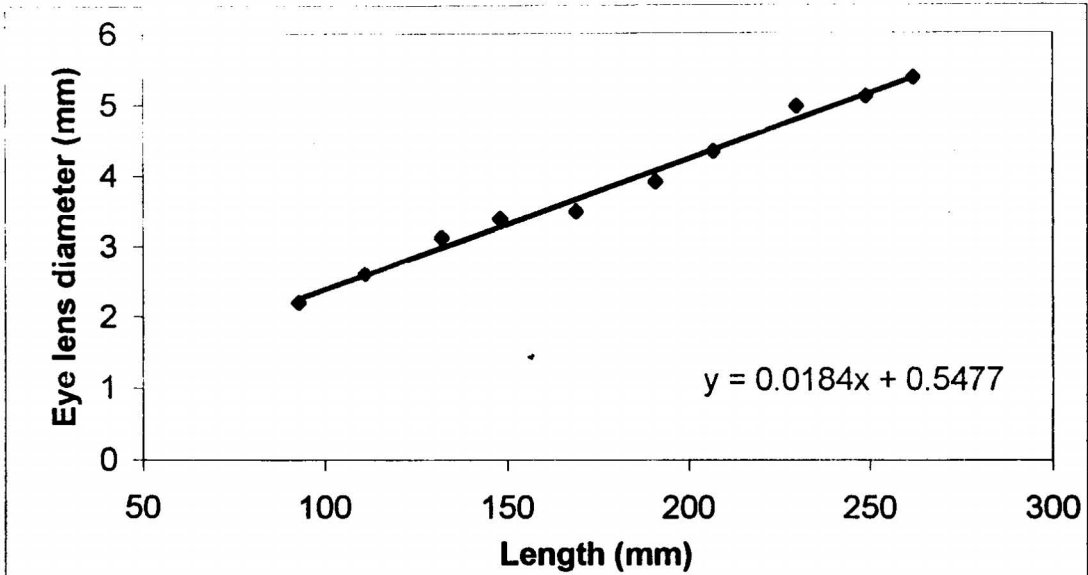


Fig. 4.7. Relationship between total length and eye lens diameter in *Lagocephalus inermis* (males)

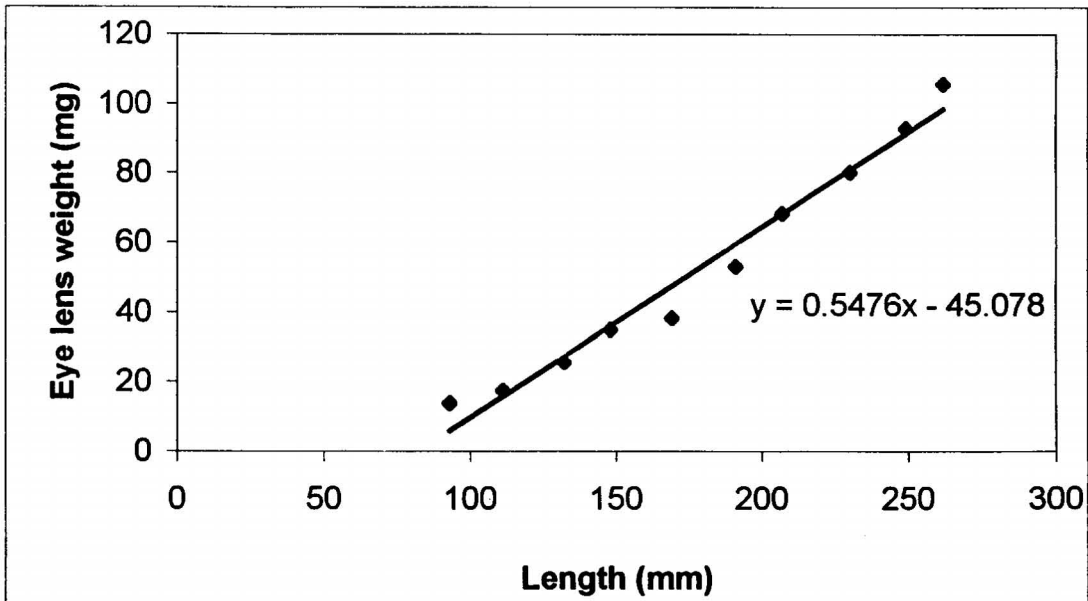
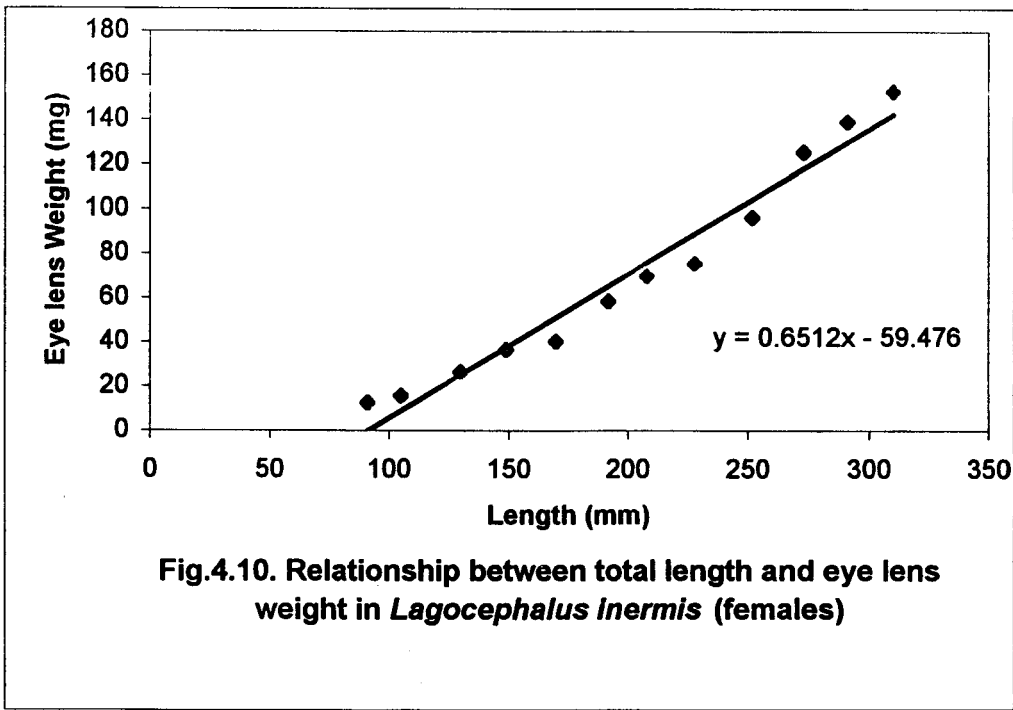
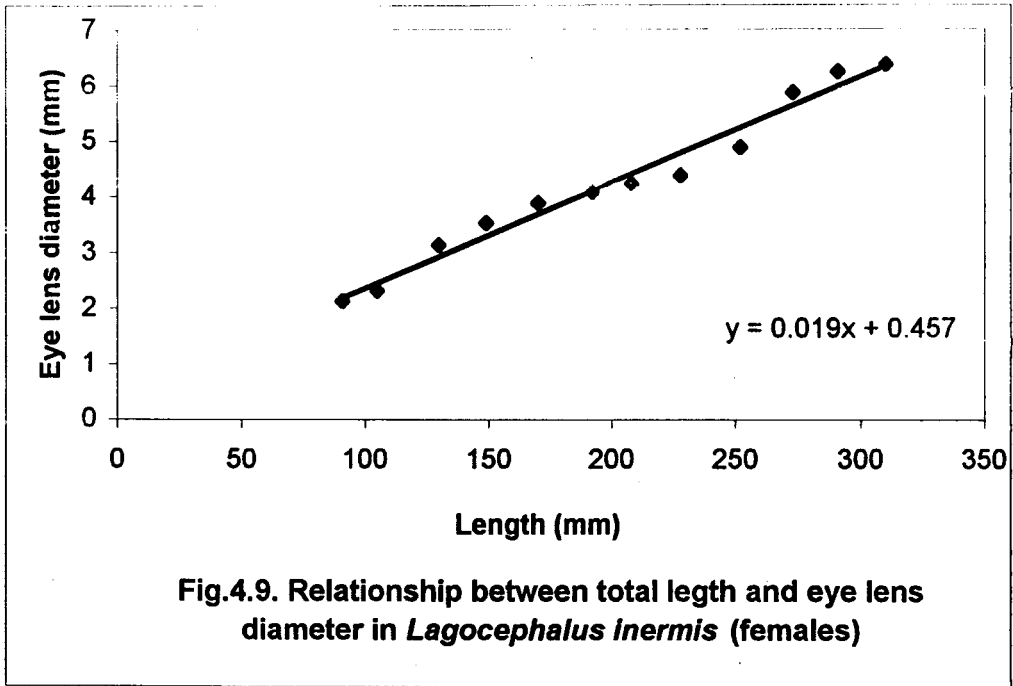
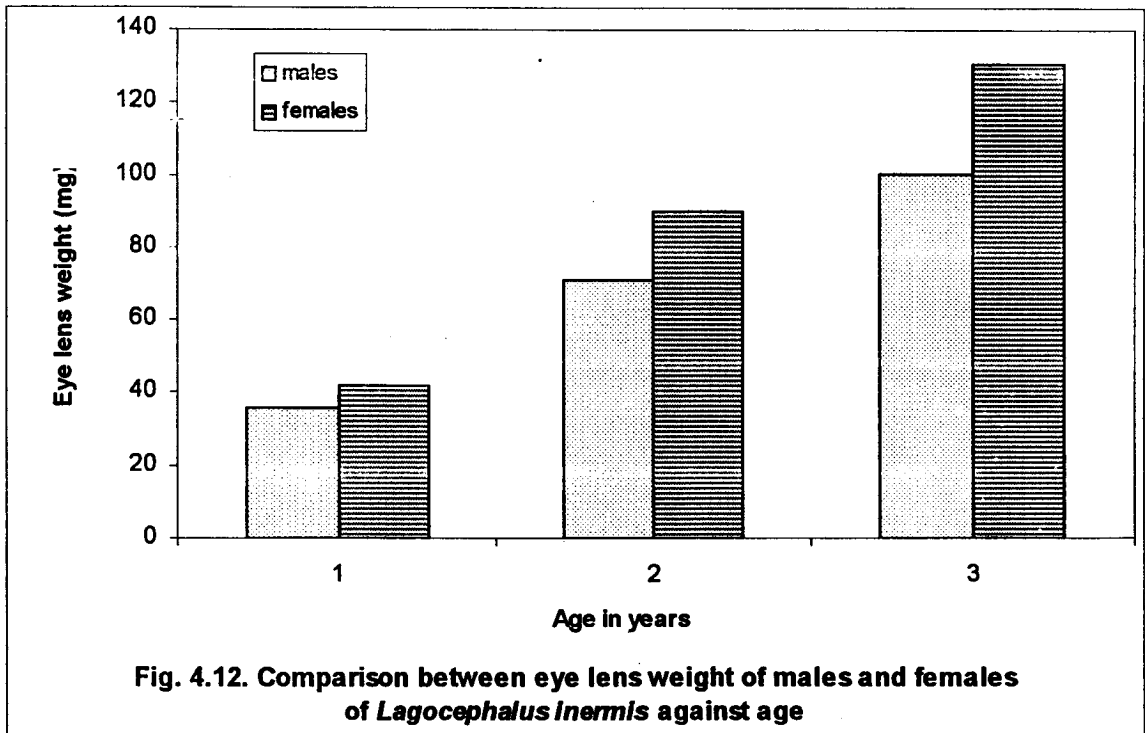
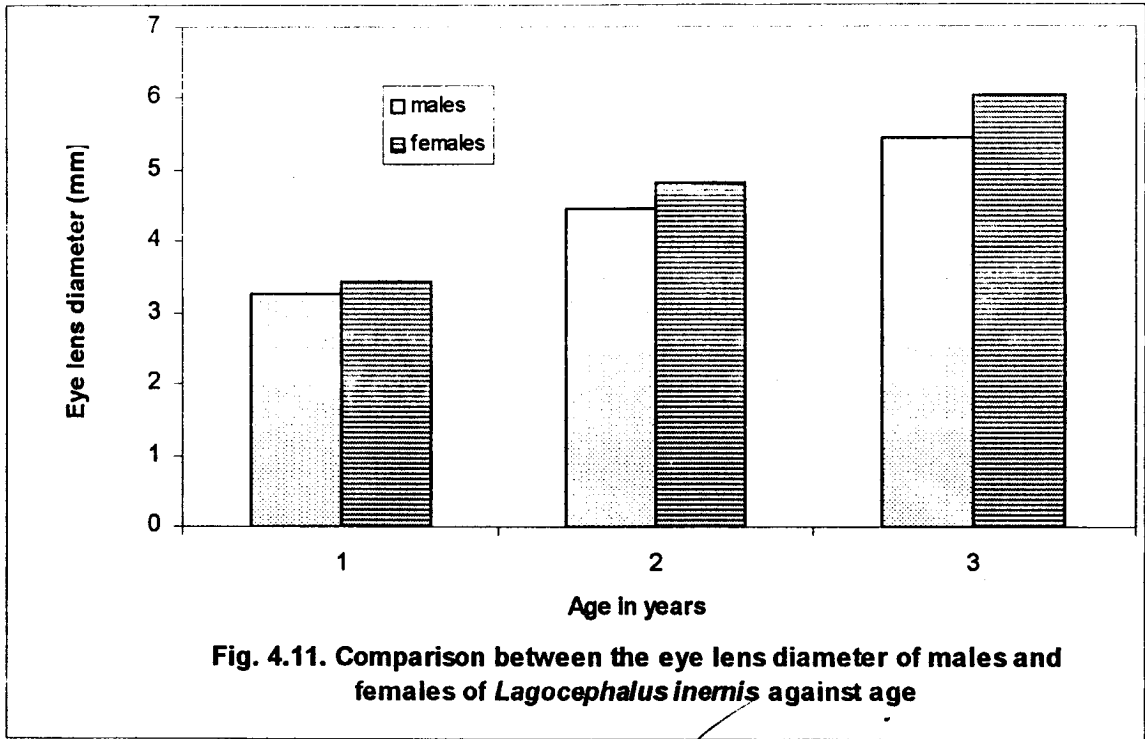


Fig.4.8. Relationship between total length and eye lens weight in *Lagocephalus inermis* (males)

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***LENGTH-WEIGHT RELATIONSHIP
AND RELATIVE CONDITION
FACTOR***

CHAPTER - V

LENGTH WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR

INTRODUCTION

Growth is the addition of material to that which has been already organized into a living pattern (Royce, 1984). Shrivastava (1985) opined that growth is increase in size, owing to conversion of food into the building matter of the body. Still an organism's somatic growth is frequently equated to an increase in bulk (Thompson, 1943; Bertalanffy, 1960). The rate of growth of fish is shown to vary much more than that of warm-blooded animals (Rounsefell and Everhart, 1953). Each part or organ of a fish has its own rate of growth (Balakrishnan and Rao, 1967) and the differential growth rates of the body parts, lead to the ultimate form of the fish.

An analysis of the length weight-relationship is of great importance in the study of the biology of any fish. The measurements of length and weight change with increasing age and contribute to the growth of an organism. It provides a mathematical relationship between length and weight of fish, enabling the calculation of one variable from the other (inter-conversion), and to measure variation from expected weight for

length of individual fish or groups of fish as indications of fatness or general well-being (Le Cren, 1951). This study also sheds light on the spawning season, variation in weight due to feeding and growth, etc. by calculating condition factor (K) and relative condition factor (Kn). Information on length-weight relationship is important in setting up equations, in estimating the number of fish landed and in comparing population in space and time (Beverton and Holt, 1957). Antony Raja (1967) expressed the view that length-weight relationship studies are important in converting catch statistics of commercially important species of fishes from weight to number, in order to obtain the abundance of stock, spatially and temporally.

The growth pattern of a fish, varies at different times in its life cycle depending on the availability of food, optimum temperature for growth, etc. The weight of the fish normally increases with increase in length. Since length is a linear measure and weight, a measure of volume, it has been shown that these two parameters can be related and described by the hypothetical cube law $W=cL^3$, where 'W' represents weight of fish, 'L' is the length and 'c' a constant. Thus, in general, the growth of fishes in weight is directly proportional to the cube of the length (Allen, 1938; Lagler, 1956). But this equation

could be applied only if form and specific gravity of the fish remain constant throughout the life period of the fish. But what happens actually is that fishes do not keep constancy in growth and body form as they pass through several stages in the course of development. The importance of variations in specific gravity of fish in relation to condition was studied by Tester (1940), which was further reviewed by Kesteven (1947).

Le Cren (1951) pointed out that the cubic expression doesn't hold good always and suggested a generalized parabolic equation, $W=aL^b$, where W and L represent weight and length of fish respectively, 'a' and 'b' constants estimated empirically from the data. The exponential value of 'b' in the parabolic equation has been found to vary from 2.5 to 4 (Hile, 1936 and Martin, 1949). Still, Beverton and Holt (1957) suggested that the value of the exponent 'b' would be near or around 3. Depending on the value of 'b' fishes can be classified into three groups: (a) $b=3$, where the body form of fish remains constant at different lengths (isometric), (b) $b<3$, when fish becomes more slender as the length increases and (c) $b>3$, where fish grows more stout with increase in length (allometric).

The constant 'a' can be used to compare an individual with others of the same species after 'b' is established. Brown

(1957) opined that the value of 'a' would depend on the fatness, as the specific gravity of the fish flesh doesn't vary much within species and it will be high in fat fishes and low in thin fishes.

The equation $W=aL^b$ can be transformed into linear function by taking logarithmic value of the length and weight data and the values of 'a' and 'b' can be estimated by regression analysis. Then the parabolic equation, $W=aL^b$ takes the form.

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

$$Y = A + bX$$

where 'Y' = log W, 'X' = log L, 'A' = log a, the intercept of the line on the 'Y'-axis and 'b', the exponent.

Length-weight relationship studies have been conducted by many workers, on a variety of fishes from Indian waters. Jhingran (1952) conducted one of the pioneering works on three species of major carps viz., *Labeo rohita*, *Cirrhina mrigala* and *Catla catla* with the application of approved modern statistical method. Others include Prabhu (1955) on ribbon fish, *Trichiurus haumela*, Bal and Joshi (1956) on *Coilia dussumieri*, Pantalu (1956) on Indian freshwater eel, Pradhan (1956) on mackerel, Radhakrishnan (1957) on *Sillago sihama*, Rao (1962) on *Pseudosciaena diacanthus*, Antony Raja (1967)

on *Sardinella longiceps*, Sekharan (1968) on *Sardinella gibbosa*, Krishnamoorthi (1971) on *Nemipterus japonicus*, Sinha (1973) on *Puntius sarana*, Anil Chatterji *et al.* (1980) on *Labeo calbasu*, James and Badrudeen (1981) on *Leiognathus dussumieri*, Srinivasan (1981) on *Decapterus dayi*, Muthiah (1982) on *Johnieops vogleri*, Udupa and Bhat (1983) on mackerel, Seshappa and Chakrapani (1984) on *Cynoglossus lida*, Shyam (1984) on *Cyprinus carpio* Anil Chatterji and Ansari (1985) on oil sardine, *Sardinella longiceps*, Kulkarni *et al.* (1986) on *Scoliodon laticaudus*, Pratap and Mkamba (1987) on the cichlid, *Oreochromis urolepis*, Madhusoodana Kurup and Samuel (1987) on *Gerres filamentosus*, Sivakami (1987) on *Ompok bimaculatus*, Gopinathan (1988) on *Tilapia mossambicus*, Rao (1988) on *Stolephorus devisi*, Das and Misra (1989) on the Indian halibut, *Psettodes erumei*, Giasuddin Khan and Gulam Mustafa (1989) on *Nemipterus japonicus*, John and Nair (1989) on *Nandus nandus*, Chakraborty (1990) on *Trichiurus lepturus*, De and Datta (1990) on *Tenualosa ilisha*, John and Balakrishnan Nair (1991) on *Nandus nandus*, Madhusoodana Kurup and Samuel (1992) on *Liza parsia* (mullet), Philip (1994) on *Priacanthus*, Tessy (1994) on *Epinephelus* species, Sivakami (1995) on the carangid, *Megalaspis cordyla*, Pandey (1995a) on *Catla catla*, Pandey

(1995 b) on *Hilsa ilisha*, Umesh and Sarma (1996) on *Clarias batrachus*, Das *et al.* (1997) on the catfish *Arius tenuispinis*, Kalita and Jayabalan (1997) on *Caranx kalla*, Sarkar *et al.* (1997) on *Catla catla*, Jayaprakash (1998) on *Cynoglossus*, Mahapatra and Dutta (1998) on *Aristichthys nobilis*, Pandey (1998) and Sarkar *et al.* (1998) on *Cirrhinus mrigala*, Sunil *et al.* (1999) on *Horabagrus brachysoma*, Shanmugam *et al.* (2000) on *Epinephelus malabaricus*, Sunil (2000) on *Rasbora daniconius*, Doddamani *et al.* (2001) on *Stolephorus bataviensis*, Khan *et al.* (2001) on *Hilsa ilisha*, Anna Mercy *et al.* (2002) on *Puntius denisonii*, Narejo *et al.* (2002) on *Monopterus albus*, Raje (2002) on *Nemipterus japonicus*, Sivashantini and Abeyrami (2003) on the silver biddy, *Gerres oblongus*, and Udupa *et al.* (2003) on *Liza tade* from estuaries of the Southern Karnataka coast.

Owing to nutritional, physiological, environmental and biological changes affecting the fish, they show variations from the expected weight for the length. Tester (1940) opined that variation in specific gravity of flesh of fish occurs during growth and its importance in the study of condition has been provided by Kesteven (1947). The variation from the expected weight for length of individual fishes or group can be detected by an analysis of the condition factor, coefficient of condition

or ponderal index (Hile, 1936; Thompson, 1943). The condition factor is given by the formula, $K = 100 \cdot W/L^3$, where 'K' represents the condition factor, 'W' represents the weight of fish and 'L' represents its length. It is based on comparison with an ideal fish which obeys cube law in the length-weight relationship. Le Cren (1951) pointed out that 'K' values get affected if the fish fails in obeying the cube law. A number of factors like age, sex, stage of maturity, availability of food, environment, degree of parasitization, etc. would affect the value of 'K' and proposed the relative condition factor 'Kn' calculated by the following formula $Kn = W/w$, where 'W' = observed weight of the fish and 'w', the calculated weight obtainable from the length-weight relationship. The difference between condition factor 'K' and relative condition factor 'Kn' is that the former gives information on deviation of an individual fish from the average weight for length while the latter expresses the variation from a hypothetical ideal fish.

In spite of the vastness in literature on scores of fishes related to length-weight relationship studies, no information is available about the same with tetraodontids. The study on the relative condition factor of the puffer fishes too remains as a neglected field of research endeavour. In the present study, an attempt has been made to study the length-weight relationship

of two tetraodontids, *Tetraodon travancoricus* and *Lagocephalus inermis*. The relative condition factors of the said fishes, month-wise as well as size-wise have also, been tried at, to draw a well-defined picture on the condition of the two fishes.

MATERIALS AND METHOD

Tetraodon travancoricus and *Lagocephalus inermis* were collected from the freshwater bodies and landing center at Munambam respectively for the studies on length – weight relationship. Samples brought to the lab were cleaned and excess moisture was blotted off. Fishes were measured to the nearest millimeter and weighed to 0.001 gm for *T. travancoricus* using a decimal 3 digit electronic balance and nearest 1gm by a 1 kg capacity monopan spring –balance for *L. inermis*. A total of 290 *T. travancoricus* males ranging between 19 mm and 34 mm and weighing 188 mg to 1250 mg and 305 females, ranging 18 to 31 mm and 181 mg to 1170 mg were taken for the study. Of the total 314 *L. inermis*, 149 were males and 165 females. Length-weight relationship was worked out separately for males and females. The length-weight relationship was calculated using the formula, $W = aL^b$. For fitting the exponential equation, the least square method was

adopted using $\text{Log } L=X$ and $\log W=Y$ to obtain ΣX , ΣX^2 , \bar{X} , ΣY , ΣY^2 , \bar{Y} and ΣXY . \bar{X} and \bar{Y} represent mean values of X and Y respectively.

The regression coefficient or slope of the regression line (b) was computed using the equation,

$$b = [\Sigma XY - (\Sigma X)(\Sigma Y)/N] / [\Sigma X^2 - (\Sigma X)^2/N]$$

where, 'N' is the number of observations. The intercept 'a' could be determined by the equation $\log a = \bar{Y} - b\bar{X}$. Using these values, the linear equation of length - weight relationship, $\text{Log } W = \text{Log } a + b \log L$ or $Y = A + bX$ was obtained (here, $A = \log a$).

The significance of variation between the regression coefficients of males and females was tested by analysis of covariance (Snedecor and Cochran, 1967), to ascertain the establishment or fitting of a single length-weight relationship equation for *T.travancoricus* and *L. inermis*.

The estimates of regression coefficients were tested for finding the deviation from the expected value of three (to gather information on whether growth follows isometric or allometric pattern) by employing the 't' test using the formula,

$$T = (b-B)/sb, \quad \text{where } B=3, b=\text{regression coefficient and } sb=\text{standard error of } b.$$

Scatter diagrams of length against weight and linear plots were prepared separately for males and females and pooled data for *T.travancoricus* and *L. inermis*.

A total of 595 (males, 290 and females, 305) *T.travancoricus* and 314 (male 149 and females 165) of *L. inermis* were used for present investigation to collect data for computing relative condition factor. The collected fishes were measured to the nearest millimeter for both the fishes and weighed to 0.001 gm for *T.travancoricus* and nearest gm for *L.inermis*. Further, fishes were grouped into length groups of 3 mm and 30 mm for *T.travancoricus* and *L. inermis*, respectively.

The relative condition factors of both the fishes were worked out based on Le Cren's formula $K_n = W/w$, where 'Kn' = relative condition factor, 'W'=observed weight and 'w' = calculated weight derived from length weight relationship. Monthly mean values of Kn were calculated for *T. travancoricus* and *L. inermis* in both the sexes for a period of two years; for the former fish from October 1999 to September 2001 and the latter from January 2001 to December 2002. Kn values of various size groups were calculated during the study period for both the fishes to observe fluctuations, if any, in the relative condition factor with respect to length of fish in males

and females. The mean pooled Kn values for two years were also found out.

RESULTS

Fig. 5.1 and Fig. 5.2 represent the scatter diagrams with exponential line for males and females of *T.travancoricus* and the parabolic equations in the said order were :

$$\text{Male } W = 0.05279 L^{2.7858}$$

$$\text{Female } W = 0.08888 L^{2.6415}$$

The same equations could be given in the linear form as

$$\text{Male } \text{Log } W = \text{Log } -1.2774 + 2.7858 \text{Log } L \quad (r=0.9397)$$

$$\text{Female } \text{Log } W = \text{Log } -1.0512 + 2.6415 \text{Log } L \quad (r=0.9041)$$

The logarithmic form of relationship is shown in Fig.5.4 (males) and Fig. 5.5 (females).

Analysis of co-variance conducted to test the difference between the regression coefficient of males and females showed that the estimates were significantly related. A common (pooled) equation was thus constructed along with logarithmic conversion of the exponential equation as follows:

$$W = 0.07489 L^{2.6866}$$

$$\text{Log } W = \text{Log } -1.1261 + 2.6866 \text{Log } L \quad (r=0.9156)$$

Fig. 5.3 and Fig. 5.6 show the scatter of weight on length and logarithmic relationship of the same respectively with the pooled data for *T.travancoricus*.

The estimates of the parameters 'a', 'b' and correlation coefficient 'r' are tabulated in Table 1 and Table 2 represents the analysis of co-variance between the 'b' values of males and females. Two tailed 't' test was applied to see whether the 'b' values arrived at for males, females and pooled were significantly different from the cube law value of 3 (Table 3). The results of the t-test applying the formula, $t = (b-B)/sb$, to test the significance of variation in the estimate of 'b' from the ideal fish were,

Males = -3.5581, Females = -4.2934 and Pooled = - 6.0385.

Length weight relationship of males and females of *L. inermis* are shown as scatter diagrams in Fig. 5.7 and Fig. 5.8. The parabolic equations for males and females are shown below.

$$\text{Males } W = 0.00003867 L^{2.8797}$$

$$\text{Females } W = 0.00003914 L^{2.8892}$$

Logarithmic transformation of the equations for males and females to get linear relationship was made to obtain the following equations

Males $\text{Log } W = \text{Log } -4.4127 + 2.8797 \text{ Log } L$ ($r=0.9831$)

Females $\text{Log } W = \text{Log } -4.4073 + 2.8892 \text{ Log } L$ ($r=0.9915$)

The corresponding graphical relationships are shown in Fig.5.9 and Fig.5.10. The degree of association in the 'b' estimates for males and females was worked out by analysis of covariance and the F ratio was found to be 13.4146. It was less than the table value of 6.70 (at 1% level) and explicitly illustrated the need for separate equations for the two sexes.

The equation constants 'a' and 'b' along with 'r' values are provided in Table 4. The calculation of F-ratio is shown in Table 5. To ascertain the adherence of cube law in the length-weight relationship in *L.inermis*, 't'-test was done for males and females. The results of the t-test for males (-2.7156), and females (-3.7306) were significant at 1% level (Table 6).

The mean Kn values in relation to size groups of *T.travancoricus* of males and females ranging in size from 18 mm to 34 mm in total length are presented in Table 5.7. The Kn values in males ranged between 0.8401 and 1.0333. The first size group (18mm-20mm) showed the lowest Kn value of 0.8401 while the second length group from 21mm-23mm provided the second lowest value. The condition of the fish was noticeably increased in the third group (24mm-26 mm) and touched 0.9954. The males belonging to the 27mm to 29mm

category showed a better condition (1.0010). The highest Kn value was shown by the 33mm–35mm category fishes. Females of *T.travancoricus* followed almost the same pattern up to the fourth size class. The first length group (18-20mm) showed Kn value of 0.9290. There was an insignificant dip in the mean Kn value to 0.9959 in the 27-29mm category from 0.9982 of 24-26mm size group. But in the last group i.e., 30mm-32mm, the Kn increased and recorded the highest value (1.0418).

In *Lagocephalus inermis*, among males, the highest Kn value was recorded in the 170mm–199mm length group (1.0281). The lowest value of 0.9920 was observed in the smallest length group i.e., 80 mm–109 mm. From that size group onwards the Kn values progressed slowly until the fourth length group category. Then, there was a sharp decrease which once again picked up and touched 1.0055 in the 260mm–289mm category. The second highest mean Kn value was calculated for the 140mm–169mm length group. Strangely enough, the second lowest condition was observed in the 200mm-229mm class. Among females, unlike in males, the highest mean relative condition value was recorded by members belonging to the 230mm–259mm length group (1.0153). The second highest mean Kn value was observed in

the 170mm-199 mm size category (1.0130). A comparative observation on the mean Kn values of males and females of *L. inermis* in different size groups are shown in Table 5.8.

The mean Kn values of males and females of *T. travancoricus* during the study period are given in Table 5.9. In the males the mean Kn values ranged from the lowest 0.9792 in March to the highest 1.0300 in July. A sharp increase was observed when Kn value moved from June to July. Though there was a dip in the Kn value in August, it gradually picked up and reached the second highest in September (1.0046). There was no sharp decrease in the Kn value for males in October and presented the third highest of 1.0036. In November it was 1.0010 and a slight increase occurred in December (1.0019). Females of the same species showed an entirely different trend. The second highest Kn value of 1.0128 in June followed the highest peak in July. The third highest Kn value was observed in April (1.0095). Another peak was observable in October. November (1.0025) and December (1.0026) showed highly insignificant variation in the condition of fishes. The lowest recorded Kn value of 0.9764 was in March. 0.9947 and 0.9969 were the Kn values showed respectively in August and September. January and May were the months in which the Kn values were again less than one.

Fig. 5.11 shows the monthly variation in the mean Kn values of males and females of *T.travancoricus* pooled for a period of two years.

The monthly Kn values of males and females of *L.inermis* for a period of twenty four months from January 2000 to December 2001 are shown in Table 5.10. The months of March and April showed high values of Kn both for males and females. In April 2001, males showed the highest value of 1.0440. Previous year, in the same month the Kn value was 1.0398. Among females, March 2001 (Kn, 1.0352) and April 2000 (Kn, 1.0297) recorded the highest values. Among males, a second highest value was found in October, but the Kn value was much smaller than the March-April values. In females, the second highest mean Kn value was in the month of October, 1.0302 in 2000 and 1.0272 in 2001. The lowest values of relative condition factor in males and females were observed in July, 2001 (0.9775) and December, 2000 (0.9423) respectively. From May to September the Kn values remained less than one in both the sexes. Monthly variation in the Kn values of males and females pooled for two years is given in Fig. 5.12. The said figure explicitly showed two peaks in the Kn values of males and females.

DISCUSSION

The present study regarding the length weight relationship and relative condition factor in two species of fishes belonging to the family Tetraodontidae ie., *Tetraodon travancoricus* and *Lagocephalus inermis* provided results of varying nature. In *T.travancoricus* unlike many a fish, males showed a higher 'b' value than females and in both sexes the exponential values were below the cube value. Though the 'b' values of fishes are seen around '3', there were a lot of cases where 'b' values remained slightly or noticeably below three. To quote a few Nugroho and Rumstam (1983), Sivakami (1987), Shyam Sunder (1990), Raje (1996) Reuben *et al.* (1996), Das *et al.* (1997), Rani Dhanze and Dhanze (1997) Naik *et al.* (1998), Shanmugam *et al.* (2000) and Tessy (2001).

In *T. travancoricus* the 'b' for males was 2.7858, a higher value than the females (2.6415). Such condition was observed by many workers earlier. Madhusoodana Kurup and Samuel (1987) while studying the length-weight relationship of *Gerres filamentosus* found the said condition. Sivakami (1987) reported a higher 'b' for males (2.8380) of *Ompok bimaculatus* than females (2.7225). The same condition was observed in males of *Gerres setifer* (Anantha,1987) and *Priacanthus*

hamrur (Philip, 1994). Observation of Raje (1996) was also not different with *Nemipterus mesoprion* (males: 2.9434 and females: 2.8572). Tessy (2001) reported a higher 'b' for males (2.9152) than the females (2.8719) while working on *Pomadasys maculatus* collected from Munambam harbour, Kerala.

Regarding the comparison or test of equality of regression coefficients of males and females of *T.travancoricus* the difference was not significant allowing a common length-weight relationship equation. The test for deviation from cube law proved that males, females and pooled categories did not follow the isometric growth. Allometric growth was reported by Sivakami (1987) in *Ompok bimaculatus*, Jayasankar (1989) in the blotched croaker, *Nibea maculata* collected from Mandapam, Reuben *et al.* (1996) in Indian drift fish, *Ariomma indica* off Andhra coast (only males), Rani Dhanze and Dhanze (1997) in the grass carp, *Ctenopharyngodon idella* grown under the agroclimatic zone of Himachal Pradesh, Naik *et al.* (1998) in *Scomberomorus guttatus* and *S.koreanus* landed by exploratory trawlers, Sunil (2000) in *Rasbora daniconius* and Tessy (2001), in males of *Pomadasys maculatus*.

Lagocephalus inermis also showed regression coefficients of less than 3, both in males and females.

Contrary to the results of *T. travancoricus*, the females had a higher 'b' value than the males, a condition that could be seen in many fishes. Chaturvedi (1976), Jayasankar (1989, 1994), Zafar Khan (1989), Reuben *et al.* (1994), Reuben *et al.* (1996), Das *et al.* (1997), Kalita and Jayabalan (1997), Sunil *et al.* (1999), Doddamani *et al.* (2001) and Sivashantini and Abeyrami (2003) are but a few references in that regard. Analysis of covariance revealed that there was significant difference in the regression estimates of males (2.8797) and females (2.8892) necessitating separate equations rather than a single length-weight relationship expression. Separate equations were needed for *Nibea maculata* (Jayasankar, 1989), *Dendrophysa russelli* (Jayasankar, 1994), *Ariomma indica* (Reuben *et al.*, 1996), *Trichiurus lepturus* (Reuben *et al.*, 1997). 't'-test conducted to study the pattern of growth in males and females provided information on the allometric nature of progression as the calculated 't' values were higher and significant at 1% level.

It is quite evident from the preceding discussion that, both the fishes did not follow the isometric growth of an ideal fish. The growth pattern had values of 'b' less than 3 and hence it could be deduced that the fishes became rather slender (not stout) as the length increased. Still, the regression

coefficients were within the range (2.5 to 4) as envisaged by Hile (1936) and Martin (1949). Recently, Abdhullah (2002) reported 'b' values between 2.50 and 3.44 for twenty-nine fishes belonging to 19 families caught by trawl fishing in the Egyptian Mediterranean waters. While a common length-weight relationship equation was possible for *T. travancoricus*, *L. inermis* provided only separate equations as the 'b' values of males and females differed significantly.

Seasonal variation in the relative condition of males and females of *T. travancoricus* showed nearly equal Kn values, around 1, which indicated almost identical 'condition' in both sexes. The fluctuation in the Kn values was rather negligible and the slightly higher condition during June and July coincided with maturation. A dip in the Kn in September might be due to the spawning activity of females. An increase of Kn in November and December could be connected with enhanced feeding intensity to recover from the spawning stress. Availability of preferred food items in the pre-monsoon time caused an elevation in the relative condition. Size-based observation on condition of fish provided the second highest Kn value in the 24-26 mm category. This length range is the one in which the first spawners occur profusely. Males showed

steady increase in the Kn values from 18-20 mm to 33-35 mm length groups.

The fluctuation in the Kn values of males and females of *L. inermis* was similar and well-synchronised with the reproductive activity. The peak Kn for females was observed in March, the month which gave highest gonadosomatic index (Chapter VI). The feeding index of the females was only 25% in March. A sharp decrease in the gastrosomatic index was also noticed in the same month. The changes registered by females were also followed by males. Another peak in the relative condition was observed in October. The feeding indices shown by males and females of *L. inermis* in the month were, 22.92% and 15%, respectively (Chapter III). It could be concluded that reproductive activity, definitely, has a bearing on the well-being (relative condition) of males and females of the smooth blaspop. The observation that females belonging to a size range of 140mm–169 mm showed a moderately high Kn value, further substantiated the view that reproductive cycle is one of the important factors influencing fluctuation in Kn values (the size at maturity worked out for the females of *L. inermis* was about 153 mm as given in chapter VI).

Various authors were of diverse view on the fluctuation of relative condition factor in fishes. Many related the

Table 5.1. Various parameters in the length-weight relationship of *Tetraodon travancoricus* (males, females and pooled)

| Group | N | Length(mm) | Weight(mg) | a | b | r |
|---------|-----|------------|------------|---------|--------|--------|
| Males | 290 | 19-34 | 188-1250 | -1.2774 | 2.7858 | 0.9397 |
| Females | 305 | 18-31 | 181-1170 | -1.0512 | 2.6415 | 0.9041 |
| Pooled | 595 | 18-34 | 181-1250 | -1.1261 | 2.6866 | 0.9156 |

Table 5.2. Comparison of regression lines in the length-weight relationship of males and females (*Tetraodon travancoricus*)

| Source of variation | df | 'b' | Deviation from regression | | | F-ratio |
|-------------------------------|-----|--------|---------------------------|---------|--------|---------------------------|
| | | | df | S S | M S | |
| Within | | | | | | |
| Males | 289 | 2.7858 | 288 | 8.4204 | | 0.0168 ----- 0.0278 |
| Females | 304 | 2.6415 | 303 | 8.0059 | | |
| Total | | | 591 | 16.4263 | 0.0278 | |
| Pooled | 593 | | 592 | 16.4431 | | =0.6043 |
| Difference between the slopes | | | 1 | 0.0168 | 0.0168 | |

F (df=1,591) : 3.85 (5%); 6.66 (1%)

Table 5.3. Statistical analysis to find deviation of *Tetraodon travancoricus* from Cube law

| Group | df | b | sb | t=b-3/sb | Remarks |
|---------|-----|--------|--------|----------|---------|
| Males | 289 | 2.7858 | 0.0602 | -3.5581 | S* |
| Females | 304 | 2.6415 | 0.0835 | -4.2934 | S* |
| Pooled | 594 | 2.6866 | 0.0519 | -6.0385 | S* |

S* = Significant at 1% level

Table 5.4. Different parameters in the length/weight relationship of males and females of *Lagocephalus inermis*

| Group | N | Length(mm) | Weight(gm) | a | b | r |
|---------|-----|------------|------------|---------|--------|--------|
| Males | 149 | 85-265 | 14-380 | -4.4127 | 2.8797 | 0.9831 |
| Females | 165 | 80-315 | 14-760 | -4.4073 | 2.8892 | 0.9915 |

Table 5.5. Comparison of regression lines of males and females of *Lagocephalus inermis*

| Source of variation | df | 'b' | Deviation from regression | | | F-ratio |
|---------------------------|-----|--------|---------------------------|---------|--------|-------------------------------|
| | | | df | SS | MS | |
| Within | | | | | | 2.5206 0.1891 =13.3295* |
| Males | 148 | 2.8797 | 147 | 22.4008 | | |
| Females | 164 | 2.8892 | 163 | 36.2331 | | |
| Total | | | 310 | 58.6339 | 0.1819 | |
| Pooled | 312 | | 311 | 61.1545 | | |
| Difference between slopes | | | 1 | 2.5206 | 2.5206 | |

*significant

F (df = 1,310): 3.86 (5%); 6.70 (1%)

Table 5.6. Analysis to find deviation of *Lagocephalus inermis* from Cube law

| Group | df | 'b' | sb | t=b-3/sb | Remarks |
|---------|-----|--------|--------|----------|---------|
| Males | 148 | 2.8797 | 0.0443 | -2.7156 | S* |
| Females | 164 | 2.8892 | 0.0297 | -3.7306 | S* |

S* = significant

12

132

Table 5.7 Relative condition factor values in different size groups of males and females of *Tetraodon travancoricus*

| Size group (mm) | Males | | Females | |
|-----------------|-------|--------|---------|--------|
| | N | Kn | N | Kn |
| 18-20 | 32 | 0.8401 | 53 | 0.9290 |
| 21-23 | 86 | 0.8613 | 102 | 0.9657 |
| 24-26 | 84 | 0.9954 | 87 | 0.9982 |
| 27-29 | 64 | 1.0010 | 55 | 0.9959 |
| 30-32 | 20 | 1.0027 | 8 | 1.0418 |
| 33-35 | 4 | 1.0333 | -- | -- |

Table 5.8. Comparison between the Kn values of males and females of *Lagocephalus inermis* belonging to various size groups.

| Size group(mm) | Males | | Females | |
|----------------|-------|--------|---------|--------|
| | N | Kn | N | Kn |
| 80-109 | 52 | 0.9920 | 40 | 1.0011 |
| 110-139 | 35 | 1.0067 | 36 | 0.9957 |
| 140-169 | 16 | 1.0093 | 28 | 1.0013 |
| 170-199 | 23 | 1.0281 | 14 | 1.0130 |
| 200-229 | 18 | 1.0013 | 20 | 0.9824 |
| 230-259 | 3 | 1.0018 | 10 | 1.0153 |
| 260-289 | 2 | 1.0055 | 8 | 0.9976 |
| 290-319 | -- | -- | 9 | 1.0036 |

variation in Kn values to the reproductive cycle i.e., maturation and spawning (LeCren, 1951; Pantulu, 1961; Qayyum and Qasim, 1965; Devaraj, 1973; Kurup and Samuel, 1987; Sivakami, 1987; Choudhury *et al.*, 1990; Reuben *et al.*, 1996; Jayapraksh, 1998; Raje, 2002). Qasim (1957), Bhat (1970) and Reuben *et al.* (1994) opined that the monthly fluctuation in Kn values was independent of the reproductive activity and associated, condition of fish, with feeding.

Blackburn (1960) could not find any specific relationship either between condition of fish and sexual cycle or condition of fish and food intake in *Thyrsites atun*. Kalita and Jayabalan (1997) reported that the relative condition factor of the golden scad, *Caranx kalla* did not follow any specific pattern in different months and inferred that the change in relative condition was independent of sexual cycle and feeding.

Tessy (2001) linked the fluctuation in the Kn values of *Priacanthus hamrur* and *Pomadasys maculatus* to feeding as well as sexual cycle. Renukadevi (2002) also related variation in Kn values to sexual cycle and feeding intensity as the known factors.

The observation on the relative condition of *T. travancoricus* and *L. inermis* proved that the two key

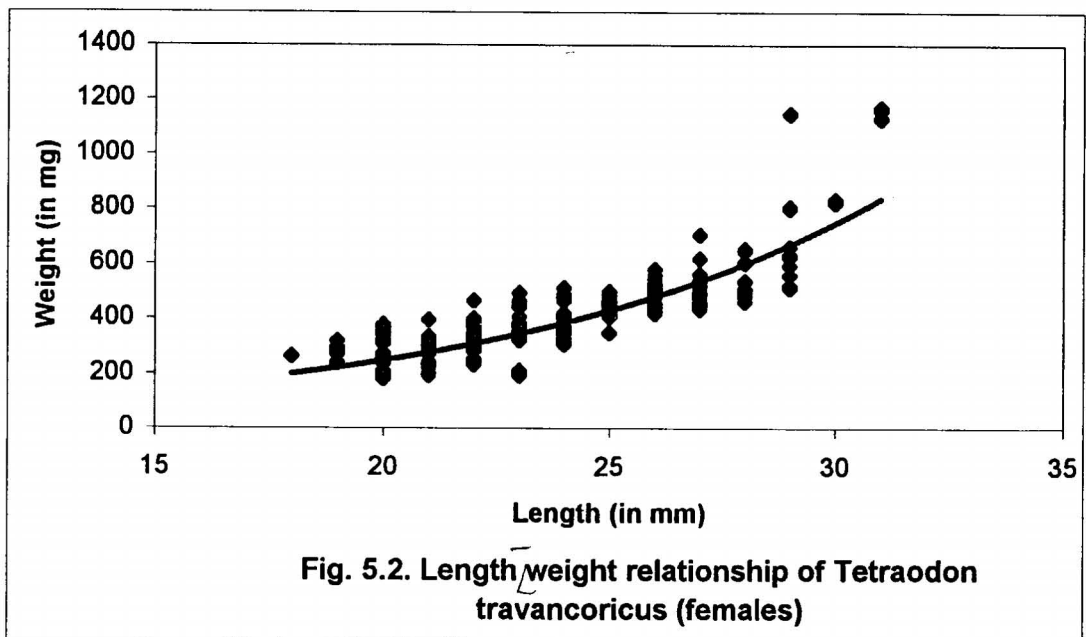
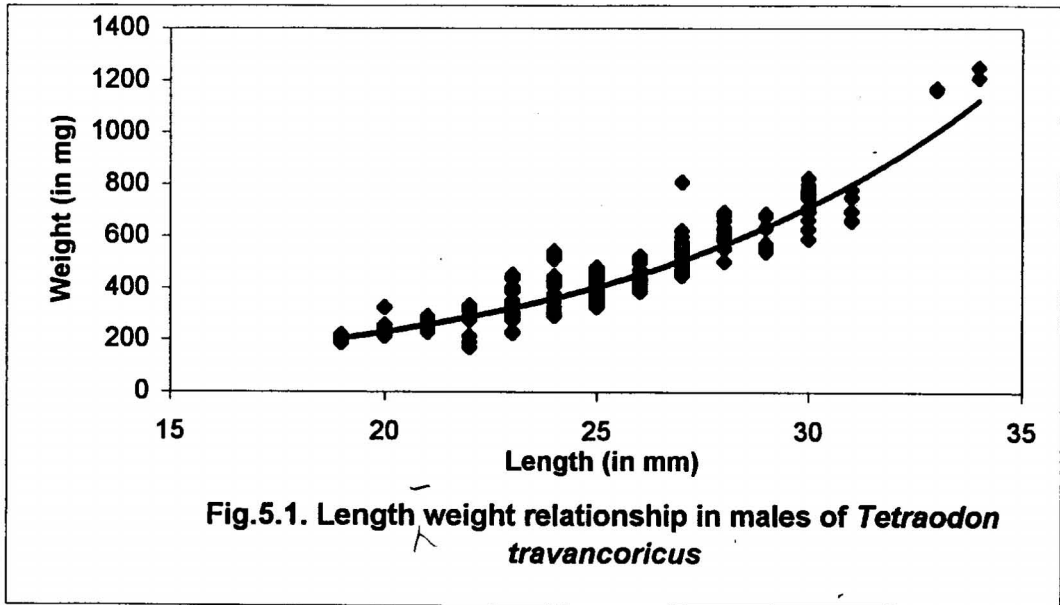
factors influencing change in the condition of fish were gonad development and spawning apart from food intake. Further, the two species showed moderately high Kn values in length groups which included maximum number of first time spawners. It was an observation which linked condition of fish to gonad enlargement.

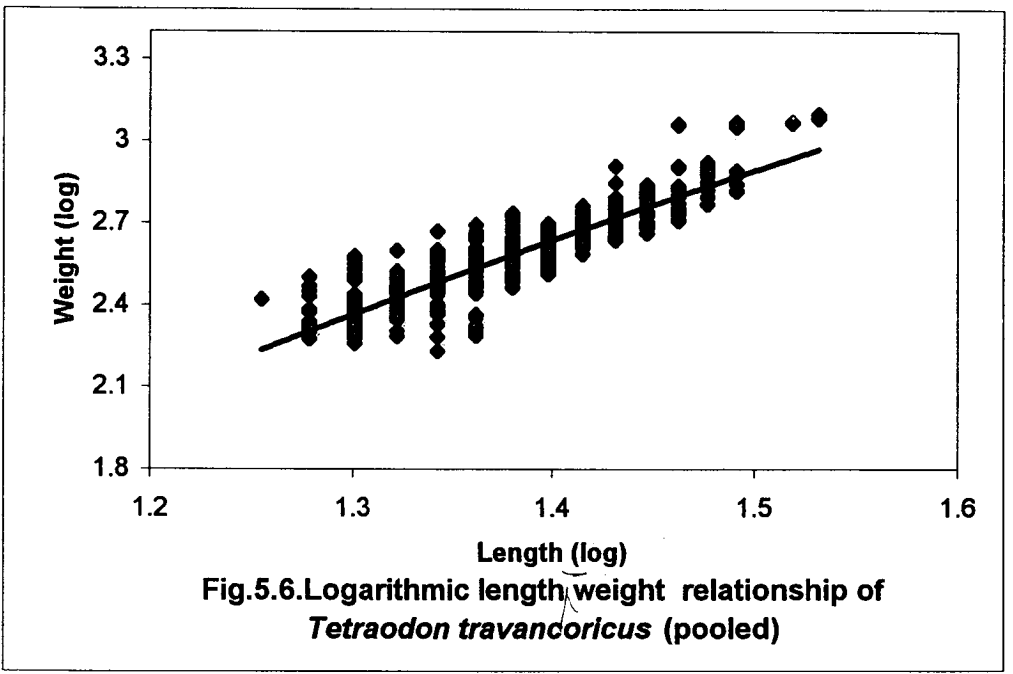
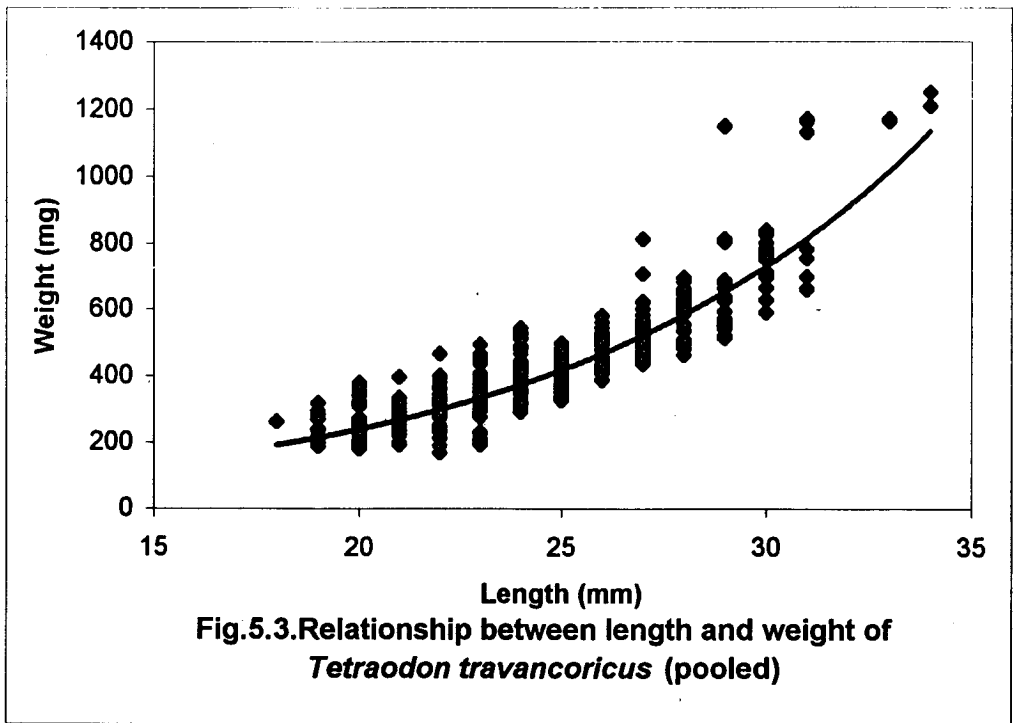
Table 5.9. Monthly Kn values of males and females of *Tetraodon travancoricus* from October 1999 to September 2001

| Month | 1999-2000 | | 2000-2001 | |
|-------|-----------|---------|-----------|---------|
| | Males | Females | Males | Females |
| Oct. | 0.9981 | 1.0030 | 1.0067 | 1.0058 |
| Nov. | 1.0005 | 1.0021 | 1.0014 | 1.0028 |
| Dec. | 1.0032 | 1.0040 | 1.0006 | 1.0011 |
| Jan. | 0.9883 | 0.9987 | 0.9939 | 0.9963 |
| Feb. | 0.9921 | 0.9991 | 0.9901 | 1.0061 |
| Mar. | 0.9812 | 0.9781 | 0.9771 | 0.9747 |
| Apr. | 1.0024 | 1.0174 | 1.0009 | 1.0014 |
| May | 0.9990 | 0.9812 | 0.9978 | 0.9621 |
| Jun. | 1.0023 | 1.0096 | 0.9980 | 1.0159 |
| Jul. | 1.0308 | 1.0286 | 1.0291 | 1.0165 |
| Aug. | 1.0008 | 0.9997 | 1.0040 | 0.9897 |
| Sep. | 0.9997 | 0.9967 | 1.0095 | 0.9970 |

Table 5.10. Monthly Kn values of males and females of *Lagocephalus inermis* from January 2000 to December 2001

| Month | 2000 | | 2001 | |
|-------|--------|---------|--------|---------|
| | Males | Females | Males | Females |
| Jan. | 0.9938 | 0.9977 | 0.9919 | 0.9989 |
| Feb. | 0.9896 | 1.0012 | 0.9910 | 1.0004 |
| Mar. | 1.0345 | 1.0297 | 1.0328 | 1.0352 |
| Apr. | 1.0398 | 1.0253 | 1.0440 | 1.0176 |
| May | 0.9997 | 0.9986 | 0.9928 | 0.9962 |
| Jun. | 0.9803 | 0.9817 | 0.9842 | 0.9911 |
| Jul. | 0.9798 | 0.9710 | 0.9775 | 0.9801 |
| Aug. | 0.9861 | 0.9910 | 0.9901 | 0.9932 |
| Sep. | 0.9955 | 0.9907 | 0.9857 | 0.9918 |
| Oct. | 1.0032 | 1.0302 | 1.0053 | 1.0272 |
| Nov. | 1.0022 | 1.0114 | 1.0028 | 1.0098 |
| Dec. | 0.9912 | 0.9423 | 0.9834 | 0.9898 |





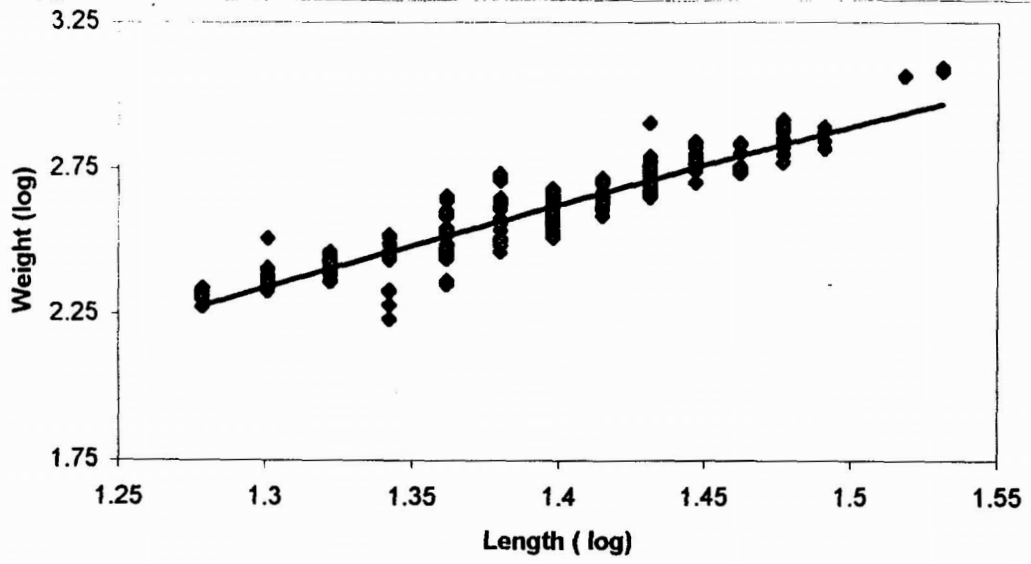


Fig.5.4. Logarithmic relationship between length and weight of *Tetraodon travancoricus* (males)

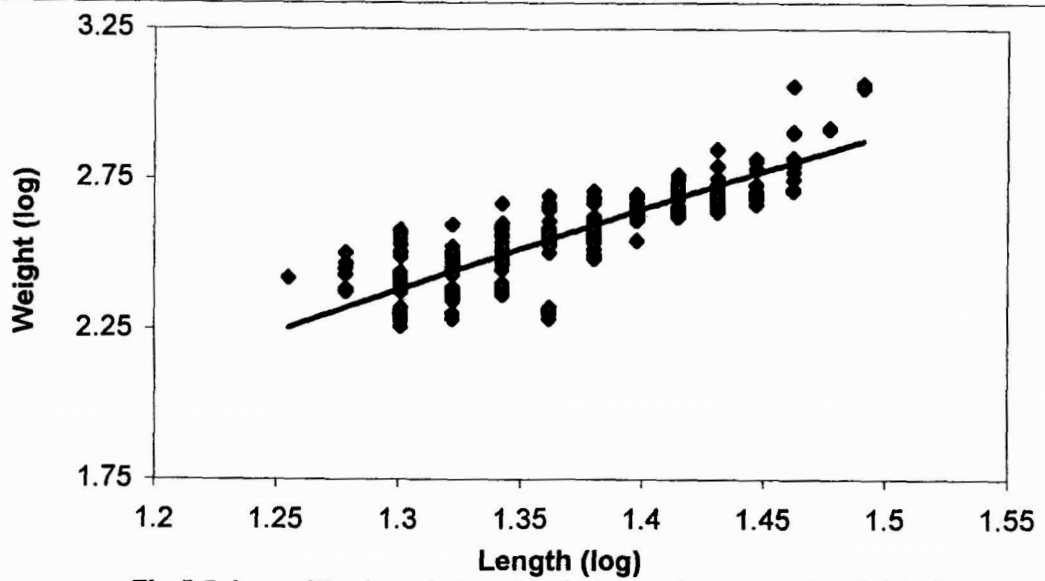
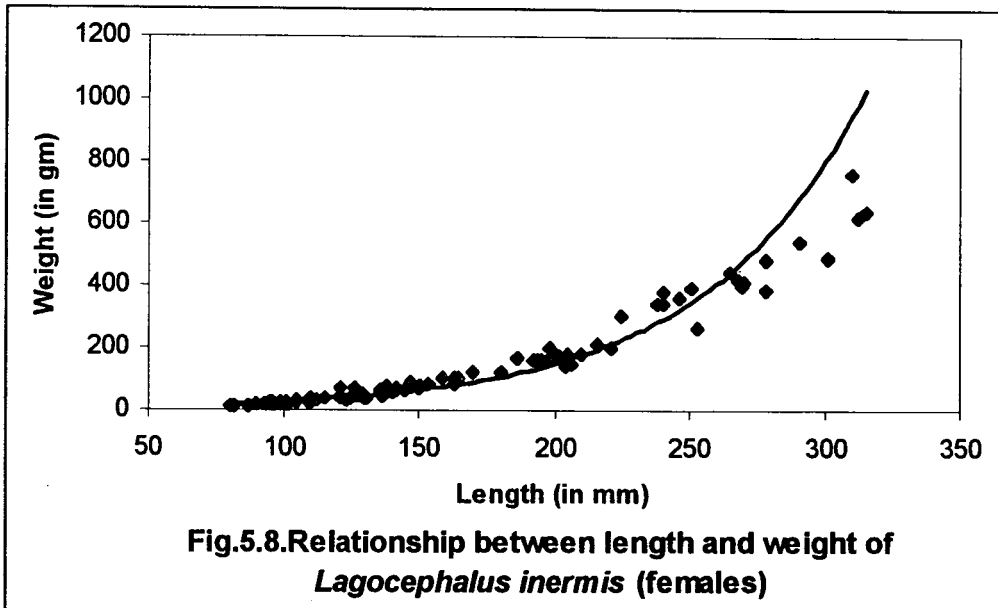
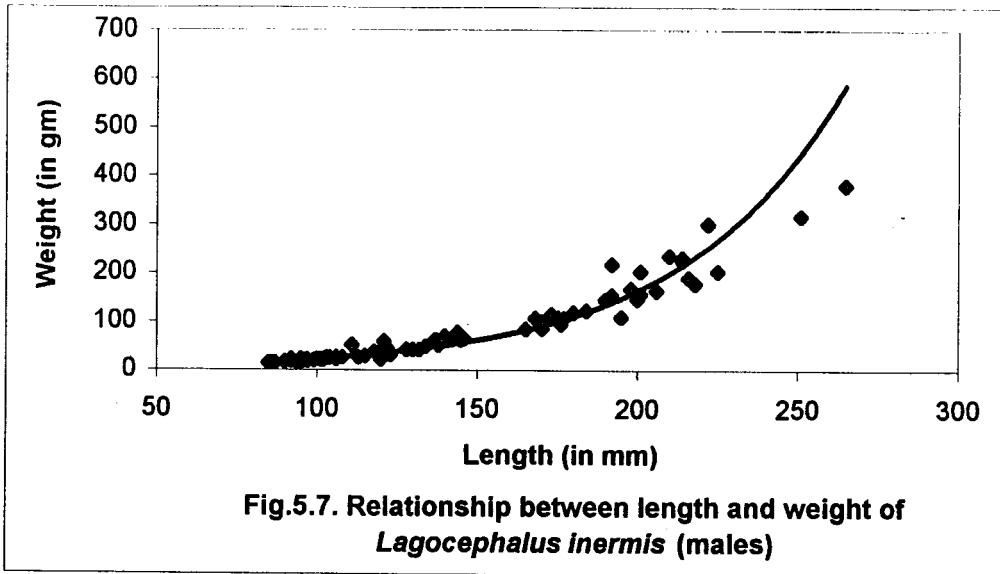
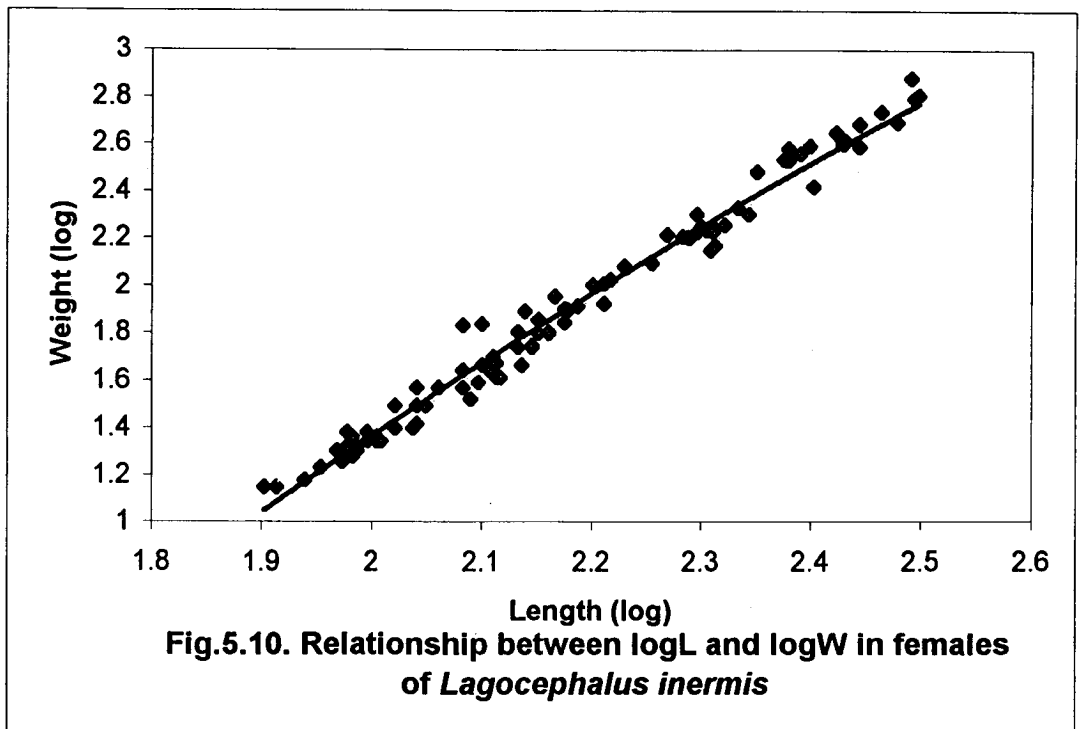
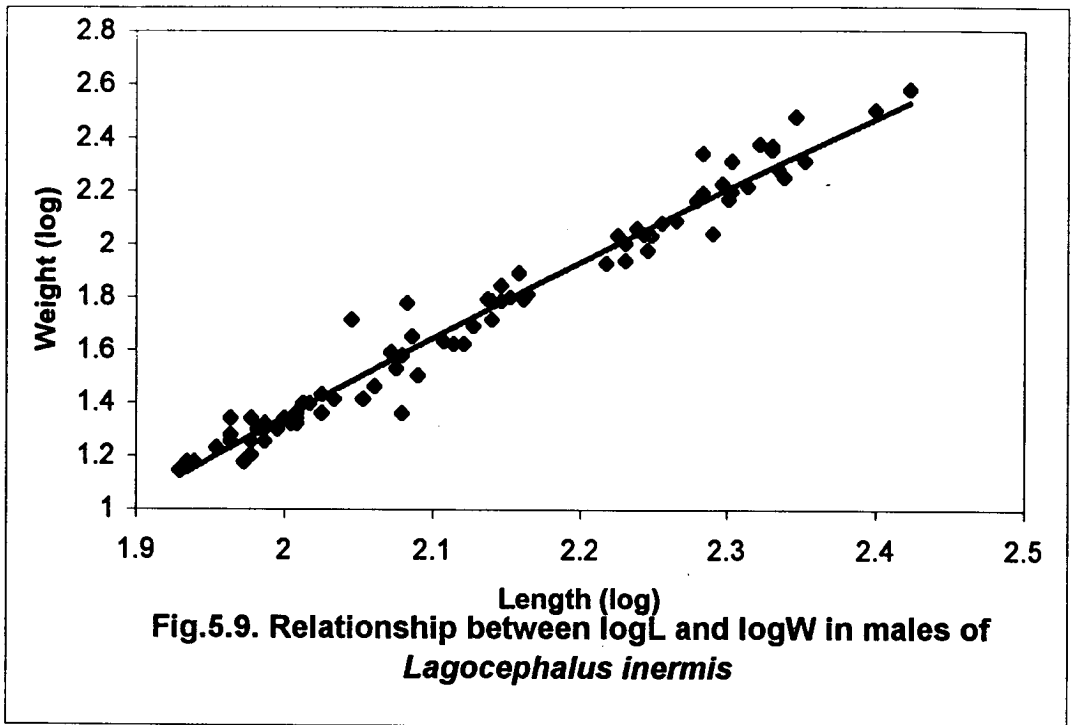


Fig.5.5. Logarithmic relationship between length and weight of *Tetraodon travancoricus* (females)





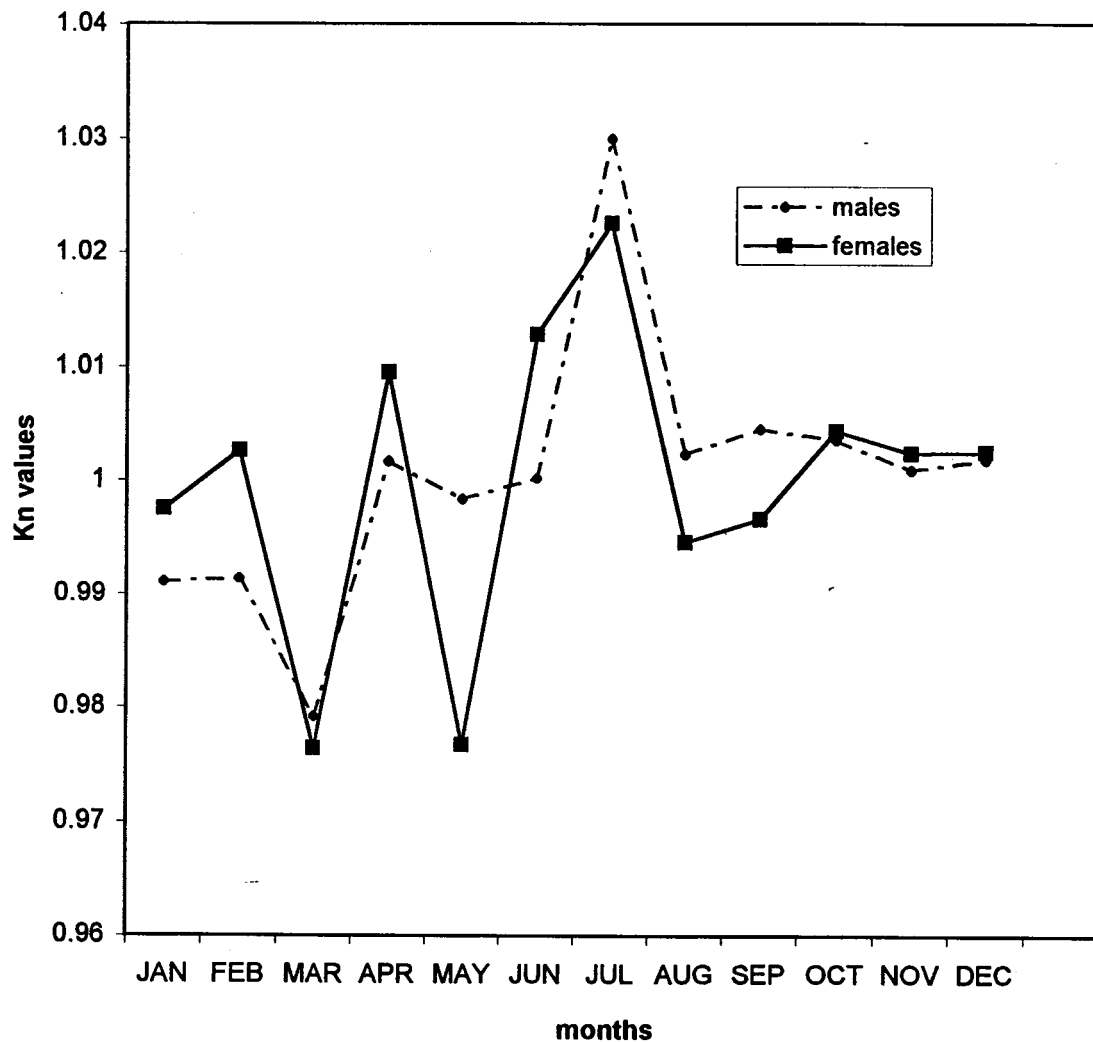


Fig. 5.11. Monthly variation in the Kn values of males and females of *Tetraodon travancoricus* (pooled)

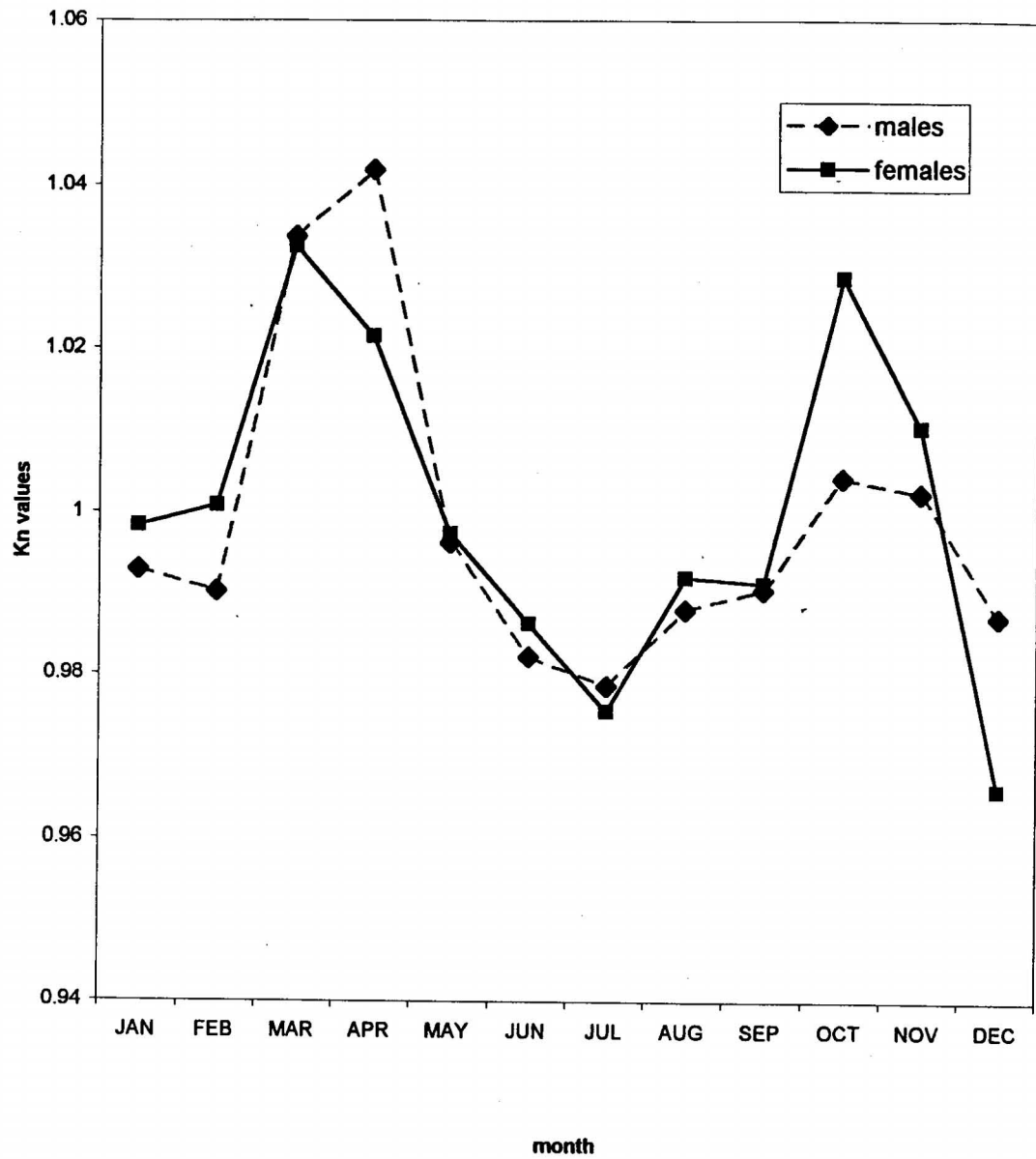


Fig.5.12. Monthly variation in the Kn values of males and females of *Lagocephalus inermis* (pooled)

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Book

REPRODUCTIVE BIOLOGY

CHAPTER -VI

REPRODUCTIVE BIOLOGY

INTRODUCTION

The variety of life history traits in fish communities involves a wide array of reproductive strategies. The success of any fish population is ultimately determined by the ability of its members to reproduce successfully in a fluctuating environment and thereby to maintain viable populations. Fishes exhibit a complexity of reproductive tactics as they occur under certain ecological conditions and therefore show special anatomical, behavioural and physiological adaptations to suit the environment in a unique way (Wootton, 1984). The mode of reproduction shown by each species is an integral part of its life style, and cannot be considered in isolation from its biological needs, such as food, or its ecology in relation to, for example, habitat type or predator avoidance (Blaber, 1997b).

Information on the basic biological factors such as maturation cycle, size at first maturity, sex ratio, spawning and fecundity of fishes is a pre-requisite for a successful management of their fisheries. Knowledge of the spawning

season is very important in fishery management and rational exploitation of economically important fishes. Information on the minimum length at maturity is essential to ensure a sustained yield by regulating the mesh-size of the net, to make sure that the smaller fish also gets an opportunity to spawn at least once in their lifetime.

Among the classic works with respect to the aforesaid aspects, mention has to be made about Clark (1934) who studied the ova diameter measurements, the maturity and spawning of the California sardine, *Sardina caerulea*, Hickling and Rutenberg (1936) on the spawning periods of hake, De Jong (1939) on the spawning habits of some fishes of Java sea, Hickling (1940) on the fecundity of herring of the Southern North sea, June (1953) on the spawning of yellow fin tuna in Hawaiian waters. Bunag (1956) on the spawning habits of the Philippine tuna, Bagenal (1957) regarding the breeding and fecundity of the long rough dab, Mac Gregor (1957) on the Pacific sardine, *Sardinops caerulea*, Howard and Landa (1958), Macer (1974) on the reproductive biology of horse mackerel in the North Sea, Fox (1978) on the reproductive strategies of the bull-head in the northern and southern England, Hunter and Goldberg (1980), Williams and Clarke (1982), Makanova and Shatunovsky (1984) on *Perca*

fluviatilis, Nair and Nair (1984) on *Chanda commersonii*, Banu and Bhakta (1985) on *Colisa fasciata*, Davis (1985), Harris (1986) on Australian bass, Kilambi (1986), Haq and Ronald (1987) on *Sillago domina*, Tucker and Faulkner (1987) on *Cynoscion nebulosus*, Wijeyaratne and Costa (1987), Cole (1990), Khan *et al.* (1990) on reproductive biology of *Mystus nemurus*, Colin (1992) and Suzuki *et al.* (2000).

Studies on the reproductive biology of fishes in Indian waters have been carried out by Panikkar and Iyer (1939), Alikunhi (1953), Pillay (1954), Seshappa and Bhimachar (1955) on the maturation and spawning of the Malabar sole, Pradhan and Palekar (1956), Prabhu (1956), Kuthalingam (1960) on the life history of *Cynoglossus lingua*, Qasim and Qayyum (1961), Jhingran (1961), Rao (1963), Pradhan (1964) on *Psettodes erumei*, Qayyum and Qasim (1965) on the butterflyfish, *Callichrous bimaculatus*, Antony Raja (1967) on Indian oil Sardine, James (1967) on ribbonfish, Pandian (1967) on the reproduction of *Mystus gulio*, Patnaik (1967) on the Indian salmon, Parulekar and Bal (1971), Qasim (1973) enlisted the work done during 1957-1970 on the maturation and spawning in marine teleosts, Varghese (1973), Devaraj (1977, 1983a, 1986, 1987), Mojumdar (1978) on maturity and

spawning of *Tachysurus thalassinus*, Sreenivasan (1978), James and Baragi (1978), Somavanshi (1980, 1985), Kaliyamurthy (1981) on *Mystus gulio*, Pathiratne and Costa (1984) on *Etroplus suratensis*, Muthiah (1985) on the maturation and spawning of *Euthynnus affinis*, Jayabalan (1986), Rao and Karam Chandani (1986) on *Ompok bimaculatus*, Gangadhara Gowda and Shanbough (1988) on the reproductive biology of grey mullet, *Valamugil seheli*, Kader *et al.* (1988) on *Gobioides rubicundus*, Irene Fernandes and Devaraj (1989) on *Coilia dussumieri*, Sudha and Shakunthala (1989) on reproductive biology of *Mystus vittatus* Kurup and Samuel (1991), Siva Reddy and Rao (1991) on gonado somatatic index and fecundity of *Heteropneustus fossilis*, Pillai *et al.* (1992) on yellow fin tuna, Inasu (1993) on the silurid, *Mystus mystus*, Yohannan (1993) on the spawning of mackerel, Kurup and Kuriakose (1994), Narasimham (1994), Ramamohana Rao *et al.* (1994) on seed production of *Clarias batrachus*, Tessy (1994) on *Epinephelus*, Krishnakumar and Balakrishnan Nair (1995), Sivakami (1995) on the reproduction of carangid fish, *Megalaspis cordyla*, Negi and Dobriyal (1997), Devadoss (1998) on breeding and development in some batoid fishes, Jayaprakash (1998) on *Cynoglossus* sp., Manali (1998) on the catfish, *Arius*

thalassinus, Suryawanshi and Wagh (1999), Tessy (2001) on *Priacanthus hamrur* and *Pomadasys maculatus*, Dasgupta (2002) on *Mystus gulio* from West Bengal and Raje (2002) on *Nemipterus japonicus*.

A search of literature on the various reproductive aspects of puffer fishes showed that researchers in our country have done no serious work on tetraodontids, outside as well. The present investigation was undertaken to gather information regarding maturity stages, ova measurements, gonado-somatic index, spawning season, fecundity and sex-ratio in two common tetraodontids, *Tetraodon travancoricus* and *Lagocephalus inermis* from inland waters and South West coast of Kerala respectively.

MATERIALS AND METHOD

The fish for study, *Lagocephalus inermis* was collected from January, 2000 to December, 2001 from Munambam harbour on a monthly basis. Fortnightly collections were also made whenever the fish was available. The collection of *Tetraodon trvancoricus* was made mainly from the Kechery river system, the station selected was Puzhakkal, Thrissur District. Some collections were also made from the kole fields of Adat, Puranattukara and Arimboor, adjoining the

main collection center. As for *L.inermis*, collections were made every month from October 1999 to September 2001. During certain months, especially at the time of spawning periods, fortnightly collections were tried.

The fish samples collected from various stations were brought to the laboratory in icebox. After washing and removing the surface moisture with blotting paper, each fish was measured for its total length to the nearest millimeter and weighed to 0.001 gm and one gram, respectively for *T.travancoricus* and *L.inermis*. The fish were dissected to record sex and stage of maturity. The ovaries were removed, weighed and then preserved in 5% formalin. It is generally assumed that the gonad weight depends on animal size and stage of gonad development (de Valming *et al.*, 1982). Ovaries were classified into five maturity stages on the basis of morphological observations and organization of the ovary. Macroscopic observations were carried out whereas microscopic studies were done with preserved ovaries. The International Council for the exploitation of the sea scale (Wood, 1930 & Lovern and Wood, 1937) was adopted for the classification of maturity stages. The ova diameter measurements were recorded to understand the duration and frequency of spawning adopting the procedures given by Clark

(1934), Hickling and Rutenberg (1936), Prabhu (1956), Rao (1963) and James (1967).

Diameters of intra-ovarian eggs were measured by using an ocular micrometer, which had a calibrated value of 0.0159 mm to each micrometer division (objective 10X & eyepiece 6X). The diameter of ova is described in micrometer divisions (m.d.) along with the millimeter conversions. The preliminary examination of distribution of ova diameter frequency from different parts of the ovary of *L.inermis* revealed that there was no difference in the size of ova from various parts of the gonad. Hence eggs were always extracted from the middle portion of the ovary. Ova measuring less than 5 m.d. were discarded. As there were only a few ova in the ovaries of *T. travancoricus*, the entire ovary with varying ova diameters was teased onto the slide for counting the ova and finding out the frequency of different classes of ova. The ova diameter frequencies from the ovaries of the same stage of maturity were pooled and plotted for both the species.

Gonado-somatic index (GSI) was found out employing the method of June (1953) as the ratio of gonad weight to body weight of fish, expressed in percentage.

$$\text{GSI} = (\text{Weight of gonad/weight of fish}) * 100$$

Gonadosomatic index is also useful to explain the state of maturity and intensity of spawning (James, 1967). The weight of the fish and its gonad weight recorded for a period of two years were used for the determination of the gonadosomatic index. In fishes, all the individuals of the same species do not mature at the same length. The information on size at first maturity of fish has great relevance in fishery biology. 274 females of *T. travancoricus* and 159 females *L.inermis* were used for the study and grouped into 2 mm and 30 mm intervals, respectively. The frequency of occurrence of different stages of maturity in various size groups was estimated. Size at first maturity was found out by considering the distribution of cumulative percentages from stage III (mature) onwards in different length groups. Maturity curves were drawn to estimate the average length at first maturity for both the species.

The sex-ratio distribution was studied to test whether the observed sex ratio in each month differed significantly from the expected ratio. The sample sizes used for the study were 848 and 313, respectively for *T.travancoricus* and *L.inermis*. During the first half of the study period, from October 1999 to September 2000, the number of fish used (*T. travancoricus*) was 445, whereas for the same length of time

from October 2000 to Sept. 2001, the number was 403. With regard to *L.inermis*, of the total of 313, in the twelve months of 2000, the number of fishes subjected for study was 163. In 2001, the number used for sex ratio calculation was 150. Chi-square test (χ^2) was employed using the equation of Fisher (1970) as followed by Dhulkhed (1971) to observe the deviation from the hypothetical 1:1 ratio (null hypothesis).

$$X^2 = \sum (O-E)^2/E$$

where, O = observed number of males and females and E = the expected number of the males and females.

Fecundity estimation was done from the mature and ripe ovaries preserved in formalin. Ovaries in stages III and IV were made moisture-free using blotting paper and weighed to the nearest 0.001 gm. A small portion of the ovary was separated and weighed before the sample was placed on the micro-slide and teased out. The mature ova were counted using the same micrometer and magnification adopted in the ova diameter studies. Fecundity was estimated using the formula,

$F = nG / g$, where, F=fecundity, n=number of eggs in the sub sample, G=weight of ovary and g = weight of the sub sample.

Gravimetric method was not employed for studying the fecundity in *T.travancoricus* as the ovaries were less than 100

mg in weight except in the month of July and the numbers of mature and ripe ova were not too many.

The relationship between fecundity and different variables like fish length, fish weight and ovary weight was worked out by the least square method, $F=aX^b$ where, F=fecundity, X=the variables, a=constant and b=regression coefficient, Regression lines were fitted to the data as reported by Jhingran (1961) and Krishnaswarup (1961). The exponential relationship was transformed into a straight-line relationship based on logarithms by following the equation, $\log F = \log a + b \log X$. To study whether the fecundity factors are influenced by the size of the fish, average number of ova per gram body weight were calculated.

Based on the progression of egg size and looking at the occurrence of largest ova in the ovaries, the spawning seasons of the two species were arrived at. Ovaries with eggs belonging to different size classes were also considered to learn about the nature and period of spawning. Gonadosomatic index values were helpful in drawing conclusions on the time of peak spawning.

RESULTS

The macroscopic and microscopic observations of the ovaries in *T.travancoricus* and *L.inermis* revealed the presence of five maturity stages, viz. immature, maturing, mature, ripe and spent, in both species. The paired ovaries in *T.travancoricus* showed association between the right and left ovaries along the mid-line till the anterior end and the ovaries were rather swollen and club-shaped in the later stages and appeared as a single unit. In *L.inermis*, a pair of ovaries lying lengthwise in the body cavity with their anterior extremities free, represented the female reproductive organs with the posterior ends bound together. The various maturity stages observed are shown below.

STAGE I -IMMATURE

Ovaries in both species were very thin and short and occupied only a small portion of the body cavity. Ova were not visible to the naked eye, measuring only up to 0.1590 mm and 0.0795mm in *T.travancoricus* and *L. inermis* respectively. Micro- scopic observations of the ova revealed the absence of yolk and transparency of the ova. (The nuclei was not distinct in ova whose diameter was below 5 m.d.). Ova diameters varied between 47.70 μ and 159.00 μ and gonad weight ranged

between 6mg and 10 mg in *T.travancoricus*. In *L.inermis* the smallest ova diameter was 47.70 μ and the largest 79.50 μ . Ovary weight extended from 32 mg to 102 mg.

STAGE II -MATURING

The ovaries became slightly enlarged and appeared light yellow in colour. Yolk formation started in some ova. The ova measured 174.90 μ to 795 μ in *T.travancoricus* and 95.40 μ to 238.50 μ in *L. inermis* and weighed between 9mg and 18 mg in the former and 100mg to 510 mg in the latter. This stage included both maturing virgins and recovering spent. In the recovering spent, there was only a slight change in the length of the ovary compared to the spent stage. Furthermore, they differed from the maturing virgins in that, specimens were larger than the minimum average size at first maturity. (Average GSI: *T.travancoricus*, 3.2480 and *L. inermis* , 0.6099).

STAGE III – MATURE

Ovaries became large occupying 2/3rd space in the body cavity. In *T.travancoricus* ova were seen at different stages of growth and the average size of the mature ova alone was 1001.70 μ . In *L.inermis* all the ova were almost the same size with an average diameter of 318 μ . Weight of the ovaries

ranged from 20mg to 72mg and 2.12g to 16.23g respectively in *T.travancoricus* and *L.inermis*. (Average gonadosomatic index: *T. travancoricus*, 5.6554 and *L.inermis* , 4.3408)

STAGE IV- RIPE

Stage IV represented the fully mature, ripe ovaries which were golden yellow in colour. Ovarian wall appeared very thin and delicate. In *T.trvancoricus* three batches of ova were obser- vable of which the largest mode, 1335.60 μ , represented the fully ripe ova. Ovary weight ranged from 39mg to 148mg in *T.travancoricus* and 5.25gm to 74.320 gm in *L.inermis*. Ovaries occupied almost the entire body cavity and were turgid with very large ova measuring on the average 445.20 μ in *L.inermis*. The average gonadosomatic index values were 9.6739 and 7.4525 respectively for *T.travancoricus* and *L.inermis*. The highest GSI observed were 12.65 (July) and 9.91 (March) respectively for *T.travancoricus* and *L.inermis*.

STAGE V – SPENT

Ovaries of this stage looked shrunken and flaccid. Colour became dull yellowish gray. There was no considerable reduction in the length of the ovary though there was reduction in the overall size of the ovaries. In

T.travancoricus, the spent ovaries were sans ova of the largest mode of 82 m.d. In *L.inermis* spent ones had ovaries with only a few ova of the ripe category.

Classification of maturity stages of *T.travancoricus* and *L.inermis* is presented in Table 6.1 and 6.2 respectively. The percentage occurrence of immature, maturing, mature, ripe and spent stages of maturity of *T.travancoricus* and *L. inermis* during the study period are tabulated in Table 6.3 and Table 6.4. In *T.travancoricus* immature stage was seen exclusively up to 19 mm. Stage II appeared in the 20-21 mm length group. 36.96% individuals belonged to the mature stage in 24-25 mm category. Spent females were first encountered in the 26-27 mm length group. The succeeding length groups did not encompass either the immature or maturing stages. 48.54% of the whole sample studied belonged to the immature stage. The split up for the rest of the maturity stages were 18.25%, 19.34%, 9.85% and 4.38% respectively for maturing, mature, ripe and spent. In *L.inermis*, the mature category was comprised of 26.42%, a shade under the % occurrence of immature stock (27.67%). The maturing stage was represented by 20.13% where as stage IV gave 18.24%. Only a few individuals were seen in the spent condition (7.55%). Highest number of ripe individuals was seen in the 210-239 mm length

group followed by 240-269 mm and 150-179 mm length classes. Tables 6.4 and 6.5 represent the percentage occurrence of various maturity stages, respectively, of *T.travancoricus* and *L.inermis* separately for the two years of study related to the two species. Largest number of mature and ripe females of the *T.travancoricus* was seen during June/July and September/October whereas the same feature was exhibited during March/April and September/ October by *L.inermis*. Figure 6.1 represents month-wise percentage frequency of females of *T.travancoricus* at different stages of maturity whereas Fig. 6.2 shows the same aspect of *L.inermis*.

The diameter of ova from ovaries of the five maturity stages was measured to understand and gather information on the growth of ova to maturity. The average ova diameter measurements of various maturity stages are shown in Figures 6.3 and 6.4, respectively for *T.travancoricus* and *L.inermis*. In stage I, the ova were in the size range of less than 10 m.d. in *T.travancoricus* with a mode at 5 m.d. and less than 5 m.d. in *L.inermis* with a mode at 3 m.d. In stage II ie., maturing, the ova diameter range was between 0.1749 mm to 0.7950 mm in *T.travancoricus* and the range was between 0.0954 mm and 0.2385 mm in *L. inermis* . In stage III, in *T.travancoricus* there appeared three different batches of ova with clear-cut

boundaries among them. The mode of the largest batch of ova was 1.0017 mm. There was a single batch of ova emerged from the earlier mode with the average size at 0.3180mm in *L.inermis*. The shift of immature ova to the third stage occurred simultaneously so that majority of the eggs were in a single flock. In stage IV, which represented the ripe condition of the ovary, the mature ova further increased in size and attained an average size of 84 m.d. (1.3356 mm) with a maximum at 90 m.d. in *T.travancoricus*. There was only one prominent mode at 28 m.d. (0.4452 mm) in *L.inermis*. The maximum size of the ova observed was 0.4929 mm (31m.d.). The fifth stage ovary (spent) in *T. travancoricus* had three prominent modes of ova with the disappearance of the largest mode of the previous stage except for a few. The Vth stage ovary was wrinkled and only a few eggs with maximum size were observed (residual) along with a number of very small eggs in *L.inermis*. The progress of ova development could be read out from Figure 6.5 (*T.trvancoricus*) and Figure 6.6 (*L.inermis*).

Females of *T.trvancoricus* and *L.inermis* from stage III onwards were only considered for determining the minimum length at maturity. The percentage of fishes belonging to the various length groups are presented in Tables 6.3 and 6.4.

Maturity curves were drawn separately for *T.travancoricus* and *L.inermis* to find out the percentage at which 50% of the individuals became mature (Figures 6.7 and 6.8). In female *L.inermis* immature and maturing stages were encountered exclusively up to 138mm. In *T.travancoricus* corresponding length was 20mm. A small fraction of mature females (27.87% and 23.07%) were observed in the 22mm to 23mm, and 120mm to 149mm length groups in *T.travancoricus* and *L.inermis* respectively. Females of ripe stage (10.89%) were first seen in 26 -27 mm class in *T.travancoricus*. The same maturity stage was first encountered in the 150mm to 179mm group in *L.inermis*. The cumulative occurrence of 50% by individuals belonging to stage III, IV and V fell in the length group of 24 mm to 25mm in *T.travancoricus* and 150mm to 179 mm in *L.inermis*. The maturity curves showed that minimum size at first maturity for *T.travancoricus* was 24.25mm.(Figure 6.7) and in the same sex of *L.inermis*, it was 152.72mm (Figure 6.8).

The monthly or seasonal fluctuation in the weight of the gonad with respect to the weight of fish was studied to access information on the development of the ovary and the spawning time. The month-wise GSI values of females of *T.travancoricus* are shown in Table 6.7 for a period of 24

months. The average maximum gonadosomatic index values (pooled) observed for *T.travancoricus* were 7.602 in June 6.492 in July and 5.850 in September. December (2.810), January (2.570), February (2.838), March (2.971), and April (3.902) showed low values of GSI compared to rest of the months. The sharp increase in GSI between the months of April and May and May and June was indicative of the surge of mature ova and their progress into the ripe condition respectively. A reduction in GSI was observed in August (4.344). Further increase in GSI occurred in the following months reaching a second highest value in September. In October also GSI was not very low (4.797) but a sudden drop was observed in November (3.307). The lean period continued till the end of April. The monthly fluctuation of GSI of *T.travancoricus* from October 1999-September 2000 and Oct.2000-Sept.2001 is shown in Figure 6.9.

The average gonadosomatic index values of *L.inermis* for a period of 24 months from January 2000 to December 2001 are shown in Table 6.8. Maximum GSI value of 4.964 was observed in March. April showed a reduction in GSI (3.416), which was abruptly dipped in May to 1.599. Another peak in GSI occurred in the month of September (3.461). A sudden drop in GSI was observed in November (1.475). Ripe

eggs were not seen in ovaries collected from fishes during the rest of the months except for a few ones in individuals belonging to the spent category. December (0.856), January (0.873), February (1.707), June (0.957), and July (1.545) were the months which showed lower average GSI values other than May and November. The highest ever-recorded gonadosomatic index was observed in March 2001 (5.052). Its lowest counter part was seen in January 2000 (0.752). Figure 6.10 represents fluctuation in the month-wise GSI in *L.inermis*.

Monthly percentage occurrence of gonads in different stages of maturity, gonadosomatic values for different months and ova diameter studies unequivocally proved that *T.travancoricus* enjoyed a period of four to five months as its successful spawning regime from July to October/November. A sudden increase in GSI between the months of May and June indicated the shifting of maturing ova into the mature class. Highest GSI and ova diameter were recorded in June and July respectively. The presence of spent fishes in July indicated the spawning. The disappearance of largest ova and a noticeable drop in GSI in August further supported the view that the spawning occurred in July. The GSI increased gradually from August and reached a second peak during September/October

with ovaries holding the largest ova once again indicated another spawning spree during a moderately long spawning period from July to October/November. Lower GSI values from November to April and the absence of mature eggs, arrived at by considering ova diameter, indicated absence of gamete release during that period.

In *Lagocephalus inermis*, the ova diameter measurements and GSI values reached maximum in two periods in a year viz., in March/April and September/October. The sharp decrease in GSI in May and collection of very young individuals in the last quarter of May and early June proved that spawning started towards the end of March and might have extended to April. A number of spent females were seen in the collections done during the middle of April and total disappearance of fishes of ripe stage in May further provided evidence for the conclusion that intense spawning occurred in April. The ova diameter studies substantiated the view that March/April was the peak spawning time. Ovaries in the mature stage were not observable till September gave the idea that egg release was restricted to distinct periods and an extended spawning regime did not exist. The second peak in GSI and ova diameter was observed in September running to October and abruptly shrinking in November. From

December to February the mature ovaries were not encountered and low GSI values were maintained. The same condition was observed from May to August. So, it could be concluded that *L.inermis* has two distinct spawning periods in a year prior to the arrival of south west monsoon and during northeast monsoon along the coast of Kerala.

Sex ratio studies were conducted to find out any deviation in a fish population from the hypothetical 1:1 ratio (null hypothesis). The month-wise observations are tabulated in Tables 6.9 and 6.10 respectively for *T.travancoricus* and *L.inermis* for a period of 24 months. The aforesaid tables also carry information on sex ratio (pooled) of *T.travancoricus* and *L.inermis* along with chi-square values. The chi-square test on the combined data and monthly observation for two years proved that the deviation from the expected ratio was non-significant at 5% level.

In *T.travancoricus* the overall observed sex ratio for the pooled data was 1:1.094 in favour of females. Though the females outnumbered the males in several months the general trend was to get less number of females than males especially during the spawning period in *T.travancoricus*. The monthly sex ratios for the pooled data in January and November were very high, though not significant at 5% level. The highest sex-

ratio of 1:1.636 in favour of females was observed in November 1999, followed by January 2000(1:1.60). January 2001(1:1.545) and Nov. 2000 (1:1.50) also provided relatively high sex ratio values with female dominance. In the year 2000, April, June, July, August and September showed ratios 1:0.810, 1:0.708, 1:0.789,1:0.923 and 1:0.760 in favour of males in that order. In July and August, 2001 once again there was male dominance in the collected samples and the sex ratio values were 1:0.632 and 1:0.706 respectively. Equal proportion of males and females was observed in April 2001. The pooled data showed ratios in favour of females except in April (1:0.886), June (1:0.875), July (1:0.711), August (1:0.837) and September (1:0.878). The highest sex-ratio calculated for the pooled sample with females outnumbering males was 1: 1.577 (January). It was closely followed by November (1:1.565). Figure 6.11. represents the sex-ratio variation in the pooled data of *T.travancoricus* against different months. The variance of homogeneity of sex ratio is given in Table 6.11.

In *L.inermis* also the combined sex ratio of 1:1.144 was non-significant at 5% level, though in some months it was significant. Table 6.10 shows the variation in the sex ratios of *L.inermis* for a period of twenty-four months with pooled data

incorporating the related chi-square values. In the first half of the study period with regard to *L.inermis*, the sex ratio for twelve months was 1:1.145 in favour of females. The highest sex ratio values with female dominance were recorded in May (1:2), Oct. (1:1.6), and March & November (1:1.5). Only in two months viz., February (1:0.80) and July (1:0.70) the sex ratio swung in favour of males. In 2001, females outnumbered males in February, March, April, June, July, September and October with highest sex ratio values of 1:1.38 in June and 1:1.29 in February. In the same year, the highest sex ratio in favour of males was in the month of December (1:0.67). July also recorded the sex ratio in which the number of females was less (1:0.89). In the pooled data, except for July and December, all other months provided sex ratio values in favour of females. The highest ever value of 1:1.5 in May was followed by 1: 1.40 in October, 1:1.36 in March, 1:1.33 in April and 1:1.31 in September and 1:1.25 in November. The overall sex ratio was 1:1.129 in favor of females for the pooled data. Monthly variation in the male to female ratio of *L.inermis* is presented in figure 6.12. The variance of homogeneity of sex-ratio in *L.inermis* along with respective chi-square values is tabulated in Table 6.13.

Fecundity was estimated by counting the total number of mature ova destined to be discharged by the females in the ensuing spawning period. Fecundity was calculated from 54 females of *T.travancoricus* ranging from 25mm to 31mm in length and 418mg to 1170 mg in weight. The fecundity varied between 69 and 139. The highest fecundity was found in a fish of 31mm length and 1170mg weight (ovary weight, 148mg). The overall average relative fecundity ie. number of ova per gram body weight was 149.5 and number of ova per gram ovary weight was 1370.5. The data regarding average values of length and weight, absolute fecundity, relative fecundity, ova per gm ovary weight, etc. are shown in Table 6.13.

The relationship between absolute fecundity and total length calculated by the least square method is presented in Figure 6.13. The corresponding equation was,

$$\text{Log F} = -2.5571 + 3.1435 \text{ Log L} \quad (r=0.9951)$$

Relationship between fecundity and total weight provided a linear association (Figure 6.14) and the values calculated were,

$$\text{Log F} = 0.1648 + 0.6473 \text{ Log W} \quad r=(0.9763)$$

Similarly the relationship between fecundity and ovary weight was also carried out using the same number of specimens (Figure 6.15) and the result obtained was,

$$\text{Log F} = 0.7929 + 0.6446 \text{ Log OW} \quad r=(0.9973)$$

A straight-line relationship was obtained for the paired variables with fecundity on one side and total length, total weight and ovary weight on the other. The best fit was obtained for relationship between fecundity and weight ($r=0.9973$).

In *L.inermis*, the maximum absolute fecundity was 1308450 for a fish of length 310mm, total weight 750gm and ovary weight 74.32gm. Lowest values for the above-mentioned parameters were 143mm, 78gm and 2.12gm in that order. The average relative fecundity was 883 per gram body weight. The number of eggs per gram ovary weight was 19200. (Table 6.14).

To find out the relationship between length of the fish and fecundity in *L.inermis* the absolute fecundity estimated for 32 fishes were plotted against their total length in a scatter diagram (Figure 6.16). Similarly the relationships between the paired variables of fecundity and total weight of fish; and

fecundity and ovary weight were also found out and are presented respectively in Figure 6.17 and Figure 6.18.

Relationship obtained between fecundity (F) and fish length (L) is as shown below:

$$\text{Log F} = -3.5524 + 3.9201 \text{ Log L} \quad (r = 0.9880)$$

The nature of association between fecundity (F) and fish weight (W) gave the following equation,

$$\text{Log F} = 2.4742 + 1.3099 \text{ Log W} \quad (r = 0.9820)$$

Similarly the relationship between fecundity (F) and ovary weight (OW) was also calculated and found to be,

$$\text{Log F} = 4.6253 + 0.9657 \text{ Log OW} \quad (r = 0.9904)$$

A straight-line relationship was obtained for the three pairs of variables with an exponential value slightly less than four for the association between fecundity and total length. The exponential values for the second and third pair of variables (fecundity- body weight and fecundity-ovary weight) were, respectively, 1.3099 and 0.9657. The logarithmic relationship between fecundity and ovary weight provided the highest correlation.

Remarkable degree of sexual dimorphism was seen in the freshwater puffer, *T.travancoricus*, especially in the breeding season. Males were more attractive than females with noticeable yellow colouration on the belly. A prominent

dark band, running antero-posteriorly up to the anal fin, along the mid-ventral line within the coloured zone, was clearly seen in males. Females lacked the aforesaid dark band and the mid-ventral region of the belly was white. The tips of the dorsal fin and anal fin were stained black in males, but females were devoid of it. Further, the central rays of the caudal fin were black in colour in males. This staining was not prominent in females. Plate 9 explicitly illustrates the sexual dimorphism in *T.travancoricus* as observed during the study period (arrows in the plate point to the differences). The smooth blaspop, *L. inermis* did not show any distinct difference in the body colouration between the sexes.

DISCUSSION

Information regarding the reproductive biology of puffer fishes is scanty and no script has been published so far on this aspect anywhere, in the recent past or earlier. While reviewing the overall reproductive parameters in fishes of tropical waters Qasim (1973) proposed that classification of gonads should be limited to five maturity stages. Tessy and Inasu (2002) suggested five-stage maturity for *Priacanthus hamrur*, Qayyum and Qasim (1965) while studying the biology of *Callichrous bimaculatus*, adopted the five-stage

classification. Instead of designating the third stage as 'mature' as has been done in the present study, the term 'ripening' was given. Kurup and Samuel (1991) followed the same pattern when spawning biology of *Gerres filamentosus* was worked out.

Unlike the five-stage pattern, Kilambi (1986) grouped the ovaries of the snakehead, *Ophiocephalus striatus* into four maturity stages. The third and fourth were designated respectively as mature and spent. Interestingly, the ova were also classified into four categories, the last of which represented the mature gametes. The third stage 'mature' ovaries contained ova of all the four stages of development. Harris (1986) investigated the gonad maturity stages using a four-stage classification in the Australian bass. Banu and Bhakta (1985), instead, identified eggs in three categories viz., immature, maturing and mature, when reproductive biology of *Colisa fasciata* was studied. Krishnakumar and Balakrishnan Nair (1995) classified the maturity stages into immature, maturing-I and II, mature, oozing and spent with reference to the breeding biology of the gray mullet, *Valamugil cannessius*. Chadhurvedi (1976) had seven maturity stages for tor mahseer, by incorporating developing as stage second in between immature and two stages of

maturing. Seven maturity stages were recognized by Shamsul Hoda and Naeemullah Qureshi (1989) for the mullet, *Liza klunzingeri* from Karachi-Sind waters. In the present study, the number of maturity stages for both the fishes was fixed as five as it was sufficient enough to delineate the gonads and hence the individuals. The monthly percentage occurrence of the various maturity stages of female *T. travancoricus* showed that ripe stage was seen in June and July followed by the presence of spent stage in July and the succeeding month. It was quite natural to get spent as well as mature stages in August as the spawning was not restricted to a single time and batches of eggs became mature during the moderately long spawning period from July to October. In all females, ovaries contained multimodal batches of eggs representing different stages of maturity all through the spawning period as was seen in *Nemipterus japonicus* (Murthy, 1984). In contrast, *L. inermis* showed discrete times for the appearance of mature, ripe and spent stages. Ripe fishes were observable in large numbers in March/April and September/October with a concomitant increase of fishes in stage V (spent) in April/May and October/November. This observation raised doubts about the opinion of James and Barangi (1980) that in majority of the marine fishes from tropical waters, maturation is a

continuous process resulting in the occurrence of mature fishes throughout the year.

The size at which 50% of female fish matured was 24.25mm in *T.travancoricus* and 152.72mm in *L. inermis*. The size at which a specimen becomes mature is a rather constant proportion of the final length or asymptotic length. The present study revealed that individuals of the same species did not mature at the same length and females of both the species were found to attain maturity in the size range of 24-25 mm and 150-179 mm in total length respectively in *T.travancoricus* and *L. inermis*. Fishes of small maximum total length mature early is a general assumption and the early onset of maturity in *T. travancoricus* at a length of 24 mm, that too at an age of approximately 0.75 years, is possibly due to small body size (maximum recorded total length in the study period was 34 mm and the estimated asymptotic length, 41.82 mm). Moreover, early maturity may be an indication of a relatively short life span. Further more, the strategy to mature at smaller sizes is advantageous for them to maximise egg production.

In *L. inermis* the relatively large size at maturity goes with the opinion of Vijay Anand and Pillai (2002) that fishes having maximum total length mature at larger lengths.

Wijeyaratne and Costa (1987) made a similar observation earlier and found that the female green-back mullet *Liza tade* attained maturity at an average length of 228 mm. Size at first maturity attained by *Sardinella dayi* was around 140 mm in a population in which the maximum length recorded was about 185 mm (Annigeri, 1989). The minimal size at maturity was 190 mm for *Schizothorax curvifrons* when fishes belonging to a length range of 83 mm-411 mm was studied (Syam Sunder, 1990). Furthermore, it can be concluded that *L. inermis* might be a species which has considerable life span.

The sex ratio studies on *T. travancoricus* and *L. inermis* proved that there was no significant variation from the null hypothesis when pooled data were analysed. Variation in the sex ratios between the observations in two years separately for both the species was also studied. There were noticeable differences in certain months regarding the sex-ratio. Nikolsky (1963) pointed out that the sex ratio differed from one population to another of the same species, and varied from year to year in the same population. Sex composition in a fish population may be affected by factors like segregation of sexes owing to age and sexual maturity, differences in natural mortality between the sexes, etc. Qasim (1966) opined that sex ratio might indicate differences in the growth rate of the

two sexes and it appeared that survival is a function of length. Menon's (1947) observation with fishes belonging to Siluridae that males outnumbered females was not applicable to the present observation. Jayaprakash (1998) got the same pattern of observation (Male: female = 1.3:1) for Malabar sole at Cochin during 1994-1995. Inasu (1993) earlier found a male dominated population for *Mystus mystus* with a sex ratio 1.1:0.44 in favour of males. The same study showed that in July 1983 and April 1984, though 86 and 180 numbers were caught respectively, not even a single female was trapped. Sex-ratio studied for some 25 reef fishes, by Vijay Anand and Pillai (2002) showed that only one species i.e., *Chaetodon octofasciatus* held a value (1.64:1) in favour of males.

The observations of the present investigation gave a slight edge for females. Females were more numerous than the males, an observation that agreed with the studies of Banu and Bhakta (1985); the male to female ratio of *Colisa fasciata* was 1:1.28, Nair and Nair (1984) reported the sex ratio of the tropical glassy perchlet, *Chanda (Ambassis) commersonii* as 1:2.5, females exceeding males. The same sex ratio was reported by Al ghais (1995) in *Pomadasys stridens*. Another female dominant population was observable (1:2.31) for

Pampus chinensis from Orissa coast (Pati, 1979). Kurup and Samuel (1991) found a ratio of 1:1.39 (male:female) in *Gerres filamentosus* (Cochin estuary). Krishnakumar and Balakrishnan Nair (1995) reported 1:1.5 as the male : female ratio in the gray mullet, *Valamugil cunnesius* from the Ahtamudi estuary. Qayyum and Qasim (1965) found a male to female ratio of 1.0:1.52 for *Callichrous bimaculatus*, Chaturvedi (1976) reported an overall sex-ratio which swung in favour of females greatly (1:1.9), Wijeyaratne and Costa (1987) observed a 1:1 ratio in *Liza tade* though males were more abundant in smaller (<320 mm) length group. Pooled data on sex ratio of *Sardinella dayi* for a period of five years from 1979 to 1983 showed equal proportion of 1:1 ratio in their population structure. (Annigeri, 1989). No significant departure from 1:1 ratio was reported by Syam Sunder (1990) in the snow trout of Kashmir. Zacharia (1991) got a 1:1.60 ratio with female dominance in *Priacanthus hamrur* collected from Mangalore. Tessy (2001) found no significant variation (1:1.026) in the sex ratio of *Pomadasy maculatus*. Tessy and Inasu (2002) while studying the reproductive biology of *Priacanthus hamrur*, also found a sex-ratio (1:1.2) in favour of females. The separate and pooled data for *T. travancoricus* and *L. inermis* provided ratios of 1:1.094 and 1:1.129 respectively,

which were, like the observations of many other workers, showed no significant variation from the expected 1:1 ratio, though there was a feeble advantage for the females.

The gonadosomatic index is used as a criterion for determining the duration and intensity of spawning in fishes. The observations on the GSI in *T. travancoricus* showed that the index increased gradually till April and sudden changes occurred in the succeeding months with the index crossing 7 and reaching the peak in June. The drop from 7.602 in the said month to 5.850 in August indicated spawning in between. The value further increased and reached a second peak during September/October. In November a sharp decrease in gonadosomatic index was observed which continued for a long period.

In contrast, *L. inermis*, showed an entirely different pattern of gonadosomatic index variation. The values increased gradually and reached a peak in March and was slightly lowered in April. From May onwards gonadosomatic index started falling back to low values and picked up and reached a second peak in September. Once again the succeeding month showed slight decrease in gonadosomatic index, which went further down in November. The nature of progression and fall in gonadosomatic indices as explained

above, pointed to the existence of two spawning periods for *L. inermis*. Further the spawning was well-synchronised and lasted only for about 2 months at two times of the year (April-May and October-November).

Fecundity is one of the best indicators of the reproductive potential of a species. Information on fecundity is very important as the success or failure of a fish population depends on its reproductive capacity. Fecundity may be affected by a number of factors including the condition of fish when germinal epithelium is laid down, condition of fish during maturation etc. (Simpson, 1951). It is a generally accepted view that fishes that can provide some sort of care to the eggs, produce fewer number of ova. On the other hand, as a sensible and viable strategy, fishes which leave their eggs to the hands of nature and mercy of aquatic environment release large numbers of eggs. According to Qasim and Qayyum (1963), to protect its position in an environment, each species reproduces to such an extent that all physical and biological hazards such as food supply, predation, sharp fluctuation in the environment etc. are effectively counteracted.

The very low fecundities in *T. travancoricus* might point to the demersal nature of the eggs and the existence of parental care. Fecundity studies of the same species revealed

that by accommodating enlarged ovaries more than once in a breeding season, the number of ova produced could be increased. It is definitely an advantage for fishes of small maximum total length, because being small, this is the only choice for them to have good number of offspring and thus perpetuate the population. Low fecundity may be related to capacity to survive in polluted waters and lower mortality i.e., high rate of survival. Relatively high fecundity indicates the pelagic spawning propensity, in *Lagocephalus inermis*. The eggs are left for the mercy of abiotic and biotic factors. A number of fishes show high fecundity values.

Fecundity has been shown to increase as square of length of fish (Clark, 1934 and Khan *et al.*, 2001), or cube of length (Simpson, 1951; Bagenal 1957; Sarojini, 1957; Pillay, 1958; Bagenal and Braum, 1978; Syam Sunder, 1990; Kurup and Samuel, 1991 and Kurup and Kuriakose, 1994) or the fourth power of length (Prabhu, 1955). In the present study, *T. travancoricus* showed a value of 3.1435 which corresponds to the observation of Syam Sunder (1990) and Kurup and Samuel (1991). But in *L. inermis*, the observed value was 3.9201 going with the observations of Jayaprakash (1998) and Renukadevi (2002) who got 3.6942 and 3.6891 respectively for *Cynoglossus macrostomus* and *Gerres filamentosus*.

The number of eggs produced by an individual female fish varies according to many a factor including size, age, food supply environment conditions (Antony Raja, 1972), etc. Fecundity appears to bear some broad relationship to the care or nature accorded to the eggs. In the stickleback (*Eucalia*), the usual number of eggs ranges from 30-100, whereas the ocean sunfish, *Mola mola*, produces some 28 million or more eggs in a single season (Lagler *et al.*, 1962).

Fecundity holds some exponential relationship with the weight of the fish. Simpson (1951) found that the fecundity is directly proportional to the fish weight. A straight-line relationship was found between fecundity and body weight both in *T.travancoricus* and *L.inermis* in conformity with the findings of Bagenal (1957), Qasim and Qayyum (1963), Parulekar and Bal (1971), Joshi and Khanna (1980), Singh *et al.* (1982), and Reddy (1991) Kurup and Kuriakose (1994), Jayaprakash (1998), Tessy (2001) and Renukadevi (2002).

Production of eggs is a dominant function of the ovary and there exists a linear relationship between the weight of ovary and fecundity and the number of ova increased at a rate of 0.6446 and 0.9657 times the ovary weight respectively in *T.travancoricus* and *L.inermis*. Present observation agreed

with the findings of Jayaprakash (1998) in *C. macrostomus* (0.8328), Khan *et al.* (2001) in *Hilsa ilisha* (0.7296) Tessy (2001) in *Pomadasys maculatus* (1.0904) Renukadevi (2002) in *Gerres filamentosus* from Sharavati estuary and Tessy and Inasu (2002) in *Priacanthus hamrur*.

It could be concluded that, in *T. travancoricus* length of fish highly correlated with fecundity than weight. In *L. inermis* also length showed an better relationship. According to Antony Raja (1972) deviation of 'b' values from 3 and 1 when fecundity is related to length and weight, respectively, may be due to age, season and environment.

Spawning season of a fish is determined on the basis of the occurrence of individuals in the mature, ripe and spent stages; ova diameter studies and progression and regression in gonadosomatic index values. Hickling and Reutenberg (1936), De Jong (1940), Prabhu (1956) and a number of other workers have divided the teleosts into four different categories based on the periodicity of spawning:

1. once a year during a definite short period,
2. once a year but with longer duration,
3. twice a year and
4. intermittently over a very long period.

According to Robertson (1991) daily, lunar and seasonal time scales produce a variety of pattern of spawning in reef fishes. The pattern of spawning in *T.travancoricus* and *L.inermis* is not identical. In the former, the breeding period is relatively long and spawning occurred at two times in a single season extending from July to October-November. During the extended spawning season ovaries of the ripe females had eggs with various diameters, i.e., containing ova in immature to ripe stages, the largest of which was seen in July, the month in which maximum gonadosomatic index was recorded. In the following month, a number of spent individuals were collected and females were not having the highest ova diameter mode and a corresponding drop in gonadosomatic index noticed. The above-mentioned features proved that the first spawning of *T.travancoricus* in the extended season occurred in July. Maturing and mature ova (average diameters 34md and 63 md respectively) grew further and attained the largest size mode in October. A concomitant increase in gonadosomatic index value also supported the presence of a second spawning time within the single season. Intra-ovarian diameter observation in the following months seldom provided ova with largest mode in any individual irrespective of their length and weight and hence age. The presence of eggs of various sizes in the

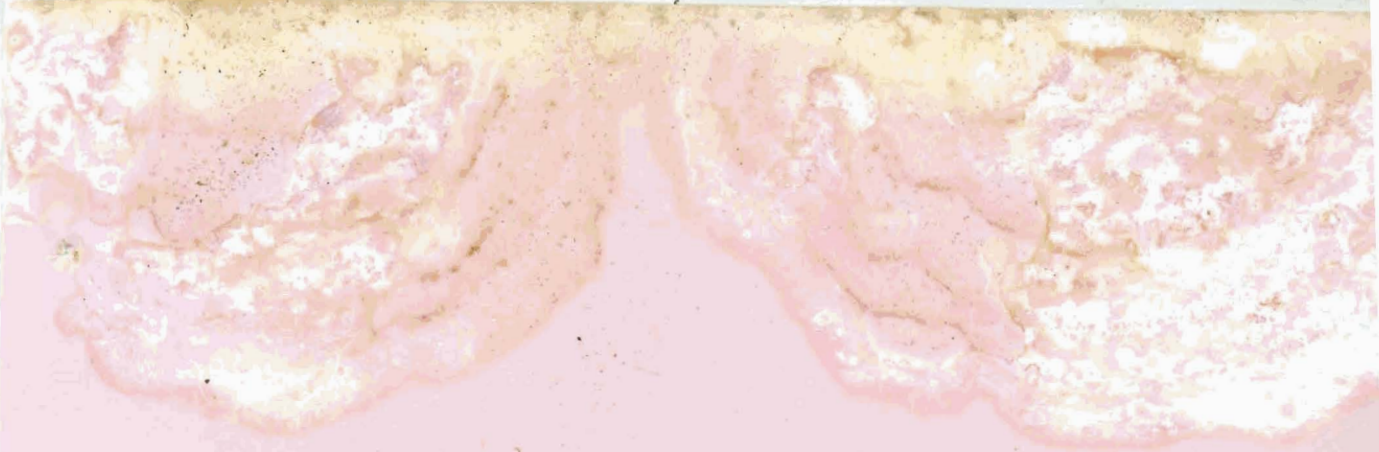
ovaries of individual fish indicated extended spawning period and there was a bimodal pattern with discrete peaks of major spawning activity. Spawning more than once in a single season- fractional spawning - is considered as an advantage for *T.travancoricus* as it decreases the chances of one or more entire generation being lost due to unfavourable environmental conditions. Pathiratne and Costa (1984) found the multiple spawning nature in the cichlid, *Etroplus suratensis*. A remarkable example for fractional spawning is the spotted sea trout which spawns up to 40-41 times between June and September (Tucker *et al.*, 1987). Kader *et al.* (1988) observed both iteroparity (spawning more than once in life time) and batch spawning in *Gobiodes rubicundus*.

In contrast, the gonadosomatic index, gonad maturation stages and ova size and occurrence of ripe and spent fishes demonstrated that *L. inermis* belonged to the third category as observed by Prabhu (1956) i.e., spawning twice a year. *L. inermis* selected pre-monsoon month of April and post-monsoon period of October for intense spawning. Ova diameter frequencies indicated that the ovaries contained a single group of eggs with maximum ova diameter. In ripe fishes this group of large oocytes is widely separated from the much smaller yolkless cells. Qasim and Qayyum (1961),

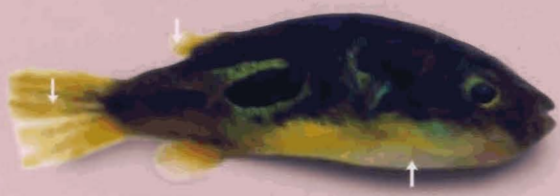
observed the same pattern while studying spawning frequencies and breeding seasons of some freshwater fishes with special reference to those occurring in the plains of north India. Spent fishes obtained in May and November contained no eggs in their ovaries except the immature small oocytes and a few large ova. It could be concluded that in fishes where a single group of ova is matured and shed, the duration of spawning is very short, lasting for one month or two. Furthermore, two seasons with favourable environmental conditions are exploited by *L. inermis*. The unusually bad weather might interfere with the timing of spawning in fishes. The characteristic avoidance of monsoon seasons by spawning individuals is perhaps to tide over the unfavourable rough weather which would transport eggs and larvae to undesirable destinations. The observations on spawning periods of *L. inermis* goes with Blaber's (1997b) opinion that there is a tendency for reproductive quiescence during the strong monsoon wind which makes the sea very turbulent and that usually spawning occurs at a time when environmental conditions are most favourable for larval survival.

It may be concluded that both *T. travancoricus* and *L. inermis* spawn more than once during their lives, a phenomenon referred to as iteroparity. Serial or batch

spawning along with iteroparous condition is exhibited by *T. travancoricus* whereas iteroparity with synchronous spawning is observed in *L. inermis*.



FEMALE



MALE

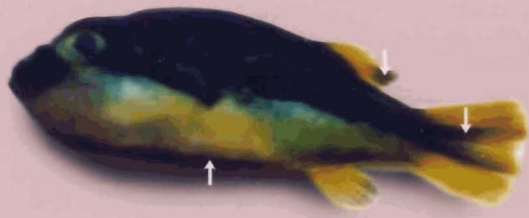


Plate 9. Sexual dimorphism in *Tetraodon travancoricus*

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Table 6.1 Classification of maturity stages of females of
Tetraodon travancoricus

| Stage of maturity | Description of ovary | Mode of largest group of ova (mm) | Maximum size of ova (mm) |
|-------------------|----------------------|-----------------------------------|--------------------------|
| I | Immature | 0.0795 | 0.1590 |
| II | Maturing | 0.5406 | 0.7950 |
| III | Mature | 1.002 | 1.1925 |
| IV | Ripe | 1.3356 | 1.4310 |
| V | Spent | 0.6678 | 0.8586 |

Table 6.2 Classification of maturity stages of females of
Lagocephalus inermis

| Stage of maturity | Description of ovary | Mode of largest group of ova (mm) | Maximum size of ova (mm) |
|-------------------|----------------------|-----------------------------------|--------------------------|
| I | Immature | 0.0477 | 0.0795 |
| II | Maturing | 0.1908 | 0.2385 |
| III | Mature | 0.3180 | 0.3816 |
| IV | Ripe | 0.4452 | 0.4929 |
| V | Spent | 0.0636 | 0.0954 |

Table 6.3 Percentage occurrence of Immature, maturing, mature, ripe and spent females of *Tetraodon travancoricus* (pooled) in different length classes.

| Length group (mm) | No. of Fish | Percentage occurrence | | | | |
|-------------------|-------------|-----------------------|----------|--------|-------|-------|
| | | Immature | Maturing | Mature | Ripe | Spent |
| 18-19 | 39 | 100 | - | - | - | - |
| 20-21 | 59 | 77.97 | 22.03 | - | - | - |
| 22-23 | 61 | 47.54 | 24.59 | 27.87 | - | - |
| 24-25 | 46 | 28.26 | 23.91 | 36.96 | 10.89 | - |
| 26-27 | 39 | 12.82 | 17.95 | 30.77 | 25.64 | 12.82 |
| 28-29 | 24 | - | 16.67 | 25.0 | 37.50 | 20.83 |
| 30-31 | 6 | - | - | 16.67 | 58.00 | 33.33 |

Table 6.4. Percentage occurrence of immature, maturing, mature, ripe and spent females of *Lagocephalus inermis* (pooled) in various length groups

| Length group (mm) | No. of Fish | Percentage occurrence | | | | |
|-------------------|-------------|-----------------------|----------|--------|-------|-------|
| | | Immature | Maturing | Mature | Ripe | Spent |
| 90-119 | 22 | 100 | - | - | - | - |
| 120-149 | 26 | 42.31 | 34.62 | 23.07 | - | - |
| 150-179 | 39 | 20.51 | 25.64 | 41.03 | 12.82 | - |
| 180-209 | 27 | 11.11 | 25.93 | 40.74 | 14.81 | 7.41 |
| 210-239 | 19 | - | 21.05 | 21.05 | 36.84 | 21.05 |
| 240-269 | 15 | - | 13.33 | 26.67 | 40.00 | 20.00 |
| 270-299 | 7 | - | - | 14.29 | 57.14 | 28.57 |
| 300-329 | 4 | - | - | - | 75.00 | 25.00 |

Table 6.5 Percentage occurrence of female of *Tetraodon travancoricus* in various maturity stages from October 1999 to September 2001

| Month | Percentage occurrence of various maturity stages | | | | | | | | | |
|-------|--|------|------|------|------|-----------------------------|------|------|------|------|
| | October 1999-Sept. 2000 | | | | | October 2000-September 2001 | | | | |
| | I | II | III | IV | V | I | II | III | IV | V |
| Oct | - | - | 30.0 | 40.0 | 30.0 | 20.0 | - | 20.0 | 30.0 | - |
| Nov | 33.3 | 44.4 | - | - | 22.2 | 55.6 | 33.3 | - | - | - |
| Dec | 60.0 | 40.0 | - | - | - | 77.8 | 22.2 | - | - | - |
| Jan | 64.3 | 35.7 | - | - | - | 84.6 | 15.4 | - | - | - |
| Feb | 75.0 | 25.0 | - | - | - | 72.7 | 27.4 | - | - | - |
| Mar | 63.2 | 36.8 | - | - | - | 81.3 | 18.7 | - | - | - |
| Apr | 58.3 | 25.0 | 16.7 | - | - | 54.5 | 18.2 | 27.3 | - | - |
| May | 27.8 | 27.8 | 45.4 | - | - | 45.5 | 18.2 | 36.3 | - | - |
| Jun | 28.5 | 14.3 | 28.6 | 28.6 | - | 15.4 | 7.7 | 53.8 | 23.1 | - |
| Jul | 38.5 | - | - | 38.5 | 23.0 | 30.0 | - | - | 40.0 | 30.0 |
| Aug | 36.4 | 18.2 | 45.4 | - | - | 33.3 | 33.3 | 33.3 | - | - |
| Sep | - | - | 55.6 | 44.4 | - | - | - | 66.7 | 33.3 | - |

Table 6.6 Monthly percentage occurrence of females of *Lagocephalus inermis* in various maturity stages from January 2000 to December 2001

| Month | Percentage occurrence of various maturity stages | | | | | | | | | |
|-------|--|------|-------|-------|-------|------|------|------|------|------|
| | 2000 | | | | | 2001 | | | | |
| | I | II | III | IV | V | I | II | III | IV | V |
| Jan | 71.4 | 28.6 | - | - | - | 44.4 | 53.6 | - | - | - |
| Feb | 37.5 | 50 | 12.5 | - | - | 33.3 | 22.2 | 44.5 | - | - |
| Mar | 16.7 | - | 58.33 | 25.0 | - | - | - | 71.4 | 28.6 | - |
| Apr | - | - | - | 57.14 | 42.86 | - | - | - | 60.0 | 40.0 |
| May | 50.0 | 50.0 | - | - | - | 100 | - | - | - | - |
| Jun | 100 | - | - | - | - | 72.7 | 27.3 | - | - | - |
| Jul | 66.9 | 33.3 | - | - | - | 37.5 | 62.5 | - | - | - |
| Aug | 20 | 70 | 10 | - | - | 50.0 | 25.0 | 25.0 | - | - |
| Sep | - | - | 72.7 | 27.3 | - | - | - | 66.7 | 33.3 | - |
| Oct | - | - | 12.5 | 50.0 | 37.5 | - | - | 16.7 | 50.0 | 33.3 |
| Nov | - | - | - | 33.3 | 66.7 | - | - | - | - | 100 |
| Dec | 50.0 | 50.0 | - | - | - | 50.0 | 50.0 | - | - | - |

Table 6.7. Monthly average of gonadosomatic indices of *Tetraodon travancoricus* (females) from October 1999 to September 2001

| Sl. No. | Month | Gonadosomatic index | | |
|---------|-----------|---------------------|-----------|--------|
| | | 1999-2000 | 2000-2001 | Pooled |
| 1 | October | 4.651 | 4.943 | 4.797 |
| 2 | November | 3.333 | 3.281 | 3.307 |
| 3 | December | 2.683 | 2.936 | 2.810 |
| 4 | January | 2.868 | 2.632 | 2.750 |
| 5 | February | 2.892 | 2.783 | 2.838 |
| 6 | March | 3.030 | 2.912 | 2.971 |
| 7 | April | 3.981 | 3.823 | 3.902 |
| 8 | May | 5.926 | 5.233 | 5.580 |
| 9 | June | 7.876 | 7.328 | 7.602 |
| 10 | July | 6.356 | 6.628 | 6.492 |
| 11 | August | 4.253 | 4.434 | 4.344 |
| 12 | September | 5.688 | 6.012 | 5.850 |

Table 6.8. Monthly average of gonadosomatic index values of *Lagocephalus inermis* (females) from Jan. 2000 to Dec. 2001

| Sl.No. | Month | Gonadosomatic index | | |
|--------|-----------|---------------------|-------|--------|
| | | 2000 | 2001 | Pooled |
| 1 | January | 0.752 | 0.993 | 0.873 |
| 2 | February | 1.431 | 1.983 | 1.707 |
| 3 | March | 4.876 | 5.052 | 4.964 |
| 4 | April | 2.959 | 3.873 | 3.416 |
| 5 | May | 1.960 | 1.237 | 1.599 |
| 6 | June | 0.892 | 1.021 | 0.957 |
| 7 | July | 1.392 | 1.697 | 1.545 |
| 8 | August | 2.351 | 2.092 | 2.222 |
| 9 | September | 3.319 | 3.602 | 3.461 |
| 10 | October | 2.453 | 2.664 | 2.556 |
| 11 | November | 1.694 | 1.255 | 1.475 |
| 12 | December | 0.815 | 0.896 | 0.856 |

Table 6.9. Monthly distribution of sexes of *Tetraodon travancoricus* during the period from Oct. 1999 to Sep. 2001

| Month | 1999 - 2000 | | | | | | 2000 - 2001 | | | | | | Pooled | | | | | | | | |
|-------|-------------|------|--------|-----------|------------------|-------------|-------------|--------|-----------|------------------|-------------|------|--------|-----------|------------------|-------------|------|--------|-----------|------------------|--|
| | No. of fish | Male | Female | Sex ratio | Chi-square value | No. of fish | Male | Female | Sex ratio | Chi-square value | No. of fish | Male | Female | Sex ratio | Chi-square value | No. of fish | Male | Female | Sex ratio | Chi-square value | |
| Oct | 31 | 13 | 18 | 1:1.385 | 0.806 | 34 | 15 | 19 | 1:1.267 | 0.471 | 65 | 28 | 37 | 1:1.321 | 1.246 | | | | | | |
| Nov | 29 | 11 | 18 | 1:1.636 | 1.689 | 30 | 12 | 18 | 1:1.50 | 1.200 | 59 | 23 | 36 | 1:1.565 | 2.864 | | | | | | |
| Dec | 37 | 17 | 20 | 1:1.176 | 0.243 | 39 | 16 | 23 | 1:1.437 | 1.256 | 76 | 33 | 43 | 1:1.303 | 1.316 | | | | | | |
| Jan | 39 | 15 | 24 | 1:1.60 | 2.077 | 28 | 11 | 17 | 1:1.545 | 1.286 | 67 | 26 | 41 | 1:1.577 | 3.358 | | | | | | |
| Feb | 32 | 15 | 17 | 1:1.133 | 0.125 | 34 | 16 | 18 | 1:1.125 | 0.118 | 66 | 31 | 35 | 1:1.129 | 0.242 | | | | | | |
| Mar | 45 | 19 | 26 | 1:1.368 | 1.089 | 48 | 22 | 26 | 1:1.182 | 0.333 | 93 | 41 | 52 | 1:1.268 | 1.301 | | | | | | |
| Apr | 38 | 21 | 17 | 1:0.810 | 0.421 | 28 | 14 | 14 | 1:1 | 0 | 66 | 35 | 31 | 1:0.886 | 0.242 | | | | | | |
| May | 25 | 10 | 15 | 1:1.50 | 1.000 | 35 | 16 | 19 | 1:1.188 | 0.257 | 60 | 26 | 34 | 1:1.308 | 1.067 | | | | | | |
| Jun | 41 | 24 | 17 | 1:0.708 | 1.195 | 34 | 16 | 18 | 1:1.125 | 0.118 | 75 | 40 | 35 | 1:0.875 | 0.333 | | | | | | |
| Jul | 34 | 19 | 15 | 1:0.789 | 0.471 | 31 | 19 | 12 | 1:0.632 | 1.581 | 65 | 38 | 27 | 1:0.711 | 1.862 | | | | | | |
| Aug | 50 | 26 | 24 | 1:0.923 | 0.080 | 29 | 17 | 12 | 1:0.706 | 0.862 | 79 | 43 | 36 | 1:0.837 | 0.620 | | | | | | |
| Sep | 44 | 25 | 19 | 1:0.760 | 0.818 | 33 | 16 | 17 | 1:1.063 | 0.030 | 77 | 41 | 36 | 1:0.878 | 0.325 | | | | | | |
| Total | 445 | 215 | 230 | 1:1.0698 | 0.506 | 403 | 190 | 213 | 1:1.121 | 1.313 | 848 | 405 | 443 | 1:1.094 | 1.703 | | | | | | |

Table 6.10. Distribution of sexes in *Lagocephalus inermis* during January 2000 to December 2001.

| Month | 1999 - 2000 | | | | | 2000 - 2001 | | | | | Pooled | | | | |
|-------|---------------|------|--------|-----------|------------------|---------------|------|--------|-----------|------------------|---------------|------|--------|-----------|------------------|
| | No. of fishes | Male | Female | Sex ratio | Chi-square value | No. of fishes | Male | Female | Sex ratio | Chi-square value | No. of fishes | Male | Female | Sex ratio | Chi-square value |
| Jan | 13 | 6 | 7 | 1:1.17 | 0.077 | 18 | 9 | 9 | 1:1 | 0 | 31 | 15 | 16 | 1:1.07 | 0.032 |
| Feb | 18 | 10 | 8 | 1:1.80 | 0.222 | 16 | 7 | 9 | 1:1.29 | 0.250 | 34 | 17 | 17 | 1:1 | 0 |
| Mar | 20 | 8 | 12 | 1:1.50 | 0.80 | 13 | 6 | 7 | 1:1.17 | 0.077 | 33 | 14 | 19 | 1:1.36 | 0.758 |
| Apr | 12 | 5 | 7 | 1:1.40 | 0.333 | 9 | 4 | 5 | 1:1.25 | 0.20 | 21 | 9 | 12 | 1:1.33 | 0.429 |
| May | 3 | 1 | 2 | 1:2.0 | 0.333 | 2 | 1 | 1 | 1:1 | 0 | 5 | 2 | 3 | 1:1.50 | 0.200 |
| Jun | 16 | 8 | 8 | 1:1 | 0 | 19 | 8 | 11 | 1:1.38 | 0.474 | 35 | 16 | 19 | 1:1.19 | 0.257 |
| Jul | 17 | 10 | 7 | 1:0.70 | 0.529 | 15 | 7 | 8 | 1:1.14 | 0.067 | 32 | 17 | 15 | 1:0.88 | 0.125 |
| Aug | 21 | 10 | 11 | 1:1.10 | 0.048 | 17 | 9 | 8 | 1:0.89 | 0.059 | 38 | 19 | 19 | 1:1 | 0 |
| Sep | 21 | 9 | 12 | 1:1.33 | 0.429 | 16 | 7 | 9 | 1:1.28 | 0.250 | 37 | 16 | 21 | 1:1.31 | 0.676 |
| Oct | 13 | 5 | 8 | 1:1.60 | 0.692 | 11 | 5 | 6 | 1:1.20 | 0.091 | 24 | 10 | 14 | 1:1.4 | 0.667 |
| Nov | 5 | 2 | 3 | 1:1.50 | 0.20 | 4 | 2 | 2 | 1:1 | 0 | 9 | 4 | 5 | 1:1.25 | 0.111 |
| Dec | 4 | 2 | 2 | 1:1 | 0 | 10 | 6 | 4 | 1:0.67 | 0.400 | 14 | 8 | 6 | 1:0.75 | 0.286 |
| TOTAL | 163 | 76 | 87 | 1:1.145 | 0.742 | 150 | 71 | 79 | 1:1.11 | 0.427 | 313 | 147 | 166 | 1:1.129 | 1.153 |

Table 6.11. Consolidated data on observed sex ratio of *Tetraodon travancoricus* with chi-square values

| Year | n | Male | Female | Sex ratio | X ² | remarks |
|--------------------------|-----|------|--------|-----------|----------------|---------|
| Oct 1999- Sept. 2000 | 445 | 215 | 230 | 1:1.0698 | 0.506 | NS* |
| Oct. 2000- Sept. 2001 | 403 | 190 | 213 | 1:1.121 | 1.313 | NS* |
| Pooled | 848 | 405 | 443 | 1:1.094 | 1.703 | NS* |

NS* non significant at 5% level for Idf

Table 6.12. Consolidated data on observed sex ratio of *Lagocephalus inermis* with chi-square values

| Year | n | Male | Female | Sex ratio | X ² | remarks |
|-----------------|-----|------|--------|-----------|----------------|---------|
| Jan-Dec 2000 | 163 | 76 | 87 | 1:1.145 | 0.742 | NS* |
| Jan-Dec 2001 | 150 | 71 | 79 | 1:1.11 | 0.427 | NS* |
| Pooled | 313 | 147 | 166 | 1:1.129 | 1.153 | NS* |

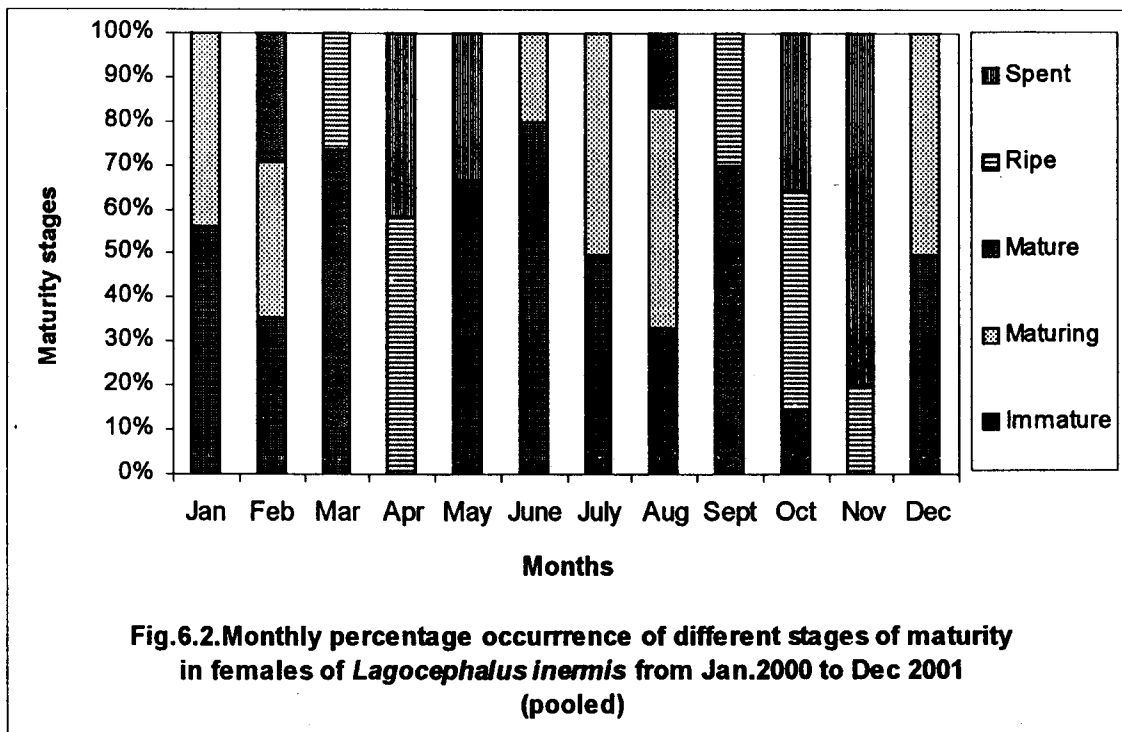
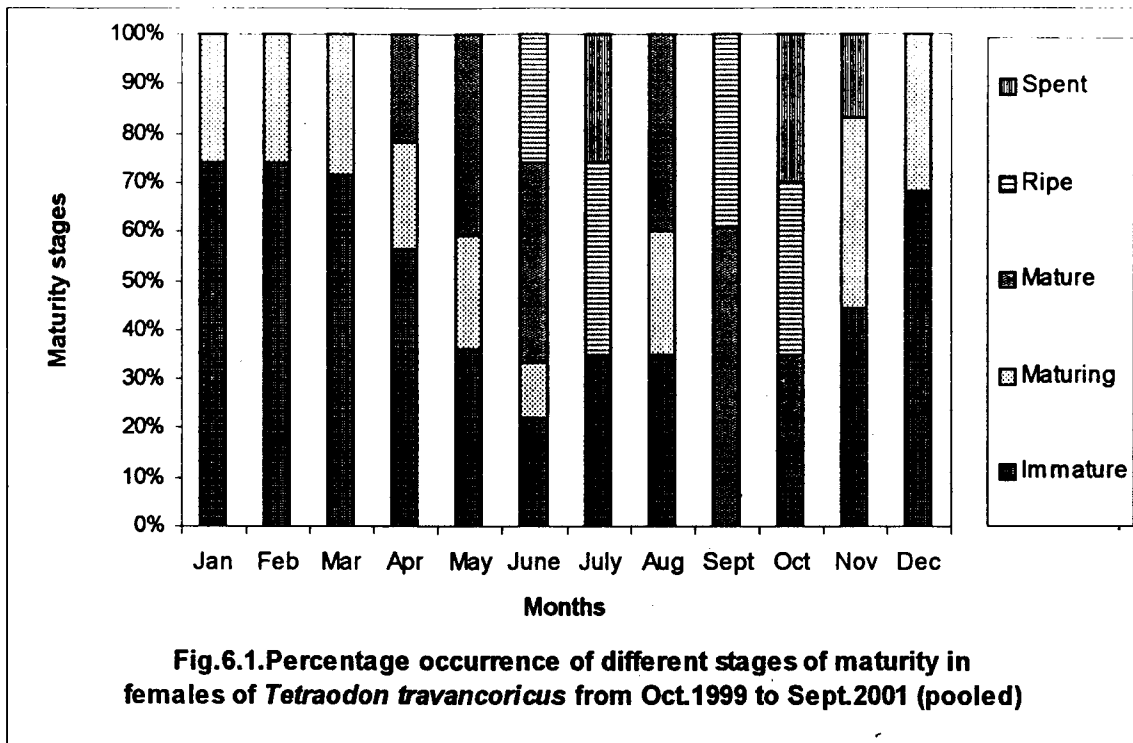
NS* non significant at 5% level for Idf

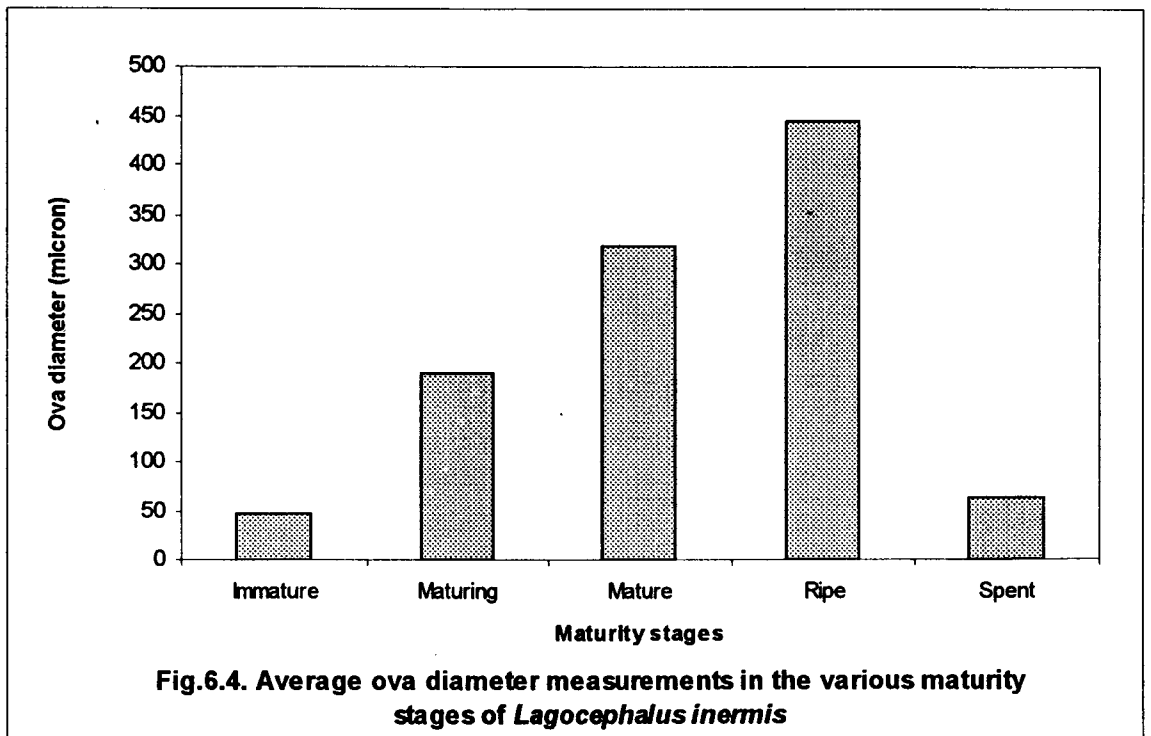
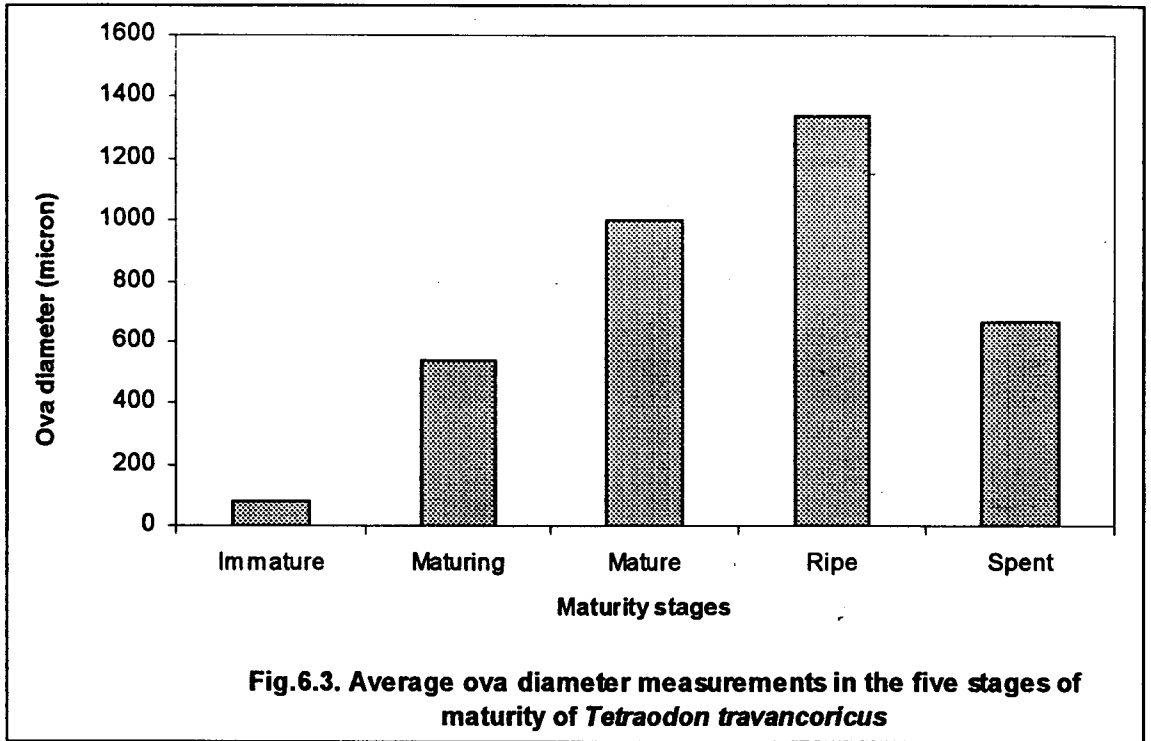
Table 6.13. Relationship between different fecundity parameters in *Tetraodon travancoricus* (pooled) from October 1999 to September 2001

| Length (mm) | Average weight (g) | Ovary weight (g) | Absolute fecundity | Ova/g body weight | Ova/g ovary weight. |
|-------------|--------------------|------------------|--------------------|-------------------|---------------------|
| 25 | 0.422 | .042 | 69 | 163.5 | 1642.8 |
| 26 | 0.431 | .049 | 76 | 176.3 | 1551.0 |
| 27 | 0.526 | .062 | 91 | 173.0 | 1467.7 |
| 28 | 0.684 | .074 | 98 | 143.3 | 1324.3 |
| 29 | 0.812 | .084 | 106 | 130.5 | 1261.9 |
| 30 | 0.963 | .102 | 121 | 125.6 | 1186.3 |
| 31 | 1.028 | .119 | 138 | 134.2 | 1159.6 |

Table 6.14. Relationship between different fecundity parameters in *Lagocephalus inermis* (pooled) from January 2000 to December 2001

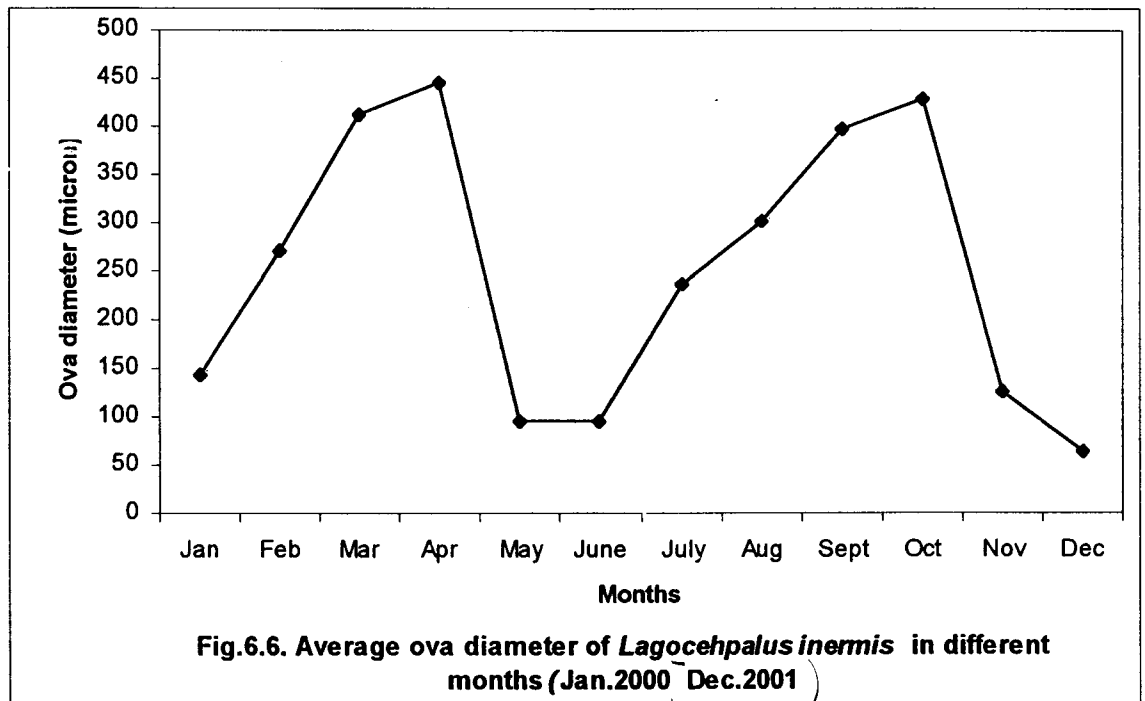
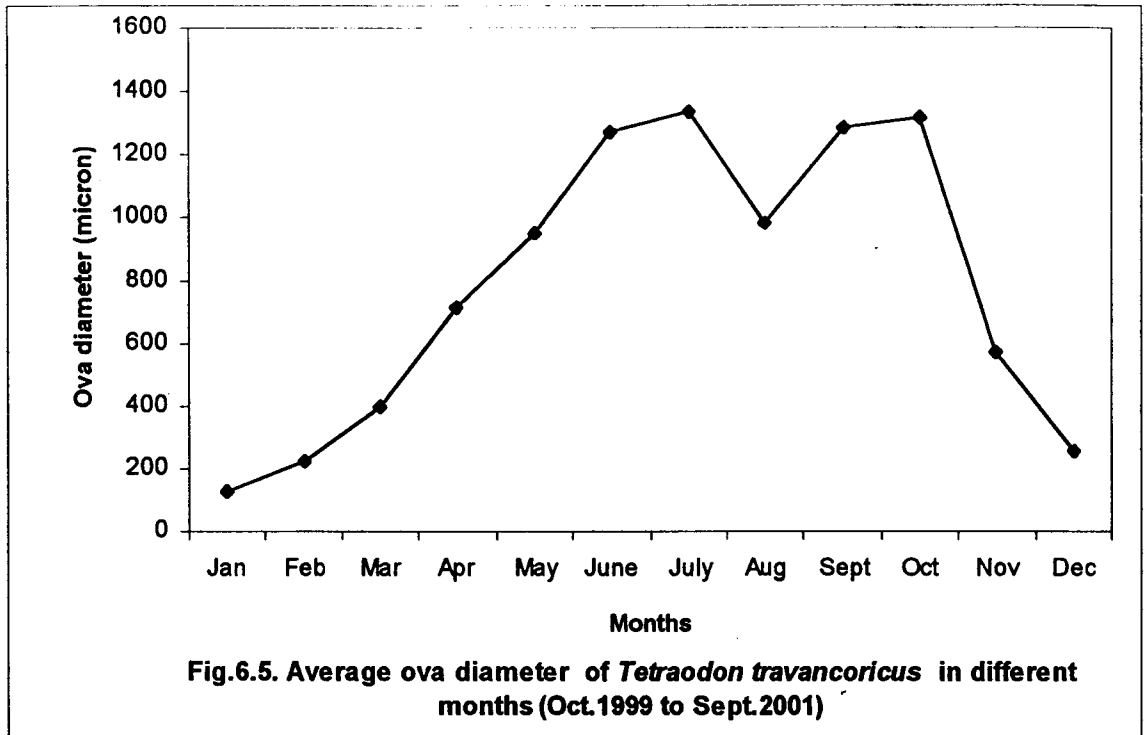
| Length group | Average length | Average weight | Ovary weight | Absolute fecundity | Ova/g body weight | Ova/g vary weight |
|--------------|----------------|----------------|--------------|--------------------|-------------------|-------------------|
| 140-159 | 153 | 86 | 2.83 | 53541 | 622 | 18919 |
| 160-179 | 169 | 106 | 4.68 | 73125 | 689 | 15625 |
| 180-199 | 191 | 165 | 5.25 | 109375 | 662 | 20833 |
| 200-219 | 212 | 199 | 6.34 | 165104 | 829 | 26041 |
| 220-239 | 232 | 339 | 9.30 | 193750 | 571 | 20833 |
| 240-259 | 245 | 388 | 18.62 | 375595 | 968 | 20171 |
| 260-279 | 278 | 484 | 35.12 | 628100 | 1285 | 17884 |
| 280-299 | 291 | 595 | 38.50 | 678571 | 1140 | 17625 |
| 300-319 | 313 | 698 | 45.28 | 822038 | 1177 | 14870 |

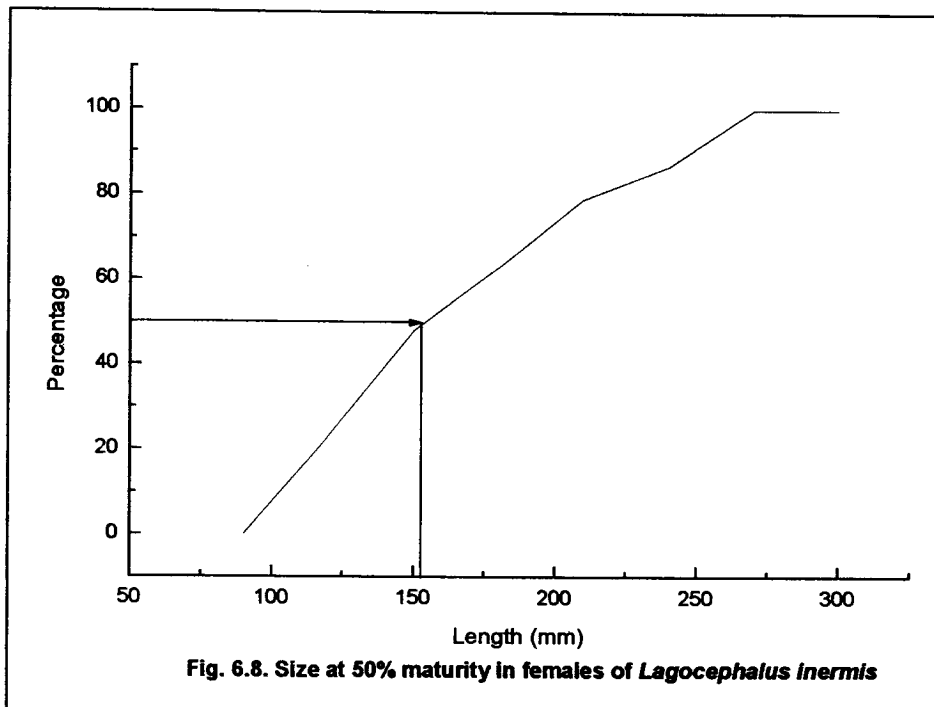
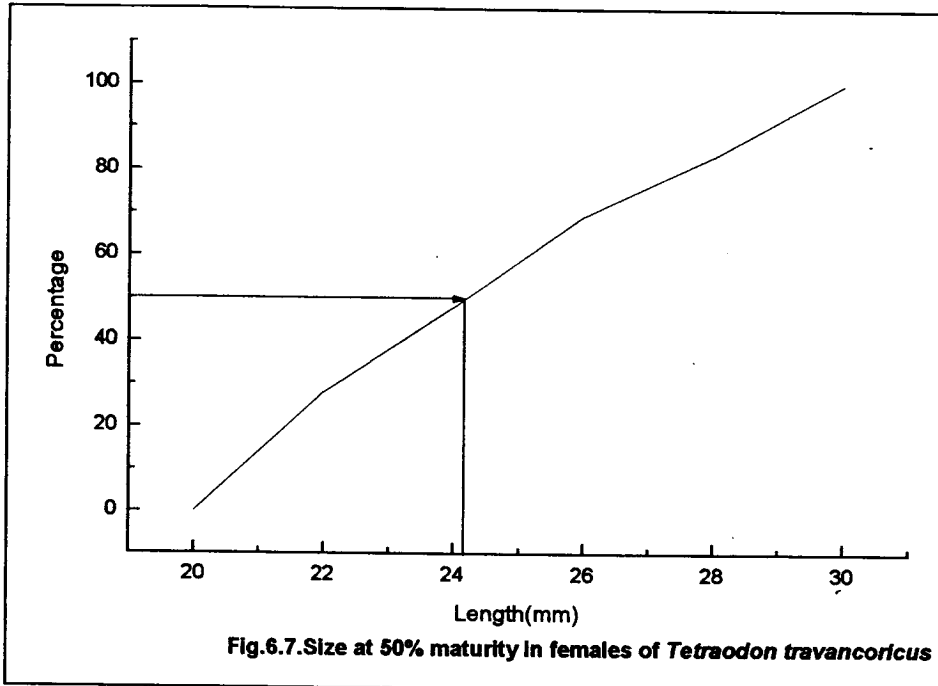


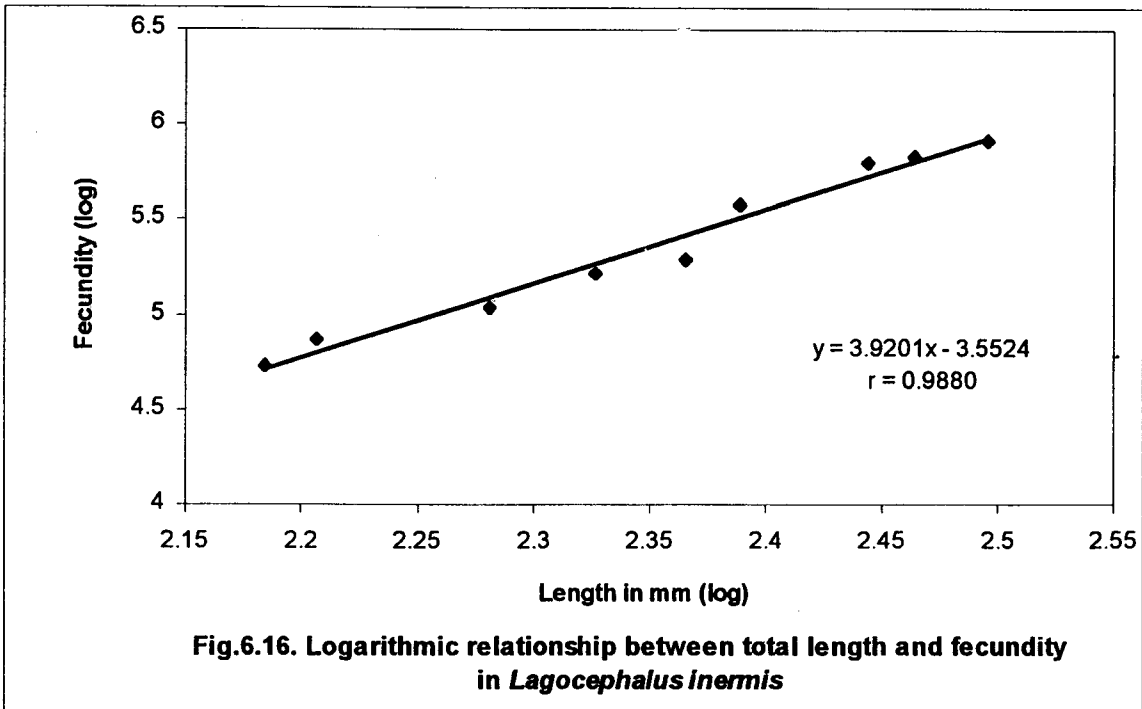
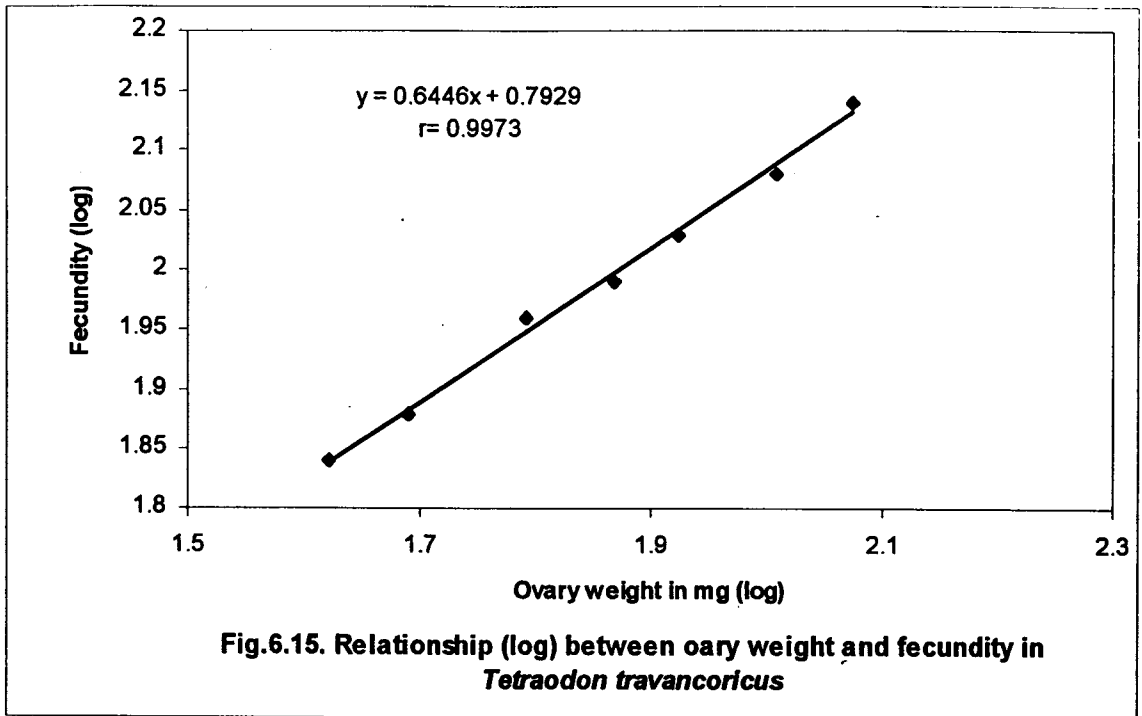


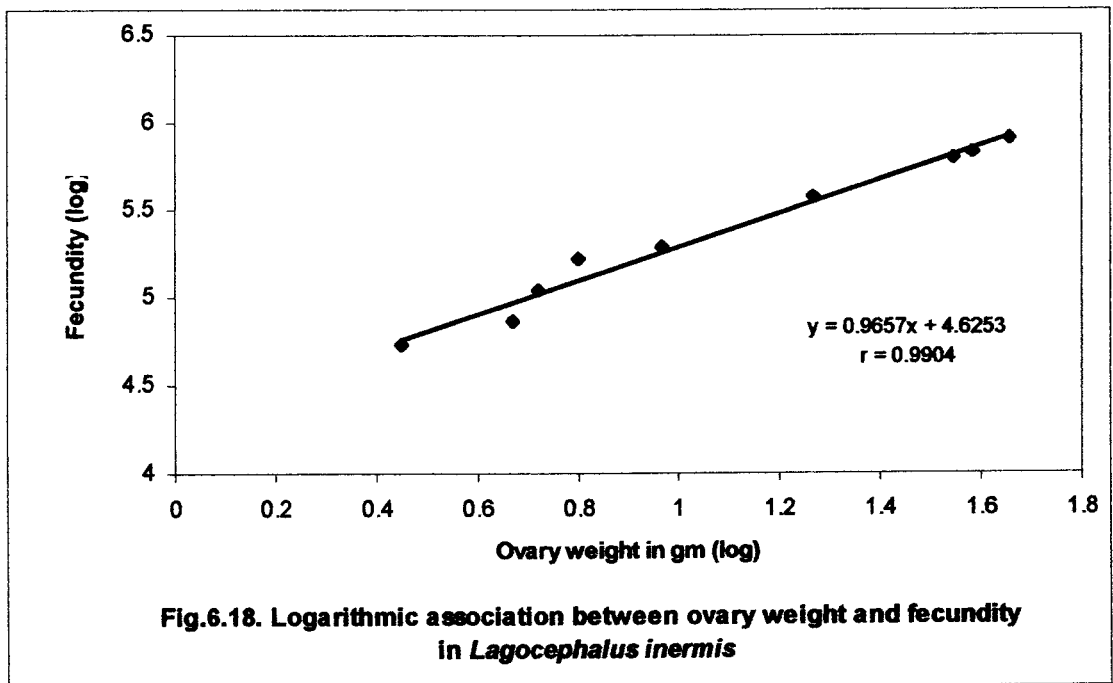
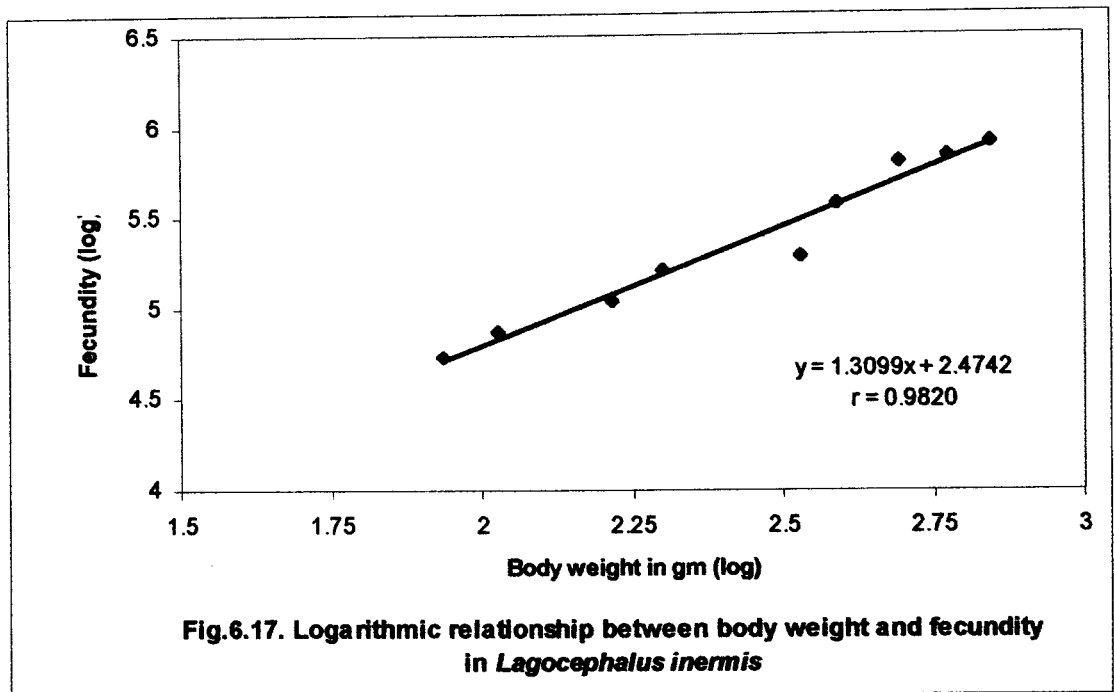
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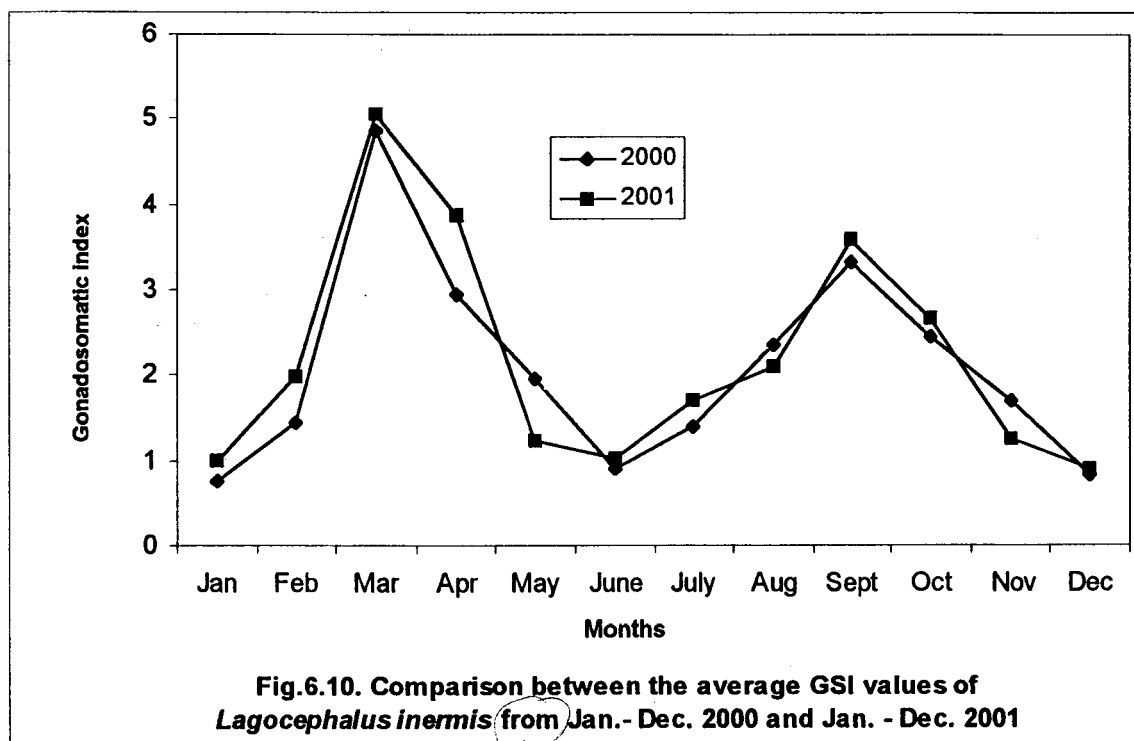
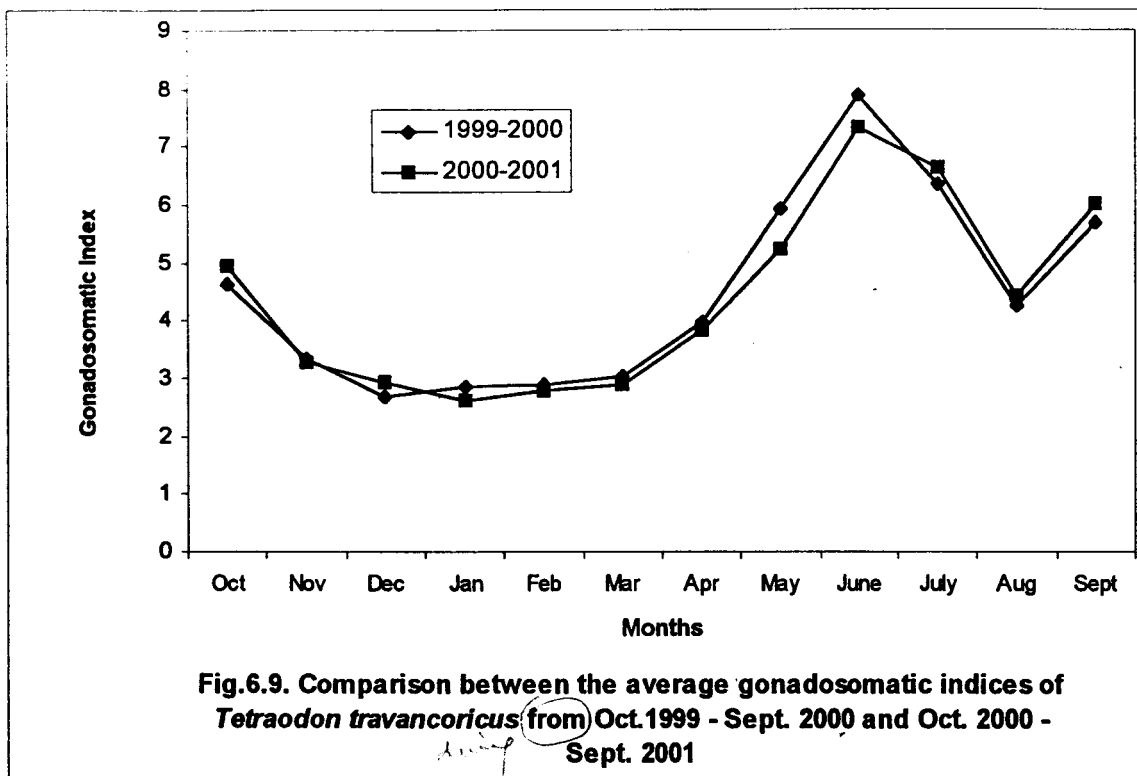


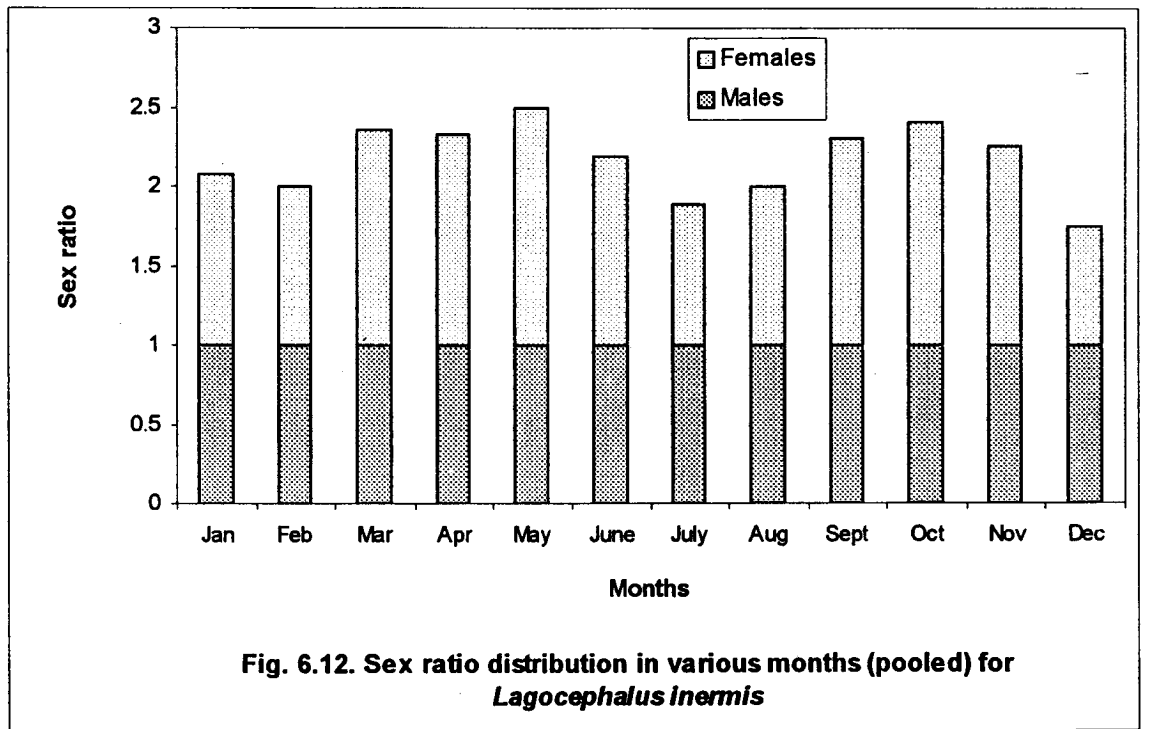
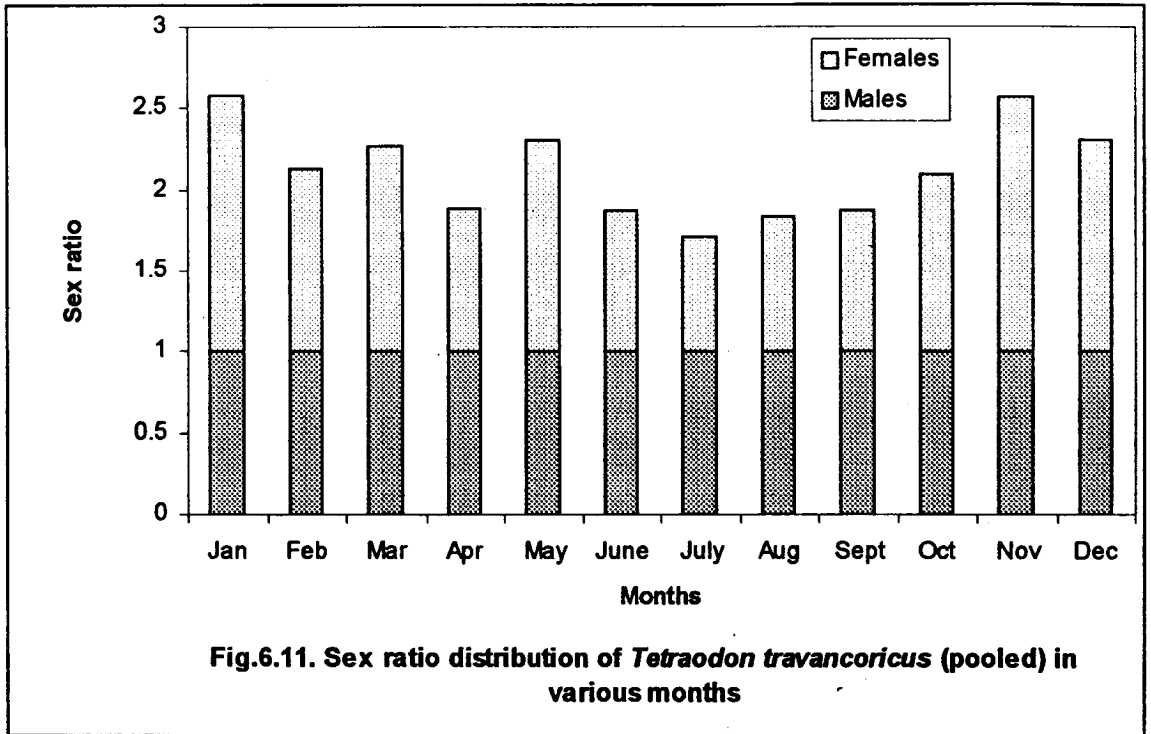


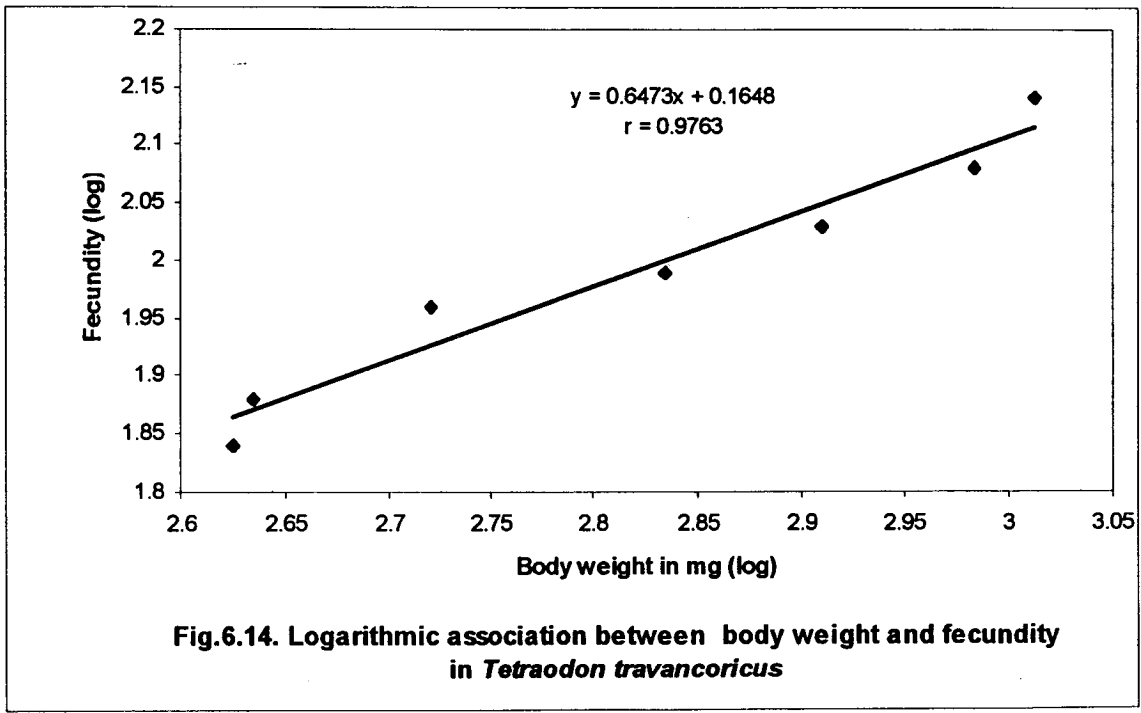
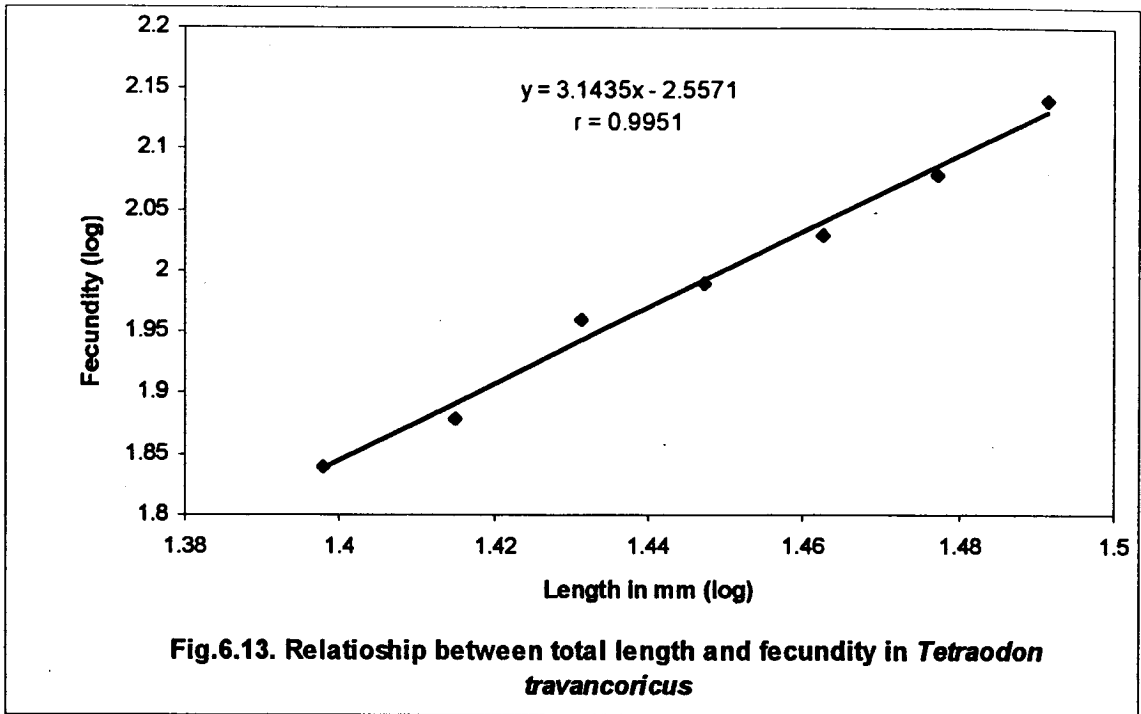


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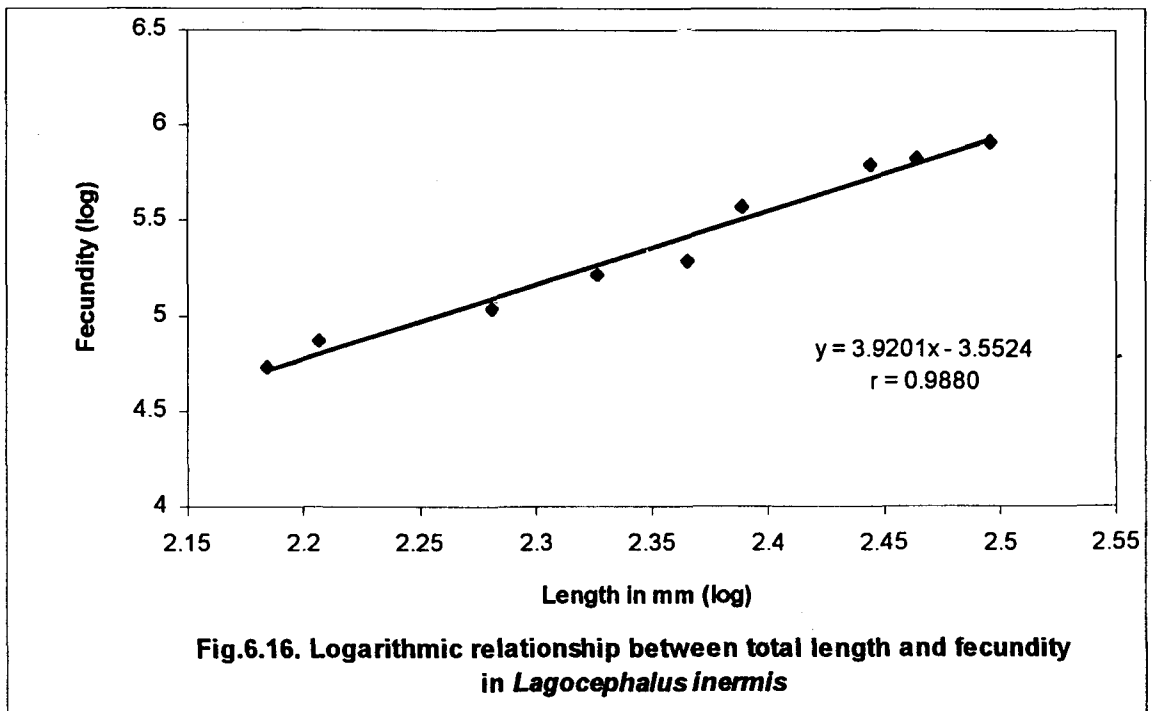
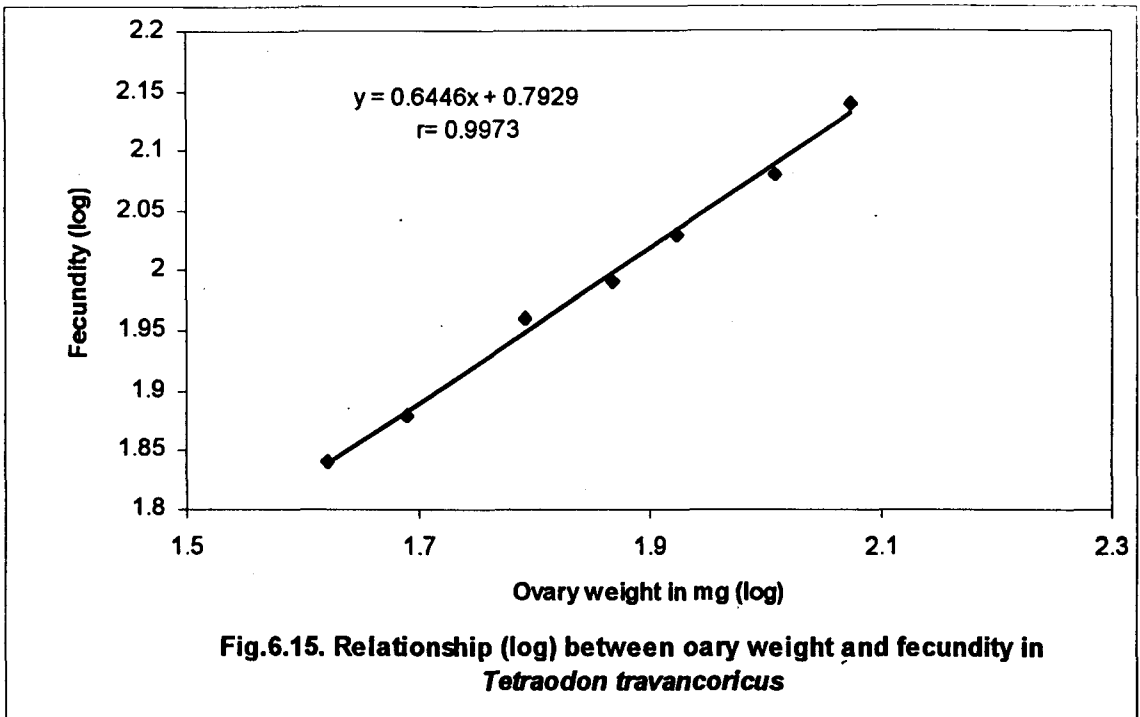
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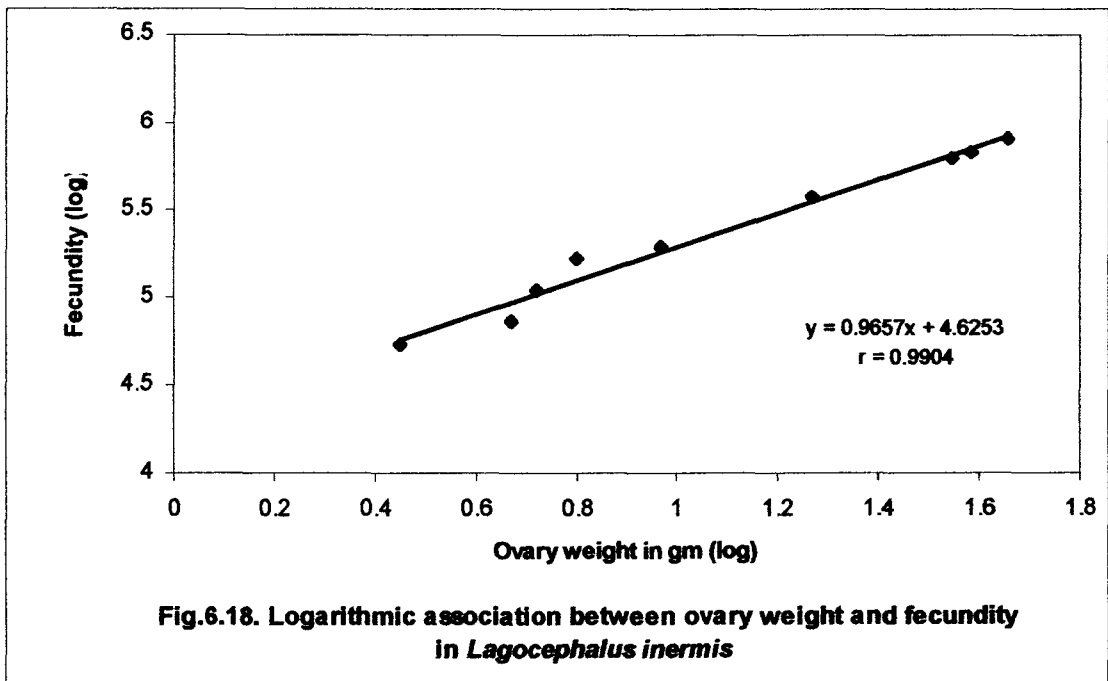
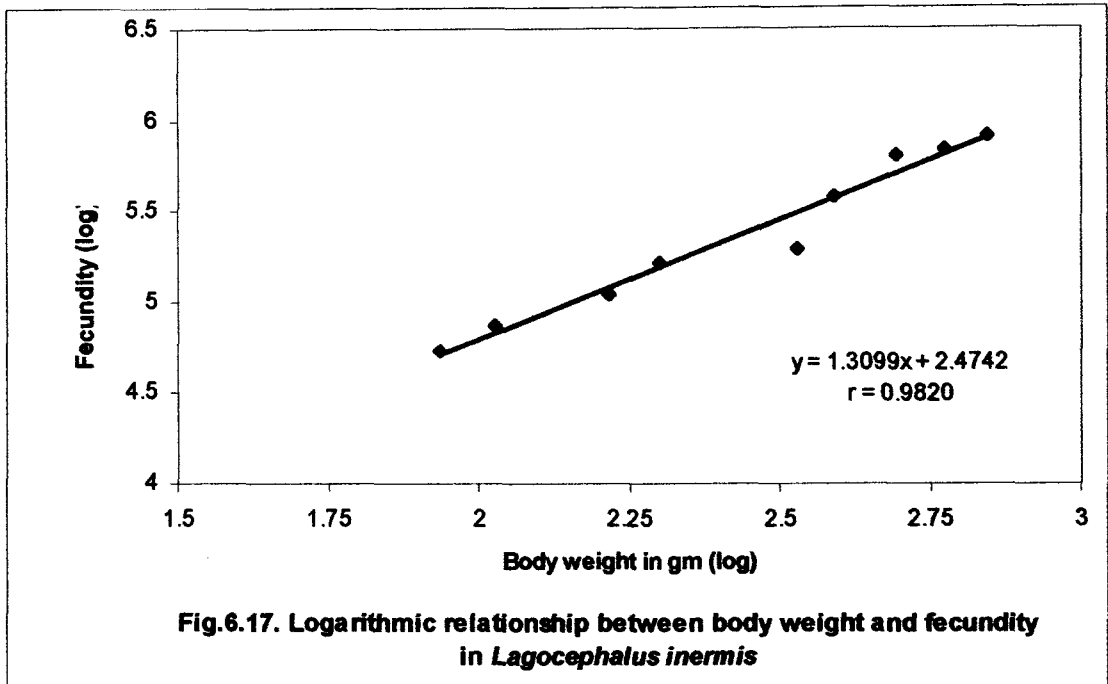






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SUMMARY

CHAPTER -VII

SUMMARY

The work entitled "Systematics and bionomics of tetraodontids along south west coast of India and inland waters of Kerala" is an attempt to access information on distribution of puffers and studying diverse biological parameters of fish like food and feeding habit, age and growth, length-weight relationship, reproduction etc. Being inedible, tetraodontids have been kept aside by fishery biologists from exploring the aforesaid aspects. The present endeavour is aimed at gathering information on the biological strategies of the only known freshwater puffer of Kerala, *Tetraodon travancoricus* and the common tetraodontid along the west coast of India, *Lagocephalus inermis*, apart from systematically arranging tetraodontids collected during the study period.

Chapter 1 – General introduction

The chapter on general introduction is mainly meant for giving an explicit idea about the objective of the whole work. Due importance has been given to the only freshwater puffer fish of Kerala, *Tetraodon travancoricus* by citing the papers on utility of the freshwater puffer in the biocontrol of mosquito larvae and the snail intermediate host of

CHAPTER -VII

SUMMARY

The work entitled "Systematics and bionomics of tetraodontids along south west coast of India and inland waters of Kerala" is an attempt to access information on distribution of puffers and studying diverse biological parameters of fish like food and feeding habit, age and growth, length-weight relationship, reproduction etc. Being inedible, tetraodontids have been kept aside by fishery biologists from exploring the aforesaid aspects. The present endeavour is aimed at gathering information on the biological strategies of the only known freshwater puffer of Kerala, *Tetraodon travancoricus* and the common tetraodontid along the west coast of India, *Lagocephalus inermis*, apart from systematically arranging tetraodontids collected during the study period.

Chapter 1 – General introduction

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schistosomiasis. Lot of research has been going on since 1996 on genome studies using tetraodontids, world-over. Some of them are known to possess the smallest identified vertebrate genomes. This unique feature qualified them as model animals in the cytogenetics studies. An exhaustive narration on the literature oriented around genome studies involving tetraodontids occupied considerable space of the first chapter. The reasons though not unjustifiable, for the total neglect of tetraodontids from subjecting them for detailed investigation on diverse biological aspects like food and feeding habit, age and growth, reproductive biology, etc. are mentioned. It is hoped that the study would delineate the position of puffers in the community structure.

Chapter II – Taxonomy

The present study related to systematic arrangement of tetraodontids provided individuals belonging to five genera – *Lagocephalus*, *Takifugu*, *Tetraodon*, *Chelonodon* and *Arothron*. A key to the systematic sequencing of the genera is prepared. Morphometric and meristic features were studied in detail for the key preparation. Key to species of different genera gave the following species – *Lagocephalus lunaris* (Bloch and Schneider), *L. inermis* (Temmick and Schlegel), *Takifugu oblongus* (Bloch), *Tetraodon travancoricus* Hora and

Nair, *Chelonodon patoca* (Hamilton-Buchnan), *C.fluviatilis* (Hamilton-Buchnan), *Arothron hispidus* (Lacepede) and *A. nigropunctatus* (Bloch and Schneider). Though tetraodontids are circum-global in distribution, some show endemicity. One of the best examples for it is *Tetraodon travancoricus* reported mainly from Kerala.

Chapter III – Food and feeding habits.

Fishes feed in a wide variety of ways, ranging from sieving phytoplankton or grazing algae, to suction feeding on benthic invertebrates and to devouring other fishes whole or in portions. This extra ordinary array of feeding adaptations and mechanisms allows fishes to exploit almost all available sources of food.

The food and feeding behaviour of *Tetraodon travancoricus* and *Lagocephalus inermis* was conducted in detail, both qualitatively and quantitatively. The qualitative analysis of *T.travancoricus* proved that, it is a plankton feeder thriving well on crustaceans. Lepidophagy was also not uncommon which warranted an entirely different type of jaw muscle activity. The abundance of food prompted the consumption of all food items in the early months of the year. *L. inermis* presented itself as an excellent pelagic carnivore, showing high degree of piscivorous inclination. Whitebaits

and silverbellies were mainly at the receiving end. The smaller fish had a diet of crustaceans and very small prey fishes. Cephalopods were also formed one of the food items, though not observed in all months.

Quantitative analysis was done by working out the percentage composition of various food items, feeding intensity, feeding index and gastro-somatic index. In *T. travancoricus*, very low rate of feeding was observed during the reproductively active time. Gradual drop in feeding intensity in the maturation phase extended into the spawning time and individuals fed voraciously to recover from the feeding quiescence. Feeding intensity was high from December to April, a period which coincided with the post-spawning season and occurrence of abundant food items in the water body. So it could be concluded that maturation and spawning had, definitely, a bearing on food intake.

In *L. inermis* also spawning periods gave lean feeding intensity. Males and females showed active feeding before the maturation phase and during the post-spawning time. The monsoon months provided juveniles of prey fishes and hence feeding intensity was high during the said period. Once again, as in *T. travancoricus*, reproductive activity and

availability of food items were the factors which influenced food acquisition by *L.inermis*.

Chapter IV – Age and growth

Information on age in association with length and weight can provide valuable clue on the stock composition, age and maturity, longevity, mortality etc. Age of fish is usually found out by direct and indirect methods. The latter method was used for estimating the age of *T.travancoricus* and *L. inermis*.

Petersen's length frequency analysis in conjunction with von Bertalanffy's growth pattern was found suitable for *T. travancoricus*. The length attained by the fish at the end of first year of growth was worked out to be 28.5 mm. The quarterly increment in the age was compared with Bertalanffy's estimation and found to be in good agreement. The various parameters in the von Bertalanffy expression, $L_t = L_\alpha(1 - e^{-k(t-t_0)})$ were the following: $L_\alpha = 41.82$ mm, $k = 0.9855/\text{year}$ and $t_0 = 0.1281/\text{yr}$.

The annual growth checks on the vertebrae of males and females were counted to arrive at the average length the fishes attain at one two and three years of age. The observed lengths were 148 mm, 212 mm and 266 mm in males and 156mm, 229mm and 292 mm in female. Of the several back-

calculation models available, the direct proportional method (DPM) and scale proportional hypothesis (SPH) were used for age estimation. The percentage difference between the observed and back-calculated lengths obviously showed that DPM was more reliable than SPH.

As a novel method, eye lens diameter and eye lens weight of fish were utilized for determination of age. There existed a linear relationship between total length and lens diameter and lens weight. The average eye lens diameter attained at one, two and three years of age were 3.27 mm, 4.45 mm and 5.44 mm (males) and 3.44 mm, 4.83 mm and 6.03 mm (females). The average values of eye lens weight acquired by the one year old, two year old and three year old fishes were 35.97 mg, 71.01 mg and 100.58 mg (males) and 42.11 mg, 89.65 mg and 130.67 mg (females).

Chapter V – L W R and Relative condition factor

In fisheries research, length-weight relationship is useful for a number of purposes, particularly to estimate the biomass apart from finding conversion of length-growth equation to corresponding weight-growth equivalents and assessing the relative well-being of fish populations.

The parabolic equation, $W=aL^b$ and its linearly transformed logarithmic equation $\text{Log } W=\log a + b \log L$ were used for finding out the length-weight relationship in

T.travancoricus and *L. inermis*. The equations for *T.travancoricus* were,

$$\text{Male } W = 0.05279 L^{2.7858}$$

$$\text{Female } W = 0.08888 L^{2.6415}$$

Analysis of co-variance proved no significant variation between the 'b' values of males and females and the common equation, $W = 0.07489 L^{2.6866}$ was fitted. The results of the two tailed 't' test showed that the estimate 'b' of males, females and pooled significantly differed from the ideal fish illustrating allometric growth

The LWR of *L. inermis* provided the following equations for males and females.

$$\text{Male } W = 0.00003867 L^{2.8797}$$

$$\text{Female } W = 0.00003914 L^{2.8892}$$

As there was significant variation between the 'b' values of males and females, a common equation was not possible. The results of 't'-test on 'b' values were significant at 1% level and hence it could be concluded that *L. inermis* did not follow isometric growth and thus cube law.

The condition of fish or its well-being, can be arrived at by finding the relative condition factor, Kn. It is worked out using the formula $Kn=W/w$, where, W=observed weight and w=the calculated weight. The relative condition was found

out on monthly basis as well as in relation to size groups. The monthly variation in the Kn values followed the gonad enlargement, spawning and active food intake in *T.travancoricus* and *L. inermis*. Length group based observation also substantiated the relationship between relative condition factor and reproductive cycle.

Chapter VI – Reproductive biology

Reproductive parameters like maturity stages, minimum size at maturity, gonadosomatic index, fecundity etc. have great relevance in the study of fisheries biology. The females of *T.travancoricus* and *L. inermis* were classified into five maturity stages viz., immature, maturing, mature, ripe and spent. The average diameters of ripe ova were 1335.6 μ and 445.2 μ respectively in the ripe ovaries of *T.travancoricus* and *L.inermis*. The size at maturity was 24.25 mm for *T.travancoricus* and 152.72 mm for *L. inermis*. Sex ratio studies proved no statistical deviation from the null hypothesis in both the species.

The average gonadosomatic index values of *T.travancoricus* fluctuated between 2.750 (January) and 7.602 (June). Spawning occurred twice during a protracted breeding period from June to October June-July and September-October were the months of intense spawning. The

fecundity varied between 69 to 138 eggs. The average relative fecundity and ova per gram ovary weight were, 149.5 and 1370.5, respectively. Of the three logarithmic relationship with fecundity on one side and total length of fish, total weight and ovary weight on the other provided the best correlation between fecundity and ovary weight ($r=0.9973$).

In *L.inermis*, the average gonadosomatic index range was between 0.856 (December) and 4.964 (March). Spawning occurred at two discrete occasions in a year with peaks during March-April and September-October. *L.inermis* is highly fecund. The absolute fecundity fluctuated between 53541 eggs (average total length -153mm) and 822038 eggs (average total length -313mm). The number of eggs per gram body weight was 883 and per gram ovary weight was 19200. The regression coefficients obtained for the logarithmic relationship between the fecundity and the three variables i.e., total length, total weight and ovary weight were 3.9201, 1.3099 and 0.9657 respectively.

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