STUDIES ON THE BIOLOGY AND FISHERY OF THE FISHES OF THE FAMILY PRIACANTHIDAE (PISCES : PERCIFORMES) OF INDIAN WATERS

THESIS

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By

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DEPARTMENT OF INDUSTRIAL FISHERIES

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DECLARATION

I, K.P. Philip, do hereby declare that the thesis entitled **"STUDIES ON THE BIOLOGY AND FISHERY OF THE FISHES OF THE FAMILY PRIACANTHIDAE (PISCES:PERCIFORMES) OF INDIAN WATERS"** is a genuine record of research work done by me under the supervision and guidance of Dr. Kuruvila Mathew, Reader, Department 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.

Kochi - 682 016

September, 1994

K. P. PHILIP

CERTIFICATE

This is to certify that this thesis is an authentic record of research work carried out by Sri. K.P. Philip, M.Sc. under my supervision and guidance in the Department 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 anyother degree.

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C O N T E N T S

GENERAL INTRODUCTION

1. GENERAL INTRODUCTION

Fisheries form an important sector in the Indian economy. With an annual production of 4.04 million tonnes in 1991 (Anon, 1994), India occupies seventh position among the fish producing nations and second among the shrimp producers of the world. Apart from providing employment for nearly 7 million fisherfolks, this sector contributes to 2.4% of the GDP from primary industries. The 7,500 km coastline has over 2500 fishermen villages and as many traditional fish landing centres. There are about 34,000 mechanised boats, 170 of them having OAL above 23 m, (Joseph and Deviah, 1993) and 1.8 lakhs traditional crafts in this country. The export of fish products from India during 1992 was 1,91, 314 tonnes valued at Rs.1581.44 crores, forming 3.5% of the total export earnings (Anon, 1993a).

The country's marine fish landings rose from an average of 0.8 million tonnes in 60's through 1.2 million tonnes in 70's and 1.6 million tonnes during 80's to the current production of 2.29 million tonnes. Of the 2.29 million tonnes of marine production in 1992,pelagic resources like sardines, mackerel, Bombay duck, ribbon fish, carangids etc. contributed to 1.19 million tonnes (52%) while the demersal resources such as elasmobranchs, lizard fish, croakers, threadfin bream, goat fish, prawns, cephalopods etc. accounted for 1.1 million tonnes (48%). The south west region with 36.1%, topped in production followed by north west (34.1%), while south east and north east accounted for 23.4 and 5.5% respectively (Anon, 1993b).

With the declaration of 200 nautical miles Exclusive Economic Zone (EEZ) in 1976, India acquired full rights to explore, exploit, manage and conserve the living and non-living resources of nearly two million sq.km. of seas around it. Attempts were made by various workers to estimate the resources potential of the EEZ by resorting to organic production and exploratory survey data (Jones and Banerji, 1973; Silas, 1977; Geoge et al. 1977; Joseph, 1980, 1985, 1987; Nair and Gopinathan, 1981; Alagaraja, 1989; Desai et al. 1989; Mathew et al. 1990 and Sudarsan et al. 1990). These estimates showed that the potential marine resources of India ranged between 2.3 to 5.5 million tonnes. As more accurate figures are needed for developmental planning, recently Government of India appointed a working committee for revalidating the fishery potential of the EEZ (Anon, 1991) and the committee estimated the resources of the EEZ as 3.92 million tonnes. Of this the demersal stocks form about 1.93 million tonnes, the coastal pelagic stocks share 1.74 million tonnes and the oceanic stocks contributed to the remaining 0.25 million tonnes (Sudarsan, 1993).

The area of operation of the entire traditional sector as well as about 90% of the mechanised sector is almost confined to the coastal waters upto 50 m depth and this zone is exploited upto 96.8% level at present (Anon, 1991). It is, therefore, imperative that further exploitation of the resources should take place only from outer continental shelf and oceanic regions by extending the fishing effort to these regions.

Lack of adequate information on the deep sea resources was often posed as one of the constraints for the development of deep sea fishing. However, the extensive surveys and studies conducted along the Indian waters by various Government agencies have thrown some light on this aspect. These surveys could delineate the availability and abundance of unexploited and under exploited fishery resources along the outer continental shelf, slope and in the oceanic region. The explorative surveys conducted by the Fishery Survey of India could also locate the fishing grounds of some non-conventional demersal resources along the shelf and slope. The results of these surveys also revealed that the demersal fishery beyond 100 m depth is supported by very few species in contrast to the multi species nature seen in the inshore waters. Some of the species or groups which are observed in abundance beyond 100 m depth such as nemipterids, lizard fish, scad, squid and cuttle fish are being exploited from the inshore waters too. The groups which are represented in deeper waters are priacanthids, black ruff (Centrolophus sp.), Indian drift fish (Ariomma indica), green eye (Chlorophthalmus spp.) and deep sea sharks. In those areas where continental shelf and slope are quite extensive, deep sea lobster (Puerulus sewelli) and deep sea prawns are present in abundance. Considering the magnitude of the stock size and potential for commercial utilization, priacanthids are the most important among the deep sea fishes. Though abundant in areas between 80-200 m depth, this group has a very wide range of distribution and are often landed by the small mechanised and traditional crafts operating in inshore waters.

Priacanthids, known as bigeye, bulleye, bullseye, glasseye, snapper etc. constitute a small group of marine percoid fishes belonging to the family Priacanthidae . The members of this family are characterised by extremely large eye with wide pupils, deep body, rough scales and bright orange red colour. The body including head and maxilla is covered by small ctenoid scales which are rough to touch. The priacanthids are noted for their remarkable 'eyeshine' caused by the brilliant reflective layer or tapetum lucidum of their large eyes. In most of the species adults do not attain more than 30 cm length while one species grows beyond 50 cm.

Priacanthids in general are epibenthic in habitat and usually found associated with rock formations or coral reefs whereas a few are often trawled from the open bottom areas (Starnes, 1988). Though the adults are epibenthic and occur in deeper waters, the juveniles are believed to be pelagic (Caldwell, 1962a,b; Hildebrand, 1954; Hoese, 1958). They are tropical and subtropical in distribution, extending into even temperate regions in association with warm ocean currents. Some species are very important in the trawl fisheries of south east Asian countries, but in most other countries it is of no commercial importance (Starnes, 1988). Priacanthids were caught from the trawling grounds along the Indian coast, but seldom brought to the shore till recent years. They are known as 'pasuwa' in Tamil, 'bochi' in Telugu and 'chempally kutti' in Malayalam.

1.1 Review of previous works

A review of the literature shows that investigations on priacanthids are mostly from three regions, viz. the Pacific, Atlantic and south east

Asia. Studies from Pacific and Atlantic regions were mainly related to distribution, systematics and some aspects of physiology. In South East Asia, priacanthids constitute an important trawl fishery and therefore, studies on the distribution, abundance, biological aspects, population parameters and fishery were attempted from the above region by several workers. However, the results were published in reports which have either very limited distribution or in languages other than English (Simpson, 1982). In India, though a few species of priacanthids were reported by earlier workers, concerted attempt to study this group was made only very recently when large quantities of this fish were located along the east and west coast during the deep sea resource surveys.

Studies on priacanthids as a group began with the work of Bleeker (1873) who studied the fishes of the Indonesian region, though the family Priacanthidae was first created by Gill (1872). The American species were reviewed by Morrison (1890) and the western Atlantic species by Caldwell (1962a,b). Eggleston (1974) presented accounts of the western Pacific and eastern Indian ocean species. Randall (1978) gave accounts of the western Atlantic species and Starnes (1981, 1984) described the eastern Atlantic and western Indian ocean species. The eastern Pacific priacanthids were subjected to detailed studies by Fitch and Crooke (1984) and a new genus Heteropriacanthus was described by them. The priacanthids inhabiting Japanese waters and yellow sea were described by Linsberg and Krasyakova (1969). Smith (1949) and Smith and Heemsta (1986) described the south African species. Altogether four genera, viz. Pristigenys, Cookcolus, Heteropriacanthus and Priacanthus are established under the family Priacanthidae (Starnes, 1988). Myers (1958) and Smith (1966) compared members of the genus Pristigenys and gave information on their distribution. The genus Pseudopriacanthus and Pristigenys are considered as synonymous by several workers.

Priacanthids were reported from different areas of the Pacific and Atlantic region by several workers. Schultz (1960) described two species viz. P. hamrur and P. cruentatus from Marshall and Marianas islands. Anderson et. al. (1972) studied the morphological and ecological aspects of priacanthid fishes of the western worth Atlantic. Reid (1944) and Fowler (1947) recorded Cookeolus boops from Virginia and New Jersey coast in the north western Atlantic region. MacKay and Gilhen (1973) reported Cookeolus boops and P. arenatus from the Canadian waters of north Atlantic. Fritzsche (1978) and Fitch and Schultz (1978) recorded Cookeolus boops from the eastern Pacific. P. hamrur and P. arenatus were reported from the Mediterranian region by Abdelmoulch (1981) and Tortonese and Cau (1984). Pseudopriacanthus altu was recorded from the Gulf of Maine by Schroeder (1938). Starnes (1988) gave a comprehensive systematic account of the recent priacanthids on a world wide basis and described 18 species under four genera, among them five are new species. Lee (1980) studied the priacanthids of Taiwan and reported six species. While analysing the results of survey of R.V.Changi in the south China sea, Senta (1977) identified five species of priacanthids, among which P. macracanthus and P. tayenus were predominant and P. hamrur occurred in small numbers. Shao and Chang (1985) advanced a hypothesis of the phylogenetic relationship of the different species of the genus *Priacanthus* of Taiwan.

Priacanthus spp. occupies second position next to red snappers in the demersal catches from most of the fishing grounds in south China sea and adjacent waters and contribute to about 10 to 20% of the total catch (Hooi, 1973; Senta and Tan, 1973; Senta *et al.* 1973). According to Joung and Chen (1992) bigeye formed a very good fishery along the north east coast of Taiwan, *P. macracanthus* being the most abundant species. Bigeye constituted about 3% of the catches of demersal fishes in Tonkin Bay (Vien, 1968) with *P. macracanthus* as the predominant species followed by *P. tayenus*.

The fishing gears commonly used for capture of priacanthids are bottom trawls, bottom set nets and hand lines. Large aggregations of *P. tayenus* and *P. macracanthus* were reported by Senta (1978) from the south China sea, along the east coast of Malay Peninsula and off the north coast of Borneo. Shoals of *P. macracanthus* were got attracted to light when lift nets were operated at night in Pannay gulf (Senta, 1978). The juveniles attracted by light were found to be feeding on the planktonic crustaceans, especially mysids. Caldwell and Bullis (1971) reported aggregation of prejuveniles of *P. arenatus* from north side, west end of Anguilla Island, West Indies attracted to light and attributed positive phototropism to the species.

The sound producing mechanism in two species viz. P. cruentatus and P. meeki from Hawaii was studied by Salmon and Winn (1966). Sound production in P. macracanthus from Australia was reported by Moulten (1962) and the sound producing muscles of this species was described by Walls (1964). The mechanism of reflection, the efficiency of tapetum and the role of retinal pigments of the eyes of Priacanthus spp. from the shelf off Port Aransas and Galveston, Texas were studied by Nicol and Zyznar (1973) and Wang et al. (1980). Nicol et al. (1973) found that tapita lucida of Priacanthus spp. is unique with highly differentiated chorioidal reflective stratum backing the retina, lined with flat guanine crystal. Diseases and parasites in priacanthids were studied by different workers (Hi, 1982; Hua and Dong, 1983).

Observations on the development of artifically fertilized eggs and post larvae were made from the south China sea by Zhang and Lu (1982). Koteswaramma (1988) described an advanced post larva of P. hamrur from the Krishna estuary of the east coast of India. Preliminary studies on population parameters, feeding biology, sex ratio and reproduction of Priacanthus spp. of south China sea were attempted by Chomjurai (1970); Wetchagarun (1971); Ambak et al. (1987); Nugroho and Rustam (1983); Ingles and Pauly (1984); Joung and Chen (1992); Dwiponggo et al. (1986); Lester (1968) and Lester and Watson (1985).

The occurrence of priacanthids from India has been reported by many workers. Day (1875) recorded two species from the Indian region including

Burma and Ceylon. Munro (1955) reported three species from Sri Lankan waters. Two species were described by Jones and Kumaran (1980) from the Laccadive islands. Talwar and Kacker (1984) reported the occurrence of three species in the Indian waters. Sujatha (1986) described three species of *Priacanthus* collected from the demersal trawl catches of Visakhapatnam coast.

Though priacanthids were reported from the Indian waters earlier, no attempt has been made until recently to study the distribution and abundance and the possibilities of commercial exploitation. *Priacanthus hamrur* was observed in the deeper waters of south west coast of India in high concentrations when the vessels of the Integrated Fisheries Project conducted survey cum fishing for deep sea lobster *Puerulus sewelli* (Oommen, 1985). However, not much attention was paid to this species since the survey was mostly aimed to study deep sea lobster and prawns. Later, with the acquisition of larger vessels, the Fishery Survey of India extended its survey operations to deeper areas in order to assess the availability of deep sea resources. Priacanthids, were reported as a major component of the catches from depths beyond 50 m, and their occurrence has been noticed in deeper areas upto 200-250 m depth. The spatial and seasonal distribution and abundance of priacanthids were reported by Joseph (1984, 1986), Sivaprakasam (1986), Philip *et al.* (1984), Sudarsan *et al.* (1987), Vijayakumaran and Philip (1990) and Vijayakumaran and Naik (1988a,b) based on the results of the exploratory survey conducted by the vessels of Fishery Survey of India.

John and Sudarsan (1988) made an assessment of the stock of priacanthids of the Indian waters based on the results of survey of the larger vessels of Fishery Survey of India while Biradar (1988) gave the estimates of stock, density, biomass and maximum sustainable yield of P. hamrur of the north west coast of India based on the catches of the research cum training vessel M.F.V. Saraswati. Naik (1990) noticed a decline in the catch rates of priacanthids and attributed it to the exploitation by the chartered vessels or inter continental migration undertaken by the species. The species composition, distribution, abundance, geographical and seasonal migrations of Priacanthus spp. were studied by Bande et al. (1990), Sivakami (1990) and James and Pillai (1990) based on the data gathered from the survey of FORV Sagar Sampada.

1.2 Review on priacanthid fishery along the Indian waters

As no separate landing data are so far maintained by the concerned agencies, no information is available on the landings of priacanthids on an all India basis. Priacanthids are seen in the fish markets at different centres in the east and west coast especially when quality fishes are scarce. These fishes might have been occurring in the commercial catches, however, they were likely to be discarded at sea itself when quality fishes are available in plenty and were brought to the shore only when other fishes become less abundant. Rao (1984) estimated a landing of 236 tonnes of P.macracanthus from the fishing harbour of Visakhapatnam during the year 1983. Occurrence of priacanthids in the landings of medium sized trawlers operating along the mid shelf off Mangalore was reported by Rao et al. (1993) and Zacharia et al. (1991).

Methods of processing priacanthids into products such as frozen blocks, fillets, minced fish, canned fillets, salted and dried fish and their marketability have been studied by Samuel et al. (1987). Dhananjaya et al. (1984) made a preliminary study on the proximate compositions of P. hamrur of Karnataka. The proximate composition, amino acid profile and nutritive quality of edible meat, cooked muscle powder and meal prepared from filleting waste of P. hamrur were studied by Lakshmi et al. (1990). The aspects of handling and processing and proximate composition of P. hamrur was also studied (Anon, 1990).

A thorough knowledge on the species composition, distribution and abundance, breeding, food and feeding habit, recruitment, population parameters and stock size are prerequisite for the proper exploitation and management of a fishery resource. These information are either scarce or totally lacking in respect of priacanthids of the Indian waters. Therefore, the present investigation was undertaken with a view to study the species composition, breeding and feeding biology, population parameters, stock size, distribution, fishery, prospects of commercial utilization etc. of the priacanthids of the Indian waters with special reference to the east coast of India.

1.3 Research approach

Preliminary investigations revealed that P. hamrur is the predominant species along the east and west coasts of India while other species are sparsely distributed and occur sporadically. In the present investigation, aspects such as population parameters, breeding and feeding biology, fishery etc. of P. hamrur of the north east coast of India (Fig.1) are dealt with.

Studies on the distribution, abundance and stock size of priacanthids all along the Indian waters were undertaken. Taxonomic studies of the priacanthid species encountered during the study from the Indian waters is also attempted.

The results are presented in nine chapters. The first chapter is general introduction including the general review of previous works on this group undertaken world over, with special reference to India. The second chapter deals with the systematics of the priacanthids collected from Indian waters. Altogether five species were collected during this study and their detailed descriptions are given. The feeding biology of P. hamrur which includes qualitative and quantitative aspects of food items in relation to season, sex, size, depth and area are dealt with in the third chapter. A comparative study of the food items of P. hamrur with similar coexisting species viz. Nemipterus japonicus taken from same hauls is made so as to elucidate the selective feeding and feeding competition, if any, among the species inhabiting the same area. Aspects of the breeding biology such as spawning season, spawning frequency, size and age at first maturity, spawning behaviour in relation to depth, area and season, fecundity and sex ratio of P. hamrur are presented in the fourth chapter. Length-weight relationship in respect of males and females and month-wise and size-wise variation in the relative condition factor (Kn) are dealt with in the fifth chapter. The aspects of age and growth of P. hamrur are presented in the sixth chapter. A comparative account of population parameters estimated by various workers from different regions in respect of various species of Priacanthus is also included in this chapter. The seventh chapter deals with mortality and exploitation of P. hamrur. The spatial and temporal distribution and abundance of Priacanthus spp. and stock size variation in different regions of Indian coast are discussed in the eighth chapter. Though very limited, the available information on the fishery, processing and product development and scope for the development of this fishery in India is also presented in this chapter. Summary of the study is given in the nineth chapter followed by the references.

Fig. 1 Map showing survey area from where samples for biological studies were collected.

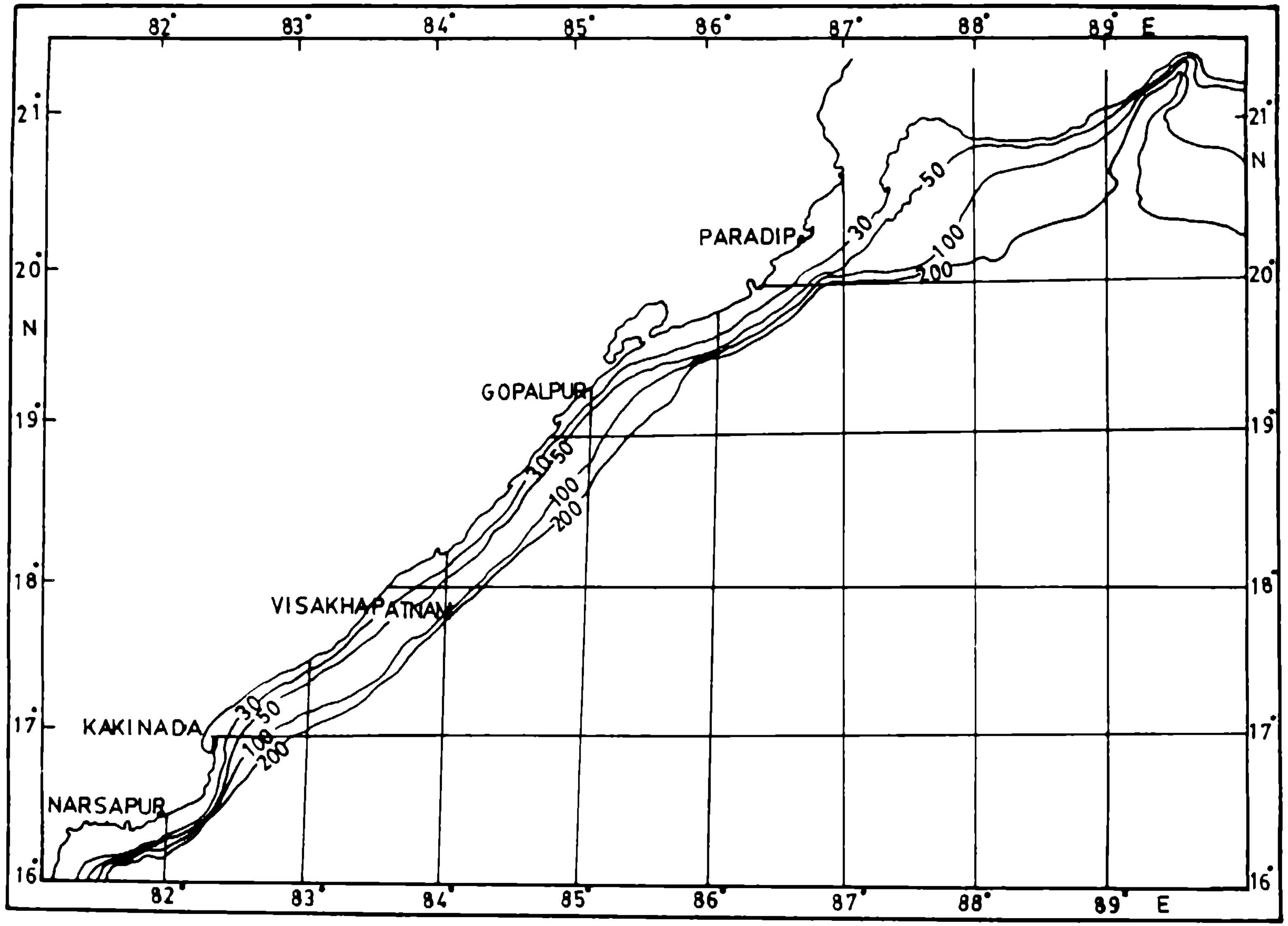
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Fig. 1

SYSTEMATICS

2. SYSTEMATICS

2.1 Introduction

The family Priacanthidae, as stated elsewhere, was erected by Gill (1872) based on the percoid group 'Priacanthina' of Gunthur (1859) which accommodated all species as members of the genus Priacanthus Oken. Systematic studies on Priacanthidae as a group began with the work of Bleeker (1873) who studied the different species of Indonesian region. The genus Pristigenys Agassiz was later included in this family by White (1936). The genus Pseudopriacanthus Bleeker is synonymised with Pristigenys Agassiz (White, 1936; Myers, 1958; Fritsche and Johnson, 1981). Fowler (1928) described four species of Priacanthus from Oceania and P. boops was placed in the newly created subgenus of Priacanthus viz. Cookeolus Fowler whereas species, cruentatus, macracanthus and hamrur were retained under subgenus Priacanthus Oken. Later Fowler (1947) elevated the sub genus Cookeolus to generic level. Recently Fitch and Crooke (1984) transferred P. cruentatus (Lacepede) to a new genus Heteropriacanthus.

The family Priacanthidae includes four genera; Pristigenys Agassiz, Cookeolus Fowler, Heteropriacanthus Fitch and Crooke and Priacanthus Oken. Starnes (1988) reviewed the family Priacanthidae and described 18 species under the above mentioned four genera. He described four species under the genera Pristigenys Agassiz, one species each in Cookeolus Fowler and

Heteropriacanthus Fitch and Crooke and 12 species in the genus Priacanthus Oken with five new species.

A new species of Pristigenys Agassiz viz. P. multifasciata was created by Yoshino and Iwai (1973) from Ryukyu Islands. A number of ichthyologists have recorded and described various species of Priacanthidae from the Pacific, Atlantic and Indian oceans, the details of which were already discussed in the general introduction.

With regard to Indian waters, Day (1875-1878) described two species, Priacanthus blochii Bleeker and P. holocentrum Bleeker. Munro (1955) reported three species viz. P. hamrur Forsskal, P. tayenus Richardson and Cookeolus boops (Schneider) from the Sri Lankan waters. P. hamrur and P. cruentatus were recorded from the Laccadive Archipelago by Jones and Kumaran (1980). Talwar and Kacker (1984) described three species viz. P. hamrur, P. tayenus and P. boops from Indian waters. According to them P. cruentatus is rare in our area and occurrence of P. macracanthus Cuvier along the Indian water is most uncertain. Rao (1984) studied the fishery and biology of P.macracanthus of Waltair coast. However, in the subsequent studies (Sujatha, 1986) and in the present study this species was not encountered from the same area. P. boops was recorded for the first time from the continental slope of the south west coast of India by Talwar (1975). Sujatha (1986) described three species viz. P. hamrur Forsskal, P. holocentrum Bleeker and P. cruentatus (Lacepede) from the Visakhapatnam coast. She considered holocentrum as a valid species which is different from P. tayenus Richardson due to the presence of truncate caudal fin and less number of lateral line scales. Starnes (1988) described a new species Priacanthus prolixus and the occurrence of this species has been reported by him from the Kerala coast (Vizhinjam) and Maharashtra coast (Bombay). Five species under the family Priacanthidae have been recorded during the present study along the Indian coast, among them P. hamrur is the most abundant while others are found rare.

2.2 Material and methods

The present study is based on samples collected from the catches of the vessels of Fishery Survey of India and Central Institute of Fisheries Nautical Engineering and Training, Visakhapatnam operating in the north east coast, vessels of FSI operating in the south west coast from the Cochin base and from the catches of FORV Sagar Sampada during its operations in the west coast. The colour of the specimens in the samples was noted in fresh condition except in the case of Pristigenys nephonius and Priacanthus cruentatus which could be noted only in preserved condition. Morphometric and meristic data were taken from fresh specimens of P. hamrur and P. holocentrum and from preserved specimens of the other three species. All measurements were taken from point to point on the left side of the fish with 1 mm accuracy. The morphometric data are presented in percentages of standard length except the snout length, eye diameter etc. which are given in percentages of head length.

2.3 Distinguishing characters of family Priacanthidae

Body laterally compressed, oval to moderately elongated; eyes large, diameter about one half of the length of head; premaxilla slightly protrusible, maxilla broad posteriorly and relatively exposed, preopercle with serrated margin, serrated preopercular spine at posterioventral angle variously developed; modified spinous cycloid scales covering the entire body and head (including maxilla); mouth large and oblique and the lower jaw upturned and strongly projecting; teeth in jaws and on vomer villiform, none on palate, nostrils paired, post orbital region of head shortened, pre-orbital often serrated, fin spines usually rough with small serrae, dorsal fin single, continuous with 10 spines and 11-15 soft rays, anal fin with 3 spines and 10-16 soft rays, pectoral fin relatively short with 17-21 rays; pelvic fin large and originating in advance of pectoral fin and broadly joined to the body along their length by a membrane, single strong spine and five soft rays; caudal fin rounded, truncate, crescentic or lunate; gill membranes separate, free from isthmus, six branchiostegals, pseudobranchs well developed.

Systematic list of species of the family Priacanthidae collected from Indian waters

Class	:	Osteichthyes
Division	:	Euteleostei
Super order	:	Acanthopterygii
Order	:	Perciformes
Sub order	:	Percoidei

Family	:	Priacanthidae
Genus	:	*Pristigenys* Agassiz, 1835
Species	:	*P. niphonius* (Cuvier, 1829)
Genus	:	*Cookeolus* Fowler, 1928
Species	:	*C. boops* (Schneider, 1801)
Genus	:	*Priacanthus* Oken, 1917
Species	:	*P. hamrur* (Forsskal, 1775)
	:	*P. holocentrum* (Bleeker, 1849)
	:	*P. cruentatus* (Lecepede, 1802)

2.4 Key to the genera of family Priacanthidae of Indian waters

1. Pelvic fins long reaching anal spines, anterior margin of the scales truncate, posterior margin with spinules. Pelvic fins reach upto origin of anal fin, anterior margin of scales with four lobes, posterior margin with serrated ridge. 3

2. 4-6 dorsal spines longest, dorsal soft rays 11-12, anal rays 10-11, lateral line scales 36-51, 9 scales above lateral line, spinules on scales 8-50 .... *Pristigenys* Agassiz

Tenth dorsal spine longest; dorsal soft rays 12-14, anal rays 12-14, lateral line scales 60-75, 16-20 scales above lateral line, spinules on scales 35-45. .... Cookeolus Fowler

3. Tenth dorsal spine longest, dorsal soft rays 10-15, anal rays 12-16, lateral line scales 56-115, scales above lateral line 8-11 .... Priacanthus Forsskal

Genus Pristigenys Agassiz

Pristigenys Agassiz, 1835:299 (type species, Chaetodon substriatus Blainville, 1818:352, a fossil, by subsequent designation of White, 1936).

Pseudopriacanthus Bleeker, 1869:241 (type species Priacanthus niphonius Cuvier, 1829 by subsequent designation of Morrison, 1889).

Broadly ovate in body profile, maximum width immediately behind the opercle; preopercle denticulate and preopercular spine obsolescent; scales of head region most modified and exposed resulting in extremely rough texture; first to fifth branchiostegal rays with well developed scales over most of length; scales present on the preopercle posterior to sensory canal; body scales relatively large, 36-51 in lateral series, scales broadly rounded posteriorly with 8-50 strong spinules along the posterior margin, anterior scale margin truncate; eyes very large; mouth large and vertical, hind nostrils very large and close before eye; gill membranes separate, gill rakers 23-29; spinous portion of the dorsal fin rounded, fourth to sixth spines longer, soft portion of the dorsal with 11-12 rays, anal rays 10-11, pectoral fin relatively short, 18-19 rays, the upper rays longest and broadly pointed, pelvic fin reaching beyond anal fin origin, ventral inserted slightly anterior to pectoral base, attached to belly by membrane, spine very strong, caudal fin rounded; soft dorsal, anal and caudal fins with black marginal band.

Distribution: Western Pacific, Indian Ocean and Western Tropical Atlantic.

Remarks: White (1936) and Myers (1958) synonymised Pristigenys Agassiz with Pseudopriacanthus Bleeker. Fitch and Lavenberg (1975) stated that Cookeolus Fowler should be synonymised with Pristigenys based on the long pelvic fins. Fritzsche (1978) stated that there was no evidence to support synonymy of Pristigenys with any of the priacanthid genera. Later, Fritzsche and Johnson (1981) changed this view and concurred with White (1936) and Myers (1958) by taking into account the genus Pristigenys as the senior synonym of Pseudopriacanthus, and arrived at the conclusion that all recent species of Pseudopriacanthus should be referred to Pristigenys.

Pristigenys niphonius (Cuvier) (Plate 1A)

Priacanthus niphonius Cuvier, 1829:107 (Japan)

Pseudopriacanthus niphonius Fowler, Bull. U.S. Nat. Mus., 100, 11, 1931:80.

Description: based on one specimen measuring 136 mm (TL).

D X, 11; A III, 10; P I, 18; scales in lateral series 43, lateral line scales 38; vertical scales 35; nine above lateral line and 25 below, gill rakers on the first arch 25 (7+1+17) (Table 1).

Diagnostic characters: Scales of mid lateral area with 18-20 strong spinules on the posterior margin, the middle spinules relatively longer, dorsal spines strong, 5th longest, anal spines similar to dorsal spines, 3rd longest, dorsal and anal spines smooth and depressible in groove; pectoral fin rounded, rays branched except the upper most one; pelvic fin large, reaching to anal origin, inner most ray attached to body by membrane, caudal fin with 16 branched rays.

In formalin, body pale, vertical stripes not distinct, dorsal, anal, pelvic fins edged with black.

Distribution: Western Pacific and Indian Ocean. In Indian Ocean it is known from South Africa, Mozambique, Seychelles (Smith, 1966). Occurrence reported from Indian waters (Talwar and Kacker, 1984). Single specimen collected during the present study from the Wadge Bank, south west coast of India in bottom trawls.

Genus Cookeolus Fowler

Cookeolus Fowler, 1928:190, (a subgenus of Priacanthus Oken, elevated to generic status by Fowler, 1947) (original type species Anthias boops Schneider in Block and Schneider, 1801).

Containing largest species of Priacanthidae; deep bodied and laterally compressed; scales relatively small, 60-80 in lateral series, scales present on first and second branchiostegal rays, scales of mid lateral area rounded to broadly pointed posteriorly with spinules at the margin, anterior margin truncate; height of dorsal spine increasing posteriorly, tenth spine longest; soft dorsal and anal fins relatively long, 12-14 and 12-13 rays respectively; pectoral fin shorter, caudal fin rounded, pelvic fin inserted anterior to pectoral fin; spinules present anteriorly on first to third dorsal spines second and third anal spines and ventral surface of pelvic spines; basal one third of soft dorsal, anal and pectoral fin rays and basal half of pelvic fin soft rays also serrated; gill rakers on the first arch 22-27; swim bladder simple, lacking anterior and posterior extensions.

Remarks: Only one species viz. *C. boops* is described under this genus which has also often been described under *Priacanthus* by some authors. Fowler (1928) first described *Cookeolus* as a subgenus of *Priacanthus*, but later elevated to the generic level (Fowler, 1947). Starnes (1988) described *C. japonicus* (Cuvier) under this genus which is a synonym for *P. japonicus.*

Cookeolus boops (Schneider, 1801) (Plate 1B)

Anthias boops Schneider, 1801, *Syst. Ichth, Bloch*: 308 (type locality : Atlantic ocean, near St. Helena).

Priacanthus boops Cuvier, *Hist. Nat. Poiss* Vol.3, 1829, 103 (St. Helena).

Priacanthus japonicus Cuvier, _Hist. Nat. Poiss._ Vol.3, 1829:106 (Japan).

Description: based on 3 specimens measuring 408-435 mm (TL).

D X, 12-13; A III, 12; P I, 16; lateral line scales 59, gill rakers 5-6+1+16-18 (Table 1).

Diagnostic characters: Maxillary extending to anterior border of pupil; anterior border of preorbital serrated; jaws with small villiform teeth, upper jaw with two rows of teeth; lower with single row, arrow head shaped band of vomerine teeth, narrow band of teeth on palate; preopercle margin almost straight, serrated, with prominent spine at angle; opercular angle rounded, head covered with small scales, posterior margin of the scale on the head with rudimentary spines; gill rakers narrow and long, their inner margin spinulose, gill filaments longer than gill rakers in lower arm; dorsal fin spines increase in length posteriorly, tenth spine longest, soft rays serrated, second to fourth soft rays longer; pectoral shorter than pelvic, pelvic long reaching the base of the first soft anal ray, upper margin of the pelvic spine serrated; caudal fin truncate; body covered with closely set scales, the anterior margin of scales straight, truncate, posterior margin with 35-45 prominent spines.

Colour dusky red on the dorsal side and flanks, light red on the ventral side; membrane of dorsal fin upto 3rd soft ray and anal fin membrane upto fourth soft ray black; pelvic fin membrane dusky to black; caudal fin margin black.

Distribution: Tropical and subtropical seas, reported from the Virginia and New Jersey coast (Reid, 1944; Fowler, 1947) western Atlantic (Caldwell, 1962), Canadian coast (MacKay and Gilhen, 1973); eastern Pacific (Fitch and Schultz, 1978 and Fritzche, 1978), African coast (Smith, 1966), and Indian waters (Talwar, 1975).

Genus Priacanthus Oken, 1817

Priacanthus Oken, Isis, 1817:1183; on Les Priacanthus Cuvier, Regna Anim., 2, 1817:281 (type locality : Anthias macrophthalmus Bloch).

This genus contains majority of members of family Priacanthidae with maximum sizes ranging from 200-300 mm SL.

Body moderately elongate, laterally compressed, maximum depth at origin of dorsal; mouth large, oblique, lower jaw projecting, small villiform teeth in bands on jaws and vomers, palatines and roof and floor of pharynx; maxilla large, reaching anterior border of pupil, its distal end broad, without supplemental bone; eyes large; preorbital and postorbital parts of head of about same length; upper and lower border of preopercle serrated, serrations extending to the edge of the spine at the angle; opercle narrow with one or two flat spines posteriorly; head covered with small rough scale; gill rakers above 20 (total number) on first arch; spines of dorsal gradually increase in length posteriorly; rays slightly longer than longest spine; dorsal with 10 spines, 11-16 rays; pelvic fin originate anterior to pectotral fin base, pelvic with one large spine and five soft rays, connected to body by a membrane from innermost rays; anal with 3 spines and 10-16 rays; spines and rays of dorsal and anal are spinulose; caudal rounded, truncate, crescentic or lunate with 14 branched rays.

Skin thick with relatively small close set scales, 56-115 in lateral series; ctenoid scales of priacanthids are unique in the sense that its posterior margin is smooth, nevertheless, in the posterior half of each scale there is a rough ridge whereby the surface of the body feels rough; posterior margin and surface of the lateral scales with spinules, anterior margin with three or four interradial projections; swim bladder with two anterior and two posterior projections; pyloric caeca 11-13; vertebrae 22; female gonads are broadly triangular.

2.5 Key to the species of Priacanthus

1. Lateral line scale 66-80; gill raker numbers 26-33, body depth 26-32% in standard length; preopercle spine relatively small in juveniles, inconspicuous in adults; pelvic fins black or partly black, no spots; caudal emarginate; pyloric caeca 11-13. .... P. hamrur

   Lateral line scales 49-66; total number of gill rakers 20-25; body depth 30-41%

in standard length; conspicuous preopercle spines; caudal truncate. 2

2. Preopercle spine very long and sharp, pelvic fins with a number of dark chocolate blotches on inner surface, other fins without spots, lateral line scales 49-59; dorsal rays 11-13. .... P. holocentrum

Preopercle spine flat; one conspicuous dark chocolate blotch at base on inner surface of pelvic fin, lateral line scales 66; dorsal rays 14. .... P. cruentatus

Priacanthus hamrur (Forsskal, 1775) (Plate 2A)

Sciaena hamrur Forsskal, 1775, Descrip. Animal., 45. (type locality : Djedda and Lohaja, Red Sea).

Description: Based on 32 specimens measuring 130-269 mm (TL).
D X, 13-15; A III, 13-15; P I, 15-19; lateral line scales 69-78, gill rakers (including rudiments) 5-8+1+19-23 = 25-32, pyloric caeca 11-13 (Table 1).

Diagnostic characters: Maxillary extending to anterior border of pupil; anterior border of preorbital serrated; jaws with small villiform teeth, upper jaw with two rows of teeth, lower with single row, arrow head shaped band of small teeth on vomer, narrow band of teeth on palatines; preopercle margin almost straight, serrated, with spine at angle, spine prominent in juveniles however less prominent in adults; the preopercle angle rounded; head covered with small scales; gill rakers narrow, long, their inner margins spinulose, gill filaments larger than gill rakers in lower arm.

Pectorals shorter than pelvics, pelvics long about 4/5th head length; pelvics reach the base of the second and spines in males, in adult females the pelvics extending only to the vent; caudal fin emarginate, posterior edge becoming crescentic with growth; body covered with close set scales, anterior margin with four projections, posterior with narrow transverse serrated ridge.

Head, dorsal side and upper flanks (above level of pectorals) bright rose pink, lower flanks become gradually paler, ventral side silvery white, in some specimens the entire body is rose pink, fresh specimens show 8-11 small blotchs along lateral line. Dorsal and anal fins grey in colour, and colour changes with age; they become pink as fish grows, the ventrals almost black, a prominent dark grey blotch in the middle of the distal half of caudal fin; pectoral yellow; caudal pink with dark grey, in some adults central rays are pink, with yellow upper and lower rays.

Distribution: Reported from the Red Sea, southern Africa, northern Australia, southern Japan, Mediterranian, Seychelles, Madagascar, Ceylon, India, south China sea. Abundant in Indian waters in the trawling grounds.

Priacanthus holocentrum Bleeker, 1849 (Plate 2,B)

Priacanthus holocentrum Bleeker, 1849, Verh, Bat, Gen. 22, Percoiden: 48. (type locality: Batavia Indonesia).

Description: Based on 22 specimens measuring 132-205 mm (TL).
D X, 10-13; A III, 13-14; P I, 16-17; lateral line scales 48-59; gill rakers 4-5+1+16-18 = 21-24; pyloric caeca 8-10 (Table 2).

Diagnostic characters: Body rectangular from behind snout to end of anal fin; maxillary extends to anterior border of pupil; vertical border of preopercle slightly oblique, entire edge finely serrated, strong, slightly curved spine at angle reaches posterior edge of operculum; head covered with small rough scales; gill rakers elongate; their inner side spinulose.

Dorsal spines spinulose, height increases towards posterior end; pectroals small, slightly longer than eye diameter; pelvics reach anal origin in young, reach only upto vent in adults; caudal truncate, skin thick with close set small rough scales.

The dorsal surface and upper flanks are rose pink, rest of flanks and ventral surface silvery white; can easily be distinguished from P. hamrur by noticing the pale colour in the former; dorsal and anal fins pink; soft part has narrow black edge; pectorals yellow; pelvics pink with a number of small chocolate coloured blotches on inner surface; a relatively large blotch present on the pelvic membrane connecting the innermost ray to the body surfae, caudal pale pink with narrow, black edge.

Gunthur (1859) described P. holocentrum, P. schmittii and P. tayenus as distinct species. According to him the caudal is truncate in the first two species whereas in P. tayenus, the caudal fin is forked with elongated upper lobe. Weber and Beaufort (1929) and Fowler (1931) placed both P. schimittii and P. holocentrum in the synonymy of P. tayenus. Sujatha (1986) is of the view that P. holocentrum with truncate caudal is a valid species and that it can be distinguished from P. tayenus, having lunate caudal with elongated tips, and this species has not so far been recorded from Indian waters.

Distribution: Malay archipelago, Sumatra, east coast of India, not observed in the trawl catches from the west coast of India.

Priacanthus cruentatus (Lacepede, 1802) (Plate 3)

Labrus cruentatus Lacepede, 1802, Hist. Nat. Poissons, 3:522 (type locality: Martinique, West Indies).

Description: Based on three specimen measuring 105-288 mm (TL).
D X, 14; A III; 15 P I, 17; lateral line scales 64; gill rakers 5+1+15 = 21 (Table 2).

Diagnostic characters: Body rectangular from behind snout to beginning of caudal peduncle; maxillary extends to anterior border of pupil; lower margin of preopercle straight, vertical margin directed obliquely towards dorsal origin, strong flat serrated spine at angle, edge of preopercle finely serrate; head covered with small scales, except for the fleshy lips; gill rakers with spinulose inner margin.

Dorsal spines not spinulose; pectorals longer than eye diameter, pelvics reach first anal ray, anal spines smooth, rays spinulose, rays much longer than spines, caudal truncate, body covered with rough scales.

In formalin preserved specimens body is pale golden brown, basal 1/3 of pelvics unpigmented, rest of fin with dusky pigmentation which increases posteriorly, at surface prominent black blotch present between the spine and the third ray at the base of the pelvic fin at its inner surface.

Remarks: Fitch and Crooke (1984) shifted P. cruentatus to a new genus Heteropriacanthus, which was erected on the basis of swimbladder structure.

Distribution: Western, eastern and mid Atlantic, South Africa and Japan. Rarely occurring in Indian waters.

Table 1. Body proportions of Pristigenys niphonius, Cookeolus boops and Priacanthus hamrur as percent of standard length and head length

Sl.No.	Character	Pristigenys niphonius	Cookeolus boops		Priacanthus hamrur	
			Range	Mean	Range	Mean
	In Standard Length					
1.	Standard length (mm)	136.00	325.00 - 348.00	334.33	102.00 - 210.00	146.34
2.	Total length	123.52	125.00 - 125.53	125.20	122.13 - 131.09	126.09
3.	Body depth	55.88	41.66 - 43.03	42.38	27.56 - 34.14	30.40
4.	Pre dorsal	36.76	33.23 - 34.84	34.18	27.87 - 32.62	30.74
5.	Pre pectoral	44.11	41.21 - 41.37	41.27	26.89 - 36.09	33.82
6.	Pre pelvic	35.29	27.69 - 30.17	29.18	24.85 - 33.33	28.33
7.	Pre anal	64.70	60.00 - 62.12	61.39	47.50 - 59.23	54.84
8.	Dorsal base	63.23	56.89 - 58.78	57.63	54.16 - 62.80	60.14
9.	Anal base	29.41	27.07 - 27.87	27.50	30.00 - 36.89	33.10
10.	Length of 10th dorsal spine	*29.41	**20.11	-	11.39 - 16.09	14.15
11.	Soft dorsal height	-	27.57 - 30.17	28.88	15.00 - 19.11	16.84
12.	Pectoral length	27.20	21.81 - 22.15	22.02	15.17 - 20.58	18.44

* Length of the 5th dorsal spine

** Single observation

..2..

Table 1. (contd......)

Sl. No.	Character	Pristigenys niphonius	Cookeolus boops		Priacanthus hamrur	
			Range	Mean	Range	Mean
13.	Pelvic length	39.70	35.75 - 38.15	36.89	25.00 - 28.96	27.27
14.	Anal height	25.73	21.53 - 22.12	21.82	13.11 - 17.68	15.72
15.	Head length	44.11	41.21 - 41.66	41.36	32.20 - 36.66	34.18
	In Head Length					
1.	Head depth	101.66	90.29 - 92.64	91.09	70.45 - 89.79	78.53
2.	Head width	56.66	39.70 - 40.29	39.99	38.09 - 56.75	43.33
3.	Eye diameter	43.33	28.96 - 30.59	29.89	34.04 - 42.85	38.42
4.	Post orbital	30.00	32.83 - 33.82	33.25	23.91 - 33.33	29.09
5.	Pre orbital	31.66	36.76 - 40.00	38.27	29.78 - 37.83	33.10
6.	Inter orbital	20.00	23.44 - 24.62	23.86	16.66 - 25.53	20.48

Table 2. Body proportions of Priacanthus holocentrum and Priacanthus cruentatus as percent of standard length and head length

Sl. No.	Character	Priacanthus holocentrum Range	Priacanthus holocentrum Mean	Priacanthus cruentatus Range	Priacanthus cruentatus Mean
	In Standard Length				
1.	Standard length (mm)	103.00 - 165.00	126.18	80.00 - 226.00	175.67
2.	Total length	121.67 - 130.63	125.56	127.43 - 131.25	129.36
3.	Body depth	32.50 - 37.86	35.43	40.00 - 44.34	41.83
4.	Pre dorsal	30.33 - 35.07	33.50	35.00 - 36.28	35.82
5.	Pre pectoral	33.60 - 37.84	35.48	39.36 - 40.00	39.58
6.	Pre pelvic	22.67 - 30.30	27.99	27.50 - 34.07	31.08
7.	Pre anal	54.33 - 59.65	57.29	57.50 - 59.72	58.39
8.	Dorsal base	48.17 - 58.77	54.68	56.19 - 59.72	58.22
9.	Anal base	28.35 - 36.04	32.16	34.07 - 37.10	35.80
10.	Length of 10th dorsal spine	15.00 - 19.30	17.11	19.45 - 20.00	19.63
11.	Soft dorsal height	18.79 - 23.68	21.50	30.00 - 30.76	30.28
12.	Pectoral length	15.83 - 19.95	18.01	18.55 - 21.25	19.46
13.	Pelvic length	26.12 - 31.58	29.43	32.50 - 37.55	34.41

..2..

Table 2. (contd......)

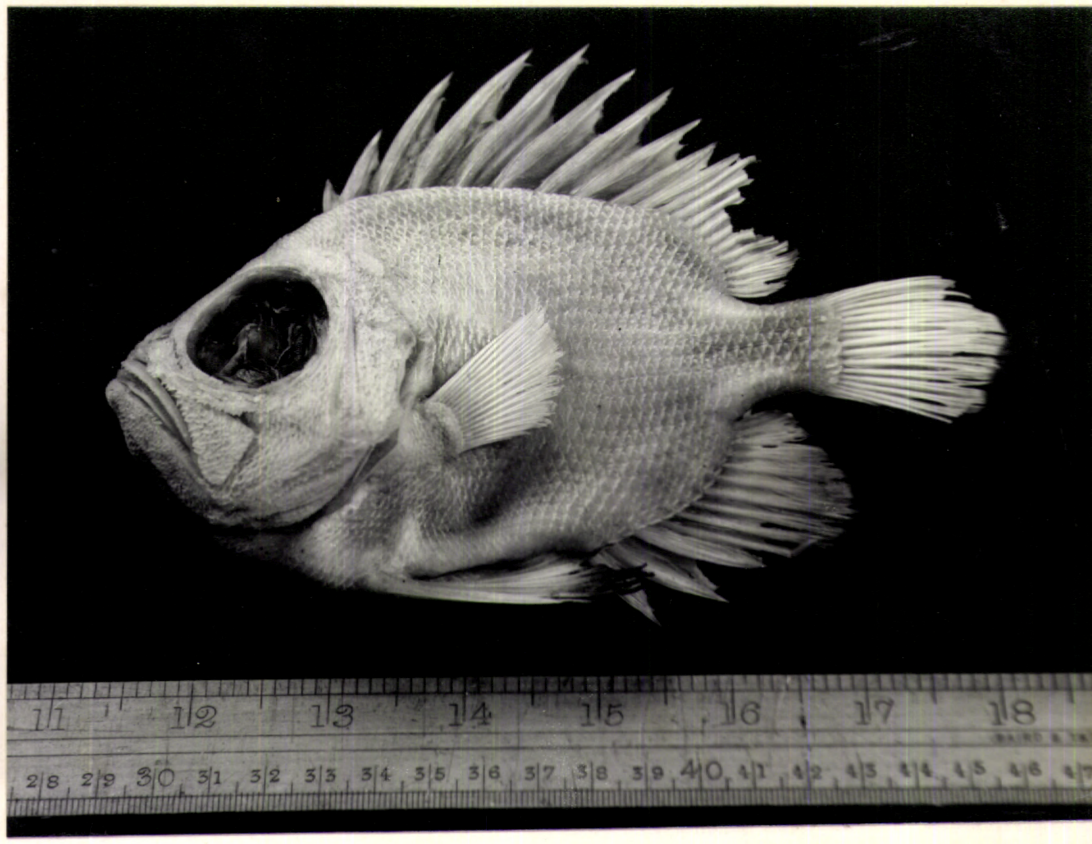
Sl. No.	Character	*Priacanthus holocentrum* Range	*Priacanthus holocentrum* Mean	*Priacanthus cruentatus* Range	*Priacanthus cruentatus* Mean
14.	Anal height	18.11 - 22.07	19.91	23.75 - 27.43	25.50
15.	Head length	34.92 - 37.01	35.75	38.49 - 40.00	39.13
	In Head Length				
1.	Head depth	73.68 - 90.91	82.98	87.50 - 93.10	91.20
2.	Head width	39.13 - 46.94	43.20	40.62 - 48.27	45.13
3.	Eye diameter	38.30 - 43.90	41.14	36.78 - 43.75	39.24
4.	Post orbital	21.74 - 29.82	25.25	24.41 - 31.25	26.98
5.	Pre orbital	30.19 - 36.17	33.43	25.00 - 38.37	33.76
6.	Inter orbital	19.30 - 24.49	21.47	18.60 - 21.87	20.38

Plate 1

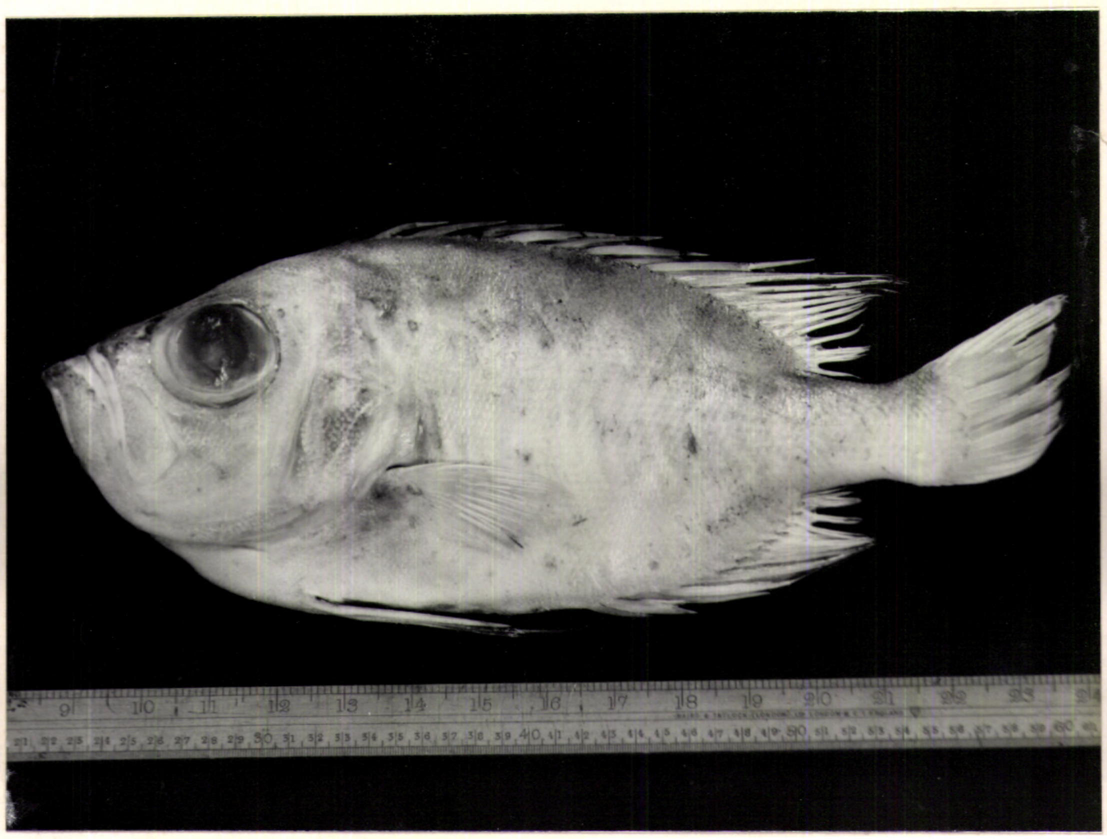
A Pristigenys niphonius (Cuvier)

B Cookeolus boops (Schneider)

PLATE 1



A



B

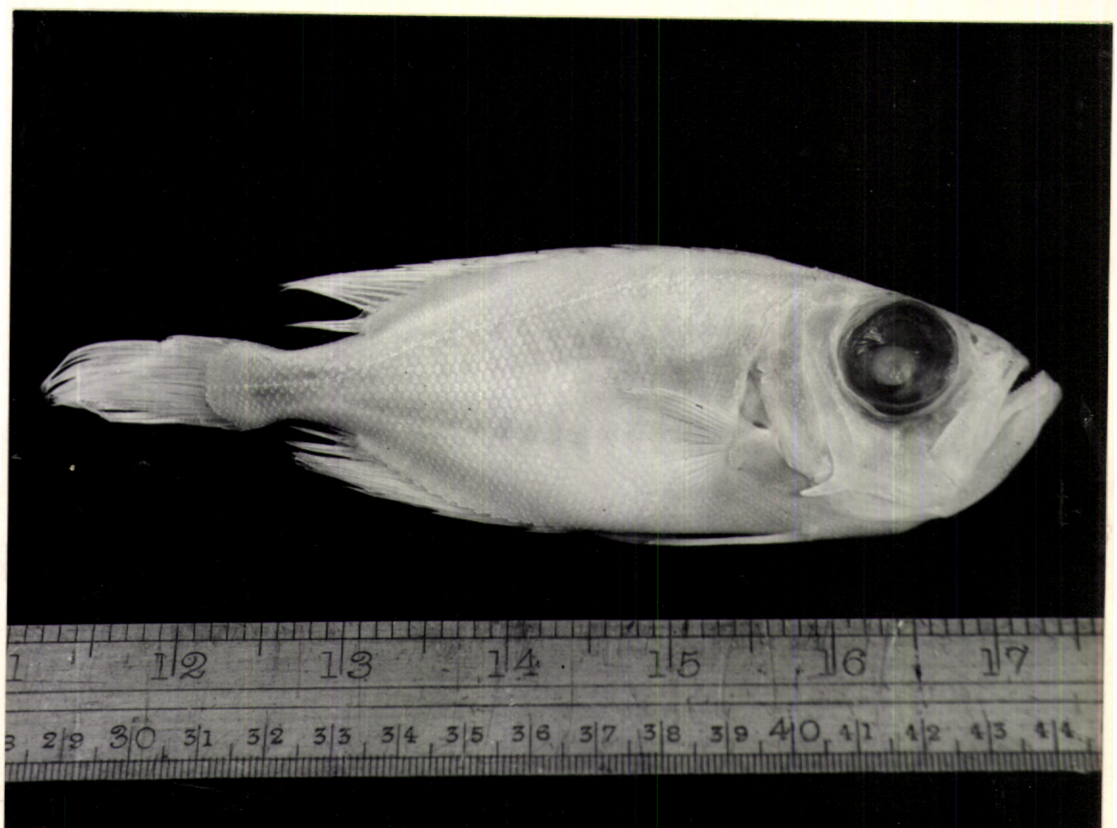
Plate 2

A. Priacanthus hamrur (Forsskal)

B. Priacanthus holocentrum (Bleeker)

PLATE 2

A



B

Plate 3

Priacanthus cruentatus (Lacepede)

PLATE 3

FOOD AND FEEDING

3. FOOD AND FEEDING

3.1 Introduction

Food is one of the important factors regulating or influencing the growth, fecundity, migration and abundance of fish stocks. Seasonal and diurnal abundance of favourite food organisms may be responsible for the horizontal and vertical movements of the fish stocks. A knowledge of the relationship between the fishes and their food items is essential for the prediction of abundance and exploitation of stocks. By identifying the favourable feeding grounds and feeding habits of commercially important fishes, appropriate fishing strategies and techniques can be designed. Further, a study of food of fishes gives some general information on their relative positions in the food chains of the ecosystem. In view of the above reasons, considerable attention has been paid by the fishery biologists on this subject all over the world from the beginning of fishery biology investigations.

Substantial work has been done by various workers on the food and feeding habits of commercially important fishes from Indian waters. Notable among them are that of Hornell and Nayudu (1924) on Sardinella longiceps, Devanesen (1932) on S. gibbossa, Job (1940) on the perches of Madras coast and Chacko (1949) on the food and feeding habits of fishes of the Gulf of Mannar. Subsequently, a number of studies on food of commercially important species from different localities were carried out by various workers, mostly as a part of the biology. They investigated aspects such as the nature of food, its seasonal variations, feeding habits in relation to sex, size, maturity stages, relation between fishery and availability of food etc. George (1953) related good fishery of sardine and mackerel along the west coast with the abundance of plankton in the inshore waters from September to December. A good fishery of the Malabar sole was reported to have coincided with the abundance of polychaetes (Seshappa and Bhimachar, 1955), while a good fishery of silver bellies and white baits was correlated with abundance of plankton food (copepods) by Venkataraman (1961). Qasim (1972) gave a critical appraisal of the existing knowledge of the food and feeding habits of some marine fishes from the Indian waters and suggested how best the problem of community nutrition could be attempted in determining the transfer of energy from one trophic level to the other.

While studying food and feeding habits of fishes from the trawl catches of Bay of Bengal, Rao (1966) made some observations on the stomach contents of P. tayenus from the north east coast. Rao (1984) also made some preliminary observations on the food contents of P. macracanthus of the east coast of India. Zacharia et al. (1991) made some preliminary observations on the food and feeding habits of P. hamrur of the Karnataka coast. Chomjurai (1970) and Wetchagarun (1971) studied the food and feeding habits of P. tayenus from the Gulf of Thailand. Mohmed Ambak et al. (1987) gave the feeding behaviour of P. tayenus and P. macracanthus of Malaysian waters. All these investigations appear to be preliminary in nature. A systematic and detailed study on the food and feeding habits of priacanthids from the Indian waters has not been attempted so far. Therefore, an attempt is made to study in detail the food and feeding habits of P. hamrur from the north east coast of India. The quantitative and qualitative variations of food of P. hamrur in relation to areas, depth, season, size etc. are studied.

3.2 Material and methods

Samples for this study were collected from the survey vessels of Fishery Survey of India during June 1991 to April 1993. Besides samples were also collected from Visakhapatnam fishing harbour during May and June 1993, when there was no fishing by vessels of FSI. Altogether 1205 stomachs collected during different months from various localities as well as different depth zones were analysed. The length, sex and feeding intensity were noted before removing the stomachs and they were preserved in formalin (5%) for stomach content analysis.

According to the food habits of fishes different methods of food analysis were adopted by various workers. Hyslop (1980) critically assessed the methods for analysing stomach contents of fish with a view to their suitability for determining dietary importance. The author also discussed difficulties in the application of different methods and proposed alternate approaches. He opined that, in order to collect maximum information an investigator should employ at least one method measuring the amount and one measuring the bulk of the food material. In the present study the stomach contents of *P. hamrur* were analysed by employing points (volumetric) method (Pillay, 1952). Since volumetric method alone is inadequate to give a correct picture of the importance of individual food items, (Natarajan and Jhingran, 1961), both occurrence and volume have been taken into consideration.

The intensity of feeding was determined by examining the conditions such as the distension of the stomachs and the amount of food in it. They were classified as full, 3/4 full, 1/2 full, 1/4 full, trace and empty and were allotted points as 100, 75, 50, 25, 10 and 0 respectively. Depending on the relative volume of the food items, points were given to each food item. From these points volume for each food item and its percentage in the total volume of all stomach contents were calculated in each month. Similarly the percentage occurrence of different items of food was determined from the total number of occurrence of all items in each month. To evaluate the importance of each food item, the 'Index of preponderence' proposed by Natarajan and Jhingran (1961) was followed. This method simultaneously takes into account both volumetric as well as occurrence method 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 and the 'Index of preponderence' values were worked out

$$I = \frac{100 \times V \times 0}{\text{Sum of } (V \times 0)} \qquad (1)$$

Where,

'I' is the 'Index of preponderence' of the food item and 'V' and '0' are its percentage by volume and occurrence, respectively.

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 in order to arrive at the feeding intensity in relation to size and season. The gastrosomatic index (GSI) was calculated to find out the feeding intensity using the formula;

$$GSI = \frac{\text{Wt. of the gut} \times 100}{\text{Total weight of the fish}} \qquad (2)$$

In order to find out the variations of food items in space and time, gut contents of specimens collected during different months from various depth zones as well as regions were analysed. For this purpose, the entire area covered in this study was divided into 1° latitude sections of 60 nautical miles width while the shelf was arbitrarily classified into various depth zones such as below 50 m, 50-100 m, 100-150 m, 150-200 m and above 200 m. Since no differences in food consumed by the males and females have been observed, the data for both females and males were pooled. In order to study size-wise variations in the composition of food, fishes were grouped in 10 mm size interval. The food items were indentified upto generic or group level as far as possible depending on the state of digestion. The fishes in the gut content were separated individually and identified to the generic or group level wherever possible. However, those fishes whose identity could not be adjudged due to mutilation were grouped under "other teleost fishes". A comparative study of food items of P. hamrur and Nemipterus japonicus was carried out by examining samples of both the species taken from the same haul for a period of three months. This was done in order to assess probable interspecific competition for food if any, between the two species that coexist in the same habitat.

3.3 Results

3.3.1 Composition of food

The summary picture of stomach contents of P. hamrur during 1991-92 and 1992-93 is shown in Fig.2. It could be seen that digested matter comprised 52-98 and 56-84% during 1991-92 and 1992-93, respectively. The index of important identifiable food items observed during 1991-92 and 1992-93 are presented in Fig.2. About 28 different groups of food items were identified from the stomach of P. hamrur in the recent study. Leaving the group "other teleost fishes" which was dominant in the year 1991-92, megalopa was found as the most important item of food during both the years forming 6.7 and 10.4 percent respectively. Crustaceans like alima, squilla, juvenile crab and prawns, euphausiids and deep sea prawns were also dominant in both the years. Squids, gastropods and fishes like eel, Bregmaceros sp. and Acropoma sp. were predominant in the first year while polychaetes, amphipods and copepods were found to be abundant in the second year. Apart from these, sporadic occurrence of isopods, mysids, Lucifer sp., zoea larvae, Acetes sp. and young spiny lobster were also noticed. Fishes like silver belly, flat fishes, juveniles of Nemipterus sp. etc. were also seen occasionally. In general, the crustaceans were found to be the most favoured group as they formed more than 60% of the identifiable food items. The deep sea prawn Solenocera sp. which is abundant in 50-100 m and 100-200 m depths was the predominant item among the prawns found in the food. Groups like echinoderms, sponges etc. were totally absent. Materials like pieces of synthetic twines, charcoal, seeds, broken pieces of plastic etc. were incidentally recorded in the stomach contents whereas sand grains and vegetable matter were not at all observed.

3.3.2 Seasonal variations in the food composition

The month-wise feeding index for 1991-92 and 1992-93 are given in Table 3. It would be seen that during July 1991, squilla, prawns and polychaetes were the most dominant food items whereas alima and megalopa were also present in significant quantities. In 1992, eel was the dominant item followed by polychaetes. No data were available for August and September 1991 since there were no fishing operations. Polychaetes were the dominant food item in August and September 1992. Euphausiids were observed in September 1992 in considerable quantitites while they were totally absent in the previous as well as succeeding months. Megalopa which was found in negligible quantities in the previous months was found to be abundant in October 1991 and 1992 the indices being 34.7 and 32.8, respectively. Food items such as squilla, prawns and polychaetes were more in October 1991. The percentage of digested matter observed during this month was small which facilitated the separation and identification of more individual items, whereas in October 1992 the digested matter was more. In November, 1991 megalopa showed the highest percentage of 9.8 followed by crab, leptocephalus, prawns and alima. Polychaetes, which formed a prominent food item in the previous months were also seen in good quantities during November 1991 and thereafter showed a decreasing trend. Main feature of this month is the higher percentage of leptocephalus, and appearance of eel and Bregmaceros sp. which were totally absent in the preceding months of study except July 1992. There was no data for November 1992 and therefore a comparison is not possible.

Megalopa and eel were the major components of the food followed by alima and prawn during December 1991. Squids were also seen in a higher percentage than the preceding months. Megalopa showed a very high index (38.2) followed by alima in December 1991 and 1992. Bregmaceros sp. was the dominant item registering high indices of 25.1 and 22.5 respectively in January 1992 and 1993. Eel, leptocephalus, squid and crab were more in January 1992. Squids were seen in relatively higher quantities in December and January though their presence could be observed only in traces in all the other months. In January 1993 apart from Bregmaceros sp., megalopa, alima, prawns and squilla were the dominant food items.

There was a high index of euphausiids (10.5) in February 1993 whereas in February 1992 they were totally absent in the stomach contents. In March 1992 and 1993 megalopa was the dominant item with the high index of 15.0 and 13.8 respectively, but in March, 1992, alima and Acetes sp. showed higher percentage than the corresponding period of 1993. The occurrence of copepods in the stomach contents was the highest in March 1993 with an index of 9.4. Bregmaceros sp. was seen in equal quantities in March, 1992 and 1993. Gastropods, copepods and leptocephalus dominated in April, 1992 whereas crab was the dominant item among the gut contents with a high index of 48.4 in April 1993. Megalopa, squilla and amphipods were the dominant food items in May 1992. Similar trend was noticed in May 1993 also in the food composition with megalopa as the major component followed by alima. In both these years amphipods formed significant portion of food item in the month of May. Euphausiids and crab were the dominant food items in June 1992. In June 1992, nearly 85% of the food contents was found to be in the digested state and therefore the presence of individual items could be noticed only in traces. In June 1993 megalopa was the dominant item followed by polychaetes. Seasonal occurrence of important food items in the stomach of P. hamrur is given below.

Item of food	Season
Megalopa	October to December, March and May
Alima and squilla	November to January, March and May
Euphausiids	September, February and June
Copepods	March and April
Amphipods	August to October, March and May
Prawns	January and February
Eel	December and January
Bregmaceros sp.	January and March
Polychaetes	July to November

3.3.3 Spatial difference in food composition

The indices of various food items observed from different areas are given in the Table 4. It could be seen that the food diversity was less in the areas falling in the latitude 16°N (off Kakinada). Alima, megalopa and crab were the predominant items present in this area. The number of food items identified from the stomach were high at latitude 17°N. Teleost fishes, magalopa, crab, polychaetes and euphausiids were the dominant items. In latitude 18°N, megalopa and alima were the dominant food items. The preponderance of euphausiids and Bregmaceros sp. in the gut contents of

P. hamrur at 18°N latitude is worth noticing. Prawns, megalopa and crab were the predominant food items from lat. 19°N. Polychaetes and amphipods recorded the highest indices in this latitude. Food diversity was the highest in this latitude. In latitude 20°N euphausiids again appeared as the predominant food items, while items like megalopa, alima, squilla and Bregmaceros sp. were present only in moderate quantities in the stomach.

3.3.4 Variations of food in relation to depth

The composition of food in the gut of P. hamrur from different depth zones are given in Table 5. It could be seen that most of the food items identified from the stomach were present in samples collected from depth zones below 50 m and 51-100 m. In the samples from areas below 50 m, 'other teleost fishes', prawns, megalopa and crabs formed the major items. Apart from this, polychaetes and eel were more in this depth zone when compared to the other depths. Megalopa was the dominant item of food in the stomachs from depth zone 51-100 m followed by crab. Euphausiids were also abundant in the stomachs from this zone whereas in other depth zones they were found to be either negligible or absent. Prawns were found as the dominant items of food in 101-150 m depth zone followed by 'other teleost fishes'. Squilla, squid, leptocephalus and Acropoma sp. were also relatively more in this depth zone. Items such as alima, megalopa and crab were fairly represented. Alima was the predominant food item from the depth zone 151-200 m followed by Bregmaceros sp. and megalopa. The percentage of euphausiids, amphipods and copepods were more in this depth compared to all other depth zones. The stomachs examined from depths beyond 200 m showed only few items wherein deep sea prawns formed the predominant component.

3.3.5 Variations of food in relation to size groups

Food items noticed in the stomach contents of different size groups of *P. hamrur* are given in Table 6. It could be seen that the food items were less diverse in smaller size groups. Alima, squilla, megalopa, amphipods, euphausiids, copepods, *Acetes* sp., prawns, leptocephalus etc. were represented in smaller size groups below 91-100 mm. *Bregmaceros* sp. eel and crab were observed in the size groups 111-120 mm onwards. Almost all varieties of food were represented in the size groups 161-170 mm to 201-210 mm. On the contrary a few items could be observed in older size groups, perhaps due to the less number of stomachs examined. Deep sea prawns, 'other teleost fishes', polychaetes, squilla and megalopa were the prominent items identified from fishes of 220 mm length and above.

3.3.6 Feeding intensity

The month-wise percentage occurrence of stomach with different feeding intensities observed during 1991-92 and 1992-93 is given in Table 7. In most of the months either 1/4 full or 1/2 full stomachs were dominant which generally determined the overall state of feeding in a given month.

Stomachs empty or having traces were noticed more during July and October to December 1991 which appeared to be the period of low feeding intensity. From January onwards the percentages of 1/2 full, 3/4 full and full stomachs were found increasing indicating that feeding intensity is high till June 1992 though there was slight decline in April 1992. Low feeding was again observed from July to December, 1992. This was succeeded by a period of high feeding intensity from January 1993 onwards. Presence of empty stomachs was noticed in all months except January, May and September 1992 and June 1993. Full stomachs were totally absent in October-November 1991 and during August to December in 1992.

3.3.7 Gastro-somatic index

The gastro-somatic indices values worked out for different months of 1991-93 is shown in Fig.4. It could be seen that the gastro-somatic index showed high values during January to July. The highest value was noticed during the month of May (4.30) followed by March (4.02). The lowest value of 2.10 was noticed in the month of August. September and November also showed very low values. Low values ranging between 2.10-2.60 were noticed during August to December.

3.3.8 Comparative study of food of *P. hamrur* with that of *Nemipterus japonicus*

Comparative account of food index of *P. hamrur* and *Nemipterus japonicus* is shown in Table 8. It could be seen that the food items were almost identical in both the species. Crab, prawns and squilla were found to be predominant in both the species. The percentage contribution of crab and prawns were more in N. japonicus, while items such as teleost fish, polychaetes, amphipods, alima and megalopa were slightly dominant in P. hamrur. Items like ocotopus and brittle star were noticed only in N. japonicus.

3.4 Discussion

A study of the food and feeding habits of Priacanthus tayenus and P. macracanthus of Malaysian waters (Ambak et al., 1987) revealed that crustaceans were the dominant food items followed by fishes and cephalopods. Lester (1968) studied the food and feeding habits of P. tayenus and P. macracanthus from Hong Kong waters and found that they were feeding on a wide variety of crustaceans. Chomjurai (1970) and Wetchagarun (1971) reported that shrimps, small fishes, crabs, squids, snails and mantis shrimps were the important items of food of P. tayenus and P. macracanthus of south east Asian waters.

Feeding on planktonic crustaceans, especially mysids by juveniles of P. macracanthus was reported by Senta (1978) from Panay Islands, where they were caught by lift nets. Large aggregations of juvenile P. macracanthus were attracted to light and found actively feeding on planktonic crustaceans under the lamps.

Rao (1967) while studying the food and feeding habits of fishes from the trawl catches of Bay of Bengal observed that the crustaceans were the main food items of P. tayenus and similar dominance was found in P. macracanthus by Rao (1984). Zacharia et al. (1991), observed that P.hamrur is highly carnivorous and found squids, lizard fish and Therapon sp. as dominant items in the food during May, 1990.

The present study revealed that P. hamrur is a carnivorous species feeding on crustaceans, teleost fishes and occasionally on other organisms like cephalopods, polychaetes, gastropods etc. The strongly oblique mouth having moderate size, slightly protrusible premaxilla, broad and relatively exposed maxilla, the upturned and strongly projecting lower jaw and the conical teeth on the premaxilla, vomer and palatine clearly indicate the carnivorous nature of feeding. According to Tamura (1959), priacanthids generally take food which are above and ahead of it i.e., in the upper and upperfore part of the visual field. The oblique nature of the mouth supports this statement. Collette and Talbot (1972) reported that P. cruentatus is a crepuscular species which continues to feed in darkened places during day time. The absence of sand grains, detritus, benthic organisms etc. in the stomach indicates that they do not browse in the sea bottom for feeding. From the nature of the organisms constituting food it can be inferred that P. hamrur generally feed on free swimming organisms near to the bottom.

Megalopa, prawns, squilla, alima, euphausiids etc. were the most common crustaceans found in the stomach. Among the fishes Bregmaceros sp., eel and leptocephalus were the dominant items. Rao (1967) observed that metazoea, megalopa, cariid prawns, amphipods, decapods and stomatopods were the main items of food of P. tayenus of the north east coast. He found that 55% of food content is constituted by crustaceans and 45% by teleost fishes. Lester (1968) also found that crustaceans formed 66-68% in P. tayenus of Hong Kong water and in P. macracanthus also the main food items were crustaceans from the same area. In the present study also it was observed that crustaceans formed about 60% of the food items. Ascidians, foraminifera, hydroids, egg mass etc. which are not recorded in P. hamrur were observed in the gut of P. tayenus and P. macracanthus by Lester (1968). Rao (1984) found that P. macracanthus of north east coast mainly feeds on crustaceans and teleosts and the crustacean diet included Penaeus spp. Metapenaeus spp. and Solenocera sp.. Similar finding was made in the present study also. The stomach contents of fishes taken from shallow water contained penaeid prawns such as Penaeus spp., and Metapenaeus spp., whereas stomachs of fishes from deeper waters contained Solenocera sp., which is reported to be abundant beyond 50 m depth.

Seasonal variations could be noticed in the food components of P. hamrur. These variations may be attributed to the changes in abundance of food organisms due to various environmental factors which affect the availability of food organisms in the habitat. Ruben (1968) reported the occurrence of euphausiid Euphausia distinquenda (Hansen) in very high percentages in the stomach of Carangoides malabaricus (Bloch & Schneider) in July 1964 and August 1966 and inferred that they have fed on thick patches of euphausiids. In corollary to this, euphausiids were noticed in the stomach of P. hamrur during the month of June, 1992 and February, 1993. During these months some of the specimens had the stomachs full with euphausiids alone. Bregmaceros sp. was dominant in the food during January-February and March of both the years. Seasonality was noticed in respect of some food items as shown in page 40. The changes in the food items during different months could have been influenced by the samplings made from different depths and areas, where the relative abundance of different food organisms shows variation.

The qualitative variations in respect of food items were found to be less in the stomachs of the specimens taken from 16°N latitude section. This could be an indication of a probable lack of diversity of fauna obviously due to the steep descent of the shelf. Similar observation was also noticed in the stomachs of specimens taken from the higher depth zones viz. 101-150 m, 151-200 m and above 200 m and this may also be attributed to the low faunistic diversity prevalent in the above depth zones.

The food of young fishes comprised a few smaller crustacean items like Acetes sp. megalopa, alima, copepods, amphipods etc. showing a preference by the young ones towards them. Teleost fishes were observed in the stomachs of fishes having a length of 100 mm and above. Food items were highly diverse in fishes in the length ranges 141-210 mm. An inverse relationship could be seen between the diversity of food items with increase in size. However, it is not fully understood whether the fishes develop specific preferences as they grow old and it can be decided only by making further studies based on sufficient number of large sized specimens.

The feeding intensity was high during the period January to June and low during July to December. A low feeding intensity was observed during November-December in the case of P. macracanthus of the north east coast by Rao (1984). Gastro-somatic index showed high values during the period January to July and low values during August to December agreeing with high and low feeding intensity during these periods. It is therefore, inferred that no significant relationship would exist between the feeding intensity and the maturation in P. hamrur. As mentioned elsewhere, the condition factor showed good correlation to the feeding than maturation (Fig.4).

A comparison of the food items identified from the stomachs of P. hamrur and N. japonicus revealed the fact that crab, prawns and squilla predominated in both the species which accounted for the major percentage of the food components. According to Johnson (1977) if the occurrence of a food item exceeded 25% in two or more species that inhabit in the same area competition was likely to take place among them. The major food items in P. hamrur and N. japonicus exceeded more them 25% which indicates that there is the possibility of competition for food between the above two species that coexist in the north east coast of India.

Table 3. Index of preponderence of food items of *P. hamrur* in different months during July 1991 to June 1993

	July		August		September		October	
	1991	1992	1991	1992	1991	1992	1991	1992
Alima	2.1	1.1	-	2.0	-	1.6	1.0	1.8
Squilla	10.1	0.6	-	0.3	-	0.6	10.3	0.1
Zoea	8.3	-	-	-	-	-	0.1	0.1
Megalopa	2.1	1.1	-	0.3	-	4.4	34.7	32.8
Crab	-	0.6	-	0.1	-	1.5	2.6	2.5
Amphipods	0.2	0.1	-	1.0	-	1.0	1.3	1.0
Isopods	-	-	-	0.7	-	0.1	-	0.2
Copepods	-	0.1	-	-	-	-	-	-
Euphausiids	-	-	-	-	-	6.4	-	-
Acetes sp.	0.2	1.1	-	-	-	-	-	-
Lucifer sp.	-	-	-	-	-	-	-	-
Mysid	-	0.1	-	0.1	-	-	-	0.1
Polychaetes	3.7	2.1	-	4.8	-	10.9	3.8	1.3
Nematodes	-	-	-	0.1	-	0.1	0.1	-
Squid	-	-	-	0.1	-	-	-	-
Cuttle fish	-	-	-	-	-	-	0.7	-
Gastropods	-	0.1	-	0.1	-	-	0.4	0.1
Bivalves	-	0.1	-	-	-	-	-	-
Lobster (juvenile)	-	1.4	-	-	-	-	0.2	-
Young sea horse	-	-	-	-	-	-	-	-
Prawns	5.7	0.4	-	0.4	-	3.3	15.1	-
Crustacean remains	11.0	8.1	-	0.6	-	20.0	1.1	2.8
Leptocephalus	-	0.1	-	-	-	-	-	-
Eel	-	4.1	-	-	-	-	-	-
Bregmaceros sp.	-	0.5	-	0.1	-	-	-	-
Acropoma sp.	-	-	-	-	-	-	-	-
Flat fish	-	-	-	0.1	-	-	-	-
Silver belly	-	-	-	-	-	-	-	-
Other teleost fish	10.7	6.3	-	0.6	-	-	8.7	0.4
Digested matter	45.9	72.0	-	88.6	-	50.1	19.9	56.8
Non-food items	-	-	-	0.1	-	-	-	-

..2..

Table 3. (contd...)

	November		December		January		February	
	1991	1992	1991	1992	1992	1993	1992	1993
Alima	5.3	-	5.2	5.0	5.2	4.9	-	1.0
Squilla	2.2	-	2.6	-	2.3	1.5	1.1	1.0
Zoea	1.1	-	0.1	0.1	0.1	0.1	-	0.1
Megalopa	9.8	-	8.9	38.2	1.2	7.6	0.2	4.6
Crab	8.4	-	3.4	-	2.3	0.3	1.5	0.8
Amphipods	0.1	-	-	0.9	0.9	0.2	0.1	0.4
Isopods	-	-	0.1	-	0.2	-	0.1	0.1
Copepods	-	-	0.1	0.1	0.1	0.1	-	-
Euphausiids	0.5	-	-	0.1	0.3	0.1	-	10.5
Acetes spp	-	-	0.1	0.8	0.5	0.1	-	-
Lucifer sp.	-	-	0.1	-	-	-	0.1	-
Mysid	0.7	-	0.1	-	0.2	0.1	0.1	-
Polychaetes	3.6	-	1.3	0.2	1.8	0.4	0.1	0.1
Nematodes	0.1	-	0.1	-	-	0.1	-	-
Squid	0.9	-	2.6	0.5	3.7	0.1	0.1	0.1
Cuttle fish	-	-	0.6	-	0.3	0.1	0.5	-
Gastropods	0.6	-	0.2	0.1	0.2	0.1	0.1	0.1
Bivalves	0.1	-	0.1	-	-	-	-	-
Lobster (Juvenile)	-	-	-	-	-	-	0.2	-
Young sea horse	-	-	-	-	-	-	-	-
Prawns	9.0	-	5.8	0.1	2.8	5.0	7.6	47.9
Crustacean remains	2.4	-	1.4	1.2	-	2.6	4.4	16.8
Leptocephalus	7.4	-	-	0.2	2.3	0.1	0.1	0.2
Eel	2.1	-	8.4	0.3	3.2	0.4	0.5	2.3
Bregmaceros sp.	2.1	-	1.3	-	25.1	22.5	1.0	0.2
Acropoma sp.	-	-	-	-	-	-	-	-
Flat fish	-	-	-	-	-	-	-	0.1
Silver belly	-	-	-	0.1	-	-	-	-
Other teleost fish	1.3	-	2.4	6.9	0.4	1.6	29.8	7.3
Digested matter	48.3	-	55.1	45.2	47.2	52.1	52.4	6.4
Non-food items	-	-	-	-	-	-	-	-

..3..

Table 3. (contd...)

	March		April		May		June	
	1992	1993	1992	1993	1992	1993	1992	1993
Alima	10.9	1.7	0.6	1.1	16.5	10.8	0.1	1.2
Squilla	2.2	0.1	0.3	0.3	3.9	2.9	0.4	0.7
Zoea	-	0.1	-	0.1	0.1	0.1	-	-
Megalopa	15.0	13.8	0.5	0.7	6.9	15.4	0.4	16.6
Crab	1.0	0.4	-	48.4	0.5	0.1	5.6	2.2
Amphipods	-	2.4	0.1	1.0	1.9	1.6	0.1	0.1
Isopods	-	0.1	-	0.1	0.1	0.1	0.1	-
Copepods	-	9.4	4.8	0.1	0.1	1.2	-	-
Euphausiids	-	1.2	-	-	-	-	0.1	5.7
Acetes spp.	5.0	0.3	0.1	0.1	0.9	1.7	0.1	0.1
Lucifer sp.	0.1	-	-	-	0.1	-	0.1	-
Mysid	-	0.1	0.1	-	0.1	0.5	0.1	-
Polychaetes	-	0.2	-	1.3	-	-	0.6	2.4
Nematodes	0.1	0.1	-	0.2	-	-	-	-
Squid	0.1	-	1.2	0.1	0.6	0.3	0.1	0.3
Cuttle fish	0.1	-	0.2	-	-	-	0.1	-
Gastropods	0.1	0.1	7.5	0.3	0.1	0.1	0.1	0.5
Bivalves	-	0.1	-	0.1	-	-	0.1	0.6
Lobster (Juvenile)	-	-	-	-	-	0.1	0.1	0.3
Young sea horse	-	0.1	-	-	-	-	0.1	-
Prawns	3.2	0.2	0.3	1.8	1.3	5.2	0.4	3.6
Crustacean remains	7.0	2.8	3.8	-	4.6	30.9	2.1	-
Leptocephalus	2.3	-	2.6	-	0.4	1.5	0.3	1.0
Eel	0.7	0.2	-	0.6	0.3	0.2	0.3	-
Bregmaceros sp.	1.7	1.7	-	-	0.6	-	1.0	-
Acropoma sp.	-	-	2.2	-	-	-	-	-
Flat fish	-	-	-	-	-	-	-	-
Silver belly	-	-	-	-	-	-	-	-
Other teleost fish	22.7	1.4	11.6	11.8	1.6	1.2	0.5	7.9
Digested matter	27.8	63.5	64.1	31.9	59.4	26.0	81.5	62.5
Non-food items	-	-	-	-	-	-	-	-

Table 4. Index of preponderence of food items of P. hamrur in different latitudes

Items	16°N	17°N	18°N	19°N	20°N
Alima	2.40	0.70	10.10	2.20	7.50
Squilla	0.10	0.80	2.90	0.90	1.60
Zoea	-	0.01	0.01	0.10	-
Megalopa	2.20	4.20	11.80	4.50	15.60
Crab	1.40	2.80	0.70	4.30	0.50
Amphipods	0.10	0.04	0.60	2.50	0.10
Isopods	-	0.01	0.01	0.10	-
Copepods	0.10	0.02	0.01	0.60	-
Euphausiids	-	1.70	3.30	0.20	22.70
Acetes spp.	0.10	0.30	0.40	0.10	0.10
Lucifer sp.	-	-	0.01	0.01	-
Mysid	-	0.01	0.01	0.03	-
Polychaetes	0.10	1.20	0.02	2.50	0.10
Nematodes	-	0.01	-	0.03	-
Cuttle fish	-	0.01	0.01	0.01	-
Gastropods	0.10	0.30	0.10	0.10	0.10
Bivalves	-	0.02	-	0.10	-
Lobster (juvenile)	-	0.10	-	0.01	-
Young sea horse	-	-	-	0.01	-
Prawns	-	1.20	0.80	4.70	2.10
Crustacean remains	3.20	4.40	5.40	3.70	3.20
Leptocephalus	-	0.30	0.80	0.10	-
Eel	0.20	0.40	0.01	0.50	0.10
Bregmaceros sp.	-	0.70	5.10	0.40	2.30
Acropoma sp.	-	-	-	0.03	-
Flat fish	-	-	-	0.01	-
Silver belly	-	-	0.01	-	-
Other teleost fish	0.10	4.50	5.50	5.00	1.50
Digested matter	89.80	76.20	51.80	67.10	42.50
Non-food items	0.10	0.03	-	0.12	-

Table 5. Index of preponderence of food items of *P. hamrur* in different depth zones

Items	<50 m	51-100 m	101-150 m	151-200 m	>200 m
Alima	1.79	1.69	2.80	8.90	0.20
Squilla	1.00	0.64	2.60	2.50	1.80
Zoea	0.02	0.01	-	-	-
Megalopa	4.36	6.30	4.80	5.30	0.10
Crab	2.32	4.80	3.90	0.10	-
Amphipods	1.10	0.13	0.20	3.30	-
Isopods	0.08	0.01	0.10	0.03	-
Copepods	0.13	0.01	0.40	3.80	-
Euphausiids	0.01	1.78	-	0.30	-
Acetes spp.	0.15	0.15	0.20	0.60	-
Lucifer sp.	0.01	-	0.10	-	-
Mysid	0.02	0.01	0.30	0.10	-
Polychaetes	1.50	1.10	0.30	0.02	0.10
Nematodes	0.01	0.01	-	-	-
Squid	0.10	0.01	2.50	0.20	0.70
Cuttle fish	0.03	0.02	-	0.01	-
Gastropods	0.24	0.08	0.20	0.10	-
Bivalves	0.02	0.01	-	-	-
Lobster (juvenile)	0.07	0.01	-	-	-
Young sea horse	-	0.01	-	-	-
Prawns	5.35	1.54	7.00	0.21	8.40
Crustacean remains	5.50	2.30	8.70	8.20	2.40
Leptocephalus	0.30	0.01	3.40	0.10	-
Eel	1.00	0.12	0.10	-	-
Bregmaceros spp.	0.49	0.64	1.10	6.32	-
Acropoma spp.	-	-	2.00	0.30	-
Flat fish	0.01	-	-	-	-
Silver belly	-	0.01	-	-	-
Other teleost fish	6.65	1.07	7.40	1.90	6.20
Digested matter	67.70	77.60	51.20	57.60	80.00
Non-food items	0.09	-	0.70	0.11	-

Table 6. Index of preponderence of food items of *P. hamrur* in different size groups

Length range (mm) Items	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-150	151-160
Alima	12.3	-	9.9	-	1.5	1.2	0.5	3.6	4.7	9.7
Squilla	-	3.2	3.5	1.3	1.8	4.2	0.1	0.6	1.4	4.0
Zoea	-	-	-	-	-	-	-	-	-	0.1
Megalopa	12.3	4.3	19.9	12.4	37.8	2.5	4.6	9.8	2.1	5.7
Crab	-	-	-	-	-	1.0	0.4	-	0.8	2.4
Amphipods	-	4.9	3.4	1.8	3.1	7.7	0.8	1.4	1.5	0.7
Isopods	-	-	-	-	-	-	-	0.1	0.1	-
Euphausiids	-	6.1	-	-	0.1	-	0.1	15.1	9.2	4.5
Acetes spp.	4.1	-	-	0.9	0.1	-	0.1	0.9	0.2	1.2
Lucifer sp.	-	-	-	-	-	-	-	-	0.1	-
Copepods	2.0	3.1	3.4	0.9	0.4	2.1	0.3	4.3	2.2	0.6
Mysid	-	-	-	-	-	1.4	0.1	0.1	0.1	0.1
Polychaetes	-	-	-	-	0.8	-	0.8	-	0.3	1.3
Nematodes	-	-	-	-	-	-	-	-	-	-
Squid	-	-	-	1.8	0.4	1.7	0.1	-	1.3	0.1
Cuttle fish	-	-	-	-	-	-	-	-	-	-
Gastropods	0.5	0.1	0.2	0.2	0.1	-	0.7	0.8	-	16.0
Bivalves	0.4	0.1	0.1	0.1	0.1	-	-	-	-	-
Lobster (juvenile)	-	-	0.1	0.1	-	-	-	-	-	-
Young sea horse	-	-	0.1	-	-	-	-	-	-	-
Prawns	3.0	2.9	8.6	2.5	0.9	6.1	0.7	68.2	-	-
Crustacean remains	7.9	4.7	8.1	8.4	2.9	0.6	-	4.9	-	-

Table 6. (contd....)

Length range (mm) items	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-150	151-160
Leptocephalus	0.2	0.1	0.1	-	0.1	-	-	-	-	-
Eel	0.5	1.6	1.1	0.1	0.2	-	-	1.6	-	-
Bregmaceros sp.	0.4	2.4	0.1	1.4	0.2	-	-	-	-	-
Acropoma sp.	-	-	0.1	-	-	-	-	-	-	-
Flat fish	-	-	-	-	-	-	-	4.7	-	-
Silver belly	-	-	0.1	-	-	-	-	-	-	-
Other teleost fish	6.6	0.7	2.8	10.8	13.1	3.1	3.3	12.2	50.0	-
Digested matter	65.0	67.4	61.8	54.4	55.1	75.5	75.6	3.9	37.0	84.0

Table 6. (contd.....)

Length range (mm) Items	161-170	171-180	181-190	191-200	201-210	211-220	221-230	231-240	241-250	251-290
Alima	4.9	1.8	2.1	1.1	7.6	1.5	2.8	-	-	-
Squilla	0.6	1.9	0.8	0.6	0.8	6.5	-	0.2	-	-
Zoea	-	-	0.1	-	0.1	-	-	-	-	-
Megalopa	5.9	5.3	4.5	5.9	13.0	0.5	8.0	2.3	-	-
Crab	1.6	5.9	4.7	8.2	1.2	0.9	0.4	-	-	-
Amphipods	0.4	0.6	0.6	0.8	0.8	0.2	1.2	-	-	-
Isopods	0.1	0.1	0.1	0.1	0.1	0.1	0.7	-	-	-
Euphausiids	0.3	0.2	0.5	0.5	0.6	-	-	0.4	-	-
<u>Acetes</u> spp.	0.5	0.1	0.2	0.4	0.3	-	-	0.4	-	-
<u>Lucifer</u> sp.	-	0.1	-	0.1	-	-	-	-	-	-
Copepods	0.4	0.1	0.1	0.1	0.1	-	-	-	-	-
Mysids	0.2	-	0.1	0.1	-	-	-	-	-	-
Polychaetes	0.4	3.7	2.6	3.8	1.7	4.9	5.8	-	13.0	-
Nematodes	0.1	0.1	0.1	0.1	-	0.1	-	-	-	-
Squid	0.1	0.1	0.1	0.1	0.3	-	0.8	0.4	-	-
Cuttle fish	-	-	0.1	0.1	0.7	-	-	-	-	-
Gastropods	-	-	-	1.8	-	-	-	0.1	0.4	0.1
Bivalves	-	-	-	-	-	-	-	-	-	-
Lobster (juvenile)	-	-	-	-	-	-	-	-	0.1	1.4
Young sea horse	-	-	-	-	-	-	-	-	-	-
Prawns	8.2	-	-	13.2	16.2	-	2.1	0.3	0.2	0.8
Crustacean remains	4.1	-	-	5.5	2.3	59.3	0.7	10.0	9.4	4.2
Leptocephalus	-	4.6	-	10.9	1.9	-	0.4	1.2	0.5	0.1

Table 6. (contd...)

Length range (mm) items	161-170	171-180	181-190	191-200	201-210	211-220	221-230	231-240	241-250	251-290
Eel	-	-	-	-	-	5.4	-	-	0.4	1.7
<u>Bregmaceros</u> sp.	-	-	-	-	-	6.2	8.7	1.2	0.1	2.9
<u>Acropoma</u> sp.	-	-	-	-	-	-	-	-	-	-
Flat fish	-	-	-	-	-	-	-	-	-	-
Silver belly	-	-	-	-	-	-	-	-	-	-
Other teleost fish	-	-	-	8.2	-	2.4	1.1	1.5	2.0	2.6
Digested matter	57.0	73.8	59.9	41.3	33.6	4.9	79.1	49.8	62.9	55.8

Table 7. Feeding intensity of P. hamrur during July, 1991 to June, 1993

Month		Empty	Trace	1/4 full	1/2 full	3/4 full	Full
July	1991	23.10	26.90	19.20	19.20	3.80	7.70
August		-	-	-	-	-	-
September		-	-	-	-	-	-
October		20.00	16.00	32.00	28.00	4.00	-
November		20.30	49.10	27.20	3.40	-	-
December		10.30	15.50	43.20	17.30	10.30	3.40
January	1992	-	16.00	18.20	47.72	11.36	6.82
February		7.30	16.40	21.80	30.90	14.50	9.10
March		4.90	3.90	22.50	40.30	19.60	8.80
April		9.80	18.30	33.80	24.00	12.70	1.50
May		-	6.50	37.00	45.70	2.20	8.70
June		6.30	9.10	30.10	39.90	8.40	6.30
July		5.30	19.70	28.90	38.20	5.30	2.60
August		9.90	4.20	49.30	29.60	7.00	-
September		-	7.40	51.90	40.70	-	-
October		8.7	-	47.80	34.80	8.70	-
November		-	-	-	-	-	-
December		10.00	3.40	43.00	30.30	13.30	-
January	1993	2.60	2.60	33.80	40.20	10.40	10.40
February		-	2.90	20.90	32.80	16.50	26.90
March		3.20	-	40.30	45.20	9.70	1.60
April		1.80	5.50	30.90	40.00	18.20	3.60
May		3.20	1.60	31.70	52.40	9.50	1.60
June		-	20.00	48.00	16.00	12.00	4.00

Table 8. Index of preponderence of food items in the gut of P. hamrur and N. japonicus taken from same hauls

Food items	Index of food items	
	P. hamrur	N. japonicus
Alima	1.0	0.1
Squilla	10.3	7.4
Zoea	0.1	-
Megalopa	2.6	0.2
Crab	34.7	45.4
Amphipods	1.3	0.5
Copepods	-	0.1
Polychaetes	3.8	0.2
Nematodes	0.1	-
Squid	-	0.4
Cuttle fish	0.7	-
Octopus	-	1.8
Gastropods	0.4	0.1
Lobster (juvenile)	0.2	-
Prawns	15.1	39.8
Crustacean remains	1.1	0.1
Teleost fish	8.7	0.7
Eel	-	-
Brittle star	-	0.1
Digested matter	19.8	2.7

Fig. 2 Pie diagram showing the gross composition of food of *P. hamrur* during 1991-92 and 1992-93.

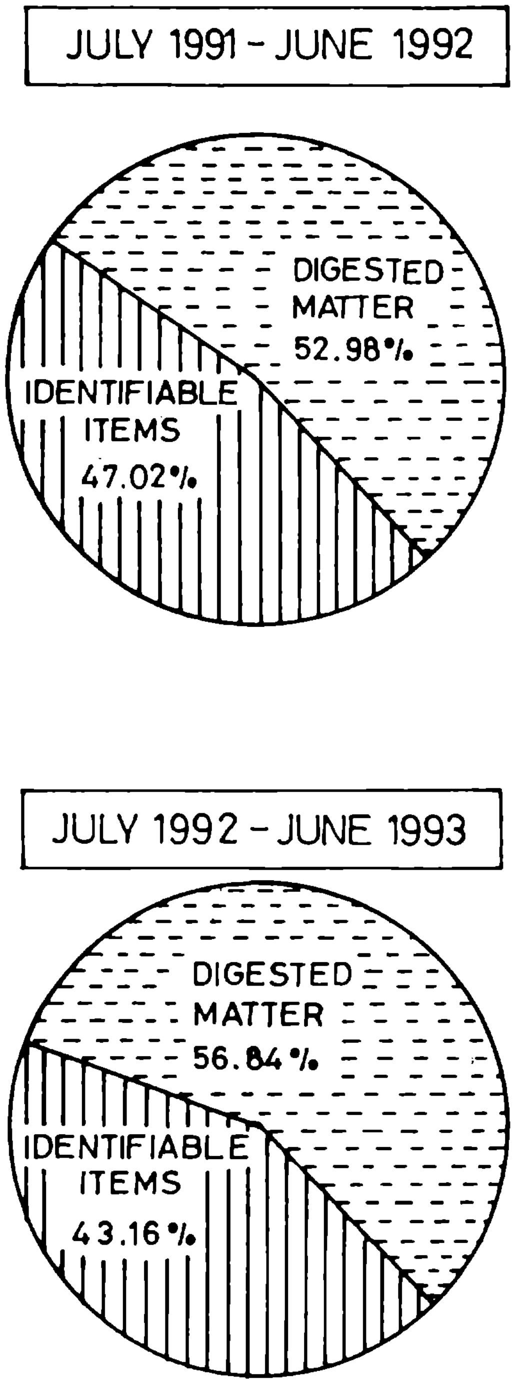

JULY 1991 - JUNE 1992
DIGESTED MATTER 52.98%
IDENTIFIABLE ITEMS 47.02%
JULY 1992 - JUNE 1993
DIGESTED MATTER 56.84%
IDENTIFIABLE ITEMS 43.16%

Fig. 2

Fig. 3 Percentage index of identifiable food items in _P. hamrur_ during 1991-92 and 1992-93.

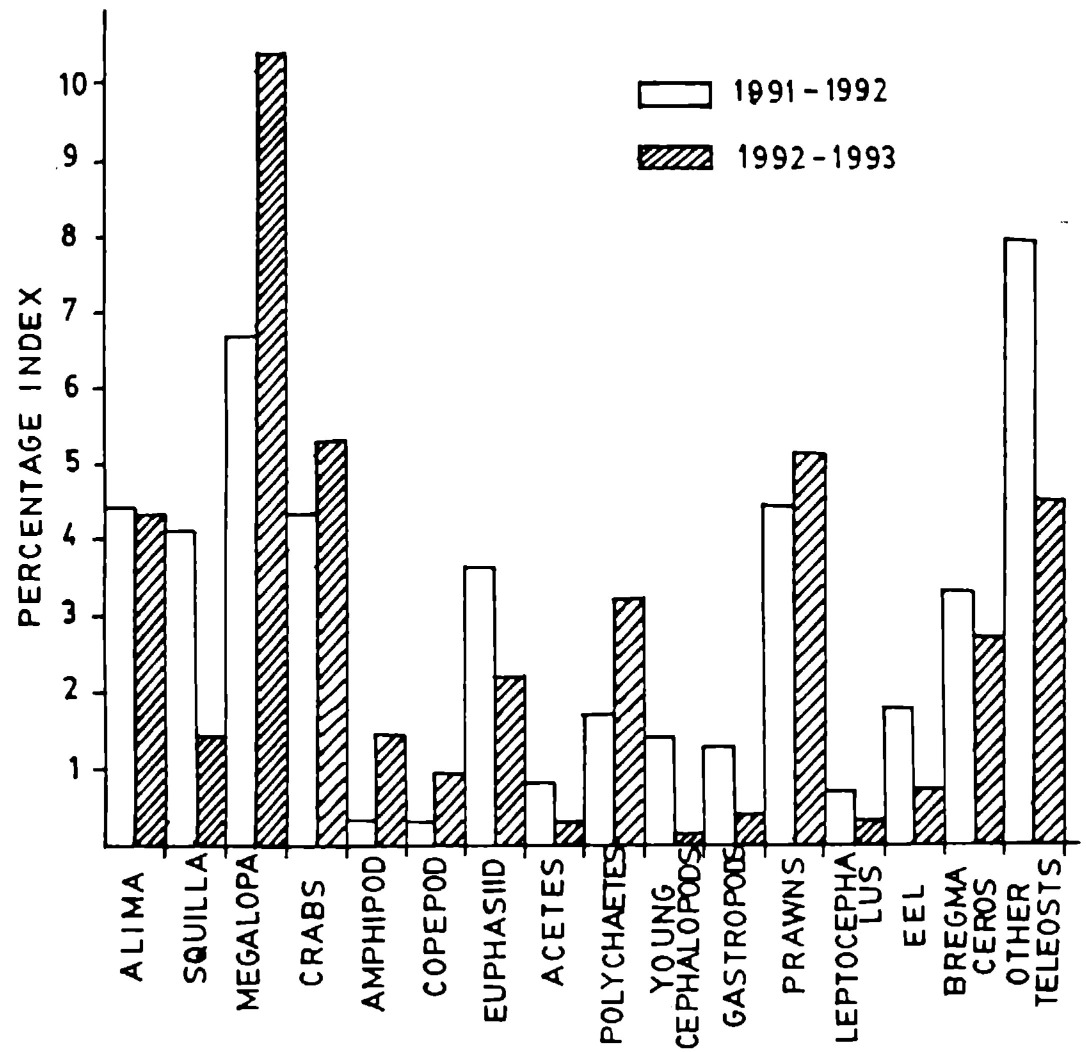

PERCENTAGE INDEX
10
9
8
7
6
5
4
3
2
1
1991-1992
1992-1993
ALIMA
SQUILLA
MEGALOPA
CRABS
AMPHIPOD
COPEPOD
EUPHASIID
ACETES
POLYCHAETES
YOUNG CEPHALOPODS
GASTROPODS
PRAWNS
LEPTOCEPHALUS
EEL
BREGMACEROS
OTHER TELEOSTS

Fig. 3

Fig. 4 (a) Monthly variations in relative condition factor (male and female combined)

(b) Monthly variations in gastro-somatic index (GSI)

(c) Relationship between gastro-somatic index and relative condition factor in *P. hamrur*

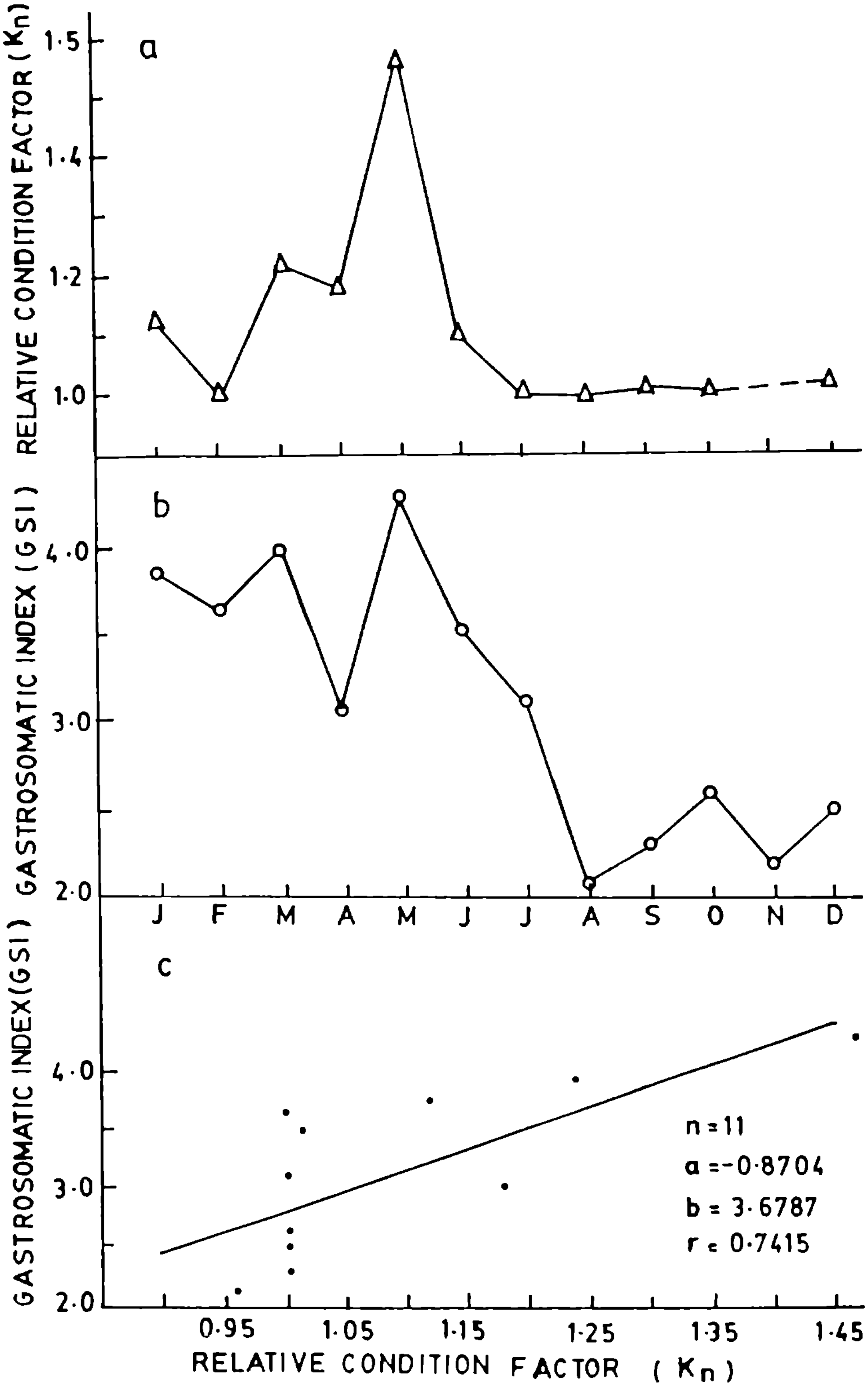

a
RELATIVE CONDITION FACTOR (Kn)
1·5
1·4
1·2
1·0
b
GASTROSOMATIC INDEX (GSI)
4·0
3·0
2·0
J F M A M J J A S O N D
c
GASTROSOMATIC INDEX(GSI)
4·0
3·0
2·0
n = 11
a =-0·8704
b = 3·6787
r = 0·7415
0·95 1·05 1·15 1·25 1·35 1·45
RELATIVE CONDITION FACTOR (Kn)

Fig. 4

MATURATION AND SPAWNING

4. MATURATION AND SPAWNING

4.1 Introduction

Information on the reproductive behaviour of a fish stock is very essential for its exploitation and proper management. Studies on the maturation cycle and spawning are essential for understanding and predicting the changes the population likely to undergo during a year. Information relating to population stability and year class fluctuations can be obtained by undertaking studies on reproductive biology. These fluctuations may be a major factor determining the variations in production from year to year. An understanding of the age and size at which the fish attains sexual maturity, time and duration of spawning and rate of regeneration of the stock are important for judicious management of the fishery resources at an optimum level. Information on the sex ratio and reproductive potential of the stock calculated from fecundity estimation is useful to assess the rate of recruitment of the stock.

Not much work has been done on the breeding biology of priacanthids from Indian waters. The only available information from India is that given by Rao (1984) and Luther et al. (1988) on Priacanthus macracanthus from the north east coast of India. Studies on reproductive biology of P. macracanthus and P. tayenus were attempted in the south east Asian waters (Chomjurai, 1970; Wetchagarun, 1971; Chantawong et al., 1984 and Ambak et al., 1987) where these two species are abundant and form a good fishery. The reproductive biology of the above two species were studied by Lester and Watson (1985) from Hong Kong waters. Hitherto no attempt has been made to study the maturation and spawning of *P. hamrur* from India or elsewhere and therefore an attempt is made to study various aspects of reproductive biology of this species collected from the north east coast of India.

4. 2 Material and Methods

Samples taken from the catches of the vessels of Fishery Survey of India, Central Institute of Fisheries Nautical Engineering and Training and small mechanised boats based at the Visakhapatnam fishing harbour, during November 1991 to October 1993 were used in this study. In order to study the depth-wise and area-wise variations in maturation and spawning, regular samples were taken from different depths as well as regions. The samples from small mechanised boats were assumed to be from inshore regions below 50 m depth off Visakhapatnam coast as these vessels mostly operate in shallow areas on daily trips.

Sexes were separated by examining the gonads as no external characters indicating the sexes were observed. Total length was measured to the nearest mm whereas total weight was taken to the nearest 0.5 g and weight of the ovary to the nearest 0.01 g. Various methods have been employed in the study of maturation and spawning of fishes, of which observation on the progression of ova as determined by diameter measurements is the most common. Maturity studies based on ova diameter measurements were first attempted by Clark (1934) on Californian sardine. Later many workers have adopted this technique to determine spawning periodicities in fishes (Hickling and Rutenberg, 1936; de Jong, 1939; Bunag, 1956; Prabhu, 1956 and Dharmamba, 1959). Apart from the ova diameter measurement, colour, shape and size of the ovary in relation to body cavity were also considered in fixing the maturity stages. In the case of males only colour, size of testes in relation to body cavity and the shape were considered for determining the stages of maturity. Ovaries were fixed in modified Gilson's fluid (Simpson, 1951) for ova diameter and fecundity studies. 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 only were taken for diameter measurement. Ova being spherical in shape, measurements of ovum were taken using stage micrometer wherein each microdivision equals 0.032 mm.

Maturity stages were quantified according to the external appearance, extent of gonads in relation to length of body cavity, modal size of ova and their appearance under microscope. Though there is a general trend for following the I.C.E.S. scale (Lovern and Wood, 1937) of maturity as done by many workers, in the present study seven stages were recognised following the scale adopted for Sardinella longiceps (Val) by Antony Raja (1966). Seven stages were identified with sub divisions to the Stage II and Stage VII and these stages were allotted to both males and females.

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

$$GSI = \frac{\text{Weight of the gonad}}{\text{Weight of the fish}} \times 100 \qquad (3)$$

This index was calculated only for females. Values were calculated on a monthly basis.

Size at first maturity was calculated for males and females by grouping them in 5 mm groups. The first, second and third stages were treated as maturing and stages four and above were considered as mature.

To determine fecundity, a portion was taken from the middle region of the ovary and weighed to the nearest 0.001 g. All the ova, contained in the sample were counted with the help of a counting slide. The number of mature ova in the whole ovary was thus calculated from this value based on the total ovary weight. Altogether 42 specimens ranging from 121 to 240 mm length were used for the purpose of estimating fecundity. The least square method was applied to find out the relation between fecundity and total length, body weight and ovary weight. The regression analysis and test of significance of 'r' values so obtained were estimated as per standard procedures (Snedecor and Cochran, 1967). The correlation coefficient obtained from the regression analysis of the data of fecundity and total length and body weight and their logarithmic transformation did not vary significantly (1%) and therefore, the former has been used for diagrammatic representation.

The males and females were grouped in 5 mm length intervals for different months to study the length-wise and month-wise variation in sex ratio. Similarly, the numbers in either sexes were tabulated against each degree latitude section from 16°N to 21°N and against different depth ranges from below 50 m to 250 m in order to ascertain whether there is any segregation of sex in different latitudes and depth zones, distribution of various stages of maturity at different depths was examined to find out the probable spawning migration if any in this species. Fishes with different maturity stages were broadly classified as immature (I, IIA), maturing (IIB, III, IV), mature (V and VI) and spent (VIIA, VIIB) for the purpose of studying the depth-wise distribution of different maturity stages. X^2 test and variance test on homogeneity were carried out as per standard procedures (Snedecor and Cochran, 1967) and the results were compared against 5% and 1% table values.

4.3 RESULTS

4.3.1 Macroscopic study of the gonads

Ovary: The ovaries are paired symmetrical organs lying ventral to the air bladder. The posterior side is slightly broader than the anterior side giving a broadly triangular shape. The lobes of the ovary remain detached throughout its length except at the junction of genital opening. When fully mature, the ovary occupies more than 75% of the body cavity extending from below oesophagus at the anterior end to little beyond genital aperture at the posterior end. Gonads are clearly visible in specimens of 65-70 mm lengths. Ovary is lightly pink or flesh coloured in the earlier stages which changes to bright yellow or orange red as it matures. The superficial blood vessels of the ovaries become enlarged and conspicuous with the advancement of ovarian maturation.

Testes: The testes first appear as slender, translucent, filament like structures, slightly broadened posteriorly and light cream or white in colour. As maturity advances, they become broad, leaf like and change into more pinkish in colour. When fully mature they become milky and occupy full length of the body cavity. Vas deferens is inconspicuous in mature testis and one or two constrictions appear at the margins giving a lobe like appearance.

4.3.2 Maturity stages

Stage I : The ovary is very small, thin and more or less triangular and pink or flesh coloured. The surface of the ovary is smooth with no sign of blood vessels and the ovaris are symmetrical. The oviducts are reduced and not very distinct. The oocytes are not visible to naked eye. Length of ovary is between 4.00 mm and 6.00 mm according to the size of the fish and occupies about 20% of the length of the body cavity. Fishes of this stage are rarely caught by the FSI vessels. They were found in large numbers during the month of May 1993 in the landings at the fishing harbour from small mechanised boats.

The testis is extremely small, thin, filament like and white in its colouration, occupying less than one third of the length of the body cavity.

Stage IIA : The ovary becomes enlarged in size, light pink or flesh coloured, and the oocytes are clearly visible under microscope. Eggs become opaque and closely arranged. The ovary measures 8.00 to 12.00 mm length and occupies about one-fourth of the length of the body cavity. The ova diameter varies from 0.032 to 0.128 mm with mode at 0.064 mm. Specimens in this stage were seen only during the month of March 1992 and May 1993.

The testis becomes little more thicker, broader, slightly elongated, light pink in colour and occupies less than one third of the body cavity.

Stage IIB : The ovary is dull red or deep flesh coloured and occupies about 25% of the length of the body cavity. The shape is not as distinct as in the case of II and tunica is very thin and soft. The ova are not clearly visible to the naked eye, and the diameter varies between 0.032 and 0.128 mm with mode at 0.064 mm.

The size and shape of testis of this stage resemble that of Stage IIA. However, they are larger in size, proportionate to the relatively larger size of the fish at this stage.

Stage III : At this stage pink colour of the ovary transforms to yellow or orange and blood vessels become slightly distinct. The ovary occupies 35-45% of the length of the body cavity. The opaque eggs become visible to naked eye. The major portion of the ova measures between 0.064 and 0.160 mm dia. with a mode at 0.096 mm.

The testis is well developed and thickened, pinkish or creamy in colour and occupies nearly half the body cavity.

Stage IV : The ovary becomes bright yellow or orange red in colour and occupies nearly 75% of the body cavity. The blood vessels are conspicuous with numerous blood capillaries. The ova diameter varies from 0.128-0.256 mm with a distinct mode at 0.160 mm.

Testis is creamy white with pinkish tinge and occupies about half of the body cavity.

Stage V : Ovary is bright yellow or orange coloured, blood vessels are prominent on the surface, granular in appearance indicating the presence of mature eggs. Ovary occupies about 75% of the body cavity. Ovarian wall becomes thin and the thickly packed eggs are clearly visible to naked eye. The eggs, opaque to translucent with yellow tinge, measure 0.128 to 0.288 mm in dia. with a mode at 0.224 mm.

At this stage the testis becomes more enlarged in size than in Stage IV. The pink colour of the testis disappears and becomes more milky and soft. It occupies a major portion of the body cavity.

Stage VI : Ovary bright yellow in colour, occupies more than 75% of the body cavity. Ova are ripe, translucent and with distinct oil globule. This type of ovary was rarely observed.

The testis, milky white in colour, becomes very extensive and fleshy and occupies the entire length of the body cavity. On exerting slight pressure on the testis milt oozes out.

Stage VIIA : The colour of the ovary is same as in the previous stage. It is flaccid, shrunk and collapsed and occupies nearly half the body cavity. The ova are of the sizes of IV and V stages. Ripe translucent ova as observed in Stage VI are seen in this stage also. This stage is determined only by examining the size of ova and size of ovary in relation to the body cavity. Larger fishes with small ovary containing ripe ova are treated here as partially spent/half spent.

The testis, milky white in colour, becomes shrunken and reduced and occupies nearly half of the body cavity.

Stage VIIB : Ovary becomes shrunk, narrower, loose and pale yellow in colour. The blood capillaries disappear. The ovary becomes pale yellow membranous sack with no distinct eggs.

The testis becomes reduced to very small in size, often to little remnants which may even disappear completely.

4.3.3 Development of ova to maturity

Diameter measurements of ova from ovaries of various maturity stages (Fig.5) show that there is only one distinct mode in all stages indicating the development of a single batch/group of ova. No measurements of ova were taken in the case of Stage I as the eggs are not distinct even under the microscope. In Stage IIA and IIB, the ova were distributed at a modal value of 0.064 mm. In Stage III, the mode was distinct at 0.096 mm and the distribution had a positive skewness. This mode progresses to 0.160 mm in Stage IV, 0.224 mm in Stage V and 0.288 mm in Stage VI. In partially spent specimens, the ovary contains eggs that can either be assigned to Stage V or VI, having the modal ova diameter of 0.256 mm. The ovary of the fully spent specimens appears to be a membranous sac with a little loose ovigerous tissues and having either a few or no distinct eggs. In the spent recovery Stage (IIB) the ovaries contain eggs of the same size similar to that of immature Stage IIA.

4.3.4 Spawning season

The seasonal distribution of maturity stages of 602 males and 1135 females during 1991-92 and 322 males and 828 females in 1992-93 were used to elucidate the probable spawning period of P. hamrur. The percentage occurrence of males and females in different stages of maturity during November 1991 to October 1992 and November 1992 to October 1993 is given in Table 9-12. It could be seen that the distribution of different maturity stages in both the sexes followed more or less similar pattern. However, the maturity stages of females are considered more relevant in delineating the spawning cycles and therefore observations followed were based on females alone.

Immature specimens at Stage I and Stage IIA were observed only during the months of May 1993 in the samples taken from Visakhapatnam fishing harbour in the landings of small mechanised crafts operating in the inshore areas. Immature fishes with Stage IIA were observed from the survey vessels in the month of March 1992 from areas below 50 m.

Observations on occurrence of different maturity stages in 1991-92 revealed that fishes at Stage IV, V and VI were more in November and December 1991. In January 1992, Stages V, VI and partially spent forms were more. In February and March partially spent specimens were found dominant. However in March all stages were present except Stage I. In April and May, the percentage of totally spent specimens was very high forming 64% and 79% respectively. In June and July, the percentage of spent resting specimens (Stage IIB) was high and during August and September, the Stages III and IV were dominant. Stage IV was predominant in September and October whereas partially spent were dominant in the month of December 1992. During January, February and March 1993, Stages IV, V, partially spent and fully spent stages were more or less equally represented while in April, partially spent specimens and spent recovering specimens showed the dominance and formed 44% and 41% respectively. In May, specimens under Stage I, IIA and VIIB were predominant in the samples taken from the catches of smaller mechanised boats. However, during the month of June 1993, though there was landing of priacanthids in the fishing harbour no specimens with Stages I and IIA were observed. On the contrary, totally spent and spent recovering were predominant. In July, spent recovering, Stage III and totally spent were dominant while during August, September and October, spent recovering and Stage III were the dominant stages whereas in October, the Stage III alone contributed 61% of the total numbers observed.

4.3.5 Depth-wise distribution of maturity stages

The distribution of P. hamrur with different maturity stages at various depths is given in Tables 13 and 14. The fishes are grouped into four stages, immature, maturing, mature and spent. X^2 test on the above contingency tables showed the differences to be significant even at 1% level. Immature specimens of both sexes were abundant in areas below 50 m depth and a decline in their abundance was noticed with increase in depth. In the case of females, similar trend was observed in respect of maturing (Stage III & IV) forms whereas the number of mature females were found more in deeper waters (Table 13). But in case of males, maturing specimens (Stages

IIB, III and IV) were seen more in the 100-200 m depth zone and the mature forms in deeper waters. It would thus appear that mature specimens of both sexes were found to be concentrated in the deeper areas viz. 100-200 m depth zone. Spent females were found more in shallow waters, while spent males were slightly more in deeper waters than in shallow waters (Table 14).

4.3.6 Size at first maturity

Sizes at first maturity was calculated for males and females separately. Percentage occurrence of different maturity stages in different size groups in respect of males and females is given in Tables 15-18. It could be seen that 100% of the males and females attained maturity at a length of 141-145 mm. On the basis of this observation data pertaining to 352 males between the length ranges 65-140 mm and 339 females between the size range 70-140 mm were taken to compute the sizes at first maturity. The length at which 50% of the fish attain maturity are shown in Fig.6 which is 123.5 mm in the case of males and 126.5 mm in the case of females.

4.3.7 Gonado-somatic index (GSI)

The GSI values for 1991-92 and 1992-93 are given in Fig.7. During the period 1991-92, the highest value was observed in December 1991. During this month most of the fishes were mature or ripe and no immature or spent specimens were available as seen in (Table 10). The lowest values were observed during April, May, June and July. During April and May, the percentages of spent specimens were more while in June and July, the spent recovering specimens and spent fish dominated which could be attributed as the reason for the low GSI values registered during these months. During the year 1992-93, the highest GSI value was observed during the month of January 1993. More or less similar trends were observed during the months of December 1992 and March 1993. However, the percentages of fishes at Stages IV, V and partially spent were more during these months. The lowest value was noticed in the month of June, when fully spent and spent recovering forms constituted more than 80%. The presence of spent recovering forms and stage III in high percentages may be the reason for comparatively low values recorded during the months of August, September and October.

4.3.8 Fecundity

Fecundity (absolute) in fishes is usually determined by the number of mature ova in the ovary. The reproductive potential of a fish population depends on the number of eggs produced by a fertile female. The number of eggs (fecundity) is related to the length and weight of the fish and the stage and condition of the ovary. Mature ovaries of *P. hamrur* contain only one group of ova with a distinct mode. Therefore, the total number of ova in the mature ovaries was taken to be the fecundity of each individual.

The fecundity of P. hamrur ranged between 15283 (TL 121 mm) and 196700 (TL 207 mm) with an average of 99323 (7616). The results of regression of fecundity on body length, body weight and ovary weight obtained (Fig.8) are shown below:

Fecundity on body length	r = 0.8019	a = 15528.3918
	b = 1352.4498	
Fecundity on body weight	r = 0.8051	a = 5098.4332
	b = 1152.2678	
Fecundity on ovary weight	r = 0.8442	a = 7732.7446
	b = 22738.7187	

The 'r' values were found to be significant at 0.001 level.

4.3.9 Sex ratio

A total of 4147 males and 5334 females collected during the perio June 1989 to April 1993 were used for the purpose of studying sex ratic The ratio between males and females of P. hamrur observed during tl entire period was 1:1.286 showing preponderance of females over mal in the population.

The sex ratio during different months varied from year to year (T 19 and 20). The ratio was not significantly different during June, Au and December 1989, February and December 1990, February to A

November and December of 1991 and January, March and July of 1992. However in the pooled data for the entire period, the difference was significant in all the months except December. A significant dominance of males observed during May of 1990 and 1991 was reflected in the pooled data also.

Sex ratio for different length groups (Table 21) showed an interesting picture of the distribution of sexes at different body lengths. Males were dominant in general in the smaller size groups upto 130 mm with significant dominance in the 81-85 mm, 86-90 mm and 126-130 mm size groups. Though females dominated in size groups beyond 135 mm, the difference was highly significant from 160 mm onwards. Depth-wise distribution of sexes shows a remarkable feature of dominance of females upto a depth of 150 m, with high significance upto 100 m (Table 22) and there was no segregation beyond 150 m depth.

Like the depth-wise distribution, the sex ratio at different latitudinal sections also showed a general dominance of females (Table 23). Though the difference was significant at all latitudes, it was highly significant in the latitude section 20°-21°N and least significant in 16-17°N section.

4.4 Discussion

Information on maturation and spawning of P. hamrur is lacking from Indian waters or elsewhere. Rao (1984) and Luther et al. (1986) gave some information on the spawning periodicity, length at maturity and some biological information on P. macracanthus from north east coast of India. However, species like P. tayenus and P. macracanthus have been studied by several workers from the South China Sea.

The classification of maturity stages as per the scale described by Antony Raja (1966) was adopted for this species also mainly because of the conformity of cyclic return of spent recovering stage as noticed in the above scale. Altogether seven stages, with subdivisions to Stages II and VII were identified. It was observed that the gonads become shrunk and rudimentary especially in completely spent males. The spent recovering ovary which appeared as baggy and larger than the developing virgin ovary was designated as intermediate ovary by Devaraj (1987) in the case of Scomberomorus sp. Spent recovery stage termed as IIB has the same and identical characteristic ova of Stage IIA. However the size of the ovary as welll as fish were found comparatively larger. Contrary to the accepted view, Murty (1984) observed that the spent stage of Nemipterus japonicus returns to Stage V instead of going back to Stage II. Fairbridge (1961) expressed the difficulty in distinguishing the recovering Stage III from an immature Stage III in Neoplatycephalus macrodon. He stated that many of the fish evidently went back to Stage IV without passing through any recognizable Stage III. In the present study spent recovery stage in the case of P. hamrur was treated as Stage IIB. The ova diameter studies revealed a unimodal distribution of developing ova in the maturing ovary.

The mature ovary of P. hamrur does not contain multimodal batches of eggs representing different stages of maturity in contrast to the observations made in respect of N. mesoprion and N. japonicus (Murty, 1981, 1984) and in lizard fishes (Rao, 1983).

Based on the spawning habits, Hickling and Retuenburg (1936) and de Jong (1939) broadly divided teleost fishes into four different groups viz. Spawning once a year during a short and definite period, spawning only once but over a long period, spawning twice in a season and spawning intermittently over a long period. In tropical waters, specimens with ripe ovaries can be found throughout the year, but it is possible that majority of the individuals may spawn within a short and definite period. Ambak et al. (1986) opined that P. tayenus and P. macracanthus from Malaysian waters spawned throughout the year as indicated by the presence of ova with advanced maturation in the ovary. In the case of P. hamrur too, ripe specimens were found throughout the year except during June-August. From the unimodal distribution of ova in the ovary and also on the basis of occurrence of Stages IV, V and VI during different months, it could be concluded that P. hamrur spawns once a year over a prolonged spawning period. Neverthless individuals spawn only over a short period during the spawning season. Rao (1984) noticed in P. macracanthus that ova in the ovary having different stages of maturity are characterised by unimodal distribution and therefore, stated that the spawning period of the fish is not a prolonged one.

While appraising the studies on maturation and spawning in marine teleosts from Indian waters, Qasim (1973) found that along the east coast, spawning mainly occurs during pre-monsoon months (February to May) whereas along the west coast the same is taking place during monsoon (June-September) and post-monsoon (October-January). As there is no published information on the spawning of P. hamrur, it would be appropriate to examine those of related species. Luther et al. (1988) and Rao (1984) observed that the peak spawning season for P. macracanthus in the north east coast is during November-February. Lester and Watson (1985) observed that P.tayenus of Hong Kong waters spawns during a short period in June and July. But in the case of P. macracanthus spawning was observed by the above authors throughout the summer with two peaks, one in May-June and the second in September. Nugroho et al. (1983) mentioned that P. macracanthus of Jawa waters spawns during February-April and September to November. Chomjurai (1970) stated that P. tayenus spawns all round the year with peaks during January to March in the Gulf of Thailand. Spawning of P.tayenus was observed by Chantawong et al. (1984) in Andaman sea (Thailand) during October to April. From the occurrence of fishes with different maturity stages during various months in the present study the spawning season of P. hamrur can be presumed to be during November-February in the first year of observation and during October to March during the second year. It may be noted that specimens with spent recovery stages were observed in April to July. It would thus appear that P. hamrur spawns during October-March in the north east coast of India with slight variations in the extent of the season from year to year. Mature specimens of both sexes were also found to be concentrated in 100-200 m depth zone. X^2 test also showed that there is significant difference in depth-wise distribution of maturity stages in males and females. The abundance of mature specimen of both sexes in the deeper waters could be taken as an indication that the fish spawns in deeper waters. The lack of segregation in sexes beyond 150 m as evident from the sex ratio studies lends support to the above findings.

The size at 50% maturity for P. hamrur was worked out to be 123.5 mm for males and 126.5 mm in females. As females are having slightly faster growth in the early age, both the sexes attain the lengths at about one and a half years. Size at maturity for P. macracanthus from north eastern coast was reported to be 170 mm (Luther et al. 1988). In case of P. tayenus the size at maturity was estimated as 140 mm and 150 mm from Gulf of Thailand (Chomjurai, 1970 and Wetchagarun, 1971) and Andaman sea (Chantawong et al., 1984), respectively. Though the present study indicates that P. hamrur attains maturity at lower size groups in comparison with other species, the age at first maturity is well comparable with other species. The gonado-somatic index is used as a criterion 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 for the year 1992-93 though did not reveal any definite pattern with the identified spawning periods, the GSI values of 1991-92 show close agreement with the above statement as the declining period of GSI in 1991-92 fully synchronised with the spawning period.

Eventhough the general relationship of fecundity with body length and weight was highly significant and positive, a few isolated incidences of values lower than expected (Eg.50116 at 187.0 mm, 51300 at 205.0 mm and 77190 at 208.0 mm) were observed. This could be considered as individual aberrations which may occur at random in any population. The fecundity of P. tayenus and P. macracanthus estimated from Malaysian waters by Ambak et al. (1987) ranged between 10,000 and 47,000. Lester and Watson (1985) estimated the fecundity of a 25 cm P. tayenus from Hong Kong waters at 1,50,000. Chomjurai (1970) and Wetchagarun (1971) estimated the fecundity of P. tayenus from the Gulf of Thailand between 56,000 and 1,52,000. The latter two observations are comparable with the present findings in P. hamrur.

The male to female ratio of P. tayenus from the Gulf of Thailand was found out to be 1:1 by Chomjurai (1970) and Wetchagarun (1971), and 1:0.72 from the Andaman sea (Chantawong et al., 1984). Ambak et al. (1987) found in the lumped data of P. macracanthus and P. tayenus from Malaysian waters a ratio of two males to one female. In the present study the male-female ratio is 1:1.28 showing slight predominance of females. Zacharia et al. (1991) observed a predominance of females, with a male to female ratio of 1:1.6, in P. hamrur collected from the trawl catches at Mangalore. Rao (1984) also observed dominance of females in his studies on P. macracanthus of the north east coast of India. Similar dominance of females over males was observed in many species like Secutor insidiator (Murty, 1990) and Polynemus heptadactylus (Kagwade, 1970). The overall dominance of females could be taken as a general feature of the stock.

Test of variance of homogeneity of sex ratio showed X^2 values significant at 1% level in all the years. This could be attributed to the wide difference in sex ratio during few months as well as non-availability of data during some months of various years. However, the dominance of either sex during different months is probably due to the combined effect of differences in areas and depths of operation and the segregation of sexes at different depths during different months. 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. Though there is an overall dominance of females in the population of P. hamrur, predominance of males was noticed in the early stages of life. Similar observation of predominance of males in smaller length groups and females in larger length groups was observed in Secutor insidiator (Murty, 1990) from Kakinada, east coast of India, and in tiger flat head, Neoplatycephalus macrodon (Fairbridge, 1951).

The latitude-wise sex ratio though significantly different in all latitudes, was most significant in 20-21°N latitude and least significant in 16-17°N sectors. The reason becomes evident by examining the contour maps of these latitudes (Fig.1). Considering the fact that the sex ratio tends to become 1:1 in deeper waters, we can presume that the steep fall of shelf in both 16-17°N and 19-20°N latitudinal sections had influenced the sex ratios of these sections. A reverse influence might have affected the sex ratio in 20-21°N where the deeper areas are comparatively less. The concentration of mature specimens in deeper waters has already been stated as an indication of the fish breeding in deeper waters. The fact that there was no sex-wise segregation beyond 150 m depth could lend support to the above findings. It could be presumed that this species congregates in almost 1:1 ratio in the breeding ground which is delineated as the deeper regions beyond 150 m depth.

Table 9. Percentage occurrence of males of *P. hamrur* in different stages of maturity in different months (1991-92)

Month		I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	Total Nos.
November	1991	-	-	-	59.52	35.71	-	-	-	4.76	42
December		-	-	-	35.48	16.13	32.26	14.51	1.61	-	62
January	1992	-	-	-	38.89	11.11	11.11	-	36.11	2.78	36
February		-	-	-	19.35	-	29.03	9.68	35.48	6.45	31
March		-	22.29	12.10	1.91	2.55	7.01	9.55	28.66	15.92	157
April		-	-	-	-	2.90	8.69	5.78	28.98	53.62	69
May		-	-	1.75	-	-	-	1.75	3.57	92.98	57
June		-	-	29.51	-	1.64	-	-	16.39	52.46	61
July		-	-	60.87	2.17	-	-	-	-	36.96	46
August		-	-	-	43.48	52.17	-	-	-	4.35	23
September		-	-	-	54.54	18.18	18.18	-	-	9.09	11
October		-	-	-	14.29	85.71	-	-	-	-	7

Table 10. Percentage occurrence of females of P. hamrur in different stages of maturity in different months (1991-92)

Month		Stages of maturity									
		I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	Total numbers
November	1991	-	-	-	27.91	20.93	44.19	2.32	-	4.65	43
December		-	-	-	-	17.65	29.41	47.06	5.88	-	17
January	1992	-	-	-	11.11	16.67	22.22	27.78	22.22	-	18
February		-	-	-	2.08	6.25	25.00	6,25	41.67	18.75	48
March		-	12.42	13.72	13.07	4.57	9.15	5.23	33.99	7.84	153
April		-	-	8.00	-	-	10.67	2.67	14.67	64.00	150
May		-	-	-	-	-	-	6.18	14.43	79.38	97
June		-	-	56.87	2.29	3.43	-	1.53	1.14	34.73	262
July		-	-	55.32	5.32	14.89	-	-	2.13	22.34	94
August		-	-	17.76	41.45	15.79	5.26	-	6.58	13.16	152
September		-	-	4.92	39.34	32.79	9.84	-	6.56	6.56	61
October		-	-	7.50	12.50	55.00	22.50	2.50	-	-	40

Table 11. Percentage occurrence of males of P. hamrur in different stages of maturity in different months (1992-93)

Month		I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	Total Nos.
November	1992	-	-	-	-	-	-	-	-	-	-
December		-	-	-	-	-	25.00	-	50.00	25.00	4
January	1993	-	-	-	18.37	24.49	22.45	6.12	26.53	2.04	49
February		-	-	-	-	4.88	26.83	12.16	36.58	19.51	41
March		-	-	-	-	3.45	20.69	-	41.38	34.48	29
April		-	-	20.00	-	-	-	-	80.00	-	5
May		28.20	51.28	1.71	1.71	1.71	-	-	-	15.38	117
June		-	-	10.00	60.00	30.00	-	-	-	-	10
July		-	-	21.43	14.28	14.28	14.28	-	7.14	28.57	14
August		-	-	37.50	25.00	25.00	-	-	-	12.50	8
September		-	-	12.19	21.95	7.32	26.83	21.95	7.32	2.44	41
October		-	-	25.00	50.00	-	25.00	-	-	-	4

Table 12. Percentage occurrence of females of *P. hamrur* in different stages of maturity in different months (1992-93)

Month		Stages of maturity									
		I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	Total numbers
November	1992	-	-	-	-	-	-	-	-	-	-
December		-	-	-	-	6.45	48.39	12.90	22.58	9.68	31
January	1993	-	-	-	4.28	23.57	27.14	0.71	21.43	22.86	139
February		-	-	1.39	1.39	29.17	18.05	1.39	30.55	18.05	72
March		-	-	1.47	-	29.41	22.06	-	26.47	22.06	68
April		-	-	41.18	-	-	2.94	-	44.12	11.76	34
May		21.43	37.86	3.57	2.86	3.57	3.57	-	8.57	18.58	139
June		-	-	38.46	7.69	11.54	-	-	-	42.31	26
July		-	-	31.32	15.66	8.43	6.02	7.23	4.82	26.51	83
August		-	-	27.34	15.53	7.91	9.35	2.88	12.95	17.98	138
September		-	-	50.75	25.37	2.98	1.49	8.95	2.98	7.46	67
October		-	-	29.03	61.29	6.45	-	-	-	3.22	31

Table 13. Contingency table showing depth-wise distribution of different maturity stages of female P. hamrur during 1991-93

Depth (meters)	Stages			
	Immature	Maturing (in number of fishes)	Mature	Spent
Below 50	264	188	80	381
50-100	173	148	83	182
100-200	70	114	97	183

X^2 = 76.44 1% Table X^2 value for 6 df : 16.81

Table 14. Contingency table showing depth-wise distribution of different maturity stages of male P. hamrur during 1991-93

Depth (meters)	Stages			
	Immature	Maturing (in number of fishes)	Mature	Spent
Below 50	131	42	39	149
50-100	50	42	24	54
100-200	29	119	81	164

X^2 = 125 1% Table X^2 value for 6 df : 16.81

Table 15. Percentage occurrence of different maturity stages of male P. hamrur in various size groups (1991-92)

Size group (mm)	Stages of maturity									Total No. of fish
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
81 - 85	-	100.00	-	-	-	-	-	-	-	4
86 - 90	-	100.00	-	-	-	-	-	-	-	13
91 - 95	-	100.00	-	-	-	-	-	-	-	9
96 - 100	-	100.00	-	-	-	-	-	-	-	5
101 - 105	-	66.66	-	33.33	-	-	-	-	-	3
106 - 110	-	16.66	-	83.33	-	-	-	-	-	6
111 - 115	-	6.25	-	87.50	6.25	-	-	-	-	16
116 - 120	-	-	-	63.63	27.27	9.09	-	-	-	22
121 - 125	-	-	-	65.00	20.00	10.00	5.00	-	-	20
126 - 130	-	-	-	46.42	14.28	17.85	3.57	10.71	7.14	28
131 - 135	-	-	5.71	11.42	5.71	2.85	11.42	40.00	22.85	35
136 - 140	-	-	7.89	10.52	2.63	13.15	-	34.21	31.57	38
141 - 145	-	-	19.64	3.57	10.71	8.92	3.57	28.57	25.00	56
146 - 150	-	-	35.71	2.38	11.90	4.76	2.38	14.28	28.57	42
151 - 155	-	-	29.16	4.16	4.16	10.41	4.16	29.16	18.75	48
156 - 160	-	-	6.66	3.33	3.33	33.33	6.66	13.33	33.33	30
161 - 165	-	-	5.88	-	11.76	11.76	17.64	17.64	35.29	17
166 - 170	-	-	17.39	-	4.34	8.69	8.69	8.69	52.17	23
171 - 175	-	-	21.21	3.03	6.06	-	12.12	9.09	48.48	33
176 - 180	-	-	20.00	6.66	13.33	3.33	10.00	13.33	33.33	30

Table 15. (contd...)

Size group (mm)	Stages of maturity									Total No. of fish
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
181 - 185	-	-	-	3.44	10.34	6.89	3.44	20.68	55.17	29
186 - 190	-	-	-	3.44	6.89	6.89	6.89	13.79	62.06	29
191 - 195	-	-	-	18.51	22.22	3.70	-	3.70	51.85	27
196 - 200	-	-	7.14	14.28	14.28	14.28	7.14	14.28	28.57	14
201 - 205	-	-	-	20.00	-	20.00	30.00	10.10	20.00	10
206 - 210	-	-	-	-	-	16.66	-	33.33	50.00	6
211 - 215	-	-	-	-	33.33	-	-	-	66.66	3
216 - 220	-	-	-	-	-	-	-	100.00	-	2
221 - 225	-	-	-	-	-	-	-	-	-	-
226 - 230	-	-	-	-	-	-	-	-	-	-
231 - 235	-	-	-	-	33.33	-	-	33.33	33.33	3
236 - 240	-	-	-	-	-	-	-	100.00	-	1

Table 16. Percentage occurrence of different maturity stages of female P. hamrur in various size groups (1991-92)

Size group (mm)	Stages of maturity									No. of fish examined
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
81 - 85	-	100.00	-	-	-	-	-	-	-	1
86 - 90	-	100.00	-	-	-	-	-	-	-	3
91 - 95	-	100.00	-	-	-	-	-	-	-	6
96 - 100	-	100.00	-	-	-	-	-	-	-	7
101 - 105	-	100.00	-	-	-	-	-	-	-	1
106 - 110	-	20.00	-	80.00	-	-	-	-	-	5
111 - 115	-	-	-	88.88	11.11	-	-	-	-	9
116 - 120	-	-	-	63.63	13.63	13.63	9.09	-	-	22
121 - 125	-	-	-	64.28	10.71	17.85	7.14	-	-	28
126 - 130	-	-	-	60.86	4.34	17.39	8.69	4.34	4.34	23
131 - 135	-	-	-	42.85	8.57	14.28	-	20.00	14.28	35
136 - 140	-	-	-	11.42	14.28	8.57	5.71	17.14	37.14	35
141 - 145	-	-	11.11	-	8.33	25.00	-	13.88	41.66	36
146 - 150	-	-	31.42	2.85	-	5.71	2.85	14.28	42.85	35
151 - 155	-	-	40.42	-	-	6.38	4.25	8.51	40.42	47
156 - 160	-	-	27.50	-	2.50	15.00	5.00	22.50	27.50	40
161 - 165	-	-	33.33	2.56	-	10.25	5.12	5.12	43.58	39
166 - 170	-	-	33.96	-	3.77	9.43	11.32	9.43	32.07	53

..2..

Table 16 (contd....)

Size group (mm)	Stages of maturity									No. of fish examined
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
171 - 175	-	-	32.92	6.09	7.31	3.65	-	9.75	40.24	82
176 - 180	-	-	44.94	3.37	5.61	2.24	-	6.74	37.07	89
181 - 185	-	-	33.69	4.34	8.69	5.43	2.17	5.43	40.21	92
186 - 190	-	-	34.31	11.76	12.74	2.94	1.96	5.88	30.39	102
191 - 195	-	-	25.74	6.93	11.88	5.94	3.96	11.88	33.66	101
196 - 200	-	-	17.64	20.58	22.05	7.35	-	8.82	23.52	68
201 - 205	-	-	17.85	8.92	16.07	7.14	3.57	21.42	25.00	56
206 - 210	-	-	5.88	-	11.76	26.47	8.82	35.29	11.76	34
211 - 215	-	-	3.12	18.75	34.37	12.50	6.25	12.50	12.50	32
216 - 220	-	-	10.52	-	10.52	10.52	5.26	31.57	31.57	19
221 - 225	-	-	9.09	-	27.27	0.09	0.09	27.27	18.18	11
226 - 230	-	-	-	28.57	14.28	-	14.28	28.57	14.28	7
231 - 235	-	-	-	-	33.33	16.66	-	50.00	-	6
236 - 240	-	-	-	-	-	-	-	50.00	50.00	4
241 - 245	-	-	-	-	50.00	-	-	50.00	-	2
246 - 250	-	-	-	-	25.00	-	25.00	-	50.00	4
251 - 255	-	-	-	-	100.00	-	-	-	-	1

Table 17. Percentage occurrence of different maturity stages of male P. hamrur in various size groups (1992-93)

Size group (mm)	Stages of maturity									No. of fish examined
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
66 - 70	100.00	-	-	-	-	-	-	-	-	5
71 - 75	100.00	-	-	-	-	-	-	-	-	6
76 - 80	100.00	-	-	-	-	-	-	-	-	15
81 - 85	50.00	50.00	-	-	-	-	-	-	-	8
86 - 90	18.18	81.82	-	-	-	-	-	-	-	11
91 - 95	3.70	96.30	-	-	-	-	-	-	-	27
96 - 100	-	92.85	-	7.14	-	-	-	-	-	14
101 - 105	-	57.14	-	28.57	14.28	-	-	-	-	7
106 - 110	-	28.57	-	42.85	28.57	-	-	-	-	7
111 - 115	-	14.28	-	42.85	28.57	14.28	-	-	-	7
116 - 120	-	9.09	-	36.36	27.27	27.27	-	-	-	11
121 - 125	-	-	-	33.33	33.33	33.33	-	-	-	12
126 - 130	-	-	-	21.42	7.14	21.42	14.28	35.71	-	14
131 - 135	-	-	11.11	-	11.11	33.33	-	44.44	-	9
136 - 140	-	-	18.18	-	9.09	27.27	27.27	-	18.18	11
141 - 145	-	-	7.69	-	15.38	-	15.38	30.76	30.76	13
146 - 150	-	-	7.14	7.14	14.28	21.42	14.28	14.28	21.42	14
151 - 155	-	-	16.66	8.33	-	8.33	8.33	16.66	41.66	12

..2..

Table 17. (contd...)

Size group (mm)	Stages of maturity									No. of fish examined
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
156 - 160	-	-	5.00	5.00	10.00	25.00	10.00	25.00	20.00	20
161 - 165	-	-	7.69	7.69	7.69	-	7.69	61.53	7.69	13
166 - 170	-	-	6.66	6.66	6.66	13.33	13.33	26.66	26.66	15
171 - 175	-	-	5.26	-	10.53	15.79	10.53	31.58	26.32	19
176 - 180	-	-	-	22.22	-	-	-	44.44	33.33	9
181 - 185	-	-	-	-	-	14.28	-	28.57	57.14	7
186 - 190	-	-	21.42	7.14	21.42	21.42	-	-	35.71	14
191 - 195	-	-	-	20.00	-	40.00	-	40.00	-	5
196 - 200	-	-	-	-	-	50.00	-	-	50.00	2
201 - 205	-	-	-	37.50	-	37.50	-	12.50	12.50	8
206 - 210	-	-	-	-	-	-	-	100.00	-	1
211 - 215	-	-	100.00	-	-	-	-	-	-	2
216 - 220	-	-	-	-	-	-	-	-	-	-
221 - 225	-	-	-	-	-	-	-	100.00	-	1
226 - 230	-	-	-	-	-	100.00	-	-	-	2
231 - 236	-	-	-	-	-	-	-	100.00	-	1

Table 18. Percentage occurrence of different maturity stages of female *P. hamrur* in various size groups (1992-93)

Size group (mm)	Stages of maturity									No. of fish examined
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
71 - 75	100.00	-	-	-	-	-	-	-	-	1
76 - 80	100.00	-	-	-	-	-	-	-	-	12
81 - 85	100.00	-	-	-	-	-	-	-	-	10
86 - 90	40.00	60.00	-	-	-	-	-	-	-	5
91 - 95	33.33	66.66	-	-	-	-	-	-	-	9
96 - 100	12.50	87.50	-	-	-	-	-	-	-	16
101 - 105	-	100.00	-	-	-	-	-	-	-	14
106 - 110	-	88.88	-	11.11	-	-	-	-	-	18
111 - 115	-	-	-	66.66	33.33	-	-	-	-	3
116 - 120	-	-	-	71.42	28.57	-	-	-	-	7
121 - 125	-	-	-	68.42	15.78	15.78	-	-	-	19
126 - 130	-	-	-	61.11	11.11	22.22	-	5.55	-	18
131 - 135	-	-	-	50.00	16.66	8.33	-	16.66	8.33	12
136 - 140	-	-	-	25.00	8.33	16.66	-	25.00	25.00	12
141 - 145	-	-	-	11.76	11.76	-	-	17.64	58.88	17
146 - 150	-	-	3.70	-	25.92	7.40	-	33.33	29.62	27
151 - 155	-	-	10.71	-	21.42	3.57	-	21.42	42.85	28

..2..

Table 18. (contd...)

Size group (mm)	Stages of maturity									No. of fish examined
	I	IIA	IIB	III	IV	V	VI	VIIA	VIIB	
156 - 160	-	-	40.90	9.09	18.18	9.09	-	4.54	18.18	22
161 - 165	-	-	43.33	10.00	-	6.66	-	10.00	30.00	30
166 - 170	-	-	38.09	2.38	4.76	7.14	2.38	23.80	21.42	42
171 - 175	-	-	36.17	4.25	2.12	6.38	-	40.42	10.63	47
176 - 180	-	-	16.92	6.15	7.69	30.76	-	18.46	20.00	65
181 - 185	-	-	30.37	12.96	20.37	3.70	1.85	18.51	22.22	54
186 - 190	-	-	18.96	5.17	13.79	13.79	-	17.24	31.03	58
191 - 195	-	-	21.27	6.38	14.89	19.14	4.25	17.02	17.02	47
196 - 200	-	-	16.66	2.08	25.00	14.58	6.25	14.58	20.83	48
201 - 205	-	-	20.51	5.12	15.38	10.25	7.69	17.94	23.07	39
206 - 210	-	-	12.82	10.25	10.25	20.51	10.25	15.38	20.51	39
211 - 215	-	-	17.94	7.69	17.94	20.51	10.25	12.82	12.82	39
216 - 220	-	-	16.66	12.50	20.83	20.83	4.16	12.50	12.50	24
221 - 225	-	-	14.28	28.57	-	21.42	-	7.14	28.57	14
226 - 230	-	-	12.50	12.50	12.50	37.50	-	12.50	12.50	8
231 - 235	-	-	-	12.50	37.50	12.50	12.50	-	25.00	8
236 - 240	-	-	-	-	28.57	28.57	14.28	-	28.57	7
241 - 245	-	-	-	16.66	33.33	33.33	-	16.66	-	6
246 -250	-	-	33.33	66.66	-	-	-	-	-	3

Table 19. Month-wise sex ratio in *P. hamrur* during 1989-93

Month	Year										Pooled (1989-93)	
	1989		1990		1991		1992		1993			
	M	F	M	F	M	F	M	F	M	F	M	F
January	-	-	75	153**	41	98**	64	45	130	227**	310	523**
February	-	-	137	147	57	48	56	93**	58	111**	308	399**
March	-	-	184	306**	32	21	232	243	112	158**	560	728**
April	-	-	54	79*	42	43	132	300**	9	58**	237	480**
May	-	-	239	173**	233	118**	71	104*	-	-	543	395**
June	81	62	148	186**	192	124**	71	348**	-	-	492	720**
July	74	111**	710	791**	95	87	106	111	-	-	985	1100*
August	239	201	-	-	-	-	96	271**	-	-	335	472**
September	-	-	-	-	-	-	16	61**	-	-	16	61**
October	-	-	-	-	11	34**	8	41**	-	-	19	75**
November	-	-	50	93**	70	60	-	-	-	-	120	153*
December	40	41	96	82	82	68	4	37**	-	-	222	228
											4147	5334**

1% (5%) table X^2 value for 1 d.f. = 3.84 (6.63)

* Sex ratio significantly different from 1:1 at 5% confidence level

** Sex ratio significantly different from 1:1 at 1% confidence level

Table 20. Test of variance of homogeneity of sex ratio in *P. hamrur* during 1989-93.

Year	df	X^2	5% table X^2
1989	3	12.783	7.81
1990	8	68.667	15.51
1991	9	78.429	16.92
1992	10	191.958	18.31
1993	3	18.562	7.81
1989-1993 (Pooled)	37	574.627	

Table 21. Sex ratio of P. hamrur in different length groups

Length groups (mm)	Male (Number)	Female (Number)	Ratio	X^2 value
61 - 65	3	-	1:0	3.000
66 - 70	1	-	1:0	1.000
71 - 75	8	2	1:0.25	3.600
76 - 80	7	3	1:0.43	1.600
81 - 85	22	10	1:0.45	4.500 *
86 - 90	59	39	1:0.66	4.082 *
91 - 95	86	72	1:0.84	1.241
96 - 100	94	96	1:1.02	0.021
101 - 105	236	220	1:0.93	0.561
106 - 110	264	276	1:1.05	0.267
111 - 115	307	288	1:0.94	0.607
116 - 120	317	307	1:0.97	0.160
121 - 125	348	316	1:0.90	1.542
126 - 130	393	325	1:0.83	6.440 *
131 - 135	310	292	1:0.94	0.538
136 - 140	285	291	1:1.02	0.063
141 - 145	251	258	1:1.03	0.096
146 - 150	233	249	1:1.07	0.531
151 - 155	172	226	1:1.31	7.327 **
156 - 160	169	175	1:1.04	0.105
161 - 165	110	192	1:1.75	22.265 **
166 - 170	102	171	1:1.68	17.440 **
171 - 175	90	224	1:2.49	57.185 **
176 - 180	72	205	1:2.85	63.859 **
181 - 185	55	189	1:3.44	73.590 **
186 - 190	45	177	1:3.93	78.487 **
191 - 195	39	175	1:4.49	86.430 **
196 - 200	24	153	1:6.38	94.017 **
201 - 205	13	116	1:8.92	82.240 **

..2..

Table 21. (contd..)

Length groups (mm)	Male (Number)	Female (Number)	Ratio	X^2 value
206 - 210	18	79	1:4.39	38.361 **
211 - 215	4	69	1:17.25	57.877 **
216 - 220	4	46	1:11.50	34.306 **
221 - 225	1	26	1:26.00	23.148 **
226 - 230	1	19	1:19.00	16.200 **
231 - 235	2	15	1:7.50	9.941 **
236 - 240	-	11	0:11.00	11.000 **
241 - 245	1	3	1:3.00	1.000
246 - 250	-	12	0:12.00	12.000 **
251 - 255	-	2	0:2.00	2.000
256 - 260	-	2	0:2.00	2.000
261 - 265	1	1	1:1.00	0.000
266 - 270	-	1	0:1.00	1.000
271 - 275	-	-	-	-
276 - 280	-	-	-	-
281 - 285	-	-	-	-
286 - 290	-	1	0:1.00	1.000

1% (5%) table value of X^2 for 1 df = 3.84 (6.63)

* Significant at 5% level

** Significant at 1% level

Table 22. Sex ratio in P. hamrur in different depth zones during 1989-1993

Sex	Depth range (m)					
	< 50	51-100	101-150	151-200	201-250	Total
Male	568	515	1815	1143	106	4147
Female	1187	968	1988	1103	88	5334
Total	1755	1483	3803	2246	194	9481
Ratio	1:2.10	1:1.88	1:1.10	1:0.97	1:0.83	1:1.29
X^2	218.326	138.374	7.870	0.712	1.670	-

1% (5%) table X^2 value for 1 df = 6.33 (3.84)

Table 23. Sex ratio of *P. hamrur* in different latitudes during 1989-93

Area °N	Male	Female	Total	Ratio	X^2 value
16	466	550	1016	1:1.18	6.945
17	1780	2209	3989	1:1.24	46.138
18	1063	1414	2477	1:1.33	49.738
19	633	748	1381	1:1.18	9.576
20	205	413	618	1:2.01	70.006

5% (1%) table X^2 value for 1 df = 3.84 (6.63)

Fig. 5 Percentage frequency of ova diameter in various maturity stages of *P. hamrur*.

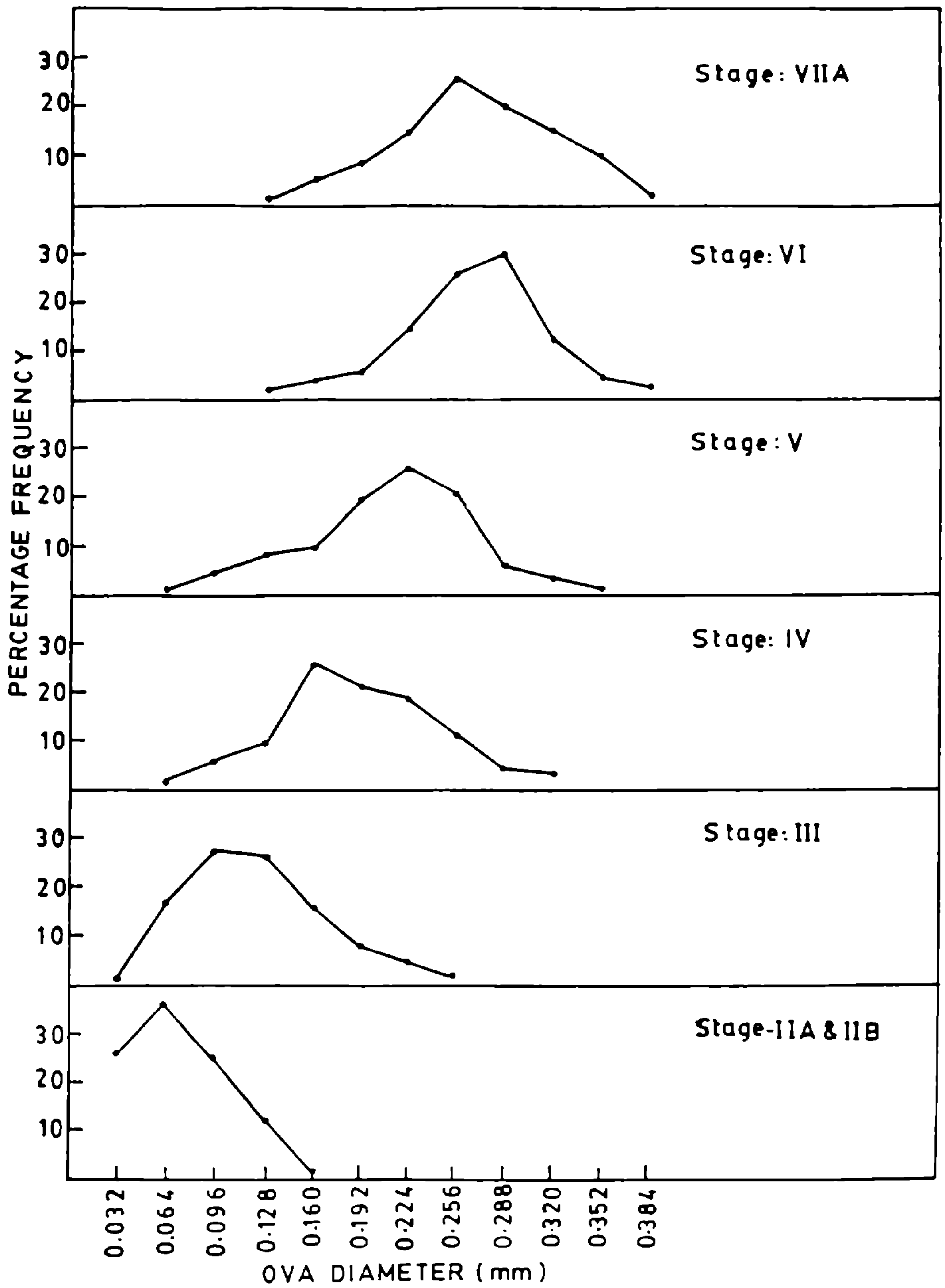
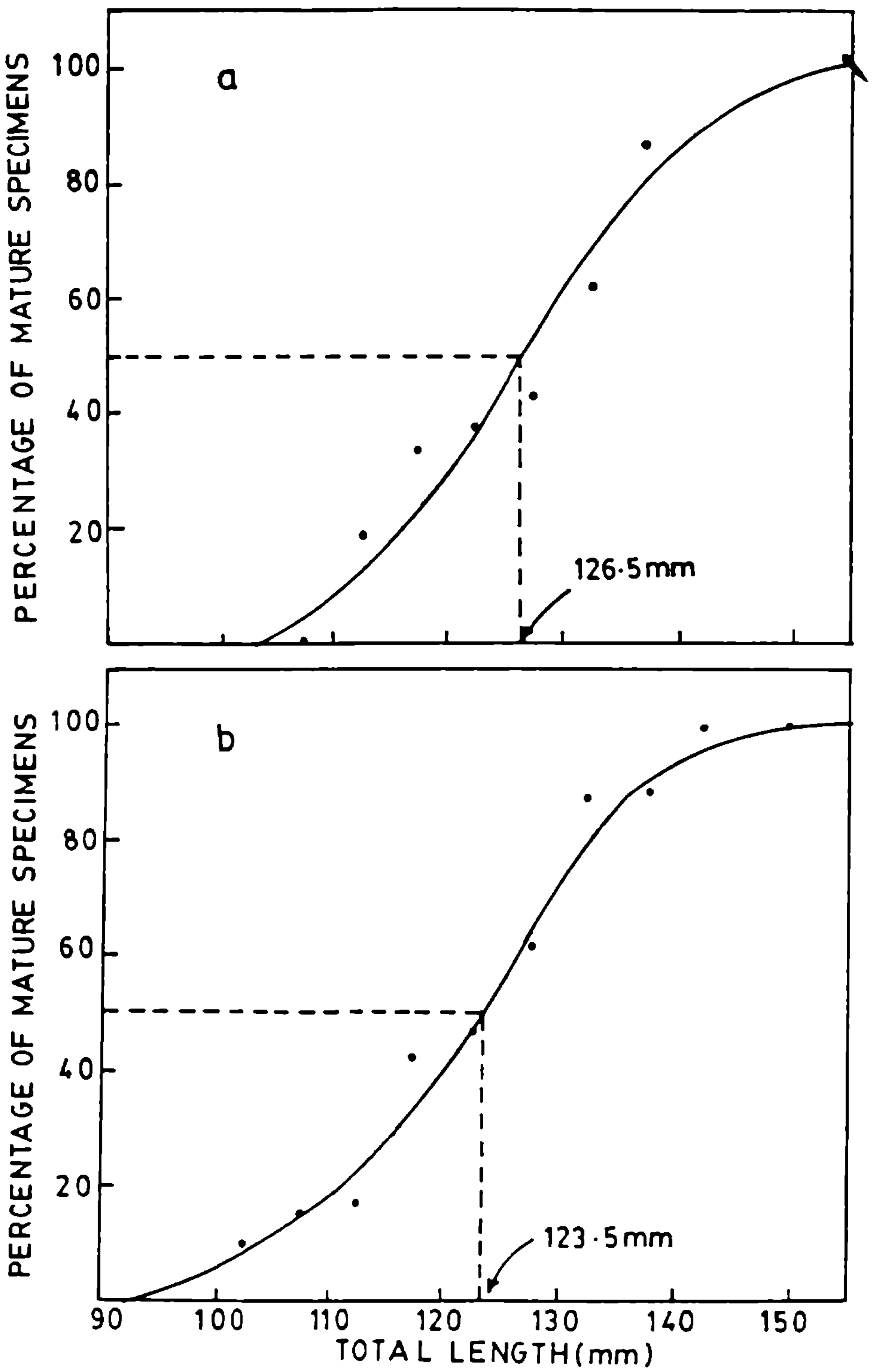

Stage: VIIA
Stage: VI
Stage: V
Stage: IV
Stage: III
Stage-IIA & IIB
PERCENTAGE FREQUENCY
10
20
30
0.032
0.064
0.096
0.128
0.160
0.192
0.224
0.256
0.288
0.320
0.352
0.384
OVA DIAMETER (mm)

Fig. 5

Fig. 6 Size at first maturity in *P. hamrur* (a) female (b) male.



a
PERCENTAGE OF MATURE SPECIMENS
100
80
60
40
20
126·5mm
b
PERCENTAGE OF MATURE SPECIMENS
100
80
60
40
20
123·5mm
90
100
110
120
130
140
150
TOTAL LENGTH(mm)

Fig. 6

Fig. 7 Monthly values of gonado-somatic index of females of *P. hamrur* (a) 1991-92 (b) 1992-93.

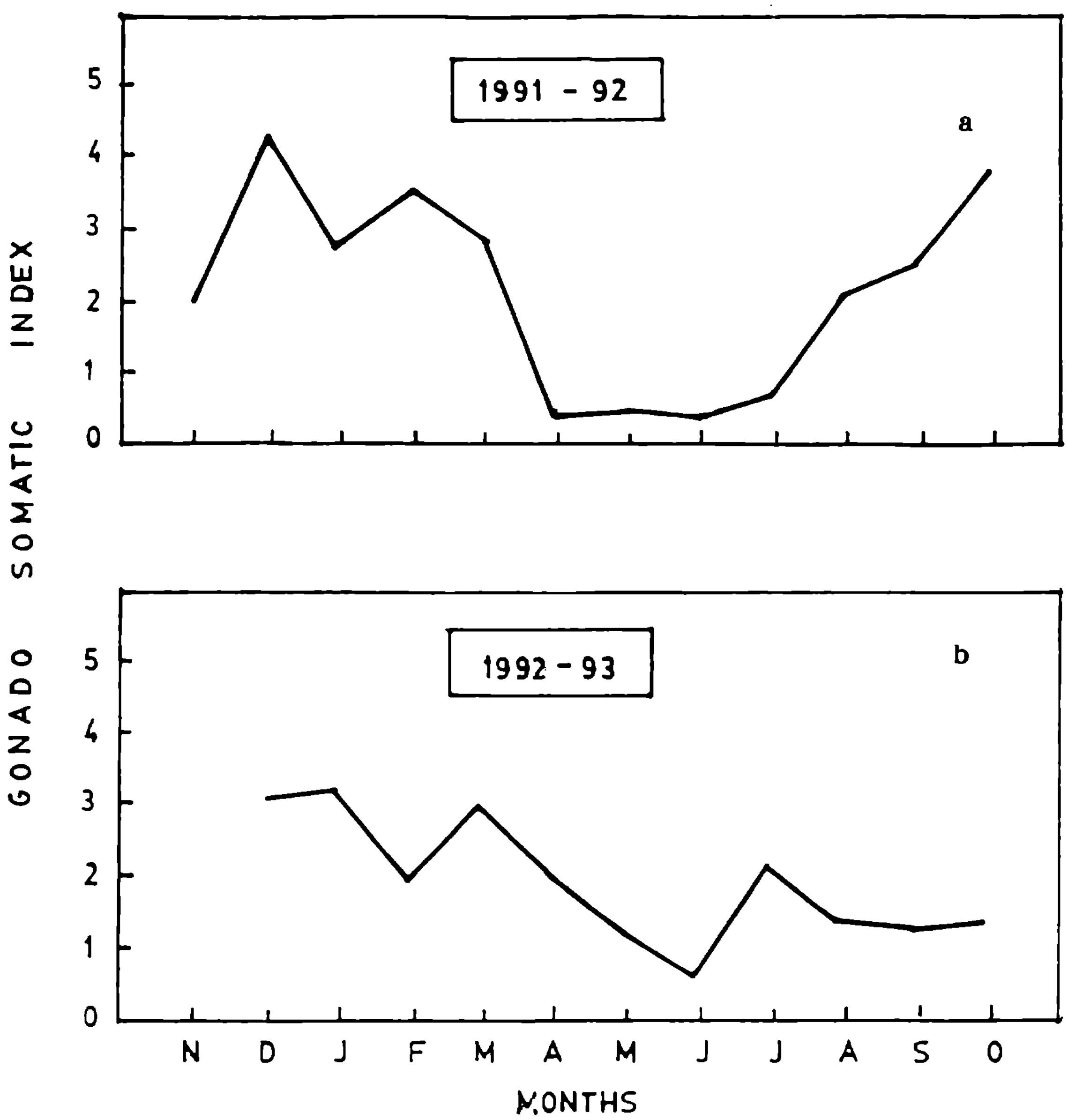

1991 - 92
a
1992 - 93
b
GONADO SOMATIC INDEX
0
1
2
3
4
5
N D J F M A M J J A S O
MONTHS

Fig. 7

Fig. 8

(a) Relationship between fecundity and total length in *P. hamrur*

(b) Relationship between fecundity and body weight in *P. hamrur*

(c) Relationship between fecundity and ovary weight in *P. hamrur*

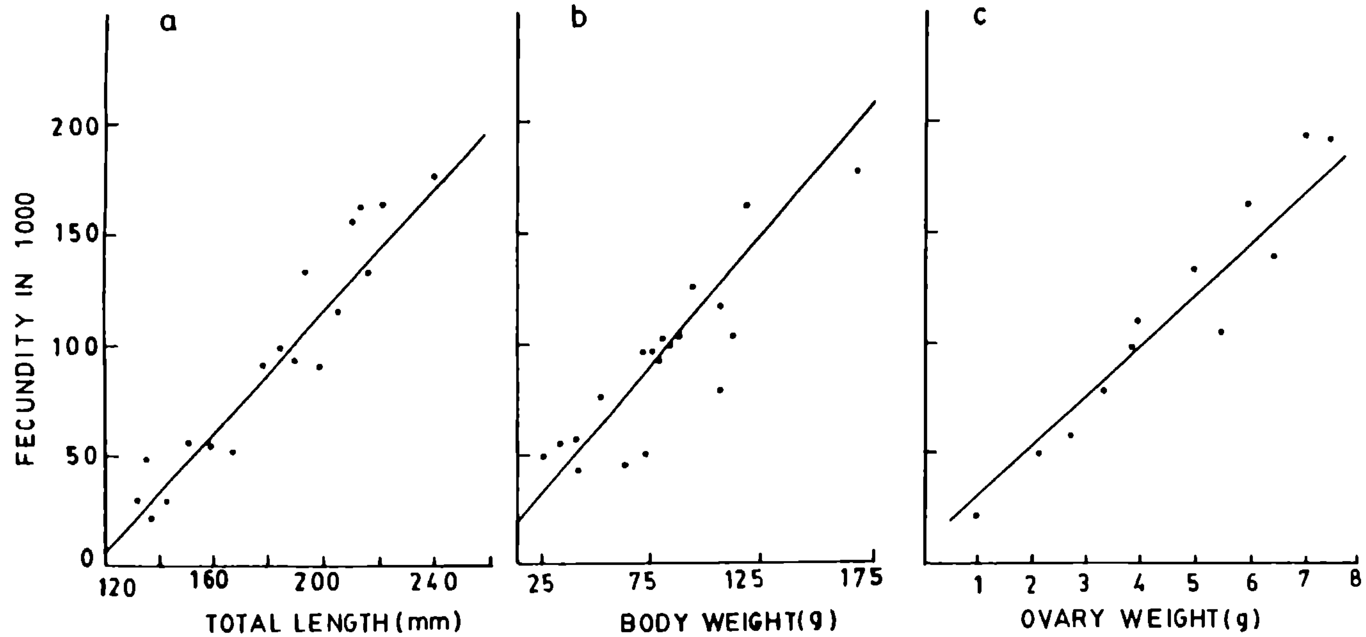

a
b
c
FECUNDITY IN 1000
0
50
100
150
200
120
160
200
240
TOTAL LENGTH (mm)
25
75
125
175
BODY WEIGHT(g)
1
2
3
4
5
6
7
8
OVARY WEIGHT(g)

Fig. 8

LENGTH-WEIGHT RELATIONSHIP
AND
RELATIVE CONDITION FACTOR

5. LENGTH-WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR

5.1 Introduction

Length-weight relationship studies of any fish species is a pre-requisite for the study of its population. The analysis of length-weight data has normally been directed towards two rather different objectives (Le Cren, 1951). Firstly, to establish the mathematical relationship between length and weight for enabling the interconversions of these variables as required for setting up of yield equations and to compare the body forms of different groups of fishes for determining the pattern of growth. Secondly, to measure the variation from the expected weight for a fish (or a group of fish) of a given length (group) due to changes in the well being, which takes place in the life cycle of all fishes. Like any other morphometric relationship, the length-weight relationship can be used as a character for differentiation of taxonomic units and this relationship may also change with the events in the life history such as metamorphosis, growth and onset of maturity (Le Cren, 1951). In cases where only length data, which are more reliable and accurate, are available, an already established length-weight relationship becomes very useful. In addition, the length-weight relationship can also be used in setting up yield equations for estimating the number of fishes landed and comparing the population in space and time (Beverton and Holt, 1957).

Individual variations from the general length-weight relationship have usually been considered more interesting than the length-weight relation itself (Le Cren, 1951) and have frequently been studied under the same condition. The importance of variations in specific gravity of fish (Tester, 1940) in relation to conditions was discussed by Kesteven (1947). However, the density of fish as a whole is maintained the same as the density of the surrounding water and therefore changes in weight for lengths are related to changes in shape or volume and not to specific gravity (Le Cren, 1951). Such changes in condition have been usually analysed by means of a condition factor or coefficient of conditions or ponderal index (Thompson, 1943; Hile, 1936). The different types of condition factors measure, in general, the variations from expected weight as a ratio of the observed weight to the expected weight; the differences being only in the expected weights assumed. The fluctuations in condition factor have been attributed to various biological factors such as fatness, gonadal development, feeding and other environmental factors. A scrutiny of the conditions at different body lengths can give valuable information regarding the maturation and spawning in the life span of the fish whereas a close look at the conditions at different months can give definite clues regarding the breeding seasons.

A review of the literature shows that the length-weight relationship of P. tayenus was estimated by Chomjurai (1970) and Wetchagarun (1971) from Gulf of Thailand and Chantawong et al. (1984) from Andaman sea

(Thailand). Though Rao (1984) has published some aspects of the biology of P. macracanthus from Waltair, the length-weight relationship of this species was not established by him. From the available literature it could be seen that no attempt on length-weight studies of P. hamrur has so far been made from Indian waters or from elsewhere. Therefore, an attempt is made here to establish the length-weight relationship and analyse the relative condition factor of P. hamrur collected from the east coast of India.

5.2 Material and methods

Samples of P. hamrur were taken from the vessels of Fishery Survey of India and Central Institute of Fisheries Nautical Engineering and Training during the period from January, 1992 to April, 1993. This was also supplemented by samples collected from commercial trawlers operating from Visakhapatnam fishing harbour during the month of May 1993. A total of 1339 females ranging from 68 to 288 mm and 693 males ranging from 65 to 245 mm were used in this study. Samples kept frozen at -15°C were thawed, cleaned and excess moisture was removed before taking the length and weight. Total length was taken from the tip of the lower jaw to the caudal fin end. Length and weight were taken upto 0.1 mm and 0.5 g respectively for both males and females.

The length-weight relationship can be expressed as:

$$W = aL^b \quad (4)$$

Logarithmic transformation of the above formula gives a linear equation:

$\ln W = \ln a + b \times \ln L$ (5)

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

The relationship was established for both male and female by linear regression of the natural logarithms of the length and weight data. Conversion of the resultant transformed equations to the original equation was achieved by rewriting the equation as:

$W = e^{a} \times L^{b}$ (b)

The regression analysis, ANOCOVA on the regression equations, 't' test on 'b' and 'r' values were carried out as per standard statistical procedures (Snedecor, 1961). Relative condition factor 'Kn' (Le Cren, 1951) was estimated for male and female using the formula:

$Kn = \frac{W}{\hat{W}}$ (6)

Where 'W' is the observed weight and '$\hat{W}$' is the expected weight derived from the length-weight relationship. 'Kn' values for the various length groups and for different months were calculated after obtaining the mean lengths and mean weights for the corresponding length groups and months.

5.3 Results

The logarithmic regression equations (Fig.9) in respect of length-weight relationship for male and female P. hamrur are as follows:

Male : $\ln W = -11.962908 + 3.113292 \times \ln L$ (r=0.9956)

Female : $\ln W = -11.727966 + 3.068493 \times \ln L$ (r=0.9977)

The corresponding exponential formula can be represented as follows: (Fig.10).

Male : $W = 0.00000638 \times L^{3.113292}$

Female : $W = 0.00000811 \times L^{3.068493}$

The confidence limits (at 5%) for the b values of male and female were estimated as:

Male : 3.093700 - 3.132813

Female : 2.932132 - 3.202792

The results of the ANACOVA on the length-weight regression equation are given in Table 24. The results of the ANACOVA showed the F values to be greater than the table values at 5% level of significance. This indicates that both the slope as well as elevation are significantly different for males and females. Their 'r' values subjected to 't' test showed significant depart at 0.1% level. Thus the length-weight relationships for male and female P. hamrur were considered as different and therefore a combined relationship could not be derived to represent for both male and female.

The relative condition factor (Kn) values of males and females for different months showed almost similar trend (Fig.11a). The highest Kn values were observed both in females (1.55338) and males (1.3827) during May while the values were lowest (M=0.9779, F=0.9009) during the month of August. While the males showed Kn values less than 1 in February, July, August and October, the females showed values below 1 only in August. Except the inflexion noticed in February, both the sexes recorded good condition during January-June period.

Kn values for different length groups of 10 mm interval in respect of males and females are depicted in Fig.11b. Length groups above 210 mm in males and 230 mm in females were not included as the specimens belonging to these groups were found to be very few. It could be seen from Fig.3b that in both the sexes, the Kn values steadily increased upto about 100 mm and remained almost stable upto about 150 mm and thereafter showed fluctuations in the size groups beyond 150 mm.

5.4 Discussion

Joung and Chen (1992) observed that the length-weight relationship between male and female was significantly different at 5% level in the case of P. macracanthus from Guei-Shan Island, Taiwan and the present findings fully conform with their observation. The b value obtained for females did not show significant variation from the isometric value of 3 whereas in males the departure from 3 is found significant. The theoretical value of b (regression coefficient) in length-weight relationship is considered as 3 when growth is isometric. For an ideal fish which maintains same shape, b value will be equal to 3 as has occasionally been observed (Allen, 1938). Slope value less than 3.0 indicates that fish becomes more slender as it increases in length while slope greater than 3.0 denotes the stoutness, leading to the conclusion that growth is allometric (Grover and Juliano, 1976). However, deviation from 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; Martin, 1949).

In the present study, the exponential value for females was 3.0684+ 0.1363 (5% confidence limit) which indicates that the growth is isometric, whereas in the case of males the b value was 3.1132+0.0195 (5% confidence limit) which denotes that in males the growth is not exactly following the cube law. It would thus appear that in P. hamrur the weight is increased by a power more than 3 with unit increase in body length as reported in female of P. macracanthus (Joung and Chen, 1992). However these findings are at variance with the available reports on the length-weight relationship of Priacanthus spp. from some other areas. Lester and Watson (1985) observed b value of 2.7 and 2.9 respectively for P. tayenus and P. macracanthus in Hong Kong waters and found that the values did not show significant deviation (P = 0.05) from isometric. Joung and Chen (1992) obtained value of 2.65 for male P. macracanthus from the Taiwan waters. From the North Java Sea Nugroho et al. (1983) got a combined b value of 2.7 for both the sexes of P. macracanthus. Chomjurai (1970) and Wetchagarun (1971) estimated values of b as 2.9 for males and females from the Gulf of Thailand. Chantawong et al. (1984) got a combined b value of 2.5 for P. tayenus from the Andaman Sea (Thailand). It may therefore be inferred that P. hamrur shows stoutish pattern of growth in contrast to its related species inhabiting south east Asian waters. The value of b is greatly influenced by the year classes of the specimens used for arriving at the length-weight relationship. Representation of younger fish in sample may yield a little higher b value while the predominance of older age group in the sample will reduce the b value. In the case of P. hamrur in the present study, older age males were less represented compared to females and this may be attributed as the reason for arriving at a higher 'b' value in males.

Variations in condition of fishes have been attributed to a variety of reasons by different workers. The low and high conditions are invariably related to two major factors viz. spawning and feeding intensity. 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. Blackburn (1960) remarked in his studies on Australian barracouta Thyrsites atun that it was not possible to interpret the changes of condition in this fish based on sexual cycle or the intake of food and that it may depend on several other inexplicable factors. James (1967) suggested that the changes in the condition of ribbon fish Eupleurogrammus intermedius are related to factors other than reproductive cycle and the feeding habits.

An inflexion in the Kn value prior to the onset of maturity indicating the physiological changes the fish undergoes was observed in some species of the north east coast (Reuben et al., 1993). However, in P. hamrur no such inflexion was observed prior to or during the size at first maturity, indicating that the sexual cycle of this fish does not have any profound influence on the condition of the fish.

Interestingly, the gastro-somatic index of both the sexes combined showed a very clear correlation with the monthly values of condition (Fig.8). A positive correlation of 0.7415 which is significant at 1% level between these two parameters lends support to this. It could, therefore, be concluded that the condition in P. hamrur is greatly influenced by feeding intensity rather than the cyclic changes taking place in the gonads.

Table 24. Comparison of regression of length-weight relationship of males and females in *P. hamrur*

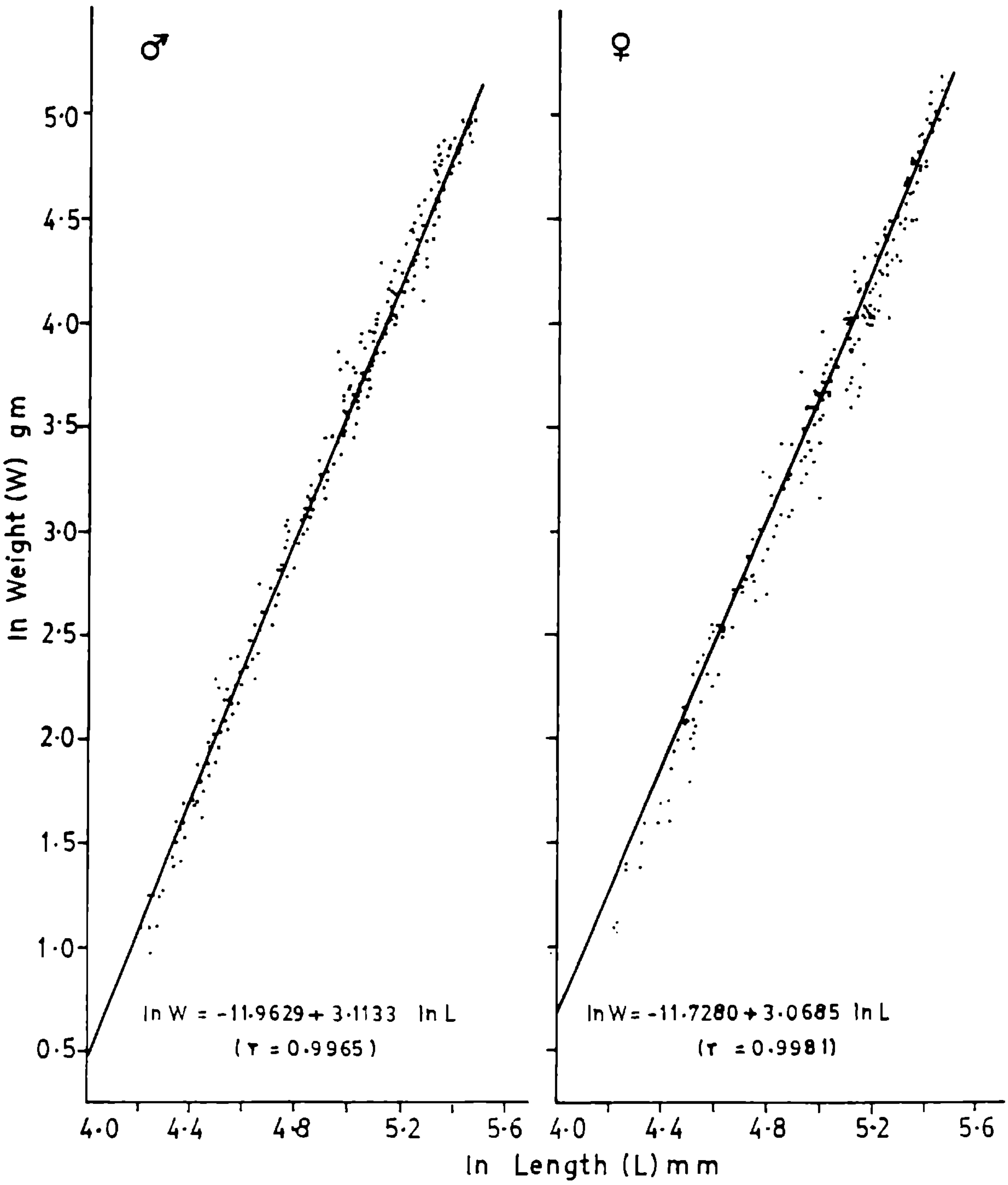
Within	df	X^2	XY	Y^2	r	df	Deviation from reg. SS	Deviation from reg. MSS
1. Male	692	51.0035093	158.7887993	497.8520983	3.113292	691	3.496256	0.005060
2. Female	1338	84.633569	259.697485	799.986032	3.068493	1337	3.106206	0.002323
3.						2028	6.602462	0.003256
4. Pooled	2030	135.637078	418.485478	1297.838130		2029	6.671305	0.003288
5. Diff. due to reg.						1	0.068843	0.068843
6. Between		13.822952	43.632512	137.721859				
7. Total	2031	149.46003	462.1179970	1435.559987		2030	6.729574	0.003315
8. Between adj. means						1	0.058269	0.058269

Comparison of slope F = 0.068843 / (df. 1,2028) = 21.143428* significant

Comparison of elevation F = 0.058269 / (df. 1,2029) = 17.721715* significant

* significant at 0.5% level (0.5% value for 1, df = 7.88)

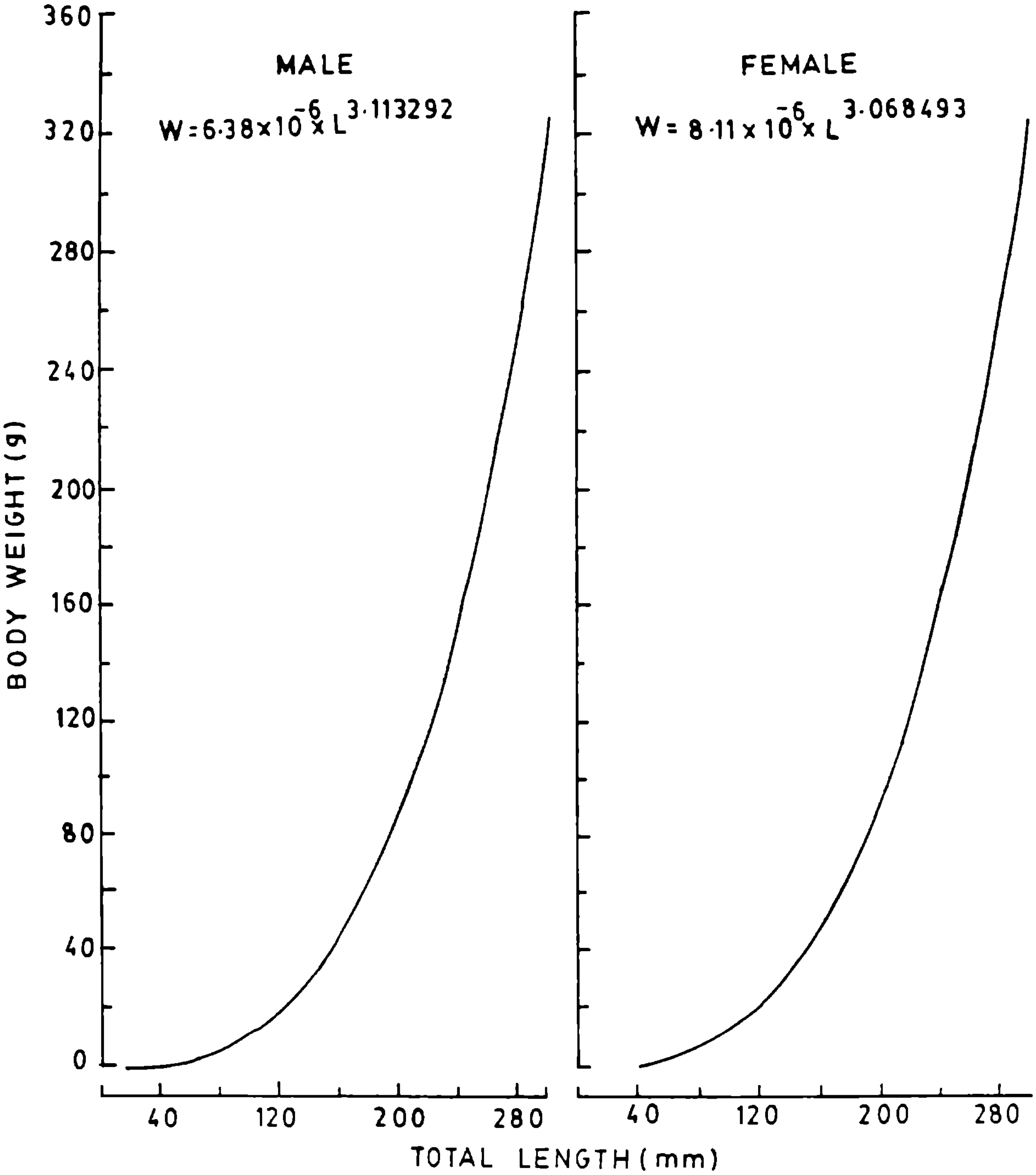
Fig. 9 Length-weight relationship of male and female *P. hamrur*.



♂
♀
ln Weight (W) gm
5·0
4·5
4·0
3·5
3·0
2·5
2·0
1·5
1·0
0·5
ln W = -11·9629 + 3·1133 ln L
(r = 0·9965)
ln W = -11·7280 + 3·0685 ln L
(r = 0·9981)
4·0
4·4
4·8
5·2
5·6
ln Length (L) mm

Fig. 9

Fig. 10 Length-weight relationship in parabolic form of *P. hamrur*



MALE
W=6·38x10⁻⁶ x L^3·113292
FEMALE
W= 8·11 x 10⁻⁶ x L^3·068493
BODY WEIGHT (g)
360
320
280
240
200
160
120
80
40
0
40
120
200
280
TOTAL LENGTH (mm)

Fig. 10

Fig.11 (a) Monthly variation of relative condition factor (Kn) of male and female of P. hamrur.

(b) Relative condition factor (Kn) for males and females of P. hamrur in different length groups.

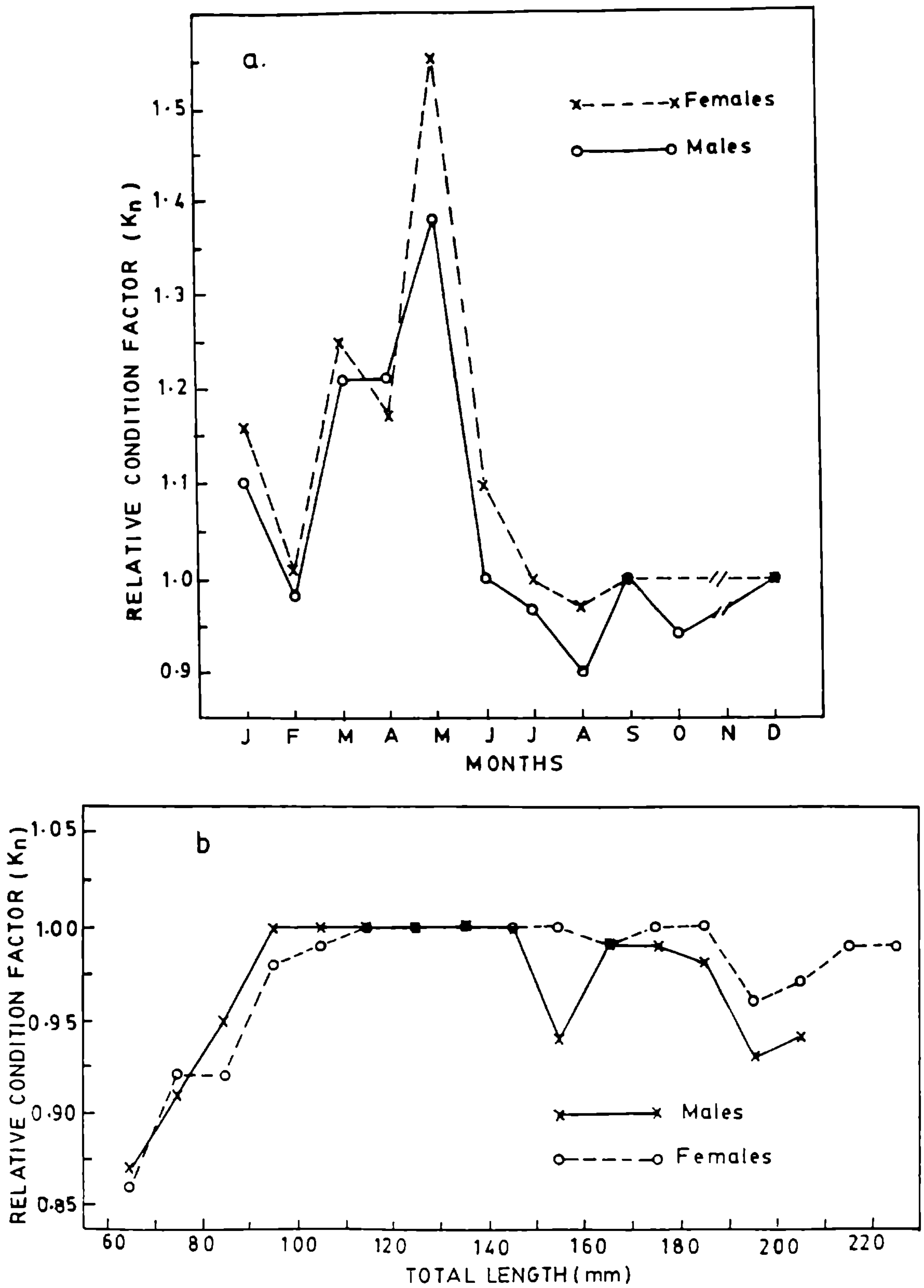

a.
x- - - - -x Females
o———o Males
RELATIVE CONDITION FACTOR (Kn)
1·5
1·4
1·3
1·2
1·1
1·0
0·9
J F M A M J J A S O N D
MONTHS
b
RELATIVE CONDITION FACTOR (Kn)
1.05
1.00
0.95
0.90
0.85
x———x Males
o- - - - -o Females
60 80 100 120 140 160 180 200 220
TOTAL LENGTH (mm)

Fig. 11

AGE AND GROWTH

6. AGE AND GROWTH

6.1 Introduction

The study of age and growth is an essential prerequisite for understanding the dynamic features of the population. Knowledge of age data, in conjunction with length and weight measurements can give valuable information on stock composition, age and maturity, longevity, mortality, growth and yield. Information on growth of fish is essential for stock assessment in the context of successful fishing resource management where simultaneous additions and losses by weight that take place in the population are decisive factors determining the stock size. Hence, the knowledge of age and growth forms the foundation on which the studies on the dynamics of fish population are built.

Information on the age and growth of Priacanthus hamrur is lacking from the Indian waters or any part of the world. However, age and growth of Priacanthus macracanthus caught by the demersal trawlers in north eastern Taiwan waters were studied by Joung and Chen (1992) using the scales. Nugroho et al. (1983) studied the population parameters of P. macracanthus from the seas north of Java. Chomjurai(1970), Wetchagarun(1971) and Chantawong et al. (1984) studied the biology and population parameters of Priacanthus tayenus from the Andaman sea (Thailand). The population parameters of P. tayenus of Samar sea were studied by Ingles and Pauly (1984). Growth of P. tayenus and P. macracanthus was estimated by Lester and Watson (1985) from Hong Kong waters while Chomjurai and Bunnag (1970) reported the daily growth rate of P. tayenus from the Gulf of Thailand based on tagging experiments. Senta (1977) also studied the daily growth rates of the same species from the Gulf of Thailand.

The main reasons for leaving this group unstudied in this country may be the highly seasonal occurrence in the commercial landings and non-availability of samples on regular basis as this group is often discarded in the fishing ground itself by the commercial vessels. But for the abundance of this species in the exploratory trawl catches of the vessels of Fishery Survey of India (FSI), this study would not have been materialised.

Whereas reasonably precise methods for determining the age by means of markings on the scales, otoliths or other hard structures, are available for many fishes (Mohr, 1927, 1930, 1934 and Graham, 1928) there is still need for developing better methods, especially for tropical marine species. There are basically three types of data which are used for estimating the growth parameters (Pauly, 1983).

i) Tagging-recapture data on individual fish

ii) Periodic markings on skeletal parts such as scales, otoliths and other hard structures.

iii) Size frequency data, most commonly length frequency data

The methods based on length frequency data have been widely applied in the tropics, in spite of frequent criticisms, because of their simplicity as well as lack of data on the other two types.

6.2 Material and methods

The von Bertalanffy growth function (VBGF) was used to describe the growth. The simplest version of VBGF has the form:

$$L_t = L_\infty \ (1-e^{-K(t-t_o)}) \qquad (8)$$

for growth in length and

$$W_t = W_\infty \ (1-e^{-K(t-t_o)})^3 \qquad (9)$$

for growth in weight

Where, L_∞ and W_∞ are asymptotic length and weight respectively attained by the fish if it were to grow infinitely; K is the growth coefficient and t_0 is the age the fish would have at length or weight zero if they had grown according to the equation. The L_t and W_t are the predicted length and weight respectively at age t.

Length data of 4147 males and 5334 females collected from catches of vessels of Fishery Survey of India and Central Institute of Fisheries Nautical Engineering and Training during 1989-93 were used for estimation of growth parameters of *P. hamrur*. Due to lack of otolith and unsuitability of scales growth studies on this species were made based only on length frequency data. The length data for males and females were treated separately. Length frequency data of 2045 fish, both males and females, collected during May 1993 from commercial catch of small mechanised boats operating from Visakhapatnam fishing harbour were also treated separately to assess the extent of variations in these estimates made from exploratory data. The analysis was carried out in the following stages.

1) Modal class progression analysis by integrated method (Pauly, 1982, 1983).

2) Estimation of L_∞ and K by Ford-Walford Plot (Ford, 1933; Walford 1946).

3) Estimation of t_0 by Beverton's method as well as by von Bertalanffy plot.

4) Fitting of von Bertalanffy growth equation.

6.2.1 Modal class progression analysis

The length frequency data for males and females for the period June 1989 to April 1993 are given in Figures 12a-h. The length data grouped at 5 mm class intervals pooled for each months were sequentially arranged over time scale. The modes of each month were marked against the mid-value of the respective classes (Fig.13&14). One month's data from commercial catches were separately analysed repeating over and over along time axis in order to study the progression of the modes (Fig.15). A single smooth growth curve connecting a majority of the modes was traced with the help of a curved ruler. Subsequently, similar curves connecting other modes were also made. Since the exploratory data were well spanned over a longer period, the same were used as such without making repetition over time.

The lengths corresponding to various ages starting from an arbitrary age were read from the selected curves at regular time intervals (quarters) and an average was arrived at. The mean lengths at different time intervals so obtained were subjected to further analysis using the For-Walford plot for estimating the growth parameters.

Ford-Walford plot

Ford-Walford plot is essentially a rewritten version of VBGF having the linear form:

$$L_{t+1} = a + bL_t \qquad (10)$$

Equation (10) can be rewritten as

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

OR

$$L_{t+1} = a + bL_t$$

The lengths at age derived from modal progression analysis were subjected to linear regression (Snedecor and Cochran, 1967). The results obtained from regression were used to calculate the growth parameters, L_∞ and K as per the following formulae.

$$L_\infty = \frac{a}{(1-b)} \quad L = \frac{a}{(1-b)} \qquad (11)$$

$$K = -\log_e b \qquad (12)$$

The time interval used was one quarter (3 months) and hence the K value obtained was multiplied by 4 to get the annual growth coefficient or curvature parameter.

Estimation of t_o

Beverton's (1954) approach was adopted to estimate the t_o value by writing the VBGF as:

$$\ln (L_\infty - L_t) = \ln L_\infty + K_{t_o} - K_t \qquad (13)$$

The Y axis intercept of the linear regression of ln $(L_\infty - L_t)$ against t can be equated to ln L_∞ + kt_o which gives:

$$t_o = \frac{1 - \ln L_\infty}{K} \qquad (14)$$

The parameters L and K used in the above formula were obtained from Ford-Walford plot.

Estimate of t_o was also made using von Bertalanffy (1934) plot in which the results of the regression of $-\ln(1-Lt/L_\infty)$ against t was used to calculate t_o as:

$$t_o = \frac{-a}{b} \qquad (15)$$

However, the values obtained from the former method was chosen for further applications:

6.2.2 Fitting of von Bertalanffy's growth equation

The growth parameters thus derived from the above methods were fitted in the VBGF to obtain growth model for males and females collected from the exploratory surveys and the combined data from the commercial catches obtained from the landing centre.

Using the length-weight relationship the corresponding VBGF for weights were also obtained. A comparison of these growth factors were made by calculating the Pauly and Munro's growth performance index PHI (Pauly and Munro, 1984) using the formula:

$$\phi' = \log K + 2 \log L_\infty \qquad (16)$$

The results of the plot of -ln (1-Lt/L) against t (Fig.17a,b, c) and the corresponding values of t_o derived from them are given below:

	a	b	r	t_o (years)
Male	0.0063	0.3585	0.9999	- 0.0176
Female	0.0054	0.3811	0.9996	- 0.0142
Commercial data (both sexes)	0.0447	0.3706	0.9995	- 0.1206

Thus the von Bertalanffy growth equations for the different sets of parameters can be written as (Fig.18a,b,c).

Male $\quad Lt = 297.0791\ (1-e^{-0.3585\ (t+0.0206)}$

Female $\quad Lt = 300.4580\ (1-e^{-0.3826\ (t+0.244)}$

Commercial data (both sexes) $\quad Lt = 283.9278\ (1-e^{-0.3722\ (t+0.1122)}$

W_∞ obtained from length-weight relations corresponding to the L_∞ and Pauly and Munro's growth performance index for the three sets of data were obtained as:

	W_∞	Ø
Male	318.8553	2.5002
Female	323.2419	2.5501
Commercial data (both sex)	274.2867	2.4772

The VBGF in respect of weight can be written for the three sets of data as:

6.3 RESULTS

The linear regression with length at age (Ford-Walford plot) gave the following results (Fig.16a,b,c).

	a	b	c
Male	25.4668	0.9143	0.9999
Female	27.4093	0.9088	0.9999
Commercial data (both sexes)	88.2334	0.6892	0.9986

The growth parameters, L_∞ and K corresponding to the above values, L_{max} observed and estimate of L_∞ as per Tayler's (1958) thump rule are given below:

	L_∞	K/year	L_{max}	L_∞ (approx.)
Male	297.0791	0.3585	265.00	278.95
Female	300.4580	0.3826	288.00	303.16
Commercial data (both sexes)	283.9278	0.3722	262.00	275.79

The results of the plot of ln (L_∞- L_t) against t and the corresponding values of t_o derived from them are given below, which are used for fitting the growth equation.

	a	b	r	t_o (years)
Male	5.6866	- 0.0896	- 0.9999	- 0.0206
Female	5.6960	- 0.0950	- 0.9997	- 0.0244
Commercial data (both sexes)	5.6070	- 0.3712	- 0.9994	- 0.1122

Male W_t = $318.8553\ (1-e^{-3585\ (t+0.0206)})^3$

Female W_t = $323.2419\ (1-e^{-3826\ (t+0.0244)})^3$

Commercial data W_t = $274.2867\ (1-e^{-3722\ (t+0.1122)})^3$

The lengths attained by the fish at different ages as computed from the growth functions and the daily growth rate at different ages are given below:

Age (years)	Male (mm)	Daily growth (mm)	Female (mm)	Daily growth (mm)	Pooled commercial (mm)	Daily growth (mm)
		0.25		0.27		0.27
1	91		97		96	
		0.17		0.18		0.16
2	153		162		155	
		0.12		0.13		0.11
3	196		208		195	
		0.08		0.08		0.07
4	227		236		222	
		0.06		0.06		0.05
5	248		257		242	
		0.04		0.04		0.04
6	263		270		255	
		0.03		0.03		0.03
7	273		280		264	
		0.02		0.02		0.02
8	280		286		270	

6.4 Discussion

Ageing of priacanthids is comparatively difficult due to various reasons. According to Whitelaw (personal communication) ageing of Priacanthus spp. based on otoliths and scales was found unsuccessful in Australian waters. Joung and Chen (1992) reported that vertebra of P. macracanthus was translucent and therefore opaque zones were inconspicuous. However, they could attempt ageing with scales in P. macracanthus. Age and growth in P. hamrur using hard parts was not attempted here due to the unsuitability of these structures for the above purpose. Modal progression analysis by integrated method (Pauly 1982 and 1983) was used due to its simplicity, fully utilizing the facility of subjective manipulation in connecting the modes and arriving at the most probable growth curve.

The growth parameters obtained for males and females of P. hamrur in the present study showed slight difference. Males showed a slower growth rate when compared to its counter part as well as a corresponding difference in the asymptotic length could also be seen between the two sexes. The approximate values of L_∞ obtained from Taylor's (1958) thump rule gave values of L_∞ much closer to that obtained from Ford-Walford plot in the case of females whereas in males, the approximate value was found to be less than that estimated from Ford-Walford plot. However t_o values, showed similarity in both males and females.

The growth parameters computed for the commercial catch showed full agreement with those estimated for males and females from exploratory data. The value of K obtained was almost nearer to the average of the same estimated for males and females of exploratory data.

Due to its deeper water inhabitance, P. hamrur tends to share some of the characters of the temperate species such as slower growth and extended life span. A differential growth in two sexes was expected as suggested (Qasim, 1966) especially when preponderence of one sex in the population was observed. In corollary with this during the present study also an overall preponderence of females over males was noticed. As a general rule in most short lived species, a differential growth rate in two sexes is unlikely (Qasim, 1973). According to Pauly (1983) t_{max} is approximately equal to 3/K. By applying this formula t_{max} of P. hamrur can be computed at 8 year. On the contrary, most of the shallow water demersal species have a longevity of about 3-6 years (Murty, 1981, 1984; Rao, 1966, 1984). Using back calculated data Joung and Chen (1992) estimated the age at maximum sizes of female (290 mm FL) and male (272 mm FL) as 6.12 and 6.03 years respectively for P. macracanthus of Taiwan waters. Pauly (1984) has cited estimates of t_{max} for some coral reef fishes of New Caledonia such as 13 years for Adioryx spinifer (Holocentridae), 16 years for Epinephelus summana (Serranidae), 18-35 years for Lutjanus spp. (Lutjanidae), 12 years for Pomadasys hasta (Pomadasyidae) and 14-15 years for Lethrinus spp. (Lethrinidae). Thus the life span of eight years presently assessed for

P. hamrur falls between those of shallow water demersal species which have a longevity of 3-6 years and larger perches which live for more than 10 years.

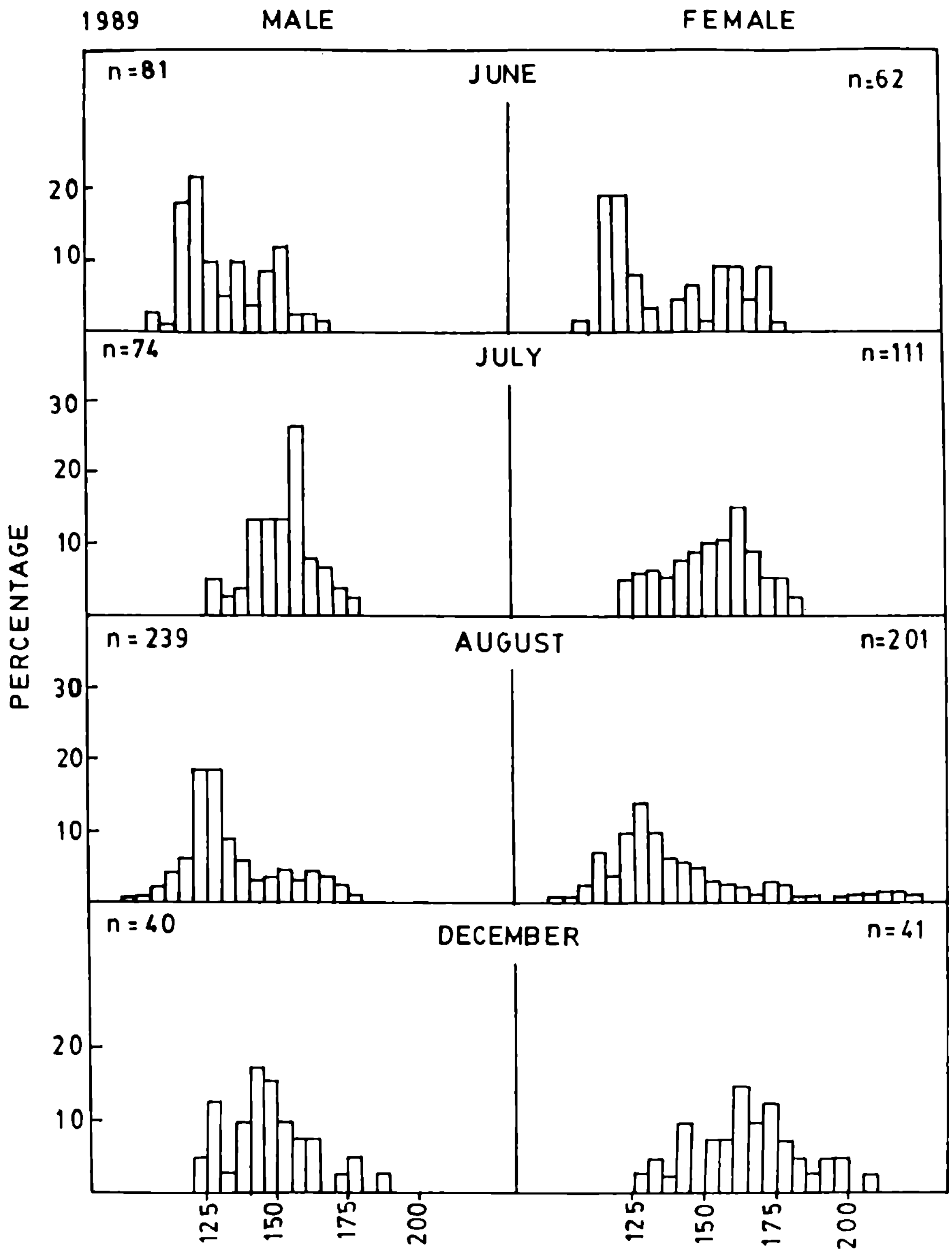
Size at first (50%) maturity for P. hamrur was estimated to be 123.5 mm for males and 126.5 mm for females in the present study. The fish attains this length at 1½ years. This observation agrees with the general statement that most fishes from Indian waters mature when they are at 1-2 years (Qasim, 1973). Though it could be seen that the prematurity phase of growth is more fast compared to the post maturity phase, the latter, however, is not so slow as attributed to the tropical fishes (Qasim, 1973).

Due to lack of published data on growth of this species, comparisons could not be made with the present results. The growth parameters worked out by various workers from different regions in respect of Priacanthus spp. are given in Table 25. It could be seen that the growth parameters estimated for Priacanthus spp. from different regions show great variations. Joung and Chen (1992) estimated the growth rate for male and female P. macracanthus as 102 and 112 mm in the first year, 44 and 40 mm in the second year, 40 and 35 mm in the third year and 37 and 32 mm in the fourth year. Senta (1977) observed that P. tayenus of Gulf of Thailand grows by 50 mm in the first six months after recruitment and again by 50 mm in one year subsequently. He has worked out a daily growth rate of 0.28 mm for the fish from 80 to 130 mm and 0.14 mm from 130 to 180 mm. Based on tagging experiments in Gulf of Thailand, Chomjurai and Bunnag (1970) estimated the daily growth rate of P. tayenus as 0.20 mm for fishes of 157-189 mm in fork length and 0.024 for fishes of 205-221 mm. Therefore, the results obtained in the present study show that the daily growth rate in P. hamrur is more or less comparable with the daily growth rates observed in P. tayenus and P. macracanthus.

Table 25. Growth parameters of *Priacanthus* spp. arrived at by various workers from different localities

Species	Authors	Locality	Method	L_{max}(mm)	L_{oo} (mm)	$K_{(year^{-1})}$	$t_{o(year^{-1})}$
P. macracanthus	Duto Nugroho & Rusmadji Rustam (1983)	Northern Java sea	Length based	260.00 (pooled)	267.00	1.360	-
P. macracanthus	Dwiponggo *et al.* (1986)	Java sea (Central Java)	Length based	-	237.50	1.300	-
P. macracanthus	Shoou-Jeng Joung and Che-Tsung, Chen (1992)	Northern Taiwan	Scales	290.00 (female)	620.00 (female)	0.088	- 1.050
				272.00 (male)	482.00 (male)	0.113	- 1.340
P. macracanthus	Lester & Watson (1985)	South of Hong Kong	Length based	-	320.00	0.700	1.000
P. tayenus	Chomjurai (1970) Wetchagarun (1971)	Gulf of Thailand	Length based	-	-	2.000 cm/month	-
P. tayenus	Chantawong *et al.*(1984)	Andaman Sea	Length based	119.00 (pooled)	-	-	-
P. tayenus	Ingles and Pauly (1984)	Samar sea	Length based	290.00 (pooled)	-	1.250	-
P. tayenus	Lester & Watson (1985)	South of Hong Kong	Length based	-	300.00	0.800	0.600
P. hamrur	Present study	North east coast of India	Length based	265.00 (male)	297.00	0.358	- 0.021
				288.00 (female)	300.45	0.382	- 0.024

Fig.12 (a) Length frequency distribution of males and females of *P. hamrur* during June 1989 December 1989.



1989
MALE
FEMALE
n=81
JUNE
n=62
n=74
JULY
n=111
n=239
AUGUST
n=201
n=40
DECEMBER
n=41
PERCENTAGE
10
20
30
125
150
175
200

Fig. 12 a

Fig. 12 (b) Length frequency distribution of male and female *P. hamrur* during January 1990 - May 1990.

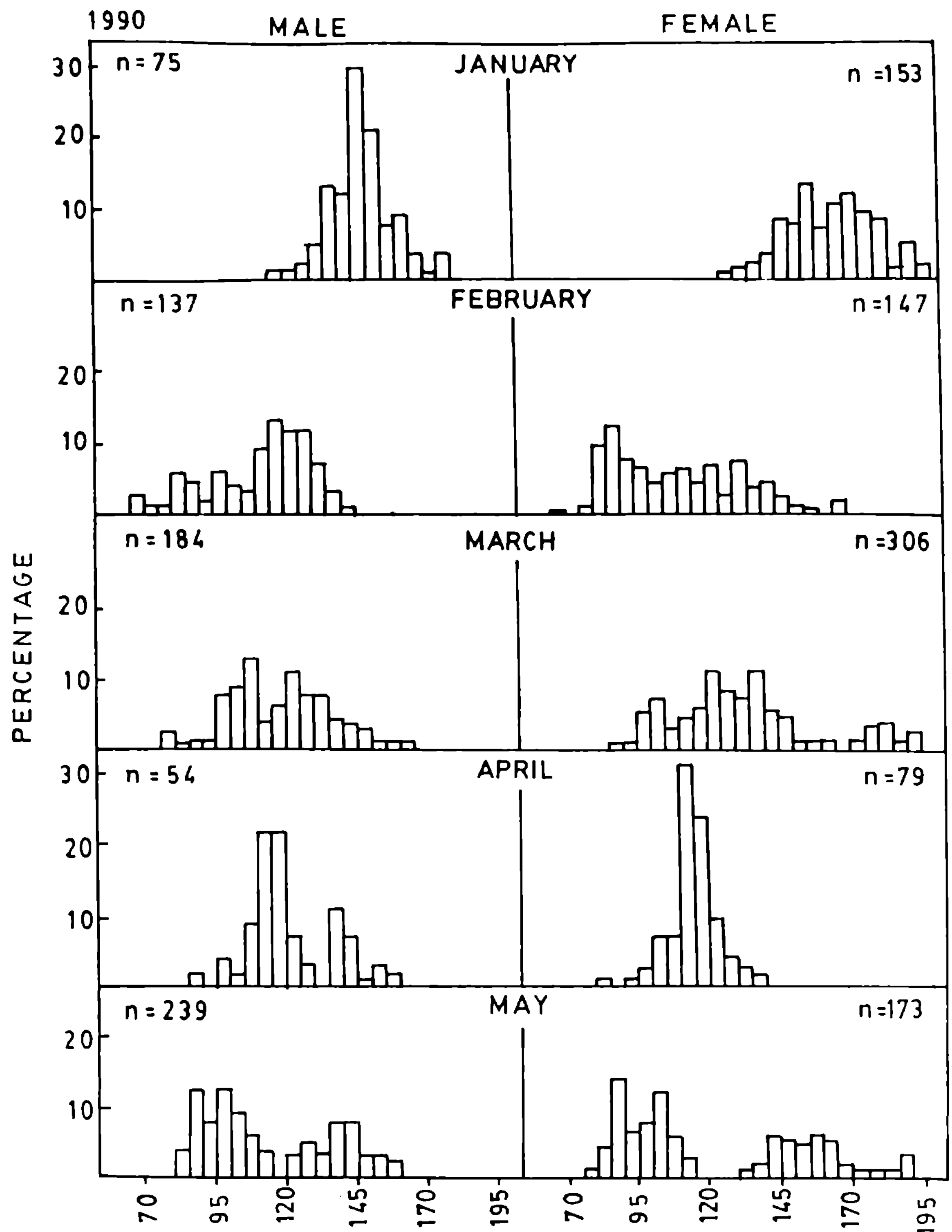

1990
MALE
FEMALE
JANUARY
n = 75
n = 153
FEBRUARY
n = 137
n = 147
MARCH
n = 184
n = 306
APRIL
n = 54
n = 79
MAY
n = 239
n = 173
PERCENTAGE
30
20
10
70
95
120
145
170
195

Fig. 12 b

Fig. 12 (c) Length frequency distribution of male and female *P. hamrur* during June 1990 - December 1990.

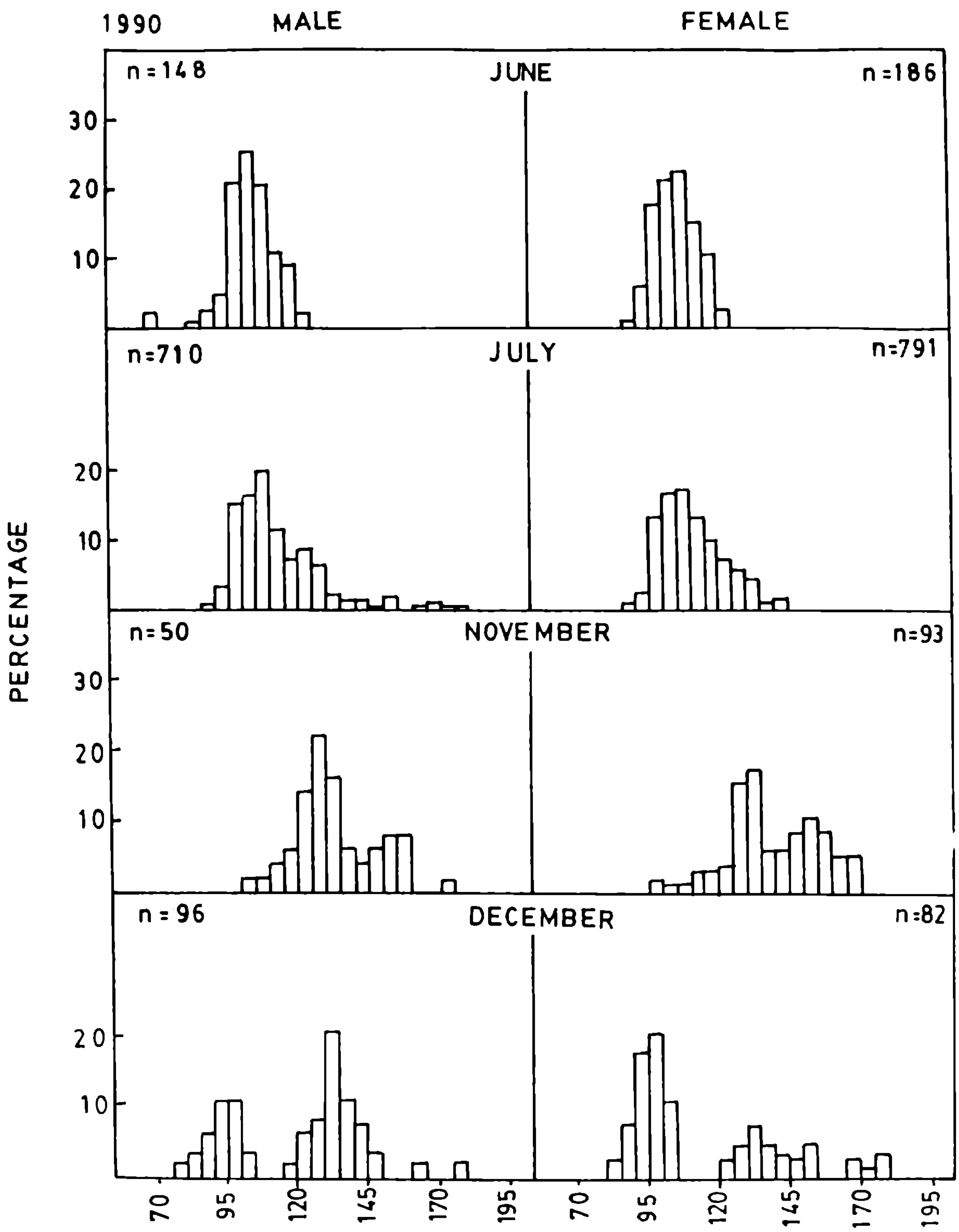
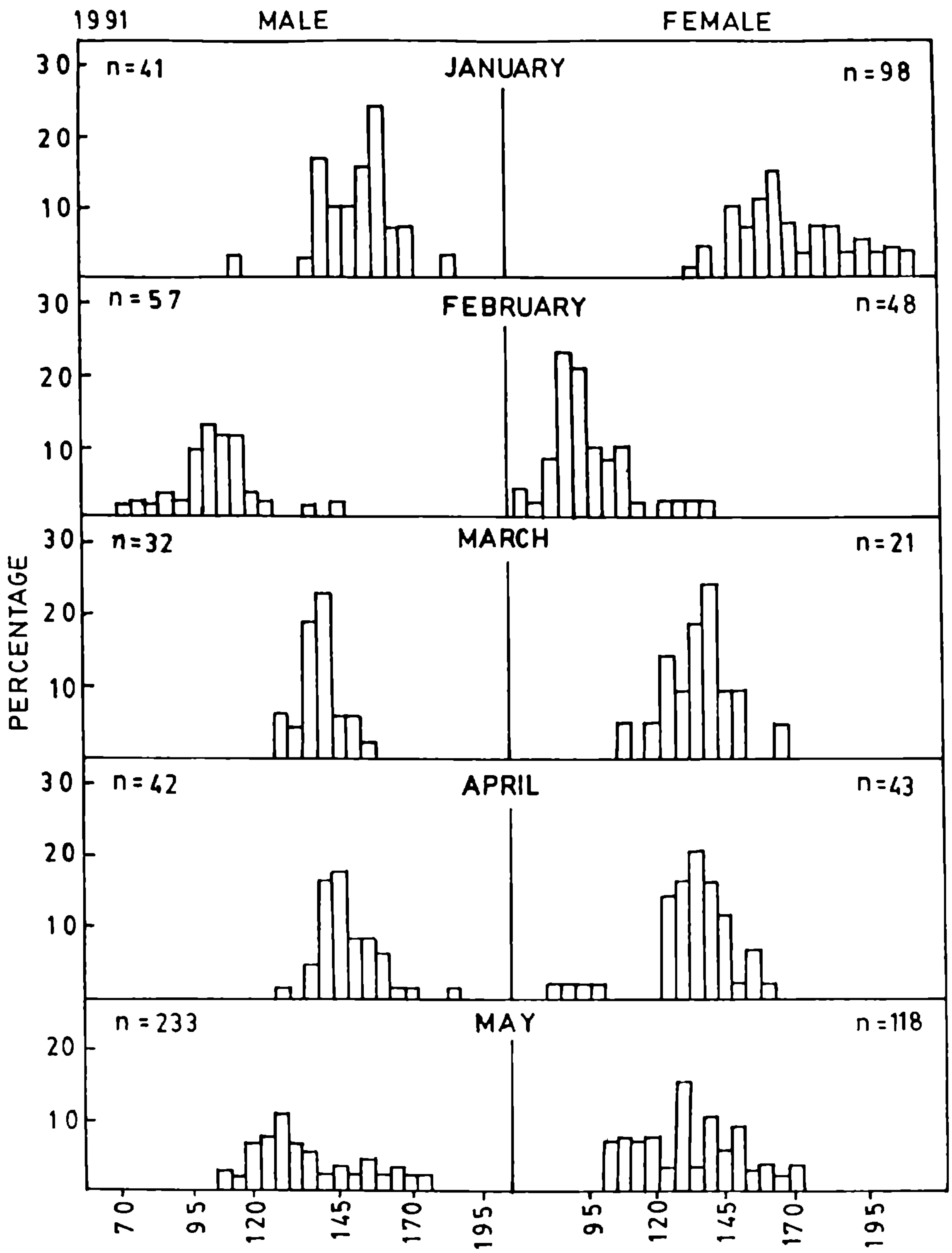

1990
MALE
FEMALE
PERCENTAGE
n=148
JUNE
n=186
n=710
JULY
n=791
n=50
NOVEMBER
n=93
n=96
DECEMBER
n=82
30
20
10
70
95
120
145
170
195

Fig. 12 c

Fig. 12 (d) Length frequency distribution of male and female *P. hamrur* during January 1991 - May 1991.



1991
MALE
FEMALE
PERCENTAGE
JANUARY
n=41
n=98
FEBRUARY
n=57
n=48
MARCH
n=32
n=21
APRIL
n=42
n=43
MAY
n=233
n=118
30
20
10
70
95
120
145
170
195

Fig. 12 d

Fig.12 (e) Length frequency distribution of male and female *P. hamrur* during June 1991 - December 1991.

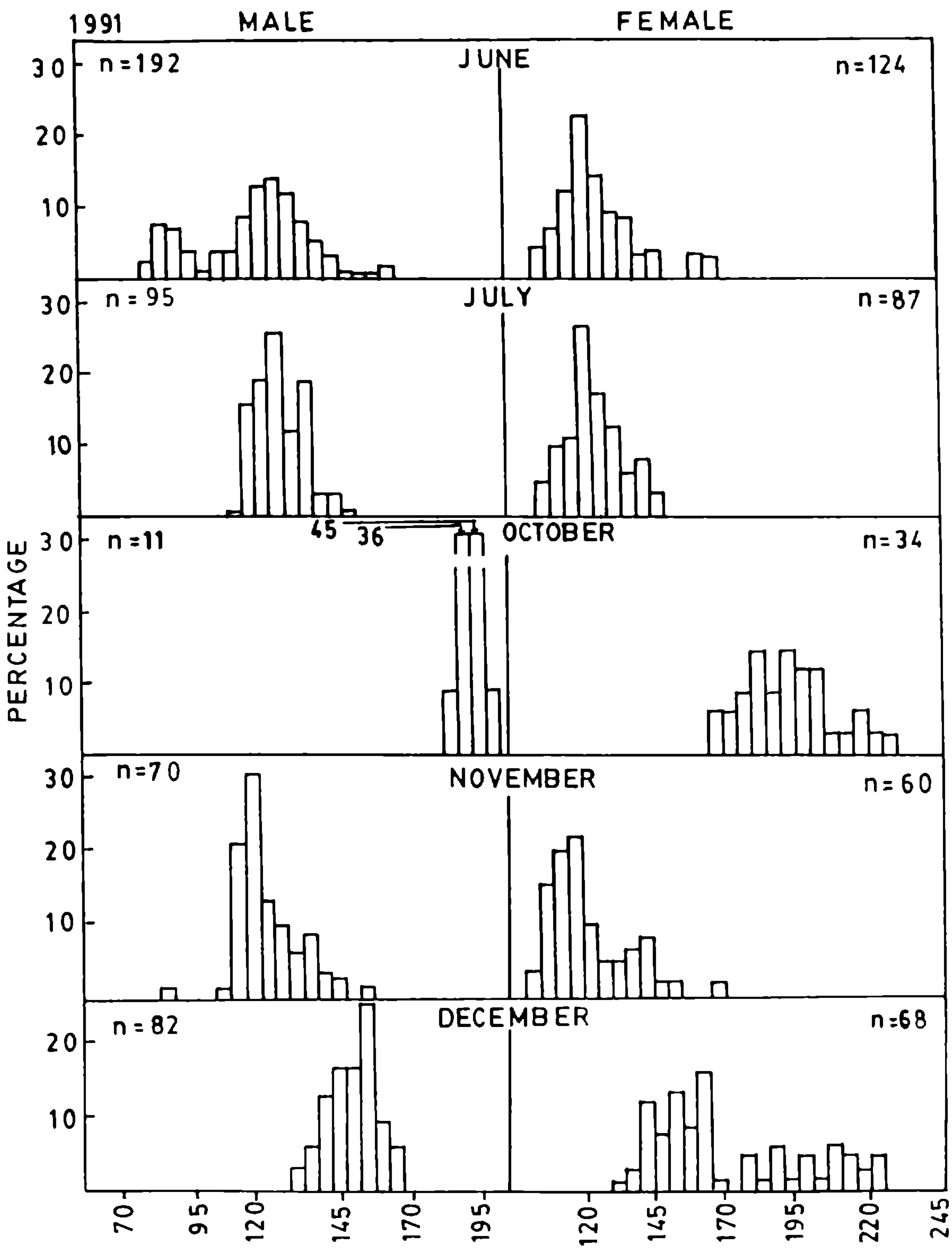

1991
MALE
FEMALE
JUNE
n=192
n=124
JULY
n=95
n=87
OCTOBER
n=11
n=34
45
36
NOVEMBER
n=70
n=60
DECEMBER
n=82
n=68
PERCENTAGE
10
20
30
70
95
120
145
170
195
220
245

Fig. 12 e

Fig. 12 (f) Length frequency distribution of male and female *P. hamrur* during January 1992 - May 1992.

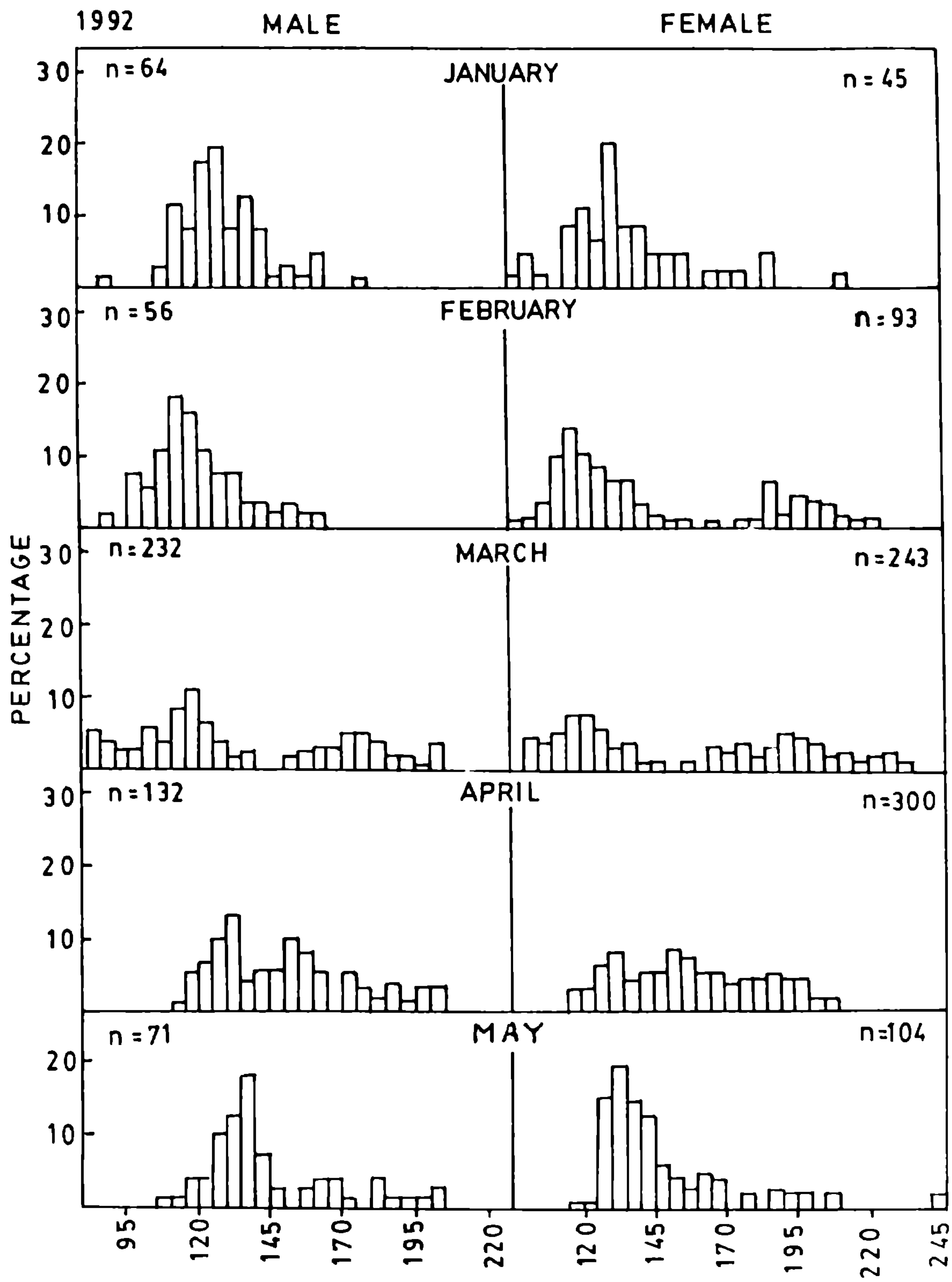

1992
MALE
FEMALE
JANUARY
n=64
n=45
FEBRUARY
n=56
n=93
MARCH
n=232
n=243
APRIL
n=132
n=300
MAY
n=71
n=104
PERCENTAGE
30
20
10
95
120
145
170
195
220
120
145
170
195
220
245

Fig. 12 f

Fig. 12 (g) Length frequency distribution of male and female _P. hamrur_ during June 1992 - December 1992.

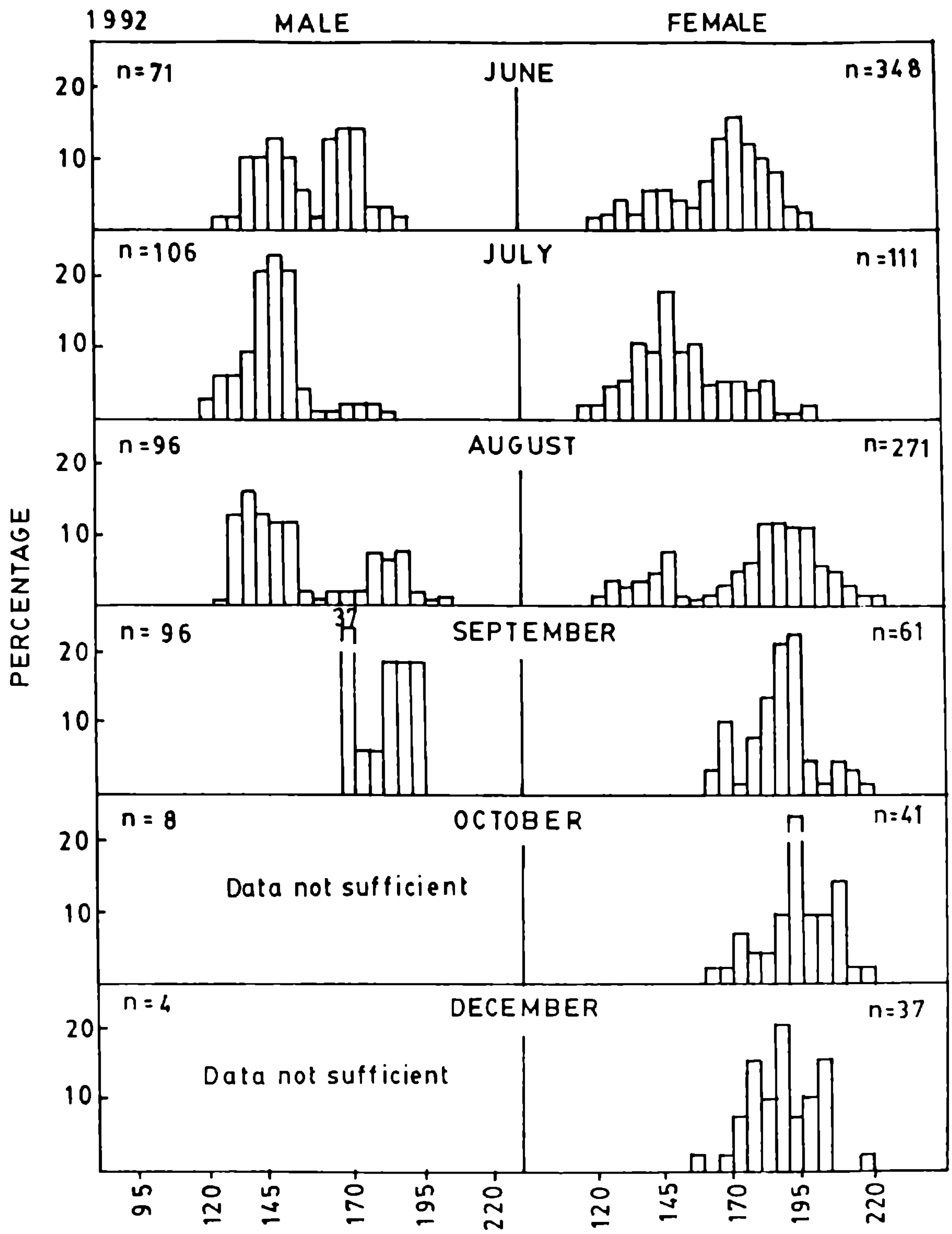
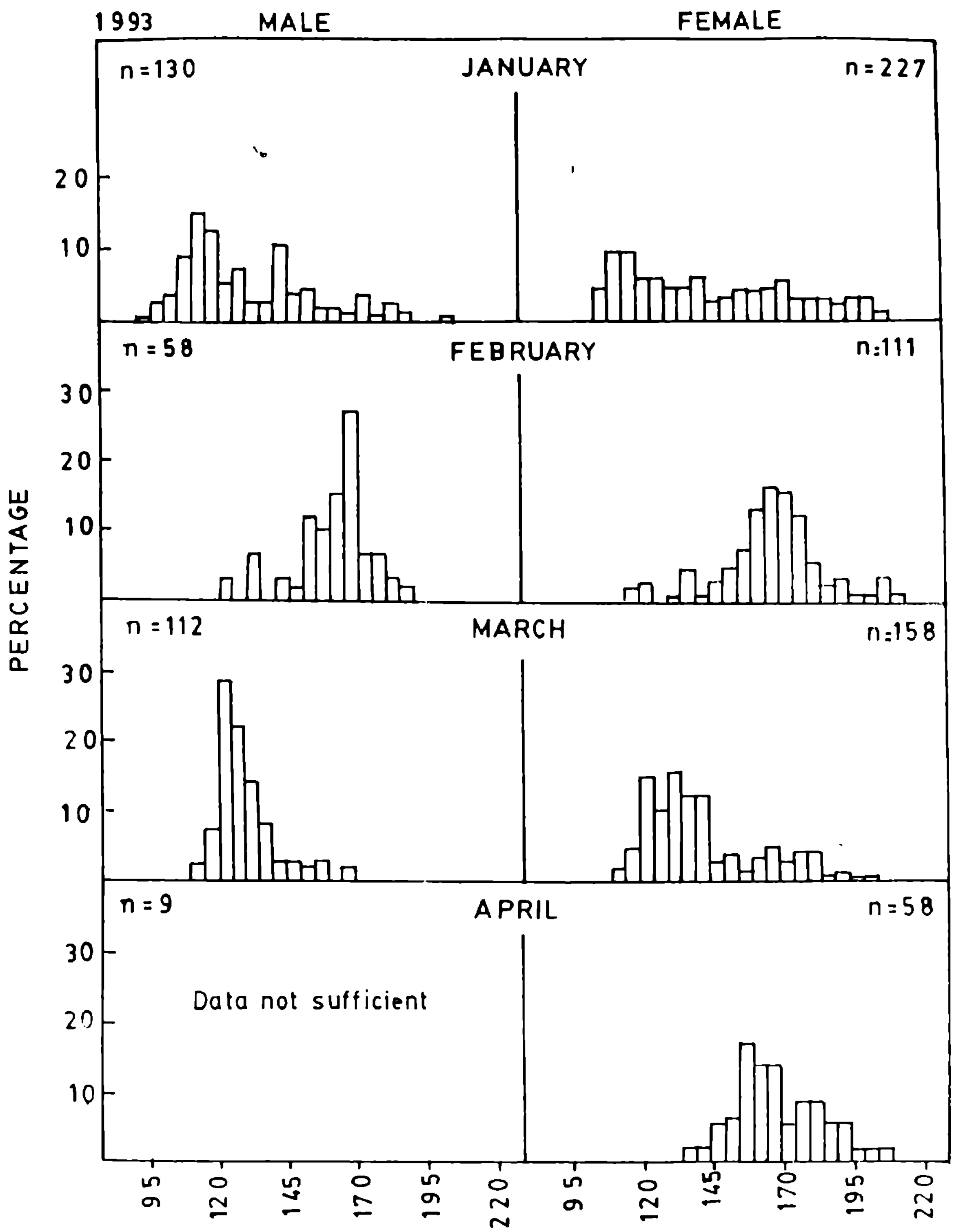

1992
MALE
FEMALE
PERCENTAGE
n=71
JUNE
n=348
n=106
JULY
n=111
n=96
AUGUST
n=271
n= 96
SEPTEMBER
n=61
37
n= 8
OCTOBER
n=41
Data not sufficient
n=4
DECEMBER
n=37
Data not sufficient
20
10
95
120
145
170
195
220
120
145
170
195
220

Fig. 12 g

Fig. 12 (h) Length frequency distribution of male and female *P. hamrur* during January 1993 - April 1993.



1993
MALE
FEMALE
n=130
JANUARY
n=227
n=58
FEBRUARY
n:111
n=112
MARCH
n:158
n=9
APRIL
n=58
Data not sufficient
PERCENTAGE
10
20
30
95
120
145
170
195
220

Fig. 12 h

Fig. 13. Growth curves connecting the monthly modes of male *P. hamrur* for integrated modal progression analysis.

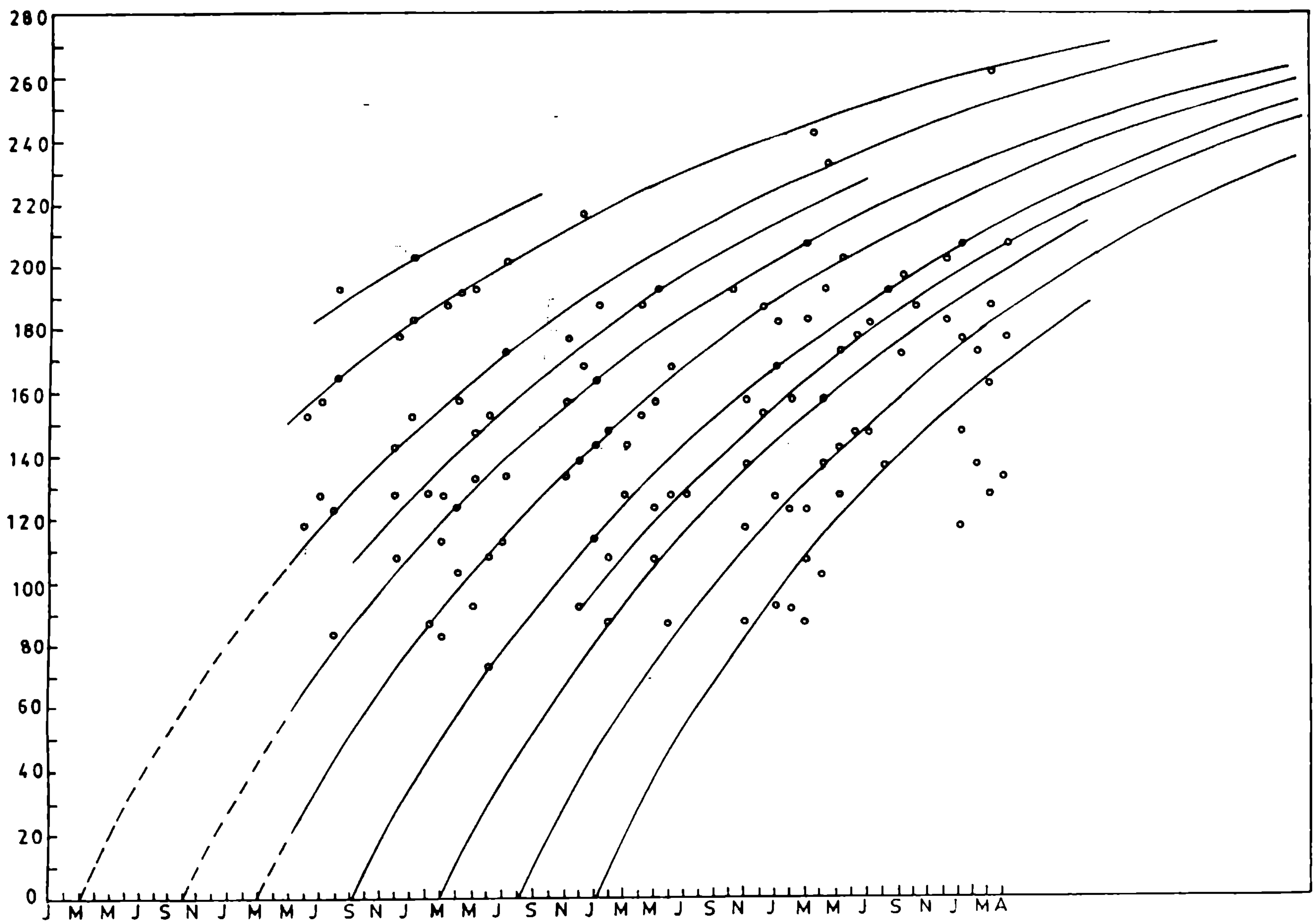

280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N J MA

Fig. 13

Fig. 14 Growth curves connecting the monthly modes of female P. hamrur for integrated modal progression analysis.

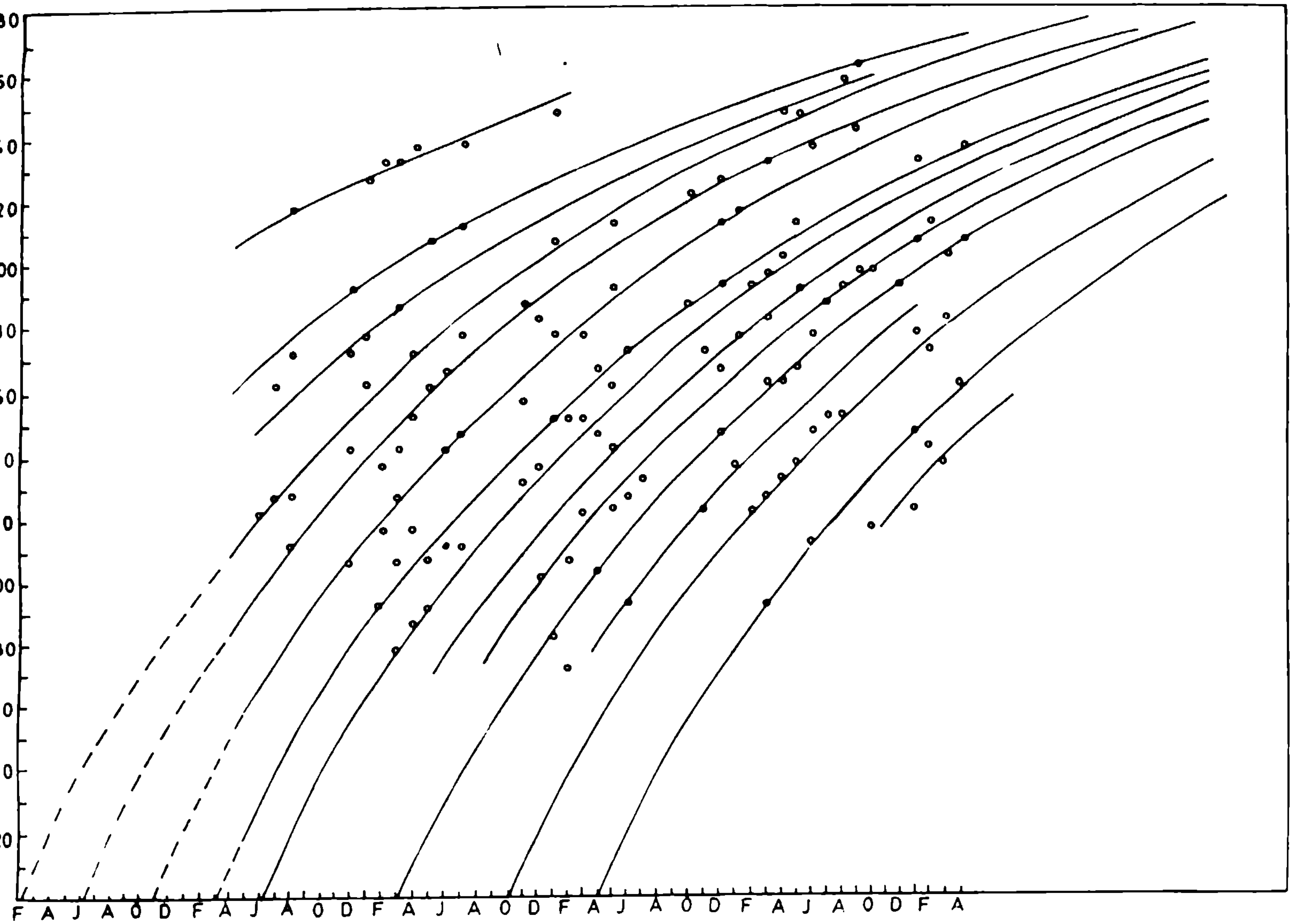
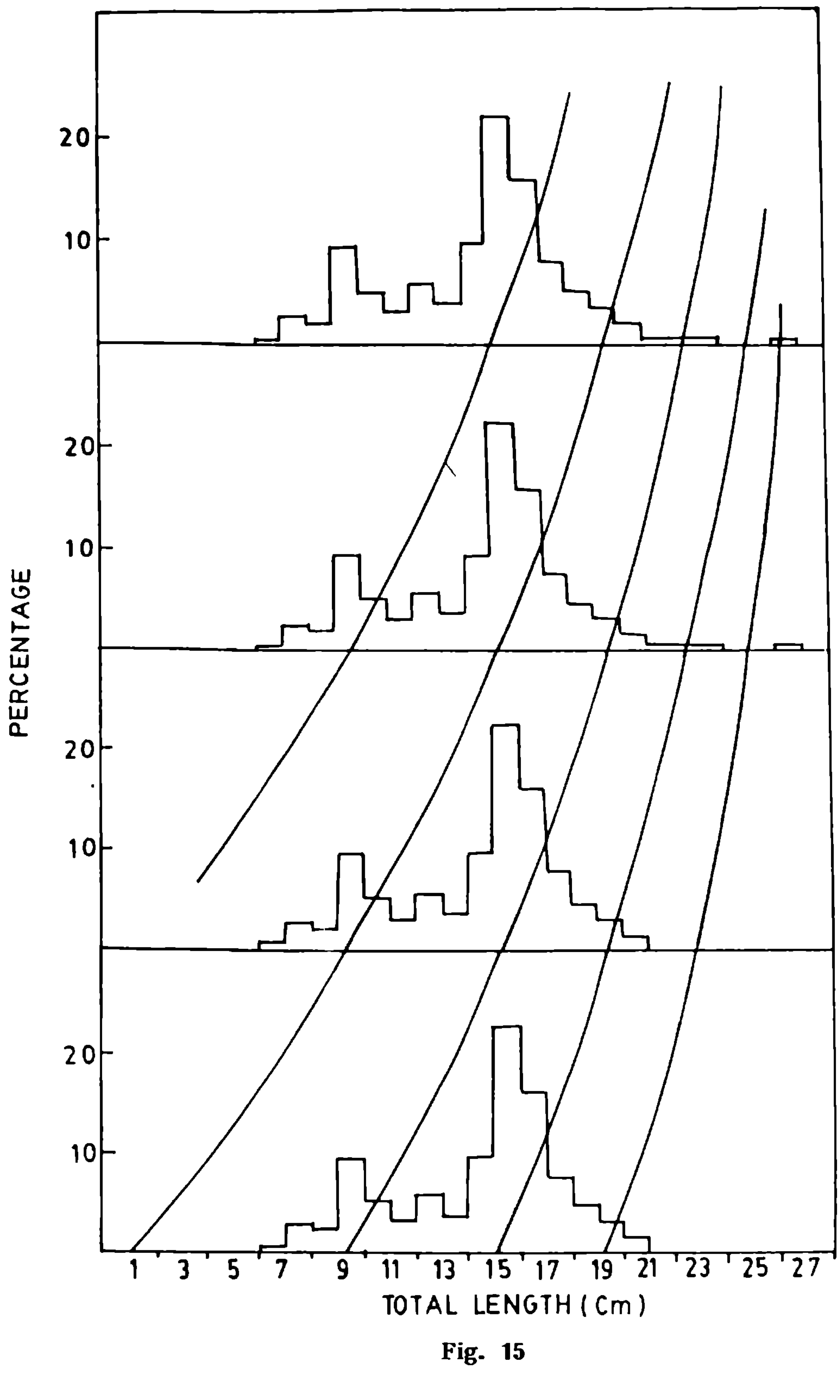

280
260
240
220
200
180
160
240
120
100
80
60
40
20
F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A

Fig. 14

Fig.15 Curves tracing the modes of frequency distribution of commercial catch of May 1993 repeated over and over for modal progression analysis.



20
10
20
10
PERCENTAGE
20
10
20
10
1 3 5 7 9 11 13 15 17 19 21 23 25 27
TOTAL LENGTH (Cm)

Fig. 15

Fig.16 Ford-Walford plot for estimating L_{∞} and K of *P. hamrur*.(a) male (b) female (c) combined commercial data.

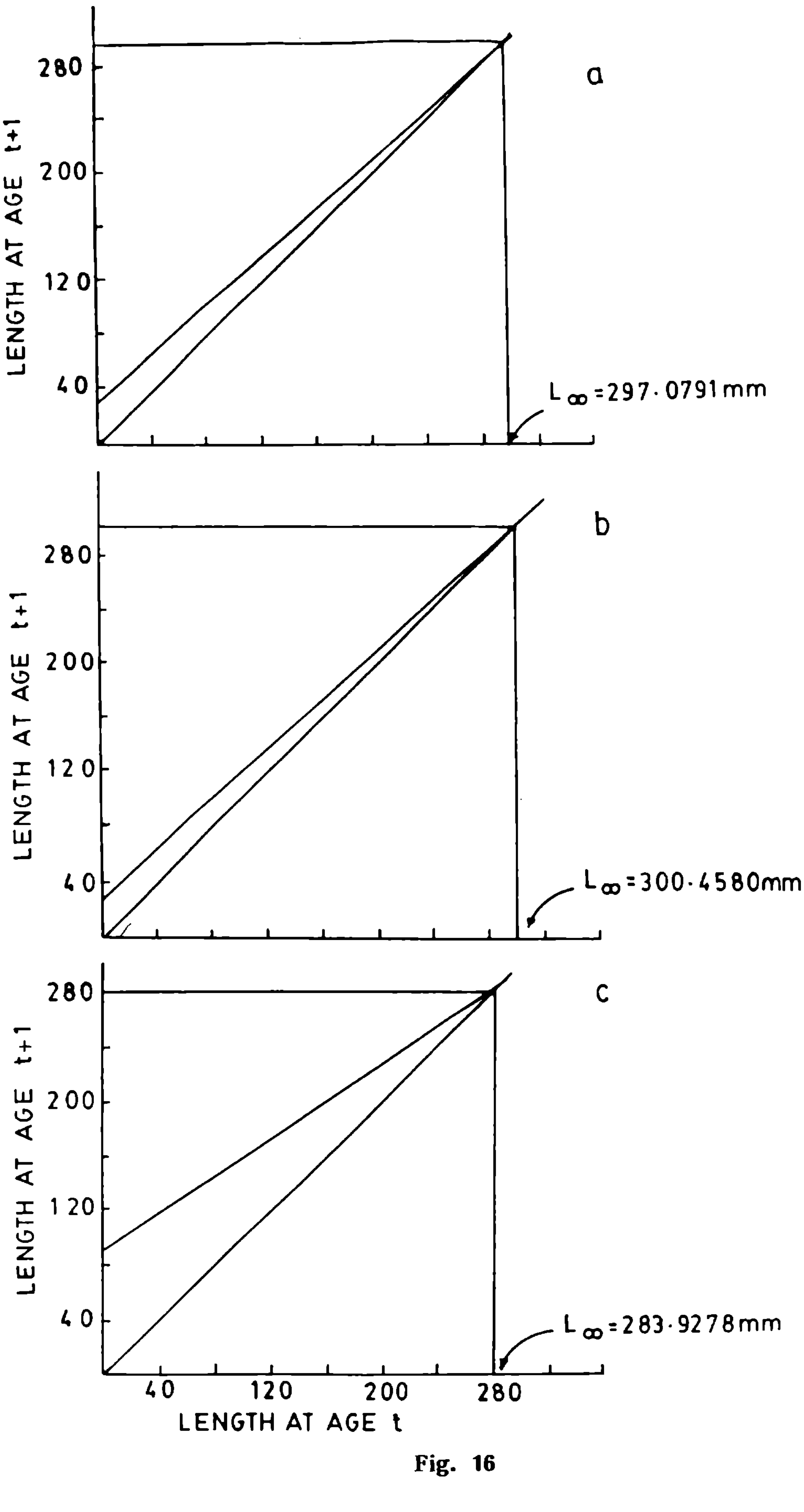

a
b
c
LENGTH AT AGE t+1
LENGTH AT AGE t
40
120
200
280
L ∞ =297·0791mm
L ∞ =300·4580mm
L ∞ =283·9278mm

Fig. 16

Fig. 17 von Bertalanffy plot for estimating t_o (a) male (b) female and (c) combined commercial data.

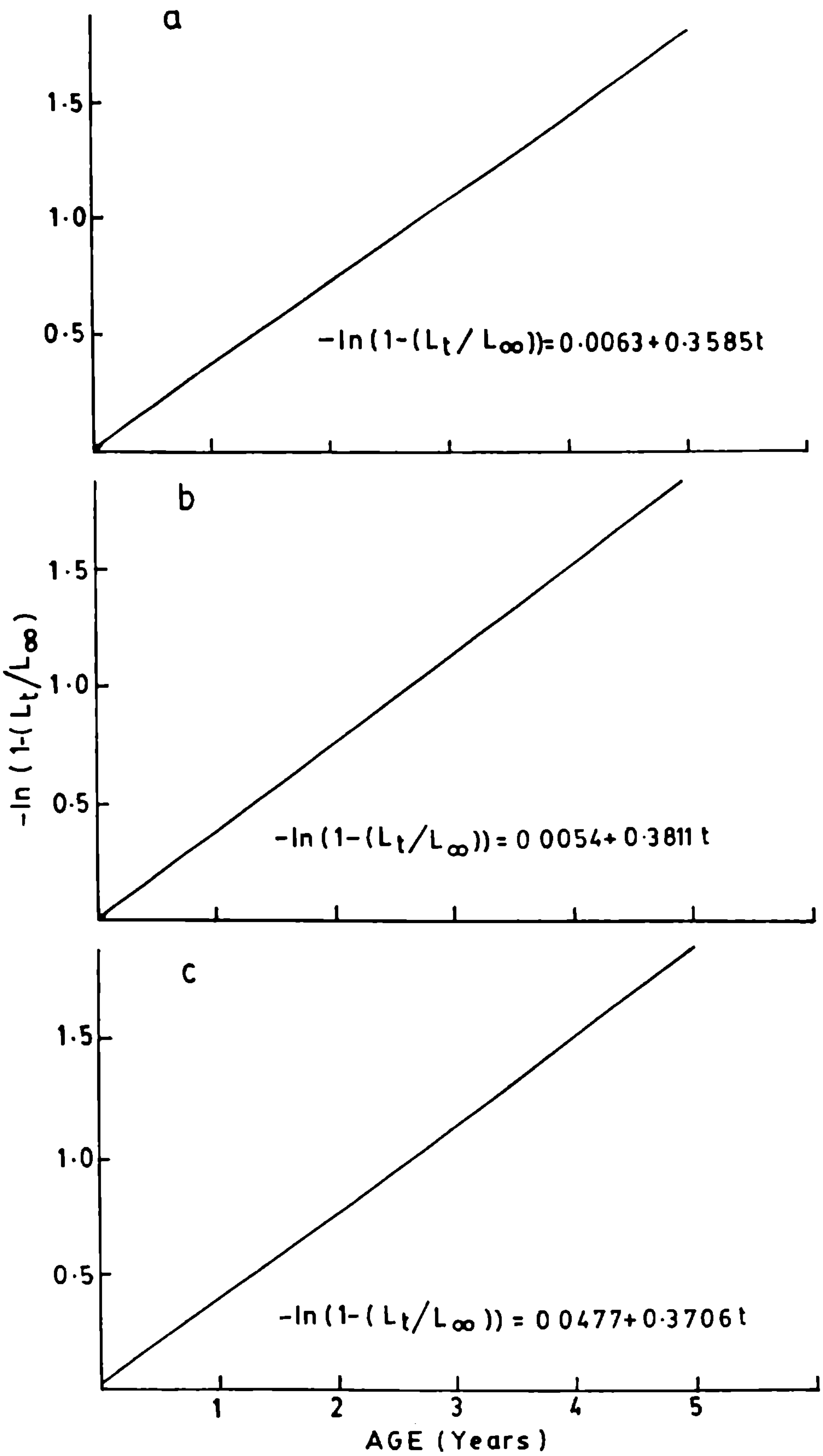

a
1·5
1·0
0·5
−ln(1−(Lt/L∞))=0·0063+0·3585t
b
1·5
−ln(1−(Lt/L8)
1·0
0·5
−ln(1−(Lt/L∞)) = 0 0054+0·3811 t
c
1·5
1·0
0·5
−ln(1−(Lt/L∞)) = 0 0477+0·3706 t
1
2
3
4
5
AGE (Years)

Fig. 17

Fig. 18 Estimated von Bertalanffy growth curve for (a) male, (b) female and (c) combined commercial data.

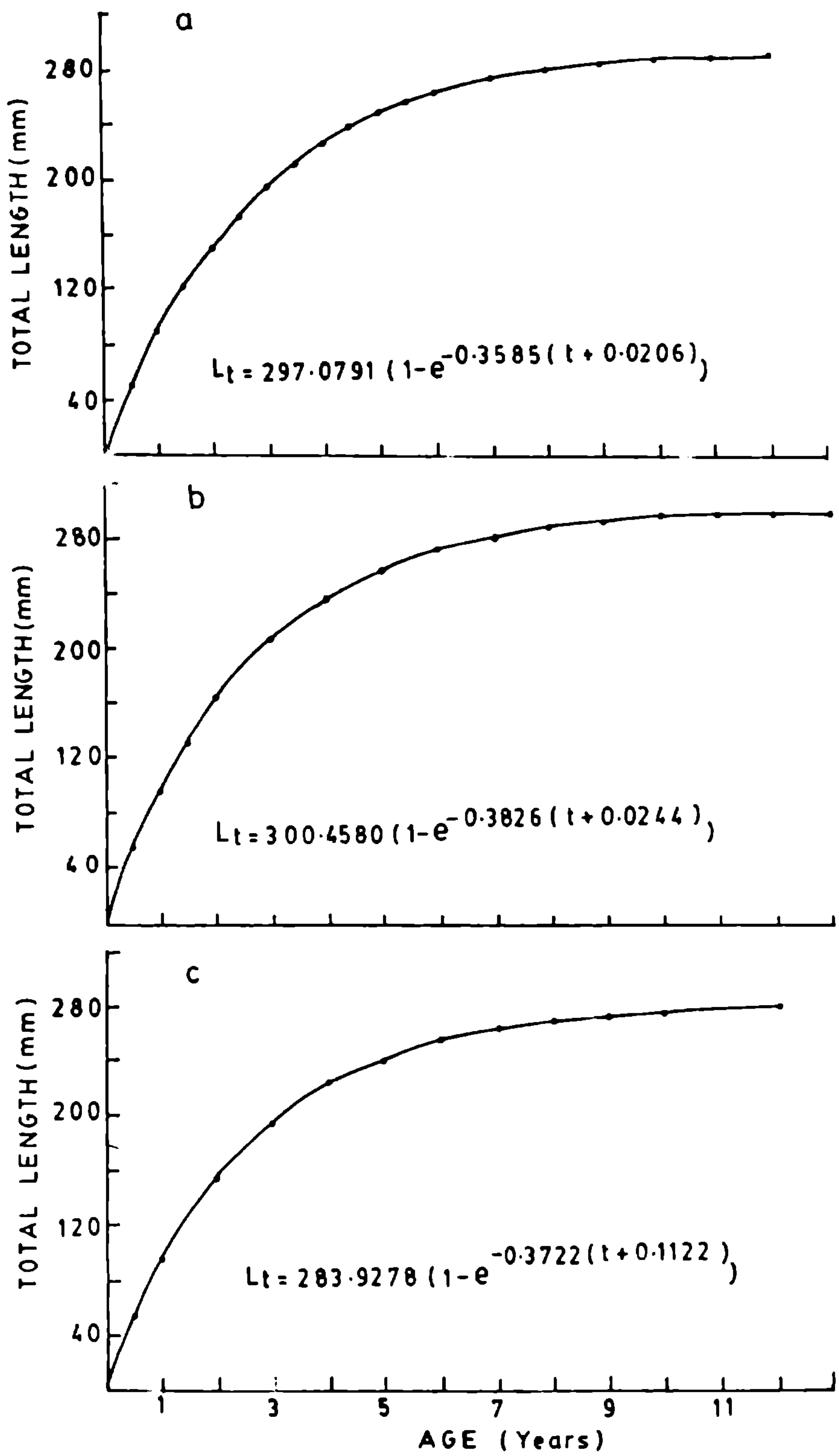

a
b
c
TOTAL LENGTH (mm)
280
200
120
40
Lt = 297·0791 (1-e^-0·3585(t + 0·0206))
Lt = 300·4580 (1-e^-0·3826(t + 0·0244))
Lt = 283·9278 (1-e^-0·3722(t + 0·1122))
1
3
5
7
9
11
AGE (Years)

Fig. 18

MORTALITY

7. MORTALITY AND EXPLOITATION

7.1 Introduction

Estimation of mortality rates is an essential requirement for the judicious exploitation and management of fishery resources. Mortality in an unexploited stock is caused by natural factors like diseases, predation, senility, whereas in an exploited stock, besides natural causes, fishing also contributes to the mortality. The instantaneous total mortality coefficient (Z) thus includes both natural mortality coefficient (M) and fishing mortality coefficient (F).

Mortality estimates have been done in almost all major exploited fish stocks with a view to arriving at optimum levels of exploitation. Recently this subject has drawn considerable attention in the context of over exploited state of major fish stocks of the world. Though investigations of mortality and exploitation of various demersal fish stocks have already been carried out from Indian waters, similar work has not been attempted on *P. hamrur*. Therefore, an attempt is made here to estimate the mortality rates, exploitation rate and exploitation ratio of *P hamrur* of the north east coast of India.

7.2 Material and methods

Length frequency data of 9481 specimens (4147 males and 5334 females) collected from exploratory trawl catches were used in this study.

Besides, length frequency data of 2045 specimens collected from small mechanised boats operating from Visakhapatnam fisheries harbour during May 1993 were also used in this study.

The following three methods were used for estimating the natural mortality.

i) **Cushing formula:**

Cushing (1968) proposed a method by which 'M' can be calculated based on longevity of the fish by applying the formula:

$$M = \frac{\ln.\ 100}{t_{max}} \quad (17)$$

Where t_{max} is the age at L_{max}, assuming that 99% of the animals in a population die before attaining L_{max}.

ii) **Pauly's (1980) empirical formula**

Pauly (1980) demonstrated a direct relationship between sea surface temperature and natural mortality. Based on 175 independent data sets, he derived the following empirical formula for computing natural mortality.

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T \qquad (18)$$

Where 'L_∞' is expressed in cm, 'K' is the annual growth coefficient and 'T', the annual mean surface temperature in °C.

iii) **Rikhter and Efanov's formula**

While investigating the comparative dynamics of high latitude stocks, Rikhter and Efanov (1976) showed a close association between natural mortality M and T_{m50}, the age at which 50% of the population attain maturity (also called the age of massive maturation). They also suggested that T_{m50} may be equal to the optimum age defined as the age at which the biomass of the cohort is maximal. The relationship can be expressed as follows:

$$M = 1.521/ (T_{m50}^{0.720}) - 0.155 \text{ per year} \qquad (19)$$

The instantaneous rate of total mortality (Z) was estimated following Beverton and Holt (1956) and Catch curve (Pauly, 1983) method.

i) **Beverton and Holt's method**

Beverton and Holt (1956) proposed a method by which total mortality can be measured in a steady state of the exploited population, which will, if the fishery is not selective, be the same as that in the catch. According to them Z can be obtained using the formula:

$$Z = K \frac{L_\infty - \bar{L}}{\bar{L} - L'} \qquad (20)$$

When L_∞ and K are von Bertalanffy growth parameters, $\bar{L}$ is the overall mean length of fish of L' and above, L' is the 50% retention length or the length of fish which is fully represented in the catches, and are under full exploitation.

ii) **Catch curve method**

This method has been reviewed in Beverton and Holt (1956), Chapman and Robson (1960), Robson and Chapman (1961) and Ricker (1975). The method essentially consists of a plot of the natural logarithm of the number of fish in various age groups (N_t) against their corresponding age (t) which gives the linear relation.

$$\ln N_t = a + bt \qquad (21)$$

The slope of the descending right arm with sign changed is taken as an estimate of total mortality Z. For correcting the effect of 'piling up' (Baranov, 1918) in the size classes pertaining to old, large and slow growing fish, the length converted catch curve was obtained using the following formula (Pauly, 1983).

$$\ln \frac{N_t}{\Delta t_i} = a + bt_i \qquad (22)$$

Where N_i = the number of specimens in the ith class and

t'_i = the relative age corresponding to the ith class

The instantaneous rate of fishing mortality was obtained by subtracting natural mortality M from the total mortality Z. The M value from Pauly's formula and Z value from catch curve method were selected for this purpose.

Exploitation rate (U): The rate of exploitation (U) is defined as the fraction of fish present at the start of the year and that is caught during the year (Ricker, 1975). It is estimated by the equation given by Beverton and Holt (1957) and Ricker (1975) as

$$U = \frac{F}{Z}(1-e^{-Z}) \qquad (21)$$

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

$$E = \frac{F}{Z} = \frac{F}{M+F} \qquad (22)$$

The ratio gives an indication whether the stock is overfished or not under the assumption that the optimal value of E equals to 0.5 or E 0.5

which in turn is under the assumption that the sustainable yield is optimised when $F \approx M$ (Gulland, 1971).

In the above two equations F, M and Z are instantaneous rates of fishing, natural and total mortalities respectively.

7.3 Results

Natural mortality coefficient was computed by applying the three methods for male and female from exploratory data and pooled data from commercial catches. The values obtained are given below:

	Cushing	Pauly	Rikhter & Efanov
Male	0.5503	0.9000	0.9928
Female	0.5874	0.9363	1.0364
Pooled (commercial)	0.5714	0.9341	1.0108

For Pauly's empirical formula, the mean surface was taken as 27°C following Rao, 1985 and Reuben et al. 1993. It could be observed that the natural mortality values computed by applying Pauly's (1980) and Rikhter and Efanov's (1976) methods were much closer compared to the values obtained by following Cushing's (1968) method.

The values of total mortality coefficient obtained by Beverton and Holts (1956) formula and catch curve methods are as follows:

	B & H	Catch curve
Male	2.2008	2.4514
Female	1.3324	1.7686
Pooled (Commercial)	2.6848	2.5047

For calculation of fishing mortality F, the M values from Pauly's formula and Z values from catch curve method were selected. Thus the values of F obtained were:

	M	Z	F
Male	0.9000	2.4514	1.5514
Female	0.9363	1.7686	0.8323
Pooled (Commercial)	0.9341	2.5047	1.5706

The exploitation ratio E and exploitation rate U were calculated using the above values of F and Z as:

	E	U
Male	0.6329	0.5783
Female	0.4706	0.3903
Pooled (Commercial)	0.6271	0.5758

7.4 Discussion

The values of K obtained in the present study indicate that P. hamrur is a relatively slow growing fish. In conforming with the generally accepted view, fishes with low K values are characterised with low natural mortality (Sparre and Vinema, 1992). In general it is asserted that natural mortality is related to age and size of the fish. Since M is related to longevity and curvature parameter K is linked to the size of the fish, the M/K ratio is found to be constant among closely related species (Beverton and Holt, 1959). The M/K ratio in fishes generally ranges from 1.5 and 2.5. The estimated annual K values in respect of P. hamrur in the present study are 0.3585, 0.3826 and 0.3722 for male, female and commercial catch respectively and the corresponding M values are 0.9000, 0.9363 and 0.9341. Therefore the M/K ratio of this species is worked out to be 2.51, 2.44 and 2.50 for male, female and commercial catch respectively. The M/K ratios, thus computed fall within the limits shown above. Regression on time series effort data against Z is also in use to arrive at M which are likely to be unrealistic including negative values (Ricker, 1975) and therefore, not attempted in the present study. As mentioned elsewhere (see chapter on age and growth) P. hamrur has an estimated longevity of eight years. However, the length frequency data indicate that 99% of the specimens are below four years of age. Therefore a rough estimate of natural mortality 'M' as per Alagaraja's (1984) concept shall be around 1.2 per year. It is worth noticing that the natural mortality coefficients arrived at by three methods in respect of P. hamrur were almost nearer to this.

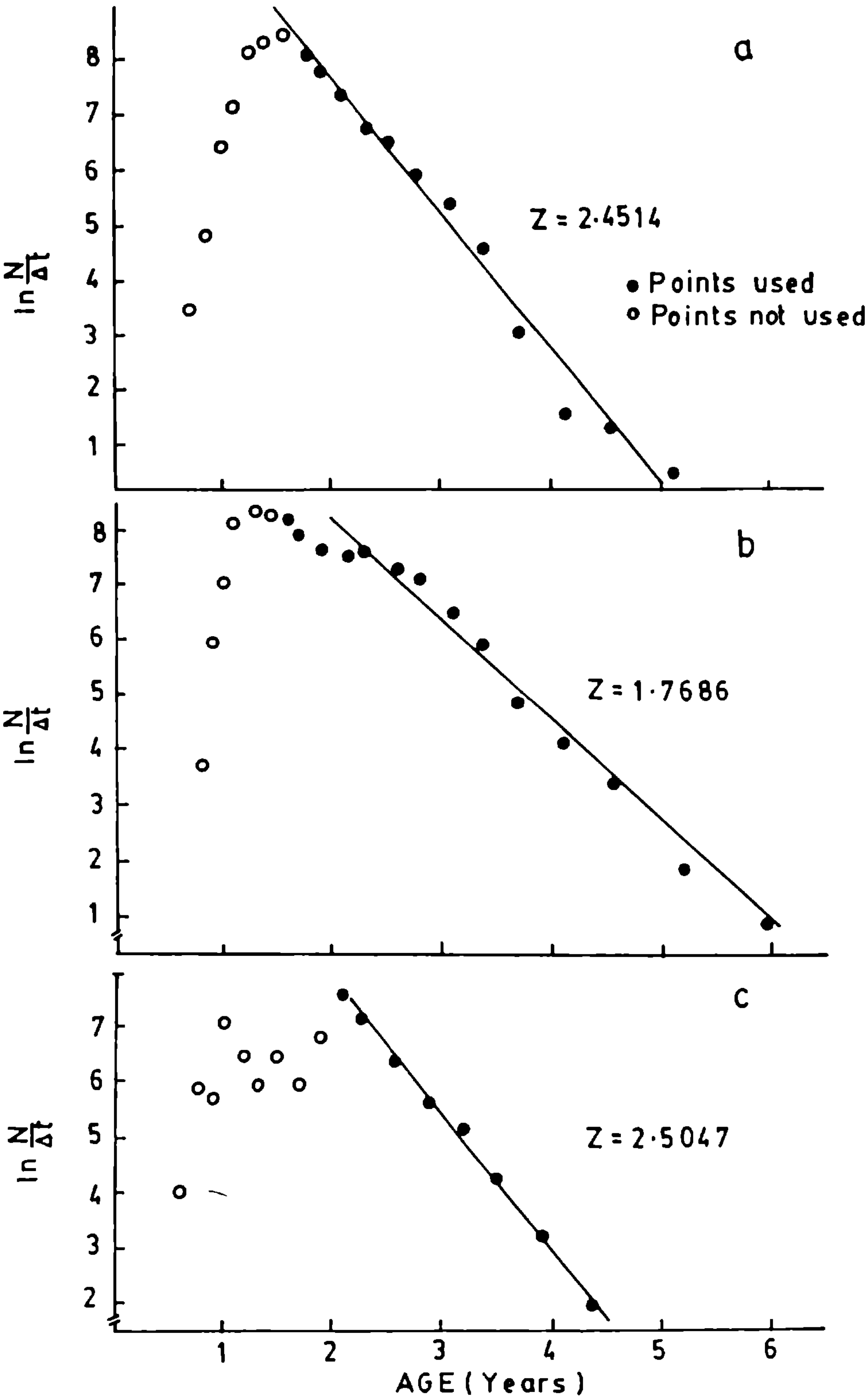
Nugroho *et al.* (1983) estimated a total mortality Z of 5.42 and natural mortality of 3.45 for *P. macracanthus* from the North Java Sea and mentioned its life span as 4-5 years with an estimated K value of 1.36 per year. The above result will yield an M/K ratio of 2.54, almost similar to that obtained for *P. hamrur* in the present study. On the contrary Ingles and Pauly (1984) estimated a total mortality of 8.95 and natural mortality of 8.09 for *P. tayenus* from the Samar Sea. The authors have estimated K as 1.25 which would yield a longevity of 2.4 years and an M/K ratio of 6.47. Lester and Watson (1985) estimated the total and natural mortality of 2.05 and 1.41 per year respectively for *P. tayenus* and 2.01 and 1.27 per year respectively for *P. macracanthus* of Hong Kong waters. Dwiponggo *et al.* (1986) estimated a total mortality of 6.38 and natural mortality of 2.28 for *P. macracanthus* with an estimation of K as 1.30 from the North Java Sea. As the values of mortality vary with species as well as fishing regions depending on the prevailing fishing pressure, a comparison of the present values with some of the previous reports are found difficult. However, the present finding fully conforms with that of Lester and Watson (1985) from Hong Kong waters in respect of *P. macracanthus.*

Unlike the commercial data, the exploratory data may not reflect the reactions of the stock in response to the fishing pressure and therefore it may lead into errors in the estimation of mortality. As the natural mortality coefficients were estimated based on parameters which do not reflect the age structure of the catch, the values obtained from all the three methods were almost comparable for male, female and commercial data. The total mortality coefficient Z estimated for males and commercial catch were compatible. However, the one derived for females appears to be low. Similar trend could be noticed in the fishing mortality coefficient 'F'. The Z value obtained from age structured catch curve will reflect the age class distribution of P. hamrur of the east coast of India age classes. A perusal of the age class data collected would reveal that the age class distribution in respect of data for the male as well as pooled commercial catch were identical while females showed difference in having more older age classes in the population, thereby, characterised with a lower total mortality coefficient when compared to the other two categories. The difference noticed in the mortality coefficients among various categories has effected similar variations in respect of exploitation rate as well as exploitation ratio of male, female and commercial catches.

Commercial data for the month of May 1993 were good enough to indicate the present condition of exploitation of the stock of P. hamrur along Visakhapatnam coast. While comparing with Ricker (1975) the exploitation ratio of 0.6271 of the commercial data indicates that the stock is being exploited just above optimum level. It may therefore be inferred that the chartered vessels and other deep sea fishing vessels operated along the north east coast of India have exerted sufficient fishing pressure on the stock of P. hamrur during recent years. A decline in the catch rate of this species noticed in the FSI vessels during recent years (Table 35 &

36) may also lend support to the above finding. The regulatory measures usually implemented for the rational management of the over-exploited stocks are introduction of closed seasons, catch quota system and mesh size regulation of the year. However proper implementation of these regulatory measures are found to be difficult due to the multispecies nature of the fishery and other social and political reasons. Neverthless, the results of the present investigation would be of immense use for finding out suitable measures for sustainable harvest of priacanthid resources by the trawlers from the north east coast of India. Investigations of similar nature from other regions would give a clear picture of the exploitation of this resources from Indian waters.

Fig.19 Estimation of total mortality (Z) based on catch curve method. (a) male (b) female and (c) combined commercial data.



a
b
c
Z = 2·4514
Z = 1·7686
Z = 2·5047
• Points used
○ Points not used
ln N/Δt
AGE (Years)

Fig. 19

DISTRIBUTION OF THE STOCK
AND
FISHERY

8. DISTRIBUTION OF THE STOCK AND FISHERY

8.1 Spatial and temporal distribution of the stock

8.1.1 Introduction

Data on distribution and abundance of stock are very essential to formulate strategies for the optimum exploitation of any fishery resource. While studying the distribution and abundance of demersal resources of the Indian waters based on the results of exploratory surveys the spatial and temporal variations in the stock of priacanthids were only partially documented. (Joseph, 1984, 1986, 1987; Philip *et al.*, 1984; Philip and Joseph, 1988; Sivaprakasam, 1986; Sudarsan *et al.*, 1988, 1990; Vijayakumaran and Philip, 1988; Vijayakumaran and Naik, 1988a; Sivakami, 1990; James and Pillai, 1990). Vijayakumaran and Naik (1988b) studied the stock of *Priacanthus hamrur* and its fluctuations during March and September of 1984, 1985 and 1986 between latitude 11°N to 16°N along the west coast of India. Biradar (1988) estimated the density, biomass and maximum sustainable yield of *P. hamrur* off the north west coast of India. Assessment of the stock of *Priacanthus* spp. from the Indian waters was made by John and Sudarsan (1988). Based on the results of the survey by FORV *Sagar Sampada* Bande *et al.*, (1990) studied the distribution and abundance of *Priacanthus* spp. of the Indian waters and estimated its total biomass in the Exclusive Economic Zone of India. In most of the above studies *Priacanthus* spp. were treated either as one of the components of the total resource under study or separately confining to a particular area and period. Therefore, an attempt is made here to study the spatial and temporal variation of Priacanthus spp. in different latitudes along the Indian coasts and to elucidate the fluctuations in abundance during different seasons and years.

8.1.2 Materials and methods

The catch data of larger exploratory survey vessels of the Fishery Survey of India (FSI) which operate mostly beyond 50 m depth were used in this study. This data pertain to the vessels of different sizes and capacities operated by FSI from its bases at Porbandar, Bombay, Goa, Mangalore, Cochin, Madras and Visakhapatnam. The salient features of the vessels and type of gears which varied from each other are given by Sivaprakasam (1986).

The details of the vessels, gears, areas and periods of operation in respect of the data used in this study are furnished in Table 26. The fish trawls were operated below 200 m depth while shrimp trawls were used in deeper areas beyond 200 m depth. The average speed of trawling was 3. 5 knots and the duration of haul was 2.5 hours till 1988 and 1.5 hours thereafter.

The continental shelf and slope of various regions were stratified based on depths, such as below 50 m, 51-100 m, 101-200 m and above 200 m in order to study the depth-wise abundance. The zone beyond 200 m includes generally areas upto 300 m depth but may reach upto 500 in certain regions like the south west coast. Beyond this level trawling was not done due to the steep fall in the shelf. Broadly, the entire area covered in this study was divided into five regions viz. north west coast, south west coast, Wadge Bank and Gulf of Mannar, lower east coast and upper east coast, for delineating the region-wise distribution and abundance. In each of these regions, variations in abundance in different latitudinal sections were also studied. To study the seasonality in abundance, the west coast was divided into three regions viz. Kerala, Karnataka-Goa and Maharashtra-Gujarat coasts. Similarly, the east coast was divided into three regions (1) Tamil Nadu (2) south Andhra and (3) north Andhra, Orissa, West Bengal. This division was made considering the differences in the nets used in the individual regions and thus making the seasonal cph values within the regions comparable. Total fishing effort spent in different areas and depth zones during the period under study along the west and east coasts are given in Table 27 and 28. Density and biomass estimates were made considering catch per unit effort as the index of abundance. Swept area method was adopted for estimating the density. The swept area of each trawl was calculated using the formula:

$$a = t.v.h.\ x^2 \qquad (23)$$

where

't' is time spent for trawling.

'v' is the velocity of the trawl over the ground when trawling

Where

(c/f) is the mean catch per unit effort.

'A' is the total area available in the stratum

'a' is the area swept by the net in a unit time, and

'x_1' is the escapement factor or the catchability coefficient i.e., the fraction of the fish in the path of the gear that are actually retained by the net.

Except for 34 m fish trawl, the catchability coefficient was taken as 0.5 for all the trawls, as followed for trawls used in south east Asia (Isarankura, 1971; Saeger et al., 1976). In the case of 34 m trawls, considering the larger mesh size, a reduced catchability coefficient of 0.4 was used assuming a higher escapement factor (Sivaprakasam, 1986; John and Sudarsan, 1988). Comparison of abundance could not be made using cph since the area swept by different nets in unit time varied as shown in Page 110. Therefore, density, which is derived by considering both cph and area swept by the net, was used for comparative purpose. The average density for different latitudinal sections as well as for various depth zones of different regions were calculated and weighted average was worked out for each region taking the area as weight. The 'area' used here to estimate the standing stock is the shelf area available for trawling in each latitude depth segment worked out by the Fishery Survey of India.

'h' is the length of the head rope, and

'x^2' is that fraction of the head rope length 'h' expressing the wing spread or width of the path swept by the trawl.

Different values were given to X^2 in different areas viz. 0.4 for the south east Asian waters (Shindo, 1973), 0.6 for Caribbean water (Klima, 1976). Pauly (1980) suggested that 0.5 is the best compromise. The wing spread varies with the trawling speed, weather condition, velocity and direction of the current and warp length (Sparre and Venema, 1992). In this study 0.4 is used as the fraction X^2 of the head rope length. The swept area per hour thus calculated for different trawl gears used are given below:

Sl. No.	Name of the trawl	Swept are (sq. km.)
1.	34 m fish trawl	0.0881
2.	27 m fish trawl	0.0700
3.	51 m expo model fish trawl	0.1322
4.	44 m star model fish trawl	0.1140
5.	45 m shrimp trawl	0.1166
6.	47 m shrimp trawl	0.1218
7.	34 m shrimp trawl	0.0881

The density and biomass were worked out for each latitude and depth zone using the formula:

$$B = \frac{(c/f).A}{a.x_1} \qquad (24)$$

8.1.3 Results

8.1.3.1 Area-wise distribution and abundance

The density (kg/sq.km) of priacanthids computed from different latitudes and depth zones along the coasts of India is shown in Fig.4. Along the north west coast, the latitudes 15°N and 16°N (between Goa and north of Ratnagiri) recorded the highest density viz. 524 and 387 kg/sq.km followed by latitudes 17°N and 21°N. The density was comparatively low in latitudes 19°N, 18°N and 20°N. The fishing effort was less in latitudes 19°N as compared to other latitudes. The average density for the north west coast was estimated as 113 kg/sq.km (Table 29).

In the south west coast, the latitude 14°N (off Karwar) showed the highest density (535 kg/sq.km) followed by latitudes 12°N and 13°N (Kasargode to Honavar). The latitudes 11°N (Calicut to Kasargode), 10°N (Cochin to Calicut) and 9°N (off Alleppey) also recorded comparatively good density. The lowest density was observed from 8°N (between Cape Comorin and Quilon). The average density for the entire south west coast was 245 kg/sq.km, which was the highest among all the regions (Table 29).

The density (kg/sq.km) of priacanthids computed from different latitudes and depth zones of Gulf of Mannar, Wadge Bank and the east coast of India is given in Table 5.

The density of priacanthids along the Wadge Bank and Gulf of Mannar was very low. The average density from this region was estimated as 28 kg/sq.km.

In the lower east coast, the latitude 12°N showed the highest density of 393 kg/sq.km followed by 11°N with 162 kg/sq.km whereas it was the lowest in the latitude 10°N. The average density for the lower east coast was 177 kg/sq.km (Table 30).

Along the upper east coast, the latitude 18°N and 19°N latitudes (between Bhimunipatnam and Paradip) were the most productive latitude with average density of 191 kg/sq.km and 178 kg/sq.km respectively. The lowest density was observed in 15°N (Kakinada to Visakapatnam). The average density observed for the upper east coast was 130 kg/sq.km (Table 30).

8.1.3.2 <u>Depth-wise distribution</u>

The density of priacanthids observed from different depth zones of various latitudes of the west coast are given in Table 29. In the north west coast, the depth zone 100-200 m recorded the highest density of 634 kg/sq.km followed by 50-100 m depth zone with 121 kg/sq.km. The lowest density was observed in the shallow waters below 50 m depth. All the latitudes of this regions showed higher density in the 100-200 m depth except latitudes 18°N and 21°N where density was high in 50-100 m depth. The density was very low in all latitudinal sections below 50 m depth (except 16°N) and above 200 m depth of all except latitude 15°N.

In corollary with the above findings, in the south west coast also high density was observed in 100-200 m depth zone (548 kg/sq.km) followed by 50-100 m depth (315 kg/sq.km). The average density below 50 m and above 200 m did not vary much. In all the latitudes, the depth zone 100-200 m was more productive except latitudes 10°N and 11°N where depth zone 50-100 m showed relatively higher density. At latitude 14°N comparatively higher density of priacanthids could be observed from beyond 200 m depth. On the contrary, this depth zone recorded very low density in all the other latitudes. In general there is a gradual decrease in density below 50 m as well as above 200 m depth zones from the northern latitudes, to the southern latitudes.

In the Wadge Bank and Gulf of Mannar, 100-200 m depth zone recorded 68 kg/sq.km during the period of observation, whereas from all other depth zones only very low density was recorded.

Along the lower east coast a very high density of 1154 kg/sq.km was observed from the 100-200 m depth zone followed by 213 kg/sq. km from depth zone above 200 m (Table 30). In all the latitudes, the 100-200 m depth was the most productive area followed by above 200 m depth zone. In the upper east coast, the depth zone 100-200 m recorded the highest density (377 kg/sq.km) followed by above 200 m depth zone (126 kg/sq.km). The 100-200 m depth of all the latitudes of this region showed higher density except latitude 16°N where the density was more in above 200 m depth. In both the upper and lower coast, the average density of 50-100 m depth zone was comparatively much lower than that of the west coast.

8.1.3.3 Seasonal abundance

Seasonal fluctuations in the catch rates from different regions and bathymetric zones are shown in Tables 31 and 32. It can be seen from the Table 31 that along the Kerala coast, in general, the period October-February yielded good catch rate from 30-200 m depth zone. Beyond 200 m, January showed the highest catch rate followed by June. In all the remaining months catch rates were very low. Along the Karnataka-Goa coast, October recorded the highest catch rate from 30-200 m zone. For areas below 200 m, the period August-January was the most productive and the least production was observed during monsoon months. In the deeper areas, November-January recorded good catch rates with the highest catch rate of 63.1 kg/hr in November and low catch rates were observed during June-October. Along the Maharashtra-Gujarat coast, October to February recorded higher rates with highest value during October. From this coast, priacanthids were recorded from above 200 m depth only in January. The catch rates were nil from February to May and in November whereas in the remaining months there was no fishing in this depth zone.

Along the Tamil Nadu coast, August-October appeared to be the best season with highest catch rate in September (Table 32). January, May, July and November recorded very low catch rates from areas below 200 m depth. February, March and August recorded good catch rates from areas above 200 m depth. Low catch rates were observed during May, June, October and December.

Along the south Andhra coast, June and July recorded the highest catch rates from areas below 200 m zone. In other months, the catch rates varied between 0.5 (January) to 9.1 (April). From the deeper areas priacanthids were recorded only during December and January with a high catch rate in January.

A specific seasonality was not seen along the North Andhra-Orissa-West Bengal coast. However, high catch rates were observed in January, June and November and low rates in February and August in areas below 200 m depth. October recorded the highest catch rate of 50.0 kg/hr from the deeper areas of this region which was the highest cph recorded from the east coast. May and November also yielded relatively high rates. There was no catch during January to March, June and August.

8.1.3.4 Contribution of priacanthids to the total catch

The total catch landed from different depth zones of various latitudes and regions of the west coast and the percentage contribution of priacanthids in the total catch are given in Table 33. Along the north west coast, priacanthids formed 6% of the total catch. It formed 18.5% of the total catch from 100-200 m depth zone and 4.7% from 50-100 m depth. A very high percentage of 21.7 noticed from areas above 200 m depth was not significant in quantity as the total catch was only 2.3 tonnes for a corresponding effort of 88.42 hours. Priacanthids formed more than 10.0% in the latitudes 15°N, 16°N and 17°N with the highest of 11.6% in latitudes 16°N. Low percentages were noticed in latitudes 18°N to 20°N where priacanthids formed less than one percent of the total catch. They formed 55.2% of the total catch from 100-200 m depth of latitude 17°N and 31.2% from the same depth of latitude 15°N. In the deeper waters at latitude 15°N and 16°N, priacanthids formed 36.5-69.9%. However, the catches from these regions were found negligible.

In the south west coast also, priacanthids formed 6% of the total catch. It formed 8.3% and 8.1% of the catch from 50-100 m and 100-200 m depth zones respectively. In shallow waters of this region, priacanthids formed 3.2% of the total catch which was high when compared to other regions. This was due to the higher concentration of priacanthids in the shallow areas of the latitudes 12°N and 13°N of this region. The highest percentage was noticed beyond 200 m depth at 14°N latitude which forms about 68% of 7.1 tonnes of catch. They formed 20.6% and 15.4% respectively from 50-100 and 100-200 m depth zones of latitude 14°N. The contribution of priacanthids was 15.0% of the total catch from this latitudianl section, which was highest among the different latitudinal sections of this region.

Priacanthids contributed only 1% to the total catches of Wadge Bank and Gulf of Mannar and this would suggest their poor density in these regions (Table 34).

Along the lower east coast, priacanthids formed 10.4% of the total catch which was much higher than the west coast. The latitude 12°N recorded the highest percentage of 15.8 whereas in other latitudes, the percentages varied from 6.92 to 8.6. There was very little fishing effort in latitude 11°N. Their contribution from below 50 m and 50-100 m zones was found negligible. The highest percentage of 45.6 was noticed from 100-200 m depth. Similar trend was noticed in all latitudes of this region except in latitude 14°N where priacanthids contributed 33.5% at depth zones beyond 200 m.

In the north east coast, the contribution of priacanthids to the total catch was 4.0%. The highest percentage of 10.3 was observed from the latitude 17°N while in other latitudes, it varied from 1.9-5.4 percent. Depth zones 100-200 and above 200 m showed higher percentages of 26.1% and 20.4% respectively. The contributions from 50-100 m and below 50 m were very poor.

8.1.3.5 Variations in annual abundance

The effort, catch rates of total fish and catch rates of priacanthids from 30-200 m and above 200 m depth zones of Karnataka-Goa coast, Kerala and lower east coast are given in Tables 35 and 36. The entire area is treated as a unit in the case of lower east coast since the gear used was the same in all depths. The data were available continuously for a period of nine years from these regions and therefore these regions were selected for comparing the catch and effort data.

It could be seen from Table 35 that along the Karnataka-Goa coast, in areas below 200 m depth the catch rates were high in 1985 and 1986 and thereafter it slowly decreased in the subsequent years. However, there was no significant drop in the total catch rates of this region during these years. Same trend was also seen in the areas beyond 200 m depth. Marginal improvement could be noticed in the landings from these regions in the years 1990 and 1991.

Along the Kerala coast also a similar declining trend in the catch rates could be seen from 1987 onwards (Table 36). In this region also highest yield rates were encountered in 1985 and 1986. The total catch rates fluctuated with significant improvement in 1989 and 1990. The catch rates of priacanthids from the areas above 200 m were insignificant (below 1.0 kg/hr) in all the years. Along the lower east coast, the highest catch rate recorded in 1986 was thereafter declined. However, it showed some improvement in 1988.

8.1.3.6 Biomass

The total biomass of priacanthids estimated from the west and east coasts are given in Table 37 and 38. The estimates are made based on the average catch per unit effort obtained from each latitudinal and depth zone. It could be seen that the stock of priacanthids along the west coast excluding the Wadge Bank and Gulf of Mannar is about 44,000 tonnes. About 12,600 tonnes estimated from the east coast was comparatively lower mainly due to the low catch rates as well as the narrow shelf in contrast to the west coast. The highest estimate of about 21,500 tonnes was observed from the 50-100 m depth zone of the west coast, followed by the 100-200 m depth zone. Along the east coast, the 100-200 m depth recorded the highest biomass.

8.2 Fishery and utilization

8.2.1 Fishery

Priacanthids form a substantial fishery only in the western Pacific and eastern Indian Ocean and is an important constituent of the demersal catches in many south east Asian countries. Vien (1968) reported that bigeyes account for as much as 3% of the catches of demersal fish from Tonkin Bay. Bigeyes ranked second among the demersal fishes in the trawling grounds of south western part of the South China Sea with a catch rate of 366.8 kg/hr where in P. tayenus showed predominant over the other priacanthid species (Senta, 1977, 1978). Joung and Chen (1992) reported 290 t of bigeye being landed annually from off north east Taiwan and cited that the annual landing in Taiwan to the tune of 6000 to 8000 t per annum valued at 7.3 million dollars (US). However, it has been reported (Stamatopoulos, 1993) that the bigeye catches from eastern Indian Ocean was 300 t in 1970, 1875 t in 1990 and 1101 t in 1990, showing an increasing trend in recent years. Priacanthids are emerging as a commercially important group in countries like Brunei, Burma, Hong Kong, Indonesia, Kampuchea, Malaysia, Philippines, Singapore, Thailand and Vietnam (Chullarson and Martosubroto, 1986). They are marketed mostly in fresh, dried-salted, or steamed conditions and in the form of fish balls (Shindo and Chullasorn, 1980).

Published account on landings of priacanthids from India are still lacking, probably due to its low commercial value and seasonal nature of occurrence and abundance. Priacanthids are generally brought to the shore only when other varieties are scarse (Personal observation). This group has not been redressed with its individual entity and therefore priacanthid landings have been included as part of miscellaneous fishes while compiling statistics of fish landings of India by the concerned agencies.

However, data are available from localised area where they form a substantial fishery. Rao (1984) estimated the landings of priacanthids by small mechanised trawlers at Visakhapatnam as 236 t, during the period 1980-82 which was later reestimated as 219 t by Luther et al. (1988). Zacharia et al. (1991) reported that priacanthid landings at Mangalore ranged between 56 in 1989-90 to 603 in 1990-91 with a maximum catch rate of 23.5 kg/unit during 1990-91. In 1990-91 priacanthids formed 3% of the trawl landings of this area and on an average formed 1.5% of the catches of the medium trawlers during the period 1986-87 to 1990-91. Rao et al. (1993) observed that priacanthids formed an average 3.3% of the commercial trawl catches (1979-80 to 1987-88) of Mangalore coast with a minimum catch of 61 t in 1982-83 and maximum of 357 t in 1985-86.

Upwelling along Visakhapattanam coast was reported to occur during the period March-May (La Fond, 1954; Rao et al., 1986). Vijayakumaran and Radhakrishna (MS) mentioned that upwelling occurs along Visakhapatnam coast in varying intensities from February to July with a peak during the period March-May. During upwelling, the cold subsurface water, having very low dissolved oxygen content is brought to the surface towards the shore. This phenomenon causes the movement of deep water fishes towards the shallow region and they become more abundant in the trawl gear or other gears being operated in the columnar water or shallow regions. Luther et al. (1988) reported that April-May was the peak period of landings for priacanthids along Visakhapatnam coast. Vijayakumaran (Personal communication) observed that during upwelling priacanthids generally succeeded similar deep water species *Nemipterus mesoprion*, in its sequence of appearance in the trawl fishery of this region.

8.2.2 Utilization

Though priacanthids were rarely used for human consumption in earlier days, it could frequently be encountered in the urban and rural fish markets, especially in Kerala recently, and are sold at more or less the same price as mackerel, sardine, cat fish etc. In the South East Asian countries, this fish is an important table fish. Better utilization of this species is warranted especially when the existence of huge stocks in deeper waters has been explored by the surveys. The food value of *P. hamrur* was found identical to most of the common table fishes and therefore found for consumption. Dhananjaya *et al.* (1984); Khasim *et al.* (1989) analysed the proximate composition, calcium and phosphorus content of *P. hamrur* of the north east coast along with four other deep sea fishes. Chemical composition and nutritive value of edible meat and fish meal from *P. hamrur* was studied by Lakshmi Nair *et al.* (1990). Processing of *P. hamrur* and other deep sea fishes collected from FORV *Sagar Sampada* was attempted by the Central Institute of Fisheries Technology (Anon, 1990). The Integrated Fisheries Project, Cochin developed products such as frozen blocks, fillets, minced fish, canned fillets and salted dried fish and reported that these products were acceptable to the consumers (Samuel et al., 1987). The authors noticed that the yield was low compared to nemipterid, lizard, fish etc. which however, may be compensated by the low price.

Though the price cost structure may not be so conducive for export markets, the scope for internal consumption is worth exploring. Strategies for judicious utilization of the resource should be formulated by taking advantage of the low price of this species and its seasonal occurrence in the catches along the Indian coasts.

8.3 Discussion

Distribution and abundance of priacanthids along the Indian waters were studied by several workers. Oommen (1985) found that Priacanthus hamrur formed 2-10 percent of the catches from different squares of one degree latitude and longitude of the south west coast based on the data from survey on deep sea lobster and deep sea prawn conducted by the vessels of the Integrated Fisheries Project during 1967-79. Priacanthids were found in abundance along the Kerala and Karnataka coasts in 100-150 m depth belt with an average catch per hour of 72.8 kg, forming 11.26% of the total fish caught (Joseph, 1984, 1986). He also recorded priacanthids at a cph of 32.04 kg from Wadge Bank and Gulf of Mannar, 62.0 kg off Andhra coast and 200 kg off Tamilnadu coast. An average catch rate of 10 kg/hour was recorded during October 1983 to March 1984 from the Gulf of Mannar (Somvanshi and Bhar, 1984). During 1983-84, good catch rates were observed from latitude 14°N to 18°N along the east coast by Ninan et al. (1984). Sulochanan and John (1988) reported high concentration of priacanthids from the deeper areas of Kerala coast, contributing 34.7% of the total catch from 50-100 m depth. Vijayakumaran and Naik (1988a) found that priacanthids were abundant in depth zone upto 100 m in latitudes 11°-12°N and 100-200 m in latitude 13°N along the west coast. While studying the demersal fishery resources off north Kerala, Karnataka and Konkan coasts. Vijayakumaran and Philip (1988) reported that priacanthids registered 110.6 kg/hr from 100-200 m depth and 232.0 kg/hr from areas beyond 200 m, constituting 43.8% and 85.5% of the total catch from these two depth zones. They observed that August-December was the best season for priacanthids from the 100-200 m zone, while April, May, July and November recorded best yield from the areas beyond 200 m along the north Kerala-Karnataka coast. They also reported the abundance of priacanthids during August-November in 100-200 m depth zone and in October in areas above 200 m off Goa. Along the Maharashtra coast, October-December was found to be the most productive season for 100-200 m depth zone.

Bande et al. (1990) gave an account of the distribution and abundance of priacanthids along the east and west coasts of India based on the survey conducted by FORV Sagar Sampada during the period February 1985 to June 1987. They have located high concentrations of priacanthids in the Wadge

Bank and Goa coast with high catch rates of 4905.5 kg and 1500.0 kg per hour respectively. The 100-200 m depth recorded the highest catch rate of 249.4 kg/hour during their study. July-November was reported to be most productive season for priacanthids along the west coast. Priacanthids were recorded in good quantities (highest cph 84.0 kg) in the catches of pelagic trawls operated at 50-100 m operational depth in oceanic waters in the Arabian Sea between depth range 2501-3719 m.

All the above studies were based on the data pertaining to the years before 1987. In this study also a part of the data pertaining to the period prior to 1987 have been used in addition to the data from recent years. Therefore, it is not surprising that the present results were comparable in many aspects to the earlier ones, especially the concentration in 100-200 m depth zone and seasonal abundance along the west coast. However, the catch rates in the present study were comparatively lower than those of the earlier studies.

Along the west coast, the area between latitudes 12°N and 17°N (Kasargode to Ratnagiri) was observed to be the most productive one. In the east coast, the latitude 12°N was more productive. In the north east coast, the highest density was observed from the latitudes 18°N and 19°N. Among the different regions the south west coast showed the highest density of 245 kg/sq. km followed by the lower east coast with 177 kg/sq.km. The lowest density of 113 kg/sq. was observed from the north west coast. According to the results obtained by FORV Sagar Sampada during January 1985 to June 1987, the south west coast was the best productive zone followed by north west coast and the lower east coast was the least productive (Bande et al., 1990). The bathymetric zone 100-200 m was the most productive zone both in the east and west coasts followed by the 50-100 m depth along the west coast and above 200 m along the east coast. In all the regions, areas below 50 m depth showed very low density. However, the shallow areas off Karnataka and Goa showed comparatively high density. In all the studies, the depth zone 100-200 m showed abundance of priacanthids. Along the west coast, August-January was the productive period while monsoon months yielded low catch rates. Along Tamilnadu coast, August-October was the best season for this group. No clear seasonality was observed along the north east coast especially in the Orissa-West Bengal coast.

Vijayakumaran and Naik (1988) has observed cases of seasonal shoreward and off shore migration along the Karnataka-Goa coast. Migration from the shallow water to deeper water was indicated in certain months by a change in the catch rates. This, however, requires further investigation. The presence of priacanthids in the pelagic haul of FORV Sagar Sampada in the oceanic region indicates the extent of distribution of this species.

Incidences of aggregation of priacanthids have been reported earlier. Caldwell and Bullis (1971) reported aggregation of prejuvenile Priacanthus arenatus (Cuvier) from West Indies. Senta (1978) described incidence of aggregations of P. tayenus and P. macracanthus in the South China Sea. Observation of high catch rates of 4905.5 kg from Wadge Bank and 1500 kg off Murmogao (Bande et al., 1990), 1425.0 kg/hour from Andhra coast (Ninan et al., 1984), 1278.2 kg/hr from the Goa (Vijayakumaran and Philip, 1990), 613 kg/hr from Karnataka coast (Joseph, 1984) indicates a high degree of aggregation of priacanthids in the Indian waters. Though species like P. hamrur, P. tayenus, P. holocentrum and P. boops and P. macracanthus were reported from the Indian waters except P. hamrur all other species are very rare and occur only in few numbers. Therefore, it could be reasonable to assume that P. hamrur is an aggregating species.

The biomass and potential yield of priacanthids were estimated by many workers. Joseph (1987) estimated a potential yield of 98,000 tonnes from the Indian waters. John and Sudarsan (1988) estimated a biomass of 1.17 lakhs tonnes and MSY of 0.82 lakhs tonnes. Sudarsan et al. (1990) estimated the biomass of priacanthids in the areas between 50-300/500 m depth range as 62,700 tonnes. Biradar (1988) estimated the biomass of priacanthids from the north west coast between latitude 15°N to 22°N as 0.88 lakhs tonnes. Bande et al. (1990) got a high estimate 3.95 lakh tonnes for the Indian EEZ. The biomass estimated in the present study is comparatively lower than the earlier estimates. A biomass of 56,500 tonnes of priacanthids is estimated from the east and west coasts excluding Wadge Bank and Gulf of Mannar. The low estimate is due to low catch rates yielded during the recent years as compared to that of the initial years of the survey which was the basis of earlier estimates. The priacanthid stocks of Indian waters cannot be treated as virgin stocks at present. The vessels operating under the schemes like chartering, joint venture are mostly fishing in the offshore waters beyond 50 m depth, where the concentration of priacanthids are high. While fishing for groups such as pink perches, lizard fish, sciaenids etc. which form the raw material for 'surumi', these vessels would have inevitably caught good quantity of priacanthids. Priacanthids have got good demand in South East Asian countries. John and Sudarsan (1988) has reported a pair trawler under charter scheme having 33 tonnes of bigeye which formed 15.35% of their catch during May 1987. Naik (1990) observed a marked decline in the catch rates of priacanthids from his onboard experience during 1988. He felt that a big share of priacanthids might have been taken by the chartered vessels which were operating in Indian waters for a long time since 1983. Being a deeper water fish characterised by slower growth and poor recruitment, the replenishment of the stock may not be so fast as to compensate the fishing pressure. The depletion of stock by putting excess pressure results in situations identical to deep sea lobster Puerulus sewelli of the south west coast of India. The decrease in the catch per hour of priacanthids during recent years must be indicative of exploitation of this resource at significant level.

Table 26. Details of vessels and gears employed during different periods at various depths and regions

Region	Name of vessel	Depth range (m)		Period of survey
		0-200	200-300/500	
West coast				
Lat 18°-22° N	Matsya Mohini	51 m Expo model fish trawl	-	May 1986 - November 1992
Lat 11°-17° N	Matsya Vishwa & Matsya Shakti	27 m fish trawl	47 m shrimp trawl	January 1984 - December 1991
Lat 8°-10° N	Matsya Nireekshini	34 m fish trawl	45 m shrimp trawl	January 1984 - December 1992
Wadge Bank & Gulf of Mannar	Matsya Nireekshini	34 m fish trawl	45 m shrimp trawl	January 1984 - December 1987
East coast				
Lat 10°-15° N	Matsya Jeevan	27 m fish trawl	47 m shrimp trawl	January 1984 - December 1991
Lat 16°-17° N	Matsya Darshini	44 m star model	34 m shrimp trawl	September 1988 - December 1992
Lat 18°-21° N	Matsya Shikari	34 m fish trawl	45 m shrimp trawl	May 1988 - December 1992

Table 27. Area-wise and depth-wise fishing effort (actual hours of trawling) along the north west coast (January 1984 to November 1992) and south west coast (January 1984 to December 1992).

Region/Latitude (°N)	Depth range (m)				Total effort (hrs)
	<50 Effort (hrs)	50-100 Effort (hrs)	100-200 Effort (hrs)	>200 Effort (hrs)	
N.W. coast					
22	196.17	397.67	122.41	6.00	722.25
21	370.09	876.17	262.66	6.00	1514.92
20	311.08	1243.42	95.08	15.58	1665.17
19	59.42	80.00	1.50	-	140.92
18	930.42	1048.00	37.33	2.00	2017.75
17	631.33	1162.25	131.17	-	1924.75
16	811.83	1048.58	328.75	23.17	2212.33
15	1388.91	1007.50	481.50	35.67	2913.58
S.W. coast					
14	999.00	881.82	570.17	130.43	2581.42
13	467.41	517.92	240.50	46.92	1272.75
12	564.25	681.41	561.58	329.92	2137.16
11	231.17	523.38	284.08	224.00	1262.63
10	390.58	565.33	244.91	195.33	1396.15
9	849.08	898.92	564.53	468.82	2781.35
8	1137.50	888.33	579.33	646.33	3251.50

Table 28. Area-wise and depth-wise fishing effort (actual hours of trawling) along Gulf of Mannar and Wadge Bank (January 1984 to December 1987), lower east coast (January 1984 to December 1991) and upper east coast (September 1988 to December 1992)

Region/Latitude (°N)	Depth range (m)				Total effort (hrs)
	<50 Effort (hrs)	50-100 Effort (hrs)	100-200 Effort (hrs)	>200 Effort (hrs)	
Wadge Bank and Gulf of Mannar					
8	1112.25	-	246.08	193.42	1551.75
7	279.25	205.33	145.25	77.75	707.58
Lower east coast					
10	371.33	356.00	311.75	156.92	1196.00
11	345.42	72.50	0.66	-	418.58
12	1042.82	730.17	238.33	59.67	2070.92
13	374.91	518.00	184.58	103.41	1180.92
14	256.25	360.83	155.08	46.92	819.08
Upper east coast					
15	115.42	654.66	182.17	57.33	1009.58
16	115.40	179.08	244.25	87.91	626.66
17	418.00	366.08	274.58	118.67	1177.33
18	477.33	251.83	213.16	51.33	993.65
19	271.42	284.17	229.17	82.58	867.34
20	87.50	102.50	424.92	-	614.92

Table 29. Area-wise and depth-wise density (kg. per sq.km) of _Priacanthus_ spp. along the west coast of India

Region/Latitude (°N)	Depth range (m)				Weighted average
	<50	50-100	100-200	>200	
North west coast					
22	6	54	146	0	25.6
21	11	224	192	0	112.0
20	11	20	45	5	14.8
19	0	2	0	5	1.1
18	9	24	20	0	20.2
17	29	360	877	117	327.7
16	137	371	1085	117	386.9
15	49	160	2183	151	523.6
Weighted average	15.1	121.1	633.8	48.8	112.5
South west coast					
14	100	657	911	589	534.5
13	277	146	529	163	241.7
12	186	366	383	15	278.0
11	46	326	266	16	180.0
10	77	247	45	2	125.7
9	23	275	587	1	134.7
8	3	62	400	11	57.0
Weighted average	111.6	315.2	548.4	125.6	244.7

Table 30. Area-wise and depth-wise density (kg. per sq.km) of *Priacanthus* spp. along the Wadge Bank and Gulf of Mannar and east coast

Region/Latitude (°N)	<50 m	50-100 m	100-200 m	Above 200 m	Weighted average
	Density	Density	Density	Density	
Wadge Bank Gulf of Mannar					
7	28.0	6.0	68.0	0.0	28.7
8	0.0	6.0	68.0	28.0	37.9
Weighted average	23.2	6.0	68.0	7.0	30.7
Lower east coast					
10	0	0	563	3	92.2
11	0	11	-	-	161.7
12	3	3	2817	277	392.9
13	20	31	386	303	102.8
14	23	49	814	483	146.8
Weighted average	6.4	11.9	1143.9	212.9	176.7
Upper east coast					
15	5	120	454	409	61.9
16	65	67	261	322	124.6
17	19	107	550	25	135.5
18	3	71	823	2	190.9
19	54	128	553	103	178.0
20	23	20	267	-	113.9
	27.5	66.4	376.9	125.8	129.8

Table 31. Seasonal abundance of Priacanthus spp. along the west coast. (Survey period as shown in Table 26)

Months	Kerala coast (8°N-11°N)		Karnataka & Goa coast (12°N-18°N)		Maharashtra & Gujarat coast (19°N-23°N)	
	Depth range (m)					
	30-200 (cph) kg	>200 (cph) kg	30-200 (cph) kg	>200 (cph) kg	30-200 (cph) kg	>200 (cph) kg
January	19.4	2.5	18.9	8.4	4.9	1.8
February	14.2	-	6.9	2.3	6.9	-
March	3.9	-	11.9	5.7	1.4	-
April	2.7	0.3	9.4	9.7	1.7	-
May	7.3	-	4.4	4.4	1.9	-
June	2.0	1.1	2.4	0.8	0.1	xx
July	0.5	-	1.9	-	0.7	xx
August	9.4	0.4	10.6	-	0.1	xx
September	0.2	-	16.7	3.9	0.1	xx
October	34.4	-	31.2	0.6	14.1	xx
November	11.2	0.1	22.4	63.1	4.5	xx
December	7.7	-	21.7	10.3	10.4	xx

xx No fishing

Table 32. Seasonal abundance of Priacanthus spp. along the east coast
(Survey period as shown in Table 26)

Months	Tamilnadu coast (10°N-15°N)		South Andhra coast (16°N-17°N)		North Andhra, Orissa & West Bengal coast (18°N-21°N)	
	Depth range (m)					
	30-200 (cph) kg	>200 (cph) kg	30-200 (cph) kg	>200 (cph) kg	30-200 (cph) kg	>200 (cph) kg
January	0.8	4.8	0.5	18.1	15.4	-
February	2.8	19.3	4.5	xx	1.4	-
March	5.3	11.1	5.1	-	4.2	-
April	1.6	5.7	9.1	xx	9.4	xx
May	0.5	-	3.9	-	5.4	5.7
June	2.3	-	39.2	xx	10.7	-
July	0.8	5.5	26.0	-	6.4	0.3
August	10.1	11.6	3.2	-	1.2	-
September	32.8	2.3	4.5	-	xx	xx
October	7.0	0.9	7.5	xx	6.2	50.0
November	0.8	2.8	2.3	xx	16.8	3.1
December	1.9	0.3	0.9	0.4	6.7	0.4

xx No fishing

Table 33. Area-wise and depth-wise total catch and percentage contribution of priacanthids during 1984-92.

Region/ Latitude (°N)	Depth range (m)								Total	
	<50		50-100		100-200		>200			
	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids
South-west coast										
8	164.1	0.1	122.3	1.6	92.2	8.8	124.4	0.30	502.9	2.1
9	52.6	1.3	185.4	4.7	234.7	5.0	86.6	0.02	559.2	3.8
10	38.6	2.8	71.8	6.8	15.1	2.6	8.3	0.30	133.8	4.8
11	20.7	1.8	56.0	11.2	50.5	4.6	88.1	0.20	215.4	4.2
12	36.3	10.0	76.9	11.4	92.8	8.1	79.0	0.90	285.0	7.1
13	31.3	13.3	38.1	6.8	42.1	9.6	0.8	33.20	112.3	9.9
14	83.9	4.3	100.0	20.6	118.2	15.4	7.1	67.90	309.2	15.3
Sub Total	427.5	3.2	650.5	8.3	645.6	8.1	394.3	1.50	2117.8	6.0
North-west coast										
15	152.8	1.9	126.1	4.2	143.6	31.2	0.9	36.5	423.4	10.6
16	89.0	4.4	103.6	3.3	71.6	17.4	0.2	69.9	264.5	11.6
17	54.7	1.2	123.2	11.9	8.0	55.2	-	-	185.9	10.4
18	144.8	0.4	173.0	0.9	4.6	1.0	-	-	322.4	0.7
19	5.9	-	14.2	0.1	-	-	-	-	19.8	0.1
20	50.5	0.4	247.5	0.6	29.8	0.9	0.5	0.8	328.4	0.6
21	77.9	0.4	209.8	6.1	43.8	7.6	0.3	-	331.7	5.0
22	30.3	0.2	85.8	1.6	11.9	8.6	0.4	-	128.3	1.9
Sub Total	605.09	1.4	1083.2	4.7	313.3	18.5	2.3	21.7	2004.4	6.9

Table 34. Area-wise and depth-wise total catch and percentage contribution of priacanthids during (1984-92)

Region/ Latitude (°N)	Depth range (m)								Total	
	<50		50-100		100-200		>200			
	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids	Catch (t)	% of priacanthids
Wadge Bank & Gulf of Mannar										
7	39.2	0.7	17.4	0.2	28.0	1.2	2.1	0.04	86.6	0.8
8	9.4	-	-	-	34.6	1.7	5.8	3.30	49.8	1.9
Sub Total	48.6	0.4	17.4	0.2	62.6	1.4	7.9	1.20	136.4	1.1
Lower east coast										
10	18.3	-	15.2	-	21.9	28.5	17.4	0.10	72.8	8.6
11	18.8	-	3.4	-	-	-	-	-	22.2	-
12	55.3	-	54.4	0.07	32.8	72.0	14.2	7.90	156.8	15.8
13	14.4	1.9	19.8	2.90	10.0	25.7	9.1	12.00	53.2	8.4
14	24.7	0.9	44.8	1.30	15.4	28.7	2.4	33.50	87.3	6.9
Sub Total	131.5	0.3	137.6	0.80	80.1	45.6	43.1	5.80	392.3	10.4
Upper east coast										
15	103.6	0.1	132.8	2.0	13.7	21.2	3.9	21.0	253.9	2.6
16	40.8	1.6	94.6	1.9	14.2	37.3	3.5	12.6	153.1	5.4
17	41.9	3.3	95.0	5.0	21.2	46.7	0.7	31.3	158.8	10.3
18	106.0	0.1	72.1	1.0	12.4	52.1	-	63.6	190.5	3.8
19	72.1	0.7	97.7	1.4	7.3	49.7	0.7	59.0	177.8	3.3
20	133.8	-	86.2	0.4	54.6	9.1	-	-	274.6	1.9
Sub Total	498.2	0.5	578.4	2.0	123.4	26.1	8.8	20.4	1208.7	4.0

Table 35. Details of annual effort (hrs), c/h of all fishes and c/h of priacanthids in various depth zones of Karnataka - Goa Coast (1984-91)

Year	Karnataka - Goa Coast (11° - 17°N)					
	Depth range (m)					
	30-200			>200		
	Effort (hrs)	c/h (all fishes)	c/h priacanthids	Effort (hrs)	c/h (all fishes)	c/h priacanthids
1984	2518	126.5	9.5	518	190.4	4.3
1985	2145	125.2	26.4	81	442.2	3.4
1986	2108	112.0	28.8	24	123.3	122.9
1987	2330	131.9	6.1	31	17.1	16.7
1988	1389	66.4	2.5	56	153.6	0.3
1989	928	133.1	4.2	45	501.0	2.9
1990	697	161.5	10.0	3	768.7	-
1991	1751	116.6	6.8	6	783.7	8.9

Table 36. Details of effort (hrs), c/h of all fishes and of c/h of priacanthids in various depth zones along the Kerala coast and lower east coast (1984-92).

Year	Kerala coast (8°N-10°N)						Lower east coast (10°N-15°N)		
	Depth range (m)								
	30-200			>200			30-200		
	Effort (hrs)	c/h (all fishes)	c/h (priacanthids)	Effort (hrs)	c/h (all fishes)	c/h (priacanthids)	Effort (hrs)	c/h (all fishes)	c/h (priacanthids)
1984	405	161.1	2.5	94	18.3	0.5	677	45.6	0.4
1985	515	174.6	22.6	154	62.6	0.1	954	69.6	
1986	1339	134.4	11.1	416	197.3	0.5	847	87.4	27.7
1987	1172	141.8	3.7	233	153.0	0.4	1445	90.0	2.6
1988	758	171.1	1.6	117	125.9	0.1	1541	92.7	7.5
1989	674	230.1	3.3	87	349.9	-	875	85.3	3.3
1990	582	225.8	3.0	177	207.6	0.1	754	137.5	0.3
1991	171	100.4	2.6	-	-	-	166	103.0	-
1992	411	102.2	1.1	40	218.0	0.5	-	-	-

Table 37. Density and estimated biomass of priacanthids in different latitudinal sections of the west coast

Latitude (°N)	Depth zone (m)												
	<50			50-100			100-200			>200			
	Density (kg/sq. km)	Area (Sq. km)	Biomass (Tonnes)	Density (kg/sq. km)	Area (sq. km)	Biomass (Tonnes)	Density (kg/sq. km)	Area (sq. km)	Biomass (Tonnes)	Density (kg/sq. km)	Area (sq. km)	Biomass (Tonnes)	Total biomass (Tonnes)
7	-	2430	-	-	4195	-	-	4300	-	-	2200	-	-
8	3	3635	11	62	3870	240	400	870	348	11	2650	29	628
9	23	3835	88	275	2350	646	587	850	499	1	2135	2	1235
10	77	4135	318	247	2555	631	45	715	32	2	415	1	982
11	46	4735	218	326	4820	1571	266	1070	285	16	985	16	2090
12	186	3800	707	366	4250	1556	383	1835	703	15	825	12	2978
13	277	5795	1605	146	6575	960	529	1875	992	163	1450	236	3793
14	100	4560	456	657	6125	4024	911	3030	2760	589	1655	975	8215
15	49	3930	177	160	5065	810	2183	2420	5283	151	830	125	6395
16	137	3325	456	371	8010	2972	1085	1725	1872	117	910	106	5406
17	29	5875	170	360	13905	5006	877	2575	2258	117	515	60	7494
18	9	6780	61	24	22570	542	20	1235	25	0	480	-	628
19	0	14530	-	2	23080	46	0	1760	-	0	1085	-	46
20	11	24760	272	20	12950	259	45	1115	50	5	760	4	585
21	11	11150	123	224	9115	2042	192	2515	483	5	890	4	2652
22	6	22480	135	54	2970	160	146	3100	453	0	675	-	748
Total	-	-	4797	-	-	21465	-	-	16043	-	-	1570	43875

Table 38. Density and estimated biomass of priacanthids in different latitudinal sections of the east coast

Latitude (°N)	Depth zone (m) <50			50-100			100-200			>200			
	Density (kg/sq. km)	Area (sq.km)	Biomass (tonnes)	Density (kg/sq. km)	Area (sq.km)	Biomass (tonnes)	Density (kg/sq. km)	Area (sq.km)	Biomass (tonnes)	Density (kg/sq. km)	Area (sq. km)	Biomass (tonnes)	Total bio-mass (tonnes)
10	0	6085	0	0	1280	0	563	1510	850	3	360	1	851
11	0	1800	0	11	675	7	1690	260	439	140	205	29	475
12	3	2325	7	3	2100	6	2817	725	2042	277	275	76	2131
13	20	1825	37	31	785	24	386	415	160	303	450	136	357
14	23	2040	47	49	525	26	814	395	322	483	120	58	453
15	5	5210	26	120	625	75	454	470	213	409	220	90	404
16	65	3530	229	67	690	46	261	1030	269	322	555	179	723
17	19	2690	51	107	4400	471	550	1255	690	25	740	19	1231
18	3	2425	7	71	3120	222	823	1465	1206	2	510	1	1436
19	54	4035	218	128	1975	253	553	1680	929	103	410	42	1442
20	23	8700	200	20	7530	151	267	9860	2633	103	1060	109	3093
Total	-	-	822	-	-	1261	--	-	9753	-	-	740	12596

Fig.20 Distribution pattern of priacanthids along the Indian coasts.

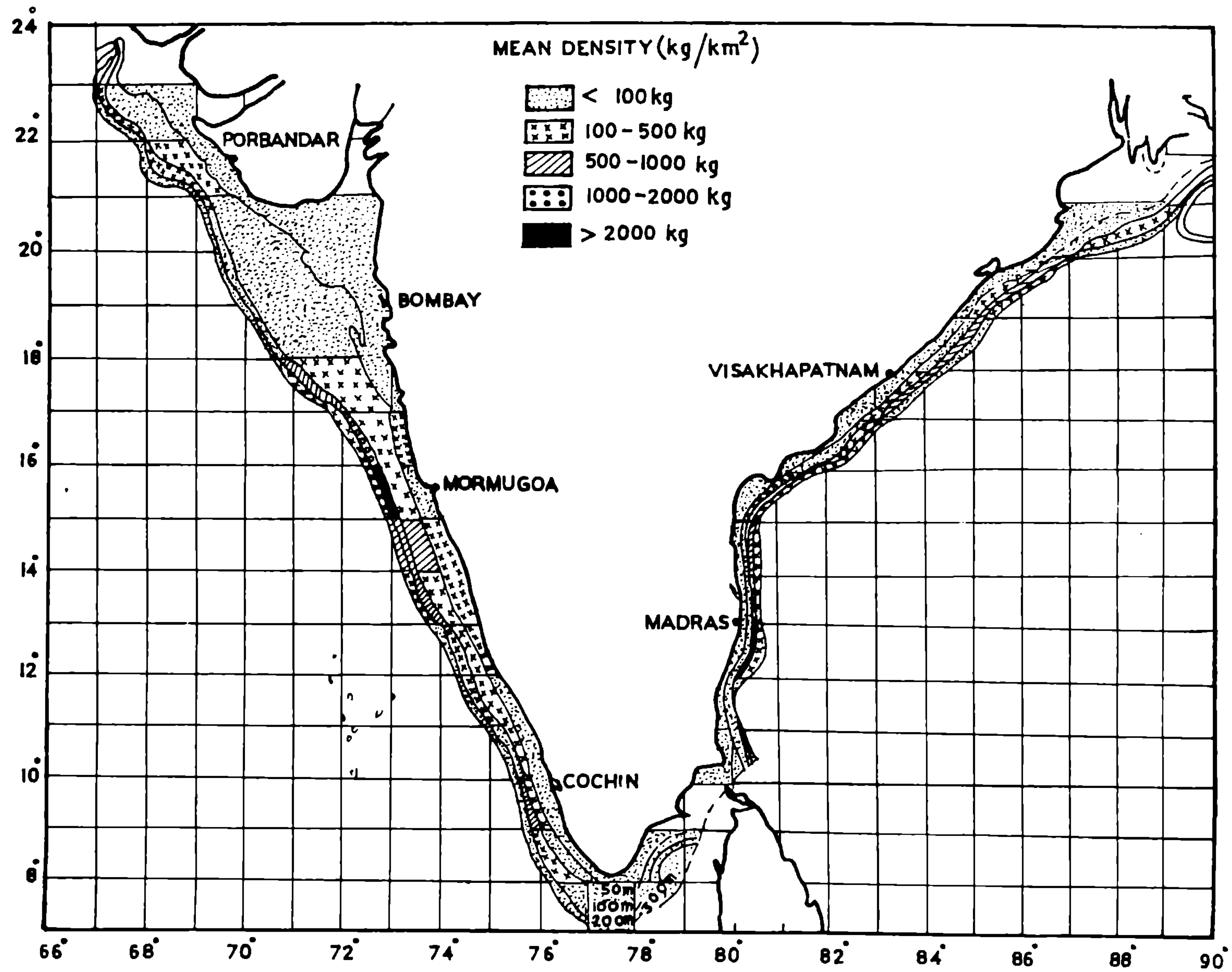

MEAN DENSITY (kg/km²)
< 100kg
100 - 500 kg
500 - 1000 kg
1000 - 2000 kg
> 2000 kg
PORBANDAR
BOMBAY
MORMUGOA
COCHIN
MADRAS
VISAKHAPATNAM
50m
100m
200m
24°
22°
20°
18°
16°
14°
12°
10°
8°
66°
68°
70°
72°
74°
76°
78°
80°
82°
84°
86°
88°
90°

Fig. 20

SUMMARY

9. SUMMARY

The exploratory surveys conducted by the vessels of the Fishery Survey of India and other Government agencies could locate stocks of non-conventional species of fishes in the offshore and deep sea waters beyond 50 m depth. The results of these surveys revealed that the demersal fishery beyond 100 m is supported by very few species in contrast to the multispecies nature seen in inshore waters. Considering the magnitude of the stock size and potential for commercial exploitation priacanthids are the most important among them. Though abundant in areas between 80-200 m depth this group is distributed in the inshore areas also and often found in the catches of smaller mechanised and traditional crafts operating in inshore waters. Priacanthids are tropical and subtropical in distribution, extending even into temperate waters in association with warm waters. They are reported from Atlantic, Pacific and Indian oceans and form a major constituent of the trawl fisheries in South East Asian countries. Along the Indian waters they constitute only an insignificant fishery, despite large quantities are reported to be exploited by the chartered vessels operated along the Indian waters. Systematics, biology, distribution and abundance and fishery of priacanthids were studied with special reference to the north east coast of India. The biological aspects were studied based on the data collected by the survey and training vessels of Government of India operated from Visakhapatnam. This was supplemented by data collected from the Visakhapatnam Fisheries harbour. The distribution and abundance of the stock were studied by making

use of the data collected by the larger vessels of Fishery Survey of India operated along the east and west coasts.

Five species of priacanthids viz. Pristigenys niphonius (Cuvier), Cookeolus boops (Schneider), Priacanthus hamrur Forsskal, Priacanthus holocentrum Bleeker and Priacanthus cruentatus (Lacepede) have been recorded in the fishery during the period of study. On the basis of morphological characters all the species were briefly described along with their geographical distribution. Of these Pristigenys niphonius is a very rare species and the present description of this species is the first from the Indian waters, though its occurrence has been mentioned by some earlier workers. While Priacanthus hamrur is very common and constitutes a fishery, the occurrence of the remaining species is quite sparse in Indian waters. Key to the genera of the family Priacanthidae and the species of the genus Priacanthus are given.

A detailed study on the qualitative and quantitative aspects of the food of P. hamrur is attempted, based on 1205 stomachs collected during 1991-93. Variations in food components in respect of season, area, depth range, size groups and feeding intensity in relation to gastro-somatic index and relative condition factor, were studied. P. hamrur is carnivorous and its food consists mainly of crustaceans such as megalopa, prawns, squilla, alima, euphausiids, copepods and teleost fishes such as Bregmaceros sp., eel and leptocephalus. Crustaceans formed about 60% of the food items predominated by Solenocera sp. Food diversity was the highest in latitude 19°N and lowest in latitude 16°N. The low diversity of food items in certain latitudes may be attributed to the deep descent of the shelf where the diversity of food items is relatively less. Similar observations were also seen in the stomachs collected from depth zones 101-150 m, 151-200 m and above 200 m which also can be attributed to the low faunistic diversity prevalent in higher depths. Significant seasonal variations could be noticed in the major food components which may be the consequence of the changes in abundance of food organisms due to variations in the environmental factors. Fishes below 100 mm feed mainly on smaller crustaceans, while fishes above 111-120 mm feed on larger food items like Bregmaceros sp., eel and crab. Feeding intensity was high during the period January to June and low during July to December. Gastro-somatic index also showed high values during January to July and low values during August to December. A significant relationship could be established between feeding intensity and relative condition factor whereas no similar relationship could be seen between feeding intensity and gonado-somatic index. A comparative study of stomach contents of P. hamrur and Nemipterus japonicus that coexist revealed that crab, prawns and squilla predominated the food of both the species. This would suggest the possibility of competition for food between these two species that inhabit in the north east coast of India.

The maturation and spawning of P. hamrur of the north east coast of India have been studied. Maturity stages, development of ova to maturity, spawning season, depth-wise distribution of various maturity stages, size at first maturity, gonado-somatic index, fecundity and sex ratio of this species have been investigated. Sexes could not be distinguished externally for want of secondary sexual characters. Gonads become clear at the size of 65-70 mm lengths. The monthly distribution of maturity stages and gonado-somatic index indicated that the spawning season of P. hamrur in the north east coast of India was a prolonged one, extending from November to February in 1991-92 and October to March in 1992-93. The gonads were quantified into seven stages with subdivisions to Stages II and VII. In ovary only one distinct mode of ova was discernible in all stages indicating the progression of a single batch of ova till spawning. The size of the ova varied from 0.064 mm in Stage II to 0.288 mm in Stage VI. The unimodal distribution of ova in all stages indicates that P. hamrur spawns only once in a year during the spawning season. It is observed that the spent forms go back to a stage which is more or less identical to the virgin Stage II. The immature and maturing specimens were abundant in the shallow waters while mature specimens of both the sexes were found to be concentrated in deeper waters between 100-200 m depth zone and therefore these regions may be considered as the probable breeding ground of this species. The GSI values were the highest during December 1991 and January 1993 during when more mature and ripe specimens could be encountered whereas low values were observed during April to July in the former and June and July in the latter periods respectively. Occurrence of spent and spent recovering specimens was found synchronised with the period of low GSI values. The average size at first maturity was 123.5 mm for males and 126.5 mm for females. Both the sexes attain these lengths at the age of about 1½ years. Fecundity showed a linear relationship with body length, body weight and ovary weight. Fecundity of P. hamrur varied from 15,283 ova (TL 121.0 mm) to 1,96,700 ova (TL 270.0 mm) with an average of 99,323 ova (± 7617). The sex ratio between males and females was 1:1.286 during the period under study, showing a preponderance of females over males in the population. Males outnumbered in the smaller size groups upto 130.0 mm whereas females were found to be dominating in the size groups above 135.0 mm. The females predominated upto a depth of 150 m and thereafter no segregation was observed.

The length-weight relationship and relative condition factor were worked out. Length-weight relationship of males and females can be expressed as follows:

Male $W = 0.00000638 \times L^{3.113292}$

Female $W = 0.00000811 \times L^{3.068493}$

Length-weight relationships of male and female were found to be different and therefore a combined relationship could not be derived to represent for both male and female. In female the growth is isometric whereas in male the growth is not exactly following the cube law. Preponderance of males in younger size groups and their poor representation in older age classes may be attributed as the reason for arriving at a higher 'b' value in the case of males. The highest 'Kn' values were observed both in females (1.5538) and males (1.3827) during May while the values were lowest, (0.9009 in females and 0.9779 in males) in August. In both the sexes the 'Kn' values steadily increased upto 100 mm length, remained more or less stable upto 150 mm and thereafter showed fluctuation.

Growth parameters were estimated using length frequency data collected from exploratory survey vessels for the period June 1989 to April 1993. Besides, for the purpose of comparison growth parameters were also computed based on one month data collected from the commercial landings. The different parameters estimated for the three groups were as follows:

	L_{max} (mm)	L_{∞} (mm)	K/year	t_0 (year)
Male	265	297.08	0.3585	- 0.0206
Female	288	300.40	0.3811	- 0.0244
Pooled commercial data	262	283.93	0.3706	- 0.1122

Males and females showed differential growth, the former having a slower growth rate as well as a lower asymptotic length. The growth parameters obtained in respect of commercial data (pooled) were comparable with that of exploratory data. The von Bertalanffy growth model obtained for males, females and pooled commercial data can be expressed as follows:

Male $L_t = 297.0791\ (1-e^{-0.3585\ (t+0.0206)})$

Female $L_t = 300.4580\ (1-e^{-0.3826\ (t+\ 0.0244)})$

Commercial data (both sex) $L_t = 283.9278\ (1-e^{-0.3722\ (t+0.1122)})$

The daily growth rates estimated in the case of P. hamrur in the present study were found comparable with those of other species of priacanthids from the South East Asian countries. Based on the growth parameters obtained the life span of P. hamrur is calculated as 8 years, which lies between those of shallow water demersal species having longevity of 3-6 years and larger perches which live for more than 10 years.

The natural mortality (M) and total mortality (Z) coefficients of male and female collected from exploratory data and pooled data from commercial landings were estimated applying three methods and the natural mortality coefficients thus computed are as follows:

	Cushing	Pauly	Rikhter and Efanov
Male	0.5503	0.9000	0.9928
Female	0.5874	0.9363	1.0364
Pooled (commercial)	0.5714	0.9341	0.0108

The total mortality coefficients (Z) computed applying Beverton and Holts formula and Catch curve method are as follows:

	B & H	Catch curve
Male	2.2008	2.4514
Female	1.3324	1.7686
Pooled (commercial)	2.6848	2.5047

The fishing mortality coefficient (F), the exploitation ratio (E) and the exploitation rate (U) obtained for male, female and pooled commercial data, using the M and Z values respectively from Pauly's and Catch curve method were as follows:

	F	E	U
Male	1.5514	0.6329	0.5783
Female	0.8230	0.4706	0.3903
Pooled (commercial)	1.5706	0.6271	0.5758

The age class structure in males as well as in pooled commercial catch appeared as identical and therefore yielded similar values in respect of mortality, exploitation ratio and exploitation rate. The exploitation ratio as well as exploitation rate indicated that this species is being exploited just above the optimum level in the north east coast of India, probably due to the fishing pressure that is being excerted by the chartered and other deep sea vessels operated in this region during the recent years.

The distribution, abundance, seasonal variation and biomass of priacanthids in the Indian waters are studied based on the data collected by the exploratory survey vessels and the results are discussed. In the north west coast latitudes 15°N and 16°N (Goa to north of Ratnagiri) recorded the highest density viz. 524 and 387 kg/sq. km while latitudes 18°N to 20°N recorded low densities. In the south west coast, highest density was recorded from the latitude 14°N (Karwar) followed by the area between Kasargode and Honawar. The density of priacanthids in the Wadge Bank and Gulf of Mannar was apparently very low. Along the lower east coast, the latitude 12°N showed the highest density while along the upper east coast the latitudes 18°N and 19°N were the most productive. Among the four regions the south west coast showed the highest average density of 245 kg/sq.km. The depth zone 100-200 m recorded the highest density followed by 50-100 m depth along the west coast. In the east coast the 100-200 m depth zone recorded the highest density followed by the areas beyond 200 m depth. August to January was the productive period while the monsoon months yielded low catch rates along the west coast. August-October was the best season along the Tamilnadu coast, whereas no clear seasonality could be observed along the north east coast. Priacanthids formed 6.0% of the total catch along the north west and south west coasts of India whereas their contributions were 10.4% and 4.0% respectively from the lower east coast and upper east coast. Priacanthids formed only one percent of the total catch from the Wadge Bank and Gulf of Mannar.

A remarkable decline in the catches of priacanthids has been observed from the coasts of Karnataka-Goa, Kerala and the lower east coast from 1985 onwards. However, similar decline was not observed in the catch rates of demersal fish stock from these areas. The biomass of priacanthids presently estimated to the tune of 56,500 tonnes from the east and west coasts excluding the Wadge Bank and Gulf of Mannar appeared to be low as compared to the earlier estimates. The decline in the catch rates is the reason for the low estimate. Data on the all India landings of this group is lacking as most of the agencies concerned grouped it as miscellaneous fish. Nevertheless from Visakhapatnam, landing of priacanthids was estimated as 236 tonnes during 1980-82. The medium sized trawlers landed 59 tonnes in 1989-90 and 603 tonnes in 1990-91 from the Mangalore coast. Studies on processing and handling showed that priacanthids are comparable to other quality fishes in its proximate composition and the products developed such as fillets, minced fish, canned fillets etc. were found readily acceptable to the consumers. Lack of separate catch statistics on Priacanthus spp. has been noticed as a major lacuna in undertaking population studies and stock assessment. At present data on the quantity of priacanthids taken by the chartered and joint venture vessels and discarded by the shrimp fishing vessels are not available and therefore these should be reckoned for arriving at realistic estimates on the exploited stock. It is, therefore, imperative that the concerned agencies must do concerted attempts to collect data on this group. This will facilitate formulation of better management strategies for the slow growing stock of Priacanthus spp. The problem of discarding the catch at sea by deep sea vessels for saving space for other valuable species has its roots in the comparative low value of this group. Therefore it is found necessary to develop products of added value and popularise them for providing an incentive for bringing the catch to shore.

REFERENCES

REFERENCES

Abdelmoulch, A. 1981. Capture d' Un Priacanthi, *Priacanthus hamrur* (Forsskal 1875). Poisson Indo-Pacifique. Dams us Eanx Tunisiennes. *Bull. Inst. Natl. Sci. Tech. Oceanogr. Peche* (Salammbo) 8: 111-114 (French).

Alagaraja, K. 1984. Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.* 31(2): 177-195.

Alagaraja, K. 1989. A brief appraisal of marine fisheries in India. National symposium on Research and Development in Marine Fisheries, Mandapam Camp, *Bull. Cent. Mar. Fish Res. Inst.*, 44: 36-41.

Allen, K.R. 1938. Some observations on the biology of the trout (*Salmo trutta*) in Windermere. *J. Anim. Ecol.* 7: 333-349.

Ambak, M.A., K. Yunus, A.K.M. Moshin, M.Z.M. Said and S. Hayase, 1987. Sex ratio, fecundity and the feeding behaviour of big eyes (*Priacanthus* spp.) *in* Abu Khair Mohd. Moshin Ridswan Abdul Rahman, Mohd. Azmi Ambak (eds) : Ekspedishi Matahari '86, Univ. Pertananian, Malaysia, Sirdag: 147-157.

Anderson, W.D., D.K. Caldwell, J.F. Mekinney and C.H. Farmer, 1972. Morphological and ecological data on the priacanthid fish *Cookeolus boops* in the Western North Atlantic. *Copeia* 1972: 884-885.

Anon, 1990. Studies on processing of deep sea fish caught on board FORV Sagar Sampada. Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5-7 June 1989: 457-465.

Anon, 1991. Report of the Working Group on revalidation of the potential marine fisheries resources of EEZ of India.

Anon, 1993a. Statistics of marine products exports 1992. The Marine Products Export Development Authority, Cochin: 152 p.

Anon, 1993b. Annual Report 1992-93. Central Marine Fisheries Research Institute, Cochin. 119 p.

Anon, 1994. Hand book on fisheries. Ed: Dixitulu, J.V.H. and G. Papparao. Global Fishing Chimes Pvt. Ltd. 771 p.

Antony Raja, B.T. 1966. On the maturity stages of Indian oil sardine Sardinella longiceps (Val) with note on incidence of atretic follicle with advanced ovaries. Indian J. Fish. 13(1&2): 27-47.

Bande, V.N., N. Gopinatha Menon and K. Balachandran, 1990. Studies on the distribution and abundance of Bull's eye (Priacanthus spp.) in the EEZ of India. Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5-7 June 1989: 233-238.

Baranov, F.I., 1918. On the question of the biological basis of fisheries. Nauchu. Issled. Ikhtiologicheskii Inst. Izv. 1: 81-128 (in Russian).

Bertalanffy, L. von, 1934. Untersuchungen uber die Gesetflichkeiten des Wachstums. 1. Allgemeine Grundlagen der Theorie. Roux' Arch. Entwicklungsmech. Org. 131: 613-653.

Beverton, R.J.H., 1954. Notes on the use of theoretical models in the study of dynamics of exploited fish population. U.S. Fish. Lab., Beaufort, N.C., Misc. contrib. 2: 159 p .

Beverton, R.J.H. and S.J. Holt, 1956. A review of the methods estimating mortality rates in fish population, with special reference to sources of bias in catch sampling. Rapp. P.V. Reun. CIEM. 140: 67-83.

Beverton, R.J.H. and S.J. Holt, 1957. On the dynamics of exploited fish population. Fish Invest. Minist. Agric. Fish Food G.B. (2 Sea Fish), 19: 533 p.

Beverton, R.J.H. and S.J. Holt, 1959. A review of the life spans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. In: CIBA Foundation, Colloquia on ageing. Vol.5. The life span of animals, edited by G.E.W. Wolstenholme and M. O'Connor, London, Churchill, Vol.5, 142-180.

Biradar, R.S., 1988. Estimates of stock, density, biomass and maximum sustainable yield of Priacanthus hamrur (Forsskal) off the north west coast of India. Fishery Survey of India Spl. pub. 2: 55-65.

Blackburn, M., 1960. A study of condition,(weight for length) of Australian barracouta Thyrsites atun (Euphrasen). Austr. J. Mar. Freshw. Res., 2(1): 14-41.

Bleeker, P., 1873. Revision des especes Into-Archipelagiques du groupe des Priacanthini. Ned. Tijdschr. Dierk, 4: 170-177.

Bunag, D.M., 1956. Spawning habits of some Philippine tuna based on diameter measurements of the ovarian ova. Philippine J. Fish 4: 145-175.

Caldwell, D.K., 1962a. Western Atlantic fishes of family Priacanthidae. Copeia 1962: 417-424.

Caldwell, D.K. 1962b. Development and distribution of the short, big eye Psuedopriacanthus altus (Gill) in the western north Atlantic. Fishery Bull. Fish. Wildl. Serv. U.S. 62: 103-150.

Caldwell, D.K. and H.R. Bullis, 1971. An unusually large aggregation of prejuvenile big eyes P. arenatus, in the West Indies, Copeia 1971: 176.

Chacko, P.I., 1949. Food and feeding habits of the fishes of the Gulf of Mannar. Proc. Indian Acad. Sci. 29B: 83-97.

Chantawong, T. et al. 1984. Trawl fisheries and present status of demersal resources in the Andaman sea. Paper presented to the Marine Fisheries Seminar, Bangkok, 4-7 September, 1984 (mimeo).

Chapman, D.G. and D.S. Robson, 1960. The analysis of a catch curve. Biometrics 1960.

Chomjurai, W., 1970. Some aspects of biology of spot-finned big eye (Priacanthus tayenus) in the inner part of Thailand (1968-1969); paper presented to the Symposium on Marine Fisheries, Bangkok, Marine Fishery Laboratory. 15 p. (mimeo).

Chomjurai, W. and R. Bunnag, 1970. Preliminary tagging study of demersal fish in the Gulf of Thailand. The Kuroshio: A Symposium on the Japanese Current (J.C. Marr. ed) East West Center Press, Honolulu, 517-524.

Chullasorn, S. and Martosubroto, P., 1986. Distribution and important biological features of coastal fish resources in South East Asia. FAO Fisheries Technical Paper 278, FAO, Rome, 84 p.

Clark, F.N., 1934. Maturity of the California sardine (Sardina caerulea) determined by ova diameter measurements. Fish. Bull. Sacraments. 42: 1-49.

Colletti, B.B. and Talbot, F.H. 1972. Activity patterns of coral reef fishes with emphasis on nocturnal-diurnal change over. Bull. nat. Hist. Mus. Los Angles Co. 14: 98-124.

Cushing, D.H., 1968. Fisheries biology. A study in population dynamics: Madison, University of Wisconsin press, 200 p.

Day, F. 1875-1878. The fishes of India, being a natural history of the fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon. Taylor and Francis, London. 778 p.

De Jong, J.K., 1939. A preliminary investigation of the spawning habits of the fishes of the Java sea. Treubia, 17: 307-330.

Desai, B.N., R.M.S. Bhargava and J.S. Sarupria, 1990. Biological productivity and estimates of fishery potential of the EEZ of India. Current trends in coastal marine sciences (Ed. Ramachandran, S. and S. Rajagopal).

Devanesan, D.W., 1932. A note on the food and feeding habits of Sardinella gibbosa J. Madras Univ., 4: 1959-1964.

Devaraj, M., 1987. Maturity, spawning and fecundity of the spotted seer, Scomberomorus gattatus in the Gulf of Mannar and Palk Bay. Indian J. Fish, 34(1): 48-77.

Dhananjaya, S., N.S. Sudhakara and G.G. Hiremath, 1984. Suitability of three deep sea fishes for consumer acceptance. Seafood Export Journal 16(10): 1-2.

Dharmamba, M., 1959. Studies on the maturation and spawning habits of some common clupeoids of Lawson's Bay, Waltair. Indian J. Fish. 6(2): 374-388.

Dwiponggo, A.T., T. Hariati, S. Banon, M.L. Palomares and D. Pauly, 1986. Growth, mortality and recruitment of commercially important fishes and penaeid shrimps in Indonesian waters. ICLARM Tech. Report 17: 91 p.

Eggleston, D., 1974. Priacanthidae. 6 pages in W. Fischer and P.J.P. Whitehead, eds. FAO species identification sheets for fishery purposes. Eastern Indian Ocean (Fishing area 57) and Western Central Pacific (Fishing area 71). Vol.3. FAO, Rome, Unpaginated.

Fairbridge, W.S., 1951. The New South Wales Tiger Flathead, Neoplatycephalus macrodon (Ogilby) I. Biology and age determination. Aust. J. mar. Fresh w. Res. 2: 117-178.

Fitch, J.E. and R.J. Lavenberg, 1975. Tidepool and nearshore fishes of California. Univ. Calif. Press. Berkeley, 156 p.

Fitch, J.E. and S.A. Schultz, 1978. Some rare and unusual occurrences of fishes off California and Bajaj California. Calif. Fish Game 64: 74-92.

Fitch, J.E. and S.J. Crooke, 1984. Revision of eastern Pacific Catalufas (Pisces : Priacanthidae) with description of a new genus and discussion of the fossil record. Proc. Calif. Acad. Sci. 43(19): 301-315.

Ford, E., 1933. An account of herring investigations conducted at Plymouth during the year 1924-1933. J. Mar. Biol. Ass., U.K. 19, 305-384.

Fowler, H.W., 1928. The fishes of Oceania. Mem. B.P. Bishop Mus. 10: 1-540.

Fowler, H.W., 1931. Contributions to the biology of Philippine Archipelago and adjacent regions. The fishes of the families Pseudochronidae, Lobotidae, Pempheridae, Priacanthidae, Lutjanidae, Pomadasyidae and Theraponidae collected by the United States Bureau of Fisheries Steamer "Albatross" chiefly in the Philippine seas and adjacent waters. Bull. U.S. Natl. Mus. 100(11): 1-388.

Fowler, H.W., 1947. The bull-eye (Cookeolus boops) from off the New Jersey coast. Not Nat Acad Nat Sci. Phila. 189: 1-3.

Fritzsche, R.A., 1978. The first eastern Pacific records of bull-eye Cookeolus boops (Bloch and Schneider, 1801). Pisces: Priacanthidae, Calif. Fish. Game 64: 219-221.

Fritzshe, R.A. and G.D. Johnson, 1981. Pseudopriacanthus Bleeker, a synonym of priacanthid genus Pristigenys Agassiz. Copeia, 1981: 490-492.

George, P.C., 1953. The marine plankton of the coastal waters of Calicut with observations on the hydrological conditions. J. Zool. Soc. India, 5(1): 76-107.

George, P.C., B.T. Antony Raja and K.C. George, 1977. Fisheries Souvenir, Silver Jubilee, Integrated Fisheries Project, Cochin, India, October, 1977: 79-116.

Gill, T., 1872. Arrangement of the families of fishes, or classes Pisces, Marsipobranchii and Leptocardii. Smithson. Misc. Collect. 11: 1-49.

Graham Michael, 1928. Studies of age determination in fish. Part II. A survey of the literature. Fishery Invest. Lond. (Ser.2), 11(2): 50 p.

Grover, H.J. and Juliano, R.O., 1976. Length-weight relationship of pond raised milk fish in the Philippines. Aquaculture 7(1976): 339-346.

Gulland, J.A., 1971. The fish resources of the ocean. West Byfleet, Surrey, Fishing News (Books) Ltd., FAO, 255 p.

Gunther, A., 1859. Catalogue of the acanthopterygian fishes in the collection of British Museum. Vol.I. British Museum, London. 524 p.

Hi, J. 1982. A study on the Plistophorais of Priacanthus tayenus with description of a new species. J. Fish. China 6: 97-106.

Hickling, C.F. and Rutenberg, E., 1936. The ovary as an indicator of spawning period in fishes. J. Mar. biol. Ass. U.K. 21: 311-317.

Hildebrand, H.H., 1954. A study of the fauna of the brown shrimp (Penaeus azetecus Ives) grounds in the Western Gulf of Maxico Contr. mar. Sci. 3, 233-366.

Hile, R., 1936. Age and growth of the CISO Leucichthys artedi (Le Sueur) in the lake of the north eastern high lands, Wisconsin. Bull. 4-5. Bur. Fish. 48: 211-317.

Hoese, H.D., 1958. A partially annotated check list of the marine fishes of Texas Contr. mar. Sci. 5: 312-352.

Hooi, K.K., 1973. A study of the catch data of the Jurong in the South China sea in 1971 and 1972. Tech. Seminar on South China sea Fish. Res. May 21-25, Bangkok. Paper S-19, 1-16.

Hornell, J. and Naudu, M.R., 1923. A contribution to the life history of the Indian sardines with notes on the plankton of the Malabar coast. Madras Fish Bull., 17: 129-197.

Hua, D.K. and H.J. Dong, 1983. A news species of Pleistophora from big eyes, Priacanthus tayenus (Richardson) and Priacanthus macracanthus (Cuvier and Valenciennes) from South China sea. J. Fish. Dis. 6(3): 293-301.

Hyslop, E.J., 1980. Stomach content analysis: A review of methods and their applications. J. Fish Biol., 17: 411-429.

Ingles, J. and D. Pauly, 1984. An atlas of the growth, mortality and recruitment of Philippine fishes. ICLARM Tech. pap. (13): 127 p.

Isarankura, A., 1971. Assessment of stocks of demersal fish off the west coast of Thailand and Malaysia. IOFC/DEV/71/20: 20 p .

James, P.S.B.R., 1967. The ribbon fishes of the family Trichiuridae of India. Memoir I. Mar. Biol. Ass. India. 226 p.

James, P.S.B.R. and V. Narayana Pillai, 1990. Fishable concentrations of fishes and crustaceans in the offshore and deep sea areas of the Indian Exclusive Economic Zone based on observations made on board FORV Sagar Sampada. Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5-7 June 1989: 201-214.

Job, T.J., 1940. Nutrition of Madras perches, Rec. Indian Mus., 42: 286-364.

John, M.E. and D. Sudarsan, 1988. Assessment of the stock of big-eye snappers (Fam. Priacanthidae) in the Indian seas with a note on their pattern of abundance. Symposium on Tropical Marine Living Resources, MBAI, 12-16 Jan., 1988, Cochin. Abstract No.232.

Johnson, F.H., 1977. Responses of walleye (Stizostedion vitreum vitreum) and Yellow Perch (Perca flavescens) populations to the removal of White Sucker (Catostomus commersoni) from a Minnesota lake 1966. J. Fish Res. Bd. Can. 34: 1633-1642.

Jones, S. and S.K. Banerji, 1973. A review of the living resources of the Central Indian Ocean. Proceed. Symp. Living Res. Seas around India, CMFRI Spl. publ. 1-17.

Jones, S. and Kumaran, 1980. Fishes of the Luccadive Archipelago. Nature Conservation and Aquatic Science Service, Trivandrum. 760 p.

Joseph, K.M., 1980. Comparative study of the demersal fishery resources of the Indian waters as assessed by 17.5 m trawlers. Bull. Expl. Fish. Proj. 10: 40 p.

Joseph, K.M., 1984. Salient observations on the results of fishery resources survey during 1983-84. Bull. Fish. Surv. India. 13: 1-11.

Joseph, K.M., 1985. Marine Fishery resources of India. In: A system frame work of marine food industry in India. E/R Kulkarni and U.K. Srivastava Ed. 90-149.

Joseph, K.M., 1986. Some observations on potential fishery resources from the Indian Exclusive Economic Zone. Bull. Fish. Surv. India, 14: 1-20.

Joseph, K.M., 1987. The fish resources of the Indian Exclusive Economic Zone. National Seminar on planning export strategy for Indian Marine Fisheries, New Delhi, March 11, 1987.

Joseph, K.M. and M.C. Deviah, 1993. Development of infrastructural facilities for landing and berthing fishing vessels in India - A retrospect and a prospectus. Development of Marine Fisheries for Higher Productivity and Export (Ed: C.P. Varghese and P.S. Joy): 188-201.

Joung Shoou-Jeng and Che-Tsung Chen, 1992. Age and growth of the big-eye Priacanthus macracanthus from the surrounding water of Guei-Shan Island, Taiwan. Nippon Suisan Gakkaishi, 58(3), 481-488.

June, F.C., 1953. Spawning and fecundity of big-eye tuna in Hawaiian waters. U.S. Wildl. Ser. Fish. Bull. 54: 47-54.

Kagwade, P.V., 1970. Maturation and spawning in Polynemus heptadactylus (Cuvier). Indian J. Fish. 17: 76-89.

Kesteven, G.L., 1947. On the ponderal index or condition factor as employed in fisheries biology. Ecology, 28: 78-80.

Khasim Immam, D., R. Chakrabarti and C.C. Panduranga Rao, 1989. Proximate composition, calcium and phosphorus contents of five varieties of deep sea fishes of Andhra coast. national Symposium on Research and Development in Marine Fisheries, Mandapam Camp. Bull. Cent. Mar. Fish. Res. Inst., 44(2): 478-479.

Klima, E.F., 1976. An assessment of the fish stocks and fisheries of the Campeche bank. WECAF Study, (5): 24 p.

Koteswaramma, R., 1982. On an advanced post larva of P. hamrur (Forsskal: Pisces: Priacanthidae) from the Krishna Estuary. Mahasagar. 15(1): 55-57.

La Fond, 1954. On upwelling and sinking off the east coast of India. Memoirs in Oceanography, Andhra University, I, 117-121.

Lakshmi Nair, Jose Stephen and K. Gopakumar, 1990. Edible meat and fish meal from Priacanthus hamrur. Chemical composition and nutritive value. Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5-7 June 1989: 449-454.

Le Cren, E.D., 1951. The length-weight relationship and seasonal cycle in gonad weight and conditions in the perch(Perca fluvialitis). J. Anim. Ecol. 20: 201-219.

Lee, S., 1980. The family Priacanthidae of Taiwan, Quart. J. Taiwan Mus. 33(1,2): 43-54.

Lester, R.J.G., 1968. Feeding of Priacanthus tayenus and P. macracanthus near Hong Kong. Publ. Seto. Mar. Biol.Lab., XVI(1): 1-6.

Lester, R.J.G. and Watson, R.A., 1985. Growth, mortality, parasitism and potential yield of two Priacanthus species in the south China sea, J. Fish. Biol. 27(3): 307-318.

Lindberg, G.U. and Z.V. Krasyukova, 1969. Fishes of the sea of Japan and the adjacent areas of the sea of Okhotsk and the Yellow sea. Part 3, Teleostomi; Key to the fauna of USSR, Zoological Institute of the Academy of Science, USSR (Translated from Russian, Israel Program for Scientific Translations, Jerusalem, 1971), 498 p.

Lovern, J.A. and Wood, H., 1937. Variation in the chemical composition of herring. J. mar. biol. Ass. U.K., 22: 281-293.

Luther, G., T. Appa Rao, S. Rueben, Y. Appanna Sastry, M.V. Somaraju, C. Gopal and K. Radhakrishna, 1988. Marine Fish Calander. Mar. Fish. Infor. Serv., T & E Ser., 80: 1-21.

MacKay, K.T. and J. Gilhen, 1973. Hirundichths rondeleti, Cookeolus boops, Priacanthus arenatus, Seriola dumerili, four species new to the Canadian Atlantic ichthyofauna. J. Fish. Res. Bd. Can. 30: 1911-1913.

Martin, W.R., 1949. The mechanics of environmental control of body form in fishes. Univ. Toronto stud. Biol. 58 (Publ. Ont. Fish. Res. Lab. 70): 1-91.

Mathew, K.J., T.S. Naomi, Geetha Antony, D. Vincent, R. Anil Kumar and K. Solomon, 1990. Studies on zooplankton biomass and secondary and tertiary production of the EEZ of India. Proc. First Workshop Scient . Resul. FORV Sagar Sampada, 5-7 June, 1989; 59-69 (1990).

Mohr, E.W., 1927. Bibliographie, der. Alters-und Wachstumsbistimmung bei. Fischen. J. Cons. perm. int. Explor. Mer 2, 236-258.

Mohr, E.W., 1930. Bibliographie, der. Alters-und. Wachstumsbistimmung bei. Fischen. J. Cons. perm. int. Explor. Mer. 5, 88-100.

Mohr, E.W., 1934. Bibliographie, der. Alters-und Wachstumsbistimmung bei. Fischen. J. Cons. perm. int. Explor. Mer. 9, 377-391.

Morrison, W.C., 1890. A review of the American species of Priacanthidae, Proc. Acad. Nat. Sci. Phila (1889): 159-163.

Moulten, J.M., 1962. Marine animal sounds of the Queens land coast. Am. Zool. 2: 54 (Abstract).

Munro, I.S.R., 1955. The Marine and Freshwater fishes of Ceylon. Department of External Affairs, Canberra. 349 pp.

Murty, V.S., 1981. Observations on some aspects of the biology of thread fin bream Nemipterus mesoprion (Bleeker) from Kakinada, Indian J. Fish., 28: 199-207.

Murty, V.. Sriramachandra, 1984. Observatiors on the fisheries of threadfin breams (Nemipteridae) and on the biology of Nemipterus japonicus (Bloch) from Kakinada. Indian J. Fish. 31(1&2): 1-18.

Murty, V. Sriramachandra, 1990. Biology and population dynamics of the silver belly Secutor insidiator (Bloch) from Kakinada. J. mar. biol. Ass. India 1990. 3(192): 10-24.

Myers, G.S., 1958. The priacanthid fish genus Pristigenys. Stanford Ich. Bull. 7(3): 40-42.

Naik, S.K., 1990. On bulls eye - the deep sea resources. Seafood Export Journal 22(12): 16-18.

Nair, P.V.R. and C.P. Gopinathan, 1981. Productivity of the Exclusive Economic Zone of India. J. mar. biol. ass. India 23(1&2): 48-54.

Natarajan, A.V. and V.G. Jhingran, 1961. Index of preponderance a method of grading the food elements in stomach analysis of fishes. Indian J. Fish., 8(1): 54-59.

Nicol, J.A.C. and Zyznar, E.S., 1973. The tapetum lucidum in the eye of the big eye Priacanthus arenatus Cuvier. J. Fish. Biol. 5: 519-522.

Nicol, J.A.C., H.J. Arnott and A.C.G. Best, 1973. Tapeta lucida in bony fishes (Actinopterygii) a survey. Can. J. Zool. 51: 69-81.

Nina, T.V., S.P. Basu and A.K. Bhargava, 1984. Observation on the demersal fishery resources along Andhra Pradesh coast. Fishery Survey of India, Bull. 13: 18-22.

Nugroho, D. and dan Rusmadji Rustam, 1983. Studies on the growth and mortality of the big eye snapper, Priacanthus macracanthus of the north coast of Java. Mar. Fish. Res. Rep. Jakarta (27): 9-11 (in Indonesian).

Oommen Varghese, P., 1985. Deep sea resources of the south west coast of India. Bulletin, IFP, 11: 1-83.

Pauly, D., 1980. On the inter-relationships between natural mortality growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. CIEH, 39(3): 175-192.

Pauly, D., 1982. Studying single species dynamics in a tropical multispecies context. In: D. Pauly and G.I. Murphy (Eds.). Theory and Management of Tropical Fisheries. Proceedings of the ICLARM/CSIRO Workshop on the Theory and Management of Multispecies Stocks. 12-21 January 1981, Cronulla, Australia, 33-70.

Pauly, D., 1983. Some simple methods for the assessment of tropical fish stocks. FAO Fish. Tech. Pap. 234: 52 p.

Pauly, D., 1984. Fish population dynamics in tropical waters: A manual for use with programmable calculators. ICLARM, Manila, Philippines, 325 p.

Pauly, D., and J.L. Munro, 1984. Once more on growth comparisons in fish and invertebrates. Fishbyte 2(1): 21.

Philip, K.P., B. Premchand, G.K. Avhad and P.J. Joseph, 1984. A note on the deep sea demersal resources of the Karnataka-north Kerala coast. Bull. Fish Surv. India, 13: 23-30.

Philip, K.P. and P.J. Joseph, 1988. Fishery resources of offshore and deep sea waters of Karnataka and the fishing efforts suggested for exploitation. Proc. Sem. Problems and Prospects of Marine Fishing and Fish Processing in Karnataka, June 19-21, 1986; 28-35.

Pillay, T.V.R., 1952. A critique of methods of study of food of fishes. J. Zool. Soc. India, 4: 185-200.

Prabhu, M.S., 1956. Maturation of intra-ovarian eggs and spawning periodicities in some fishes. Indian J. Fish. 3(1): 69-90.

Qasim, S.Z., 1957. The biology of Blennius pholis L. (Teleostei) Proc. Zool. Soc. Lond., 128: 161-208.

Qasim, S.Z., 1966. Sex ratio in fish populations as a function of sexual difference in growth rate. Curr. Sci., 35: 140-142.

Qasim, S.Z., 1972. The dynamics of food and feeding habits of some marine fishes. Indian J. Fish. 19: 11-28.

Qasim, S.Z., 1973a. Some implications of the problem of age and growth in marine fishes from the Indian waters. Indian J. Fish. 20: 351-371.

Qasim, S.Z., 1973b. An appraisal of the studies on the maturation and spawning in marine teleosts from the Indian waters. Indian J. Fish. 20(1): 166-181.

Randall, J.E., 1978. Priacanthidae, 7 pages, in W. Fischer, ed. Species identification sheets for fishery purposes. Western central Atlantic (fishing area 31) Vol.4 FAO, Rome, unpaginated.

Rao, G. Sudhakara, 1985. Studies on the biology and fishery of the brown prawn *Metapenaeus monoceros* (Fabricius 1798) along the Kakinada coast. Ph.D. Thesis, Andhra University, Waltair.

Rao, G. Sudhakara, 1993. An appraisal of the marine fishery resources of Visakhapatnam coast. *Fishing Chimes,* 13(1): 81-88.

Rao, Narasimha, T.V., D. Ponakala Rao, B. Prabhakara Rao and V.S. Rama Raju, 1986. Upwelling and sinking along Visakhapatnam coast. *Indian J. Mar. Sci.* 15: 84-87.

Rao, K.S. 1967. Food and feeding habits of fishes from trawl catches in the Bay of Bengal with observations on diurnal variation in the nature of feed. *Indian J. Fish.* 11(1): 277-314.

Rao, T. Appa, 1984. On some aspects of the biology of *Priacanthus macracanthus* (Cuvier) *Indian J. Fish.* 31(3): 380-382.

Rao, K.V.N., K.K. Sukumaran, K. Sunilkumar Mohamed, P.U. Zacharia and K. Uma, S. Bhat, 1993. Trawl fishery of the mid-shelf region off Mangalore coast in Varghese T.J. et. al. (editors). *The second Indian Fisheries Forum Proc.* 27-31, May 1990, Mangalore, India, 160-165.

Rao, K.V.S., 1966. Age and growth of 'Ghol', Pseudosciaena diacanthus (Lacepede) in Bombay Saurashtra Waters. Indian J. Fish. 13(1&2): 257-292.

Rao, K.V.S., 1983. Maturation and spawning of lizard fishes (Saurida spp.) from north western part of Bay of Bengal Indian J. Fish. 30(1): 27-45.

Rao, K.V.S., 1984. Age and growth of lizard fishes (Saurida spp.) from the northern Bay of Bengal. Indian J. fish. 31(1): 19-30.

Reid, E.D., 1944. Descriptive notes on two rare fishes from off the Virginia capes. Copeia: 215-217.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish Res. Board. Can. 191: 382 p .

Rikhter, V.A. and V.N. Efanov, 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res. Doc., 76/VI/8: 12 p.

Robson, D.S. and D.G. Chapman, 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc., 90(2): 181-189.

Rueben, S., 1968. A note on the food of Malabar trevally Carangoides malabaricus (Bloch and Schneider) from the north Western Bay of Bengal. J. Mar. Biol. Ass. India, 10(1): 182-183.

Rueben, S., K. Vijayakumaran and K. Chittibabu, 1993. Growth, maturity and mortality of Upenus sulphurius (Cuvier) from Andhra, Orissa coast. Indian J. Fish (under publication).

Saeger, J., P. Martosubroto and D. Pauly, 1976. First report on the Indonesian German Demersal Fisheries Project. Results of a trawl survey in the Sanda shelf area No.1: 1-16.

Salmon, M. and H.E. Winn, 1966. Sound production by Priacanthid fishes. Copeia 1966: 869-872.

Samuel, G.E., S. Girija and C.J. Jos, 1987. Processing of Priacanthus. In· Proc. Diversification of post harvest technology for low cost fish. pp.223-230. Society of Fisheries Technologists (India).

Schroeder, W.C., 1938. Records of Psuedopriacanthus altus (Gill) and Fundulus majalis (Walbaum) from the Gulf of Maine. Copeia 1937: 238.

Schultz, L.P., 1960. Fishes of the Marshall and Marianas Islands U.S. Nat. Mus. Bull. 202: 499-502.

Senta, T. and S.M. Tan, 1973. Trawl fishing grounds in north Andaman sea. Tech. Seminar on South China Sea Fish. Res. May 21-25, Bangkok, paper S-12, 1-11.

Senta, T. and S.M. Tan and P.V. Lim, 1973. Results of the experimental trawl fishing in the South China Sea by R.V. Changi in the years 1970 to 1972. Ibid. paper S-10, 1-13.

Senta, T., 1977. Species and size composition of Priacanthid fishes in the South China Sea and adjacent waters. Bull. Fac. Fish. Nagasaki Univ., 42: 25-31.

Senta, T., 1978. High incidence of aggregation of the big eyes Priacanthus tayenus and Priacanthus macracanthus in the South China Sea. Bull. Fac. Fish. Nagasaki. Univ., 45: 1-4.

Seshappa G. and B.S. Bhimachar, 1955. Studies on the fishery and biology of Malabar sole Cynoglossus semifasciatus, Day. Indian J. Fish. 2: 180-230.

Shao, K. and W. Chang, 1985. Phylogenetic inference of Priacanthidae from morphometric studies. Bull. Inst. Zool. Academia. Sinica 24: 273-288.

Shindo, S., 1973. General review of the trawl fishery and the demersal fish stocks of the South China Sea. FAO Fish Tech. pap., 120: 49 p.

Shindo, S. and S. Chullasorn, 1980. Economically important marine fishes in the South East Asian waters. Text Reference Book series No.17 514-516 Training Department, South East Asian Fisheries Development Centre.

Silas, E.G., 1977. Indian Fisheries 1947-1977. Issued at IOFC, Vth Session, Cochin, 19-27 October 1977: 96 p.

Simpson, A.C., 1951. The fecundity of the plaice. Fishery Invest. Lond. Ser. 2, 17, 5, 1-27.

Simpson, A.C., 1982. A review of the data base on tropical multispecies stocks in the South East Asian region. Theory and Management of Tropical Fisheries. Proceedings of the ICLARM/CSIRO Workshop on the Theory and Management of Tropical Multispecies Stocks, 12-21 January, 1981. Cronulla, Australia, 5-32.

Sivakami, S., 1990. Observations on the demersal fishery resources of the coastal and deep sea areas of the Exclusive Economic Zone of India. Proc. First Workshop Scient. Result. FORV Sagar Sampada, 5-7 June, 1989: 215-232.

Sivaprakasam, T.E., 1986. What is in store in deep sea? Results of exploration into the demersal fishery resources of the Indian EEZ. Occ. pap. Fish. Surv. India 3: 23 p.

Smith, J.L.B., 1949. The sea fishes of Southern Africa. Central News Agency Ltd., Cape Town, 550 p.

Smith, J.L.B., 1966. The rare big eye *Pristigenys niphonia* (C.V.) in South Africa. Rhodes Univ. Dept. Ich. Occ. Pap. 9: 97-102.

Smith, M. Margaret and Philip C. Heemsta, 1986. Smith's sea fishes, Springer-Verlag publ. 1041 p.

Snedecor, G.W., 1961. Statistical methods applied to experiments in agriculture and biology, Allied Pacific Pvt. Ltd., Bombay.

Snedecor, G.W. and W.G. Cochran, 1967. Statistical Methods, Sixth Edition Oxford and IBH Publishing Co., New Delhi, 593 p.

Somvanshi, V.S. and P.K. Bhar, 1984. A note on the demersal fishery resources survey of Gulf of Mannar. Fishery Survey of India, Bull. No.13: 12-17.

Sparre, P. and S.C. Venema, 1992. Introduction to tropical fish stock assessments Part I - Manual. FAO Fish. Tech. pap. 306/1: 376 p.

Stamatopoulos, C., 1993. Trends in catches and landings. Indian ocean fisheries; 1970-1991. FAO Fisheries Circular No.855.2 Rome, FAO. 1993, 91 pp.

Starnes, W.C., 1981. Priacanthidae; 5 pages in W. Fischer, G. Bianchi and W.B. Scott, eds. FAO species identification sheets for fishery purposes. Eastern central Atlantic, fishing area 34, 47 (in part). FAO and Can. Dept. Fish. Oceans, Ottawa, Unpaginated.

Starnes, W.C., 1984. Priacanthidae, 12 pages in W. Fischer and G. Bianchi, eds. FAO species identification sheets for fishing purposes. Western Indian Ocean (fishing area 51) Vol.3. FAO, Rome, Unpaginated.

Starnes, W.C. 1988. Revision, phylogeny and biogeographic comments on the circumtropical marine percoid fish family Priacanthidae. Bull. Mar. Sci. 43(2): 117-203.

Sudarsan, D., T.E. Sivaprakasam, V.S. Somvanshi, M.E. John, K.N.V. Nair and Antony Joseph, 1988. An appraisal of the marine fishery resources of the Indian Exclusive Economic Zone. Bull. Fish. Surv. India, 18: 81 p.

Sudarsan, D., M.E. John and V.S. Somavanshi, 1990. Marine Fishery Resources potential in the Indian Exclusive Economic Zone - An update. Bull Fish. Surv. India. 20: 27. p.

Sudarsan, D., 1993. Marine fishery resources of the Exclusive Economic Zone of India. Proceedings of the National Workshop on Low Energy Fishing, 8-9 August 1991, Cochin, 1-11.

Sujatha, K., 1986. Fishes of family Priacanthidae of Visakhapatnam. J. Aqua. Biol. 4(1&2): 10-15.

Sulochanan, P. and John, 1988. Offshore, deep sea and oceanic fishery resources of Kerala coast. Fishery Survey of India, Bull. 16: 27-48.

Talwar, P.K., 1975. Record of the bathypelagic fish Priacanthus boops (Schneider) from the continental slope of the south west coast of India. Zool. Sur. India Newsletter 1(1): 7-9.

Talwar, P.K. and R.K. Kacker, 1984. Commercial Sea Fishes of India. Director, Zoological Survey of India, 997 p.

Tamura, T., 1959. Fundamental studies in the visual sense in fish. In Modern Fishing Gear of the World (ed. H. Kristjonsson); Fishing News Books, London. 543-547.

Taylor, C.C., 1958. Cod growth and temperature. J. Cons. CIEM 23: 266-270.

Tester, A.L., 1940. A specific gravity method for determining fatness (condition) in herring (Clupea pallasii). J. Fish. Res. Bd. Canad. 4: 461-471.

Thomas, P.A., 1969. The goat fishes (family, Mullidae) of the Indian Seas, Mem. III. J. Mar. Biol. Ass. India.

Thompson, D.A.W., 1943. On growth and form. 2nd ed. University Press, Cambridge.

Tortonese, Eland A. Cau, 1984. Una famiglia di pesci period; nuova nel Mediterranion: Priacanthidi. Quad. Civ. Stn. Idrobiol. milano 12: 57-60.

Venkataraman, G., 1961. Studies on the food and feeding relationships of the inshore fishes off Calicut on the Malabar Coast. Indian J. Fish., 1960, 7(2): 275-306.

Vien, L.M., 1968. Commercial ichthyofauna of the Tonkin Bay. Voprosi Ikhti, 8, 817-883 (in Russian).

Vijayakumaran, K. and S.K. Naik, 1988a. Fin fish resources in the inner continental shelf of the EEZ. National Workshop on Fishery Resources Data and Fishing Industry, 14-15 October, 1988, Visakhapatnam, 71-79.

Vijayakumaran, K. and S.K. Naik, 1988b. A study of the stock of Priacanthus hamrur (Forsskal) during March and September between lat. 11°N-16°N along the west coast of India. Fishery Survey of India Spl. pub. 2: 106-119.

Vijayakumaran, K. and K.P. Philip, 1990. Demersal fishery resources of north Kerala, Karnataka and Konkan coasts. J. mar. biol. ass. India, 32(1&2): 177-186.

Vijayakumaran, K. and K. Radhakrishna, 1994. Relation between wind speed and coastal upwelling off Visakhapatnam coast (M.S.).

Walls, P.D., 1964. The anatomy of the sound producing apparatus of some Australian fishes. Honours thesis, Bowdoun College.

Wang, R.T., J.A.C. Nicol, E.L. Thurston and M. Mc Cants, 1980. Studies on the eyes of big eye (Teleostei-Priacanthidae) with special reference to tapetum lucidum. Proc. R. Soc. Lond. Ser B., 210(1181): 499-512.

Weber, M. and L.F.de Beaufort, 1929. The fishes of the Indo-Australian Archipelago, E.I. Brill, Leiden 5, 458 p.

Wetchagarun, K., 1971. Some aspects of the biology of spot-finned big eye (Priacanthus tayenus) in the inner part of Gulf of Thailand (1969-1970); Paper presented to the second symposium of marine fisheries, Bangkok, Marine Fisheries Laboratory, 19-20, April 1971. 24 p (Memeo).

White, E.I., 1936. On certain Eocene percoid fishes. Ann. Mag. Nat. Hist. Ser. 10, 18 (103): 43-54.

Yoshino, T. and Tamotsu Iwai, 1973. Pristigenys multifasciata, a new priacanthid fish from the Ryukyn Island, Japanese Journal of Ichthyology, 20(2): 61-66.

Yuen, H.S.W., 1955. Maturity and fecundity of big eye tuna in the Pacific. Spec. Sci. Rep. U.S. Fish Wild Serv. 150: 30-32.

Zacharia, P.U., K. Sunilkumar Mohamed, P.P. Pillai and C. Purandhara, 1991. Bull's eye - An emerging trawl fishery resource along Dakshina Kannada coast. Mar. Fish. Infor. Serv. T & E. Ser. 114: 29-31.