SYSTEMATICS AND BIOLOGY OF FISHES OF THE FAMILY HEMIRAMPHIDAE OF COCHIN COAST

THESIS
Submitted to
THE COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
in partial fulfilment of the requirements for the degree of
DOCTOR OF PHILOSOPHY

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2005

DECLARATION

I, Aleyamma Saji Varghese, do hereby declare that the thesis entitled **"SYSTEMATICS AND BIOLOGY OF FISHES OF THE FAMILY HEMIRAMPHIDAE OF COCHIN COAST"** is a genuine record of research work done by me under the supervision and guidance of Dr. Kuruvila Mathew, Professor (Retd.), School of Industrial Fisheries, Cochin University of Science and Technology and has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any university or Institution.

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CERTIFICATE

This is to certify that this thesis is an authentic record of research work carried out by **Mrs. Aleyamma Saji Varghese, M.Sc., B.Ed., M.Phil.** under my supervison and guidance in the School of Industrial fisheries, Cochin University of Science and Technology in partial fulfilment of the requirements for the degree of Doctor of Philosophy and that no part thereof has been submitted for any other degree.

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ACKNOWLEDGEMENT

I wish to express my sincere thanks and deep sense of gratitude to my guide Dr. Kuruvila Mathew, Professor (Retd.), School of Industrial Fisheries, Cochin University of Science and Technology, Cochin 682016 for his unfailing guidance, valuable suggestions and close supervision during the entire course of this work.

I acknowledge my sincere thanks to Prof. (Dr.) Ramakrishnan Korakandy, Director, School of Industrial Fisheries and Prof. (Dr.) C. Hridayanathan, Former Director of the School for providing necessary facilities to carry out this work successfully.

I am very much thankful to the Management of Mar Thoma College for Women, Perumbavoor for permitting me to undertake this study.

The author is grateful to the Cochin University of Science and Technology for giving registration for Ph.D. degree and University Grant Commission for granting FIP leave for the completion of this work.

I am deeply indebted to Dr. B. Madhusoodana Kurup, Professor, School of Industrial Fisheries, CUSAT for critically going through the manuscripts and giving me valuable suggestions.

I am thankful to Dr. K. Gopakumar, D.D.G. (Retd.), Ministry of agriculture, Govt. of India and Dr. Saleena Mathew, Professor, SIF, CUSAT for their timely advice during biochemical analysis and going through the manuscript.

I also acknowledge the help rendered by Dr. A.Gopalakrishnan, Senior Scientist, NBFGR, CMFRI, Cochin and Dr. Susan Abraham, Lourdes Hospital, Cochin for their valuable help in histological studies.

I thank Dr. Gopinathan, Senior Scientist, CMFRI, Cochin for the help rendered by him to identify the different algal species.

My thanks are due to Dr. C.J. Cherian , Professor, College of Fisheries, Kerala Agricultural University for his timely help in the preparation of the thesis and to Dr. T.M. Jacob, Nirmala College, Moovattupuzha and Dr. Harikrishnan, St. Alberts College, Ernakulam for statistically analysing and computing the data.

The encouragement and assistance extended by Dr. K.T. Thomson, Reader, SIF, CUSAT, all the research scholars, office staff, library staff, and technical staff, SIF, CUSAT are sincerely acknowledged.

I owe a lot to my husband, Rev. Johnson Varghese and children Pretty, Priya and Nancy for their continuous encouragement, valuable prayers and moral support rendered during this study period.

Above all I thank the Lord Almighty for all the blessings showered upon me.

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CHAPTER 1.

GENERAL INTRODUCTION

1. GENERAL INTRODUCTION

1.1. Introduction

India is one of the leading fish producing nations in the world with an average annual production of 6.1 million tonnes of fish and shell fish from capture and culture fisheries in 2001 (Ayyappan and Biradar, 2002). Fisheries play a very significant role in the Indian economy by providing employment to nearly 7 million people directly or indirectly, supplying rich protein food and earning valued foreign exchange. For the last one decade the growth of marine fish production is at very slow pace. However, the inland fish production has registered steady increase during the past two decades and the share of inland fisheries sector in the total fish production of the country is about 50% in 1999 -2000 (Keremane and Naik, 2001). With a production of over 2.8 million tonnes from the inland sector, India occupies the second position, next to China, in aquaculture (Sankar and Ramachandran, 2002). This spectacular growth was achieved as a result of the overwhelming growth of fresh water aquaculture during the past two decades.

India has a long coastline of about 8118 kilometre (km) with an Exclusive Economic Zone (EEZ) of 2.02 million sq.km for exploration and exploitation of resources therein. Inland fishery resources in India are very rich and varied comprising an extensive network of 45,000 kilometres of rivers, 1,26,334 kilometres of canals, 2.05 million hectares (ha) of man made reservoirs, 2.7 million ha. of estuaries, 1.42 million ha. of brackish waters, 1.3 million ha. of oxbow lakes and derelict water bodies and 2.36 million ha. of ponds and tanks dispersed over varied geoclimatic situations (Ayyappan and Biradar, 2002).

Globally the per capita fish consumption increased from 13 kg in 1990 to 16kg in 2001 and the demand is still growing (Verdegam, 2005).The current level of marine fish production from the country is about 2.70 million tonnes whereas the estimated potential from the Indian EEZ is 3.92 million tonnes. The production from the pelagic fish resources in India is 1.43 million tonnes in 2003 (CMFRI, 2004). The coastal zone upto a depth of 50m is prone to tremendous fishing pressure by the traditional, small and large mechanized vessels leaving little scope for further exploitation. Increase in marine fish production can be achieved only with the exploitation of deep sea and oceanic regions where the level of exploitation is marginal. A wide variety of fishes, crustaceans, molluscs etc. contribute to the marine and inland fish production. According to Nelson (1994) there are 24,618 species of fishes belonging to 482 families and 4,258 genera. Jayaram (1999) reported that in Indian region alone 2500 species of fishes are present, out of which 930 are freshwater inhabitants and 1570 are marine. Among these, the fishes of the family Hemiramphidae constitute a minor pelagic fishery of the country. They inhabit the marine, brackish and fresh water environments.

Species of the family Hemiramphidae have a very wide distribution. They are distributed in the western and eastern Indian Ocean, African coast including Madagascar and Mauritius, Red Sea, Pakistan, India and Sri Lanka.

They are also found in the Indo-Pacific region, Indo-Australian archipelago and Mediterranean Sea.

Fishes of the family Hemiramphidae are commonly called 'half beaks'. They are inhabitants of both sea and fresh water. The body is elongated with a prolonged lower jaw and a short triangular upper jaw with minute teeth except in the genus *Oxyporhamphus* where the lower jaw is not noticeably elongated. The half beaks are omnivores, feeding on floating sea grass, algae, crustaceans and small fishes. They are prone to leap and skitter on the surface and one offshore species, *Euleptorhamphus viridis* leaps out of the water and glides like a flying fish. They are generally egg layers except the fishes of the genera *Demogenys, Hemiramphodon* and *Nomorhamphus* which are livebearers. In the males of these fishes a part of the anal fin is modified as an intromittent organ known as andropodium. The freshwater species are mostly viviparous in contradiction to the marine species.

The hemiramphids live close to the surface and are protectively coloured for their pelagic mode of life by being green or blue on the back and silvery white laterally and ventrally. The tip of the lower jaw is usually bright red or orange. They are mainly caught with seines and pelagic trawls and dip netted under lights at night.

Hemiramphids are known as 'kola' / 'pookola' in Kerala, 'mural' in Tamil Nadu, 'mudduru' / 'kosalsa' in Andhra Pradesh, 'surali kondai' / 'konthi' in Karnataka and 'sumbo' / 'Tol' in Maharashtra. Half beaks and full beaks contribute significantly to the marine landings of Tamil Nadu, Kerala and Andhra Pradesh. It is a very prominent fishery in Tamil Nadu constituted by the marine species. Kerala state stands second in the production of hemiramphids. Considering the importance of this group and lack of detailed information on their biology, histology, and biochemistry the present study was undertaken.

1.2. Review of literature

The genus *Hemiramphus* was first cited by Cuvier(1817) and the type he noted was *Esox brasiliensis* L. The family Hemiramphidae under the order Synentognathi (Jordan, 1963) includes *Hemiramphus* Cuvier 1817, *Dermogenys* Van Hasselt 1823, *Cobitopsis* Pomel 1853, *Hyporhamphus* Gill 1859, *Euleptorhamphus* Gill 1859, *Zenarchopterus* Gill 1863, *Oxyporhamphus* Gill 1866, *Hemiramphodon* Bleeker 1866, *Arrhamphus* Günther, 1866, *Hemilampronites* Geinitz 1868, *Chriodorus* Goode and Bean 1882, *Hemiexocoetus* Fowler 1901, *Labidorhamphus* Fowler 1919, *Rogenites* Jordan 1919, *Zelosis* Jordan and Gilbert 1920, *Rhamphodermogenys* Fowler and Bean 1922 and *Nomarhamphus* Weber 1922.

Van Hasselt (1823) described *Hemiramphus erythrorinchus* and *Euleptoramphus viridis*. Seven species of hemiramphids were reported by Cuvier and Valenciennes (1846) from the Western Indian Ocean. Bleeker, (1858) and Günther (1866) reported *Hemiramphus balinensis, H. capensis* and *H. affinis* respectively. Weber and de Beaufort (1922) listed thirty two species of hemiramphids from the Indo- Australian Archipelago. South African species of the genus *Hemiramphus* Cuvier was described by Smith (1933,1949). A new species of, *Hyporhamphus patris* from Sinaloa, Mexico was described by Miller (1945); Herre (1944) gave a review of the half beaks of the Philippines and adjacent waters. Miller (1945) used the names *Hyporhamphus roberti* and *Hyporhamphus hilderbrandi* for the same halfbeak fish of Tropical America. Fowler (1950) described the halfbeak, *Hyporhamphus unifasciatus* on the Virginia coast. A new species of hemiramphid from Philippines was recorded by Sarenas and Ronquillo (1952). Munro (1955) reported six species from the Sri Lankan waters. Parin (1961) described a new species of flying half beak, *Oxyporhamphus meristocystis* from the waters of the Indo Malayan Archipelago. Collette (1962) described a new half beak *Hemiramphus bermudensis* from Bermuda. Hemiramphids from tropical West Africa were described by Collette (1965). Classification, geographic variation and distribution of the oceanic hemiramphid *Euleptorhamphus viridis* were given by Parin (1966). A new half beak species *Rhynchorhamphus arabicus* was reported from southern Yemeni waters by Parin and Shcherbachev (1972). Collette (1973) reported a hybrid half beak *Hyporhamphus australis* x *Hy. melanochir* and listed two species from Australian waters.

Two new species, *Rhynchorhamphus malabaricus and R. naga* under the subgenus *Rhynchorhamphus* from the Indo-Pacific region were described by Collette (1976). Five more new species under the genus *Hemiramphus* from Indo- Pacific region were described by Collette (1978). The status of the two names of South African half beaks *Hyporhamphus delagoae* (Bernard) and *Hyporhamphus improvisus* (Smith) was mentioned by Collette (1982). Two new species of fresh water half beaks *Zenarchopterus roberisi* and *Z. alleni* from New Guinea were described by Collette (1982). A new species of freshwater halfbeak, *Zenarchopterus ornithocephala*, from the Vogelkop Peninsula of New Guinea was reported by Collette (1985). Collette and Su (1986) described the hemiramphids of the Far East. Fishes of the family Hemiramphidae of Africa were reported by Collette (1986). Chen (1988) reported on the flying halfbeaks, *Oxyporhamphus* of Taiwan. Six species of fresh water viviparous half beaks of the genus *Hemirhamphodon* from southern Thailand were reported by Anderson and Collette (1991).

In India, studies on hemiramphids commenced with the work of Day (1878,1889) who recorded thirteen species of hemiramphids from the Indian waters. Talwar and Chakrapany (1970) listed five species from this area. The occurrence and abundance of *Hyporhamphus (Hyporhamphus) xanthopterus* (Valenciennes) in the Vembanad Lake of the south west coast of India was reported by Kurup and Samuel (1980). A rediscovery of *H. (H) xanthopterus* endemic to Vembanad Lake, Kerala was done by Collette (1981). The occurrence of *H. (H) xanthopterus* (Valenciennes) in the lakes of southern Kerala was reported by Nair *et al* (1983). Talwar and Kacker (1984) reported 13 species and Talwar and Jhingran (1991) reported 10 species of the family

Hemiramphidae from Indian waters. A detailed description of 3 genera of the family Hemirhamphidae was done by Jayaram (1999); Shaji and Easa (2001) recorded two species of Hemirhamphidae, *Hyporhamphus (Hyporhamphus) limbatus* and *H.(H) xanthopterus* from the freshwaters of the Western Ghats of Kerala.

Attempts were made by several workers to study the biology and fishery of hemiramphids in many areas all over the world. A note on the females and eggs of *Hemiramphus far* was given by Wickstead (1956). Reproduction, development and distribution of the flying half beak *Oxyparhamphus micropterus* were reported by Kovalevskaya (1963). A study of half beak larvae and juveniles from Chesapeake Bay was done by Hardy and Johnson (1974). The biology of two exploited half beaks *Hemiramphus brasiliensis and H. balao* of South East Florida coast were investigated by Berkeley and Houde (1978). McBride *et al.* (2003) has studied the spatial and temporal spawning pattern of the above mentioned two species which form a valuable bait fishery along the South Florida coast. The reproductive biology of these two species was studied in detail by McBride and Thurman (2003).

The gut contents of the needlefish *Hyporhamphus knysnaensis* from Rondeveil, Southern Cape was reported by Coetzee (1981). Changes of chemical composition during the early development of egg and larva in H*emiramphus sajori* was reported by Kimata (1982). Feeding habit of the

Southern Australian garfish *Hyporhamphus melanochir*, a diurnal herbivore and nocturnal carnivore was reported by Robertson and Klumpp (1983). Nutrition of the Southern sea garfish *Hyporhamphus melanochir* was studied by Klumpp and Nichols (1983). They studied the assimilation of two types of food, the sea grass and crustaceans. Changes of chemical composition during the early development of eggs and larvae of the horn fish, *Hemiramphus sajori* (Temminck et Schiegel) were reported by Kim *et al.*(1984). Montgomery and Saunders (1985) described the functional morphology of the piper *Hyporhamphus ihi* with reference to the role of the lateral line in feeding. They proposed a hypothesis that the piper uses the anterior lateral line system in prey detection. Its elongated body form, swimming behaviour and lack of a specialized visual system are all consistent with this hypothesis. A unique spermatozeugmata in the testes of the genus *Zenarchopterus* wherein the method of sperm packing and morphology of spermatozeugmata are unique was observed by Grier and Collette (1987). They indicate that these fishes practice internal fertilization. Kawamura *et al.* (1990) described the larval growth and the age and size related variation in the development of sense organs in the half beak *Hemiramphus sajori*. Some aspects of the biology of *Hyporhamphus gaimardi* in Uda Walawe reservoir, in Sri Lanka were reported by Chandrasoma and Wijeratne (1990). Yacapin (1991) described the growth, mortality and recruitment of *Oxyporhampus micropterus* in Bohal Sea, Philippines and also established that the annual recruitment of this species is strongly bimodal.

A study of the host-parasite relationships between copepods and needle fishes was done by Cressey and Collette (1971). Natarajan and Nair (1972) gave a description on the nature of attachment of the copepod *Lernaeenicus hemiramphi* Kirtisingh to the host fish *Hemiramphus xanthopterus*. A new cymathoid isopod, *Glossobius hemiramphi* from the mouth of the Ballyhoo, *Hemiramphus brasiliensis* in the Caribbean Sea was recorded by Williams (1985). A new host record of *Cymathoa indica* (Schioedte and Meinert) from Sundarbans, West Bengal was given by Misra and Nandi (1986). Species of the parasitic isopod genera *Ceratothoa* and *Glossobius* (Crustacea) were recorded by Neil and Thomas (1989) from the mouths of flying fishes and half beaks. Analysis of the carotenoids present in the red coloured integuments of mandible of *Hemiramphus sajori* was done by Maisuno and Ookubo (1981) and opined that it was due to ketocarotenoids.

In the Indian waters more work was carried out along the Tamil Nadu coast especially in the Gulf of Mannar and Palk Bay. Studies on the food and feeding relationships of the hemiramphids from the Gulf of Mannar and Palk Bay were done by Talwar (1962 a). A contribution to the biology of *Hyporhamphus georgii* of the Gulf of Mannar and Palk Bay was done by Talwar (1962 b). The biology of *Hemiramphus marginatus* in the Mandapam area has been discussed by Talwar (1967). The biology of *Hemiramphus gaimardi* of the Pulicat Lake was studied in detail by Sultana *et al.* (1980). The breeding biology of *Hyporhamphus unifasciatus* from coastal waters of Parangipettai, east coast of India was explained by Durai *et al.*(1988). The length-weight relationship of *Hemiramphus marginatus* of the Gulf of Mannar caught by drift gill net was studied by Kasim *et al.* (1996). Though landing of half beaks has been recorded from the backwaters of Kerala no significant work has so far been made on the biological aspects of these species.

1.3. Fishery

Half beaks and full beaks constitute a very significant portion in the marine fish landings of Tamil Nadu, Kerala and Andhra Pradesh. The exact landing figures of this group are not available as many states have no separate landing data of hemiramphids. This group might have been included under half beaks and full beaks together or under the miscellaneous category. The estimated half beaks and full beaks landings in India is 7316 tonnes in 2000, 4378 tonnes in 2001, 5922 tonnes in 2002 and 5649 tonnes in 2003, respectively (CMFRI 2002; 2004). Kurup *et al.* (1993) estimated that the percentage contribution of half beaks is 1.16% (84.25 tonnes) towards the fishery of the Vembanad Lake, Kerala. However, Kasim *et al.* (1996) estimated that Tamil Nadu and Kerala contributed 42.6 and 25.6 percent respectively of the total landings of hemiramphids. The contribution of other maritime states are nominal. *Zenarchopterus dispar, Hemiramphus archipelagicus, H. lutkei, Hyporhamphus (H) limbatus H.(H) xanthopterus, Rhynchorhamphus georgii,* and *R. malabaricus* constitute the landings from Kerala, especially from the Cochin coast.

A diversified type of fishing crafts and gears were employed prior to the introduction of mechanized fishing in our country. The traditional dug-out canoes varying from 3 to 8mts. length and plank built canoes (kettuvallam) were employed in the back waters of Kerala. These crafts employed all types of indigenous fishing gears such as long lines, gill nets, boat seines, shore seines etc. Because of the body shape and pelagic habitat of the species most of the indigenous fishing gears are not exactly suitable for capturing the hemiramphids. The type of gear that is operated exclusively for half beaks is 'murasu vala' with length 80-140 m; width 40-104 cm; and mesh size 7x5 cm (Kurup and Samuel, 1984).

1.4. Description of the study area

Monthly samples of fishes were collected from fish landing centre like Munambam, markets of Cochin coast like Ernakulam and some fishing grounds in Vembanad Lake like Eloor, Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map. (Fig. 1.1). A brief description of the study area is given below.

The study area, which is part of Cochin coast is located between Lat. $9^0 28'$ and 10^0 N and Long.76^0 13' and 76^0 31 E. Lying parallel to it is an estuary which is commonly called the Cochin backwaters which has a total area of about 200 sq.miles. To the north and south it is continuous with shallow brackish water lagoons which stretch for the most part parallel to the coast line, separated from the sea on the west belts of sand. On the western side, between Fort Cochin and Vypeen it is permanently connected with the Arabian Sea by a narrow channel of about 450 meters width. Two large rivers, the Periyar on the north and the Pampa on the south, flow into the backwaters. Fringed by the mainland and many thickly populated islands, the backwaters also receives a complex system of canals, rainwater and sewage drains, semi-perennial and seasonal rivers and their tributaries. Some of these maintain permanent connections with the sea while others develop only seasonal contacts during the monsoon months (June to September). The inflow of freshwater from several sources particularly during the monsoon months, is considerable and it is in the backwaters that the mixing of salt and fresh water occurs. The continual discharge of freshwater on the one hand and the inward influx of seawater on the other, bring out highly dynamic conditions reflecting the balance of forces associated with each. These conditions make the backwaters an extremely interesting environment.

The depth of the Cochin backwaters varies from 10 to 15m in the upper reaches close to the sea. The lower reaches of the estuary, which are close to the fresh water zone, are relatively shallower, with depths ranging from 5 to 7m. The bottom of the estuary is generally muddy. The tidal amplitude is about 1m in the coast area, decreasing to less than 1m in the central zone. It is very little in the lower reaches.

To acquaint with the conditions of the environment from where the samples of fishes were collected, a brief outline of the general hydrographic conditions are given below.

The temperature of the study area is maximum in April (32^{0}C) and minimum in September (26^{0}C). In the post-monsoon months the temperature difference from the surface to the bottom is only about 1°C, but in the monsoon months, June to September, normal variation is about 3-4°C. From June to September, the temperature gradually decreases and from October to April and May, it shows a progressive increase.

The study area is subjected to wide variations in salinity from place to place, season and surface to bottom. Seasonal changes in salinity are very well marked. From October onwards the salinity begins to rise, reaching its maximum in May. In the upper reaches, during April and May, the conditions are predominantly marine. In June, with the onset of monsoon, a sharp fall in the salinity occurs. The differences in salinity from the upper reaches to the lower are more pronounced at the surface than at deeper layers. Maximum salinity values range from 28 to 35‰ and minimum from 1.5 to 14‰. During the period of high salinity there is little difference in values from the surface to the bottom in the upper reaches of the study area whereas during the monsoon months the differences in the vertical profile are more pronounced.

The pH shows a seasonal cycle. Maximum values are obtained when the salinity is high and the minimum during the monsoon months when the salinity is low. The general increase in the pH is found from the freshwater zone to the marine and from the surface to the bottom, which corresponds to the increase in salinity. The values range between 6.2 and 8.2

Seasonal changes in the oxygen values at the sub-surface level show two distinct phases. The phase of high dissolved oxygen values during monsoon months, (June to September) and the phase of low dissolved oxygen values during the period of pre-monsoon months (February to May) In the post-monsoon months (October to January) the values progressively decline. The changes in the oxygen values seem inversely related to the changes in salinity. The vertical distribution of oxygen is also interesting. In the pre-monsoon months, minimum values are observed at the surface and maximum values at the bottom. During the monsoon months, maximum values occur at the surface and minimum at the bottom.

Seston values were generally very high. During the monsoon months, the values at the surface ranged from 7mg/litre, to 65 mg/litre. There was a progressive increase in the seston values from the surface to the bottom. In the post-monsoon months, the values decreased considerably.

Phytoplankton organisms showed a high level of abundance and diversity. The organisms which constituted the main crop were diatoms and dinoflagellates belonging to Bacillariophyceae, Dinophyceae , Chlorophycae, Myxophyceae. During the monsoon months there was considerable degree of fluctuation in the abundance of these forms. In the post-monsoon months, however, the organisms became more abundant and consistent. Maximum counts of these organisms were recorded in the pre-monsoon months.

The organisms of common occurrence in the study area are copepods, decapods, barnacles, nauplii and cyprids, brachyuran zoeas, lamellibrachs larvae and gastropod veligers, medusae, ctenophores, mysids, chaetognaths and fish eggs and larvae.

During the monsoon months a considerable decline occurs in the abundance of zooplankton in the study area. The only forms present in substantial numbers from June to September were copepods and molluscan larvae. With the increase in salinity during the post-monsoon months, more and more organisms appear in the backwater and in the pre-monsoon months (February to May), when the salinity is at its maximum, almost all forms mentioned above, are abundantly seen. The total volume of the zooplankton has a direct correlation with he salinity changes.

The fishes inhabiting the study area regions are such species that can tolerate considerable variations in salinity. The most important among these fishes are the mullets, cat fishes, jew fishes, thread fins, perches and the carangids. There are also half beaks, gar fishes, silver bellies, eels, sharks, and rays but they are not very abundant. The salinity is subjected to regular seasonal and daily fluctuations. During the period of heavy rainfall, the inflow of water from the rivers lowers the salinity. Similarly, when the tide is high, the influx of sea water increases the salinity and the migrants from the sea are not adversely affected, whereas, the migrants from the fresh water if any, have to either adapt themselves to changing salinity or move on to such regions of the estuary where fluctuations are not so intense. When the salinity is lowered, the migrants from the fresh water easily adapt themselves, whereas, those migrants from the sea will have to either adapt themselves to the conditions of lowered salinity or return to the sea.

The microfauna of these area includes bivalves, polychaetes and gastropods. Foraminifera and nematodes formed the dominant groups of the meiofauna. The abundance of foraminiferans progressively decreased from marine to freshwater zone, suggesting that these are restricted to higher salinity areas only. Nematodes on the other hand, were most common in the study area.

1.5. Objectives of the study

The hemiramphids constitute a minor pelagic fishery of Cochin coast. Detailed information on the biology of these fishes is an essential prerequisite for their proper exploitation, management and conservation of the resources. Any information on the biochemical composition of fishes will be of immense use in assessing their nutritive value. The importance of understanding the body composition during growth is essential in production studies. Considering the importance of this group and the lack of detailed information, a comprehensive study was undertaken on the systematics of hemiramphids available along the Cochin coast with special emphasis on the biology, histology and biochemical aspects of *Hyporhamphus (H) limbatus* and *H. (H) xanthopterus,* two estuarine species. *H. (H) limbatus* is a co-existing species of *H. (H) xanthopterus.* Though *H. (H) xanthopterus* is described to be a rare species, it is abundant in the coastal waters of Cochin (Kurup and Samuel 1980). Collette (1981) reported that *H. (H) xanthopterus* is endemic to Vembanad Lake. Nair *et al.* (1983) reported the occurrence of *H. (H) xanthopterus* in the lakes of southern Kerala. The studies on the biological, histological and biochemical aspects of hemiramphid species are scarce and not properly known. The present investigation was undertaken to study these aspects in detail.

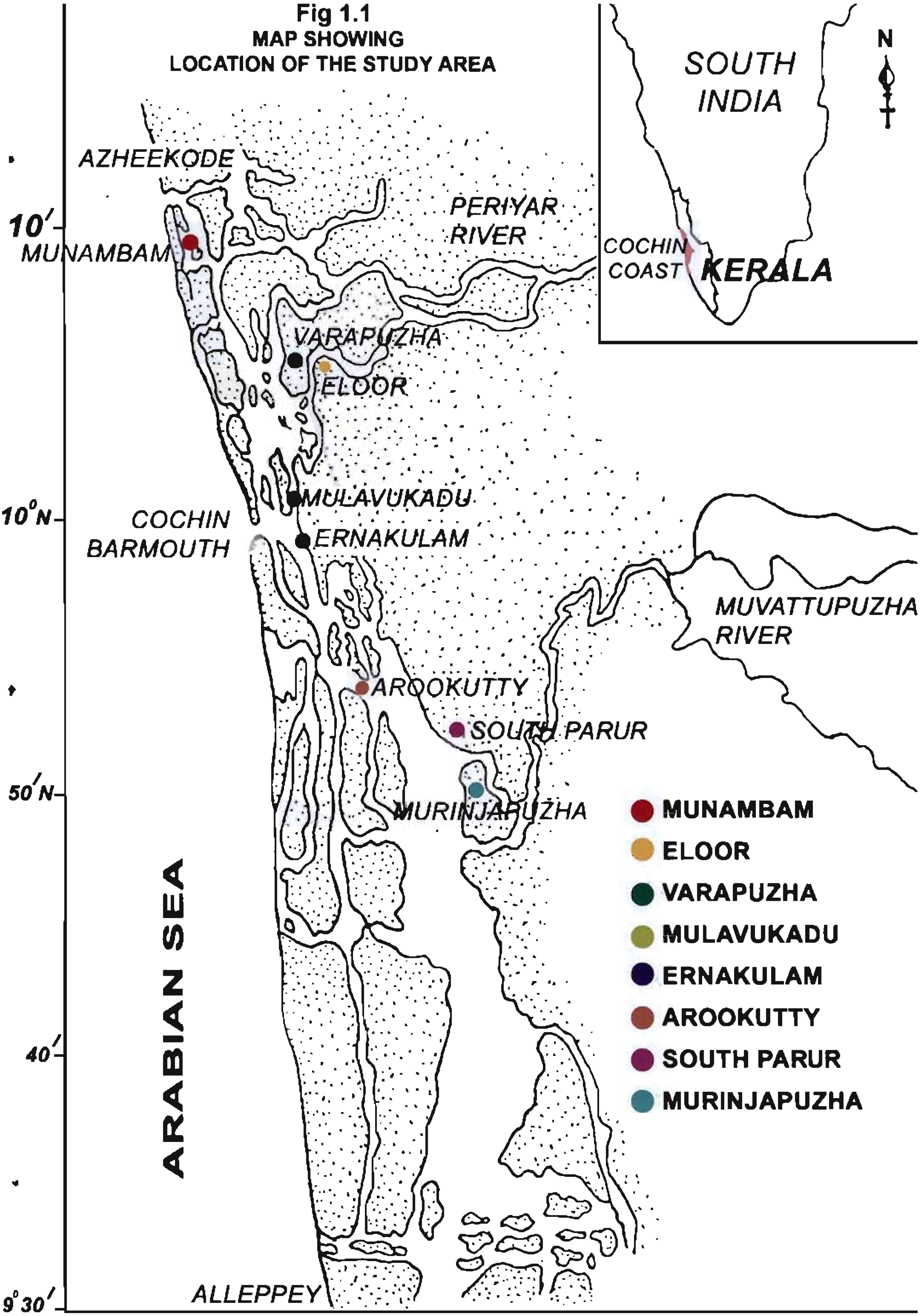
1.6. Research approach

The available literature reveals that biological, histological and biochemical studies on hemiramphid species are scarce and incomplete. In the present investigation attempts are made to inquire about the biological, histological and biochemical aspects of *H.(H) limbatus* and *H. (H) xanthopterus,* the two half beak species which are contributing to the half beak fishery Cochin coast. The results are presented in nine chapters.

The first chapter is a general introduction including the review of previous works done on this genus. It also contains an account of the distribution of hemiramphid species and their fishery along the Indian coast in general during the period of investigation. The second chapter deals with the systematics of the hemiramphids collected from Cochin coast. Altogether seven species were collected during the study and their detailed descriptions are given. The qualitative and quantitative analysis of the food items, feeding behaviour and feeding intensity in relation to season, size, sex and stages of maturity of *H. (H) limbatus* and *H. (H) xanthopterus* are dealt with in the third chapter. The fourth chapter incorporates the findings on the breeding biology of the two species covering details on the spawning season, spawning frequency, size and age at first maturity, seasonal variation in condition factor, sex ratio and fecundity. Histological studies of ovary and testes of the two species are included in the fifth chapter.

The sixth chapter incorporates the finding on the length- weight relationship and relative condition factor of *H. (H) limbatus* and *H. (H) xanthopterus*. In the seventh chapter age and growth of the two species are described. The growth parameters are described using ELEFAN -1 programme and von Bertalanffy's growth equation (VBGE). The eighth chapter includes the results of the proximate composition of muscles and liver of *H. (H) limbatus* and *H. (H) xanthopterus*. Summary of the study is given in the ninth chapter followed by the references.

Fig 1.1
MAP SHOWING
LOCATION OF THE STUDY AREA



CHAPTER 2.

SYSTEMATICS

2. SYSTEMATICS

2.1. Introduction

The hemiramphids or half beaks are a group of near shore, epipelagic fishes of the family Hemiramphidae belonging to the order Beloniformes and the suborder Exocoetoidei, which also includes marine flying fish and needle fish. Hemiramphids inhabit marine, brackish and freshwater habitats throughout the world. This family consists of 12 genera and 75 species (Collette *et al.*1984). There are 18 species and subspecies in six genera in the Far East region, the distribution of most of them are limited to tropical region, and only a few species such as *Hyporhamphus (Hyporhamphus) sajori, H. (H) intermedius and H. (H) gernaerti* are characteristic of subtropical and temperate waters (Collette and Su, 1986).

A series of works have been carried out in India and abroad on the systematics of hemiramphid fishes. From Indian waters, Day (1878, 1889) reported 13 species. Weber and de Beaufort (1922) reported 32 species from the Indo-Australian Archipelago; Smith (1949) listed 8 species from South Africa and Munro (1955) reported 6 species from Sri Lanka. Collette (1962) described a new half beak from Bermuda. Talwar and Chakrapany (1970) listed 5 species in the catalogue of Day's figured specimens at Zoological Society of India, Calcutta. Collette (1973) reported a hybrid half beak and listed 22 species from Australia. Two new species under the subgenus *Rhychorhamphus* were described from Indo-Pacific region (Collette, 1976). Collette (1978) also described five more new species of half beak under the genus *Hemiramphus* and subgenus *Hyporhamphus* from the Indo-West Pacific region and also listed six genera under the family Hemiramphidae. Collette and Su (1986) described 18 species of halfbeak from the Far East region. Talwar and Jhingran (1991) described 10 species of Hemiramphidae from the inland waters of India. Jayaram (1999) mentioned 3 genera of the family Hemiramphidae. Shaji and Easa (2001) reported 2 species of Hemiramphidae from the rivers of the Western Ghats.

The systematics and distribution of hemiramphid fishes of Cochin coast are inadequate. No attempt has been reported so far to give a detailed systematic account of hemiramphid fishes of Cochin coast except that of Kurup and Samuel (1980) and Collette (1982) on the little known fish *Hyporhamphus (Hyporhamphus) xanthopterus* from Vembanad Lake, Kerala. The specific identity of the available species of Cochin coast is a prerequisite for the study of fish and fisheries of this area. The present comprehensive study describes the diagnostic characters and provides a key for identification of hemiramphid fishes of Cochin coast and adjacent brackish waters.

2.2. Materials and Methods

Monthly samples of fishes were collected from fish landing centre like Munambam, markets of Cochin coast like Ernakulam and some fishing grounds in Vembanad Lake like Eloor, Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map. (Fig.1.1). The various fishing methods used for hemiramphid fishery are stake net, pattukanni vala, peru vala (drag nets) and murasu vala (gill net) and Chinese shrimp nets. Among these murasu vala is a specialized gear exclusively operated for catching half beaks (length 80-140 m; width 40-104cm,mesh size 7 x 5cm) (Kurup and Samuel, 1984).

The colour and pigmentation of fresh specimens were recorded immediately and detailed observations were made on preserved specimens in the laboratory. Except for total length, all measurements were taken from point to point (straight line) on the left side of the fish (with mouth closed). A pair of dividers and vernier callipers were used for the length measurements which were rounded off to the nearest millimetre. The morphometric data are presented in percentages of standard length, except the pre orbital length, post orbital length, eye diameter, inter orbital width, upper jaw length, lower jaw length, and gape width which are given in percentages of head length. The gill raker numbers of the first left gill arch were noted. Measurements and counts are made according to Collette (1974) and Lowe-Mc Connell (1971). Students '*t*' test was applied to compare the morphometric characters of different species coming under the same genus. Identification of fishes were done following Day (1878 and 1889) and FAO species identification sheets 1983. A key for identification of hemiramphids of Cochin coast was prepared following the methods of Jayaram (1999). A table was prepared showing the occurrence and frequency of different species of hemiramphid fishes of Cochin coast following the classification of Kurup and Samuel (1983).

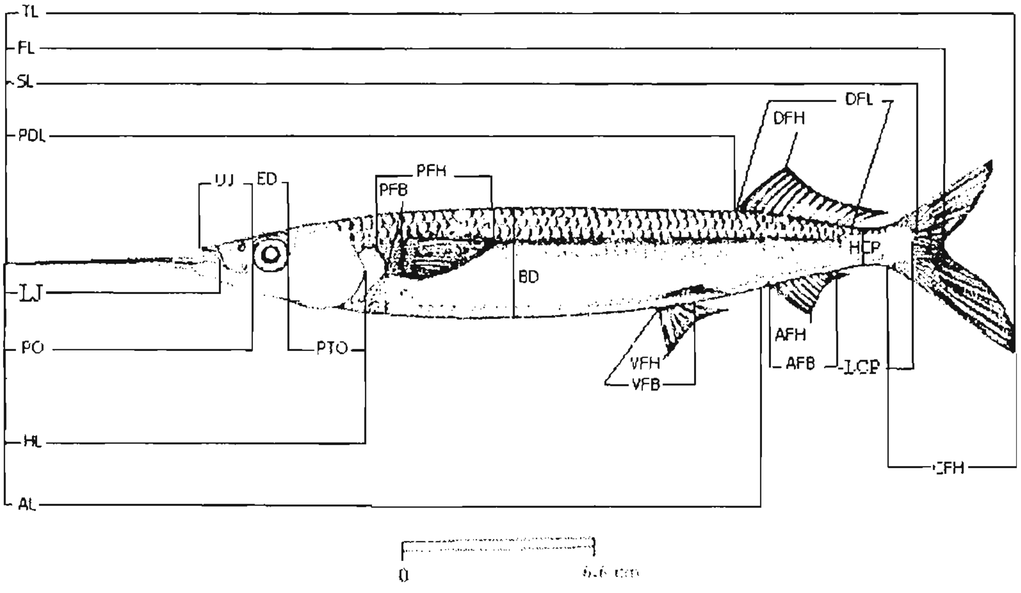


Fig. 2.1 Diagrammatic sketch of *Hemiramphus sp.* showing various morphometric measurements.

The following abbreviations are used (all measurements in mm) for characters used in this study (Fig. 2.1).

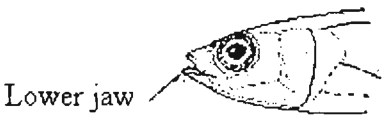
TL	Total length, from tip of lower jaw to tip of longest caudal fin.
FL	Fork length, from tip of lower jaw to the fork of caudal fin.
SL	Standard length, from tip of lower jaw to caudal base (hypural bone junction).
AL	Pre anal length, from tip of lower jaw to anus.
PDL	Pre dorsal length, from tip of lower jaw to origin of dorsal fin.
BD	Body depth, distance between dorsal and ventral surface at the deepest point.
DFH	Dorsal fin height, length of largest fin ray of dorsal fin.
DFL	Dorsal fin base, length from origin of dorsal fin base to last ray.
PFH	Pectoral fin height, length of largest fin ray of pectoral fin.

PFB	Pectoral fin base, length from origin of pectoral fin base to last ray.
VFH	Ventral fin height, length of largest fin ray of ventral fin.
VFB	Ventral fin base, length from origin of ventral fin base to last ray.
AFH	Anal fin height, length of largest fin ray of anal fin.
AFB	Anal fin base, length from origin of anal fin base to last ray.
CFH	Caudal fin height, length of largest fin ray of caudal fin.
HCP	Height of caudal peduncle, width of caudal peduncle at the point of least depth.
LCP	Length of caudal peduncle, from the end of anal fin to the base of median caudal ray.
HL	Head length, from tip of lower jaw to posterior edge of opercular bone.
PO	Pre orbital length, from the tip of the body to the front margin of the orbit.
PTO	Post orbital length, from the posterior margin to the end of opercular bone.
ED	Eye diameter, horizontal distance between anterior and posterior rims of the eye.
UJ	Upper jaw length, from anterior part of upper jaw to the first margin of eye.
LJ	lower jaw length, from anterior part of lower jaw to the intersection of upper and lower jaw.

2.3. Results

2.3.1. Distinguishing characters of family Hemiramphidae

Fishes of the family Hemiramphidae can be easily distinguished due to the presence of the following characters. They are elongated fishes with a prolonged lower jaw except in *Oxyporhamphus* (Collette and Su,1986) and a short triangular upper jaw (Fig. 2.2a and 2.2b). Teeth minute; upper part of lower jaw in front of upper jaw without teeth. Nostrils in a pit anterior to eyes. No spines in fins; dorsal and anal fins posterior in position; pelvic fins abdominal, with six rays; pectoral fins usually short. Lateral line running low down, from pectoral fin origin and then backward along ventral profile of body. Scales moderately large, cycloid (smooth) can easily be detached. Caudal fin rounded, truncate or forked. Tips of lower jaw bright red or orange in most species.



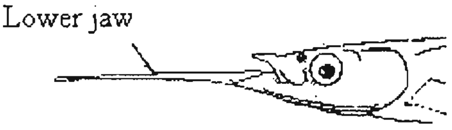


Fig 2.2a. *Oxyporhamphus*

b. Lower jaw prolonged in all species except *Oxyporhamphus*

The hemiramphids live on the surface and are protectively coloured and adapted for this mode of life by being green or blue on the back and silvery-white on the sides and ventrally. These are fishes which lay eggs while a few are live bearers; the latter a part of the anal fin is modified as an intromittant organ called andropodium. They are omnivorous. They used to leap and skitter at the surface and one offshore species, *Euleptorhamphus viridis* leaps out of the water and glides like a flying fish (FAO, 1983). Their pectoral fins are long and the number of dorsal and anal fin rays are high compared to other hemiramphids. Half beaks are regularly seen in local markets of Cochin. The flesh is excellent and utilized as food in many parts of the world. They are mainly caught with 'murasu vala' in Vembanad Lake and are utilized fresh, dried, salted and smoked.

The important genera of the family Hemiramphidae are *Oxyporhamphus* Gill, *Zenearchopterus* Gill, *Euleptorhamphus* Gill, *Hemiramphus Cuvier*, *Hyporhamphus* Gill and *Rhynchorhamphus* Fowler (Collette and Su,1986).

Systematic list of species of the family Hemiramphidae of Cochin coast

Class - Osteichthyes
Division - Euteleostei
Super order - Actinopterygii
Order - Beloniformes
Sub order - Exocoetoidei
Family - Hemiramphidae
Genus - *Zenarchopterus* Gill 1864
Species - *Zenarchopterus dispar* Valenciennes 1846

Genus - *Hemiramphus* Cuvier 1817

Species - *Hemiramphus archipelagicus* Collette and Parin 1978

Species - *Hemiramphus lutkei* Valenciennes 1846

Genus - *Rhynchorhamphus* Fowler 1928

Species - *Rhynchorhamphus malabaricus* Collette 1976

- *Rhynchorhamphus georgii* Valenciennes 1846

Genus - *Hyporhamphus* Gill 1859

Sub Genus - *Hyporhamphus (Hyporhamphus)*

Species - *Hyporhamphus (H) limbatus* Valenciennes 1846

Hyporhamphus (H) xanthopterus Valenciennes 1846

2.3.2. A key for identification of hemiramphids of Cochin coast

1. Nasal papilla elongated and pointed, not fimbriate, projecting well beyond nasal fossa (Fig. 2.3a). Caudal fin rounded or truncated with the longest rays in the middle. Triangular part of upper jaw broader than long, Anal fin of males modified. ....*Zenarchopterus dispar*

Nasal papilla rounded, fan shaped or fimbriate, (divided into many small filaments) (Fig. 2.3 b,c,d), not projecting far beyond nasal fossa. Caudal fin emarginated or forked, frequently with an elongated lower lobe. ....2.

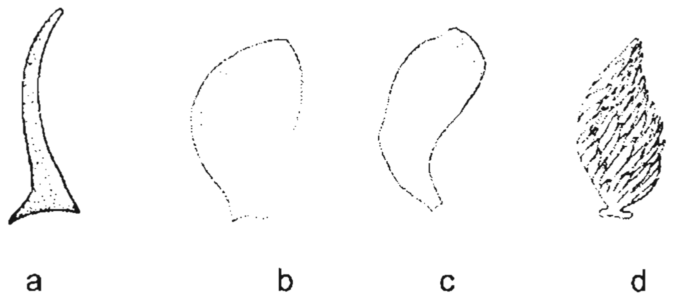


Fig. 2.3. Nasal papillae of

a.	*Zenarchopterus*	b.	*Hemiramphus*
c.	*Hyporhamphus*	d.	*Rhyncorhamphus*

2. Pre orbital ridge absent. Upper jaw without scales (Fig. 2.4 a), Swim bladder alveolar .... *Hemiramphus. (3)*

Pre orbital ridge present. Upper jaw covered with scales (Fig. 2.4 b). Swimbladder simple (single chambered). ......*(4)*

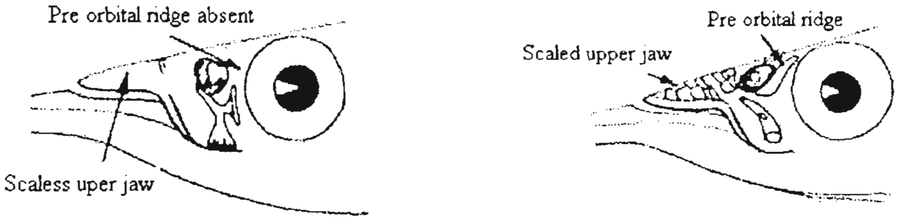


Fig. 2.4. a. *Hemiramphus* b. *Hyporhamphus* and *Rhynchorhamphus*

3. Total number of Gill rakers on first gill arch 25-32; Pectoral fin short, not reaching past nasal pit when folded forward ....*H. archipelagicus.*

Total number of gill rakers on first gill arch 33 – 46, Pectoral fins long, reaching beyond anterior margin of nasal pit when folded forward. .... *H. lutkei.*

4. Nasal papilla fimbriate, upper jaw domed (Fig. 2.5a). Lateral line with two branches, ascending towards pectoral fin origin. ....*Rhynchorhamphus .(5)*

Nasal papilla not fimbriate. Upper jaw projection flat or nearly flat. Lateral line with one branch (Fig. 2.5 b), ascending towards pectoral fin origin ....*Hyporhamphus (6)*

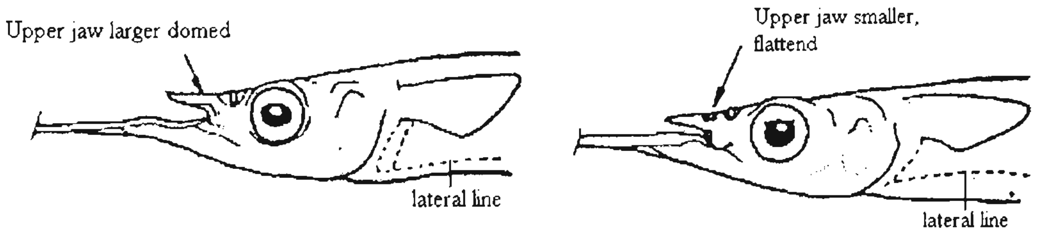


Fig. 2.5. a. *Rhynchorhamphus* b. *Hyporhamphus*

5 Total Number of gill rakers on first gill arch is 57 to 71. Sum of dorsal and anal fin rays equal to 28 or less. Upper jaw is less highly domed (Fig. 2.6a). ...*Rhynchorhamphus malabaricus*

Total number of gill arch 47 to 67. Sum of dorsal and anal fin rays equal to 29 or more upper jaw longer and more highly domed (Fig. 2.6 b). ...*Rhynchorhamphus georgii.*

Less highly domed upper jaw — More highly domed upper jaw

Fig. 2.6 a. *R. malabaricus* — b. *R. georgii*

6. Pre orbital canal simple (Fig. 2.7 a), without posterior branch. Caudal fin weakly or moderately forked. ...*Hyporhamphus (Hyporahamphus) (7)*

Pre orbital canal T shaped (Fig. 2.7 b), with posterior branch. Caudal fin strongly forked, usually with elongated lower lobe. .....*Hyporhamphus (Reporhamphus)*

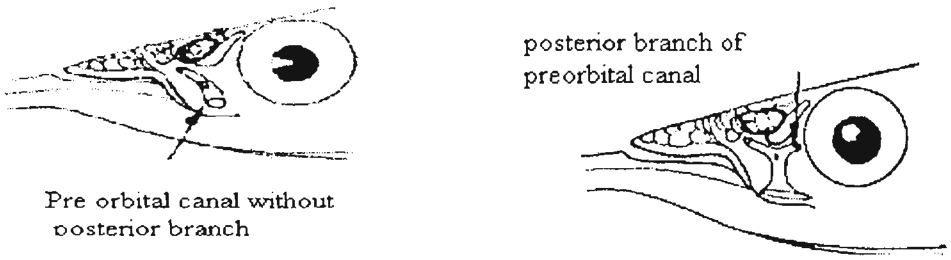


Fig. 2.7 a.*Hyporhamphus (Hyporhamphus)* b.*Hyporhamphus (Reporhamphus)*

7. Total gill rakers on first arch 28 to 36, on second arch 16 to 28. Head length shorter than beak length, dorsal fin with 12 to 16 rays. Upper jaw wider than length (Fig. 2.8 a). Its width 0.6 to 6.8 times its length. Fins hyaline. ...*Hyporhamphus (H) limbatus*

Total gill rakers on first arch 41 to 53, on second arch 39 to 47. Head length much greater than beak length. Dorsal fin with 14 to 16 rays, anal fin 14 to 17. Upper jaw longer than width (Fig. 2.8 b) . Its width 0.8 to 1.0 times its length. Fins yellow. ....*Hyporhamphus (H) xanthopterus*

Fig. 2.8 a. Upper jaw of *H. (H) limbatus* b. Upper jaw of *H. (H) xanthopterus*

2.3.3. *Zenarchopterus dispar* Valenciennes 1846 (Plate 1A)

Hemirhamphus dispar Cuvier and Valenciennes, *Hist. Nat. Poiss* xix, 1846, P58.

Hemirhamphus dispar (nec Valenciennes) Day, 1877, *Fishes of India*: 517, Pl. 119, Fig.5; Day, 1889, *Fauna Br. India* Fishes 1:426.

Zenarchopterus brevirostris (nec Cuvier) Herre, 1939, *Rec. Indian Mus.*, 41(3); 332; Herre, 1941, *Mem. Indian Mus.*, 13(3): 343.

Zenarchopterus gilli Smith, 1945, *Bull U.S. nation. Mus.*, (188); 432 (type-locality; East Indies) new name to replace *Hemiramphus brevirostris* Gunther, preoccupied by *H. brevirostris* Cuvier.

Zenarchopterus dispar (nec Valenciennes) Munro, 1955, *Marine and Fresh Water Fishes of Ceylon*. 73, Pl.13, Fig.203.

Common name : Viviparous half beak

Meristic formula : D 11-12; A 11-12; P 9; V 6; C 15.

Distinctive characters

An elongated fish; upper jaw broader than long. Mandibles prolonged into a long beak, bordered by a fairly conspicuous fold of skin along the edge of each side and a third fold along middle of underside. Teeth small and conical. Nasal papilla elongated and pointed, strongly projecting beyond nasal fossa (Plate 1B). Dorsal fin inserted slightly before anal fin; anal fin base much shorter than dorsal fin base; Anal fin rays modified in males into andropodium. Caudal fin usually rounded, or truncated (Plate 1B). Scales moderate, deciduous. At the tip of the elongated lower beak is borne a coloured flap or sensory organ. Fishes of this species appear to have internal fertilization but are oviparous.

Colour

In life, yellowish, scales above densely striped with fine dots making the back brownish; silvery lateral band bordered above by a black line; mandibles dark brown or blackish, with a white tip.

Geographical distribution

Western Indian Ocean, Andaman Islands, the East Indies, Caroline Island, Fiji, Guam, Australia and Cochin. Primarily marine, enters estuaries and tidal rivers.

Remarks

It attains a length of 20cm. It is one of the most widespread species of the genus. Along Cochin coast they are present during November and December.

2.3.4. Hemiramphus archipelagicus **Collette & Parin 1978** (Plate 2A)

Hemiramphus marginatus Forsskal. P. 1775 *observarit Descript animal : quae in itinere orientali observarit Huaniae.* 1.64.

H. archipelagicus : Collette B.B. and N.V. Parin 1978 *Proc. Biol. Soc. Washington* 91 (3) : 731 – 741 (type locality – Indo Pacific)

Common name : Jumping half beak.

Description : Based on 30 specimens measuring 312 to 361 mm total length(TL) and 261 to 308mm standard length (SL).

Meristic formula : D 12-15;A 10-13; P 11-13;V6; C 16.

Morphometric data are summarized in Table 2.1 (a).

In percentage of standard length : head length 16.73 – 19.18 (M = 17.95, S.D = 0.94) anal length 83.64 - 85.71 (M = 82.43, S.D = 1.08); pre dorsal length 80.90 – 83.77 (M = 88.43, SD= 1.08); body depth 13.72 – 16.10 (M = 14.46, S.D = 0.71); depth at dorsal fin 9.89 – 12.33 (M = 11.07, SD = 0.65); pectoral fin 11.61 – 13.83 (M = 12.41, SD = 0.68); anus 8.73 – 11.99 (M = 10.72, SD = 0.991); fin height : dorsal 6.91 – 9.22 (M = 8.46, SD 0.77); pectoral 12.36 – 14.61 (M = 13.6, SD = 0.76); ventral 6.03 – 8.22 (M = 6.79, SD = 0.68); anal 4.36 – 6.93 (M = 5.89, SD = 0.72); caudal 16.36 – 18.49 (M = 17.62, SD = 0.69); fin base : dorsal 11.91 – 14.49 (M = 13.47, SD = 0.90); pectoral , 2.74 – 3.57 (M = 3.22, SD = 0.25); ventral 1.71 – 2.53 (M = 2.11, SD = 0.26); anal 6.51 – 9.49 (M = 8.00, SD = 0.95) ; least depth of caudal peduncle 4.73 – 11.99 (M = 6.21, SD = 2.22) ; length of caudal peduncle 6.86 – 9.93 (M = 8.31, SD = 1.09); girth length 33.72 – 37.67 (M = 35.14, SD = 1.07).

In percentage of head length : length of pre orbit 32.14 – 40.00 (M = 36.26, SD = 2.62); post orbit 40.68 - 46.43 (M = 44.1, SD = 1.9); eye diameter 19.61 – 28.89; (M = 24.44, SD = 3.19); inter orbital width 27.08 – 30.43 (M = 28.41, SD = 1.15); upper jaw length 12.5 – 22.92 (M = 17.29, SD = 3.27); lower jaw length 121.43 – 148.89 (M = 137.10, SD = 10.42); gape width 16.95

– 37.25 (M = 22.24, SD = 6.45); head depth 50.85 – 58.7 (M = 55.16, SD = 2.47); depth at eye 37.50 – 51.11 (M = 44.16, SD = 3.92); depth at mouth 16.95 – 24.44 (M = 20.07; SD = 2.81).

Distinctive characters

An elongated fish with a greatly prolonged, beak-like lower jaw; upper jaw short, triangular and scale less; pre orbital ridge absent. Nasal papilla rounded not projecting beyond nasal fossa. Total number of gill rakers on first gill arch 25 to 32; 6 to 8 on upper and 19 to 24 on lower limb of arch. No spines in fins; pectoral fin short, not reaching past nasal pit when folded forward, caudal fin deeply forked, lower lobe much longer than upper. Predorsal scales 34 to 36.Inter orbital distance equal to or greater than orbit diameter.

Colour

Dark bluish above, silvery white below, without any vertical bars on sides. Beak dark with a bright red fleshy tip.

Geographical distribution

Western part of the Indian Ocean from Bombay to the southern tip of India, Cochin and Sri Lanka. Also found in the eastern Indian Ocean and Western Central Pacific, extending eastward to new Guinea and western Polynesia.

Remarks

They are available along Cochin coast during November and December. Caught in purse seines at Karwar on the west coast of India and by dol nets at Bombay

2.3.5. *Hemiramphus lutkei* Valenciennes 1846. (Plate 2B)

Hemiramphus lutkei Valenciennes, 1846. *Hist. Nat Poiss*, 5 : 49 (type – locality Manila Philippines); Parin, Collette and Shcherbachev, 1980, *Trudy Inst. Okean*, 97 : 115, fig.33

Hemiramphus georgii (nec Valenciennes). Day 1877, Fishes of India : P1. 120 fig 2.

Hemiramphus marginatus (nec Forsskal). Talwar, 1967, *J. Mar biol. Ass. India* 9 (1) : 61

Common name: Lutkei half beak / barbed half beak.

Description : Based on 35 specimens measuring 305 to 350mm TL and 260 to 302 mm SL.

Meristic formula : D 13-14; A 10-13;P 10-12;V 6; C16.

Morphometric data are summarized in Table 2.1(b).

In percentage of standard length : head length 16.00 – 19.66 (M = 18.62, SD = 0.99), anal length 83.62 – 85.52 (M = 85.52, SD = 0.73); pre dorsal length 81.98 – 83.68 (M=84.4, SD=0.54); body depth 10.00-13.5 (M = 12.26, SD=0.99); depth at : dorsal fin 10.24-12.69 (M=10.84, SD=0.79); pectoral fin 9.89-11.76 (M =11.36, SD=0.52); anus 9.19-10.34 (M=9.99, SD=0.42); fin height : dorsal 5.88-7.42 (M =6.72, SD=0.44); pectoral 13.6-14.93 (M=14.29, SD=0.41); ventral 5.65-7.77 (M = 6.93, SD = 0.70); anal 3.53-5.86 (M =4.81, SD 0.69); caudal 16.9-18.37 (M = 17.43, SD = 0.42); finbase : dorsal 11.09 – 12.33 (M= 11.65, SD = 0.44); ventral 2.04-2.31 (M = 2.11, SD = 0.08); anal 5.30-7.67 (M = 6.67, SD= 0.63); depth of caudal peduncle 4.44-6.36 (M = 4.95, SD = 0.54); length of caudal peduncle 6.92-9.89 (M = 8.18, SD = 0.93); girth length 30.72-33.91 (M = 32.02, SD=1.23).

In percentage of head length : pre orbital length 30.93-39.58 (M=33.33, SD= 2.21); post orbital length 41.58-50.00 (M = 43.83, SD = 2.18); eye diameter 23.58-29.17 (M = 24.79, SD = 1.64); inter orbital width 25.45-33.33 (M = 27.66, SD = 2.47); upper jaw length 13.86-18.75 (M = 16.28, SD = 1.15); lower jaw length 131.58-160.42 (M = 139.35, SD= 7.81); gape width 15.84 – 22.92 (M = 18.08, SD = 1.97); head depth52.83 – 66.67 (M = 56.5, SD = 3.71); depth at eye 40.35 – 47.92 (M = 43.06, SD = 1.98); depth at mouth 17.54 – 27.08 (M = 20. 50, SD = 2.97).

Distinctive characters

An elongated fish with a greatly prolonged, beak like lower jaw; upper jaw short, triangular and scale less, pre orbital ridge (bony ridge behind nostril) absent. Nasal papilla rounded not projecting beyond nasal fossa. Total number of gill rakers on first gill arch 36 to 41; 9 to 14 on upper and 24 to 32 on lower limb of arch. No spines in fins. Pectoral fins relatively long, reaching beyond anterior margin of nasal pit when folded forward. Caudal fin deeply forked, lower lobe much larger than upper. Predorsal scales 37-41. Inter orbital distance narrower or less than orbit diameter.

Colour

Iridescent blue, belly silvery, with lateral silvery band bordered by narrower black stripe. Dorsal and caudal fins bordered with black.

Geographical distribution

From Mozambique, Zanzibar, Aldraba, the Comores islands, Vizhinjam and Cochin on the southern west coast of India and Sri Lanka. Also found in the Eastern Indian Ocean and Western Central Pacific eastward to southern Japan, the Gilbert Island and Samoa.

Remarks

This species occurs along the Cochin coast during November and December. They are also available at Kilakkarai in the Gulf of Mannar from November to December. Usually seen in kalachivala nets at Vizhinjam.

Students '*t*' test was conducted to compare the morphometric characters of *H. archipelagicus* and *H. lutkei* in percent of standard length and head length and described in Table 2.1. It was noted that these two species of the genus *Hemiramphus* showed significant difference in all body characters except in depth at dorsal fin, ventral fin height, ventral fin base, caudal fin height, caudal peduncle length, pre and post orbital lengths and depth at mouth.

2.3.6. *Hyporhamphus (Hyporhamphus) limbatus* Valenciennes 1846 (Plate 3A)

Hemiramphus limbatus Valenciennes, in Cuvier and Valenciennes 1846, *Hist. Nat. Poiss;* 19:44 (type locality: India, Malabar coast, Bombay, Pondicherry).

Hemiramphus limbatus : Day 1877, *Fishes of India* ; 516, Pl, 119, Fig 3; Day, 1889, Fauna Br. India, Fishes 1 : 426.

Hemiramphus gaimardi Valenciennes : Jones and Sujansinghani, 1954, *Indian J. Fish.*, 1:264 (name only)

Hemiramphus gorakhpurensis Srivastava , 1967, *J. Bombay nat. Hist. Soc* 64(1): 93 (type locality : Gorakhpur, Uttar Pradesh).

Common name : Valenciennes half beak / Congaturi half beak/ Gaimardis half beak.

Description : Based on 75 specimens specimens measuring 108 to 214 mm TL and 95to 186mm SL.

Meristic formula

D 12-16;A 13-16; P 10-11;V 6; C 14.

Morphometric data are summarized in Table 2.2 (a).

In percentage of standard length : head length 14.55 – 32.41 (M = 20.07, SD = 20.07); anal length 68.28 – 82.14 (M = 78.12, SD = 1.96); pre dorsal length 37.50 – 84.32 (M = 80.93, SD = 6.30); body depth 7.86 – 14.11 (M = 11.37, SD = 1.33); depth at dorsal fin 6.86 – 12.34 (M = 10.32, SD = 1.10) ; depth at pectoral fin 8.82 – 11.92 (M = 10.67, SD = 0.91); depth at anus 5.95 – 12.88 (M = 10.48, SD = 1.30); fin height : dorsal 6.43 – 13.53 (M = 9.69, SD = 1.73); pectoral 9.80 – 17.20 (M = 12.48, SD = 1.47); ventral 2.68 – 9.80 (M = 7.46, SD = 1.08); anal 8.05 – 15.79 (M = 10.24, SD = 1.71) ; fin base : dorsal 9.80 – 16.67 (M = 14.48, SD = 1.66); pectoral 2.86 – 8.04 (M = 3.86, SD = 3.86; ventral 1.79 – 3.57 (M = 2.51, SD = 0.50); anal 9.5 – 20.00 (M = 12.91, SD = 2.35); depth of caudal peduncle 4.4 – 6.47 (M = 5.41, SD = 0.61) ; length caudal peduncle 4.76 – 17.18 (M = 8.47, SD = 2.73) and girth length 23.17 – 44.83 (M = 31.75, SD = 2.29).

In percentage of head length : pre orbital length 28.57 – 53.19 (M = 35.12, SD = 4.63); post orbital length 27.66 – 45.95 (M = 39.67, SD = 3.80); eye diameter 19.15 – 35.71 (M = 25.22, SD = 5.24); inter orbital width 19.15 – 37.50 (M = 29.94, SD = 3.88) ; upper jaw length 8.51 – 25.93 (M = 17.43, SD = 4.25); lower jaw length 61.70 – 131.25 (M = 102.21, SD = 11.89); gape width 10.71 – 50.00 (M = 23.06, SD = 8.59); head depth 14.89 – 60.71 (M = 39.20, SD = 11.60); depth at eye 25.53 – 67.86 (M = 45.32, SD = 10.88) and depth at mouth 8.51 – 42.86 (M = 22.59, SD = 11.52).

Distinctive characters

An elongated fish, body somewhat compressed with a greatly prolonged beak-like lower jaw, equal to, or more than head length; upper jaw length slightly less than width, triangular and scaly, its width 0.6-0.8 times its length; pre orbital ridge present. Posterior branch to pre orbital canal absent. Nasal papilla fan shaped. Total number of gillrakers on first gill arch 23 to 37, 6 to 11 on upper and 17 to 26 on lower limb of arch. No spines in fins, caudal fin emarginated, not strongly forked. Anterior part of dorsal and anal fins covered with scales. Pre dorsal scales 32 to 35. Pectoral fins short not reaching to middle of orbit when folded forward.

Colour

Greenish above, the silvery lateral stripe widening posteriorly, white ventrally. Fleshy tip of beak reddish. The dorsal and anal fins are black in colour. Other fins hyaline.

Geographical distribution

Persian Gulf, Pakistan, India, Sri Lanka, Burma to Thailand and China.

Remarks

H.(H) limbatus is a true estuarine species occurs throughout the year in the catches from Cochin coast. It is one of the most abundant species and contributes about 50% of the total halfbeak fishery. They are euryhaline fishes and are relatively abundant in the mouth, middle and lower reaches of the estuary where salinity is invariably high during the pre-monsoon period. During monsoon season almost freshwater conditions prevail in the lake, so that its availability is reduced but during inter-monsoon months fairly good catches are noticed when the salinity and temperature are comparatively high.

2.3.7. *Hyporhamphus (Hyporhamphus) xanthopterus* Valenciennes 1846

(Plate 3B)

Hemiramphus xanthopterus Valenciennes, 1846, *Hist. nat Poiss*, 19:47 (type – locality : Alleppy, Kerala); Day, 1877, *Fishes of India* : 514, Pl. 119, fig 2; Day, 1889, *Fauna Br. India, Fishes* 1:425.

Hyporhamphus xanthopterus (Valenciennes)

Munro, 1955, *The Marine and fresh water fishes of Ceylon* P.74. Pl. 204.

Hyporhamphus (Hyporhamphus) xanthopterus Valenciennes. Kurup and Samuel 1980. *Bull. Dept. Mar Sci. Univ. Cochin*, 1980, X1, 2, 1-9.

Hyporhamphus xanthopterus: Collette, 1982, *Matsya* (7) : 29, Fig.1 (Redescription) .

Common name : Vembanad half beak/Red tipped half beak

Description : Based on 75 specimens measuring 95 to 226mm TL and 84 to 207mm SL.

Meristic formula : D 14-16; A14-17; P 10;V 6; C 15.

Morphometric data are summarized in Table 2.2 (b).

In percentage of standard length : head length 13.74 – 43.33 (M = 24.37, SD = 4.99); anal length 71.65 – 94.44 (M = 79.66, SD = 3.43); pre dorsal length 72.67 – 109.15 (M = 81.89, SD = 5.54); body depth 4.44 – 17.34 (M = 9.57, SD = 2.16); depth at dorsal fin 1.77 – 11.90 (M = 8.01, SD = 2.04); depth at pectoral fin 4.23 – 11.56 (M = 8.25, SD = 1.70) ; depth at anus 3.47 – 11.80 (M = 8.19, SD = 1.86); fin height : dorsal 6.87 – 15.06 (M = 9.82, SD 1.94); pectoral 7.52 – 15.08 (M = 11.04, SD = 1.29); ventral 5.56 – 10.67 (M =

7.64, SD = 0.92); anal 5.78 – 17.86 (M = 8.62, SD = 1.69); caudal 9.83 – 24.07 (M = 16.70, SD = 2.23); fin base : dorsal 6.76 – 16.67 (M = 12.03, SD = 2.61); pectoral 1.85 – 4.44 (M = 3.06, SD = 054); ventral 0.57 – 5.79 (M = 2.13, SD = 0.73), anal 1.32 – 18.68 (M – 12.31, SD = 2.43); depth of caudal peduncle 4.49 – 6.19 (M = 5.18, SD = 0.48); length caudal peduncle 6.08 – 13.27 (M = 8.97, SD = 2.08) and girth length 25.17 – 46.83 (M = 33.77, SD = 3.39).

In percentage of head length : pre orbital length 31.58 – 40.63 (M = 36.16, SD = 1.64) ; post orbital length 41.03 – 50.00 (M = 45.29, SD = 1.92); eye diameter 9.38 – 23.68 (M = 18.55, SD = 2.82); inter orbital width 12.50 – 45.71 (M = 24.07, SD = 6.23); upper jaw length 13.16 – 33.33 (M = 22.92, SD = 4.74); lower jaw length 62.50 – 106.06 (M = 81.52, SD = 9.59); gape width 7.89 – 25.71 (M = 16.96, SD = 4.31); head length 15.63 – 39.39 (M = 27.92, SD = 4.84); depth at eye 14.29 – 46.15 (M = 26.89 , SD = 6.69) and depth at mouth 5.71 – 30.77 (M = 14.08, SD = 4.65).

Distinctive characters

An elongated fish with prolonged lower jaw, shorter than head length; upper jaw length slightly greater than width, triangular and scaly; its width 0.8 to 1.0 times its length. Nasal papilla fan shaped. Pre orbital ridge present. Posterior branch to pre orbital canal absent. Total number of gill rakers on first gill arch, 41 to 53. 9 to 13 on upper and 32 to 40 on lower limb of arch. No spines in fins. Caudal fin emarginated, not strongly forked.

Anterior part of dorsal and anal fins covered with scales. Pectoral fin short, reaching to middle of orbit when folded forward. Pre dorsal scales 34 to 38.

Colour

Dorsal body profile is greenish yellow, ventral profile silvery. Scales on dorsal profile mottled with black, thus imparting a slight black colouration. Three lines on dorsal side commencing from occipital region and ending slightly in front of dorsal fin, bordered above by dark green stripe, extending up to caudal fin base. Opercle shining silvery. The region between the orbit and commencement of jaws silvery. Lower jaw having slight bluish tinge in fresh condition, blackens after preservation; upper jaw black. Tip of lower jaw has an orange red spot. Pectoral axil black; caudal and dorsal fins yellow; other fins transparent.

Geographical distribution:

H. (H) xanthopterus (Val.) is known to occur only along the south west coast in India. This half beak is fairly common in the Vembanad Lake, Kerala. They are known as Vembanad half beak.

Remarks

H. (H) xanthopterus is abundant in the Vembanad Lake. Its occurrence is noticed in the zone of transition in the lake from brackish water to fresh water throughout the year. They prefer low salinity areas. During monsoon and inter monsoon months fairly good catches were noticed whereas its availability was reduced during pre-monsoon months (January to May) when the salinity is high. But during these months they are available in the southern region of the Vembanad Lake where the salinity is very low. From January to May it is the most abundant species among the half beaks of Vembanad Lake (Kurup and Samuel 1980).

Students '*t*' test was conducted to compare the morphometric characters of *H.(H) limbatus* and *H.(H). xanthopterus* in percent of standard length and head length and described in Table 2.2. It was noted that these two species of the genus *hyporhamphus* showed significant difference in all body characters except in dorsal fin height, ventral fin height, depth of caudal peduncle and length of caudal peduncle.

2.3.8. ***Rhynchorhamphus malabaricus* Collette 1976** (Plate 4A)

Hemirhamphus georgii (*nec* Valenciennes). Day, 1877 *Fishes of India* : 515 (ne. Pl : 120 Fig.2 which is *Hemiramphus lutkei);* Day, 1889, *Fauna Br. India*, Fishes 1:424.

Hemiramphus georgii. Munro, 1955: 74 (description, in part: The Marine and Fresh Water Fishes of Ceylon; pl. 13, fig.206,).

Hyporhamphus georgii (*nec* Valenciennes).

Talwar, 1962a : *Indian. J. Fish.* 3 (stomach contents of 1042 specimens; Gulf of Mannar and Palk Bay). Talwar, 1962b: 168-196 (racial analysis, biology; Gulf of Mannar and Palk Bay). Talwar, 1967: 67-68 (54 myotomes). Qasim, 1973: 18 (feeding habits, after Talwar).

Rhynchorhamphus malabaricus : Collette 1976, *Bull. Mar. Sci.*, 26 (4) : 84, Fig 8b (type locality : Myliddy near Kankesanthrai, Sri Lanka)

Common name : Malabar half beak

Description : Based on 30 specimens measuring 299 to 345 mm TL and 262 to 301 mm SL.

Meristic formula : D 13-15;A12-14;P 11-12;V 6; C 16.

Morphometric data are summarized in Table 2.3 (a).

In percentage of standard length: head length 16.17-18.45 (M=17.52,SD=0.57); anal length 83.10 – 85.22 (M=83.94, SD=0.67); pre dorsal length 80.66-84.39 (M82.95,SD=1.03); body depth 7.25-11.63 (M=10.54,SD=1.08); depth at dorsal fin 8.40-10.96 (M=9.78,SD=0.62; depth at anus 7.25-10.00 (M=0.01,SD=0.77); fin height : dorsal 5.32-7.72 (M=6.84,SD=0.71); pectoral 8.33-12.41 (M=10.63, SD=0.91); ventral 4.12-7.04(M=5.50,SD=0.65); anal 4.43-7.04(M=5.99,SD=0.78); caudal 14.48-16.42(M=15.47,SD=0.71); fin base : dorsal 11.62-13.67 (M=12.33, SD=0.54); pectoral 2.00-3.44 (M=2.78, SD= 0.34); ventral 1.00-2.19 (M-1.75, SD=0.33); anal 6.39-8.97(M=7.77, SD=0.73); depth of caudal peduncle 3.82-5.32(M=4.49, SD=0.43);length of caudal peduncle 7.63-10.33 (M=8.88, SD=0.77) and girth length 27.55-31.56 (M=29.7 SD=1.5).

In percentage of head length : pre orbital length 38.30-42.59 (M-40.39, SD-40.39); post orbital length 34.00-38.46 (M=36.29, SD 1.29); eye diameter 20.19-26.00 (M=23.46, SD1.74); inter orbital width 27.78-34.88

(M=31.45, SD=2.09); upper jaw length 21.15-31.00 (M=24.90, SD=2.72); lower jaw length 144.68-176.74 (M=157.67, SD=7.35); gape width 13.95-25.53(M=20.58, SD=3.17); head depth 25.00-55.32 (M=45.64, SD=7.93); depth at eye 36.17-53.19 (M=40.91, SD=4.17) and depth at mouth 19.61-30.23 (M=22.36, SD = 2.56).

Distinctive characters

An elongated fish with greatly prolonged beak like lower jaw; upper jaw about as long as wide, its width is 0.90 to 1.2 times of its length, domed and covered with scales; pre orbital ridge present. Nasal papilla fimbriate; total number of gill rakers on first arch 57 to 71. 15 to 20 on upper and 42 to 51 on lower limb of arch. No spines on fins; caudal fin distinctly forked, lower lobe longer than upper. Two branches of lateral line running from ventral outline of fish towards pectoral fin base.

Colour

Body greenish above, silvery below; with a silvery stripe on sides of the body; bordered by a narrow blue stripe. Mandibular flaps black, tip of lower jaw greenish. Fins hyaline, dorsal and caudal fins distinctly bordered with black.

Geographical Distribution

Coasts of Southern India and Sri Lanka.

Remarks

The occurrence of these species was noticed along the Cochin coast from January to March when the salinity and temperature were comparatively high. The fishery is chiefly confined to Theedai (Palk Bay) and is of the greatest economic importance. The season of the fishery in this area coincides with the spawning season (March – April). The shore-seine 'Karal-Valai' is used for the capture of these species in the Palk Bay and Gulf of Mannar whereas the drift gill net 'murasu vala' is used in the Cochin coast.

2.3.9. *Rhynchorhamphus georgii* Valenciennes 1846 (Plate 4B)

Hemirhamphus georgii Valenciennes in Cuvier and Valenciennes, 1846: 37-39 (original description; Bombay and Coromandel, India).

Hemirhamphus russeli Valenciennes in Cuvier and Valenciennes, 1846: 32-33 (original description; Pondichery, India).

Hemirhamphus leucopterus Valenciennes in Cuvier and Valenciennes, 1846 : 48 (original description; Bombay, India).

Hemirhamphus eclancheri Valenciennes in Cuvier and Valenciennes, 1846: 51-52 (original description; "Marquesas Is").

Hemirhamphus plumatus. De Silva, 1956: 51 (listed; after Blyth, 1859 and Day, 1873; Ceylon and Bengal).

Hemirhamphus cantori. Talwar and Chakrapany , 1970: 128 (re-examination of specimen [ZSI 1300] figured by Day, 1878, pl. 119, fig.1).

Rhynchorhamphus georgii. Collette 1976: *Bull. Mar. Sci.*, 26 (4) 90-94 (synonymy, description, range), fig 9.

Description : Based on 40 specimens measuring 253 to 312 mm TL and 222 to 273mm SL.

Meristic formula

D13 – 17; A13- 15; P 10 – 12; V 6; C 16.

Morphometric data are summarized in Table 2.3 (b).

In percentage of standard length : head length 15.98-18.92 (M-16.73, SD=0.92); anal length 81.53-84.59 (M=83.42, SD=0.84); pre dorsal length 80.63-84.21) (M=82.55, SD=1.14); body depth 8.42-10.70(M=9.67, SD=0.65); depth at dorsal fin 7.52-9.17 (M=8.43, SD=0.60); depth at pectoral fin 8.61-10.42 (M=9.34, SD=0.72); depth at anus 7.81-10.26 (M=8.63, SD 0.67); fin height : dorsal 6.69-8.56 (M=7.45, SD=0.56); pectoral 8.42-11.71 (M=10.38, SD=0.97); ventral 4.78-7.66(M=5.45, SD=0.79); anal 5.83-8.64 (M=6.82, SD = 0.79); caudal (8.42-14.75 (M=10.96, SD = 2.20); fin base : dorsal 11.89-13.96 (M=12.91, SD=0.69); pectoral 2.39-3.76 (M=3.11, SD=0.52); ventral 1.25-2.46 (M=1.81, SD 0.43); anal 7.08-10.70 (M=8.34 SD=0.95); depth of caudal peduncle 3.76 – 4.58 (M=4.31, SD=0.29); length caudal peduncle 4.51-9.17 (M=7.70, SD=1.31) and girth length 22.66-26.25 (M=25.25, SD=1.05.

In percentage of head length : pre orbital length 38.64-46.34 (M=42.26, SD=2.52); post orbital length 30.23-44.19(M=39.22, SD=23.61, SD=2.22); inter orbital width 29.27-33.33 (M=31.16, SD=1.55); upper jaw length 24.39-31.82 (M=27.05, SD=2.12); lower jaw length 121.43-184.09 (M=167.16, SD=17.09); gape width 20.93-27.27 (M=25.12-1.91); head depth

40.91-48.84 (M=47.01, SD=2.57); depth at age 33.33-48.84 (M=42.58, SD=4.55 and depth at mouth 19.05-25.58 (M=22.05, SD=2.24).

Distinctive characters

An elongated fish with a greatly prolonged beak like lower jaw; upper jaw longer and more domed; its width is 1.2 to 1.3 times of its length; covered with scales; pre orbital ridge present; nasal papilla fimbriate ; total number of gill rakers on first arch 47 to 67. 11 to 14 on upper and 36 to 43 on lower limb of arch; caudal fin distinctly forked, lower lobe longer than upper. Two branches of lateral line running from ventral outline of fish toward pectoral fin base.

Colour

Bluish green above, silvery white below. Fleshy tip of beak red.

Distribution

R. georgii has the widest distribution among the species of *Rhynchorhamphus.* In the Indian Ocean it is found from the Persian Gulf thorough the Arabian sea and Bay of Bengal, Malacca Peninsula, gulfs of Thailand and Tonkin, South China Sea, Southern East China Sea, Philippines, Indo-Malayan Archipelago, New Guinea, northern and north-eastern Australia. It is found throughout the Philippine Islands and there are records from Borneo, New Guinea, and the Northern Territory and Queens land of Australia.

Remarks

R. georgii occurs from April to May in the catches of Cochin coast when the salinity and the temperature are comparatively high. Absent during the monsoon months.

Students '*t*' test was conducted to compare the morphometric characters of *R. malabaricus* and *R. georgii* in percent of standard length and head length and the results are given in Table 2.3. It was noted that these two species of the genus *Rhynchorhamphus* showed significant difference in all body characters except in depth at anus, pectoral fin height, ventral fin height, ventral fin base, depth of caudal peduncle, eye diameter, inter orbital width and depth at mouth.

2.4. Discussion

The Cochin coast and the adjacent back water system of Kerala have a rich and diversified fish fauna. The hemiramphid fishes constitute a minor fishery of this area. The occurrence of seven species of hemiramphid fishes was noticed during 2001 May to 2003 April. They are *Z. dispar, H. archipelagicus, H. lutkei, H. (H) limbatus, H. (H) xanthopterus, R. malabaricus and R. georgii.* Shetty (1965) conducted a preliminary study on the fish and fisheries of Vembanad Lake and reported the presence of *H. (H) limbatus* and *H. cantori* Bleeker. Kurup and Samuel (1980) reported the presence of *H. (H) xanthopterus, H (H) limbatus, Z. dispar* and *R. georgii* in Vembanad Lake.

Collette (1981) rediscovered *H. (H) xanthopterus* a half beak endemic in Vembanad Lake, Kerala.

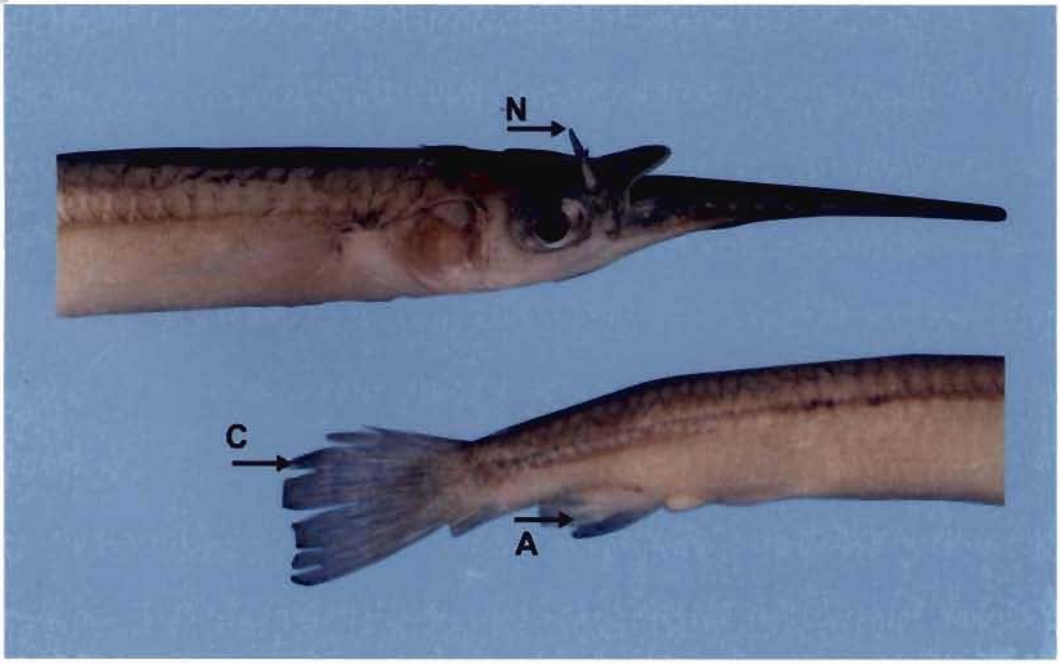
The study on the distribution and availability of hemiramphid fishes present in the Cochin coast shows that they evince different patterns of distribution. The occurrence of *Z. dispar* was noticed only very sporadically from the stations near the estuarine mouth of Cochin. It is predominantly a marine species which migrates accidentally into the backwaters during November and December. *H. archipelagicus* and *H. lutkei* are strictly marine and migrate to backwaters during November and December, when the temperature and salinity are high. *H. (H) limbatus* and *H. (H) xanthopterus* are true estuarine species and found in Cochin backwaters throughout the year. *R. malabaricus* and *R. georgii* are marine and migrate to Cochin backwaters from January to May.

The occurrence and frequency of different species of hemiramphid fishes of Cochin coast are classified following the classification of Kurup and Samuel (1983) (Table 2.4). Of the seven species of hemiramphids, four species, *H. archipelagicus*, *H. lutkei*, *R. malabaricus* and *R. georgii* can be characterized as ' migrants' i.e., they migrate from the coastal areas into the backwaters during pre and post - monsoon periods of the year; one species, *Z. dispar* is 'vagrant' i.e., they come to the backwaters only accidentally and two species, *H. (H) limbatus* and *H. (H) xanthopterus* are residents i.e., they constitute the stock of hemiramphid fishery of the Cochin coast and the adjacent backwaters. The data on the species composition and the pattern of distribution of hemiramphid fishes of Cochin coast and the adjacent backwaters clearly indicate that most of them have a marine origin. Gopalakrishnan (1973) reported that, in the several areas of Indo-Pacific region, fishes of the marine origin move into estuaries and constitute local fisheries of considerable importance.

It was found that salinity has an important bearing on the distribution and abundance of the fish fauna of the Cochin coast and nearby brackish water (Kurup and Samuel, 1980). Temperature change may also lead to changes in distribution pattern of fishes both seasonally and geographically. The relationship between the distribution of separate species and temperature is very strong (Nikolsky, 1963). The fluctuation in temperature from monsoon to pre-monsoon periods (24.6 – 34.5° C) may also have some effect on seasonal distribution and abundance of hemiramphid fishes of Cochin coast.

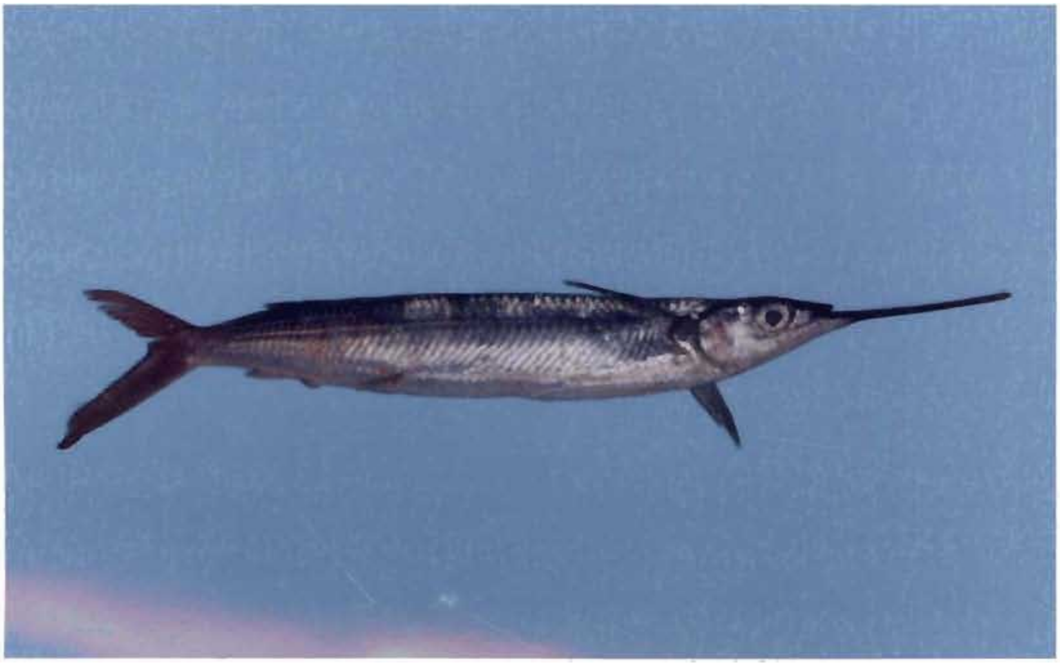
PLATE 1

A. *ZENARCHOPTERUS DISPAR* VALENCIENNES 1846

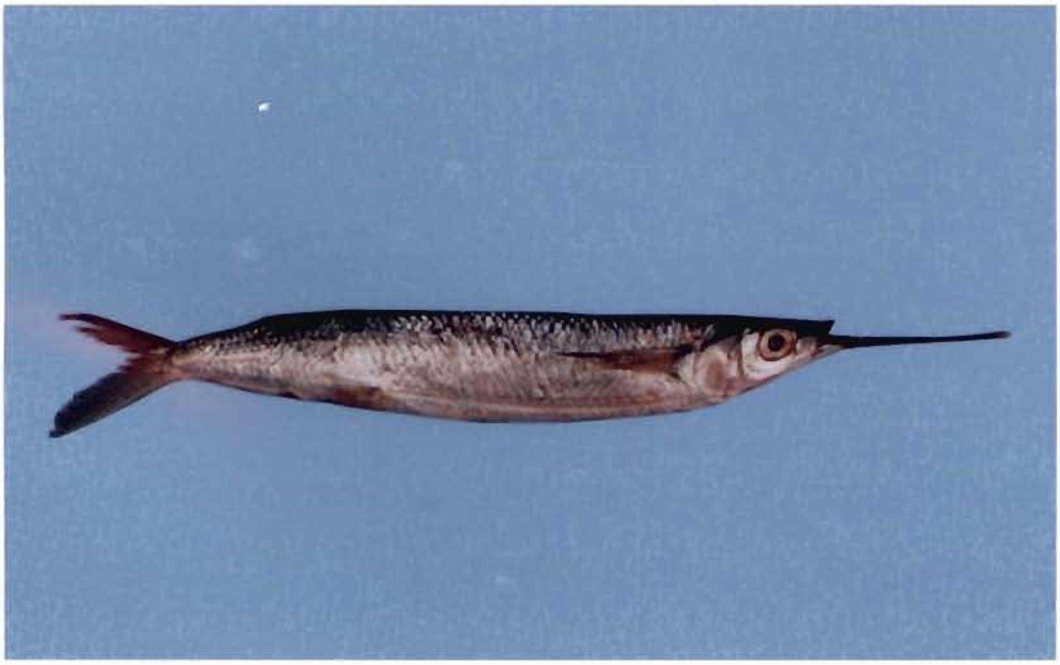


B. NASAL PAPILLA (N), CAUDAL FIN (C) AND ANDROPODIUM (A) OF *Z. DISPAR*

PLATE 2



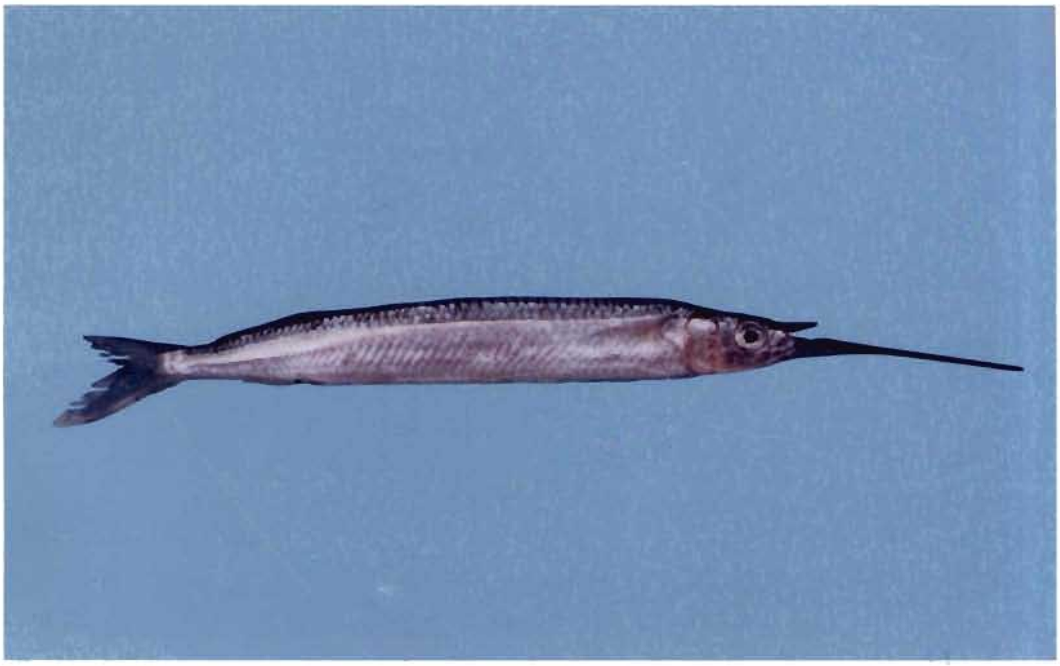
A. *HEMIRAMPHUS ARCHIPELAGICUS* COLLETTE AND PARIN 1978



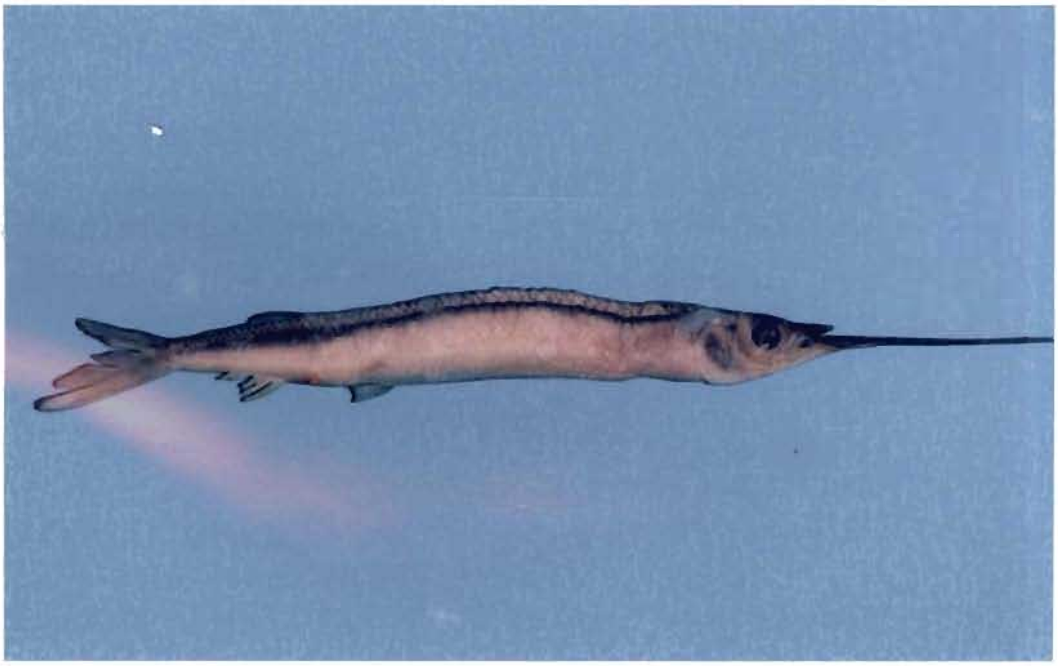
B. HEMIRAMPHUS LUTKEI VALENCIENNES 1846

A. *HYPORHAMPHUS (H) LIMBATUS* VALENCIENNES 1846

B. HYPORHAMPHUS (H) XANTHOPTERUS VALENCIENNES 1846



***A. RHYNCHORHAMPHUS MALABARICUS* COLLETTE 1976**



***B. RHYNCHORHAMPHUS GEORGII* VALENCIENNES 1846**

Table 2.1
Body proportions of *Hemiramphus archipelagicus* and *Hemiramphus lutkei* as percent of standard length and head length

Characters	*(a)* *H. archipelagicus*			*(b)* *H. lutkei*			Students 't' test
	Range	**Mean**	**S.D**	**Range**	**Mean**	**S.D**	
In standard length							
Standard length	261.00 - 308.00	279.89	13.87844	260.00 - 302.00	288.45	11.17	10.12 *
Total length	115.64 - 119.54	117.96	1.419012	114.78 - 118.73	116.81	0.98	4.39 *
Fork length	104.73 - 107.49	105.90	0.885063	102.75 - 110.00	105.30	1.87	2.14 *
Anal length	83.64 - 85.71	84.68	0.854671	83.62 - 85.52	85.52	0.73	3.95 *
Pre dorsal length	80.90 - 83.77	82.43	1.083743	81.98 - 83.68	84.40	0.54	9.15 *
Body depth	13.72 - 16.10	14.46	0.713796	10.00 - 13.50	12.26	0.99	9.97 *
Depth at dorsal fin	9.89 - 12.33	11.07	0.649925	10.24 - 12.69	10.84	0.79	1.13
Depth at pectoral fin	11.61 - 13.83	12.41	0.67748	9.89 - 11.76	11.36	0.52	5.68 *
Depth at anus	8.73 - 11.99	10.72	0.995548	9.19 - 10.34	9.99	0.42	3.63 *
Dorsal fin height	6.91 - 9.22	8.46	0.770459	5.88 - 7.42	6.72	0.44	9.36 *
Dorsal fin base	11.91 - 14.49	13.47	0.901834	11.09 - 12.33	11.65	0.44	9.30 *
Pectoral fin height	12.36 - 14.61	13.60	0.767071	13.60 - 14.93	14.29	0.41	3.76 *
Pectoral fin base	2.74 - 3.57	3.22	0.258109	2.73 - 3.33	2.96	0.24	2.18 *
Ventral fin height	6.03 - 8.22	6.79	0.684377	5.65 - 7.77	6.93	0.70	0.70
Ventral fin base	1.71 - 2.53	2.11	0.260391	2.04 - 2.31	2.11	0.08	0.00
Anal fin height	4.36 - 6.93	5.89	0.723443	3.53 - 5.86	4.81	0.69	5.37 *
Anal fin base	6.51 - 9.49	8.00	0.947423	5.30 - 7.67	6.67	0.63	6.26 *
Caudal fin height	16.36 - 18.49	17.62	0.693096	16.90 - 18.37	17.43	0.42	1.07
Least depth of caudal peduncle	4.73 - 11.99	6.21	2.224033	4.44 - 6.36	4.95	0.54	4.48 *
Length caudal peduncle	6.86 - 9.93	8.31	1.092984	6.92 - 9.89	8.18	0.93	0.54
Girth length	33.72 - 37.67	35.14	1.071668	30.72 - 33.91	32.02	1.23	12.17 *
Head length	16.73 – 19.18	17.95	0.94	16.00 - 19.66	18.62	0.99	2.86 *
In head length							
Head length	45.00 - 59.00	50.25	4.89	48.00 - 57.00	53.68	3.27	7.10*
Pre orbital length	32.14 – 40.00	36.26	2.62	30.93 - 39.58	33.33	2.21	7.88 *
Post orbital length	40.68 – 46.43	44.10	1.90	41.58 - 50.00	43.84	2.18	0.76
Eye diameter	19.61 – 28.89	24.44	3.19	23.58 - 29.17	24.79	1.64	0.94
Inter orbital width	27.08 – 30.43	28.41	1.15	25.45 - 33.33	27.66	2.47	2.33 *
Upper jaw length	12.50 – 22.92	17.27	3.27	13.86 - 18.75	16.28	1.15	2.79 *
Lower jaw length	121.43 –148.89	137.10	10.42	131.58 - 160.42	139.35	7.81	3.12 *
Gape width	16.95 – 37.25	22.24	6.45	15.84 - 22.92	18.08	1.97	8.48 *
Head depth	50.85 – 58.70	55.16	2.47	52.83 - 66.67	56.50	3.71	3.19 *
Depth at eye	37.50 – 51.11	44.16	3.92	40.35 - 47.92	43.06	1.98	2.68 *
Depth at mouth	16.95 – 24.44	20.07	2.81	17.54 - 27.08	20.50	2.97	1.06

* Significant

Table 2.2

Body proportions of *Hyporhamphus (H) limbatus* , *Hyporhamphus (H) xanthopterus* as percent of standard length and head length

Character	*(a) H. (H) limbatus*			*(b) H. (H) xanthopterus*			*Students*
In standard length	**Range**	**Mean**	**S.D**	Range	**Mean**	**S.D**	*'t' test*
Standard length	95.00 – 186.00	147.67	18.39	84.00 –207.00	153.37	24.36	5.16 *
Total length	85.71 - 117.81	114.27	4.39	106.17 – 133.57	116.30	4.51	4.03 *
Fork length	105.26 – 112.24	109.39	1.50	100.54 – 123.31	108.58	3.98	2.05 *
Anal length	68.28 – 82.14	78.12	1.96	71.65 – 94.44	79.66	3.43	3.92 *
Pre dorsal length	37.50 – 84.32	80.93	6.30	72.67 – 109.15	81.89	5.54	1.65 *
Body depth	7.86 – 14.11	11.37	1.33	4.44 –17.34	9.57	2.16	5.70 *
Depth at dorsal fin	6.86 – 12.34	10.32	1.10	1.77 – 11.90	8.01	2.04	7.71 *
Depth at pectoral fin	8.82 – 11.92	10.67	0.91	4.23 – 11.56	8.25	1.70	8.86 *
Depth at anus	5.95 – 12.88	10.48	1.30	3.47 - 11.80	8.19	1.86	7.62 *
Dorsal fin height	6.43 –13.53	9.69	1.73	6.87 – 15.06	9.82	1.94	0.40
Dorsal fin base	9.80 –16.67	14.48	1.66	6.76 – 16.67	12.03	2.61	7.01*
Pectoral fin height	9.80 – 17.20	12.48	1.47	7.52 – 15.08	11.04	1.29	5.13 *
Pectoral fin base	2.86 – 8.04	3.86	0.77	1.85 – 4.44	3.06	0.54	4.14 *
Ventral fin height	2.68 – 9.80	7.46	1.08	5.56 – 10.67	7.64	0.92	0.75
Ventral fin base	1.79 – 3.57	2.51	0.50	0.97- 5.79	2.13	0.73	2.03 *
Anal fin height	8.05 –15.79	10.24	1.71	5.78 – 17.86	8.62	1.69	39.23 *
Anal fin base	9.50 – 20.00	12.91	2.35	1.32 – 18.68	12.31	2.43	46.72 *
Caudal fin height	3.91 –13.73	10.28	2.06	9.83 – 24.07	16.70	2.23	18.34 *
Least depth of caudal peduncle	4.14 – 6.47	5.41	0.61	4.49 – 6.19	5.18	0.48	1.30
Length caudal peduncle	4.76 – 17.18	8.47	2.73	6.08 – 13.27	8.97	2.08	1.35
Girth length	23.17-44.13	31.75	2.29	25.17 – 46.83	33.77	3.39	2.55*
Head length	14.55 – 32.41	20.07	4.13	13.74 – 43.33	24.37	4.99	8.42 *
In head length							
Head length	16.00 – 47.00	29.26	5.57	25.00 – 40.00	36.19	2.98	14.02 *
Pre orbital length	28.57 – 53.19	35.12	4.63	31.58 – 40.63	36.16	1.64	2.48 *
Post orbital length	27.66 – 45.95	39.67	3.80	41.03 – 50.00	45.29	1.92	13.90 *
Eye diameter	19.15 – 35.71	25.22	5.24	9.38 – 23.68	18.55	2.82	13.90 *
Inter orbital width	19.15 – 37.50	29.94	3.88	12.50 – 45.71	24.07	6.23	10.92 *
Upper jaw length	8.51 – 25.93	17.43	4.25	13.16 – 33.33	22.92	4.74	10.84 *
Lower jaw length	61.70 – 131.25	102.21	11.89	62.50 – 106.06	81.52	9.59	26.42 *
Gape width	10.71 – 50.00	23.06	8.59	7.89 – 25.71	16.96	4.31	10.05 *
Head depth	14.89 – 60.71	39.20	11.60	15.63 – 39.39	27.92	4.84	16.47 *
Depth at eye	25.53 – 67.86	45.32	10.88	14.29 – 46.15	26.89	6.69	26.01 *
Depth at mouth	8.51 – 42.86	22.59	11.52	5.71 – 30.77	14.08	4.65	12.52 *

* Significant

Table 2.3

Body proportions of *Rhynchorhamphus malabaricus* and *Rhynchorhamphus georgii* as percent of standard length and head length

Character	*(a)* ***R. malabaricus***			*(b)* ***R. georgii***			***Students 't' test***
	Range	**Mean**	**S.D**	**Range**	**Mean**	**S.D**	
In standard length							
Standard length	262.00 - 301.00	282.00	13.47	222.00 - 273.00	251.64	15.55	33.34 *
Total length	113.19 - 114.66	113.86	0.47	112.70 - 115.64	114.02	0.73	0.86
Fork length	104.48 - 107.41	106.26	1.00	105.33 - 106.77	105.98	0.54	1.33
Anal length	83.10 - 85.22	83.94	0.67	81.53 - 84.59	83.42	0.84	2.50 *
Pre dorsal length	80.66 - 84.39	82.95	1.03	80.63 - 84.21	82.55	1.14	1.61
Body depth	7.25 - 11.63	10.54	1.08	8.42 - 10.70	9.67	0.65	3.91 *
Depth at dorsal fin	8.40 - 10.96	9.47	0.85	7.52 - 9.17	8.43	0.60	5.11 *
Depth at pectoral fin	8.65 - 11.30	9.78	0.62	8.61 - 10.42	9.34	0.72	2.25 *
Depth at anus	7.25 - 10.00	9.01	0.77	7.81 - 10.26	8.63	0.67	1.87
Dorsal fin height	5.32 - 7.72	6.84	0.71	6.69 - 8.56	7.45	0.56	3.20 *
Dorsal fin base	11.62 - 13.67	12.33	0.54	11.89 - 13.96	12.91	0.69	3.09 *
Pectoral fin height	8.33 - 12.41	10.53	0.91	8.42 - 11.71	10.38	0.97	0.65
Pectoral fin base	2.00 - 3.44	2.78	0.34	2.39 - 3.76	3.11	0.52	2.11 *
Ventral fin height	4.12 - 7.04	5.50	0.65	4.78 - 7.66	5.45	0.79	0.25
Ventral fin base	1.00 - 2.19	1.75	0.33	1.25 - 2.46	1.81	0.43	0.41
Anal fin height	4.43 - 7.04	5.99	0.78	5.83 - 8.64	6.82	0.79	3.92 *
Anal fin base	6.39 - 8.97	7.77	0.73	7.08 - 10.70	8.34	0.95	2.60 *
Caudal fin height	14.48 - 16.42	15.47	0.71	8.42 - 14.75	10.96	2.20	15.64 *
Least depth of caudal peduncle	3.82 - 5.32	4.49	0.43	3.76 - 4.58	4.31	0.29	1.25
Length caudal peduncle	7.63 - 10.33	8.88	0.77	4.51 - 9.17	7.70	1.31	4.84 *
Girth length	27.55- 31.56	29.77	1.5	22.66 - 26.25	25.25	1.05	2.5 *
Head length	16.17 - 18.45	17.52	0.57	15.98 - 18.92	16.73	0.92	3.83 *
In head length							
Head length	43.00 - 54.00	49.39	2.79	39.00 - 44.00	42.00	1.48	21.16 *
Pre orbital length	38.30 - 42.59	40.39	1.17	38.64 - 46.34	42.26	2.52	5.76 *
Post orbital length	34.00 - 38.46	36.29	1.29	30.23 - 44.19	39.22	3.74	7.73 *
Eye diameter	20.19 - 26.00	23.46	1.74	20.45 - 26.83	23.61	2.22	0.45
Inter orbital width	27.78 - 34.88	31.45	2.09	29.27 - 33.33	31.16	1.55	0.90
Upper jaw length	21.15 – 31.00	24.90	2.72	24.39 - 31.82	27.05	2.12	5.78 *
Lower jaw length	144.68 - 176.74	157.67	7.35	121.43 - 184.09	167.16	17.09	11.36 *
Gape width	13.95 - 25.53	20.58	3.17	20.93 - 27.27	25.12	1.91	11.92 *
Head depth	25.00 - 55.32	45.64	7.93	40.91 - 48.84	47.01	2.57	2.50 *
Depth at eye	36.17 - 53.19	40.91	4.17	33.33 - 48.84	42.58	4.55	3.35 *
Depth at mouth	19.61 - 30.23	22.36	2.56	19.05 - 25.58	22.05	2.24	0.84

* Significant

Table 2.4
Occurrence, season and frequency of the seven species of hemiramphid fishes of Cochin coast.

SPECIES	OCCURRENCE	SEASON	FREQUENCY
Zenarchopterus dispar	Vagrant	November- December	Very rare
Hemiramphus archipelagicus	Migrant	November –December	Common
H. lutkei	Migrant	November –December	Common
Hyporhamphus.(H) xanthopterus	Resident	Throughout the year	Fairly common
H. (H)limbatus	Resident	Throughout the year	Fairly common
Rhynchoramphus malabaricus	Migrant	January-March	Not very common
R. georgii	Migrant	April-May	Not very common

CHAPTER 3.

FOOD AND FEEDING

3. FOOD AND FEEDING

3.1. Introduction

The food and feeding habits of fishes have attracted the attention of fishery biologists even from the early days of investigation in fishery biology. Generally, stomach sampling is employed for gaining knowledge on the feeding habits of fishes. This gives general information on the food items of the fish concerned and it can be useful in evaluating aspects like the rate of feeding, geographical, seasonal and diurnal variations in the composition of food, competition for food and the prey - predator relationship. The qualitative and quantitative studies on the food of fishes are prerequisites to formulate strategies for the judicial exploitation and maintenance of the biodiversity of the fishery resources.

3.2. Review of literature

The morphology of organs of alimentation in fishes has attracted the attention of ichthyologists since very early times. The first indication of the alimentary canal and the nature of feeding in fish is found in the voluminous works of Cuvier and Valenciennes (1828-1849) in which the authors observed that the ratio of intestinal length to body length was grater in herbivores than in carnivores, a fact that is true not only for fishes but also for many other groups of vertebrates. Jacobshagen (1911) working on a large number of fishes agreed in general with the findings of Cuvier and Valenciennes. The earliest significant contribution on the study of food and feeding was made by

Day (1882) who investigated the food of herring. Some of the important works that followed are by Herdman and Corbin (1892), Scott (1902), Johnstone (1906) and Hardy (1924). Since then a number of papers dealing with the food and feeding habits of fishes have been published.

Substantial work has been done by various workers on the food and feeding habits of commercially important fishes from Indian waters. Some of the early studies are those of Hornell and Nayadu (1924) on *Sardinella longiceps*, Devanesan (1932) on S. *gibbosa*, Job (1940) on the perches of Madras coast and Chacko (1949) on some fishes of the Gulf of Mannar. Subsequently, a number of studies on the food of commercially important species from different localities have been carried out by various workers. George (1953) related good fishery of sardine and mackerel along the west coast of India with the abundance of plankton in the inshore waters from September to December. Seshappa and Bhimachar (1955) reported a good fishery of the Malabar sole coinciding with the abundance of polychaetes in the benthos while a good fishery of silver bellies and white baits was correlated with the abundance of planktonic copepods by Venkataraman (1960). Qasim (1972) reviewed the existing information on the food and feeding habits of some marine fishes from the Indian waters. Allen and Webb (1966) have pointed out the significance of the relationship between the structure and position of the mouth of fishes and their food and feeding habits. Allen and Welsh (1968) related the daily feeding periodicities, food uptake rates and dietary changes with hour of day in some lake fishes.

Investigations on the feeding habits of some fishes of the Calicut and Madras coasts by Venkataraman (1960); of the Gulf of Mannar and the Palk Bay by Talwar (1962a); of the Bombay coast by Suseelan and Nair (1967) and of some species of *Priacanthus* from the deeper regions of the Indian seas by Philip (1994) are a few other works on the subject. Among others particular mention should be made of the works of Bhimachar (1952), Sarojini (1954), Menon and Chacko (1957), Kuthalingam (1959), Noble (1962), Dhulked (1962), Kagwada (1964), Pandian (1966), Rao (1968), Jayaprakash (1974), Sreenivasan (1974; 1979) David and Rajagopal (1975), Lazarus (1977), Pati (1977), Saxena (1980), Nair (1982), Sunder *et al.* (1984), Mohan (1985), Kurup and Samuel (1986, 1988), Mathew (1988), Dasgupta (1988), Geetha *et al.* (1990), Rao and Rao (1991), Sastry (1993), Sivakami (1996), Dasguptha (1996), Badrudeen and Madhavan Pillai (1996), Pandian and Rahman (1999) and Basudha and Viswanath (1999).

Studies on the anatomy and histology of the alimentary canal of *Megalops cyprinoid* were carried out by Pasha (1964). Adaptation of the alimentary canal tract to feeding habits in fishes of genus *Channa* was pointed out by Dasgupta (2000). Food and feeding habits of *Puntius melanompyx* (Day) was reported by Mercy *et al.* (2001), food and feeding habits of *Glossogobius giuris* from Gostani estuary was studied by Rao and Rao (2002) and the dial of feeding patterns, gastric evacuation rate and diets of the mullet, *Valamugil seheli* (Forskal) in the Mulki estuary, west coast of India was given by Moorthy *et al.* (2002).

Pioneering studies on the food and feeding habits of hemiramphids from different regions are those of Schlesinger (1909) on *Scombresocidae*, *Uchida* (1930) on *Hemiramphus sajori*, Smith (1933) on *Hemiramphus* Cuvier, Devanesan (1937), Gnanamuthu (1943) and Chacko (1949) on *H. georgii*, Vijayaraghavan (1957) on *Hemiramphus far* and Ling (1958) on *Reporhamphus melanochir.*

All these works are related mainly to limited period and aspects like seasonal variations in the composition of gut contents have not been attempted. Thomson (1959) and Berkley and Houde (1978) have reported on food and feeding habits of *H. ardelio*, *H. australis*, *H. brasiliensis* and *H. balao.* Upskaya (1980) gave a report on the feeding and food requirements of the young of the small wing flying fish, *Oxyporhamphus micropterus micropterus.* Coetzee (1981) analysed the gut content of the needle fish, *Hyporhamphus knysnaensis* from Rendevlei, Southern Cape. Robertson and Klumpp (1983) investigated the feeding habit of southern Australian garfish *Hyporhamhus melanochir.* Klumpp and Nichols (1983) described the nutrition of the Southern Sea garfish *Hyporhamphus melanochir.* Chandrasoma and Wijeratne (1990) reported the food and feeding of *Hyporhamphus gaimardi* in Uda Walawe reservoir, Sri Lanka. *Talwar* (1962 a) conducted a detailed study on these aspects of *Hyporhamphus georgii*, *H.*

quoyi and *Hemiramphus marginatus* from the Gulf of Mannar and Palk Bay in the Indian Coast. The present study was undertaken with a view to providing detailed information on the various aspects of food and feeding habits of *Hyporhamphus (H) limbatus* and *H. (H) xanthopterus* common in coastal waters of Cochin, Kerala, India.

3.3. Materials and Methods

Monthly samples of fishes were collected from different fish landing centres, markets of Cochin coast and some fishing grounds in Vembanad Lake like Eloor, Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map. (Fig. 1.1). A total number of 1088 specimens (528 males and 560 females) of *H.(H)limbatus* and 970 specimens (375 males and 596 females) of *H.(H) xanthopterus* were examined. After fully establishing the identity of these fishes, their total length to the nearest mm, weight to the accuracy of 0.1g, sex, maturity stages and feeding intensity were noted. The guts were dissected out and preserved separately in 5% neutral fomalin for further analysis.

The relative length of gut (RLG), a useful index which gives an idea of the nature of food is calculated using the formula

$$RLG = \frac{Length\ of\ the\ gut}{Total\ body\ length}$$ (Al-Hussainy, 1949).

It has been observed by Job (1940) that when a fish is captured or put into formalin for preserving, very often it vomits the remains of the last meal, due to the shock sustained so that the stomach may be empty while the gut may show the presence of partially digested food matter. Because of this, Kjelson *et al.*(1975) followed the method of examining the entire alimentary canal of fishes. In the present study also the contents of the entire alimentary canal were taken for examination. Food organisms were generally found uniformly distributed throughout the greater part of the alimentary tract, and for this reason it was considered necessary to examine the contents of the whole digestive tract. Each gut was split open and all the contents were washed into a petri dish and examined under a binocular microscope.

The fish being omnivorous, the point method of Swynnerton and Worthington (1940) and Hynes (1950) as reviewed and modified by Nair and Sobhana (1980) and adopted by Kurup and Samuel (1988) was found to be suitable in evaluating the different food organisms. The food items were identified upto generic level or groups, depending on their state of digestion. For evaluating the preference of food consumed, the different food items were assessed by a general examination and listed under the categories 'swarms', 'plenty', 'common', 'few', 'little' and 'rare'. Giving due consideration to the size of the food organisms as well as its abundance points 50,40,30,20,10 and 5 were allotted to each category respectively. From these points volume for each item and its percentage in the total volume of all stomach contents were calculated each month.

Similarly the percentage occurrence of different items of food was determined from the total number of occurrence of all items each month. To evaluate the importance of each food item, the index of preponderance proposed by Natarajan and Jhingran (1962) was followed. This method simultaneously takes into account both volumetric and occurrence methods in respect of individual food element based on its relative importance. The monthly averages obtained by volumetric and occurrence methods were substituted in the following formula

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

Where,

'I_i' is the index of preponderance; V_i and O_i represent the percentage volume and occurrence of particular food (i), respectively.

The intensity of feeding can be judged by the degree of distension of the stomach, or by the quantity of food contained in it. The distension of the stomach was judged visually and classified as 'gorged' or 'distended' 'full', ¾ full,' ½ full', 'little' or 'trace' and 'empty' with due regard to the distension to its walls and the quantity of the food in it, and points were allotted as 100, 75, 50, 25, 10 and 0 respectively. Stomachs were considered 'gorged' when it was expanded fully with packed food and the walls thin and transparent, 'full' when it was filled with food normally and the walls thick and intact and '¾ full' when it was partly collapsed and walls thick. Stomachs were designated '½ full' and 'trace' based on the food present and nature of the walls. For the sake of convenience, fishes with 'gorged' and 'full' stomach were considered to have actively fed, '¾ full', '½ full' stomach as moderately fed and 'trace' as poorly fed. The percentage frequency of 'empty', 'trace', '½ full,' ¾ full' and 'gorged' stomachs were calculated from the total number of fishes examined each month. The degree of fullness of the stomach was noted every month and the percentage occurrence of stomach with different intensity of feeding was worked out.

The gastrosomatic index (GSI) was calculated to find out the feeding intensity using the formula

$$\mathrm{GSI} = \frac{\text{wt. of the gut (g)}}{\text{weight of the fish (g)}} x100 \quad \text{(Desai, 1970)}:$$

and the average was calculated for each month.

3.4. Results

The alimentary canal is simple and takes a straight course from the oesophagus to the anus in both *H. (H) limbatus* and *H. (H) xanthopterus*. The stomach and pyloric caecae are absent. Such a type of alimentary tract is classified by Jacobshagen (1911) as the most primitive type under category 'A' of his classification. Similar type of primitive gut was described for *H.*

georgii by Talwar (1962a). In hemiramphids the lower jaw projects into a beak often a third of the length of the fish itself, with the mouth opening above it. Half beaks are usually surface feeding fishes.

3.4.1. *Hyporhamphus (H) limbatus*

3.4.1.a. Food composition in relation to size

Juvenile fishes were found to feed on smaller food items. In the early stages they consumed algae like *Leptocylindrus* sp., *Skeletonema* sp., *Thalassiosira* sp., *Coscinodiscus* sp., *Pleurosigma* sp., *Nitzschia* sp., *Navicula* sp., *Biddulphia* sp., *Melosira* sp., *Hemidiscus* sp., *Spirogyra* sp., *Schizothrix* sp., *Lyngbya* sp., *Nostoc* sp. and *Oscillatoria* sp.

No significant variation could be observed between the food of juveniles, adult males and females of *H. (H) limbatus*. The percentage composition of different food items or the index of preponderance of food items of *H. (H) limbatus* is given in Fig. 3.1 and Table 3.1. The results of the study reveal that prawns constituted the most abundant food item of adult *H. (H) limbatus* followed by algae, other crustacean parts, polychaetes worms, nematode parts, digested animal and vegetable matter and mud particles.

Among prawns, *Penaeus* sp. constituted the major part of the diet throughout the year. Algae that occurred in the food in all the months of the year were *Leptocylindrus* sp., *Skeletonema* sp., *Thalassiosira* sp., *Coscinodicsus* sp., *Pleurosigma* sp., *Nitzschia* sp., *Navicula* sp., *Biddulphia* sp., *Melosira* sp. and *Hemidiscus* sp.. Maximum presence of algae in the stomach contents was found during the period from June to December. They include *Spirogyra* sp., *Schizothrix* sp., *Lyngbya* sp., *Spirulina* sp., *Nostoc* sp., and *Oscillatoria* sp. Among them the percentatge of *Oscillatoria* sp., was more. Crustacean remains include crustacean larvae like zoea and prawn larvae. Insect parts were noticed in the stomach content. The polychaete worms also formed a fraction of their food. Some worms belonging to the family *Terebellidae* and *Glyceridae* were noticed. Nematodes in small fractions were noticed in the stomach. The other contents of the stomach were digested animal and vegetable matter. The rest of the matter inside the stomach was mud and sand. The presence of both animal and plant matter in the gut content of *H.(H) limbatus* shows that these fishes are omnivorous.

3.4.1.b. Feeding intensity

The percentage occurrence of stomach in different degrees of fullness in adult *H. (H) limbatus* is given in Fig 3.2 and Table 3.3. 'Empty' stomachs were absent and the percentage of 'gorged' stomachs was lower than that of the other categories. 'Gorged' stomachs were absent in April, November and December. The highest percentage of 'gorged' stomach was noticed in February (13.64%) and the lowest in October (3.23%). 'Full' stomachs were present in all the months and the feeding intensity was observed to be high throughout the year. Their percentage was the highest in February (29.33%) and the lowest in December (14.55%). '¾ full' guts were also abundant throughout the year with the highest percentage during September (50.00%)

and the lowest during February (20.45%). Fishes with '½ full' and '¼ full' stomachs were present throughout the year. Fishes with '½ full' stomachs were more in April (39.58%) and less in September (18.75%), respectively. Guts with 'trace' or 'little' food contents were observed in all the months with the highest percentage in May (19.23%) and the lowest in September (4.69%). Fishes with empty stomachs were not observed during this study.

The monthly variations in stomach fullness under the categories, 'actively fed', 'moderately fed' and 'poorly fed' are shown in Fig. 3.3. The percentage occurrence of 'actively fed' specimens was high in January, February, June and July. From March and June onwards there was gradual increase in feeding intensity followed by a deep decline during April-May and November-December. The percentage occurrence of 'moderately fed' stomach was high from February to May and low from September to December. The percentage occurrence of 'moderately fed' was found to be higher than that of actively fed stomachs. The percentage occurrence of poorly fed stomach was low in all the months.

3.4.1.c. Seasonal variations in diet

Seasonal variations in the food of *H. (H) limbatus* during the two-year period (from April 2001 to May 2002) have been studied (Table 3.1).

During pre-monsoon period (February – May) the major food item was prawns and algae formed the next major component the food throughout the season. Insect parts and wings were noticed in all the months except

January. A considerable amount of digested matter comprising both animal and vegetable matter was present throughout the season. Nematode parts were also noticed during February.

During the monsoon season (June – September) also body parts of prawns and algae were abundant. Insect wings and parts were observed only in September. Polychaete remains were present throughout the season. Sand and mud particles were also noticed in May, July and August.

During the post-monsoon season (October – January) algae were found to be abundant along with prawn particles. Polychaete remains were noticed in all the months. Insect parts were present only in September. Mud particles were noticed only in December. Presence of nematodes during September, October and November was also noticeable.

3.4.1.d. Feeding in relation to spawning

Any significant difference was not noticed in the rate of feeding depending on spawning. The guts were less 'gorged' during April, November and December. More than a reduction in feeding, the animal exhibited a selection in feeding during this period. For the purpose of analysis of the gut contents the specimens were grouped as

i. Maturing (stage II – IV)
ii. Fully ripe – spawners (stage V-VI)

iii. Spent (stage VII)

The main diet during the maturing phase was algae. Prawns were frequently observed. Polychaete remains and insect parts were also encountered. The diet of the spawners mainly consisted of prawn parts. Food of the spent fishes was similar to that of immature fishes and consisted of filamentous algae, diatoms, prawns, other crustacean remains and insect parts.

3.4.1.e. Relative length of gut (RLG)

The relative length of gut was found to be between 0.4 and 0.6.

3.4.1.f. Gastro-somatic index (GSI)

Gastro somatic index varied monthly (Fig. 3.4). A sharp fall in the GSI value was seen in March and April followed by an increase in May to October. Succeeding this peak, a general decrease in the value was noted in November and December. The rise and falls in the GSI values coincide with the spawning season of the fish.

3.4.2. *Hyporhamphus (H) xanthopterus*

3.4.2.a. Food composition in relation to size

The percentage composition of different food items of the juveniles and adults of *H. (H) xanthopterus* is given in Fig. 3.5 and Table 3.2. The major food constituents of *H. (H) xanthopterus* could be grouped into filamentous algae, diatoms, prawn parts, insect wings, parts of nematode worms, crustacean remains and mud particles.

The analysis of the gut content of the juveniles revealed that algal filaments and other vegetable matter formed the major portion of the food. They include *Spirogyra* sp. and *Ulothrix* sp. of Chlorophyceae, *Oscillatoria* sp., *Lyngbia* sp. *and Nostoc* sp. of Cyanophyceae, *Skeletonema* sp., *Coscinodiscus* sp., *Nitzschia* sp., *Biddulphia* sp., *Thalassiosira* sp. *and Pleurosigma* sp. *of* Bacillariophyceae. Rare occurrence of animal matter was also noticed.

On analysing the stomach content of adults, no significant variation could be observed between the food habits of males and females. They consumed algae like *Spirogyra* sp., *Ulothrix* sp. *Oedogonium* sp. *Oscillatoria* sp. *Lyngbia* sp. *Spirulina* sp. *Nostoc* sp., *Coscinodisucs* sp., *Fragilaria* sp., *Pleurosigma* sp., *Navicula* sp., *Skeletonema* sp., *Nitzschia* sp., *Melosira* sp., *Campylodiscus* sp., *Biddulphia* sp., *Leptocylindrus* sp., *Thalassiosira* sp., *Gyrosigma* sp., *Guinardia* sp. and *Pinnularia* sp. The prawns include *Parapenaeopsis stylifera, Metapenaeus dobsoni* etc. Other crustaceans such as copepods and mysids were also present in lesser quantities. However, nematode worms were encountered occasionally. Insect parts, prawn larvae and other crustacean larvae also formed minor fractions of the diet. Digested matter comprising animal and vegetable matter formed another major category whereas mud and sand formed a small category. This shows that *H. (H) xanthopterus* is omnivorous.

3.4.2.b. Feeding intensity

The percentage occurrence of feeding intensity of *H. (H) xanthopterus* is given in Fig. 3.6 and Table 3.4. In general the percentages of 'gorged' and 'full' stomachs were high compared to those of other categories. Fish with 'gorged' stomach were present in all months except July. The highest percentage of 'gorged' stomachs was observed in March (22.39 %) and the lowest in August (1.96 %). Fishes with 'full' stomachs were more in March (37.31 %) and the minimum (13.7 %) in August. '¾ full' and '½full' stomachs were present throughout the year. The percentage of '¾ full' stomachs ranged between 39.13 % in December and 15.69 % in August. The highest percentage of '½ full' gut was noticed in July (43.21 %) and the lowest in March (14.93 %). Stomachs with 'little' or 'trace' food items were fewer compared to the other groups. The highest percentage of occurrence was found in August (29.41 %) and the lowest in March (2.99 %). Empty stomachs were not found throughout the year:

The results of the monthly variations in stomach fullness under various categories are shown in Fig. 3.7. It is seen that the percentage occurrence of 'actively fed' specimens was high from January to April and September to December. From May onwards there was a gradual decline in feeding intensity followed by a deep decline during June to August. This was followed by a sudden increase in October to December. The percentage occurrence of 'moderately fed' individuals was found to be high in all the months except in March. The percentage occurrence of poorly fed stomach was low in all the months.

3.4.2.c. Seasonal variations in the food

Seasonal variations in the food of juveniles and adults of *H. (H) xanthopterus* during the two year period from May 2001 to April 2003 are presented in Table 3.2. Any significant variation in feeding could not be observed in both the years.

In the adults of *H. (H) xanthopterus* algae and prawns appeared as major food items throughout the year. Algae dominated from June to January. The most dominant one was *Spirogyra* sp. During pre-monsoon period i.e., February, March, April and May a drop in the index of algae could be noticed. Algae dominated the food during May, June, August, February, March and April. Prawns formed another major food item of *H. (H) xanthopterus* throughout the year. Insect wings and parts appeared in the diet of these fishes during August, February, March and April. Nematode parts were noticed in the gut *of H. (H) xanthopterus* in August, September, October, November and February. Parts of crustaceans like mysids, prawn larvae and other crustacean larvae were found in August, December, March and April. Digested vegetable and animal matter formed a considerable part of the diet throughout the year. Mud and sand particles were observed during February, March, May, July and August.

3.4.2.d. Feeding in relation to spawning

During the spawning season the feeding intensity was less. The animal exhibited a selection rather than a reduction in feeding during this period.

For gut content analysis the fish were grouped as

(i) Maturing (stage II- IV)

(ii) Fully ripe – spawners (stage V – V I)

(iii) Spent (stage VII)

The main diet during maturing phase was algae. Prawn parts are frequently observed. The diet of the spawners mainly consisted of prawn parts. Algae especially *Spirogyra* sp. were also encountered. Food of the spent and immature fishes also consisted of filamentous algae, diatoms, prawn parts, insect wings, other crustacean remains, nematode remains, digested matter and mud particles.

3.4.2.e. Relative length of gut (RLG)

In *H. (H) xanthopterus* the RLG value was found to be between 0.5 and 0.8.

3.4.2.f. Gastro-somatic index (GSI)

The GSI showed variations during different months of the year (Fig.3.8). During June to August the GSI values were low coinciding with the decrease in feeding intensity of the fishes. In all other months the GSI values were high which may be due to active feeding. The decrease in feeding intensity coincided with the spawning season of the fish.

3.4.3. Feeding in relation to habitat

H. (H) limbatus and *H. (H) xanthopterus* collected from places near the sea and from the backwaters showed variations in their food contents. Animal matter was abundant in specimens collected from coastal area whereas they were in small numbers in specimens collected from backwaters. Not much difference was noticed in the presence of algal filaments in the gut contents of fishes from the two localities. *Spirogyra* sp. was the most common form present in the gut contents of fishes from the backwaters whereas they were very few in specimens from the marine environment. Comparatively more vegetable matter was observed in the stomach content of fishes from the backwaters.

3.4.4. Feeding intensity in relation to day and night hours

Significant difference in day and night feeding was noticed in *H. (H) limbatus* and *H. (H) xanthopterus*. Reduced rate of feeding was noticed in the dark hours of the day. Fishes caught in the night hours and early in the morning never had 'gorged' or 'full' stomachs and only semi filled stomachs with digested matter were observed. This may be due to the lack of active feeding during night. The gut walls of fish caught in the night were thick and collapsed compared to the guts of fish collected during daytime, in which the gut walls were thin and transparent.

3.4.5. Comparison of food composition

Comparative study of the gross food composition of *H. (H) limbatus* and *H. (H) xanthopterus* from May 2001 to April 2003 was given in Fig. 3.9. and Fig. 3.10. The gut content of *H. (H) limbatus* consisted of 41.53% algae, 36.46% prawn parts, 0.49% other crustacean remains, 0.51% nematodes, 2% insect parts, 2.09% polychaete remains, 13.53% digested matter and 3.38% mud particles. The gut content of *H. (H) xanthopterus* consisted of 56.24% algae, 27.72% prawn parts, 1.47% other crustacean remains, 0.47% nematode parts, 0.95% insect parts, 9.34% digested matter and 3.82% mud particles.

3.5. Discussion

The juveniles and adults of H. *(H) limbatus* and *H. (H) xanthopterus* are surface feeding omnivores. They feed on filamentous algae, diatoms, prawns and other crustaceans, insects, polychaetes, and other nematode parts. The lower jaw projects into a beak often a third of the length of the fish itself, with the mouth opening above it in both H. *(H) limbatus* and *H. (H) xanthopterus.* The smaller mouth and gut of hemiramphids might not have permitted them to prey upon large organisms.

It is evident from various items of food found in the stomach of the fish that these species are selective surface or sub-surface feeders on pelagic plant and animals including prawns and algae which form the bulk of the food, although a great variety of other organisms are available within the habitat of the fish. Chacko (1949) reported that H. *georgii* of the Gulf of Mannar is a plankton feeder. The occurrence of *Creseis acicula* and foraminifers in the guts of H. *georgii* of Krusadi islands has also been reported by Gnanamuthu (1943). Vijayaraghavan (1957) has observed in his studies on *H. far* from Madras Coast that it is a "typical surface feeder often browsing among seaweeds and algae and supplementing this vegetable diet with an equal amount of crustacean and other zooplankton". Thomson (1959) found the seagrass *Zostera* to be the major food item of the Australian halfbeak, *Hyporhamphus regularis ardelio*. In *H. australis* he found algae and crustaceans to be the major food.

Talwar (1962a) studied the food and feeding relationship of *Hyporhamphus georgii*, H. *quoyi*, *Hemiramphus marginatus* and *H.far* from the Gulf of Mannar and Palk Bay and concluded that *H. georgii* and *H. marginatus* are omnivores whereas *H. quoyi* and *H. far* feed exclusively on seagrass and green algae and occasionally on polychaetes. In a study of the food habits of West Indian reef fishes, Randall (1967) found only animal matter in the stomachs of *Hemiramphus balao*. Berkley and Houde (1978) studied the half beaks from southeast Florida and reported that larval *Hemiramphus brasiliensis* ate zooplankton. Juveniles and adults of H. *brasiliensis* ate both seagrass and zooplankton, but *H. balao* ate only zooplankton. Coetzee (1981) reported *H. knysnaensis* from Rondevlei, Southern Cape as an omnivore. Robertson and Klump (1983) studied the feeding habits of the southern Australian garfish, *Hyporhamphus melanochir* and reported that they are diurnal herbivores and nocturnal carnivores. Chandrasoma and Wijeratne (1990) analysed the gut content of *Hyporhamphus gaimardi* of Uda Walawe reservoir, Sri Lanka and found out that 80% of their diet consisted of crustacean zooplankton.

The major difference in food habits between the two species is that *H. (H) limbatus* feed mainly on prawns along with algae and other animal and vegetable matter whereas *H. (H) xanthopterus* consumed algae, especially *Spirogyra* sp. in large quantities besides prawns, diatoms and other animals and plants. The different feeding habits may be due to the regional difference in the nature of the environment and availability of food and seasonal variations.

Variations in the quantity of different food items of the gut content were observed in the fishes caught from different localities. The experiments of Drenner *et al.* (1978) show that the feeding selectivity is influenced by the capture probability which in turn is directly proportional to the abundance of the food organisms in the habitat. The suggestions of Jacob and Nair (1982) and Cyrus and Blaber (1983) that the composition of the diet is probably a reflection of the food in the habitat, sustains validity in this case.

In *H. (H) limbatus* 'gorged' stomachs were not observed in April, November and December whereas in *H. (H) xanthopterus* 'gorged' stomachs were not observed in July. These months are reported to be the breeding period of the fish. The increased demand of the maturing gonads for space may be the probable reason to avoid very active feeding and absence of 'gorged' stomachs during these months. Moderate feeding was observed during this period as fishes with 'empty' stomachs were absent. Since food scarcity is very rare regarding an omnivore, only physiological parameter like breeding could be considered to influence feeding. In *H. (H) limbatus* the percentage occurrence of 'gorged' and 'full' stomachs was less compared to *H. (H) xanthopterus*. The main difference is the supply of food in the habitat, which is high in the Vembanad estuary compared to the coastal areas of Cochin. Bhimachar (1952) reported that the Indian Mackeral *Rastrelliger kanagurta,* feeds throughout the year although the feeding intensity varied from season to season.

In the present study diurnal variation in feeding is noticed for both *H. (H) limbatus* and *H. (H) xanthopterus*. Low rate of feeding was noticed during night in both the species. The Australian garfish *Hyporhamphus melanochir* is a diurnal herbivore and a nocturnal carnivore (Robertson and Klumpp, 1983). Rao (1964) reported that feeding takes place only to a limited extent in darkness and that too probably by contact. Northcote and Lorz (1966) stated that intensity of light influences prey selection and variation in feeding can occur according to day-night changes. Reduced feeding is observed in *Mystus gulio* (Pandian 1966) and *Scatophagus argus* (Mathew 1988) during night time.

Seasonal variation in the feeding habit of *H. (H) limbatus and H. (H) xanthopterus* was studied. During pre-monsoon periods, diatoms dominated and during monsoon season filamentous algae dominated whereas during post-monsoon season all of them were observed. Prawns were found to be present in the diet throughout the year. Seasonal variation in feeding was observed in both the species during spawning season. The main diet of maturing *H.(H) limbatus* and *H.(H) xanthopterus* was algae and that of spawners was prawns and that of spent fishes consisted of algae, prawns, other crustaceans and insects.

H. (H) limbatus and H. (H) xanthopterus seem to be highly selective in their feeding with a preference for vegetable matter at the time when the gonads are ripening and for prawns in the spawning and for vegetable and animal matter during spent stage. Similar observations were made by Talwar (1962a) on the food and feeding relationships of the half beak fishes, *H. georgii, H. quoyi*, *H. marginatus* and *H. far* from the Gulf of Mannar and Palk Bay. He reported that *H. georgii* is omnivorous and highly selective in its feeding with a preference for vegetable matter at the time when the gonads are ripening and for prawns in the spawning and for algae, prawns and other animal and vegetable matter during spent stages whereas others feed mainly on *Cymodocea* sp., green algae, diatoms, foraminifers, polychaetes, *Acartia erythraea, Lucifer* sp. and *Creseis acicula*

The above studies have shown that different types of feeding relationships were maintained by different species. A shift in emphasis is noticed as regards certain food elements depending on the maturity condition in *H. (H) limbatus and H. (H) xanthopterus* rather than on the availability of food items. *H. (H) limbatus and H. (H) xanthopterus* may be considered to be selective in their food habits as noticed in the case of *H georgii*, *H. quoyi*, *H. marginatus* and *H. far* by Talwar (1962 a). Several authors like Pearse(1915), Lebour(1919), Russel (1929), and Shelbourne(1953) have emphasized the capacity of some fishes for selective feeding. A similar observation was made by Thomson (1959) on *Hemiramphus ardelio* and Talwar(1962 a) on *H.georgii and H. quoyi.*

It is interesting to note that there was no evidence of a cessation of feeding during spawning in both H. *(H) limbatus and* H. *(H) xanthopterus*. Among these species not a single fish with a completely 'empty' gut was encountered during the whole period of study. Suyehiro (1935) working on the Japanese flying fish, *Cypselurus agoo* and Hatanaka (1956) on the Japanese saury *Cololabis saria* drew similar conclusions. Talwar (1962a) noted similar condition in *H.georgii* , *H.quoyi,H.marginatus*, and *H. far*. However a total cessation of feeding was reported in Australian garfish, *Reorhamphus melanochir* by Ling (1958).

In *H. (H) limbatus* and *H. (H) xanthopterus* the relative length of gut (RLG) was found to be ranging from 0.4 to 0.6 and 0.5 to 0.8 respectively. It is evident that RLG has a close relationship with the nature of food of the fishes. In the herbivorous fishes such as *Labeo rohita* and *L. genius* (Das and Moitra, 1956 a) the RLG values were about 12 and 9.5 respectively. In omnivorous fishes the RLG values were lower as in *Puntius conchonius (*3.3) and *Barbus hexastichus* (2.3). In carnivorous fishes the RLG values were generally low, as in *Bagarius bagarius* (0.8) and *Notopterus chitala* (0.4) (Das and Moitra, 1956a). Talwar (1962 b) reported that *H. margiantus, H. georgii* and *H. quoyi* are zooplankton feeders and carnivores. Eventhough the RLG values are low in both H. *(H) limbatus* and *H. (H) xanthopterus they* are considered as omnivores because both plant and animal matter are found in the guts of both.

In *H. (H) limbatus* and *H. (H) xanthopterus* the gastro-somatic index (GSI) differed every month. In *H. (H) limbatus* from February onward there was a gradual decline in the gastro-somatic index till May and another decline from October to December. This may be due to the decline in feeding intensity of the organism, due to the peak spawning activity. During February and July gastro-somatic index was high which can be due to active feeding.In *H. (H) xanthopterus* the lowest values of GSI from June to August coincided with peak spawning period. A subsequent increase in the value of GSI in October and December may be due to active feeding after peak spawning in July. These findings conforms with the views of Sultana *et al.* (1980) in *H.gaimardi* where the high index value coincided with the peak spawning periods .

The difference in the food habit of *H. (H) limbatus and H. (H) xanthopterus* from other hemiramphids in other parts of the world may be due to the regional difference determined by the nature of the surface waters, availability of food and seasonal variations . Similar observations were made by Qasim (1972) in other teleosts of tropics region. Fishes with 'empty' stomach were absent and poorly fed individuals were few in number during the spawning period. Feeding intensity was found to be high in immature and maturing forms. At the beginning of the breeding season the fish becomes more voracious but when breeding is progressing feeding becomes steady.

It can be concluded that *H. (H) limbatus and* H. *(H) xanthopterus* are omnivores consuming a wide range of food items. The juveniles feed mainly on algae and crustacean larvae. Both of them are selective surface feeders. The feeding decreases during night time and during the spawning season. No significant difference in the composition of the diet of the two sexes has been observed. *H. (H) limbatus* and *H. (H) xanthopterus* are two co-existing species. The diet is almost identical both qualitatively and quantitatively. Their daily feeding rhythms also coincide. Hartley (1948) has suggested that there is a greater food overlap in fish which occur together than in mammals or birds. This contradicts the accepted concept that animal species from the same or similar habitats show a high degree of "ecological exclusion".

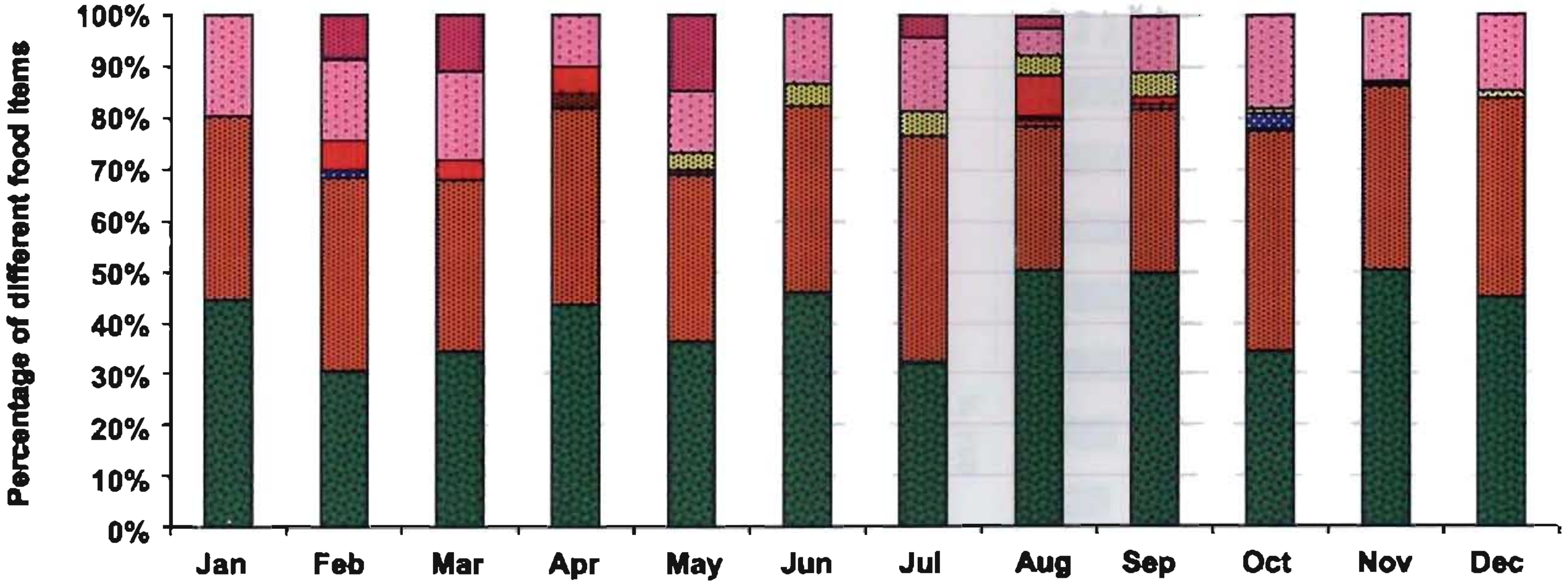


Fig. 3.1
Percentage composition of different food items in *H. (H) limbatus*

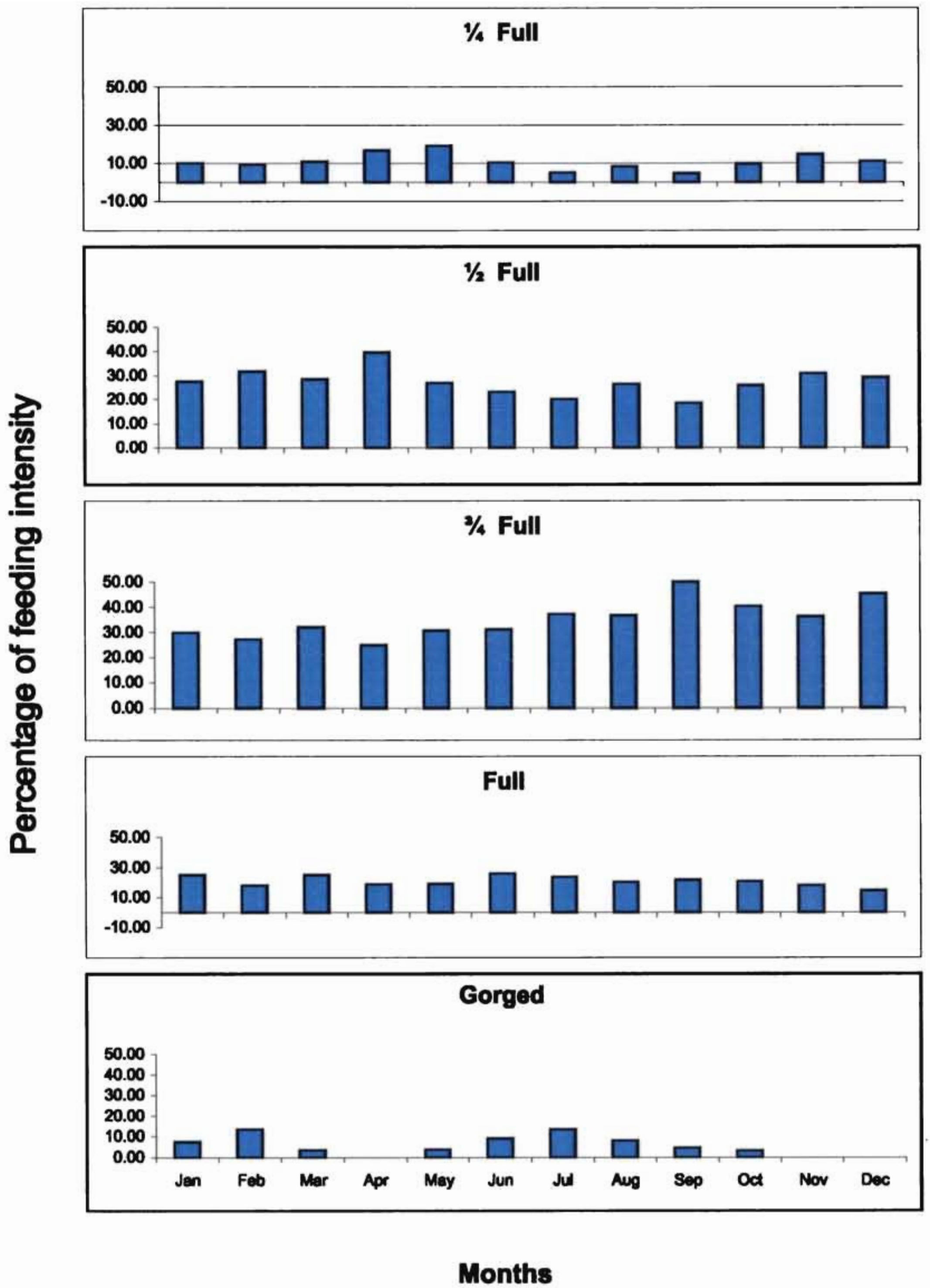


Fig. 3.2

Monthly percentage of feeding intensity in *H. (H) limbatus*

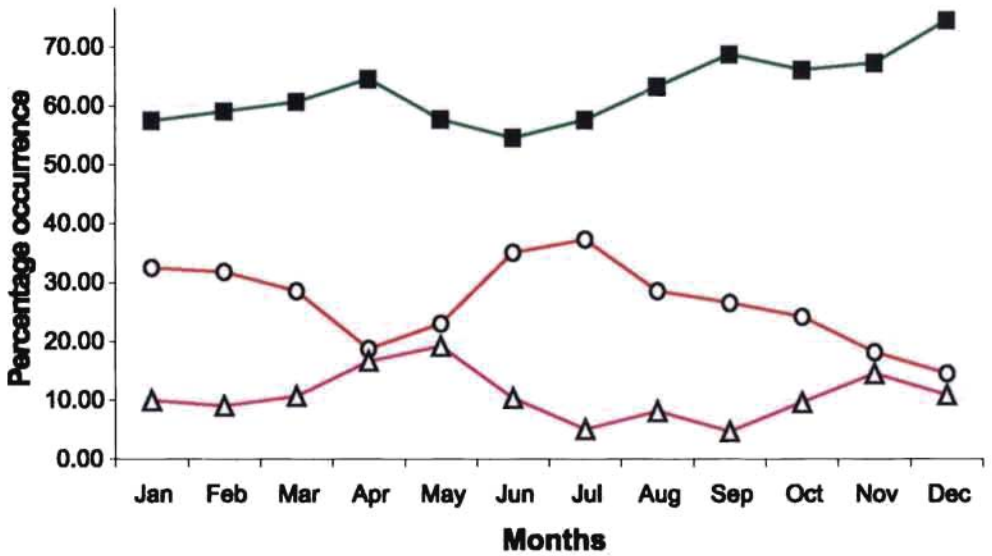


Fig. 3.3
Monthly percentage occurrence of different feeding intensities in *H. (H) limbatus*
—○— Actively fed—■— Moderatly fed—△— Poorly fed

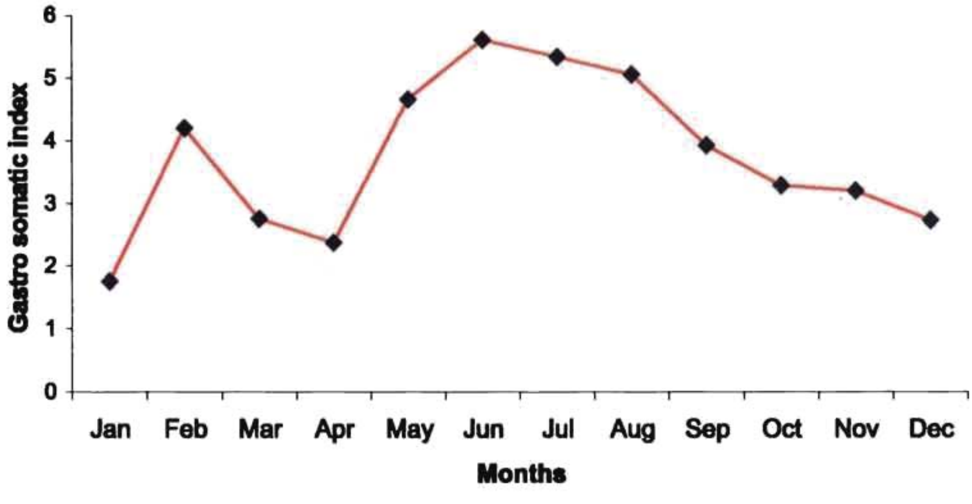


Fig. 3.4
Gastro-somatic index of*H. (H) limbatus*

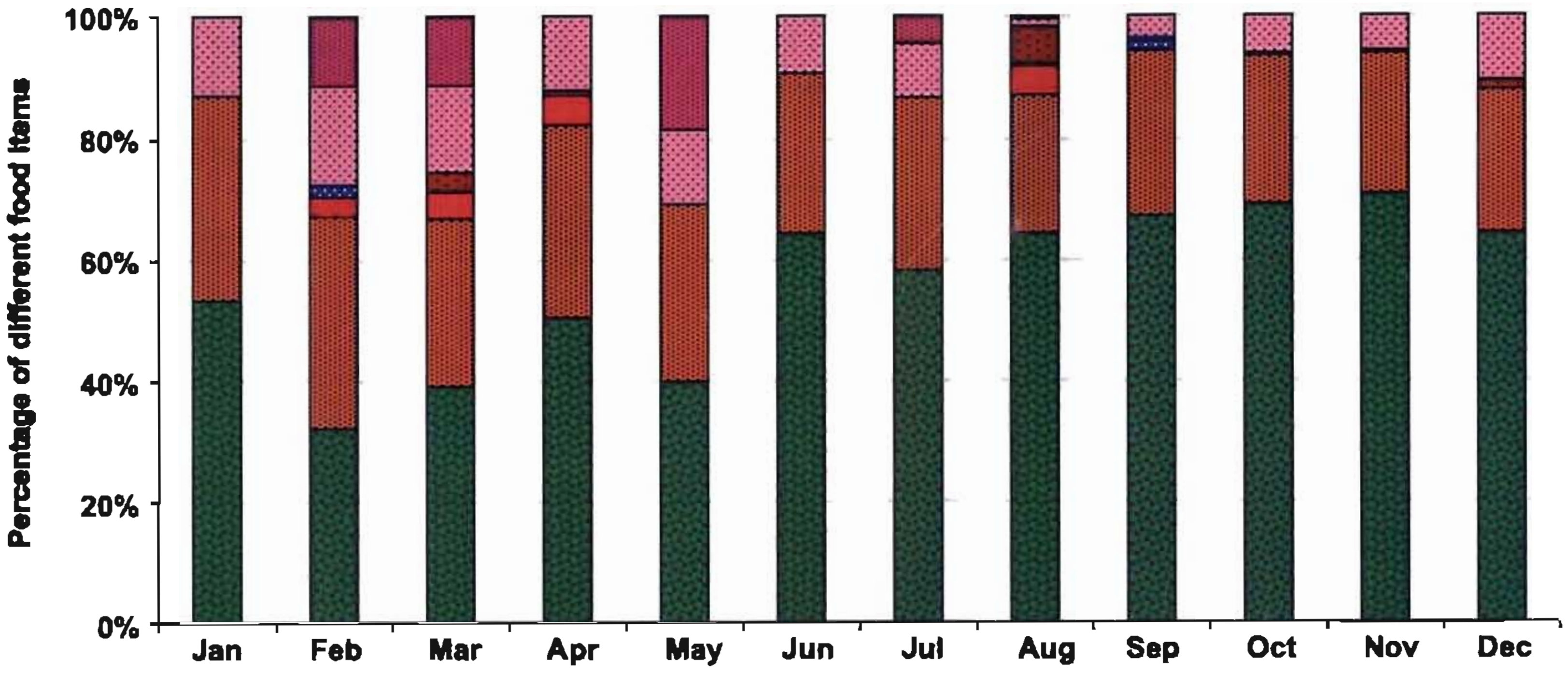


Fig. 3.5
Percentage composition of different food items in *H. (H) xanthopterus*

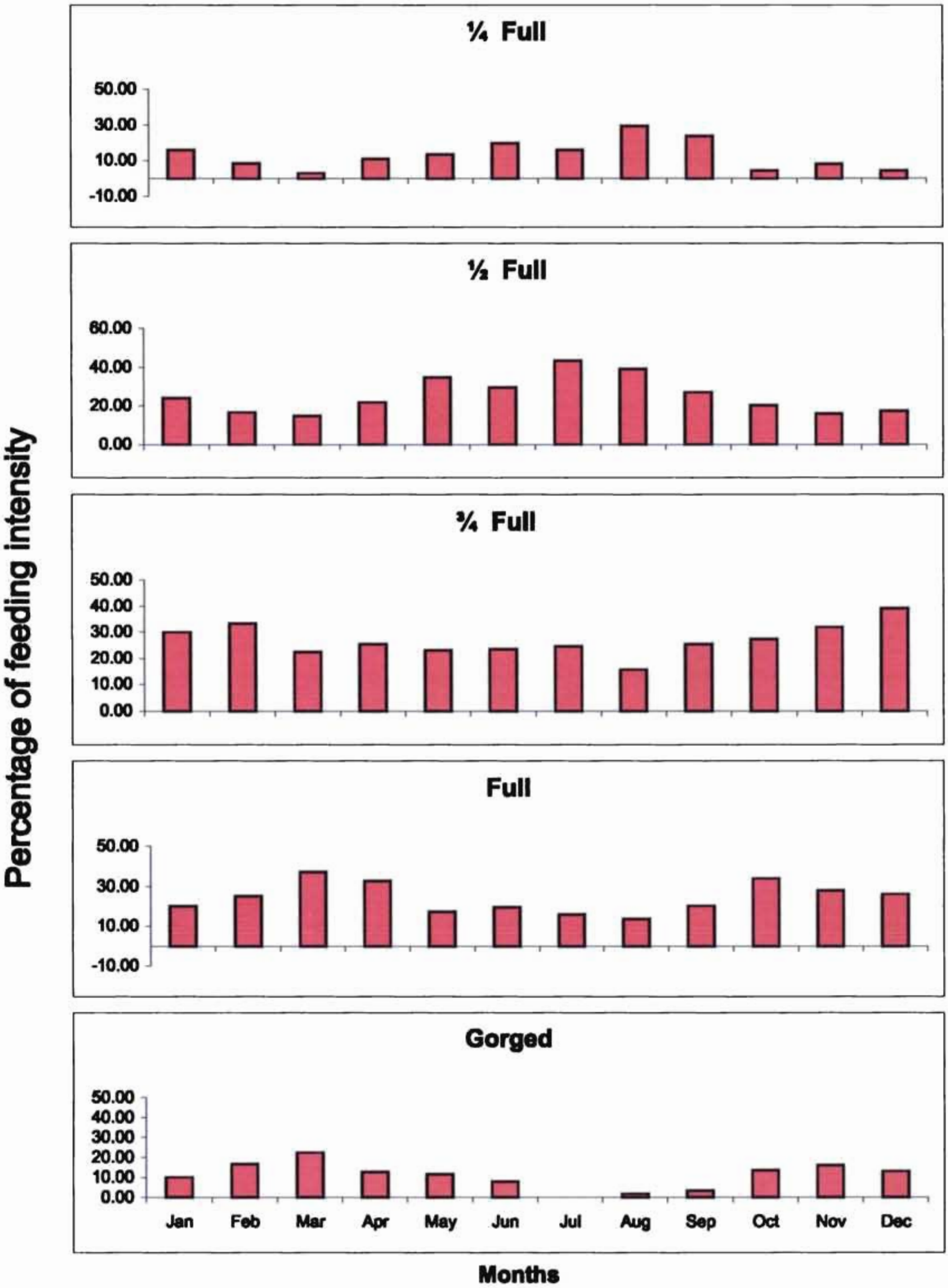


Fig. 3.6
Monthly percentage of feeding intensity in *H. (H) xanthopterus*

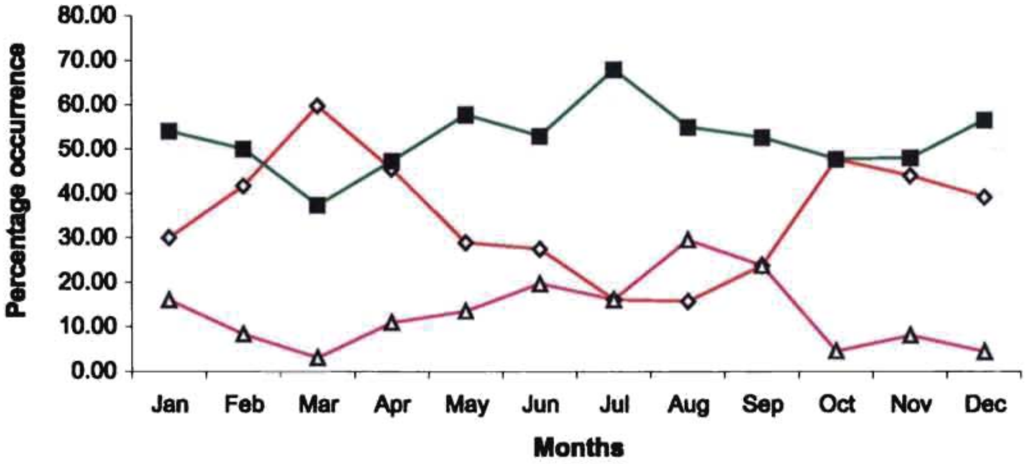


Fig. 3.7
Monthly percentage occurrence of different feeding intensities in *H. (H) xanthopterus*

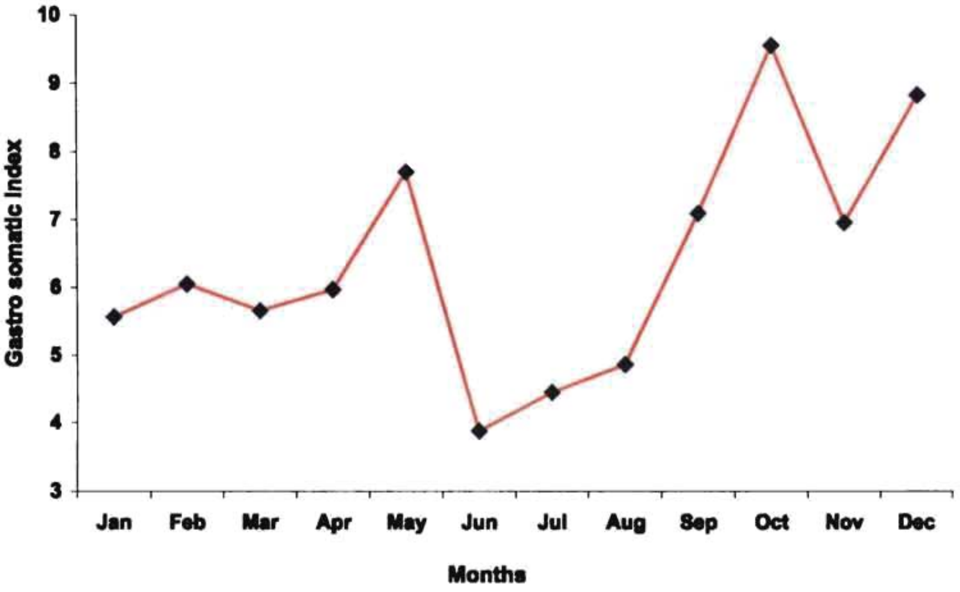


Fig. 3.8
Gastro-somatic index of *H. (H) xanthopterus*

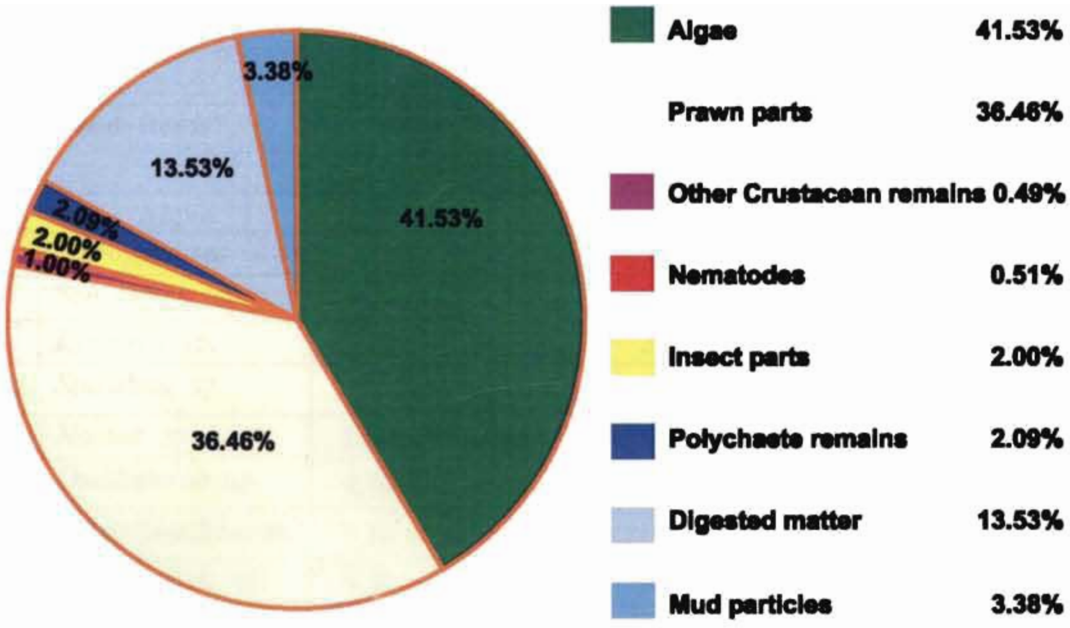


Fig. 3.9
Food composition of *H. (H) limbatus*
in different months during April 2001 - May 2003

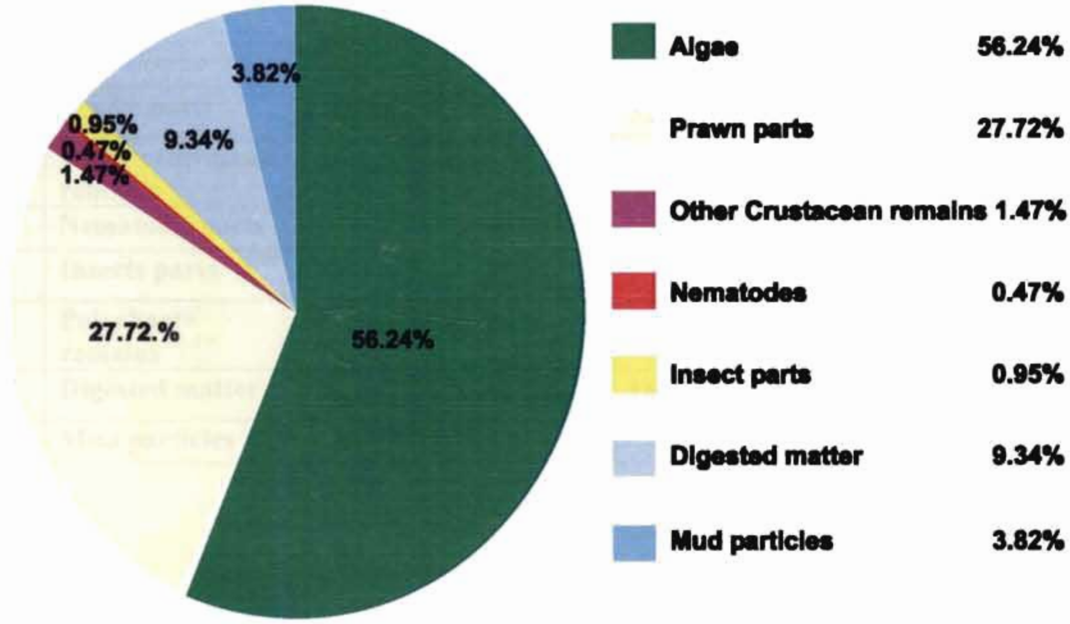


Fig. 3.10
Food composition of *H. (H) xanthopterus*
in different months during April 2001 - May 2003

Table. 3.1
Index of preponderance of food items of *H. (H) limbatus* in different months during May 2001 – April 2003

Food items		May		June		July		August	
		2001	2002	2001	2002	2001	2002	2001	2002
I	**Algae**							-	-
1	*Spirogyra* sp.	-	-	2.10	3.20	2.02	1.20	-	2.10
2	*Schizothrix* sp.	-	-		2.03	-	0.50	-	2.20
3	*Lyngbya* sp.	2.10	2.10	4.16	2.10	6.00	3.10	-	-
4	*Spirulina* sp.		1.20	2.14	3.05	3.80	-	-	-
5	*Nostoc* sp.	1.80	-	-	4.05	-	5.20	3.10	4.40
6	*Oscillatoria* sp.	4.10	3.20	12.25	7.10	-		5.10	12.23
7	*Leptocylindrus* sp.	5.50	5.10	5.10	-	-	-	1.30	1.10
8	*Skeletonema* sp.	4.20	-	-	2.12	10.10	3.00	-	4.30
9	*Thalassiosira* sp.	40.0	2.50	-	4.20	6.20	2.10	20.10	3.05
10	*Coscinodiscus* sp.	3.20	-	-	4.10	3.10	1.20	-	2.20
11	*Pleurosigma* sp.	3.00	-	-	2.10	2.04	-	6.05	2.20
12	*Nitzschia* sp.	2.40	2.10	8.18	3.05	1.06	1.15	5.10	3.20
13	*Navicula* sp.	2.00	3.10	4.20	-	-	1.05	4.05	4.20
14	*Biddulphia* sp.	1.10	9.10	3.10	9.05	-	6.20	3.20	-
15	*Melosira* sp.	5.20	6.10	2.20	1.20	-	5.50	2.10	9.10
16	*Hemidiscus* sp.	-	-	1.60	-	-	-	-	-
II	**Prawn parts**	36.34	28.90	39.92	32.64	43.20	45.90	34.31	22.95
III	**Other crustacean remains**	-	1.50	-	-	-	-	-	2.67
IV	**Nematode parts**	-	-	-	-	-	-	0.80	-
V	**Insects parts**	-	-	-	-	-	-	-	16.0
VI	**Polychaete remains**	4.10	3.11	5.05	4.01	4.30	5.20	-	8.10
VII	**Digested matter**	10.81	12.84	10.00	16.00	12.50	15.60	10.50	-
VIII	**Mud particles**	10.15	19.15	-	-	5.50	3.10	4.20	-

Table. 3.1 cont'd.

Index of preponderance of food items of *H. (H) limbatus* in different months during April 2001 - May 2003.

	Food items	September		October		November		December	
		2001	2002	2001	2002	2001	2002	2001	2002
I	**Algae**								
1	*Spirogyra* sp.	2.20	-	-	1.04	3.30	3.00	1.10	2.10
2	*Schizothrix* sp.	1.60	-	-	-	3.20	5.10	-	-
3	*Lyngbya* sp.	-	-	-	3.10	3.10	-	3.10	-
4	*Spirulina* sp.	-	2.10	3.26		1.20	4.11	-	2.05
5	*Nostoc* sp.	4.20	1.20	-	4.05	-	-	-	3.20
6	*Oscillatoria* sp.	7.10	7.20	1.20	8.06	9.20	13.10	11.30	12.10
7	*Leptocylindrus* sp.	-	5.20	6.50	2.41	-	-	-	2.10
8	*Skeletonema* sp.		2.50	-	-	2.05	-	-	1.05
9	*Thalassiosira* sp.	-	2.30	2.02	1.40	4.40	-	15.10	-
10	*Coscinodiscus* sp.	3.00	4.30	-	1.40	5.10	1.50	6.20	-
11	*Pleurosigma* sp.	2.50	3.20	6.10	-	-	3.50	5.05	-
12	*Nitzschia* sp.	1.50	6.20	5.02	-	4.20	-	4.05	3.10
13	*Navicula* sp.	1.03	4.30	4.10	-	4.10	1.20	3.10	3.10
14	*Biddulphia* sp.	6.00	10.20	1.05	8.10	7.10	8.02	-	6.10
15	*Melosira* sp.	5.50	11.20	1.02	6.10	8.05	4.20	-	5.00
16	*Hemidiscus* sp.	4.05	1.10	-	3.05	-	2.10	-	1.10
II	**Prawn parts**	38.32	26.49	37.30	48.64	28.30	43.27	29.40	48.38
III	**Other crustacean remains**	-	-	1.01	-	-		-	-
IV	**Nematode parts**	1.40	-	5.90	-	1.10	-	-	-
V	**Insects parts**		2.51	-	-	-	-	-	-
VI	**Polychaete remains**		10.0	-	2.10	1.20		3.00	-
VII	**Digested matter**	21.60		25.51	10.55	14.40	10.90	18.60	10.62
VIII	**Mud particles**			-	-			-	-

Table. 3.1 cont'd.
Index of preponderance of food items of *H. (H) limbatus* in different months during April 2001 - May 2003.

	Items	January		February		March		April	
		2002	2003	2002	2003	2002	2003	2002	2003
I	**Algae**								
1	*Spirogyra* sp.	-	-	-	-	-	-	-	-
2	*Schizothrix* sp.	-	-	-	-	2.50	1.50	-	-
3	*Lyngbya* sp.	2.20	2.50	0.85	2.60	1.40	2.50	3.20	-
4	*Spirulina* sp.	4.20	-	-	-	-	-	1.10	1.10
5	*Nostoc* sp.	-	-	1.90	1.25	4.10	4.00	-	1.20
6	*Oscillatoria* sp.	10.10	6.50	-	-	-	-	4.10	4.50
7	*Leptocylindrus* sp.	-	6.20	-	-	2.20	2.10	-	5.20
8	*Skeletonema* sp.	8.20	4.40	4.20	2.50	-	-	9.21	-
9	*Thalassiosira* sp.	6.10	3.20	3.10	2.50	-	1.10	8.30	3.80
10	*Coscinodiscus* sp.	5.10	2.20	2.50	1.90	1.20	1.10	7.22	-
11	*Pleurosigma* sp.	4.50	1.20	-	-	-	-	6.21	-
12	*Nitzschia* sp.	4.10	5.10	-	-	4.20	3.20	-	6.15
13	*Navicula* sp.	3.50		1.51	-	3.20	2.30	-	-
14	*Biddulphia* sp.	-	10.20	8.40	10.20	5.50	8.20	-	11.2
15	*Melosira* sp.	-	-	6.20	8.50	8.20	10.20	-	9.10
16	*Hemidiscus* sp.	-	-	-	3.30	-	-	-	5.50
II	**Prawn parts**	31.50	40.00	35.89	39.85	30.51	36.61	48.18	28.20
III	**Other crustacean remains**	-	-	-	-	-	-	3.50	3.10
IV	**Nematode parts**	-	-	1.50	1.50	-	-	-	-
V	**Insects parts**	-	-	5.30	6.30	3.54	4.64	4.50	5.30
VI	**Polychaete remains**	-	-	-	-		-	-	-
VII	**Digested matter**	20.50	18.50	16.50	14.50	18.10	16.10	4.48	15.58
VIII	**Mud particles**	-	-	12.15	5.10	15.35	6.45	-	-

Table. 3.2
Index of preponderance of food items of *H. (H) xanthopterus* in different months during May 2001 – April 2003

	Food items	May		June		July		August	
		2001	**2002**	**2001**	**2002**	**2001**	**2002**	**2001**	**2002**
I	**Algae**								
1	*Spirogyra* sp.	6.30	2.50	28.58	22.10	35.57	37.04	23.66	24.62
2	*Ulothrix* sp.	1.50	1.90	1.61	1.68	2.50	1.50	-	2.16
3	*Oedogonium* sp.	-	-	2.11	2.15	-	-	2.10	1.15
4	*Oscillatoria* sp.	1.20	1.50	2.65	3.10	1.51	1.21	2.21	2.16
5	*Lyngbia* sp.	0.80	0.90	1.80	2.50	0.81	0.95	1.56	1.22
6	*Spirulina* sp.	-	-	-	1.60	0.50	0.29	0.50	-
7	*Nostoc* sp.	-	-	-	1.50	0.61	0.18	0.62	0.62
8	*Coscinodiscus* sp.	-	1.50	1.30	0.95	-	-	0.94	1.31
9	*Fragilaria* sp.	-	-	-	-	1.80	5.05	23.35	27.38
10	*Pleurosigma* sp.	15.82	10.82	3.20	3.51	2.10	1.15	1.49	1.73
11	*Navicula* sp.	2.89	3.89	2.10	2.61	1.30	0.95	0.96	-
12	*Skeletonema* sp.	-	-	1.10	2.25	-	-	-	-
13	*Nitzschia* sp.	4.81	5.91	3.20	2.95	1.20	0.85	-	-
14	*Melosira* sp.	2.51	2.24	1.60	-	0.90	0.80	0.91	0.85
15	*Campylodiscus* sp.	4.87	1.33	-	1.12	-	-	-	-
16	*Biddulphia* sp.	1.61	1.27	1.80	1.13	-	-	-	0.91
17	*Leptocylindrus* sp.	-	2.30	12.92	10.15	8.03	6.05	3.04	-
18	*Thalassiosira* sp.	-	1.40	1.50	1.15	1.50	0.31	0.72	1.25
19	*Gyrosigma* sp.	-	-	-	-	1.10	-		-
20	*Guinardia* sp.	-	-	-	-	-	1.17	1.10	-
21	*Pinnularia* sp.	-	-	-	-	-	-	-	-
II	**Prawn parts**	27.90	30.45	26.02	29.34	26.37	30.15	25.19	20.27
III	**Insect wings & parts**	-	-	-	-	-	-	-	10.16
IV	**Nematode parts**	-	-	-	-	-	-	0.97	-
V	**Other crustacean remains**	-	-	-	-	-	-	9.10	2.67
VI	**Digested matter**	10.64	13.84	8.51	10.21	8.50	9.25	1.22	1.33
VII	**Mud particles**	19.15	18.25	-	-	5.70	3.10	0.36	0.21

Table. 3.2 cont'd.
Index of preponderance of food items of *H. (H) xanthopterus* in different months during May 2001 – April 2003

	Food items	September		October		November		December	
		2001	2002	2001	2002	2001	2002	2001	2002
I	**Algae**								
1	*Spirogyra* sp.	38.45	40.11	37.6	45	45.04	40.11	32.5	40.05
2	*Ulothrix* sp.	-	-	2.74	1.56	1.18	2.10	1.60	1.50
3	*Oedogonium* sp.	1.56	-	-	1.01	-	1.50	2.50	-
4	*Oscillatoria* sp.	2.16	1.34	3.51	2.85	1.98	2.50	3.10	2.60
5	*Lyngbia* sp.	1.15	0.91	1.69	0.85	1.86	1.10	2.50	1.60
6	*Spirulina* sp.	0.95	-	-	-	1.03	-	-	-
7	*Nostoc* sp.	0.85	-	1.11	1.15	.85	2.10	1.60	-
8	*Coscinodiscus* sp.	0.89	2.10	-	1.25	1.21	-	1.41	1.40
9	*Fragilaria* sp.	1.99	10.11	2.47	-	2.10	-	3.10	-
10	*Pleurosigma* sp.	1.38	-	-	-	1.15	3.10	1.90	-
11	*Navicula* sp.	0.98	2.60	1.65	2.50	1.05	-	1.65	1.25
12	*Skeletonema* sp.	-	1.50	-	-	-	-	-	-
13	*Nitzschia* sp.	1.33	2.5	1.85	4.10	1.85	7.60	1.85	1.90
14	*Melosira* sp.	-	1.10	0.95	-	0.85	-	-	1.08
15	*Campylodiscus* sp.	-	-	-	-	-	-	-	-
16	*Biddulphia* sp.	0.85	0.15	1.02		1.42		1.30	1.50
17	*Leptocylindrus* sp.	9.21		4.84	5.84	4.05	10.53	6.05	10.41
18	*Thalassiosira* sp.	0.95	5.05	3.46	1.35	1.01	2.10	1.50	1.15
19	*Gyrosigma* sp.	-	-	1.95	-	-	2.30	-	1.65
20	*Guinardia* sp.	-	4.51	-	6.50	-	-	-	-
21	*Pinnularia* sp.	-	-	-	-	-	-	-	-
II	**Prawn parts**	29.67	24.16	27.35	20.83	26.91	19.46	27.01	20.27
III	**Insect wings & parts**	-	-	-	-	-	-	-	-
IV	**Nematode parts**	1.50	2.51	1.01	-	1.17	-	-	-
V	**Other crustacean remains**	-	-	-	-	-	-	-	3.39
VI	**Digested matter**	6.13	1.35	6.80	5.21	5.29	5.50	10.43	10.25
VII	**Mud particles**	-	-	-	-	-	-	-	-

Table. 3.2 cont'd.
Index of preponderance of food items of *H. (H) xanthopterus* in different months during May 2001 – April 2003

	Food items	January		February		March		April	
		2002	2003	2002	2003	2002	2003	2002	2003
I	**Algae**								
1	*Spirogyra* sp.	25.59	24.94	1.50	1.90	4.00	-	2.50	-
2	*Ulothrix* sp.	-	3.56	-	-	1.50	-	1.79	2.10
3	*Oedogoniumi* sp.	2.60	-	-	-	2.50	4.10	-	-
4	*Oscillatoria* sp.	2.10	4.10	0.75	1.20		6.10	4.50	4.40
5	*Lyngbia* sp.	1.80	2.20	-	0.65	-	1.10	-	2.30
6	*Spirulina* sp.	-	-	-	-	-	-	-	-
7	*Nostoc* sp.	1.60	1.10	0.50	-	-	-	-	-
8	*Coscinodiscus* sp.	0.98	1.60	2.51	1.51	1.50	2.20	3.30	5.60
9	*Fragilaria* sp.	-	-	-	-	3.10	2.10	-	3.40
10	*Pleurosigma* sp.	4.97	4.50	5.20	2.10	10.0	10.5	10.01	11.80
11	*Navicula* sp.	1.41	1.50	4.62	9.80	3.10	3.80	3.10	5.50
12	*Skeletonema* sp.	-	-	-	-	-	-	4.10	3.10
13	*Nitzschia* sp.	1.62	2.10	4.28	5.10	2.90	4.10	4.10	5.10
14	*Melosira* sp.	-	0.90	1.67	6.70	-	-	2.10	2.60
15	*Campylodiscus* sp.	-	-	3.73	-	-	-	-	2.40
16	*Biddulphia* sp.	-	-	2.32	-	1.30	1.00	3.30	-
17	*Leptocylindrus* sp.	2.69	6.70	4.60	2.50	-	-	2.20	2.10
18	*Thalassiosira* sp.	-	-	-	1.80	-	-	4.20	-
19	*Gyrosigma* sp.	5.96	2.20	-	-	8.30	2.50	6.01	-
20	*Guinardia* sp.	-	-	-	-	-	1.50	-	-
21	*Pinnularia* sp.	-	-	-	-	1.50	-	-	-
II	**Prawn parts**	33.69	34.08	35.27	34.66	26.51	28.5	30.31	32.98
III	**Insect wings & parts**	-	-	3.30	3.50	3.51	5.50	4.30	5.10
IV	**Nematode parts**	-	-	2.57	1.50	-	-	-	-
V	**Other crustacean remains**	-	-	-	-	-	6.31	1.40	-
VI	**Digested matter**	14.99	10.52	15.54	16.50	18.10	10.50	12.78	11.52
VII	**Mud particles**	-	-	12.14	10.58	12.18	10.19	-	-

Table. 3.3
Percentage occurrence of stomachs in different degrees of fullness in adults of *H. (H) limbatus*

Month	**Gorged**	**Full**	**¾ full**	**½ full**	**¼ full**	**Empty**
January	7.50	25.00	30.00	27.50	10.00	0.00
February	13.64	29.33	20.45	34.22	5.84	0.00
March	3.57	25.00	32.14	28.57	10.71	0.00
April	0.00	18.75	25.00	39.58	16.67	0.00
May	3.85	19.23	30.77	26.92	19.23	0.00
June	9.09	25.97	31.17	23.38	10.39	0.00
July	13.56	23.73	37.29	20.34	5.08	0.00
August	8.16	20.41	36.73	26.53	8.16	0.00
September	4.69	21.88	50.00	18.75	4.69	0.00
October	3.23	20.97	40.32	25.81	9.68	0.00
November	0.00	18.18	36.36	30.91	14.55	0.00
December	0.00	14.55	45.45	29.09	10.91	0.00

Table. 3.4
Percentage occurrence of stomachs in different degrees of fullness in adults of *H. (H). xanthopterus*

Month	Gorged	Full	¾ full	½ full	¼ full	Empty
January	10.00	20.00	30.00	24.00	16.00	0.00
February	16.67	25.00	33.33	16.67	8.33	0.00
March	22.39	37.31	22.39	14.93	2.99	0.00
April	12.73	32.73	25.45	21.82	10.91	0.00
May	11.54	17.31	23.08	34.62	13.46	0.00
June	7.84	19.61	23.53	29.41	19.61	0.00
July	0.00	16.05	24.69	43.21	16.05	0.00
August	1.96	13.73	15.69	39.22	29.41	0.00
September	3.39	20.34	25.42	27.12	23.73	0.00
October	13.64	34.09	27.27	20.45	4.55	0.00
November	16.00	28.00	32.00	16.00	8.00	0.00
December	13.04	26.09	39.13	17.39	4.35	0.00

CHAPTER 4.

MATURATION AND SPAWNING

4. MATURATION AND SPAWNING

4.1. Introduction

Studies on the reproductive behaviour of a fish stock are quite useful for the proper management and exploitation of its fishery. Information on the maturation cycle and spawning behaviour is essential for understanding and predicting the changes the population is likely to undergo during a year. Inferences relating to population stability and year class fluctuations can be obtained by undertaking studies on reproductive biology. These fluctuations may play a major role in determining the variations in production from year to year. An understanding of the age and size at which the fish attains sexual maturity, the time and duration of spawning and the rate of regeneration of stocks are also important for the judicious management of the fishery resources. Information on sex ratio and the reproductive capacity of the stock, calculated from fecundity estimation coupled with the size and age at first maturity, is helpful to assess the age at which the fishes are to be caught, since many species of fish are easily trapped during spawning season. However, all these studies are essentially meant for elucidating both short term and long-term variations in the production of fish broods, which are finally recruited in the population as exploitable stocks.

4.2. Review of Literature

Attempts were made by several workers to study the reproductive biology of hemiramphids in many areas all over the world. Noteworthy among them are those of Ling (1958) on *Reporhamphus melanochir* of Australia, Berkeley and Houde (1978) on *Hemiramphus brasiliensis* and *H. balao* from south east Florida and Chandrasoma and Wijeratne (1990) on *Hyporhampus gaimardi* of Sri Lanka. Unique spermatozeugmata in the testes of halfbeaks of the genus *Zenarchopterus* was reported by Grier and Collette (1987).

Much of the study on reproductive biology of hemiramphids carried out in India was by Talwar (1962 a and b, 1967) on *Hyporhamphus georgii* and *Hemiramphus marginatus* of the Gulf of Mannar and Palk Bay; by Sultana *et al.* (1980) on *Hemiramphus gaimardi* of Pulicat Lake and by Durai *et al.* (1988) on the breeding biology of *Hyporhamphus unifasciatus* from coastal waters of Parangipettai, east coast of India.

Bhattacharya (1916) described the young stages of *Hemiramphus limbatus* from Chilka lake. Job and Jones (1938) and Nair (1952) described several larval stages of *H. gaimardi* from Madras waters. The eggs and larvae of *H. georgii* were described by Devanesan (1937), Chidambaram and Menon (1948) and Kuthalingam (1959). Vijayaraghavan (1957) made a study of the eggs and larvae of *H. far* from Madras waters. Jones and Pantulu (1958) reported three post-larval stages of *Zenarchopterus buffoni* from Orissa waters. Sudarsan (1966) has worked on the eggs and early larvae of

Hyporhamphus quoyi from Mandapam area. Talwar (1967) identified the larval stages of *H. marginatus* from Gulf of Mannar.

Hitherto no attempt has been made to study the maturation and spawning of *H. (H). limbatus* and *H. (H). xanthopterus* abundant along the Kerala coast and therefore an attempt is made to study various aspects of reproductive biology of these species collected from Cochin waters.

4.3. Materials and Methods

Monthly samples of fishes were collected from different fish landing centres, markets of Cochin coast and some fishing grounds in Vembanad Lake like Eloor Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map. (Fig. 1.1). A total number of 1441 (681 males and 760 females) fishes of *H. (H) limbatus* and 961 (363 males and 598 females) fishes of H. *(H) xanthopterus* were taken for detailed studies. The total length of the fish was measured to the nearest mm and each specimen was weighed to the accuracy of 0.1g.

4.3.1. Macroscopic study of gonads

Sexes were separated by examining the gonads as no external characters indicating the sexes were observed. The condition, colour, shape, length to the nearest mm and weight to 0.01gm of the gonads were recorded. The ovaries were preserved in modified Gilson's fluid (Simpson, 1951) for the measurement of ova diameter and fecundity studies.

4.3.2. Maturity stages

Maturity stages were quantified according to the ova diameter measurement, colour, shape and size of the ovary in relation to body cavity in the case of females and the shape and size of the testes in relation to body cavity in the case of males. Though the ICES (International Council for the Exploration of the Sea) scale was followed generally, in the present study the ovaries and testes were categorized following the method adopted by Talwar (1962 b) in *H. georgii.*

4.3.3. Measurement of ova diameter

The progression of ova is studied by ova diameter measurements following the method of Clark (1934). Since there was no variation in the ova diameter examined from the anterior, middle and posterior regions of the ovary, ova from the middle region of the right and the left lobe of the ovary were taken for diameter measurements. About a hundred ova from each ovary in different stages were taken at random and their diameters recorded. Ova being spherical in shape, measurements of ovum were taken using stage micrometer wherein each micro meter division equals 0.029mm.

4.3.4. Length at first maturity

Length at first maturity was calculated for males and females by grouping them in 10mm groups and plotting the percentage of the number of males and females in maturity stages to the total number of fishes examined.

(Hodgkiss and Man,1978) Fish with gonads in stage three in the case of males and fourth and above in the case of females were considered mature.

4.3.5. Gonado-somatic index(GSI)

The relative gonad weight or gonado-somatic index (GSI) was calculated by applying the method of June (1953) and Yuen (1955) using the formula.

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

This index was calculated for both males and females on a monthly basis.

4.3.6. Condition factor ('K')

The general well being of fish is measured by the unit called 'condition factor' or 'ponderal index'. Condition factor 'K' for both *H.(H) limbatus* and *H.(H) xanthopterus* was calculated using the formula.

$$K = \frac{W x\ 10^5}{L^3}$$

where 'W' is the weight in gm and 'L' the length in mm. of the fish (Hile, 1936) . The number 10^5 is a factor to bring ponderal index (K) to near unity (Carlander, 1970).

4.3.7. Fecundity

For calculating the fecundity (F), the gravimetric method was adopted (Bagenal 1967) wherein the number of eggs in the sub samples weighed to the nearest 0.001 gm. were counted and the same was multiplied by the total weight of the ovaries using the formula, $F = \frac{nG}{g}$, where 'F' is fecundity, 'n' is the number of eggs in sub sample, 'G' is total weight of ovary and 'g' is weight of sub sample in the same units. The final figures of fecundity were arrived at based on the average of the weights and number of eggs in three sub samples of each ovary.

The fecundity (F) thus computed was correlated to several variables such as total length (TL) in mm, body weight (W) in g., ovary length (OL) in mm, and ovary weight (OW) in g. using regression analysis. Fecundity indices such as the number of ova produced per gram body weight (relative fecundity) (Bagenal, 1963), the number of ova present per gram ovarian weight, the ovarian weight as percentage of total fish weight or the co-efficient of maturity (Bagenal & Braum, 1968) and the gono - somatic index or the ovarian weight in relation to fish weight excluding ovary weight (Somvanshi, 1985) were computed following standard procedures (Snedecor and Cochran, 1967).

The correlation coefficient obtained from the analysis of the data of fecundity and their logarithmic transformation did not vary significantly (1%) and therefore, the former has been used for diagrammatic representation.

4.3.8. Sex ratio

The males and females were grouped in 10mm length intervals for different months to study the length-wise and month wise variation in sex ratio which was tested by Chi-square test, $\chi^2 = \frac{(O-E)^2}{E}$ where O is the observed number and E is the expected number, and variance test of homogeneity was carried out as per standard procedures (Snedecor and Cochran, 1967)

4.4. Results

4.4.1. Macroscopic study of the gonads

The testes and ovary in *H. (H) limbatus* and *H. (H) xanthopterus* are located just above the alimentary canal in the abdominal cavity and both are bilobed. The two lobes are elongated and asymmetrical in length in maturing gonads, the left lobe being longer than the right and became symmetrical in the mature gonads. The two lobes form a U-shaped loop and open to the outside by a common duct.

In an immature ovary the lobes are slender and pale yellowish in colour. As the ovary becomes mature the girth or thickness of the lobes increase and the colour changes from yellowish orange to orange green. When fully mature they occupy the full length of the body cavity.

The testes first appear as slender, translucent filament like structure, light cream or white in colour. As maturity advances, they become sub cylindrical and change into more pinkish in colour. When fully mature they become milky and occupy the full length of the body cavity.

4.4.2 . Classification of maturity stages

The classification of maturity stages based on colour, size and shape of the gonads in relation to body cavity and appearance and size of ova is aimed to study the spawning period and the age at sexual maturity. Ovaries have been used more often and more easily for the classification rather than the testes because the progress of maturation can be ascertained more easily in the ovaries than the testes. Seven stages of maturity were recorded in females and four in males of both *H. (H) limbauts* and *H. (H) xanthopterus* (Plate 5-7).

a. Female

The maturity stages of the females were as follows.

Stage I : Immature: ovary pale white in colour, transparent, slender, small and ova not visible to the naked eye. Under microscope the ova appear small, transparent, yolkless and not easily separable.

Stage II : Developing virgin or recovered spent : Ovary, pale yellow in colour, slightly slender, small, transparent, ova visible to the naked eye. Under magnification the ova appear round and transparent with prominent nuclei in the centre.

Stage III : Maturing : Ovary pale yellowish orange in colour, lobes become slightly thicker, ova opaque under magnification, ova appear golden yellow. Ovary occupying nearly half of the body cavity.

Stage IV : Mature : Ovary yellowish orange in colour, lobes become thicker, ova golden yellow and opaque; ovary occupying half of the body cavity.

Stage V : Ripe : Ovary light greenish yellow in colour, lobes much thickened, ova attaining a golden yellow transparency, ova have burst from the follicles; ovary occupying about 75% of the body cavity. A prominent blood vessel on the dorsal side of the ovary extending its entire length.

Stage VI : Spawning : Ovary greenish orange colour with large transparent ova, with oil globules. At a slight prick, gelatinous mass of transparent ova flows out. Ova can be extruded under slight pressure externally. Ovary occupying the entire body cavity.

Stage VII : Spent : Lobes flabby and contracted, a few large transparent ova seen in the ovary, occupying half the length of the body cavity.

b. Male

The maturity stages of the male were as follows.

Stage I : Immature : testes extremely small, thin, filament like and white in its coloration, occupying less than one third of the length of the body cavity.

Stage II : Maturing : Testes well developed and thickened, pinkish or creamy in colour and occupy nearly half of the body cavity.

Stage III : Mature : Testes milky white in colour, occupies the entire length of the body cavity. On exerting slight pressure on the testis milt oozes out

Stage IV : Spent : Testes, milky white in colour, becomes shrunken and reduced to a very small size often to little remnants which may even disappear completely.

4.4.3. Development of ova to maturity and frequency of spawning

Ova diameter studies are generally used to determine the time of spawning and the spawning periodicity of fishes. Development of the ova up to maturity was studied by recording the ova diameter of all stages using an ocular micrometer. Each micrometer division (m.d.) was equal to 0.029mm. The diameter frequency has been categorized into groups of three micrometer division each.

The intra ovarian eggs in the mature ovaries of both the species are classified into immature ova which are minute, transparent and possessing a nucleus and a protoplasmic layer, maturing ova which are small and opaque in which the formation of yolk has just commenced, mature ova that are opaque and full of yolk with distinct yolk spherules, but still contained within the follicle and ripe ova which include fully mature, large free transparent eggs which have burst from the follicles (Clark, 1934).

In *H.(H) limbatus* four distinct categories of oocytes were observed during its maturation (Fig 4.1). During stage 1 the majority of the ova ranged between 3 and 10 micrometer divisions (m.d.) (0.087 - 0.29 mm). A few larger ova measuring 12-15 m.d. (0.348 - 0.435mm) were also observed. In stage II, apart from the immature stock, a stock of ova measuring between 21 and 24 (0.609-0.696mm) were also recorded, the maximum size of ova being 24 m.d. (0.696mm). In stage III, two modes were noticed. The mode which made its appearance in stage II, i.e, 21-24m.d. (0.609-0.696mm) was shifted to 27-30 m.d. (0.783 – 0.870mm) and the rest measured 12-15 m.d. (0.348 - 0.435mm). At stage IV three modes were observed. The maturing group increased further in its size with the mode at 33-36 m.d. (0.957 – 1.044mm) the second mode at 18-21m.d. (0.522-0.609mm), the third being 9-12 m.d. (0.261-0.348mm). In stage V the mature ova measured 39-42m.d. (1.131 – 1.218mm) the maturing ova measured 21-24 m.d. (0.609-0.696) immature ova 12-15m.d. (0.348 - 0.435mm). In stage VI four types of ova were noticed. The ripe ova measuring 48-53m.d. (1.392-1.537mm) the free mature ova 27-30 m.d. (0.783 - 0.870mm), maturing ova 15-18m.d. (0.435 - 0.522mm) and the immature ova measuring 3-8m.d. (0.087 - 0.232mm). In the spent (stage VII) ovaries most of the eggs are the immature measuring 3-10m.d. (0.087 - 0.29mm), some eggs measuring 18-21m.d. (0.522 - 0.609mm) were also found along with a few ripe ova.

In *H. (H). xanthopterus* during stage I majority of the ova were transparent with distinct nuclear measuring between 3 and 9m.d. (0.087 - 0.261mm) in diameter (Fig.4.2). A few large size ova 15-18m.d. (0.435 – 0.522 mm) were also noticed. At stage II a group of yolked eggs with a mode 18-21m.d. (0.522 - 0.609mm) could be seen along with another group measuring 12-15m.d. (0.348 -0.435mm). At stage III the maturing group of ova shifted to 30-33m.d. (0.870-0.957mm) in addition to other groups of ova ranging 21-24 m.d. (0.609 - 0.696mm) and 9.12m.d. (0.261 - 0.348mm). At stage IV three sets of ova were distinct. Mature ova measuring 39-42m.d. (0.870 - 0.957mm) maturing ova measuring 21-24m.d. (0.609 - 0.696mm) and the immature ova measuring 15 -18m.d. (0.435 - 0.522mm). At stage V the mature ova still increased in size to 42-45 m.d. (1.218 – 1.305mm). Three other modes 33-36m.d. (0.957 - 1.044mm), 24 – 27m.d. (0.696 - 0.783mm) 15-18m.d. (0.435 - 0.522mm) were also observed. At stage VI ripe eggs measuring 48-55 m.d. (1.392 – 1.595mm) along with eggs measuring 30-33m.d. (0.870 - 0.957mm), 24 – 27m.d. (0.696 - 0.783mm), and 12-15m.d. (0.348 - 0.435mm) were observed. At stage VII most of the eggs were immature measuring 3-9m.d. (0.087-0.261mm), some eggs measuring 12-15m.d. (0.348 - 0.435mm) were also found along with a few ripe ova measuring 18-21 m.d. (0.522 - 0.609mm).

In the ovaries of both *H. (H) limbatus* and *H. (H). xanthopterus* immature ova measuring 3-10m.d. (0.087-0.261 mm) were present in all stages of maturity. Since the eggs in the mature stock vary in diameter from 40-55m.d. (1.16 – 1.595 mm) it is quite likely that the actual process of shedding of the ova may not be limited to a very short period but extended over a longer period. Multiplicity of modes in the above analysis indicate that *H. (H). limbatus* and *H (H). xanthopterus* are continuous breeders and spawn more than once in each spawning season. The secondary modes indicate the growth of intraovarian eggs which are ready for release in the next batch.

In both the species, mature ova were spherical and transparent with a soft texture. Immature ova were much smaller, yellowish in colour and had a harder texture. The chorion of all near ripe ova bore thread like filaments that presumably allow attachment of fertilized eggs to weeds or algae.

The structure of egg was more or less similar in both *H.(H) limbatus* and *H.(H) xanthopterus*. The main difference was in the size of the egg. The maximum ova diameter in the ripe individuals of *H.(H). limbatus* was 53 m.d (1.537mm) whereas that *of H.(H). xanthopterus* was 55 m.d. (1.595mm) The mature eggs of *H.(H). xanthopterus* were larger than that of *H.(H). limbatus*

4.4.4. Seasonal occurrence of maturity stages and spawning season

Percentage occurrence of fishes with gonads in different stages of maturity during different months were examined to delineate the spawning season (Table 4.1–4.4). Though both the sexes followed a similar pattern of distribution of various stages, maturity stages of females are more relevant to determine the spawning period.

In *H. (H) limbatus* immature (stage 1) ovaries were noticed during July, August and October 2001, January-March and May – July 2002 and January and March 2003. Developing virgin (stage II) ovaries were present in all the months except May, June, November and December 2001, September, October and December 2002 and January – April 2003. Maturing (stage III) ovaries were present in all the months of observation except in October 2002. Ripe and spawning (stage IV and V) ovaries were present throughout the year. Spawning (stage VI) ovaries were noticed in May-July and November-December 2001 January, February, April-August and October-December 2002 and January, February and April 2003. Spent (stage VII) showed their presence in May 2001, January, February, May and June 2002 and January and February 2003.

In *H. (H) xanthopterus* stage 1 ovaries were present in November and December 2001, January, April, May and December 2002 and March and April 2003. Stage II ovaries were present in May, July-September, November and December 2001, January, April-June, August and December 2002 and January and April 2003. Stage III ovaries were present in almost all months except in June and September 2001, March – May, July, September, October and December 2002 and March and April 2003. Stage IV ovaries were present throughout the year except in April 2002 August, October and December 2002 and April 2003. Stage V ovaries were present throughout the observation period. Stage VI ovaries were present in all months except October and December 2001 January, February, March and December 2002 and January and February 2003. Stage VII ovaries were observed in May August, September and November 2001 and August – October 2002.

The presence of fully ripe ovaries (stage V) from January to December in both the species indicate that these fishes are continuous spawners. However in *H. (H) limbatus* during April - May and November - December the percentage of fishes with fully ripe ovaries was more than the other months indicating peak spawning activity during these months. In the case of males also fully ripe testes were observed in all the months throughout the year especially during April - May and November - December indicating peak spawning activity.

In *H. (H) xanthopterus* the percentage of fishes with fully ripe ovaries was more during July – August than other months indicating peak spawning activity during these months. In the case of males also fully ripe testes were observed in all the months throughout the year with a peak during July - August indicating peak spawning activity.

4.4.5. Length at sexual maturity

A knowledge of minimum length at sexual maturity is helpful to ensure a sustained yield by regulating the mesh size of the net during fishing operations. The smaller sized fish may also get an opportunity to spawn at least once in their life time by regulating the mesh size. Length at first maturity was determined at peak spawning season, when most of the adult fishes with mature gonads could be selected.

Length at first maturity was calculated for males and females of *H.(H) limbatus* and *H.(H) xanthopterus* separately. Percentage occurrence of different maturity stages in different size groups in males and females is given in Table 4.5-4.8 It could be seen that in *H. (H) limbatus* the length at first maturity was 125mm (TL) for males and 145mm (TL) for females (Figs. 4.3 and 4.4). Hundred percent of the males and females attained maturity at a length of 195mm and 225mm respectively. The length at which fifty percent of the fish attain maturity is 159 mm in the case of males and 175mm in the case of females.

In *H. (H) xanthopterus* (Fig. 4.5 and 4.6) it is observed that the males attain sexual maturity at 135mm (TL) and females at 155mm (TL) where as fifty percent of theses fishes attain maturity at 178mm in males and 199mm in females. However hundred percent maturity was found in 230mm males and 270 mm females.

4.4.6. Gonado – somatic index (GSI)

Gonado somatic index is used to find the duration and intensity of breeding. The seasonal changes in gonad weights are more pronounced in females than in males, the discharged weight of the sexual products being much more in the former. The development of gonads and the general growth of the fish are closely associated. The index increased gradually during the development of the gonads and declined at the commencement of spawning. Therefore the GSI may be a useful criterion for determining the duration and intensity of spawning as shown in many other fishes (June, 1953, Thomas, 1969.)

In the present study the GSI was calculated for both male and female *H. (H) limbatus* and *H. (H) xanthopterus* and monthly values are shown in Fig 4.7 and 4.8. In females of *H. (H). limbatus* the highest GSI values were observed in April and November and lowest from June to October and December to March of both the years of observation. In *H (H) xanthopterus* the highest GSI values were observed in females from June to August and lowest from November to May in both the years of observation. An abrupt inflection is noticed in January. Thereafter the indices followed a steady and rapid increase.

The mean GSI value followed a similar trend in males and females of both species except that the changes in weight of the testes are nominal. The high GSI values registered in respect of these two species indicated their peak spawning season. The fluctuations in the index during spawning indicate a synchronous maturation of gonads, confirming an extended spawning season. The peak spawning as indicated by GSI is in general agreement with the percentage occurrence of maturity stages. Hence it can be concluded from the above observations that these two species of hemiramphids breed continuously throughout the year with April and November as peak spawning periods in the case of *H. (H) limbatus* and June to August in the case of *H. (H) xanthopterus* . Otherwise the spawning period of *H. (H) limbatus* is post-monsoon and pre-monsoon seasons and that of *H. (H) xanthopterus* is the monsoon season.

4.4.7. Condition factor (K)

Individual variation from general length weight relationship is usually analysed by means of 'condition factor' or 'K-factor' or 'ponderal index'. The condition factor can be used to compare the general well being, fatness or the state of development of gonad (Thomas 1969). The condition of a fish is influenced by the seasonal changes in gonads and feeding intensity. It also varies depending on the amount of food in the gut and fatness of body (Rangaswamy 1973) but with the increase in age, there is a lower level of condition throughout the seasonal cycle consequent upon the increased metabolic strain of spawning (Radhakrishnan,1957). The condition factor also gives an indication of size at first maturity in fishes (Cone, 1989).

The mean condition factor 'K' in respect of both species was computed using the samples collected from May 2001 to April 2003. Males and females were studied separately. In *H. (H) limbatus* the 'K' values (Fig. 4.9) showed more or less a similar trend in both males and females throughout the year. An increase in 'K' values could be noticed from February to April and from September to November and a decrease from December onwards. The rise in the condition was due to the presence of mature and ripe gonads during these months.

In H. *(H) xanthopterus* also the 'K' values (Fig. 4.10) showed similar trends in both males and females as in the case of *H.(H) limbatus*. The condition factor was maximum during the period June to August. A decrease in values could be noticed thereafter. Occurrence of mature and ripe gonads in the samples coincided with higher values of condition. The low condition observed may be due to the cessation of breeding which is further indicated by the relative abundance of fishes with spent and immature gonads during these months.

Thus in both the species the rise in 'K' value synchronizes with the peak spawning months and agrees with the seasonal occurrence of maturity stages and GSI values.

4.4.8 . Fecundity

Fecundity has been considered as the number of ripening eggs in the ovary prior to spawning (Bagenal and Braum, 1968). The reproductive potential of a fish population depends on the number of eggs produced by a fertile female. Fecundity is associated with the size and weight of the fish and the stage and condition of the ovary. In the present study the relationship between fecundity and body length, fecundity and body weight, fecundity and ovary weight, fecundity and ovary length were considered. Fecundity models are fitted after transforming the data to log base and regression lines were drawn by the method of least squares, expressing the relationship by the following equation.

$$\text{Log fecundity} = \log a + b \log x$$

where x is the length (TL) of the fish or weight (W) or ovary weight (OW), or ovary length (OL).

a. Relationship between fecundity and total length

The absolute fecundity varied from 390 to 2412 in *H. (H) limbatus* ranging in length 147-224mm(TL) and 587 to 1554 in *H. (H) xanthopterus* ranging from 165 to 245 mm(TL). The number of eggs produced increase with an increase in length. The logarithmic relationship between fecundity (F) and total length(TL) are linear in respect of *H. (H) limbatus* and *H. (H) xanthopterus* (Fig 4.11 and 4.17) and the calculated equations are given below.

$\text{Log } F = 0.920 + 3.160 \log TL$ $r = 0.640$ $P<.01$ (*H. (H) limbatus)*

$\text{Log } F = 0.988 + 3.150 \log TL$ $r = 0.687$ $P<.01$ (*H. (H) xanthopterus)*

The results indicate a direct proportional increase in fecundity with increase in length in both the species.

b. Relationship between fecundity and body weight

The weight of the fishes considered for fecundity varied from 10.25 to 30.55 g. in *H. (H) limbatus* and 1.21 to 45.01 g. in *H. (H) xanthopterus.* Body weight also showed a linear relationship (Fig 4.12 and 4.18) with fecundity. The regression of fecundity (F) with body weight (W) can be expressed as follows:

$\text{Log } F = 1.545 + 1.194 \log W$ $r = 0.661$ $P<.01$. (*H.(H) limbatus)*

$\text{Log } F= 1.261 + 1.206 \log W$ $r = 0.716$ $P<.01$ (*H. (H) xanthopterus)*

c. Relationship between fecundity and ovary length

In *H. (H) limbatus* the ovary length varied from 41 to 71mm and in *H. (H) xanthopterus* it was from 47 to 79mm. The logarithmic relationship between fecundity and ovary length can be expressed (Fig. 4.13 and 4.109) as follows.

$\text{Log } F = 1.970 + 1.533 \log OL$ $r = 0.614$ $P<.01$. (*H.(H) limbatus)*

$\text{Log } F = 1.012 + 2.425 \log OL$ $r = 0.706$ $P<.01$. (*H. (H) xanthopterus)*

Fecundity increased with length of ovaries in both the species.

d. Relationship between fecundity and ovary weight

The ovary weight varied from 0.58 to 3.06 g. in *H. (H) limbatus* and from 0.62 to 2.48 g. in *H.(H) xanthopterus.* The logarithmic relationship between fecundity (F) and ovary weight (OW) can be expressed (Fig. 4.14 and 4.20) as follows :

Log F = 3.130 + 0.619 log OW r = 0.734 P<.01. for *H. (H) limbatus*

Log F = 2.963 + 1.029 log OW r = 0.721 P<.01 for *H. (H) xanthopterus*

The high correlation found between fecundity and ovary weight indicate that the number of ova produced were closely related to weight of the gonad.

Comparison of correlation coefficient values with fish length, fish weight, ovary length and ovary weight indicated that body weight and ovary weight are closely related to fecundity.

Regression of ovary weight with total fish length and total fish weight are given in Figures 4.15, 4.16, 4.21, and 4.22 respectively.

e. Relation between ovary weight and fish length

The relationship between ovary weight and fish length was found to be

Log OW = 1.970 + 1.530 log TL r = 0.614 P<.01. for *H.(H) limbatus* and

Log OW = -4.603 + 1.959 log TL r = 0.600 P<.01. for *H.(H) xanthopterus*

The correlation coefficient ‘r’ being 0.614 and 0.600 for *H. (H). limbatus* and *H. (H) xanthopterus* respectively, there exists a positive correlation between ovary weight and fish length.

f. Relation between ovary weight and fish weight

The logarithmic relationship between ovary weight and fish weight were calculated as

Log OW = 1.656 + 1.220 log W. $r = 0.720$ $P<.01$. for *H. (H) limbatus.*

Log OW = 1.410 + 0.666 log W $r = 0.620$ $P<.01$. for *H. (H) xanthopterus.*

Thus a positive correlation is seen to exist between the weight of the ovary and the weight of the fish in the case of *H. (H) limbatus* and *H. (H) xanthopterus.*

In order to examine whether there is any influence in fecundity indices by the fish size, the data were grouped in to 10mm length intervals and the average values for each length group were calculated (Table 4.9 and 4.10). In *H. (H) limbatus* the number of ova per gram fish weight varied from 38 (in 140 -149mm length group) to 120 (in 160-169 mm length group), the number of ova per gram ovarian weight varied from 647 (in 140-149mm length group) to 2167 (in 210-219mm length group), the maturity index is between 3.70 (in 200-209) and 8.77 (in 220-229mm), the gono somatic index is between 3.87 (in 200-209mm) and 10.29 (in 160-169mm). The average absolute fecundity varied from 390 (in 140-149mm length group) to 2412 (in 220-229 mm length group).

In *H. (H) xanthopterus* the number of ova per gram fish weight varied from 25 (in 230-239mm length group) to 41 (in 160-169 mm length group), the number of ova per gram ovarian weight varied from 1335 (in 220-229mm length group) to 756 (in 230-239mm length group), the maturity index is between 3.26 (in 220-229) and 4.98 (in 170-179mm), the gono somatic index is between 3.34 (in 230-239mm) and 5.26 (in 170-179mm). The average absolute fecundity varied from 587 (in 160-169mm length group) to 1554 (in 240-249 mm length group).

4.4.9. Sex ratio

The sexes were determined by examining the gonads and sex ratio was recorded for each month, year and length group. Sexual dimorphism was not observed in the case of both the species during the study. The observed ratios were tested against an expected 1:1 ratio by Chi square (χ^2_1) test. The observed results during the study period (May 2001 to April 2003) are given in Tables 4.11 to 4.16.

In H. (H) limbatus, females outnumbered males in most of the months however their preponderance was very glaring during November and December 2001 and January to April 2002 and 2003. The skewed sex ratio during September and December 2001 and July and December 2002 was due to preponderance of males (Table 4.11).

The sex ratio of males to females was 1:0.68 from May to December 2001, 1:1.09 from January to December 2002 and 1:3.241 from January to April 2003. The sex ratio of the total number of fishes observed was 1:1.11, Chi square value was 4.003 and P value was significant at 5% level (Table 4.12).

An evaluation of the probability of equal abundance of the sexes in each length group, showed that there was no significant departure from the expected 1:1 ratio up to a length of 119mm. From 120mm to 149mm length group the males were significantly abundant. The females however were more abundant in the higher size groups with a significant preponderance in the length group 170mm and above. It was noted that in 150 to 169mm length groups the sexes were more or less equally distributed (Table 4.15).

In *H. (H) xanthopterus* predominance of females was noticed from May to July, November and December 2001, June and December 2002 and March 2003 whereas predominance of males was noticed in September and October 2001 and July and August 2002 (Table 4.13).

The sex ratio of male to female was 1:2.42 for the year 2001 and the Chi-square value for the year show significant difference. In the year 2002 and 2003 the sex ratio (1: 1.08 and 1:1.25) did not skew much from the hypothetical value 1:1 but the predominance of females could be discernible. The total sex ratio of males to females was 1:1.60, the Chi-square value was

51.68 and P value was significant at 5% level. Altogether an overall dominance of females was noticed in *H. (H) xanthopterus* during the observation period (Table 4.14).

The sex ratios were also pooled in accordance with different length groups with a view to examine variation if any, among various size groups (Table 4.16). Chi-square values indicated that there were no significant difference from 1:1 ratio up to 140-149mm length group whereas in 150 – 159mm length group the skewed sex ratio was due to the predominance of males. From 160-169mm length group onwards females showed dominance over its counter parts.

4.5. Discussion

Information on maturation and spawning of *H. (H) limbatus* and *H. (H) xanthopterus* was totally lacking from Indian waters as well as from other parts of the world. However some information are available in respect of the species occurring along the east coast of India. The works of Talwar (1962a, 1962b, 1967) on the biology of hemiramphids of the Gulf of Mannar and Palk Bay, Sultana *et al.* (1980) on H. gaimardi of Pulicat Lake, Durai *et al.* (1988) on *H. unifasciatus* from coastal waters of Parangipettai are worth mentioning.

Altogether seven stages were identified in females, based on external appearance, extent of gonads in relation to length of body cavity, modal size of ova and their appearance under microscope and four for males as followed by Talwar (1962 b and 1967) in the case of *H. georgii* and *H.* marginatus. Sultana *et al.*(1980) used a similar seven stage classification for staging the ovaries of *H. gaimardi*. Durai *et al.* (1988) reported seven stages of maturity in female and three in male *H. unifasciatus*.

Ova diameter studies in *H. (H) limbatus* and *H. (H) xanthopterus* showed multiplicity of modes of ova in the maturing ovary. Multiplicity of modes in the frequency curves of ova diameters from maturing females suggests three possibilities: (i) either the fish spawn more than once during a spawning period or the spawning season may be a prolonged one and the process of maturation may be continuous. (ii) the secondary mode represents the eggs which are to be carried over to the next spawning season. (iii) they comprise eggs which never ripen but will degenerate at the close of breeding season (Clark 1934). In *H. (H) limbatus* and *H. (H) xanthopterus* no maturing ova were present in ovaries between two successive spawning interval. Hence the possibility of being carried over to the next season could be ruled out. Similarly the percentage of degenerative ova in spent fishes was very low and so the possibility of complete degeneration of secondary and tertiary modes could also be ruled out. So the first possibility could be taken for granted in both the species. Since the eggs in the mature stock vary in diameter 40-55m.d. (1.16-1.595mm) it was quite clear that the actual process of shedding of the ova may not be limited to a very short period but extended over a longer period as noticed in *Cypsilurus oligolepis* (Prabhu, 1956). The secondary modes indicate the growth of intraovarian eggs which are ready for release in the next batch. Similar multimode batches of eggs were noticed in *H. georgii* (Talwar 1962 a) *H. gaimardi* (Sultana *et al.* 1980, Chandrasoma and Wijaratne 1990) *H. unifasciatus* (Durai *et al.* 1988) and *H.brasiliensis* and *H.balao (McBride and Thurman, 2003).*

Based on the difference in the development of intraovarian eggs Prabhu (1956) distinguished four distinct types of spawning among teleost fishes viz type A: spawning taking place only once a year during a definite short period, type B: spawning taking place only once a year but with a larger duration, type C: spawning twice a year, type D: spawning throughout the year, but intermittently. In both *H. (H) limbatus* and *H. (H) xanthopterus* the presence of fully ripe ovaries (stage V and VI) was found from January to December. From the multimode distribution of intra ovarian eggs in the mature ovary and also on the basis of occurrence of ripe ovaries throughout the year it could be concluded that both *H. (H) limbatus* and *H. (H) xanthopterus* are continuous spawners and the spawning season is a prolonged one exhibiting 'type D' spawning as described by Prabhu (1956).

In both the species the mature ovaries were characterized by the presence of spherical and transparent eggs surface of which are covered with filaments. Similar eggs were reported in *H. georgii* (Devanesan 1937), *H. far, (Vijayaraghavan, 1957), H. quoyi* (Sudarsan, 1966), *H. marginatus (Talwar 1967), H. brasiliensis* and *H. balao* (Berkeley and Houde, 1978) and in *H. gaimardi* (Sultana *et al.*1980). The size of ripe ovum ready for release from *H. (H) limbatus* and *H. (H) xanthopterus* measured 53 m.d. (1.537 mm) and 55m.d. (1.595 mm) respectively. The eggs of similar size were reported in *H. georgii* (Devanesan, 1937) and in *H. gaimardi* (Sultana *et al.* 1980) whereas the eggs of *H.far* (Vijayaraghavan, 1957) and *H. quoyi* (Sudarsan, 1966) were slightly larger with an average diameter of 2.2 to 2.6mm. In the present study it was noted that the eggs of *H (H) xanthopterus* was slightly larger than that of *H (H) limbatus*. The presence of filaments in the eggs of other hemiramphid species and their usefulness in attachment to the weeds after release into the external environment have noted by many authors. (Jones, 1946; Devanesan and Chidambaram, 1948; Ling, 1958; Vijayaragavan, 1957; Talwar, 1967 and Sultana *et al.*1980).

The occurrence of fully ripe ovaries (stage V and VI) from January to December in both the species indicated that both are continuous spawners with peak spawning activity during April and November for *H. (H) limbatus* and June to August for *H. (H) xanthopterus.* This conforms with the findings of Qasim (1973) with regard to other Indian teleost fishes. Continuous spawning was noticed in other hemirhamphids as reported by Sultana *et al.* (1980) in *H. gaimardi* throughout the year with peak spawning activity during April, July/August and November, Chandrasoma and Wijeratne (1990) in *H. gaimardi* of Uda Walawe, Sri Lanka with February-March as the peak spawning season, Durai *et al.* (1988) in *H. unifasciatus* with peak period from March to October. On the other hand Talwar (1962 b, 1967) observed only short and restricted spawning periods in hemiramphids of the Gulf of Mannar and Palk Bay with March/April and November / December as the peak periods in the case of *H. georgii* and *Hemiramphus marginatus* respectively. In the ovary of all these hemiramphids there is a residue of tiny ova which are angular and quite transparent so that the nuclei are visible, present throughout the year. Hickling (1930) mentioned this residue of tiny ova as "reserve fund"

Panikkar and Aiyar (1939) studied the various types of breeding in brackish water animals of Madras and contradicted the belief that tropical marine species breed continuously. They observed that brackish water animals do exhibit certain definite breeding periodicities. However, there is a controversial opinion among fishery biologists as to whether the advanced group of yolked oocyte alone or all the yolked oocytes are spawned during the spawning season.

The length at first maturity was 125mm (TL) in males and 145 mm in females of *H. (H) limbatus* and 135mm(TL) in males and 155mm (TL) in females of *H. (H) xanthopterus*. Talwar (1962b) reported that the size at first maturity of males of *H. georgii* was 153mm and that of the female was 149mm respectively. Sultana *et al.* (1980) noticed that the smallest fully mature female fish of *H. gaimardi* measured 102 mm length and 50% level of maturity was at 158mm. Durai *et al.(*1988) found that in *H. unifasciatus* males attained first maturity at a smaller size (140mm TL) than females (151mm TL). Woodhead (1978) reported that fish becomes sexually mature for the first time at a size which is rather constant proportion of their final length; this value is given as close to two thirds of the final body length.

The gonado somatic index is used as a criterian for determining the duration and intensity of spawning as shown in many fishes (June, 1953; Yuen, 1955 and Thomas, 1969). The index gradually increases during development of gonads and declines at the commencement of spawning. The GSI values of *H. (H) limbatus* and *H. (H) xanthopterus* show close agreement with the above statement. The high GSI values of both the species coincide with their peak spawning periods.

In both the species seasonal fluctuations in condition factor coincide with their spawning period. The 'K' values rise at the time of peak spawning season of these species. Same results were observed by Sultana *et al.* (1980) in *H. gaimardi*, Passoupathy (1980) in sciaenid fishes and Sivakumar (1981) in *Thryssa* sp have also observed high condition factor during the spawning period. However, the variations in spawning in different species have been attributed to different factors. The low conditions before spawning, in the Cornish pilchards *Sardina pilchardus*, were due to sexual cycle and the availability of food respectively (Hickling, 1945). According to Qasim (1957) variations in conditions were probably due to the general building up and losing of biochemical reserves respectively. Thomas (1969) from his studies on *Upeneus tragula* concluded that the changes in the condition factor did not appear to be related to either the sexual cycle or the feeding intensity but to some other factors. A direct relation is found between the feeding intensity and fluctuation in the relative condition factor in *L. macrolepsis* and *M. cephalus* collected from the Mandapam lagoon (Luther, 1963). The condition factor depended on physiological factors like maturity and spawning and environmental factors like availability of food (Brown, 1957). The reason for the fluctuation of condition factor can be spawning activity as well as feeding intensity as Rao (1983) observed in *Saurida tumbil,* while Venkataramani (1979) working on carangid fishes of Porto Novo waters reported that changes in the condition factor reflected the spawning cycle.

The absolute fecundity varied from 390 to 2412 in fishes ranging in length 147 to 224 mm total length (TL), 10.25 to 30.55g body weight, 41 to 71mm ovary length and 0.58 to 3.06g ovary weight in *H. (H) limbatus* and 587 to 1554 ova in fishes ranging in length 165 to 245mm total length (TL), 12.10 to 45.01g body weight, 47 to 79mm ovary length and 0.62 to2.48g ovary weight in *H. (H) xanthopterus.* The fecundity of *H. georgii* of the Gulf of Mannar was estimated to range from 1110 to 3430 (Talwar, 1962b) and that of *H. marginatus* of the same area from 4248 to 8930 (Talwar, 1967). In *H. gaimardi* the fecundity was found to vary from 555 to 9065. (Sultana *et al.* 1980). Durai *et al.* (1988) reported the fecundity of *H. unifasciatus* ranging from 712 to 3356 and Chandrasoma and Wijeratne (1990) estimated the fecundity of *H. gaimardi* Uda Walawe reservoir Sri Lanka as 210- 459 eggs per individual. Berkeley and Houde(1978) noted that the fecundity of *H. brasiliencis* was 619-3621 with a mean 1476 and that of *H. balao* was 1483-

9451 with a mean of 4949. Smith (1933) had reported that the fecundity of *H. far* was 12,000 and that of *H. knysnaensis* was 10, 000. Ling (1958) noted that the number of eggs spawned by *Reporhamphus melanochir* is relatively small, ranging from 9000 to 10,000.

In both *H. (H) limbatus* and *H. (H) xanthopterus* the fecundity increased linearly as a function of fish length, fish weight and ovary weight. The exponential values usually reported as 3.0 when fecundity is related to length and 1.0 when fecundity is related to weight of the fish (Bagenal and Braum, 1978). In the present study when fecundity is related to length the exponential value is 3.16 for *H. (H) limbatus* and 3.15 for *H. (H) xanthopterus.* which is in close agreement with the generally accepted view that fecundity is related to the length of the fish by a factor close to the cube (Bagenal, 1957). Similar linear relationship between fecundity and length was observed in *H. gaimardi (*Sultana *et al. 1980)* where b is 2.9475 and *H. georgii* (Talwar, 1962 b) where it is 3.814. When fecundity is related to weight the exponential value is 1.19 in *H. (H) limbatus* and 1.20 in *H. (H) xanthopterus.* Similar linear relationship between fecundity and body weight have been reported by Talwar (1962 b) in *H. georgii* which lend to support the present findings. In the present study it is noted that fecundity is highly correlated with weight than length of the fish. The linear relationship noticed in between fecundity and ovary length in *H. (H) limbatus* and *H. (H) xanthopterus* was in agreement with the findings of Simpson (1951) and Somvanshi (1985). According to

Bagenal and Braum (1978) changes in the environment may also result in significant changes in fecundity.

It is significant to note that among various parameters studied, fecundity is highly related to ovary weight because the weight of ovaries of fish is mainly influenced by the ova contained in them. Hickling (1940) stated "since the production of egg is the dominant function of the ovary, a close relationship should be expected between the weight of the ovary and the number eggs produced". The linear relation between fecundity and ovary weight as observed *in H. (H) limbatus* and *H. (H) xanthopterus* is in full agreement with similar studies in other fishes (Khan and Jhingran, 1975; Siddiqui *et al.* 1976).

On comparison with other hemiramphids like *H. marginatus, Reporhamphus melanochir* and *H. gaimardi* the fecundity of *H. (H) limbatus* and *H. (H) xanthopterus* was relatively less. This may be the reason for the low population of *H. (H) limbatus* and *H. (H) xanthopterus* in Cochin backwaters. This is similar to the views of Kurup (1990) that the low values of fecundity registered in *Labeo dussumieri* was the reason for depletion of the stock in those regions where its availability has been spares.

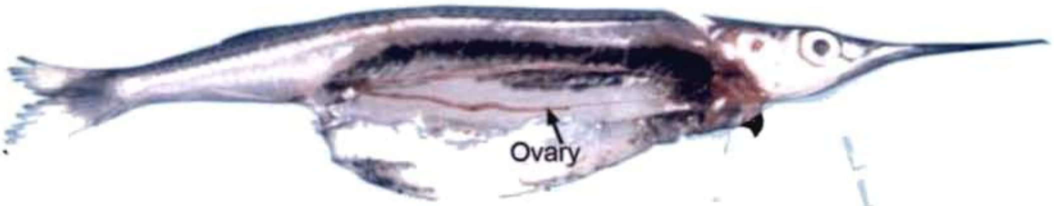
The sex ratio of both *H. (H) limbatus* and *H. (H) xanthopterus* showed predominance of females. In the case of the half beaks of the Gulf of Mannar and Palk Bay predominance of males is observed in the catches (Talwar, 1962 b;1967). Berkeley and Houde (1978) noticed that in *H. balao* and *H. brasiliensis* the sex ratio was 1:1. Sultana *et al.* (1980) and Chandrasoma and Wijeratne (1990) found that females dominated the population of *H. gaimardi.* Durai *et al.* (1988) reported that the male:female ratio was 1:2.6 in *H.unifasciatus.*

It appears that the males and females of *H. (H) limbatus* and *H. (H) xanthopterus* congregate into separate schools as noticed by Talwar (1962 b) in the case of *H. georgii* and by Ling (1958) in respect of *Reporhamphus melanochir*

The overall dominance of females could be taken as a general feature of the stock. This may be due to the easy vulnerability of the shoaling migrating stocks to fishing pressures because of their sluggishness. Test of variance of homogeneity of sex ratio showed χ_1^2 values significant at 1% level in all the years. However the dominance of either sex during different months is probably due to the combined effect of differences in areas and the segregation of sexes during different months (Reynolds, 1974). Qasim (1966) has opined that in several fish population the preponderance of one sex in the population is because of the difference in growth rates of either sex. The faster growth rate lead increasingly to less loss from predation and this might influence the sex ratio. In the present investigation also maximum size was recorded in the outnumbered sex. De Martine and Fountain (1981) suggested that the males dominated in places where spawning occurs. Magnuson and Prescott (1966) and Hunter and Goldberg (1980) have reported that during courtship a single female was followed by a group of males. Collington (1960) suggested that the sex ratio change might be due to migration. The diversity in the sex ratio is due to the partial segregation of mature forms either through habitat preference or because of school formation, then rendering one sex to be more easily caught than the other (Reynolds, 1974). However, Baglin (1982) stated that the deviation might be due to the behavioural differences between sexes, thereby any one of the sexes evolved has more accessibility than the other, during fishing operations. During the peak spawning season females were more in number compared to males in both the species and such preponderance could be due to the segregation of sexes during different months. In the present observations, though there is an overall dominance of females in the population of *H. (H) limbatus* and *H. (H) xanthopterus* predominance of males were noticed in the early stages of life. Vinci and Sugunan (1981) attributed this condition to the heavy mortality of young males due to their agile nature while as compared to its counter part.

PLATE 5

STAGE I



STAGE II

STAGE III

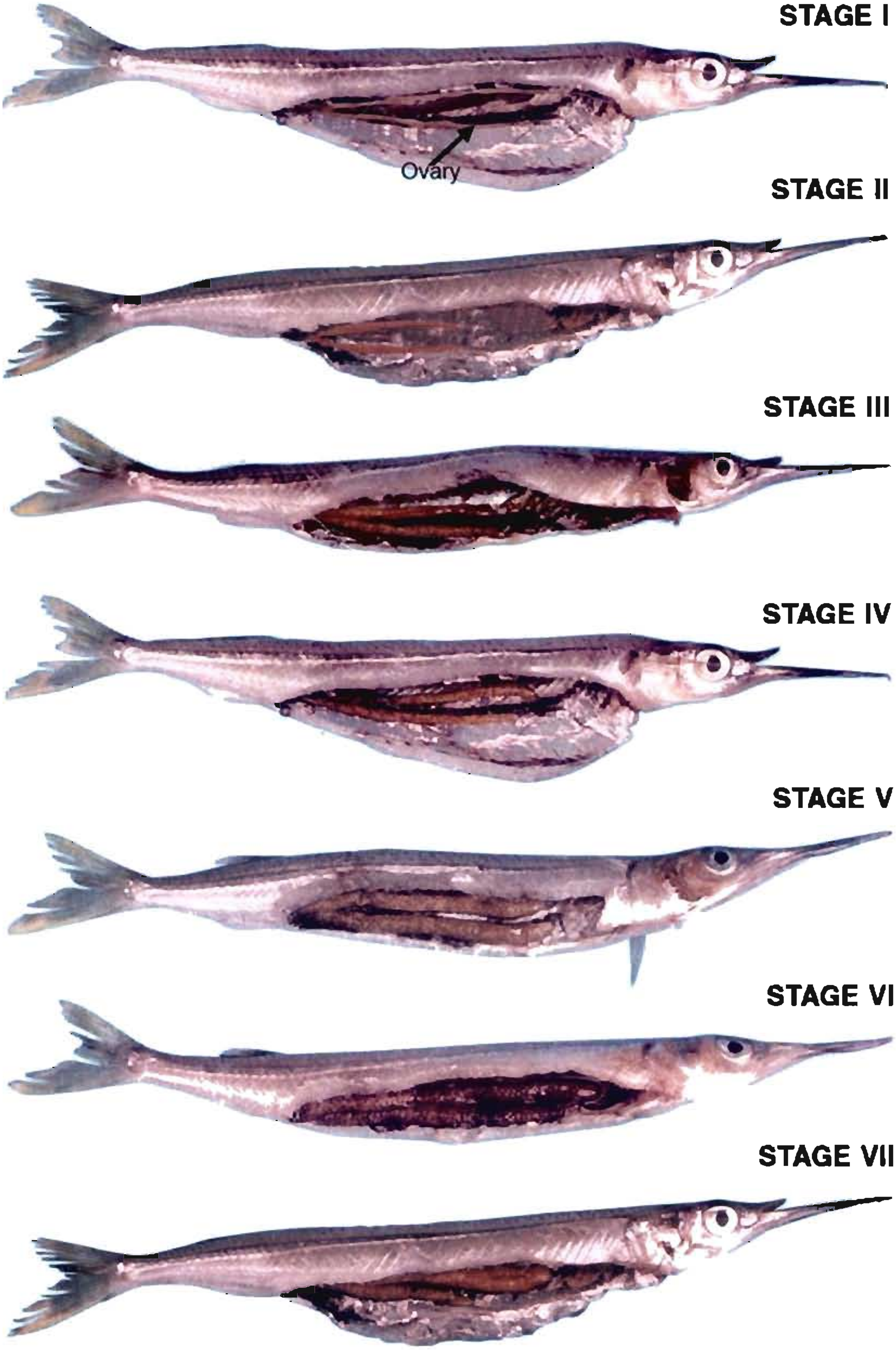
STAGE IV

STAGE V

STAGE VI

STAGE VII

PLATE 6



STAGE I

STAGE II

STAGE III

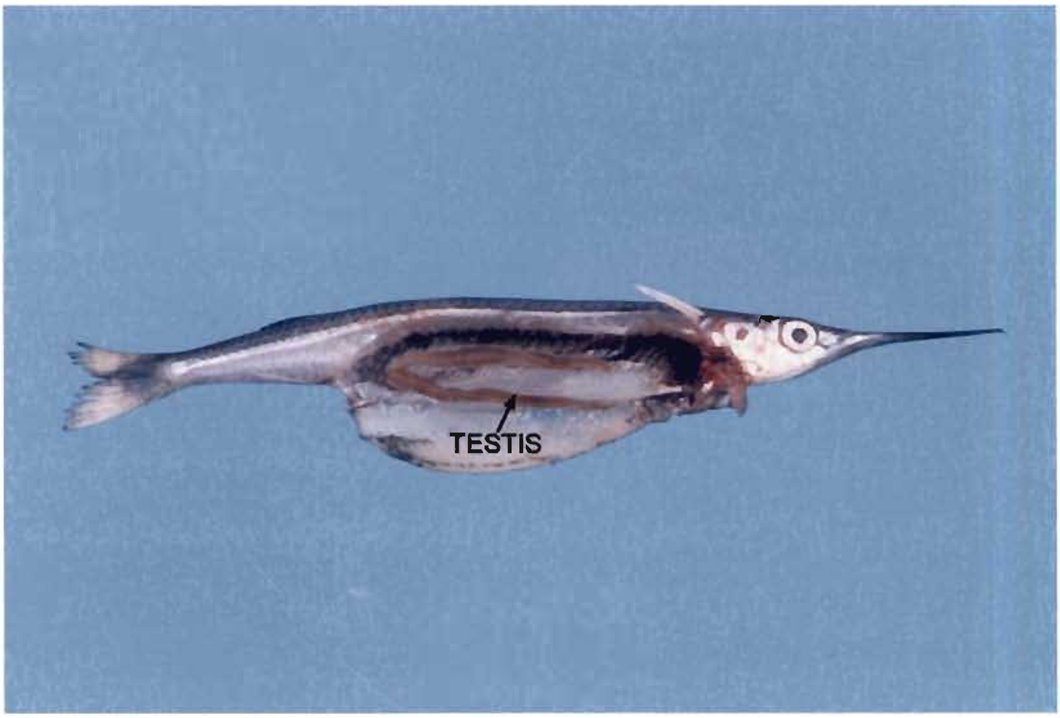
STAGE IV

STAGE V

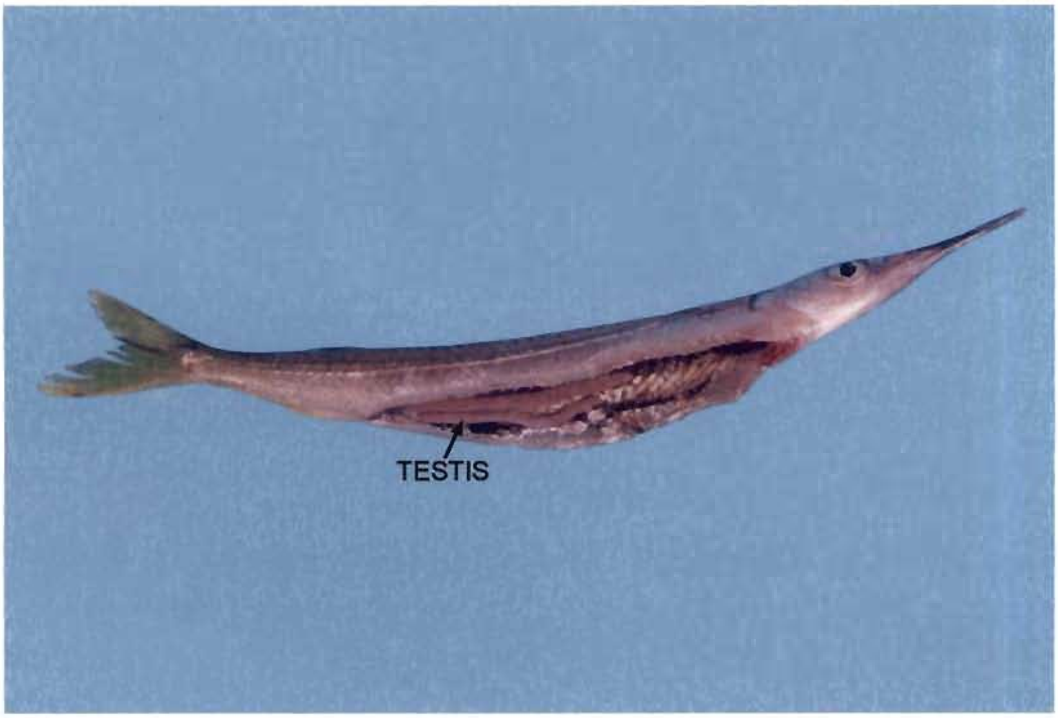
STAGE VI

STAGE VII

Different maturity stages (I-VII) of *H.(H) xanthopterus* females.



A. Maturing (Stage II) male of *H. (H) limbatus*



B. Maturing (Stage II) male of *H. (H) xanthopterus*

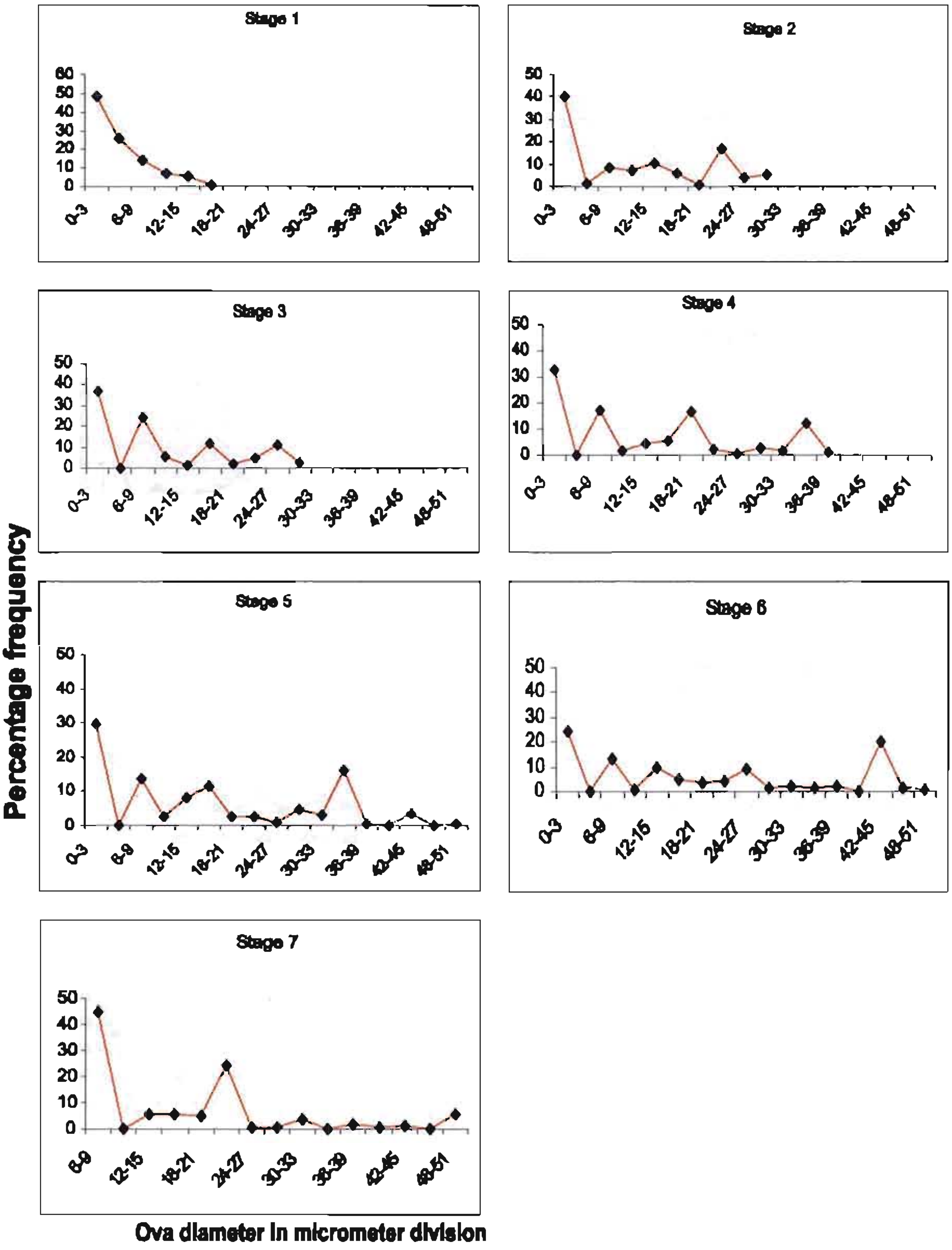


Fig. 4.1
Percentage frequency of ova diameter in various maturity stages
of H. (H) limbatus

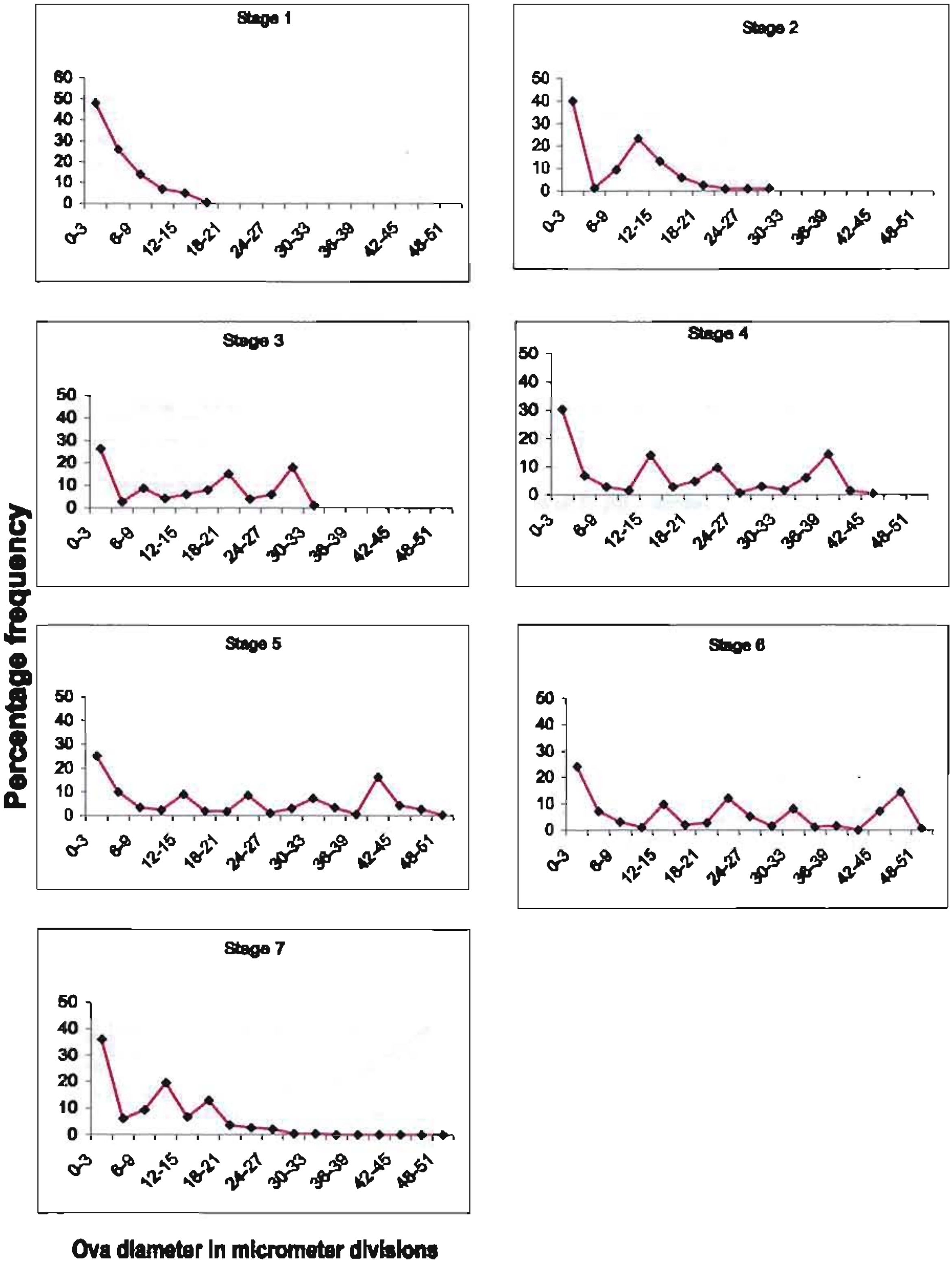


Fig. 4.2
Percentage frequency of ova diameter in various maturity stages
of H. (H) xanthopterus

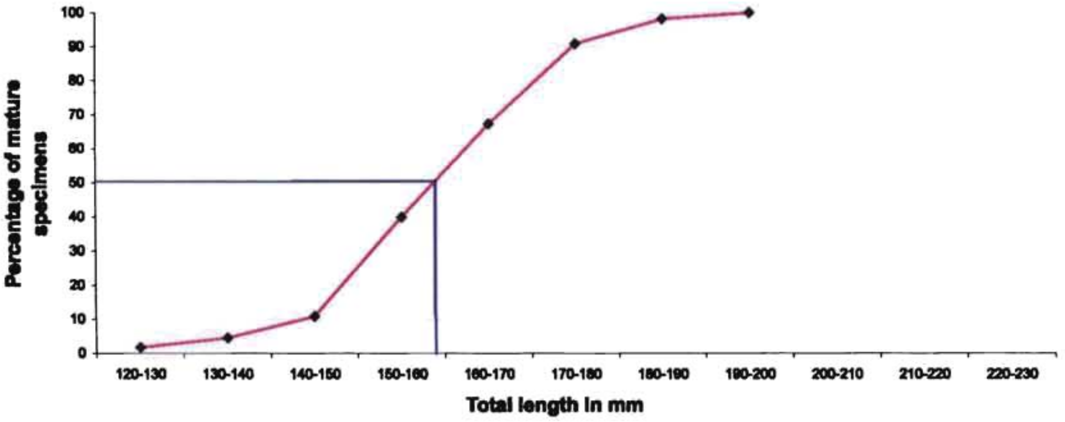


Fig. 4.3
Lenght at first maturity in males of *H. (H) limbatus*

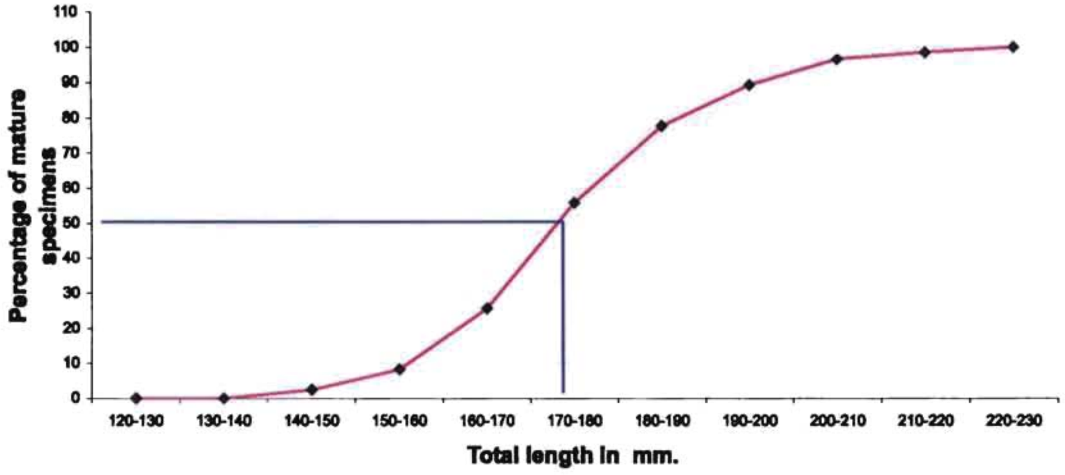


Fig. 4.4
Length at first maturity in females of *H . (H) limbatus*

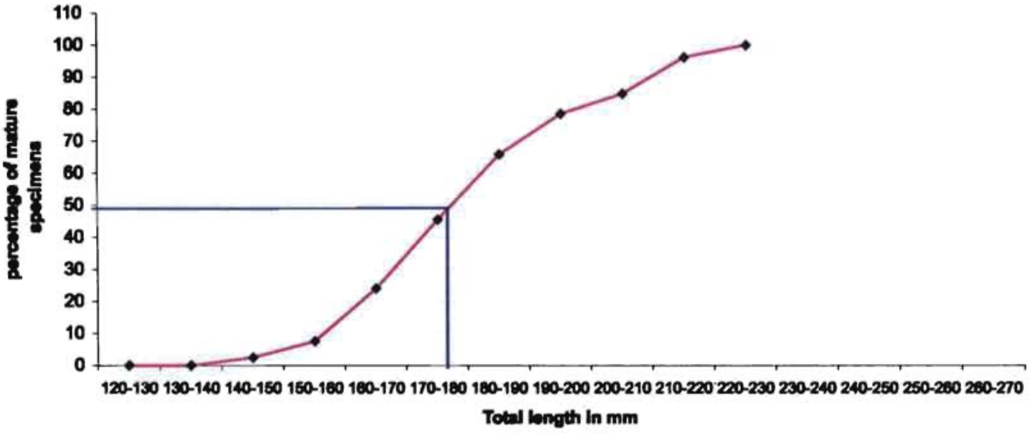


Fig. 4.5
Length at first maturity in males of *H. (H) xanthopterus*

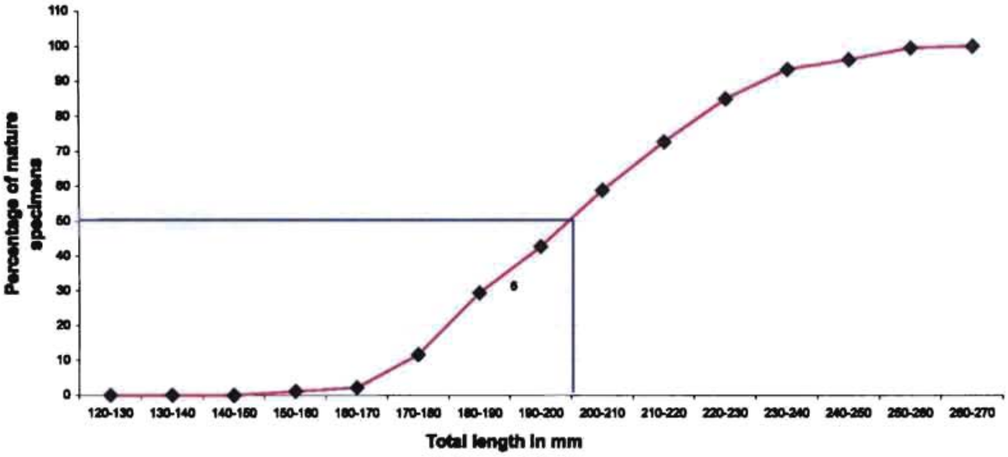


Fig. 4.6
Length at first maturity in females of *H. (H) xanthopterus*

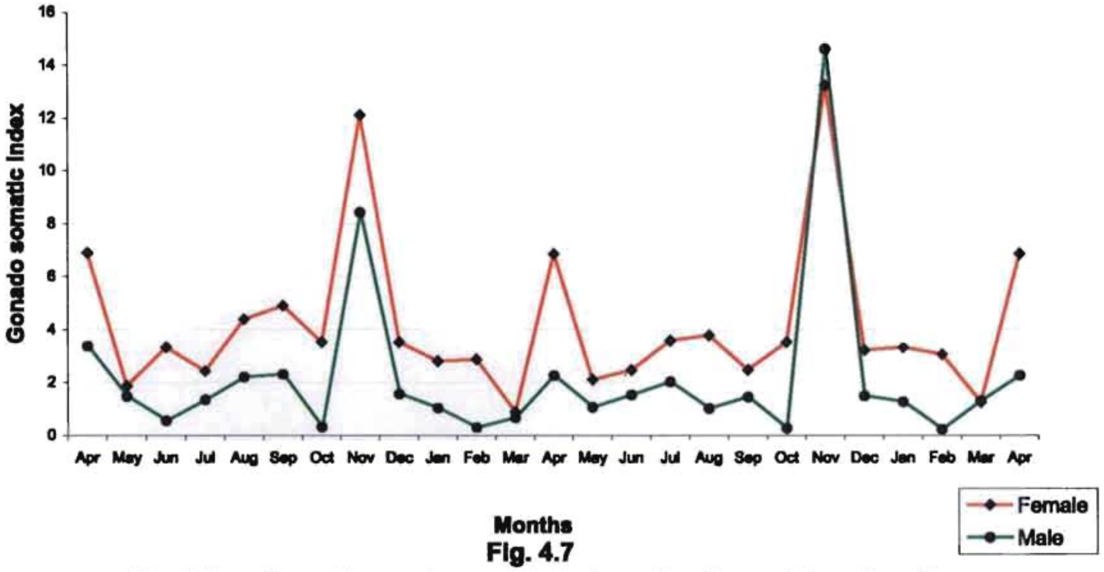


Fig. 4.7

Monthly values of gonado-somatic index of males and females of *H. (H) limbatus*

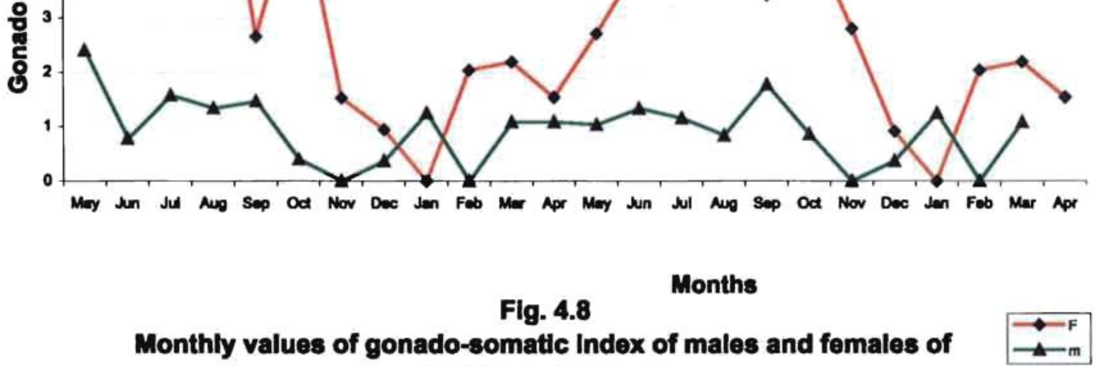


Fig. 4.8

Monthly values of gonado-somatic index of males and females of *H. (H) xanthopterus*

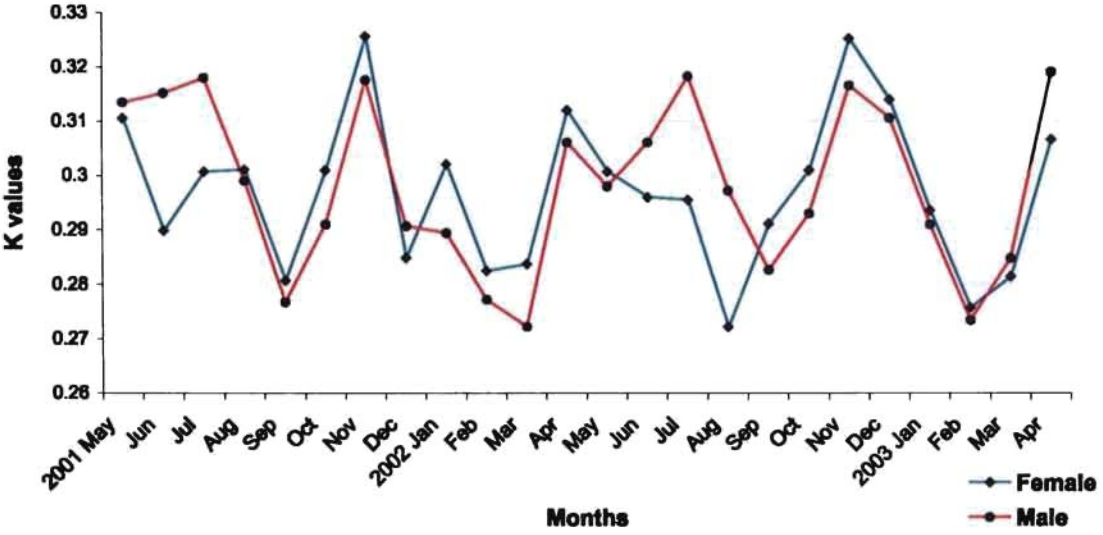


Fig. 4.9
Monthly K values of males and females of *H. (H) limbatus*

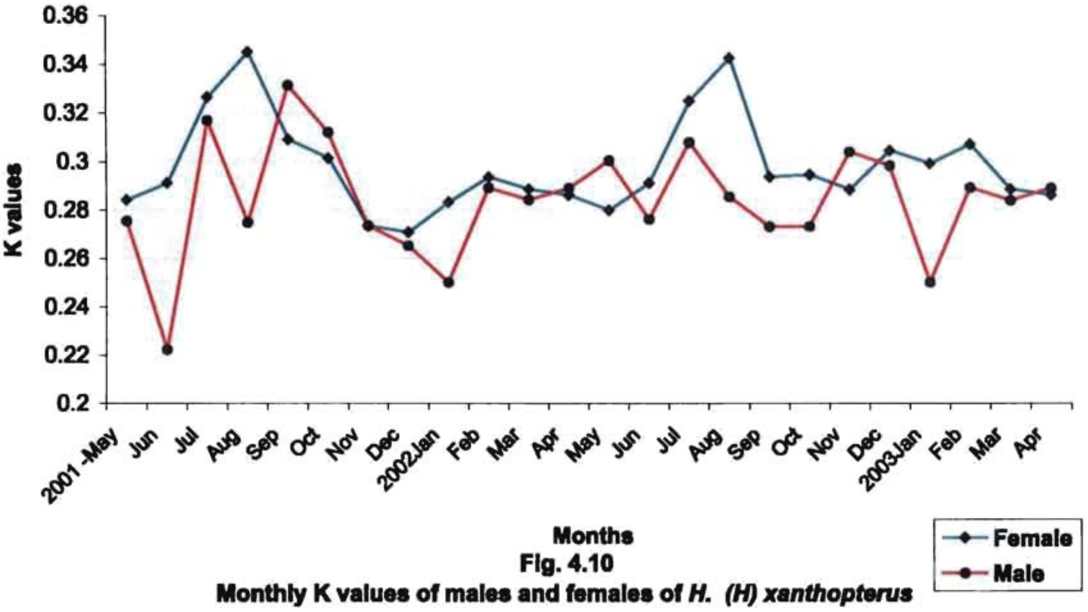


Fig. 4.10
Monthly K values of males and females of *H. (H) xanthopterus*

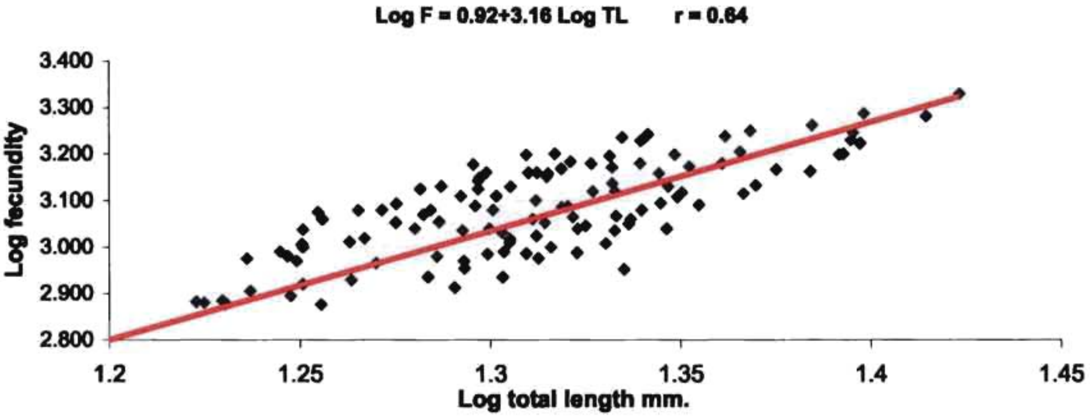


Fig. 4.11
Relationship between fecundity and total length in
H. (H) limbatus

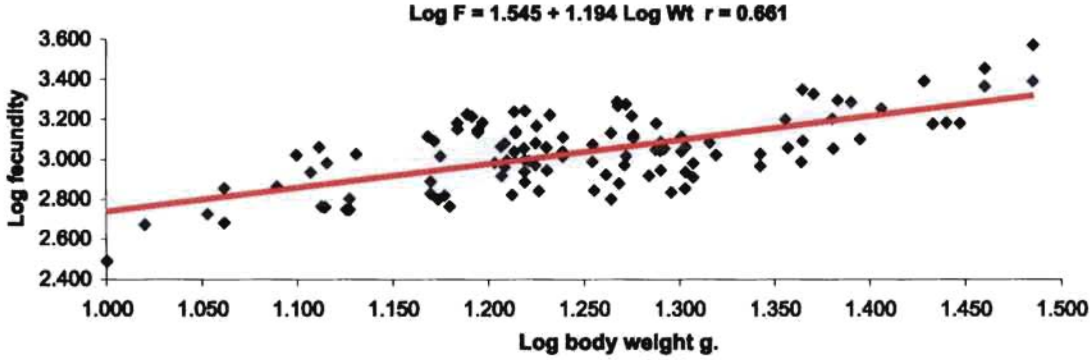


Fig. 4.12
Relationship between fecundity and body weight in
H. (H) limbatus

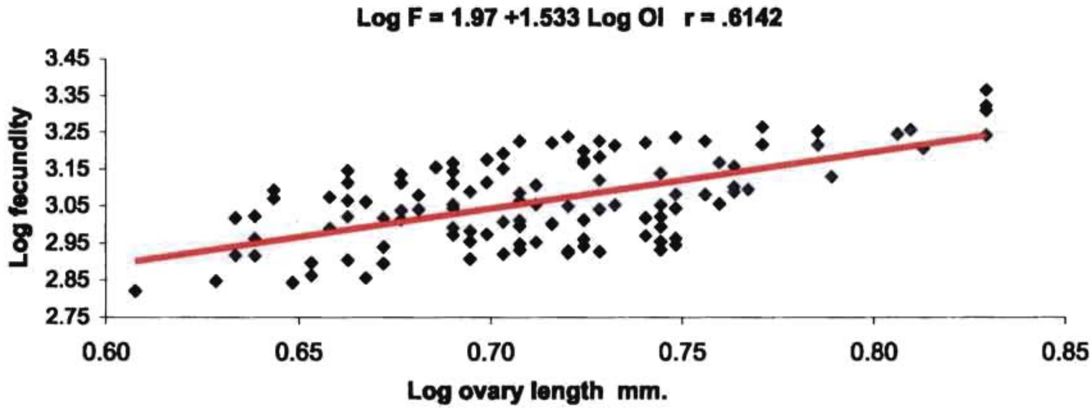


Fig. 4.13
Relationship between fecundity and ovary length in
H. (H) limbatus

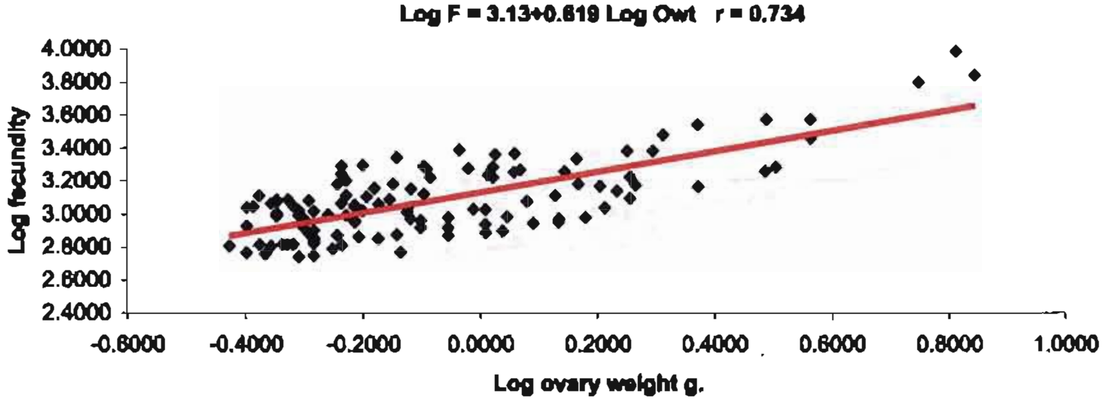


Fig. 4.14
Relationship between fecundity and ovary weight in
H. (H) limbatus

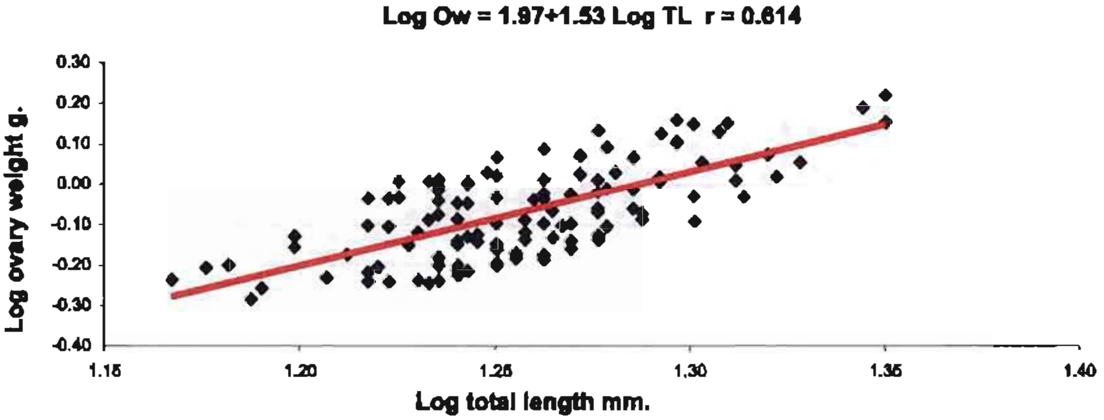


Fig. 4.15
Relationship between ovary weight and total length in
H. (H) limbatus

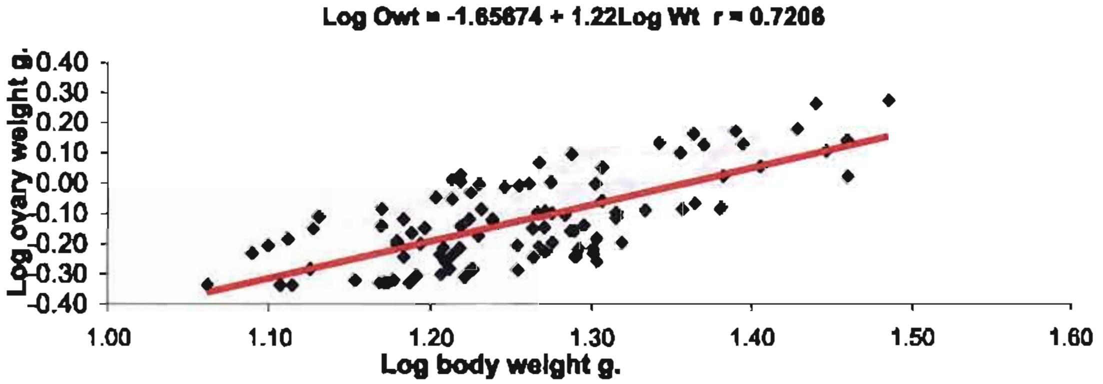


Fig. 4.16
Relationship between ovary weight and body weight in
H. (H) limbatus

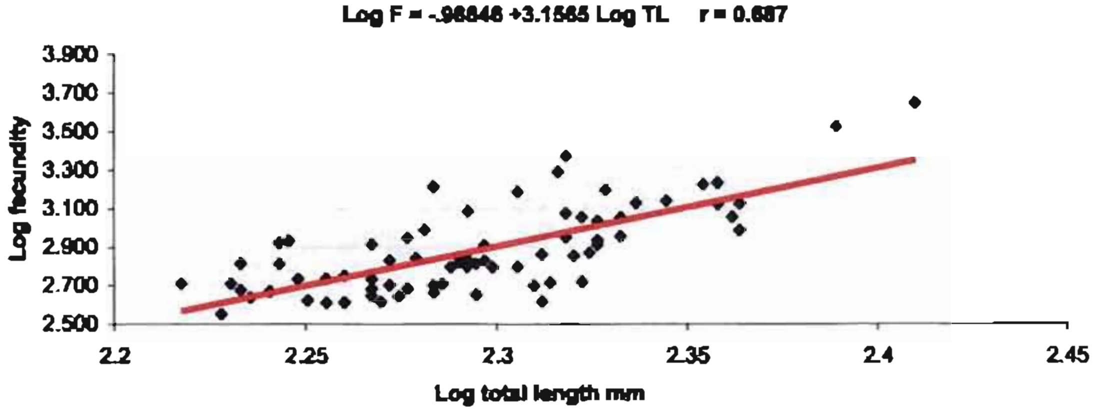


Fig. 4.17
Relationship between fecundity and total length in
H. (H) xanthopterus

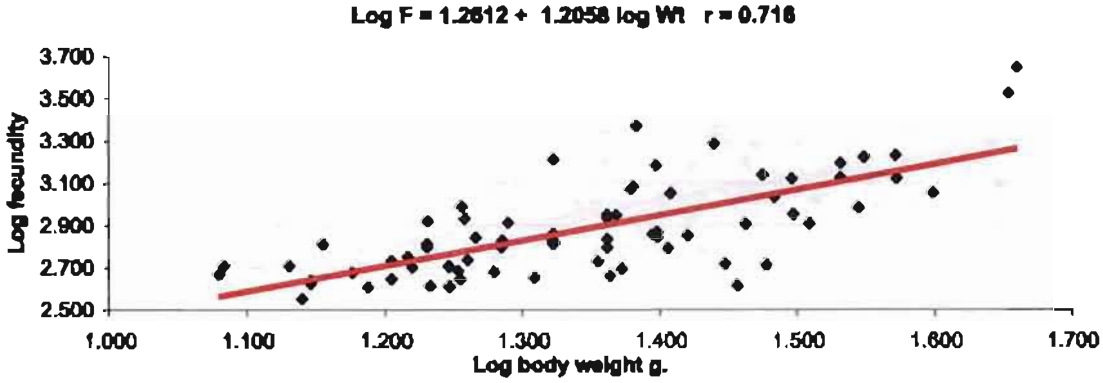


Fig. 4.18
Relationship between fecundity and body weight in
H. (H) xanthopterus

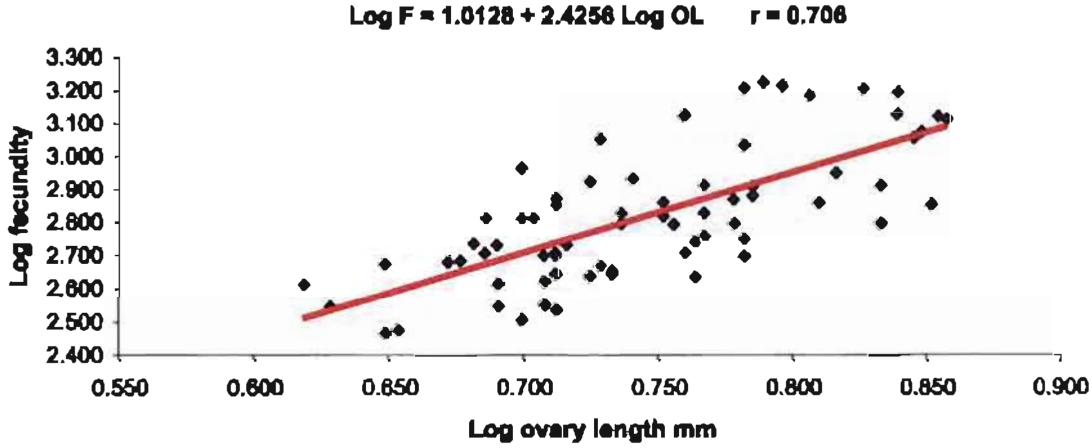


Fig. 4.19
Relationship between fecundity and ovary length in
H. (H) xanthopterus

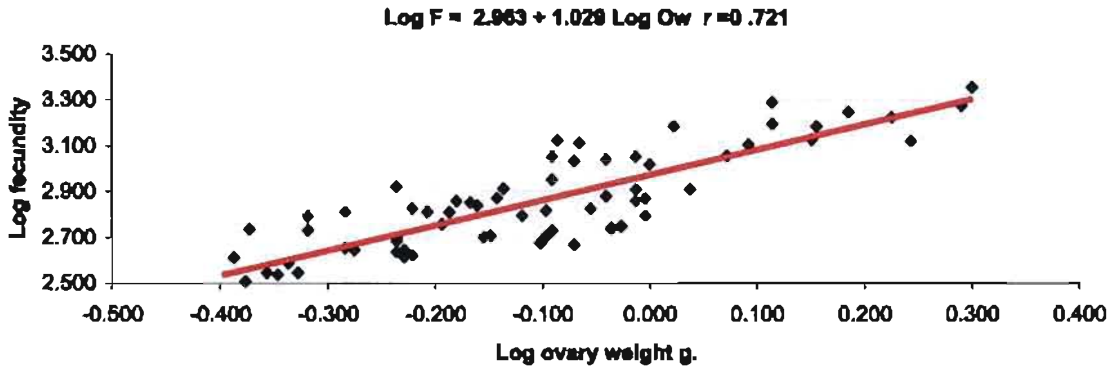


Fig. 4.20
Relationship between fecundity and ovary weight in
H. (H) xanthopterus

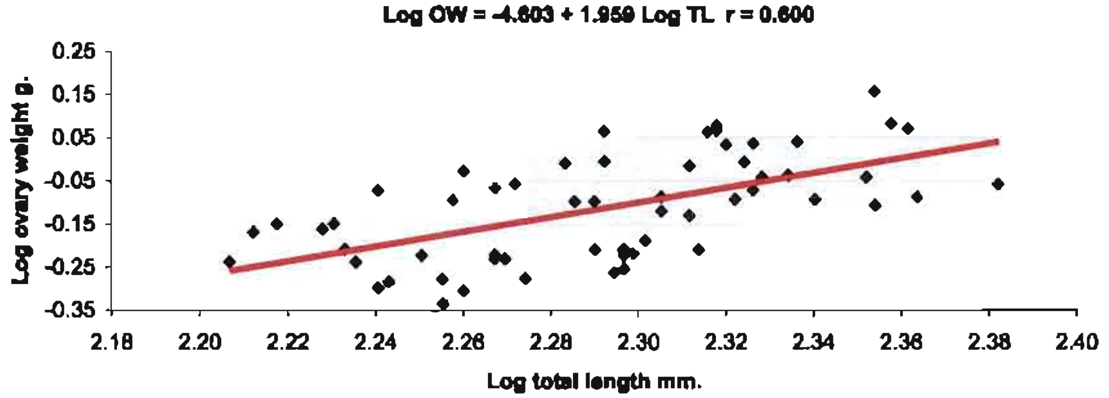


Fig. 4.21
Relationship between ovary weight and total length in
H. (H) xanthopterus

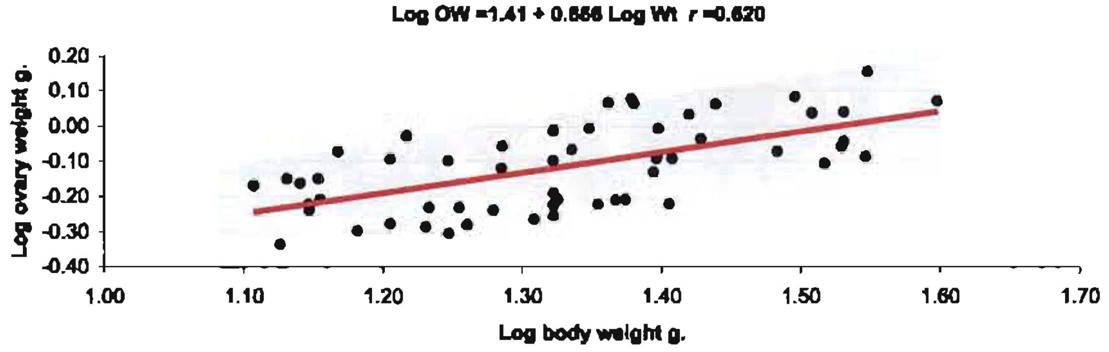


Fig. 4.22
Relationship between ovary weight and body weight in
H. (H) xanthopterus

Table 4.1

Percentage occurrence of females of *H.(H) limbatus* in different stages of maturity during different months (May 2001- April 2003).

Month	Stages of maturity							
	Year	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
May	2001	-	-	24.38	16.06	38.38	6.28	15.10
June	2001	-	-	40.00	20.00	20.00	20.00	-
July	2001	10.00	27.78	11.11	40.00	05.56	05.55	-
August	2001	26.67	13.33	13.33	33.33	13.34	-	-
September	2001	-	25.00	25.00	25.00	25.00	-	-
October	2001	28.12	12.50	23.44	26.57	09.37	-	-
November	2001	-		17.86	28.44	35.86	17.84	
December	2001	-	-	33.34	31.14	33.38	2.14	
January	2002	16.48	18.82	09.41	23.52	14.12	15.29	02.36
February	2002	03.03	18.18	30.30	24.24	09.09	12.13	03.03
March	2002	40.91	20.81	13.08	05.10	20.10	-	-
April	2002	-	06.25	15.00	10.00	40.00	28.75	-
May	2002	12.50	25.00	19.05	06.20	18.75	06.25	12.25
June	2002	37.50	23.00	04.17	16.52	08.33	08.33	2.15
July	2002	33.33	08.33	16.67	16.67	16.67	08.33	-
August	2002	-	33.33	31.14	20.14	13.24	02.15	-
September	2002	-	-	33.34	33.33	33.33	-	-
October	2002	-	-	-	33.34	33.33	33.33	-
November	2002	-	10.15	9.88	28.53	43.94	07.50	-
December	2002			20.14	31.14	46.57	02.15	
January	2003	08.57	11.43	14.29	28.57	17.14	17.14	02.86
February	2003	-	21.74	34.78	30.43	04.35	04.35	04.35
March	2003	40.00	30.00	15.00	10.00	05.00	-	-
April	2003	-	10.25	15.50	18.25	45.50	10.50	-

Table 4.2
Percentage occurrence of males of *H. (H) limbatus* in different stages of maturity during different months (May 2001-April 2003).

Month	Stages of maturity				
	Year	I	II	III	IV
May	2001		34.00	57.60	08.40
June	2001	-	50.00	25.00	25.00
July	2001		50.00	50.00	-
August	2001	14.35	49.00	36.65	-
September	2001	14.93	46.87	38.20	-
October	2001	50.00	30.00	20.00	-
November	2001	25.00	20.88	54.12	-
December	2001	17.86	35.86	28.43	17.85
January	2002	46.37	14.55	25.09	13.99
February	2002	50.00	25.00	25.00	-
March	2002	60.91	19.09	20.00	-
April	2002	-	30.00	60.00	10.00
May	2002	45.00	35.00	14.00	6.00
June	2002	27.04	31.11	29.75	2.10
July	2002	14.09	39.00	41.00	5.91
August	2002	-	50.00	50.00	-
September	2002	12.50	50.00	37.50	-
October	2002	25.00	40.00	35.00	-
November	2002	14.28	21.43	64.29	-
December	2002	24.29	17.14	45.25	13.32
January	2003	35.00	25.00	25.00	15.00
February	2003	-	50.00	50.00	-
March	2003	33.33	33.33	33.34	-
April	2003	-	30.00	60.00	10.00

Table 4.3
Percentage occurrence of females of *H.(H) xanthopterus* in different stages of maturity during different months (May 2001- April 2003).

Month		Stages of maturity						
		I	II	III	IV	V	VI	VII
May	2001	-	07.27	03.64	10.91	30.91	36.36	10.91
June		-	-	-	09.09	63.64	27.27	-
July		-	15.00	05.00	10.00	40.00	30.00	-
August		-	5.00	20.00	15.00	30.00	25.00	05.00
September		-	16.67	-	20.67	21.00	21.66	20.00
October		-	-	25.00	50.00	25.00	-	-
November		48.03	10.32	12.90	12.90	5.52	3.87	6.46
December		36.11	27.58	15.10	10.10	11.11	-	-
January	2002	30.00	20.00	20.00	18.00	12.00	-	-
February		-	-	40.00	40.00	20.00	-	-
March		-	-	-	40.00	40.00	20.00	-
April		28.57	28.57	-	-	28.57	14.29	-
May		06.67	13.33	-	46.67	26.67	06.66	-
June		0.60	03.23	03.23	12.90	38.70	41.94	-
July		-	-	-	33.34	33.33	33.33	-
August		-	10.00	30.00	-	30.00	20.00	10.00
September		-	-	-	25.00	25.00	25.00	25.00
October		-	-	-	25.00	25.00	25.00	25.00
November		-	-	25.00	25.00	25.00	25.00	-
December		63.16	26.32	-	-	10.52	-	-
January	2003	-	25.00	25.00	25.00	25.00	-	-
February		-	-	50.00	25.00	25.00	-	-
March		28.57	-	-	14.29	28.57	28.57	-
April		26.60	30.54	-	-	28.57	14.29	-

Table 4.4

Percentage occurrence of males of *H.(H) xanthopterus* in different stages of maturity during different months (May 2001- April 2003).

Month		Stages of maturity			
		I	II	III	IV
May	2001	31.25	37.50	31.25	-
June	2001	50.00	-	50.00	-
July	2001	-	32.5	53.21	14.29
August	2001	-	27.81	54.14	18.05
September	2001	9.76	32.57	38.57	19.1
October	2001	-	45.00	35.00	20.00
November	2001	40.00	30.00	30.00	-
December	2001	-	-	50.00	50.00
January	2002	50.00	25.00	25.00	-
February	2002	-	50.00	50.00	-
March	2002	50.00	25.00	25.00	-
April	2002	56.67	21.11	22.22	-
May	2002	50.00	25.00	25.00	-
June	2002	25.00	20.00	36.08	18.92
July	2002	30.03	20.81	43.70	5.46
August	2002	38.90	19.05	28.57	13.48
September	2002	-	-	50.00	50.00
October	2002	50.00	50.00	-	-
November	2002	60.00	28.57	11.43	
December	2002	50.00	25.00	25.00	-
January	2003	25.00	50.00	25.00	-
February	2003	50.00	50.00	-	-
March	2003	--	50.00	50.00	-
April	2003	30.00	25.00	35.00	10.00

Table 4.5
Percentage occurrence of different maturity stages of female *H. (H) limbatus* in various size groups (May 2001-April 2003)

Length group (mm)	Stages of maturity						
	I	II	III	IV	V	VI	VII
80-89	100	-	-	-	-	-	-
90-99	100.00	-	-	-	-	-	-
100-109	100.00	-	-	-	-	-	-
110-119	100.00	-	-	-	-	-	-
120-129	50.00	50.00	-	-	-	-	-
130-139	50.00	33.33	16.67	-	-	-	-
140-149	41.18	17.65	11.76	11.76	17.65	-	-
150-159	17.50	37.50	17.50	7.50	5.00	10.00	5.00
160-169	13.79	32.18	13.79	18.39	5.75	12.64	3.45
170-179	12.50	9.62	18.27	27.88	16.35	13.46	1.92
180-189	2.82	9.86	23.94	35.21	15.49	9.86	2.82
190-199	6.06	12.12	9.09	33.33	15.15	21.21	3.04
200-209	11.10	-	5.56	22.22	27.78	27.78	5.56
210-219	-	-	-	-	50.00	25.00	25.00
220-229	-	-	-	-	-	100.00	-

Table 4.6
Percentage occurrence of different maturity stages of male *H. (H) limbatus* in various size groups (May 2001-April 2003)

Length group (mm)	Stages of maturity			
	I	II	III	IV
60-69	100.00	-	-	-
70-79	-	-	-	-
80-89	100.00	-	-	-
90-99	100.00	-	-	-
100-109	100.00	-	-	-
110-119	50.00	50.00	-	-
120-129	47.06	41.18	11.76	-
130-139	42.30	42.31	11.54	3.85
140-149	37.50	39.58	14.58	8.34
150-159	12.82	38.46	34.36	14.36
160-169	18.39	39.08	31.84	10.69
170-179	11.32	30.75	39.06	18.87
180-189	23.53	33.53	32.65	10.29
190-199	-	-	100.00	-
200-209	-	-	-	100

Table 4.7
Percentage occurrence of different maturity stages of female *H. (H) xanthopterus* in various size groups (May 2001-April 2003)

Length group (mm)	Stages off maturity						
	I	II	III	IV	V	VI	VII
90-99	-	100.00	-	-	-	-	-
100-109	-	-	-	-	-	-	-
110-119	-	-	-	-	-	-	-
120-129	-	-	-	-	-	-	-
130-139	83.33	-	16.67	-	-	-	-
140-149	25.00	25.00	25.00	25.00	-	-	-
150-159	55.56	22.22	-	11.11	11.11	-	-
160-169	44.44	18.52	5.56	9.26	9.26	9.26	3.70
170-179	41.77	12.66	6.33	12.66	15.19	5.06	6.33
180-189	31.11	13.33	2.22	17.78	13.33	17.78	4.45
190-199	12.82	5.13	7.69	20.51	23.08	20.51	10.26
200-209	-	3.57	7.14	3.57	35.71	46.44	3.57
210-219	-	4.17	4.17	12.51	25.00	50.00	4.17
220-229	-	-	-	13.33	26.67	53.33	6.67
230-239	-	-	-	-	40.00	40.00	20.00
240-249	-	-	-	16.67	16.67	66.66	-
250-259	-	-	-	-	-	100.00	-

Table 4.8

**Percentage occurrence of different maturity stages of male *H. (H) xanthop*
various size groups (May 2001-April 2003)**

Length group (mm)	Stages of maturity			
	I	II	III	IV
90-99	100.00	-	-	-
100-109	-	-	-	-
110-119	-	-	-	-
120-129	100.00	-	-	-
130-139	-	66.67	33.33	-
140-149	44.44	33.34	11.11	11.11
150-159	14.29	57.14	21.43	7.14
160-169	36.67	46.67	13.33	3.33
170-179	35.00	40.00	20.00	5.00
180-189	27.27	30.24	30.36	12.13
190-199	20.83	22.67	31.50	25.00
200-209	17.57	22.14	31.57	28.72
210-219	3.08	56.15	33.08	7.69
220-229	5	30	45	20
230-239	-	-	-	100
240-249		50	-	50

Table 4.9
Average values of fecundity indices in the spawners of *H (H) limbatus*

Length group (mm)	Average fish length (mm)	Average fish weight (g).	No of specimens examined	Average ovarian weight (g).	No of eggs per g. fish weight	No of eggs per g. ovarian wt.	Maturity index	Gono somatic index	Absolute fecundity
140-149	148.50	10.24	2	0.60	38	647	5.86	6.23	390
150-159	155.83	12.05	6	0.72	62	1115	5.90	6.29	737
160-169	166.80	14.21	15	1.15	120	1221	8.14	10.29	1143
170-179	174.86	16.36	42	0.76	71	1809	4.68	4.97	1140
180-189	185.76	19.23	33	0.76	66	1851	3.88	4.09	1236
190-199	196.01	22.34	15	1.38	77	1638	5.83	6.37	1751
200-209	204.89	26.54	9	0.98	48	1487	3.70	3.87	1259
210-219	213.00	24.15	1	1.06	95	2167	4.39	4.59	2297
220-229	223.00	29.69	3	2.59	80	977	8.77	9.65	2412

Table 4.10
Average values of fecundity indices in the spawners of *H. (H) xanthopterus*

Length group (mm)	Average fish length (mm)	Average fish weight (g.)	No of specimens examined	Average ovarian weight (g.)	No of eggs per g. fish weight	No of eggs per g. ovarian wt.	Maturity index	Gono somatic index	Absolute fecundity
160-169	165.60	14.24	5	0.67	41	891	4.90	4.94	587
170-179	175.50	15.42	14	0.77	40	979	4.98	5.26	631
180-189	186.27	18.87	15	0.62	38	1212	3.33	3.40	720
190-199	195.37	21.68	19	0.97	31	804	4.47	4.68	673
200-209	206.56	25.04	16	1.14	37	884	4.50	4.77	912
210-219	214.00	28.40	11	1.16	31	841	4.20	4.26	884
220-229	226.29	34.35	7	1.11	36	1335	3.26	3.34	1225
230-239	232.67	36.50	3	1.64	25	756	4.55	4.70	908
240-249	243.67	38.84	3	1.36	37	1054	3.42	3.63	1554

Table 4.11
Sex ratio for different months of *H. (H) limbatus* from May 2001 –April 2003 with Chi square χ_1^2 values

Year	Month	Male	Female	M:F	% Male	% Female	χ_1^2	P-Value
2001	May	25	33	1:1.32	43.10	56.90	1.818	0.178
	June	4	10	1:2.50	28.57	71.43	1.786	0.181
	July	2	36	1:18.00	5.26	94.74	28.650	0.001*
	August	46	30	1:0.65	60.53	39.47	2.9610	0.085
	September	67	4	1:0.06	94.37	5.63	54.141	0.001*
	October	10	6	1:0.60	62.50	37.50	0.562	0.453
	November	34	56	1:1.65	37.78	62.22	4.900	0.026*
	December	87	13	1:0.15	87.00	13.00	53.29	0.000*
2002	January	44	85	1:1.93	34.10	65.89	12.403	0.004*
	February	4	66	1:16.50	5.71	94.29	53.157	0.001*
	March	22	44	1:2.00	33.33	66.67	6.682	0.009*
	April	10	32	1:3.20	23.81	76.19	10.500	0.001*
	May	24	32	1:1.33	42.86	57.14	0.875	0.350
	June	54	48	1:0.89	52.94	47.06	0.245	0.621
	July	66	24	1:0.36	73.33	26.67	18.678	0.001*
	August	2	12	1:6.00	14.29	85.71	5.780	0.016
	September	16	6	1:0.38	72.72	27.27	3.682	0.055
	October	6	6	1:1.00	50.00	50.00	0.083	0.770
	November	14	17	1:1.21	45.16	54.84	0.129	0.719
	December	88	12	1:0.14	88.00	12.00	56.25	0.000*
2003	January	40	70	1:1.75	36.36	63.64	7.645	0.005*
	February	2	46	1:23.00	4.17	95.83	38.521	0.001*
	March	6	40	1:6.67	13.04	86.96	23.674	0.007*
	April	10	32	1:3.20	23.81	76.19	10.500	0.001*

*Significant at 5% level

Table 4.12
Sex ratio for different years of *H. (H) limbatus* from May 2001 –April 2003 with Chi square χ_1^2 values

Year	Month	Male	Female	M:F	% Male	% Female	χ_1^2	P -Value
2001	May-Dec	275	188	1:0.68	59.40	40.60	61.924	0.000*
2002	Jan-Dec	350	384	1:1.09	47.68	52.32	1.484	0.223
2003	Jan-Apr	58	188	1:3.24	23.58	76.42	67.646	0.000*
Total		683	760	1:1.11	47.33	52.67	4.003	0.045*

*Significant at 5% level

Table 4.13

Sex ratio for different months of *H. (H) xanthopterus* from May 2001 – April 2003with Chi square χ_1^2 values

Year	Month	Male	Female	M:F	% Male	% Female	χ_1^2	P-Value
2001	May	32	55	1:1.720	36.78	63.22	5.56	0.01*
	June	2	22	1:11.00	8.83	91.67	15.04	0.00*
	July	16	40	1:2.500	28.57	71.43	9.44	0.00*
	August	14	20	1:1.430	41.18	58.82	0.74	0.39
	September	42	12	1:0.290	77.78	22.22	15.57	0.00*
	October	24	4	1:0.170	85.71	14.29	12.89	0.00*
	November	10	155	1:15.50	6.06	93.94	125.67	0.00*
	December	2	36	1:18.00	5.26	94.74	28.65	0.00*
2002	January	8	10	1:1.250	44.44	55.56	0.06	0.81
	February	2	5	1:2.50	28.57	71.43	0.57	0.44
	March	4	10	1:2.50	28.57	71.43	1.79	0.18
	April	18	15	1:0.83	54.55	45.45	0.12	0.73
	May	16	30	1:1.88	34.78	65.22	3.68	0.06
	June	20	62	1:3.10	24.39	75.61	20.50	0.00*
	July	74	12	1:0.16	86.05	13.95	44.698	0.00*
	August	42	20	1:0.48	67.74	32.26	7.11	0.01*
	September	2	4	1:2.00	33.33	66.67	0.17	0.68
	October	2	4	1:2.00	33.33	66.67	0.17	0.69
	November	7	4	1:0.57	63.64	36.36	0.36	0.53
	December	4	38	1:9.5	9.52	19.48	25.93	0.00*
2003	January	8	8	1:1.00	50.00	50.00	0.06	0.80
	February	2	4	1:2.00	33.33	66.67	0.17	0.68
	March	2	14	1:7.00	12.50	87.50	7.56	0.01*
	April	20	14	1:0.70	58.82	41.18	0.74	0.15

*Significant at 5% level

Table 4.14

Sex ratio for different years of *H. (H) xanthopterus* from May 2001 – April 2003with Chi square χ_1^2 values

Year	Month	Male	Female	M:F	% Male	% Female	χ_1^2	P –Value
2001	May-Dec	142	344	1:2.42	29.22	17.78	83.13	.001*
2002	Jan-Dec	199	214	1:1.08	48.18	51.82	0.475	0.490
2003	Jan-Apr	32	40	1:1.25	44.44	55.56	0.681	0.409
Total		373	598	1:1.60	38.41	61.59	51.675	0.001*

*Significant at 5% level

Table 4.15
Sex ratio for different length groups of *H. (H) limbatus*
from May 2001 –April 2003 with Chi square χ_1^2 values

Length Group	Male	Female	M:F	% Male	% Female	χ_1^2	P-Value
80-89	4	2	1:0.50	66.67	33.33	0.167	0.683
90-99	6	4	1:0.67	60.00	40.00	0.100	0.752
100-109	8	6	1:0.75	57.14	42.86	0.071	0.780
110-119	17	8	1:0.47	68.00	32.00	2.56	0.110
120-129	36	18	1:0.5	66.67	33.33	5.352	0.021*
130-139	54	25	1:0.46	68.35	31.65	9.924	0.002*
140-149	96	60	1:0.63	61.54	38.46	7.853	0.005*
150-159	156	174	1:1.12	47.27	52.73	0.876	0.350
160-169	162	197	1:1.22	45.13	54.87	3.220	0.073
170-179	106	144	1:1.36	42.40	57.60	5.476	0.019
180-189	30	67	1:2.23	30.92	69.08	13.361	0.000*
190-199	2	39	1:19.50	4.87	95.13	31.610	0.000*
200-209	2	8	1:4	20.00	80.00	2.5	0.114
210-219	-	5	-	-	100	-	-
220-229	-	3	-	-	100	-	-

*Significant at 5% level

Table 4.16
Sex ratio for different length groups of *H. (H) xanthopterus*
from May 2001 – April 2003 with Chi square χ_1^2 values

Length Group	Male	Female	M:F	% Male	% Female	χ_1^2	P-Value
90-99	2	4	1:2.00	33.33	66.67	0.167	0.683
100-109	2	-	-	100	-	-	-
110-119	-	-	-	-	-	-	-
120-129	2	-	-	100	-	-	-
130-139	7	6	1:0.09	53.85	46.15	0.001	0.991
140-149	14	7	1:0.50	66.67	33.33	1.714	0.190
150-159	26	12	1:0.46	68.42	31.58	4.47	0.030*
160-169	46	90	1:1.96	33.82	66.18	13.60	0.002*
170-179	78	127	1:1.76	36.28	63.72	15.65	0.000*
180-189	70	109	1:1.56	39.10	60.90	8.06	0.005*
190-199	44	76	1:1.73	36.67	63.33	8.01	0.005
200-209	32	56	1:1.75	36.36	63.64	6.01	0.014*
210-219	26	50	1:1.92	34.21	65.79	6.961	0.008*
220-229	10	22	1:2.20	31.25	68.75	3.781	0.050*
230-239	4	14	1:3.50	22.22	77.78	4.500	0.339
240-249	2	13	1:6.50	13.33	86.67	6.667	0.000*

*Significant at 5% level

CHAPTER 5.

HISTOLOGY OF GONADS

5. HISTOLOGY OF GONADS

5.1. Introduction

Spawning in teleosts occurs during a particular phase of the reproductive cycle. Some breed once annually, some breed at regular intervals throughout the year, and in some, such as the Pacific salmon, death follows spawning (Mollah, 1986). A correct picture of maturation and spawning in fish can hardly be obtained by the arbitrary classification of gonads. Similarly conventional methods such as the study of progression of oocytes, only give evidence of an exploratory nature of spawning (Qasim, 1973). Histological and cytological studies give greater details of spermatogenesis and oocyte growth. Two great advantages of histological classification are that the frequency of multiple spawning fish populations can be accurately estimated and regressing gonads could be distinguished from immature and postovulatory ones (Hunter and Macewiz, 1985).

Most teleosts are cyclical breeders and the ovary varies greatly in appearance at different times in the cycle. According to the pattern of oocyte development three ovarian types have been classified (Wallace and Selman, 1981). The total synchronous ovary contains oocytes all at the same stage of development; found in teleosts which spawn only once and then die, such as anadromous *Oncorhynchus* sp. or catadromous eels. The group synchronous ovary consists of at least two populations of oocytes at different developmental stages; found in teleosts which spawn once a year and have a relatively short breeding season such as the flounder, *Liopsetta abscura* and the rainbow trout, *Salmo gairdneri* and the asynchronous ovary contains oocytes at all stages of development; occurring in teleosts which spawn many times during a prolonged season as in medaka and the gold fish, *Carassius auratus* (Nagahama, 1983)].

During the past one and a half decades, there has been considerable expansion in the knowledge of fish gametogenesis by the application of cytological and electron microscopy, that enabled the workers to understand the different aspects of origin and development of the reproductive element of the ultra structural level (Gopalakrishanan, 1991; Lal, 1991).

5.2. Review of Literature

Reviews on testicular histology of teleosts are those of Dodd (1960), Hoar (1969), Kaul and Rishi (1986), Mollah (1988), Joshi and Joshi (1989), Matsura *et al.* (1987), Murayama *et al.*(1991).

Investigations on the seasonal changes in the oocytes of teleosts are many, among which the more relevant to the present study include those of Yamamoto (1956 a,b,c,d), Chopra (1958), Sathyanesan (1960, 1961), Yamamoto and Yamazaki (1961), Yamamoto *et al.* (1965), Rajalakshmi (1966), Lambert (1970a), Beams and Kessel (1973), Khoo (1975; 1979), Guraya *et al.*(1977), Ritakumari and Padmanabhan (1976), Sobhana and Nair (1977), Htun-Han (1978 a), Guraya and Kaur (1979), Shackley and King(1979), Pankhurst(1982), Cyrus and Blaber (1984), Hunter and Macewiz (1985), Selman *et al.*(1986), Mayer *et al.*(1988), Mollah (1986; 1988), Jayasankar (1989), Sahu *et al.*(1990), Gopalakrishnan (1991), Elordy-Gray *et al.*(1994), Janssen *et al.*(1995), Palmer *et al.*(1995), Coward and Bromage (1998), Maddock and Burton (1999), Rideout *et al.*(1999)and Rhodes and Sadovy (2002).

Among hemiramphids, the histological features of ovarian and oocyte developments for *H.brasiliensis* was studied by McBride and Thurman(2003). So far no attempt has been made to carry out the histological and cytological studies on gonad development of *H. (H) limbatus* and *H. (H) xanthopterus*. So the present study was carried out.

5.3. Materials and Methods

Monthly samples of fishes were collected from different fish landing centres, markets of Cochin coast and some fishing grounds in Vembanad Lake like Eloor, Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map. (Fig. 1.1). After identifying the stages of the gonads, portions of the anterior, middle and posterior regions of both testes and ovary were fixed in Bouin's fixative.

After 24 hours of fixation, they were washed under tap water and stored in 70% ethyl alcohol until further processing. Each tissue sample was given a code number and its details recorded. The stored tissues were later dehydrated following the standard procedure in graded alcohol series. The tissues were then cleared in xylene or methyl benzoate, impregnated with and embedded in paraffin wax (58 – 60°C melting point). The paraffin blocks were catalogued and stored in labelled polythene bags. Sections were cut at 5-7 μm thickness in a Fuji optex (Japan) rotary microtome.

Mayer's egg albumin (Gray, 1973) was used as the adhesive for fixing the paraffin ribbon with sections, on to the clean dry glass slides. This adhesive is a combination of egg white and glycerol in 1:1 ratio. The sections were deparaffinised, hydrated and stained with Haematoxylin (Gray, 1973) and 1% aqueous eosin as the counter stain. DPX was used as the mounting medium for all the slides.

5.4. Results

5.4.1. Morphology and Histology of testis

The changes in the morphological appearance of the testis can be categorized into four stages of development. Stage I immature, Stage II maturing, Stage III mature and Stage IV Spent (Refer chapter on maturation and spawning for details) .

The testes of *H (H) limbatus* and *H (H) xanthopterus* are paired elongated strap like organs connected to the body dorsally by a thin membrane called mesoarchium Dorsally, each testis is composed of thick tunica albuginea consisting of smooth muscles, connective tissue, spermducts and blood vessels. The sperm ducts variable in number run throughout the length of the testis. Towards the ventral side, testis consists of irregularly branching seminiferous tubules packed with germinal cysts. Thin septa originating from tunica albuginea, ramify forming the thin tubular walls. Within the tubules, cells in various stages of spermatogenesis were present in discrete nests of cells, each nest consisting of cells at the same stage of development. During the breeding season the tubules became greatly distended with spermatids and spermatozoa.

The testes in *H (H) limbatus* and *H.(H) xanthopterus* are typical atheriniform type exhibiting the tubular or restricted spermatogonial pattern (Plate 8 A and 10 A). Each tubule is completely surrounded by a thin basal lamina. The Intertubular space consists of flat, spindle shaped myoid cells, arranged in single to multiple layers. The zone between myoid cells and basal lamina consists of connective tissue containing collagen fibres. Interstitial areas, are mostly angular spaces, arising due to compact arrangement of the tubules. Leydig cells usually present in these areas, are of irregular shape, distributed single or in clusters.

The tubules are regularly oriented between the external tunica propria (blind end) and a central cavity into which the spermatozoa are released. Primary spermatogonia are located only at the blind end of the tubule immediately beneath the tunic albuginea. As spermatogenesis and spermiogensis proceed, the germinal cyst moves centrally within the testis towards the vas efferens (efferent duct); there is no structure corresponding to the lobular lumen in this type. Inside the tubular compartment two types of cells can be distinguished, sertolicells and germ cells. Sertoli cells are somatic cells found in close association with the germ cells.

5.4.2. Spermatogenesis

In the maturing testes of both *H.(H) limbatus* and *H.(H) xanthopterus* germ cells at the different stages of spermatogenesis are observed (Plate 8 B and 10B). In both species the pattern of development is more or less same. The different stages of spermatogenesis identified with the help of light microscope are the following .

5.4.2.a. Primordial germ cells (PGC)

PGCs are only observed in the newly differentiating testis. These cells, found in clusters of variable sizes, are characterized by polygonal shape and a highly basophilic nucleus. PGCs proliferate mitotocally and arrange in the form of single layer around newly forming tubules, prior to their transformation into spermatogonia.

5.4.2.b. Spermatogonia (SG)

These cells are smaller than the primordial germ cells. The nucleus of a spermatogonium had a nucleolus at the middle or towards one side. The spermatogonial cells are seen arranged in the form of a layer of cells separated from each other by strands of sertoli cell cytoplasm. Tubular configuration of the testis is still not fully established. Spermatogonia are more or less oval cells with regular outline.

5.4.2.c. Primary spermatocytes (PSP)

Primary spermatocytes are smaller cells with highly basophilic nuclei destined to undergo meiosis. Spermatocytes contain oval nuclei. First meiotic division gives rise to secondary spermatocyte.

5.4.2.d. Secondary spermatocytes (SSP)

SSP are much smaller cells with very scanty cytoplasm surrounding an intensely staining, basophilic nucleolus. The secondary spermatocytes undergo maturation division (meiosis II) to produce spermatids.

5.4.2.e. Spermatids (ST)

Spermatids are the final products of meiosis. Young spermatids, enclosed within the germinal cyst are undifferentiated cells with nearly spherical, centrally positioned nucleus. Spermatid metamorphose into highly specialized spermatozoa through a specific process, spermiogensis, involving concurrently occurring events viz-condensation of nuclear chromatin, development of flagellum, formation of midpiece and expulsion of excess cytoplasm. Spermiogenesis is divisible into two discrete phases with respect to changes in nuclear chromatin. Chromatin granules become finer in size and homogeneously distributed in the nucleus of spermatid. During the spermiogenesis, the cell volume is reduced considerably. This makes the plasma membrane to closely adhere to the nucleus in the mature spermatozoon.

5.4.2.f. Spermatozoa (SP)

Mature spermatozoa is divisible in to head, midpiece and tail. Mature spermatozoa are released from germinal cyst into the sperm duct. Initially, the spermatozoa are seen as clumps with their tails held together (Plate 9A and 11A). Gradually, individual spermatozoa separate out and are packed in tubules of ripe testis.

During the spawning phase the tubules and spermaducts are filled with milt and do not have spermatogenetic cysts (Plate 11B). After the spawning, the tubules contain residual spermatozoa and the spermaducts are mostly empty (Plate 9B). After the spent stage, the testis revert to recovering spent to resume the cycle for the next spawning season.

5.4.2.g. Relationship between histological observation and morphological appearance of the testis.

Stage I. Immature

The testis are thin, translucent and pale in colour. The tubules are small thick walled and filled with a large number of spermatogonia. Some of the spermatogonia are seen in a state of division to form primary spermatocytes.

Stage II Maturing

The testis show gradual increase in their volume and weight and become opaque. The tubules slightly increase in diameter, and the connective tissue occupying the intertubular space is slightly reduced. The tubule wall becomes thin and cysts contain germ cells in varying stages of maturity. As spermatogenesis progresses further, the primary spermatocytes are reduced in number. Secondary spermatocytes and spermatids become the dominating cells in the tubes.

Stage III Mature

Tubules of the testis fully packed with sperms are seen in many specimens.

Stage IV Spent

Testis become thin, slender, translucent assume white or pale yellow colour. Tubules become comparatively smaller. A few relic masses of sperms are also seen in the lobules. Spermatocytes are almost absent indicating the cessation of spermatogenesis.

5.4.3. Morphology and histology of the ovary

The general morphological appearance of the ovaries of *H.(H)limbatus* and *H.(H)xanthopterus* at different stages of development is summarized in to seven stages. They are stage 1 immature, stage II developing virgin or recovered spent, stage III maturing, stage IV mature, stage V ripe, stage VI spawning and stage VII spent (Refer chapter on maturation and spawning for details).

In both *H.(H) limbatus* and *H.(H) xanthopterus* the ovaries are covered by a thin outer coat (serosa), the tunica albuginea, beneath which lie the thick ovarian wall consisting mainly of connective tissue containing numerous blood vessels and smooth muscles. Oocytes at various stages of maturity are embedded within the folds of the connective tissue, the ovigerous lamellae. These lamellae project from the ovarian wall into the ovarian cavity, the ovocoel.

The walls of the ovary consist of tunica albuginea, a thick layer of connective tissue containing numerous blood vessels and smooth muscle fibres. The ovary is attached to the dorsal wall of the body cavity by a thin peritoneum. The tunica albuginea projects into the ovarian cavity to form a relatively few ovigerous folds. The developing oocytes (the oogonia) lie along these folds, embedded in the loose connective tissue.

Oocyte development occurs in a temporal and spatial pattern in the ovary of *H (H) limbatus* and *H (H) xanthopterus.* It is now generally recognized that oogenesis occurs in four distinct phases.

1. **The primary growth phase** - involves oogonial proliferation by mitotic division, meiotic transformation of oogonia into primary oocytes and growth of primary oocytes concomitant with nuclear changes (Tokarz, 1978; Khoo, 1979).
2. **The secondary growth phase** - involves deposition of yolk viz, vitellogenesis and is characterized by rapid oocyte growth.
3. **Oocyte maturation** – which involves resumption of meiosis, germinal vesicle break down, coalescence of yolk and hydration of oocytes to form the ripe egg.
4. **Ovulation** – the process by which the eggs after the completion of first meiotic division are released into the ovarian or peritoneal cavity. In histological preparations the above mentioned phases can be further classified into seven stages as mentioned below.

Stage I. - Oogonia, found within the germinal ridge

Primary growth phase

Stage II - Chromatin nucleolus oocytes

Stage III - Perinucleolar oocytes

Secondary growth phase

Stage IV - Corticle alveoli formation

Stage V - Vitellogenic oocytes

Oocyte maturation

Stage VI - Maturational oocytes

Ovulation

Stage VII - Ovulated mature eggs

5.4.4. Oogenesis

The classification of the main stages of oogenesis followed in the present study is based on the developmental sequence laid by Yamamoto and Yamazaki (1961), Guraya (1986), Mayer *et al.*(1988) and Begovac and Wallace (1988) and Gopalakrishnan (1991) for different teleosts.

5.4.4.a. Oogonia .

Oogonia are observed in the ovaries of both *H.(H)limbatus* and *H.(H)xanthopterus* (Plate 12A and 15A). The oogonia constitute the stem cells of the germ cell lineage. Oogonia are found in the luminal epithelium near the germinal ridge itself. The germinal ridge is an out pocketed region of the ovarian luminal epithelium (Begovac and Wallace, 1987)

The oogonia appear as oval or rounded cells, having an almost regular outline. Although they are observed singly, the cells tend to occur in nests (4-6 cells together) in the stroma of ovigerous folds. The large ovoid or roughly spherical nucleus is situated almost centrally and has a regular outline. The nuclear envelope is nearly smooth; the chromatin appears rather granular and dispersed in the nucleoplasm, but small dense clumps are found associated with the inner side of the nuclear membrane. The oogonial cytoplasm is basophilic. These cells are observed rarely because they are immersed in the stroma, and this tissue is generally lost during processing.

Primary growth phase (PGP)

5.4.4.b. Chromatin nucleolus stage

The chromatin nucleolus stage is observed in the ovaries of both *H.(H)limbatus* and *H.(H)xanthopterus* (Plate 12A and 15A). The primary growth stage is initiated by true oogenesis, or oocytes formation. It is the period of follicle formation and an increase in the amount of cytoplasm and cellular organelles within the oocytes. Chromatin nucleolus oocytes are round or oval cells having an almost regular outline. They are found within the germinal ridge and have not yet become incorporated into definitive follicles. The roughly spherical and slightly eccentrically located nucleus is well developed and occupies the greater part of the cell. The thin layer of cytoplasm is strongly basophilic.

5.4.4.c. Perinucleolar stage

Early and late perinucleolar stages are clearly observed in both *H.(H)limbatus* and *H.(H)xanthopterus* (Plate 12B and 15B).

a. Early perinucleolus stage

This phase of primary growth typically begins as the definitive follicle separates from the germinal ridge. The perinucleolar oocytes are transparent, round or oval or polygonal and are arranged in ovigerous lamellae with the nucleolus clearly visible. The large, spherical centrally located nucleus now referred to as "germinal vesicle" shows an almost smooth outline.

The nucleus contains multiple nucleoli in a perinuclear position adjacent to the inner layer of the nuclear envelop. In early perinucleolus oocytes, most of the cellular organelles are typically present in a juxtanuclear mass commonly known as the Balbiani vitelline body (Guraya, 1979). The ooplasm is homogeneous and highly basophilic.

A thin basal lamina lies closely on the granulose cells. A layer of thecal cells associated with the follicle cells external to the basal lamina. Dense-cored granules can still be observed in oocyte nuclei. During this stage, the nucleus increases in size and the nucleoli increase in number.

b. Late perinucleolus stage

The oocytes are round in this stage. The nucleus increases in size and stains basophilic more lightly. The cytoplasm is still basophilic and homogeneous in appearance.

As this stage progresses the balbiani vitelline body shifts to form first a crescent shape, then progress to a perinuclear ring that finally disperse throughout the oocytes by late perinuclear growth. Thus during primary growth phase, while the nucleus to cell ratio decreases as the oocyte volume increases, the absolute size of the nucleus increases and multiple nucleoli appear.

Secondary growth phase

5.4.4.d. Cortical alveoli stage

Early and late cortical alveoli stages are identified in the ovaries of both *H.(H) limbatus and H.(H) xanthopterus* (Plate 13 A, 16 A and 16 B). This stage is characterized by the initial appearance of three components : 1) cortical alveoli 2) vitelline envelop and 3) lipid. The cortical alveoli and vitelline envelope initially appear at approximately the same time. Cortical alveoli, are first observed in the light microscope throughout the peripheral cytoplasm of oocytes. The early cortical alveoli are membrane-limited,clear structures having a homogeneous appearance. As oocytes increase in size, the cortical alveoli increase in number, purple in colour and became heterogeneous in size as they fill much of the oocytes cytoplasm. This is the late cortical alveoli stage. In *H.(H) limbatus* the cortical alveoli are slightly basophilic and not very much distinct compared to that of *H.(H) xanthopteus* where they are eosinophilic and prominent.

Under light microscope, the follicular layer is observed as lightly basophilic layer external to the acidophilic zona radiata. The minute nuclei of which are highly basophilic. The follicular epithelium is made up of outer thecal layer and inner zona granulosa. This vitelline envelope is observed in between the oocyte and overlying follicle cells (Plate 14 A and 16 A).

A third process that occurs in cortical alveoli stage oocytes is the formation and accumulation of lipid droplets in the cytoplasm along with cortical alveoli.

5.4.4.e. Vilellogenesis

a) Early yolk globule stage

Vitellogenesis involves the accumulation of exogenously derived yolk protein into the oocytes and is responsible for the majority of oocytes growth (Wallace, 1985). Oocytes in early vitellogenesis are characterized by the appearance of individual small yolk spheres in the oocyte periphery and interior in both *H.(H) limbatus and H.(H) xanthopterus* (Plate 13 B , 17 A and 17 B). These yolk spheres can be distinguished as primary, transitional and mature. As oocytes growth proceeds, the interior yolk spheres become heterogeneous in size while smaller yolk spheres still are present in the peripheral ooplasm. The accumulation of yolk spheres in oocyte interior results in the progressive displacement of cortical alveoli and lipid to the peripheral cytoplasm. The larger yolk spheres apparently form by fusion of the smaller yolk spheres.

Yolk protein appeared initially near the nucleus but later expanded throughout the cytoplasm and became globular (Plate 17 A, 17 B). Several events occur during the vitellogenic stage. By mid vitellogenesis, the vitelline envelope has undergone condensation.

b) Late yolk globule stage

In late vitellogenic oocytes, most of the individual yolk spheres disappear and a large central fluid yolk mass is formed (Plate 14 A and 18 A). The cytoplasm containing small yolk spheres, cortical alveoli and lipid is displaced to the thin rim at the oocyte periphery (Plate 18 B). The nucleus becomes more irregular in outline and the peripheral nucleoli have become smaller and more irregular in shape. The major change observed in the ooplasm in comparison to the earlier stage is the appearance of minute acidophilic yolk globules in the peripheral cytoplasm (Plate 13 B). The thin layer of basophilic ooplasm (cortical alveoli) is still visible in the cortex of oocytes. The zona radiata increases further in thickness. At the end of the late yolk granule stage, when the sequestration of yolk material has been curtailed, the oocytes reach a critical size, which is species specific and now termed “post-vitellogenic oocytes”.

Oocyte maturation

5.4.4.f. Migratory nucleus stage

Migratory nucleus stage is observed in both *H.(H) limbatus and H.(H) xanthopterus* ovaries (Plate 14 A and 18 B). When oocytes reach this stage, they become capable of resuming first meiotic division by undergoing germinal vesicle breakdown (GVBD). Structurally, the post vitellogenic oocyte contains a large, central fluid yolk mass and has at its periphery a thin rim of cytoplasm containing mostly cortical alveoli and lipid. Lipid droplets in prematurational oocytes are generally distributed around the entire oocyte periphery prior to maturation.

5.4.4.g. Mature egg

This stage is the culmination of oocyte development and represents a cell capable of being fertilized. Macroscopically, the egg is oval to pear-shaped (Plate 18 B). No coloured pigments are present in the egg; so the egg is colourless. The nucleus has undergone dissolution as a result of final maturation. The mature egg retains the large central fluid yolk mass. Cortical alveoli are uniformly distributed around the oocyte periphery beneath the oolemma. Complete fusion of the yolk globules is seen together with an overall increase in the oocyte translucency. Its eosinophilic nature is reduced.

Postovulatory follicles are observed in both *H.(H) limbatus and H.(H) xanthopterus* (Plate 14 B and 19 A). Unspawned atretic oocytes also noticed (Plate 14 B). The overall observation of ovaries of both the species revealed that both are multiple spawners with group synchronus oocyte development (Plate 19 B). A schematic representation of sequential stages of oocyte development of *H.(H) xanthopterus* is illustrated in Fig. 5.1. The mature eggs of both the species are covered with filaments(Plate 13B and 16B).

5.4.4.h. Relationship between histological observation and morphological appearance of ovary.

The seven histological stages identified in the ovary of *H. (H) limbatus* and *H. (H) xanthopterus* can be correlated to seven morphological stages in the following manner.

Stage I : Ovary contains oogonia and chromatin nucleolar oocytes.

Stage II : Ovary contains a large reserve of early and late perinucleolar oocyte.

Stage III : Cortical alveoli stage oocytes.

Stage IV : Cortical alveoli and lipid accumulate in the oocytes.

Stage V : Yolk globules are also present along with cortical alveoli and lipid droplets in the oocytes.

Stage VI : Ovary contains mainly late yolk-globule oocytes..

Stage VII : Spent ovary contains predominantly degenerating oocytes and some oogonia.

5.5. Discussion

Histological techniques made it possible to delineate different testicular types in teleosts, lobular and anastomosing tubular (Grier, 1993; Grier and Nostro, 2000). The testis in *H. (H) limbatus* and *H. (H) xanthopterus* are tubular type. This type is restricted to the atheriniform group, such as the guppy, *Poecilia reticulata* (Grier, 1993; Grier and Nostro, 2000). Nagahama (1983) reported that lobular type testis is typical of most teleosts.

Generally, the entire testis is histologically identical and fertile (Khanna and Pant 1966). Similar condition is noticed in the testes of *H. (H) limbatus* and *H. (H) xanthopterus*.

Grier and Nostro (2000) classified testicular structure into unrestricted spermatogonial testis and restricted spermatogonial testis according to the distribution of spermatogonia. *H. (H) limbatus* and *H. (H) xanthopterus* possess restricted spermatogonial testis which is characteristic of the order *Atheriniformis*, to which hemiramphids belong. According to Grier and Nostro (2000), there is a common origin of follicle from the germinal epithelium in *Hemiramphus brasiliensis* (order *Atheriniformis*)

Among teleosts, the spermatogenic activity commences at various times of the yearu (Kaul and Rishi, 1986). In *H. (H) limbatus* and *H. (H) xanthopterus* continuous spermatogenesis was noticed throughout the year with peak activity during spawning seasons. The presence of dense connective tissue and occasional blood vessels in the tunica albuginea covering the testis was noticed in both these species as in the case of *Clarias macrocephalus* (Mollah, 1988). The intertubular space of the testis of both *H. (H) limbatus* and *H. (H) xanthopterus* is occupied by blood vessels, nerve fibres and collagen fibres. It was Craig-Bennett (1931) who suggested that elastic tissue might be responsible for contraction of testis and discharge of sperm. It is now well established in many teleosts the germ cells occur in cysts, within each of which the germ cells develop synchronously (De Vlaming, 1972; Davis, 1977; Mollah, 1988). However some investigators have designated these cells as sertoli cells (Grier, 1975). In *Clarius macrocephalus* the sertoli cells were mostly seen in the immature testis (Mollah, 1988).

In *H. (H) limbatus* and *H. (H) xanthopterus* four maturity stages of testicular development were established on the basis of histological studies, immature, maturing, mature and spent. Spermatozoa appear even in the early stage of testicular development. Such an early appearance of spermatozoa is also known in the dab *Limanda limanda* (Htun- Han, 1978). The testis in which the tubules and vas deference were filled with spermatozoa were judged to be mature. A similar type of tubular testis was noticed in the red sea bream *Pagrus major* (Matsura *et al.*1987*)*. Such type of tubular testis is considered as primitive.

The ultra structural images of the spermatozoon of the hemiramphid, *Hemiramphodon pogonognathus,* which is an internally fertilizing species show modifications like elongation of the nucleus and extension of the mitochondria of the mid piece as an elongated shape around the proximal region of the axoneme, whereas these modifications are absent in other hemiramphids in which external fertilisation occurs as reported in the case of *Arramphus sclerolepis* (Jamieson, 1989). Further detailed ultrastructural structure of spermatozoon of *H. (H) limbatus* and *H. (H) xanthopterus* are required for observing their fine structure to record species-specific differences if any.

Several staging series for teleost oocyte development have been described (Wourms, 76; Shackley and king, 1977; Selman *et al.* 1986). These staging series are helpful for understanding cellular events during oogenesis and serve as the basis for experimentation and comparison to other species.

Oocyte growth in *H.(H) limbatus* and *H.(H) xanthopterus* follows a similar general pattern in most teleosts. Oogonia give rise to immature oocytes with multiple peripheral nucleoli. The perinucleolar oocytes then undergo primary vitellogenesis, the accumulation of mucopolysaccharides in cortical alveoli (Khoo, 1979). The oocyte enlarges and its zona radiata thickens as vitellogenic yolk is deposited (N'Da and Deneil, 1993). The nucleus migrate to the animal pole prior to the break down of the nuclear membrane (Yamamoto, 1956a). Hydration precedes ovulation and the appearance of these hyaline oocytes is an indication of imminent spawning (West, 1990). The follicle collapses after the oocyte has been released to form structures called postovulatory follicles which are indications of recent spawning and are not thought to persist for a long time.

Major developmental events in *H. (H) limbatus* and *H.(H) xanthopterus* can be divided into oogenesis, primary oocyte growth, cortical alveolar stage, vitellogenesis, maturation and ovulation. Similar developmental pattern is noticed in *Syngnathus scovelli* (Begovac and Wallace, 1988) and in *Tilapia zilli* (Coward and Bromage, 1998) and *H.brasiliensis(McBride and Thurman, 2003)*.

Oocyte development in *H. (H) limbatus* and *H. (H) xanthopterus* is characteristic with a heterogeneous population of different stage oocytes. Many of the cellular processes that occur during oocytes development in *H.(H) limbatus* and *H. (H) xanthopterus* parallel those found in the non-mammalian vertebrates. These include oogonial proliferation (Tokarz, 1978), formation and dispersal of a Balbiani vitelline body (Guraya, 1979, Heasman *et al.*1984 and Gopalakrishnan, 1991), formation of cortical alveoli and a vitelline envelop (Anderson, 1967, 1968; Selman, *et al.*1986), vitellogenesis (Anderson, 1968; Selman and Wallace, 1983; Wallace, 1985) and oocyte maturation (Masui, 1985). The unique features of oogenesis relate to the ovarian anatomy whereby oocytes are sequentially arranged according to developmental age (Begovac and Wallace,1987). This arrangement is particularly useful when examining specific cellular events such as oogonial dynamics, vitelline envelop formation and vitellogenesis.

The initial phase of oocyte development involves the true genesis of an oocyte as a result of oogonial proliferation and differentiation. The period of oogonial proliferation varies from species to species and may be continuous or cyclical in teleosts (Tokarz, 1978). In *H. (H) limbatus* and *H. (H) xanthopterus* oogonial proliferation is probably continuous because fully developed ovaries are present throughout the year as in pipe fish (Begovac and Wallace, 1988). The germinal ridge region of the ovary is the proliferative germinal segment that serves as the source of all newly formed oocytes.

Oogonial proliferation and transformation to oocytes are gonadotropin independent processes (Gopalakrishnan, 1991). Following this proliferative phase, the oogonial cells must undergo a phenotypic change as they transform to oocytes. In *H. (H) limbatus* and *H. (H) xanthopterus* , the earliest changes seen in newly formed oocytes are an increased size with greater amounts of cellular organelles that redistribute to a juxtanuclear aggregate. This type of redistribution has also been noted in *Syngnathus scovelli* (Begovac and Wallace, 1988) and in the flounder, *Pleuronectes flesus* (Janssen *et al.*1995).

The Balbiani vitelline body within young oocytes of many organisms has been described (Guraya, 1979). The Balbiani vitelline body is the predominant cytoplasmic structure within the perinucleolar stage half beak oocyte. It disperses throughout the oocyte prior to cortical alveoli formation. In early perinucleolus oocytes, most of the cellular organelles are typically present in a juxtanuclear mass commonly known as the Balbiani vitelline body (Guraya, 1979) or mitochondrial cloud (Heasman *et al.* 1984). Mitochondria and multivesicular bodies comprise the major components of the Balbiani vitelline body (Begovac and Wallace, 1988). Further in-depth observation using Electron microscope is required to study the composition of the Balbiani vitelline body in both *H.(H) limbatus* and *H. (H) xanthopterus.*

On attaining their maximum size, the late perinucleolus stage oocytes remain inactive for long periods until they are recruited into the secondary growth phase (vitellogenesis). Begovac and Wallace (1988) termed these oocytes as 'resting oocytes', the chromosomes of which are arrested during late chromatin nucleolus stage or early perinucleolus stage at the prophase (diplotene stage) of the first meiotic division.

Three types of inclusion are formed during vitellogenesis of In *H. (H) limbatus* and *H. (H) xanthopterus* . They are cortical alveoli, protein yolk globules and lipid droplets. They differ distinctly in their morphology, staining properties and chemical nature and they deposit sequentially although considerable overlap occurs .

The first type of inclusion to accumulate in the developing oocytes is the cortical alveoli (carbohydrate yolk or yolk vesicles) which release their contents in to the perivitelline space during cortical reaction. For this reason, they cannot be considered as yolk in the strict sense. This inclusion appears as a narrow zone below the zona radiata, after both lipid yolk and protein yolk formation have started. In majority of the teleost species, the cortical alveoli formation occurs prior to both lipid and protein yolk formation (Begovac and Wallace, 1988 and Janssen *et al.*1995) whereas in *M. cephalus* (Gopalakrishnan, 1991) and in *Sillago sihama* (Jayasankar and Alagarswami, 1994), the cortical alveoli formation occurs after both lipid and protein yolk formation.

Protein yolk accumulation (yolk globule stage) occurs after, and concomitant to cortical alveoli formation in *H. (H) limbatus* and *H. (H) xanthopterus*. Protein yolk (glycolipophosphoprotein) is distinguished as discrete, membrane limited, electron dense, acidophilic, fluid filled yolk globules as noticed in *M. cephalus* (Gopalakrishnan, 1991).

Small yolk globules first appear in the cortical region of the oocytes and later they fill the entire ooplasm in the form of larger globules. In many teleosts, the smaller yolk globules before becoming larger (mature) ones, pass through certain transitional stages and undergo further chemical processing. Similar yolk protein development was noticed in *H.brasiliensis* (Mc Bride and Thruman, 2003)

Lysosomes and multivesicular bodies are detected during the transitional stages (Begovac and Wallace, 1988). But during hydration of oocyte, the protein globules fuse and form a continuous mass of yolk, as a result of which, the ripe eggs become transparent. Subsepquently the cytoplasm changed from red to pink as the result of hydration and nucleus break down occurred as in *H.brasiliensis* (McBride and Thruman, 2003). It is now generally accepted that the protein yolk is hepatically produced (exogenous in origin). The yolk precursor having been identified as the female specific serum glycolipophosphoprotein complex, vitellogenin (Vtg) (Guraya, 1986).

The third and quantitatively minor type of inclusion is the lipid yolk (triglycerides) in the form of distinct lipid droplets. Shackley and King (1977) suggested that the synthesis of lipid droplets is probably endogenous (occurring in the perinuclear ooplasm). The lipid inclusion may keep the eggs buoyant as suggested by Gopalakrishnan (1991).

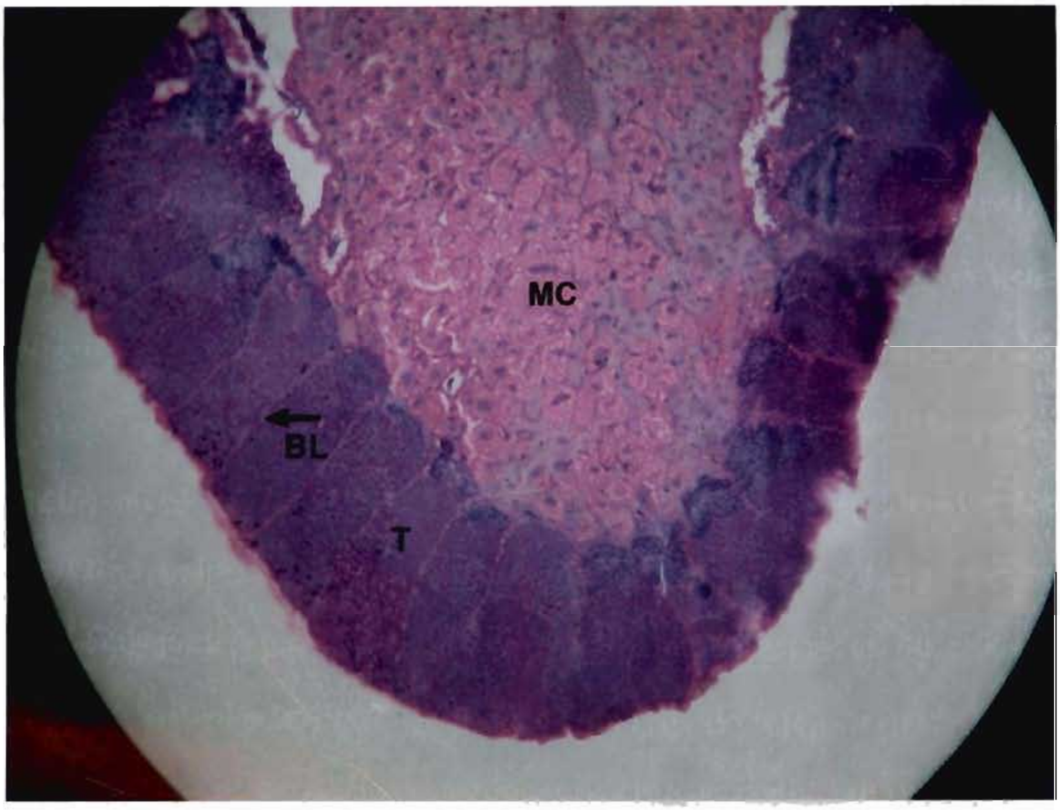
The oocyte maturation in *H. (H) limbatus* and *H. (H) xanthopterus* is initiated with the migration of the germinal vesicle to the periphery of the oocyte and its subsequent break down (GVBD). These changes in the oocytes are the indications of resumption of meiosis I and the liberation of first polar body (Guraya, 1986). The remaining haploid set of chromosomes enters the second meiotic metaphase and the meiosis is arrested once again and the egg becomes 'mature'. Another noticeable change during this period is the increase in size of the oocyte due to hydration. This rapid water intake is characteristic of many marine teleosts, especially hemiramphids (McBride and Thruman, 2003) and as a consequence of this, the eggs are rendered buoyant in sea water (Wallace,1985). This process is accompanied by the coalescence of protein yolk globules to form a uniform mass and the ripe eggs look translucent. In certain teleosts hydration coupled to yolk protein proteolysis has been found to be a prominent feature of maturation (Greelay *et al.* 1986 b). In teleost oocytes, all these maturational changes are induced by the maturation hormone, 17α, 20 β - DHP (Guraya, 1986). The formation of the thick zona radiata give a mechanical protection to the oocyte without preventing nutrition.

In *H.(H) limbatus* and *H.(H) xanthopterus* different batches of oocytes were found passing from one stage to another successively. Ripe ovary contains all the stages and this observation suggests that the type of oocyte development is 'multiple clutch group synchrony' (De Vlaming, 1983; and Jayasankar and Alagarswami, 1994).

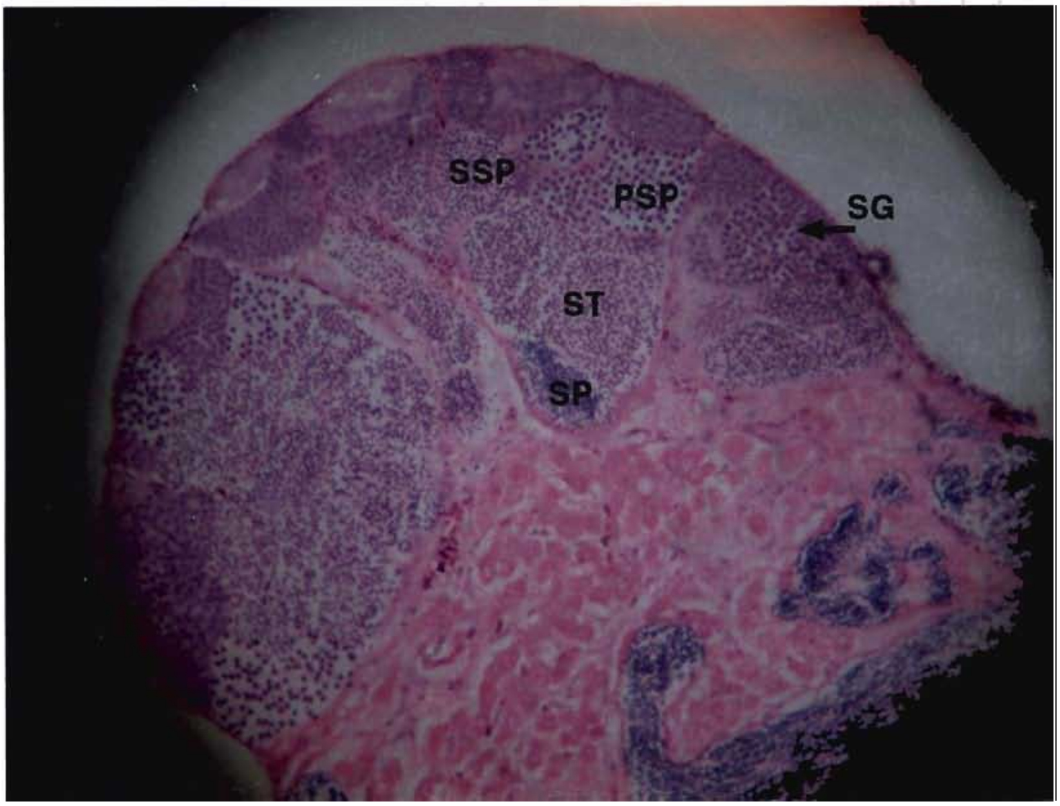
The present results on the monthly variation in oocyte diameter indicate that both *H.(H) limbatus* and *H.(H) xanthopterus* are continuous spawners with peak activity during pre and post-monsoon seasons in *H.(H)* *limbatus* and monsoon season in *H.(H) xanthopterus*. In the present study histological evidence of imminent or recent spawning was provided by the presence of hyaline oocytes. Similar conditions were reported by Jayasankar and Algarswami (1994) in the sand whiting *Sillago sihama*. Eggs of both *H.(H) limbatus and H.(H) xanthopterus* are stored within the ovarian lumen until the time of fertilization. The layer contracts which results in the disruption and collapse of the follicular fabric and finally the release of the ripe eggs from it.

The histological findings are concluded as follows.

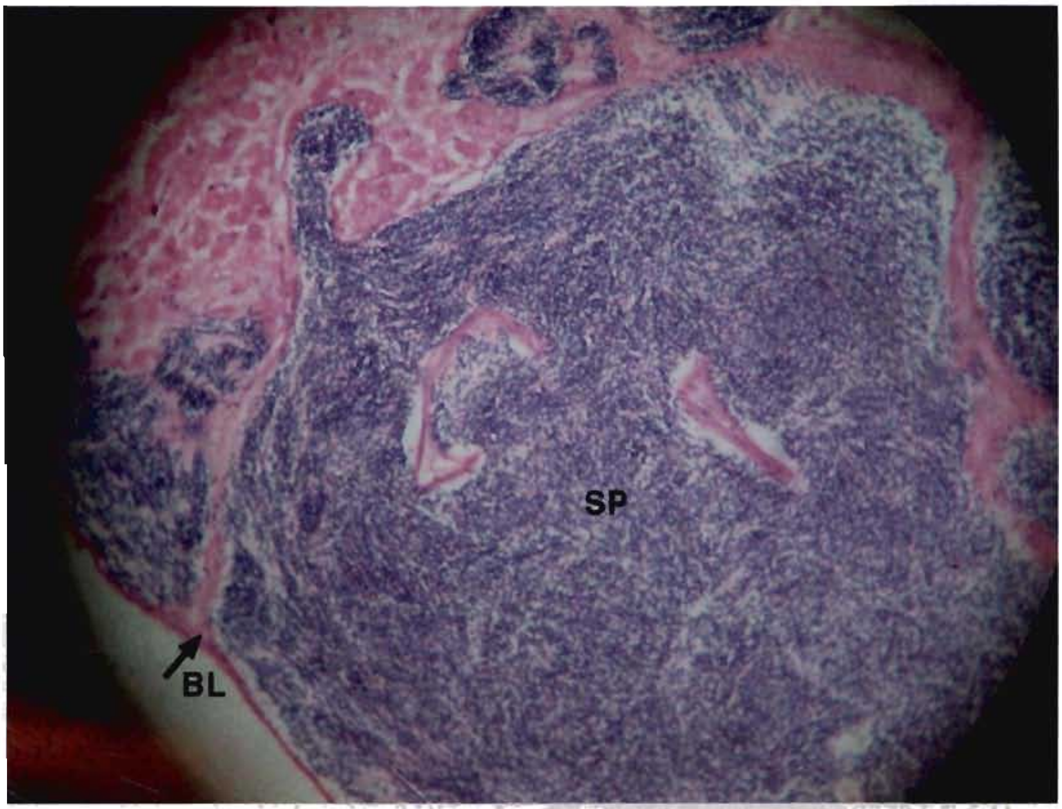
In *H.(H) limbatus and H.(H) xanthopterus* the testes are typical atheriniform type exhibiting tubular or restricted spermatogonial pattern. The oogonia and chromatin nucleolus oocytes are present in the germinal ridge of the ovarian luminal epithelium. Early and late pennucleolar stages with balbiani vilelline body are present in both species; the ooplasm is homogeneous and highly basophilic. Cortical alveoli and lipid droplets present in the oocytes of *H.(H) limbatus* are not as pronounced as in *H.(H) xanthopterus*. In *H.(H) limbatus* they are slightly basophilic whereas in *H.(H) xanthopterus* they are eosinophilic. The zona radiata of *H.(H) limbatus* are thicker and has spherical cells compared to *H.(H) xanthopterus* where these cells are more or less rectangular. The yolk globules of *H.(H) limbatus* are eosinophilic compared to *H.(H) xanthopterus* in which they are basophilic. In the ovaries of both *H.(H) limbatus* and *H.(H) xanthopterus* oocytes at different stages of development are observed. This supports the findings that these species are continuous breeders. Postovulatory follicles are observed in both the species. The eggs of *H.(H) limbatus* are slightly eosinophiic whereas *H.(H) xanthopterus* are basophilic. In both species eggs are covered with filaments, which is a characteristic feature of hemiramphid eggs.



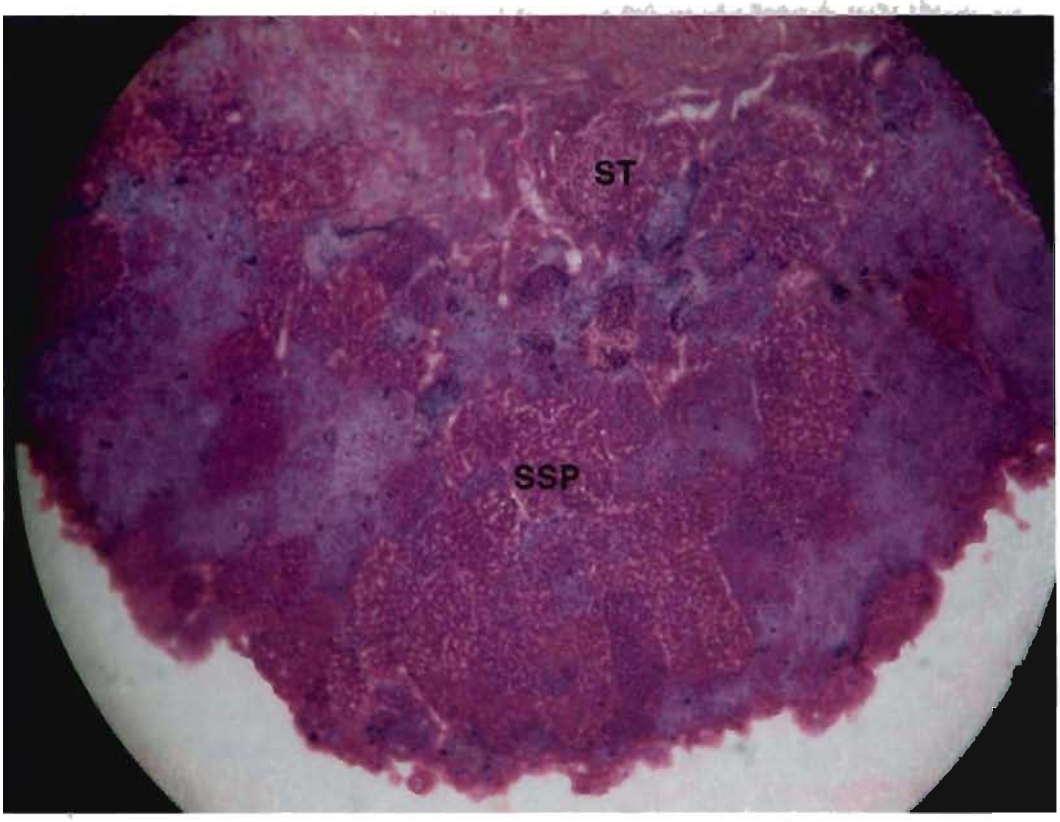
A. Cross section of maturing testis of *H. (H) limbatus* showing mesenchyme cells (MC), basal lamina (BL) and tubules (T) x 40



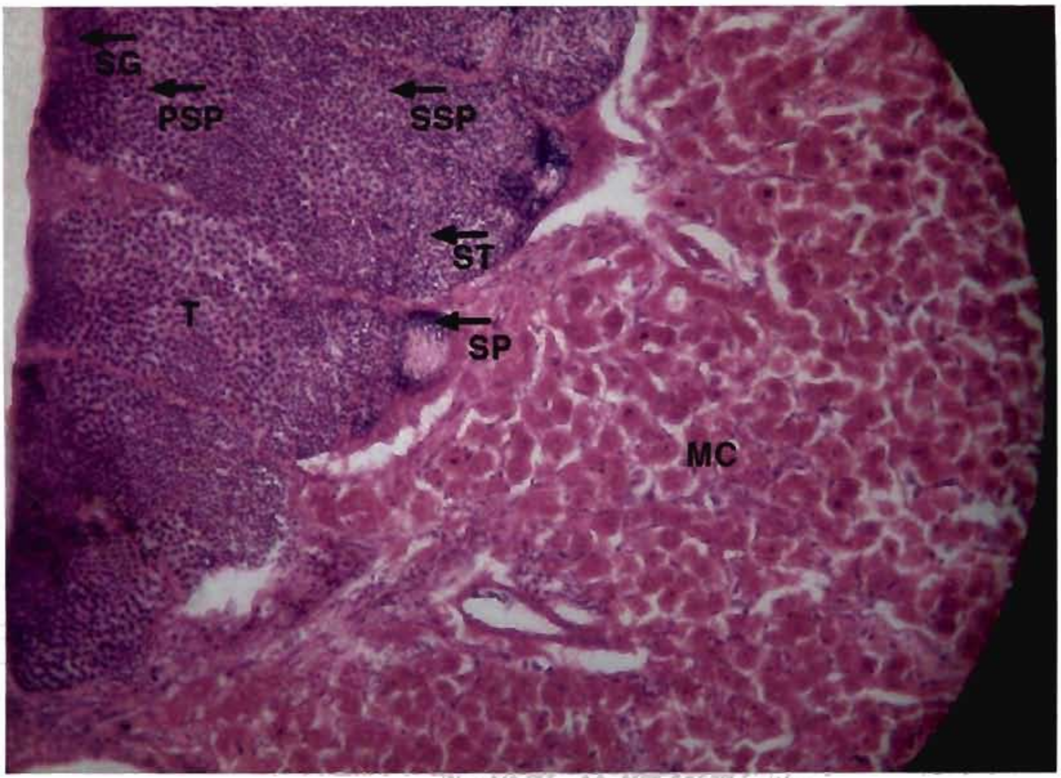
B. Cross section of maturing testis of *H.(H) limbatus* with spermatogonia (SG), primary spermatocytes (PSP), secondary spermatocytes (SSP), spermatids (ST) and sperms (SP) x 40



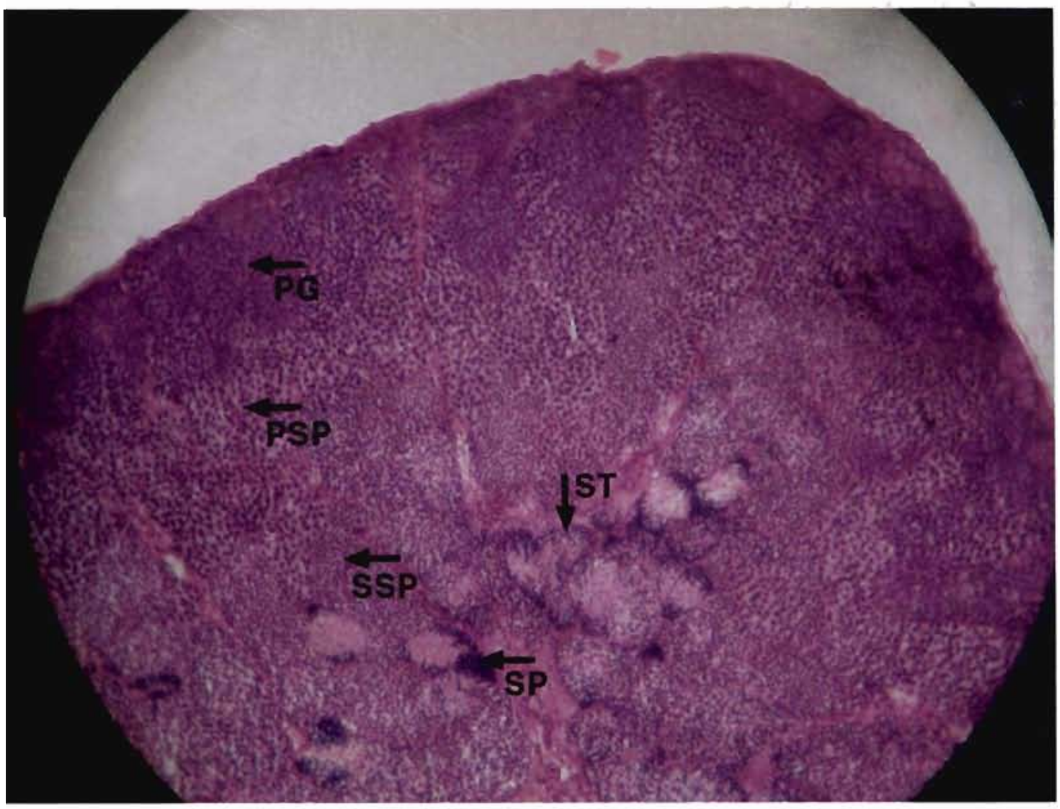
A. Cross section of mature testis of *H. (H) limbatus* with sperms (SP). BL - Basal lamina x 40



B. Cross section of spent testis of *H. (H) limbatus* with secondary spermatocytes (SSP) and spermatids (ST) x 40.

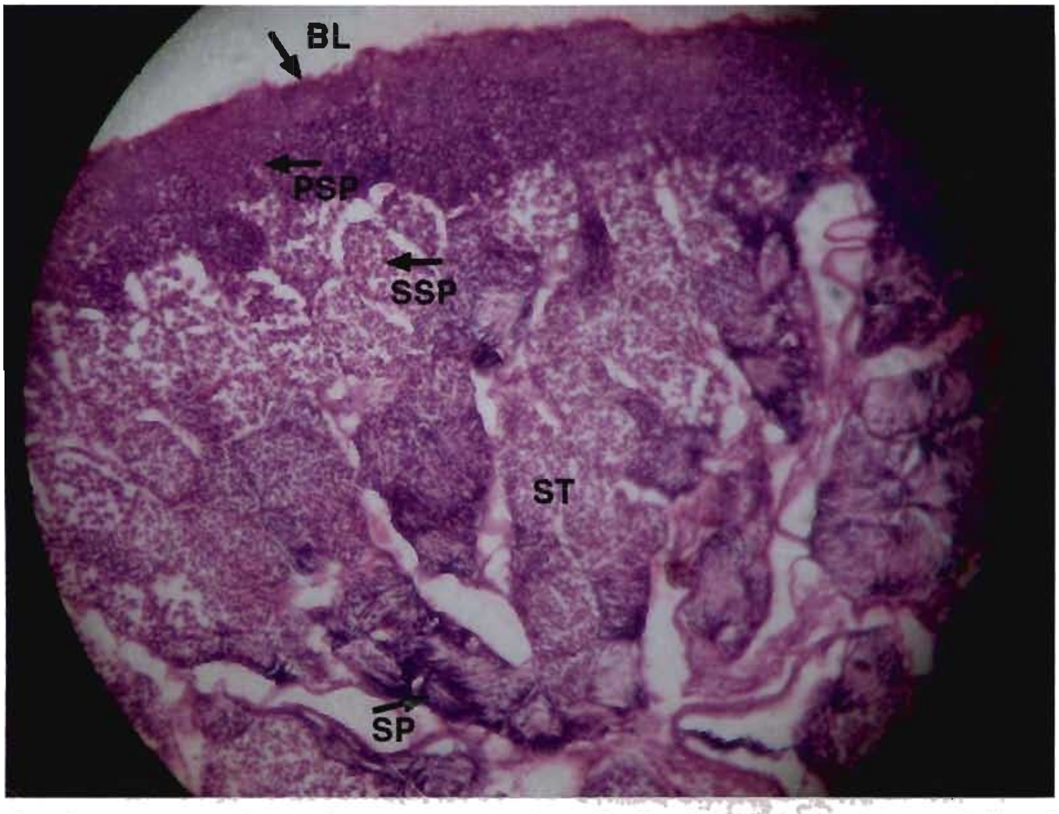


A. Cross section of maturing testis of *H. (H) xanthopterus* x 100.

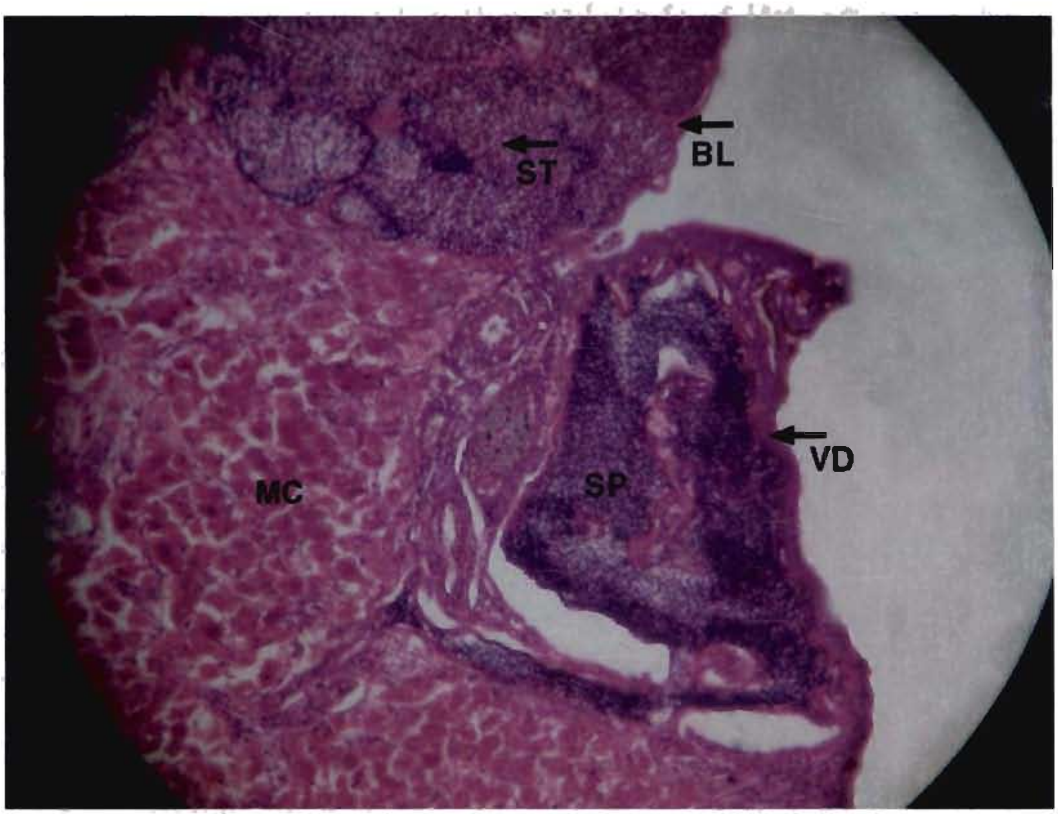


B. Cross section of mature testis of *H. (H) xanthopterus* x 40.

T-Tubules, SG - Spermatogonia, PSP - Primary Spermatocytes, SSP - Secondary Spermatocytes, ST - Spermatids, SP - Sperms and MC - Mesenchyme cells.

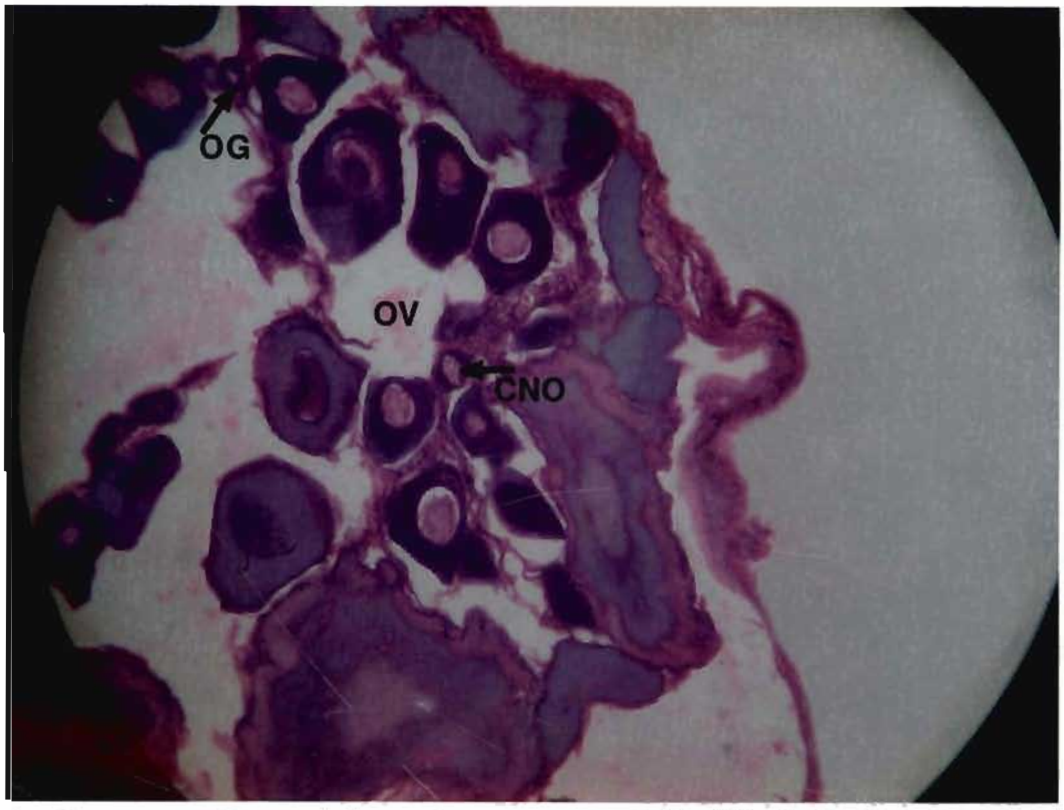


A. Cross section of mature testis of *H. (H) xanthopterus* full of spermatids and sperms x 100.

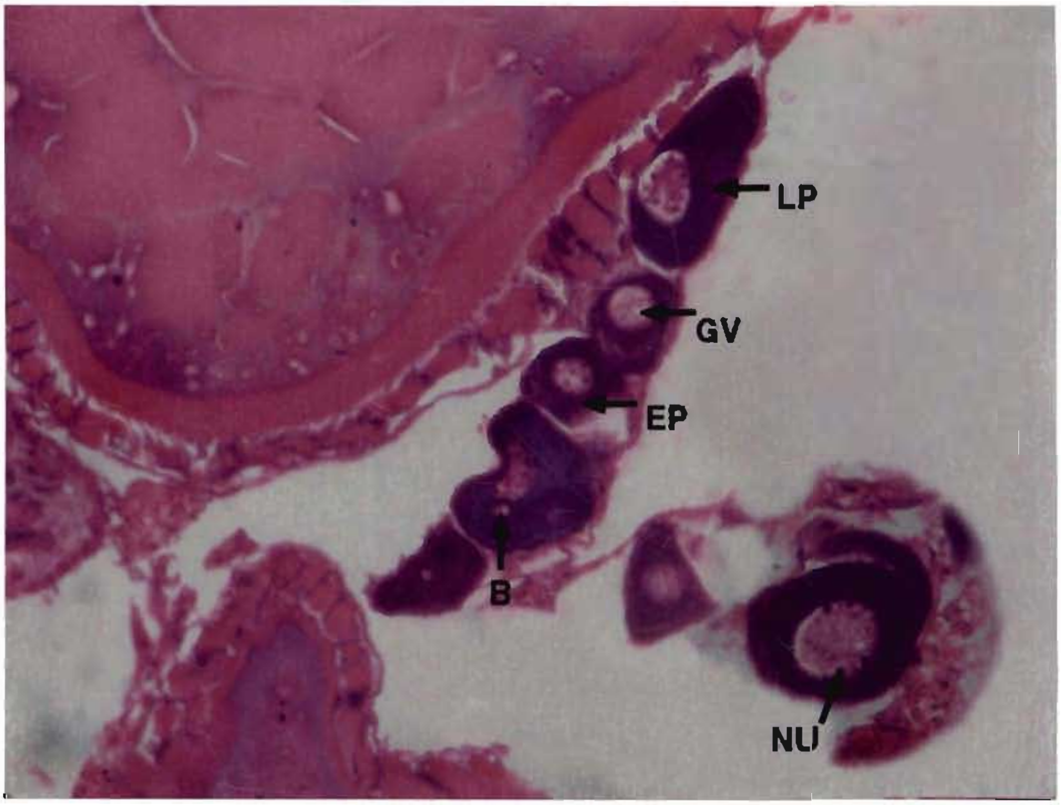


B. Cross section of testis and vas deferens (VD) full of sperms of *H. (H) xanthopterus* x 100.

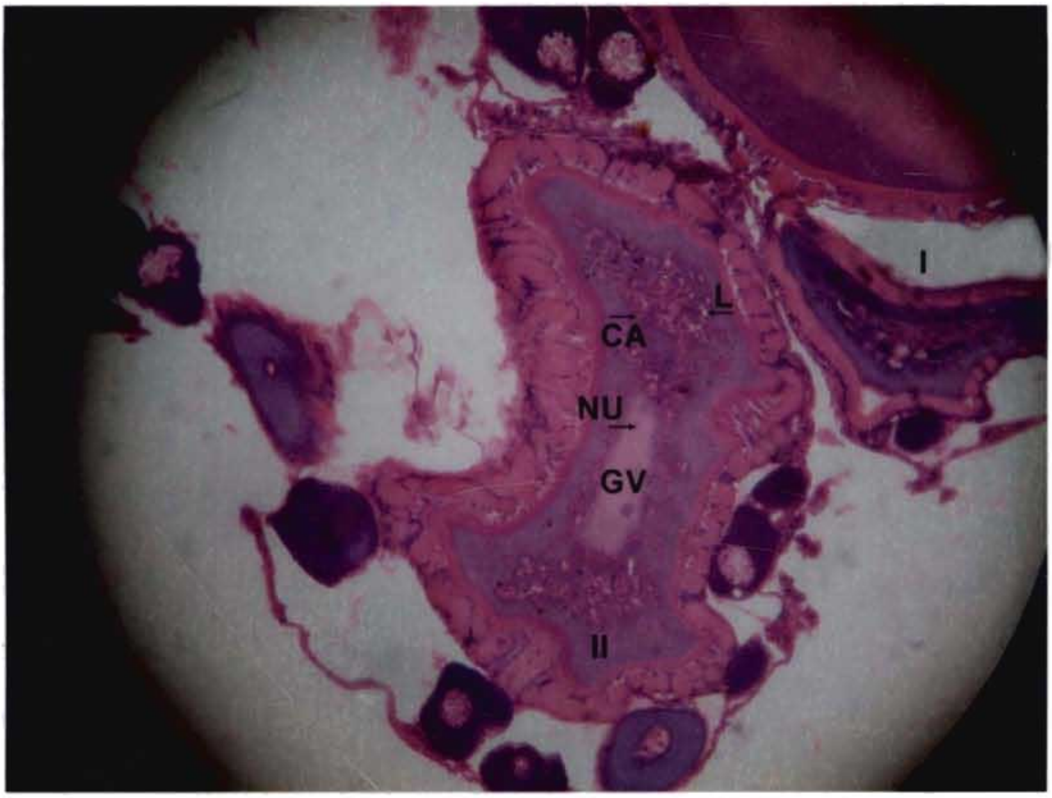
BL- Basal lamina, PSP - Primary Spermatocyte, SSP - Secondary Spermatocytes, ST - Spermatids, SP - Spermatozoa and MC - Mesenchyme cells.



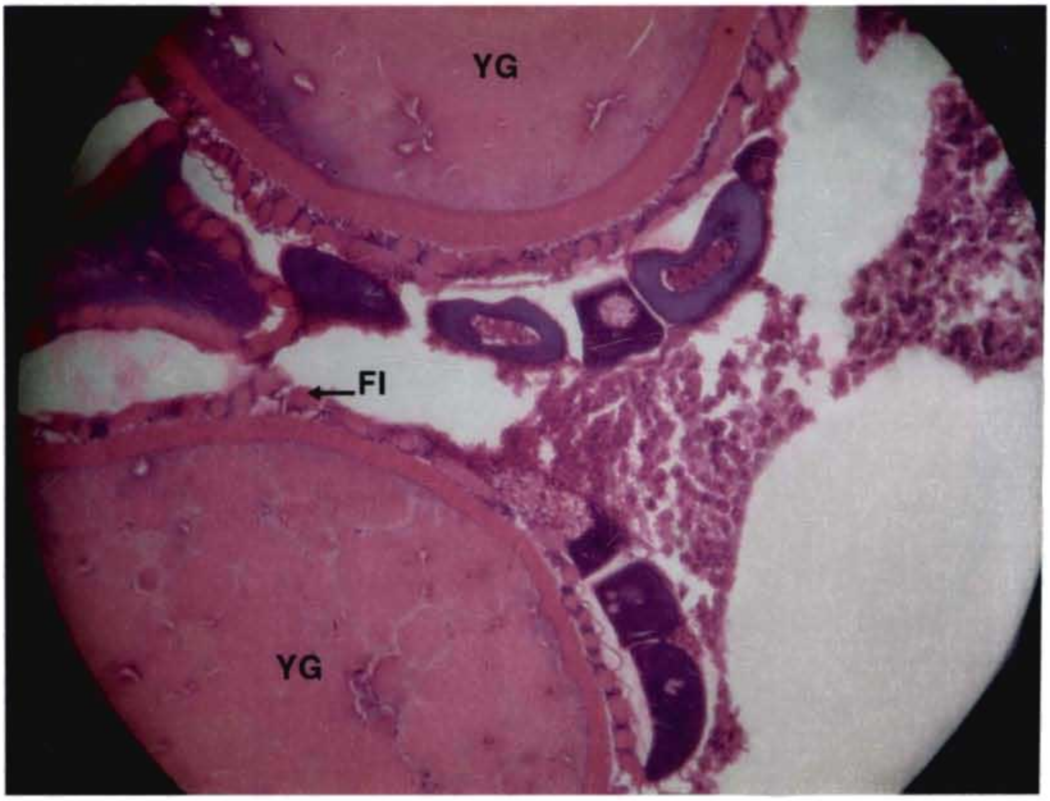
A. Cross section of immature ovary of *H. (H) limbatus* showing oogonium (OG) and chromatin nucleolus oocytes (CNO) in the ovocoel (OV) x 40.



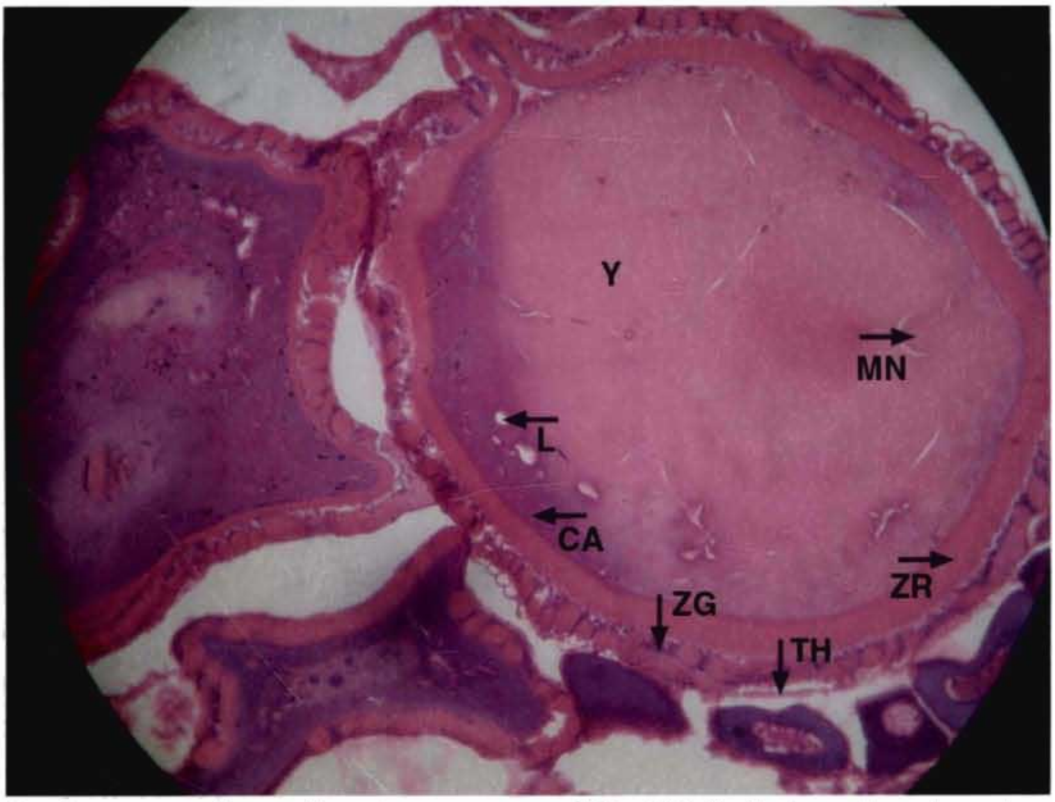
B. Cross section of perinucleolar stage ovary of *H. (H) limbatus* showing early and late nucleolar oocytes (EP, LP), germinal vesicle (GV), nucleolus (NU) and balbiani vitelline body (B) x 100.



A. Cross section of cortical alveolar stage ovary of *H. (H) limbatus* showing early and late cortical alveolar oocytes (I & II), lipid droplets (L), cortical alveoli (CA), germinal vesicle (GV) & nucleolus (NU)x100



B. Cross section of yolk globule stage ovary of *H. (H) limbatus* showing yolk globules (YG), FI - Filaments x 100.

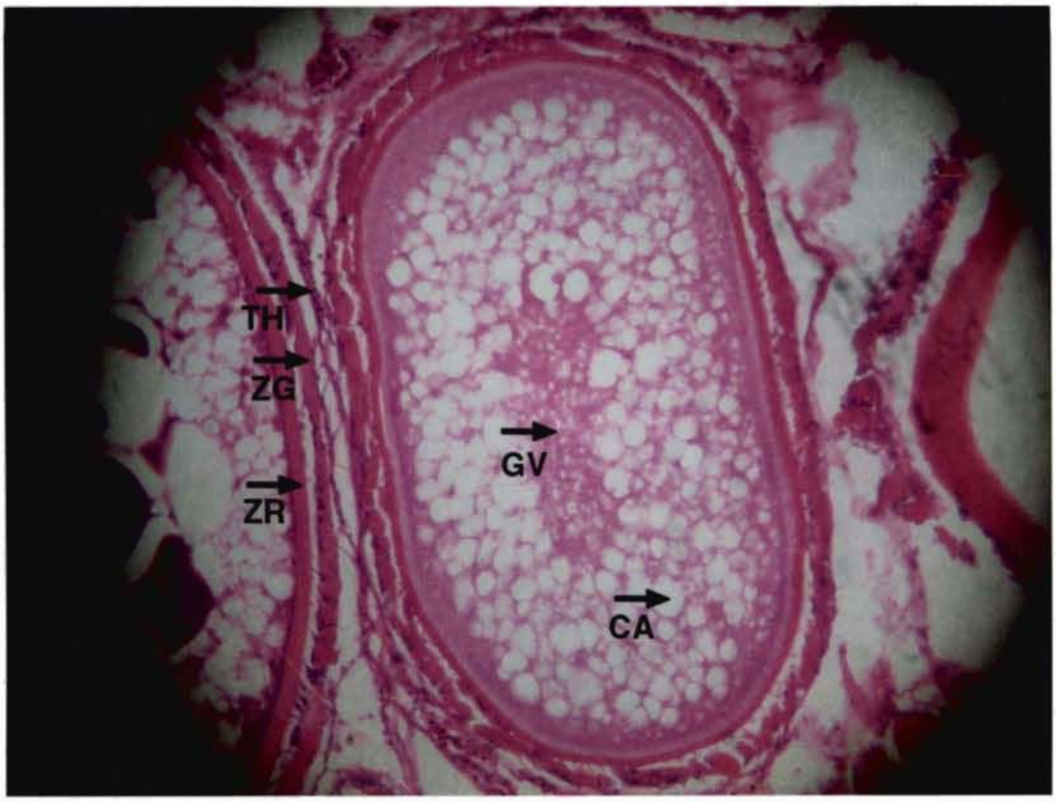


A. Cross section of mature ovary of *H. (H) limbatus* showing ripe oocytes after GVBD, yolk (Y) , migratory nucleus (MN), lipid (L), cortical alveoli (CA) , zona radiata (ZR), zona granulosa (ZG) and thecal layer (TH) x 100.

B. Cross section of spent ovary of *H. (H) limbatus* showing post ovulatory follicle (POF) and unspawned atretic oocytes (AO) x 40.

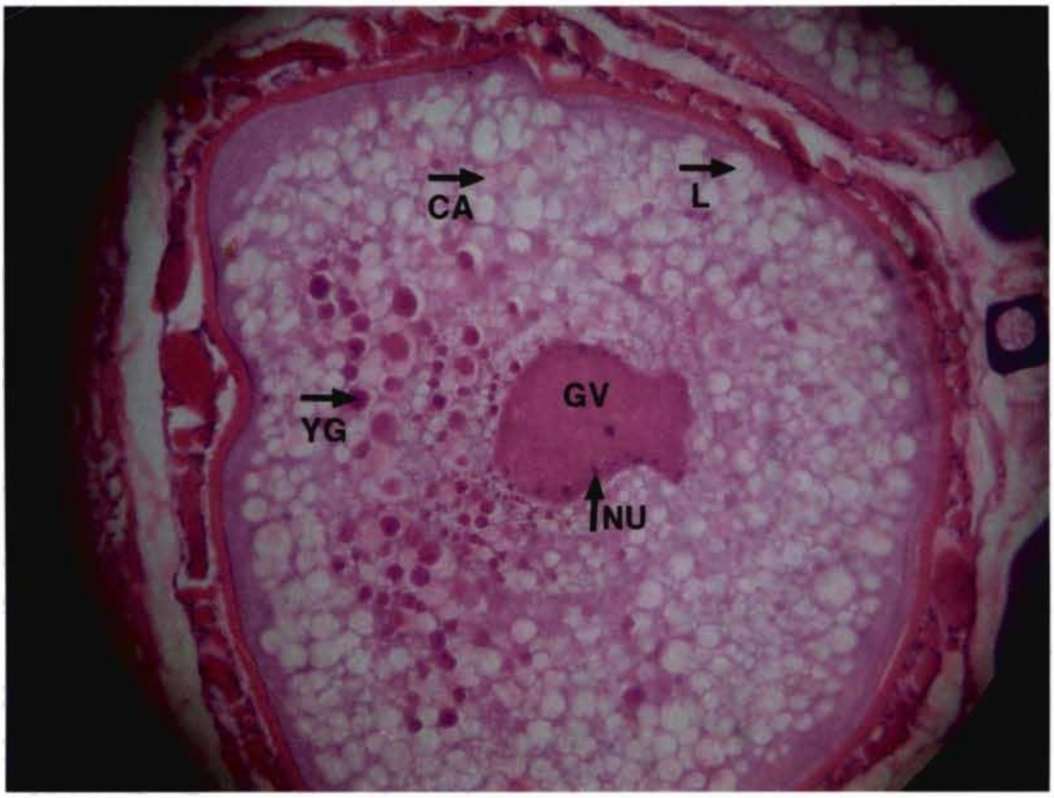
A. Cross section of the ovary of *H. (H) xanthopterus* showing oogonium (OG), chromatin nucleolus oocyte (CNO) and germinal ridge (GR) x 40.

B. Cross section of perinucleolar stage ovary of *H. (H) xanthopterus* showing early and late perinucleolar oocytes (EP & LP), balbiani vitelline body (B), germinal vesicle (GV) and nucleolus (NU) x 100.



A. Cross section of early cortical alveolar stage ovary of *H. (H) xanthopterus* showing early cortical alveoli (CA), germinal vesicle (GV), zona radiata (ZR), zona granulosa (ZG) and thecal layer (TH) x 100.

B. Cross section of late cortical alveolar stage ovary of *H. (H) xanthopterus* showing late cortical alveoli (CA), lipid droplet (L) and filament (FL) x 100.

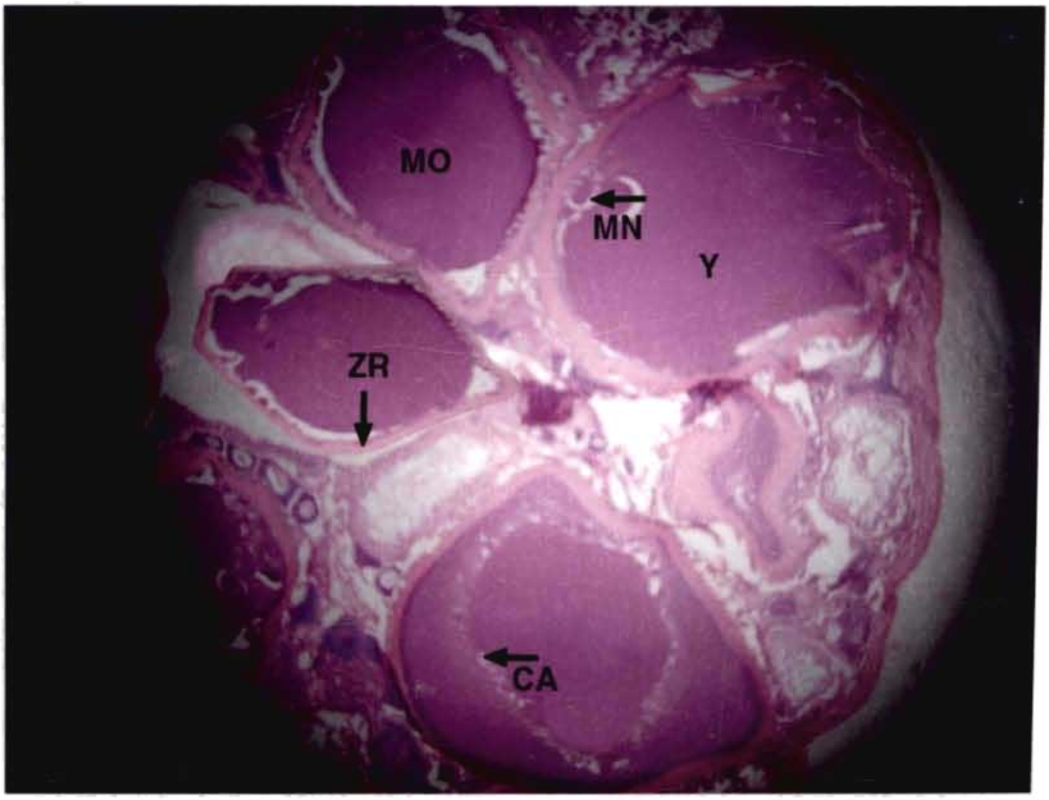


A. Cross section of early vitellogenic oocyte of *H. (H) xanthopterus* showing small yolk globules (YG), cortical alveoli (CA), lipid droplet (L), germinal vesicle (GV) and nucleoli (NU) x 100.

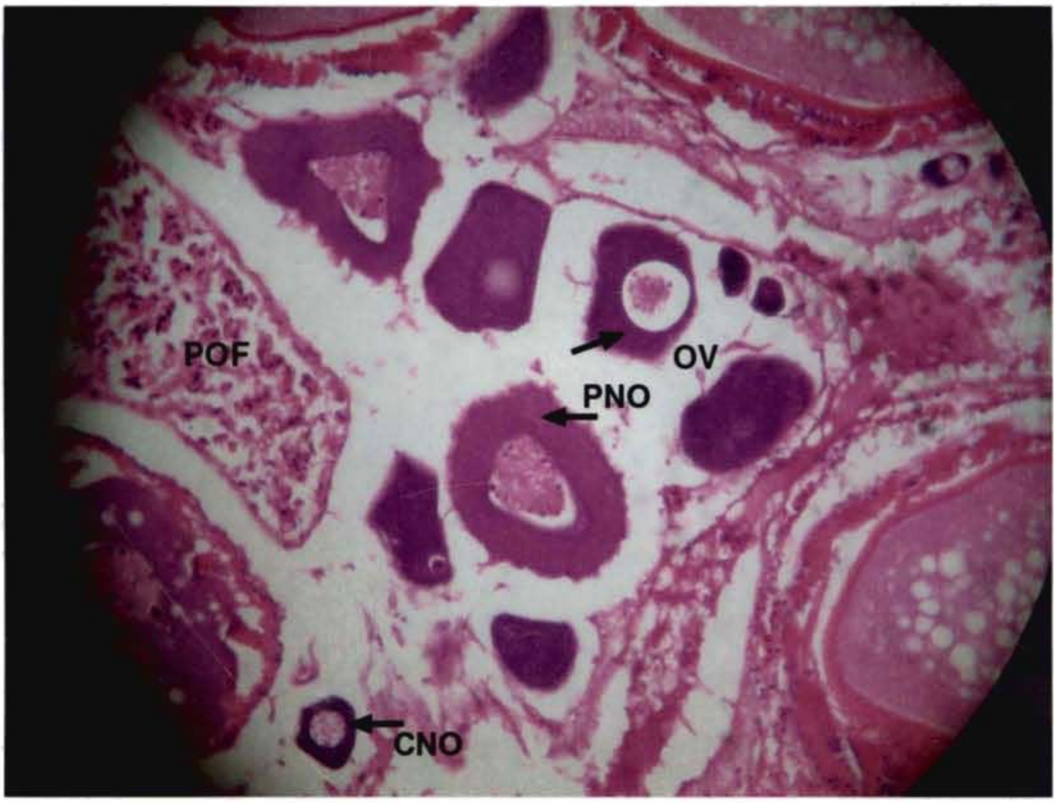
B. Cross section of mid vitellogenic oocyte of *H. (H) xanthopterus* showing large yolk globules (YG), germinal vesicle (GV), nucleoli (NU), zona radiata (ZR), zona granulosa (ZG) and thecal layer (TH) x 100.

PLATE 18

A. Cross section of late vitellogenic stage ovary of *H. (H) xanthopterus* showing late vitellogenic oocyte in which most of the yolk globules coalesced to form a large central yolk mass (Y). L-Lipid and CA-cortical alveoli x 40.



A. Cross section of spawning stage ovary of *H. (H) xanthopterus* with hyaline ripe oocytes (MO), migratory nucleus (MN), yolk (Y), zona radiata (ZR) and cortical alveoli (CA) x 40.



A. Cross section of spent ovary of *H. (H) xanthopterus* showing post ovulatory follicle (POF), chromatin nucleolus oocytes (CNO) and peri nucleolar oocytes (PNO) in the ovocoel (OV) x 40.

B. Cross section of mature ovary of *H. (H) xanthopterus* with I to VI stages of oocytes x 40.

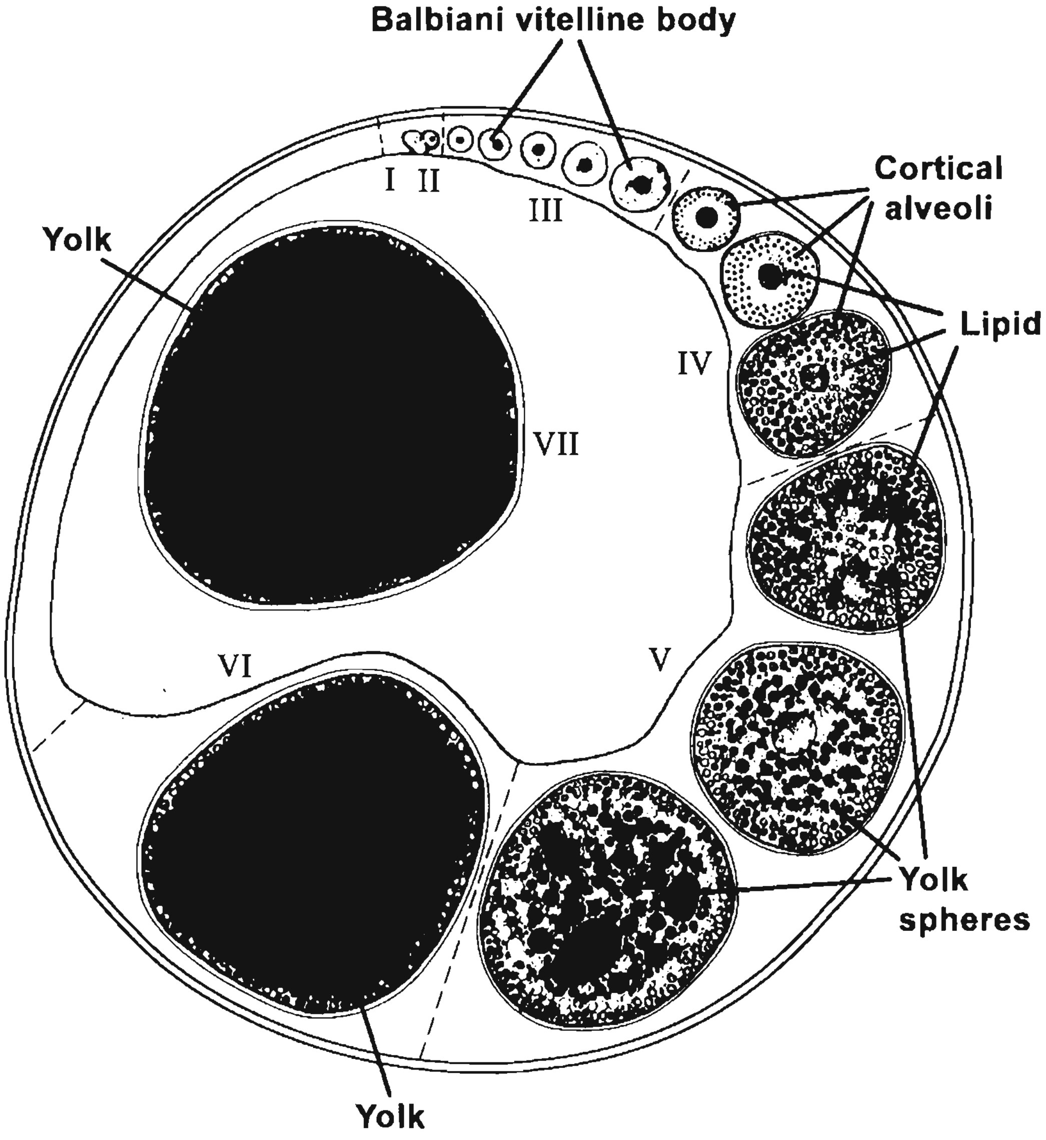


Fig. 5.1

Schematic diagram illustrating sequential stages of oocyte development in an optimal section of the ovary of *H. (H) xanthopterus*. It is not fully drawn to scale.

I . Oogonia
II. Chromatin nucleolus stage
III. Perinucleolar stage
IV. Cortical alveoli stage
V. Vitellogenesis
VI. Migratory nucleus stage
VII. Mature egg

CHAPTER 6.

LENGTH – WEIGHT RELATIONSHIP

AND

RELATIVE CONDITION FACTOR

6. LENGTH – WEIGHT RELATIONSHIP
AND
RELATIVE CONDITION FACTOR

6.1. Introduction

Length – weight relationship studies in fishes serve to establish a mathematical relationship between length and weight and their interconversion (Beyer,1987) as required in the setting up of yield equations for estimating population strength (Beverton and Holt, 1957). It also helps to measure the variations from the expected and observed weight for length of individual fish as indication of the pattern of growth, fatness, general well being or gonad development (Le Cren, 1951; Bolger and Connolly, 1989). Growth fluctuations are more frequent in fishes of tropical and subtropical waters due to variations in seasons, multiple spawning and food composition. (Rounsefell and Everhart, 1953; Lagler, 1956).

Information on the length-weight relationship of fishes of the family Hemiramphidae from Indian waters are limited to *H.georgii* of the Gulf of Mannar and Palk Bay (Talwar, 1962 b); *H. gaimardi* of Pulicat Lake (Sultana *et al.* 1980) and *H. marginatus* of Gulf of Mannar (Kasim *et al.* 1996). Length-weight relationship of *H. brasiliensis* and *H. balao* of South East Florida was described by Berkeley and Houde (1978).

No information is available on the length-weight relationship and relative condition factor of *H. (H). limbatus* and *H.(H). xanthopterus* of the Cochin coast. Hence an attempt is made to work out the length-weight relationship and condition factors of these two species from the south-west coast of India.

6.2. Materials and Methods

Monthly samples of fishes were collected from different fish landing centres, markets of Cochin coast and some fishing grounds in Vembanad Lake like Eloor, Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map. (Fig. 1.1). These fishes were caught mainly by the drift gill net, murasu vala. Fishes were separated into three categories as males, females and indeterminates after examining the gonads. Fishes were measured and weighed in fresh condition. Total length was taken from the tip of the lower jaw to the end of caudal fin ray to the nearest millimetre and weight was recorded up to 0.01g.

A total of 865 specimens of *H.(H) limbatus* comprising 503 males, ranging from 120 to 202mm total length (TL) and 4.05 to 24.30g weight; 344 females ranging from 126 to 229 mm TL and 4.51 to 30.55g weight and 18 indeterminates ranging from 68 to 121 mm TL and 0.82 to 4.02g weight were studied. In the case of *H. (H) xanthopterus* a total of 540 specimens comprising 238 males ranging from 139 to 220mm TL and 7.43 to 42.07g weight; 282 females ranging from 131 to 249mm TL and 7.10 to 54.35g weight and 20 indeterminates ranging from 75 to 130mm TL and 1.01 to 6.90 g weight were used for the present study.

The data on length-weight relationship were analysed separately for each category as per Le Cren (1951). The length-weight relationship can be expressed as:

$$W = aL^b. \text{ (Huxley, 1924)}$$

Logarithmic transformation of the above formula gives a linear equation :

$$\ln W = \ln a + b \times \ln L \text{ (Le Cren, 1951)}$$

Where W = weight in g, L =total length in mm, 'a' and 'b' are constants.

Conversion of the resultant transformed equation to the original equation was achieved by rewriting the equation as :

$$W = e^a \times L^b$$

Significance of difference at 5% level between regression coefficients of the sexes were tested by ANACOVA (Snedecor and Cochran 1967; Zar 1996). To test whether the regression co-efficient depart significantly from 3, 't' test was employed by using the formula

$$t = b-3/Sb$$

where b, the regression coefficient and S, the standard error of b.

Relative condition factor 'Kn' for different months as well as different length groups of 10mm class interval was also estimated by employing the equation of Le Cren (1951).

$$Kn = \frac{W}{\hat{W}}$$

Where 'W' represents the observed weight and $\hat{W}$ the expected weight derived from the length-weight relationship.

6.3. Results

6.3.1. Length-weight relationship

Statistical details regarding the length-weight relationship of *H.(H) limbatus* and *H.(H) xanthopterus* are shown in Table 6.1. The logarithmic relationship between length and weight of males, females and indeterminates are presented Figs. 6.1 to 6.6. The logarithmic regression equations were as follows.

H. (H) limbatus

Male	$\ln W = -14.123 + 3.266 \ln TL$	$r=0.970$
Female	$\ln W = -13.986 + 3.244 \ln TL$	$r= 0.983$
Indeterminates	$\ln W = -14.873 + 3.401 \ln TL$	$r=0.934$

H.(H) xanthopterus

Male	$\ln W = -12.860 + 3.025 \ln TL$	$r= 0.963$
Female	$\ln W = -12.128 + 2.941 \ln TL$	$r = 0.948$
Indeterminates	$\ln W = -15.491 + 3.589 \ln TL$	$r = 0.949$

The corresponding exponential relationship can be represented in Figs. 6.7 to 6.12 and the exponential formula can be represented as follows.

H.(H) limbatus

Male $W = 1.139\ \text{E-02}\ L^{3.266}$

Female $W = 1.072\ \text{E-02}\ L^{3.244}$

Indeterminates $W = 6.288\ \text{E-03}\ L^{3.401}$

H.(H) xanthopterus

Male $W = 9.969\ \text{E-03}\ L^{3.025}$

Female $W = 1.355\ \text{E-02}\ L^{2.941}$

Indeterminates $W = 1.342\ \text{E-02}\ L^{3.589}$

The regression equations of males and females of the two species were subjected to analysis of covariance ANACOVA (Snedecor and Cochran, 1967; Zar 1996) and the results are presented in Table 6.2 and 6.3. The results of analysis of covariance revealed significant difference at 5% levels in both the species. Therefore the length-weight relationships for males and females of *H. (H) limbatus* and *H. (H) xanthopterus* were considered as different and therefore combined relationships could not be derived. Separate regression analysis was needed and carried out.

The co-efficient of correlation (r) for males and females and Indeteminates of *H. (H) limbatus* was 0.970, 0.983 and 0.934 and those of *H.(H) xanthopterus* was 0.963, 0.948 and 0.949, respectively. This showed that there is a very good relationship between the measures of length and weight of *H.(H) limbatus* and *H.(H) xanthopterus*.

In *H.(H) limbatus* the b values were 3.266 for males, 3.244 for females and 3.401 for indeterminates whereas that of *H.(H) xanthopterus* were 3.025 for males 2.945 for females and 3.589 for indeterminates. The 't' test was conducted to see whether the 'b' values of these two species were different from the expected value 3.0 for ideal fish. The 't' values revealed that the regression coefficient of males and females of *H.(H). limbatus* differed significantly from 3.0 while the indeterminates did not show any significant difference from the isometric value of 3.0. In the case of *H.(H) xanthopterus* the males and females strictly followed the cube law while the indeterminates deviate from it significantly.

6.3.2. Relative condition factor

Monthly and length-wise fluctuations in relative condition ('Kn') values of males and females of *H.(H) limbatus* and *H.(H) xanthopterus* during 2001 May to 2003 April are depicted in Fig 6.13 to 6.16.

In *H.(H) limbatus* the relative condition factor ('Kn') values were highest during November and April (1.04) in both the years for females whereas that of males were in November and March (1.04) in the first year and February and September (1.03) in the second year. The lowest 'Kn' values were observed in the month of May (0.97) during the first year and June and January (0.98) during the second year for females whereas in the case of males the months April and May (0.96) showed low values during the first year and October (0.95) in the second year.

In *H.(H) xanthopterus* the highest 'Kn' values were observed for females during the month of June (1.039) whereas lowest values were observed in September (0.96) in both the years. In the case of males the highest values were observed in the month of May and November (1.02) during the first year and August (1.01) during the second year whereas the lowest values were in September (0.98) in the first year and March 0.99 in the second year. The variation in 'Kn' values can be attributed to the maturity process in the fish as manifested by increase in weight of gonads and to spawning activity as manifested by loss of weight.

In the case of females of *H. (H) limbatus* the 'Kn' values were above 1.0 in length groups 120-130mm and 140-180mm. Values less than 1.0 were noticed in the older and younger length groups. In males the highest values were observed in 110-130mm length group. In all other length groups the males followed the same pattern as in the case of females.

The length groups 160-180mm and 210-230mm showed 'Kn' values above 1.0 with the highest 'Kn' value 1.07 in the 220-230mm length group in the case females of *H. (H) xanthopterus* The lowest values were observed in the 130-140mm length group. In males the lowest 'Kn' value was in the 130-140mm and highest in 210 to 230 mm length group. Males followed a more or less similar pattern as that of females in all other length groups. 'Kn' values were high in younger fishes, however, a decline in the values with length increment is noteworthy.

6.4. Discussion

Significant differences could be found while comparing the regression co-efficient of males and females *H. (H) limbatus H. (H) xanthopterus* and so separate equations were computed to describe the length-weight relationship of males and females of both species. Talwar (1962 b) reported separate regression equation for *H.georgii.* Contrary to this Sultana *et al.*(1980) used a common regression equation for *H. gaimardi.* The 'b' values obtained for males and females of *H. (H) limbatus* and indeterminates of *H. (H) xanthopterus* showed significant variation from the isometric value of '3' whereas the males and females of *H.(H) xanthopterus* and indeterminates of *H. (H) limbatus* did not show significant variation from the cube law.

In ideal fish which exhibits isometric growth, the value of regression coefficient shall not be different significantly from 3.0 (Allen, 1938). In this study the 'b' values of *H. (H) limbatus* were slightly above the isometric value of 3.0, indicating that the weight increased by a power more then three with unit increase in body length. Similar results were reported in *H. gaimardi* (Sultana *et al.*1980), males of *H.georgii* (Talwar, 1962 b) and *H.brasiliensis* (Berkley and Houde 1978. However, *in H. (H) xanthopterus* males and females strictly followed cube low indicating that the weight increased by a power of 3 with unit increase in body length as observed in females of *H. georgii* (Talwar, 1962b) and *H. margiantus (*Kasim *et al.1996).* Slope value less than 3.0 indicates that the fish becomes more slender as it increase in length while slope greater than 3.0 denotes the stoutness, leading to the conclusion that growth is allometric (Grover and Juliano, 1976). However a deviation from the cube law is often observed in most of the fishes as they change their body shape during growth. The value of 'b' usually varies between 2.5 and 4.0 (Hile, 1936 and Martin, 1949). The reasons for this variation are seasonal fluctuations in environmental parameters, physiological conditions of the fish at the time of collection, sex, gonadal development and nutritive conditions of the environment of the fishes (Sinha, 1973).

While discussing the merits of allometric formula with cube formula-Beverton and Holt (1957) have stated that instances of important deviation from isometric growth in fishes are rare. In the present study deviation from the isometric value of '3' was evident in *H.(H) limbatus* and such deviation has been reported by Venkataramani and Kingsten (1998) in *Selaroides leptolepis,* Sunil (2000) in Rasbora daniconius, Doddamani *et al.* (2001) in *Stolephorus batavience* whereas *H.H. xanthopterus* follow isometric pattern of growth and similar instances were reported by Batcha and Badrudeen (1992) in *Leiognathus brevirostris,* Venkataramani and Gopalakrishnan (1993) in *Parastromateus niger* and Sunil Kumar *et al.*(1999) in *Horabagrus brachysoma.*

The relative condition factor values were highest during April and November in the case of *H. (H) limbatus* and in June and July for *H.(H) xanthopterus*. These months were considered as the spawning period of these fishes (Refer the chapter on maturation and spawning for details). It may therefore be inferred that the high condition values may be due to intense gonad maturation, as reported by Sultana *et al.*(1980) in *H. gaimardi*. High Kn values noticed in the younger length group fishes of *H.(H) limbatus* and *H.(H) xanthopterus* can be attributed to the high feeding intensity of the young growing fish. In *P. hamrur* the condition is greatly influenced by feeding intensity rather than the cyclic changes taking place in the gonads (Philip and Mathew, 1996). Qasim (1957) explained that the increase or decrease of condition in the shanny *Blennius pholis* is probably due to general building up and loss of reserves respectively. It is reported that 'Kn' values depend on physiological factors like maturity and spawning and environmental factors like availability of food (Brown, 1957).

The 'Kn' values of males and females of *H.(H) limbatus* and *H.(H) xanthopterus* were around and above 1 in most of the months, which indicated that these fishes showed good condition throughout the year. Berkley and Houde (1978) reported that the males of *H.brasiliensis* had a higher condition factor.

The reason for the incidental fluctuation of 'Kn' values are not fully understood and therefore assumed as due to inexplicable causes. It may be inferred that Kn values were not only influenced by sexual cycle but also due to some other unknown factors. James (1967) suggested that the changes in the condition of ribbon fish *Eupleurogrammus intermedius* was related to factors other than reproductive cycle and the feeding habits.

Significant differences could be found while comparing the regression co-efficient of males and females *H. (H) limbatus H. (H) xanthopterus* and so separate equations were computed to describe the length-weight relationship of males and females of both species. The 'b' values obtained for males and females of *H. (H) limbatus* and indeterminates of *H. (H) xanthopterus* showed significant variation from the isometric value of '3' whereas the males and females of *H.(H) xanthopterus* and indeterminates of *H. (H) limbatus* did not show significant variation from the cube law.

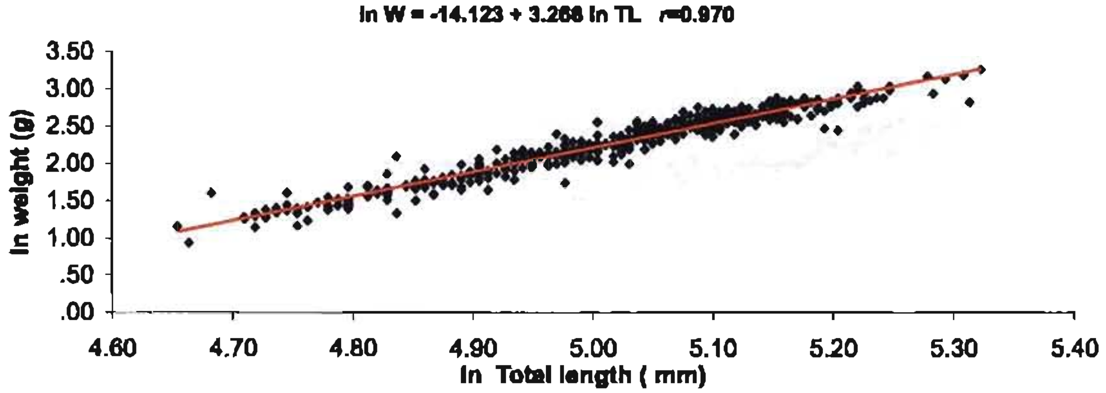


Fig. 6.1
Length weight relationship of *H. (H) limbatus* male

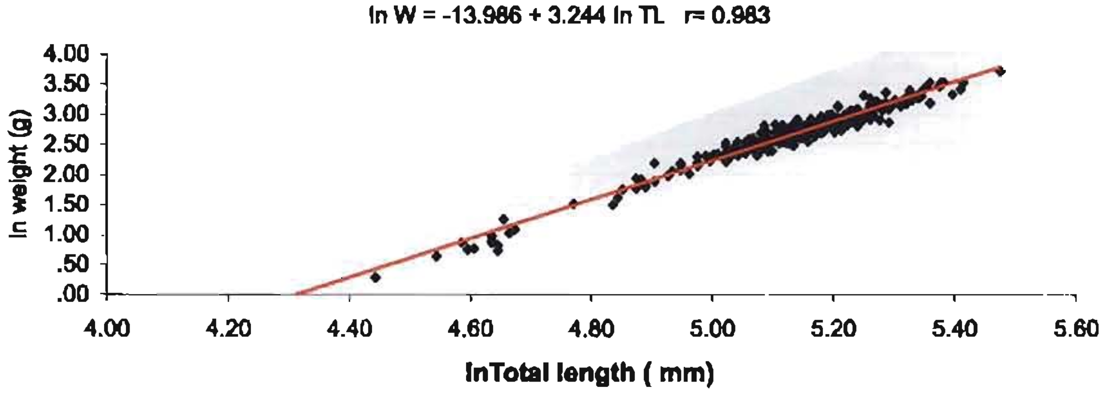


Fig. 6.2
Length weigth relationshipof *H. (H) limbatus* female

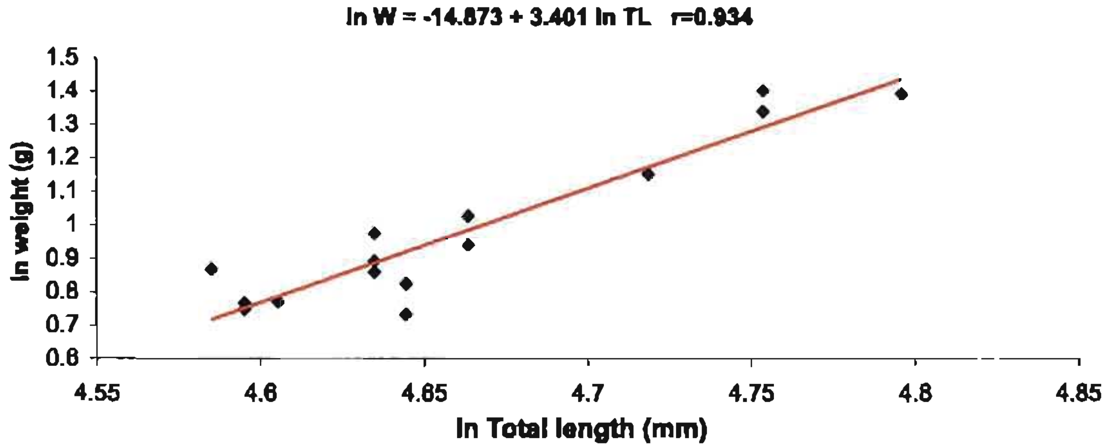


Fig. 6.3
Length weight relationship of *H. (H) limbatus* Indeterminates

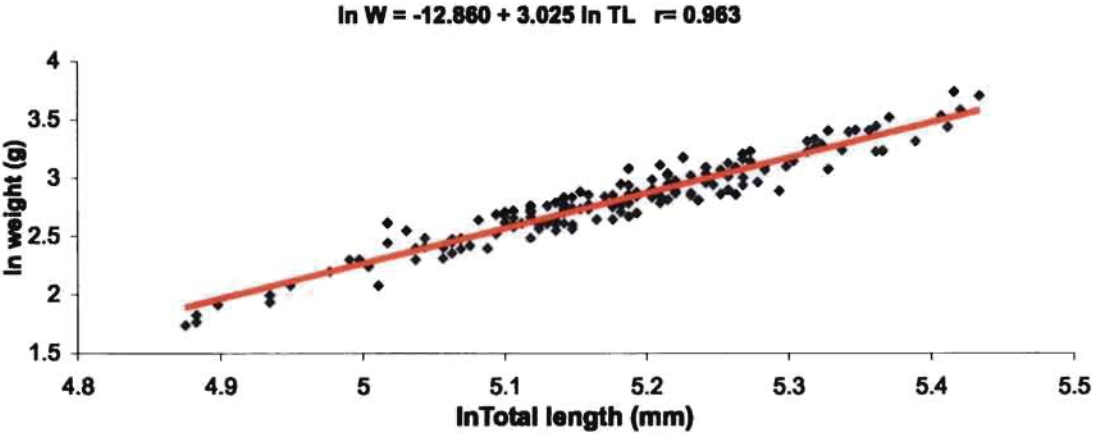


Fig. 6.4

Length weight relationship of *H. (H) xanthopterus* male

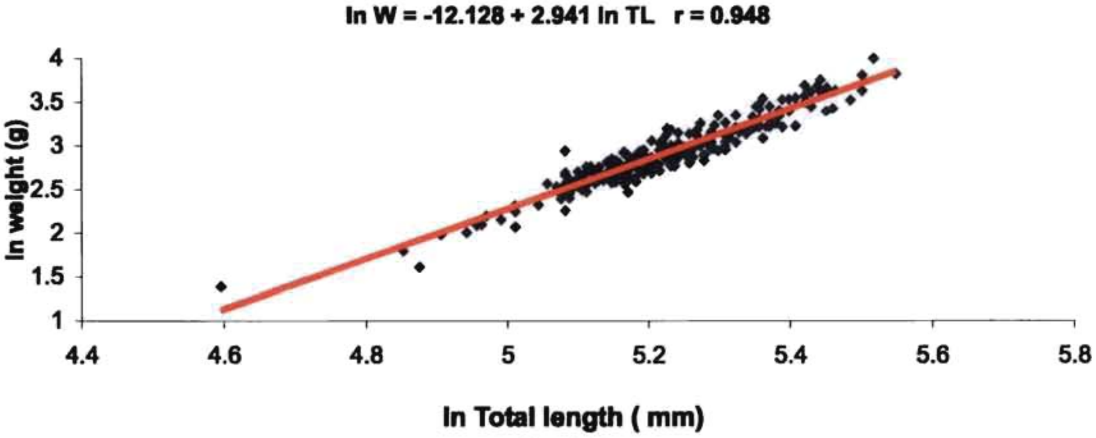


Fig. 6.5

Length weight relationship of *H. (H) xanthopterus* female

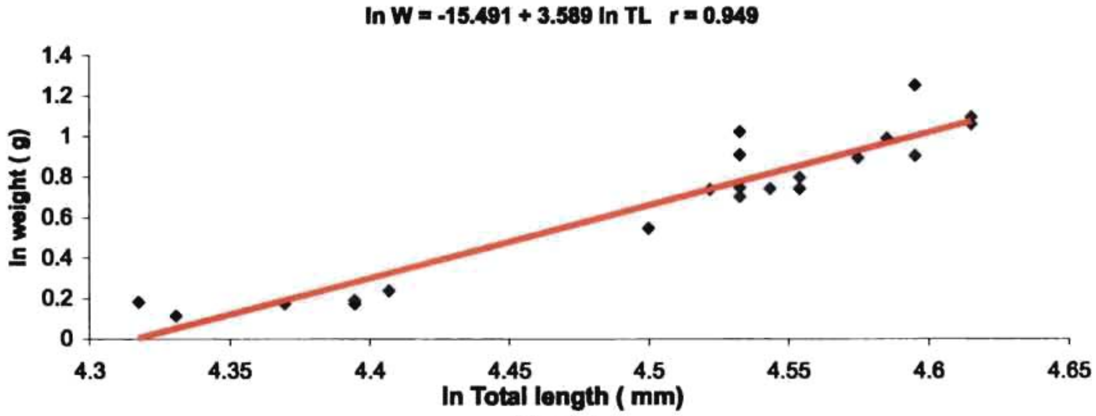


Fig. 6.6

Length weight relatioship of *H. (H) xanthopterus* indeterminates

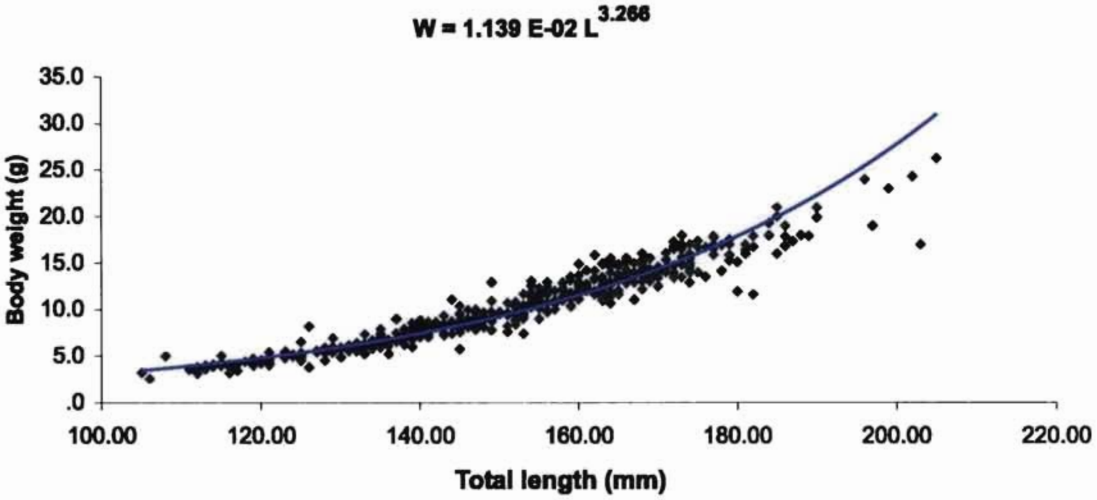


Fig.6.7
Length weight relatioship in exponential form of *H. (H) limbatus* male

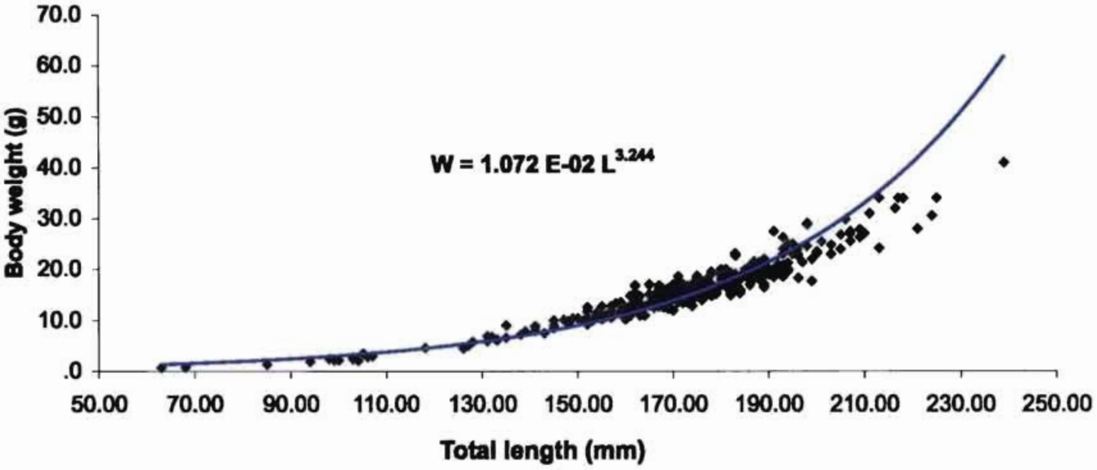


Fig. 6.8
Length weight relationship in exponential form of *H. (H) limbatus* female

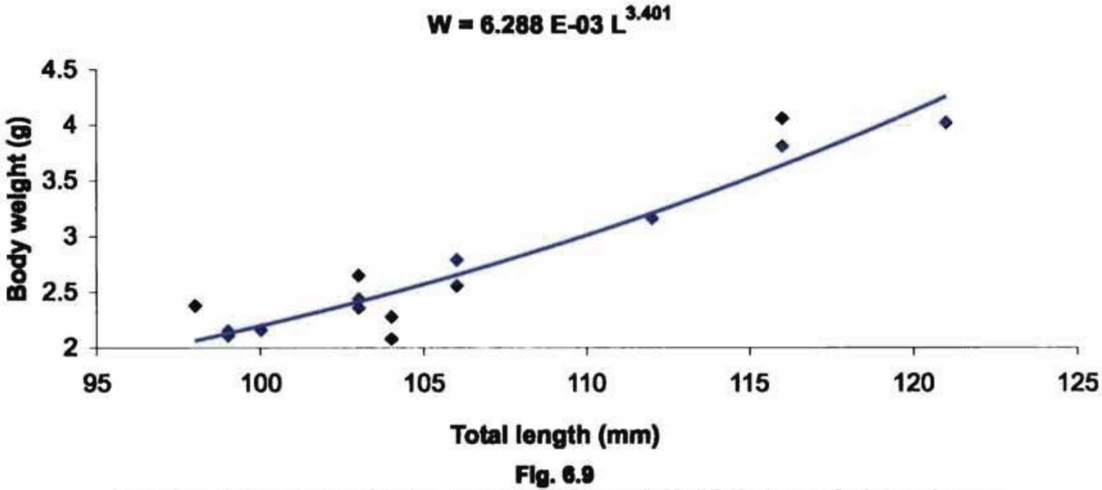


Fig. 6.9
Length weight relationship in exponential form of *H. (H) limbatus* indeterminates

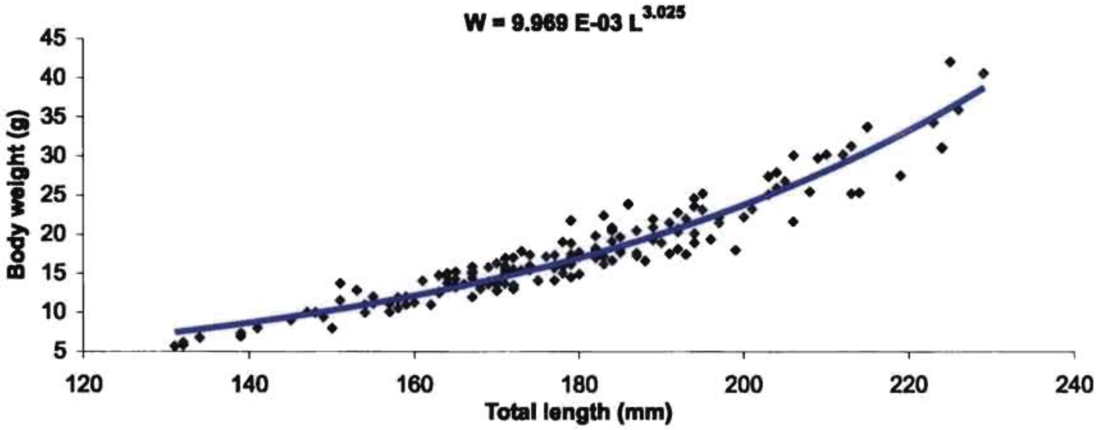

$W = 9.969\ E\text{-}03\ L^{3.025}$

Fig. 6.10
Length weight relatioship in exponential form of
***H. (H) xanthopterus* male**

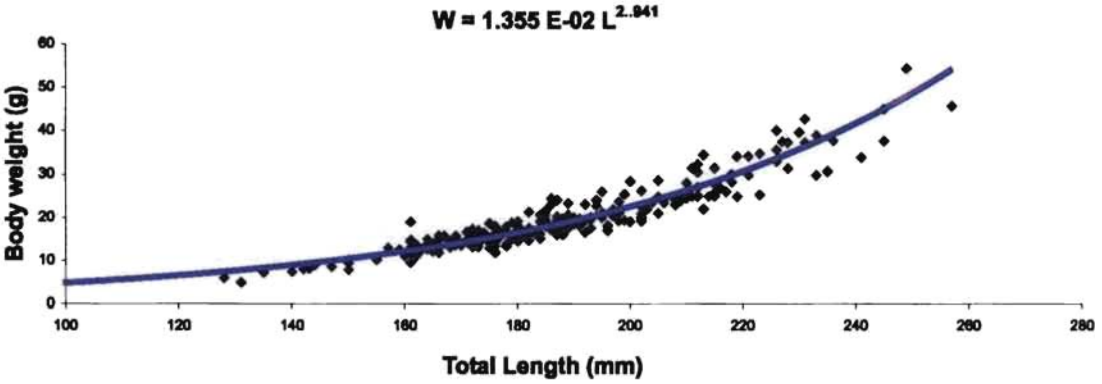

$W = 1.355\ E\text{-}02\ L^{2..941}$

Fig. 6.11
Length weight relationship in exponential form of
***H. (H) xanthopterus* female**

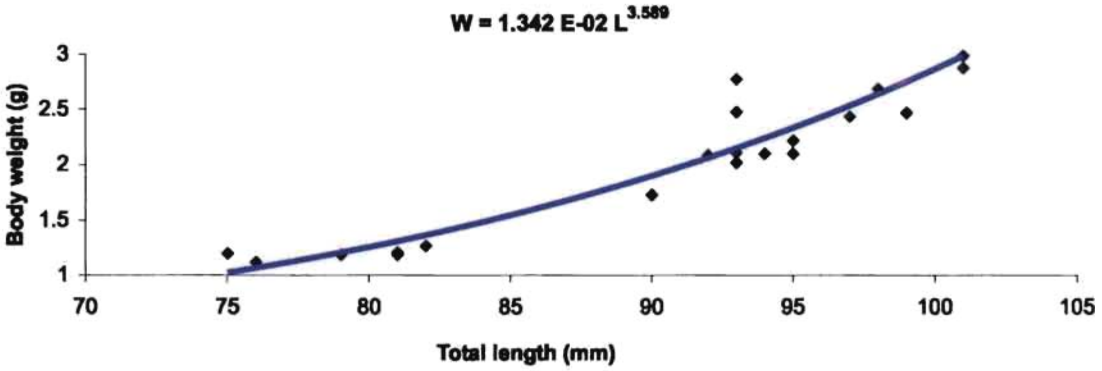

$W = 1.342\ E\text{-}02\ L^{3.589}$

Fig. 6.12
Length weight relatioship in exponential form of
H. (H) xanthopterus Indeterminates

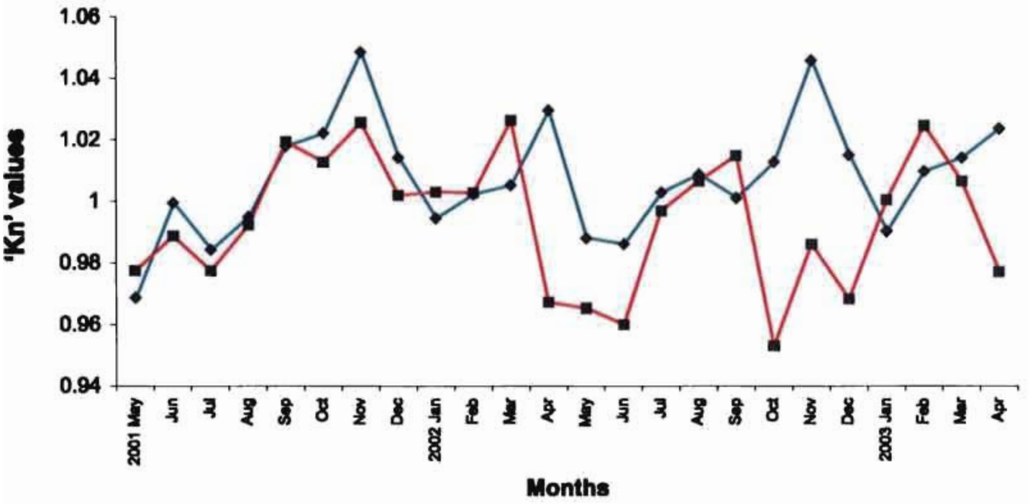


Fig. 6.13
Monthly 'Kn' values of males and females of *H. (H) limbatus*

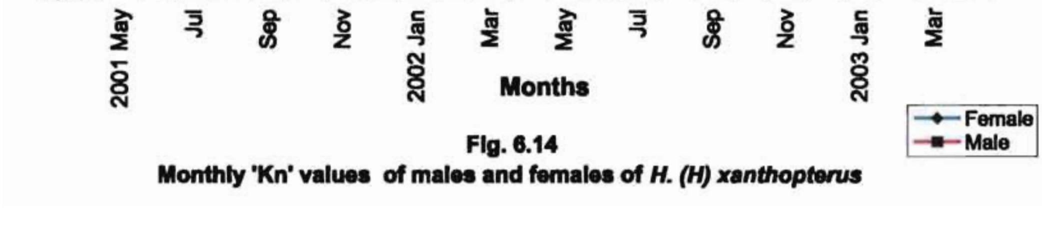


Fig. 6.14
Monthly 'Kn' values of males and females of *H. (H) xanthopterus*

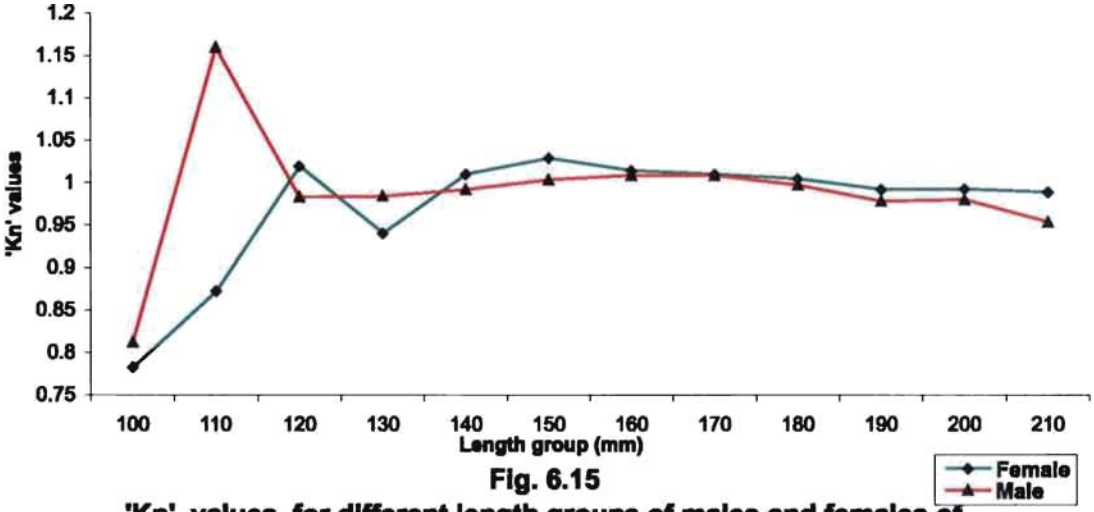


Fig. 6.15

'Kn' values for different length groups of males and females of *H. (H) limbatus*

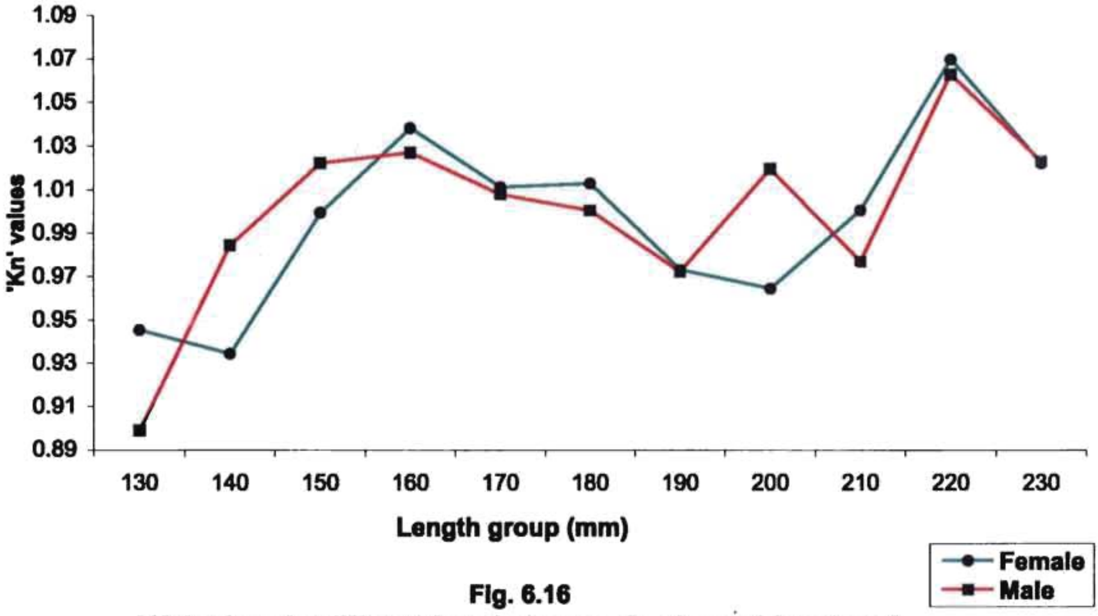


Fig. 6.16

' Kn' values for different length groups of males and females of *H. (H) xanthopterus*

Table 6.1

Details of statistical analysis of length weight relationship of *H.(H) limbatus and H.(H) xanthopterus*

Source	**Number**	**Regression Co-efficient b**	**Intercept log a**	**Correlation coefficient r^2**	**Standard error of b Sb**	**t= b-3 / Sb**	**Relation to '3'**
H.(H) limbatus							
Males	503	3.266	-14.123	0.970	-0.037	7.24	Different *
Females	344	3.244	-13.986	0.983	-0.033	7.39	Different *
Indeterminates	18	3.401	-14.873	0.934	-0.314	1.27	Not different
H.(H)xanthopterus							
Males	238	3.025	-12.860	0.963	-0.059	0.424	Not different
Females	282	2.941	-12.228	0.948	-0.058	2.01	Not different
Indeterminates	20	3.589	-15.491	0.949	-0.274	2.14	Different *

* Significantly different from 3.

Table 6.2

Comparison of regression lines of males and females of *H. (H) limbatus* by ANACOVA

Dependent variable : LOG_WT

Source	Type III Sum of Squares	Df	Means Square	F	P value
Corrected model	223.057	2	111.529	10039.318	0.000*
Intercept	139.842	1	139.842	12588.011	0.000*
LOG_TL	193.143	1	193.143	17385.903	0.000*
Sex	4.891E-02	1	4.891E-02	4.402	0.036*
Error	9.398	846	1.111E-02		
Total	5200.487	849			
Corrected Total	232.455	848			

* Significant at 5% level.

Table 6.3
Comparison of regression lines of males and females of *H. (H) xanthopterus* by ANACOVA

Dependent variable : LOG_WT

Source	Type III Sum of Squares	df	Means Square	F	P value
Corrected model	61.495	2	30.747	2571.626	0.000*
Intercept	39.367	1	39.367	3292.511	0.000*
LOG_TL	59.830	1	59.830	5004.030	0.000*
Sex	5.999E-02	1	5.999 E-02	5.017	0.026*
Error	6.205	519	1.196 E-02		
Total	4439.651	522			
Corrected Total	67.700	521			

* Significant at 5%level.

CHAPTER 7.

AGE AND GROWTH

7. AGE AND GROWTH

7.1. Introduction

Age determination of fish is one of the most important prerequisite in the studies on population dynamics. It forms the basis for calculations leading to the knowledge on growth, mortality, and recruitment of fishes and also helps to assess the sustaining power of the fishery stock. It has been widely accepted that the growth of a fish is not uniform throughout its life and even throughout the year. The growth is rapid in certain parts of the year and slower or even ceases to grow in other parts of the year.

Basically three types of data are used for estimating the growth parameters (Pauly, 1983), such as tagging – recapture data on individual fish, periodic markings laid down on skeletal parts like scales, otoliths and other hard structures, and length frequency data. Of these, the former two methods have the distinct advantage of direct evidence but are difficult to carryout for want of sufficient infrastructure facilities to carry out the programme. The other methods employed are indirect. Growth determination from marking on the hard parts has been successfully and widely used in temperate waters. During summer and autumn, fish in temperate ecosystem tend to register maximum growth due to adequate food supply and optimal environmental conditions. The growth becomes slow during winter and spring due to poor food availability and hostile environmental factors. The annual markings in the hard parts are seen as widely spaced or opaque zones due to fast growth during summer followed by narrower and more transparent spaced zones owing to slow growth during winter. However, the principle and methodology used for the study of age and growth of temperate species are not suitable for tropical fish which live in a most stable environment and have continuous breeding habits. The problems involved in age determination of tropical marines fishes have been discussed by Qasim (1973a).

7.2. Review of Literature

A number of workers have reviewed the method of age determination with particular reference to temperate and tropical fishes. Age determination in fishes using hard parts are two centuries old. A Swedish clergy man determined the age of pike (*Esox lucius*) and other species by counting the rings on the vertebrae and his findings were similar to modern readings (Hederstrom, 1959, original version, 1759). Maier (1906) reviewed the history of age determination of fishes from the 17th century to the end of the 19th. Hoffbauer's (1898) groupings of circuli in carp and interpreting them as yearly marks tempted Thompson (1904) to apply this method in marine fishes. Knowledge on age and growth relating to various fish species is already published, initially by Graham (1929), Van oosten (1929), Menon (1950) and Chuganova (1963) while the contribution of Chuganova (1926), Hickling (1933), Hile (1936), Jones and Hynes (1950), and Kelly and Wolf (1959) are a few outstanding publications on this subject.

Age and growth of marine teleosts from Indian waters were studied mostly based on length frequency distribution or by the discontinuities occurring in their skeletal structures like scales, otolith, bones etc. Qasim(1973 a) while critically reviewing the earlier works on age and growth by Indian workers, outlined the difficulties in determining the age in tropical fish. A more substantive view of the problem for age determination in tropical fish has been discussed by several authors notably by De Bont (1967), Bagenal and Tesch (1978) and Weatherlay and Rogers (1978).

The available literature on age determination of tropical fishes following length frequency distribution include the studies on *Rastrelliger kanagurta* (Devanesan and John, 1940; Seshappa, 1958 and Radhakrishnan, 1962), *Sardinella longiceps (*Hornell and Nayadu, 1923; Nair, 1953; Sekharan, 1955; Antony Raja, 1964; Annigeri, 1969 and Kumar *et al.*1990) *S. labella* (Sekharan, 1955), *S. fimbriata* (Radhakrishnan, 1963), *S. gibbosa* (Annigeri, 1989), *Harpoden nehereus,* (Palekar and Karandikar,1952), *Cynoglossus semifasciatus* (Seshappa and Bhimachar, 1954), *Polydactylus indicus* (Nayak,1959 and Karekar and Bal 1960), *Coilia borneensis* (Varghese, 1961), *Pseudosciaena diacanthus* (Rao, Venkatasubba, 1963), *Lethrinus bentjorn* (Toor, 1964), *Pseudosciaena coiba (*Rajan, 1964), *Upeneus tragula* (Thomas, 1969), *Harpodon nehereus* (Bapat, 1970), *Nemipterus japonicus* (Krishnamurthy, 1971) and *Priacanthus hamrur* (Philip and Mathew, 1996).

Since the age determination in tropical fishes can seldom be made with certainty from length frequency distribution owing to the entry of multiple recruits in a year, age determination from hard parts is also equally important. In Indian waters, age was determined using hard parts are in *Cynoglossus semifasciatus* (Seshappa and Bhimachar, 1954; 1955), *Mugil parsia* (Sarojini, 1957), *Hilsa ilisha* (Pillay, 1958), *Sillago sihama* (Radhakrishnan, 1957), *Mystus gulio*, (Pantulu, 1961), *Catla catla* (Natarajan and Jhingaran, 1963), *Ophiocephalus punctatus (*Qasim and Bhatt, 1966). *Mugil parsia* (Sarojini, 1957), *M. cunnesius* (Sarojini, 1958), *Rastrelliger kanagurta* (Seshappa, 1972) and *Barbus sarana* (Murty ,1976).

In tropical waters, the growth markings were laid down in hard parts of the fish at different periods due to multiple factors. The growth markings have been attributed to paucity of food during monsoon in Malabar sole (Seshappa and Bhimachar, 1955), and grey mullets (Sarojini, 1957) whereas starvation was found as a causative factor in mrigal (Kamal, 1969). In Catla (Natarajan and Jhingran, 1963) and in Indian Mackeral (Seshappa, 1958) spawning stress was attributed as the reason while the continuous effect of food of low nutritive value and spawning stress was found as factors for the same in the fresh water cat fish *Pangasius pangasius* (Pantulu, 1962).

Mathew and Zacharia (1982) described the age and growth of three major Indian carps. The other important works are that of Luther (1985) on *Chirocentrus* sp., Rao and Rao (1986) on *Nemipterus japonicus,* Devi *et al.*

(1990) on cat fish *Rita rita*, Nair (1991) on *Dussumeria acuta*, Singh *et al.* (1998) on *Labeo rohita*, Jayaprakash (1998) on *Cynoglossus macrostomus*, Kurup (1997) on *Labeo dussumieri*, Seshappa (1999) on Indian fishes. Vilizzi and Walker (1999) studied the age of *Cyprinus carpio* and Chung and Woo (1999) determined the age of *Pomacanthus imperator.*

Some recent studies on age and growth are that of Borges (2000) in *Macrorhamphus* sp., Rico *et al.* (2001) in *Beryx splendens,* Pereda *et al.* (2001) in *Lophius piscatorius* and *L. budegassa*, Albert *et al.* (2002) in *Cyclopterus lumpus,* Hesp *et al.* (2002) in *Glaucosoma hebracium,* Newman (2002) in *Lutjanus malabaricus*, Somarakis and Machias (2002) in *Pagellus erythrinus*, Lorenzoni *et al.* (2002) in *Micropterus salmoides*, Etim *et al.* (2002) in *Periophthalmus barbarus,* Radabe *et al.* (2002) in *Rhabdosargus sarba,* Yoneda *et al.* (2002) in lizard fish *Saurida* sp. and Türkmen *et al.* (2002) in *Capoeta capoeta umbla.*

Investigations on the age and growth of the family *Hemiramphidae* from the Indian waters or other parts of the world are relatively few. Uchida (1930) and Hattori and Seki (1959) determined the age and growth of *Hemiramphus sajori* from Japan. Ling (1958) studied the age and growth of *Hyporhamphus melanochir* collected from south Australia whereas Berkeley and Houde (1978) and McBride and Thurman (2003) studied the same in *Hemiramphus brasiliensis* and *H. balao* from south east Florida. Talwar (1962 b) determined the age and growth of *Hyporhamphus georgii* from Gulf of Mannar and Palk Bay. Sultana *et al.* (1980) estimated the age and growth of *Hemiramphus gaimardi* of Pulicat Lake. However, no attempt has so far been made to study the age and growth of *H. (H) limbatus* and *H. (H) xanthopterus.*

7.3. Materials and Methods

Monthly samples of fishes were collected from different fish landing centres, markets of Cochin coast and some fishing grounds in Vembanad Lake like Eloor, Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map. (Fig. 1.1). The males and females were distinguished by examining the gonads. The total length was measured from tip of lower jaw to tip of caudal fin using a dial reading caliper. A total number of 1094 (506 males and 588 females) fishes of *H. (H) limbatus* and 1128 (436 males and 692 females) fishes of H. *(H) xanthopterus* were used for length frequency studies.

The length frequency data were grouped in to 10mm size classes, and arranged sequentially for two years for males and females separately. The growth parameters $L\infty$ and K were estimated using ELEFAN 1 program. (Gayanilo *et al.* 1996). Lengths at age of 3 months intervals were obtained with the help of growth curve from ELEFAN 1 programme and t_0 was calculated using von Bertalanffy plot from the result of regression of $-\ln(l-t/L\infty)$ against t from the equation $t_0 = \frac{-a}{b}$.

The von Bertalanffy Growth Equation (VBGE) (Bertalanffy, 1938) was used to describe growth as

$$Lt = L\infty \, (1-e^{-k\,(t-to)})$$

Where Lt is the length at age t, $L\infty$ the asymptotic growth attained by the fish if it were allowed to grow infinitely; K is a growth coefficient and t_0 is the age the fish would have length zero if they had grown according to the above equation.

Estimation of 'growth performance' index (ϕ)

Based on the VBG function expressed as total length in mm and K year $^{-1}$ and the base of logarithm ($\log_{10}$) as 10, Pauly and Munro's 'growth performance index' ϕ was calculated using the formula, (Pauly and Munro, 1984).

$$\phi = \log K + 2 \log L\alpha$$

The ϕ enables comparison of growth parameter estimates of one stock with that of another.

7.4. Results

The growth curves of males, females and both sexes combined in *H. (H) limbatus* and *H. (H) xanthopterus* following ELEFAN 1 are shown in Figs.7.1 to 7.6 The maximum lengths (L_{max}) recorded in males and females of *H. (H) limbatus* during the study period were 197 and 239 mm respectively while the same in *H. (H) xanthopterus* were 249 and 259mm respectively.

The growth parameters in males, females and combined population of both the species computed from ELEFAN 1 in the present study are given in Tables 7.1 and 7.2.

The L_∞, K and t_0 in *H. (H) limbatus* male, are 224mm, 0.97.(year^{-1}) and -0.839 whereas that of *females* are 251mm, 0.72 (year^{-1}) and –0.721 and that of both sexes combined are 252mm, 0.70 (year^{-1}) and –0.708. In the case of *H. (H) xanthopterus* these values are 262 mm, 0.63 (year^{-1}) and –0.817 for male, 273mm, 1.50, (year^{-1}) and –0.820 for *female* and 271mm, 1.10, (year^{-1}) and –0.731 for both sexes combined respectively.

Using the growth parameters arrived at in the present study, von Bertalanffy growth equation (Bertalanffy, 1938) for two species can be written as follows : (Figs. 7.7 and 7.8)

For *H. (H) limbatus*

male, $Lt = 224\ (1\text{-}e^{-097\ (t\ +\ 0.839)})$

female, $Lt = 251\ (1\text{-}e^{-0.72(t+0.7215})$

both sexes, $Lt = 252\ (1\text{-}e^{-0.71\ (t\ +\ 0.708)})$.

For *H. (H) xanthopterus*

Male $Lt = 262\ (1\text{-}e^{-0.63\ (t\ +\ 0.816)})$

Female $Lt = 273\ (1\text{-}e^{-1.50\ (t\ +\ 0.820)})$

Both sexes $Lt = 271\ (1\text{-}e^{-1.1\ (t\ +\ 0.731)})$.

The growth performance index ϕ (Pauly and Munro 1984) was worked out separately for males and females of the two species studied and are given in Tables 7.1 and 7.2 The ϕ values were found comparable in males (4.69) and females (4.66) of *H. (H) limbatus* while in *H. (H) xanthopterus* the value worked out for female was 5.05 which was clearly higher than that of males (4.64). Also the growth performance of both sexes pooled together, the value of *H (H) xanthopterus* was higher (4.91) than that of *H(H) limbatus* (4.65).

The length arrived at annually by *H.(H)limbatus* for four years are (Table7.3)186.45, 209.59, 218.31, 221.61mm for males, 178.33, 215.61,233.17 and 242.58mm for females and 175.78, 214.13, 233.176 and 242. 58mm for both sexes combined respectively; whereas that of *H.(H) xanthopterus* are (Table 7.4) 178.59,217.58, 238.58 and 249.39mm for males, 255.09, 268.62,271.60 and 272.26mm for females and 230.38,257.71,266.90 and 272.30mm for both sexes combined respectively. Aging results indicated that the life span of *H (H) limbatus* and H *(H) xanthopterus* is between 2 and 4 years.

7.5. Discussion

Determination of age of hemiramphids is comparatively difficult due to various reasons. Talwar (1962 b) found that ageing of *Hemiramphid* sp. based on otoliths and scales unsuccessful and therefore used Petersen's length-frequency method. In *H (H) limbatus* and H *(H) xanthopterus* the scales are cycloid and deciduous. Examination of the scales collected from lateral sides and from either sides of dorsal fin gave no indication of growth marks. Otoliths from fishes of different sizes were examined for growth marks in assessing the age of the fish. However, no indication of markings could be observed. Therefore, it was found that only length frequency data can only be employed for age determination of these species.

In the present study, it was found that the growth parameters obtained for males and females of both species showed variations. The L_∞ is higher in females than in males of both *H.(H) limbatus* and *H.(H) xanthopterus.* A differential growth between the two sexes was noticed in the present study as observed by Qasim (1966) especially when preponderance of one sex in the population was observed. *H. (H) xanthopterus* (K= 1.1) grows at a faster rate than *H.(H) limbatus* (K 0.70). Ricker (1979) reported that availability of food is an important factor influencing growth. Borges (2000) opined that the difference in growth rates may reflect the different characteristics of the habitat. In the present study, it was found that both species grow rapidly during their first year, which concurs with the findings of Borges (2000) in *Macrorhamphus* sp. However the growth rate becomes slower glaringly during the second year and this shows very strong agreement with that of Rico *et al* (2001) in *Beryx splendens.*

In the present investigation, no clear progression of modes could be seen from the length frequency studies. This may be due to the extended recruitment of fishes of different age group into the fishery. It has been observed that *H. (H) limbatus* and *H. (H) xanthopterus* are continuous spawners, (Ref. Maturity and spawning chapter) as a result of which fishes of different age groups are seen almost throughout the year. Similar condition was reported by Sultana *et al.* (1980) in *H. gaimardi.*

The result of the present study revealed that, *H. (H) limbatus* grows to about 175.78 mm during first year, 214.13 mm during second year and 233.18mm during third year. Its L_{max} was found to be 239mm. On the contrasts in *H. (H) xanthopterus* the length attained at the end of first, second and third years were found to be 230.38, 257.71, and 266.90mm respectively while the maximum length recorded was to be (L_{max}) 259mm. The faster growth rate during the first year and the subsequent slowing down during succeeding years have been unanimously reported a series of other workers in hemiramphid fishes. Uchida (1930) and Hattori and Seki (1959) reported that *Hemiramphus sajori* had attained a length of 150-200mm during the first year and 160-250mm, during the second year. Ling (1958) stated that the mean length of males and females of *Reporhamphus melanochir* collected from south Australia, were 210 .4 and 143.3mm respectively at the first year. However, relatively slow rate of growth was recorded in higher age groups. Talwar (1962b) reported that *H. georgii* attained 175mm during the first year, 40mm during the second year and

20mm during the third year. Berkeley and Houde (1978) and Mc Bride and Thurman (2003) determined the growth rate for *H. brasiliensis* and *H. balao* from South East Florida. The rate of growth was 216.1mm for *H. brasiliensis* and 209.0mm for *H. balao* during the first year. The life span of *H. brasiliensis* was 2 years and that of *H. balao* was I year. Sultana *et al.* (1980) reported that *H. gaimardi* grows to about 100 to 120mm during first year, but the growth rate slowed down and is found to be about 30mm in the second year. In the case of *H. (H) limbatus* male, L_{max} was 197mm and that of female was 239mm whereas the L_{max} of *H. (H) xanthopterus* male was 249mm and that of female was 259mm respectively.

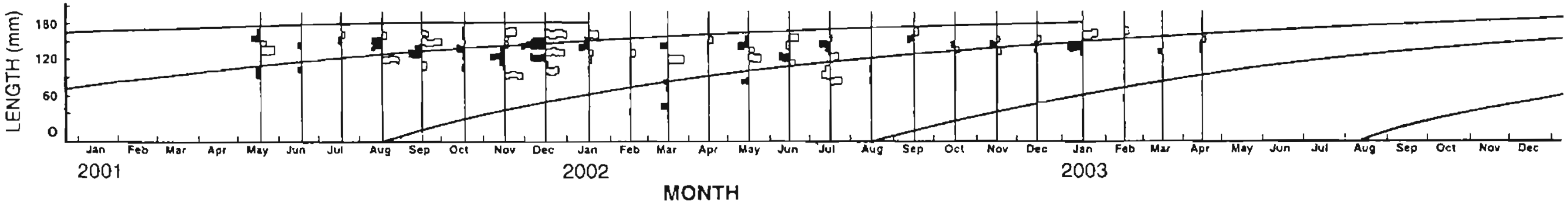
Most of the shallow water species have a longevity of about 3-6 years. (Murthy, 1984). The life span assessed for *H.(H) limbatus* and *H.(H) xanthopterus* falls between 2 and 4 years which concur with shallow water fish species.

Size at first maturity was estimated to be 125mm (TL) for male and 145mm (TL) for female of *H.(H) limbatus* and 135mm (TL) and 155mm (TL) respectively for males and females of *H.(H) xanthopterus.* (Refer chapter on maturation and spawning for details). These species attained the above length in the first year of its life history itself. This observation shows very strong agreement with previous findings that most fishes from Indian waters mature when they are at 1-2 years (Qasim, 1973). The prematurity phase of growth is faster compared to the post maturity phase which is very slow in the tropical fishes (Qasim, 1973). The present results reveal that prematurity growth phase in *H. (H) limbatus* and *H. (H) xanthopterus* are very fast. After an initial fast growth, the rate slowed down apparently due to energy diversion for maturation and gonadal development. The monthly variation in modal length frequency showed that the periods of uniform growth mostly coincided with the time immediately after spawning. This indicates the recovery of these fishes from the spawning stress.

In both species the females were more robust compared to their male counterparts. The variation may be due to gonad development as reported in the case of *Rita rita* by Devi *et al.* (1990). The growth potential in a female is directed more towards gonad development than to body increment when compared to males. Therefore, it is obvious that in the early part of the life, the males reveal better absolute growth than females. The apparent spawning stress is reflected in the body growth of females.

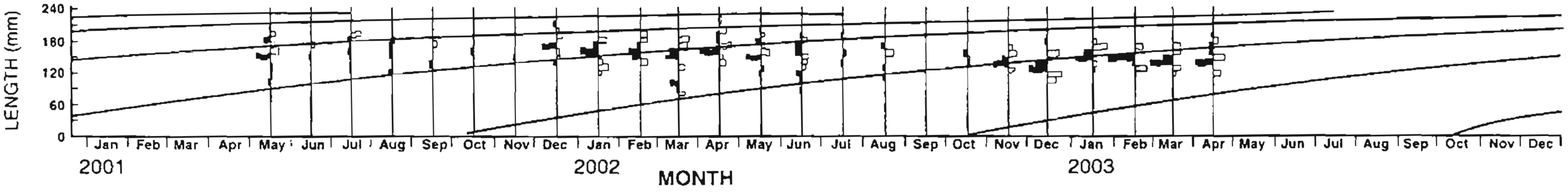
Investigations on age and growth of fishes are of prime importance in the planning and management of their fishery. Growth studies from Indian waters are largely based on length frequency distribution as age determination by other conventional methods are found difficult and not practical as in some fishes, though the hard parts like scales, otoliths and bones show clear zonations, it is difficult to conclude that these are formed annually only (Qasim, 1973a).

The rapid growth rate, early maturation and short life span are characteristic features of *H. (H) limbatus* and *H. (H) xanthopterus* as in the case of *H.brasiliensis and H.balao(Mc Bride and Thurman (2003)*. The results indicate that of the present study manifest the possibility of life span of *H. (H) limbatus* and *H. (H) xanthopterus* between two and four years and these findings are corollary to earlier reports in hemiramphids (Ling, 1958; Talwar, 1962b). The $L\infty$ values of *H. (H) limbatus and H. (H) xanthopterus* are low and this can be attributed to the short life span as reported in *Labeo dussumieri* by Kurup (1997).



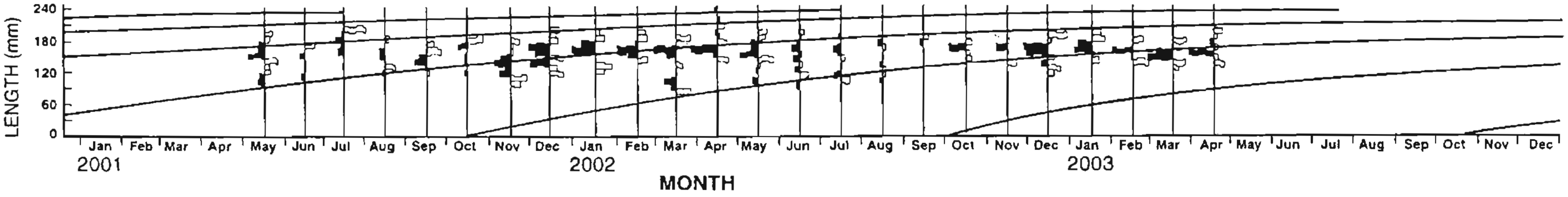
L∞ : 224.00
K : 0.970
Rn : 0.231

Fig. 7.1 Monthwise restructured length frequency distribution for the males of *H. (H) limbatus* estimated using ELEFAN - 1 Programme



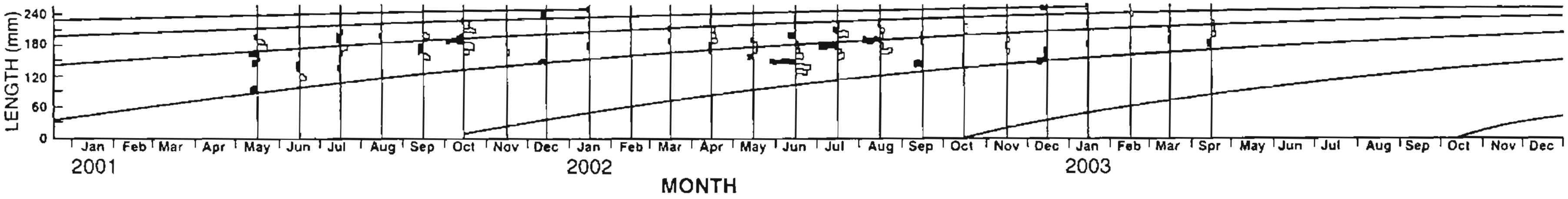
L∞ : 251.00
K : 0.720
Rn : 0.217

Fig. 7.2 Monthwise restructured length frequency distribution for the females of *H. (H) limbatus* estimated using ELEFAN - 1 Programme.



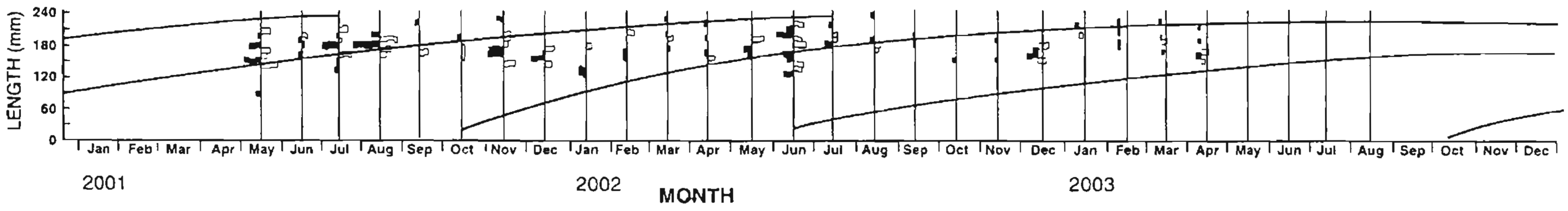
L∞ : 252.00
K : 0.700
Rn : 0.177

Fig. 7.3 Monthwise restructured length frequency distribution for *H. (H) limbatus* pooled (males and females) estimated using ELEFAN - 1 Programme



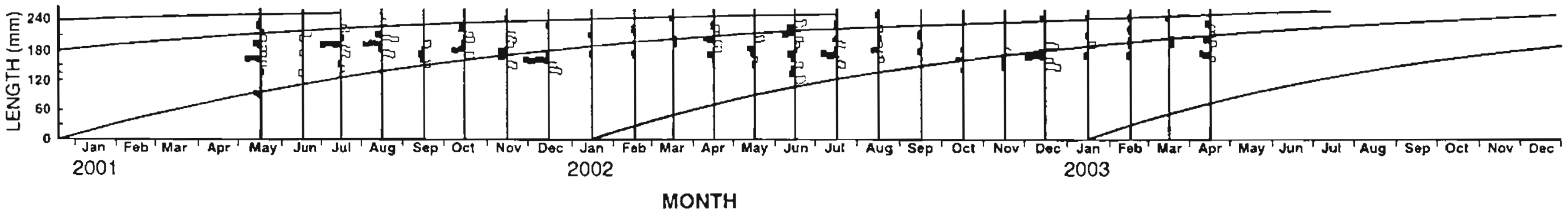
L∞ : 262.00
K : 0.630
Rn : 0.240

Fig. 7.4 Monthwise restructured length frequency distribution for the males of *H. (H) xanthopterus* estimated using ELEFAN - 1 Programme



L∞ : 273.00
K : 1.520
Rn : 0.214

Fig. 7.5 Monthwise restructured length frequency distribution for the females of *H. (H) xanthopterus* estimated using ELEFAN - 1 Programme.



L∞ : 271.00
K : 1.130
Rn : 0.156

Fig. 7.6 Monthwise restructured length frequency distribution for *H. (H) xanthopterus* pooled (males and females) estimated using ELEFAN - 1 Programme

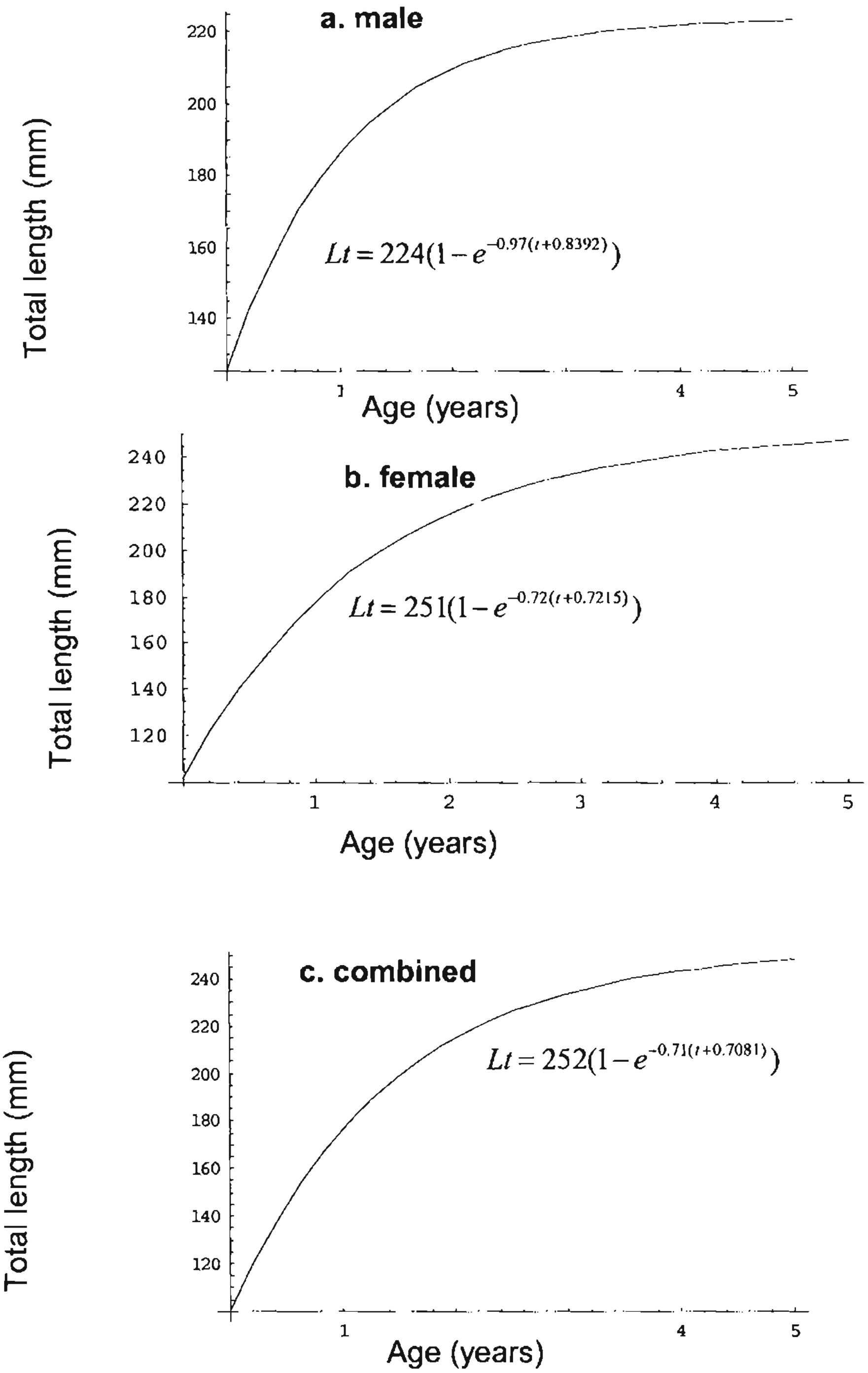


Figure 7.7

Von – Bertalanffy growth curve for *H. (H) limbatus*

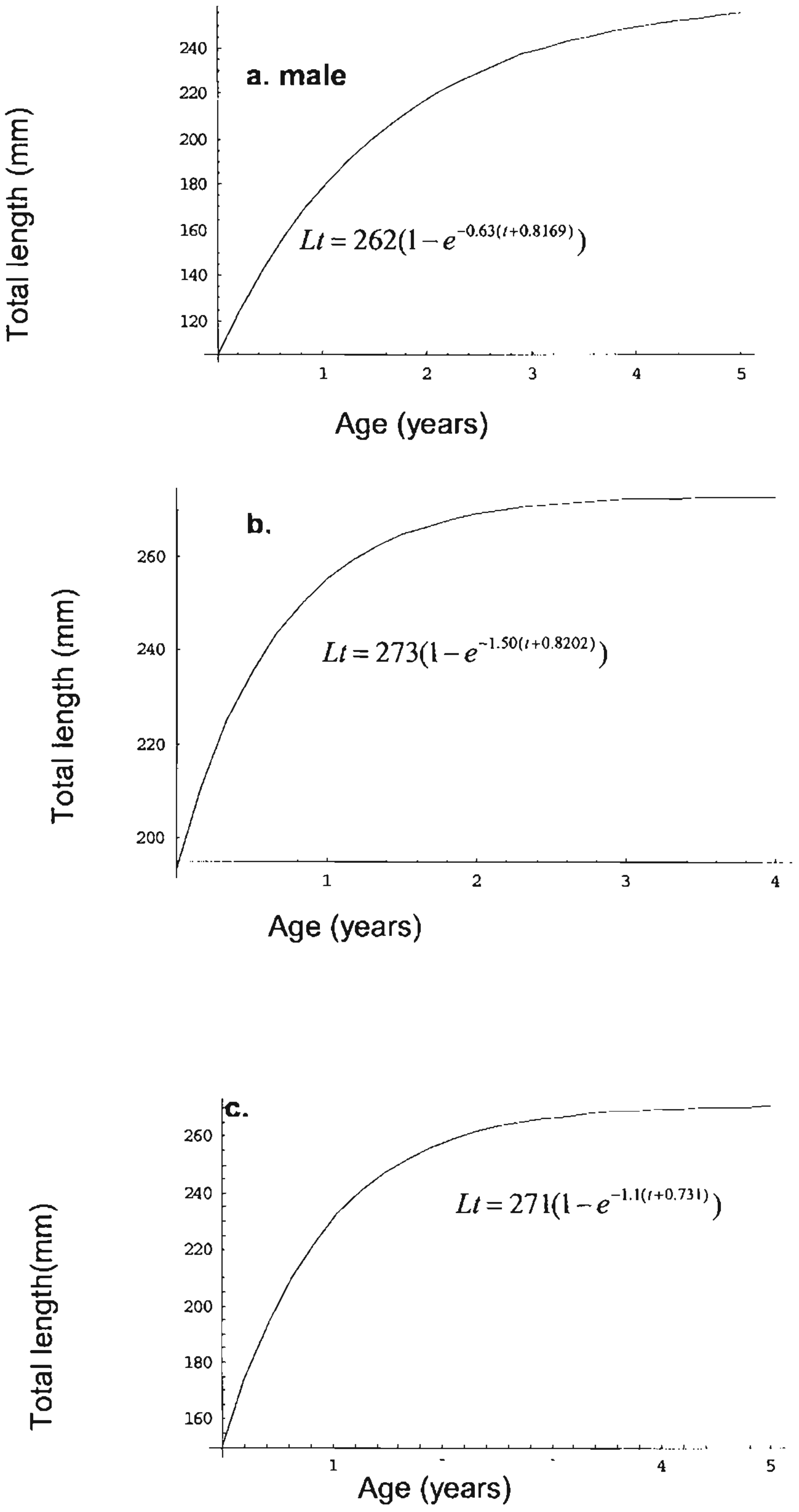


Figure 7.8

Von – Bertalanffy growth curve for *H. (H) xanthopterus*

Table – 7.1

The maximum length, growth parameters and growth performance index (ϕ) arrived at in males, females and combined population of *H. (H) limbatus.*

Sex	L_{max} mm	$L\infty$ mm	K	t_0	ϕ	Rn values from ELEFAN 1
Males	197	224	0.97	-0.84	4.69	0.23
Females	239	251	0.72	-0.72	4.66	0.22
Both sexes	239	252	0.70	-0.71	4.65	0.18

Table 7.2

The maximum length, growth parameters and growth performance index (ϕ) arrived at in males females and combined population of *H (H) xanthopterus*

Sex	L_{max} mm	$L\infty$ mm	K	t_0	ϕ	Rn values from ELEFAN 1
Males	249	262	0.63	-0.82	4.64	0.24
Females	259	273	1.50	-0.82	5.05	0.21
Both sexes	259	271	1.10	-0.73	4.91	0.16

Table – 7.3

The estimated lengths of males, females and combined stock of *H. (H) limbatus* based on the growth parameters estimated

Length arrived at annually				
Sex	1 year mm	2 year mm	3 year mm	4 year mm
Males	186.45	209.59	218.31	221.61
Females	178.33	215.61	233.17	242.58
Both sexes	175.78	214.13	233.17	242.58

Table – 7.4

The estimated lengths of males, females and combined stock of *H. (H) xanthopterus* based on the growth parameters estimated

Length arrived at annually				
Sex	1 year mm	2 year mm	3 year mm	4 year mm
Males	178.59	217.58	238.58	249.39
Females	255.09	268.62	271.60	272.26
Both sexes	230.38	257.71	266.90	272.3

CHAPTER 8.

BIOCHEMICIAL COMPOSITION

8. BIOCHEMICAL COMPOSITION

8.1. Introduction

The geometrically increasing world population is in need of an important source of nutritive food. The easy accessibility, and high nutritive value of fishes substitute it as another source of protein enriched food for the populous world.

It is the content of proteins, fats, vitamins and minerals that makes fish the most valuable food. The presence of omega three poly unsaturated fatty acids in fishes is good for human heart and for lowering the blood cholesterol level. A knowledge of the biochemical composition of fish muscle is of great help in evaluating its nutritive value and estimating yields of products such as fish protein concentrate, fish meal and fish oil (Kingsten and Venkataramani, 1994). Most tropical fish contain, on an average, water 70 to 80 per cent, protein 14 to 22 per cent, lipids 0.5 to 20 per cent and minerals 0.1 to 5 per cent although extreme cases far exceeding these level are sometimes seen as in the case of Bombay duck (*Harpedon neharius)* whose water content is as high as 90 per cent. Lipids of tropical fish are relatively more saturated, compared to those of cold water species. Protein efficiency ratio of most Indian fishes are in the range three to four showing that they have a balanced amino acid make up (Gopakumar, 1997).

8.2. Review of Literature

It was Drummond (1918) who first studied the nutritive quality of fish protein. Beveridge (1947) carried out experiments by comparing fish protein with that of livestock origin. He concluded that fish protein was better than beef or egg protein. Stansby and Olcott (1963) stated that out of the 19 amino acids occurring in fish, 10 are supposed to be essential to man. Elaborate work on the nutritive value of fishes was carried out by Heart *et al.*(1940) regarding the proximate composition of herring in British Columbia. Idler and Binters (1960) studied the biochemical composition of sockeye salmon during spawning migration. Water content of cod muscle was estimated by Love (1960). Thurston (1961) estimated the proximate composition of nine species of rock fishes.

Goodyear and Boyd (1972) analysed the elemental composition of large mouth bass. Nimmi (1974) investigated the relationship between the ash content and body weight in lamprey, trout and large mouth bass. Studies on fat and moisture composition of some Canadian fishes by Eaton *et al.*(1975) and seasonal changes in fat content of yellow perch by Newsome and Leduc (1975) are some of the important works in this field.

The seasonal changes in protein, lipid and energy content of carcasses, ovaries and liver of adult plaice *Pleuronectus platessa* were reported by Dawson and Gremm (1980). Proximate composition of various stages of adult life of lamprey was studied by Bird and Potter (1983). Proximate composition of certain Red Sea fishes were estimated by Hanna (1984) and river lamprey by Heikkala *et al.* (1984). Seasonal variation in fat content and fatty acid composition of *Coregonid bondella* was reported by Luzzana *et al.* (1996).

In India, works on the nutritive value of fishes are comparatively scarce. Saha (1940) made investigations on the value of the proteins of fishes of Bengal. Other reports on the nutritive value of fishes are that of Setna *et al.*(1944) on some marine fishes off Bombay and Chari (1948) on some fishes off Madras coast. Chidambaram *et al.*(1952) studied the fat variations in Mackeral. Venkataraman and Chari (1953) correlated the fat variations of Mackeral and plankton on which they feed. Notable works on the chemical composition of freshwater fishes are those of Natarajan and Sreenivasan (1961) on thirty five species of freshwater fishes, Jafri *et al.*(1964) and Khawaja (1966) on various species of freshwater fishes. Gopakumar (1965) published an account of the seasonal variations in lipid of oil sardine.

Some other noteworthy studies in this field are that of Radhakrishnan *et al.*(1972), Jafri (1974), Kutty *et al.*(1976), Mukundan and James (1978) and Mukundan *et al.* (1979). Some of the other recent reports of concern are those of Mukundan *et al.* (1981), Afsar (1982), Bhagawati and Ratha (1982), Mukundan *et al.* (1982), Keshava and Sen (1983) and Vijayakumar (1987). Some recent works are those of Kingston and Venkataramani (1994) on the biochemical composition of yellow stripe scad, *Selaroides leptolepis*, Antony and Antony (2001) on the biochemical composition of *Lucifer hanseni* from Cochin estuary, Kosygin *et al.*(2001) on the proximate composition of commercially important hill stream fishes of Manipur and Sankar and Ramachandran (2001) on changes in biochemical composition in Indian major carps in relation to size.

Despite the extensive information available regarding the chemical composition and nutritive values of many estuarine and marine fishes, the studies regarding the biochemical composition of hemiramphid fishery are very meagre. Hence the present investigation was undertaken to study the biochemical constituents like water content, lipid, total protein, carbohydrates, and minerals in different body tissues like muscle and liver in relation to annual breeding cycle of *H. (H) limbatus and H.(H) xanthopterus* for better understanding of their nutritive value, their dietary significance and for the standardization of proper processing methods by the fishing industry.

8.3. Materials and Methods

Monthly samples of fishes were collected from different fish landing centres, markets of Cochin coast and some fishing grounds in Vembanad Lake like Eloor, Varapuzha, Mulavukadu, Arookutty, South Parur and Murinjapuzha. The locations of collection are shown in the map (Fig. 1.1). The fishes were immediately brought to the laboratory where they were cleaned and samples of muscle and liver were taken for the study. Care was taken to ensure that the muscle was free of bones. The wet samples were weighed and dried in an oven at 100-105°C till a constant weight was attained. The dried tissue was then ground well to make it into powder and stored in a desicator for further analysis. Moisture, protein, fat and ash were determined according to the methods of AOAC (1990).

Moisture was estimated by the hot air oven method. Protein was analysed by Microkjeldhal method and the total value was obtained by multiplying the value of nitrogen by Kirks conversion coefficient 6.25 (Hawk, 1954). Fat content of moisture free sample was determined by extracting the fat with diethyl ether using a Soxhlet apparatus. Ashing was carried out in a muffle furnace at 500 ± 5°C. The results were obtained on dry weight basis (DWB) for all components except for moisture and later converted to wet weight basis (WWB) and expressed.

8.4. Results

8.4.1. Moisture level

The moisture level of muscle tissue of *H. (H) limbatus* varied from 76.25% (g/100g wet fish) in August to 79.78% (g/100g wet fish) in April and 79.68% (g/100g wet fish) in November (Table 8.1). The liver tissue had a lesser amount of moisture when compared to muscle and it was between 70.55% (g/100g wet fish) in August and 75.18% (g/100g wet fish) in April and 75.21% (g/100g wet fish) in November (Table 8.2).

The moisture level of In *H. (H) xanthopterus* ranged between 73.2% and 77.90% (g/100g wet fish) in the muscle tissue (Table 8.3). The lowest moisture level was noticed in January and the highest in July. The liver tissue of *H. (H) xanthopterus* registered a lower level of moisture than the muscle tissue ranging from 68.36% in January to 74.10% (g/100g wet fish) in July (Table 8.4). The highest levels of moisture mentioned above coincided with the spawning months, April and November in *H. (H) limbatus* and June and July in *H. (H) xanthopterus* (Fig 8.1). Error bar chart revealed that the moisture percentage is high in the muscles and liver of *H. (H) limbatus* compared to that of *H. (H) xanthopterus.* (Fig. 8.2)

8.4.2. Protein level

In *H. (H) limbatus* the protein values varied between 15.35% (g/100g wet fish) in April and 18% (g/100g wet fish) in August (Table 8.1). In November it was 15.46 % (g/100g wet fish). The liver tissue of *H. (H) limbatus* contained a lesser level of protein than the muscle tissue. The highest level of protein in liver tissue was recorded in August (15.7% g/100g wet fish) and the lowest in April and November (12.83% and 12.80% g/100g wet fish) (Table 8.2). The protein level expressed an irregular trend with considerable monthly fluctuations.

Protein values were rather higher in the muscles tissue of *H. (H) xanthopterus.* Though the protein values varied monthly, it never reached above 19.4% (g/100g wet fish) and below 16.55% (g/100g wet fish) (Table

8.3). Higher amount of protein in muscle tissue was in February and the lowest in July. In all other months, the fluctuation was negligible. As in the case of *H. (H) limbatus* the protein level in the liver tissue of *H. (H) xanthopterus* was lower than in the muscle tissue. The highest value of 15.10% (g/100g wet fish) was recorded in December and the lowest value of 13.45% (g/100g wet fish) was recorded in July (Table 8.4). The monthly fluctuations were slightly irregular. The lowest levels of protein values were noticed in both the species during their peak-breeding season, April and November in *H. (H) limbatus* and June and July in *H. (H) xanthopterus.* (Fig. 8.3). Error bar chart showed that protein values were higher in the muscles and liver of *H. (H) xanthopterus* compared to that of *H. (H) limbatus*. (Fig. 8.4).

8.4.3. Fat level

The fat values of muscle tissue of *H. (H) limbatus* varied from 3.45% to 4.31% (g/100g wet fish) the lowest values were noticed in November and April and the highest in June (Table 8.1). The fat level in the liver tissue of *H. (H) limbatus* was high and it varied from 8.64% in April and 8.62% (g/100g wet fish) in November to 9.62 % (g/100g wet fish) in June (Table 8.2). In all other months the fat level of muscle and liver tissue exhibited slight fluctuations.

In the muscle tissue of *H. (H) xanthopterus* the fat level was higher than the carbohydrate level and it varied from 4.1% (g/100g wet fish) in July and 5.60% (g/100g wet fish) in January (Table 8.3). The liver tissue of H. *(H)* *xanthopterus* contained a higher level of lipid than the muscle tissue (Table 8.4). The highest level of fat was recorded in January and December (11.65% g/100g wet fish) and the lowest in July (8.7% g/100g wet fish) which was considered as their breeding period (Fig. 8.5). The percentage of fat in the muscles and liver tissues of *H.(H) xanthopterus* was higher than that of *H.(H) limbatus* as noticed from the error bar chart (Fig. 8.6)

8.4.4. Carbohydrate level

Carbohydrate level of the muscle tissue of *H. (H) limbatus* was found to be very low. It varied from 0.32% to 0.45% (g/100g wet fish) in November and January respectively (Table 8.1). In April also it was very low, 0.34% (g/100g wet fish). The liver tissue of H. *(H) limbatus* registered a higher level of carbohydrate than the muscle tissue. The level varied between 2.80% (g/100g wet fish) in April, 2.82% (g/100g wet fish) in November and 3.85% (g/100g wet fish) in February. (Table 8.2). Monthly fluctuations of carbohydrate value in the other months were negligible.

The level of carbohydrate present in the muscle tissue of *H.(H) xanthopterus* was low. It showed a range of 0.30% to 0.47% (g/100g wet fish) (Table 8.3). The months of July and January recorded the lowest and the highest levels respectively. The results of the analysis of carbohydrate in the liver tissue of *H. (H) xanthopterus* varied from 3.30% (g/100g wet fish) in July to 4.80% (g/100g wet fish) in February (Table 8.4). The values were considerably higher than that of the muscle tissue of the same fish. The low levels of carbohydrate noticed in the liver tissues coincided with their reproductive period. (Fig. 8.7). The carbo hydrate content in the muscle tissue of *H. (H) limbatus* and *H. (H) xanthopterus* was more or less same, whereas it was higher in the liver tissue of *H.(H) xanthopterus* as shown in the error bar chart (Fig. 8.8).

8.4.5. Ash level

Ash content of muscle tissue of *H. (H) limbatus* ranged between 1.07% and 1.41% (g/100g wet fish) The lowest value was noticed in April and November and the highest value in September (Table 8.1). In the case of liver tissue the range was between 0.55% and 0.75% (g/100g wet fish) in April and November respectively. (Table 8.2)

As in the case of *H. (H) limbatus*, the ash level in the muscle tissue of *H. (H) xanthopterus* was lower and recorded to be 1.15% to 1.80%. (g/100g wet fish). The lower value was noticed in July and the higher value in December (Table 8.3). The liver tissue of *H. (H) xanthopterus* contained a very low percentage of minerals, which varied from 0.41% (g/100g wet fish) in June and 0.75% (g/100g wet fish) in March (Table 8.4). The level of ash content in the muscle and liver tissue of both *H.(H) limbatus* and *H.(H) xanthopterus* was represented in Fig. 8.9. The error bar chart showed that the mineral content was higher in the muscle tissue of *H. (H) xanthopterus* when compared to *H.(H) limbatus* whereas that was higher in the liver tissue of *H. (H) limbatus* when compared to *H.(H) xanthopterus* (Fig. 8.10).

Comparison of the biochemical composition of muscle and liver tissues of *H. (H) limbatus* and *H. (H) xanthoptreus* for moisture protein, fat, carbohydrate and ash were shown in Table 8.5 and 8.6. It was clear that there was significant difference at 5% level between the biochemical composition of muscle tissue of *H.(H) limbatus* and *H.(H) xanthopterus* for moisture, protein, fat and ash whereas no significant difference at 5% level was noticed between carbohydrate. Also it was noted that there was significant difference between the biochemical composition of the liver tissue of *H. (H) limbatus* and *H. (H) xanthopterus* for moisture , protein, fat and carbohydrate whereas no significant difference was noticed between ash.

8.5. Discussion

H. (H) limbatus and *H. (H) xanthopterus* are continuous breeders with peak breeding season during April - May and November-December for *H. (H) limbatus* and July – August for *H. (H) xanthopterus* (Refer maturation and spawning chapter for details).

8.5.1. Moisture

The moisture content of *H.(H) limbatus* muscles tissue was 76.25% to 79.78% (g/100g wet fish) and liver tissue was 70.55% to 75.18% (g/100g wet fish). In H.*(H) xanthopterus* it was 73.20% to 77.9% (g/100g wet fish) in muscle tissue and 68.36% to 72.60% (g/100g wet fish) in liver tissue. The highest moisture values were noticed during their peak spawning periods.

Dambergs (1964) reported a similar increase in water level of the muscle tissue during maturation. This again confirmed with the findings of Eaton *et al.* (1975) in Canadian capelin, and Kutty *et al.* (1976) in some Indian fishes.

Gopakumar (1997) reported that the water content of fish may vary between 65.00% and 80.00 % (g/100g wet fish). But there are exceptions such as Bombay duck (*Harpodon nehereus)* which contains about 90% moisture and the species of *Hippoglossides platissoides* which has a higher moistures content of about 96% during starvation. In each species of fish the water content is highly variable due to growth, maturity, spawning, feeding and starvation. The water content has an important role in deciding the shelf life and texture of food material. The higher the water content the higher is the chance of spoilage and vice versa.

The proximate analysis of hemiramphids reveal a definite reciprocal relationship between moisture and fat content, which was more predominant in liver tissue than in muscle tissue since the liver tissue contained more fat than the muscle tissue. Similar results were reported by Bruce, as early as in 1924 in herring and as late as in 1986, by Mukundan *et al.* in some fresh water fishes. A similar inverse relationship was recorded earlier by some workers like Natarajan and Sreenivasan (1961), Gopakumar (1965), Rao (1967), Jafri (1968), Love (1970) and Vijayakumar (1987). Jafri (1974) reported that this fat-water inverse relationship was constant under different conditions associated with seasonal cycles.

8.5.2. Protein

In the present study the level of protein was 15.25% -18% (g/100g wet fish) in muscles tissue and 12.50%-15.7%(g/100g wet fish) in liver tissue of *H. (H) and limbatus* and 16.45% and 19.4% (g/100g wet fish) in muscle tissue and 13.45%-14.53% (g/100g wet fish) in the liver tissue of *H. (H) xanthopterus*. Monthly fluctuations of protein in the muscle tissue of both species were low throughout the year. Nutritionally proteins were the most important organic constituent of fish muscles accounting for 15 -20% (g/100g wet fish) However, variations can occur due to various reasons such as water temperature, availability of food, spawning and starvation (Gopakumar,1997).

Perusal of the Table 8.1 – 8.4 reveals that protein content of muscles shows constant low values during the month of April and November in *H. (H) limbatus* and in July in *H. (H) xanthopterus* which are the peak breeding periods of these fishes. This low level of protein may probably be due to its active utilization by the ovaries during the process of vitellogenesis going on in the ovaries. Support for this may be drawn from the observations of Love (1970) who stated that the building up of gonads is always accomplished at the expense of body proteins. Similar results have been reported by John and Shahul (1995) who also observed a gradual decline in alkali soluble muscle protein in *Nemipterus japonicas* during spawning season.

In all other months muscle and liver protein is high in both *H. (H) limbatus and H. (H) xanthopterus.* Jafri (1968) recorded a similar increase in protein content of muscle with maturation of gonads, which according to him was the result of active feeding during this phase. Shreni (1980) contrarily stated that the protein cycle in fishes is more synchronized with maturation rhythm of fishes than their feeding. Contrasting results have also been put forth by Dambergs (1964) who observed a decline in muscle protein on cod (*Gadus morhua)* during growth of gonads.

The protein and moisture contents in both the hemiramphid species are inversely related, like the fat / water relationship. Love (1962) opined that as protein is removed from the muscle, the water content rises steadily and so is a useful index of the state of depletion of the fish.

In both the fishes under present study, muscle tissue contained higher amount of protein, than liver tissue. In the liver tissue the protein content ranged between 12.5% to 15.7% (g/100g wet fish) in *H.(H) limbatus* and 13.45% to 15.10% (g/100g wet fish) in *H.(H) xanthopterus*. Dambergs (1964) made a similar observation in his studies on cod. Mukundan *et al.*(1982) registered a higher level of protein in white muscle of oil sardine. Rifaat and Hanna (1984) estimated protein content in Red Sea fishes and classified muscle into five fat-protein content categories. In all these previous investigations, it is suggested that the relative quantity of flesh is a decisive factor influencing the protein content of the fish. A plankton rich feed is reported to increase the protein content in fishes (Marinkovic and Zei, 1959). The two fishes investigated at present, which were omnivores recorded a higher protein level. Out of the two fishes *H.(H) xanthopterus* consume more algae than *H.(H) limbatus*. That may be the reason for high protein content of *H. (H) xanthopterus* than *H.(H) limbatus.*

Kleimenov (1971) reported the protein values of highly demanded table fishes. According to him Barracuda (21. 30%) Drenpane (18.2% - 18.4%), Caranx (19.8%), striped mullet (19.6%), Flounder (18.20%), Butterfish (19.50%), Swordfish (19.4%), Halibut (18.2%), Threadfin (18.3%), Indian mackeral (20.5%) and Lizardfish (194%) are highly nutritive due to their protein value. The results of the present analysis suggested that the two species studied can also be included in this group since their protein level (17.2%-22.5% g/100g wet fish) are similar to the above mentioned fishes.

8.5.3. Fat

In the present observation the fat content was 3.45% to 4.20% (g/100g wet fish) in the muscle tissue and 8.62% to 9.65% (g/100g wet fish) in the liver tissue of *H. (H) limbatus* and 4.1% to 5.60% (g/100g wet fish) in the muscle tissue and 8.70% to 11.65% (g/100g wet fish) in the liver tissue of *H.(H) xanthoptrus*. The lowest percentage of fat was recorded in April and November in the case of *H. (H) limbatus* and in July in the case *H. (H) xanthopterus*. These periods are the peak breeding season of both these fishes. These results probably indicate the importance of lipid reserves as major source of energy during gonadal maturation. Similar findings were observed in *Sardinella longiceps* (Gopakumar, 1965). Luzzana *et al.* (1996) in *Core*gonid *bondella* suggested that the mobilization of fatty acid precursor from muscle to gonads takes place during vitellogenesis. On the other hand, Wood (1958) in herrings observed augmented lipid level other than its loss during the period of gonad development, which they maintain because of its deposition in the body.

In both these hemiramphids the percentage of muscle and liver lipid start rising in all other months, possibly due to the accumulation of fats in body muscles and liver tissue due to active feeding. Many of the teleost fishes are known to build up large quantities of fat in their tissues during feeding season to be used as a readily available source of energy for period of food scarcity which is accounted as the reason for the fluctuations of fat content in different months of the year (Lovern and Wood, 1937 and Jafri, 1968). Love (1970) observed a marked increase in fat content of fish muscles with the growth during feeding season and a depletion during spawning season. Fat is usually considered as the largest biochemical fraction, second to protein and this fat content varies with season related to sexual cycle.

The muscle tissue of *H. (H) xanthopterus* contained more fat than the muscle tissue of *H. (H) limbatus*. The difference in the fat content may be due to their diet. *H. (H) limbatus* feed more on animal matter than *H. (H)* *xanthopterus* which feed more on algal matter, even though both of them are omnivores. That may be the reason for the lower values of fat in *H. (H) limbatus* and the higher values of fat in *H. (H) xanthopterus*. The variation in fat content in fishes based on their feeding habits was reported earlier by Venkataraman and Chari (1953). According to them, fishes feeding on plankton-rich feed contain more lipid. Sreenivasan and Natarajan (1961) while studying the chemical composition of some fishes of Bhavanisagar reservoir revealed that predatory and carnivorous fishes have a lower fat content than plankton feeding fishes. Venkataraman *et al.*(1968) suggested that the quantity of fat in fish is dependant on the nature of their diet.

The fat content increases towards the abdominal region and from interior towards exterior in the musculature. There is always a higher percentage of fat in the ventral side than the dorsal side. The storage of fat in this manner helps to reduce the 'drag' during swimming. During starvation or spawning, fat is easily depleted from the musculature or liver as the case may be. As far as the nutritional value of fish is concerned, fish with higher fat content have high calorific value. Generally most of the fish fall in the low-fat high-protein group. The fish oils, particularly the marine fish oils contain a special type of polyunsatururated fatty acid, which in human diet can relieve problems of blood pressure and thrombosis (Mathew, 1988).

8.5.4. Carbohydrate

This is a minor nutrient in most of the fish and its content varies between 0.1 to 0.5% (g/100g wet fish). Low carbohydrate values were recorded in the muscle tissue of both. *H. (H) limbatus* (0.32% to 0.45% (g/100g wet fish)) and *H. (H) xanthopterus* (0.3% to 0.47% g/100g wet fish) but higher values were present in the liver tissue of both the fishes, 2.1% to 3.84% (g/100g wet fish) in *H. (H) limbatus* and 3.1% to 4.8% (g/100g wet fish) in *H. (H) xanthopterus.* The carbohydrate level in muscle and liver show a constant low value during the breeding seasons. This decline possibly indicates its continuous use as energy source for different activities including gonad maturation. Somvanshi (1983) observed a decline in glycogen content in female *Garra mullya* muscles during the maturing stage. He also stressed its utilization as an energy source in addition to fat during ripening of gonads. Dawson and Gremm (1980) in female, *Pleuronectes platessa* and Shreni (1980) in *Heteropneustes fossilis* have independently observed a marked depletion of body lipid and glycogen during the gonadal development.

In all other months the carbohydrate content showed slight variation in both the species (Tables 8.1-8.4). The higher value of carbohydrate during this period can be attributed to favourable feeding season and seemingly lesser requirement of carbohydrate for gonads after spawning. The variation in the values of carbohydrate in the muscle and liver tissues of some fishes has been established by some earlier workers. According to Caulton and Bursel (1977), liver is the storage site of glycogen and the role of muscle in the storage of glycogen is very little. Based on the studies on three spined sticklebacks, Wotton *et al.* (1978) showed that the glycogen content of the carcass was negligible when compared to liver. This variation in carbohydrates has been proved by Vijayakumar (1987) in *Puntius filamentosis.* The fishes under the present study also show that the glycogen content is only a little in the body tissue. This situation is explained by Shul'man (1972) that glycogen is the main source of energy only in animals with low levels of energy metabolism and which reside in anaerobic conditions. In very active animals like fishes, this role is taken up by some other factors with a higher energy content and less solubility.

8.5.5. Ash

The ash content of fish varies from 0.5% – 2.0% (g/100g wet fish) and an inverse relationship has been observed between ash and water content, (Gopakumar, 1997) especially when the latter rises during depletion or starvation. In the present study the ash content of muscle tissue ranged between 1.07% to 1.41% (g/100g wet fish) in *H. (H) limbatus* and 1.15% to 1.80% (g/100g wet fish) in *H. (H) xanthopterus* and that of the liver tissue was between 0.55% to 0.75% (g/100g wet fish) in *H. (H) limbatus* and 0.41% to 0.75% (g/100g wet fish) in *H. (H) xanthopterus.* Nimmi (1974) remarked that a variation in ash content upto 1% of the body weight can occur based on feeding levels. There is no marked seasonal variation in the ash contents of muscle tissue and liver tissue of the two fishes.

The ash content gives an index of the total quantity of various inorganic elements in the body. The sodium and potassium content showed wide variations, but the mineral composition was seen to be relatively uniform, regardless of species, size, season or fishing ground (Thurston, 1961). In general, the larger fishes are more depleted than smaller ones, and a general demand for inorganic elements during early phase of growth seems valid (Khawaja and Jafri, 1967).

Besides minerals such as calcium, sodium and potassium, which normally form the major constituents of ash, the fish may also contain copper, iron, magnesium, etc, as minor constituents. Certain elements such as lead, cadmium, mercury, arsenic and selenium are some times found in traces and are toxic. Most of the heavy metals are cumulative in nature and their levels tend to increase with the size and age of fish (Mathew,1988).

8.5.6. Inter-relationship of constituents

Fish, which store fat in the musculature, show an inverse relationship between lipid content and water content, ie. when lipid content rises water content falls. However the average value of lipid and water together will be around 80% (g/100g wet fish), though slight variations in total percentage are often observed. In the case of fish, especially lean fish, a decrease in protein content is often associated with an increase in water content, though this is not as clearly marked as that of water lipid relationship.

8.5.7. Conclusion

In short, certain conclusions can be arrived at for better understanding of the nutritive value of hemiramphid fishes and their dietary significance. Both *H. (H) limbatus* and *H. (H) xanthopterus* are highly nutritious having high protein and fat content. The moisture and fat content showed an inverse relationship in all the tissues. In both fishes the muscles registered a higher level of protein than liver. Of the two fishes, *H. (H) xanthopterus* had an increased level of fat in their tissues than *H.(H) limbatus.* This difference was attributed to the difference in the diet. The levels of fat in the muscle and liver tissue *H. (H) limbatus* and *H. (H) xanthopterus* were low during the spawning period.

The carbohydrate level in the liver tissues was high when compared to muscle tissue in the two species of fishes. The carbohydrate level decreased during the spawning season. Ash content of the tissues was low in both the fishes. It was almost steady throughout the year, without much fluctuation. The fishes during the early stages of maturation seem to have high fat and protein content in the muscle. Such fishes are an excellent source of rich animal protein for man.

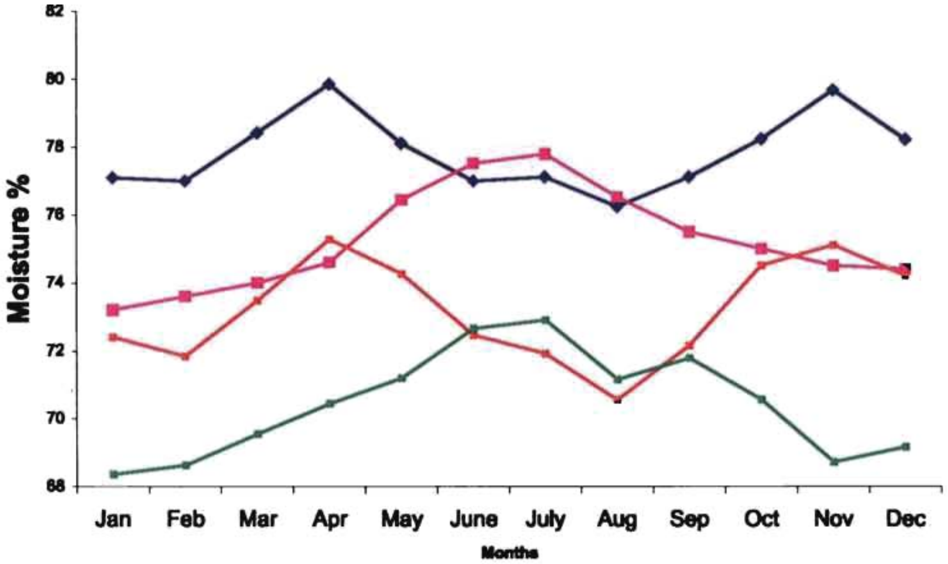


Fig. 8.1

Monthly moisture (% wet weight) content in muscle and liver tissues of *H. (H) limbatus* and *H. (H) xanthopterus*

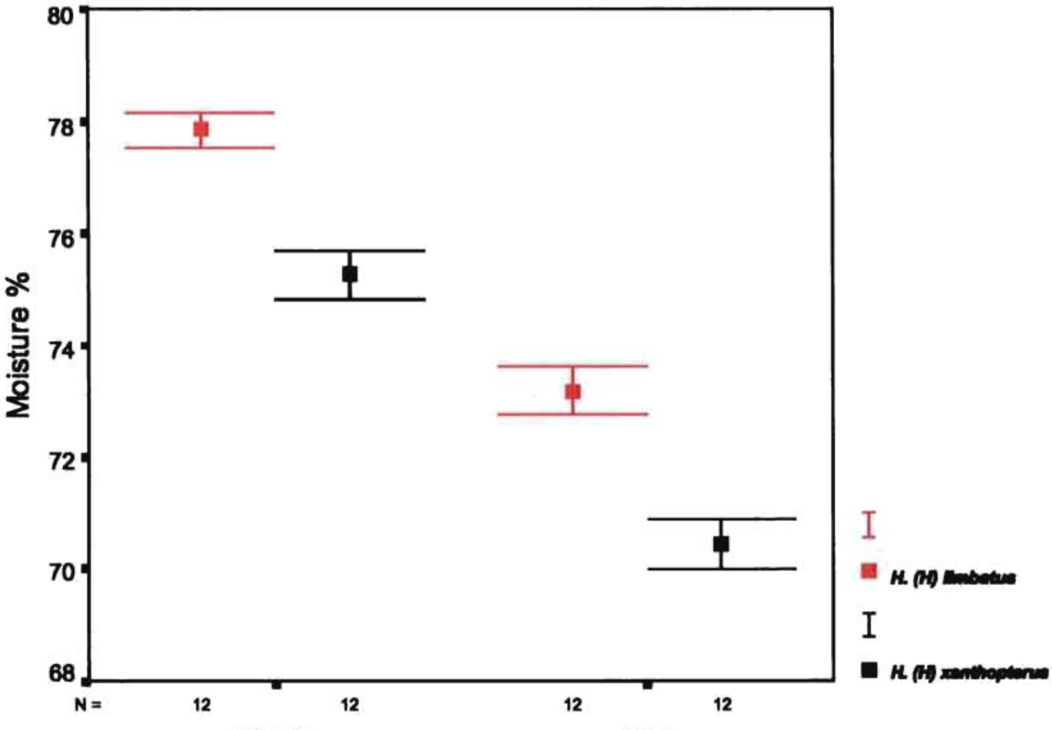


Fig. 8.2

Error bar chart of *H. (H) limbatus* and *H. (H) xanthopterus* showing moisture percentage (wet weight) in muscle and liver tissues

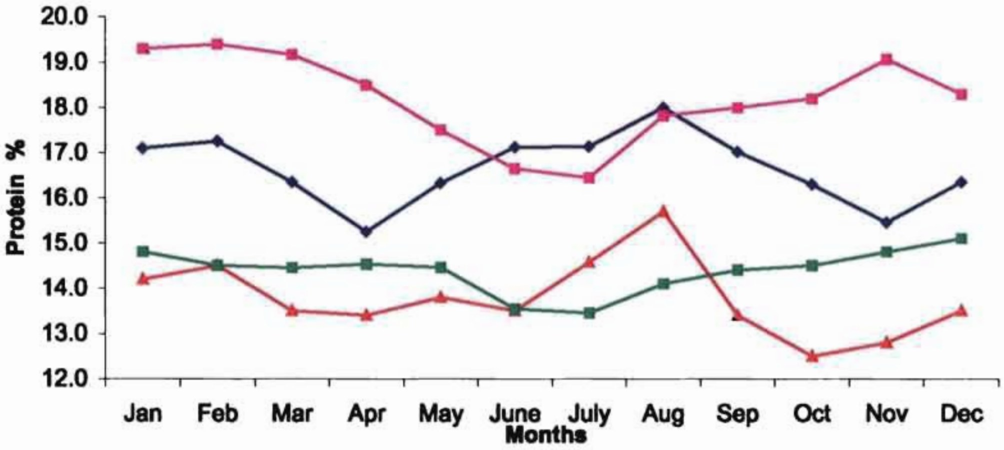


Fig. 8.3

Monthly protein (% wet weight) content in muscle and liver tissues of *H. (H) limbatus* and *H. (H) xanthopterus*

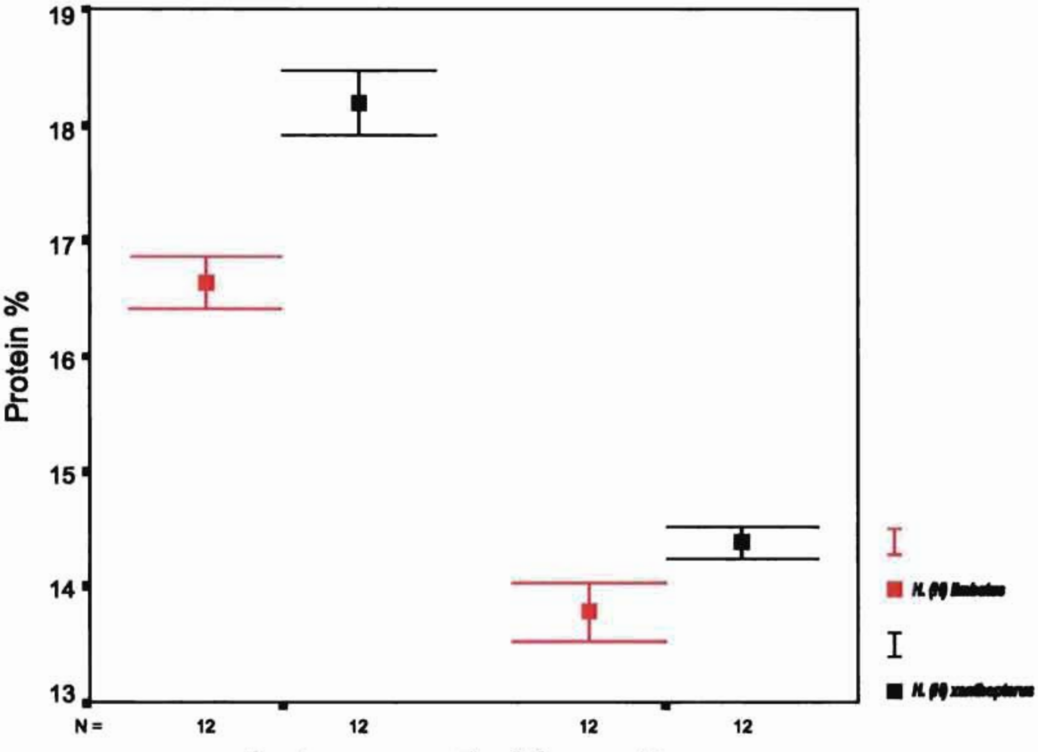


Fig. 8.4

Error bar chart of *H. (H) limbatus* and *H. (H) xanthopterus* showing protein percentage (wet weight) in muscle and liver tissues

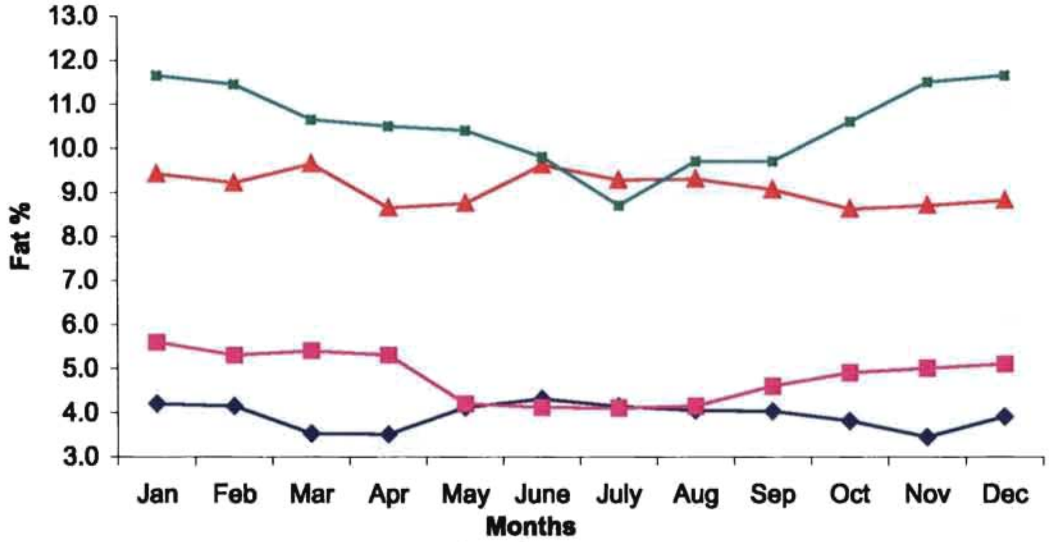


Fig. 8.5

Monthly fat (% wet weight) content in muscle and liver tissues of *H. (H) limbatus* and *H. (H) xanthopterus*

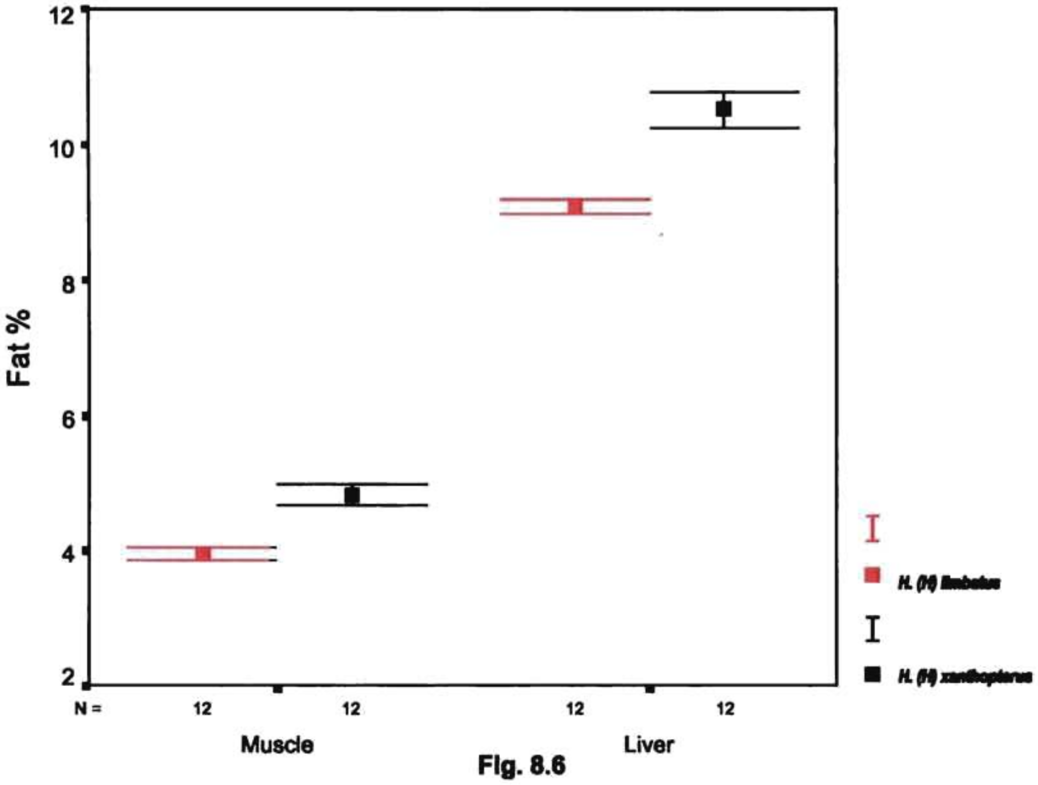


Fig. 8.6

Error bar chart of *H. (H) limbatus* and *H. (H) xanthopterus* showing fat percentage (wet weight) in muscle and liver tissues

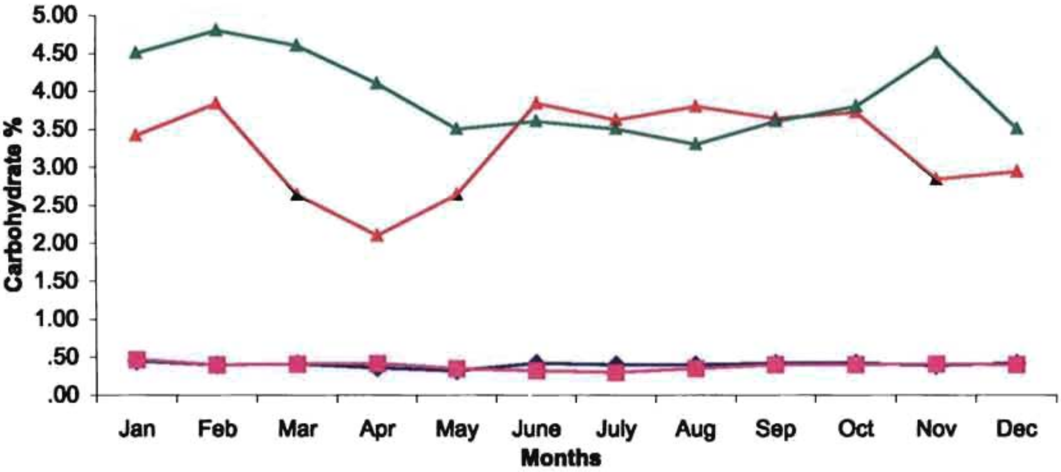


Fig. 8.7

Monthly carbo hydrate (% wet weight) content in muscle and liver tissues of *H. (H) limbatus* and *H. (H) xanthopterus*

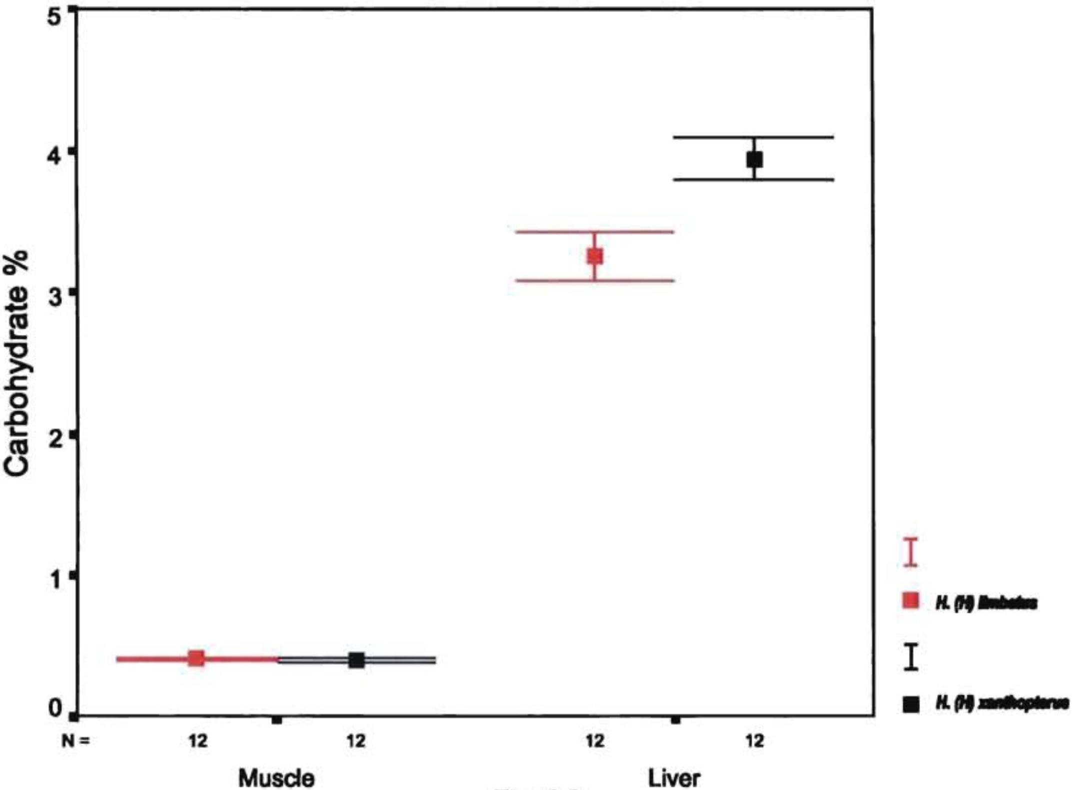


Fig. 8.8

Error bar chart of *H. (H) limbatus* and *H. (H) xanthopterus* showing carbohydrate percentage (wet weight) in muscle and liver tissues

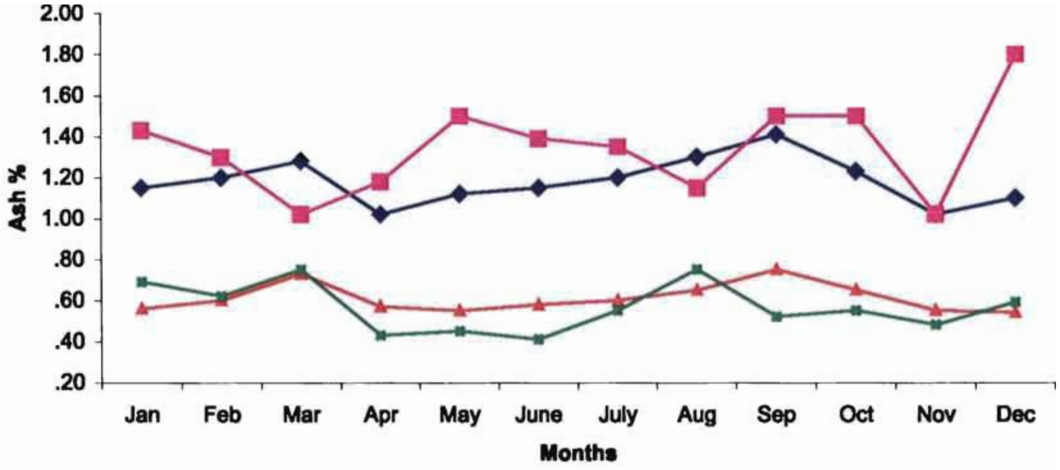


Fig. 8.9
Monhly ash (% wet weight) content in muscle and liver tissues of *H. (H) limbatus* and *H. (H) xanthopterus*

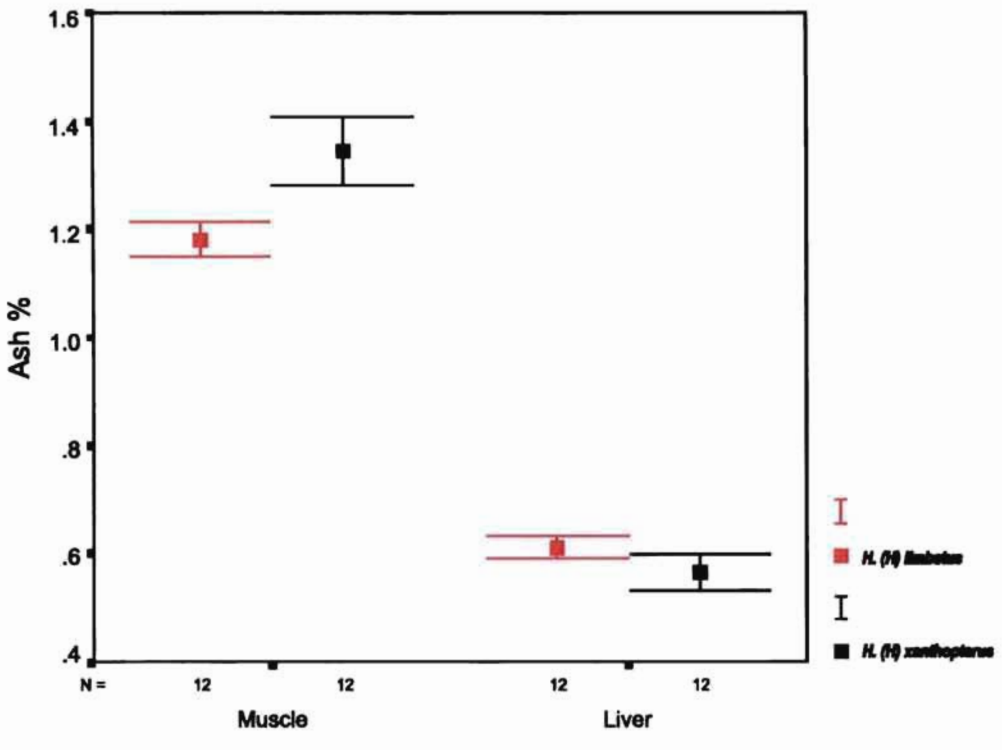


Fig. 8.10
Error bar chart of *H. (H) limbatus* and *H. (H) xanthopterus* showing ash percentage (wet weight) in muscle and liver tissues

Table 8.1

BIOCHEMICAL COMPOSITION OF MUSCLE TISSUE OF *H. (H) LIMBATUS*

Biochemical composition (g/100g wet fish),	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Moisture	77.10	77.00	78.43	79.78	78.04	77.00	77.12	76.25	77.12	78.24	79.68	78.22
Protein	17.10	17.25	16.35	15.35	16.33	17.12	17.14	18.00	17.02	16.30	15.46	16.35
Fat	4.20	4.15	3.53	3.46	4.12	4.31	4.14	4.05	4.03	3.81	3.45	3.91
Carbohydrate	0.45	0.40	0.41	0.34	0.39	0.42	0.40	0.40	0.42	0.42	0.32	0.42
Ash	1.15	1.20	1.28	1.07	1.12	1.15	1.20	1.30	1.41	1.23	1.09	1.10

Table 8.2

BIOCHEMICAL COMPOSITION OF LIVER TISSUE OF *H. (H) LIMBATUS*

Biochemical composition (g/100g wet fish),	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Moisture	72.4	71.85	73.48	75.18	74.26	72.46	71.92	70.55	72.15	73.53	75.21	74.20
Protein	14.20	14.50	13.50	12.83	13.80	13.50	14.58	15.70	13.40	13.40	12.80	13.50
Fat	9.42	9.22	9.65	8.64	8.75	9.62	9.28	9.30	9.06	8.70	8.62	8.82
Carbohydrate	3.42	3.85	2.64	2.80	2.64	3.84	3.62	3.80	3.64	3.72	2.82	2.94
Ash	0.56	0.60	0.73	0.55	0.55	0.58	0.60	0.65	0.75	0.65	0.55	0.54

Table 8.3

BIOCHEMICAL COMPOSITION OF MUSCLE TISSUE OF *H. (H) XANTHOPTERUS*

Biochemical composition (g/100g wet fish),	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Moisture	73.20	73.60	74.60	74.70	76.45	77.52	77.90	76.43	75.50	75.00	74.52	74.40
Protein	19.30	19.40	19.27	18.50	17.60	16.65	16.55	17.72	18.00	18.20	18.37	18.30
Fat	5.60	5.30	5.40	5.30	4.20	4.12	4.10	4.15	4.60	4.90	5.08	5.10
Carbohydrate	0.47	0.40	0.41	0.42	0.35	0.32	0.30	0.35	0.40	0.40	0.41	0.40
Ash	1.43	1.30	1.32	1.38	1.40	1.39	1.15	1.35	1.50	1.50	1.62	1.80

Table 8.4

BIOCHEMICAL COMPOSITION OF LIVER TISSUE OF *H. (H) XANTHOPTERUS*

Biochemical composition (g/100g wet fish),	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Moisture	68.36	68.63	69.55	70.34	71.14	72.65	74.10	72.21	71.78	70.55	68.72	69.16
Protein	14.80	14.50	14.45	14.53	14.46	13.54	13.45	14.10	14.40	14.50	14.80	15.10
Fat	11.65	11.45	10.65	10.50	10.40	9.80	8.70	9.70	9.70	10.60	11.5	11.65
Carbohydrate	4.50	4.80	4.60	4.10	3.50	3.60	3.30	3.50	3.60	3.80	4.50	3.50
Ash	0.69	0.62	0.75	0.53	0.50	0.41	0.45	0.49	0.52	0.55	0.48	0.59

Table 8.5
Comparison of Biochemical composition of muscle tissue (g/100g wet fish) of *H.(H) limbatus and H.(H) xanthopterus*

Biochemical composition (g/100g wet fish)	Fish	Mean	SE	t. Value	df	Significance
Moisture	*H.(H) limbatus*	77.84	0.32	-4.771	22	0.000*
	H. (H) xanthopterus	75.26	0.44			
Protein	*H.(H) limbatus*	16.64	0.23	-4.296	22	0.000*
	H. (H) xanthopterus	18.20	0.23			
Fat	*H.(H) limbatus*	3.93	0.08	-4.840	22	0.000*
	H. (H) xanthopterus	4.81	0.16			
Carbo hydrate	*H.(H) limbatus*	0.40	0.01	0.899	22	0.379
	H. (H) xanthopterus	0.39	0.01			
Ash	*H.(H) limbatus*	1.18	0.03	-.2.226	22	0.037*
	H. (H) xanthopterus	1.25	0.07			

* Significant at 5% level

Table 8.6
Comparison of Biochemical composition of liver tissue (g/100g wet fish) of *H.(H) limbatus and H.(H) xanthopterus*

Biochemical composition (g/100g wet fish)	Fish	Mean	SE	t. Value	df	Significance
Moisture	*H.(H) limbatus*	73.18	0.43	-4.414	22	0.000*
	H. (H) xanthopterus	70.42	0.45			
Protein	*H.(H) limbatus*	13.78	0.25	-2.119	22	0.046*
	H. (H) xanthopterus	14.39	0.14			
Fat	*H.(H) limbatus*	9.09	0.11	-4.935	22	0.000*
	H. (H) xanthopterus	10.53	0.27			
Carbo hydrate	*H.(H) limbatus*	3.25	0.17	-0.003	22	0.007*
	H. (H) xanthopterus	3.94	0.15			
Ash	*H.(H) limbatus*	0.61	0.02	1.135	22	0.268
	H. (H) xanthopterus	0.57	0.03			

* Significant at 5% level

CHAPTER 9.

SUMMARY

9. SUMMARY

The Cochin coast and the adjacent back water system of Kerala has a rich and diversified fish fauna. The hemiramphid fishes constitute a minor fishery of this area. The occurrence of seven species of hemiramphid fishes was noticed during 2001 May to 2003 April. They are *Z. dispar, H. archipelagicus, H. lutkei, H. (H) limbatus, H. (H) xanthopterus, R. malabaricus and R. georgii.* The study on the distribution and availability of hemiramphid fishes present in the Cochin coast shows that they evince different patterns of distribution. The occurrence of *Z. dispar* was noticed only sporadically from the stations near the estuarine mouth of Cochin. It is predominantly a marine species which migrates accidentally into the backwaters during November and December. *H. archipelagicus* and *H. lutkei* are strictly marine and migrate to backwaters during November and December, when the temperature and salinity are high. *H. (H) limbatus* and *H. (H) xanthopterus* are estuarine species and found in Cochin backwaters throughout the year. *R. malabaricus* and *R. georgii* are marine and migrate to backwaters from January to May.

Analysis of the gut contents of the juveniles and adults of *H.(H) limbatus* and *H.(H) xanthopterus* showed that these species are surface feeding omnivores. They feed on filamentous algae, diatoms, prawns and other crustaceans, insects, polychaetes, and vegetable matter. The lower jaw projects into a beak often a third of the length of the fish itself, with the mouth opening above it in both species. It is evident from the various items of food found in the stomach of the fish that these species are selective surface or sub-surface feeders feeding on pelagic plant and animal matter including prawns and algae which form the bulk of the food, although a great variety of other organisms are available within the habitat of the fish. The major difference in food habits between the two species is that *H. (H) limbatus* consumed prawn in large quantites along with algae and other animal and vegetable matter whereas *H.(H) xanthopterus* feed mainly on algae, especially *Spirogyra* sp. in plenty besides prawns, diatoms and other animal and vegetable matter. In *H. (H) limbatus* 'gorged' stomachs were not observed in April, November and December whereas in *H. (H) xanthopterus* 'gorged' stomachs were not observed in July. These months are reported to be the breeding period for the fish. The increased demand of the maturing gonads for space may be the probable reason to reason for the absence of 'gorged' stomach. But active feeding was observed since 'full' stomachs were present. In general feeding was moderate and fishes with empty stomachs were absent. The percentage occurrence of 'gorged' and 'full' stomachs was less in *H. (H) limbatus* compared to *H. (H) xanthopterus*. In the present study diurnal variation in feeding is noticed in both *H. (H) limbatus* and *H. (H) xanthopterus.* Decreased rate of feeding was noticed during night in both the species. Seasonal variation in the feeding habit of *H. (H) limbatus and* H. *(H) xanthopterus* was studied. During premonsoon periods, diatoms dominated in the food and during monsoon season filamentous algae dominated whereas during post-monsoon season both diatoms and filamentous algae were observed. Prawns were present in the diet throughout the year. Seasonal variation in feeding was observed in *H. (H) limbatus* and *H. (H) xanthopterus* during spawning season. The main diet of maturing *H.(H) limbatus* and *H.(H) xanthopterus* was algae and that of spawners were prawns and that of spent fishes consisted of algae, prawns, other crustaceans remains and insect parts. Both the species seem to be highly selective in their feeding habit with preference for vegetable matter at the time when the gonads are ripening and for prawns during the spawning period and for vegetable and animal matter during spent stages. It is interesting to note that there was no evidence of a cessation of feeding during spawning in both *H.(H) limbatus and H.(H) xanthopterus.* In both the species not a single fish with a completely 'empty' gut was encountered during the whole period of study. In *H. (H) limbatus* and *H. (H) xanthopterus* the relative length of gut (RLG) was found to be ranging from 0.4 to 0.6 and 0.5 to 0.8 respectively. Eventhough the RLG values were low in both the species they were considered as omnivores because both plant and animal matter were found in their guts. The gastro-somatic index (GSI) differed in both the species every month. In *H. (H) limbatus* from February onward there was a gradual decline in the gastro somatic index till May and another decline from October to December. This may be due to the decline in the feeding intensity, in the peak spawning period whereas during February and July gastro somatic index was high which could be due to active feeding. In *H.(H) xanthopterus* the lowest values of gastro somatic index from June to August coincided with peak spawning period. A subsequent increase in the value of gastro somatic index in

October and December may be due to active feeding after peak spawning in July. It can be concluded that *H.(H) limbatus and H. (H) xanthopterus* are omnivores consuming a wide range of food materials. The feeding decreased during night time and during the spawning season. No significant difference in the composition of the diet of the two sexes has been observed. *H.(H) limbatus* and *H.(H) xanthopterus* are two co-existing species. The diet is almost identical both qualitatively and quantitatively.

Maturation and spawning of *H.(H) limbatus* and *H.(H) xanthopterus* were studied from May 2001 to April 2003. Altogether seven stages were identified for females, based on external appearance, extent of gonads in relation to length of body cavity, modal size of ova and their appearance under microscope and four stages for males. Ova diameter studies in *H. (H) limbatus* and *H.(H) xanthopterus* showed multiplicity of modes of ova in the maturing ovary. In both the species the mature ovaries were characterized by the presence of spherical and transparent eggs surface of which are covered with filaments. The size of ripe ovum ready for release from *H.(H) limbatus* measured 53 micrometer division (1.537 mm) and from *H.(H) xanthopterus measured* 55 micrometer division (1.595 mm). In the present study it was noted that the filaments present on the surface of the eggs are useful in attaching to the weeds after release into the external environment. The occurrence of fully ripe ovaries (stage V and VI) from January to December was noticed in both the species with peak spawning activity during April and November for *H.(H) limbatus* and June to August for *H.(H)* *xanthopterus*. In the ovary of these hemiramphids there is a residue of tiny ova which are angular and quite transparent with visible nuclei throughout the year. The length at first maturity was 125mm (TL) in males and 145 mm in females of *H.(H) limbatus* and 135mm(TL) in males and 155mm (TL) in females of *H. (H) xanthopterus*. The high gonado somatic index values of both the species coincide with their peak spawning periods. Seasonal fluctuations in condition factor coincide with their spawning period in both the species. The 'K' values rise at the time of peak spawning season of these two species. The absolute fecundity varied from 390 to 2412 in fishes ranging from 147 to 224 mm total length (TL), 10.25 to 30.55g body weight, 41 to 71mm ovary length and 0.58 to 3.06g ovary weight in *H.(H) limbatus*. The absolute fecundity varied from 587 to 1554 ova in fishes ranging from 165 to 245mm total length (TL), 12.10 to 45.01g body weight, 47 to 79mm ovary length and 0.62 to2.48g ovary weight in *H.(H) xanthopterus*. In both *H.(H) limbatus* and *H.(H) xanthopterus* the fecundity increased linearly as a function of fish length, fish weight and ovary weight. In the present study it is noticed that fecundity has high correlation with weight than length of the fish. It is significant to note that among various parameters studied, fecundity is highly related to ovary weight because the weight of ovaries of fish is mainly influenced by the ova contained in them. The sex ratio of *H.(H) limbatus* and *H.(H) xanthopterus* showed predominance of females. The overall dominance of females could be taken as a general feature of the stock. Test of variance of homogeneity of sex ratio showed χ_1^2 values significant at 1% level in all the years. In the present observations, though there is an overall dominance of females in the population of *H.(H) limbatus* and *H.(H) xanthopterus,* predominance of males was noticed in the early stages of life.

Histological studies revealed that the spermatogenesis in both *H.(H) limbatus and H.(H) xanthopterus,* consists of spermatogonia, primary spermatocytes secondary, spermatocytes, spermatids and spermatozoa whereas in the oogenesis of both the species, the following structures were observed. Oogonia and chromatin nucleolus oocytes are present in the germinal ridge of the ovarian luminal epithelium. Early and late perinucleolar stages with balbiani vilelline body are present in both species. The ooplasm is homogeneous and highly basophilic. In the cortical alveoli stage of *H.(H) limbatus*, cortical alveoli and lipid droplets are not as pronounced as in *H.(H) xanthopterus.* In *H.(H) limbatus* they are slightly basophilic whereas in *H.(H) xanthopterus* they are eosinophilic. The zona radiata of *H.(H) limbatus* are thicker and has spherical cells compared to *H.(H) xanthopterus* where these cells are more or less rectangular. The yolk globules of *H.(H) limbatus* are eosinophilic compared to *H.(H) xanthopterus* in which they are basophilic. In the ovaries of both *H.(H) limbatus* and *H.(H) xanthopterus* oocytes at different stages of development are observed. This supports the findings that these species are continuous breeders. Postovulatory follicles are observed in both the species. The eggs of *H.(H) limbatus* are slightly eosinophiic whereas that of *H.(H) xanthopterus* are basophilic. In both species eggs are covered with filaments, which is a characteristic feature of hemiramphid eggs.

Length-weight and relative condition factor studies revealed that significant differences could be found while comparing the regression co-efficient of males and females of *H.(H) limbatus H. (H) xanthopterus* and so separate equations were computed to describe the length-weight relationship of males and females of both species. . The 'b' values obtained for males and females of *H.(H) limbatus* and indeterminates of *H. (H) xanthopterus* showed significant variation from the isometric value of '3' whereas the males and females of *H.(H) xanthopterus* and indeterminates of *H.(H) limbatus* did not show significant variation from the cube law. In *H. (H) limbatus* the relative condition factor values were highest during April and November and that of *H.(H) xanthopterus* were during June and July. These months were considered as the spawning period of these fishes. High Kn values noticed in the younger length group fishes of *H.(H) limbatus* and *H.(H). xanthopterus* can be attributed to the high feeding intensity of the young growing fish. The 'Kn' values of males and females of *H.(H) limbatus* and *H.(H) xanthopterus* were around or above one in most of the months, which indicated that these fishes showed good condition throughout the year.

Age and growth of *H.(H) limbatus* and *H.(H) xanthopterus* were determined by resorting to length frequency studies. In the present study, it was found that the growth parameters obtained for males and females of both species showed variations. The $L\infty$ is higher in females than in males of both *H.(H) limbatus* and *H.(H) xanthopterus. H.(H) xanthopterus* (K= 1.1) grows at a faster rate than *H.(H) limbatus* (K 0.70). The result of the present study revealed that, *H. (H) limbatus* grows to about 175.78mm during first year, 214.13mm during second year, 233.18mm during third year and 242.58 mm during the fourth year. Its L_{max} was found to be 239mm. On the contrary in *H.(H) xanthopterus* the length attained at the end of first, second ,third and fourth years were found to be 230.38, 257.71, 266.90 and 272.3mm respectively while the maximum length recorded was to be (L_{max}) 259mm. In *H.(H) limbatus* male, L_{max} was 197mm which is attained by the second year and that of female was 239mm attained by the third year whereas in *H. (H) xanthopterus male* the L_{max} was 249mm which is attained by fourth year and that of female was 259mm which is attained by the second year. The life span assessed for *H.(H) limbatus* and *H.(H) xanthopterus* falls between 2 and 4 years, which concur with shallow water fish species. Size at first maturity was estimated to be 125mm (TL) for male and 145mm (TL) for female of *H.(H) limbatus* and 135mm (TL) and 155mm (TL) respectively for males and females of *H.(H) xanthopterus.* The present results reveal that prematurity growth phase in *H.(H) limbatus* and *H.(H) xanthopterus* are very fast. In both species the females were more robust compared to their male counterparts. The rapid growth rate and early maturation were characteresitic features of *H.(H) limbatus* and *H. (H) xanthopterus.*

Proximate composition of muscle and liver tissues of both *H.(H) limbatus* and *H.(H). xanthopterus* was analysed. The moisture content of *H.(H) limbatus* muscle tissue and liver tissue was high compared to that of H.*(H) xanthopterus.* The highest moisture values were noticed during their peak spawning periods. The proximate analysis of hemiramphids reveal a definite reciprocal relationship between moisture and fat content, which was more predominant in liver tissue than in muscle tissue since the liver tissue contained more fat than the muscle tissue. In the present study the level of protein was low in muscle tissue and liver tissue of *H.(H) limbatus* when compared to that of *H.(H) xanthopterus*. Protein content of muscles showed constant low values during the month of April and November in *H. (H) limbatus* and July in *H.(H) xanthopterus* which are the peak breeding periods of these fishes. In both the fishes studied, muscle tissue contained higher amount of protein, than liver tissue. In the present observation the fat content was low in the muscle and liver tissue of *H.(H) limbatus* when compared to that of *H.(H) xanthoptrus*. The lowest percentage of fat was recorded in April and November in the case of *H.(H) limbatus* and in July in *H.(H) xanthopterus*. These periods are the peak breeding season of both of these fishes. In both these hemiramphids the percentage of muscle and liver lipid start rising in all other months, possibly due to the accumulation of fats in body muscles and liver tissue due to active feeding. The muscle tissue of *H.(H) xanthopterus* contained more fat than the muscle tissue of *H.(H) limbatus*. The difference in the fat content may be due to their diet. *H.(H) limbatus* feeds more on animal matter than *H. (H) xanthopterus* which feeds more on algal matter, even though both of them are omnivores. This may be the reason for the lower values of fat in *H. (H) limbatus* and the higher values of fat in *H.(H) xanthopterus*. Low carbohydrate values were recorded in the muscle tissue of both *H. (H) limbatus* and *H.(H) xanthopterus* but higher values were present in the liver tissue of both the fishes. The carbohydrate level in muscle and liver show a constant low value during the breeding seasons. There is no marked seasonal variation in the ash content of muscle tissue and liver tissue of the two fishes. Both *H.(H) limbatus* and *H.(H) xanthopterus* are highly nutritious having high protein and fat content. The moisture and fat content showed an inverse relationship in all the tissues. In both fishes the muscles registered a higher level of protein than liver. Of the two fishes, *H.(H) xanthopterus* had an increased level of fat in their tissues than *H.(H) limbatus.* This difference was attributed to the difference in the diet. The levels of fat in the muscle and liver tissue of *H.(H) limbatus* and *H.(H) xanthopterus* were low during the spawning period.

H.(H) limbatus and *H.(H) xanthopterus* are two estuarine hemiramphid fishes of Cochin Coast. *H.(H) xanthopterus* is considered endemic to Vembanad Lake. The estimated marine fish landing reports from CMFRI (2004) showed that these species are undergoing depletion year after year. The main reason for this is the pollution from the factories in Cochin and nearby areas. In addition to that eutrophication, habitat modification, inappropriate fishing pressure and poor fishery management are some other factors that contributed to this decline. So there is a need to conserve this important resource and therefore a detailed knowledge on the salient biological features of this species would be invaluable. Therefore this biological study will be useful in implementation of proper measures of conservation and management so that further devastation of the hemiramphids of Cochin Coast can be controlled.

The important conservation methods suggested are the following.

i) Ensure sustainable development of hemiramphids with due concern for ecological integrity and biodiversity so as to increase the per capita fish protein intake of the masses. ii) The FAO Code of Conduct for Responsible Fisheries should be incorporated. iii) Instead of obtaining maximum sustainable yield, a concept of obtaining ecological sustainable yield is a necessary instrument in achieving the conservation of this endemic species. Iv) Special hatchery should be set up for conserving hemiramphids as in the case of prawns and other cultured fishes and ranching activities need to be enhanced with the stake holder participation. v) Emphasis should be given to basic education and technical skills to the fishers because most of them are illiterate and this limit their social mobility. vi) The Marine Fishing Regulation Acts (MFRA) aiming at sustainable fishing with measures like, imposing closed season during monsoon, restricting fishing effort and banning destructive gears should be strictly followed.

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