

**FISHERY, BIOLOGY AND POPULATION DYNAMICS OF THE MARINE
CRABS, *PORTUNUS (PORTUNUS) SANGUINOLENTUS* (HERBST)
AND *PORTUNUS (PORTUNUS) PELAGICUS* (LINNAEUS)
ALONG THE KARNATAKA COAST**

By

K.K. SUKUMARAN, M.Sc.,

SCHOOL OF OCEAN SCIENCES,
KARNATAK UNIVERSITY,
POST GRADUATE & RESEARCH CENTRE,
KODIBAG, KARWAR, INDIA.

1995

**FISHERY, BIOLOGY AND POPULATION DYNAMICS OF THE MARINE
CRABS, *PORTUNUS (PORTUNUS) SANGUINOLENTUS* (HERBST)
AND *PORTUNUS (PORTUNUS) PELAGICUS* (LINNAEUS)
ALONG THE KARNATAKA COAST**

By

K.K. SUKUMARAN, M.Sc.,

SCHOOL OF OCEAN SCIENCES,
KARNATAK UNIVERSITY,
POST GRADUATE & RESEARCH CENTRE,
KODIBAG, KARWAR, INDIA.

THESIS SUBMITTED TO THE KARNATAK UNIVERSITY, DHARWAD
FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
in
MARINE BIOLOGY

1995

KARNATAK



UNIVERSITY

DEPARTMENT OF POST-GRADUATE STUDIES
AND RESEARCH IN MARINE BIOLOGY
KARNATAK UNIVERSITY-P. G. CENTRE
KODIBAG, KARWAR-581 303 INDIA PHONE : 5372.

Certificate

This is to certify that the thesis entitled "Fishery, biology and population dynamics of the marine crabs, *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus) along the Karnataka coast" submitted by Mr. K.K. Sukumaran for the award of Doctor of Philosophy in Marine Biology is based on the results of experiments carried out by him under my supervision. The thesis or part thereof has not been previously presented for any Degree or Diploma.

Karwar.

Date: 17th Nov 95

(B. NEELAKANTAN)

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude and indebtedness to Prof.(Dr.) B. Neelakantan, M.Sc., M.Sc.(MB)., Ph.D., Dip. (Norway), C.J.F., F.A.Z., M.F.S.T., F.A.E.B., Professor, School of Ocean Sciences, Karnatak University P.G & Research centre, Karwar, for his invaluable guidance, constant encouragement and unfailing interest throughout the course of this study and in the preparation of this thesis.

I am extremely thankful to Dr. W.A. Van Engel, Dr. Paul A. Haefner Jr., Dr. E.G. Lewis, Dr. Paul A. Sandifer of the Virginia Institute of Marine Science, USA; Dr. R.G. Hartnoll of Port Erin Marine Laboratory, University of Liverpool, UK; Dr. W.D. Sumpton, Dr. G.B. Campbell, Dr. M.A. Potter, Dr. J.C. Potter, Dr. G.S. Smith of Southern Fisheries Research Centre, Queensland, Australia for making me available their valuable publications on the subject.

I am deeply indebted to Dr . P.Vedavyasa Rao, Principal Scientist (Retd.), CMFR Institute, Cochin for his keen interest shown in my work, encouragements, fruitful discussions, invaluable suggestions throughout the course of this study and going through all chapters critically and suggesting improvements.

I am very much thankful to Prof.(Dr.) Kusuma Neelakantan, Chairman, School of Ocean Sciences, Karnatak University P.G. & Research Centre, Karwar, for her valuable suggestions and encouragements.

I am thankful to Dr. M. Devaraj, Director, CMFR Institute, Cochin for his keen interest shown in this study.

I thank Prof. (Dr.) S.L. Shanbhogue, Professor, College of Fisheries, Mangalore for the keen interest shown in this study and encouragements.

I wish to thank my friend Mr. M. Kathirvel, Sr. Scientist, CJBA, Madras for making me available the bibliography on portunids prepared by him and for his invaluable suggestions.

I am very much thankful to my colleagues Dr. C. Suseelan, Dr. P.P. Pillai, Mr. M. Srinath, Dr. K. Sunilkumar Mohamed, Mr. P.U. Zacharia and Ms. Prathibha Rohit

for all round help and cooperation and reading through some chapters and suggesting improvements.

I am thankful to my colleague Dr. P. K. Krishnakumar for the photographs of crabs and invaluable suggestions.

My sincere thanks to Dr. N.N. Pillai, Dr. V.S. Kakati, Mr. P. K. Asokan, Ms. K. Preetha, Upadhyaya for the help and cooperation extended to me during the course of this study. I wish to acknowledge the excellent cooperation extended to me by S/Shri T.K. Puttaswamy and Devaraj, College of Fisheries, Mangalore during the course of this study.

Thanks are also due to Dr. P.N. Prasad and Dr. K.K. Balasubramanian and Dr. Ameer Hamsa for making me available their collected reprints on crabs.

I wish to record my high appreciation and thanks to my colleagues S/Shri C.K. Dinesh, C.G. Ulvekar, R. Appaya Naik, Ms Uma S. Bhat, Alli C. Gupta, S/Shri D. Nagaraja, B. Shreedhara, Y. Muniyappa, H.S. Mahadewaswamy, C. Purandhara, C.H. Vaman Naik (late), G.S. Bhat, Lingappa, Bhaskaran, N.Chinnappa Gowda, N.G. Vaidya and L.K.Suvarna for all the help they rendered in the field as well as in the laboratory.

I owe my thanks to Dr. U.G. Bhat, Dr. U.G. Naik, S/ Shi K. Vinod, S. Sampathkumar, Ms Sadhana, S.L. Bhat of School of Ocean sciences, Karwar for all the help they rendered during the course of this study.

Thanks are also due to all staff of School of Ocean Sciences, Karwar, Research centre of CMFRJ Karwar and Mangalore for the all the help and cooperation.

Thanks are also due to M/S Essel Lasers, Mangalore, for computerising this thesis in an excellent manner.

Finally, I am greatly indebted to my wife, Mangala who looked after the children and household affairs silently when I was busy in my research activities and without her whole hearted cooperation, help and encouragements it would not have been possible for me to complete this piece of work.


(K.K. Sukumaran)

PREFACE

In a developing country like India, the importance of fisheries needs no emphasis. To meet the increasing demand for protein-rich food, to earn valuable foreign exchange and to provide gainful employment to the coastal rural population, the development of fisheries has been assigned the highest priority in the national five year plans since the post independence period.

With a coastline of 7,517 km and forming a continental shelf of about 3,11,680 sq. km., the marine fishery resources of India are rich and diverse comprising a large assemblage of finfishes and shellfishes. The annual marine fish production of the country is of the order of about 2.24 million tonnes. The export of fish and fish products from the country has earned about Rs. 2,503.6 crores during 1993-94.

The marine shellfishes of India is chiefly constituted by crustaceans and molluscs. Among crustaceans, penaeid prawns are most important in view of the quantum of landings, value and increasing demand for export trade. These are followed by crabs and lobsters.

Although there are over 600 species of crabs recorded from Indian waters, only a few of them are being used for food purposes (Rao *et al.*, 1973). The commonly utilised crab species for food in this country belongs to three families, viz., Calippidae, Portunidae and Grapsidae. Of them, Portunidae is important in that it includes the commercially important species such as *Scylla serrata*, *Portunus*

sanguinolentus, *P. pelagicus*, *Charybdis (Charybdis) feriatus*, *C. annulata*, *C. natator* (Bal and Rao, 1984).

There are no noteworthy organised fishery for crabs in any part of this country. They are caught in small quantities in gears used for catching general fish resources. Of late, however, trawl nets operated by mechanised boats and other powered vessels catch considerable quantities of crabs.

The annual average yield of marine crabs in our country was around 4,000 tonnes in early sixties. With the advent of mechanised trawling in fifties for prawns and ground fishes and the subsequent strengthening of the trawler fleet, the exploitation of the demersal living resources has been intensified over the years. Increased deployment of medium-sized trawlers (9.75 - 15.0 m) fitted with 37-102 HP engines for over- night fishing and extension of fishing ground upto 75 m depth in the recent years, resulted in increased exploitation of crab resources. Consequently, the present annual average yield of crabs in our country from the marine sector is around 23,137 tonnes for the 11 year period from 1983 to 1993, which is 500 % more than the catch realised 30 years before. During the last 5 years, the annual catch fluctuated between 16,191 (1989) and 28,489 tonnes (1991).

To augment crab production, the unexploited resources like the swarming crabs can be exploited. According to the recent exploratory surveys conducted by the FORV *SAGAR SAMPADA*, the swarming crab, *Charybdis (Goneohellenus) Smithii* is found to be a potentially important deep sea resource occupying the outer shelf and upper continental shelf regions and occurring along the west coast of India

(Balasubramanian and Suseelan, 1990).

Since crab meat is a delicacy in many parts of the world, it is exported alive, frozen and canned to several foreign countries. During 1993-94 alone, crabs worth Rs.196.4 million (2,034 tonnes) were exported from India which formed 0.78 % in terms of value and 0.83 % in quantity of the total export of marine products from the country during this period. The countries importing crab meat from India are Japan, USA, Belgium, Thailand, Portugal, Indonesia, Malaysia, Singapore and United Kingdom.

Due to the ever-increasing demand for live crabs for human consumption, there has been a recent upsurge of interest in the culture of crabs to augment the resource in several countries. Among crabs there are many potential candidates for culture. Reproductively most crabs offer little problem for artificial propagation. Although crabs continue to be a major subject of research, the number of species being cultured commercially for food is small. However, in Taiwan, Indonesia and the Philippines, efforts have been made to culture *Scylla serrata* as a subsidiary crop in milk fish ponds (Bardach *et al.*, 1972; Escritor, 1970, 1972). Experimental culture of *S. serrata* has been tried in Australia (Heasman and Fielder, 1983), India (Naidu, 1955; Kathirvel, 1980; Marichamy, 1980; Marichamy *et al.*, 1980 and 1986; Raman *et al.*, 1980, Marichamy and Rajapackiam 1984; Srinivasagam *et al.*, 1984 and Bensam, 1986), Indonesia (Grino, 1977), Malaysia (Ong, 1964 and 1966), and the Philippines (Arriola, 1940; Escritor, 1972; Lavina and Buling, 1977; Motoh *et al.*, 1977).

Investigations on the marine crab resources of India are limited to only a few works. Most of the works are confined to reporting on the species represented in general account of the fishery. Anywhere studies on the biology and population structure of the commercially exploited species have not been attempted. In the context of increased importance of crab resources and the interest evinced in the culture, there is an urgent need to study the biology and ascertain the present status of the crab stocks for the rational exploitation of the resources and to augment production through culture practices. Hence, the present study was taken up, and an attempt has been made for the first time to assess the present status of the stocks of the marine portunids based on the data collected from Karnataka.

It is hoped that the present study will enhance our knowledge on various aspects of fishery, biology and population dynamics of the resource of portunids of Karnataka which in turn will form the basis for evolving management strategies for the judicious exploitation of these valuable resources on an all India basis.

CONTENTS

	Page No.
Chapter I: GENERAL INTRODUCTION	1
Chapter II: FISHERY	19
Chapter III: FOOD AND FEEDING	38
Chapter IV: CARAPACE WIDTH (LENGTH) - WEIGHT RELATIONSHIP	47
Chapter V: REPRODUCTION	52
Chapter VI: AGE AND GROWTH	86
Chapter VII: STOCK ASSESSMENT	101
GENERAL DISCUSSION	120
EXECUTIVE SUMMARY	124
REFERENCES	129

Chapter I

**GENERAL
INTRODUCTION**

Crabs represent the peak of evolution within the Crustacea and, with 4500 species, form the largest part of Decapoda, which in turn dominates the Sub-Class Malacostraca containing 70 % of all crustaceans (Jones, 1984).

Crabs are members of Crustacea (from Latin *crusta*, a hard shell), a class of invertebrate Phylum Arthropoda (from Greek *arthron*, joint + *pous*, foot), that includes the animals with jointed legs and a hardened outer covering or exoskeleton. Most crustacea are aquatic animals. Crabs belong to the order Decapoda (from Greek *deka*, ten + *pous*, foot) a name which refers to the fact that the members of this order have 5 pairs of legs. The true crabs are placed in the Suborder Brachyura (from Greek *bachys*, short + *oura*, tail), an appropriate name for this group, as their shortened flap-like abdomen or tail is folded under the body(Rees, 1963).

Crabs form one of the fascinating groups under Decapoda. The true crabs range in size from not larger than a grain of wheat to any known crustaceans (Rees, 1963). They have developed highly successful relationships between the environment and the biological mechanisms involved in evolutionary processes (Warner, 1977). They are filter feeders, sand cleaners, mud, plant and carrion feeders, predators, commensals, and parasites (Caine, 1974; Virnstein, 1977; Castro, 1978; Telford, 1978). Some are temporary swimmers, but most are walking bottom dwellers. Some even climb trees and construct burrows on land (Waterman and Chace, 1960).

The Brachyura show extreme versatility in distribution. They are found from the shore to deep sea, in marine, brackish and fresh water environments, in all climates (tropical, subtropical and temperate regions) and in terrestrial and semiterrestrial conditions. The Podotremata (Guinot, 1977) are exclusively marine, most other taxa

include brackish water species as well as marine forms, which invade estuarine habitats. The family Pseudothelphusidae contains most of the typically fresh water species that complete their life cycles in that habitat (Chace and Hobbs, 1969), but there are also fresh water representatives in Potamidae (Rathbun, 1901) and Hymenosomatidae (Griffen, 1970). There are various degrees of terrestrialism in crabs. Today, the marine littoral zone is conspicuously rich in crabs (Haefner, 1985).

The world crab fisheries accounted for 15,84,647 tonnes during 1992. Most productive geographical regions in terms of crab fisheries are North Pacific, Western Central Atlantic, Western Central Pacific, Southwest Atlantic, Southeast Pacific, and Northwest Atlantic. Western Indian Ocean contributes to 6,000 tonnes, while the Eastern Indian Ocean, 10,000 tonnes.

1.1.0. REVIEW OF LITERATURE

1.1.1. A world review

There have been extensive researches on the taxonomy, distribution, biology and exploitation of brachyurans from various parts of the world. Since the literature available on brachyurans is enormous, the present review is limited to the works on marine and brackish water forms only.

1.1.1.1. Taxonomy and distribution

Earlier works mainly relate to faunistic investigations. Recently, Browman and Abele (1982) reviewed the classification of Crustacea. In an earlier account Guinot (1977) has classified Decapoda. Rice (1980) provides an excellent review of the classification of Brachyura. Some of the other important works on the taxonomy were

those of Sakai (1934, 1936, 1976), Shen (1932, 1937) and Stephenson and Campbell (1959).

Some of the recent works on the distribution of brachyurans were those of Campbell and Stephenson (1970), Manning and Holthuis (1981), Sakai (1974), Stephenson (1961, 1972, 1972a), Stephenson and Campbell (1960), Stephenson and Rees (1967).

1.1.1.2 Biology and exploitation

One of the earlier studies on the life history of *Scylla serrata* was made by Arriola (1940). The various aspects of breeding and growth in *Cyclograpsus punctatus* was investigated by Broekhuysen (1941). The relative growth of the European edible crab, *Cancer pagurus* was made by MacKay (1942). In another study, the same author (MacKay, 1942a) gave a comprehensive account of the distribution, life history, growth and migration of the Pacific edible crab, *Cancer magister*, from the west coast of North America. Spalding (1942) reported on the nature and formation of sperm plug in *Carcinus maenas*. Histological study of the development of ovary and testis of the blue crab *Callinectes sapidus* was made by Cronin (1942, 1947). The general biology of the lined shore crab *Pachygrapsus crassipus* was investigated by Hiatt (1948). Differential growth and moulting characteristics of *Callinectes sapidus* was studied by Newcombe *et al.* (1949). Comparative studies of oogenesis and spermatogenesis in *Scylla serrata* was made by Estampador (1949). Catch composition of the sand crab (*P. pelagicus*) fishery at Moreton Bay was given by Thompson (1951). A brief account on the migration of the adult female of blue crab, *Callinectes sapidus* in Chesapeake Bay and adjacent waters was given by Cargo (1958). Van Engel (1958) reported on the reproduction, early development, growth and migration of *Callinectes sapidus* in Chesapeake Bay. Various aspects of crustacean physiology relating to moulting has been extensively reviewed by

Passano (1960). Various aspects of crustacean reproduction have been extensively reviewed (Charniaux -Cotton, 1960). Knudsen (1960) investigated on the reproduction, life history and larval ecology of the California Xanthidae, the pebble crab. Breeding procedure along with the onset of maturity in *Cancer magister* in the British Columbia was reported by Butler (1960). The same author (Butler, 1961) investigated on the growth and age determination in *Cancer magister* from the same area. Van Engel (1962) described various types of gears employed in blue crab fishery in the Chesapeake Bay. Hartnoll (1963) gave a comprehensive account of the taxonomy, distribution, food and feeding, growth and breeding of manx spider crabs from British waters. A brief account on the sex ratio and distribution of spawning King crabs, *Paralithodes camtschatica* in Alaska was given by Gray and Powell (1966). Morphometric analysis of certain western American swimming crabs of the genus *Portunus* was made by Stephenson (1965). Crothers (1967) reported on some aspects of biology of *Carcinus maenas*. Ryan (1967, 1967a, b) investigated on the structure, function of the reproductive system of males and females, and sexually mature instars of the crab *Portunus sanguinolentus* from Hawaiian waters. Ropes (1968) studied the feeding habits of *Carcinus maenas*. Food and feeding relationships of the crab, *Paralithodes camtschatica* was studied by Cunningham (1969). Hartnoll (1969) reviewed the different forms of mating in Brachyura. The courtship, copulation, and ovulation in *Corystes cassivelaunus* was reported by Hartnoll (1968). Some aspects of biology of *Callinectes sapidus* was studied by Tagatz (1968). Haley (1969) traced the relative growth and sexual maturity of the Texas ghost crab, *Ocypode quadrata* of the Texas coast. Meagher (1970) reported on the larval ecology of *Portunus pelagicus* in Australia. Watson (1970) reported on maturity, mating and egg laying in *Chionoecetes opilio*. Du Plessis (1971) gave an account on feeding, growth, reproduction and larval rearing of *Scylla serrata* held in captivity. Some aspects of biology of *Lupa pelagicus* was reported by Al-Kholy and El-Hawary (1970). Lucas and Hodgekin (1970) studied some aspects of growth and

reproduction of *Halicarcinus australis* from western Australia. Structure of the reproductive organs and the seasonal changes associated with gonad maturity in *Pachygrapsus crassipes* have been described by Chiba and Honma (1971, 1972). Fielder and Eales (1972) made observations on courtship, mating and sexual maturity in *Portunus pelagicus*. Hoopes and Karinen (1972) investigated on the longevity and growth of tagged king crabs in the Bering Sea. Brown and Powell (1972) determined the size at maturity in male Alaskan crab, *Chionoecetes bairdi* based on chela allometry, reproductive tract weights and size of pre-copulatory males. Hartnoll (1972) investigated on the burrowing habits, food and feeding, relative growth and reproduction of the burrowing crab, *Corystes cassivelaunus* from British waters. Haley (1973) used morphometric data to determine the sexual maturity in *Ocypode quadrata*. Turoboyski (1973) reported on the biology and ecology of the crab, *Rhithropanopeus harrisi* ssp. *tridentatus* from Poland. Hartnoll (1974) reported on the variation in growth pattern between some secondary sexual characters in some brachyuran crabs. Bennet (1974) traced the growth of *Cancer pagurus* off southwest England. Caine (1974) investigated the feeding and morphological adaptations for a burrowing existence in *Ovalipes quadulpenis*. Haefner and Van Engel (1975) dealt with moulting, growth and survival of male rock crab, *Cancer irroratus* in Chesapeake Bay. Hill (1975) reported on the abundance, breeding and growth of *Scylla serrata* in South African estuaries. In another study, the same author (Hill, 1976) investigated on natural food, foregut clearance rate of *Scylla serrata*. Kurata and Midorikawa (1975) traced the larval development of *Portunus pelagicus* and *P. sanguinolentus*. Fielding and Haley (1976) reported on sex ratio, size at maturity and reproduction in *Raina vanina*. Haefner (1976) studied the distribution, reproduction and moulting of *Cancer irroratus* in the Mid-Atlantic Bight (USA). Lewis (1977) investigated on relative growth and sexual maturity of *Bathynectes superbus* of American coast. Heasman and Fielder (1977) discussed the problems in the management and exploitation of mud crab fishery in Queensland. Gotshall (1977) examined the stomach contents of

Cancer magister. Gross morphology and histology of ovarian development and seasonality of reproduction, distribution, relative abundance of *Chaceon quinquedens* was investigated by Haefner (1977, 1978). Laboratory breeding and production of first crab stages in *Scylla serrata* and *Portunus pelagicus* was made by Motoh (1977, 1978). Kwei (1978) observed the size composition, growth and sexual maturity of *Callinectes latimanus*.

Edwards (1979) dealt with the edible crab, *Cancer magister* and its fishery in British waters. Hill (1979) gave a brief account on the population structure, gut contents and hypersalinity tolerance of *Scylla serrata* in a South African estuary. Elner (1980) examined the influence of temperature, sex and chela size in the foraging strategy of *Carcinus maenas*. Aspects of general biology and fishery of *Scylla serrata* in Moreton Bay was given by Heasman (1980). The mating system of *Uca pugilator* was investigated by Christy (1980). The reproductive system of *Callinectes sapidus* has been described by Johnson (1980). Food of *Paralithodes camtschatica* and *Cancer magister* was studied by Feder and Paul (1981) from Alaskan waters. Natural diet, feeding and predatory activity of the crabs *Callinectes arcautus* and *C. toxotes* was studied by Paul (1981) from the Pacific coast of Mexico. Observations were made on the maturation and spawning behaviour of *Seserma haematoecheirs* in the sea of Japan by Honma and Chiba (1981).

Williams (1981) commented on the methods of analysis of natural diet in portunid crabs of Australia. In another study, the same author (Williams, 1982) investigated on the natural food and feeding of *Portunus pelagicus* in Moreton Bay, Queensland. Smith (1982) reviewed the status, potential and biology of *Portunus pelagicus* in south Australia. Teissier (1982) reviewed the relative growth in crustaceans. The mating behaviour of *Chinoecetes bairdi* has been described by Adams (1982). Various aspects of crustacean growth have been extensively reviewed (Hartnoll, 1982). Feeding habits of *Callinectes sapidus* was investigated by Laughlin (1982). Jewett and Feder (1982, 1983) investigated on the food and feeding of *Paralithodes camtschatica* and *Chinoecetes bairdi* of the Alaskan coast. The life cycle of *Carcinus maenas* was traced by Berril (1982). Stevens

et al. (1982) reported on the feeding habits of *Cancer magister* as determined by the index of relative importance. An attempt has been made to study the seasonal abundance, size composition and growth of *Cancer irroratus* from Californian coast by Carroll (1982).

McLay (1982) briefly dealt with the population biology of the sponge crab, *Cryptodromia hilgendorfi* in the Moreton Bay. Hill *et al.* (1982) observed the distribution of juvenile, subadults and adults of *Scylla serrata* in the tidal flats in Australia. Potter *et al.* (1983) mentioned on the spawning period, pattern of growth and age structure of the population of *Portunus pelagicus* in Peel-Harvey estuarine system (Australia). Food of the tanner crab, *Chionoectes bairdi* was studied by Jewett and Feder (1983) from Alaska. Stephen and Feder (1983) examined the food of *Chinocoetes bairdi* from the Alaskan waters. Population dynamics, spatial distribution and somatic growth in *Uca pugilator* was reported by Colby and Fonseca (1984). Yoodee and Okawara (1984) reported on gill net and trap for catching *Portunus pelagicus* in Japan. A comparative study of adult sexual behaviour and larval ecology of three portunid crabs of Moreton Bay, Queensland was made by Campbell (1984). Goy *et al.* (1985) reported on the induced breeding of the mud crab, *Rhithropanopeus harrisi* during non-breeding season in north California.

Haefner (1985) dealt with morphology, reproduction, diet and epizoites of *Ovalipes stephensoni*. In another study the same author (Haefner, 1985a) reviewed various aspects of the biology and exploitation of crabs. Dittel *et al.* (1985) dealt with the population biology of the portunid crab *Callinectes arcuatus* in the Gulf of Nicoya (Central America). Heasman *et al.* (1985) remarked on the mating and spawning in the mud crab, *Scylla serrata* in Queensland. Campbell and Fielder (1986) reported on the size at maturity and occurrence of ovigerous females in three commercially exploited portunid crabs of S.E. Queensland. Natural diet and feeding habits of the crabs, *Liocarcinus puber* and *L. holsatus* was studied by Choy (1986) from South Wales. In another study, the same author (Choy, 1988) investigated on the reproductive biology of *Liocarcinus puber* and *L. holsatus*. Seiple and Salmon (1987) reported on the reproduction, growth

and life history contrasts between two species of grassid crabs, *Sesarma cinerium* and *S. reticulatum* from north California. El-Sherief (1987, 1988, 1991) reported on the histochemical study of spermatophores, and fine structure of sperm and spermatophores of *Portunus pelagicus*. Natural diet of the crab *Ovalipes catharus* was studied by Wear and Haddon (1987) from New Zealand. Factors affecting the distribution and abundance of the Blue crab in the Chesapeake Bay was investigated by Van Engel (1987). Growth and development of the external sexual characters of *Portunus pelagicus* have been studied by Yatsuzuka and Meruane (1987) in the Japanese waters. Beninger *et al.* (1988) reported on functional anatomy of the male reproductive system and female spermatheca in the snow crab *Chionoecetes opilio* from Nova Scotia. The ultrastructure of the sperm and spermatophores of the golden crab, *Chaceon fenneri* and a closely related species *C. quinquedens* from the Gulf of Mexico was reported by Hinch (1988). Hines (1988) dealt with fecundity and reproductive output in *Chaceon fenneri* and *C. quinquedens*. Ropes (1988) studied the food habits of five species of crabs from Rhode Island. Reproductive cycle of *Portunus pelagicus* based on anatomical changes of spermatheca was studied by Bawab and El-Sherief (1988). Erdman and Blake (1988) studied the reproductive ecology of *Chaceon fenneri* from Florida coast. Some aspects of biology and fishery of *Portunus pelagicus* was reported by Ingles (1988) from the Philippines. In another study, the same author (Ingles, 1989) investigated on reproduction and larval ecology of *P. pelagicus*. The structure and function of the reproductive system of the spider crab *Inachus phalangium* was investigated by Diesel (1989) from the Mediterranean coast. Abello (1989) reported on some aspects of reproduction and moulting in *Liocarcinus depurator*. The behaviour of sand crab, *Portunus pelagicus* at trap entrances was studied by Smith and Sumpton (1989) from Queensland. Bailey and Elner (1989) discussed the problems in the management of the Northwest Atlantic snow crab fishery. Bawab and El-Sherief (1989) reported on the origin, nature and formation of the sperm plug in spermatheca of the female of *Portunus pelagicus* from the Alexandria. Management

problems of Dungeness crab (*Cancer magister*) fisheries of the Pacific coast of North America was discussed by Methot (1989). Edwards (1989) described the present status of the British crab fishery and measures currently used to manage the stocks. The commercial pot and trawl fisheries for *Portunus pelagicus* in the Moreton Bay has been reported by Sumpton *et al.* (1989). The same authors (Sumpton *et al.*, 1989a) gave a brief account on the biology of *Portunus sanguinolentus* from the Queensland waters. Sumpton and Smith (1990) investigated on the effect of temperature on the emergence, activity and feeding in *Portunus pelagicus*. Brief accounts on the relative growth, and biology of the crab, *Charybdis natator* in the Moreton Bay (Queensland) were given by Sumpton (1990, 1990a). Shields *et al.* (1990) investigated on fecundity and reproductive potential of *Cancer anthonyi* of Californian coast. Morphology and size at maturity of *Callinectes ornatus* in Bermuda was observed by Haefner (1990). Creswell and Marsden (1990) investigated on the morphology of the feeding apparatus of *Cancer novaezelandiae* in relation to diet and predatory behaviour from New Zealand. Archambault *et al.* (1990) traced the life history and abundance of *Callinectes sapidus*. Van Engel (1990) described the development of the reproductively functional form in the male blue crab, *Callinectes sapidus* of the Virginia coast. Ehrhardt (1990) studied the mortality and catchability estimates for *Menippe mercenaria* of the North American coast by tagging experiments. Moulting in the mature female crab, *Callinectes sapidus* was investigated by Havens and McConaughy (1990). The diet of four *Callinectes* spp. were examined by Stoner and Buchanan (1990). Jones *et al.* (1990) presented the first estimates of spawning stock size of blue crab, *Callinectes sapidus* in Chesapeake Bay using trawl surveys. Fecundity of *Callinectes sapidus* was studied by Prager *et al.* (1990). Lipcius and Van Engel (1990) investigated on the variation in abundance and stock recruitment functions in *Callinectes sapidus* in Chesapeake Bay. Edgar (1990) reported on the distribution and diet of *Portunus pelagicus* in Western Australia. Smith and Jamieson (1991) attempted to study the movement, spatial distribution and mortality on *Cancer magister* of American coast.

Movement, fishing sector impact and factors affecting the recapture rate of tagged sand crabs, *Portunus pelagicus* in the Moreton Bay has been investigated by Potter *et al.* (1991). Attrill and Hartnoll (1991) reported on some aspects of the biology of the deep sea crab, *Chaceon trispinosus* from the Porcupine Seabight (UK). Henmi *et al.* (1993) observed the mating behaviour of the sand bubbler crab, *Scopimera globosa* from Japan. Hoggarth (1993) reported on the life history of the lithodid crab, *Paralomis granulosa* in the Falkland Islands (South America). Stehlik (1993) analysed the stomach contents of *Cancer irroratus*, *C. borealis* and *Ovalipes ocellatus* in the New York Bight. Lovrich and Vinuesa (1993) investigated on the reproductive biology of *Paralomis granulosa* from Argentina. Hartnoll *et al.* (1993) observed the spatial and temporal variations in the size distribution in spider crab populations around Isle of Man (UK). Depth-stratified population structure of geryonid crabs in the Eastern Gulf of Mexico was reported by Lindberg and Lockhart (1993). Sainte-Marie (1993) investigated on the reproductive cycle and fecundity of *Chionoecetes opilio* in the Gulf of Laurence. The offshore spawning of *Scylla serrata* was reported by Hill (1994). Relative growth and morphometric maturity of males and females of *Necora puber* were analysed by Gurriaran and Freire (1994) from Spain. Emmerson (1994) reported on the seasonal breeding cycles and sex ratios of eight species of crabs from Southern Africa. Kennelly and Watkins (1994) observed fecundity, and reproductive period, and their relationship to catch rates of *Ranina ranina* off the east coast of Australia. Feeding habits and food niche segregation of *Callinectes sapidus*, *C. rathbunae*, *C. similis* in a lagoon of Mexico was studied by Rosas *et al.* (1994). Sumpton *et al.* (1994) studied growth and reproduction in *P. pelagicus* from Australia.

1.1.2 Review of literature in India

Study relating to systematics, distribution, biology and exploitation of marine portunids along the coast of India are very few. A brief review of literature which are relevant to the present study, is presented below.

1.1.2.1. Taxonomy and distribution

The pioneering work of Alcock (1895, '96, '98, '99, 99a, 1900, 1901) was the first comprehensive and detailed study on the carcinological fauna of India. Other important faunistic works were those of Pillai (1951), Chhapgar (1957, 1957 a) and Sankarankutty (1961, 1962, 1962a, 1965).

Datta (1973) reported on the edible crabs of West Bengal. Chandy (1973) reported on some brachyuran crabs of Gulf of Kutch. Anzari and Harkantra (1976) has given a brief account on the crab resources of Goa. Srinivasagam (1975) reported on the edible crabs of Porto Novo.

1.2.2.2. Biology and fisheries

a) Fisheries

The first work on crab fisheries of India was that of Rai (1933) who gave a brief account on the shell fisheries of Bombay. Hora (1935) dealt with the bionomics of estuarine crabs along with fishing methods at lower Bengal. Chopra (1936, 1939) described important crabs, their food habits and fishing methods. Prasad and Tampi (1951) gave a brief account on the fishing methods for *Neptunus (Portunus) pelagicus* in the Palk Bay and Gulf of Mannar. Jones and Sujasinghani (1952) outlined the crab fishery of Chilka lake. The crab fishery of Ennur (near Madras) was studied by Chacko and Palani (1952). The crab fishery of Malabar coast was reported by Menon (1952), while George and Nayak (1961) studied the crab fishery of Mangalore coast. George and Rao (1967) compiled a detailed annotated bibliography of the fishery and biology of the edible crabs of India. Rao and Kathirvel (1971) reported on the seasonal occurrence of *Portunus pelagicus* in the Cochin backwaters. Thomas (1972) gave an account of the crab fishery of the Pulicat Lake. While describing the crab fishery of the Indian coast, Rao *et al.* (1973) mentioned the bionomics and marketing of commercial species of crabs.

Trivedi and Patel (1975) reported on the crab fishery of Gujarat. Dhawan *et al.* (1976) reported on the potential fishery of the crab, *Portunus pelagicus* in the Zuari estuary in Goa. The fishery of the Palk Bay and Gulf of Mannar was described by Hamsa (1978). Radhakrishnan and Samuel (1980) reviewed the prospects of fishery, utilisation and culture of crabs in India. Shanmugham and Bensam (1980) dealt with the fishery of *Scylla serrata* at Tuticorin. Bal and Rao (1984) gave a general account on the crab resources of India. Srinivasagam and Raman (1985) reported on the crab fishery of Pulicat lake. Lalithadevi (1985) gave an account of the crab fishery of the Kakinada coast, while Sukumaran *et al.* (1986) reported on the fishery of *Portunus sanguinolentus* of the South Kanara coast. Reddy and Shanbhogue (1990) reported on the estuarine fishery resources of Uttar Kannada district, Karnatakā.

b) Carapace width-weight relationship

Dhawan *et al.* (1976) reported on the carapace width- weight relationship of *Portunus pelagicus* from Goa. Thomas (1984) investigated on the carapace width-weight relationship of *P. pelagicus* and *Portunus sanguinolentus* from the Cochin area. Lalithadevi (1985) dealt with the carapace length-weight relationship of *P. pelagicus* and *P. sanguinolentus* from Kakinada. Sukumaran *et al.* (1986) reported on the carapace width-weight relationship of *Portunus sanguinolentus* from Mangalore. Prasad *et al.* (1989c) studied the carapace width-weight relationship of *P. pelagicus* and *P. sanguinolentus* from Karwar.

c) Food and feeding

Little has been published on the feeding biology of marine portunids, i.e., *P. sanguinolentus* and *P. pelagicus*, although there are several accounts on the feeding biology of other brachyurans. George and Nayak (1961) mentioned the major food items found

in the gut of *Portunus sanguinolentus* at Mangalore. Patel *et al.* (1983) reported the stomach contents of *P. pelagicus* from Gujarat coast. Prasad and Nelakantan (1988a) investigated on the food and feeding of *Scylla serrata* from Karwar. In another study, the same authors (Prasad and Neelakantan, 1988) reported on the feeding ecology of *Scylla serrata*.

d) Reproduction

Rai (1933) commented on the breeding season of some crabs of Bombay Presidency. Panikkar and Aiyer (1939) studied the breeding habits of some brackish water crabs of Madras. George (1949) studied on some aspects of biology of *Portunus sanguinolentus* from the Madras coast. Menon (1952) mentioned on the breeding season of *Neptunus (Portunus) sanguinolentus* while investigating the fishery and bionomics of the species from Malabar coast. The breeding season of *Neptunus (Portunus) pelagicus* was reported by Prasad and Tampi (1953) from Mandapam. Naidu (1955) described the early development of *Scylla serrata* and *Neptunus sanguinolentus*. Chhapgar (1956) observed the breeding period of some portunids from the Bombay area. George (1961, 1961a, 1961b, 1963) investigated on the anatomy of the internal musculature, nervous system, sense organs, respiratory, excretory, blood vascular and reproductive systems and embryological studies of *Neptunus (portunus) sanguinolentus* from Madras. The reproductive and nutritional cycles of *P. pelagicus* were studied by Rahman (1967) and Krishnaswamy (1967) from the southwest coast of India. The correlation between the breeding periodicities of *Charybdis variata* with reproductive and nutritional cycles was investigated by Chandran (1968). Rekha (1968) studied some aspects of biology of *Scylla serrata* from Bombay. The endocrine control reproduction in decapod crustacea has been reviewed by Adiyodi and Adiyodi (1970). Pillay and Nair (1971, 1973b) dealt with the reproductive cycles in some crabs from the southwest coast of India. While studying on the ecology of *P. pelagicus*, in the Zuari estuary in Goa, Dhawan *et al.* (1976) mentioned

the breeding season of this crab. Radhakrishnan (1979) dealt with the breeding biology of *P. sanguinolentus* and *P. pelagicus* from Porto Novo. Kannaiah (1980) studied the fecundity in some crabs from Porto Novo. Kathirvel (1980) reported on the abundance of portunid crab seeds in Cochin backwaters. Farooqui (1980) reported on the reproductive physiology of *Scylla serrata*. Nagabhooshanam and Farooqui (1981) investigated on the photoperiodic stimulation of ovary and testis maturation in *S. serrata*. The breeding biology of *Portunus pelagicus* and *Thalamita crenata* was studied by Sethuramalingam *et al.* (1982) from Porto Novo coast. Ezhilarasi and Subramoniam (1982) investigated on the spermathecal activity and ovarian development in *Scylla serrata*. Joel and Raj (1982) dealt with the breeding aspects of the portunid crabs, ie., *P. pelagicus*, *S. serrata* and *S. tranquibarica* of the Pulicat lake. Various physiological aspects of reproduction have been extensively reviewed (K.G. Adiyodi and R.G. Adiyodi, 1970 ; R.A. Adiyodi, 1985). Natarajan and Thangaraj (1983) studied the growth of *Scylla serrata* in the backwater cage at Tuticorin. Prasad (1987) investigated on the breeding biology of *Scylla serrata* from Karwar. Aruldas *et al.* (1980) studied the germinal zone activity and oocyte differentiation in the marine crab *Portunus pelagicus*. Sukumaran *et al.* (1986) traced the breeding biology of *Portunus sanguinolentus* from the South Kanara coast. Raman *et al.* (1987) reported on the larval rearing of *Portunus pelagicus* at Ennore hatchery. The morphological changes in the ovary and the anatomical changes on oocytes in eye-ablated females of *Scylla serrata* was reported by Simon and Sivadas (1988, 1989). Prasad and Neelakantan (1989a, 1989b; 1990) studied the maturity, breeding and fecundity of *Scylla serrata* from Karwar. Sheeba (1988) mentioned briefly on size distribution and reproductive biology of *Scylla serrata* at Cochin. Prasad *et al.* (1990) reported on the distribution and abundance of *Scylla serrata* in the Karwar waters. Jacob *et al.* (1990) studied the size at maturity in females of *Portunus sanguinolentus* and *P. pelagicus* from Karwar. Reeby *et al.* (1990) dealt with the size at maturity in males of *Portunus sanguinolentus* and *P. pelagicus* from Karwar. The same authors (Reeby *et al.*, 1990a)

studied the fecundity of these crabs from Karwar.

e) Age and growth

While studying on the bionomics and fishery of *Neptunus (Portunus) sanguinolentus*, Menon (1952) briefly mentioned about growth. Relative growth studies of the crab *Neptunus (Portunus) pelagicus* in relation to different parts of body was investigated by Prasad and Tampi (1954). A brief account on the growth of *Scylla serrata* was given by Chakrabarti (1981) from Gujarat. Hamsa (1982) studied the moulting and growth of *Portunus pelagicus* in the experimental tanks at Mandapam. Sukumaran *et al.* (1986) mentioned about the growth of *P. sanguinolentus* from the South Kanara waters. Thomas (1984) investigated on the growth of *P. sanguinolentus* and *P. pelagicus* from Cochin.

f) Stock assessment

No information is available on growth parameters, mortality, or stock assessment of these portunids from anywhere.

1.2. DESCRIPTION OF STUDY AREA

Karnataka is located on the west coast of the south Indian peninsula. Geographically, the state is wedged between the western Ghats to the east and the Arabian sea to the west. The state is situated between 11° 31' and 18° 45' north latitude and 74° 12' and 78° 40' east longitude and lies in the west central part of the peninsular India.

This state with about 300 km of coast line and a continental shelf area of 25,000 sq. km. has been selected as the study area (Fig. 1.1).

Twentytwo west flowing rivers originating in the Western Ghats flowing through the state and drains into the Arabian sea. Netravati, Gurpur, Gangavali, Sitanadi, Aghanashini, Kali and Sharavati are the principal rivers. Six estuaries, which includes Aghanashini and Kali, in the river systems are considered particularly important from the ecological and biological productivity standpoint. The state is well forested and characterised by a rich flora and fauna. The weather is hot and humid most of the year. The annual rainfall is more than 4400 mm.

There are 28 fish landing centres of which Mangalore, Malpe, and Karwar are the major fishing harbours, while Honavar and Tadri are minor fishing harbours. For the present study, three major centres (Mangalore, Malpe and Karwar) were selected for observation of crab landings and collection of samples for biological and other related studies.

1.3. RESEARCH APPROACH

Despite its commercial importance and wide distribution, present knowledge on the Indian marine portunids are meagre. Since there is considerable lacunae on various aspects of biology of the marine portunid crabs, the present study is directed to give a comprehensive account on the fishery, food and feeding, carapace^a width-weight relationship, reproduction, age and growth, growth parameters, mortality, yield-per-recruit and stock assessment.

1.4. SPECIES COVERED

The study was made on the following two commercially important marine portunid crabs of Karnataka.

1. *Portunus (Portunus) sanguinolentus* (Herbst) (Pl. 1)

This is a marine species and contributes to fishery in all maritime states of India. It is caught from the inshore and estuarine waters often in appreciable quantities. It is distributed from east coast of Africa, Asia, Red sea, Persian Gulf, Pakistan, India, Srilanka, China Sea, Philippines, Japan to Australia and Hawaii.

2. *Portunus (Portunus) pelagicus* (Linnaeus) (Pl. 2)

This marine species supports a fishery of considerable significance in all the maritime states of India. It is fished from inshore and brackish water areas in appreciable quantities. Its distribution ranges from east coast of Africa, Persian Gulf, Pakistan, India, Srilanka, China sea, Philippines, Japan to Australia, New Zealand and Hawaii.

Although the latest nomenclature of the portunid crabs studied are *Portunus (Portunus) sanguinolentus* and *Portunus (Portunus) pelagicus*, for the sake of brevity, the nomenclature *Portnus sanguinolentus* and *Portunus pelagicus* are used through out the text.

The results of the present study are presented in 7 chapters. The first chapter includes the general introductory part, review of literature, description of study area, research approach and species covered.

The second chapter deals with the fishery of these species and includes information on their annual catch trends, seasonal fluctuations and percentage composition at selected centres.

The third chapter pertains to the food and feeding habits of the two marine portunids selected for study.

The fourth chapter deals with carapace width-body weight relationships of *P. sanguinolentus* and *P. pelagicus*.

The fifth chapter relates to reproduction in these two crabs and includes information on maturity stages in males and females, size at maturity, spawning season, frequency of spawning, spawning population, spawning ground, sex ratio, ovigerous females, fecundity and reproductive potential.

The sixth chapter deals with age and growth and includes the aspects such as the growth rate, life span, growth parameters and growth equation of the two species selected for study.

The seventh chapter pertains to stock assessment with information on mortality, yield-per-recruit, standing stock, annual average stock and maximum sustainable yield (MSY) of *P. sanguinolentus* and *P. pelagicus*.

A general discussion is given at the end of all chapters.

The salient findings of the present study are given in the summary which is followed by a list of references.

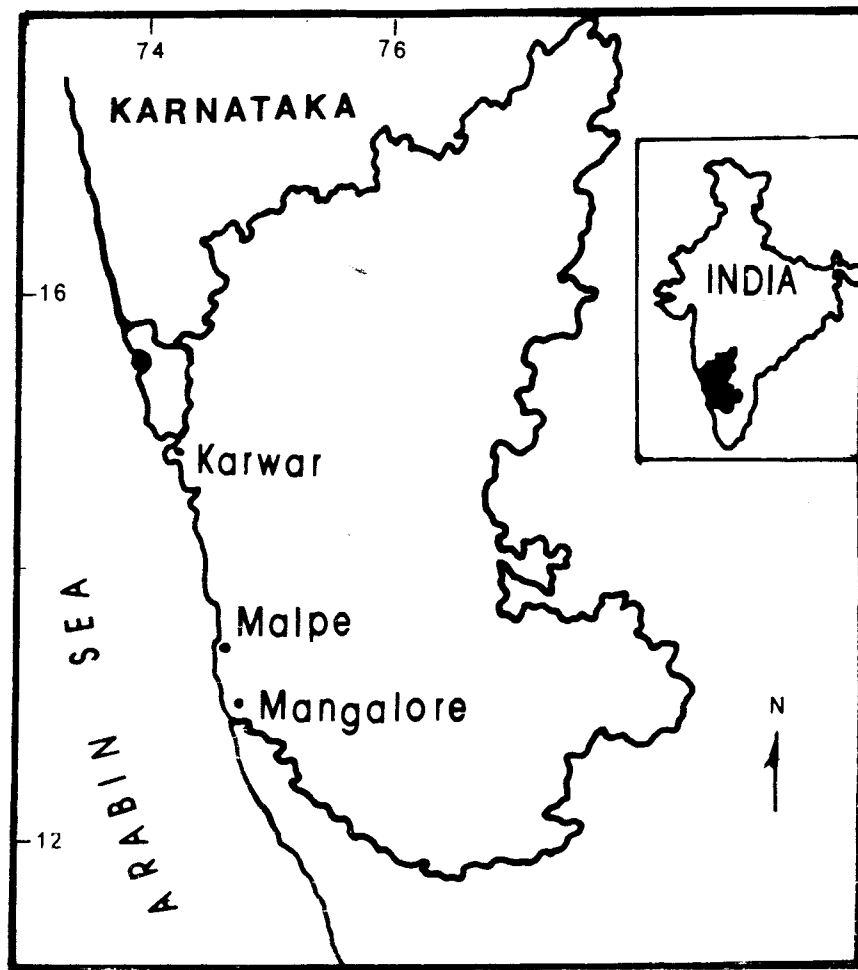


Fig. 1.1. Map of Karnataka showing the sampling centres.

Chapter II

FISHERY

2.0.

FISHERY

2.1.0. INTRODUCTION

The present marine fish production of India of 2.24 million tonnes (1993) is about 50 % of the potential fishery resources estimated for EEZ of the country (George *et al.*, 1977). The annual average production is stagnating around 2.2 million tonnes during the past five years (Annon., 1995).

India with its long coast line of 7,512 km and 2.02 million sq. km. of EEZ, has rich and varied fishery resources. The major marine fish resources of India comprise of:

- a) Pelagic fishery resources, such as, oil sardine, mackerel, white bait, Bombay duck, seer fish, tuna and carangids, and
- b) Demersal fishery resources, such as, perches, catfish, pomfrets, sharks, flatfish, cephalopods and crustaceans, viz. prawns, lobsters and crabs.

Crabs exploited from the marine region, although do not enjoy the status of penaeid and non-penaeid prawns in terms of quantity landed, contribute to a fishery of considerable significance all along the Indian coast. Maximum landing was recorded in Tamil Nadu followed by Gujarat and Andhra Pradesh. The landings in Kerala and Karnataka are moderate. Among the species, *Portunus sanguinolentus*, *P. pelagicus* and *Charybdis (Charybdis) feriatus* grow to large size and commercially very important.

The last two decades have witnessed remarkable development in the mechanised sector. The trawl fishery has been intensified with the introduction of more and more boats of varying size and HP, coupled with the extension of fishing ground upto 75 m depth besides a change in the pattern of fishing from single day to multi-day fishing, to meet the incessant demand for prawns for freezing and export. The increased

exploitation by the mechanised units has resulted in substantial increase in crab landings in the country, and the current catch is around 27,000 tonnes.

Although crabs worth Rs. 196.3 million were exported during 1993-94 (Marine Products Export Review 1993-94, MPEDA) it formed only mere 9.2 % of the annual crab landings in the country. Penaeid prawns contribute to 85-90 % of our seafood export. Further increase in the prawn catch for export may not be possible since the stocks are fully exploited with little opportunity to increase total catches (George, 1982; Ramamurthy and Sukumaran, 1984). In view of this, it is imperative that the export of crabs should be stepped up substantially as only 9.2 % of the annual catch of this resource is exported at present.

For better understanding of the magnitude of exploitation and to evolve management strategies for conservation and judicious exploitation of this valuable resource, estimation of catch assumes great significance. Information on the crab fishery and fishing methods of different parts of Indian region are available in the accounts given by Rai (1933), Hora (1935), Chopra (1939), Prasad and Tampi (1951, 1953), Jones and Sujasingani (1952), Menon (1952), George and Nayak (1961), Chhapgar (1962), Wealth of India published by CSIR (1950), Hamsa (1978), Dhawan *et al.* (1976) and Sukumaran *et al.* (1986). These accounts mainly deal with bionomics, species composition, seasons, gears employed and method of fishing and disposal. Rao *et al.* (1973) estimated the potential marine crab resources on an all India basis.

As there is no comprehensive information on catch and effort, and catch rate from Karnataka state, an attempt has been made to study abundance and production of the commercially exploited portunids, i.e., *Portunus sanguinolentus* and *P. pelagicus* from major fish landing centres of Karnataka with a view to enrich our knowledge on the marine crab fishery resources of the state. This information would help for the

development and management of the crab fishery of this region.

2.2.0. MATERIAL AND METHODS

The present study is based on the data collected from Mangalore, Malpe and Karwar, three major fish landing centres in Karnataka, during the periods 1992-93 and 1993-94.

Regular observations were made on an average 8 days in a month at Mangalore and Malpe, and 4 days in a month at Karwar, to monitor catch statistics. On each observation day, catch and effort data were collected at random from approximately 10% of the units landed at that centre. In the case of mechanised trawls, two category of units were in operation. The first category consisting of small boats (< 9.75 m) make daily cruises. The second category comprising medium sized boats (9.75-15.0 m) make multi-day fishing cruises. In the case of units making multi-days operation, the number of days the observed boat was away from the landing centre was ascertained by enquiry and the catch details were noted. The multi-day boats were grouped as 1 night, 2 night, 3 night, 4 night etc. for facilitating the estimation of effort in actual fishing hours. On an average, 6.6 hours was spent for actual fishing out of each 12 hour absence from the harbour by these units. Accordingly, the effort in actual fishing hours for 1 night, 2 night, 3 night and 4 night was 6.6 hours (6.6 hour x 1 unit of 12 hours), 19.8 hours (6.6 hour x 3 units of 12 hours), 33 hours (6.6 hours x 5 units of 12 hours), 46.2 hours (6.6 hours x 7 units of 12 hours) respectively. The number of units landed belonging to different category was also monitored on each observation day. For units which make daily cruises, an average of 5 hour was taken as the effort in fishing hours. The mean catch and effort for the observed units under different category on each observation day was raised to the total units of the respective type landed on that day to get the estimate for the day. By pooling the estimates for different observation days and raising to the total

number of fishing days in that month, catch and effort data for the month was obtained.

Statewise and all India marine fish production/ crab landings were taken from publications of the Central marine Fisheries Research Institute, Cochin. Export figures were obtained from the Marine Export Annual Review of 1993-94 published by the Marine Products Export Development Authority, Cochin.

2.3.0. RESULTS

2.3.1. ALL INDIA CRAB PRODUCTION

2.3.1.1. Catch trends

Marine crab production in India for the years 1983 to 1993 is shown in Table 2.1 and Fig.2.1. With the total production of 26,977 tonnes in 1993, crabs constituted 7.5 % of the crustacean landings (CMFRI Annual Report, 1993-94) and 1.19 % of the marine fish landings in the country.

Annual crab landings in India showed wide fluctuations (Table 2.1 and Fig. 2.1). From a moderate catch of 19,357 tonnes in 1983, it improved remarkably to 28,708 tonnes in 1984, and thereafter fell to 20,780 tonnes in 1986. This declining trend continued till 1989 (16,191 tonnes) except in 1987 when it was at 23,127 tonnes. The following year, the crab fishery witnessed remarkable recovery with an annual catch of 24,243 tonnes (around 50 % increase from that of previous year) and a high yield of 28,489 tonnes was realised in 1991. However, the fishery suffered marginally in the subsequent years and stood at 26,977 tonnes in 1993.

The maximum, the minimum and the average annual catch for the 11 year period from 1983 to 1993 were 28,708 tonnes (1984), 16,191 tonnes (1989) and 23,137 tonnes respectively.

2.3.1.2. Fishing ground

The fishing ground exploited by the indigenous gears are mostly restricted to shallow water regions of the coast at depths upto 15 m. During monsoon, fishing is generally carried out at very close to the shore. Trawl fishing is done in deeper waters extending upto 75 m depth. The fishing ground is generally characterised by muddy or loamy bottom.

2.3.1.3. Gears employed

Indigenous gears, such as, shore seine, cast net and gill net are operated chiefly to catch inshore fishes and crabs form an ancilliary catch often in appreciable quantities.

Gill nets with minor modifications, locally known as 'jeppubale,' 'nanduvalai and 'peethuvalai' are employed in South Kanara, Gulf of Mannar and Palk Bay and Kakinada coasts respectively. Baited lines are also used to lure crabs in Kakinada and in lagoons and creeks of Sundarban area. In addition, trawl nets are used by mechanised boats all along the coast for catching ground fishes, prawns and crabs.

2.3.1.4. Commercial species and their seasons

Although crabs are caught throughout the year at various regions of the coast, the main season vary from place to place.

In Andhra Pradesh, the main season of the coastal fishery is from April to December with peak catches obtaining in May. The important species contributing to the fishery are *Portunus sanguinolentus*, *P. pelagicus*, *Charybdis (C.) feriatus*, *Charybdis* sp. in the order of their abundance.

In Tamil Nadu and Pondicherry, the fishing season is from March to June and

from October to December with peak catches in May at Madras and in September in Mandapam and Palk Bay. The important species contributing to the fishery are *Portunus sanguinolentus*, *Charybdis* sp., *P. pelagicus*, *Podaphthalmus vigil* in Madras and *P. pelagicus* and *P. sanguinolentus* at Mandapam.

In Kerala, the important species are *Portunus sanguinolentus*, *Charybdis* (*C.*) *feriatus*, *P. pelagicus* during September-July with maximum catch realising in December.

In Karnataka and Goa, the main season is from December to May with peak catches obtaining in February and April. The fishery is mainly constituted by *Portunus sanguinolentus*, *P. pelagicus* and *Charybdis* (*C.*) *feriatus* in the order of abundance.

In Maharashtra, the species supporting the crab fishery are *Charybdis* (*C.*) *feriatus*, *Portunus pelagicus*, *C. granulosa* and *P. sanguinolentus* and the peak season is from August to October, While in Gujarat, *Charybdis lucifera*, *P. sanguinolentus*, *Thalamita* sp. and *C.(C.) feriatus* are the important species with principal season extending from July to September.

From the above, it is seen that there is considerable amount of variation in the species composition as well as in their seasonal abundance at various coastal regions of the country.

2.3.1.5. Crab production along the west and east coasts

Along the southwest coast, Kerala, Karnataka and Goa together contributed to 21.60 % of the marine crab landings in the country (Table 2.2), whereas, along the northwest coast, Maharashtra and Gujarat together formed 28.24 %. In the west coast maximum catches were obtained in Gujarat (6,033 tonnes), while the landings were relatively low in Maharashtra (501 tonnes). Kerala, Karnataka and Goa supported

fisheries of considerable magnitude with maximum catch realising in Kerala (2,745 tonnes), followed by Karnataka (1,179 tonnes) and Goa (1,073 tonnes).

Along the southeast coast, Tamil Nadu and Andhra Pradesh together constituted 46.40 % of the annual average marine crab landings in the country, whereas, West Bengal and Orissa, on the northeast coast, formed less than 2 %. In the east coast, maximum catch was recorded in Tamil Nadu (8,026 tonnes) followed by Andhra Pradesh (2,710 tonnes). The landings in Orissa and West Bengal were relatively low.

2.3.1.6. Crab landings in different states

The estimated crab landings in different maritime states of India with their percentage contribution along with the annual average catch for 1983-1993 period is given in Table 2.2 and Fig 2.2. From Table 2.2 it is discernible that with an annual average catch of 8026 tonnes, Tamil Nadu ranked first in crab production among the maritime states and formed 34.69 % of the total marine crab landings in the country. The maximum and the minimum catches of 10,701 tonnes and 5,842 tonnes were obtained in this state in 1993 and 1989 respectively.

With an annual average of 6,033 tonnes, Gujarat ranked second in crab production contributing 26.08 % of the all India crab catch. A maximum of 14,450 tonnes and a minimum of 2,383 tonnes were recorded in 1984 and 1993 respectively.

Ranking third, Kerala's contribution to total crab landing in the country was 11.86 % with an annual catch of 2,745 tonnes. The highest catch of 5,612 tonnes was realised in 1993, while the lowest of 474 tonnes in 1983.

Andhra Pradesh was the fourth in the order of abundance with an annual average of 2,710 tonnes constituting 11.71 % of the all India crab catch. The maximum and the

minimum were 3,963 tonnes in 1993 and 1,587 tonnes in 1985 respectively.

With an annual average of 1,179 tonnes and forming 5.10 % Karnataka ranked fifth in the order of abundance. Best catches were realised in 1987 (2,575 tonnes), while the catches were poor in 1984 (476 tonnes).

Goa contributed to 4.64 % with an annual average of 1,073 tonnes.

Maharashtra's contribution to all India crab landing was 2.17 % (501 tonnes), while that of Pondicherry was only 1.64 % (379 tonnes).

The crab landings in Orissa, West Bengal and Andaman and Nicobar Islands were relatively low and formed around one or less than 1 % each.

2.3.2.0. CRAB LANDINGS IN KARNATAKA

Karnataka with a coastline of 300 km and a continental shelf area of about 25,000 sq. km. is endowed with a rich and varied marine fishery resources.

The stretch of 18,000 sq. km. of land along the 300 km coastline is divided into two districts, viz., Dakshina Kannada (South Kanara) and Uttara Kannada (North Kanara). In these two districts adjoining the coastline are located 203 fishing villages and 28 fish landing centres. Among them, Mangalore, Malpe, Ganguli, Bhatkal, Honavar, Tadri and Karwar are the major fishing centres.

The introduction of mechanised trawling in the early sixties for prawns and ground fishes and purse seining in the mid-seventies for pelagic resources at some major centres, has revolutionised marine fisheries sector in Karnataka. Due to the rapid development in the mechanised sector along with the increased exploitation of marine fish resources by shrimp trawlers, the crab fishery by improvised gears, such as, cast net, gill net, drag

net, stake net, shore seine etc., which were in vogue since several centuries, have been either eliminated due to poor return or confined to near shore waters, estuaries and back waters of coastal areas. With the result, bulk of the crab catches are landed by shrimp trawlers and the landing by traditional gears have been relatively low.

The crab landings in Karnataka from the marine fisheries sector along with its percentage contribution for the period 1983 to 1993 is presented in Table 2.1 and Fig. 2.3. It is seen that the catch showed wide fluctuations. From a moderate catch of 533 tonnes in 1983, the crab landings in the state improved over the years and reached an all time high of 2,575 tonnes in 1987 (383 % increase) and thereafter sharply fell to 762 tonnes in the following year. In the subsequent years, the fishery registered remarkable improvement and stood at 2,069 tonnes in 1992 and since then declined to 1,174 tonnes in 1993.

The maximum, the minimum and the average annual catch were 2,575 tonnes (1987), 476 tonnes (1984) and 1,179 tonnes respectively.

The important species contributing to the fishery are *Portunus sanguinolentus*, *P. pelagicus* and *Charybdis (C) feriatus* in the order of abundance, and the main fishing season extends from December to May, though stray catches occurred during other months.

2.3.2.1. Crab fishery at Mangalore, Malpe and Karwar

2.3.2.1.1. Craft and Gears employed

In addition to trawl net operated by mechanised vessels from major centres, the following traditional gears are employed in Karnataka.

In the Mangalore-Malpe area, for inshore fishing, eventhough *kairampani* net

(shore seine), cast net, gill net, mini trawl, *ranibale/matabale* (small version of purse seine) are used, crabs are caught in minitrawl and in some modified gill nets (*jeppubale* and *kanthabale*) only. These indigenous gears are employed for inshore fishing mainly during monsoon months (June- August).

In the Netravati-Gurupur estuary (Mangalore), the fishery is highly seasonal and crabs are mostly caught in minitrawls during February-June.

The indigenous gears used for crab fishing in the Karwar area are shore seines (*Yendibale*) and gill nets (*Chitkantabale*).

The craft and gears used in the crab fishery are briefly described below.

Mechanised Trawl : Wooden boats measuring an over all length of 9 to 15 m fitted with 37-102 HP engines are employed in operating otter trawl nets (head rope length 16-32 m; mesh size at the cod end 28-35 mm) from certain centres. These units make 1-6 day cruises and operate the net upto a depth of 75 m. The number of crew is 4-5.

Minitrawl : The gear is basically a four seam trawl net similar to the conventional trawl net operated by small mechanised boats. The cod-end mesh size is 5 mm. The gear is operated throughout the year in the Mangalore estuary from small wooden canoes upto a depth of 3 m, whereas, its operation is restricted to monsoon months in the coastal waters at Malpe employing canoes (3-4 m length) fitted with outboard engines. One to two persons are employed in operating this net.

Jeppubale : It is a modified gill net without any floats. It is 80-120 m in length and 1 m depth. The mesh size varies from 50-56 mm. It is set at the bottom of the sea, at a depth of 6-10 m, in the evening and hauled in the following morning. The catch mainly include crabs, mullets, sciaenids, *Platycephalus* sp. and carangids. It is generally operated in the

coastal inshore waters during monsoon months. For operating the net, dug out canoes (5-6 m length) without outboard engines are used. Two to three persons are employed in the operation of the net.

Kanthabale : It is a modified gill net. The length of the net is 200-300 m and depth is 3.6 -4 m with a mesh size of 52-56 mm. It is operated in the inshore waters at 4-18 m depths throughout the year at certain centres for sciaenids, mackerel, carangids and scomberoids. This gear is operated from Panambur harbour (near Mangalore) during monsoon months and often crabs are caught in appreciable quantities. Four to five fishermen are employed in operating the net from wooden canoes (7.6-9.2 m length) fitted with outboard engines.

Kai-rampani net/ yendi (shore seine) : It is a small shore seine made up of 50-60 pieces. Total length of the net ranges from 400-500 m with a depth 7-8 m. The mesh is 5-6 mm in the middle. It is generally operated upto a depth of 6 m. It is a popular gear at Karwar employed in the nearshore waters for shoaling fishes, prawns and crabs throughout the year. Depending on the size of the net 8-20 persons are employed in operating the net.

2.3.2.1.2. Catch and effort (mechanised trawl)

Specieswise crab landings and effort by shrimp trawlers at Mangalore and Malpe for the fishing seasons 1980-81 to 1993-94 and at Karwar for 1991-92 to 1993-94 are given in Tables 2.3-2.5.

The annual crab catch by shrimp trawlers showed fluctuations over the years at all centres (Figs. 2.4-2.6). The maximum, the minimum and the average annual catch were 715.0 tonnes (1985-86), 95.2 tonnes (1981-82) and 282.0 tonnes at Mangalore, 314.5 tonnes (1985-86), 47.5 tonnes (1982-83) and 164.8 tonnes at Malpe and 38.3 tonnes (1991-92), 6.8 tonnes (1993-94) and 20.3 tonnes at Karwar respectively (Tables 2.3-2.5).

Among the species, *P. sanguinolentus* with an annual average catch of 148.4 tonnes, 77.4 tonnes and 9.8 tonnes formed 52.62 %, 46.97 % and 48.28 % of the total crab catch at Mangalore, Malpe and Karwar respectively (Tables 2.3 - 2.5; Figs. 2.4 - 2.6).

The annual average catch of *P. pelagicus* was 97.1 tonnes (34.43 %) at Mangalore, 73.4 tonnes (44.54 %) at Malpe and 10.5 tonnes (51.72 %) at Karwar (Tables 2.3 - 2.5 and Figs. 2.4 - 2.6).

At Mangalore, the effort in fishing trip or boat trip(bt) showed remarkable increase from 20,907 in 1980-81 to 56,128 bt in 1984-85. Thereafter, it registered a declining trend and stood at 36,076 bt in 1993-94 with an annual average of 38,650 bt at Mangalore (Table 2.3). On the otherhand, the effort in actual fishing hours (fh) showed sharp increase. From 94,083 fh in 1980-81, it increased to 6,93,649 fh in 1993-94, thereby registering an increase over 600 % (Table 2.3). The average time spent by an individual fishing unit for actual fishing per trip has increased from 4.5 hours in 1980-81 to 19.2 hours in 1993-94. This increased fishing effort by individual fishing units is the result of the change in the pattern of fishing from a single day to multi-day (2-6 days/nights) fishing by large number of trawlers in the recent years.

At Malpe also, a similar trend was observed. The effort in boat trip increased from 19,600 in 1980-81 to 45,824 bt in 1984-85 and thereafter, reduced to 27,843 bt in 1993-94 registering 39 % reduction in boat trips with an annual average of 31,764 bt for the period 1980-81 to 1993-94. The effort in actual fishing hours increased from 88,269 fh in 1980-81 to an all time high of 3,73,631 fh in 1993-94 thereby registering 323 % increase in fishing hours in 13 years (Table 2.4). The average time expended by each unit for actual fishing has been increased from 4.5 hours to 13.4 hours in 1993-94.

At Karwar also, the effort in boat trips increased from 8,329 in 1991-92 to 16,244

bt in 1993-94 (95 % increase) with an annual average of 10,943 bt (Table 2.5).

At Mangalore, the catch rate for total crabs ranged between a maximum of 2.38 kg/fh in 1985-86 and a minimum of 0.28 kg/fh in 1993-94 and the average annual catch rate was 0.72 kg/fh (Table 2.3).

For *P. sanguinolentus*, at Mangalore, the maximum, the minimum and the average catch rate were 1.53 kg/fh (1985-86), 0.09 kg/fh (1993-94) and 0.38 kg/fh respectively. For *P. pelagicus*, the highest catch rate of 0.68 kg/fh was recorded in 1985-86, while the lowest of 0.07 kg/fh was obtained in 1993-94. The annual average was 0.25 kg/fh (Table 2.3).

At Malpe, the catch rate for total crabs registered a maximum of 1.76 kg/fh in 1985-86 and a minimum of 0.11 kg/fh in 1987-88 with an annual average of 0.68 kg/fh during the 14 year period (Table 2.4).

For the species, the maximum, the minimum and the average annual catch rate recorded in respect of *P. sanguinolentus* at this centre was 0.92 kg/fh in 1985-86, 0.03 kg/fh in 1987-88 and 0.32 kg/fh respectively. For *P. pelagicus*, a maximum catch rate of 0.75 kg/fh was recorded in 1985-86 and a minimum of 0.07 kg/fh in 1983-84 with an annual average of 0.30 kg/fh for the entire period (Table 2.4).

At Karwar, for the total crabs, a maximum catch rate of 4.6 kg/bt was obtained in 1991-92 and a minimum of 0.42 kg/bt in 1993-94 with an annual average of 1.86 kg/bt for 1991-92 to 1993-94 period (Table 2.5).

At this centre, the maximum, the minimum and the average catch per boat trip for *P. sanguinolentus* was 2.20 kg/bt in 1991-92, 0.18 kg/bt in 1993-94 and 0.90 kg/bt respectively. A maximum of 2.35 kg/bt (1991-92), and a minimum of 0.24 kg/bt (1993-94) with an average of 0.95 kg/bt was obtained for *P. pelagicus* during this period (Table 2.5).

Seasonal abundance

Monthwise landing of *P. sanguinolentus* and *P. pelagicus* during different fishing seasons at Mangalore, Malpe and Karwar is presented in Tables 2.6 - 2.10 and Figs. 2.7-2.9. It is evident that although the trawling season is extended from September to May end or early June, *P. sanguinolentus* catches were poor in September, October and November (Tables 2.6, 2.7, 2.10). Bulk of the catch was recorded during December-May with peak landings in January and April at Mangalore and Malpe, and during January-March at Karwar (Figs. 2.7-2.9).

Similarly, for *P. pelagicus*, fishing is extended from September to late May or early June. Stray catches were only occurred during September-November period (Tables 2.8 - 2.10). Bulk of the landing was observed during December-May with peak catches in January and April at Mangalore and Malpe, while at Karwar, catches were more during January-March (Figs. 2.7-2.9).

2.3.2.1.3. Catch and effort (indigenous gears)

Crab landings by 'yendi' (shore seine) at Karwar, by minitrawl at Mangalore (estuary) and Malpe (inshore), and by 'jeppubale' (gill net) and 'kanthabale' (gill net) at Panambur Harbour near Mangalore (inshore) during 1992-93 and 1993-94 are given in Tables 2.11 - 2.13.

It is seen from Table 2.11 (Fig. 2.10) that 'yendi' is operated throughout the year in the Karwar Bay and the crab catch, eventhough, occurred all through the year, was only moderate. For the entire period, a maximum of 1,098 kg was obtained in February 1994, while it was low in September 1992 (6 kg). The catch rate was 6.83 kg/unit in 1992-93, while it was 4.35 kg/unit in 1993-94. The catch rate ranged between 0.92 kg/unit (September '92) and 20.70 kg/unit (December '92) in 1992-93 and between 0.35 kg/unit

(November '93) and 9.72 kg/unit (February '94) in 1993-94 during different months (Table 2.11).

For *P. sanguinolentus*, the catch ranged between 17 kg (0.25 kg/unit) in November 1993 and 880 kg (10.0 kg/unit) in August 1993. The annual catch rate was 3.37 kg/unit in 1992-93 and 1993-94.

In *P. pelagicus*, a maximum catch of 934 kg (20.30 kg/unit) was obtained in December 1992 and a minimum of 4.0 kg (0.06 kg/unit) was recorded in May 1994. The catch rate was better in 1992-93 (3.46 kg/unit) as compared to that of 1993-94 (0.97 kg/unit).

Among the species, *P. sanguinolentus* was the dominant species contributing to 65.29 %, while *P. pelagicus* formed the rest (34.71 %) in the crabs landed by 'yendi' during 1992-93 to 1993-94 (Fig.2.9).

Eventhough minitrawl is employed in the Mangalore estuary throughout the year, crab fishery was seasonal and catch occurred only during February-June period (Table 2.12) when *P. pelagicus* (size ranging from 50-120 mm cw) found entering the estuary from the inshore waters in large numbers resulting in a fishery of appreciable magnitude. The catches were relatively high in February (3,400 kg and 1,875 kg in February 1993 and February 1994 respectively) when the season started and the following months revealed a downward trend in crab landings with the lowest catch of 265 kg obtaining in June 1993 (Fig. 2.11).

Like catch, the catch rate also showed a similar trend obtaining maximum values in February 1993 (8.25 kg/unit) while a minimum in June 1993 (3.53 kg/unit).

Among the species, *P. pelagicus* formed the bulk of the catch (93.2 %), while *P.*

sanguinolentus formed only 6.8 % (Fig. 2.11).

It is seen that crab catches occurred only in 'jeppubale' (modified bottom set gill net) and 'kanthabale' (bottom set gill net) at Panambur Harbour and in minitrawl at Malpe eventhough several types of indigenous gears are employed at these centres during monsoon months. The catch and effort details in respect of minitrawl at Malpe and 'jeppubale' and 'kanthabale' at Panambur Harbour are presented in Table 2.13. It was found that among the gears, a maximum catch of 13,629 kg was recorded in minitrawl for the two seasons (1993 and 1994) put together at Malpe followed by 'jeppubale' (1,319 kg) and 'kanthabale' (730 kg) at Panambur Harbour. A better catch rate of 5.4 kg/unit was obtained for 'jeppubale', whereas, it was only 4.8 kg/unit for minitrawl and 1.5 kg/unit for 'kanthabale' during this period.

Among the species, *P. pelagicus* formed 80.1 %, 67.4% and 83.7 %, and *P. sanguinolentus* constituted 18.9 %, 31.3 % and 16.3 % in minitrawl, 'jeppubale' and 'kanthabale' respectively (Fig. 2.12).

2.3.2.1.4. Marketing and disposal

Crab catches landed by mechanised trawlers/ indigenous gears are generally auctioned as a lot. Fisherwomen who purchase these crabs sell it in the nearby markets, while the merchants who auction it, transport these crabs in bulk to consumer centres in Kerala, Bangalore and other interior places where it is sold to local merchants/ fisherwomen at a premium price. The landing price roughly ranges between Rs.5 to 15/- per kg depending on the catch trends, freshness of the catch, size of the crabs landed, and demand.

Since crab meat is a delicacy in many parts of the world, it is exported alive, frozen and canned to several foreign countries. During 1993-94, crabs worth Rs. 196.3 million

(2,034 tonnes) were exported which formed 0.78 % in terms of value and 0.83 % in quantity of the total export of marine products from our country during this period (Tables 2.14 - 2.15).

2.4.0. DISCUSSION

With an annual average of 1,179 tonnes during 1983-93, crab landings in Karnataka formed around 5.1 % of the all India crab catch. Special type of gears operated exclusively for catching these crabs are not occurring anywhere in the state. Crabs are caught as ancillary item in gears operated in general fisheries. Eventhough different type of gears were in operation, bulk of the crab catch was obtained by mechanised trawls. The catch obtained by indigenous gears like minitrawl, gill net, shore seine etc., was negligible and restricted its operation to some centres only. The important species contributing to the marine crab fishery were *P. sanguinolentus*, *P. pelagicus* and *Charybdis (C) feriatus* in the order of their abundance. Although crabs were caught in varying quantities from September to May, bulk of the catch was landed during January-February. Despite a steep rise in trawl effort, there has been no proportional increase in crab landings which is stagnating around 1,000-2,000 tonnes in the last few years.

Most of the advanced fishing countries of the world have adopted certain measures for the proper management of fisheries. But in India, no conservatory measure even of elementary nature is observed by fishermen. Due to this, immature, moulting and berried crabs are fished indiscriminately (Joel and Raj, 1980). Since most of the gears employed are non-selective (shrimp trawl, minitrawl, and shore seine), enormous quantity of immature and juveniles are caught inadvertently and destroyed indiscriminately. In *P. sanguinolentus*, juveniles (< 80 mm cw) formed upto 58 % in shrimp trawls and 82 % in indigenous gears, whereas, in *P. pelagicus*, juveniles (< 80 mm cw) constituted upto 25

% in shrimp trawls and 71 % in indigenous gears in the present study (Table 2.16). This large scale destruction of young crabs would obviously have adverse effect on the crab resources. To control these unscrupulous and indiscriminate fishing of juveniles, berried and soft crabs, unfortunately, there is no fishery regulation in force in our country. This situation can be remedied to large extent by educating the fishermen through media, such as, TV, radio, newspaper etc., about the adverse effect of catching and destroying these young ones on the crab stocks, and also creating an awareness among them about the importance of releasing young crabs back into the sea or fattening of crabs through short term culture, for the sustenance of these valuable resources. In addition, Government has to enforce certain regulations like fixing legal minimum size (across the broadest part of carapace), protection of ovigerous crabs, and protection of soft shelled crabs (freshly moulted crabs) as practiced in several advanced fishing countries. All these management measures are bound to improve the status of the crab stocks resulting in higher yield.

The current catch in India, though amounted to 27,000 tonnes, barely 2,034 tonnes of crabs valued at Rs. 196.3 million were exported to countries like Japan, USA, Belgium, Thailand, Portugal, Thailand, Singapore, Hongkong and UK (MPEDA, Marine Export Review, 1993-94). A comparison of crab landings with that of export figures (Tables 14-15) reveal that the export status of edible crabs in India is not comparable with that of prawns and lobsters. This is because, crab fishery is not given adequate attention and importance it deserves in our country. On the contrary, in countries like United Kingdom, crabs have become one of the most important sources of income to shellfish fishermen (Edwards, 1979). This may perhaps be due to the ever-increasing demand for crab meat in USA, UK and several European countries.

Although crab meat is a delicacy among the people of the coastal belt of Karnataka, Tamil Nadu and Kerala, it is not yet a popular item of seafood in our country.

The image of crab meat can be upgraded through women's magazines, TV and radio cookery programmes. The utilisation of crab meat into 'crab cakes', 'crab sausages' or other attractive fish products could further help to stimulate demand. Large scale canning also can be considered.

Further, there is every possibility of increasing the export of crabs as the present export forms only just 9.2 % of the total crab catch landed.

Soft-shelled crabs are considered a delicacy and brings a much higher price than hard shelled crabs in USA and several European countries, whereas, in India, it is discarded since there is no demand for it. These soft crabs which constitute appreciable quantities in certain period of the year, also can be exported to USA and European countries and earn foreign exchange.

By increasing the export of crabs, the fishermen will get realistic price for their products thereby improving the income from the crab fishery, which is not only an encouragement but also an impetus to fishermen to catch more crabs for export as well as for local consumption.

TABLE 2.1.
Marine crab landings (in tonnes) in India.

Year	All India	Karnataka	% contribution of Karnataka to all India crab catch
1983	19,357	533	2.75
1984	28,708	476	1.66
1985	22,264	596	2.68
1986	20,780	1,886	9.08
1987	23,127	2,575	11.13
1988	17,422	762	4.37
1989	16,191	771	4.76
1990	24,243	948	3.91
1991	28,489	1,181	4.04
1992	26,948	2,069	9.52
1993	26,977	1,174	4.32
Average	23,137	1,179	5.10

TABLE 2.2.
Crab production (in tonnes) in different maritime states of India.

States	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Average	%
W.Bengal	359	111	210	93	130	66	26	24	125	27	139	119	0.43
Orissa	186	103	127	180	368	230	398	148	199	548	712	291	1.27
Andhra Pradesh	3047	1889	1587	3220	2312	2116	2395	2063	3447	3768	3963	2710	11.71
Tamil Nadu	10172	8586	6575	5875	7801	7039	5842	6827	10016	8851	10701	8026	34.69
Pondicherry	711	736	430	326	205	377	86	310	413	282	296	379	1.64
Kerala	474	505	974	1373	2560	2151	2664	4704	4317	4864	5612	2745	11.86
Karnataka	533	476	596	1886	2575	762	771	948	1181	2069	1174	1179	5.10
Goa	737	1032	1789	2872	2325	497	327	569	435	332	890	1073	4.64
Maharashtra	329	790	494	360	393	211	195	414	638	674	1008	501	2.17
Gujarat	2779	14450	9452	4560	4433	3973	3445	7987	7469	5434	2383	6033	26.08
Andaman & Nicobar I.	10	30	30	35	25	0	42	249	249	99	99	79	0.48
Lakshadweep	0	0	0	0	0	0	0	0	0	0	0	0	0
Bigger trawlers	20	0	0	0	0	0	0	0	0	0	0	2	0
Total	19357	28708	22264	20780	23127	17422	16191	24243	28489	26948	26977	23137	100.00

TABLE 2.3
Crab catch (in tonnes) and effort by shrimp trawlers at Mangalore during 1980/81 - 1993/94.

Fishing Seasons	<i>P.sanguinolentus</i>		<i>P.pelagicus</i>		Others	Total		Effort	
	C	C/fh	C	C/fh	C	C	C/fh	BT	FH
1980-81	86.3	9.2	40.1	0.43	-	126.7	1.35	20907	94083
1981-82	57.1	0.37	38.1	0.25	-	95.2	0.62	34196	153944
1982-83	75.5	0.27	74.4	0.27	-	149.9	0.54	45553	275513
1983-84	101.8	0.37	30.7	0.11	89.0	221.5	0.79	38371	278752
1984-85	59.7	0.14	136.8	0.33	5.2	201.7	0.48	56128	420600
1985-86	459.3	1.53	205.1	0.68	50.6	715.0	2.38	42986	299895
1986-87	146.0	0.35	134.2	0.32	21.3	301.5	0.72	44480	419778
1987-88	42.0	0.11	62.5	0.17	2.1	106.6	0.29	41756	366897
1988-89	76.7	0.13	124.9	0.21	29.8	231.4	0.29	35539	585873
1989-90	70.2	0.20	90.9	0.25	17.4	178.5	0.50	30487	356996
1990-91	140.0	0.33	157.7	0.37	109.9	407.6	0.97	33928	421791
1991-92	209.0	0.43	45.6	0.07	45.3	413.9	0.85	42607	488118
1992-93	492.6	0.76	58.1	0.09	54.2	603.9	0.93	38098	649241
1993-94	62.1	0.09	45.6	0.07	87.0	194.7	0.28	36076	693649
Average	148.4	0.38	97.1	0.25	36.5	282.0	0.72	38650	393224
%	52.62		34.43		12.95				

C - catch; C/fh - catch per hour; BT - boat trip; FH - fishing hour

TABLE 2.4
Crab catch (in tonnes) and effort by shrimp trawls at Malpe during 1980/81 - 1993/94.

Fishing Seasons	<i>P.sanguilentus</i>		<i>P.pelagicus</i>		Others	Total		Effort	
	C	C/fh	C	C/fh	C	C	C/fh	BT	FH
1980-81	65.8	0.75	46.6	0.53	-	112.4	1.27	19600	88269
1981-82	63.9	0.39	60.1	0.54	0.3	104.3	0.93	24785	111575
1982-83	28.5	0.17	19.0	0.12	-	47.5	0.29	30248	165175
1983-84	70.9	0.35	14.9	0.07	39.7	125.5	0.62	37352	203385
1984-85	49.4	0.19	112.6	0.43	1.6	163.6	0.63	45824	261248
1985-86	164.4	0.92	134.3	0.75	15.8	314.5	1.76	32727	178261
1986-87	141.5	0.63	121.5	0.54	18.7	281.5	1.25	38193	226060
1987-88	9.5	0.03	19.2	0.07	-	28.7	0.11	42431	272312
1988-89	59.7	0.19	81.5	0.26	32.0	173.3	0.55	35714	315267
1989-90	78.4	0.31	114.1	0.45	14.7	207.2	0.82	23379	254035
1990-91	40.9	0.13	68.5	0.21	2.8	112.2	0.35	25556	319523
1991-92	101.0	0.39	86.7	0.33	9.0	196.7	0.75	27312	261796
1992-93	143.2	0.55	77.2	0.22	10.4	230.8	0.66	33734	347624
1993-94	85.9	0.23	71.1	0.19	51.5	208.8	0.56	27843	373631
Average	77.4	0.32	73.4	0.30	14.0	164.8	0.68	31764	241297
%	46.97		44.54		8.49				

C - catch; C/fh - catch per hour; BT - boat trip; FH - fishing hour

TABLE 2.5.
Crab catch (in tonnes) and effort by shrimp trawls at Karwar during 1992/92 - 1993/94.

Fishing Seasons	<i>P.sanguilentus</i>		<i>P.pelagicus</i>		Others	Total		Effort
	C	C/bt	C	C/bt	C	C	C/bt	BT
1991-92	18.6	2.2	19.6	2.35	0.1	38.3	4.60	8329
1992-93	7.9	0.96	8.0	0.97	-	15.9	1.92	8256
1993-94	2.9	0.18	3.9	0.24	-	6.8	0.42	16244
Average	9.8	0.90	10.5	0.95	-	20.3	1.86	10943
%	48.28		51.72					

C - catch; C/bt - catch per boat trip; BT - boat trip

TABLE 2.6.
Month-wise landings (in kg) of *P.sanguinolentus* by shrimp trawlers from 1980-81 to 1993-94 at Mangalore.

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Total
1980-81	0	0	0	0	14266	20696	12558	16340	22423	0	86283
1981-82	0	0	0	3296	9523	9811	12106	15427	6491	420	57074
1982-83	0	0	0	2150	23515	14855	7620	16842	9130	1350	75462
1983-84	0	0	0	49446	36159	10595	1560	4068	0	0	101828
1984-85	0	0	0	0	18319	14180	7750	13406	6026	0	59681
1985-86	0	0	0	57350	91332	101990	58191	118090	32384	0	459337
1986-87	0	0	0	10604	54912	25280	18216	14780	22264	0	146056
1987-88	0	0	0	447	9918	10676	5610	8834	6514	0	41999
1988-89	0	120	17	2626	22106	1412	21166	10603	18333	0	76383
1989-90	0	145	0	105	14342	12744	13408	18605	10910	0	70259
1980-91	53	0	0	1430	33713	9095	22207	34613	38686	0	139797
1991-92	0	0	0	11519	28847	41076	29977	49770	47786	0	208975
1992-93	0	169	6038	154216	268192	22940	15178	12500	12356	0	491589
1993-94	480	1230	1570	9193	30660	6465	3460	4244	4587	0	61889
Average	38	119	545	21620	46843	21558	16370	24080	16992	126	148291

TABLE 2.7.**Month-wise landings (in kg) of *P. sanguinolentus* by shrimp trawlers from 1980-81 to 1993-94 at Malpe.**

Year	Sep.	Oct	Nov	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Total
1980-81	0	0	0	0	5756	21490	9661	23720	5193	0	65820
1981-82	0	0	0	60	9320	18479	6373	5520	3750	350	43852
1982-83	0	0	0	11250	5616	2366	639	2288	4680	1650	28489
1983-84	0	0	0	30126	30160	7995	2262	375	0	0	70918
1984-85	56	1550	0	5900	17468	8440	4810	7695	3510	0	49429
1985-86	8000	0	0	11730	30750	15218	25440	22800	50430	0	164368
1986-87	0	0	0	2160	68347	25568	14060	14544	16815	0	141494
1987-88	1266	0	282	95	1241	4952	910	360	396	0	9502
1988-89	249	0	549	9042	1250	6380	7212	24426	10572	0	59680
1989-90	0	0	0	2862	20400	9503	20410	11140	14068	0	78383
1990-91	3150	43	137	7425	9930	6306	1907	6444	5554	0	40896
1991-92	0	17	251	32426	15096	17278	12600	12893	10447	0	101008
1992-93	130	0	3910	43271	39773	32151	13545	6228	4153	0	143161
1993-94	567	413	6206	12079	9978	6986	14542	22394	12762	0	85927
Average	958	145	810	12030	18938	13079	9598	11488	10166	143	77355

TABLE 2.8.
Month-wise landings (in kg) of *P. pelagicus* by shrimp trawlers from 1980-81 to 1993-94 at Mangalore.

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Total
1980-81	0	0	0	0	6170	10707	7242	10200	6106	0	40425
1981-82	0	0	241	5447	5046	9150	12142	4703	1352	0	38081
1982-83	0	0	0	1432	23804	17676	5865	13764	11748	75	74364
1983-84	0	0	0	7813	8466	4871	2067	7488	0	0	30705
1984-85	0	0	0	0	52319	43040	14125	21508	5819	0	136811
1985-86	0	0	0	12110	20633	31850	27566	80675	32252	0	205086
1986-87	0	0	0	3344	29480	19440	27468	22971	31460	0	134163
1987-88	0	50	95	801	25840	6618	5312	14547	9220	0	62483
1988-89	645	120	189	959	43514	8506	41731	9533	19673	0	124870
1989-90	0	75	0	38	11772	10774	10467	45110	12695	0	90931
1990-91	259	0	193	170	23614	35528	14539	51921	31477	20	157721
1991-92	0	0	930	1369	37103	38404	23070	28628	30049	0	159553
1992-93	0	0	0	0	0	16480	8901	9300	23460	0	58141
1993-94	491	384	0	1563	7224	7022	4070	12687	12163	0	45604
Average	100	45	118	2503	21070	18576	14612	23788	16248	7	97067

TABLE 2.9.
Month-wise landings (in kg) of *P. pelagicus* by shrimp trawlers from 1980-81 to 1993-94 at Malpe.

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Total
1980-81	0	0	0	0	4235	13720	7725	18300	2604	0	46584
1981-82	0	0	1118	180	7150	35517	4072	6105	5640	350	59782
1982-83	0	0	0	3750	6084	2366	880	773	4914	300	18767
1983-84	0	0	0	3914	5590	2021	2976	375	0	0	14876
1984-85	3496	150	0	37050	46860	9540	7218	5130	1755	0	111199
1985-86	48000	0	0	1668	3530	5168	22080	24000	29880	0	134326
1986-87	6125	1914	68	1632	25932	22508	18700	27360	17328	0	121567
1987-88	6096	0	2889	1700	2389	2475	803	2542	326	0	19220
1988-89	490	0	202	3311	1664	13708	10140	39681	12288	0	81484
1989-90	174	0	0	1933	28492	13943	16650	28647	24243	0	114082
1990-91	11623	345	698	8525	22663	7961	3440	9584	3650	0	68489
1991-92	1467	923	1047	30831	7716	8408	14490	14706	7152	0	86740
1992-93	2998	19385	0	2330	1470	12745	14453	16825	6947	0	77153
1993-94	782	1440	2516	5655	7692	6818	13571	22093	9966	0	70533
Average	5804	1826	530	7320	12248	11207	9800	15437	9047	46	73219

TABLE 2.10
Crab landings (in Kg) by shrimp trawls during different months
from 1991-92 to 1993-94 at Karwar.

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jul.	Aug.	Total
<i>P.pelagicus</i>												
1991-92	0	0	0	217	4860	6800	4250	2530	450	25	510	19642
1992-93	15	0	0	283	2384	1785	1801	1108	221	40	320	7957
1993-94	0	0	20	35	914	1126	1261	456	51	0	0	3863
Average	5	0	7	178	2719	3237	2437	1365	241	22	277	10487
<i>P.sanguinolentus</i>												
1991-92	0	0	0	382	4920	5190	5420	2100	310	17	281	18620
1992-93	1	0	0	498	2412	1363	2294	933	155	71	168	7895
1993-94	0	0	48	300	810	700	141	609	289	0	0	2897
Average	0	0	16	393	2714	2418	2618	1214	251	29	150	9803

TABLE 2.11.
Crab landings by shore seines (yendi) during 1992-94 at Karwar.

Period	Units operated	<i>P.sanguinolentus</i>		<i>P.pelagicus</i>		Total	
		C	C/U	C	C/U	C	C/U
Sep.92	39	0	0	6	0.92	6	0.92
Oct.	80	49	0.61	170	2.13	219	2.74
Nov.	63	25	0.40	141	2.24	166	2.63
Dec.	46	18	0.17	934	20.30	952	20.70
Jan.93	29	42	1.45	164	5.66	206	7.10
Feb.	39	229	5.87	148	3.79	377	9.67
Mar.	37	172	4.65	30	0.81	202	5.46
Apr.	34	77	2.26	35	1.02	112	3.29
May	40	76	1.90	23	0.58	99	2.48
Jun.	42	124	2.95	90	2.14	214	5.10
Jul.	47	276	5.87	69	1.47	345	7.34
Aug.	88	880	10.00	210	2.39	1090	12.39
Total	584	1968	3.37	3020	3.46	3988	6.83
Sep.93	79	153	1.94	38	0.48	191	2.42
Oct.	91	410	4.51	70	0.77	480	5.27
Nov.	68	17	0.25	7	0.10	24	0.35
Dec.	95	630	6.63	272	2.86	902	9.49
Jan.94	111	428	3.86	130	1.17	558	5.03
Feb.	113	791	7.00	307	2.72	1098	9.72
Mar.	118	364	3.08	209	1.77	573	4.86
Apr.	110	330	3.00	103	0.94	433	3.94
May	68	140	2.06	4	0.06	144	2.12
Jun.	148	328	2.22	8	0.05	336	2.27
Jul.	62	150	2.42	5	0.08	155	2.50
Aug.	126	270	2.14	5	0.04	275	2.18
Total	1189	4011	3.37	1158	0.97	5169	4.35

C - catch in Kg; C/U - catch per unit of effort in Kg.

TABLE 2.12
Crab landings by minitrawl during 1993 and 1994 from the Mangalore estuary.

Period	Units operated	<i>P.sanguinolentus</i>		<i>P.pelagicus</i>		Total	
		C	C/U	C	C/U	C	C/U
Feb.93	412	390	0.94	3010	7.31	3400	8.25
Mar.	356	160	0.45	2200	6.18	2360	6.63
Apr.	338	40	0.12	2300	6.80	2340	6.92
May	243	20	0.08	15400	6.33	1560	6.42
Jun.	75	5	0.07	260	3.47	265	3.53
Total	1424	615	0.43	9310	6.54	9925	6.97
Feb.94	318	65	0.20	1810	5.69	1875	5.90
Mar.	262	220	0.84	1620	6.18	1840	7.02
Apr.	280	188	0.67	1500	5.36	1688	6.03
May	250	38	0.15	1200	4.80	1238	4.95
Total	1110	511	0.46	6130	5.32	6641	5.98

C - catch in Kg; C/U - catch per unit of effort in Kg.

TABLE 2.13
Crab landings (in Kg) by indigenous gears during monsoon months at Malpe and Panambur.

Month	Effort	<i>P.sanguinolentus</i>	<i>P.pelagicus</i>	Total	
MALPE (Mini trawl)					
				C/U	
Jun.'93	264	27	681	849	3.2
Jul.	534	279	852	1131	2.1
Aug.	736	1271	7471	8742	11.1
Jun.'94	392	796	1096	1892	4.8
Jul.	708	202	704	906	1.3
Aug.	218	0	109	109	0.5
Total	2852	2575	10913	13629	4.8
%		18.9	80.1		
PANAMBUR (Jeppubale)					
Jun.'93	55	0	303	303	5.5
Jul.	71	91	205	296	4.2
Aug.	38	52	267	319	8.4
Jun.'94	15	15	45	70	4.7
Jul.	45	225	0	225	6
Aug.	20	30	70	100	5
Total	244	413	890	1319	5.4
%		31.3	67.4		
PANAMBUR (Kanthabale)					
Jun.'93	102	0	479	479	4.7
Jul.	19	6	12	18	1
Aug.	17	0	0	0	
Jun.'94	315	45	90	135	0.4
Jul.	30	68	30	98	3.3
Aug.	20	0	0	0	
Total	503	119	611	730	1.5
%		16.3	83.7		

C/U= Catch/unit effort in Kg

TABLE 2.14.
Export growth of Indian marine products.

Year	Quantity in tonnes	Value in Rs.Crores
1983-84	92,187	384.29
1984-85	86,187	384.29
1985-86	83,651	398.00
1986-87	85,843	460.67
1987-88	97,174	531.20
1988-89	99,777	597.85
1989-90	110,843	634.99
1990-91	139,419	893.37
1991-92	171,820	1373.85
1992-93	208,602	1767.43
1993-94	243,960	2503.62

Source: Marine Products Export Review 1993-94 (MPEDA)

TABLE 2.15.
Export to Indian marine products.

Products	1991-92		1992-93		1993-94	
	Quantity	Value	Quantity	Value	Quantity	Value
Frozen crab meat	575	27.4	630	54.0		
Canned crab meat	3	0.1	52	2.9		
Live crabs	591	19.0	556	28.7		
Total	1169	46.5	1238	85.6	2034	196.3
Contribution of crabs (%) to total export	0.68	0.34	0.59	0.48	0.83	0.78

Quantity in tonnes; Value in million Rupees.

Source: Marine Products Export Review 1993-94 (MPEDA)

TABLE 2.16.

Juveniles of *P. sanguinolentus* and *P. pelagicus* (in nos.) in the samples obtained from the catches landed by different gears at Mangalore, Malpe and Karwar during 1992/93- 1993/94.

	Mangalore (T)		Malpe (T)		Karwar (T)		Karwar (IG)		Mangalore (IG)		Malpe (IG)	
	males	females	males	females	males	females	males	females	males	females	males	females
<i>P. sanguinolentus</i>												
Juveniles (crabs < 80 mm)	484	481	1702	1502	50	66	770	557	121	96	176	172
Total crabs	1515	1613	2900	2629	750	461	945	665	143	179	241	224
% of juveniles	31.5	29.8	59.2	57.3	6.7	14.3	81.5	83.8	84.6	53.6	73.0	76.8
Juveniles (male + female)	965		3220		116		1327		217		348	
Total (male+female)	3148		5529		1211		1610		322		465	
% juveniles (male +female)	30.7		58.2		9.6		82.4		67.4		74.4	
<i>P. pelagicus</i>												
Juveniles (crabs < 80mm)	864	207	173	153	45	55	338	357	451	440	28	31
Total crabs	980	925	724	652	504	586	506	476	733	802	88	86
% of juveniles	26.9	22.4	23.9	23.5	8.9	9.4	70.8	75.0	61.5	54.9	31.8	36.0
Juveniles (male+female)	471		326		100		695		891		59	
Total (male+female)	1905		1376		1090		982		1535		174	
% juveniles (male+female)	24.7		23.7		9.32		70.8		58.1		33.1	

T-Trawl; IG-indigenous gear:

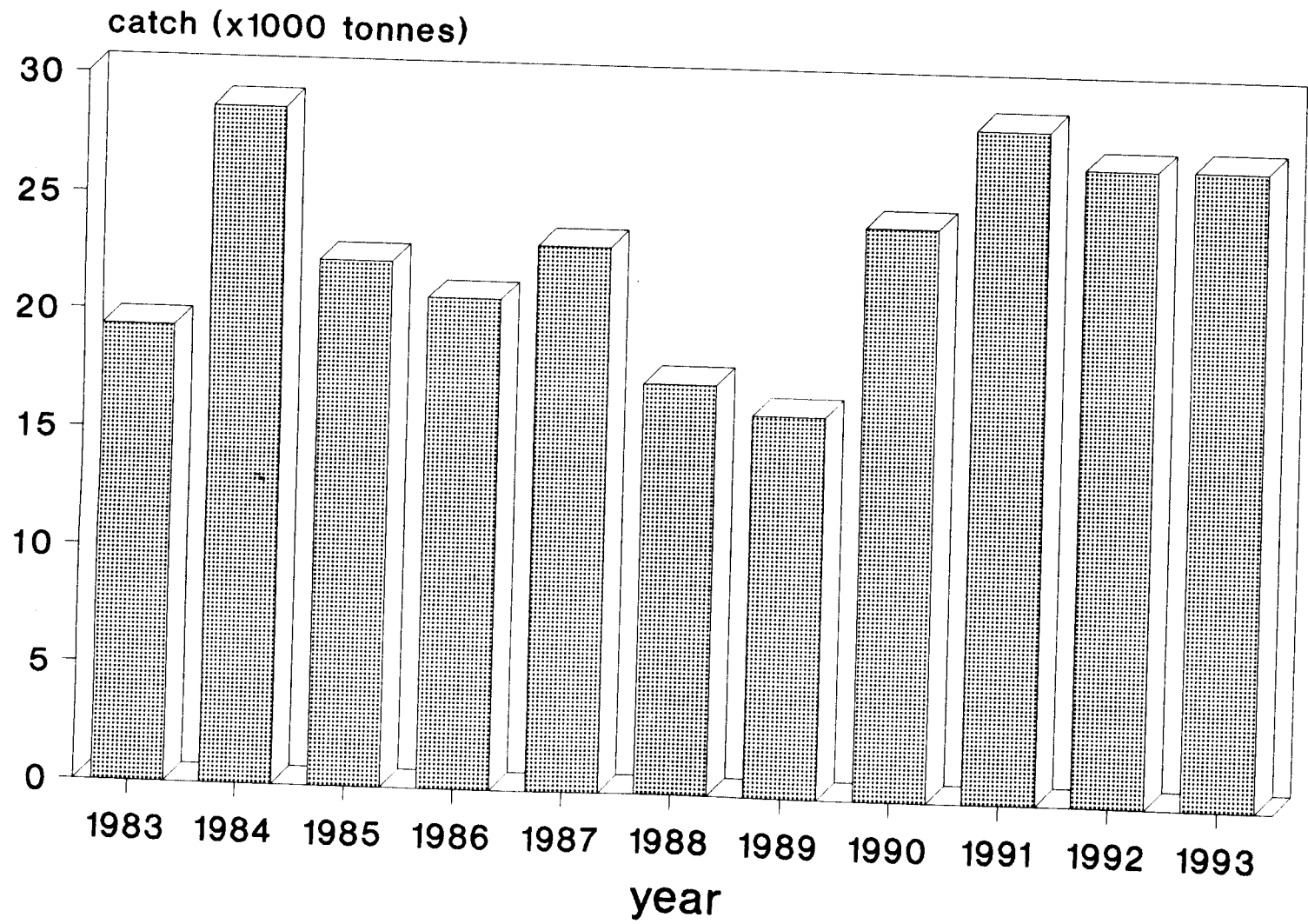


Fig. 2.1. Marine crab landings in India.

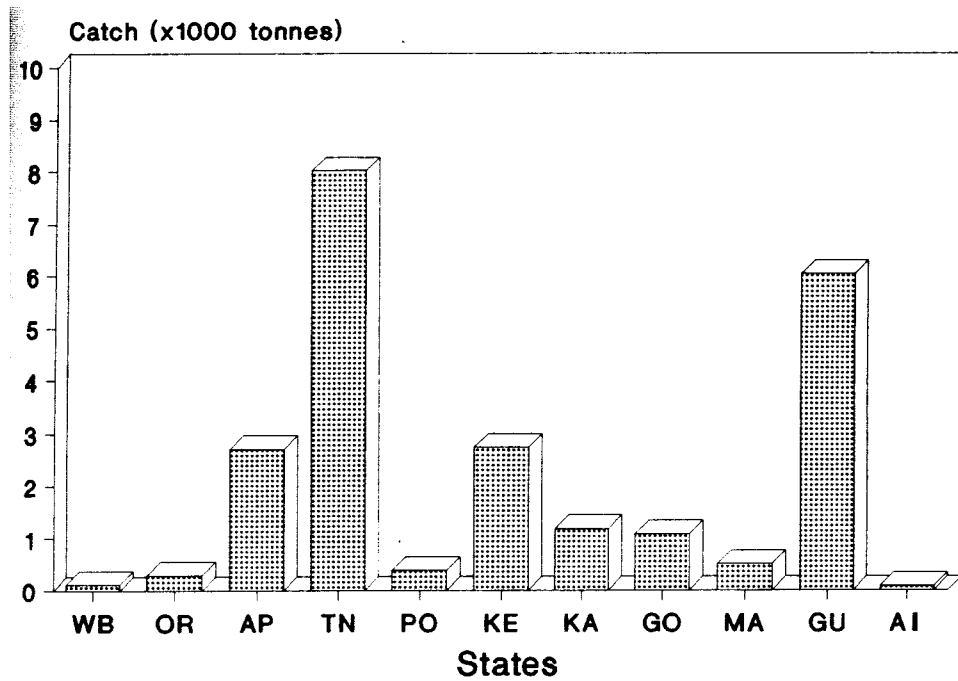


Fig. 2.2. Marine crab landings in different states. WB - West Bengal; OR - Orissa; AP - Andhra Pradesh; TN -Tamil Nadu; KE -Kerala; KA - Karnataka; MA - Maharashtra; GU - Gujarat; AI -Andaman and Nicobar Islands.

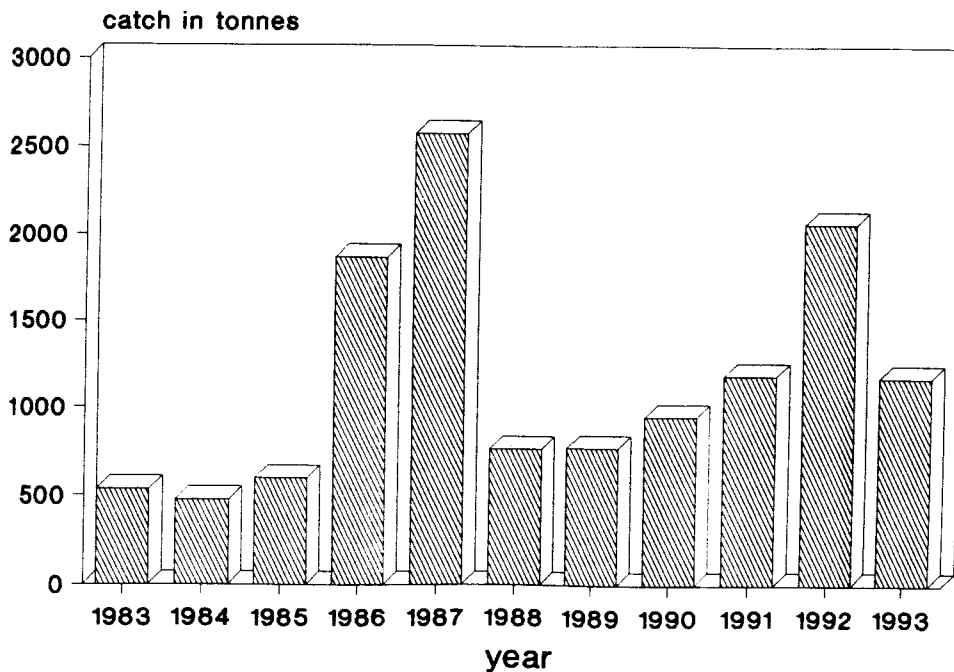


Fig. 2.3. Marine crab landings in Karnataka.

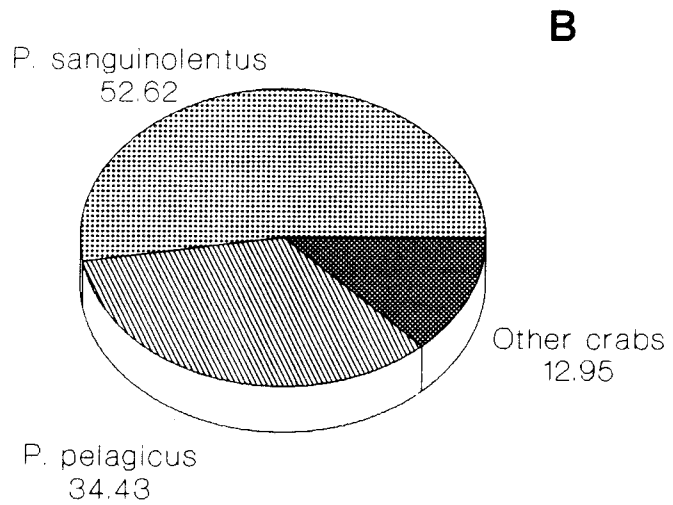
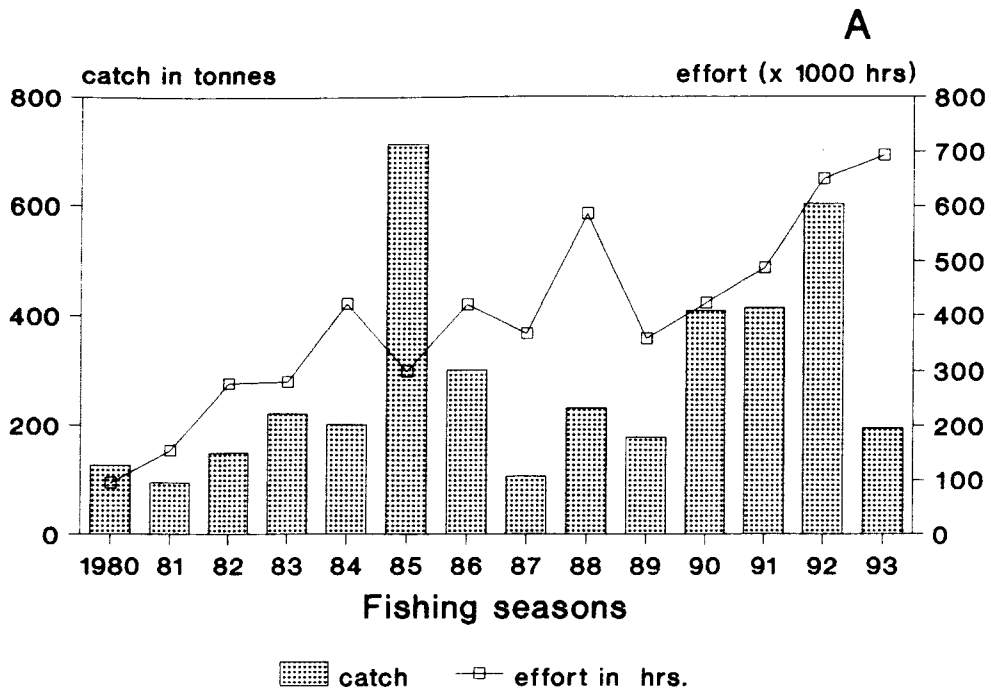


Fig. 2.4. A - Crab landings by mechanised trawlers at Mangalore during 1980/81 - 1993/94; B - species composition.

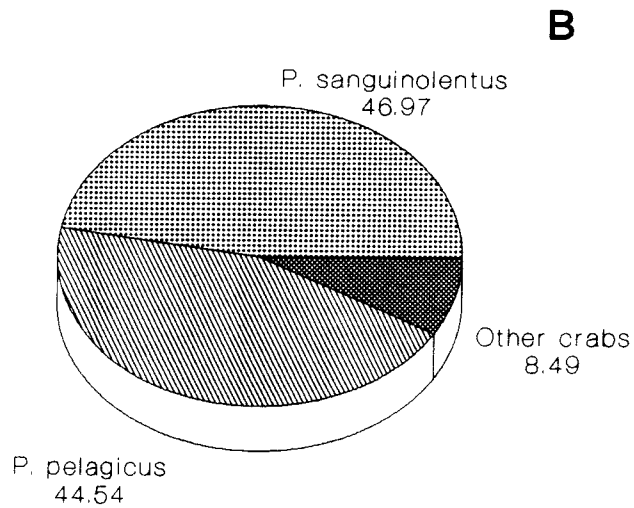
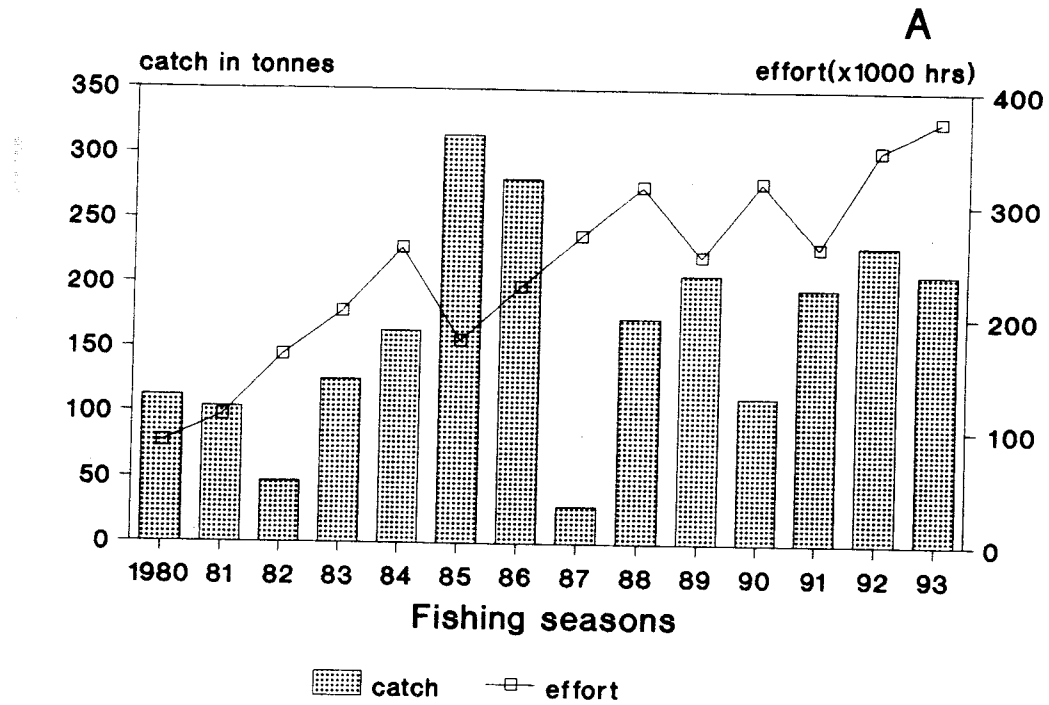


Fig. 2.5. A - Crab landings by mechanised trawlers at Malpe during 1980/81 - 1993-94;
B - species composition.

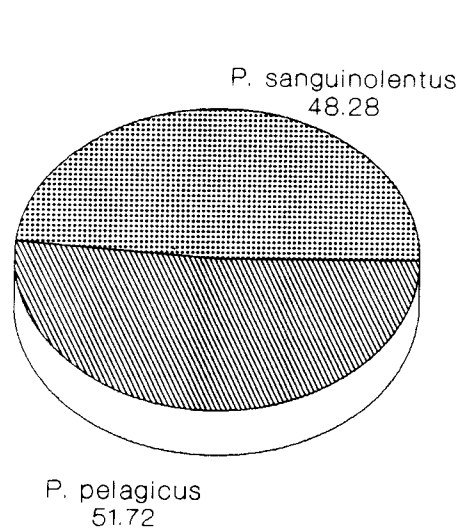
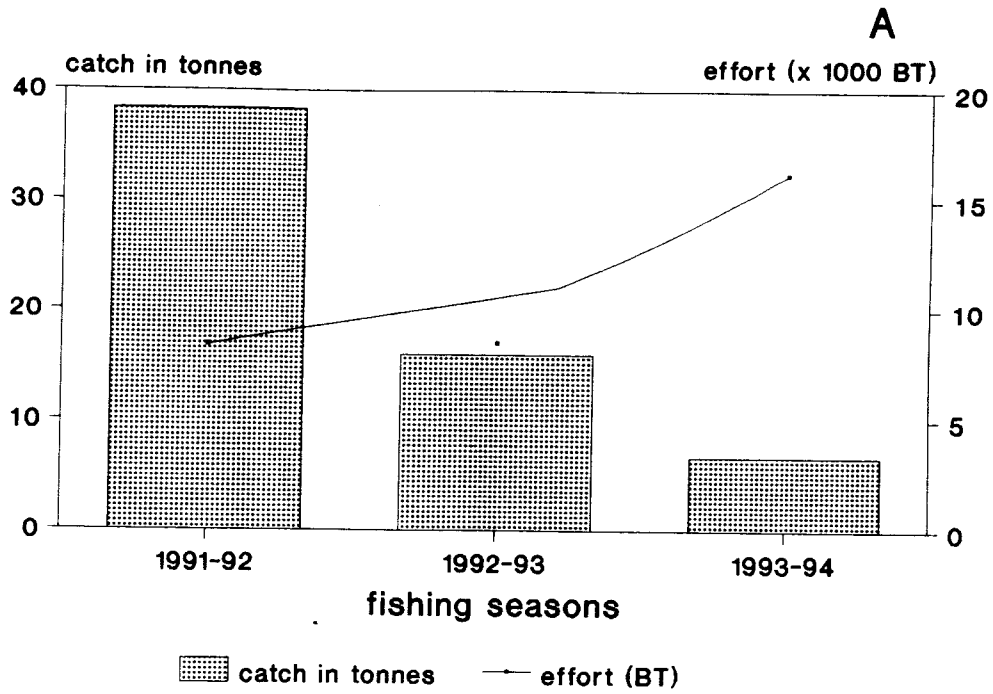


Fig.2.6. A - Crab landings by mechanised trawlers at Karwar during 1991/92 - 1993/94;
 B - species composition.

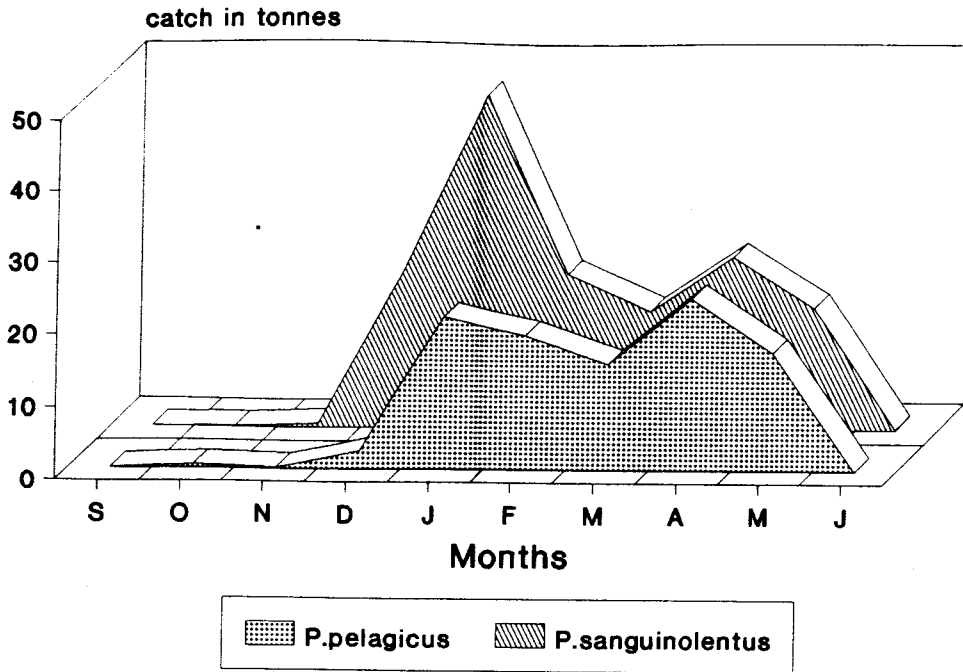


Fig. 2.7. Average monthly landings of *P.sanguinolentus* and *P.Pelagicus* by mechanised trawlers at Mangalore.

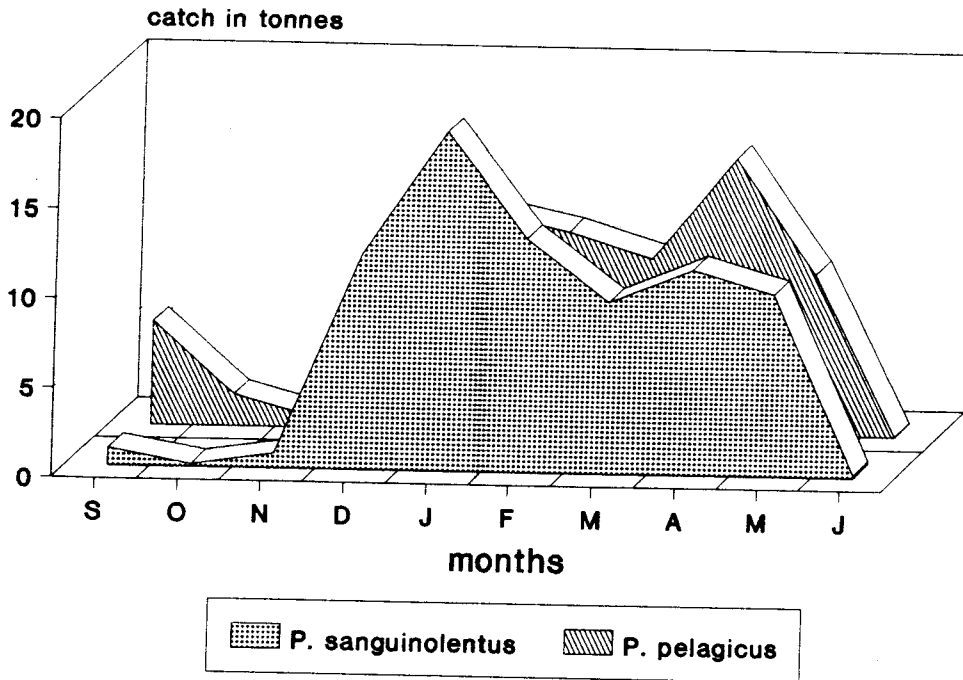


Fig. 2.8. Average monthly landings of *P.sanguinolentus* and *P.pelagicus* by mechanised trawlers at Malpe.

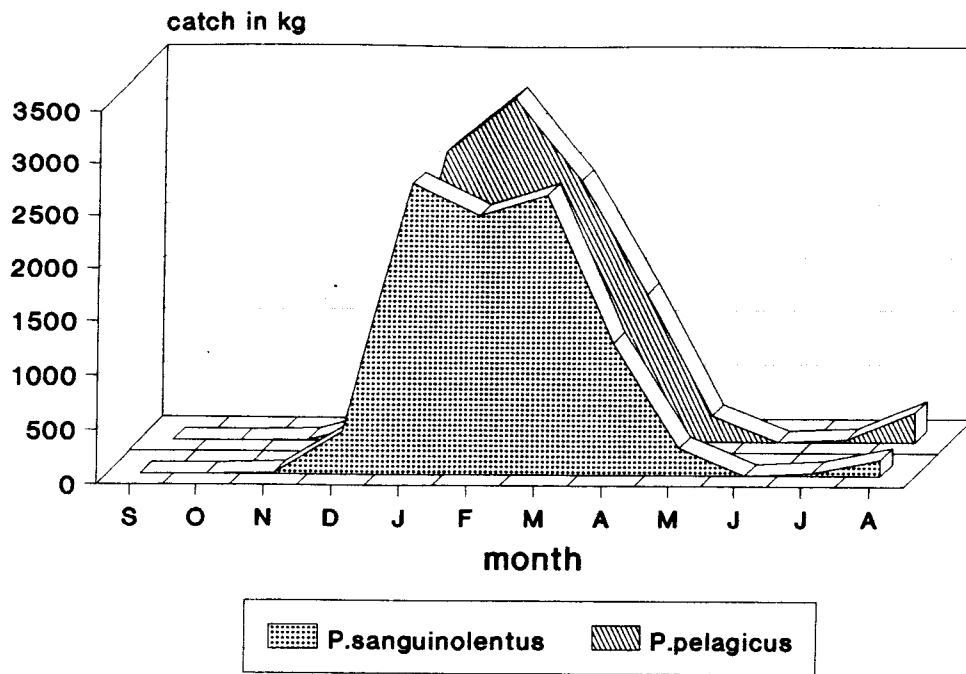
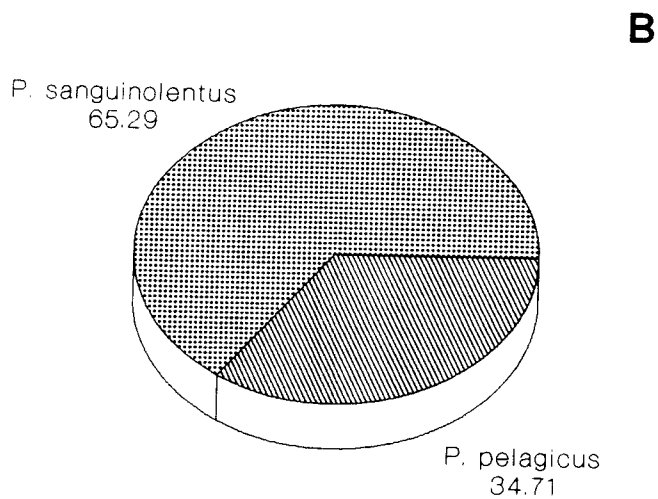
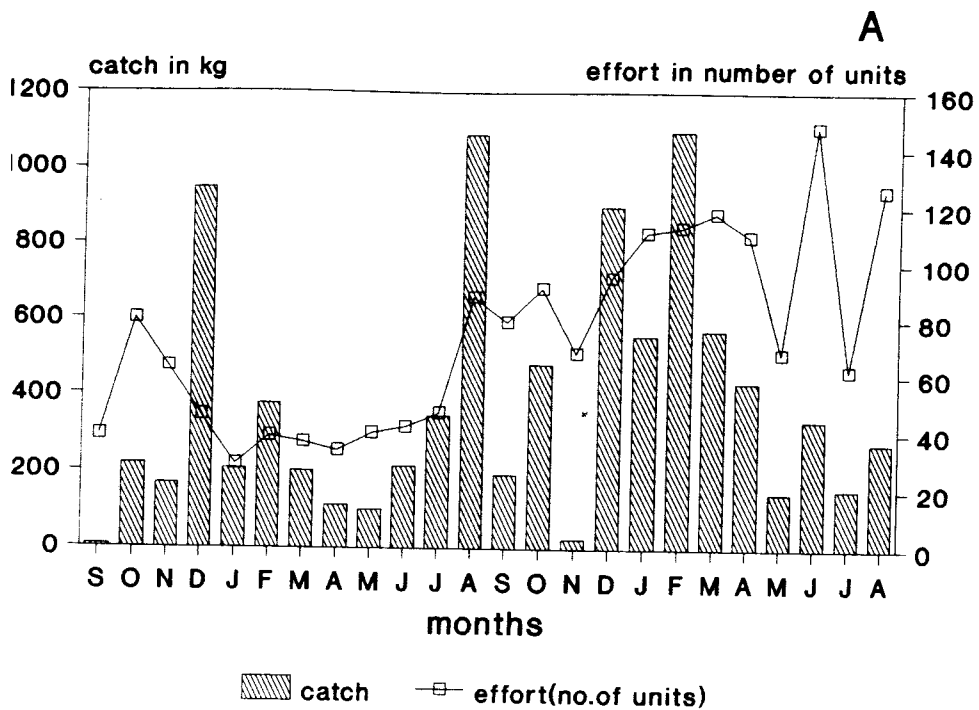


Fig.2.9. Average monthly landings of *P.sanguinolentus* and *P.pelagicus* by mechanised tralers at Karwar.



ig. 2.10. A - Crab landings by indigenous gear ('yendibale') during 1992-94; B - species composition.

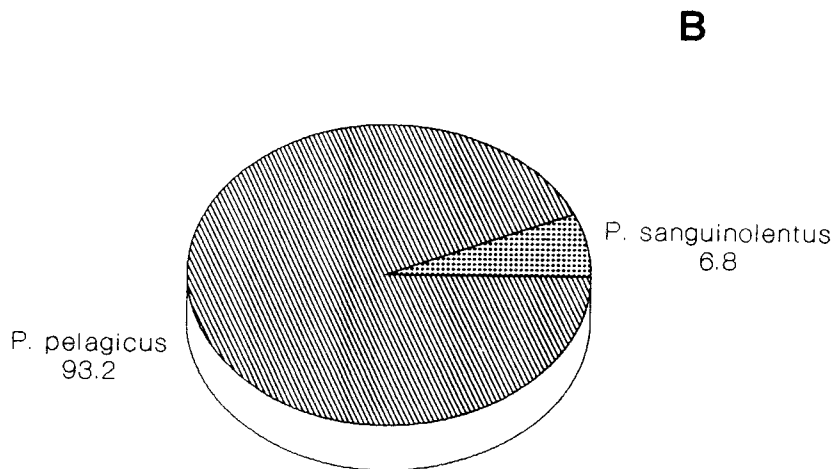
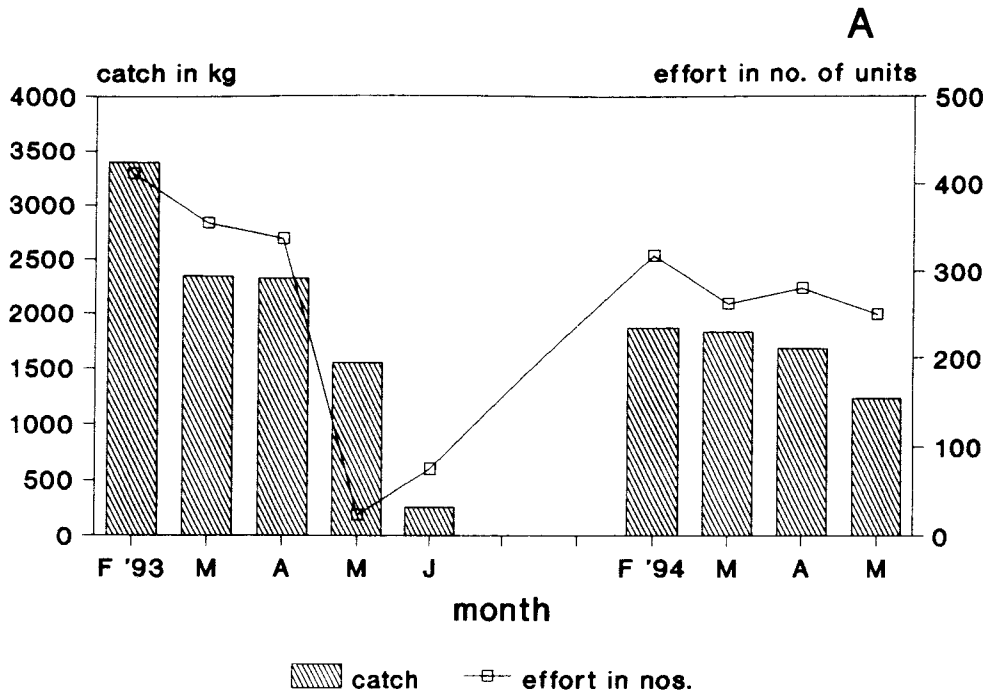
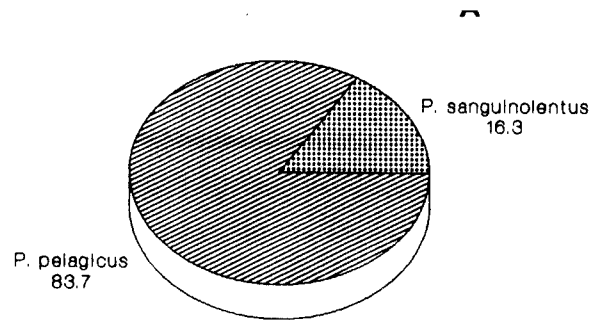
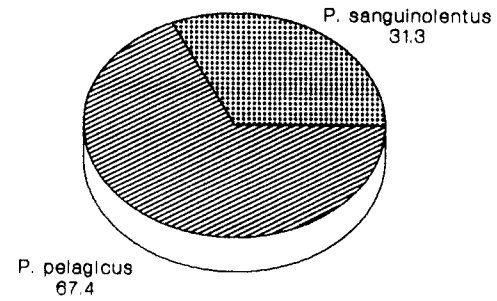


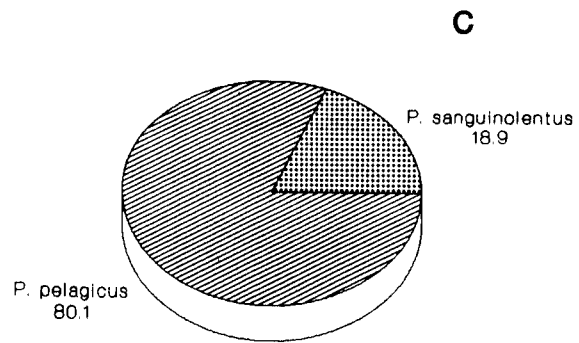
Fig. 2.11. A - Crab landings by minitrawl from the Netravati-Gurupur estuary (Mangalore) during 1992-94; B - species composition.



kanthabale catch at Panambur



jeppubale catch at Panambur



minitrawl catch at Malpe

Fig. 2.12. Species composition in the crab landings by indigenous gears at Panambur and Malpe.

Chapter III

FOOD AND FEEDING

FOOD AND FEEDING

INTRODUCTION

Food is vitally important to every organism as its growth, development, reproduction and other metabolic activities depend on the energy it receives from food (Bal and Rao, 1984). Fish are no exception to this and information on their food and feeding habits is very essential for a better understanding of their life history including growth, breeding and migration and also for the management of the commercially important fisheries. Besides, a study of the food of fish is useful to determine their habitat, distribution, and associated factors (Bal and Rao, 1984). Further, a knowledge of the natural diet of an animal is required for its study of nutritional requirements, its interaction with other organisms and its potential for culture (Williams, 1981).

The food habits and feeding ecology of several brachyurans have been investigated. Important studies are those on *Callinectes* spp. (Tagatz, 1968; Paul, 1981; Laughlin, 1982; Ropes and Buchanan, 1990), *Carcinus maenas* (Ropes, 1968, 1988; Dare *et al.*, 1983), *Libinia* spp. (Caine, 1974; Du Preez, 1984; Ropes, 1988; Wear and Haddon, 1987), *Carcinus* spp. (Choy, 1986; Ropes, 1988), *Paralithodes* spp. (Jewett and Feder, 1982), *Decapoda* spp. (Feder and Jewett, 1977, 1980; Feder and Paul, 1981; Feder and Hoberg, 1982; Jewett and Feder, 1983), *Cancer novaezelandiae* (Creswell and Marsden, 1990), *Libinia* spp. (Arriola, 1942; Deshmukh, 1968; Hill, 1976, 1979; and Prasad and Lakantan, 1988, 1988a).

Although *Portunus sanguinolentus* and *P. pelagicus* enjoy a wide distribution and are commercially harvested in many areas within its geographical ranges, investigations on the feeding biology of these crabs are meagre. Prasad and Tampi (1953) referred to *P. pelagicus* as "scavengers and cannibals" but they noted that these crabs fed readily on

meat, prawns and small fish. Guinot (1966) referred to this species as a carnivore and gave no evidence for this. Eales (1972) examined the gut content of *P. pelagicus* in trawls in the Moreton Bay and reported that lemnibranch shells were the common type of recognisable food. Patel *et al.* (1978) examined the gut content of *P. pelagicus* from Gujarat coast, and Williams (1981, 1982) and Wassenberg and Hill (1982) on the same species from Queensland. George and Nayak (1961) mentioned that the food of *P. sanguinolentus* consisted of detritus, polychaete remains, bits of prawns and mussels. Other than this, practically no information is available on the food habits of *P. sanguinolentus*. Therefore, an attempt has been made to study the diet of these two species of crabs from the present study area to enhance our knowledge on the feeding biology of these crabs.

MATERIAL AND METHODS

For food and feeding studies, *Portunus sanguinolentus* and *P. pelagicus* were collected from the commercial landings by shrimp trawlers at Mangalore and Malpe. All crabs were preserved in 10 % formalin for a week. To facilitate penetration of formalin to preserve the gut regions, the dorsocardiac region was pierced with a sharp needle before preserving in formalin. After recording the carapace width, sex and moulting stage, the body of the crab was cut open from the dorsal side and the foregut was removed carefully. It was cut open and the contents were washed out into a petri dish with water. The gut contents were identified and separated into different food groups under a binocular microscope.

Altogether 157 crabs (*P. sanguinolentus* - 65 nos. size range- 60-140 mm cw; *P. pelagicus* - 92 nos. size range - 60 -160 mm cw) were examined for food studies. The contents of stomach was visually examined at 0, 25, 50, 75, 100 %.

Many of the decapods mainly feed on macroscopic organisms. Eventhough, crabs feed on macroscopic benthic invertebrates, most of the food found in the foregut were already broken down into small fragments by the mouth parts and gastric mill ossicles and hence, identification of food types and quantifying them have been extremely difficult. Due to this, few items could not be assigned to any taxonomic category. Hence the gut contents were broadly classified into the following five categories as suggested by Prasad and Neelakantan (1988).

- 1) Crustacean remains
- 2) Fish remains
- 3) Molluscan remains
- 4) Miscellaneous items
- 5) Debris

The percentage of the total volume of the stomach contributed by each food group was determined visually (Elner, 1980; Williams, 1981; Stehlik, 1953). Importance of food groups was evaluated by ranking them by percentage frequency of occurrence in percentage points. Percentage frequency of occurrence is the number of stomachs containing a particular food group divided by the number of stomachs with food multiplied by 100. To estimate the volume of food group, points were assigned to each food group using a modification of methods of Elner (1980), Williams (1981), and Elner (1990) as suggested by Stehlik (1993). As an example, a food group that was 50% of the volume of the stomach which was 50% full was assigned

$$40 \text{ points} \times 0.50 = 20 \text{ points.}$$

Percentage point is the point of a particular food group divided by the total points of all food groups multiplied by 100.

10. RESULTS AND DISCUSSION

Percentage points along with frequency of occurrence of major food categories in diet of *P. sanguinolentus* and *P. pelagicus* are presented in Tables 3.1 - 3.2 and Figs.

3.1- 3.2. Percentage points of major food groups in various size groups as well as in different months are given in Tables 3.3 -3.6 and Figs. 3.3-3.4.

In general, the diet of *P. sanguinolentus* and *P. pelagicus* mainly consisted of crustaceans, fishes, molluscs, large quantity of unidentifiable matter and debris. A check list of major food items along with their relative occurrence is given in Table 3.9.

Out of the 157 stomachs examined 70.8 % in the former and 63.0 % of the latter only contained food.

The present study has indicated that the crustaceans are the most favoured food group, which occurred in 80.4 % and 74.1 % of the stomachs that contained food in *P. sanguinolentus* and *P. pelagicus* respectively (Fig.3.1) and consisted primarily of decapods along with macroscopic cumaceans, amphipods, isopods and stomatopods. This contributed to 47.1 % in the former and 42.6 % in the latter species of the gut content by volume (Tables 3.1-3.2 and Fig.3.2). In different size groups, the crustacean remains varied between 34.1 % (crabs of 60-80 mm cw) and 53.2 % (crabs of 100-120 mm cw) in *P. sanguinolentus*, and between 35.9 % (crabs of 100-120 mm cw) and 63.6 % (crabs of 140-160 mm cw) in *P. pelagicus* (Table 3.3-3.4 and Fig. 3.3).

The important groups of crustaceans contributing to the diet are penaeid prawns, crabs and stomatopods. Mostly the food items were in broken down condition. However, appendages, rostrum, petasma and telson of these crustaceans were found intact in several cases due to their chitinous nature although the body tissues were in a semidigested condition.

Fish formed the second important item of food. The occurrence of fish in diet could be identified by the presence of vertebrae, bones, scales and fins. The body soft tissues were digested by the time they were analysed. Although it was not possible to

Identify the fish from scales, vertebrae and bones, they might have been benthic species like soles, gobies and juveniles of Pleuronectids which are known to coexist and are caught frequently together in trawls. Fish remains were present in 67.4 % and 41.4 % of the stomachs that contained food in *P. sanguinolentus* and *P. pelagicus* respectively (Fig.3.1). This food group formed 29.0 % by volume of the gut content in the former and 10.4 % in the latter (Table 3.1-3.2 and Fig. 3.2). The occurrence of fish remains varied between 0 % (in crabs of between 60-80 mm cw) and 45.8 % (in crabs of 120-140 mm cw) in *P. sanguinolentus* and 0 % (in crabs ranging between 60-80 mm cw) and 39.4 % (in crabs ranging between 120-140 mm cw) in *P. pelagicus* in different size groups (Tables 3.3-3.4 and Fig. 3.3).

The third predominant category of food was molluscs which formed 5.7 % of the gut content by volume in *P. sanguinolentus* and 20.0 % in *P. pelagicus* (Fig.3.2). Frequency of occurrence study indicated that this item occurred in 28.3 % and 53.4 % of the stomachs that contained food in *P. sanguinolentus* and *P. pelagicus* respectively (Tables 3.1-3.2 and Fig.3.1). Molluscs mainly consisted of bivalves and gastropods (*Meretrix casta*, *Alaphia* sp., *Crassostrea* sp., and *Telescopium* sp.). Even though the soft tissues of molluscs were digested, the shells were often intact and the identification of the food item was possible to a certain extent. The mollusc remains ranged between 3.2 % (in crabs of 120-140 mm cw) and 16.9 % (in crabs of 80-100 mm cw) in *P. sanguinolentus* and between 18.8 % (in crabs of 140-160 mm cw) and 38.8 % (in crabs of 60-80 mm cw) in *P. pelagicus* among different size groups (Table 3.3-3.4 and Fig. 3.3).

The miscellaneous dietary group mainly comprised of unidentified tissue matter, polychaetes (*Neries* sp., *Glycera* sp.), ophiuroids, nematodes, foraminiferans and algal filaments. This group contributed to 13.3 % in *P. sanguinolentus* and 12.3 % in *P. pelagicus* by volume of gut content (Tables 3.1-3.2 and Fig.3.2). This group occurred practically in all stomachs that contained food (100 % in the former and 94.8 % in the

tr species) (Fig.3.1). In different size groups, miscellaneous items varied between 12.4 % (in crabs of 100-120 mm cw) and 37.9 % (in crabs of 60-80 mm cw), and between 8.6 % (in crabs ranging of 140-160 mm cw) and 13.5 % (in crabs of 80-100 mm cw) in *P. sanguinolentus* and *P. pelagicus* respectively (Tables 3.3-3.4 and Fig.3.3).

The detritus formed 4.9 % and 4.7 % of the gut content of *P. sanguinolentus* and *P. pelagicus* respectively (Fig.3.2). It was available in 63.0 % and 58.6 % of the stomachs containing food in these two portunids (Tables 3.1-3.2 and Fig.3.1). The occurrence of detritus varied between 2.9 % (in crabs of 120-140 mm cw) and 18.2 % (in crabs of 60-80 mm cw) in *P. sanguinolentus* and between 1.2 % (in crabs of 60-80 mm cw) and 6.5 % (in crabs of 80-100 mm cw) in *P. pelagicus* in different size groups (Tables 3.3-3.4 and Fig.3.3).

Ontogenic variability of diet

Diet difference in different size groups have been frequently reported in other species of crabs (Ropes, 1968; Paul, 1981; Jewett and Feder, 1982; Gotshall, 1977; Ven et al., 1982; Prasad and Neelakantan, 1988; Stoner and Buchanan, 1990). In the present study, an attempt was made to ascertain whether there was any significant variation in diet of these crabs at different sizes/ juveniles, subadults and adults. It is evident from Tables 3.3-3.4 that juveniles of *P. sanguinolentus* (< 80 mm cw) preferred miscellaneous items (37.9 %) followed by crustaceans (34.1 %) as diet, whereas, juveniles of *P. pelagicus* (< 80 mm cw) had a strong preference for crustacean diet (51.3 %) followed by molluscs (38.8 %). In the sub adults (80-100 mm cw), crustaceans and miscellaneous groups (46.9 % and 18.1 % respectively) were the dominant items in *P. sanguinolentus*, while in *P. pelagicus*, it was crustaceans and molluscs (43.0% and 25.8 % respectively). In adults (> 100 mm cw), crustaceans were the principal food category closely followed by fishes in both species of crabs. It was found that adult crabs showed

strong preference for fishes instead of molluscs, as it grows in size (see Table 3.3-3.4 (Fig. 3.3). It is noted that fishes replaced crustaceans as principal food (45.8%) in *P. quinolentus* (120-140 mm cw). Elner (1980) is of the opinion that the difference in diet composition of juveniles and adult *Liocarpus puber* presumably result from the size difference, change in cheliped strength and foraging behaviour. This may be true of *P. quinolentus* and *P. pelagicus* also.

Seasonal variability in diet

Williams (1982) found that the diet did not vary seasonally for juveniles of *P. pelagicus* in intertidal areas in the Moreton Bay, Queensland. The seasonal variation in animal diet of *Liocarpus holsatus* and *L. puber* are presumably due to changes in availability of prey organisms (Elner, 1980). The variation in diet of *P. sanguinolentus* and *P. pelagicus* during different months as evident from Tables 3.5-3.6 (Fig. 3.4) may be due to change in availability of prey organisms.

Sexwise variability of diet

Williams (1982) reported that male and female of *P. pelagicus* ate similar quantities of food and the food was of a similar type in the Moreton Bay. Laughlin (1982) in *Callinectes sapidus* and Stevens *et al.*(1982) in *C. margin* found a lack of variation in diet with sex of crabs. However, sexwise difference in dietary composition of crabs have been demonstrated in some portunid crabs (Ropes, 1968; Elner, 1980). Elner (1986) showed that for male *Liocarcinus puber* molluscs formed a greater portion of the diet than in female crabs and concluded that these differences reflected cheliped strength, with male crab possessing larger and, stronger chela than females. In the present study also, certain amount of variation in the food types and the quantity of food consumed has been observed between the sexes (Tables 3.7-3.8 and Fig. 3.5). *P.*

pelagicus males showed strong preferences for crustaceans and molluscs, whereas, females preferred fishes in addition to crustaceans. In *P. sanguinolentus* females, fishes were the second important food item.

1.4. Feeding behaviour

Some works are available on the feeding behaviour of crabs. Hill (1970) reported that *Scylla serrata* remained buried during the day and emerging only after sun set to feed.

Prasad and Tampi (1953) referred to *P. pelagicus* as "Scavengers and Cannibals" but they also noted that these crabs fed readily on clam meat, prawns and small fish in the laboratory. Guinot (1966) referred to *P. pelagicus* as a carnivore but gave no evidence for this. According to Williams (1982), this crab is a bottom feeding carnivore eating on a wide variety of sessile and slow moving invertebrates and the food mainly consisted of bivalves and ophiuroids.

The analysis of the foregut contents of *P. sanguinolentus* and *P. pelagicus* in the present study indicated that they are primarily predators of sessile and slow moving benthic macro invertebrates. It is seen that *P. pelagicus* had a strong preference for bivalves as food as evident from the occurrence of large number of bivalve shells in the gut contributing upto 90 % of the gut content by volume. The presence of detritus and unidentified items in the stomach also suggest that these crabs are detritivorous consuming decaying plant debris and inorganic material and scavengers consuming fresh and decaying flesh of all kinds.

Although fish remains are abundant in the foreguts of these crabs, it is doubtful that these crabs can prey on active and healthy fish. Kwei (1974) observed that *Decapoda latimanus* could stalk and kill *Tilapia* sp. Paul (1981), based on his laboratory

ies, opined that much of the fish eaten by the crabs is through scavenging dead fish waste products abundantly discarded by fishermen during shrimp fishing season in areas near the fishing villages. Wassenberg and Hill (1987) reported that ingested fish remains were not found in the foreguts of crabs captured when trawling was not taking place. During trawling times, however, when by-products were being discarded, both food items were found in the foreguts. The undigested appearance of this material and the rapid clearance rate indicate that it had been recently ingested. This may be true of *P. sanguinolentus* and *P. pelagicus* also.

Differences in the contribution of food types in the diet of *Callinectes arcuatus* in different areas of the lagoon system probably result from difference in prey availability (Ennis, 1981). Ennis (1973) reported that the percentage occurrence of various prey species in the lobster stomachs reflected the relative abundance of the prey species in the habitat. This may be true of *P. sanguinolentus* and *P. pelagicus* also.

The most significant difference between the diet of *P. sanguinolentus* and *P. pelagicus* was that the former feeds more on fish and the latter on molluscs, in addition to crustaceans as main diet in both species.

TABLE 3.1.
Percentage points and frequency of occurrence of major food groups
in *P. sanguinolentus*.

Items	Points	Percentage points	Percentage frequency of occurrence
Crustacean remains	1441.5	47.1	80.4
Molluscan remains	174.8	5.7	28.3
Fish remains	888.4	29.0	67.4
Miscellaneous items	407.1	13.3	100.0
Debris	149.1	4.9	63.0
Total	3060.9	100.0	

Number of crabs analysed : 65

TABLE 3.2.
Percentage points and frequency of occurrence of major food groups in
***P. pelagicus*.**

Items	Points	Percentage points	Percentage frequency of occurrence
crustacean remains	1119.2	42.6	74.1
Molluscan remains	525.0	20.0	53.4
Fish remains	535.1	20.4	41.4
Miscellaneous items	322.0	12.3	94.8
Debris	123.6	4.7	58.6
Total	2624.9	100.0	

Number of crabs analysed : 92

TABLE 3.3.
Percentage points of major food groups in various size groups
in *P. sanguinolentus*.

Size group(mm)	No.	CR	MR	FR	M	D	Total
60-80	3	35.0	10.0	-	38.3	18.7	102.5
		(34.1)	(9.8)	-	(37.9)	(18.2)	
80-100	6	187.6	67.5	17.5	72.6	55.0	400.2
		(46.9)	(16.9)	(4.4)	(18.1)	(13.7)	
100-120	25	858.8	67.3	438.4	200.9	47.7	1613.1
		(53.2)	(4.2)	(27.2)	(12.4)	(3.0)	
120-140	12	360.1	30.0	432.5	94.8	27.7	945.1
		(38.1)	(3.2)	(45.8)	(10.0)	(2.9)	
Total	46	1441.5	174.8	888.4	407.1	149.1	3060.9
		(47.1)	(5.7)	(29.0)	(13.3)	(4.9)	

TABLE 3.4.
Percentage points of major food groups in various size groups in *P. pelagicus*.

Size groups (mm)	No.	CR	MR	FR	M	D	Total
60-80	3	51.3	38.8	-	8.7	1.2	100.0
		(51.3)	(38.8)	-	(8.7)	(1.2)	
80-100	29	597.8	358.6	155.1	187.8	90.2	1389.5
		(43.0)	(25.8)	(11.1)	(13.5)	(6.5)	
100-120	14	251.2	107.6	273.5	84.6	19.7	700.6
		(35.9)	(15.4)	(33.9)	(12.0)	(2.8)	
120-140	7	107.6	15.0	102.5	84.6	8.8	260.1
		(41.4)	(5.8)	(39.4)	(12.0)	(3.4)	
140-160	5	111.3	5.0	40.0	15.0	3.7	175.0
		(63.6)	(2.8)	(22.8)	(8.6)	(2.1)	
Total	58	1119.2	525.0	535.1	322.0	123.6	2624.9
		(42.6)	(20.0)	(20.4)	(12.3)	(4.7)	

Percentage is given in parenthesis
 CR -Crustacean remains; MS - Molluscan remains; FS - Fish remains;
 M - Miscellaneous items; D - Debris

TABLE 3.5.
Percentage points of major food groups during different months
in *P. sanguinolentus*.

Period	No.	CR	MR	FR	M	D
Dec.'92	26	857.6	31.1	447.9	245.0	66.6
		(52.0)	(1.9)	(27.2)	(14.9)	(4.0)
Jan.'93	12	413.9	36.2	320.5	92.1	25.0
		(46.6)	(4.1)	(36.1)	(10.4)	(2.8)
Mar.'93	5	50.0	97.5	-	40.0	37.5
		(22.2)	(43.3)		(17.8)	(16.7)
May '93	3	120.0	10.0	120.0	30.0	20.0
		(40.0)	(3.3)	(40.0)	(10.0)	(6.7)
Total	46	1441.5	174.8	888.4	407.1	149.1
		(47.1)	(5.7)	(29.1)	(13.3)	(4.9)

TABLE 3.6.
Percentage points of major food groups during different months in *P. pelagicus*.

Period	No.	CR	MR	FR	M	D
Mar. '93	14	63.8	293.8	16.2	95.5	52.9
		(12.2)	(56.3)	(3.1)	(18.3)	(10.1)
Apr. '93	21	567.7	169.9	138.9	126.0	42.3
		(54.3)	(16.3)	(13.3)	(12.1)	(4.0)
May '93	23	487.7	61.3	380.0	100.5	28.4
		(46.1)	(5.8)	(35.9)	(9.5)	(2.7)
Total	58	1119.2	525.0	535.1	322.0	123.6
		(42.6)	(20.0)	(20.4)	(12.3)	(4.7)

Percentage is given in parenthesis

CR -Crustacean remains; MS - Molluscan remains; FS - Fish remains;

M - Miscellaneous items; D - Debris

TABLE 3.7.
Percentage points of major food groups in *P. sanguinolentus*
males and females.

ITEMS	MALE		FEMALE	
	Points	%	Points	%
Crustacean remains	306.3	63.3	1135.2	44.1
Molluscan remains	10.0	2.1	164.8	6.1
Fish remains	55.0	11.4	833.4	32.3
Miscellaneous items	81.4	16.8	325.7	12.6
Debris	31.2	6.4	117.9	4.6
Total	483.9	100.0	2577.0	100.0

Number of crabs : males - 10 ; females - 36.

TABLE 3.8.
Percentage points of major food groups in males and females of *P. pelagicus*.

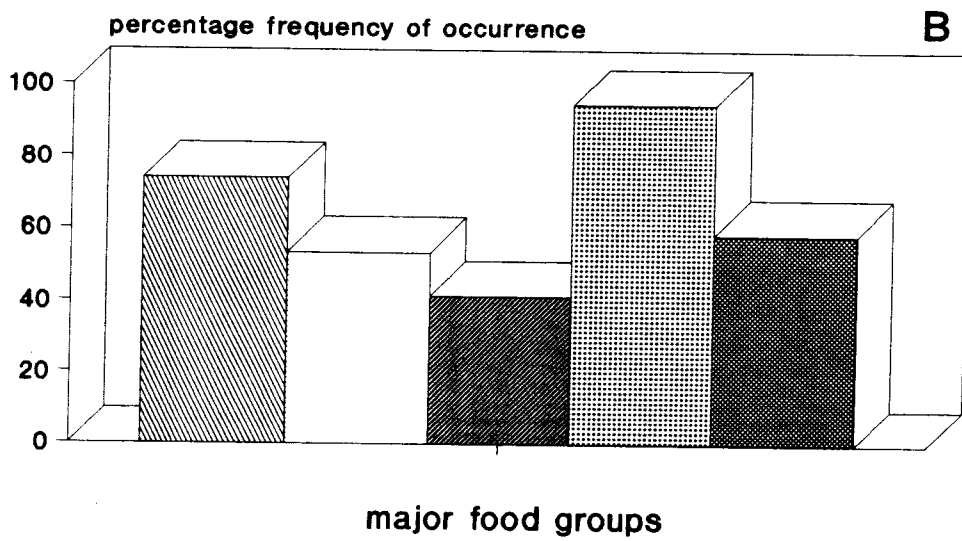
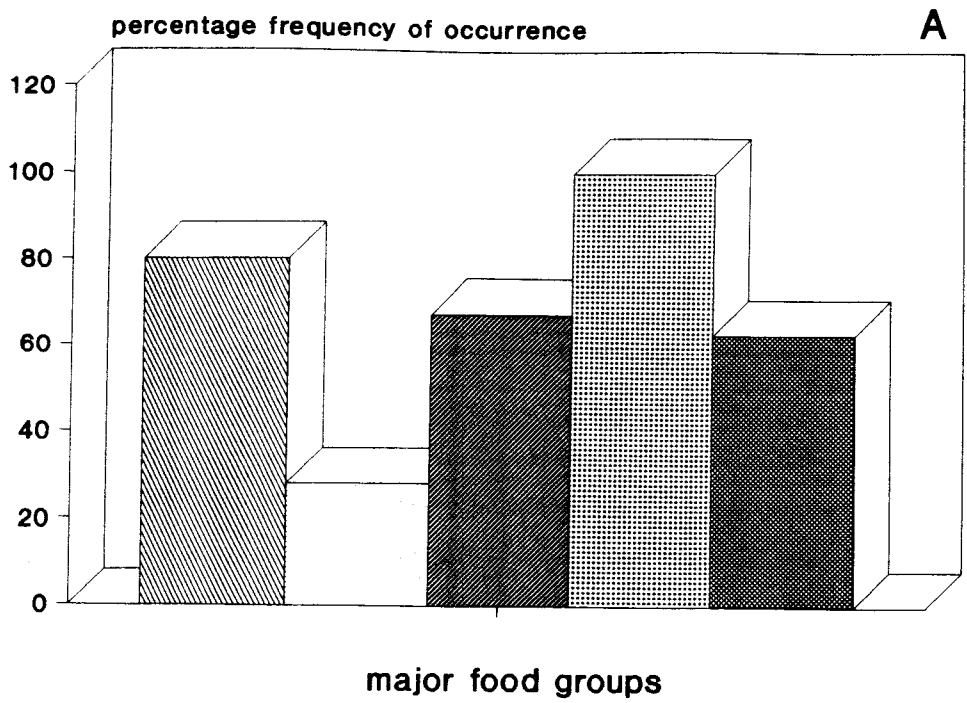
Items	MALE		FEMALE	
	Points	%	Points	%
Crustacean remains	349.0	40.1	770.2	43.9
Molluscan remains	238.8	27.5	286.2	16.3
Fish remains	73.8	8.5	461.3	26.2
Miscellaneous items	133.0	15.3	189.0	10.8
Debris	75.0	8.6	48.6	2.8
Total	869.6	100.0	1755.3	100.0

No. of crabs: Males - 21; Females - 37.

TABLE 3.9.
Check list of stomach contents of *P. sanguinolentus* and *P. pelagicus*.

		<i>P. sanguinolentus</i>	<i>P. pelagicus</i>
CRUSTACEA			
	Penaeid prawn body parts	vc	vc
	Crab body parts		
	Amphipods	c	c
	Isopods	c	c
	Cumaceans	c	c
	Unidentified crustacean remains	vc	vc
	Stomatopod body parts	vc	vc
MOLLUSCA			
	Bivalve shells pieces	c	vc
	Gastropod shell pieces	c	c
FISH			
	Scales, bones, vertebrae, fins	vc	vc
ZOOPLANKTON			
	Foraminiferan shells	c	c
	Copepods	a	r
MISCELLANEOUS ITEMS			
	Unidentified items	vc	vc
	Algal filaments	r	r
	Nematods	r	r
	Ophiuroids	a	r
DEBRIS			
	Sand and mud	vc	vc

vc - very common; c - common; r - rare; a - absent



crustacean remains
 molluscan remains
 fish remains

miscellaneous items
 debris

g. 3.1. A - Percentage frequency of occurrence of major food groups for *P. sanguinolentus*;
 B - percentage frequency of occurrence of major food groups for *P. pelagicus*.

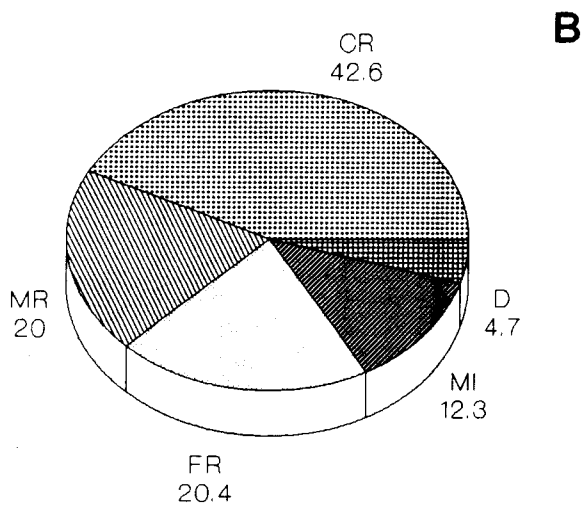
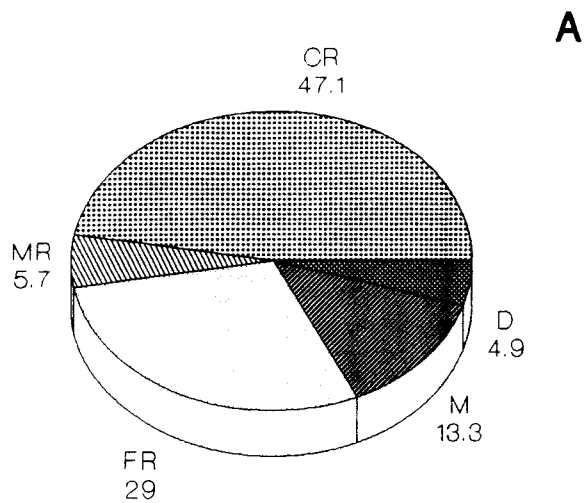


Fig. 3.2. A - Percentage points of major food groups for *P. sanguinolentus*; B - percentage points of major food groups for *P. pelagicus*. CR - Crustacean remains; MR - Molluscan remains ;FR - Fish remains; MI - Miscellaneous items; D - Debris.

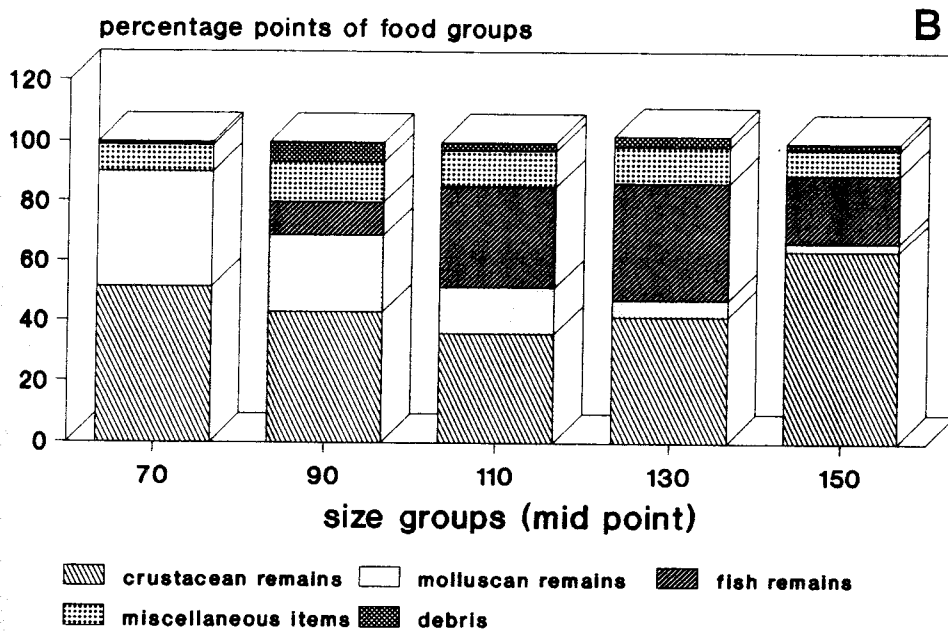
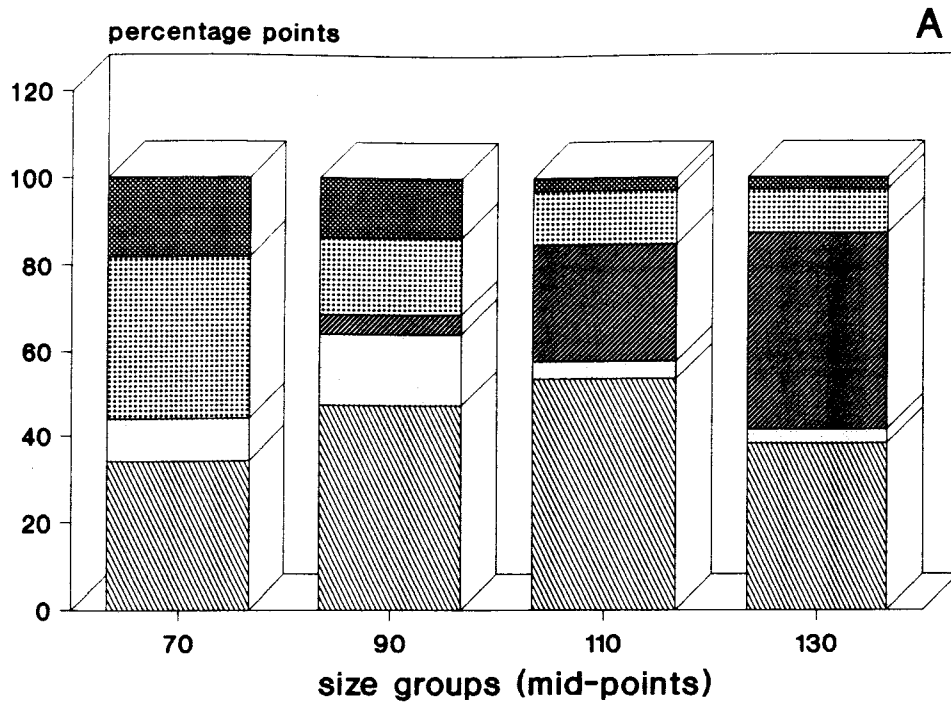
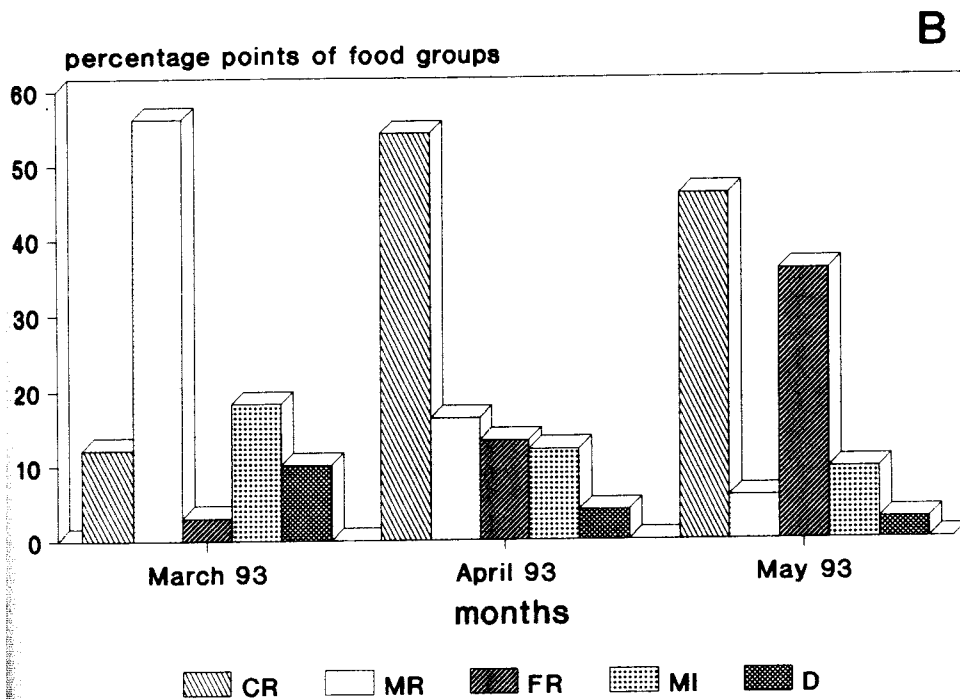
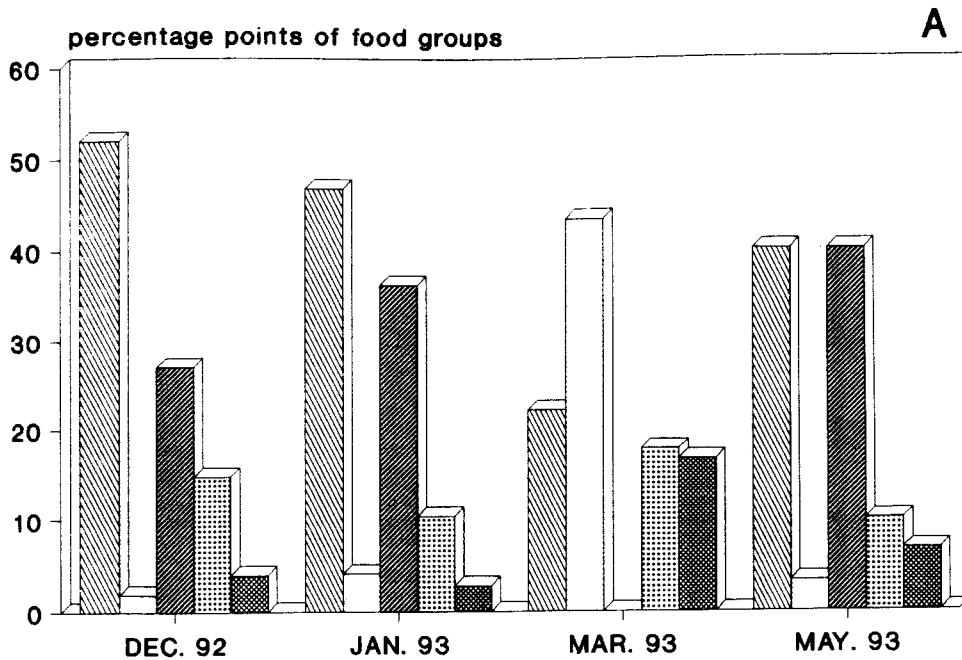


Fig. 3.3. A - Percentage points of major food groups at various size groups for *P. sanguinolentus*;
 B - percentage points of major food groups for *P. pelagicus*.



3.4. A - Percentage points of major food groups during different months for *P. sanguinolentus*;
 B - percentage points of major food groups for *P. pelagicus*.
 CR - Crustacean remains; MR - Molluscan remains; FR - Fish remains; MI -Miscellaneous items; D -Debris.

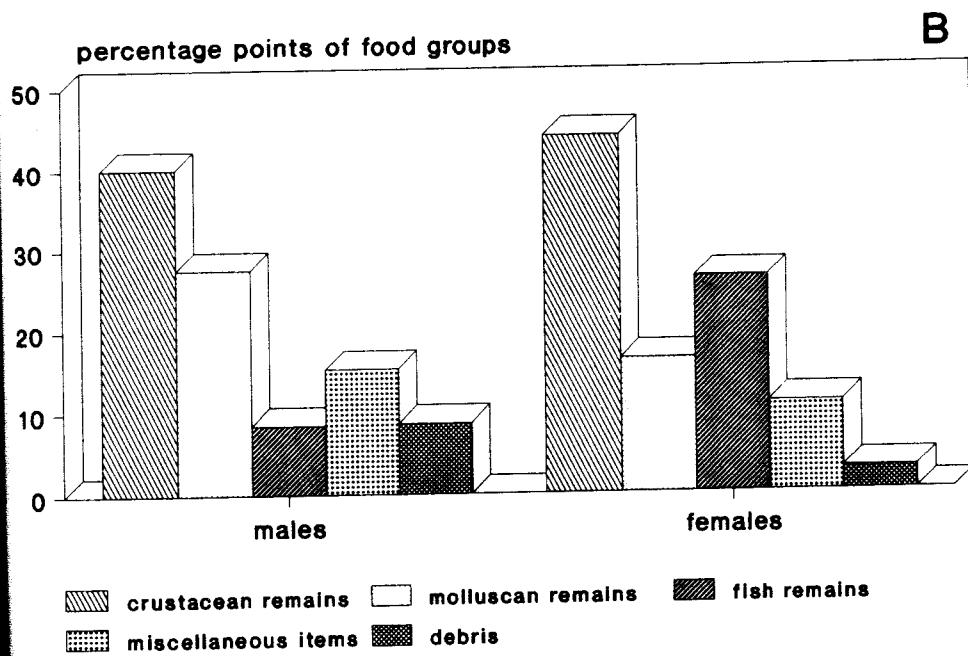
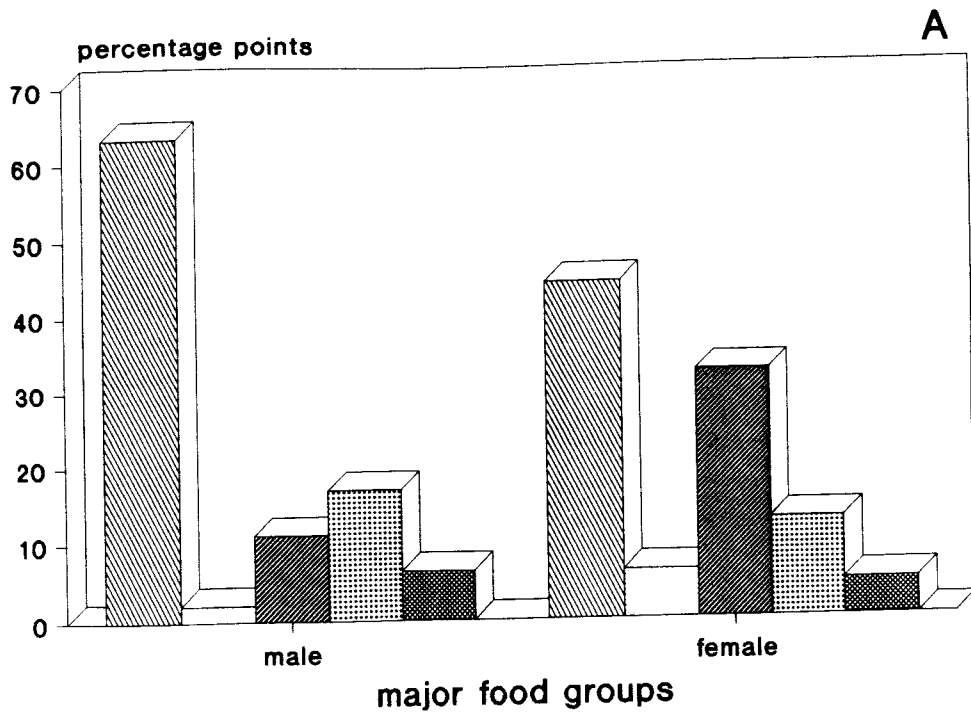


Fig. 3.5. A - Percentage points of major food groups in males and females of *P. sanguinolentus*;
 B - percentage points of major food groups in males and females of *P. pelagicus*.

Chapter IV
**CARAPACE WIDTH (length)-
WEIGHT RELATIONSHIP**

CARAPACE WIDTH (LENGTH) - WEIGHT RELATIONSHIP

INTRODUCTION

Study of length-weight relationship is of vital importance in fishery biological investigations. It helps to establish a direct mathematical relationship between two variables, namely, length and weight, so that, if one is known the other could be easily estimated. This also helps to know variations from the expected weight for the known length which in turn reflects its fatness, general well-being of the animal, gonad development and the suitability of the environment.

The weight of the animal is a function of length and since length is a linear measure and weight is a measure of volume, the relationship between the length and weight of an animal could be expressed by the hypothetical cube law, $W = CL^3$, where W and L are the weight and length of the animal and C is a constant. This relation holds good only when the specific gravity and the form of the animal remain constant. But most of the animals tends to change their shape or form as they grow in size. In such cases, the formula has been modified as $W = aL^b$, where, W and L are weight and length respectively and a is an equivalent of C , and b is another constant to be determined empirically from the data. However, significant variation from isometric growth ($b=3$) is uncommon (Beverton and Holt, 1957) and b will be equal to 3 in an ideal situation where the animal maintains its body proportions throughout its life (Ricker, 1938).

Although there have been several works relating to length weight relationship in crustaceans (Jhingran, 1952; Pillay, 1954; Prabhu, 1955; Narasimham, 1970; Neelakantan, 1981; Sankaranarayanan, 1983) similar studies on brachyurans are relatively few (Dhawan *et al.*, 1976; Sankaranarayanan, 1982; Jameson *et al.*, 1982; Suhalya and Rasham, 1986; Potter *et al.*, 1983; Lalitha

Devi, 1985; Sukumaran *et al.*, 1986; Prasad *et al.*, 1989c; Sumpton *et al.*, 1989a).

4.2. MATERIAL AND METHODS

Altogether 579 crabs comprising 267 numbers of *P. sanguinolentus* and 312 numbers of *P. pelagicus* collected from the commercial trawl landings at Mangalore and Malpe were analysed for studying the length-weight relationship. Out of the 267 *P. sanguinolentus*, 97 were juveniles (30-79 mm cw), 86 adult males (80-154 mm cw) and 84 adult females (80-144 mm cw). Similarly, in *P. pelagicus*, out of 312 crabs examined, 95 were juveniles (30-79 mm cw), 111 were adult males (80-159 mm cw) and 106 were adult females (80-164 mm cw).

Crabs in the intermoult stage with all appendages intact were only considered for the study. All material was analysed in the fresh condition.

The crabs were washed thoroughly to remove all mud, sand and epizoic forms. Individual carapace widths (CW) between tips of the largest lateral spines across the body, and carapace length (CL) along the middle line between the frontal notch and posterior margin, were measured (see Fig. 5.1A) to the nearest millimeter using a vernier caliper and the individual weight was recorded to an accuracy of 0.001 g using an electronic balance after removing all adhering water from the body using a blotting paper. Males and females measuring 80 mm CW and above were classified as adults.

The carapace width/carapace length and weight relationship was determined by employing the Le Cren's (1951) non-linear equation, $W = aL^b$, where, 'W' and 'L' are weight in g and carapace width/length in mm respectively, and 'a' and 'b' are parameters. This parabolic equation can be transformed into a linear equation of the form, $Y = a + bX$ by taking logarithms on both sides as,

$$\text{Log}_{10} W = \text{Log}_{10} a + b \text{Log}_{10} L,$$

where, $\text{Log}_{10} W = Y$

$$\text{Log}_{10} L = X$$

$$\text{Log}_{10} a = a$$

This linear equation was fitted for juveniles, adult males and adult females separately for *P. sanguinolentus* and *P. pelagicus*. The regression analysis was performed to determine the constants 'a' and 'b' and relationship between carapace width/length and weight with the help of a computer.

The coefficient of determination (R squared) was determined to know the pattern of association of the two variables involved.

Analysis of covariance (Snedecor and Cochran, 1967) technique was used to test for significant difference in the relationship between the sexes.

4.3. RESULTS AND DISCUSSION

Carapace width, carapace length and weight data in respect of juveniles, adult males and adult females of *P. sanguinolentus* and *P. pelagicus* are given in Tables 4.1-4.6. The regression output, the linear regression equations along with the parabolic equations of carapace width/length and weight in these two species are indicated in Tables 4.13-4.16. The non-linear curves of width/length and weight relationship are shown in Figs. 4.1-4.6. Average and standard deviation (SD) of carapace width, carapace length and weight in respect of juveniles, adult males and adult females of *P. sanguinolentus* and *P. pelagicus* are given in Tables 4.7-4.12 for interconversion of the parameters. Sum of squares and products, corrected sum of squares and products and analysis of covariance of carapace width-weight data for *P. sanguinolentus* and *P. pelagicus* are presented in Tables 4.17-4.18.

Present study has indicated that males are heavier than females at a given width in both the species. The difference in weights at a given carapace width between males and females was predominant above 120 mm cw in *P. sanguinolentus* and above 115 mm cw in *P. pelagicus* (Tables 4.8-4.9 and 4.11-4.12). The non-linear curves plotted based on the expected values along with the observed values in Figs. 4.1 -4.6 suggested that there was direct relationship between the observed and calculated values of carapace width/length and weight in juveniles, adult males and adult females in these portunids.

The coefficient of determination (R squared) computed from carapace width-weight data for juveniles (0.974328), adult males (0.977131), and adult females (0.964351) in *P. sanguinolentus* and the similar values for juveniles (0.931881), in adult males (0.970253) and adult females (0.976566) in *P. pelagicus* were significant at 5 % level (Tables 4.13 -4.14).

The exponent (b) values of 3.02612 in juveniles, 3.09969 in adult males and 2.96044 in adult females of *P. sanguinolentus* indicated that the increase in body weight in juveniles and adult males was proportional to the cube of width, while in adult females, the body weight was lower than the width cube (Figs. 4.1- 4.3). In the case of *P. pelagicus*, the exponent (b) values of 2.87333, 3.61676 and 3.25274 respectively in juveniles, adult males and adult females suggested that the body weight of adults (males and females) grew faster than the cube of carapace width, whereas, in juveniles, the increase in body weight was lower than the cube of width (Figs. 4.4 - 4.6).

Analysis of covariance of carapace width-weight data in *P. sanguinolentus* and *P. pelagicus* suggested that between males and females no significant difference was observed in the former species, whereas, significant difference was observed between the slopes of the regression equations in the latter species (Tables 4.17-4.18).

Similarly, relationship between carapace length and weight of juveniles, adult males and adult females in respect of *P. sanguinolentus* and *P. pelagicus* was found to be direct and non-linear (Tables 4.1-4.12 and Figs. 4.1-4.6).

The present results indicate that the tendency of males being heavier than females in portunids which is in conformity with the observations of Potter *et al.* (1983) in *P. pelagicus* from Australia, Thomas (1984) in *P. pelagicus* and *P. sanguinolentus* from Cochin, Sumpton *et al.* (1989a) in *P. sanguinolentus* from Australia, and Lalithadevi (1985) in *P. pelagicus* and *P. sanguinolentus* from Kakinada coast, Sukumaran *et al.* (1986) in *P. sanguinolentus* from Mangalore, and Prasad *et al.* (1989) on *P. sanguinolentus*, *P. pelagicus* and *Scylla serrata* from Karwar. In this context, the observation of Dhawan *et al.* (1976) that females of *P. pelagicus* are heavier than males at a given length in the Goan waters needs reexamination in view of the present studies as well as the studies made by several workers on this species from different regions.

Eventhough there is general agreement in the fact that males are heavier than females, there has been variations in the results obtained by various workers while studying on the carapace width/length and weight relationship in portunids from various localities (Potter *et al.*, 1983; Thomas, 1984; Sumpton *et al.*, 1989a; Lalithadevi 1985; Sukumaran *et al.*, 1986 ; Prasad *et al.*, 1989c).

The differences in exponential values in juveniles, adult males and adult females may be attributed to the differential diet presumably resulting from size difference, change in cheliped strength, foraging behaviour and metabolic rate of the animal.

TABLE 4.1.

P. sanguinolentus juveniles carapace width/ carapace length and body weight data.

CW	CL	Weight	CW	CL	Weight
33.2	14.8	2.007	68.9	29.4	18.219
35.2	15.1	2.343	69	28.7	16.427
37.4	16.5	2.883	69.1	28.1	19.406
39.5	18.1	3.96	69.5	30.3	18.773
39.5	17	3.337	69.5	28.8	18.371
40.2	16.8	2.929	69.9	30.1	18.954
42.6	18.1	4.33	70	33.2	26.198
44	19.1	4.842	70	30.5	23.21
44.2	19	4.302	70	30.3	17.082
47.5	21.2	6.684	70.2	30.1	20.816
48.1	21.2	6.849	70.7	31.7	24.445
49.5	21.1	6.117	71	30.5	18.612
53.1	23.2	7.527	71	30.5	21.043
54.5	24.6	9.74	71	30.7	33.21
55.8	24.7	10.607	71.4	30.1	20.113
57.2	24.6	10.391	71.8	29.5	19.702
57.5	24.1	11.009	72	31.6	23.873
57.9	24.1	9.96	72.2	31.6	18.608
58	25.3	11.257	72.5	29.8	19.059
58.1	25.7	12.058	72.5	31.1	20.522
59	25.2	11.911	72.8	30.3	20.133
59.1	26.2	11.692	73.1	30.7	21.868
59.8	25.6	11.852	73.2	31.3	20.292
60	26.4	12.324	74	31.2	21.566
60.3	26.2	12.39	74	32.8	23.568
60.5	25.6	13.249	74.1	33.1	21.959
60.9	26.8	13.75	74.2	31.4	23.199
62	26.1	13.278	74.5	31.6	24.093
62.5	27	14.325	75	32.2	24.515
62.7	27.8	15.798	75.5	33.6	24.314
62.8	27.4	14.766	75.5	32.3	25.523
62.8	27.8	16.188	75.8	32.7	24.066
63.4	29.1	14.668	75.9	31.1	20.655
63.5	28.5	14.03	76.1	32.2	24.809
63.7	27.8	13.642	76.2	32.6	23.703
64	26.4	15.089	76.5	33.2	25.955
64.4	29	17.165	76.9	33.3	27.213
64.8	23.7	16.682	77	33.4	26.637
64.9	28.2	14.58	77	32.4	25.179
65.6	28.4	16.814	77.1	33.2	25.079
65.7	29.1	17.312	77.1	33.4	26.768
66.4	30.3	18.518	77.5	33.1	25.636
66.7	29.2	18.426	78.1	33.1	26.619
67.5	29	17.203	78.7	33.1	23.916
67.7	28.2	17.94	79	32.8	27.21
68.4	29.2	18.823	79.2	32.8	26.509
68.6	30.5	19.02	79.6	34.7	26.167
68.7	30.8	20.327	79.8	34.3	28.107
68.7	29.1	18.625			

CW= carpace width in mm; CL=carapace length in mm; weight in g.

TABLE 4.2.
***P. sanguinolentus* males carapace width/ carapace length-body weight data.**

	Cw	CL	Weight	CW	CL	Weight
80	33.3		25.386	125	53.2	121.615
80.1	34.1		27.177	125	53.7	122.144
82.1	35.9		33.451	126	53.2	131.103
82.4	35.9		34.188	127	53	120.386
82.6	36.3		31.163	128	52.3	118.94
83	35.1		30.446	129	56.2	142.941
84	34.8		30.655	130	56.3	150.052
84.1	35.6		27.539	131	56.3	138.75
84.6	36.3		36.264	131	54.5	130.089
85.5	36.5		35.718	132	54	128.5
85.8	35.2		31.879	132	57.3	146.831
86.5	37.2		37.977	132	57.1	150.85
87	35.1		34.326	132	57.1	152.312
89.8	38.2		44.262	132	64.2	132.7
89.9	38.6		42.289	134	57.2	142.306
90	38.2		43.797	134	58.4	153.373
90.5	36.8		36.954	135	57.1	138
91	38.5		40.265	135	54.2	134.078
93.1	38.7		41.77	135	57.2	155.95
93.3	38.8		42.293	136	58.2	164.8
93.9	43.4		68.073	136	55.3	146.913
96.8	42.1		54.38	137	60.2	172.874
98.3	41.3		54.075	138	58.6	162.411
99.1	41.5		54.925	139	55.2	136.176
102	45		66.602	140	59.1	157
104.7	43.3		58.708	141	61.6	170.011
106.5	45.8		75.836	141	58.3	168.175
108	45.8		79.1	142	60.5	178.2
108.4	45.1		74.55	142	59.4	160.5
110	45.1		62.325	143	57.6	145.2
112.1	48.6		88.324	143	60.2	176.508
113.2	48.4		90.785	143	58.4	157.8
113.8	49.1		98.37	144	59.7	173
113.8	47.1		86.707	145	59.2	168.954
114	47.9		89	145	60.2	196.2
116.1	49.1		87.115	146	62.1	197.982
117	48.5		88.64	147	60.7	170.7
119	49.1		100.075	149	63.1	201.7
120.5	52.1		112.364	149	61.7	175.5
121	53		118.971	150	60.8	184.2
122.1	50.3		103.929	152	60.2	164.617
122.8	50.5		106.888	154	62.1	214.406
124	50.5		103.939	154	64.3	206.395

CW=carapace width in mm; CL=carapace length in mm ; weight in g.

TABLE 4.3.

***P. sanguinolentus* females carapace width/ length - body weight data.**

CW	CL	Weight	CW	CL	Weight
80.8	38.4	27.033	115	50	97.5
81.2	34	27.588	115	49.1	99
81.3	34.1	28.795	115	49.1	80.2
81.6	33.1	27.209	116	47.8	85.306
82	38.4	28.39	116	50.2	87.5
83	35.8	27.528	116	47.8	87.432
86	37.2	34.5	116	50.5	101.373
86	37.2	38.951	116	50	83.6
87.4	37.5	43.435	116	50.2	82.5
87.8	36.2	36.26	117	48.2	87.5
88	37.4	39.5	117	56	93.441
89.1	38.3	43.288	118	50	81.417
91	38.4	46	118.2	51.2	108.307
91	38.7	41	120	50.3	86
91	38.5	41.5	120	53.3	92
91	38.4	41	120	50.9	93.494
91	38.5	41.5	120	52.2	84.125
91.6	40.1	47.688	120	50.3	92.5
91.8	38.7	39.696	120	51	96.332
92.7	39.1	40.286	121	52.4	99.5
94	40.3	44.779	123	52.2	91.199
96	44.5	53	123.6	53.3	113.918
97	44.5	57	124	52.4	106.869
97.1	39.8	49.554	124	52.2	88.88
98.1	41.4	50.333	124.3	55.4	111.908
98.2	42.6	53.637	125	53.2	92.323
99.1	44.8	60.595	126	50.4	99.7
100.2	43.7	56.977	126	52.3	117.539
101	44.1	56.39	127	57.5	121
101	44.5	55	128	56.2	132.241
102.5	44.3	52.592	128	55.1	117.2
103	44.2	48.793	128	55	107.286
103.7	44	63.568	129	57.5	120.2
104	44.7	51	130	54.5	106.609
106.2	46.6	72.66	130	54.9	115.2
107	46.2	61.67	131.5	56.1	125.065
108	46.5	57.5	134.5	56.4	127.378
111	46.5	79.5	137	58.1	137.552
111	46.2	74.404	137	58.5	136.273
112	47.7	83.5	140	60.1	133.594
113	48.8	83.095	143	60.1	152.7
114	48.2	90.5	146	60.2	164.5

CW= carapace width in mm; CL=carapce length in mm; weight in g.

TABLE 4.4.
***P. pelagicus* juveniles carpace width/carapace length -body weight relationship.**

CW	CL	Weight	CW	CL	Weight
54	24.1	9.125	69.5	28.7	15.422
54.3	24.8	9.044	69.5	29.1	17.027
57.1	25.3	10.745	70	29.6	19.371
57.2	25.1	10.286	70	28.5	15.742
58	25	9.048	70.2	30.2	19.238
58.1	24.6	10.004	70.3	31.2	21.643
58.2	25.8	9.764	70.5	29.7	17.392
58.2	26.2	11.691	70.6	29.1	17.466
58.7	27.1	12.051	71	29.4	18.476
59.1	25.2	11.243	71	29.3	18.343
59.5	26.1	11.585	71.1	29.8	17.992
59.5	26.7	11.348	71.1	30	19.15
60.3	26.1	11.63	71.3	27.5	21.975
61.1	26.2	11.473	71.6	28.8	16.77
61.7	27.1	12.147	71.8	31.1	20.491
62.4	27	13.887	72	30.5	16.025
63.1	26.1	11.227	72.2	31.4	19.848
64.1	29.1	14.493	72.3	31.6	22.45
64.1	27.1	13.8	72.7	31.5	21.078
64.1	30.1	15.78	73.2	32.1	24.02
64.5	27.4	12.843	74.3	31.5	22.547
65	28.6	15.76	75	31.9	20.535
65.1	28.8	14.618	75.5	32.6	25.011
65.1	28	13.851	75.6	32.8	23.565
65.2	27.4	14.41	75.8	32.3	24.574
65.5	28.2	16.192	75.8	32.1	22.366
65.6	29.8	16.021	76.4	31.2	22.86
65.9	28.3	15.534	76.5	33.2	21.004
66.1	29.3	15.802	77	32.8	23.152
67.1	28	13.853	77	32.5	22.625
67.1	28.2	15.243	77.1	32.8	25.106
67.3	28	16.422	77.1	32.6	24.02
67.5	28.8	15.237	77.8	32.2	24.912
67.8	29.2	16.189	78	34.1	24.293
68	27.5	15.233	78	33.8	25.254
68.1	28.5	15.219	78	33.4	25.677
68.1	29.7	16.962	78.2	34.4	24.856
68.1	29.1	14.943	78.2	33.2	25.08
68.2	29.7	18.265	79	33	24.927
68.3	29	18.546	79	33.3	25.585
68.5	29.3	17.346	79.2	33.2	25.903
68.5	28.8	16.77	79.5	33.2	27.881
68.6	28.2	14.87	79.6	33.8	25.78
68.7	28.1	16.527	79.7	34.2	26.996
68.7	29.2	16.767	79.8	33	22.755
68.9	29.1	17.404	79.9	34.1	26.3
69.2	30.1	19.16			
69.2	29.2	17.853			
69.3	27.8	18.24			

CW=carapace width in mm; CL=carapace length in mm ; weight in g.

TABLE 4.5.
***P. pelagicus* male carapace width/ carapace length - body weight data.**

CW	CL	Weight	CW	CL	Weight
81.1	33.2	23.292	98.5	41.6	48.982
81.2	33.9	28.25	99	44	51.527
81.5	35.7	27.57	99	41.6	53.527
81.7	44.2	29.719	99.1	42.6	54.075
82	35	30.377	99.2	42.1	52.067
82.1	35.3	29.67	100.4	42.3	52.475
82.1	34.2	29.242	101.1	42.5	53.874
82.1	35.2	30.772	102.2	42.7	54.887
82.3	34.5	29.226	103	43.2	59.158
83.2	36.5	34.387	103.8	48.9	59.367
83.5	34.1	22.133	104.4	43.8	56.152
83.6	35.5	30.043	105.1	45.5	64.954
83.7	36	37.655	106	45	58.44
84.5	36.3	32.507	108	46.1	60.898
84.8	35.4	31.575	109	44.5	59.547
84.9	34.6	29.662	109	48	65.802
85	36.5	28.803	110.2	46.2	67.03
85.1	36.1	32.858	110.2	47.1	75.72
85.6	36.8	35.188	110.5	46.1	70.264
86.1	35.1	33.722	113	48.8	73.884
86.2	36.6	32.678	114	49.4	86.06
87	36.5	31.19	114.1	50.6	95.513
87	35.8	26.652	114.8	51.8	90.632
87.1	36.5	34.16	117.9	61.1	100.274
87.1	36.4	33.66	118.2	53.4	140.22
88	37.2	34.446	121	53.5	122.023
88.1	35.1	32.519	124	54	109.527
88.2	29.3	17.702	124	56.3	118.76
88.2	38.1	38.053	126	54.8	130.609
89.3	37.2	35.937	127	54.5	119.832
89.5	38.2	37.789	127	56.1	143.431
89.5	36.4	37.655	128	56.4	153.502
90.1	42.1	52.144	128	57.1	143.171
90.2	39.1	42.303	130	58.5	157.28
90.5	38.2	38.394	131	57.1	149.16
91.4	39.7	43.474	132	60.5	173.053
91.8	38.6	30.958	135	60.5	166.408
92.1	40.1	39.75	137	62.1	182.86
92.5	39.9	44.81	141	64.3	224.986
93.8	38.2	39.39	141	63.9	199.122
94	40.2	39.075	141	63.2	186.576
94.1	40.8	39.747	143	66.7	214.389
94.5	39.5	45.246	147	67.1	248.785
94.6	40	42.066	147	67.3	241.996
95	41.2	48.548	147	66.2	216.37
95.1	42.2	52.004	147	67.1	240.525
95.5	40.1	41.946	148	67.3	236.687
96.5	40.5	42.117	152	72.2	262.951
97	43.3	57.77	153	68.2	275.132
97	42.2	53.611	153	68.4	260.013
97.5	42.3	53.643	156	65.2	215.703
97.5	40.5	42.009	157	71.1	259.608
97.6	42.1	51.94	158	72.1	295.73
97.7	40.2	46.55	159	71.8	292.03
98.2	42.5	50.338	167	74.3	270.827
98.2	42.1	49.8			

TABLE 4.6.

***P. pelagicus* females carapace width/carapace length - body weight data.**

CW	CL	Weight	CW	CL	Weight
80.2	34.0	25.822	95.0	39.2	39.652
81.0	34.4	25.701	95.1	41.1	47.596
82.3	35.1	27.582	95.3	40.2	45.425
82.5	35.0	30.206	95.3	40.8	50.347
83.0	35.7	30.984	95.4	39.4	41.134
83.3	33.4	27.821	96.0	40.5	44.358
83.4	34.8	29.540	96.1	40.6	44.242
83.7	34.5	28.238	96.6	41.8	52.251
84.0	35.1	29.093	96.7	40.8	45.473
84.0	34.2	29.463	97.6	40.8	48.170
84.1	35.6	32.608	98.2	41.5	49.646
84.2	35.1	31.325	99.0	41.5	47.725
84.2	35.7	30.701	99.0	40.7	44.450
84.4	36.5	34.451	99.9	43.2	54.522
84.4	34.1	30.926	100.0	42.2	47.653
84.7	34.2	28.160	101.1	42.5	54.655
85.0	36.2	30.505	102.4	42.5	55.240
85.3	35.5	31.789	103.0	45.0	64.616
85.4	35.5	31.722	103.1	44.5	58.131
85.6	35.7	30.176	103.8	43.2	54.180
85.6	35.9	32.516	104.1	44.8	63.076
87.1	35.6	31.845	104.7	44.5	61.235
87.5	36.8	30.017	104.9	44.1	63.302
87.5	37.1	34.027	105.1	43.2	55.807
87.6	36.2	33.287	105.4	44.5	65.602
88.2	37.5	35.291	108.1	46.3	63.161
88.2	36.7	35.256	110.0	47.5	62.496
88.3	37.1	35.802	110.0	46.1	62.130
88.9	38.2	39.037	111.0	46.2	71.274
89.0	36.9	34.150	111.2	46.1	67.184
89.1	37.2	37.405	111.4	47.2	71.541
89.1	37.2	36.109	112.0	46.5	51.299
89.1	38.2	40.268	113.2	48.8	87.428
89.3	36.8	35.409	114.0	49.5	70.712
89.6	38.7	37.799	114.0	48.1	77.756
89.7	37.1	38.893	114.9	48.8	78.341
89.8	42.8	49.806	115.8	50.5	91.470
89.9	37.8	40.338	117.0	50.5	87.834
90.0	37.5	37.103	117.1	49.8	80.132
90.1	37.7	38.626	117.1	48.8	74.630
90.3	38.1	37.567	119.0	51.0	94.367
90.8	37.1	39.421	120.0	52.5	82.853
90.9	38.2	36.455	121.0	54.4	115.086
91.2	37.7	33.417	122.4	53.3	102.380
92.1	38.7	41.092	140.0	64.1	182.770
92.7	39.1	43.548	143.0	62.7	152.457
93.2	39.1	41.756	144.0	62.4	180.606
93.2	38.2	41.862	149.0	65.8	205.887
93.6	39.1	42.981	152.0	66.8	190.457
93.8	39.1	42.258	155.0	74.1	254.590
94.1	39.3	42.436	157.0	71.1	254.154
94.2	39.4	42.096	161.0	73.8	270.401
94.7	39.2	42.561	173.0	76.6	317.256

CW=carapace width in mm; CL=carapace length in mm; weight in g.

TABLE 4.7.
Average and SD of carapace width, carapace length and total weight in different size groups of *P. sanguinolentus* juveniles.

Sl.No.	Size group (mm)	N	Carapace width (mm)	Carapace length (mm)	Weight (g)
1	30-35	13	32.1 ± 1.61	14.6 ± 0.20	2.48 ± 0.96
2	35-40	15	37.5 ± 1.60	16.8 ± 0.63	3.16 ± 0.55
3	40-45	12	42.1 ± 1.29	18.4 ± 0.60	4.46 ± 0.61
4	45-50	11	47.6 ± 1.43	21.2 ± 0.52	6.17 ± 0.29
5	50-55	13	52.7 ± 1.47	23.5 ± 0.68	8.36 ± 1.01
6	55-60	17	56.9 ± 1.56	25.3 ± 0.98	11.09 ± 0.81
7	60-65	23	62.6 ± 1.53	27.1 ± 1.42	14.21 ± 1.62
8	65-70	23	67.7 ± 1.51	29.0 ± 1.65	17.51 ± 1.34
9	70-75	24	72.3 ± 1.54	30.9 ± 0.91	21.17 ± 2.01
10	75-80	22	77.1 ± 1.44	33.0 ± 0.74	25.57 ± 1.60

TABLE 4.8.
Average and SD of carapace width, carapace length and total weight in different size groups of *P. sanguinolentus* males.

Sl.No.	Size group (mm)	N	Carapace width (mm)	Carapace length (mm)	Weight (g)
1	80-85	9	82.54 ± 1.64	35.25 ± 1.03	30.697 ± 3.56
2	85-90	7	87.66 ± 1.90	37.00 ± 1.45	38.714 ± 5.05
3	90-95	6	91.97 ± 1.66	39.07 ± 2.24	45.525 ± 11.29
4	95-100	4	97.30 ± 1.81	41.23 ± 0.88	54.460 ± 0.43
5	100-105	3	102.57 ± 1.91	42.93 ± 2.97	62.656 ± 5.58
6	105-110	5	106.78 ± 1.41	45.10 ± 0.73	76.495 ± 2.35
7	110-115	7	112.41 ± 1.77	45.57 ± 1.36	90.638 ± 4.56
8	115-120	3	117.37 ± 1.48	48.97 ± 0.42	91.944 ± 7.08
9	120-125	7	121.49 ± 1.53	50.46 ± 1.71	109.218 ± 6.45
10	125-130	7	126.43 ± 1.62	53.26 ± 1.53	126.188 ± 9.26
11	130-135	10	131.90 ± 1.37	57.24 ± 2.78	142.576 ± 9.55
12	135-140	8	136.38 ± 1.51	57.00 ± 2.01	151.400 ± 14.71
13	140-145	9	142.11 ± 1.27	59.42 ± 1.24	165.155 ± 10.80
14	145-150	6	146.83 ± 1.83	61.17 ± 1.41	185.173 ± 14.99
15	150-155	4	152.50 ± 1.91	61.85 ± 1.82	192.404 ± 22.50

TABLE 4.9.
Average and SD of carapace width, carapace length and total weight
in different size groups of *P. sanguinolentus* females.

Sl.No.	Size group (mm)	N	Carapace width (mm)	Carapace length (mm)	Weight (g)
1	80-85	6	81.65 ± 0.77	34.42 ± 2.32	27.794 ± 0.74
2	85-90	4	87.72 ± 0.98	37.20 ± 0.91	40.483 ± 3.50
3	90-95	8	92.03 ± 0.59	39.40 ± 0.89	42.557 ± 4.45
4	95-100	4	98.18 ± 0.90	42.15 ± 2.11	53.530 ± 5.03
5	100-105	4	101.90 ± 1.59	43.70 ± 0.65	59.132 ± 3.27
6	105-110	4	107.22 ± 0.84	46.20 ± 0.29	72.590 ± 2.02
7	110-115	6	112.33 ± 1.15	47.57 ± 1.31	73.056 ± 10.78
8	115-120	11	116.65 ± 1.59	50.00 ± 0.98	91.784 ± 8.85
9	120-125	6	122.10 ± 2.02	52.32 ± 1.93	96.540 ± 11.31
10	125-130	5	127.71 ± 1.25	54.84 ± 2.68	118.893 ± 8.93
11	130-135	4	131.50 ± 2.12	56.38 ± 1.32	124.563 ± 9.56
12	135-140	8	137.33 ± 0.58	58.43 ± 0.31	136.691 ± 0.75
13	140-145	2	141.50 ± 2.12	60.60 ± 0.71	143.147 ± 13.51

TABLE 4.10
Average and SD of carapace width, carapace length and total weight
in different size groups of juveniles of *P. pelagicus*.

Sl.No	size group (mm)	No.	Carapace width (mm)	Carapace length (mm)	Total weight (g)
1	30-35	5	32.4 ± 0.97	14.7 ± 0.15	2.08 ± 0.16
2	35-40	5	37.8 ± 1.13	17.3 ± 0.94	3.39 ± 0.34
3	40-45	6	42.6 ± 1.75	18.9 ± 0.41	4.08 ± 0.40
4	45-50	9	46.7 ± 1.33	20.8 ± 1.05	5.50 ± 0.54
5	50-55	8	53.0 ± 1.51	23.9 ± 0.70	9.79 ± 0.64
6	55-60	17	57.6 ± 1.45	25.3 ± 1.03	10.58 ± 0.97
7	60-65	14	62.9 ± 1.48	27.1 ± 1.55	12.83 ± 1.56
8	65-70	31	67.5 ± 1.51	28.7 ± 0.71	16.07 ± 1.36
9	70-75	23	71.8 ± 1.36	30.6 ± 1.76	19.41 ± 2.05
10	75-80	33	77.6 ± 1.52	33.2 ± 0.91	23.72 ± 1.81

TABLE 4.11
Average and SD of carapace width, carapace length and total weight
in different size groups of *P. pelagicus* males.

Sl. No.	Size group (mm)	No.	Carapace width (mm)	Carapace length (mm)	Total weight (g)
1	80-85	18	82.69 ± 1.25	35.50 ± 2.35	29.43 ± 3.12
2	85-90	17	87.44 ± 1.52	36.21 ± 1.94	32.69 ± 5.04
3	90-95	19	91.80 ± 1.67	39.61 ± 0.99	41.44 ± 5.05
4	95-100	21	97.30 ± 1.46	41.91 ± 1.41	50.03 ± 4.58
5	100-105	10	101.99 ± 1.58	43.59 ± 1.94	55.99 ± 2.81
6	105-110	6	107.27 ± 1.64	45.87 ± 1.21	61.93 ± 3.28
7	110-115	8	111.75 ± 1.91	48.30 ± 1.76	78.92 ± 11.76
8	115-120	10	118.12 ± 2.77	51.34 ± 4.13	101.25 ± 28.17
9	120-125	7	122.14 ± 1.46	54.48 ± 1.24	111.76 ± 0.34
10	125-130	6	126.83 ± 1.17	55.78 ± 1.10	138.00 ± 11.67
11	130-135	5	131.20 ± 0.84	58.44 ± 1.92	159.83 ± 12.15
12	135-140	4	137.00 ± 1.63	61.60 ± 0.74	177.26 ± 9.40
13	140-145	9	141.33 ± 0.87	64.83 ± 1.34	202.15 ± 13.42
14	145-150	5	147.20 ± 0.45	67.02 ± 0.47	236.87 ± 12.27
15	150-155	4	152.50 ± 0.58	69.55 ± 1.84	266.03 ± 8.02
16	155-160	4	157.60 ± 1.14	70.05 ± 3.26	282.46 ± 19.87

TABLE 4.12.
Average and SD of carapace width, carapace length and total weight
in different size groups of *P. pelagicus* females.

Sl. No.	Size group (mm)	No.	Carapace width (mm)	Carapace length (mm)	Total weight (g)
1	80-85	24	83.01 ± 1.54	35.03 ± 1.00	29.54 ± 2.33
2	85-90	27	87.48 ± 1.64	36.79 ± 0.88	34.84 ± 3.26
3	90-95	18	92.33 ± 1.69	38.78 ± 1.19	40.04 ± 3.00
4	95-100	14	96.88 ± 1.63	40.86 ± 0.99	46.80 ± 4.08
5	100-105	8	102.72 ± 1.76	43.60 ± 1.13	57.84 ± 4.87
6	105-110	4	107.46 ± 1.65	44.78 ± 1.29	61.48 ± 5.24
7	110-115	10	112.59 ± 1.71	47.48 ± 1.27	72.04 ± 7.56
8	115-120	8	116.86 ± 1.32	49.85 ± 0.81	87.85 ± 10.49
9	120-125	4	121.71 ± 1.43	53.28 ± 0.82	100.68 ± 13.26
10	125-130	6	126.57 ± 1.62	56.43 ± 3.27	114.09 ± 22.28
11	130-135	4	131.50 ± 1.29	58.28 ± 1.86	149.46 ± 32.93
12	135-140	7	137.00 ± 1.55	61.33 ± 3.63	159.84 ± 19.37
13	140-145	14	141.86 ± 1.35	62.59 ± 2.11	177.17 ± 23.62
14	145-150	9	147.50 ± 1.44	64.63 ± 2.06	205.78 ± 26.83
15	150-155	6	151.59 ± 1.59	65.53 ± 2.13	207.04 ± 9.21
16	155-160	7	156.55 ± 1.71	70.67 ± 1.80	254.62 ± 19.72
17	160-165	3	161.33 ± 1.21	71.03 ± 3.22	257.27 ± 15.46

TABLE 4.13.

Regression output for the carapace width/ carapace length - body weight relationship in *P. sanguinolentus*.

	Carapace width-Body weight			Carapace length-Body weight		
	Juveniles	Males	Females	Juveniles	Males	Females
Constant	-4.29131	-4.440683	-4.181464	-3.25558	-3.400819	-3.081659
Std Err of Y Est	0.042079	0.041625	0.038951	0.046499	0.033158	0.049066
R Squared	0.974328	0.977131	0.964351	0.968513	0.985488	0.943433
No. of Observations	97	86	84	97	86	84
Degrees of Freedom	95	84	82	95	84	82
X Coefficient(s)	3.026118	3.099690	2.960443	3.074684	3.171573	2.953153
Std Err of Coef.	0.05396	0.051739	0.062856	0.056748	0.041991	0.079855

TABLE 4.14.

Regression output for carapace width/carapace length - body weight relationship in *P. pelagicus*.

	Carapace width-Body weight			Carapace length-Body weight		
	Juveniles	Males	Females	Juveniles	Males	Females
Constant	-4.045736	-5.494555	-4.786672	-3.32701	-3.453287	-3.051902
Std Err of Y Est	0.033190	0.056404	0.037444	0.038336	0.052617	0.027985
R Squared	0.931881	0.970253	0.976566	0.90912	0.974113	0.986910
No. of Observations	95	111	106	95	111	106
Degrees of Freedom	93	109	104	93	109	104
X Coefficient(s)	2.873327	3.616762	3.252738	3.106021	3.178652	2.931174
Std Err of Coef.	0.080555	0.060656	0.049408	0.101831	0.049631	0.033101

TABLE 4.15.**Linear and parabolic relationship of carapace width/length and weight in *P.sanguinolentus*.**

Measurements	Logarithmic equation	Parabolic equation
Juveniles		
Carapace width and weight	Log W= -4.2913+3.02612 Log L	W= 0.0000511 L ^{3.02612}
Carapace length and weight	Log W= -3.2556+3.07468 Log L	W= 0.0005552 L ^{3.07468}
Adults (males)		
Carapace width and weight	Log W= -4.4407+3.09969 Log L	W= 0.0000362 L ^{3.09969}
Carapace length and weight	Log W= -3.4008+3.17157 Log L	W= 0.0003974 L ^{3.17157}
Adults (females)		
Carapace width and weight	Log W= -4.1815+2.96044 Log L	W= 0.0000658 L ^{2.96044}
Carapace length and weight	Log W= -3.0816+2.95315 Log L	W= 0.0008287 L ^{2.95315}

TABLE 4.16.**Linear and parabolic relationship of carapace width/length and weight in *P.pelagicus*.**

Measurements	Logarithmic equation	Parabolic equation
Juveniles		
Carapace width and weight	Log W= -4.04573+2.87333 Log L	W= 0.0000900 L ^{2.87333}
Carapace length and weight	Log W= -3.32701+3.10602 Log L	W= 0.0004709 L ^{3.10602}
Adults (males)		
Carapace width and weight	Log W= -5.49455+3.61676 Log L	W= 0.0000032 L ^{3.61676}
Carapace length and weight	Log W= -3.45328+3.17865 Log L	W= 0.0003521 L ^{3.17865}
Adults (females)		
Carapace width and weight	Log W= -4.78667+3.25274 Log L	W= 0.0000163 L ^{3.25274}
Carapace length and weight	Log W= -3.05190+2.93117 Log L	W= 0.0008874 L ^{2.93117}

TABLE 4.17.

Sum of Squares and Products, Corrected Sum of Squares and Products, Regression Coefficients and deviation from regression and Analysis of Covariance of carapace width and weight data of males and females of *P. sanguinolentus*.

Sex	N	SX	SY	SX ²	SY ²	SXY	
Males	86	177.7408	169.0428	367.9938	338.6373	351.3761	
Females	84	171.0402	155.1118	348.6549	289.9148	316.9745	
		Sum of Squares			Errors of estimate		
Sex	D.F.	x ²	y ²	xy	B	D.F.	S.S.
Males	85	0.6474	6.3644	2.0063	3.0990	84	0.1469
Females	83	0.3841	3.4902	1.1370	2.9604	82	0.1245
						166	0.2714
Pooled	168	1.0315	9.8546	3.1433	3.0473	167	0.2760

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	Observed F	5%F
Deviation from individual regression with in sexes	166	0.2714	0.001635		
Difference between regression	1	0.0046	0.0046	2.1835*	3.90
Deviation from average regression	165	0.276			

* not siglificant at 5% level.

SX, SY = Sum of logarithmic values of C.width and weight respectively;

SX²,SY² and SXY = Sum of Squares and Products;

D.F. = Degrees of freedom; x²,y²,xy = corrected Sum of Squares and Products;

B = regression coefficient; S.S. = Sum of squares

TABLE 4.18.

Sum of Squares and Products, Corrected Sum of Squares and Products, Regression Coefficients and deviation from regression and Analysis of Covariance of Carapace width and weight data of males and females of *P.pelagicus*.

Sex	N	SX	SY	SX ²	SY ²	SXY	
Males	111	224.2796	201.2703	454.0299	376.6155	409.8015	
Females	106	211.7165	181.2710	423.4411	316.2149	363.9255	
		Sum of Squares			Errors of estimate		
Sex	D.F.	x ²	y ²	xy	B	D.F.	S.S.
Males	110	0.8647	11.6629	3.1274	3.6167	109	0.3519
	105	0.5743	6.2227	1.8683	3.2527	104	0.1448
						213	0.4967
Pooled	215	1.4390	17.8856	4.9957	3.4716	214	0.5423

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	Observed F	5%F
Deviation from individual regression with in sexes	213	0.4967	0.002332		
				19.5540*	3.87
Difference between regression	1	0.0456	0.00456		
Deviation from average regression	214	0.5423			

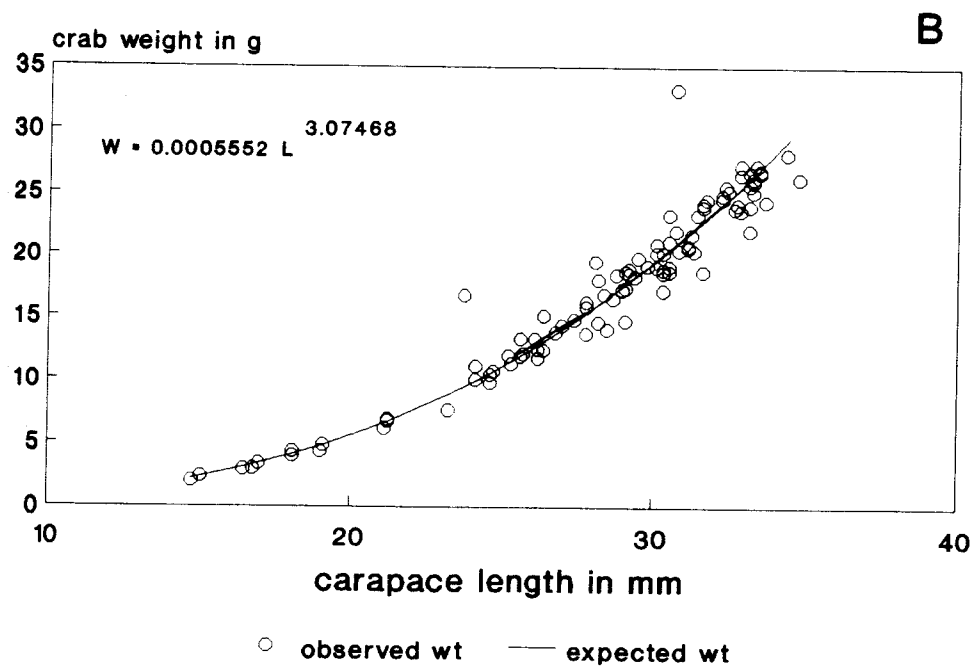
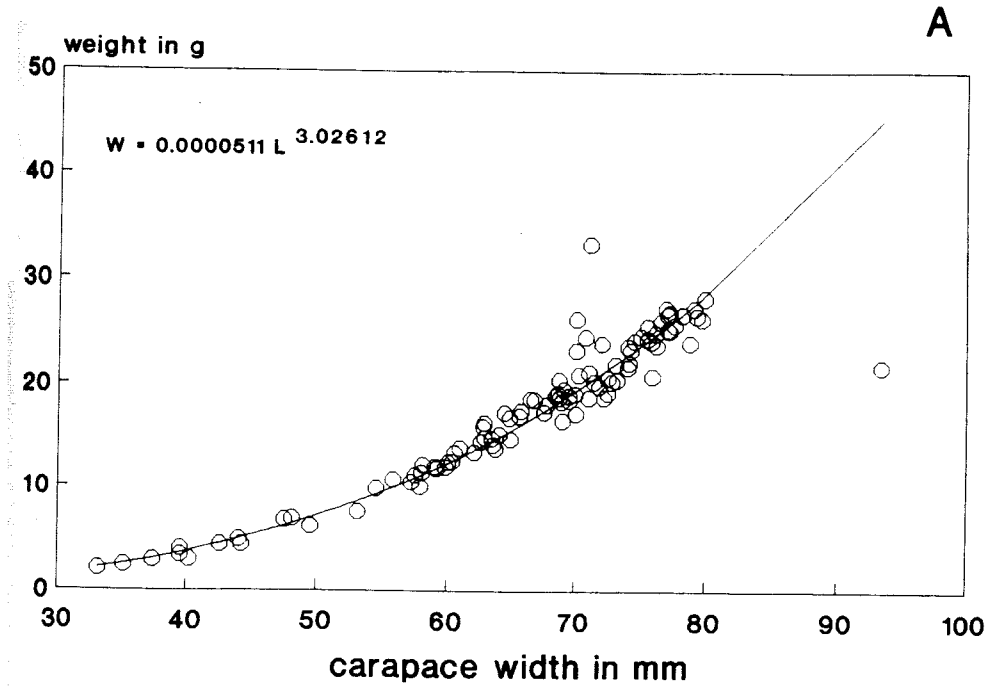
* significant at 5% level.

SX, SY = Sum of logarithmic values of C.width and weight respectively;

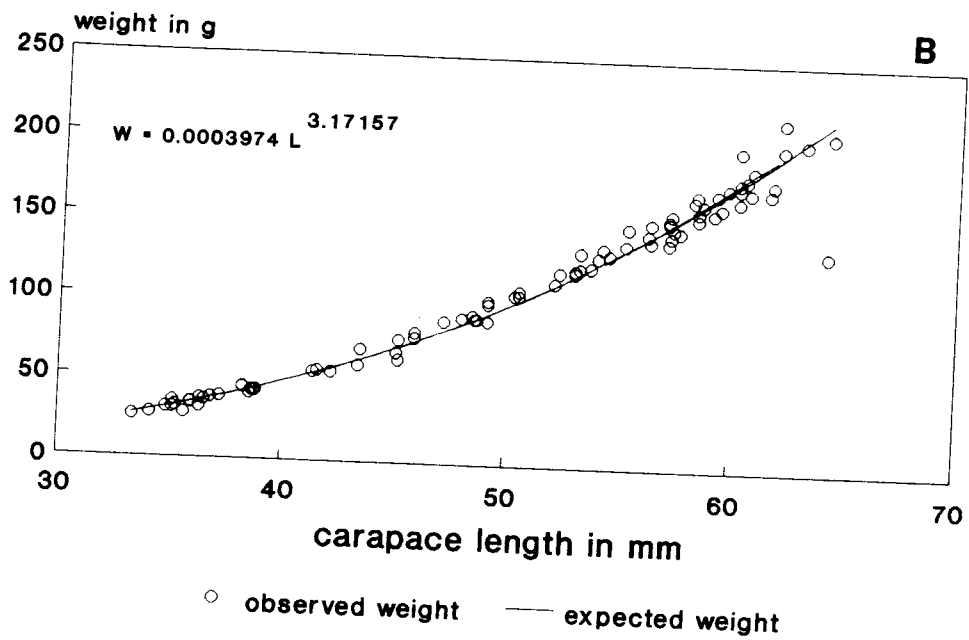
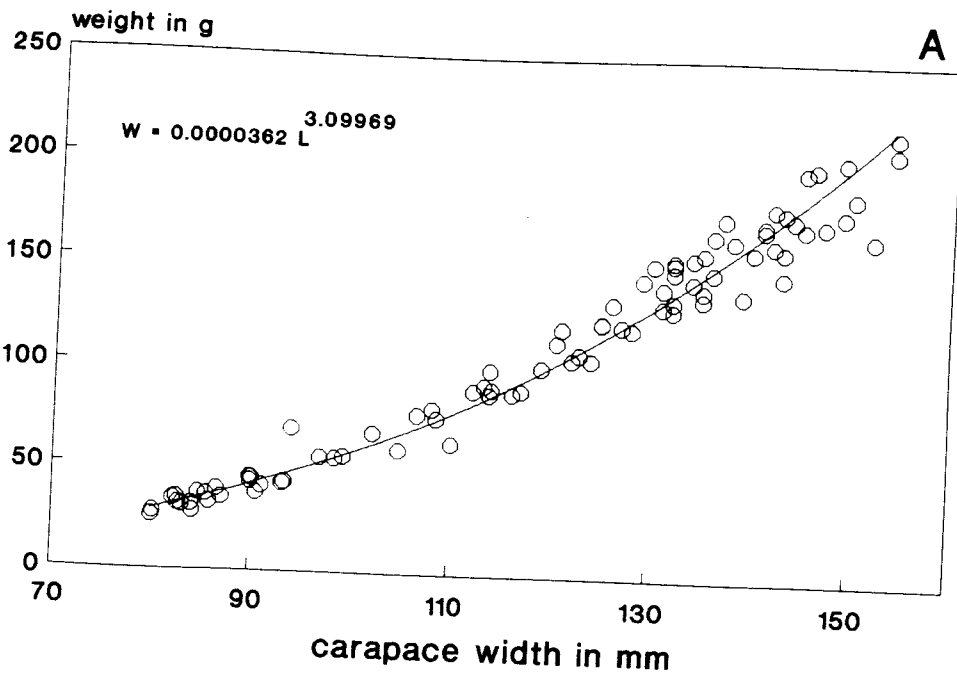
SX²,SY² and SXY = Sum of Squares and Products;

D.F. = Degrees of freedom; x²,y²,xy = corrected Sum of Squares and Products;

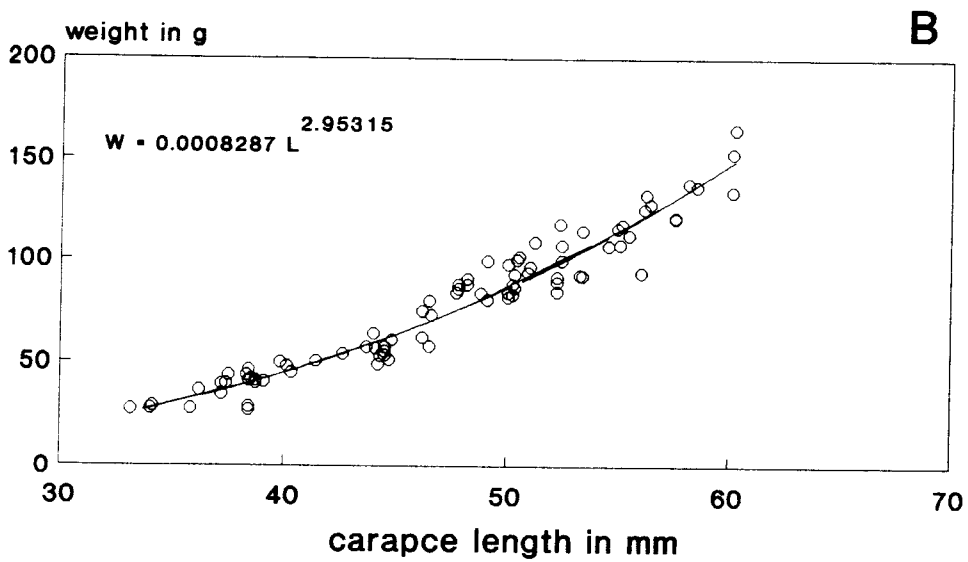
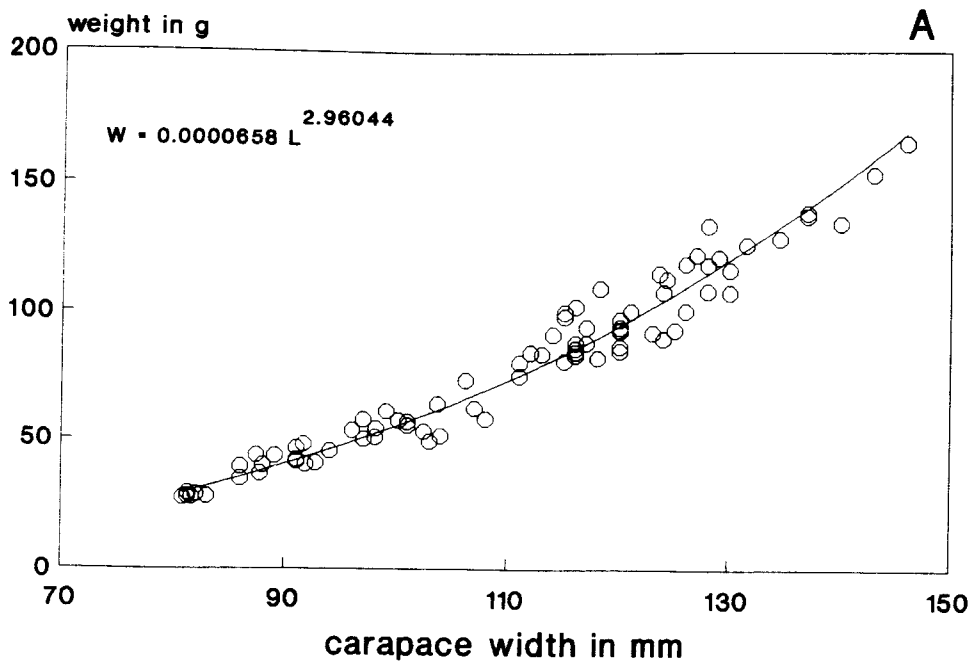
B = regression coefficient; S.S. = Sum of Squares



- j. 4.1.** *P. sanguinolentus* juveniles.
 A - Carapace width - body weight relationship;
 B - carapace length - body weight relationship.

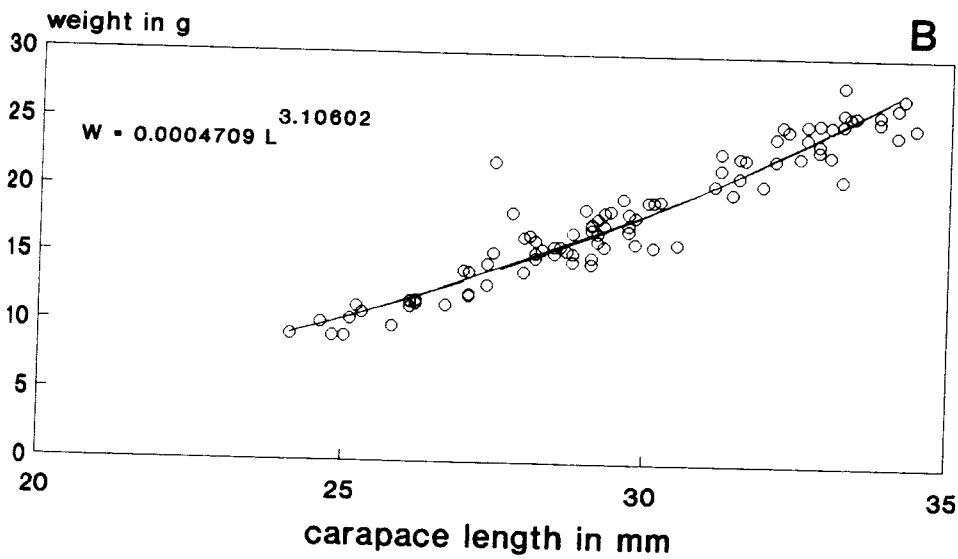
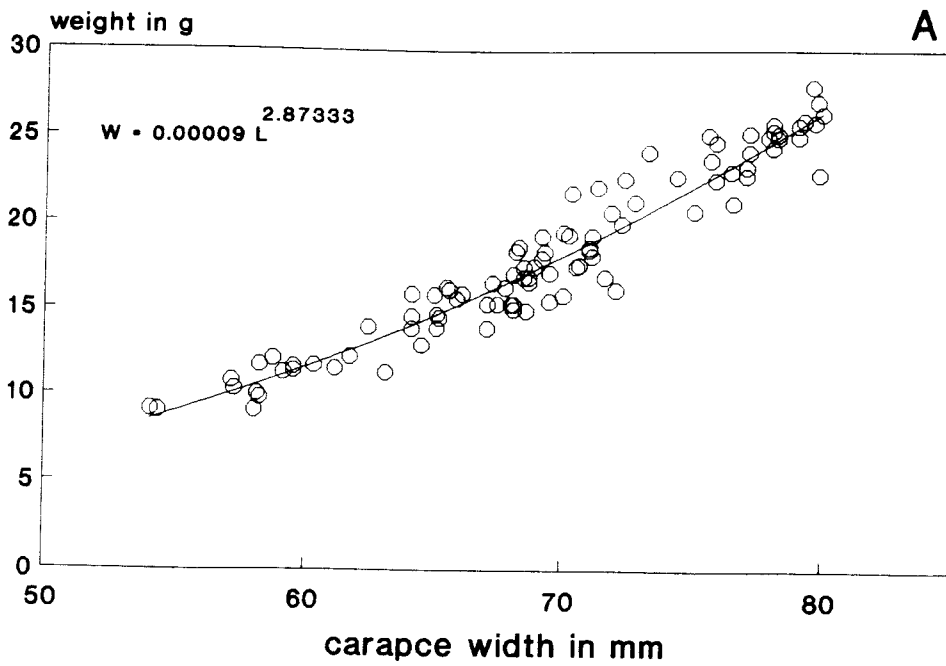


- 4.2. *P. sanguinolentus* males.
 A - Carapace width - body weight relationship;
 B - carapace length - body weight relationship.



○ observed weight — expected weight

g. 4.3. A - *P. sanguinolentus* females. Carapace width - body weight relationship;
 B - carapace length - body weight relationship.



○ observed weight — expected weight

- 4.4. *P. pelagicus* juveniles.
 A - Carapace width - body weight relationship;
 B - carapace length - body weight relationship

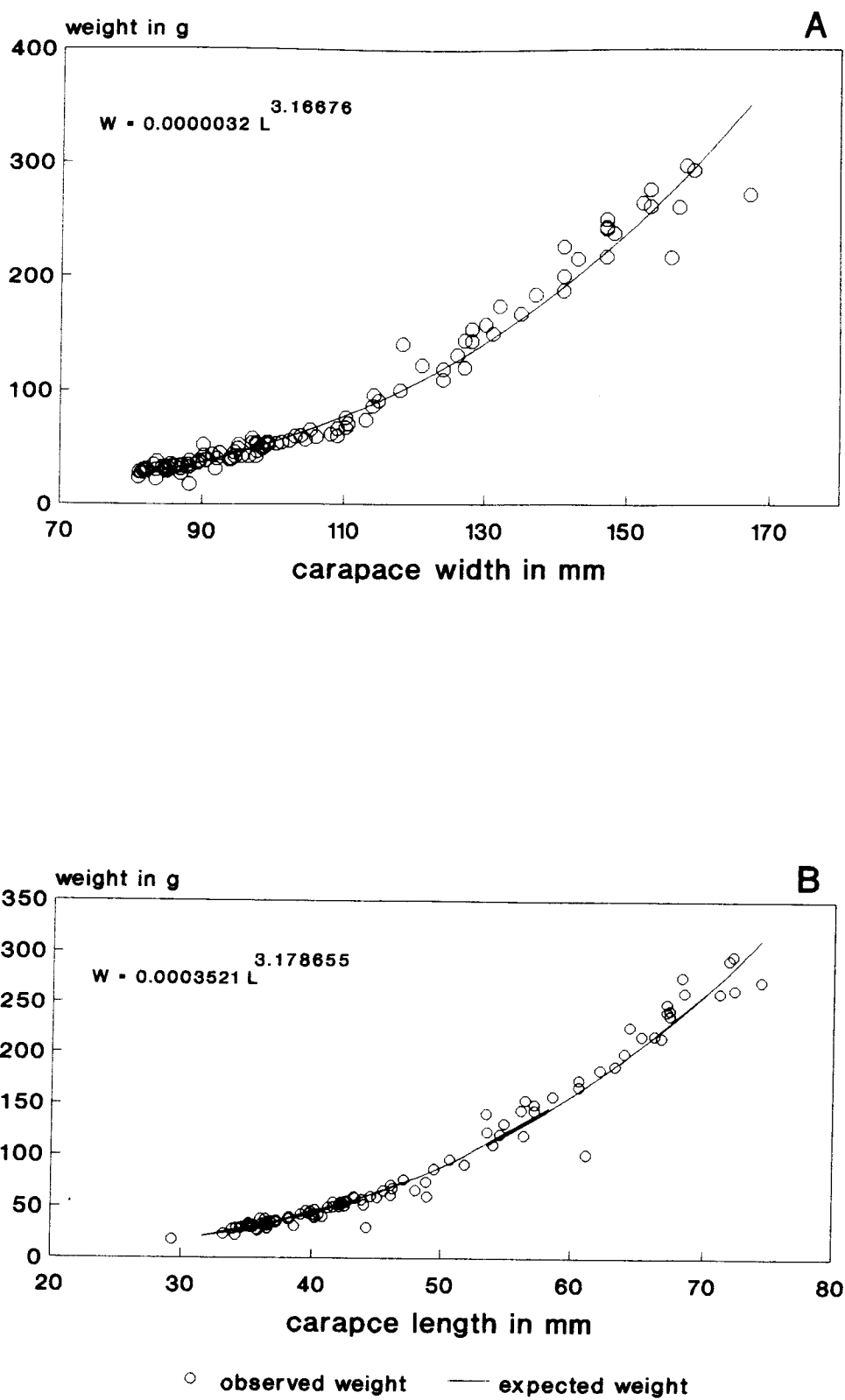
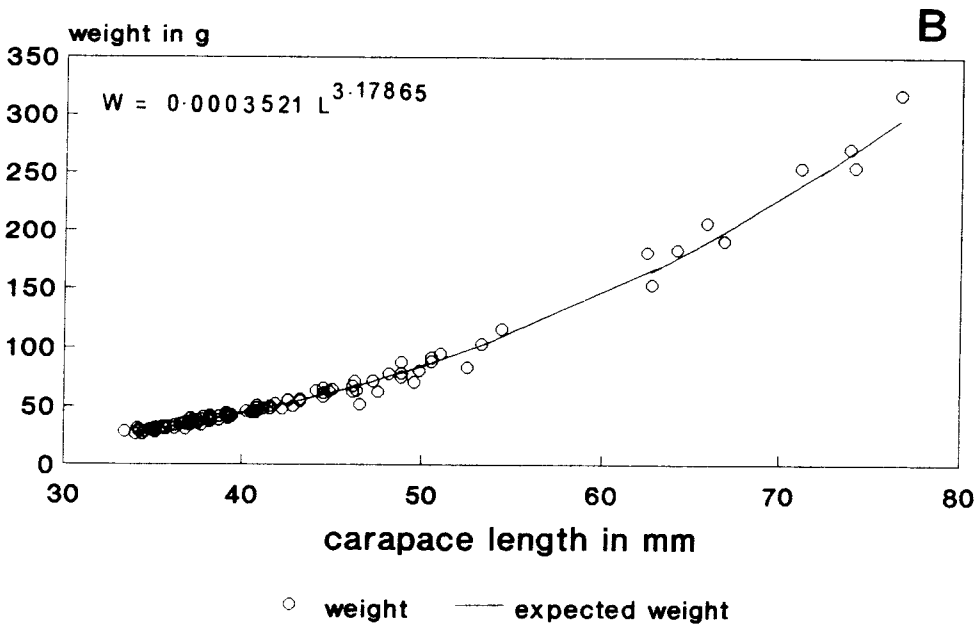
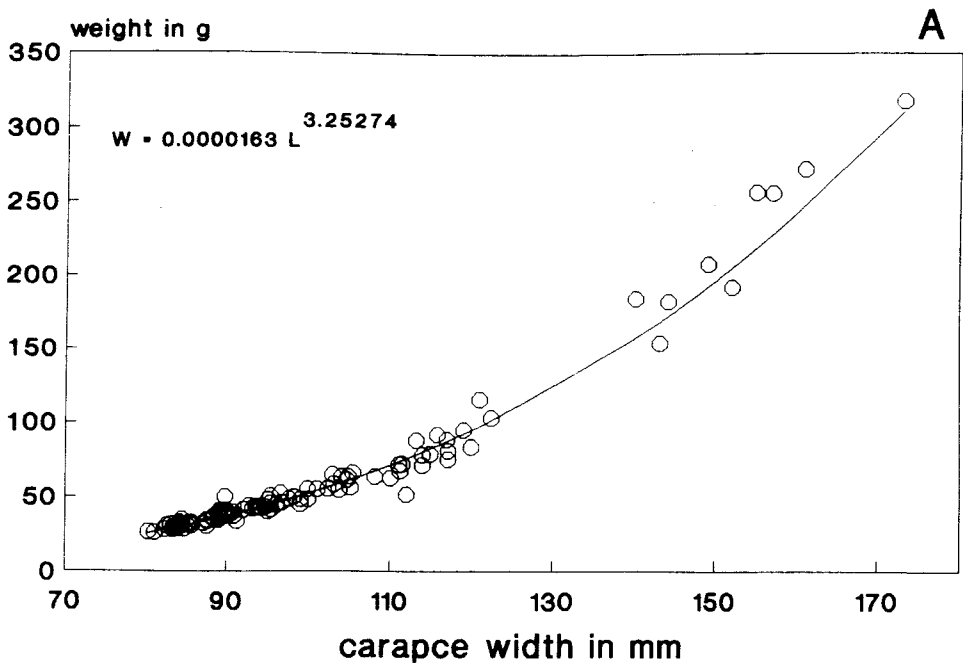


Fig. 4.5. *P. pelagicus* males.
 A - Carapace width - body weight relationship;
 B - carapace length - body weight relationship.



g. 4.6. *P. pelgicus* females.
 A - Carapace width -body weight relationship,
 B - carapace length - body weight relationship.

ing of
 turity,
 ction,
 ulture

s are
 1947;
 1970;
 utler,
 942),
 991),

ectus
Uca
 940;
 land
 89a,
 94),
 irth,

d *P.*
 lese
 De

Chapter V
REPRODUCTION

REPRODUCTION

INTRODUCTION

Studies on the reproductive biology are important for a better understanding of annual regeneration of stocks. Reproductive parameters such as size at first maturity, spawning frequency, fecundity and recruitment are of great value in fishery prediction, formulation of management strategies and to increase production through aquaculture practices (Bal and Rao, 1984).

Extensive researches on the reproductive biology of several brachyurans are available. Some of the important studies are on *Callinectes* spp. (Cronin, 1942, 1947; Van Engel, 1958, 1990; Johnson, 1980; Haefner, 1990), *Chionoecetes* spp. (Watson, 1970; Brown and Powell, 1972; Adams, 1982; Beninger *et al.*, 1988), *Cancer* spp. (Butler, 1960; Haefner, 1976; Edwards, 1979; Shields *et al.*, 1991), *Carcinus* spp. (Spalding, 1942), *Chaceon* spp. (Erdman and Blake, 1988; Hines, 1988; Attrill and Harnoll, 1991), *Paralithodes* spp. (Gray and Powell, 1966), *Inachus* spp. (Diesel, 1989), *Bathynectus superbus* (Lewis, 1977), *Sesarma* spp. (Seiple and Salmon, 1987; Emmerson, 1994), *Uca* spp. (Emmerson, 1994), *Ocypoda quadrata* (Haley, 1969), *Scylla serrata* (Arriola, 1940; Estampador, 1949; Hill, 1980, 1994; Hill *et al.*, 1982; Williams and Hill, 1982; Hyland *et al.*, 1984; Haesman *et al.*, 1985; Sheeba, 1988; Prasad and Neelakantan, 1988, 1989a, 1989b, 1990; Jeyalectumi and Subramoniam, 1989; Robertson and Kruger, 1994), *Libinia* spp. (Sumpton, 1990, 1990a; Padayatti, 1990), *Paralomis granulosa* (Hoggarth, 1993; Lovrich and Vinuesa, 1993), and *Necora puber* (Gurriran and Freire, 1994).

Notwithstanding the commercial importance of *Portunus sanguinolentus* and *P. magicus* in their distributional ranges, the information on the spawning biology of these crabs is rather fragmentary and limited to the works of Stead (1898), Delsman and De

an (1925), George (1949), Thompson (1951), Menon (1952), Prasad and Tampi (1953, 1954), Chhapgar (1956), George and Nayak (1961), Rahman (1967), Ryan (1967, 1977a), Chandran (1968), Al-kholy and El-Hawary (1970), Pillay and Nair (1970, 1971, 1976), Radhakrishnan (1979), Aruldas *et al.* (1980), Sukumaran *et al.* (1986), Sumpton *et al.* (1989a, 1994), Campbell and Fielder (1986), Reeby *et al.* (1990, 1990a), and Jacob *et al.* (1990). Most of these studies are only brief accounts on some aspects like relative growth, sexual maturity, maturity stages, sex ratio, mating behaviour, fecundity and spawning from various regions. The present study gives a fairly comprehensive account on the reproductive biology of *Portunus sanguinolentus* and *P. pelagicus* from the Karnataka coast on the central west coast of India.

10. MATERIALS AND METHODS

Portunus sanguinolentus and *P. pelagicus* caught by different gears were sampled from Mangalore, Malpe and Karwar fish landing centres on a regular basis. In the laboratory, the samples were washed thoroughly to remove mud, sand and other epizoic organisms. After sexwise sorting, the samples were analysed for carapace width, weight, sex and maturity conditions.

Altogether 12,285 *P. sanguinolentus* and 7,152 *P. pelagicus* were analysed for the present study.

Crabs were classified as juvenile if the abdominal flap was firmly attached to the carapax (Van Engel, 1958).

Moult condition was determined and grouped into the following three stages based on the degree of hardness according to the subjective system developed by Hiatt (1948) and followed by Sumpton *et al.* (1989a).

- Premoult: New cuticle formed beneath carapace. Integument partially rigid but easily depressed.
- Postmoult : Branchiostegite and sternite flexible, no cuticle beneath carapace; completely flexible.
- Intermoult : Branchiostegite and sternite inflexible, completely rigid (completely sclerotized).

Sex was differentiated by the abdominal shape. The abdomen is narrow and inverted V shaped in males (Plate 3), while it is triangular in immature females. Adult females are identified by the broader abdominal flaps (Plate 4). It was difficult to differentiate sex in smaller crabs measuring less than 30 mm as the shape of the abdominal flap is more or less similar in both sexes. However, sex was differentiated even in crabs measuring 20 mm or less by the marginal variation noticed in the abdominal flaps in males and females.

2.1. Maturity stages

The gonadal developmental stages were ascertained by the following methods:

- By gross examination of gonads.
- By studying the ova diameter frequency distributions.

In the first method, for describing the gross maturity stages of ovary, the five stage classification given by Aruldas *et al.* (1980) and Prasad and Neelakantan (1989b) modified to separate "immature virgins" from the ovaries immediately after spawning. The following stages were recognised. 1) Immature virgins, 2) immature resting 3) early maturing, 4) late maturing, 5) mature and 6) spent. A few ovaries belonging to each stage were examined microscopically for size of ova and the extent of yolk deposition.

Male gonad of 3,077 *P. sanguinolentus* and 2,252 *P. pelagicus* were examined. The maturity in male crabs was determined based on the thickness and colour of vas deferens. In the fully mature crabs, the vas deferens is thick and white in colour due to the accumulation of spermatozoa while in maturing ones it is thin and opaque or white in colour. In the immature ones, it is transparent and not easily recognisable.

The crabs with both developed testes and vas deferentia were considered as mature following Meagher (1971).

In the second method, the oocyte diameter measurements were taken from ovaries belonging to various developmental stages and oocyte size frequency polygons were constructed with a view to trace the development of ova from immature stage to mature condition (Clark, 1934; Prabhu, 1955). The colour and general appearance of gonads were noted down in the fresh condition. For ova diameter studies preserved crabs were used. The diameter of each ova was measured along the horizontal axis by using an ocular micrometer, fitted to a microscope, which was calibrated using a stage micrometer (each ocular division was found to be equal to 0.0101 mm at a magnification of 150 X). About 100 ova were measured from the immature ovary, 200 from the early maturing, and 300 from the late maturing and mature ovaries.

In order to bring out the natural sequence of maturity stages which the ova pass through before becoming fully mature, the ova diameter measurements taken from individual ovaries were classified according to the size frequency distribution of ova and the position of the mode of the most mature groups of ova as suggested by Devaraj (1977). Ova diameter polygons belonging to the same developmental stage were pooled and then reduced to the basis of 100, 200, and 300 depending upon the stage of maturity.

The gonadosomatic index (GSI) which is useful in determining the reproductive

cycle and for separating the spawning and non-spawning crabs, was also estimated monthwise. For this purpose, adult males and females in the intermoult stage were weighed individually to the nearest g after drying it. The gonad was dissected out from the crab carefully and weighed to the nearest mg by using an electronic balance. The GSI was calculated by the following formula:

$$\text{GSI} = \text{weight of the gonad} / \text{weight of the crab} \times 100$$

5.2.2. Size at sexual maturity

The size at maturity was determined based on examining 5,899 crabs belonging to the species *P. sanguinolentus* and 4,650 crabs belonging to the species *P. pelagicus* and tabulating the mature crabs (late maturing, mature, spent and immature resting) in relation to size and finding out the percentages. The size at which 50% of crabs found to be mature was taken as the size at sexual maturity.

Most brachyurans show sexual differences in the relative size of abdomen and chela. Relative growth studies in crabs provide possible indications of the size at sexual maturity for both males and females since maturity often coincide with critical moult (pubertal moult) at which there are changes in allometry and relative size (Hartnoll, 1969, 1974). In females, the abdomen, pleopods and thoracic sterna are greatly changed, and in males, the shape and size of chela are often modified.

Width, carapace length, chelar propodus depth, chelar propodus length in males, and abdominal length, and width of fourth abdominal segment of females were measured to the nearest 0.1 mm with vernier calipers as indicated below and in Fig. 5.1.

Carapace width (CW) between the tips of the largest spines (tips of epibranchial spines). Carapace length (CL) along the middle line between the frontal notch and posterior margin of carapace.

Chelal propodus length (Ch L) from the tip of the propodus fixed finger to the base of the propodus.

Chelal propodus depth (Ch D) across the widest region of the cheliped palm.

Abdomen width (Ab W) across mid-line of the fourth segment.

Abdomen length (Ab L) along the mid-line from the frontal margin of the first segment to the posterior margin of the last segment of abdomen.

Regression equations were calculated assuming an allometric growth equation, $Y = a + bx$, where, X = carapace width/length, and Y = abdomen width or length/propodus length or propodus depth as the case may be. In order to determine the constant 'b' all data were transformed into logarithms and regressions performed (Simpson *et al.*, 1960).

The correlation coefficients (r) were employed to know the relationship between abdomen/propodus and carapace dimensions.

2.3. Spawning season, spawning frequency and spawning ground

In the present study, the preponderance of the fully mature and spent females, high values of GSI and the occurrence of ovigerous females in the monthly samples were considered for determining the spawning season, the frequency of spawning and the spawning ground.

To determine the time of hatching, the developmental stages of eggs on copepods were grouped into one of the following three stages based on gross examination.

No embryonic structure visible, eggs lemon yellow in colour.

Eye spot with a small amount of yolk, eggs light grey in colour.

Prominent eye spots; chromatophores well developed; larvae ready to hatch; eggs dark grey in colour.

Sex ratio

The sex ratio of the adult population was studied as there was no apparent variation in sex ratio in juvenile crabs. All crabs measuring 80 mm CW and above were considered suitable for the present study. The overall sex ratios were tested using the chi-square.

Fecundity

Fecundity studies were made on the basis of the extruded eggs on pleopods. After measuring the carapace width, the crabs were blotted dry and weighed along with the pleopods. Then the whole eggmass was carefully removed from the pleopods and weighed with an accuracy of 0.001 g using an electronic balance after removing the excess water from the eggmass with the help of a blotting paper. A sample of eggs was taken and weighed accurately, and the number of eggs in the weighed sample was counted using a counting chamber under a binocular microscope (27 X). Then the fecundity was computed employing the following equation:

$$\text{Fecundity} = \frac{\text{weight of the eggmass}}{\text{weight of the known sample}} \times \text{no. of eggs in the known sample}$$

The relationship between carapace width and eggmass weight/ fecundity, and crab weight and eggmass weight/ fecundity, and eggmass weight and fecundity were determined by regression analysis.

Sex index was found out using the following formula:

$$\text{Sex mass index} = \frac{\text{mean eggmass weight}}{\text{mean crab weight}} \times 100$$

Mating period

It is generally difficult to ascertain the peak mating season of crabs in the natural

relation. Even the incidence of females with recently implanted spermatophores was low in the samples. Whatever the knowledge we have on the mating behaviour of these crabs is essentially based on observations made under aquarium conditions. Since mating takes place between hard-shelled male and a soft-shelled female in portunids (Hartnoll, 1969) and moulting is closely associated with reproduction, the mating period could be determined from the occurrence of soft females. Accordingly, 5,280 females belonging to both the species, measuring 80 mm CW and above were analysed for soft females to ascertain the mating period.

7. Reproductive potential

To estimate the reproductive potential for each size class, taking into consideration the variations observed with regard to the egg carrying capacity as well as the percentage of females in berry in different size groups, an index of class reproductive potential was determined based on the following method suggested by Kanciruk and Herrnkind (1976):

$$\text{index} = (A.B.C) / D,$$

$$A = \% \text{ of females in class/ total females,}$$

$$B = \text{Propensity of size class to carry eggs (\% of females in berry in the size group),}$$

$$C = \text{Egg carrying capacity of size class female (mean fecundity of size group),}$$

$$D = \text{Constant (47.6 for } P.\text{sanguinolentus} \text{ and 27.2 for } P.\text{pelagicus}).$$

The constant, D was chosen to set the 130-140 mm class's index in *P. sanguinolentus* and the 140-150 mm class's index in *P. pelagicus* to 100 as the standard. For example, the 140 mm class in the former species which make up 5.9 % of all females analysed at 80 mm and above, has a 10.9 % propensity to carry eggs, and when gravid, a female in the class carries approximately 7.4×10^5 eggs. The calculated index is $= (0.059 \times 0.109) \times 10^5 / 47.6 = 100$.

Treated in this manner, a size class-index of reproductive potential was calculated for *quinolentus* and *P. pelagicus*.

RESULTS AND DISCUSSION

MATURITY

Maturation process in female

1. Structure of adult ovary

The ovary in both the species is paired and approximately H-shaped in form (Fig.) lies dorsal to hepatopancreas and extend posteriorly upto the narrow abdomen along side of the hind gut. Anterior to heart, the ovaries join at a commissure just posterior stomach, with lobes that extend anteriolaterally around the gastric region and into prothorax on each side. Spermathecae, which arise from the mid lateral portion, extend distally to gonopores that open on the sixth thoracic somite.

2. Maturity stages of ovary (gross examination)

In the present study, the following six stages of maturity have been recognised in the development in *P. sanguinolentus* and *P. pelagicus*.

Immature virgins (Stage I) : The ovary is colourless, thread-like.

Immature resting/intermediate (Stage II): After ovulation, ovary return to immature stage before rematuration. The ovary in this stage is thick and translucent or yellow orange or brown orange or brown tan in colour. Crabs having broader abdominal flaps with immature ovary and measuring 100 mm CW and above are included in this stage.

Early maturing (Stage III) : The ovary is slightly enlarged and characterised by an ivory or yellow colour.

Late maturing (Stage IV) : The ovary at this stage is swollen with pronounced lobulations often obscuring the antero-lateral portions of hepatopancreas. Colour varies from yellow to orange.

Mature (Stage V) : Mature ovaries are deep orange in colour and the greatly swollen anterior lobes completely obscure the underlying hepatopancreas and extend into the available space in the haemocoel.

Spent (Stage VI) : The ovary is very flaccid and ivory or yellow orange or tan in colour.

3. Maturity stages in female (by microscopical studies)

On the basis of ova diameter frequency analysis of *P. sanguinolentus* and *P. pelagicus* arbitrary stages were recognised and designated serially A to I (Figs. 5.3S and 5.3P). Description of the stages is given below.

ure

Clusters of primary/young oocytes present.

Stage A: Mode at 3.03 μm . No ova beyond 4.4 μm .

Stage B : Mode at 3 - 4 μm . No ova beyond 8.08 μm .

maturing

Oocytes with clear nucleus and are in various stages of development.

Stage C: The mode of the most mature group of ova is 6.1 - 7.1 μm . No ova beyond 11 μm .

Stage D : The mode of the most mature group of ova is between 9.1 - 11.0 μm and no ova beyond 18 μm . In *P. sanguinolentus*, another secondary mode at 5.05 μm also noticed.

maturing

Many of the oocytes in late phases of vitellogenesis and exhibit a granular appearance due to the accumulation of yolk granules obscuring the nucleus completely.

Stage E: The mode of the most mature group of ova is between 13 - 15 μm . No ova beyond 23 μm . A minor mode at 7 μm seen in *P. pelagicus*.

Stage F: The mode of the most mature group of ova is between 18 - 22 μm and a minor mode between 5-7 μm . No ova beyond 32 μm .

ure

Ovary is dominated by mature ova which are granular in appearance as the oocytes are completely filled with yolk material.

Stage G: The mode of the most mature group of ova between 23-25 μm and separated from the succeeding group of ova by a deep trough. The mode at 7 μm showed no sign of development. No ova beyond 38 μm .

Stage H: The mode of the most mature group of ova between 29- 34 μm . The minor mode at 7 μm of Stage G became insignificant. No ova beyond 47 μm .

Mature unspawned ova undergoing resorption are often present.

Stage I: No clear modes. No ova beyond 27 μm .

In a number of crustaceans the ovary goes through changes in colour and size during oocyte development (Sastry, 1983). Development stages have been assigned by

ent authors based on oocyte size, colour, or ovary size to determine the ductive condition in several brachurans (Conover, 1967; Haefner, 1977; Aiken and y, 1980). Five stages have been recognised in the development of ovary in *P. pelagicus* uldhas *et al.* (1980), and in *Scylla serrata* by Prasad and Neelakantan (1989b), whereas, ton *et al.* (1989a, 1994) described four maturity stages of ovary in *P. sanguinolentus*.

2. Maturation process in male

2.1. Structure of adult testis (gross examination)

The male reproductive system consists of a pair of testes and vas deferens (Fig. 5.2B). Paired testes are slender, white convoluted tubes interconnected medially by a fissure. The vas deferens extends from the posterior end of testes and pass through thoracic cavity and pereopodal musculature of eighth thoracic segment where it ends in penile papillae on the coxae of the fifth periopod.

The vas deferens is divided into four regions, the proximal vas deferens, mid vas deferens, distal vas deferens and ejaculatory duct. The proximal vas deferens is tightly coiled and dull white in colour and lies anterior to the pericardial region. The milky white mid vas deferens is loosely coiled and constituting the largest part of the system. The distal vas deferens is transparent and highly convoluted partly extending into muscular ejaculatory duct.

2.2. Maturity stages of testis

Immature (Stage I) : Testes and vas deferentia not clearly differentiated; gonad small on either side of stomach; vas deferentia are thin, translucent straight tubes; spermatozoa absent. Gonad of males measuring below 80 mm CW were in this stage of development.

Maturing (Stage II) : Testes and vas deferentia well developed. Testes are large coiled tube spreading laterally and posteriolaterally from the stomach. Vas deferentia opaque or white coiled mass, about 0.5 -1.0 mm thick extending to both sides of heart. Spermatozoa present.

Mature (Stage III) : Testes showed further enlargement. Vas deferentia are very much swollen, 2-3 mm thick and milky white mass extending to fill most body cavity. Spermatophores present.

The development of testes was determined based on colour and thickness of vas deferentia. Four stages of vas deferentia development were observed by Watson (1970) in *Decapoda opilio*.

3. Gonado-somatic index (GSI)

The gonado-somatic index is widely used to study their reproductive cycle of fishes and shell fishes (Giese, 1959; Giese and Pearse, 1974; Rahman, 1967; Chandran, 1968; Pillay and Subramoniam, 1971; Ajmal Khan and Natarajan, 1977; Subramoniam, 1979; Radhakrishnan, 1979). To determine the relationship between GSI and reproductive cycle, it was studied in relation to various maturity stages in *P. sanguinolentus* and *P. pelagicus* during different months.

It is seen that the GSI in females showed clear cyclic pattern with high values during January-February in *P. sanguinolentus* and during September and January-February in *P. pelagicus* (Figs. 5.4A and 5.4B) when the incidence of mature crabs were relatively high (Figs. 5.20-5.22 and 5.26-5.28) and low values during other months.

Since the gonad index did not show any definite pattern in males (Figs. 5.4A and

the breeding potential of male could be assessed only by the morphological condition of the gonad.

Sumpton *et al.* (1989, 1994) reported that male GSI values were highest in May indicating peak mating activity in the following months.

4. Size at sexual maturity

4.1. Size at sexual maturity by gonad studies

The percentage occurrence of mature crabs in relation to size is graphically plotted in Figs. 5.5- 5.8. It is seen from Fig. 5.5A and 5.6A that the 50 % level of maturity in males and females of *P. sanguinolentus* were 98 mm and 91 mm at Mangalore, 98 mm and 96 mm at Malpe and 96 mm and 93 mm at Karwar. In *P. pelagicus*, these values were 106 mm and 89 mm, 105 mm and 106 mm, and 103 mm and 101 mm at Mangalore, Malpe and Karwar respectively (Fig.5.7A and 5.8A). The marginal variation in the size at maturity observed in males and females at various centres may possibly be due to difference in growth rate or due to sampling variation. In order to arrive at a common value, the data obtained in respect of *P. sanguinolentus* and *P. pelagicus* from all centres were pooled together and presented in Figs.5.5B, 5.6B, 5.7B, 5.8B.

From Figs. 5.5 -5.8, it is found that the smallest crab with fully mature ovary measured 78 mm and 82 mm in *P. sanguinolentus* and *P. pelagicus* respectively. However, the 50% level of maturity was attained at a mean size of 92 mm in the former and 99 mm in the latter species.

In males, the smallest mature crab measured 83 mm in *P. sanguinolentus* and 88 mm in *P. pelagicus* and the 50 % level of maturity was observed at a mean size of 97.0 mm in the former and 105.0 mm in the latter species. At 130.0 mm cw and above, all males were mature including crabs undergoing moult.

Sumpton *et al.* (1989) found that the smallest sexually mature male and female *P. pelagicus* measured 83.0 mm and 73.0 mm respectively in the Australian waters. In a recent study by the same authors (Sumpton *et al.*, 1994) mentioned that most crabs of the species *P. pelagicus* were sexually mature in the same area. Reeby *et al.* (1990) reported that the onset of sexual maturity in male was at 81-85 mm cw in *P. sanguinolentus* and 86-90 mm cw in *P. pelagicus* and the 50 % sexual maturity was at 100 mm in the former and 98 mm in the latter in the Karwar waters. Jacob *et al.* (1990) found that females of these two species attained sexual maturity at 81-85 mm cw and above.

4.2. Size at maturity by observing the smallest berried crab

The smallest berried crab also indicate the size at sexual maturity. It is seen that the smallest crab in berry measured 81 mm cw in *P. sanguinolentus* and 89 mm cw in *P. pelagicus*. The smallest berried female of *P. sanguinolentus* observed by Menon (1952) measured 78 mm cw, whereas George and Nayak (1961) found that the smallest berried female measured 84 mm cw at Mangalore. Radhakrishnan (1979) reported that the smallest berried female crab of this species measured 75 mm cw from Porto Novo waters. Thomas (1984) mentioned that the smallest crab in berry measured 62.5 mm from Cochin, while Maran *et al.* (1986) found that the smallest ovigerous female measured 78 mm cw in South Kanara waters.

The smallest ovigerous female of *P. pelagicus* observed by Thompson (1951) from Malabar, Prasad and Tampi (1953) from Mandapam, Pillay and Nair (1971a) from West coast of India, Radhakrishnan (1979) from Porto Novo and Thomas (1984) from South Kanara measured 106 mm, 92 mm, 95 mm, 113 mm and 92 mm respectively.

4.3. Size at maturity by relative growth studies

Among brachyura, morphometric analysis has been used to study attainment of sexual

ity (Sieple and Salmon, 1987; Atrill *et al.*, 1991; Lovrich and Vinuesa, 1993; Gurriran and Azeiteiro, 1994). Within Portunidae, relative growth has been studied by Newcombe *et al.* (1965), Ryan (1967), Lewis (1977), Prasad and Neelakantan (1988a), Sumpton (1990), Gher (1990), Jacob *et al.* (1990) and Reeby *et al.* (1990).

In the present study, an attempt has been made to analyse the morphometric data to define growth patterns of male and female of *P.sanguinolentus* and *P. pelagicus* and to study changes in form with onset of maturity.

The morphometric characters studied in males were carapace width and chelar propodus length, carapace width and chelar propodus depth, carapace length and chelar propodus length, carapace length and chelar propodus depth and chelar propodus length and chelar propodus depth. The characters studied in females were carapace width and abdomen width, carapace width and abdomen length, carapace length and abdomen width, carapace length and abdomen length, and abdomen width and abdomen length.

Morphometric characteristics of immature and mature males of *P. sanguinolentus* and *P. pelagicus* are given in Tables 5.1-5.4 and corresponding allometric equations are presented in Tables 5.5-5.8. The length and depth of chelar propodus of *P. sanguinolentus* and *P. pelagicus* are plotted against carapace width and carapace length in Figs. 5.9 -5.12. The growth variation of chelar propodus depth of these two species are plotted in relation to chelar propodus length in Figs. 5.13A and 5.13B.

The morphometric characters of immature and mature females of *P.sanguinolentus* and *P. pelagicus* are presented in Tables 5.9-5.12 and the corresponding allometric equations with respect to immature and mature females of these two species are indicated in Tables 5.13-5.16.

The relationship between the morphological characters in females of these species

shown in Figs. 5.14- 5.18. Morphological analysis revealed transitions in the cheliped dimensions and abdominal widths of *P. sanguinolentus* and *P. pelagicus* (Figs. 5.9-5.18). It is often inferred that such transitions are related to prepubertal and postpubertal changes associated with gonadal development and onset of sexual maturity (Hartnoll, 1982). The present study presents evidence that support such inference.

The chelar propodus length of males of *P. sanguinolentus* and *P. pelagicus* exhibited positive allometry in both immature and mature crabs (Tables 5.6 and 5.8) and the mature crabs showed slightly higher levels of allometry as compared to immature ones. The present study has indicated that males of *P. sanguinolentus* and *P. pelagicus* may undergo pubertal moult at a carapace width ranging between 80-85 mm as evident from the sudden increase in morphometric characteristics (Figs 5.9A, 5.9B, 5.11A, 5.11B).

Females of *P. sanguinolentus* and *P. pelagicus*, on the other hand, exhibited positive allometry of abdomen width and length against carapace width and length in immature and mature crabs with a marked increase in size of abdomen at a mean size of 80-90 mm cw (Tables 5.14 and 5.16, and Figs. 5.14-5.18).

The allometric relation between the set of characters studied suggested that the relationship was positive and significant as evident from Tables 5.14 and 5.16.

In males, the general criterion of maturity is the vas deferentia contain large number of spermatophores. In addition, external morphological changes affecting the chelae in particular, coinciding with maturity, also occur at the "puberty moult". In females, in contrast to males, maturity can not be determined from the condition of gonads as the ovary regresses back to immature stage after spawning. Fortunately, the moult of puberty is much more prominently developed in females than in males, and can involve changes in features like abdomen, pleopods and sternum.

Sulkin (1977), Berrill (1982) and Smith (1982) opined that the size at which portunid crabs reach maturity may vary according to their geographical location. Such variations in size at maturity was observed in the same species caught from different locations in the present investigations as well as in the study made by several researchers from different regions (Thompson, 1951; Prasad and Tampi, 1953; Pillay and Nair, 1971a; Radhakrishnan, 1979; and Thomas, 1984). Even in the same locality, the size at maturity of individual crabs of the same species may vary because the pubertal moult occurs over a wide range of size. It is observed that the pubertal moult may possibly be delayed for a considerable amount of time when the breeding activity is low resulting marked variation in the size at which both sexes mature.

2.0. SPAWNING

2.1. Mating

According to Ryan (1967) mating appears to be initiated by a pheromone released into the ambient medium by the premoult female of *P. sanguinolentus*. Joel and Raj (1982) reported that males of several brachyurans carry mature peeler crabs for 2 to 3 days until the female shed their exuvia. The female mostly moult during night and mating ensued the following day.

To determine the mating period, the moult data of adult females of *P. sanguinolentus* and *P. pelagicus* sampled from Mangalore, Malpe and Karwar during different months is presented in Figs. 5.19A and 5.19B. It is possible to deduce from Figs 5.19A and 5.19B that soft females were available most of the months in varying proportions with maximum abundance during December-March in *P. sanguinolentus* and April-May in *P. pelagicus* indicating peak mating activity during these months. Sumpton *et al.* (1989a) reported that May is the major mating period in *P. sanguinolentus* in the Queensland waters of Australia. The same authors (Sumpton *et al.*, 1994) found that May-June is the peak mating

mod in *P. pelagicus*. According to Penn (1977) and Smith (1982) mating activity was highest during February-March in this species in the temperate waters of Australia.

Examination during the present course of study showed that ovary was neither mature nor in maturing condition in soft shelled females. This means that ovary was not mature at the time of impregnation. While studying the reproductive biology of the portunid crab, *Alpheidae* from American waters, Van Engel (1958) reported that sperm can be stored in spermathecae several months before fertilization of eggs takes place. Following impregnation two or three batches of eggs may be produced in this crab without intervening moult (Van Engel, 1958). This means, therefore, that the spermatozoa stored in the female are probably sufficient to fertilize several batches of eggs. This may possibly be true of *P. sanguinolentus* and *P. pelagicus* also (see section 5.3.2.3. Spawning frequency). In the marine populations of *P. pelagicus*, copulation can occur in autumn (December) at the time of annual moult, with females storing sperms until following spring or autumn in the Australian waters (Smith, 1982).

2.2. Spawning season

The gonadal developmental stages of males and females of *P. sanguinolentus* and *P. pelagicus* caught in different type of gears during different months and also in various size classes at Mangalore, Malpe and Karwar are presented in Tables 5.17-5.28 and Figs. 5.20-5.27. The incidence of ovigerous females in *P. sanguinolentus* and *P. pelagicus* during different months and in relation to size at Mangalore, Malpe and Karwar are given in Tables 5.32 and Figs. 5.28 and 5.29. Gonadosomatic index in respect of females of *P. sanguinolentus* and *P. pelagicus* during different months is shown in Fig. 5.4A and 5.4B.

It is seen from Tables 5.20-5.22 that even though the spawning season is prolonged from November to May, peak activity was recorded during December-February in *P.*

sinolentus as evident from high incidence of mature and spent crabs along with maximum values of GSI during this period (Figs. 5.21 and 5.4A). The maximum abundance of ovigerous females during the above period was in accordance with the above observations (Tables 5.29-5.30, Fig.5.28A).

The recruitment of younger juveniles of *P. sanguinolentus* (20-50 mm cw) into the fishery from October to July with maximum intensity in December-April suggests prolonged breeding cycle of this species from August to May (see also chapter on Age and Growth).

In the case of *P. pelagicus*, the spawning activity was pronounced during January-February and in September even though mature, spent or berried females were available practically in all months from August to May (Tables 5.26-5.28, 5.31-5.32; Figs. 5.23A, 5.23B, 5.23C) suggesting prolonged breeding in this species. Maximum values of GSI in September and January-February indicating peak gonad activity during these months (Fig. 5.4B) was in conformity with the results obtained by the observation of gonadal development/ovigerous females in this species.

In *P. pelagicus*, the recruitment of juveniles (50-80 mm cw) from November to April with maximum intensity during December-January suggests that the breeding activity is extended over several months in this species as in *P. sanguinolentus*. However, the peak breeding observed in September and January-February from gonadal studies and ovigerous females was not reflected by intensive recruitment of younger juveniles (20-50 m cw) into the fishery during the subsequent months.

Menon (1952) while studying on the biology of *P. sanguinolentus* found that the species is breeding during February-April along the Malabar coast. George and Nayak (1961) reported year-round spawning with peak activity during March-April along the Mangalore coast, while Chhapgar (1956) noticed that the crab is breeding throughout the

in the Bombay area. Rao *et al.* (1971) observed that this species is spawning during February-April in the Cochin waters, whereas, Sukumaran *et al.* (1986) mentioned that this species is breeding all through the season with maximum intensity in February and April-May along the South Kanara coast. Ryan (1967) indicated that the Hawaiian population of this species spawn year-round with a peak season from October to February. Pillay and Nair (1970, 1976) found that the breeding is almost continuous throughout the year except July with peak activity in February along the southwest coast of India. The same authors (Pillay and Nair, 1976) observed high incidence of ovigerous females in the population with peak in February. According to Campbell and Fielder (1980), *P. sanguinolentus* displayed a single spawning period extending from October to February in the Australian waters. In an earlier study, Sukumaran (unpubl.) has found that this crab is having a prolonged breeding with peaks during April-May at Mangalore, December and April-May at Cochin, and during September-January at Kakinada.

Stead (1898) has reported that the spawning season in *Neptunus (Portunus)* in Australian waters is from August to November. Delsman and De Man (1925) have not observed any definite breeding period for *Neptunus (Portunus) pelagicus* in Batavia and remarked that berried crabs occur throughout the year, whereas, according to Thompson (1961) the egg bearing season is from September to April in this species. Two peaks in the presence of gravid females of *P. pelagicus*, one in September and another in February were observed by Campbell and Fielder (1986) from the Australian waters. According to Prasad *et al.* (1989), the presence of egg remnants on female pleopods of *P. pelagicus* in Moreton Bay indicates that some spawning occurred throughout the year in Moreton Bay, Queensland. In contrast, population of the same species from more temperate waters of Australia have shorter spawning periods extending from February to April (Sumpton *et al.*, 1989). While studying on the breeding biology of *P. pelagicus*, Prasad and Tampi (1953) reported that the species breeds throughout the year with maximum intensity during

September-March in the Mandapam area on the southeast coasts of India. Rahman (1967) mentioned that this crab is a continuous breeder with three periods of maximum gonad activity in November, January and June with greater activity during November-January along the Madras coast. Pillay and Nair (1973) observed high gonad index in this species for several months from August to March with definite peaks during December-January along the southwest coast of India suggesting peak breeding during that period. The same authors (Pillay and Nair, 1970, 1976), by following the incidence of ovigerous females observed that the breeding in this species is from August to April with peak in January. Dhawan *et al.* (1976) mentioned that the breeding in *P. pelagicus* takes place during February-March in the Hari estuary in Goa. According to Joel and Raj (1982), this crab is breeding in the Pulicat lagoon in Madras during non-monsoon months. Sukumaran (unpubl.) in an earlier study, observed a prolonged spawning period in this species from September to April with maximum intensity during January-March and September along the South Kanara coast, in February-March in Cochin and in March and September at Mandapam. The low proportion of gravid females and high incidence of females with inactive gonads (Stage I and Stage II) during certain part of the year (during October-November and April-May in *P. sanguinolentus* and during April-June in *P. pelagicus*) indicate that these crabs do not spawn throughout the year in the tropical waters along the Karnataka coast.

2.3. Spawning frequency

The multimodal distribution pattern of ova diameter polygons is useful in studying the frequency of spawning in several fishes (Clark, 1934; Prabhu, 1955; Devaraj, 1977). But in the present study, the unimodal distribution of ova in the Stages G-H (Figs.5.3S and 5.3P) indicates that *P. sanguinolentus* and *P. pelagicus* may release all mature eggs by a single spawning act. However, the occurrence of maturing and fully mature ovaries in several ovigerous females during December-February in *P. sanguinolentus* and in January-March in *P. pelagicus* tends to suggest that these crabs might produce a further batch of eggs

Shortly after the eggs carried in the pleopods are hatched.

Multiple oviposition during a single reproductive season has been reported for *Cancer anthonyi* (Shields *et al.*, 1991), *C. antennarius* (Shields per. obs.) and *C. productus* (Knudsen, 1964). Further, Van Engel (1958) reported that following impregnation, two or three successive batches of eggs might be produced in *Callinectes sapidus* without an intervening moult. Campbell (1984) reported that *P. pelagicus* can extrude 4 batches of eggs after each mating. Since *P. sanguinolentus* and *P. pelagicus* are having a prolonged breeding season with one or two peaks, it is reasonable to surmise that an individual female may spawn at least 2-3 times in a spawning season. Ryan's (1967) observation that *P. sanguinolentus* may spawn at least 3 times in a mature instar is in conformity with the present view.

3.2.4. Spawning population

The gonadal developmental stages in males and females of *P. sanguinolentus* and *P. pelagicus* in relation to size is given in (Figs. 5.24-5.27). It is seen that all males above 20 mm cw and 130 mm cw were fully mature in the former and latter species respectively, although mature males were available in all sizes above 80 mm cw (Figs. 5.24 and 5.26). Similarly, even though spawning females occurred in all sizes above 80 mm cw, pronounced breeding activity was noticed in size groups between 100 and 130 mm in *P. sanguinolentus*, and between 100 and 160 mm in *P. pelagicus* (Figs. 5.25 and 5.27). This has been corroborated by the results obtained by studying the incidence of vigorous females in relation to size (Figs. 5.29A and 5.29B).

A reanalysis of the whole data on maturity indicated that 60-80 % of males in *P. sanguinolentus* and 28-65 % males in *P. pelagicus* were actively involved in mating. It is seen that among adults females, 40-60 % of the former and 22-65 % of the latter were

tively engaged in spawning. Even during the peak period of breeding, 35-60 % of the adults of *P. sanguinolentus* and 25-70 % of *P. pelagicus* were only actively involved in spawning while the rest were either in immature or in early stage of ovarian development. It was interesting to note that the gill net catch in September-October consisted of 100 % of males and 89 % of females in spawning condition.

3.2.5. Spawning ground

Sumpton *et al.* (1989a) are of the opinion that mature females of *P. sanguinolentus* move into deeper oceanic waters to spawn. The present data, however, indicate that the spawning ground is within the fishing ground itself during the non-monsoon months, although there are some size and sex related segregated movements. This view is based on the occurrence of large number of mature, spent and berried crabs of *P. sanguinolentus* and *P. pelagicus* throughout the peak breeding season in otter trawls operating with in 40 m depth. Even the shore seines operating in the Karwar bay and the minitrawl operating in the Mangalore estuary caught crabs in berry of both these species, though in fewer numbers, which tends to suggest that these crabs may spawn in the coastal waters itself during the non-monsoon months. Eventhough berried females were caught from the estuary, it is not known whether these crabs are actually breeding in the estuarine environment. However, the non -occurrence of berried crabs in advanced stage of development or females with empty egg cases on pleopods in the estuary indicate that these crabs may move out to more saline areas for hatching their eggs. Similar view has been expressed by Potter *et al.* (1983) while studying on *P. pelagicus* from an Australian estuary. However, the occurrence of brachyuran zoea in fairly large numbers during February-April in the coastal waters of Mangalore as reported by George and Nayak (1961) tends to suggest that these crabs are not moving far away from the fishing ground for hatching their their eggs.

It is probable that the adult population which move out of the inshore/estuarine waters during the monsoon months when the low saline conditions prevail in the coastal waters to deeper areas as the salinity regime in that environment is favourable for spawning. The peak recruitment of younger juveniles in October-November and the incidence of berried crabs in gill net (operated at 40-50 m depth) collections in November tends to support this view.

2.6. Sex ratio

Sex ratio indicates the proportion of males and females in the population. This is expected to be 1:1 in nature. The sexes may become segregated at certain seasons of the year resulting in variation in sex ratio. This variation in sex ratio may be attributed to differential behaviour of sexes, environmental conditions and fishing. Sex ratio studies generally indicate segregation, aggregation of sexes according to feeding, breeding, or migratory behaviour (Bal and Rao, 1984).

The sex ratio distribution of the spawning population of *P. sanguinolentus* and *P. indicus* caught in different type of gears at Mangalore, Malpe and Karwar during different months is shown in Tables 5.33-5.38, and Figs.5.30A -5.30B. From Tables 5.33-5.35, it is seen that the incidence of males of *P. sanguinolentus* in trawl catches was higher at Karwar with a male to female ratio of 1.29 : 1 (annual), whereas, at Mangalore, the ratio was nearly equal (0.93 : 1). At Malpe, males and females were more or less equally distributed (1.06 :1) although there was variation during different months. However, chi-square values were significant in *P. sanguinolentus* at all centres except in 1992-94 at Malpe and in 1992-93 at Karwar indicating that there was significant variation in sex ratio (Table 5.39).

Radhakrishnan (1979) and Thomas (1984) found that the ratio was nearly equal

crab at Porto Novo and Cochin.

Sex distribution in this crab in relation to size indicated that females were more pronounced in the smaller sizes, whereas, males dominated in the larger sizes (Fig. 5.31A) as observed by Sumpton *et al.* (1989a) in this species from Australian waters. The abundance of females in the lower size groups might have resulted from the tendency of reproductively active females to postpone somatic growth thereby causing them to accumulate in these sizes as observed by Cristy (1980) and Colby and Fonseca (1984) in *Portunus pugio* in Southern Florida.

In *P. pelagicus*, the male to female ratio was 1:1 in the trawl catches at Mangalore (Table 5.36), while it was nearly equal at Malpe (0.99 : 1) although there was month to month variation (Table 5.37). At Karwar, on the otherhand, the proportion of males in the trawl catches was low, the ratio being 0.84 : 1, whereas, males outnumbered females in shore seine catches at this centre with a ratio of 1.26 : 1 (Table 5.38). In trawl catches from the estuary and gill net catch from the inshore waters of Mangalore showed the preponderance of female (0.78 : 1 and 0.81 : 1 respectively) (Table 5.36). In this species, the chi-square values were not significant during 1992-93 at Mangalore and Karwar, and significant during other periods at all centres suggesting marked variation in sex ratio during these periods (Table 5.39).

Sex distribution in relation to size in *P. pelagicus* did not show any clear pattern as the ratio varied in different size groups in various gears at all centres (Figs. 5.31B).

In contrast, Thompson (1951) stated that the male to female ratio in *P. pelagicus* was 4.3:1 in the Australian waters. Prasad and Tampi (1953) reported that the male to female ratio was 2.4 : 1 in the Mandapam area due to segregation of sexes particularly in larger crabs. The same authors (Prasad and Tampi, 1953) opined that among juveniles

30 mm cw) no marked difference in sex ratio was seen since there was no segregation of sexes in juveniles. Potter *et al.* (1983) mentioned that the proportion of females exceeded that of males in this species particularly in January and February, reflected in the catches of this sex taken in the otter trawls operating in the Australian coast. Swan *et al.* (1976) reported that males were dominant in this crab in the Zuari estuary, Goa. Sumpton *et al.* (1994) found that males were predominant in *P. pelagicus* in the Breton Bay, Australia and opined that the migration of mature females onto sandbanks of the bay for egg extrusion was partially responsible for the variation in sex ratio in this species.

5.2.7. Ovigerous females

In order to study the reproductive cycle of *P. sanguinolentus* and *P. pelagicus*, the incidence of ovigerous females of these crabs caught in different type of gears during different months at Mangalore, Malpe and Karwar was analysed and the results are summarised in Tables 5.29-5.32; Figs. 5.28A-28B. Similarly, the occurrence of berried crabs of these two species at various size groups at Mangalore, Malpe and Karwar are shown in Figs. 5.29A and 5.29B.

It is possible to deduce from Tables 5.29-5.30 that the ovigerous females of *P. sanguinolentus* started appearing in the fishery in December and steadily increased its abundance, attaining higher values in December, January or February at all centres in the trawl catches during 1992-93 and 1993-94 seasons (Fig.5.28A). In the following months, the proportion of ovigerous females was relatively low. It was found that berried crabs of this species occurred in the catches in all months in various proportions except when there was no catch.

In *P. pelagicus*, crabs in berry started appearing in the catch in August, steadily

Increased obtaining maximum values in January-February in the trawl catches during 1992-93 and 1993-94 seasons and marginally reduced in March. There were only few crabs in berry in April, May and August. In July, no berried crabs was taken in any trawls. In September and October, the incidence of ovigerous females was observed to be high (Tables 5.31-5.32, Fig. 5.28B). According to Sumpton *et al.* (1994), ovigerous females occurred throughout the year with maximum during August-October in *P. pelagicus* in the Moreton Bay, Australia.

The study of the incidence of ovigerous females in relation to size indicated that the proportion of these crabs in berry increased upto 110-120 mm size groups and thereafter, showed a reduction in their occurrence in larger sizes in both these species (Figs. 5.29A and 5.29B).

These data clearly suggest that the peak time of fertilization was during December-February in both these species. This view is based on the occurrence of berried crabs in higher proportions coupled with the sudden rise in the incidence of spent females in these months (Tables 5.29-5.32, 5.20-5.22, 5.26-5.28; Figs. 5.21, 5.23 and 5.28). Sumpton *et al.* (1983) opined that the peak time of fertilization in this crab was during January and February in the Australian waters.

When first laid, eggs are bright yellow/ orange in colour, but during the period of incubation before hatching they become yellow, grey and later dark grey due to the gradual absorption of yellow egg yolk by the embryo and the development of dark pigment in the eyes (Plates 5-6). The development stages of the eggs on pleopods have been studied by Boolootian *et al.* (1959), Eickstaedt (1969) and Subramoniam (1979).

The incidence of various developmental stages of eggs on pleopods during different months in respect of *P. sanguinolentus* and *P. pelagicus* are given in Tables

5.40-5.41. From Tables 5.40-5.41, it is seen that the eggs in highly advanced stage of development (Stage III) was occurring more during December-February and April in the former species and during January-February in the latter suggesting peak hatching in these months.

Females which have been recently hatched were often taken in considerable numbers in otter trawls operating from Mangalore, Malpe and Karwar during December-May in *P. sanguinolentus* and March-May in *P. pelagicus*. Crabs which have been carrying eggs can easily be recognised by the presence of egg capsules left on the swimmerets of the abdomen. These crabs also have a characteristic appearance, their abdomen being dirty and discoloured and their shells are usually heavily encrusted with epifauna such as barnacles and tube worms. The discoloured appearance of the body may be due to their habit of partially burying themselves in the sea bed when carrying eggs. (Edwards, 1979). The encrusted condition of the carapace with epifauna (Plate. 7) is believed to be due to longer intermoult periods as they carry successive broods of eggs.

Within 2-3 days after hatching, female crabs strip off empty and dead egg cases from pleopods. The setae of the cleaned pleopods attained a golden sheen comparable to their appearance to freshly moulted crabs (Shields *et al.*, 1991). In the present study, large number of females with pleopods having a golden sheen appearance were seen during December-February and April in *P. sanguinolentus* and during January-February in *P. pelagicus* suggesting peak hatching in these months which is in conformity with the earlier observation.

The occurrence of juveniles of *P. sanguinolentus* (20-50 mm cw) in large numbers in trawl and shore seines, operating in the nearshore waters practically in all months with maximum abundance during December-April, suggests that hatching may possibly be taking place in shallow coastal waters itself.

In contrast, the occurrence of juveniles of *P. pelagicus* (50-80 mm cw) in small numbers and the rarity of younger juveniles (20-50 mm cw) in trawl, minitrawl (estuary) and shore seine catches throughout the year tends to suggest that the berried crabs particularly the larger ones, probably move to more saline deeper waters for hatching. The low incidence of ovigerous crabs in comparison to that of *P. sanguinolentus* can well be explained by the offshore migratory behaviour of these crabs for hatching.

5.2.8. Fecundity

The term fecundity is defined as the total number of eggs carried by each female at any given time during incubation (Shields *et al.*, 1991). Crab fecundity was significantly different between broods in different stages of embryogenesis. However, clutch size did not differ significantly between broods in early and middle stage of development (Shields *et al.*, 1991) and hence these stages were combined for the size and fecundity studies.

The carapace width, crab weight, egg mass weight and fecundity in *P. sanguinolentus* and *P. pelagicus* are given in Tables 5.42-5.43. The average carapace width, average weight of the crab, egg mass weight, average fecundity per brood and egg mass per gram of crab for the two species are shown in Tables 5.44-5.45.

Present study indicated that there is an apparent increase in the number of eggs carried with the increase in size of crab, although there was some variation at certain sizes (Tables 5.42-5.45). An ovigerous crab carried an estimated 0.044 - 1.19 million eggs in *P. sanguinolentus*, and 0.056 - 1.07 million eggs in *P. pelagicus*.

The statistical relationships between fecundity and egg mass in relation to carapace width and carapace length in respect of *P. sanguinolentus* and *P. pelagicus* are presented in Tables 5.46 and Figs. 5.32- 5.35 which suggest an exponential relation between the

ables in both these species. It is also noted that there was a direct relationship between egg mass weight and fecundity. (5.36A and 5.36B). Highly significant positive relation ($P \leq 0.001$) was observed in all relationships studied (Table 5.46 and Figs. 2-5.36).

There has been considerable variation in the results obtained by various workers who studied fecundity of these portunids from different regions. Ryan (1967) reported that the number of eggs carried by a gravid female of *P. sanguinolentus* ranged between 0.6 and 2.25 million eggs in the Hawaiian waters. According to Pillay and Nair (1976) fecundity varied between 0.15 and 0.31 million eggs in this species. Radhakrishnan (1979) mentioned that the fecundity of this crab varied between 0.015 and 0.15 million eggs in the Porto Novo waters, while Kannaiah (1981) found it ranged between 0.52 and 0.9 million eggs in this species from the same area. The fecundity varied between 0.045 and 0.80 million eggs at Cochin (Thomas, 1984), while Reeby *et al.* (1990a) found it ranged from 0.16 to 0.71 million eggs in this crab at Karwar.

Prasad and Tampi (1953) reported that the number of eggs carried by an ovigerous female of *P. pelagicus* ranged between 0.19 and 0.46 million eggs in the Andapam area, whereas, Pillay and Nair (1976) recorded that the number of eggs carried by a berried crab ranged from 0.18 to 0.46 million eggs at Cochin. Potter *et al.* (1983) found that the fecundity of this crab ranged between 0.27 and 0.85 million eggs in the Peel-Harvey estuarine system in Australia. It varied between 0.08 and 0.86 million eggs in this species at Karwar according to Reeby *et al.* (1990a). The maximum number of egg mass was approximately 1.7 million and 2.4 million for *P. sanguinolentus* and *P. pelagicus* respectively in Australian waters (Campbell, 1984).

While studying the fecundity in *Scylla serrata*, Prasad and Neelakantan (1989a) found that the egg mass weight and carapace width are better indices for estimation of

reproductive potential than the weight of the crab. Shields *et al.* (1991) found that fecundity in rock crab, *Cancer anthonyi* varied seasonally. Several factors such as salinity, temperature, photoperiod, abundance of food in the environment and intrinsic size of the animal have been attributed to both interspecific and intraspecific variability in fecundity (Giese and Pearse, 1974).

2.9. Reproductive potential

The egg bearing propensity (percentage of females in a given size class with eggs), egg carrying capacity, contribution of each size class to total egg production in respect of *P. sanguinolentus* and *P. pelagicus* are given in Table 5.47. Eventhough the percentage of females in berry vary among different size groups, it is observed that the larger females had a larger egg carrying capacity. In *P. sanguinolentus*, the size class 120-130 mm cw represented only 10.5 % of all females (80 mm cw and above), yet contributed 22.9 % of the estimated egg production of all females with a "productivity" rating of 2.2 which was found to be the maximum for this species. The newly matured females in the size class of 80-90 mm cw represented 24.8% of all females (80 mm and above), yet produced only 1.8 % of the estimated total egg production (productivity = 0.1), making them 22 times less productive than 120-130 mm size group. The crabs measuring 130 mm and above produced an estimated 6.7 % of the total egg production (productivity = 1.1 and 1.2). It is observed that the productivity in crabs belonging to different size groups found increasing from a low of 0.1 in 80-90 mm cw to a maximum of 2.2 in 120-130 mm cw and thereafter showed a steep fall in the rest of the size groups in this species.

In *P. pelagicus*, although the females in the size group 130-140 mm cw, represented only 7.1 % of all females measuring 80 mm and above, produced 15.5 % of the estimated total egg production of all females (productivity = 2.2). The newly matured females of this species in the size group of 80-90 mm cw represented 22.6 % of all

ales, yet produced only 1.4 % of the estimated egg production (productivity = 0.1) making them 22 times less productive than the 130-140 mm size class. It is seen that the productivity was found increasing from 0.1 (80-90 mm cw) to 2.2 (130-140 mm cw) and then registered a fall in the rest of the size groups.

One among the many factors influencing peak breeding activity along the southwest coast of India, seems to be abundance of rich planktonic food produced at the onset of the SW monsoon and also by the upwelling of bottom water during postmonsoon period (Panikkar and Jayaraman, 1966). While studying the reproductive ecology of the hermit crab, *Emerita asiatica*, Subramoniam, (1979) observed that the breeding activity is steadily increasing in the post monsoon months from January to May, but fluctuates regularly during the rest of the months. In the present study, it is seen that the breeding activity in *P. sanguinolentus* and *P. pelagicus* is found increasing from December to late February or early March, reduced sharply in April and May and low in the rest of the months except perhaps another peak in September in the latter species. The steady increase in breeding activity during December-March may be attributed to the increase in temperature, salinity and availability of food.

Quantitative studies describing the ovarian cycles that can provide information on the period and amplitude of gonadal growth in brachyurans are relatively few (Sastry, 1963). However, Pillay and Nair (1971) determined the temporal patterns of ovarian cycles by the gonad index method for three populations of tropical decapods. These authors (Pillay and Nair, 1971) found that the reproductive period of *Uca lactea annulepis* extends for several months from July to April during which time three gonad index peaks occur for the population and the gonad index peaks are followed by the occurrence of the highest number of ovigerous females. According to Pillay and Nair (1971), *P. pelagicus* exhibited more than one gonad index peak during the annual cycle, with each peak followed by the occurrence of a high number of ovigerous females. In the present study,

However, one gonad index peak was observed in *P. sanguinolentus*, whereas *P. pelagicus* exhibited two. Moreover, the gonad index peaks and maximum abundance of ovigerous males were observed more or less in the same period (January-February in the former species and in September and January-February in the latter).

Pillay and Nair (1971) reported that the breeding activity is reduced for a larger part during rainy season in the marine and shore crabs, whereas, it ceases completely for several months in many of the estuarine crabs studied. The present study showed that the breeding activity in *P. sanguinolentus* and *P. pelagicus* was much reduced in the coastal waters during the peak monsoon months possibly due to the low saline conditions prevailing in the nearshore waters during that period.

The recruitment of younger juveniles during October-April (November-April in *P. pelagicus*) suggests peak spawning activity during August-February in these marine portunids, although the incidence of ovigerous and mature / spent females indicated peak activity only during December-February in *P. sanguinolentus* and in September-October and January-February in *P. pelagicus*. It is possible that the adult population which has moved into deeper waters during monsoon months due to low saline conditions prevailing in the nearshore waters, may be breeding in the deeper waters during monsoon months (August-September), where the hydrological conditions may be more favourable resulting in recruitment of younger juveniles into the fishery in October/November period. The high incidence of ovigerous and mature/spent females of *P. pelagicus* in the samples obtained in September is also in conformity with this view. Pillay (1994) opined that the spawning in *Scylla serrata* in offshore waters may probably provide a dispersal mechanism for larvae to enable the megalopae stage to recruit to habitats distant from the parents. This may be true of these portunids also.

TABLE 5.1.

Morphometric characters in immature males of *P. sanguinolentus*.

Sl. No.	CW	CL	Ch L	Ch D	Sl.No.	CW	CL	Ch L	Ch D
1	31.3	14.2	14.7	4.5	47	60.2	26.4	32.2	8.9
2	32.3	14.1	14.8	4.3	48	60.9	26.8	31.1	7.5
3	34.1	14.2	14.7	4.5	49	61.9	26.8	30.5	7.1
4	34.3	14.3	14.6	4.3	50	62.5	26.1	32.6	8.9
5	37.4	16.5	17.4	4.8	51	62.5	27.0	31.2	8.4
6	39.0	18.4	14.1	5.3	52	63.0	26.6	32.5	8.0
7	39.5	17.0	18.3	5.2	53	63.4	29.1	32.7	8.9
8	39.5	17.8	17.3	4.1	54	63.5	26.8	31.8	8.6
9	39.5	18.1	19.8	5.6	55	63.5	26.2	30.2	8.1
10	40.2	16.8	18.0	4.6	56	64.0	28.1	35.1	7.9
11	41.0	17.7	19.2	4.8	57	64.3	28.5	32.1	8.1
12	44.2	19.1	21.4	5.2	58	64.4	29.0	33.7	9.2
13	44.2	19.0	20.6	5.5	59	64.9	28.2	33.6	8.7
14	45.3	19.0	21.3	4.8	60	65.7	29.1	34.0	9.3
15	46.5	20.8	18.3	4.5	61	65.5	28.2	32.8	8.2
16	47.5	21.1	24.1	6.9	62	65.6	28.4	27.2	6.4
17	48.1	21.1	24.2	6.7	63	65.7	29.1	33.4	8.4
18	48.3	20.0	24.7	6.9	64	66.4	30.3	35.8	9.4
19	49.1	22.1	25.4	7.8	65	66.5	38.2	33.6	8.5
20	49.5	21.4	23.1	6.2	66	67.3	29.1	34.2	9.3
21	50.1	21.6	23.5	5.8	67	67.5	29.0	33.1	8.0
22	50.3	22.7	25.4	6.0	68	68.4	29.2	33.5	8.0
23	51.6	22.1	25.9	6.4	69	68.7	30.8	37.2	9.8
24	52.0	23.8	26.4	7.3	70	68.7	29.1	35.4	9.8
25	52.3	23.8	26.8	6.8	71	69.1	28.7	35.8	8.8
26	53.1	23.7	24.8	6.6	72	69.2	32.0	29.7	9.6
27	53.1	23.2	25.7	6.5	73	69.5	30.3	36.8	9.3
28	53.5	23.8	26.5	7.3	74	70.2	30.3	35.3	9.1
29	53.8	23.7	25.6	6.4	75	70.2	30.1	36.4	9.7
30	55.2	24.3	29.5	7.5	76	71.0	30.7	37.8	9.2
31	55.3	28.6	33.5	9.3	77	71.4	30.1	36.1	9.2
32	55.3	25.1	27.3	7.5	78	71.8	29.5	35.4	8.2
33	55.5	25.5	28.5	7.8	79	72.5	29.8	35.5	9.1
34	55.7	24.2	27.8	7.5	80	72.8	30.3	35.2	9.6
35	55.8	24.7	27.5	7.3	81	73.4	32.1	37.2	10.4
36	56.9	25.6	28.8	7.1	82	74.5	31.6	38.8	8.7
37	57.1	24.1	28.2	7.4	83	74.5	31.0	36.5	10.0
38	57.5	24.1	28.7	7.2	84	75.0	32.2	39.2	10.1
39	58.0	25.8	32.5	8.5	85	75.8	32.7	40.1	10.0
40	58.1	25.3	29.0	7.1	86	75.9	31.1	39.1	9.6
41	58.1	25.7	29.2	8.8	87	76.5	33.2	41.6	10.5
42	58.4	25.1	29.5	7.9	88	76.7	31.0	38.8	9.9
43	58.5	26.0	28.0	6.6	89	77.0	32.4	39.8	10.2
44	58.5	25.6	29.8	8.1	90	78.4	33.1	40.2	11.0
45	59.0	25.2	29.8	8.2	91	79.2	32.8	41.2	10.1
46	59.8	25.6	30.3	7.2	92	79.8	34.3	41.5	10.6

CW=carapace width ; CL=carapace length ; Ch L=chelar propodus length ;
Ch D=chelar propodus length. all measurements in mm.

TABLE 5.2.
Morphometric characters in mature males of *P. sanguinolentus*.

Sl.No.	CW	CL	Ch L	Ch D	Sl.No.	CW	CL	Ch L	Ch D
1	80.0	33.3	40	10	48	122.1	50.3	74.1	17.1
2	80.1	34.1	42.1	10	49	122.8	50.5	75.6	17.6
3	82.1	35.9	44	10.2	50	124	50.5	74.8	16.8
4	82.4	35.9	43	10.3	51	125	53.7	79.4	16.3
5	82.6	36.3	43.4	10.1	52	125	53.2	77.7	16.1
6	83	35.1	45.2	11.1	53	125	51.2	76.6	17.5
7	84	34.8	44.5	11.4	54	126	53.2	81.1	18.4
8	84.1	35.6	42.3	10.1	55	127.5	53	78.6	16.1
9	84.6	36.3	47.7	11.2	56	128	52.3	75.9	17.8
10	85.5	36.5	45.6	11.5	57	129	56.2	85.4	17.7
11	85.8	35.2	45.8	11.4	58	130	56.3	86.7	18.4
12	86.5	37.2	46.3	11.9	59	130	54.5	79.5	19.8
13	87	35.1	49.1	11.5	60	131	56.3	87.3	17.3
14	89.1	38.2	49.3	10.5	61	132	64.2	91.8	17.8
15	89.8	38.2	50.5	11.8	62	132	57.1	86.2	19
16	89.9	38.6	50.9	12.3	63	132	54.2	82.9	17.9
17	90	38.2	49.1	12.6	64	132	57.1	87.5	18.4
18	90.5	36.8	38.6	12.5	65	132	57.3	87.2	18.5
19	91	38.5	50	12.3	66	134	57.2	78.3	15.7
20	93.1	38.7	48.7	11.9	67	134	58.4	81.1	17.9
21	93.3	38.8	49.5	11.3	68	135	57.2	87	17.3
22	93.9	43.4	60.6	13.8	69	135	54.2	85.8	16.8
23	95	40	51.8	12.3	70	135	57.1	85.3	18.3
24	96.8	42.1	58.3	13.3	71	136	55.3	86.5	17.2
25	98.3	41.3	55.6	13.4	72	136	58.2	87.5	20.4
26	99.1	41.5	54.8	12	73	137	60.2	87	18.9
27	101	40.5	56.8	14	74	138	58.6	92.7	20.2
28	102	45	58.2	14.1	75	139	55.2	83	18.3
29	104.7	43.3	59.1	13.5	76	140	59.1	89	19.5
30	105	44.7	61	13.2	77	141	61.6	92.3	18.6
31	106	44.1	59.2	14	78	141	58.3	92.1	19.3
32	106.5	45.8	66	13.5	79	142	59.4	79	16.3
33	108	45.8	63.1	12.8	80	142	59.4	79	16.3
34	108.4	45.1	62.1	15	81	143	58.4	89.5	19.7
35	110	45.1	50.4	11.2	82	143	57.6	93.6	19.4
36	110	46.8	65.9	14.2	83	143	60.2	98.2	19.5
37	112.1	48.6	68.7	14.9	84	144	59.7	93.2	20
38	113.2	48.4	68.1	14.6	85	145	60.2	96.7	21.1
39	113.8	49.1	71.1	16.8	86	145	59.2	91.3	20.1
40	114	47.9	66.7	10.6	87	146	62.1	94.3	22.1
41	116.1	49.3	67.3	17.1	88	147	60.7	99.1	19.4
42	117	48.5	64.6	14.2	89	149	61.7	96.3	19.7
43	119	49.1	71.1	16.1	90	149	63.1	95.3	22
44	120	48.3	64.5	13.5	91	150	60.8	95.6	20.7
45	120	48.9	68.2	14.6	92	152	60.2	89	18
46	120.5	52.1	75.1	18	93	154	62.1	101	18.6
47	121	53	77.3	18.2	94	154	64.1	103.2	21.7

CW=carapace width; CL= carapace length; Ch D= chelar propodus depth,
 Ch L=chelar propodus length. all measurements in mm.

TABLE 5.3.
Morphometric characters in immature males of *P. pelagicus*.

Sl.No.	CW	CL	Ch L	Ch D	Sl. No	CW	CL	Ch L	Ch D
1	32	14.5	16.3	4.7	41	68.3	29	33.7	9.5
2	32.3	14.9	15.8	5	42	68.3	28.1	34.2	8.4
3	33.5	14.8	16.5	5.8	43	68.5	29.3	32.7	7.4
4	36.8	16.4	17	4.1	44	68.5	28.8	33.1	9
5	37	16.3	18.4	5	45	68.6	28.2	33.4	8.4
6	39	18.1	20.6	5.7	46	68.7	29.2	38.1	8
7	40	19.1	20.5	5.5	47	68.7	28.1	34.2	8.4
8	42.5	18.4	19.5	4.7	48	68.9	29.1	34.4	9.1
9	43.5	19	21.3	5.4	49	69.2	30.1	36.4	9.2
10	45	19.2	21.5	6.4	50	69.5	29.1	34	8.4
11	45	20.5	22.1	5.8	51	70	28.5	34.2	9.3
12	48	21.8	24	5.5	52	70.6	29.1	34.8	9.5
13	48	21.9	22.2	5.6	53	71	29.4	35	9.1
14	51.5	24.2	27.8	6.7	54	71.1	29.8	36.3	9.3
15	54	23.7	27.5	6.8	55	71.1	29.8	35.5	9.4
16	54.5	24.1	26.2	6.9	56	71.2	29.3	33.6	9.4
17	55.5	23.5	27.5	7.2	57	72	30.5	36.8	9.1
18	56	24.4	27.3	6.8	58	72	31.7	37.3	8
19	57.1	25.3	25.6	5.4	59	72.2	31.4	36.2	9.7
20	57.2	25.1	30.1	7.5	60	72.9	30.4	37.3	7.9
21	58.1	24.6	27.3	7.2	61	74	31.1	38.3	8.5
22	58.7	27.1	31.2	8.1	62	75	32.2	40.5	7.5
22	58.7	27.1	31.2	8.1	63	75	31.9	37.9	9.5
23	59.1	25.2	28.6	7.9	64	76	33.1	39.1	9.8
24	59.5	26.7	30.5	8.4	65	76.4	31.2	39.2	10.1
25	59.5	26.1	30.1	8.3	66	76.5	33.5	44.1	11.1
26	60.3	26.1	26.1	6.1	67	76.5	35.8	38.2	7.8
27	61.7	27.1	32.1	8.1	68	77	32.8	41.1	10.8
28	62.5	23.6	30.3	9.1	69	77	32.5	38.1	8.4
29	63.5	27.6	27.8	7.2	70	77.8	32.2	40.5	10.5
30	64	27.5	25.3	6.9	71	78	33.8	41.8	10.2
31	64.1	30.1	34.5	9.6	72	78.5	34	42.9	9
32	64.1	29.1	33.1	8.4	73	78.5	33.2	38.5	10.5
33	65	28.6	39.5	8.8	74	79	33	39.3	10.1
34	66.1	27.4	34.1	8.8	75	79.5	33.2	41.1	10.2
35	67.1	28.2	32.4	7.7	76	79.6	33.8	41.8	11
36	67.1	28	34.4	9.2	77	79.6	34.2	42.5	10.9
37	67.5	28.8	34.7	9.1	78	79.8	33	42	10.5
38	68	27.5	34.2	8.3	79	79.9	34.1	42.4	10.6
39	68.1	28.5	32.5	2.3					
40	68.1	29.2	34.2	8.4					

CW =carapace width; CL= carapace length; Ch L=chelar propodus length;
 Ch D= chelar propodus depth. all measurements in mm.

TABLE 5.4.
Morphometric characters in mature males of *P. pelagicus*.

Sl.No	CW	CL	Ch L	Ch D	Sl.No	CW	CL	Ch L	Ch D	Sl.No	CW	CL	Ch L	Ch D
1	81.1	33.2	39.4	9.9	45	91.4	39.7	49.1	10.2	89	109.0	44.5	66.8	14.0
2	81.2	35.6	43.2	12.0	46	91.8	38.6	48.6	11.8	90	109.0	48.	67.3	14.5
3	81.2	33.9	37.5	7.8	47	92.0	40.1	53.8	13.3	91	110.0	49.4	67.1	13.8
4	81.5	35.7	43.8	11.4	48	92.1	40.1	50.3	12.1	92	110.0	48.1	69.6	14.5
5	81.7	44.2	43.0	11.1	49	92.5	39.9	50.2	12.3	93	110.2	46.2	62.4	14.1
6	82.0	35.0	44.5	10.6	50	92.8	38.2	45.0	10.3	94	110.2	47.	63.4	14.1
7	82.1	35.3	40.8	10.4	51	94.0	40.6	53.4	12.0	95	110.5	46.1	61.1	14.8
8	82.1	34.2	41.8	10.3	52	94.5	39.5	51.3	12.3	96	111.0	48.5	68.7	14.5
9	82.1	35.2	43.5	11.4	53	94.1	40.8	50.5	12.1	97	112.0	47.3	68.9	13.5
10	82.3	34.5	42.6	10.5	54	94.6	40.0	50.1	11.5	98	113.0	48.8	71.3	15.2
11	82.4	33.8	42.3	11.5	55	95.0	41.2	54.2	11.6	99	114.0	49.0	66.8	13.4
12	83.2	36.5	46.2	11.8	56	95.1	42.2	54.3	13.2	100	114.0	50.4	62.2	12.1
13	83.0	33.8	42.3	11.5	57	95.2	41.9	53.5	12.7	101	114.1	50.6	69.2	13.2
14	83.5	34.1	40.5	9.1	58	95.5	38.7	49.5	12.9	102	114.8	51.8	72.7	14.6
15	83.6	35.5	44.6	10.8	59	95.5	40.1	52.3	12.9	103	115.0	50.5	67.6	12.6
16	83.7	36.0	43.7	10.5	60	96.0	44.5	61.9	13.6	104	115.5	49.1	69.7	13.9
17	84.5	36.3	45.2	10.2	61	96.5	40.5	54.8	12.4	105	116.0	54.0	60.1	11.8
18	84.5	35.4	43.4	11.0	62	97.0	42.2	55.3	13.1	106	117.0	50.1	67.4	16.9
19	84.9	34.6	41.4	9.0	63	97.0	43.3	61.1	10.5	107	117.9	61.1	73.5	16.4
20	85.0	36.5	45.3	11.1	64	97.5	42.3	56.1	12.6	108	121.0	54.0	76.9	15.0
21	85.1	36.1	45.1	11.4	65	97.5	42.3	51.4	12.5	109	124.0	54.1	78.5	15.1
22	85.6	36.8	45.8	11.2	66	97.6	42.1	56.7	11.6	110	124.5	56.3	93.2	16.7
23	86.1	35.3	45.2	10.7	67	97.7	40.2	50.7	11.8	111	127.0	54.5	75.1	17.1
24	86.2	36.6	44.5	10.0	68	98.2	42.1	51.4	10.2	112	128.5	57.1	86.3	17.2
25	87.0	35.8	44.4	9.5	69	98.2	42.5	54.9	11.5	113	131.0	57.1	90.9	17.2
26	87.0	36.5	47.2	10.1	70	98.5	41.6	52.8	10.8	114	132.5	60.1	92.2	19.0
27	87.1	36.5	47.0	11.0	71	99.0	41.6	53.1	12.8	115	140.0	60.3	101.5	15.4
28	87.1	36.4	46.1	11.2	72	99.0	44.0	59.3	11.8	116	141.0	66.1	115.1	21.4
29	88.0	37.2	46.2	11.1	73	99.0	44.0	58.4	14.1	117	141.5	63.2	104.4	21.1
30	88.1	35.7	46.5	12.3	74	99.1	42.6	54.7	13.7	118	141.5	63.9	100.7	20.1
31	88.2	38.1	45.0	10.6	75	99.2	42.1	56.0	13.2	119	141.5	64.3	115.5	20.1
32	88.2	29.3	35.0	10.0	76	100.0	42.6	49.8	10.1	120	147.0	67.1	115.9	20.1
33	89.3	37.2	47.2	10.0	77	100.4	42.3	54.8	12.5	121	147.5	67.1	112.2	21.1
34	89.5	37.0	47.4	9.7	78	101.1	42.5	48.2	10.2	122	147.5	67.3	118.3	18.2
35	89.5	36.4	48.6	11.1	79	102.0	42.9	58.5	15.0	123	147.5	66.2	111.2	18.4
36	89.5	38.2	50.7	11.5	80	102.2	42.7	48.2	10.0	124	148.0	67.3	111.4	18.1
37	90.0	39.2	47.9	12.2	81	103.0	44.0	57.0	11.8	125	152.0	72.2	120.2	24.1
38	90.0	38.0	48.2	10.5	82	103.0	43.2	56.8	10.8	126	153.0	68.2	114.2	22.3
39	90.0	39.7	51.0	11.2	83	103.8	48.9	59.5	10.8	127	153.5	68.4	120.1	23.5
40	90.1	42.1	55.1	13.3	84	104.4	43.8	58.4	13.2	128	156.0	65.2	115.0	17.8
41	90.5	38.2	39.1	8.7	85	105.1	45.5	59.8	12.6	129	157.0	71.1	122.0	22.5
42	90.6	40.1	49.2	10.7	86	106.0	45.0	61.5	15.1	130	158.0	72.1	119.2	22.9
43	91.0	39.5	43.5	9.0	87	106.8	46.1	67.3	14.1	131	159.0	71.8	121.5	22.6
44	91.0	39.1	50.9	12.5	88	108.0	46.1	53.5	9.6					

W = carapace width; CL = carapace length; Ch L = chelar propodus length;
Ch D = chelar propodus depth all measurements in mm.

TABLE 5.5
Allometric growth equations in immature and mature males of
***P.sanguinolentus*.**

Sl.No.	Independent variable	Dependent variable	Allometric growth equation	n
	X	Y	($Y=a+bX$)	
Immature males				
1.	Carapace width	Chelar propodus depth	$Y = -0.0411 + 0.1320 X$	92
2.	Carapace width	Chelar propodus length	$Y = -3.9362 + 0.5696 X$	92
3.	Carapace length	Chelar propodus depth	$Y = -0.4538 + 0.3195 X$	92
4.	Carapace length	Chelar propodus length	$Y = -5.7314 + 1.3781 X$	92
5.	Chelar propodus length	Chelar propodus depth	$Y = 0.8762 + 0.2318 X$	92
Mature males				
1.	Carapace width	Chelar propodus depth	$Y = 0.0417 + 0.1328 X$	94
2.	Carapace width	Chelar propodus length	$Y = -23.6330 + 0.8036 X$	94
3.	Carapace length	Chelar propodus depth	$Y = -1.6660 + 0.3509 X$	94
4.	Carapace length	Chelar propodus length	$Y = -27.6180 + 1.9943 X$	94
5.	Chelar propodus length	Chelar propodus depth	$Y = 3.2079 + 0.1758 X$	94

TABLE 5.6.
Allometry levels (b) and correlation coefficients (r) between morphometric
parameters of males *P.sanguinolentus*.

Sl.No.	Parameters		'b'	'r'+	d.f.
Immature males					
1.	C.W.	Ch.D.	0.9792	0.996	90
2.	C.W.	Ch.L.	1.1645*	0.998	90
3.	C.L.	Ch.D.	1.0479	0.992	90
4.	C.L.	Ch.L.	1.2214*	0.997	90
5.	Ch.L.	Ch.D.	0.8573	0.995	90
Mature males					
1.	C.W.	Ch.D.	1.0677	0.924	92
2.	C.W.	Ch.L.	1.3491*	0.996	92
3.	C.L.	Ch.D.	1.1089	0.998	92
4.	C.L.	Ch.L.	1.4031*	0.997	92
5.	Ch.L.	Ch.D.	0.7890	0.989	92

C.W.= carapace width; C.L.= carapace length; Ch.D.= chelar propodus depth;

Ch.L.= chelar propodus length

The constants of allometry (b) based on log-log transformations

Asterisk indicates high positive allometry

+ significant at $P < 0.001$

TABLE 5.7

Allometric growth equations in immature and mature males of *P.pelagicus*.

SL.No.	Independent variable	Dependent variable	Alloetric growth equation	n
	X	Y	($Y=a+bX$)	
Immature males				
1.	Carapace width	Chelar propodus depth	$Y= 0.6915+0.1151 X$	79
2.	Carapace width	Chelar propodus length	$Y= -2.4856+0.5462 X$	79
3.	Carapace length	Chelar propodus depth	$Y= 0.2164+0.2842 X$	79
4.	Carapace length	Chelar propodus length	$Y= -4.9126+1.3554 X$	79
5.	Chelar propodus length	Chelar propodus depth	$Y= 1.2773+0.2086 X$	79
Mature males				
1.	Carapace width	Chelar propodus depth	$Y= -2.6966+0.1532 X$	132
2.	Carapace width	Chelar propodus length	$Y= -49.3541+1.0697 X$	132
3.	Carapace length	Chelar propodus depth	$Y= -0.7919+0.311 X$	132
4.	Carapace length	Chelar propodus length	$Y= -35.3478+2.1559 X$	132
5.	Chelar propodus length	Chelar propodus depth	$Y= 4.3431+0.1437 X$	132

TABLE 5.8.

Allometry levels (b) and correlation coefficients (r) between morphometric parameters of males *P.pelagicus*.

SL.No.	Parameters		'b'	r'+	d.f.
Immature males					
1.	C.W.	Ch.D.	0.8353	0.998	77
2.	C.W.	Ch.L.	1.0683	0.992	77
3.	C.L.	Ch.D.	0.9176	0.982	77
4.	C.L.	Ch.L.	1.1689*	0.989	77
5.	Ch.L.	Ch.D.	0.8027	0.986	77
Mature males					
1.	C.W.	Ch.D.	1.2807*	0.980	130
2.	C.W.	Ch.L.	1.7037*	0.987	130
3.	C.L.	Ch.D.	1.1678*	0.986	130
4.	C.L.	Ch.L.	1.5549*	0.988	130
5.	Ch.L.	Ch.D.	0.7513	0.993	130

C.W.= carapace width; C.L.= carapace length; Ch.D.= chelar propodus depth;

Ch.L.= chelar propodus length

The constants of allometry (b) based on log- log transformations

Asterisk indicates high positive allometry

+ significant at $P < 0.001$

TABLE 5.9.**Morphometric characters in immature females of *P. sanguinolentus*.**

No.	CW	CL	Ab W	Ab L	Sl.No.	CW	CL	Ab W	Ab L
1	33.2	14.8	8.1	11.7	21	71	30.5	18.6	23.5
2	35.2	15.1	9.1	13.1	22	71	30.5	19.4	23.6
3	42.6	18.1	10	13.4	23	72.2	29.5	18.4	23.2
4	49.5	21.1	11.8	16	24	72.5	31.1	19.2	22.6
5	54.5	24.6	14.5	18.6	25	73.1	30.7	19.6	24.6
6	57.2	24.6	15.1	18.3	26	74	31.2	18	23.5
7	59.1	26.2	16.1	20	27	74.1	32.8	18.6	23.2
8	60.3	25.6	15.5	18.4	28	74.2	31.4	20.1	24.5
9	60.5	25.6	15.5	18.4	29	74.1	23.1	19.5	24.3
10	62.7	27.8	17.1	21.8	30	75.5	32.3	20.7	25.8
11	62.8	27.4	17	20.2	31	75.5	33.6	20.3	25.3
12	63.7	27.8	17.2	20.7	32	76.2	32.6	20.7	26.2
13	64.8	23.7	17.5	22.7	33	76.2	32.2	19.9	25
14	66.7	29.2	18	22.3	34	76.9	33.3	20.5	25.7
15	67.5	28.2	17.9	22.4	35	77	33.4	20.3	20.3
16	68.6	30.5	17.8	23.8	36	77	33.2	21.6	28.5
17	68.9	29.4	18.6	21.3	37	77.5	33.1	20.2	25.5
18	69.5	28.8	18.2	22.7	38	77.1	33.2	20.7	24.5
19	70.7	31.7	20.5	26.1	39	77.1	33.4	19.4	24.9
20	70	30.5	18.5	24.2	40	78.1	33.1	20.3	25.1

CW = carapace width; CL = carapace length; Ab L = abdomen length; Ab W = abdomen width

TABLE 5.10
Morphometric characters in mature females of *P. sanguinolentus*.

Sl.No.	CW	CL	AB W	Ab L	Sl.No.	CW	CL	Ab W	Ab L
1	80.8	38.4	19.8	25.9	23	116.0	50.5	36.6	39.3
2	81.2	34.0	21.7	24.8	24	117.0	50.0	33.4	39.3
3	81.3	34.1	21.7	25.3	25	117.0	48.2	38.8	39.4
4	81.6	33.1	23.2	27.6	26	118.2	51.2	35.4	40.2
5	83.0	35.8	22.1	28.1	27	120.0	50.3	36.1	39.1
6	87.8	36.2	26.3	30.5	28	120.0	51.0	37.4	41.1
7	89.1	38.3	29.5	30.1	29	120.0	50.3	35.1	38.2
8	91.6	40.1	29.1	32.3	30	123.6	53.3	38.2	41.2
9	91.8	38.7	27.7	29.5	31	124.0	52.2	36.6	41.3
10	92.7	39.1	27.8	30.6	32	124.0	52.4	37.5	42.3
11	97.1	39.8	29.2	32.5	33	124.3	55.4	38.2	43.2
12	98.1	41.4	30.0	32.6	34	126.0	50.4	37.5	43.2
13	98.2	42.6	31.1	33.4	35	128.0	55.1	38.3	44.0
14	99.3	44.8	33.1	34.9	36	128.0	56.2	39.0	44.0
15	100.2	43.7	31.6	33.3	37	128.0	55.0	36.2	40.2
16	103.7	44.0	32.1	35.3	38	129.0	57.5	38.3	45.8
17	106.2	46.6	33.9	35.1	39	130.0	54.9	38.8	44.6
18	113.0	46.2	34.2	35.9	40	131.5	56.1	39.9	44.0
19	113.0	48.8	35.2	37.0	41	134.5	56.4	39.7	44.1
20	115.0	49.1	33.5	37.6	42	137.0	58.1	40.2	47.2
21	115.0	50.0	35.6	39.6	43	137.0	58.5	41.7	45.3
22	116.0	50.0	34.2	38.7	44	140.0	60.1	43.1	48.2

CW = carapace width; CL = carapace length; Ab W = abdomen width; Ab L = abdomen length

TABLE 5.11.

Morphometric characters in immature females of *P. pelagicus*.

No.	CW	CL	Ab W	Ab L	Sl.No.	CW	CL	Ab W	Ab L
1	31.1	14.7	10.2	5.8	33	67.3	28	20.5	16.5
2	32	14.8	10.2	5.8	34	67.8	29.2	21.5	16.2
3	37.3	18	11.9	6.6	35	68.1	29.1	21.2	16
4	39	18.1	12.4	6.5	36	68.2	29.7	21.1	16.2
5	41.3	18.7	13.2	7.3	37	69.2	29.2	22.1	16.2
6	44.1	19.6	13.4	7.4	38	69.3	27.8	22.3	17.1
7	44.4	18.6	13.5	7.5	39	69.5	28.7	21.2	16.5
8	45	18.6	13.5	8.1	40	70	29.6	22.7	17.2
9	47.9	20	15.5	7.7	41	70.2	30.2	23.2	16.8
10	48.1	21.8	15	9.2	42	70.3	31.2	24.4	17.1
11	50.5	22.7	15	8.9	43	70.5	29.7	24.1	16.8
12	51.8	23.5	16	8.7	44	71.1	30	21.3	17.5
13	54	24.1	18.1	13.2	45	71.8	31.1	21.6	17.4
14	54.3	24.8	18	13.2	46	72.3	31.6	23.2	18.2
15	55	23.9	17	10.5	47	72.7	31.5	25	18.1
16	58.1	25	17.2	13.5	48	73.2	32.1	25.2	17.6
17	58.2	26.2	20.4	14.1	49	73.2	33.2	25.5	19.1
18	58.2	25.8	18.1	13.6	50	73.5	32.6	25.1	18.3
19	59.2	25.9	16.4	11.5	51	74.3	31.5	23.8	18.7
20	61.1	26.2	19.3	14.5	52	75.5	32.6	24.5	18.1
21	62.2	26.4	17.3	14	53	75.6	32.8	24.2	18.7
22	62.4	27	19.5	15.2	54	75.8	32.1	24.8	19.2
23	63.1	26.1	20	15.2	55	75.8	32.3	25.2	19.1
24	64.1	27.1	20.1	16.1	56	76.5	31.8	24	18.6
25	64.5	27.4	19.9	14.4	57	77.1	32.6	24.3	19.1
26	65.1	28	20	15.6	58	78	33.4	24.8	19
27	65.1	28.8	20.4	15.3	59	78	34.1	24.6	20
28	65.2	27.4	20	15.9	60	78.2	34.4	25.1	19.3
29	65.5	28.2	22	15.8	61	79	33.3	26.1	19.3
30	65.6	20.4	16.4	16.4	62	79.2	33.2	25.7	18.8
31	65.9	28.3	21.1	16.1	63	79.7	34.2	24.2	22
32	66.1	29.3	21	16.2					

CW = carapace width; CL = carapace length; Ab W = abdomen width; Ab L = abdomen length

TABLE 5.12.

Morphometric characters in mature females of *P. pelagicus*.

CW	CL	Ab W	Ab L	Sl.No	CW	CL	Ab.W	Ab L	Sl.No	CW	CL	Ab W	Ab L
80.0	34.2	24.1	19.2	44	89.1	37.2	28.2	22.2	87	110.0	46.2	36.6	28.1
80.0	35.1	24.8	19.3	45	89.3	36.8	28.3	21.7	88	111.2	46.1	35.6	27.8
80.2	34.0	25.8	19.5	46	89.6	38.7	27.6	22.6	89	112.0	46.5	37.6	34.5
80.5	34.3	25.5	20.5	47	89.7	37.1	29.2	22.2	90	114.0	49.5	39.5	34.3
81.0	34.4	25.1	20.0	48	89.8	42.8	32.3	25.6	91	114.9	48.8	37.8	33.2
82.3	35.1	25.1	20.1	49	89.9	37.8	29.1	23.1	92	115.8	50.5	39.8	35.4
82.5	35.0	25.3	20.1	50	90.0	37.5	28.2	23.0	93	117.0	50.5	50.5	34.0
83.0	35.7	27.4	21.4	51	90.1	37.7	29.2	20.8	94	117.0	49.5	40.3	36.5
83.3	33.4	24.7	19.8	52	90.3	38.1	28.8	22.1	95	117.1	49.8	39.0	35.0
83.5	34.3	25.5	20.7	53	90.8	37.1	29.1	22.2	96	117.1	48.8	39.0	35.0
83.4	34.8	20.7	25.9	54	90.9	38.2	27.7	21.5	97	120.0	52.5	49.5	36.8
83.7	34.5	25.0	20.4	55	91.0	41.6	30.6	24.5	98	122.4	53.3	42.1	38.8
84.0	35.3	27.3	20.8	56	91.0	37.5	27.6	22.0	99	124.0	52.9	40.1	34.5
84.0	35.1	26.1	21.5	57	91.2	37.7	28.4	22.8	100	125.5	53.4	43.1	38.7
84.0	34.2	25.7	20.6	58	92.1	38.7	29.1	24.1	101	127.0	55.5	44.0	41.1
84.1	35.6	27.3	20.6	59	92.7	39.1	29.8	23.1	102	128.0	55.6	44.7	39.4
84.1	34.1	26.2	21.0	60	93.1	38.2	30.1	23.6	103	129.0	54.4	41.7	36.5
84.2	35.7	26.7	21.2	61	93.2	39.1	30.7	23.2	104	132.0	56.2	43.2	38.7
84.2	35.0	27.5	20.7	62	93.5	39.1	30.7	23.2	105	136.0	57.2	45.1	39.2
84.4	36.5	27.1	22.0	63	94.0	39.9	30.5	24.9	106	136.0	58.1	41.5	45.1
84.4	36.5	27.1	22.0	64	94.1	39.3	30.3	23.2	107	138.0	62.1	46.8	40.2
84.7	34.2	26.5	20.8	65	94.2	39.4	29.2	24.1	108	140.0	59.0	46.5	43.2
85.0	35.7	26.2	20.2	66	95.0	39.2	31.3	28.0	109	140.0	59.1	45.1	42.1
85.0	35.7	26.9	20.2	67	95.1	41.1	32.1	25.0	110	140.5	64.1	49.1	48.1
85.3	35.5	27.5	21.1	68	95.3	40.2	30.3	28.1	111	142.0	63.1	49.9	45.1
85.4	35.5	26.1	21.0	69	95.3	40.8	31.8	24.4	112	142.0	63.8	51.5	44.1
85.5	36.6	27.6	23.2	70	95.4	39.4	30.5	23.5	113	143.0	62.7	48.1	43.5
85.6	35.9	27.1	20.6	71	96.0	40.5	28.8	24.4	114	143.0	60.3	48.2	43.2
85.6	35.7	27.0	19.7	72	96.1	40.6	30.5	23.9	115	144.0	63.1	50.7	44.1
87.0	37.5	27.8	26.1	73	96.6	41.8	31.6	26.0	116	144.0	62.5	50.5	49.2
87.0	36.7	27.5	22.0	74	96.7	40.8	30.0	24.7	117	144.0	62.8	48.8	45.3
87.0	36.7	27.5	22.0	75	97.6	40.8	32.1	25.1	118	146.0	63.2	48.3	46.9
87.1	35.6	26.2	21.4	76	98.2	41.8	32.2	24.4	119	149.0	65.8	52.4	47.8
87.5	37.1	27.6	22.1	77	99.0	41.5	30.1	25.2	120	150.0	61.7	49.1	45.5
87.5	36.8	26.4	21.4	78	99.0	40.7	31.8	27.4	121	152.0	66.8	56.6	56.4
87.6	36.2	26.2	20.8	79	99.9	43.2	33.8	25.3	122	152.0	66.8	54.5	48.7
88.2	37.5	28.9	21.7	80	100.0	42.2	32.7	28.3	123	155.0	74.1	56.5	54.0
88.2	36.7	29.1	21.7	81	103.1	44.5	33.7	27.2	124	157.0	71.1	57.1	52.3
88.3	37.1	28.2	21.5	82	103.8	43.2	36.1	25.6	125	158.0	69.1	54.1	51.1
88.9	38.2	28.4	22.2	83	104.9	44.1	36.1	25.6	126	161.0	73.8	59.3	56.3
89.0	36.9	28.5	21.9	84	105.1	43.2	35.8	25.1	127	162.0	67.5	52.1	42.2
89.1	37.2	29.2	23.1	85	110.0	46.1	37.1	28.1	128	173.0	76.6	64.1	58.3
89.1	38.2	29.6	22.1	86	110.0	47.5	37.1	34.4					

CW=carapace width; CL=carapace length; Ab W=abdomen width; Ab L=abdomen length.
Measurements in mm.

TABLE 5.13

Allometric growth equations in immature and mature female of *P.sanguinolentus*.

Sl.No.	Independent variable	Dependent variable	Allometric growth equation	n
	X	Y	(Y=a+bX)	
Immature females				
	Carapace width	Abdomen width	Y= -0.6941+0.2728 X	40
	Carapace width	Abdomen length	Y= 2.0707+0.2997 X	40
	Carapace length	Abdomen width	Y= -1.6347+0.6684 X	40
	Carapace length	Abdomen length	Y= 1.0185+0.7350 X	40
	Abdomen length	Abdomen width	Y= -2.5393+0.9083 X	40
Mature females				
	Carapace width	Abdomen width	Y= -0.4864+0.3087 X	44
	Carapace width	Abdomen length	Y= -1.4127+0.3479 X	44
	Carapace length	Abdomen width	Y= 2.0989+0.6682 X	44
	Carapace length	Abdomen length	Y= -1.0537+0.8063 X	44
	Abdomen length	Abdomen width	Y= 0.9257+0.8831 X	44

TABLE 5.14

Allometry levels(b) and correlation coefficients between morphometric parameters of females *P.sanguinolentus*.

Sl.No.	Parameters		'b'	'r'+	d.f.
Immature females					
1.	C.W.	A.W.	1.0255	0.994	38
2.	C.W.	A.L.	1.0155	0.995	38
3.	C.L.	A.W.	1.1509*	0.992	38
4.	C.L.	A.L.	1.1429*	0.994	38
5.	A.W.	A.L.	0.9869	0.996	38
Mature females					
1.	C.W.	A.W.	1.0527	0.983	42
2.	C.W.	A.L.	1.0427	0.993	42
3.	C.L.	A.W.	1.0401	0.952	42
4.	C.L.	A.L.	1.0276	0.995	42
5.	A.W.	A.L.	0.9012	0.985	42

W= carapace width; C.L.= carapace length; A.W= abdomen width; A.L.= abdomen length

The constants of allometry (b) based on log- log transformations

*sterisk indicates high positive allometry

+ significant at P <0.001

TABLE 5.15
Allometric growth equations in immature and mature females of *P.pelagicus*.

Sl.No.	Independent variable	Dependent variable	Allometric growth equation	n
	X	Y	($Y=a+bX$)	
Immature females				
1.	Carapace width	Abdomen width	$Y= -1.027+0.3334 X$	63
2.	Carapace width	Abdomen length	$Y= -6.2675+0.3319 X$	63
3.	Carapace length	Abdomen width	$Y= -2.165+0.8164 X$	63
4.	Carapace length	Abdomen length	$Y= -0.5474+0.7817 X$	63
5.	Abdomen length	Abdomen width	$Y= 5.7681+0.9708 X$	63
Mature females				
1.	Carapace width	Abdomen width	$Y= -1.851+0.3178 X$	128
2.	Carapace width	Abdomen length	$Y= -1.2183+0.3467 X$	128
3.	Carapace length	Abdomen width	$Y= -0.916+0.7237 X$	128
4.	Carapace length	Abdomen length	$Y= -0.4490+0.7949 X$	128
5.	Abdomen length	Abdomen width	$Y= -0.258+0.9037 X$	128

TABLE 5.16.
Allometry levels (b) and correlation coefficients between morphometric parameters of females *P.pelagicus*.

Sl.No.	Parameters		'b'	'r'+	d.f.
Immature females					
1.	C.W.	A.W.	1.4875*	0.992	61
2.	C.W.	A.L.	0.9729	0.995	61
3.	C.L.	A.W.	1.6806*	0.979	61
4.	C.L.	A.L.	1.1014	0.978	61
5.	A.L.	A.W.	1.5182*	0.995	61
Mature females					
1.	C.W.	A.W.	1.4492*	0.996	126
2.	C.W.	A.L.	1.1851*	0.999	126
3.	C.L.	A.W.	1.3160*	0.998	126
4.	C.L.	A.L.	1.0756	0.998	126
5.	A.L.	A.W.	1.2221*	0.998	126

C.W.= carapace width; C.L.= carapace length; A.W.= abdomen width;
A.L.= abdomen length

The constants of allometry (b) based on log- log transformations

Asterisk indicates high positive allometry

+ significant at $P < 0.001$

TABLE 5.17.

Monthly distribution of various maturity stages of *P.sanguinolentus* males in the inshore/estuarine waters at Mangalore.

Period	STAGE I (Immature)		STAGE II (Maturing)		STAGE III (Mature)		Total
	n	%	n	%	n	%	n
TRAWL CATCH (inshore)							
Nov.92	13	25.49	19	37.25	19	37.25	51
Dec.	46	19.57	61	25.96	128	54.47	235
Jan.93	1	0.57	3	1.72	170	97.70	174
Feb.	7	8.43	7	8.43	69	83.13	83
Mar.	22	36.07	16	26.23	23	37.70	61
Apr.	13	13.4	20	20.62	64	65.98	97
May	6	13.04	11	23.91	29	63.04	46
Nov.	4	100	-	-	-	-	4
Dec.	16	23.53	6	8.82	46	67.65	68
Jan.94	13	9.63	33	24.44	89	65.93	135
Feb.			1	25.00	3	75.00	4
Mar.	12	21.43	13	23.21	31	55.36	56
Apr.	2	11.11	5	27.78	11	61.11	18
May	3	16.67	2	11.11	13	72.22	18
Total	158	15.05	197	18.76	695	66.19	1050
MINI TRAWL (estuarine)							
Mar.93	-	-	-	-	3	100.00	3
Apr.	-	-	-	-	4	100.00	4
May	1	7.14	2	14.29	11	78.57	14
Mar.94	-	-	2	66.67	1	33.33	3
Apr.	1	20.00	1	20.00	3	60.00	5
May	-	-	-	-	5	100.00	5
Total	2	5.88	5	14.71	27	79.41	34

TABLE 5.18.
Monthly distribution of various maturity stages of *P. sanguinolentus* males
in the inshore waters at Malpe.

Months	STAGE I (Immature)		STAGE II (Maturing)		STAGE III (Mature)		Total
	n	%	n	%	n	%	n
TRAWL CATCH							
Nov.92	12	20.69	25	43.10	21	36.21	58
Dec.	14	8.43	40	24.10	112	67.47	166
Jan.93	0	0	2	2.35	83	97.65	85
Feb.	25	19.68	29	22.83	73	57.48	127
Mar.	21	13.64	59	38.31	74	48.05	154
Apr.	13	11.71	29	26.13	69	62.16	111
May	12	14.81	16	19.75	53	65.43	81
Sep.	0	0	0	0	5	100.00	5
Oct.	1	100.00	0	0	0	0	1
Nov.	2	3.77	21	39.62	60	56.60	53
Dec.	2	2.86	18	25.71	50	71.43	70
Jan.94	15	24.59	16	26.23	30	49.18	61
Feb.	3	4.48	12	17.91	52	77.61	67
Mar.	4	80.00	0	0	1	20.00	5
Apr.	11	17.74	18	12.90	33	69.35	62
May	9	11.11	40	49.38	32	39.51	81
Total	144	12.13	335	28.22	708	59.65	1187
MINI TRAWL							
Jul.93'	8	25.00	13	40.62	11	34.78	32
Aug.	1	4.76	4	19.05	16	76.19	21
Jun.94	4	57.14	3	42.86	0	0	7
Jul.	3	60.00	1	20.00	1	20.00	5
Total	16	24.62	21	32.31	28	43.08	65

size range 80-170 mm CW

TABLE 5.19.

Monthly distribution of various maturity stages of *P. sanguinolentus* males in the inshore waters at Karwar.

Months	STAGE I (Immature)		STAGE II (Maturing)		STAGE III (Mature)		Total
	n	%	n	%	n	%	n
AWL CATCH							
Dec. 92	0	0	0	0	40	100.00	40
Jan. 93	0	0	4	9.52	38	90.48	42
Feb.	1	3.03	2	6.06	30	90.91	33
Mar.	5	8.77	12	21.05	40	70.18	57
Apr.	9	8.49	17	16.04	80	75.47	106
May	6	13.95	5	11.63	32	74.42	43
June	4	7.02	32	56.14	21	36.84	57
Jan. 94	1	1.56	7	10.94	56	87.50	64
Feb.	1	10.00	1	10.00	8	80.00	10
Mar.	0	0	0	0	2	100.00	2
Apr.	4	8.33	16	33.33	28	58.33	48
Total	31	6.18	96	19.12	375	74.70	502
SHORE SEINE (HAND) CATCH							
Nov. 92	0	0	3	42.86	4	57.14	7
Dec.	0	0	0	0	0	0	0
Jan. 93	0	0	0	0	2	100.00	2
Feb.	5	13.51	13	35.14	19	51.35	37
Mar.	2	5.88	5	14.71	27	79.41	34
April	2	33.33	2	33.33	2	33.33	6
May	0	0	1	33.33	2	66.67	3
Jan. 94	3	50.00	2	33.33	1	16.67	6
Feb.	0	0	3	25.00	9	75.00	12
Mar.	6	17.64	7	20.59	21	61.76	34
Apr.	4	17.39	5	21.74	14	60.87	23
May	3	25.00	2	16.67	7	58.33	12
Total	25	14.20	43	24.43	108	61.36	176

Size range 80-170 mm CW

Monthly distribution of various maturity stages of *P. sanguinolentus* females in the inshore /estuarine waters at Mangalore

Months	Stage I (IV)		Stage II (IR)		Stage III (EM)		Stage IV (LM)		Stage V (M)		Stage VI (SP)		Total
	n	%	n	%	n	%	n	%	n	%	n	%	n
TRAWL CATCH													
Nov..92	17	23.61	29	40.28	23	31.94	0	0	0	0	3	4.17	72
Dec.	26	10.20	56	21.96	102	40.00	37	14.41	1	0.39	33	12.94	255
Jan. 93	0	0	32	20.38	29	18.47	16	10.19	13	8.29	67	42.68	157
Feb.	5	3.52	33	23.24	48	33.80	28	19.72	12	8.45	16	11.27	142
Mar	26	44.07	16	27.12	12	20.34	2	3.39	1	1.69	2	3.39	59
Apr.	9	13.04	26	37.68	13	18.84	18	26.09	1	1.45	2	2.90	69
May	6	13.33	21	46.67	5	11.11	12	26.67	0	0	1	2.22	45
Dec.	6	9.57	57	60.64	8	8.51	9	9.57	4	4.26	7	7.45	94
Jan. 94	10	9.26	50	46.30	13	12.04	15	13.88	10	9.26	10	9.26	108
Feb.	0	0	3	33.33	0	0	3	33.33	3	33.33	0	0	9
Mar.	20	29.41	12	17.65	19	27.94	11	16.18	1	1.74	5	7.35	68
Apr.	5	19.23	5	19.23	3	11.54	6	23.08	6	23.08	1	3.84	26
May	7	24.14	7	24.14	1	3.45	6	20.68	7	24.14	1	3.45	29
Total	140	12.36	347	30.63	276	24.36	163	14.39	59	5.20	148	13.06	1133
MINI TRAWL CATCH													
Mar.93	15	51.72	3	10.34	9	31.03	2	6.90	0	0	0	0	29
Apr.	2	66.67	1	33.33	0	0	0	0	0	0	0	0	3
May	4	44.44	2	22.22	0	0	3	33.33	0	0	0	0	9
Mar.94	2	100.00	0	0	0	0	0	0	0	0	0	0	2
Apr.	1	25.00	3	75.00	0	0	0	0	0	0	0	0	4
May	2	5.40	12	32.43	6	16.21	8	21.61	9	24.32	0	0	37
Total	26	30.95	21	25.00	15	17.86	13	15.48	9	10.71	0	0	84

Size range 80 - 170 mm CW

IV = immature virgins; IR = immature resting ; EM = early maturing; LM = late maturing; M = mature; SP = spent

TABLE 5.21.

Monthly distribution of various maturity stages of *P. sanguinolentus* females in the inshore waters of Malpe

Months	STAGE I (IV)		STAGE II (IR)		STAGE III (EM)		STAGE IV (LM)		STAGE V (M)		STAGE VI (SP)		TOTAL	
	n	%	n	%	n	%	n	%	n	%	n	%	n	
TRAWL CATCH														
Oct. 92	0	0	2	100.00	0	0	0	0	0	0	0	0	0	2
Nov.	14	43.75	11	34.78	7	21.87	0	0	0	0	0	0	0	32
Dec.	16	10.74	37	28.83	38	25.50	15	10.07	21	14.09	22	14.77	149	
Jan. 93	0	0	23	15.13	42	27.63	37	24.34	10	6.58	40	26.32	152	
Feb.	37	36.63	40	39.60	4	3.96	10	9.90	7	6.93	3	2.98	101	
Mar	29	25.22	53	46.09	11	9.56	17	14.78	0	0	5	4.35	115	
Apr.	16	18.39	34	39.08	17	19.54	12	13.79	8	9.20	0	0	87	
May	7	13.46	21	40.38	9	17.31	6	11.54	5	9.62	4	7.69	52	
Sep.	0	0	9	90.00	0	0	0	0	1	10.00	0	0	10	
Oct.	1	33.33	1	3.33	1	33.33	0	0	0	0	0	0	3	
Nov.	1	1.85	19	35.19	18	33.33	9	16.67	3	5.56	4	7.40	54	
Dec.	19	25.33	25	33.33	14	18.67	17	22.67	0	0	0	0	75	
Jan. 94	27	35.06	30	38.96	8	10.39	8	10.39	1	1.30	3	3.90	77	
Feb.	13	16.46	37	46.84	23	29.11	6	7.59	0	0	0	0	79	
Mar.	3	50.00	2	33.3	1	16.67	0	0	0	0	0	0	6	
Apr.	32	52.46	22	36.06	5	8.20	2	3.28	0	0	0	0	61	
May	34	56.67	17	28.33	2	3.33	4	6.67	2	3.33	1	1.67	60	
Total	249	22.33	383	34.35	200	17.94	143	12.83	58	5.20	82	7.35	1115	
MINI TRAWL														
Jul.93	8	47.06	7	41.17	1	5.88	0	0	1	5.88	0	0	17	
Aug.	5	23.81	14	66.67	2	9.52	0	0	0	0	0	0	21	
Jul. 94	4	30.76	7	53.85	1	7.69	0	0	0	0	1	7.69	13	
Total	17	33.33	28	54.90	4	7.84	0	0	1	1.96	1	1.96	51	

Size group 80 - 170 mm CW IV = immature virgins; IR = immature resting; EM = early maturing; LM = late maturing; M = mature; SP = spent

TABLE 5.22.

Monthly distribution of various maturity stages of *P. sanguinolentus* females in the inshore waters at Karwar.

Months	STAGE I (IV)		STAGE II (IR)		STAGE III (EM)		STAGE IV (LM)		STAGE V (M)		STAGE VI (SP)		TOTAL
	n	%	n	%	n	%	n	%	n	%	n	%	n
TRAWL CATCH													
Dec. 92	0	0	1	4.35	8	34.78	7	30.43	1	4.34	6	26.09	23
Jan. 93	0	0	11	26.83	17	41.46	2	4.88	2	4.88	9	21.95	41
Feb.	1	4.54	8	36.36	9	40.91	2	9.09	1	4.55	1	4.55	22
Mar.	14	27.45	22	43.14	10	19.61	1	1.96	0	0	4	7.84	51
Apr.	14	22.58	23	37.10	12	19.35	6	9.68	1	1.61	6	9.68	62
May	7	25.93	11	40.74	2	7.41	4	14.81	2	7.41	1	3.70	27
Dec.	18	34.62	15	28.85	5	9.61	5	9.61	4	7.69	5	9.62	52
Jan. 94	3	5.08	25	42.38	7	11.86	8	13.56	9	15.26	7	11.86	59
Feb.	1	5.56	8	44.44	1	5.56	4	22.22	4	22.22	0	0	18
Mar.	0	0	5	55.56	0	0	0	0	2	22.22	2	22.22	9
Apr.	9	33.33	9	33.33	4	14.82	0	0	3	11.11	2	7.41	27
Total	67	17.14	138	35.29	75	19.18	39	9.97	29	7.42	43	11.00	391
SHORE SEINE (YENDI) CATCH													
Nov. 92	3	100.00	0	0	0	0	0	0	0	0	0	0	3
Jan. 93	0	0	0	0	3	100.00	0	0	0	0	0	0	3
Feb.	4	33.33	5	41.67	2	16.67	1	8.33	0	0	0	0	12
Mar.	3	30.00	6	60.00	1	10.00	0	0	0	0	0	0	10
Apr.	1	100.00	0	0	0	0	0	0	0	0	0	0	1
Jul.	4	66.67	1	16.67	0	0	0	0	0	0	1	16.67	6
Dec.	5	45.45	3	27.27	0	0	2	27.27	1	9.09	0	0	11
Jan. 94	5	100.00	0	0	0	0	0	0	0	0	0	0	5
Feb.	2	20.00	6	60.00	1	10.00	1	10.00	0	0	0	0	10
Mar.	6	27.27	12	54.54	1	4.55	0	0	3	13.64	0	0	22
Apr.	2	22.22	3	33.33	0	0	0	0	3	33.33	1	11.11	9
Aug.	2	12.50	9	56.25	1	6.25	0	0	2	12.50	2	12.50	16
Total	37	34.26	45	41.67	9	8.33	4	3.70	9	8.33	4	3.70	108

Size group 80 - 170 mm CW

IV = immature virgins; IR = immature resting; EM = early maturing; LM = late maturing; M = mature; SP = spent

LE 5.23.

Monthly distribution of various maturity stages of *P.pelagicus* males in the inshore/estuarine waters at Mangalore.

Months	STAGE I (Immature)		STAGE II (Maturing)		STAGE III (Mature)		TOTAL
	n	%	n	%	n	%	n
WL CATCH (inshore)							
93	8	42.10	2	10.53	9	47.37	19
	22	55.00	7	17.50	11	27.50	40
	54	73.97	10	13.70	9	12.33	73
	81	55.10	19	12.93	47	31.97	147
94	5	14.71	9	26.47	20	58.82	34
	8	12.12	8	12.12	50	75.76	66
	89	68.46	18	13.85	23	17.69	130
	111	69.81	22	13.84	26	16.35	159
	31	59.62	9	17.31	12	23.09	52
	409	56.81	104	14.44	207	28.75	720
TRAWL CATCH (estuarine)							
93	10	52.63	4	21.05	5	26.32	19
	59	81.95	5	6.94	8	11.11	72
	18	28.57	10	15.87	35	55.56	63
	5	50.00	5	50.00	0	0	10
94	3	9.68	4	12.90	24	77.52	31
	26	81.25	3	9.37	3	9.38	32
	27	93.10	2	6.90	0	0	29
	20	76.92	6	23.08	0	0	26
	168	59.57	39	13.83	75	26.60	282
NET CATCH (inshore)							
92	0	0	0	0	7	100.00	7
	0	0	0	0	5	100.00	5
93	0	0	0	0	31	100.00	31
	0	0	0	0	43	100.00	43

groups 80 - 170 mmCW

FIG 5.24.

Monthly distribution of various maturity stages of *P. pelagicus* males in inshore waters at Malpe.

Months	STAGE I (Immature)		STAGE II (Maturing)		STAGE III (Mature)		TOTAL n
	n	%	n	%	n	%	
WL CATCH							
02	2	16.67	2	16.67	8	67.66	12
	0	0	0	0	3	100.00	3
	1	100.00	0	0	0	0	1
	1	33.33	0	0	2	66.67	3
03	2	40.00	0	0	3	60.00	5
	18	35.30	5	9.80	28	54.90	51
	27	40.91	10	15.15	29	43.94	66
	13	19.70	7	10.61	32	48.49	52
	12	26.67	3	6.67	30	66.67	45
	2	3.23	0	0	60	96.67	62
	2	4.00	1	2.00	47	94.00	50
	3	100.00	0	0	0	0	3
04	8	38.10	0	0	13	61.90	21
	5	9.62	7	13.46	40	76.92	52
	5	38.46	2	15.38	6	46.16	13
	23	47.92	8	16.67	17	35.41	48
	27	77.14	2	5.72	6	17.14	35
	6	21.43	3	10.71	19	67.86	28
Total	157	28.55	50	9.09	343	62.36	550
TRAWL CATCH							
03	5	100.00	0	0	0	0	5
	11	68.25	1	6.25	4	25.00	16
	0	0	0	0	36	100.00	36
Total	16	28.07	1	1.75	40	70.18	57

group 80 - 170 mm CW

TABLE 5.25.
Monthly distribution of maturity stages of *P. pelagicus* males
in the inshore waters at Karwar.

Months	STAGE I (Immature)		STAGE II (Maturing)		STAGE III (Mature)		TOTAL n
	n	%	n	%	n	%	
AWL CATCH							
1992	14	66.67	5	23.81	2	9.52	21
1993	16	37.21	15	34.88	12	27.91	43
1994	24	47.06	8	15.69	19	37.25	51
1995	6	24.00	5	20.00	14	56.00	25
1996	11	20.37	4	7.41	39	72.22	54
1997	0	0	1	2.78	35	97.22	36
1998	11	16.42	16	23.88	40	59.70	67
1999	16	34.04	12	25.53	19	40.43	47
2000	2	2.41	2	2.41	79	95.18	83
2001	11	42.31	5	19.23	10	38.46	26
Total	111	24.50	73	16.11	269	59.38	453
ORE SEINE (YENDI) CATCH							
1992	0	0	0	0	1	100.00	1
1993	14	66.67	5	23.81	2	9.52	21
1994	16	37.21	15	34.88	12	27.91	43
1995	11	37.93	4	13.79	14	48.28	29
1996	5	83.33	1	16.67	0	0	6
1997	0	0	0	0	2	100.00	2
1998	0	0	2	50.00	2	50.00	4
1999	1	100.00	0	0	0	0	1
2000	6	85.71	0	0	1	14.29	7
2001	15	53.57	4	14.29	9	32.14	28
2002	3	42.86	1	14.28	3	42.86	7
Total	71	47.65	32	21.48	46	30.87	149

groups 80 - 170 mm CW

TABLE 5.26.

Monthly distribution of various maturity stages of *P. pelagicus* females in the inshore/ estuarine waters at Mangalore

Months	STAGE I (IV)		STAGE II (IR)		STAGE III (EM)		STAGE IV (LM)		STAGE V (M)		STAGE VI (SP)		TOTAL n
	n	%	n	%	n	%	n	%	n	%	n	%	
TRAWL CATCH (inshore)													
Feb. 93	8	30.77	14	53.85	0	0	1	3.85	0	0	3	11.54	26
Mar.	22	55.00	15	37.50	3	7.50	0	0	0	0	0	0	40
Apr.	63	86.30	7	9.59	0	0	0	0	0	0	3	4.11	73
May	106	72.60	38	26.03	2	1.37	0	0	0	0	0	0	146
Dec.	2	16.67	10	83.33	0	0	0	0	0	0	0	0	12
Jan. 94	8	16.33	14	28.57	17	34.69	7	14.29	1	2.04	2	4.08	49
Feb.	3	4.76	26	41.28	2	3.17	9	14.29	13	20.63	10	15.87	63
Mar.	20	22.73	31	35.23	6	6.82	17	19.32	9	10.22	5	5.68	88
Apr.	114	87.94	16	11.35	1	0.71	0	0	0	0	0	0	131
May	61	67.03	30	32.97	0	0	0	0	0	0	0	0	91
Total	407	56.60	201	27.96	31	4.31	34	4.73	23	3.20	23	3.20	719
MINI TRAWL CATCH (estuarine)													
Mar.	16	76.19	5	23.81	0	0	0	0	0	0	0	0	21
Apr.	56	93.33	4	6.67	0	0	0	0	0	0	0	0	60
May	88	94.62	5	5.38	0	0	0	0	0	0	0	0	93
Jun.	21	100.00	0	0	0	0	0	0	0	0	0	0	21
Feb. 94	3	8.11	15	40.54	1	2.70	5	13.51	10	27.03	3	8.11	37
Mar.	30	52.63	20	35.09	1	1.75	1	1.75	3	5.26	2	3.52	57
Apr.	21	91.30	2	8.70	0	0	0	0	0	0	0	0	23
May	50	100.00	0	0	0	0	0	0	0	0	0	0	50
Total	285	78.73	51	14.09	2	0.55	6	1.66	13	3.59	5	1.38	362
GILL NET CATCH (inshore)													
Sep.92	0	0	5	55.56	1	11.11	3	33.33	0	0	0	0	9
Oct.	0	0	7	70.00	0	0	0	0	0	0	3	30.00	10
Sep. 93	0	0	10	33.33	5	16.67	5	16.67	0	0	10	33.33	30
Total	0	0	22	44.90	6	12.24	8	16.33	0	0	13	26.53	49

Size group 80 - 170 mm CW

IV = immature virgins; IR = immature resting; EM = early maturing; LM = late maturing; M = mature; SP = spent

Monthly distribution of various maturity stages of *P. pelagicus* females in the inshore waters at Malpe.

Months	STAGE I (IV)		STAGE II (IR)		STAGE III (EM)		STAGE IV (LM)		STAGE V (M)		STAGE VI (SP)		TOTAL n
	n	%	n	%	n	%	n	%	n	%	n	%	
TRAWL CATCH													
Sep. 92	1	4.55	8	36.36	5	22.73	7	31.81	1	4.55	0	0	22
Oct.	0	0	2	8.70	13	56.52	5	21.74	3	13.04	0	0	23
Dec.	2	66.67	1	33.33	0	0	0	0	0	0	0	0	3
Jan. 93	1	25.00	0	0	2	50.00	1	25.00	0	0	0	0	4
Feb.	14	35.90	11	28.21	5	12.82	7	17.94	0	0	2	5.13	39
Mar.	42	54.54	26	33.77	4	5.19	1	1.30	1	1.30	3	3.90	77
Apr.	21	37.50	27	48.21	7	12.50	1	1.79	0	0	0	0	56
May	3	7.50	33	82.50	2	5.00	1	2.50	0	0	1	2.50	40
Aug.	0	0	23	74.19	8	25.81	0	0	0	0	0	0	31
Sep.	2	7.14	16	57.14	10	35.72	0	0	0	0	0	0	28
Nov.	1	50.00	0	0	0	0	1	50.00	0	0	0	0	2
Dec.	7	46.67	0	0	2	13.33	5	33.33	0	0	1	6.67	15
Jan. 94	3	13.64	11	50.00	3	13.64	3	13.64	0	0	2	9.08	22
Feb.	9	21.95	10	24.39	8	19.51	6	14.63	2	4.88	6	14.64	41
Mar	5	22.72	4	18.18	1	4.55	1	4.55	10	45.45	1	4.55	22
Apr.	41	87.23	4	8.51	1	2.13	0	0	0	0	1	2.13	47
May	15	53.57	8	28.57	3	10.71	0	0	0	0	2	7.15	28
Sep.	1	1.75	14	24.56	16	28.07	19	33.33	5	8.77	2	3.51	57
Total	168	30.16	198	35.55	90	16.16	58	10.41	22	3.95	21	3.77	557
MINI TRAWL CATCH													
Jun. 93	9	100.00	0	0	0	0	0	0	0	0	0	0	9
Jul.	11	39.29	15	53.57	2	7.14	0	0	0	0	0	0	28
Aug.	1	5.56	15	83.33	1	5.56	0	0	0	0	1	5.56	18
Total	21	38.18	30	54.55	3	5.45	0	0	0	0	1	1.82	55

Size group 80 - 170 mm CW

IV = immature virgins; IR = immature resting; EM = early maturing; LM = late maturing; M = mature; SP = spent

TABLE 5.28.**Monthly distribution of various maturity stages of *P. pelagicus* females in the inshore waters at Karwar.**

Month	STAGE I (IV)		STAGE II (IR)		STAGE III (EM)		STAGE IV (LM)		STAGE V (M)		STAGE VI (SP)		TOTAL
	n	%	n	%	n	%	n	%	n	%	n	%	n
TRAWL CATCH													
Dec. 92	8	33.33	1	4.17	6	25.00	4	16.67	0	0	5	20.83	24
Jan. 93	2	3.17	2	3.17	33	52.39	17	26.98	3	4.76	6	9.53	63
Feb.	53	77.94	12	17.65	2	2.94	0	0	0	0	1	1.47	68
Mar.	9	28.13	19	59.39	1	3.12	1	3.12	1	3.12	1	3.12	32
Apr.	42	56.76	31	41.89	1	1.35	0	0	0	0	0	0	74
May	6	14.63	34	82.93	0	0	1	2.44	0	0	0	0	41
Jan. 94	29	23.96	56	46.28	3	2.48	9	7.44	6	4.96	18	14.88	121
Feb.	12	46.15	10	38.46	1	3.85	0	0	2	7.69	1	3.85	26
Mar.	2	3.51	42	73.68	1	1.75	4	7.02	1	1.75	7	12.30	57
Apr.	28	87.50	4	12.50	0	0	0	0	0	0	0	0	32
Total	191	35.50	211	39.22	48	8.92	36	6.69	13	2.42	39	7.25	538
SHORE SEINE (YENDI) CATCH													
Nov. 92	1	20.00	3	60.00	1	20.00	0	0	0	0	0	0	5
Dec.	2	28.57	0	0	3	42.86	0	0	0	0	2	28.87	7
Jan. 93	3	21.43	2	14.29	8	57.14	1	7.14	0	0	0	0	14
Feb.	7	28.00	8	32.00	1	4.00	0	0	1	4.00	8	32.00	25
Mar.	1	100.00	0	0	0	0	0	0	0	0	0	0	1
Nov.*	0	0	5	31.25	1	6.25	4	25.00	0	0	6	37.50	16
Dec.	2	20.00	7	70.00	0	0	1	10.00	0	0	0	0	10
Jan. 94	6	85.71	0	0	0	0	1	14.29	0	0	0	0	7
Feb.	4	66.66	1	16.67	1	16.67	0	0	0	0	0	0	6
Mar.	19	82.61	4	17.39	0	0	0	0	0	0	0	0	23
Apr.	4	100.00	0	0	0	0	0	0	0	0	0	0	4
Total	49	41.53	30	25.42	15	12.71	7	5.93	1	0.85	16	13.56	118

Size groups 80 - 170 mm CW

IV = immature virgins; IR = immature resting; EM = early maturing; LM = late maturing; M = mature; SP = spent

Asterisk indicates gill net catch

TABLE 5.29.

Distribution of ovigerous females of *P. sanguinolentus* in different months in the inshore waters at Mangalore, Malpe and Karwar.

(TRAWL CATCH)

Months	MANGALORE			MALPE			KARWAR		
	Berried females	Total females	Berried females	Berried females	Total females	Berried females	Berried females	Total females	Berried females
	n	n	%	n	n	%	n	n	%
Oct. 92	-	-	-	0	2	0	-	-	-
Nov.	0	72	0	0	32	0	-	-	-
Dec.	26	255	10.20	20	149	13.42	6	23	26.09
Jan. 93	36	157	22.93	57	152	37.50	5	41	12.20
Feb..	45	142	31.69	14	101	13.86	2	22	9.09
Mar.	2	59	3.39	8	115	6.96	1	51	1.96
Apr.	11	69	15.94	17	87	19.54	5	62	8.06
May	13	45	28.89	10	52	19.23	2	27	5.41
Sep.	-	-	-	3	10	30.00	-	-	-
Oct.	-	-	-	0	3	0	-	-	-
Nov.	-	-	-	0	54	0	-	-	-
Dec.	17	94	18.09	8	75	10.67	8	52	15.38
Jan. 94	13	108	12.04	20	77	25.97	15	59	25.42
Feb..	1	9	11.11	17	79	21.52	4	18	22.22
Mar.	8	68	11.76	1	6	16.67	5	9	55.56
Apr.	3	26	11.54	2	61	3.28	3	27	11.11
May	2	29	6.90	2	60	3.33	-	-	-
Total	177	1133	15.62	179	1115	16.05	56	391	14.32

For all females crabs measuring 80 mm CW and above considered

TABLE 5.30.

Distribution of ovigerous females of *P. sanguinolentus* in different months in the inshore/ estuarine waters at Mangalore, Malpe and Karwar.

Months	INDIGENOUS GEARS								
	MANGALORE(estuarine)			MALPE (inshore)			KARWAR (inshore)		
	Berried females n	Total females n	Berried females %	Berried females n	Total females n	Berried females %	Berried females n	Total females n	Berried females %
Nov. 92	-	-	-	-	-	-	-	-	-
Dec.	-	-	-	-	-	-	0	3	0
Jan. 93	-	-	-	-	-	-	-	-	-
Feb.	-	-	-	-	-	-	0	3	0
Mar.	3	29	10.34	-	-	-	2	10	20.00
Apr..	0	3	0	-	-	-	0	1	0
May..	0	9	0	-	-	-	-	-	-
Jul..	-	-	-	0	17	0	0	6	0
Aug.	-	-	-	0	21	0	-	-	-
Dec.	-	-	-	-	-	-	1	11	9.09
Jan. 94	-	-	-	-	-	-	0	5	0
Feb.	-	-	-	-	-	-	1	10	10.00
Mar.	0	2	0	-	-	-	2	22	8.00
Apr..	0	4	0	-	-	-	0	9	0
May..	1	37	2.70	-	-	-	-	-	-
Jul.	-	-	-	1	13	7.69	-	-	-
Aug.	-	-	-	-	-	-	2	16	12.50
Total	4	84	4.76	1	51	1.96	8	111	7.21

TABLE 5.31.
Distribution of ovigerous females of *P. pelagicus* in different months in the inshore waters at Mangalore, Malpe and Karwar.

Months	MANGALORE			MALPE			KARWAR		
	Berried females	Total females	Berried females	Berried females	Total females	Berried females	Berried females	Total females	Berried females
	n	n	%	n	n	%	n	n	%
Sep. 92	-	-	-	4	22	18.18	-	-	-
Oct.	-	-	-	3	23	13.04	-	-	-
Nov. 92	-	-	-	-	-	-	-	-	-
Dec.	-	-	-	0	3	0	4	24	16.67
Jan. 93	-	-	-	1	4	25.00	16	63	25.40
Feb.	3	26	11.54	15	39	38.46	6	68	8.82
Mar	3	40	7.50	6	77	7.79	3	32	9.38
Apr.	0	73	0	0	56	0	0	74	0
May	0	146	0	1	40	2.50	0	41	0
Jul.	-	-	-	-	-	-	-	-	-
Aug.	-	-	-	2	31	6.45	-	-	-
Sep.	-	-	-	1	28	3.57	-	-	-
Oct.	-	-	-	-	-	-	-	-	-
Nov.	-	-	-	0	2	0	-	-	-
Dec.	2	12	16.67	4	15	26.67	-	-	-
Jan. 94	15	49	30.61	8	22	36.36	41	121	33.88
Feb.	30	63	47.62	11	41	26.83	2	26	7.69
Mar.	22	88	25.00	3	22	13.64	13	57	22.81
Apr.	1	131	0.76	0	47	0	0	32	0
May	0	91	0	0	28	0	-	-	-
Sep.	-	-	-	5	57	8.77	-	-	-
Total	76	719	10.57	64	557	11.49	85	538	15.80

TABLE 5.32.

Distribution of ovigerous females of *P. pelagicus* in different months in the inshore/ estuarine waters at Mangalore, Malpe and Karwar.

Months	MANGALORE (estuarine) Mini trawl catch			MALPE (inshore) Mini trawl catch			KARWAR (inshore) Mini trawl catch		
	Berried females	Total females	Berried females	Berried females	Total females	Berried females	Berried females	Total females	Berried females
	n	n	%	n	n	%	n	n	%
Sep. 92*	1	9	11.11	-	-	-	-	-	-
Oct. *	3	10	30.00	-	-	-	-	-	-
Nov.	-	-	-	-	-	-	1	5	20.00
Dec.	-	-	-	-	-	-	1	7	14.29
Jan. 93	-	-	-	-	-	-	0	14	0
Feb.	-	-	-	-	-	-	1	25	4.00
Mar.	0	21	0	-	-	-	0	1	0
Apr.	0	60	0	-	-	-	-	-	-
May.	0	93	0	-	-	-	-	-	-
Jun.	0	21	0	0	9	0	-	-	-
Jul.	-	-	-	0	28	0	-	-	-
Aug.	-	-	-	1	18	5.56	-	-	-
Sep. *	18	30	60.00	-	-	-	-	-	-
Oct.	-	-	-	-	-	-	-	-	-
Nov. *	-	-	-	-	-	-	7	16	43.75
Dec.	-	-	-	-	-	-	1	10	10.00
Jan. 94	-	-	-	-	-	-	0	7	0
Feb.	3	37	8.11	-	-	-	0	6	0
Mar.	10	57	17.54	-	-	-	2	23	0
Apr.	0	23	0	-	-	-	0	4	0
May.	0	50	0	-	-	-	-	-	-
Jul.	-	-	-	-	-	-	-	-	-
Aug.	-	-	-	-	-	-	2	16	12.50
Total	35	411	8.52	1	55	1.82	11	118	9.32

Asterisk indicates gill net catch from inshore waters

TABLE 5.33.**Monthly distribution of sex ratio in adult crabs of *P. sanguinolentus* in the inshore estuarine waters at Mangalore.**

Months	Males n	Females n	Total n	% Males	% Females	Sex ratio (M/F)
TRAWL CATCH						
Nov. 92	51	72	123	41.46	58.54	0.71
Dec.	235	255	490	47.96	52.04	0.92
Jan. 93	174	157	331	52.57	47.43	1.11
Feb.	83	142	225	36.89	63.11	0.58
Mar.	61	59	120	50.83	49.17	1.03
Apr.	97	69	166	58.43	41.57	1.41
May	46	45	91	50.55	49.45	1.02
Nov.	4	0	4	100.00	0	-
Dec.	68	94	162	41.98	58.02	0.72
Jan. 94	135	108	243	55.56	44.44	1.25
Feb.	4	9	13	30.77	69.23	0.44
Mar.	56	68	124	45.16	54.84	0.82
Apr.	18	26	44	40.91	59.09	0.69
May	18	29	47	38.30	61.70	0.62
Total	1050	1133	2183	48.10	51.90	0.93
MINI TRAWL CATCH (estuarine)						
Mar. 93	3	29	32	9.38	90.62	0.10
Apr.	4	3	7	57.14	42.86	1.33
May	14	9	23	60.87	39.13	1.56
Mar. 94	3	2	5	60.00	40.00	1.50
Apr.	5	4	9	55.56	44.44	1.25
May	5	37	42	11.90	88.10	0.14
Total	34	84	118	28.81	71.19	0.40

Crabs measuring 80 mm CW and above were treated as adults

TABLE 5.34.

Monthly distribution of sex ratio in adult crabs of *P. sanguinolentus* in the inshore waters at Malpe.

Months	Males n	Females n	Total n	% Males	% Females	Sex ratio (M/F)
TRAWL CATCH						
Oct. 92	0	2	2	0	100.00	-
Nov.	58	32	90	64.44	35.56	1.81
Dec.	166	149	315	52.70	47.30	1.11
Jan. 93	85	152	237	35.86	64.14	0.56
Feb.	127	101	228	55.70	44.30	1.26
Mar.	154	115	269	57.25	42.75	1.34
Apr.	111	87	198	56.06	43.94	1.28
May	81	52	133	60.90	39.10	1.56
Sep.	5	10	15	33.33	66.67	0.50
Oct.	1	3	4	25.00	75.00	0.33
Nov.	53	54	107	49.53	50.47	0.98
Dec.	70	75	145	48.25	51.72	0.93
Jan. 94	61	77	138	44.20	55.80	0.79
Feb.	67	79	146	45.89	54.11	0.85
Mar.	5	6	11	45.45	54.55	0.83
Apr.	62	61	123	50.41	49.59	1.02
May	81	60	141	57.45	42.55	1.35
Total	1187	1185	2302	51.56	48.44	1.06
MINI TRAWL CATCH						
Jul. 93	32	17	49	65.31	34.69	1.88
Aug.	21	21	42	50.00	50.00	1.00
Jun. 94	7	0	7	100.00	0	-
Jul.	5	13	18	27.78	72.22	0.38
Total	65	51	116	56.03	43.97	1.27

Crabs measuring 80 mm CW and above were treated as adults

TABLE 5.35.

Monthly distribution of sex ratio in adult crabs of *P. sanguinolentus* in the inshore waters at Karwar.

Months	Males n	Females n	Total n	% Males	% Females	Sex ratio (M/F)
TRAWL CATCH						
Dec. 92	40	23	63	63.49	36.51	1.74
Jan. 93	42	41	83	50.60	49.40	1.02
Feb.	33	22	55	60.00	40.00	1.50
Mar.	58	51	109	53.21	46.79	1.14
Apr.	106	62	168	63.10	36.90	1.71
May.	43	27	70	61.14	38.57	1.59
Dec.	57	52	109	52.29	47.71	1.10
Jan. 94	64	59	123	52.03	47.97	1.08
Feb.	10	18	28	35.71	64.29	0.56
Mar.	2	9	11	18.18	81.82	0.22
Apr.	48	27	75	64.00	36.00	1.78
Total	503	391	894	56.26	43.74	1.29
SHORE SEINE (YENDI CATCH)						
Nov. 92	7	3	10	70.00	30.00	2.33
Jan. 93	2	3	5	40.00	60.00	0.67
Feb.	38	12	50	76.00	24.00	3.17
Mar.	34	10	44	77.27	22.73	3.40
Apr.	0	1	1	0	100.00	-
Jul	6	6	12	50.00	50.00	1.00
Dec.	3	11	14	21.43	78.57	0.27
Jan. 94	7	5	12	58.33	41.67	1.40
Feb.	12	10	22	54.55	45.45	1.20
Mar.	34	22	56	60.71	39.29	1.54
Apr.	23	9	32	71.88	28.12	2.56
Aug.	12	16	28	42.86	57.14	0.75
Total	178	108	286	62.24	37.76	1.65

Crabs measuring 80 mm CW and above were treated as adults

TABLE 5.36.

Monthly distribution of sex ratio in adult crabs of *P. pelagicus* in the inshore/estuarine waters at Mangalore.

Months	Males n	Females n	Total n	% Males	% Females	Sex ratio (M/F)
TRAWL CATCH						
Feb. 93	19	26	45	42.22	57.78	0.75
Mar.	40	40	80	50.00	50.00	1.00
Apr.	73	73	146	50.00	50.00	1.00
May.	147	146	293	50.17	49.83	1.01
Dec.	0	12	12	0	100.00	-
Jan. 94	34	49	83	40.96	59.04	0.69
Feb.	66	63	129	51.16	48.84	1.05
Mar.	130	88	218	59.63	40.37	1.48
Apr.	159	131	290	54.83	45.17	1.21
May	52	91	143	36.36	63.64	0.57
Total	720	719	1439	50.03	49.97	1.00
MINI TRAWL CATCH (estuarine)						
Mar. 93	19	21	40	47.50	52.50	0.90
Apr.	72	60	132	54.55	45.45	1.20
May	63	93	156	40.38	59.62	0.68
Jun.	10	21	31	32.26	67.74	0.48
Feb. 94	31	37	68	45.59	54.41	0.84
Mar.	32	57	89	35.96	64.04	0.56
Apr.	29	23	52	55.57	44.23	1.26
May	26	50	76	34.21	65.79	0.52
Total	282	362	644	43.79	56.21	0.78
GILL NET CATCH (inshore)						
Sep. 92	7	9	16	43.75	56.25	0.78
Oct.	5	10	15	33.33	66.67	0.50
Sep. 93	29	30	59	49.15	50.85	0.97
Total	41	49	90	45.56	54.44	0.84

Crabs measuring 80 mm CW and above were treated as adults

TABLE 5.37.
Monthly distribution of sex ratio in adult crabs of *P. pelagicus*
in the inshore waters at Malpe.

Months	Males n	Females n	Total n	% Males	% Females	Sex ratio (M/F)
TRAWL CATCH						
Sep. 92	12	22	34	35.29	64.71	0.55
Oct. 92	3	23	26	11.54	88.46	0.13
Nov.	1	0	1	100.00	0	-
Dec.	3	3	6	50.00	50.00	1.00
Jan. 93	5	4	9	55.56	44.44	1.25
Feb.	51	39	90	56.67	43.33	1.31
Mar.	66	77	143	46.15	53.85	0.86
Apr.	52	56	108	48.15	53.85	0.93
May.	45	40	85	52.94	47.06	1.13
Aug.	62	31	93	66.67	33.33	2.00
Sep.	50	28	78	64.10	35.90	1.79
Nov.	0	2	2	0	100.00	-
Dec.	3	15	18	16.67	83.33	0.20
Jan. 94	21	22	43	48.84	51.16	0.95
Feb.	52	41	93	55.91	44.09	1.27
Mar.	13	22	33	39.39	66.67	0.59
Apr.	48	47	95	50.53	49.47	1.02
May	35	28	63	55.56	44.44	1.25
Sep.	28	57	85	32.94	67.06	0.49
Total	550	557	1107	49.68	50.32	0.99
MINI TRAWL CATCH						
Jun. 93	5	9	14	35.71	64.29	0.56
Jul.	16	28	44	36.36	63.64	0.57
Aug.	36	18	54	66.67	33.33	2.00
Total	57	55	112	50.89	49.11	1.04

Crabs measuring 80 mm CW and above were treated as adults

TABLE 5.38.
Monthly distribution of sex ratio in adult crabs of *P. pelagicus*
in the inshore waters at Karwar.

Months	Males n	Females n	Total n	% Males	% Females	Sex ratio (M/F)
TRAWL CATCH						
Dec. 92	21	24	45	46.67	53.33	0.88
Jan. 93	43	63	106	40.57	59.43	0.68
Feb.	51	68	119	42.86	57.14	0.75
Mar.	25	32	57	43.86	56.14	0.78
Apr.	54	74	128	42.19	57.81	0.73
May	36	41	77	46.75	53.25	0.88
Jan. 94	67	121	188	35.36	64.36	0.53
Feb.	47	26	73	64.38	35.62	1.81
Mar.	83	57	140	59.29	40.71	1.46
Apr.	26	32	58	44.83	55.17	0.81
Total	453	538	991	45.71	54.29	0.84
SHORE SEINE (YENDI CATCH)						
Nov. 92	1	5	6	16.67	83.33	0.20
Dec.	21	7	28	75.00	25.00	3.00
Jan. 93	43	14	57	75.44	24.56	3.07
Feb.	29	25	54	53.70	46.30	1.16
Mar.	6	1	7	85.71	14.29	6.00
Apr.	-	-	-	-	-	-
Nov.*	2	16	18	11.11	88.89	0.13
Dec.	4	10	14	28.57	71.43	0.40
Jan. 94	1	7	8	12.50	87.50	0.14
Feb.	7	6	13	53.85	46.15	1.17
Mar.	28	23	51	54.90	45.10	1.22
Apr.	7	4	11	63.64	36.36	0.64
Total	149	118	267	55.80	44.19	1.26

Asterisk indicates gill net catch

Crabs measuring 80 mm CW and above were treated as adults

TABLE 5.39.

Chi-square analysis of sex ratio in *P. sanguinolentus* and *P. pelagicus* at Mangalore, Malpe and Karwar during 1992-93 and 1993-94.

Centre	Gear	Period	<i>P. sanguinolentus</i>			
			d.f.	Chi-square	Significant at	
					5%	1%
Mangalore	trawl	1992-93	6	23.7352	S	S
	trawl	1993-94	6	16.8137	S	S
	minitrawl	1992-93	2	29.0593	S	S
	minitrawl	1993-94	2	12.0950	S	NS
Malpe	trawl	1992-93	7	41.4468	S	S
	trawl	1993-94	8	8.3764	NS	NS
Karwar	trawl	1992-93	5	5.2772	NS	NS
	trawl	1993-94	4	12.3383	S	NS
	shore seine	1992-93	4	6.1994	NS	NS
	shore seine	1993-94	6	12.6614	S	NS
<i>P. pelagicus</i>						
Mangalore	trawl	1992-93	3	1.0017	NS	NS
	trawl	1993-94	5	36.1378	S	S
	minitrawl	1992-93	3	8.2665	S	NS
	minitrawl	1993-94	3	7.6502	NS	NS
Malpe	trawl	1992-93	8	21.036	S	S
	trawl	1993-94	9	41.4854	S	S
Karwar	trawl	1992-93	5	1.0309	NS	NS
	trawl	1993-94	3	26.7033	S	S
	shore seine	1992-93	4	14.5800	S	S
	shore seine	1993-94	5	17.2054	S	S

TABLE 5.40.

Developmental stages of eggs on pleopods in *P. sanguinolentus* at Mangalore, Malpe and Karwar.

	MANGALORE						MALPE			KARWAR								
	STAGE I		STAGE II		STAGE III		STAGE I		STAGE II	STAGE III	STAGE I		STAGE II		STAGE III			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%		
Dec. 92	21	80.77	5	19.23	0	0	15	75.00	3	15.00	2	10.00	5	88.33	1	16.67	0	0
Jan. 93	24	66.67	7	19.44	5	13.89	38	66.67	9	15.79	10	17.54	4	80.00	0	0	1	20.00
Feb.	29	64.44	11	24.44	5	11.11	3	21.43	4	28.57	7	50.00	2	100.00	0	0	0	0
Mar.	2	100.00	0	0	0	0	8	100.00	0	0	0	0	0	0	0	0	1	100.00
Apr.	11	100.00	0	0	0	0	14	82.35	1	5.88	2	11.76	3	60.00	2	40.00	0	0
May	13	100.00	0	0	0	0	8	80.00	1	10.00	1	10.00	0	0	2	100.00	0	0
Sep.	-	-	-	-	-	-	3	100.00	0	0	0	0	-	-	-	-	-	-
Dec.	8	47.06	6	32.29	3	17.65	7	87.50	1	12.50	0	0	6	75.00	1	12.50	1	12.50
Jan. 94	12	92.31	0	0	1	7.69	11	55.00	3	15.00	6	30.00	10	66.67	4	26.67	1	6.67
Feb.	0	0	0	0	1	100.00	15	88.24	1	5.88	1	1.88	4	100.00	0	0	0	0
Mar.	8	100.00	0	0	0	0	1	100.00	0	0	0	0	4	80.00	1	20.00	0	0
Apr.	2	66.67	0	0	1	33.33	2	100.00	0	0	0	0	0	0	1	33.33	2	66.67
May	2	00.00	0	0	0	0	1	50.00	1	50.00	0	0	-	-	-	-	-	-
Jul.	-	-	-	-	-	-	1	100.00	0	0	0	0	-	-	-	-	-	-

TABLE 5.42.
Carapace width, crab weight, egg mass weight and fecundity in
***P. sanguinolentus*.**

Carapace width (mm)	Crab weight (g)	Egg mass weight (g)	Fecundity
82	32.74	3.34	216150
87	46.01	4.65	380350
88	37.31	5.41	270230
89	51.31	6.11	285920
92	44.51	7.67	430200
93	44.72	2.68	200490
94	42.01	7.42	385310
94	55.75	7.75	346500
95	63.8	6.97	685490
95	44.42	3.39	210570
95	45.25	3.21	216150
95	45.61	3.39	240780
97	55.35	7.4	428650
100	88.5	3.81	165020
100	49.5	7.1	386450
102	53.64	8.8	618870
104	68.3	11.65	424870
105	74.65	11.25	543750
107	72.02	12.2	542630
108	73.16	13.81	738380
110	85.29	13.49	548670
110	120.2	10.02	431300
111	127.7	8.84	681250
112	88.9	20.5	696250
113	79	5.15	319640
114	84.59	9.33	525120
115	82.69	7.2	519640
115	83.18	11.35	571020
116	82.32	9.64	341280
116	127.5	15.83	577490
116	66.2	8.7	312520
116	79.27	5.07	199300
116	69.79	7.3	342590
117	90.59	13.54	660380
118	122.9	7.23	283840
118	104.52	13.06	467750
118	130.4	17.68	787700
120	103.12	14.4	841430
121	91.2	12.1	520650
122	108.48	13.94	656050
122	118.24	12.5	711080
124	135.12	20.25	894760
124	125.12	15.46	826520
126	120.1	9.4	318360
127	115.69	9.73	523640
130	186.2	29.6	578850
131	143.71	17.08	1190160
131	132.21	16.66	1015600
132	123.08	16.63	693720
133	128.29	8.65	281460
135	160.7	17.25	700940
136	142.74	23.59	881820
138	160.87	17.1	102070
139	136.21	15.39	1096350
142	150.66	17.33	387990
154	217.41	18.36	1030270

TABLE 5.43.
Carapace width, crab weight, egg mass weight and fecundity in
***P. pelagicus*.**

Carapace width (mm)	Crab weight (g)	Egg mass weight (g)	Fecundity
88	35.33	1.84	56420
89	38.7	2.14	77480
95	52.23	5.42	222690
97	50.97	5.61	131940
100	73.88	8.74	792970
100	101.13	14.82	375870
104	102.45	7.25	256010
104	82.48	4.56	158080
105	83.09	5.72	218100
109	72.04	7.79	357110
110	48.6	5.34	157830
110	117.53	11.5	393140
113	103.87	16.14	689010
115	90.66	5.2	118430
115	90.75	7.28	213240
115	62.01	6.2	155960
117	108.8	12.55	390610
118	121.06	13.19	475530
120	119.39	16.08	624860
121	132.24	13.12	352730
122	118.05	11.36	442560
125	142.36	15.72	659770
127	144.19	8.78	163500
127	142.49	21.54	614220
130	181.91	14.12	402580
130	225.03	29.17	672060
135	235.01	44.22	110920
136	178.61	15.13	576620
137	170.27	14.38	470880
140	175.12	24.73	1073570
140	186.8	10.84	329570
140	180.01	31.71	753550
140	198.54	13.79	274140
141	179.49	12.26	335250
142	230.33	18.14	584650
145	202.01	12.1	512850
147	220.34	20.22	469300
150	210.02	23.21	413840
150	244.12	25.75	693460
155	219.75	7.35	179950
158	292.02	29.42	938740
159	348.01	28.42	890040
163	355.12	22.42	850250
165	352.02	24.12	875400
171	382.05	26.16	946720
176	368.02	24.32	862020

TABLE 5.44.

Average carapace width, average weight, eggmass weight, average fecundity per brood and eggmass index in *P. sanguinolentus*.

Sl No.	Size group (mm)	n	Carapace width (mm)	Average weight (g)	Eggmass weight (G)	Total no. of eggs	Eggmass index
1	80-90	4	86.5 ± 3.11	41.15 ± 9.41	4.87 ± 1.18	2,88,162	11.83
2	90-100	9	94.3 ± 1.42	48.63 ± 7.11	5.26 ± 2.32	3,36,926	10.82
3	100-110	8	103.6 ± 3.12	67.43 ± 13.78	10.25 ± 3.55	4,88,528	15.20
4	110-120	17	114.7 ± 2.84	81.42 ± 11.41	10.71 ± 4.67	4,83,789	13.40
5	120-130	8	123.2 ± 2.40	112.35 ± 8.10	14.22 ± 4.46	7,42,477	12.66
6	130-140	6	133.8 ± 3.11	146.0 ± 19.98	17.99 ± 5.56	7,37,886	12.32
7	140-150	3	145.0 ± 3.40	153.74 ± 15.20	18.83 ± 1.73	4,67,880	12.24
8	150-160	2	154.0 ± 1.41	228.77 ± 16.06	19.58 ± 1.72	9,20,510	8.56

TABLE 5.45.

Average carapace width, average weight, eggmass weight, average fecundity per brood and eggmass index in *P. pelagicus*.

Sl.No.	Size group (mm)	n	Carapace width (mm)	Average weight (g)	Eggmass weight (G)	Total no. of eggs	Eggmass index
1	80-90	2	88.3 ± 1.06	37.01 ± 2.38	1.99 ± 0.22	66,950	5.37
2	90-100	2	96.2 ± 1.04	52.88 ± 2.31	5.84 ± 0.58	1,90,017	11.05
3	100-110	6	103.7 ± 3.39	85.99 ± 13.10	8.15 ± 3.59	1,46,515	9.47
4	110-120	8	114.1 ± 2.95	92.91 ± 11.41	9.67 ± 4.18	3,24,218	10.41
5	120-130	6	123.7 ± 3.08	132.12 ± 11.94	14.43 ± 4.42	4,76,273	10.84
6	130-140	5	133.6 ± 3.36	198.16 ± 29.59	23.40 ± 13.26	6,46,412	11.81
7	140-150	8	141.3 ± 2.69	196.58 ± 20.21	17.97 ± 7.32	5,41,610	9.14
8	150-160	5	154.4 ± 4.28	262.77 ± 57.23	22.83 ± 8.98	6,23,206	8.69
9	160-170	2	164.0 ± 1.41	353.56 ± 2.21	23.27 ± 1.19	8,62,825	6.58
10	170-180	2	173.5 ± 3.54	375.32 ± 9.64	25.29 ± 1.30	9,04,370	6.72

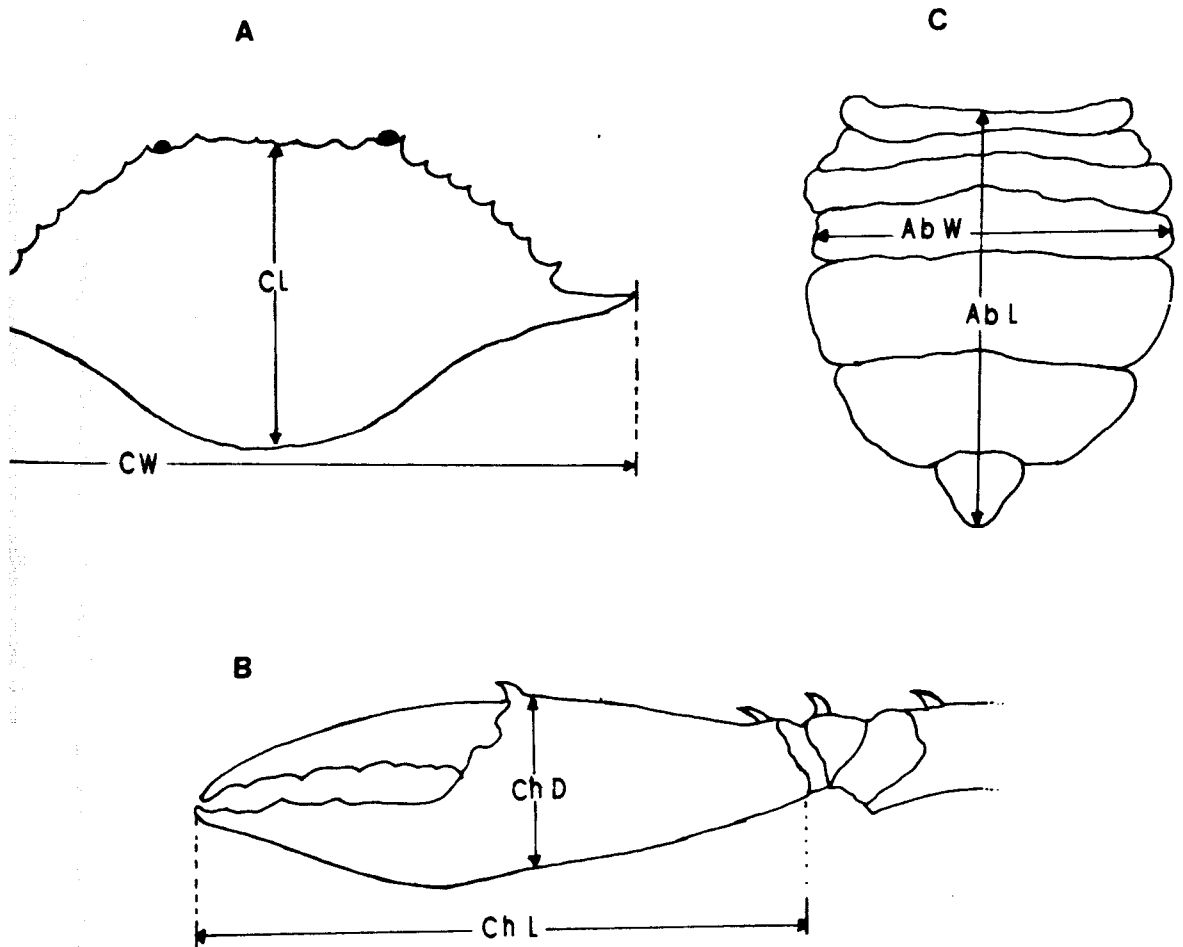
TABLE 5.46.

Statistical relationships between carapace width and eggmass weight/ fecundity and crab weight and eggmass weight/ fecundity, and eggmass weight and fecundity in *P. sanguinolentus* and *P. pelagicus*.

Variables		Constant	St. Err. Y. est	R. squared	no. of ob.	d.f.	X coefficient	St. Err of coeff.
X	Y							
<i>P. sanguinolentus</i>								
Carapace width	Eggmass weight	-11.63054	0.3909	0.5639	57	55	2.9467	0.3494
Carapace width	Fecundity	4.55172	0.5595	0.1732	57	55	1.7888	0.5271
Crab weight	Eggmass weight	-1.95773	0.3551	0.6003	57	55	0.9527	0.1048
Crab weight	Fecundity	10.29268	0.5491	0.2035	57	55	0.6077	0.1621
Eggmass weight	Fecundity	11.59027	0.5086	0.3167	57	55	0.6167	0.1221
<i>P. pelagicus</i>								
Carapace width	Eggmass weight	-12.1915	0.4468	0.5971	46	44	3.0425	0.3765
Carapace width	Fecundity	0.20362	0.5705	0.4010	46	44	2.6091	0.4807
Crab weight	Eggmass weight	-2.98089	0.1376	0.9618	46	44	1.1144	0.0335
Crab weight	Fecundity	8.23468	0.4590	0.6201	46	44	0.9307	0.1117
Eggmass weight	Fecundity	10.75587	0.4559	0.6175	46	44	0.8225	0.0976

TABLE 5.47.
Reproductive potential in *P. sanguinolentus* and *P. pelagicus*.

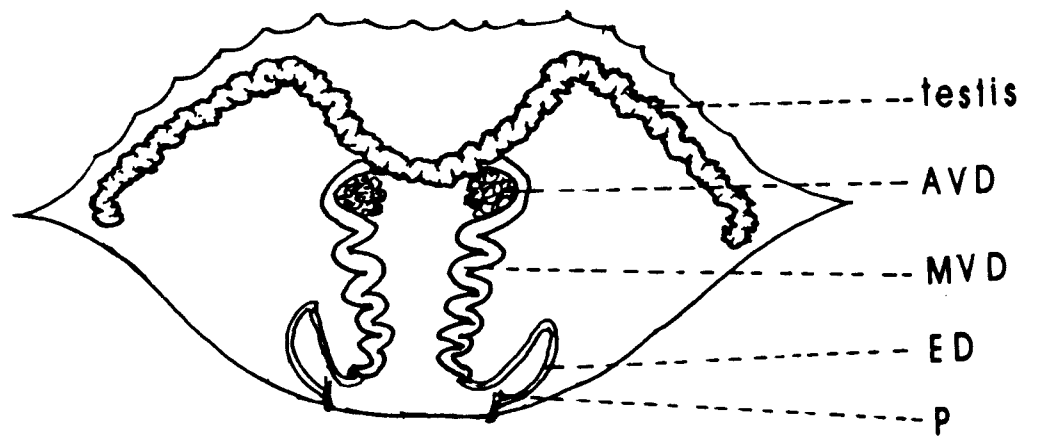
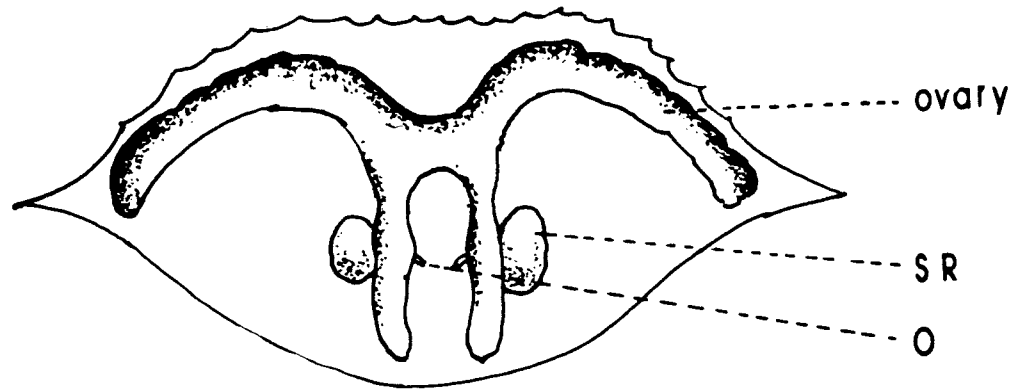
	Size class of females (CW in mm)								
	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160	160-170
<i>P. sanguinolentus</i> (n = 2882)									
A % of total females	24.8	22.3	18.3	16.1	10.5	5.9	1.8	0.3	-
B % berry	1.9	12.6	19.7	30.3	21.8	10.9	2.2	0.5	-
C mean fecundity (x 100,000)	2.9	3.4	4.9	4.8	7.4	7.4	4.7	9.2	-
D IRP (47.6)	28.7	200.7	371.1	491.9	355.9	100.0	3.9	0.3	-
E % of total egg production	1.8	12.9	23.9	31.7	22.9	6.4	0.3	0.0	-
F E/A (Productivity)	0.1	0.6	1.3	2.0	2.2	1.1	0.2	0.0	-
<i>P. pelagicus</i> (n = 2387)									
A % of total females	22.6	22.2	18.5	10.9	7.3	7.1	5.2	5.9	0.8
B % berry	3.0	14.6	21.7	15.0	11.6	11.2	9.7	9.0	4.1
C mean fecundity (x 100,000)	0.7	1.9	1.5	3.2	4.8	6.5	5.4	6.2	8.6
D IRP (27.2)	17.4	226.4	221.4	192.4	149.4	190.0	100.0	121.0	10.4
E % of total egg production	1.4	18.4	18.0	15.7	12.2	15.5	8.1	9.9	0.8
F E/A (Productivity)	0.1	0.8	1.0	1.4	1.7	2.2	1.6	1.7	1.0



1 The measurements made on each specimen of *P. pelagicus* and *P. sanguinolentus* for morphometric studies.

A - carapace dorsal view; B - chela; C - abdomen.

CW -carapace width; CL -carapace length; Ch L -chelar propodus length; Ch D - chelar propodus depth; Ab W - width of fourth abdominal segment; Ab L - length of abdomen.



A - Diagrammatic representation of female (A) and male (B) reproductive organs of *P. sanguinolentus* and *P. pelagicus*.
 SR - seminal receptacle; O - oviduct; AVD - proximal vas deferens; MVD - mid vas deferens; ED - ejaculatory duct; P - penis.

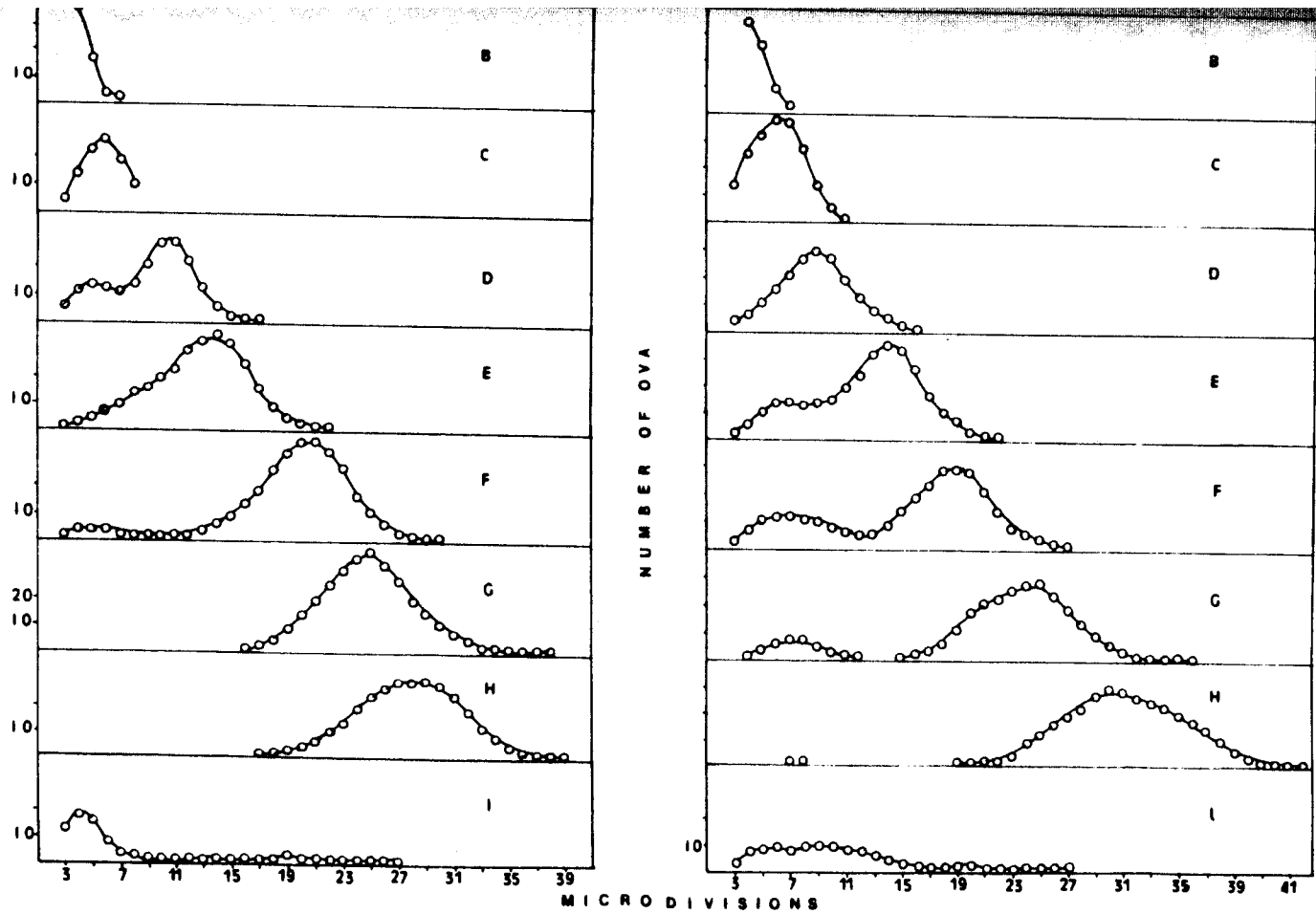


Fig. 5.3. Ova diameter frequency polygons showing the development of ova from immature to mature stage in *P. sanguinolentus* (S) and *P. pelagicus* (P).

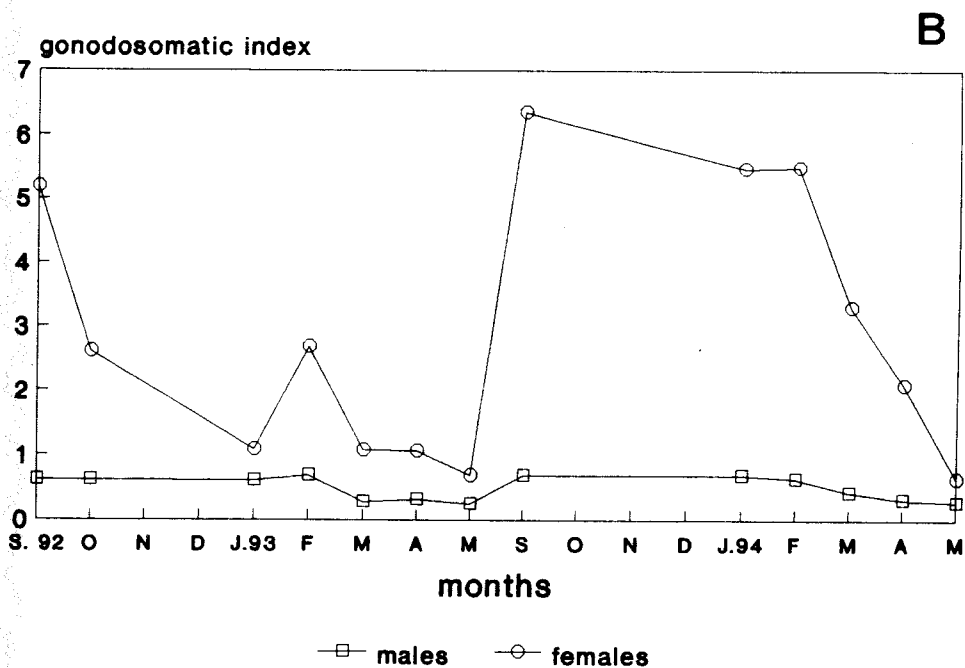
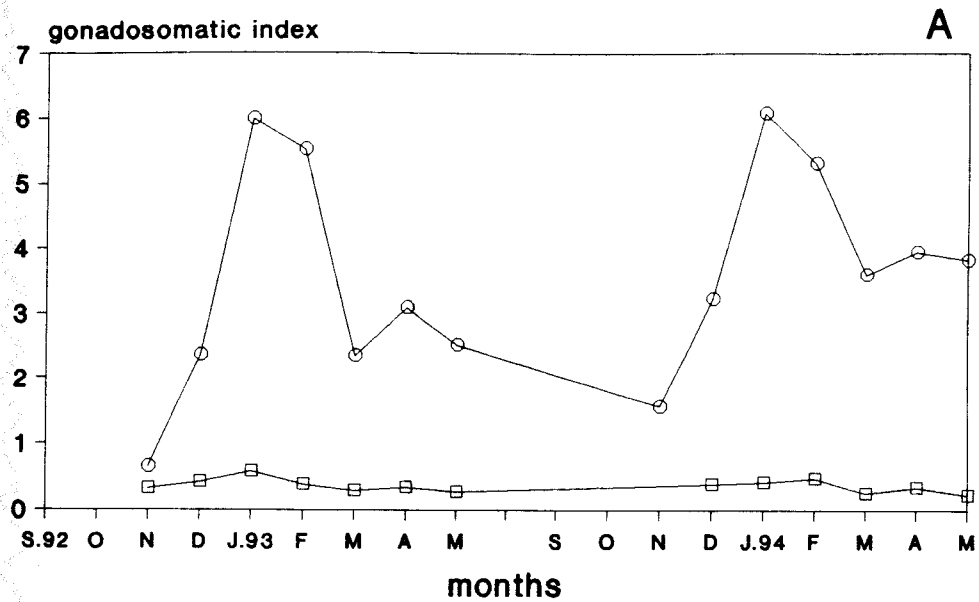
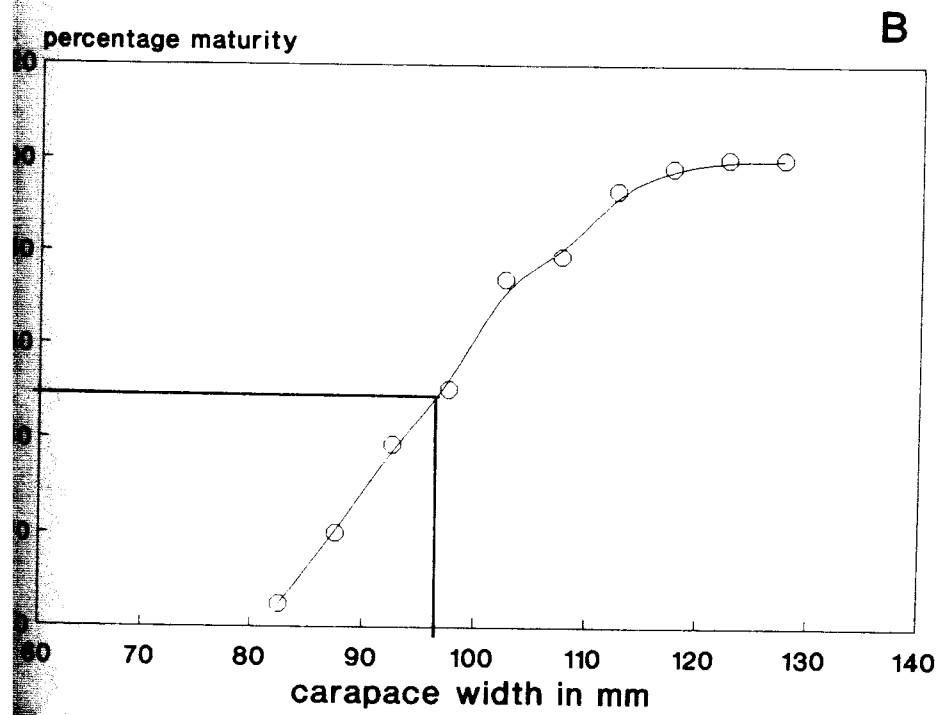
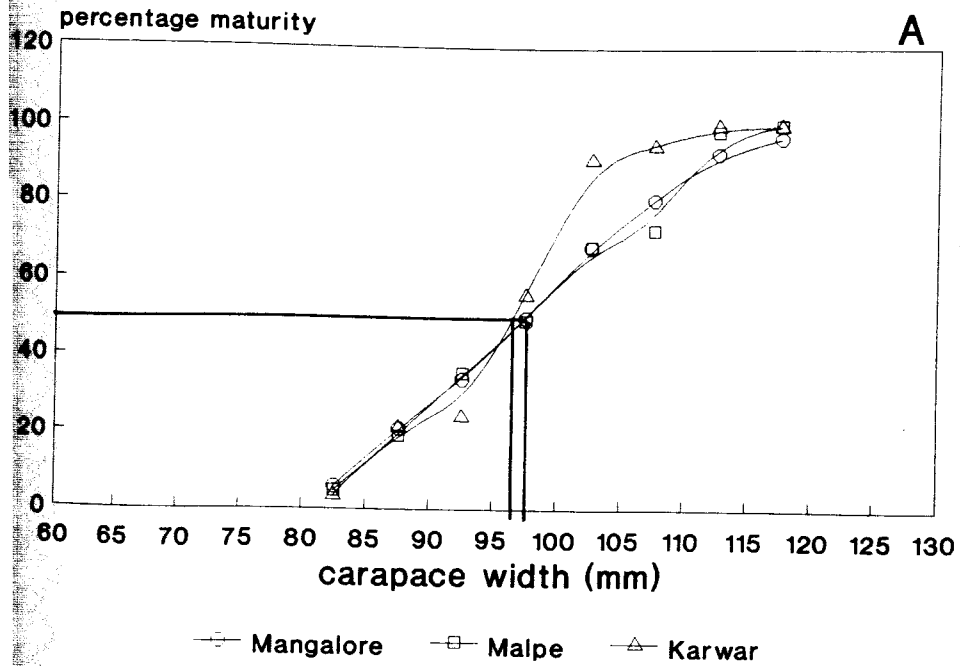


Fig. 5.4. A - Gonadosomatic index (GSI) for *P. sanguinolentus*;
 B - Gonadosomatic index (GSI) for *P. pelagicus*.



5.5. *P. sanguinolentus* males.
Size at sexual maturity centre-wise (A) and pooled (B).

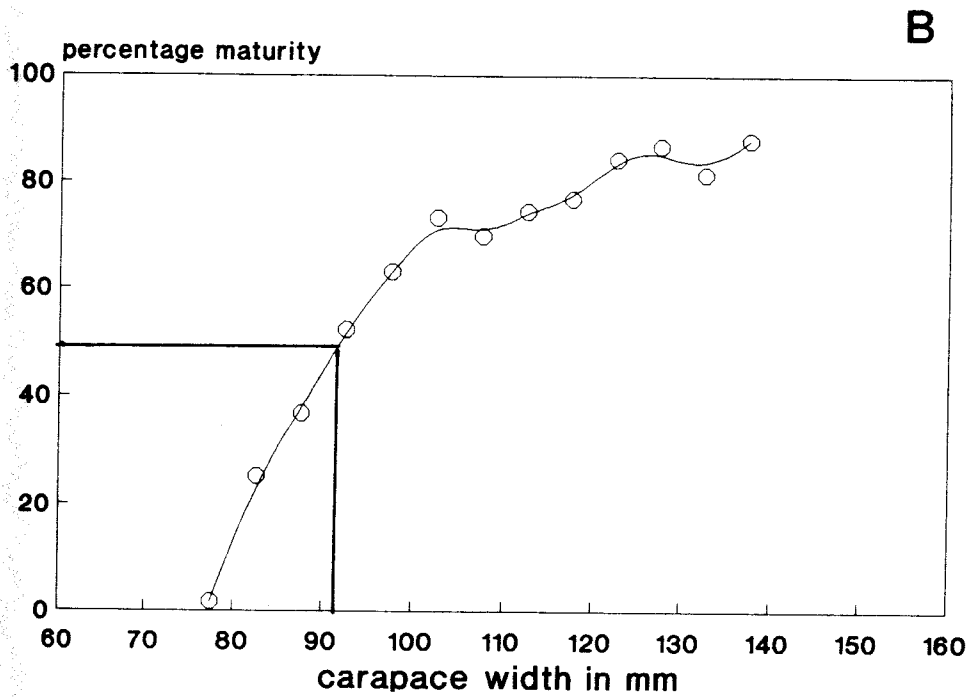
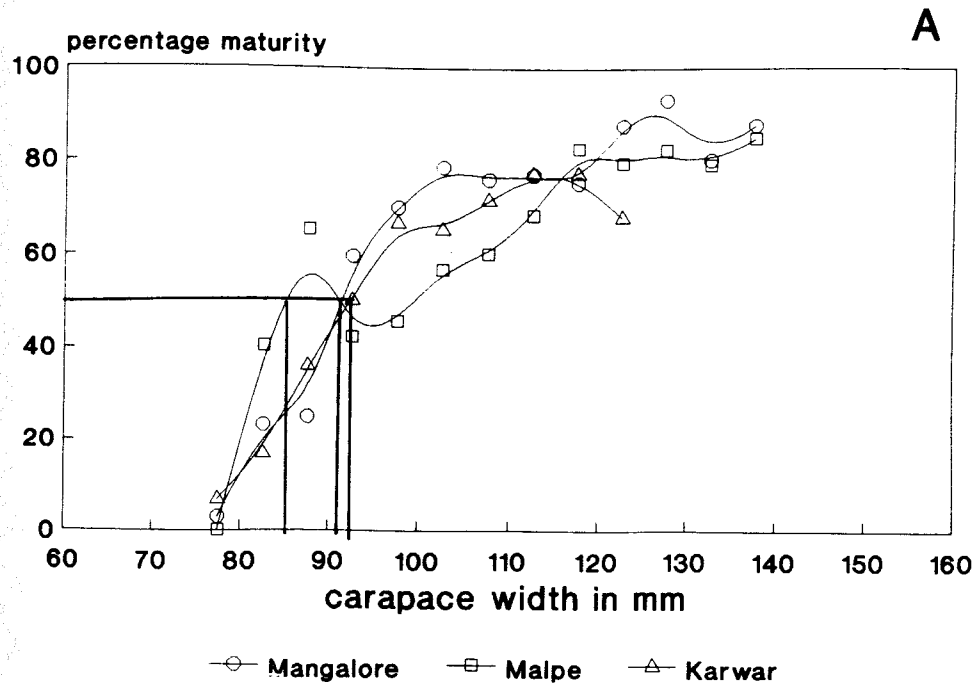


Fig. 5.6. *P. sanguinolentus* females.
Size at sexual maturity centre-wise (A) and pooled (B).

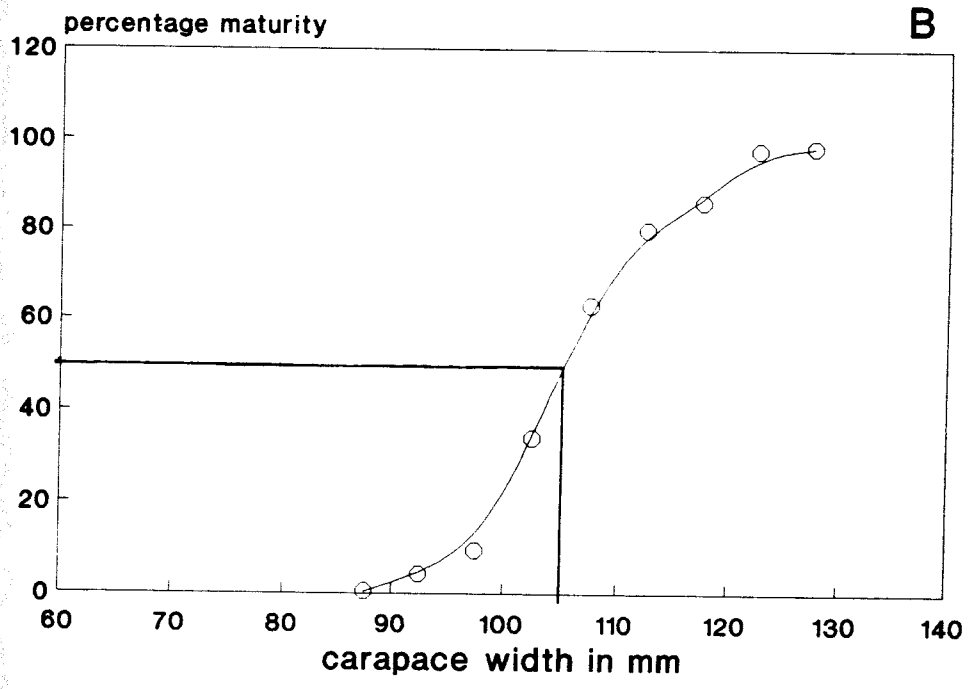
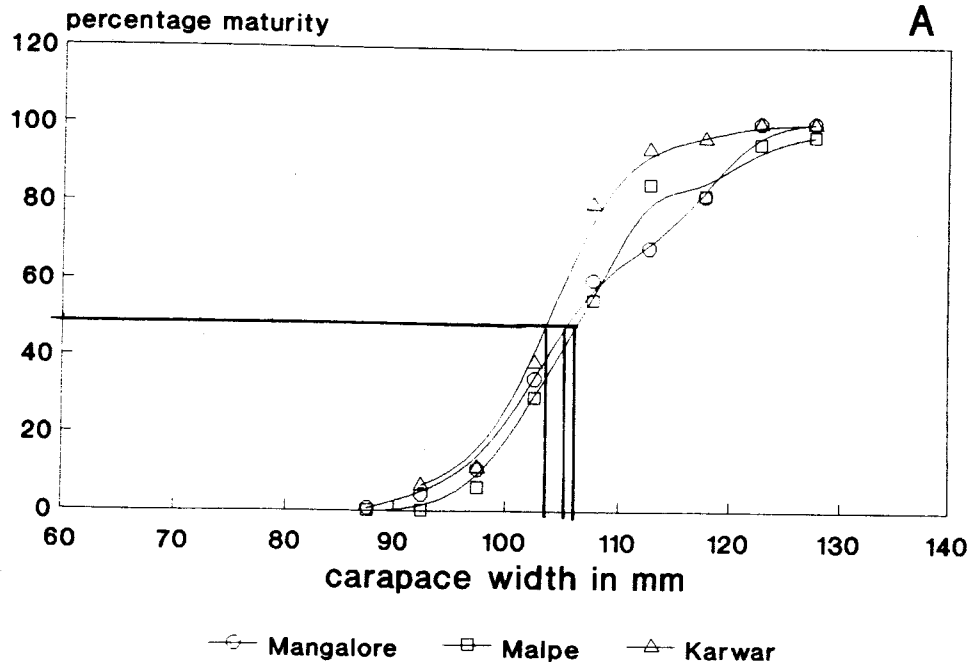


Fig. 5.7. *P. pelagicus* males. Size at sexual maturity centre-wise (A) and pooled (B).

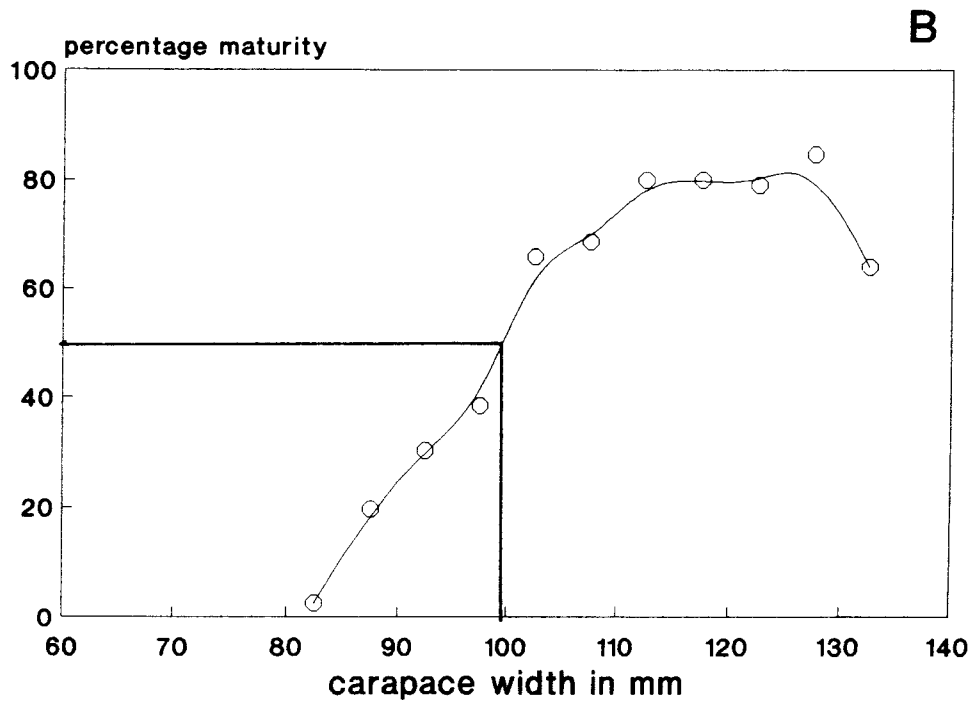
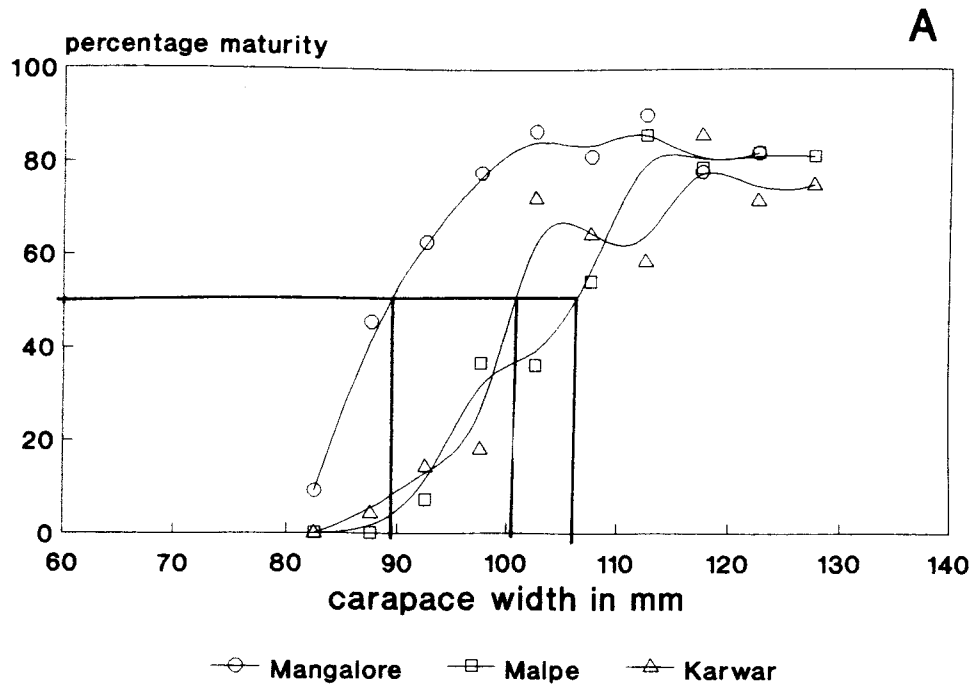
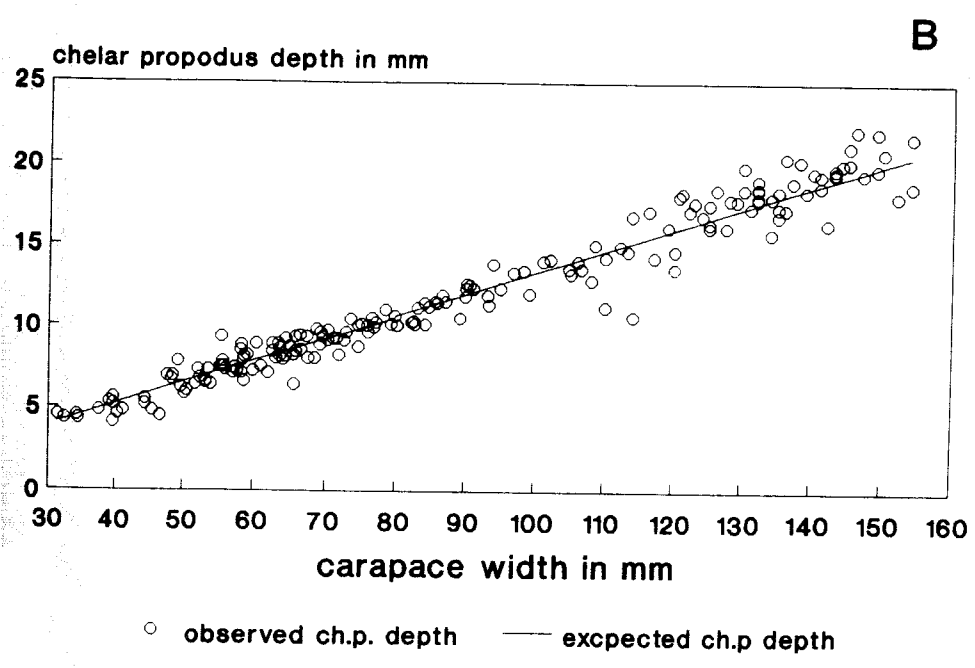
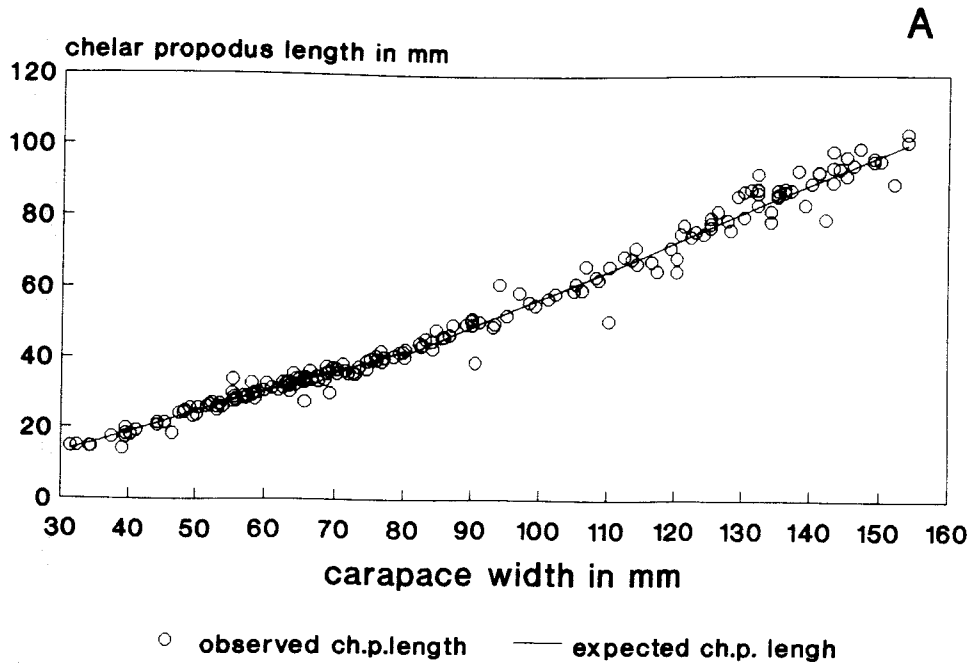
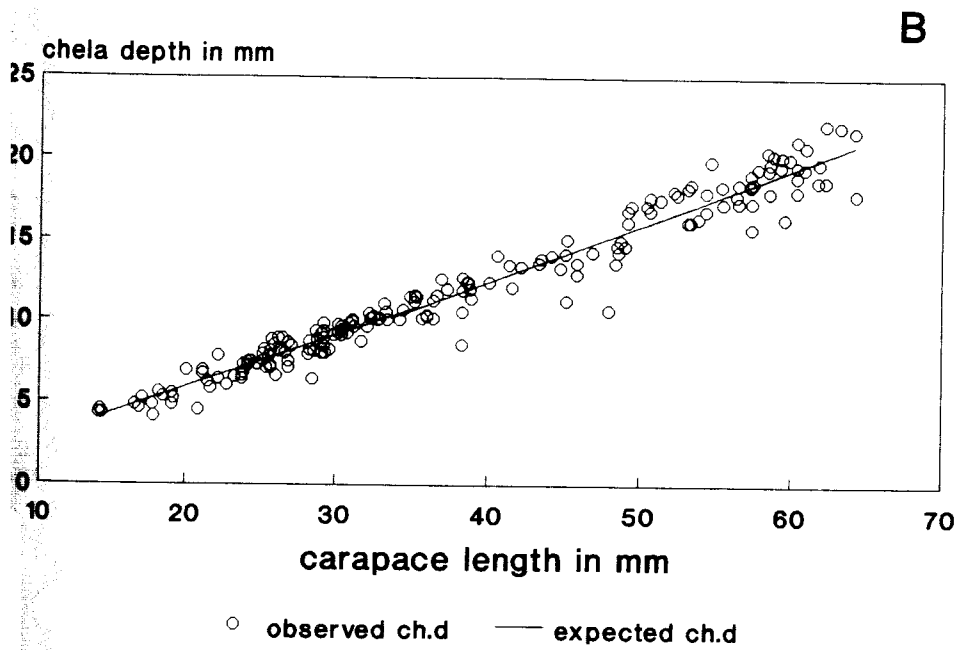
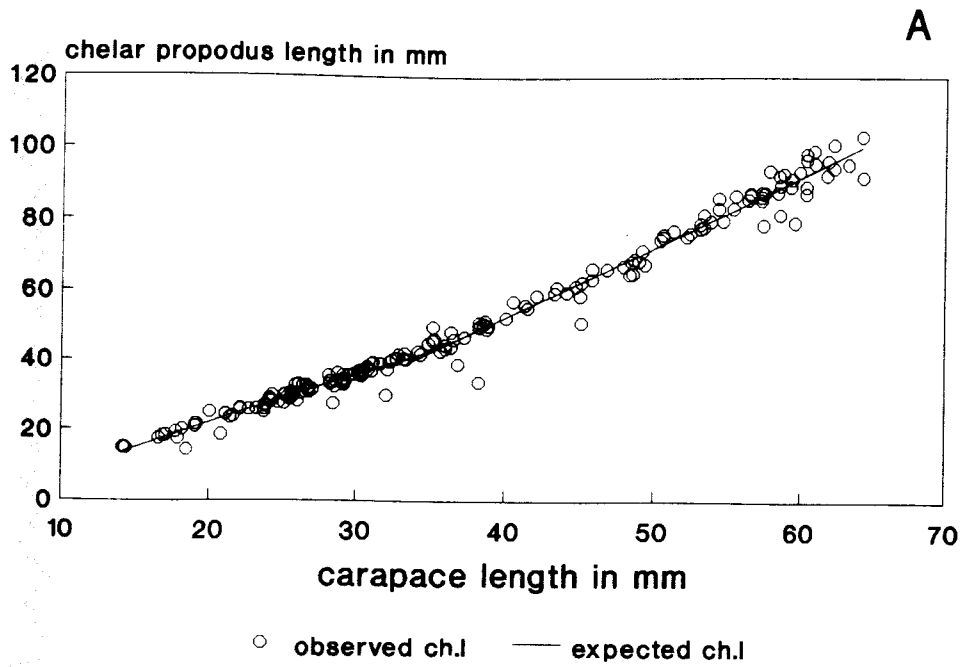


Fig. 5.8. *P. pelagicus* females.
Size at sexual maturity centre-wise (A) and pooled (B).



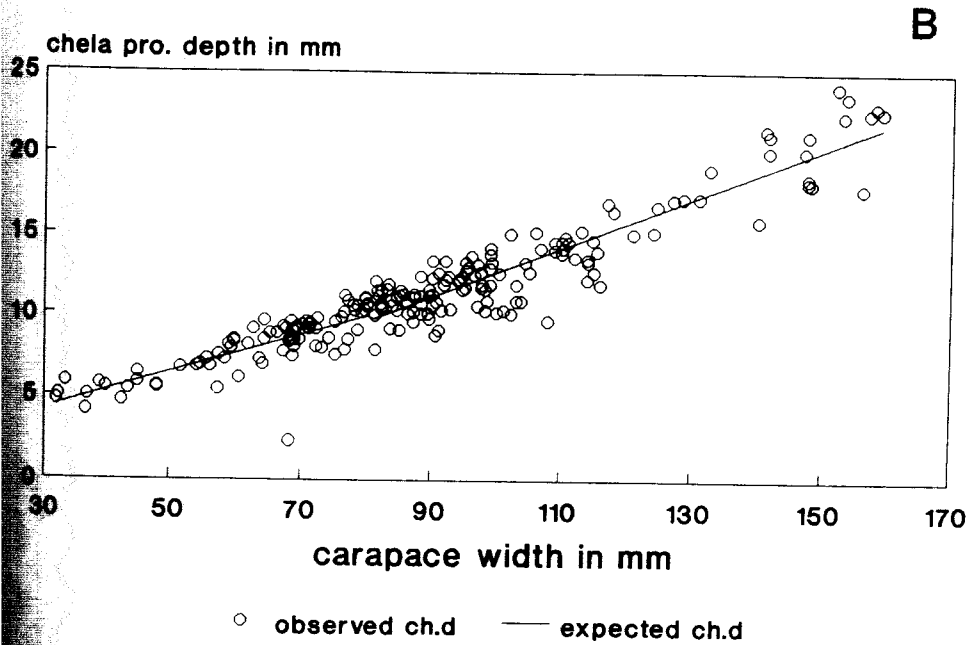
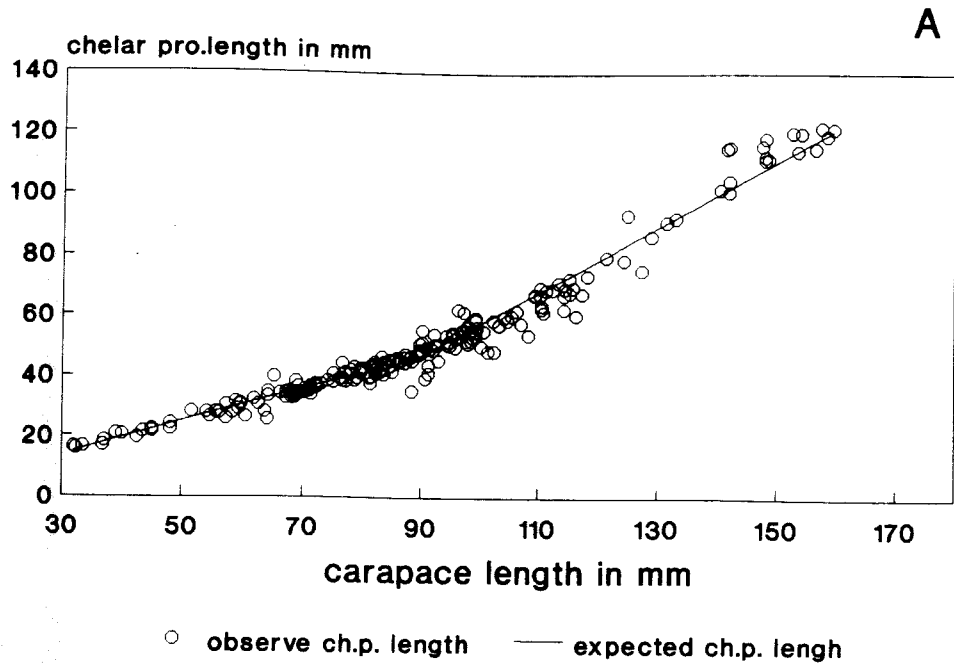
5.9. *P. sanguinolentus* males.
 A - growth pattern of chelar propodus length in relation to carapace width
 B- growth pattern of chelar propodus depth in relation to carapace width.



5.10. *P. sanguinolentus* males.

A - growth pattern of chelar propodus length in relation to carapace length.

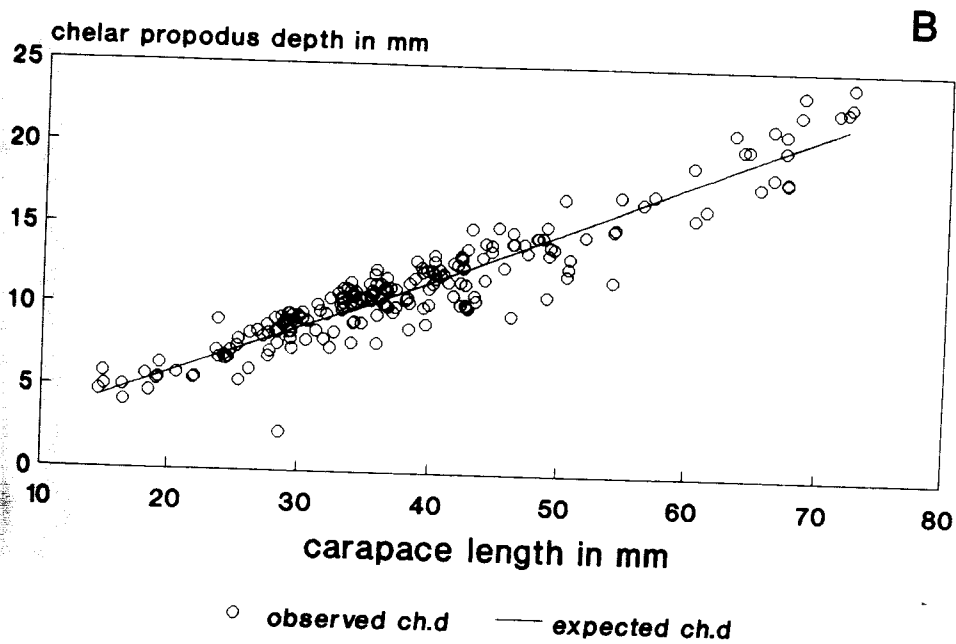
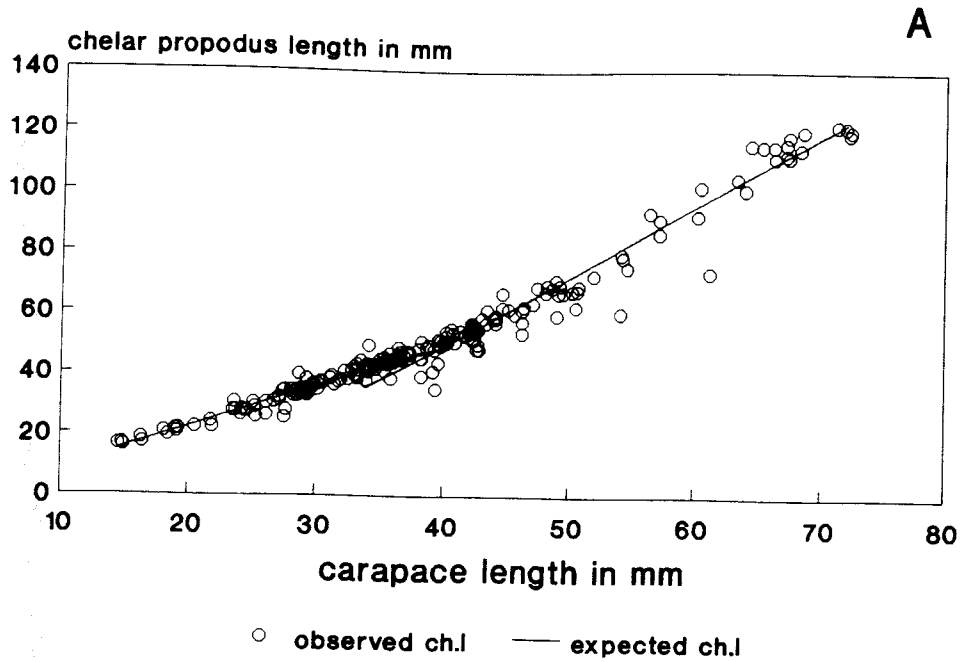
B - growth pattern of chelar propodus depth in relation to carapace length.



5.11. *P. pelagicus* males.

A - growth pattern of chelar propodus length in relation to carapace width.

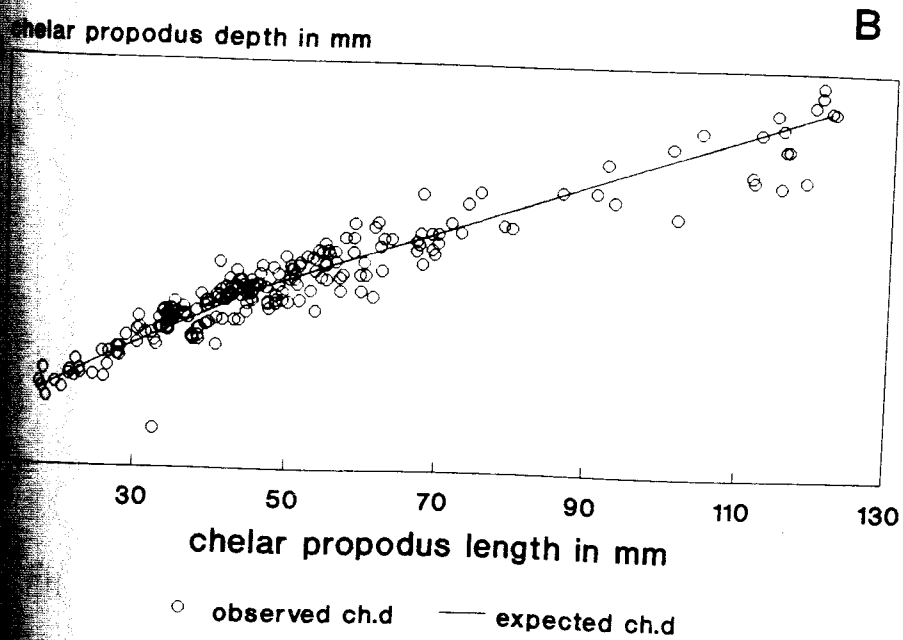
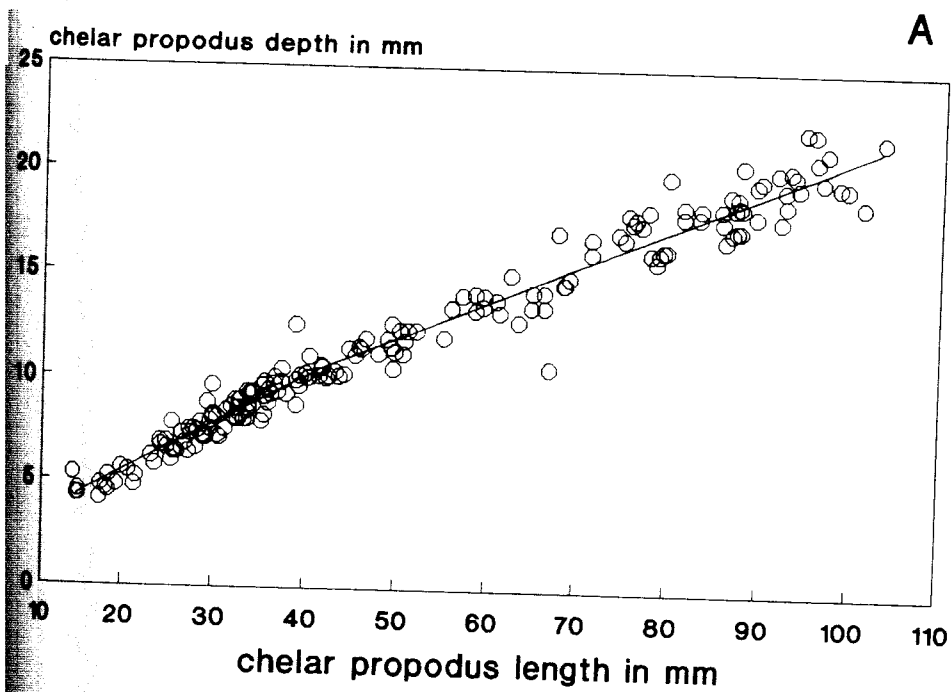
B- growth pattern of chelar propodus depth in relation to carapace width.



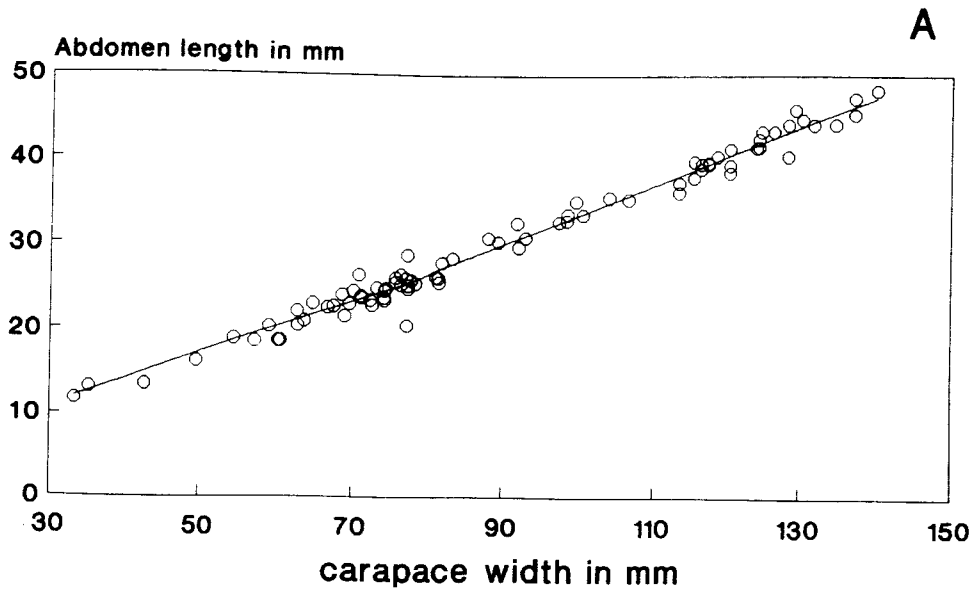
P. pelagicus males.

▲ - growth pattern of chelar propodus length in relation to carapace length.

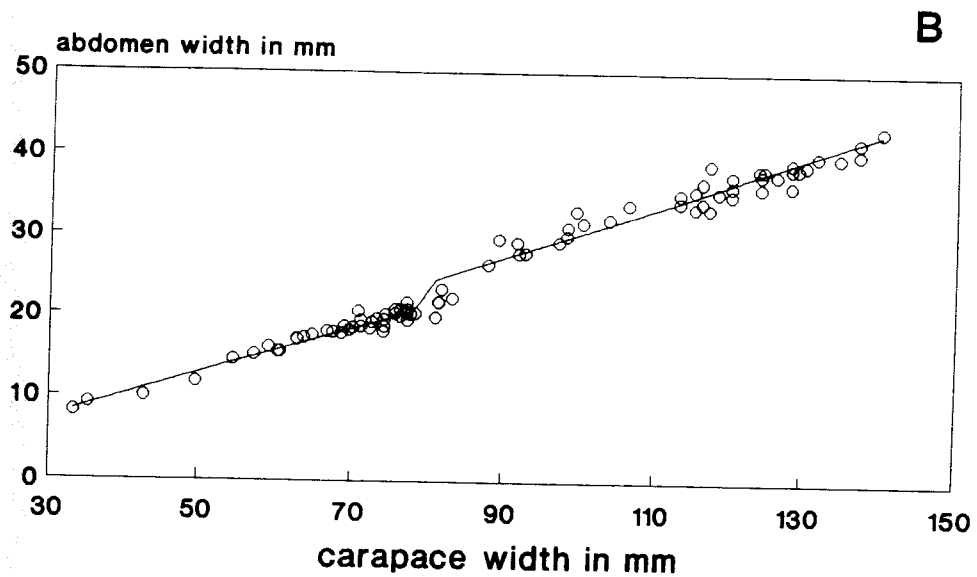
○ - growth pattern of chelar propodus depth in relation to carapace length.



3. A - Growth variation of chelar propodus depth in relation to chelar propodus length in *P. sanguinolentus*.
 B - growth variation of chelar propodus depth in relation to chelar propodus length in *P. pelagicus*.



○ observed ab.l — expected ab.l



○ observed ab.w — expected ab.w

Fig. 5.14. *P. sanguinolentus* females.
 A - growth pattern of abdomen length in relation to carapace width.
 B - growth pattern of abdomen width in relation to carapace width.

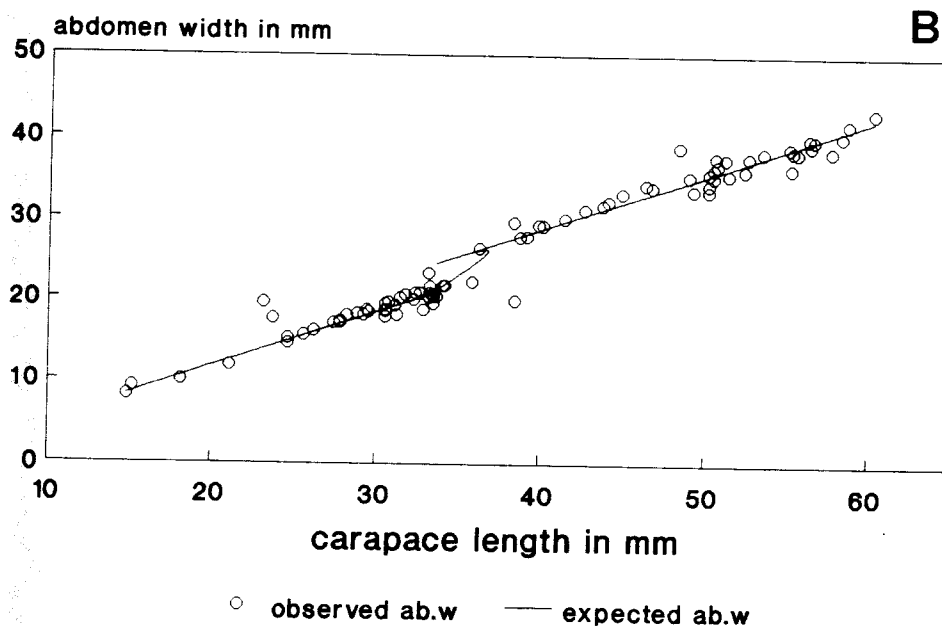
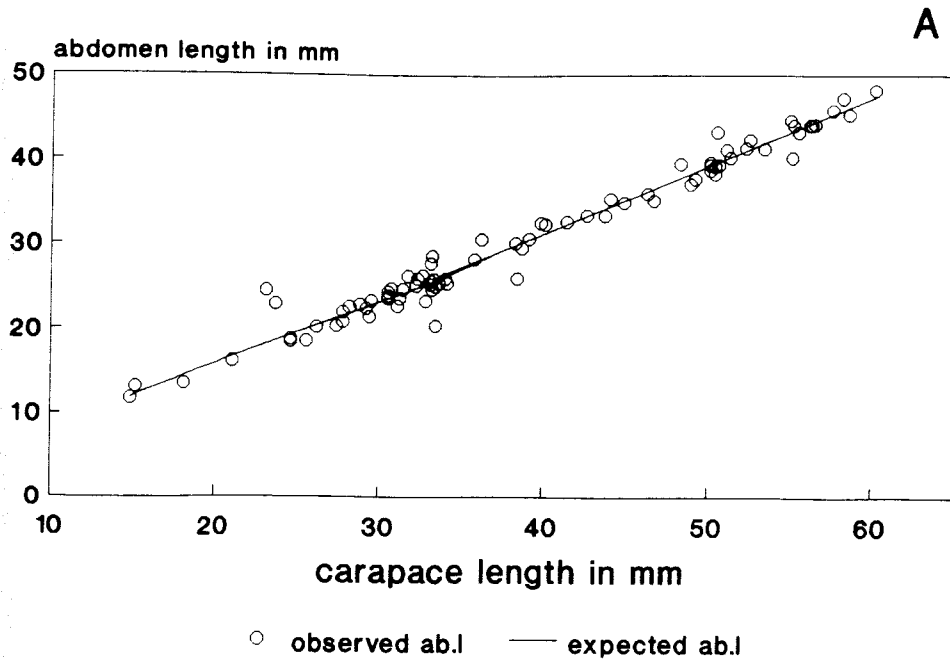
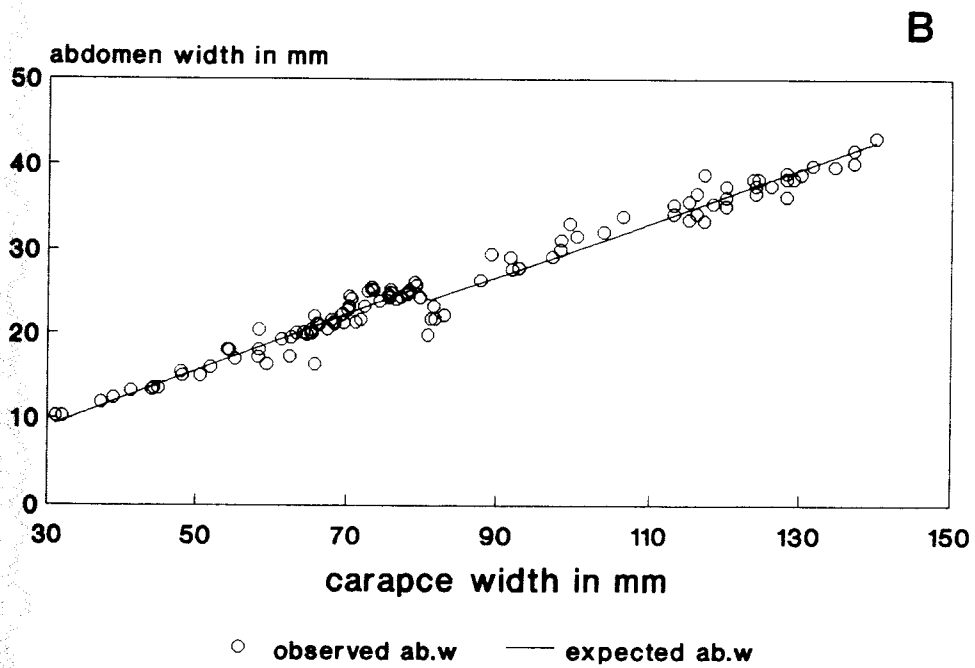
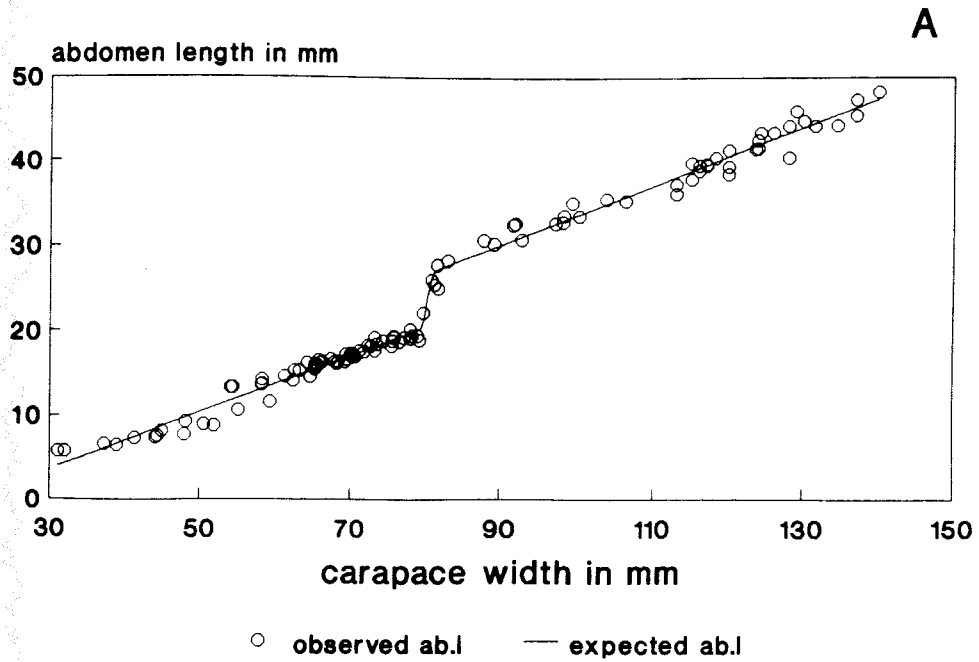


Fig. 5.15. *P. sanguinolentus* females.
 A - growth pattern of abdomen length in relation to carapace length.
 B - growth pattern of abdomen width in relation to carapace length.



5.16 *P. pelagicus* females.

A - growth pattern of abdomen length in relation to carapace width.

B - growth pattern of abdomen width in relation to carapace width.

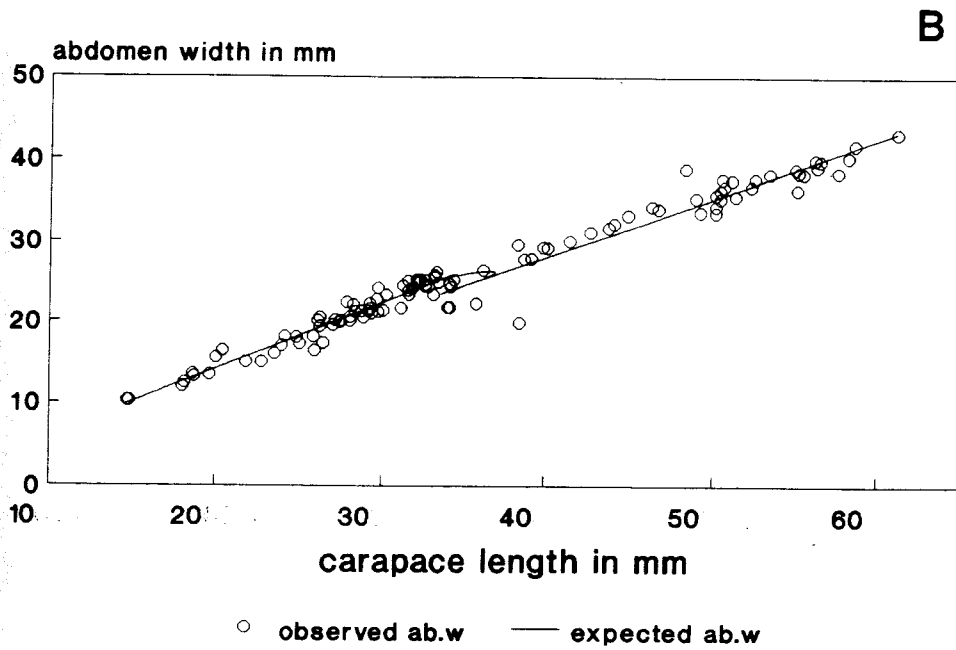
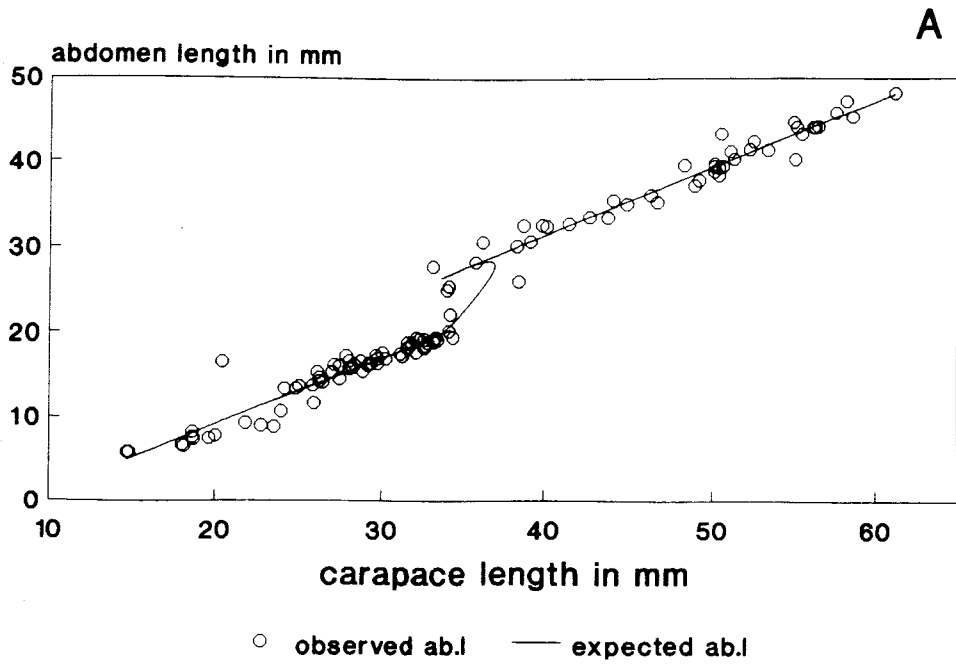
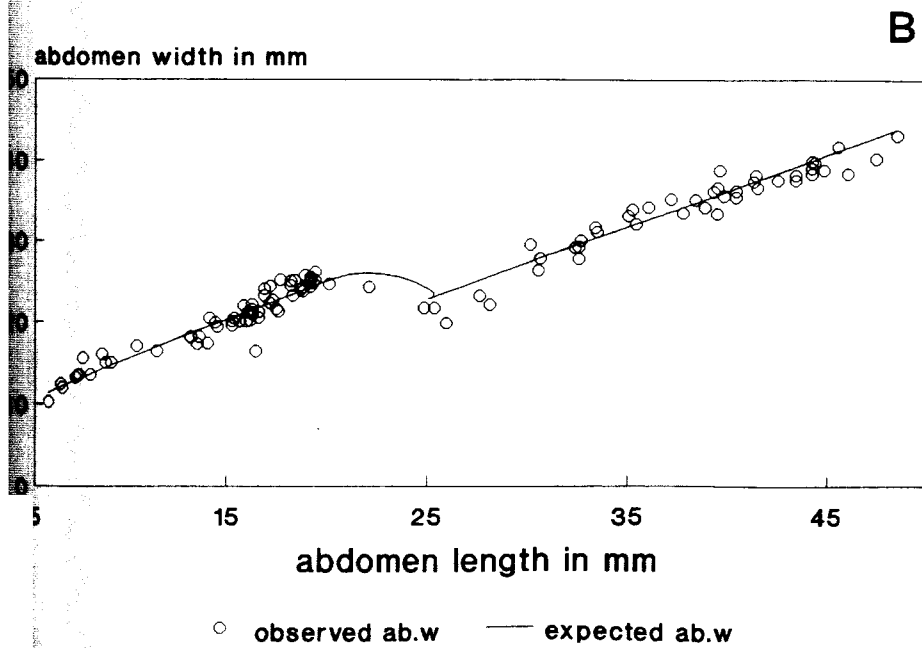
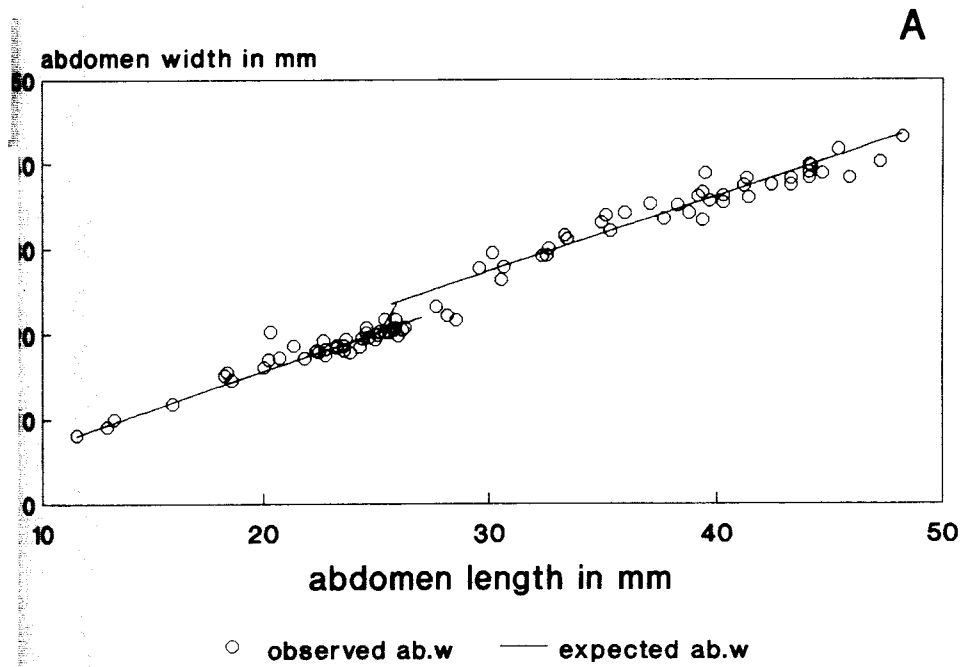


Fig. 5.17. *P. pelagicus* females.
 A - growth pattern of abdomen length in relation to carapace length.
 B - growth pattern of abdomen width in relation to carapace length.



5.18. A - growth variation of abdomen width in relation to abdomen length in *P. sanguinolentus*;
 B - growth variation of abdomen width in relation to abdomen length in *P. pelagicus*.

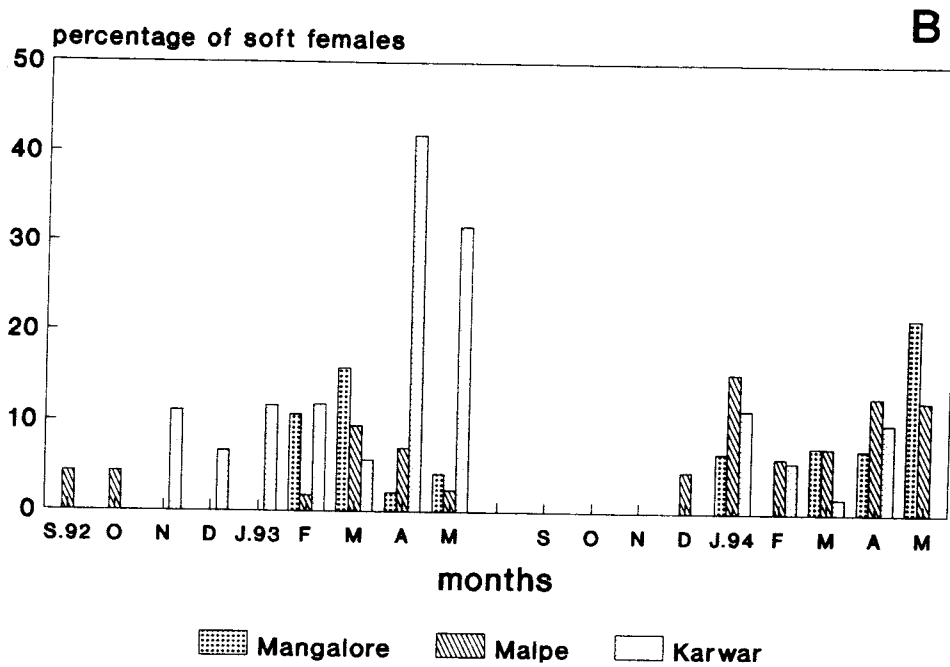
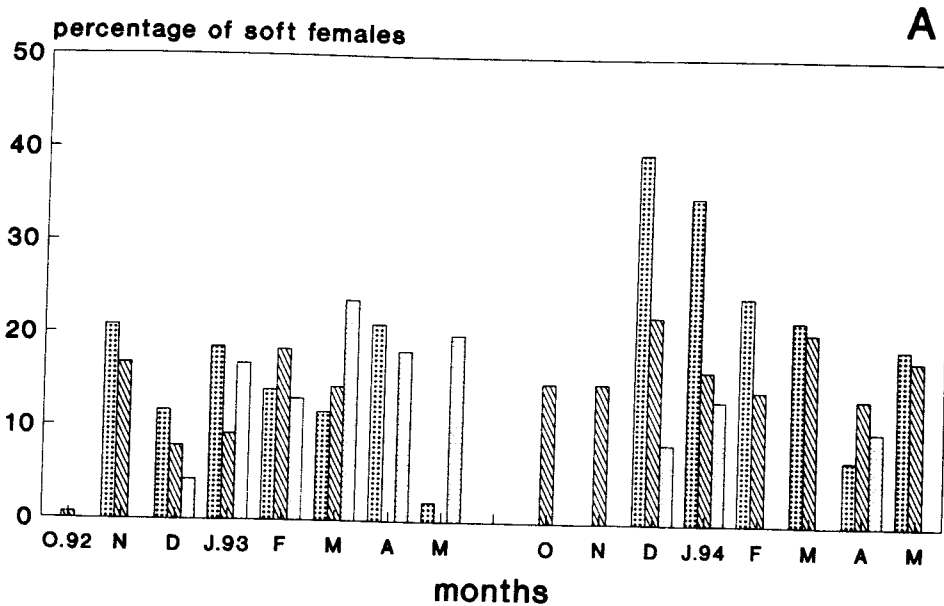


Fig. 5.19. A - monthwise distribution of soft females in *P. sanguinolentus*; B - monthwise distribution of soft females in *P. pelagicus*.

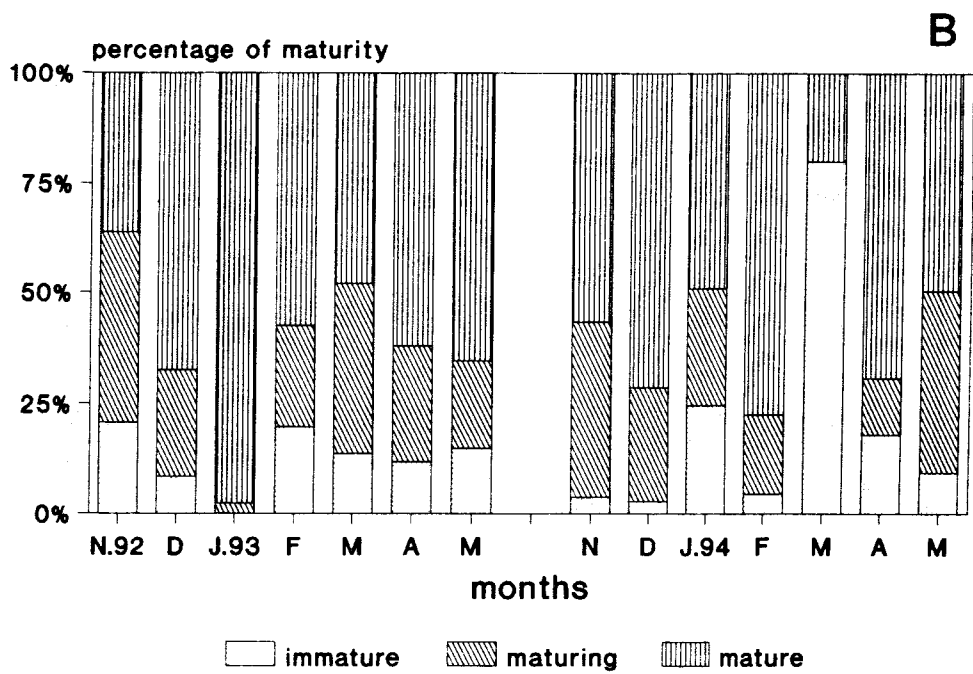
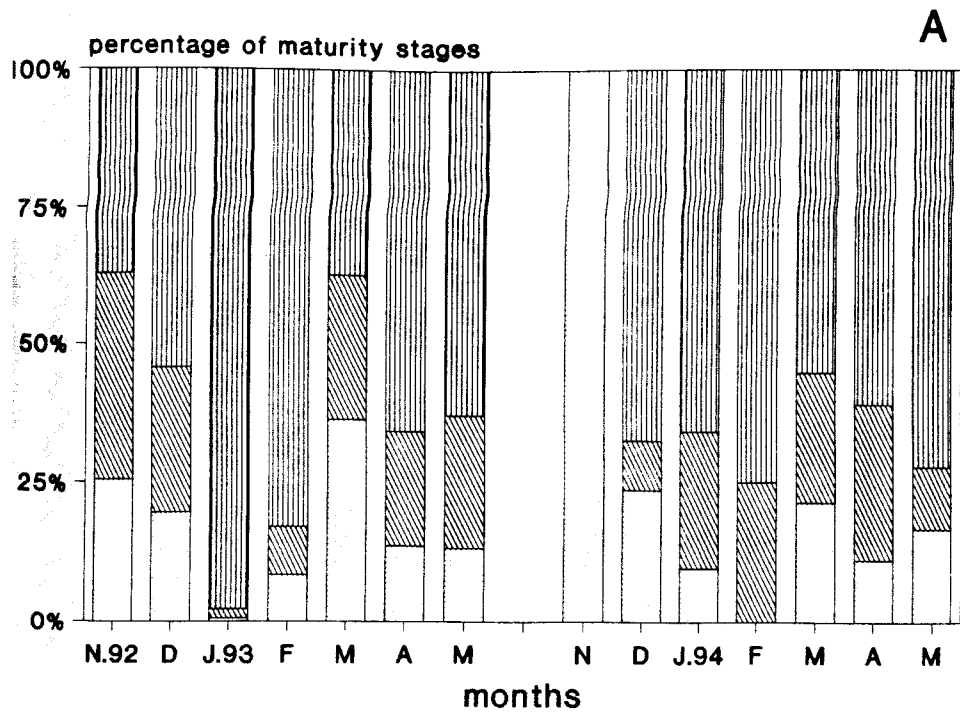
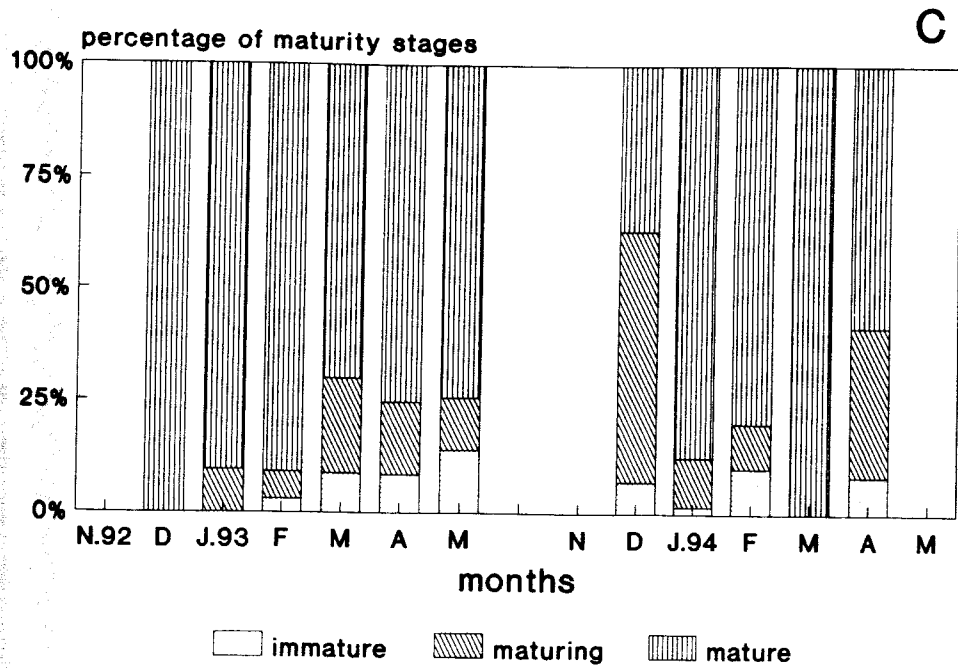


Fig. 5.20. *P. sanguinolentus* males.
 A - monthwise distribution of maturity stages at Mangalore;
 B - monthwise distribution of maturity stages at Malpe;



g. 5.20. *P. sanguinolentus* males.
 C -monthwise distribution of maturity stages at Karwar.

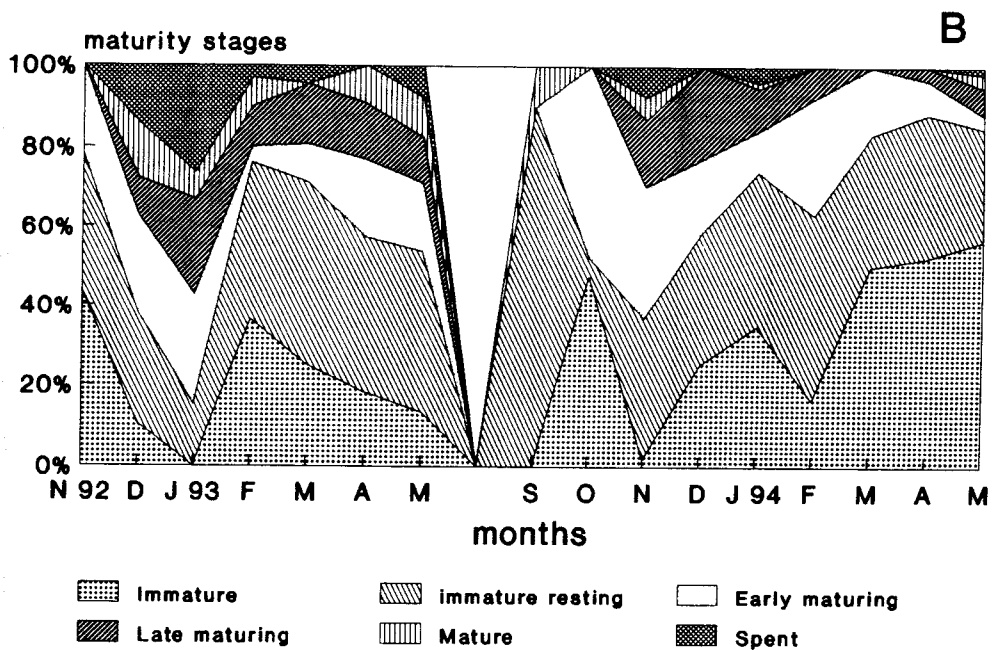
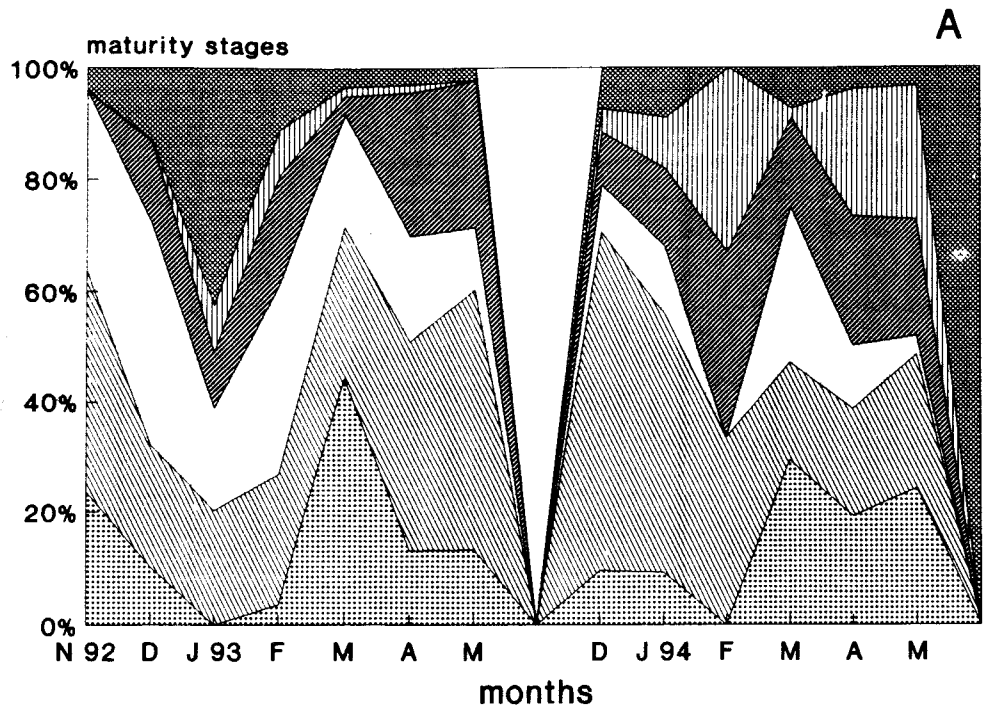


Fig. 5.21. *P. sanguinolentus* females.
 A - monthwise distribution of maturity stages at Mangalore;
 B - monthwise distribution of maturity stages at Malpe.

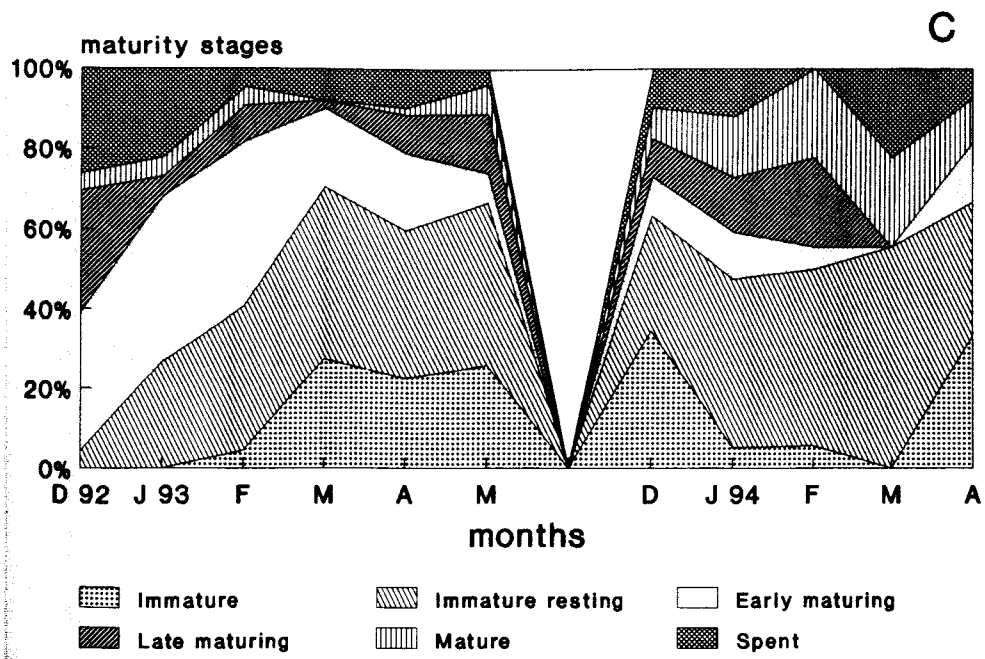


Fig. 5.21. *P. sanguinolentus* females.
 C - monthwise distribution of maturity stages at Karwar.

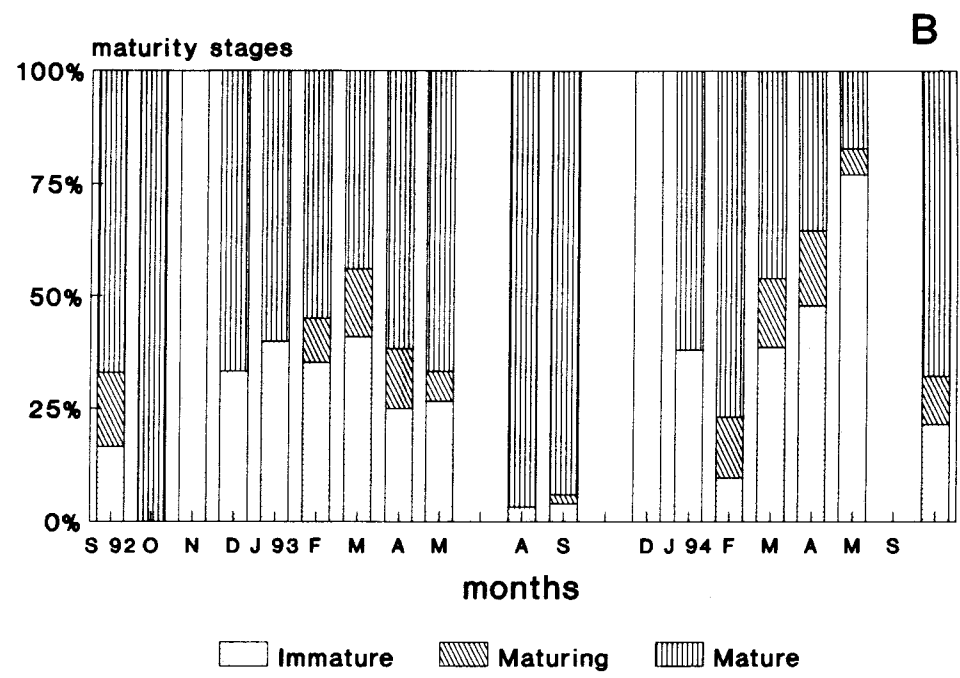
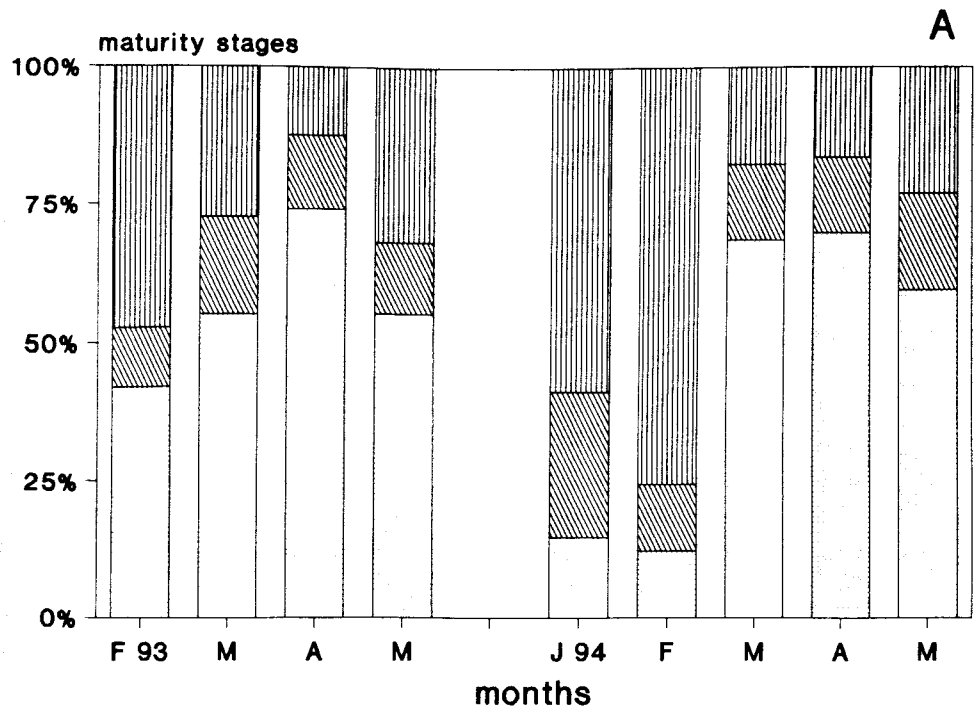


Fig. 5.22. *P. pelagicus* males.
 A - monthwise distribution of maturity stages at Mangalore;
 B - monthwise distribution of maturity stages at Malpe.

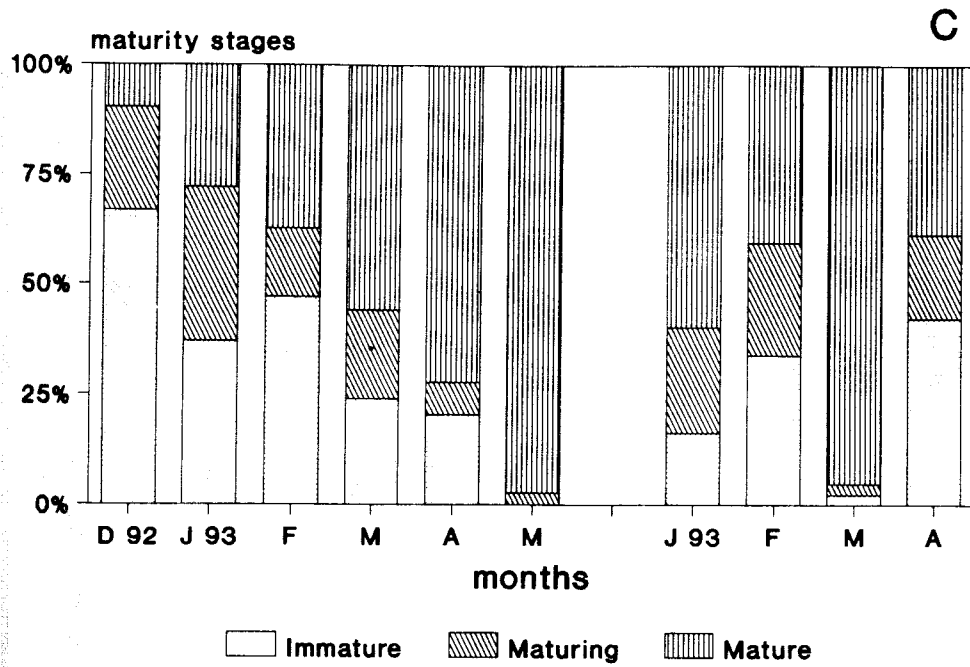


fig. 5.22. *P. pelagicus* males.
 C- monthwise distribution of maturity stages at Karwar.

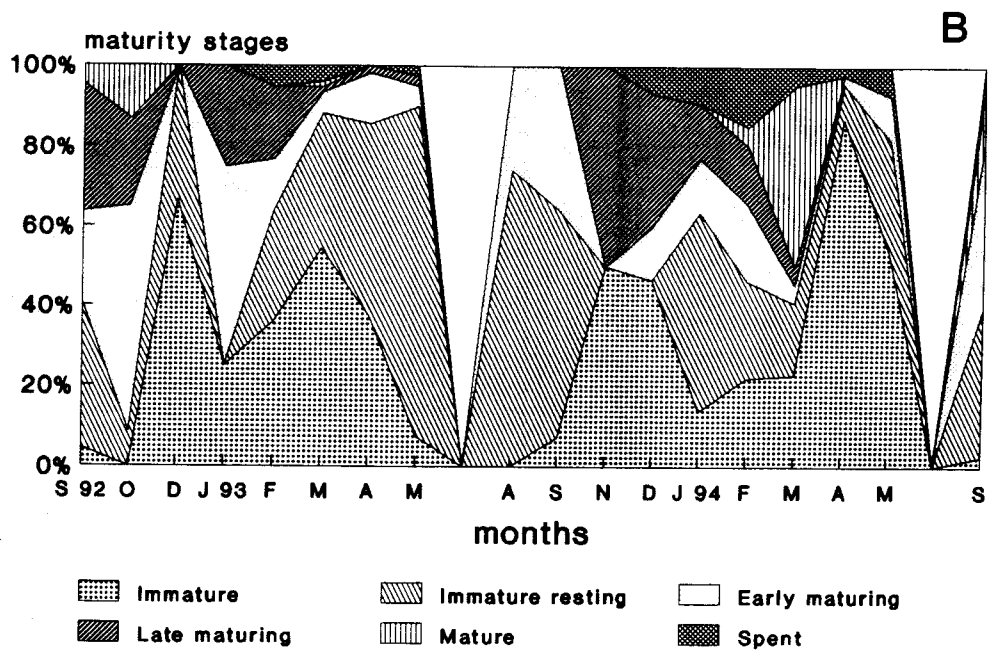
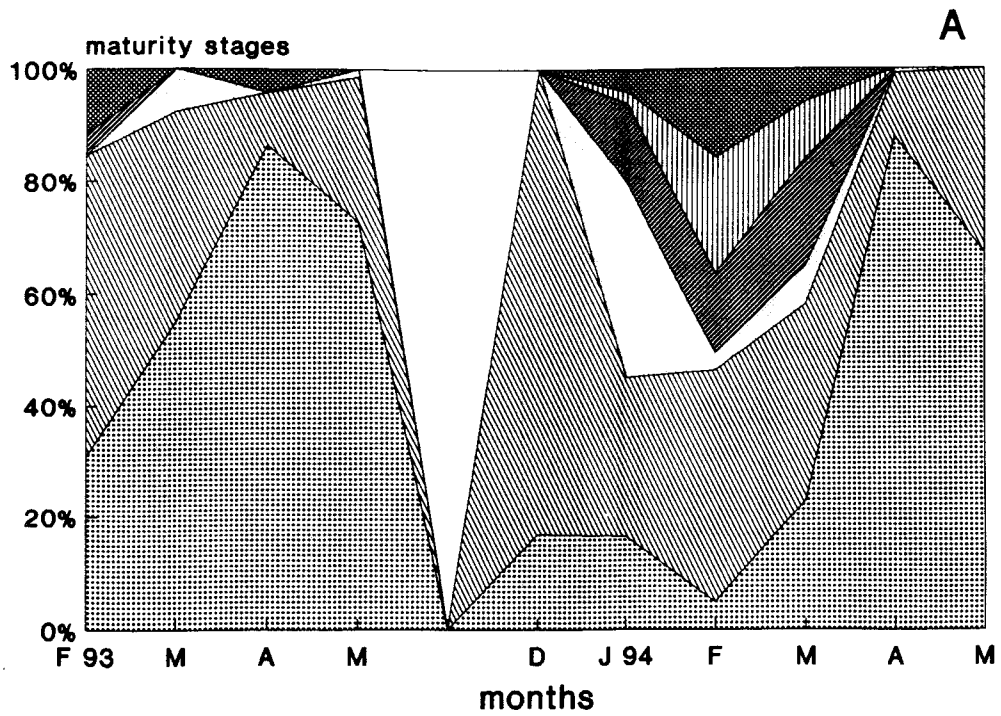


Fig. 5.23. *P. pelagicus* females.
 A - monthwise distribution of maturity stages at Mangalore;
 B - monthwise distribution maturity stages at Malpe.

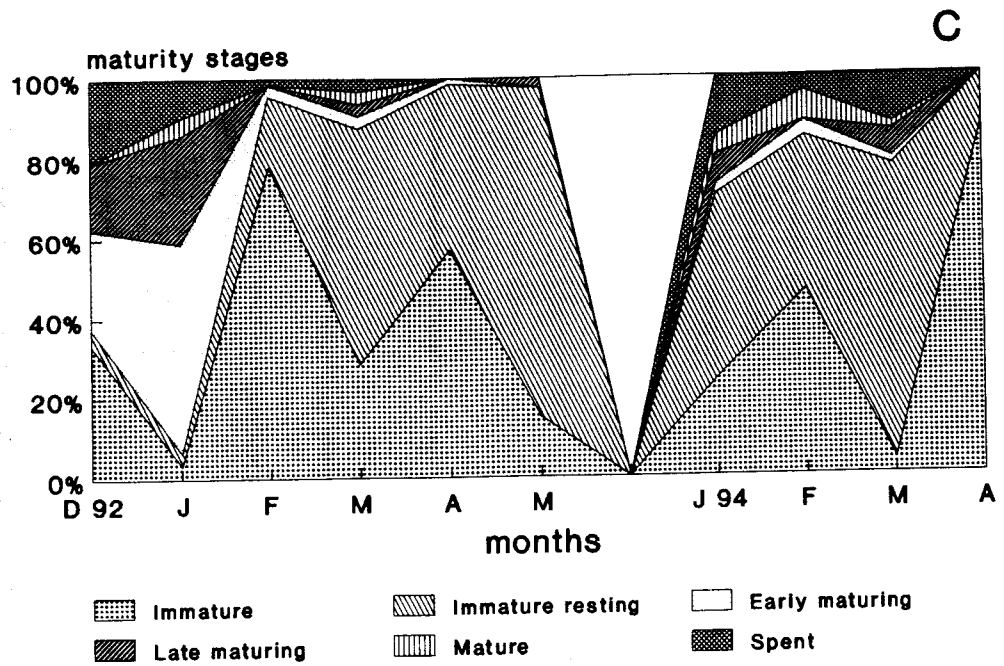


Fig. 5.23. *P. pelagicus* females.
C -monthwise distribution of maturity stages at Karwar.

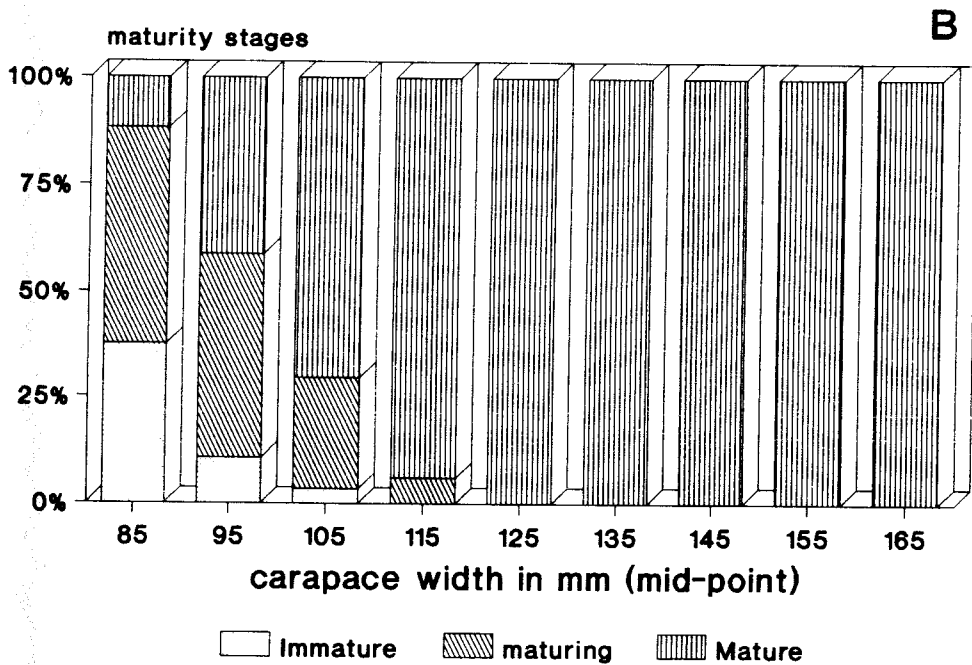
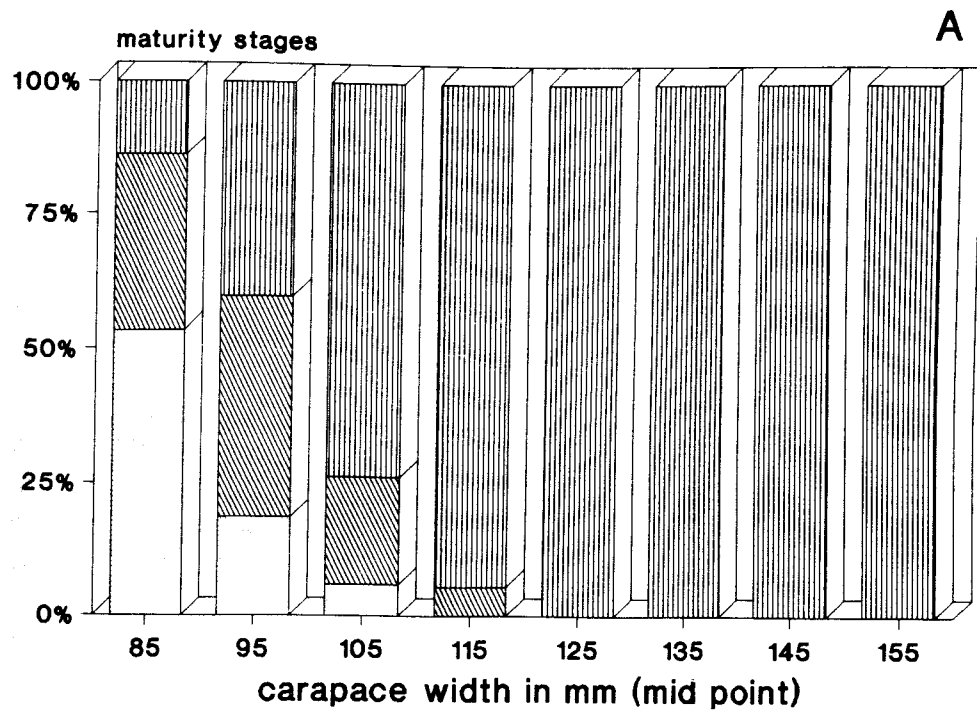


Fig. 5.24. *P. sanguinolentus* males.
 A - size-wise distribution of maturity stages at Mangalore;
 B - size-wise distribution of maturity stages at Malpe.

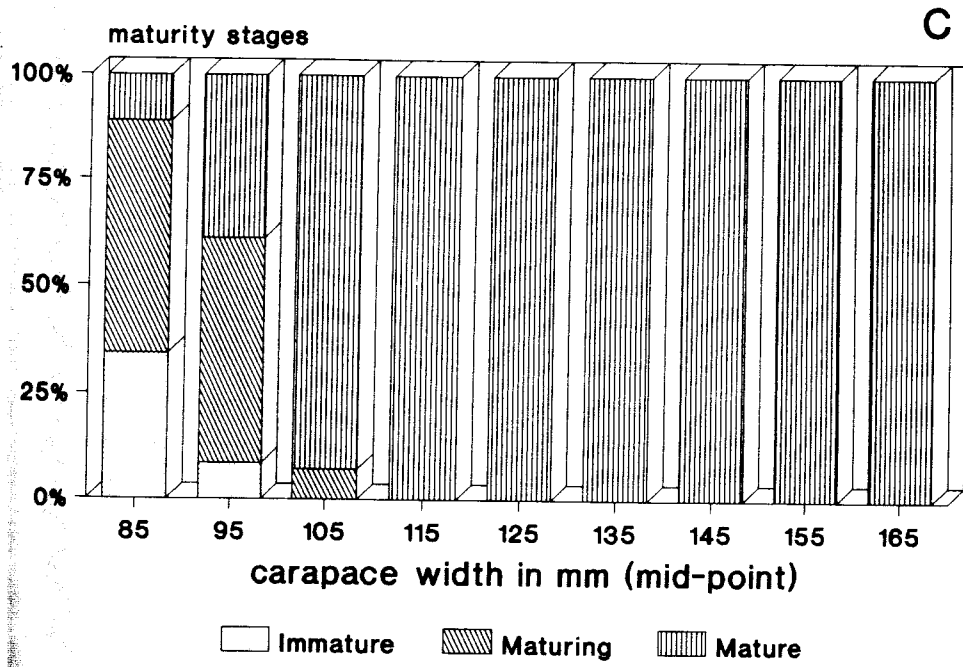


Fig. 5.24. *P. sanguinolentus* males.
 C - size-wise distribution of maturity stages at Karwar.

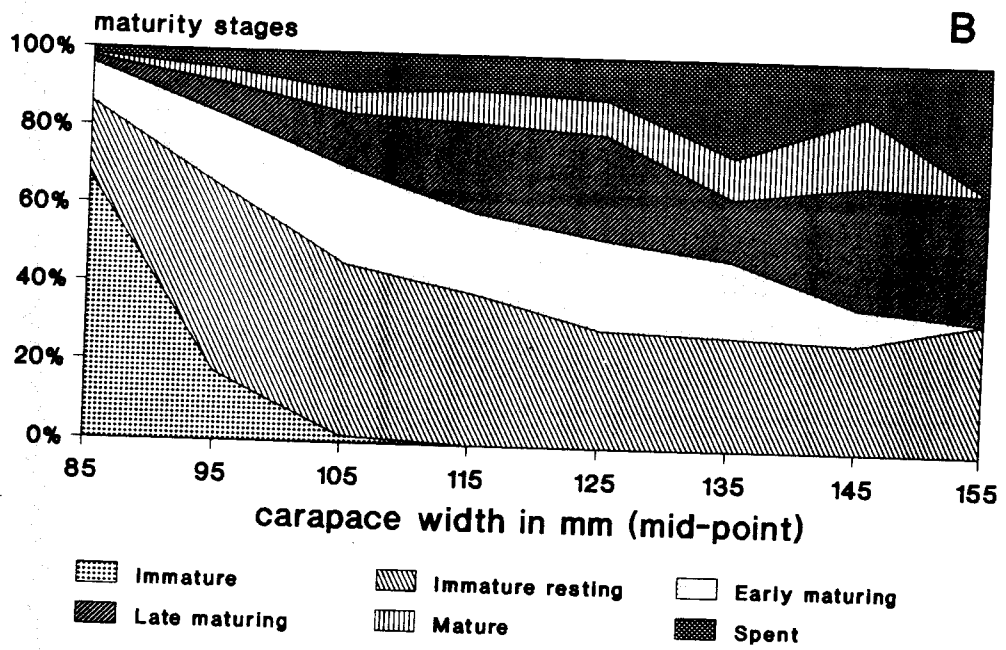
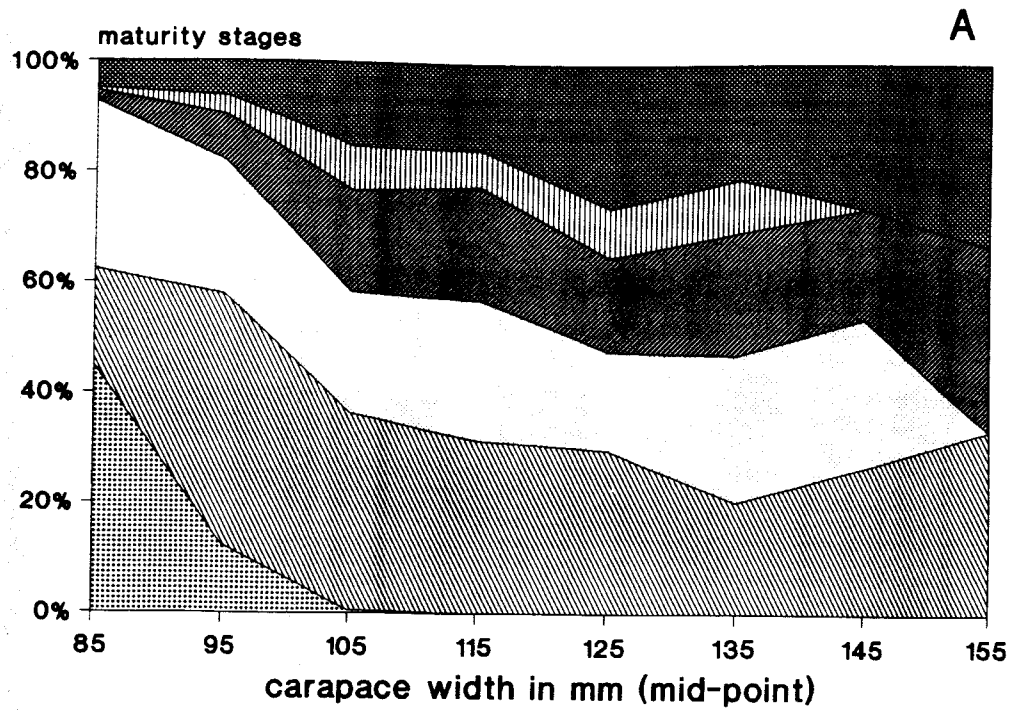


Fig. 5.25. *P. sanguinolentus* females.
 A - size-wise distribution of maturity stages at Mangalore;
 B - size-wise distribution of maturity stages.

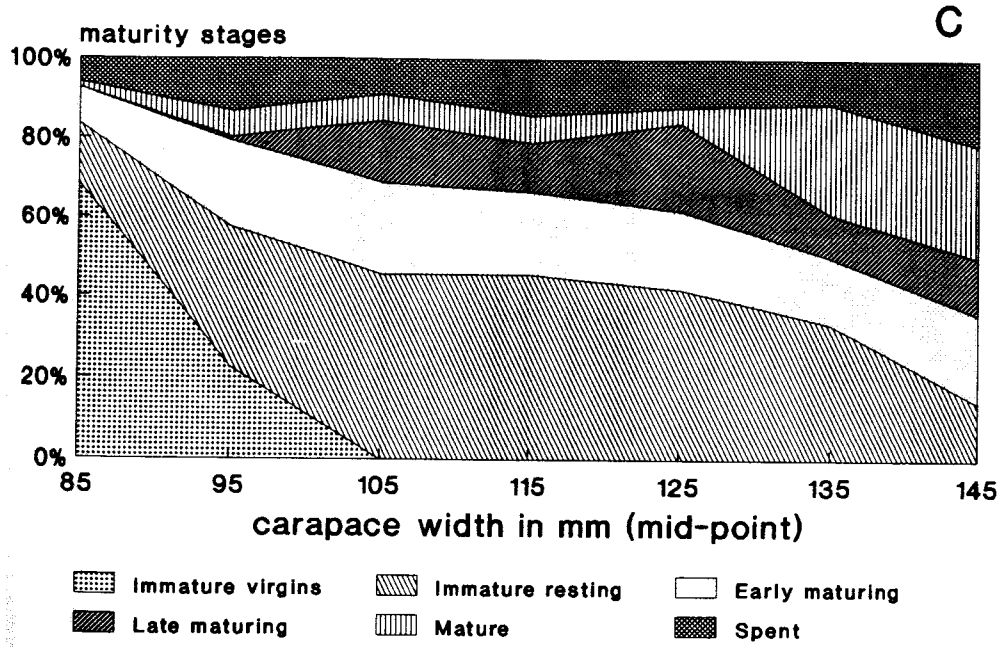


fig. 5.25. *P. sanguinolentus* females.
 C - size-wise distribution of maturity stages at Karwar.

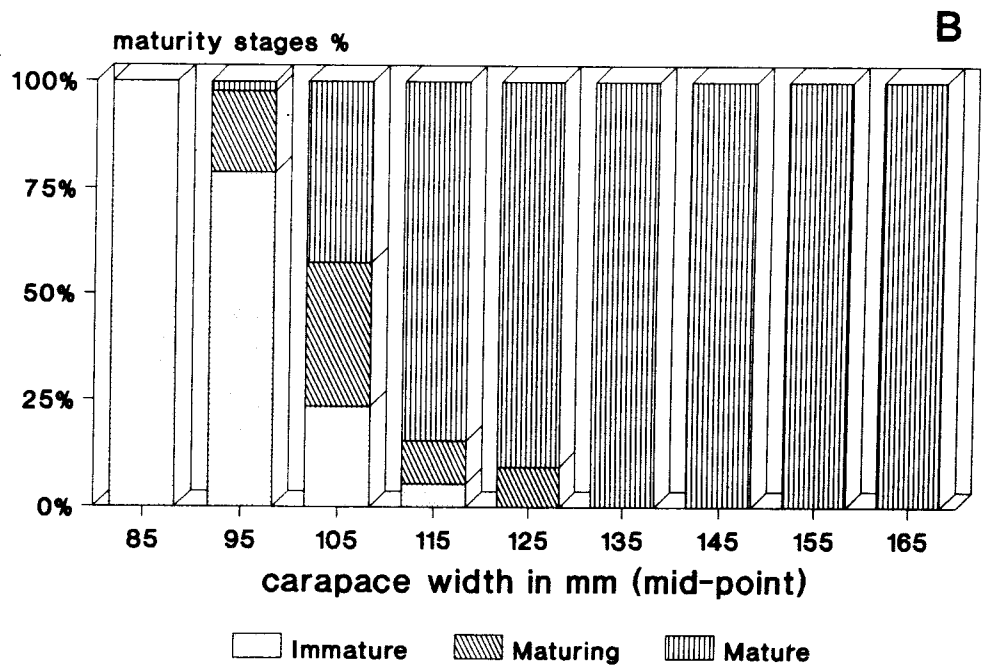
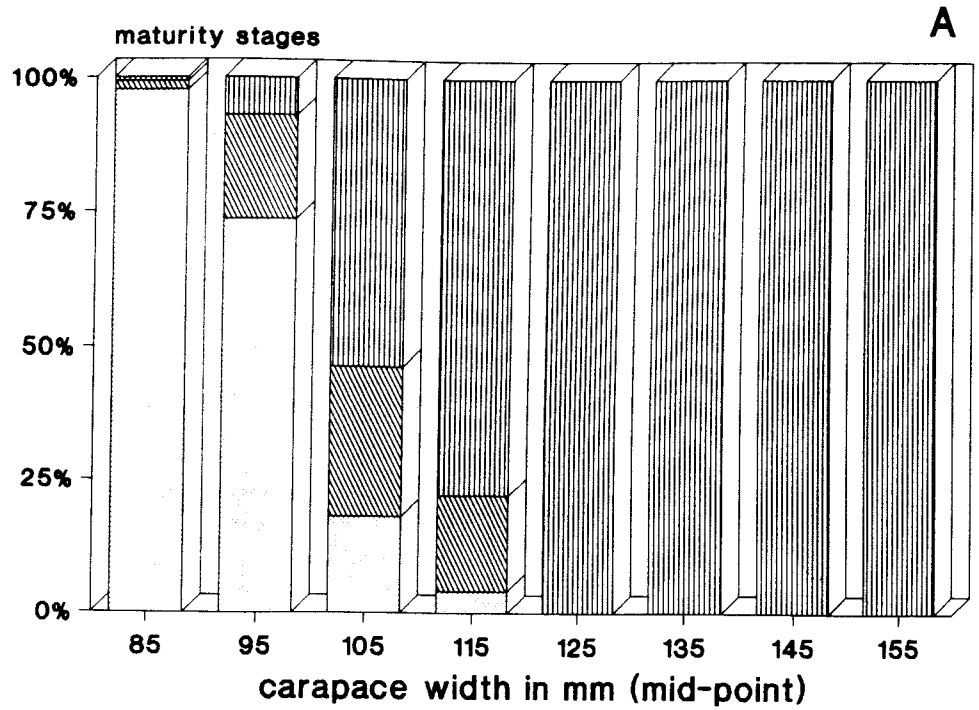


Fig. 5.26. *P. pelagicus* males.
 A - size-wise distribution of maturity stages at Mangalore;
 B - size-wise distribution of maturity stages at Malpe.

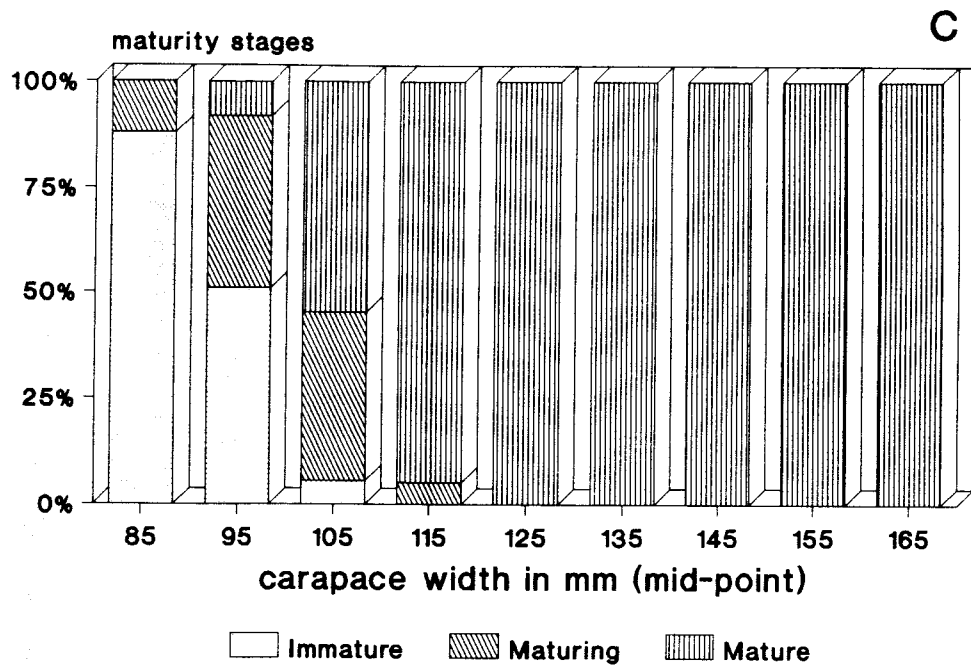


Fig. 5.26. *P. pelagicus* males.
 C - size-wise distribution of maturity stages at Karwar.

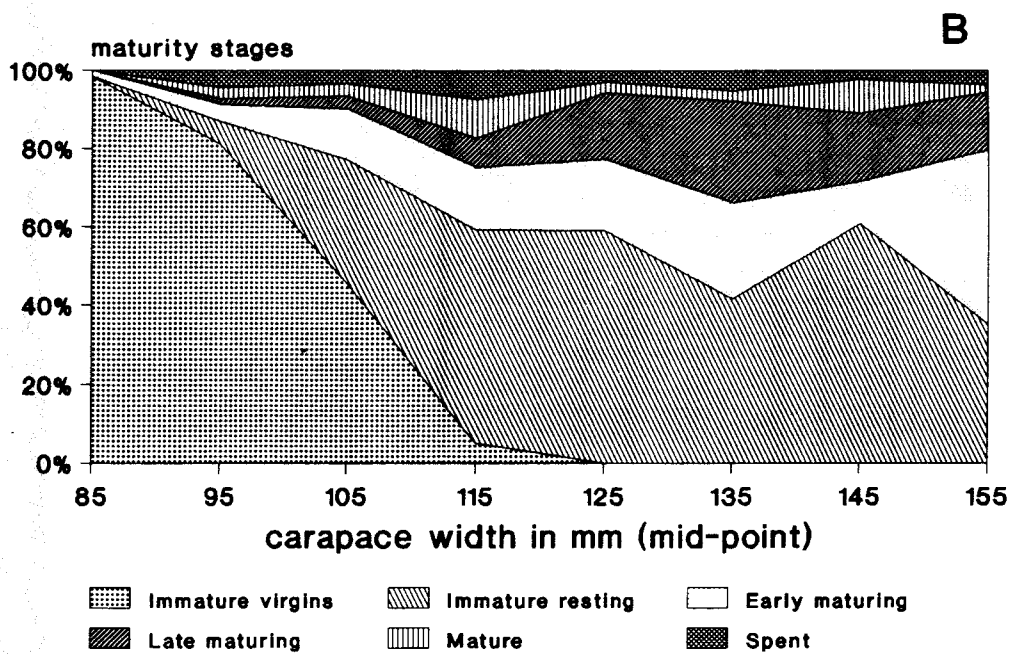
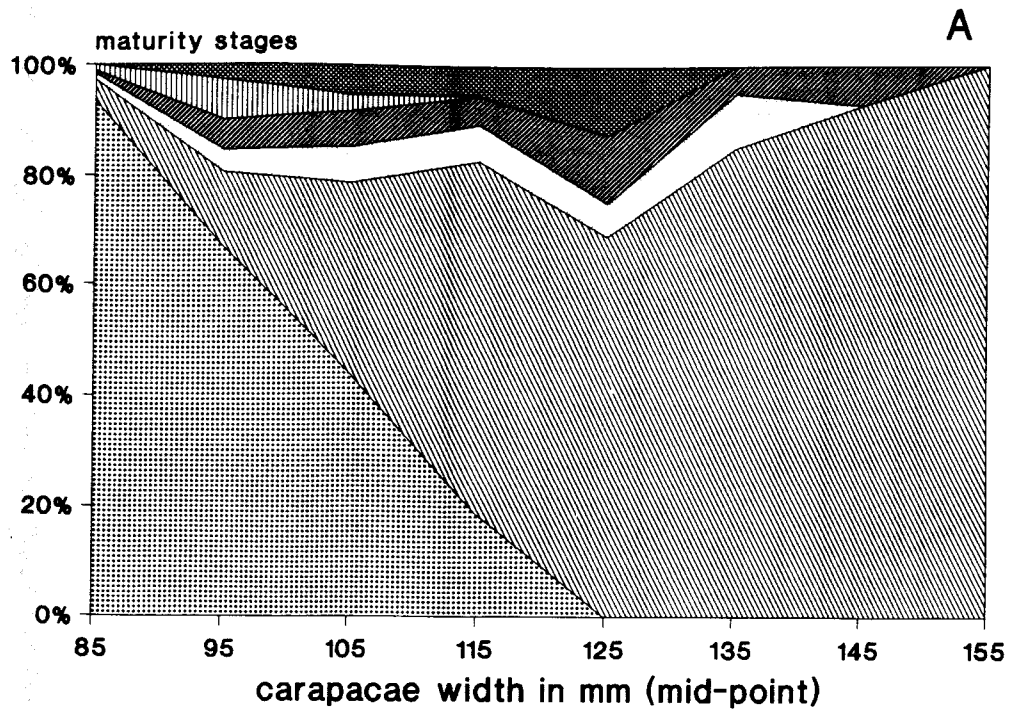


Fig. 5.27. *P. pelagicus* females.
 A - size-wise distribution of maturity stages at Mangalore;
 B - size-wise distribution of maturity stages at Malpe.

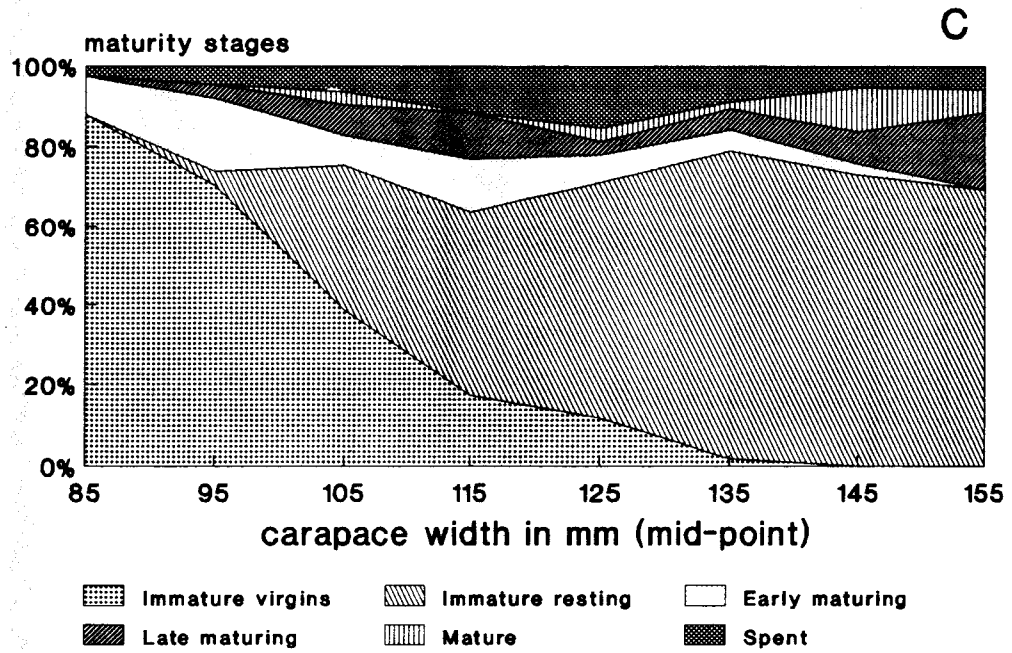
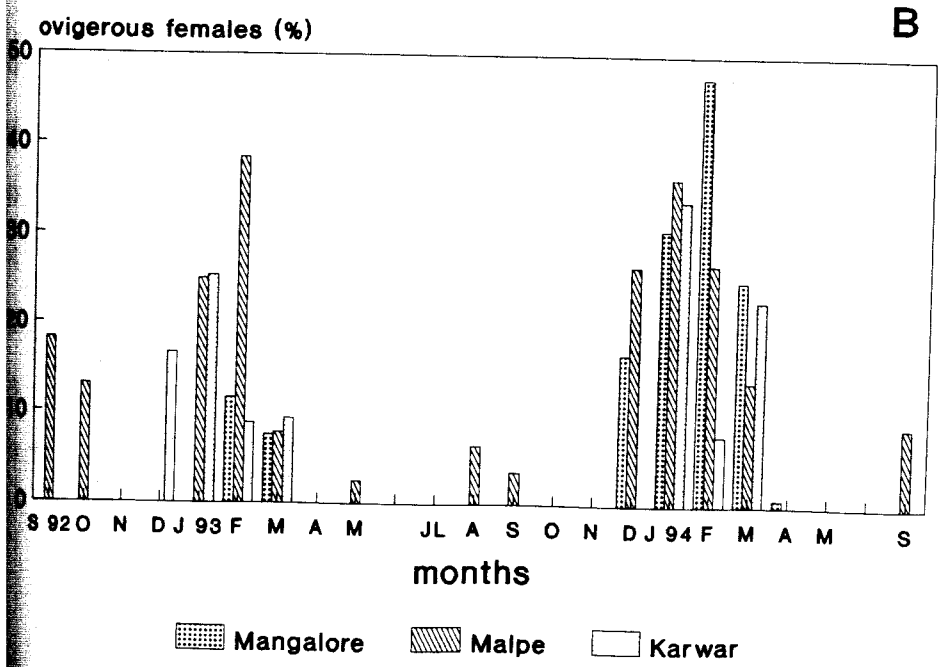
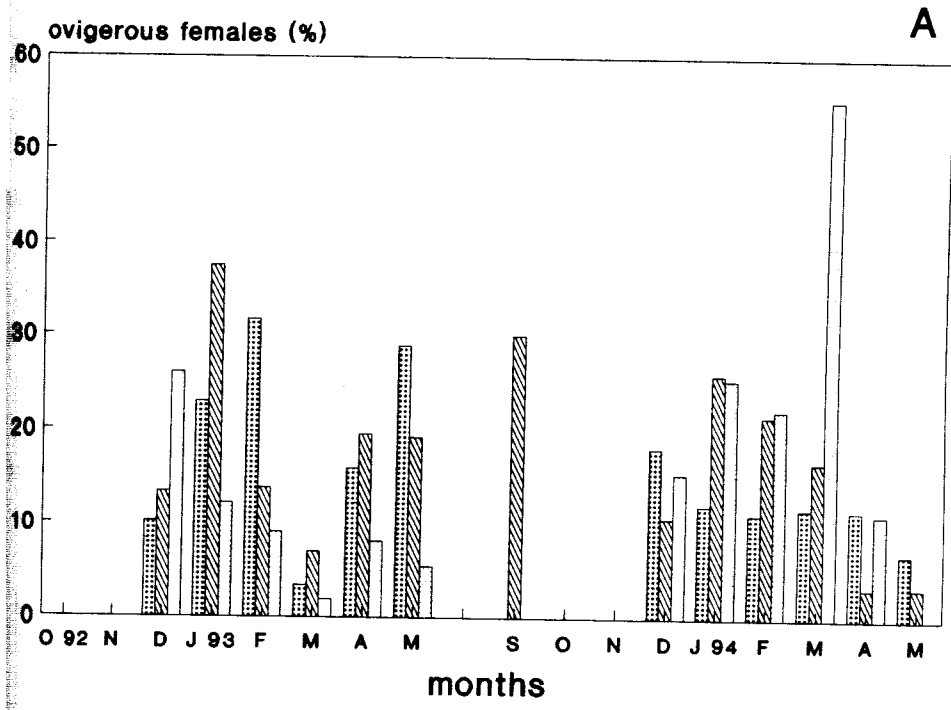
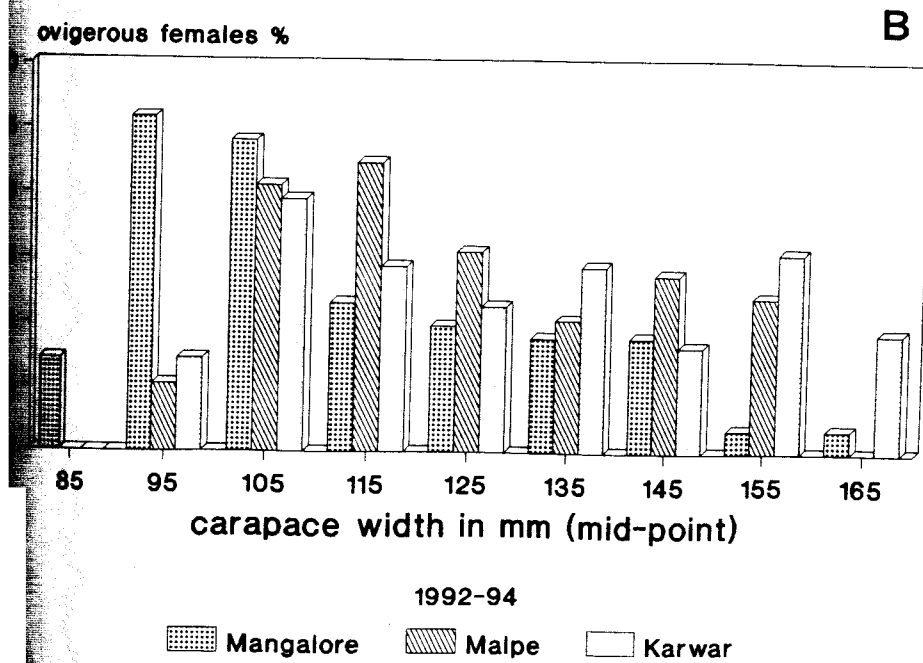
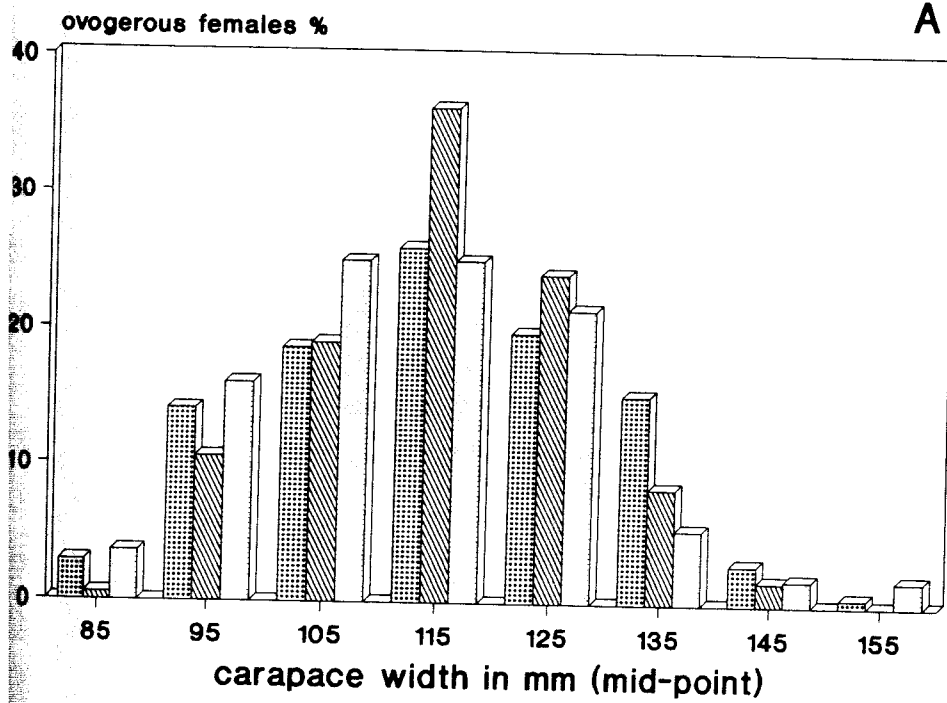


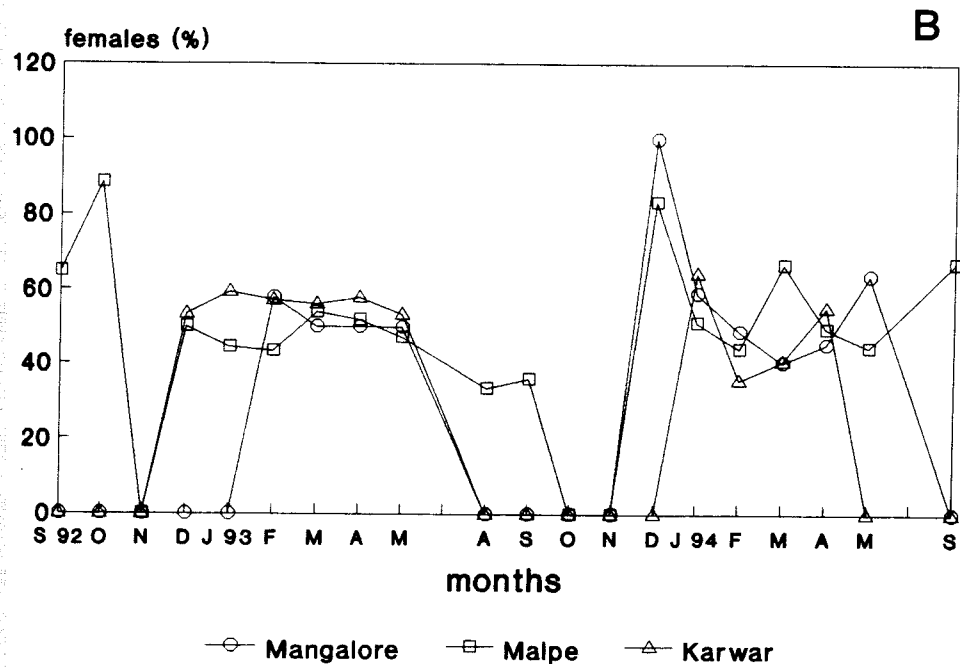
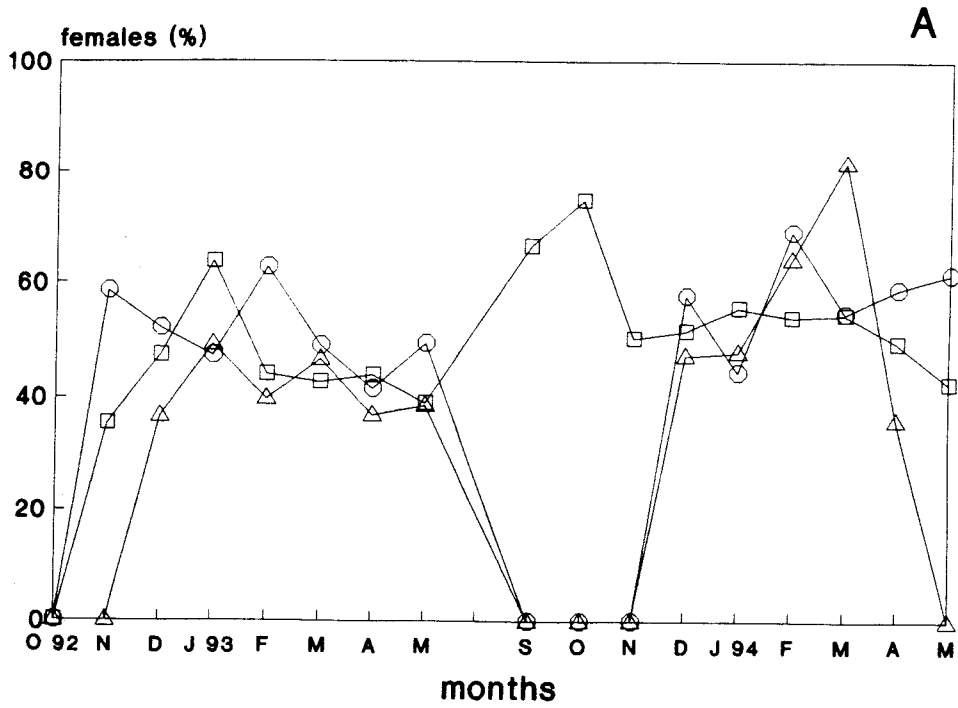
Fig. 5.27. *P. pelagicus* females.
 C - size-wise distribution of maturity stages at Karwar.



5.28. A - monthwise distribution of ovigerous females of *P. sanguinolentus* at Mangalore, Malpe and Karwar.
 B - monthwise distribution of ovigerous females of *P. pelagicus* at Mangalore, Malpe and Karwar.



29. A - size-wise distribution of ovigerous females of *P. sanguinolentus* at Mangalore, Malpe and Karwar.
 B - size-wise distribution of ovigerous females of *P. pelagicus* at Mangalore, Malpe and Karwar.



g. 5.30. A - monthwise distribution of sex ratio in *P. sanguinolentus*; B - monthwise distribution of sex ratio in *P. pelagicus*.

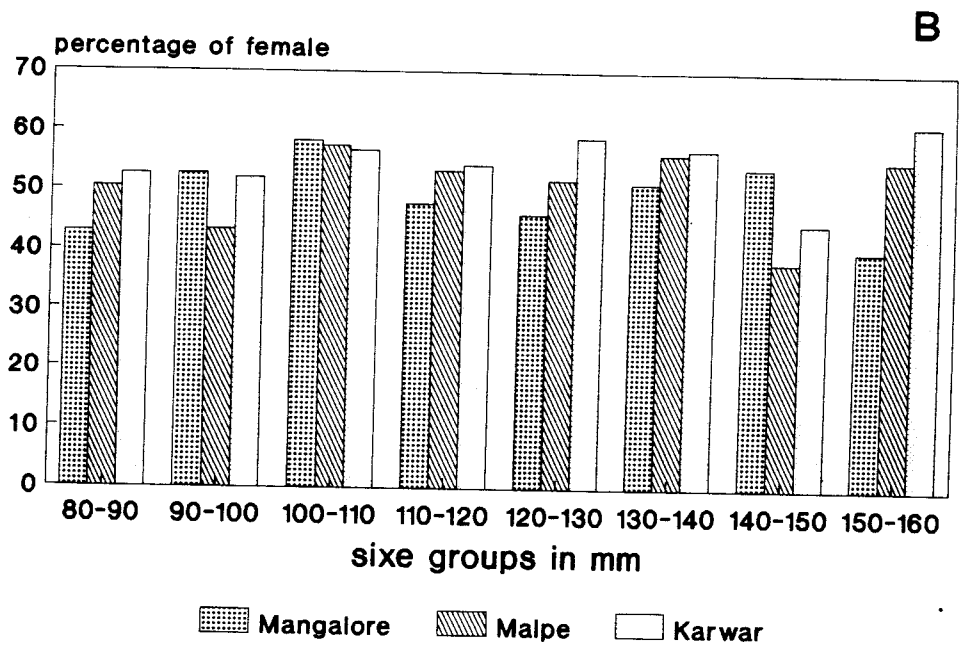
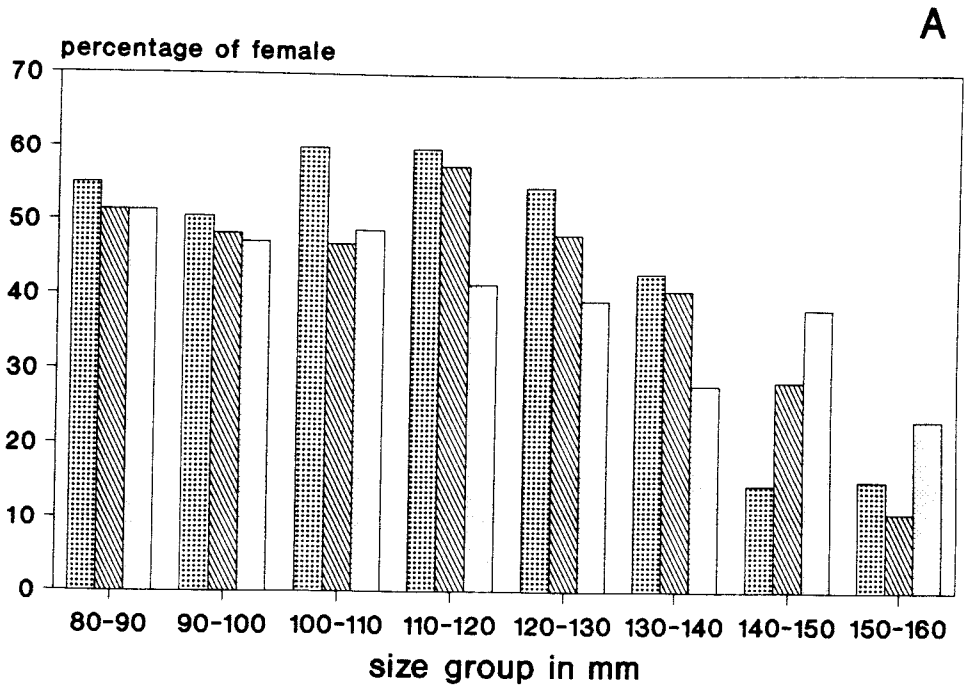
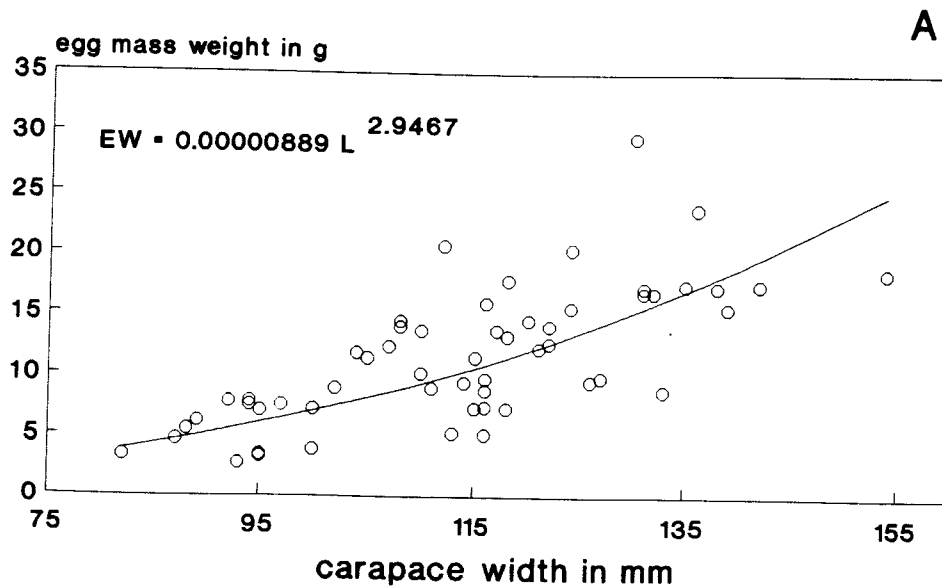
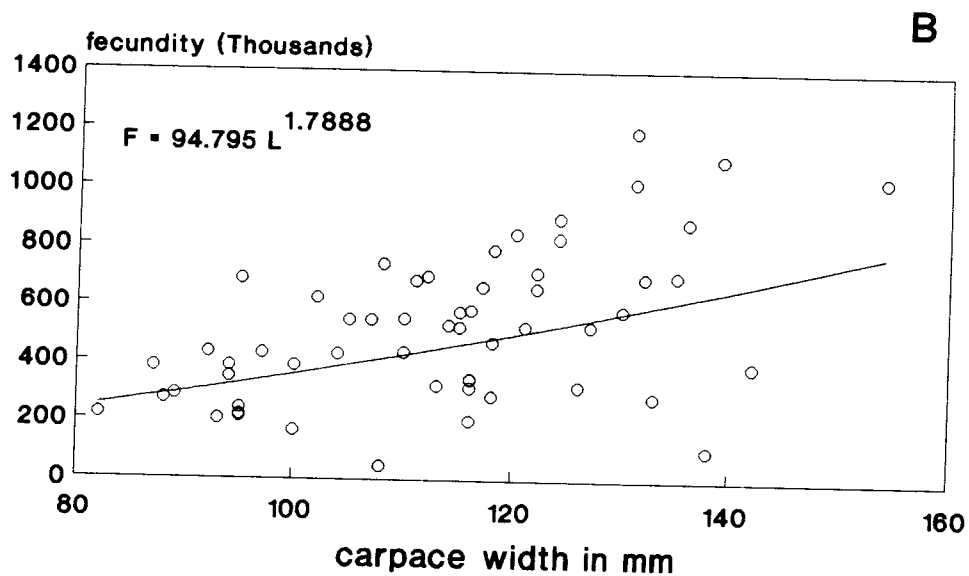


Fig. 5.31. A - sizewise distribution of sex ratio in *P. sanguinolentus*;
 B - sizewise distribution of sex ratio in *P. pelagicus*.



○ observed egg mass wt — expected eggmass wt



○ Observed fecundity — expected fecundity

Fig. 5.32. *P. sanguinolentus*.
 A - carapace width - eggmass weight relationship;
 B - carapace width - fecundity relationship.
 L = Carapace width; EW = eggmass weight; F = fecundity.

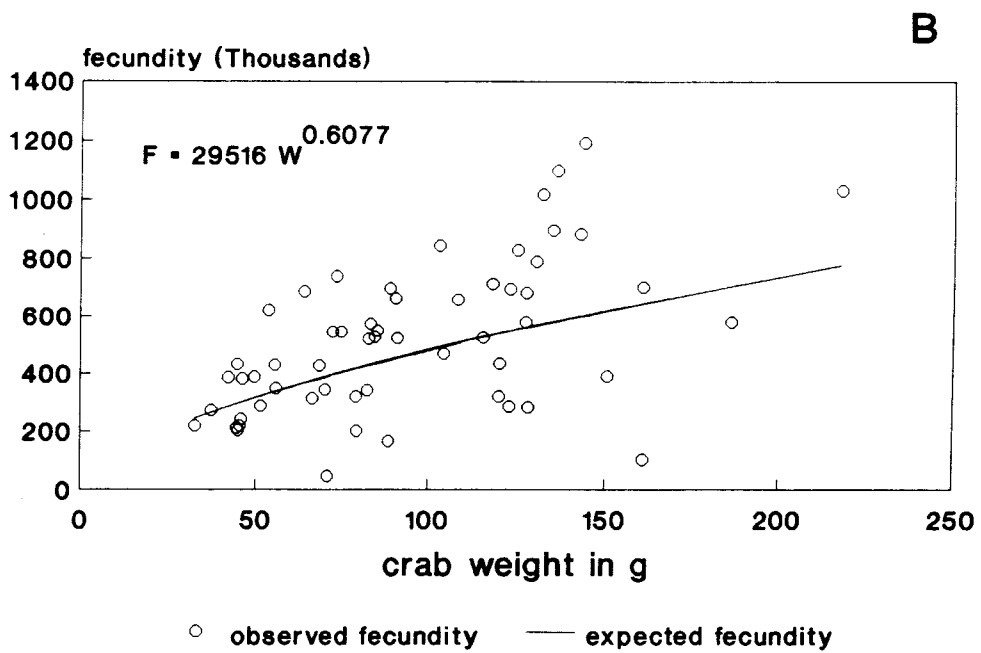
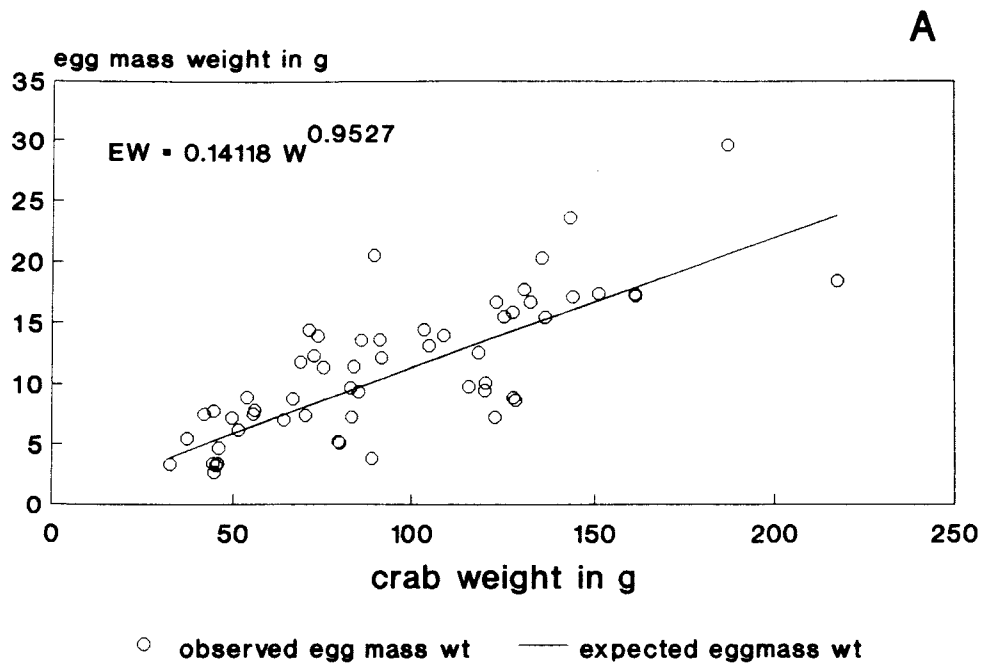


Fig. 5.33. *P. sanguinolentus*.
 A - body weight- eggmass weight relationship;
 B - body weight - fecundity relationship.
 W= body weight; EW= eggmass weight; F= fecundity

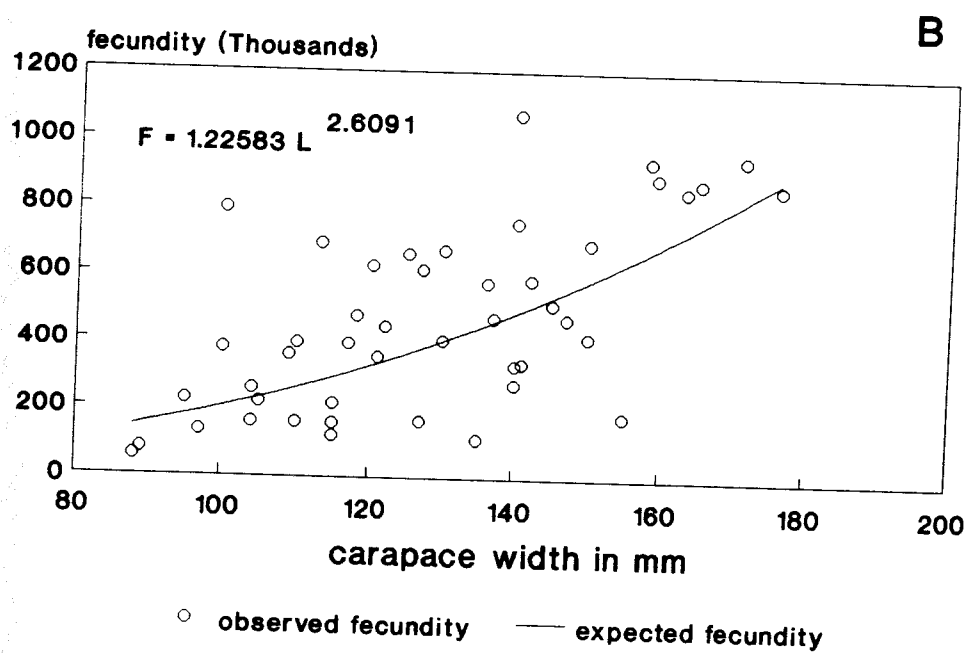
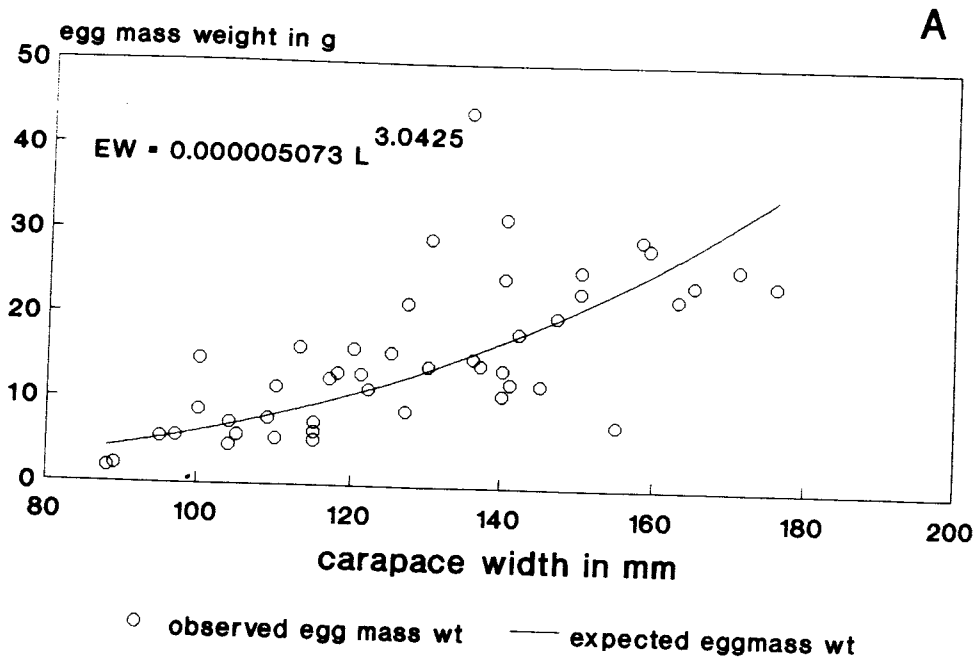


Fig. 5.34. *P. pelagicus*.
 A - carapace width - eggmass weight relationship;
 B - carapace width - fecundity relationship.
 L = Carapace width; EW = eggmass weight; F = fecundity.

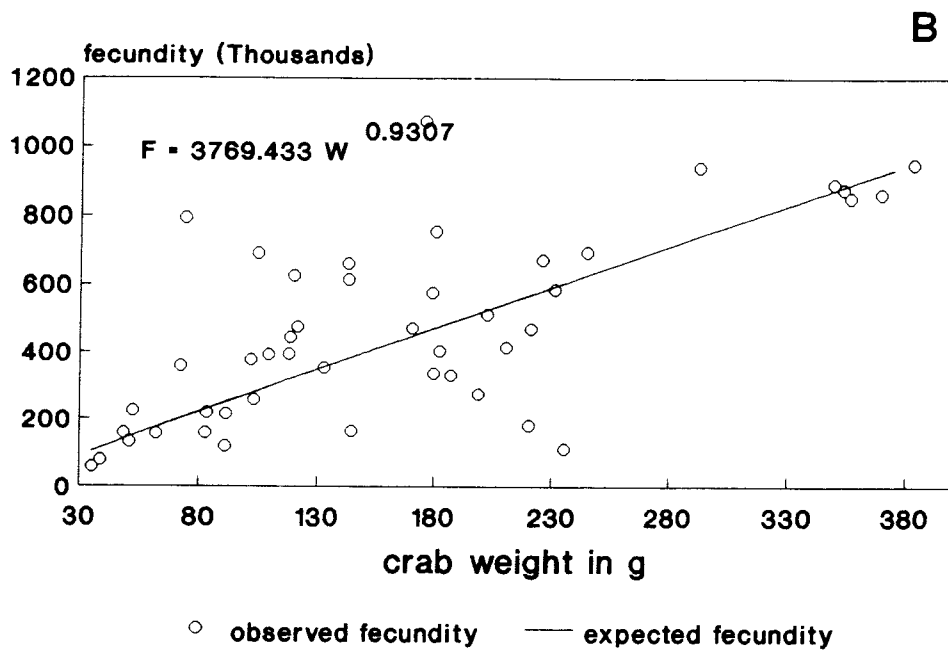
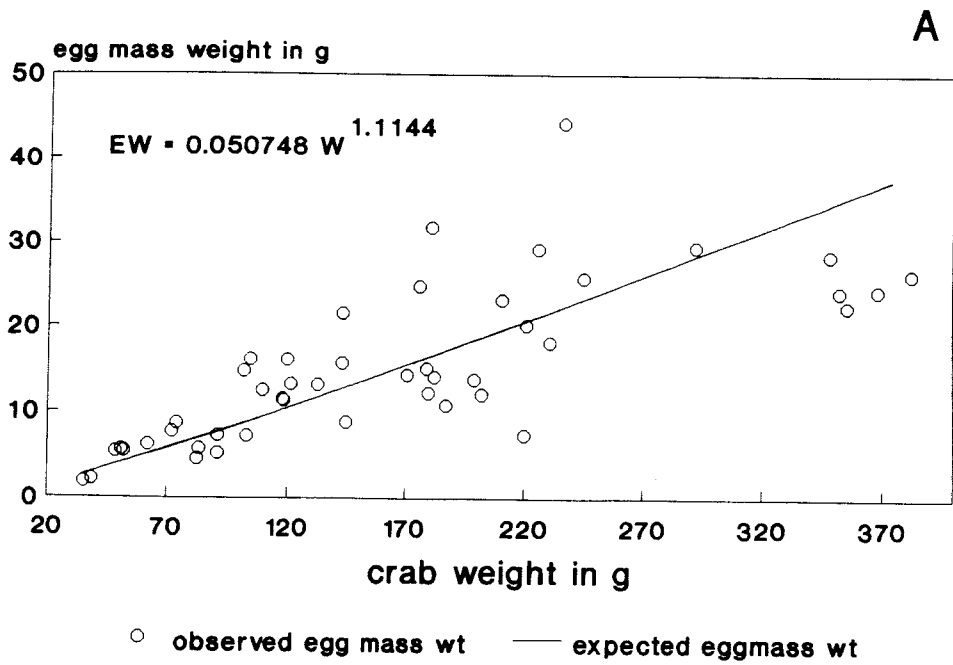


Fig. 5.35. *P. pelagicus*.
 A - body weight - eggmass relationship;
 B - body weight - fecundity relationship.
 W = body weight; EW = eggmass weight; F = fecundity

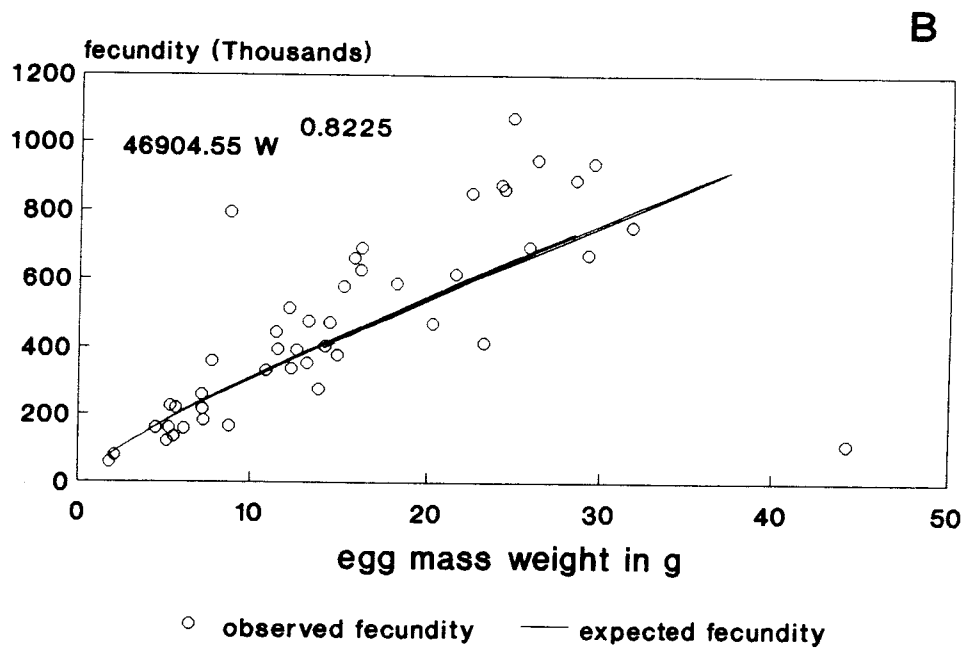
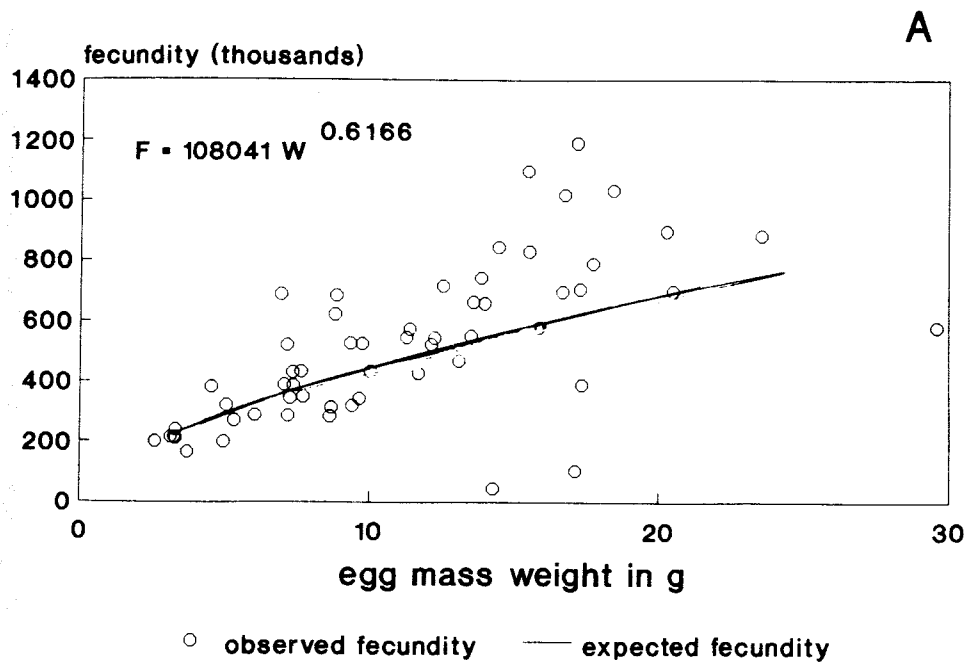


Fig. 5.36. A - eggmass weight - fecundity relationship in *P. sanguinolentus*;
 B - eggmass weight - fecundity relationship in *P. pelagicus*.
 EW= eggmass weight; F= fecundity.

Chapter VI
AGE AND GROWTH

AGE AND GROWTH

INTRODUCTION

Age and growth studies are directed to understand the age composition of the population, age at maturation, life span and pattern of growth of a species in different phases of its life history. Information on these aspects are useful in determining the parameters such as, L_{∞} , K and t_0 from which mortality, survival rate and recruitment and stock assessment studies are made. These parameters are further used for evolving effective management strategies for the development and judicious exploitation of the resources (Bal and Rao, 1984).

The study of growth means basically the determination of the body size as a function of age. Growth can be expressed as an increase of length, volume, wet weight or dry weight with time (Hartnoll, 1982). It is essential to have an understanding of length and age/ size relationship, if one is to apply equilibrium yield models to the management of a fishery (Melville-Smith, 1989).

Age and growth studies are available on several brachyurans. Some of the recent important studies are on *Halicarcinus australis* (Lucas and Hodgekin, 1970); *Aratus pisoni* (Hamer, 1967); *Rithropanopeus harrisi* (Turoboyski, 1973); *Pachygrapsus crassipes* (Hiatt, 1963); *Carcinus maenas* (Crothers, 1967); *Callinectes sapidus* (Tagatz, 1968); *Paralithodes australis* (Hoopes and Karinen, 1972); *Cancer magister* (Butler, 1961; Carroll, 1982); *Libinia emarginata* (Bennet, 1974); *Uca pugilator* (Colby and Fonseca, 1984); *Cryptodroma noronhai* (McLay, 1982) and *Chaceon maritae* (Melville-Smith, 1989).

Despite their commercial importance and wide distribution, no detailed studies are available on the age and growth of *P. sanguinolentus* and *P. pelegicus* other than a few accounts based on tagging/ rearing experiments (Prasad and Tampi, 1953; Hamsa,

82; Smith, 1982; Potter *et al.*, 1983; Sumpton and Smith, 1991) and by modal regression analysis (Thomas, 1984 and Sumpton *et al.*, 1994).

The present study is, therefore, directed to understand the age and growth of *P. sanguinolentus* and *P. pelagicus* from the Karnataka coast.

2. MATERIALS AND METHODS

2.1. MATERIAL

The material for the study included:

Samples taken once a week on a random basis from the commercial trawl landings at Mangalore and Malpe during September 1992 through September 1994.

Monthly samples from the commercial trawl and shore-seine landings at Karwar during September 1992 through September 1994.

Occasional samples taken during 1993 and 1994 from the mini-trawl catches landed from the Netravati-Gurupur estuary (Mangalore).

Occasional samples during 1993 and 1994 from the indigenous gears (minitrawl, gill net) catch at Panambur (near Mangalore) and Malpe during monsoon months (June-September).

2. METHODS

2.1. Size frequency analysis

Age determination was made by applying Peterson's (1891) method of size frequency analysis. For this, carapace width measurements of *P. sanguinolentus* and *P. pelagicus* including spine were taken using a graduated measuring board. These measurements were classified into size groups with a class interval of 5 mm (eg. size

groups 20-25 mm, 25-30 mm include carapace measurements from 20 to 24.9 mm and to 29.9 mm with a mid point at 22.5 and 27.5 mm respectively) and pooled monthwise data subjected to three point moving average to remove possible errors in sampling. The monthly size frequency were plotted sexwise, gearwise and centrewise for *P. guinolentus* and *P. pelagicus*. As the number of crabs measured was not constant, the size frequency distribution was made comparable by converting them into percentages except in the case of pooled data.

Growth patterns were determined by graphical analysis of the progression of modes in successive size frequency distribution. The progression of modes was traced by trend lines.

2.2. Modal progression analysis

The scatter diagram for modes against months was drawn and trend lines tracing growth of successive broods by means of modal progression through time were fitted free hand as adopted by Devaraj (1983). These lines were extrapolated to intersect the x-axis in order to resolve the periodicity and frequency of brood production during a spawning season and also the growth of each brood through successive months. The modal mean for the growth at age in months for the population was derived from the growth of individual broods.

2.3. Growth equation

Von Bertalanffy (1934) developed a mathematical model for individual growth which has been shown to conform to the observed growth of most fish species. This equation is based on the concept of growth as a net result of the interaction of two opposite processes such as those tending to increase the mass (anabolism), and those tending to decrease it (catabolism), thus giving the growth curve fitting well with the

with rates of many species of organisms (Beverton, 1954; Beverton and Holt, 1957). This mathematical model expresses the length, L as a function of the age of the fish, t .

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

where,

- L_t = length at age t
- L_∞ = theoretical asymptotic length
- e = base of the naperian or natural logarithm
- k = coefficient of catabolism
- t = age of fish
- t_0 = age at which length of fish was theoretically zero.

To determine the parameters of the von Bertalanffy's growth model such as, L_∞ , and t_0 , the carapace widths at age in months in the monthly modal distribution for the fish broods were tabulated and the mean size at age was determined.

Using this length at age data as the input, the growth parameters, L_∞ and K were estimated by the Ford-Walford plot (Ford, 1933; Walford, 1946) and the Gulland and Holt plot (1959). To estimate the L_∞ and K by the Ford-Walford plot, the von Bertalanffy's growth equation has been rewritten in a form relating to lengths at two ages separated by a constant time interval (e.g., a year, a month or a week etc.), l_t and l_{t+1}

$$l_{t+1} = l_\infty (1 - e^{-k}) + l_t e^{-k}$$

which is a linear expression.

Taking $L_t = x$

$$L_{t+1} = y,$$

$$a = L_\infty (1 - e^{-k}), \text{ and}$$

$$b = e^{-k}$$

the same can be rewritten as

$$y = a + b x$$

By the method of least squares, the values of a and b can be found out. By substituting the values in the following equation K and L_{∞} can be found out.

$$K = -\ln b$$

$$L_{\infty} = a/1-b$$

Gulland and Holt (1959) have suggested the following equation for determining the growth parameters, L_{∞} and K .

$$\Delta L / \Delta t = K L_{\infty} - K L(t)$$

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

$$\Delta L / \Delta t = a + b L(t).$$

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

$$K = -b ; \text{ and } L_{\infty} = -a/b.$$

The L_{∞} has been estimated by graphical methods also by plotting L_{t+1} against L_t (Walford, 1946) and by plotting growth increment against mean length (Gulland and Holt, 1959). The perpendicular drawn from the intersection between the regression line and 45 % line from the origin to X-axis gives the L_{∞} in the former method, while the intersection point between the regression line and X-axis gives the L_{∞} in the latter.

The growth parameters K and t_0 can be estimated from age/ length data employing the Bertalanffy growth plot for which L_{∞} is used as input. For this purpose, the growth equation is rewritten as follows:

$$-\ln (1-L(t)/ L_{\infty}) = -Kt_0 + Kt$$

With the age, t , as the independent variable (X) and $-\ln (1-L(t)/L_{\infty})$ as dependent variable (Y), the equation defines a linear regression, where K represents the slope and t_0 the intercept, while $t_0 = -a/b$.

The growth parameters were also determined by following the method of

EFAN (Pauly and David, 1981). The growth parameters were estimated using the pooled monthly size frequency distribution for each centre as well as for the data pooled from all centres, for males and females of *P. sanguinolentus* and *P. pelagicus* separately.

The expected lengths of *P. sanguinolentus* and *P. pelagicus* at different ages (months) were determined by employing the von Bertalanffy's equation.

2.0. RESULTS

2.1. SIZE FREQUENCY ANALYSIS

The monthwise size frequency distribution of males and females of *P. sanguinolentus* and *P. pelagicus* caught in different gears at Mangalore, Malpe and Karwar is given in Tables 6.1-6.20 and Figs. 6.1- 6.6. The size frequency data in respect of the former and latter species collected from different type of gears from Mangalore, Malpe and Karwar were pooled sexwise and presented in Figs. 6.7- 6.8 to get a comprehensive picture as there has been much variation in the data obtained from different centres and gears. The progression of modes in the size frequency distribution (Figs. 6.1-6.6) indicating the initial mode, the month of its appearance, the final mode, the month upto which the mode could be traced, the growth increment, duration and the average growth of males and females of *P. sanguinolentus* and *P. pelagicus* for Mangalore, Malpe and Karwar are presented in Tables 6.21-6.26.

A close look at the size frequency distribution of males and females of *P. sanguinolentus* given in Figs. 6.1- 6.3 and 6.7 indicate that the fishery in January and February is often supported by two major size classes, one large size class (size range 100-160 mm) with a mode at 120-140 mm and another smaller size class of juveniles with modal size at 40-60 mm (size range 20-70 mm). These two broods might represent the progeny of two peak spawning seasons. Hence, the large size class of 120-140 mm, in

th sexes, are one year olds, a product of peak spawning during January- february of the previous season/year, while the smaller brood of 40-60 mm might be the product of peak spawning during September-October and may be 3-4 months old. This brood first appeared in the fishery in October at 32.5 mm and be traced upto May. By that time it attained a size of 100-110 mm thereby registering 70-80 mm growth in 7 months. The progression of individual broods through successive months are given in Tables 6.21-6.22 and 6.25.

It is seen that the larger size classes are removed by the intensive trawl fishery during January-February and occur only in fewer numbers in the following months during monsoon months (June-August) since the salinity is low in the coastal waters, the larger crabs probably migrate to more saline deeper waters and seldom return to fishery before late December or early January.

In the case of *P. pelagicus*, the fishery was supported by one size class with size ranging between 35 and 85 mm (mode at 62.5 mm in males and 57.5 mm in females) in January 1993 at Malpe (Fig.6.5). This brood might be the progeny of peak spawning in September-October 1992 and hence 3-4 months old. This size class was grown to a size of 147.5 mm and 132.5 mm in males and females respectively by September 1993 when complete one year. Similarly, the mode at 47.5 mm in males and females in September 1992 in the pooled data for all centres (Fig.6.8) could be traced upto the beginning of September at 147.5 mm and 137.5 mm on completion of one year. The progression of various other broods has been shown in Tables 6.23-6.24, 6.26 and Figs. 6.25-6.28.

GROWTH RATE

The size frequency analysis indicated that the growth rate is more or less similar

juveniles of males and females, while the adults showed marked variation in their growth. It is found that the growth rate is high in juveniles, whereas the adults registered low rate of growth in both these species.

The mean monthly growth rate was found to be 10.3 mm in males and 8.8 mm in females of *P. sanguinolentus* (Tables 6.21-6.22). The pooled data for Mangalore, Malpe and Karwar indicated a mean monthly growth rate of 10.9 mm in males and 8.9 mm in females (Table 6.25) which is very close to the results obtained by analysing the data for each centre separately and given above. This species attained a mean carapace width of 141.1 mm in males and 112.5 mm in females on completion of one year (Tables 6.27-6.28). Sukumaran *et al.* (1986) observed that the growth rate in *P. sanguinolentus* is more or less uniform in both sexes in the South Kanara waters.

In the case of *P. pelagicus*, the overall growth rate was 11.0 mm and 9.6 mm in males and females respectively (Tables 6.23-6.24). Pooled data for Mangalore, Malpe and Karwar showed a mean monthly growth rate of 11.0 mm and 9.5 mm in males and females respectively (Table 6.26) which is more or less similar to the results obtained by analysing the data of this species for each centre separately and given above. This species attained a carapace width of 145.2 mm in males and 132.5 mm in females at the end of one year (Tables 6.29-6.30).

6.3. MODAL PROGRESSION ANALYSIS

The scatter diagram for modes against months was drawn and trend lines tracing the growth of the successive broods by means of modal progression through time was drawn free hand in respect of males and females of *P. sanguinolentus* and *P. pelagicus* (Tables 6.9-6.12). The grand mean for the growth at age in months for the population of *P. sanguinolentus* and *P. pelagicus* was derived from the monthly modal distribution for the

in broods and tabulated in Tables 6.27-6.30.

The maximum size recorded in males and females were 169 mm and 166 mm in *P. sanguinolentus* and 174 mm and 171 mm in *P. pelagicus* respectively. It is seen from Tables 6.27-6.28 that the maximum age upto which a brood could be traced was 17 months in the former species when it attained a mean size of 147.5 mm in males and 125 mm in females. In the case of the latter species, the maximum age upto which the brood could be traced was 15 months in males (152.5 mm) and 17 months in females (152.5 mm) (Tables 6.29-6.30). It is possible that crabs may live a few more months. It is therefore, reasonable to surmise that the life span of these crabs may be around 2.5 years although most of them are fished out by the intensive trawl fishery in the early part of their life leaving only a few to attain their maximum age.

4. GROWTH PARAMETERS

The input data for estimating the growth parameters, L_{∞} and K in *P. sanguinolentus* and *P. pelagicus* by the Ford-Walford plot (Ford 1933; Walford, 1946) and Gulland and Holt plot (1959) given in Table 6.31 are based on the grand mean size and the growth at age at months tabulated from the monthly modal size distribution and given in Tables 6.27-6.30. The growth parameters estimated by the above methods and following the method of ELEFAN in respect of males and females of *P. sanguinolentus* and *P. pelagicus* are presented in Table 6.32.

In *P. sanguinolentus*, the values of the growth parameters, L_{∞} , and K estimated by the Ford-Walford Plot (Ford, 1933; Walford, 1946) and the Gulland and Holt Plot (1959) were very close to each other (Table 6.32). The values in males were 195.38 mm and 0.9937 by the former method and 195.39 mm and 0.9889 by the latter method. In females of this species, these values were 187.85 mm and 0.8256 by the former method

and 188.0 mm and 0.8215 by the latter method. The t_0 estimated by the von Bertalanffy Plot (1934) were -0.0132 in males and -0.0975 in females. The same parameters obtained by ELEFAN method were 172.0 mm, 0.54 in males and 175.0 mm, 0.57 in females. In *P. pelagicus* males, the values were 210.82 mm and 1.1416 and 211.0 mm and 1.319 by the Ford-Walford plot and the Gulland and Holt plot respectively. In females of this species, the values were 202.66 mm and 0.9843 and 204.39 mm and 0.9635 by these methods. The t_0 estimated by von Bertalanffy Plot were -0.0194 and -0.0691 in males and females respectively. The parameters determined by ELEFAN method were 183.0 mm, 0.72 in males and 181.0 mm, 0.59 in females respectively. The growth curves based on the growth parameters estimated by Gulland and Holt plot and the Ford-Walford plot and by ELEFAN are superimposed on the restructured size frequency data (pooled) for *P. sanguinolentus* and *P. pelagicus* are illustrated in Figs. 6.13-6.16.

The L_∞ values obtained by graphical methods were 195.0 mm in males and 187.0 mm in females by the Ford-Walford plot and 195.0 mm and 188.0 mm by the Gulland and Holt plot in *P. sanguinolentus* (Fig. 6.17). In *P. pelagicus*, the L_∞ values obtained were 210.0 mm and 202.0 mm in males and females by the former method and 211.0 mm and 200.0 mm by the latter method (Fig. 6.18).

5. VON BERTALANFFY'S GROWTH EQUATION

The von Bertalanffy's growth equation in respect of males and females of *P. sanguinolentus* and *P. pelagicus* are as follows:

P. sanguinolentus

$$\text{male} : L_t = 195.0 [1 - e^{-0.99(t + 0.0132)}]$$

$$\text{female} : L_t = 188.0 [1 - e^{-0.82(t + 0.0975)}]$$

pelagicus

$$\text{male} : L_t = 211.0 [1 - e^{-1.14(t + 0.0194)}]$$

$$\text{female} : L_t = 204.0 [1 - e^{-0.97(t + 0.0691)}]$$

For fitting the von Bertalanffy's growth equation, the average values of the parameters obtained by the Gulland and Holt Plot and the Ford and Walford Plot were used since these values were found to be more realistic. Employing these equations, size at different ages were determined for males and females of *P. sanguinolentus* and *P. pelagicus*. It is found that the estimated size at different ages (Fig. 19) were very close to the observed values (Table 6.27-6.30). The growth curves for these species based on estimated size at different ages are illustrated in Fig.6.19.

POPULATION AGE STRUCTURE

The age composition of males and females of *P. sanguinolentus* and *P. pelagicus* in the samples analysed during the course of present study is summarised in Tables 6.33-6.34. It is possible to deduce from the Tables 6.33-6.34 that in the former species, 89.0 % of the population exploited by the fishery belongs to 0-year class, while 11.0 % formed by 1-year olds. In the indigenous gears, 0-year class contributed the bulk of the fishery (99 %) (Table 6.33).

In the case of *P. pelagicus*, about 95 % of the population exploited by the trawl gear was constituted by 0-year class, while the 1-year olds formed the rest (5 %). In the indigenous gears, 0-year class contributed to 93 %, whereas, 1-year olds formed the rest (7 %) (Table 6.34).

DISCUSSION

Since the body is enclosed in a hard shell, the growth in crabs is not continuous but occurs when the shell is cast. The nature of crab growth by moulting has led to

such difficulty in determining the true growth rate under natural conditions. Most of the earlier studies on the growth has been made on crabs kept in tanks and more recently tagging. Growth studies under controlled conditions may not give a true picture to growth under natural conditions (Edwards, 1979). Tagging has been most valuable advance in growth studies particularly in crustaceans. But the success of the study greatly depends on the rate of recovery which often found to be low.

The present investigation has indicated that although the growth studies by regression of modes of the size frequency distribution is highly subjective, it gives certain amount of success in determining the growth rate and life span of the individual species.

In the present study, the growth is found to be rapid in these portunids and the adult size may be reached in less than a year after hatching (Plate 8). According to Smith (1982), the moulting and growth in *P. pelagicus* in South Australia is virtually stopped in winter. The same author (Smith, 1982) found that the Australian population of this species reach a size of 150 mm in about 18 months. More recently, Sumpton and Smith (1991) mentioned that this crab grows to a size of approximately 150 mm within 12 months of hatching from the egg in Australian waters, while Potter *et al.* (1983) reported that the female of *P. pelagicus* attains a carapace width of 127 mm at the end of 1st year in the same area. Hamsa (1982) found that 11-25 mm cw crabs kept in tanks attained a size of 140-150 mm at 12 moults after a period of 14 months at Mandapam. The present results (attaining a carapace width of 145.2 mm in males and 132.5 mm in females on completion of one year in this species) are close to the results obtained by Sumpton and Smith (1991)(150 mm within 12 months in males) and Potter *et al.* (1983)(127 mm on completion of one year in females) from Australia. Thomas (1984), while studying on the growth of these portunids by size frequency analysis from Cochin reported that *P. pelagicus* attained a size of 90 mm at the end of one year which appears to be a very low estimate in view of the present studies as well as the

Observations made by Smith (1982), Potter *et al.* (1983) and Sumpton and Smith (1991) in Australia.

A distinctive feature of the growth of these crabs is the difference between males and females. Present study has indicated that males grow more rapidly so that females of the same age are smaller. Hartnoll (1982) observed that after attaining sexual maturity a clear difference is often apparent with larger intermoult periods in females, mainly associated with egg bearing and thus, after puberty, females usually moult less frequently, grow more slowly, and attain a smaller size than males. One would expect heavy demands on the nutrient reserves in females during gonad maturation (Passano, 1960) and inhibition of moulting when eggs are being carried. Colby and Fonseca (1984) found that the growth of the fiddler crab, *Uca pugilator* slowed or ceased temporarily once it attained sexual maturity in North Carolina (USA). This is to be expected because egg production poses high nutritional demands (Christy, 1980). In contrast, the growth of males appears to be more continuous during warmer months, even though Hiatt (1977) found that the feeding rate drops sharply during the period of courtship.

Even though crabs of the genus *Portunus* continue to moult throughout their life span, the intermoult period is larger and the length attained after each moult gets reduced as it grows resulting in considerable overlap in the actual age of crabs in the different size classes. This can result in the larger size class making up a disproportionately larger share of the adult population during certain seasons. Despite the growth and size difference, it appears that male and female live up to a maximum age of about 2.5 years.

Crustacean growth is dependent upon the duration of intermoult (moult interval) and the size increase at each moult (moult increase) (Hartnoll, 1982). Moult frequency is largely determined by environmental (eg. temperature, light, salinity) and physiological factors (nutrition, regeneration etc.) (Passano, 1960). It is possible that the number of

It is fixed and that a crab stops growing after shedding certain number of times during its life span (Van Engel, 1958). The great difference in size of crabs of the same age or of adult crabs may be simply the result of different percentage of increase in size at each moult (Van Engel, 1958).

Within a species, the form of the growth curve may differ between the sexes as seen in *P. sanguinolentus* and *P. pelagicus* in the present study (Fig. 6.19A and 6.19B). This is the general pattern, with the growth is of similar rate in both sexes upto maturity, subsequently slower in females due to smaller increments and larger intermoult intervals associated with egg production and incubation (Hartnoll, 1982). Similar difference occur in *Homarus gammarus* (Simpson, 1961), *Porcellio scaber* (Kurata, 1962) and *Cancer* (Bennet, 1974). As a result of this, males reach a larger size in most crustacea and are more abundant in larger size groups (Hartnoll, 1982).

Although *P. sanguinolentus* and *P. pelagicus* are having a possible life span of up to 2.5 years, often they are taken at an age at which most of them might not have mated once. The present study has indicated that the population of these crabs which are exploited by various type of gears comprised mainly of 0-year class, whereas one year olds formed only 11.0 % in the former and 5.0 % in the latter species in trawls (Tables 6.33-6.34). In the indigenous gears, one year old groups contributed to only 1 % and 2 % respectively in these species except in gill nets where the one year class of *P. pelagicus* formed upto 70 % during September-October. The large proportion of one year olds in gill nets may possibly be due to its large mesh size (60-65 mm) as well as the highly selective nature of the gear coupled with the short duration of the fishery at a time when the population was comprised of mostly larger crabs.

As such, there is no worthwhile study on the growth parameters of these species from anywhere. Although the growth parameters of *P. sanguinolentus* and *P.*

were determined by Thomas (1984) from Cochin area, the L_{∞} values were very unrealistic (L_{∞} of 318.63 mm and 394.68 mm against observed maximum size of 170 mm and 170 mm respectively for *P. sanguinolentus* and *P. pelagicus*), while the K values were very low (0.1327 for *P. sanguinolentus* and 0.1231 for *P. pelagicus*) in view of the fast growth and short life span. Further, no attempt was made to determine the growth parameters for males and females separately. In contrast, the L_{∞} determined by Sumpton (1974) for *P. pelagicus* from Australia (175 mm for males and 170 mm for females) was relatively low in view of the L_{max} at 195mm recorded by them in their study. The parameter complements (L_{∞} and K) estimated in the present study for *P. sanguinolentus* (195 mm and 0.99 for males and 188 mm and 0.82 for females) and *P. pelagicus* (211 mm and 1.14 for males and 204 mm and 0.97 for females) were found to be realistic and fairly accurate and the size at age determined by the von Bertalanffy's equation fitted with these values, were very close to the observed values. Hence, the present study tends to suggest that the traditional methods were found to be more effective in determining the growth parameters in the brachyurans studied.

(TRAWL CATCH)

Size group (mm)	M O N T H S														
	O	N	D	J 93	F	M	A	M	N	D	J 94	F	M	A	M
20 - 25						1									
25 - 30	3					-						2			9
30 - 35	-	2				5				1		5	1		6
35 - 40	5	-				9				2	5	3	-	8	26
40 - 45	-	9				6				1	1	6	-	1	12
45 - 50	1	7				7				4	1	3	5	7	7
50 - 55		4				5				6	2	3	-	8	6
55 - 60		-				12				4	1	2	1	4	5
60 - 65		2	1			8				6	1	4	11	6	1
65 - 70		5	-		1	16	3			8	1	3	10	4	1
70 - 75		6	5		3	19	1	3	1	13	-	1	15	1	3
75 - 80		7	8		11	18	3	2	1	9	6	-	18	1	3
80 - 85		10	21		7	14	6	3	1	7	8	-	14	6	2
85 - 90		11	30		9	14	10	7	2	4	9	-	6	5	1
90 - 95		18	38	1	6	10	20	9	1	3	18	1	10	1	1
95 - 100		10	26	2	1	9	6	1		7	17	-	9	2	2
100 - 105		2	9	-	4	3	7	6		11	21	1	5	3	3
105 - 110			11	6	-	4	9	2		9	15	-	2	1	3
110 - 115			23	8	2	2	12	3		6	10	-	2		1
115 - 120			23	10	2	2	8	3		7	3	-	1		2
120 - 125			14	11	6	2	11	4		4	7	-	4		1
125 - 130			8	15	5	1	6	2		2	10	-	1		1
130 - 135			9	31	10		1	4		3	8	-	1		1
135 - 140			13	26	8		1	-		2	5	2	1		
140 - 145			7	34	12			1		3	3				
145 - 150			-	22	5			-			1				
150 - 155			1	7	3			1							
155 - 160			1	1	3										
160 - 165			1												
Total	9	93	249	174	98	167	104	51	6	122	153	36	117	58	97

(TRAWL CATCH)

Size group (mm)	M O N T H S																	
	O	N	D	J93	F	M	A	M	S	O	N	D	J94	F	M	A	M	
15 - 20	1																	
20 - 25	10																	
25 - 30	114		1	2		2		1					1	1			1	
30 - 35	23	2	-	4	2	4		4		4		1	1	3	1		3	
35 - 40	12	1	-	14	4	20		1		-		3	4	8	14		9	
40 - 45	19	23	1	13	5	25		12		2	2	4	5	15	16		16	
45 - 50	4	37	-	19	16	12	1	12		6	5	4	10	6	10		24	
50 - 55	2	20	-	28	15	15	1	19		6	1	3	11	16	20	1	32	
55 - 60	2	15	1	19	11	25	1	8		4	1	14	22	13	12	1	19	
60 - 65	-	22	2	13	12	19	10	7		6	2	9	7	14	11	3	9	
65 - 70	1	20	1	15	24	15	2	11		2	6	7	10	19	10	9	13	
70 - 75		16	9	12	27	12	6	5		1	7	14	14	17	9	23	19	
75 - 80		20	6	4	23	11	12	3		1	5	10	3	15	2	13	17	
80 - 85		20	11	1	20	15	14	4		1	8	9	7	9	4	17	13	
85 - 90		14	15	-	18	20	12	7			13	7	4	6	1	15	6	
90 - 95		13	12	-	13	18	10	7			18	6	11	7		6	22	
95 - 100		4	7	1	8	21	14	7			8	5	10	10		8	14	
100 - 105		1	16	-	10	10	12	8			5	10	6	3		4	9	
105 - 110		4	21	2	14	18	12	10			1	4	6	7		4	5	
110 - 115		1	24	1	3	11	10	2	1			10	6	8		4	4	
115 - 120		-	15	1	1	14	10	9	1			8	-	3		-	1	
120 - 125		1	23	7	2	13	5	3	2			6	2	5		1	4	
125 - 130			8	12	3	5	6	3	-			2	5	1		1	1	
130 - 135			6	13	6	5	1	10	-			1	2	3		1	-	
135 - 140			5	11	3	2	4	3	1			2	-	1		1	2	
140 - 145			2	16	5	1	-	3				2	1					
145 - 150			1	11	9	1	1	3						-				
150 - 155				8	7			1						2				
155 - 160				1	4			1						1				
160 - 165					1													
Total	188	234	187	228	266	316	144	164	5	33	82	139	148	199	114	112	247	

(TRAWL CATCH)

Size group (mm)	M O N T H S														
	D	J93	F	M	A	M	S	O	N	D	J94	F	M	A	M
30 - 35				1											
35 - 40				-											
40 - 45				-											
45 - 50				1											
50 - 55				-											
55 - 60				-		1									
60 - 65				1		-									2
65 - 70			1	4		1				1	1	1			4
70 - 75		1	-	4		-				1	2	1			3
75 - 80		1	-	9	3	-				-	-	-			6
80 - 85		-	1	8	6	4				4	1	1			3
85 - 90		4	1	6	6	3				5	3	-			8
90 - 95		-	1	6	12	4				14	4	-			9
95 - 100		2	4	3	10	5				17	6	-			6
100 - 105		4	5	7	17	3				10	2	-			8
105 - 110		4	-	2	14	4				2	6	2			5
110 - 115	4	1	2	8	6	5				1	9	1			5
115 - 120	7	3	3	5	11	2				2	5	1			-
120 - 125	9	10	2	9	12	5				-	4	2	1		2
125 - 130	7	1	3	-	3	2				1	3	1	-		1
130 - 135	6	6	2	-	4	2				-	3	-	-		1
135 - 140	4	2	4	1	2	1				1	6	-	-		
140 - 145	1	4	3	2	1	2					1	1	-		
145 - 150	2	-	1	1	1	-					6	-	-		
150 - 155		1	-		1	1					5	-	1		
155 - 160			1									-			
160 - 165												-			
165 - 170												1			
Total	40	44	34	78	109	45				59	67	12	2		63

Size frequency distribution (nos.) of *P. sanguinolentus* males during different months in the inshore waters at Karwar.

(SHORE SEINE CATCH)

Size group (mm)	M O N T H S																
	N	D	J 93	F	M	A	M	JL	O	N	D	J 94	F	M	A	M	A
15 - 20													1	10			
20 - 25				1							1		2	32	1		
25 - 30		1		-	1						27		18	45	5		
30 - 35		-	3	1	4						3	2	17	54	5	1	
35 - 40		1	3	1	12	1					4	4	27	35	11	-	
40 - 45	1	-	4	2	11	2		3			8	4	7	19	10	4	
45 - 50	-	2	7	2	6	2		3			1	4	9	24	7	9	1
50 - 55	2	1	11	5	9	2		4			3	5	5	15	1	5	4
55 - 60	2	-	11	5	4	1		3			1	8	3	10	3	4	4
60 - 65	3	1	6	3	4	1		1			2	4	2	3	4	6	4
65 - 70	3		2	5	2	1		2			1	3	2	7	5	7	13
70 - 75	3		3	2	1	1		3			-	3	-	9	4	3	2
75 - 80	1		1	3	2			4			-	1	-	5	1		3
80 - 85	3		-	2	2			1			-	2	1	5	5		4
85 - 90	1		-	5	-			2			-	2	-	7	4		2
90 - 95	2		-	3	1			1			1	1	2	4	3		2
95 - 100	1		-	7	4			-			1	-	1	3	3		1
100 - 105			1	10	3			-			-	2	2	8	5		1
105 - 110			1	3	2			1			-		1	1	3		-
110 - 115				1	6			1			1		-	2			1
115 - 120				-	7								1	1			1
120 - 125				-	4								-	2			
125 - 130				1	2								1	-			
130 - 135				2	2								1	-			
135 - 140				3	1								1	1			
140 - 145				-									-				
145 - 150				1									-				
150 - 155													1				
Total	22	6	53	68	90	11		29			54	45	105	302	80	39	43

inshore/ estuarine waters of Mangalore and Malpe.

Size group (mm)	M O N T H S													
	JL 93	A		J 94	JL			M 93	A	M		M 94	A	M
	MALPE (Mini trawl catch -inshore)						MANGALORE (Mini trawl catch -estuarine)							
20 - 25				8										
25 - 30				10					1	1			1	
30 - 35				34					-	-			-	
35 - 40				14				3	3	-			-	
40 - 45		1		2	2			2	2	-			-	
45 - 50	1	-		2	4			4	-	-			-	
50 - 55	3	1		3	9			9	3	-			-	1
55 - 60	6	3		1	11			2	2	-		1	-	1
60 - 65	4	3		1	3			1	-	3		7	3	-
65 - 70	8	4		1	3			6	-	9		9	-	2
70 - 75	8	5		-	2			-	-	7		6	2	5
75 - 80	11	6		1	1			1	-	7		1	1	3
80 - 85	8	1		2	2			1	-	4		2	1	-
85 - 90	7	8		5	1			2	1	2		-	1	2
90 - 95	5	-			1				-	3		-	1	-
95 -100	3	3			1				-	3		-	1	1
100 -105	7	2							2	1		-	1	-
105 -110	1	5							1	1		-		1
110 -115	-	1										-		-
115 -120	-	-										-		1
120 -125	-	1										-		
125 -130	1											-		
130 -135												-		
135 -140												-		
140 -145												1		
Total	73	44		84	40			31	15	41		27	12	17

(TRAWL CATCH)

Size group (mm)	M O N T H S																
	O	N	D	J93	F	M	A	M			N	D	J94	F	M	A	M
20 - 25	1													1			1
25 - 30	-											2		1			13
30 - 35	4	1										-	2	9			15
35 - 40	1	-				2						-	-	7	1	1	27
40 - 45	2	8				5						2	1	5	-	3	8
45 - 50		5				7						4	2	2	2	6	6
50 - 55		2				10						8	1	2	5	2	4
55 - 60		6				12					1	3	-	4	3	4	5
60 - 65		5				9					-	4	2	1	3	8	3
65 - 70		2	2			12					-	9	3	1	10	1	3
70 - 75		5	4		3	19	3	1			-	8	4	2	21	1	4
75 - 80		9	20		5	20	4	3			-	8	5	1	15	5	4
80 - 85		18	37		4	16	5	4			-	6	5	-	9	2	5
85 - 90		29	44	1	4	11	8	3			-	6	6	-	14	5	3
90 - 95		19	48	1	5	7	9	7			-	9	6	-	10	7	5
95 - 100		6	24	2	7	8	9	5			-	7	10	1	16	5	4
100 - 105			25	14	4	8	11	1			1	19	16	3	6	2	7
105 - 110			15	8	2	7	7	3				16	19	2	3	2	2
110 - 115			19	23	9	1	11	7				15	12	1	1	1	3
115 - 120			22	28	11	-	3	4				9	9	-	3	1	
120 - 125			12	22	14	-	3	3				5	9	-	1		
125 - 130			7	28	17	-	1	5				1	8	-	3		
130 - 135			1	14	31	-	2	1				1	4	1	1		
135 - 140			-	13	23	1		-					3		-		
140 - 145			-	2	6			-					-		1		
145 - 150			-	1	4			1					-				
150 - 155			-		-								-				
155 - 160			1		1								-				
160 - 165													-				
165 - 170													1				
Total	8	115	281	157	150	155	76	48			2	142	138	44	128	57	122

Size frequency distribution (nos.) of *P. sanguinolentus* females during different months in the inshore waters at Malpe.

(TRAWL CATCH)

Size group (mm)	M O N T H S																
	O	N	D	J93	F	M	A	M	S	O	N	D	J94	F	M	A	M
15 - 20	4																
20 - 25	9																
25 - 30	81	1		4	1	3							1		2		2
30 - 35	15	2		2	1	7		2		2		2	1	4	8		5
35 - 40	13	7		14	4	8		10		2		3	1	7	6		13
40 - 45	10	24	1	9	10	17	1	9		4	1	1	7	10	11		15
45 - 50	1	23	-	32	8	12	3	9		13	3	6	6	8	18	2	24
50 - 55	4	11	-	39	27	13	5	20		11	2	10	8	8	18	2	18
55 - 60	3	13	1	18	15	25	2	13		4	2	11	6	18	5	1	14
60 - 65	-	20	1	7	8	24	5	5		2	2	5	4	13	12	6	15
65 - 70	-	21	4	12	8	13	7	8		3	8	5	11	20	4	11	12
70 - 75	1	14	9	10	14	18	3	9		3	15	6	8	21	6	15	20
75 - 80		11	12	7	22	16	9	7		-	7	11	10	15	1	13	21
80 - 85		14	18	2	16	17	11	3	1	-	9	12	14	8	2	20	18
85 - 90		7	18	2	12	16	6	3	-	2	11	12	6	13	1	16	13
90 - 95		6	16	3	8	18	13	9	1	-	19	8	10	9	1	8	12
95 - 100		4	11	-	6	16	7	4	5	1	9	10	6	9	1	8	6
100 - 105		1	15	8	12	9	12	7	2		4	6	5	6	-	2	7
105 - 110			13	10	6	13	14	2	-		1	6	7	5	-	3	2
110 - 115			23	21	6	15	11	4	-		-	12	11	3	1	2	1
115 - 120			22	29	5	4	4	3	-		1	8	8	7		1	-
120 - 125			9	15	6	4	3	5	-			1	7	8		1	1
125 - 130			3	25	7	3	2	3	-				4	5			
130 - 135			1	18	7	2	1	4	-				-	2			
135 - 140				13	1		2	3	1				-	1			
140 - 145				6	7		1	-					-	2			
145 - 150					2			-					1	-			
150 - 155								-						-			
155 - 160								2						1			
Total	143	179	177	304	219	273	122	144	10	47	94	135	142	203	97	111	220

(TRAWL CATCH)

Size groups (mm)	M O N T H S													
	D	J93	F	M	A	M	S	O	N	D	J94	F	M	A
50 - 55														3
55 - 60											1			3
60 - 65		1		1						1	-	1		-
65 - 70		-		2		1				-	-	3		-
70 - 75		1	1	8		3				4	2	1		1
75 - 80		1	-	10	3	4				2	2	2		5
80 - 85		3	1	14	6	2				7	-	-		4
85 - 90		4	-	6	4	2				5	-	1		6
90 - 95	2	5	-	6	9	4				13	4	-		6
95 -100	-	5	1	7	8	4				13	1	1	1	4
100 -105	2	5	3	4	11	3				11	12	2	-	2
105 -110	2	6	3	5	7	4				2	5	2	-	1
110 -115	1	3	3	2	5	3				-	8	1	1	2
115 -120	4	5	4	3	2	1				1	5	1	1	-
120 -125	2	2	1	3	-	3					7	3	1	1
125 -130	7	1	2	1	1	1					10	2	1	1
130 -135	2	-	-		3						2	2	1	
135 -140	-	1	2		1						3	-	1	
140 -145	1	1	2		2						3	2	-	
145 -150					1						1	1	2	
150 -155					1						2		-	
155 -160					1								1	
160 -165														
165 -170														
Total	23	44	23	72	65	35				59	68	25	9	39

Frequency distribution (nos.) of *P. sanguinolentus* females during different months in the inshore waters at Karwar.

Size groups (mm)	SHORE SEINE (YENDI CATCH)																	
	M O N T H S																	
	N	D	J 93	F	M	A	M	JL	O	N	D	J 94	F	M	A	M	A	
15 - 20																		
20 - 25														3				
25 - 30					1						2	3	1	5				
30 - 35					2						18	-	18	18	5			
35 - 40				2	2						2	2	8	31	9			
40 - 45			15	-	7			2			13	2	24	20	4			
45 - 50	2		4	2	4	1		1			11	5	8	20	1	3		
50 - 55	2		4	1	5	-		2			-	6	7	22	7	6	1	
55 - 60	1		3	5	6	-		2			3	5	3	12	1	8	5	
60 - 65	7		2	9	3	1		2			3	5	-	2	1	1	1	
65 - 70	3		1	1	1	-		2			1	10	-	5	1	4	6	
70 - 75	3		-	10	2	-		1			-	6	1	12	3	1	4	
75 - 80	-		2	6	-	-		4			-	1	-	4	-	1	6	
80 - 85	2		-	1	3	1		3			1	1	3	4	2		3	
85 - 90	1		-	2	1			1			1	2	1	4	-		4	
90 - 95			1	4	2			-			4	2	1	3	2		2	
95 - 100				1	2			-			4		-	6	4		1	
100 - 105				3	1			-			2		2	1	-		1	
105 - 110				-	-			-			1		1	2	-		2	
110 - 115				1	1			2			-		-	-	-		2	
115 - 120											-		1	-	1		-	
120 - 125											1		-	-			-	
125 - 130													1	-			1	
130 - 135														1				
135 - 140														1				
Total	21		32	48	43	3		21			64	51	82	186	41	27	43	

Size frequency distribution (No.) of *Siganus lineatus* larvae during different months in the inshore/ estuarine waters of Mangalore and Malpe.

Size group (mm)	M O N T H S													
	JL 93	A		JU 94	JL			M 93	A	M		M 94	A	M
	MALPE (Mini trawl catch -inshore)							MANGALORE (Mini trawl catch - estuarine)						
20 - 25				9										
25 - 30				8										
30 - 35				28										
35 - 40				15	1									
40 - 45				2	2									
45 - 50				3	3									
50 - 55	3			3	3				1				1	1
55 - 60	2	2		1	11			1	-	1		1	1	2
60 - 65	3	4		2	17			2	2	4		7	-	4
65 - 70	5	6		-	2			7	2	-		13	1	2
70 - 75	6	7		1	2			9	1	2		4	1	6
75 - 80	10	8		1	2			10	-	1		1	-	8
80 - 85	4	4			3			8	1	2		2	2	5
85 - 90	4	5			3			2	1	2			1	8
90 - 95	2	2			2			9	1	3			1	4
95 -100	3	2			3			5		-				3
100 -105	1	5			1			2		2				11
105 -110	2	1			1			3						6
110 -115	1	2												
Total	46	48		73	56			58	9	17		28	8	60

at Mangalore.

(TRAWL CATCH)

Size group (mm)	M O N T H S																	
	S 92*	O*		J 93	F	M	A	M	S*	O	N	D	J 94	F	M	A	M	
25 - 30																		1
30 - 35																		1
35 - 40																		1
40 - 45													1					9
45 - 50						1							-	1				13
50 - 55						2							-	-				9
55 - 60						2							1					7
60 - 65						7		2					2	2	-	4		14
65 - 70					2	5	2	5					2	-	-	4		16
70 - 75					1	2	4	3					1	2	-	7		21
75 - 80					2	11	11	14					-	-	-	33	31	1
80 - 85					1	5	13	22					-	3	-	26	31	5
85 - 90					1	8	18	31					1	5	2	31	38	4
90 - 95					4	5	13	15					-	8	4	19	17	9
95 - 100					4	6	15	16					-	7	6	16	22	9
100 - 105					-	5	3	12	2				-	4	14	14	11	5
105 - 110					1	3	4	9	-				-	2	8	7	12	5
110 - 115					4	2	5	11	1				-	1	7	8	6	6
115 - 120					2	2	1	7	-				-	2	5	3	9	1
120 - 125	1				1	3	1	4	-				1	1	4	2	2	6
125 - 130	1	1			1	1		1	-				-	-	4		4	1
130 - 135	-	1						1	-				-	1	7		2	1
135 - 140	2	-						3	1				1		4		-	
140 - 145	1	1						2	7				1		2		-	
145 - 150	-	2						5	7				1				-	
150 - 155	-							4	5				1				-	
155 - 160	1							4	1								1	
160 - 165	1								4									
165 - 170									4									
Total	7	5			25	70	90	171	29				13	38	68	177	278	57

asterisk indicates gill net catch

(TRAWL CATCH)

Size group (mm)	M O N T H S																					
	S 92	O	N	D	J 93	F	M	A	J*	JL*	A*	A	S	N	D	J 94	F	M	A	M	S	
20 - 25																						
25 - 30																						
30 - 35						1											1					
35 - 40					1	-								1			1	1				
40 - 45					2	5								1			-	-				
45 - 50					3	2								3			-	3				
50 - 55					2	1			1					1			-	3			1	
55 - 60					8	4			2	1				2	1		1	3			-	
60 - 65					7	4			4	1	1			-	3		6	2			5	
65 - 70			2		7	1	1		4	-	1			1	-	1	4	3	1		5	
70 - 75	1		1	1	7	1	2		5	1	-			1	-	1	1	1	5		4	
75 - 80	-		2	-	4	-	8		1	6	-		1		2	-	2	4	5		10	
80 - 85	-		1	1	2	3	10	1	1	5	-		1		2	3	2	2	2		7	
85 - 90	-			-	-	7	3	2	2	3	-		1		-	2	-	1	4		6	
90 - 95	1			-	-	3	11	4	-	5	-		-		-	1	3	1	5		6	
95 - 100	2			-	-	7	7	7	2	-	-	2	-		-	2	6	1	8		6	
100 - 105	1			-	-	3	2	4		1	-	-	-		-	2	4	2	10		3	
105 - 110	1			-	-	3	5	4		1	-	-	2		1	-	4	2	10		3	
110 - 115	-	1		1	1	2	5	8		1	2	2	2		2	6	1	2	3		1	
115 - 120	-	-		1	-	1	4	2		1	-	-	3		2	7	-	3			6	
120 - 125	3	-			-	3	2	6		2	-	-	3		3	7	1	6			1	
125 - 130	1	-			-	6	5	4			2	2	2		1	2	-	4			1	
130 - 135	1	-			-	3	4	5			1	3	3		-	4	-	-			3	
135 - 140	2	1			1	3	3	1			3	5	3		1	3	1	1			3	
140 - 145		1			1	6	3	4			7	11	5		-	-	-	-			1	
145 - 150						1	2	-			10	15	9		1	2		-			-	
150 - 155								-			10	13	9		-			-			1	
155 - 160								-			1	3	6		1			1				
160 - 165								-				4	1		-							
165 - 170									1						1							
170 - 175																						
Total	12	3	6	4	46	70	77	53	22	28	38	62	51	10	9	23	68	35	59	60	28	

asterisk indicates mini trawl catch

Size frequency distribution (nos.) of *P. pelagicus* males during different months in the inshore waters at Karwar.

(TRAWL CATCH)

Size group (mm)	M O N T H S											
	D 92	J 93	F	M	A	M			J 94	F	M	A
30 - 35	1											
35 - 40	1											
40 - 45	3											
45 - 50	-		1									
50 - 55	1		-									
55 - 60	1		-									
60 - 65	-		2		1					2		1
65 - 70	1	2	-	1	-				1	3		-
70 - 75	1	-	1	1	1				1	2		1
75 - 80	1	4	2	1	-				2	2		3
80 - 85	3	3	8	2	4				2	7		4
85 - 90	1	5	9	1	5				-	4		3
90 - 95	5	6	10	3	3				8	6	2	3
95 -100	1	10	3	2	4	1			9	3	1	2
100 -105	1	12	5	3	2	-			11	8	-	2
105 -110	3	10	4	2	1	-			11	4	1	4
110 -115	1	4	3	4	3	1			4	5	5	3
115 -120	4	3	1	3	1	-			10	3	6	1
120 -125	-	-	2	1	1	3			4	3	6	1
125 -130	2	-	1	1	1	2			2	4	8	
130 -135		2	1	1	3	-			6		10	
135 -140			1	1	5	1					12	
140 -145			1	1	6	4					12	
145 -150					6	7					8	
150 -155					2	6					8	
155 -160					5	8					4	
160 -165					1	1						
165 -170					-	2						
170 -175					1							
Total	31	61	55	29	58	36			71	56	83	27

TABLE 6.14.

Size frequency distribution (nos.) of *P. pelagicus* males during different months in the inshore waters at Karwar.

Size group (mm)	SHORE SEINE (YENDI)CATCH												
	M O N T H S												
	N 92	D	J 93	F	M	A	M	N*	D	J 94	F	M	A
20 - 25		2	1										
25 - 30	2	9	2	1	1				2			3	
30 - 35	2	12	2	1	-				1			3	
35 - 40	2	19	13	1	-				-	3		2	
40 - 45	5	9	7	1	1				2	-	2	-	
45 - 50	6	5	4	-	-				1	1	1	-	
50 - 55	10	23	10	1	1				1	1	-	3	
55 - 60	4	24	11	-	-				2	-	-	2	
60 - 65	3	16	5	5	-				10	1	-	1	
65 - 70	2	5	6	3	-				5	1	1	8	1
70 - 75	2	7	5	3	-				8	1	1	6	-
75 - 80	1	3	9	4	-				4	1	1	5	-
80 - 85	-	5	3	4	2				-	-	2	7	-
85 - 90	-	6	9	1	-				1	-	2	2	-
90 - 95	1	3	8	5	1				1	1	1	4	2
95 -100	-	4	7	6	1				-		1	3	1
100 -105	-	2	6	4	1				1		-	3	-
105 -110	-	-	4	4	1				1		-	4	-
110 -115	-	1	2	3							-	2	2
115 -120	-		2	-							-	1	1
120 -125	-		1	1							-	2	
125 -130	1		-								-		
130 -135			1								-		
135 -140											-		
140 -145											1		
145 -150													
150 -155								2					
155 -160													
160 -165													
165 -170													
170 -175													
Total	41	155	118	48	9			2	40	10	13	61	7

asterisk indicates gill net catch

TABLE 6.15.
Size frequency distribution (nos.) of *P. pelagicus* males during different months in the estuarine waters at Mangalore.

(MINI TRAWL CATCH)

Size group (mm)	M O N T H S									
	M 93	A	M	J			F 94	M	A	M
20 - 25										
25 - 30										
30 - 35										
35 - 40									1	
40 - 45		1							-	
45 - 50		2							-	
50 - 55		-						1	-	
55 - 60	3	1	6	2				6	9	
60 - 65	2	6	17	6			1	17	23	1
65 - 70	9	22	25	16			-	22	29	-
70 - 75	9	30	32	9			-	17	16	2
75 - 80	2	34	24	9			3	24	9	3
80 - 85	5	19	15	6			2	8	9	4
85 - 90	4	26	15	2			4	9	10	8
90 - 95	4	12	9	1			5	7	5	7
95 -100	3	5	10	1			9	3	3	5
100 -105	3	3	5				6	3	-	-
105 -110		2	6				3	2	1	2
110 -115		1	2				2		1	
115 -120		3	-							
120 -125		1	1							
125 -130		-								
130 -135		-								
135 -140		1								
Total	44	168	167	52			35	119	116	33

TABLE 6.16.

Size frequency distribution (nos.) of *P. pelagicus* females during different months in the inshore waters at Mangalore.

Size group (mm)	(TRAWL CATCH)														
	M O N T H S														
	S 92*	O*	F 93	M	A	M	S*	O	N	D	J 94	F	M	A	M
20 - 25															
25 - 30															
30 - 35															
35 - 40										1					1
40 - 45										-					-
45 - 50				1						-					2
50 - 55				2						1	1				5
55 - 60			1	2						-	-				5
60 - 65			-	5	1	1				-	-		1	16	
65 - 70			-	-	4	2				-	1		1	11	
70 - 75			-	3	11	5				-	1		2	15	
75 - 80			1	2	8	11				-	4		14	17	2
80 - 85			-	7	10	24				-	5		15	23	4
85 - 90			2	6	9	27				1	5		6	23	7
90 - 95			3	2	21	18				1	3	5	14	32	4
95 - 100			10	7	10	20				-	10	5	9	24	10
100 - 105			4	2	8	14				-	12	12	12	8	18
105 - 110			3	3	8	7	1			-	3	11	16	20	18
110 - 115			4	8	3	7	-			-	8	10	14	10	14
115 - 120				2	1	4	2			-	-	4	6	7	11
120 - 125				1	1	2	-			1	2	4	3	4	7
125 - 130	1	1		-	1	1	1			-	3	6	2	1	-
130 - 135	-	-		1	1	4	2			3	-	3	3	1	2
135 - 140	3	2		-		4	5			2	1	1	2	1	
140 - 145	1	4		-		5	4			1	1	-			
145 - 150	3	1		1		4	8			1	1	1			
150 - 155	1	1				3	-			1		1			
155 - 160		1				1	3			1					
160 - 165						-	3								
165 - 170						-	-								
170 - 175						1	1								
Total	9	10	28	55	97	165	30			14	61	63	120	226	97

* Asterisk indicates gill net catch

Size frequency distribution (nos.) of *P. pelagicus* females during different months in the inshore waters at Malpe.

(TRAWL CATCH)

Size group (mm)	M O N T H S																						
	S 92	O	N	D	J 93	F	M	A	M	J*	JL*	A*	A	S	N	D	J 94	F	M	A	M	S	
30 - 35																							
35 - 40					1	3													2				
40 - 45					2	-													-				
45 - 50					3	4													1				
50 - 55					1	6	3												2	1			
55 - 60					-	4	4	2		1	5								4	4	-	1	
60 - 65					1	-	7	3	-	-	6	3	1						2	1	9	4	1
65 - 70					2	-	5	-	3		-	4	-	-					1	-	1	6	3
70 - 75	1				-	-	3	1	-	-	4	1	-						-	3	1	4	-
75 - 80	-				1	-	1	-	2	1	-	4	3	-					-	2	-	1	1
80 - 85	-				1	1	2	9	2	-	7	2	-						-	3	1	1	13
85 - 90	1				-	-	2	6	5	-	2	4	-						1	1	-	2	1
90 - 95	-				1	-	3	9	3	1		5	-						1	1	-	2	1
95 -100	-				-	-	3	11	3	-	-	1	-						-	-	-	-	2
100 -105	2				-	-	5	9	6	1		2	2	1	1	-			1	-	1	5	2
105 -110	1				-	-	4	8	9	-		4	-	2	-				-	-	5	2	4
110 -115	1	1			-	1	3	10	8	2		1	-	-	-				-	-	2	8	3
115 -120	2	-			-	1	2	5	4	1		3	1	-	2	-			-	-	1	3	3
120 -125	3	1			-	-	4	2	2	4		2	2	1	1	-			-	-	3	1	1
125 -130	1	3			-	1	4	7	3	7		2	1	2	4	-			-	-	-	-	1
130 -135	3	3			-		3	1	5	2		1	3	4	5	1			-	1	4	-	1
135 -140	2	2			-		2		3	4		2	3	4	3				1	-	3	1	-
140 -145	3	5			-		2		3	7			2	2	3				1	1	-	1	1
145 -150	2	1			1					1			2	9	2				5	1	-		
150 -155	1	2								5			-	1	4				1	4	-		
155 -160	1									2			1	4	2							1	
160 -165										1				1									
165 -170										1				1									
170 -175										1													
Total	23	23	4	4	36	57	84	57	41	32	35	19	31	28	4	22	26	66	41	66	40	59	

asterisk indicates mini trawl catch

TABLE 6.18.

Size frequency distribution (nos.) of *P. pelagicus* females during different months in the inshore waters at Karwar.

Size group (mm)	(TRAWL CATCH)									
	MONTHS									
	D 92	J 93	F	M	A	M	J 94	F	M	A
20 - 25										
25 - 30										
30 - 35	1									
35 - 40	1									
40 - 45	-									
45 - 50	-									
50 - 55	-								1	
55 - 60	-							1	-	1
60 - 65	3	1	1					3	-	-
65 - 70	-	2	1	1			1	2	-	-
70 - 75	-	5	1	2			-	2	-	3
75 - 80	1	6	5	-	2		1	1	-	4
80 - 85	5	2	12	1	2		4	4	-	7
85 - 90	6	5	14	4	5		6	2	-	7
90 - 95	2	11	12	-	7	1	3	2	1	-
95 -100	-	12	10	6	4	2	10	-	-	3
100 -105	1	10	6	2	7	-	10	4	-	5
105 -110	3	6	5	3	3	1	17	4	2	3
110 -115	-	8	3	1	5	-	8	1	5	3
115 -120	1	4	1	2	4	1	9	4	4	1
120 -125	1	3	1	3	3	2	4	2	10	1
125 -130	1	-	2	2	5	3	4	-	10	-
130 -135	-	1	2	1	4	6	1	1	11	1
135 -140	-	-		1	8	8	3	2	9	-
140 -145	-	-		3	4	4	6		1	1
145 -150	1	-		1	3	3	9		1	
150 -155	-	-		1	3	4	7		1	
155 -160	1	-		-	2	3	5		1	
160 -165	1	1		-	1	3			-	
165 -170	-			1	1				-	
170 -175	1								1	
Total	30	77	76	35	74	41	123	35	58	40

TABLE 6.19.

Size frequency distribution (nos.) of *P. pelagicus* females during different months in the inshore waters at Karwar.

SHORE SEINE (YENDI) CATCH

Size group (mm)	M O N T H S												
	N 92	D	J 93	F	M	A	M	N*	D	J 94	F	M	A
20 - 25		3							1				
25 - 30		23							2			3	
30 - 35	5	13	2	3	1				-	1		1	
35 - 40	2	22	7	-	-				-	1		-	
40 - 45	2	13	6	2	-				2	1	1	3	
45 - 50	8	13	5	1	-	1			4	-	-	2	1
50 - 55	5	18	9	1	-	-			3	1	-	1	-
55 - 60	2	39	7	3	-	1			4	1	2	1	1
60 - 65	5	17	4	7	-	-			4	2	-	1	-
65 - 70	5	4	4	-	1	1			5	-	1	4	-
70 - 75	4	2	2	-	-	1			8	2	-	5	-
75 - 80	2	1	6	2	-				1	-	-	1	1
80 - 85	2	1	4	3	-				1	2	-	4	-
85 - 90	-	3	4	6	-				-	2	-	4	-
90 - 95	-	3	3	5	-				1	1	1	4	2
95 -100	-		-	3	-				-	1	1	3	1
100 -105	-		1	4	-				-	-	1	4	-
105 -110	-		-	4	1				1	-	1	1	-
110 -115	-		1						1	1	1	1	1
115 -120	-		1						2		1	-	-
120 -125	-								1			1	1
125 -130	-								-			-	
130 -135	-							2	-			-	
135 -140	-							2	-			-	
140 -145	1							5	-			1	
145 -150	-							-	-				
150 -155	1							5	-				
155 -160	-							2	1				
160 -165	-								1				
165 -170	-								1				
170 -175	1								1				
Total	45	175	66	44	3	4		16	44	16	10	45	8

* Asterisk indicates gill net catch

TABLE 6.20.

Size frequency distribution (nos.) of *P. pelagicus* females during different months in the estuarine waters at Mangalore.

(MINITRAWL CATCH)

Size group (mm)	MONTHS							
	M93	A	M	J	F 94	M	A	M
20 - 25								
25 - 30							1	
30 - 35							-	
35 - 40							-	
40 - 45		1					-	
45 - 50		-	1				-	
50 - 55		6	-			2	2	
55 - 60		1	4	2	1	4	7	2
60 - 65	1	6	21	8	2	13	19	2
65 - 70	3	20	23	17	2	15	29	2
70 - 75	1	23	38	25	6	7	19	1
75 - 80	5	18	38	5	3	14	13	7
80 - 85	5	19	25	9	10	12	8	5
85 - 90	4	16	17	6	6	7	2	9
90 - 95	5	11	19	3	6	10	7	18
95 -100	-	6	6	2	5	11	2	10
100 -105	3	4	15	1	6	9	2	8
105 -110	1	-	6		3	2	2	
110 -115	2	-	2		1	3		
115 -120	-	2	2			2		
120 -125	1	1	-			1		
125 -130		1	1					
Total	31	136	218	78	51	112	113	64

TABLE 6.21.

Progression of size modes and rate of growth in *P. sanguinolentus* males.

Centre	Initial mode (mm)	Month	Final mode (mm)	Month	Growth increment (mm)	Duration in months	Average growth/month (mm)
PALPE	67.5	Nov. 92	132.5	May 93	65	6	10.8
	32.5	Oct. 92	102.5	May 93	70	7	10.0
	52.5	Jan. 93	82.5	Apr. 93	30	3	10.0
	42.5	Mar. 93	92.5	Aug. 93	50	5	10.0
	52.5	Oct. 93	92.5	Jan. 94	40	3	13.3
	52.5	Jan. 94	92.5	May 94	40	4	10.0
	Average				295	28	10.5
MANGALORE	112.5	Dec. 92	137.5	Feb. 93	25	2	12.5
	32.5	Oct. 92	107.5	May 93	75	7	10.7
	72.5	Mar. 93	92.5	May 94	20	2	10.0
	77.5	Mar. 94	102.5	May 94	25	2	12.5
	37.5	Feb. 94	77.5	May 94	40	3	13.3
	Average				185	16	11.6
BARWAR	122.5	Dec. 92	137.5	Feb. 93	15	2	7.5
	62.5	Nov. 92	102.5	Apr. 93	40	5	8.0
	82.5	Mar. 93	102.5	May 93	20	2	10.0
	52.5	Jan. 93	107.5	Jul. 93	55	6	9.2
	42.5	Mar. 93	77.5	Jul. 93	35	4	8.8
	57.5	Jan. 94	92.5	Apr. 94	35	3	11.7
	32.5	Feb. 94	62.5	May 94	30	3	10.0
	32.5	Mar. 94	52.5	Apr. 94	20	2	10.0
	Average				250	27	9.3
All centres combined average					730	71	10.3

BLE 6.22.

Progression of size modes and rate of growth in *P. sanguinolentus* females.

Centre	Initial mode (mm)	Month	Final mode (mm)	Month	Growth increment (mm)	Duration in months	Average growth/month (mm)
MANGALORE	112.5	Dec. 92	122.5	Jan. 93	10	1	10.0
	77.5	Nov. 92	122.5	May. 93	45	6	7.5
	32.5	Oct. 92	97.5	May 93	65	7	9.3
	52.5	May 93	97.5	Sep. 93	40	4	10.0
	92.5	Nov. 93	117.5	Feb. 94	25	3	8.3
	52.5	Oct. 93	77.5	Jan. 94	25	3	8.3
	52.5	Dec. 93	82.5	Apr. 94	30	4	7.5
	47.5	Mar. 94	87.5	Jul. 94	40	4	10.0
	47.5	May 94	62.5	Jul. 94	15	2	7.5
	Average				295	34	8.7
MANGALORE	122.5	Jan. 92	132.5	Feb. 93	10	1	10.0
	87.5	Dec. 92	117.5	May 93	30	5	6.0
	32.5	Oct. 93	92.5	May 94	60	7	8.6
	72.5	Dec. 93	102.5	May 94	30	5	6.0
	37.5	Feb. 94	57.5	Apr. 94	20	2	10.0
	Average				150	20	7.5
MANGALORE	87.5	Nov. 92	132.5	Apr. 93	45	5	9.0
	62.5	Nov. 92	102.5	Apr. 93	40	5	8.0
	47.5	Jan. 93	97.5	May 93	50	4	12.5
	52.5	Mar. 93	82.5	Jul. 93	30	4	7.5
	97.5	Dec. 93	122.5	Feb. 94	25	2	12.5
	62.5	Jan. 94	92.5	Apr. 94	30	3	10.0
	32.5	Feb. 94	67.5	Mar. 94	35	3	11.7
	Average				255	26	9.8
All centres combined average					700	80	8.8

TABLE 6.23.
Progression of size modes and rate of growth in *P. pelagicus* males

Centre	Initial mode (mm)	Month	Final mode (mm)	Month	Growth increment (mm)	Duration in months	Average growth/month (mm)
MALPE	132.5	Feb. 93	142.5	Mar. 93	10	1	10.0
	92.5	Feb. 93	147.5	Aug. 93	55	6	9.2
	62.5	Jan. 93	147.5	Sep. 93	85	8	10.6
	67.5	Jun. 93	82.5	Jul. 93	15	1	15.0
	52.5	Mar. 94	82.5	May. 94	30	2	15.0
	Average				195	18	10.8
MANGALORE	72.5	Feb. 93	147.5	Sep. 93	75	7	10.7
	67.5	Mar. 93	87.5	May 93	20	2	10.0
	62.5	Apr. 93	72.5	May 93	10	1	10.0
	92.5	Jan. 94	107.5	Feb. 94	15	1	15.0
	72.5	Mar. 94	92.5	May 94	20	2	10.0
	Average				140	13	10.8
KARWAR	87.5	Dec. 92	152.5	May 93	65	5	13.0
	52.5	Nov. 92	122.5	May. 93	70	6	11.7
	42.5	Dec. 92	87.5	Apr. 93	45	4	11.2
	67.5	Dec. 93	107.5	Apr. 94	40	4	10.0
	72.5	Mar. 94	82.5	Apr. 94	10	1	10.0
	Average				230	20	11.5
All centres combined average					565	51	11.0

TABLE 6.24.

Regression of size modes and rate of growth in *P. pelagicus* females.

Centre	Initial mode (mm)	Month	Final mode (mm)	Month	Growth increment (mm)	Duration in months	Average growth/month (mm)
MUMBAI	102.5	Feb. 93	132.5	May 93	30	3	10.0
	57.5	Jan. 93	132.5	Sep. 93	75	8	9.4
	97.5	Mar. 93	147.5	Aug. 93	50	5	10.0
	77.5	Dec. 93	97.5	Mar. 94	20	3	6.7
	62.5	Feb. 93	82.5	Apr. 94	20	2	10.0
	57.5	Mar. 94	82.5	May 94	25	2	12.5
	Average				220	23	9.6
MANGALORE	97.5	Feb. 93	142.5	Sep. 93	45	7	6.4
	82.5	Mar. 93	92.5	Apr. 93	10	1	10.0
	67.5	Mar. 93	87.5	May 93	20	2	10.0
	57.5	Mar. 93	77.5	May 93	20	2	10.0
	82.5	Dec. 94	102.5	Feb. 94	20	2	10.0
	77.5	Jan. 94	102.5	Mar. 94	25	2	12.5
	77.5	Mar. 94	102.5	May 94	25	2	12.5
	Average				165	18	9.2
MADRAS	67.5	Nov. 92	102.5	Mar. 93	35	4	8.8
	87.5	Dec. 92	137.5	May 94	50	5	10.0
	47.5	Nov. 92	97.5	Apr. 93	50	5	10.0
	32.5	Dec. 92	57.5	Feb. 94	25	2	12.5
	107.5	Jan. 94	127.5	Mar. 94	20	2	10.0
	67.5	Dec. 93	102.5	Apr. 94	35	4	8.8
	57.5	Feb. 94	82.5	Apr. 94	25	2	12.5
	Average				240	24	10.0
All centres combined average					625	65	9.6

TABLE 6.25.

Progression of size modes and rate of growth in *P. sanguinolentus* (all centres data pooled).

	Initial mode (mm)	Month	Final mode (mm)	Month	Growth increment (mm)	Duration in months	Average growth/month (mm)
FEMALES	117.5	Dec. 92	137.5	Feb. 93	20	2	10.0
	32.5	Oct. 92	97.5	Apr. 93	65	6	10.8
	42.5	Mar. 93	77.5	Jul. 93	35	4	8.8
	32.5	Dec. 93	97.5	May 94	65	5	13.0
Average					185	17	10.9
MALES	112.5	Dec. 92	132.5	Feb. 93	20	2	10.0
	32.5	Oct. 92	97.5	May 93	65	7	9.3
	72.5	Aug. 93	122.5	Feb. 94	50	6	8.3
	52.5	Oct. 93	92.5	Mar. 94	40	5	8.0
	52.5	Dec. 93	87.5	Apr. 94	35	4	8.8
	42.5	May 94	72.5	Aug. 94	30	3	10.0
Average					240	27	8.9

TABLE 6.26.

Progression of size modes and rate of growth in *P. pelagicus* (all centres data pooled).

	Initial mode (mm)	Month	Final mode (mm)	Month	Growth increment (mm)	Duration in months	Average growth/month (mm)
FEMALES	87.5	Dec. 92	152.5	May 93	65	5	13.0
	47.5	Nov. 92	147.5	Aug. 93	100	9	11.1
	37.5	Dec. 92	82.5	Mar. 93	45	3	15.0
	42.5	Jan. 93	82.5	Apr. 93	40	3	13.3
	42.5	Feb. 93	82.5	May 93	40	3	13.3
	67.5	Jun. 93	82.5	Jul. 93	15	1	15.0
	47.5	Nov. 93	117.5	Sep. 94	70	10	7.0
Average					375	34	11.0
MALES	67.5	Nov. 92	152.5	Aug. 93	85	9	9.4
	47.5	Nov. 92	152.5	Jan. 94	105	14	7.5
	32.5	Dec. 92	82.5	May 93	50	5	10.0
	67.5	Dec. 93	97.5	Mar. 94	30	3	10.0
	67.5	Feb. 94	137.5	Sep. 94	70	7	10.0
Average					360	38	9.5

TABLE 6.27.

Modal sizes (mm) from the size frequency data corresponding to age in months as read from Fig. 6.9 for *P. sanguinolentus* males.

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Broods (month of origin)																		
MANGALORE																		
Nov. 91																		
Jan. 92													137.5					
Feb.													137.5			147.5		
Apr.							87.5	92.5										
May																		
Aug.		32.5	47.5			82.5		92.5	107.5									
Sep.								92.5										
Oct.					72.5			92.5										
Dec.					72.5													
Feb. 93																137.5		
Mar.																		
Jun.								97.5										
Aug.						77.5												
Sep.										102.5								
Oct.																		
Nov.					67.5													
Feb.94		37.5																
		37.5																
MALPE																		
Oct. 91																		
Feb. 92																137.5	142.5	
Mar.																		
May																		
Jun.																		
Jul.					67.5													
Aug.		32.5	47.5															
Sep.																		
Oct.				52.5	67.5			82.5										
Nov.					62.5													
										102.5								

contd.....

TABLE 6.27. (contd.)

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dec.			42.5					82.5										
Jan. 93				52.5		77.5	82.5				117.5	127.5						
Feb.					72.5				107.5									
Mar.								92.5										
Apr.								92.5										
Jun.				52.5			77.5											
Aug.			47.5															
Sep.				52.5	67.5			92.5										
Oct.						77.5												
Dec.			42.5			82.5												
Jan. 94				52.5														
Mar.				57.5														
Apr.		32.5																
KARWAR																		
Nov. 91																		
Dec.																		137.5
Feb. 92												122.5	127.5	137.5				
Mar.												122.5						
Jul.											117.5							
Aug.										102.5								
Sep.											107.5							
Oct.						57.5												
Dec.				42.5										132.5				147.5
Jan.93							77.5							132.5				
Feb.														132.5				
Mar.				52.5								112.5						
Apr.																		
Jun.								92.5										
Aug.								97.5										
Sep.								97.5										
Oct.		32.5		57.5														
Dec.		32.5																
Jan. 94		32.5	42.5	52.5														
Mar.					62.5													
Average		33.8	45.8	53	68	78.4	86.2	93	104.2	110.5	113.8	124.1	133.5	136.3	137.5	145	147.5	

TABLE 6.28.

Modal sizes from the size frequency data corresponding to age in months as read from Fig. 6.10 for *P. sanguinolentus* females.

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Broods (month of origin)																
MANGALORE																
Sep. 91																132.5
Nov.														122.5		
Mar. 92								87.5								
Apr.								87.5					117.5			
May											107.5					
Jul.									97.5							
Aug.		32.5	47.5													
Sep.						77.5		92.5								
Jan. 93											107.5					
Feb.											107.5					
Mar.											107.5					
Jun.						72.5			92.5		102.5					
Jul.									92.5							
Sep.						72.5		82.5								
Dec.		37.5		57.5												
Mar. 94		32.5														
MALPE																
Nov. 91													117.5	122.5		
Mar. 92														122.5		
Apr.							77.5	87.5								
May											107.5					
Jul.							77.5									
Aug.		32.5							97.5							
Sep.				52.5			82.5									
Oct.					62.5											
Nov.			47.5													

Contd..

TABLE 6.28. (Contd.)

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dec.									97.5			112.5				
Jan. 93				52.5		72.5			92.5			112.5	117.5			
Feb.						72.5										
May							82.5									
Jun.				52.5			77.5									
Aug.				52.5		67.5		82.5								
Sep.				52.5												
Oct.							77.5									
Dec.			47.5													
Jan. 94				52.5												
Feb.					62.5											
Aug.		32.5														
KARWAR																
Sep. 91																
Dec.															127.5	
Feb. 92																132.5
Mar.								87.5		102.5		112.5				
Jun.					62.5					102.5						
Aug.									97.5							
Sep.					67.5	77.5										
Oct.			47.5													
Nov.				52.5												
Dec.							82.5							122.5		
Feb. 93											107.5					
Mar.				57.5					97.5	107.5						
Jul.									92.5							
Aug.					62.5	72.5										
Sep.											107.5					
Oct.		32.5			67.5											
Dec.	27.5	32.5			67.5											
Jan. 94		32.5														
Feb. 94		32.5	47.5			72.5										
Average	27.5	33	47.5	53.6	64.6	73.1	79.6	86.8	95.3	102.5	106.9	112.5	117.5	122.5	127.5	132.5

TABLE 6.29.

Modal sizes from the size frequency data corresponding to age in months as read from Fig. 6.11 for *P. pelagicus* males.

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Broods (Month of origin)														
MANGALORE														
May 92												147.5		
Aug.						92.5								
Sep.												147.5		
Oct.				72.5	82.5	92.5								
Nov.				72.5										
Dec.					87.5									
Jan. 93			62.5	72.5								147.5		
Feb.				72.5			107.5							
Mar.														
Jul.						92.5	107.5						142.5	
Aug.						97.5								
Oct.					82.5									
Nov.				72.5	82.5	92.5								
Dec.				67.5										
MALPE														
Dec. 91									127.5					
Apr.										132.5	142.5			
May												137.5	147.5	
Jul.									122.5					
Aug.						92.5								
Sep.							107.5	112.5						
Oct.			62.5		87.5								147.5	
Dec.		47.5												
Jan. 93													142.5	

Contd.....

TABLE 6.29.(contd.)

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Feb.				67.5	82.5									
Apr.			52.5		82.5									
May								117.5						
Jun.								117.5						
Jul.									122.5					
Aug.					87.5		107.5							
Sep.			52.5											
Oct.				67.5		97.5								
Nov.				72.5										
Dec.			52.5											
Jan. 94								117.5						
Mar.						97.5								
KARWAR														
Mar. 92														152.5
Apr.												142.5		
Jun.						87.5	102.5							
Jul.							102.5							
Aug.			52.5				102.5		122.5					
Sep.			62.5	72.5	87.5	97.5								
Oct.		42.5	57.5	67.5										
Nov.		42.5			87.5									
Mar. 93												142.5		
Jun.							102.5							
Jul.							107.5							
Aug.				67.5		97.5								
Sep.					87.5									
Nov.				72.5	82.5									
Dec.		47.5												
Average		45	56.4	70.5	85	94.3	105.3	116.3	123.8	132.5	140	145.2		152.5

TABLE 6.30.

Modal sizes from the size frequency data corresponding to age in months as read from Fig. 6.12 for *P. pelagicus* females.

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Broods (Month of origin)																	
MANGALORE																	
Mar. 92																	
Jul.							97.5	107.5						142.5			
Sep.						87.5	92.5							142.5			
Nov.				67.5	77.5	87.5											
Oct			57.5		77.5												
Feb. 93				67.5									132.5				
Jun.						82.5	97.5	102.5									
Jul.								102.5									
Aug.					77.5	87.5											
Sep.								102.5									
Oct.					77.5	87.5	92.5										
Dec.				67.5													
MALPE																	
Aug. 91																	
Mar. 92													137.5	142.5			
May											127.5		137.5				
Jun.												132.5			147.5		
Aug.							97.5										
Sep.							97.5										152.5
Oct.				57.5			97.5					132.5					
Nov.				52.5					102.5								

Contd....

TABLE 6.30.(contd.)

Age in months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Jan. 93					77.5	87.5											
Feb.				67.5			97.5										
Mar.												132.5					
May									112.5								
Jul.					77.5												
Aug.					77.5		97.5										
Oct.				62.5		82.5							137.5				
Nov.					87.5												
Dec.			52.5							117.5							
KARWAR																	
May																	
Jan. 92														142.5			
Mar.														142.5			
Apr.											127.5						
Jun.						87.5	97.5			107.5			132.5	137.5			
Jul.				67.5		82.5		102.5									
Aug.						87.5											
Sep.		47.5	57.5	72.5			97.5								147.5		152.5
Oct.																	
Nov.	22.5	47.5	57.5										137.5				
Feb. 93																	
Apr.										117.5							
May											127.5						
Jun.								107.5									
Aug.								107.5									
Nov.			52.5		82.5	87.5	97.5	102.5									
Jan. 94		47.5															
Average	22.5	47.5	55.4	67.5	79.5	86.1	96.7	104.2	114.2	117.5	127.5	132.5	137.5	142.5	147.5		152.5

TABLE 6.31.

Pairs of consecutive lengths (mm) with $\Delta t = 0.25$ year used as input data for determining growth parameters by Ford-Walford Plot and Gulland-Holt Plot.

Species	t	Ford-Walford Plot		Gulland -Holt Plot	
		X	Y	Y	X
		L(t)	L(t+ Δt)	$\Delta L / \Delta t$ (growth increment)	X/L (mean size)
<i>P. sanguinolentus</i>					
males	1	45.0	78.0	33.0	61.5
	2	78.0	104.0	26.0	91.0
	3	104.0	124.0	20.0	114.0
females	1	47.0	73.0	26.0	60.0
	2	73.0	95.0	22.0	84.0
	3	95.0	112.0	17.0	103.5
<i>P. pelagicus</i>					
males	1	56.0	94.0	38.0	75.0
	2	94.0	124.0	30.0	109.0
	3	124.0	145.0	21.0	134.5
females	1	55.0	86.0	31.0	70.5
	2	86.0	114.0	28.0	100.0
	3	114.0	132.0	18.0	123.0

TABLE 6.32.
Growth parameters estimated by various methods in males and females of
***P. sanguinolentus* and *P. pelagicus*.**

Species	Sex	Growth parameter	Methods				Lmax
			Ford-Walford Plot	Gulland & Holt Plot	von Bertalanffy Plot	ELEFAN method	
<i>P. sanguinolentus</i>	male	L ∞	195.38	195.39	-	172.0	169.0
		K	0.9937	0.9886	0.9941	0.54	
		t zero	-	-	-0.0132		
	female	L ∞	187.85	188.00	-	175.0	166.0
		K	0.8256	0.8215	0.8265	0.57	
		t zero	-	-	-0.0975		
<i>P. pelagicus</i>	male	L ∞	210.82	211.00	-	188.0	174.0
		K	1.1416	1.1319	1.1431	0.72	
		t zero			-0.0194		
	female	L ∞	202.66	204.39	-	181.0	171.0
		K	0.9843	0.9635	0.9772	0.59	
		t zero	-	-	-0.0691		

L ∞ in mm; K and t zero are annual values

TABLE 6.33.

Age composition of *P. sanguinolentus* at Mangalore, Malpe and Karwar.

Age groups	MALE						FEMALE					
	MANGALORE (TN)		MALPE (TN)		KARWAR (TN)		MANGALORE (TN)		MALPE (TN)		KARWAR (TN)	
	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94
<0.5	198	286	1043	675	28	22	131	251	787	553	17	20
0.5 - 1.0	508	260	600	371	250	148	577	310	562	445	217	168
1.0 - 1.5	221	44	159	26	68	25	266	60	204	56	8	12
1.5 - 2.0	18	-	23	3	4	7	16	2	16	3	1	-
2.0 - 2.5	-	-	-	-	-	-	-	-	2	1	-	-
Sample size	945	590	1825	1075	350	202	990	623	1571	1058	243	200
sum nos. x age	738.3	321.5	949.8	484.8	286.5	160.0	826.0	373.8	905.8	550.8	178.8	146.0
mean age	0.78	0.54	0.52	0.45	0.82	0.79	83.0	0.60	0.58	0.52	0.74	0.73
Age groups	MANGALORE (IG) (estuary)		MALPE (IG)		KARWAR (IG)		MANGALORE (IG) (estuary)		MALPE (IG)		KARWAR (IG)	
	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94
	<0.5	66	43	64	112	193	577	32	44	38	113	410
0.5 - 1.0	19	11	53	12	72	86	52	52	56	16	47	66
1.0 - 1.5	-	1	-	-	12	4	-	-	-	-	-	7
1.5 - 2.0	-	-	-	-	-	1	-	-	-	-	-	-
sample size	85	55	117	124	277	668	84	96	94	129	170	483
sum nos. x age	30.8	20.3	55.8	37.0	117.3	215.5	47.0	50.0	51.5	40.3	66.0	160.8
mean age	0.36	0.37	0.48	0.30	0.42	0.32	0.56	0.52	0.55	0.31	0.39	0.34

TN = trawl net; IG = indigenous gear

Age composition in nos.

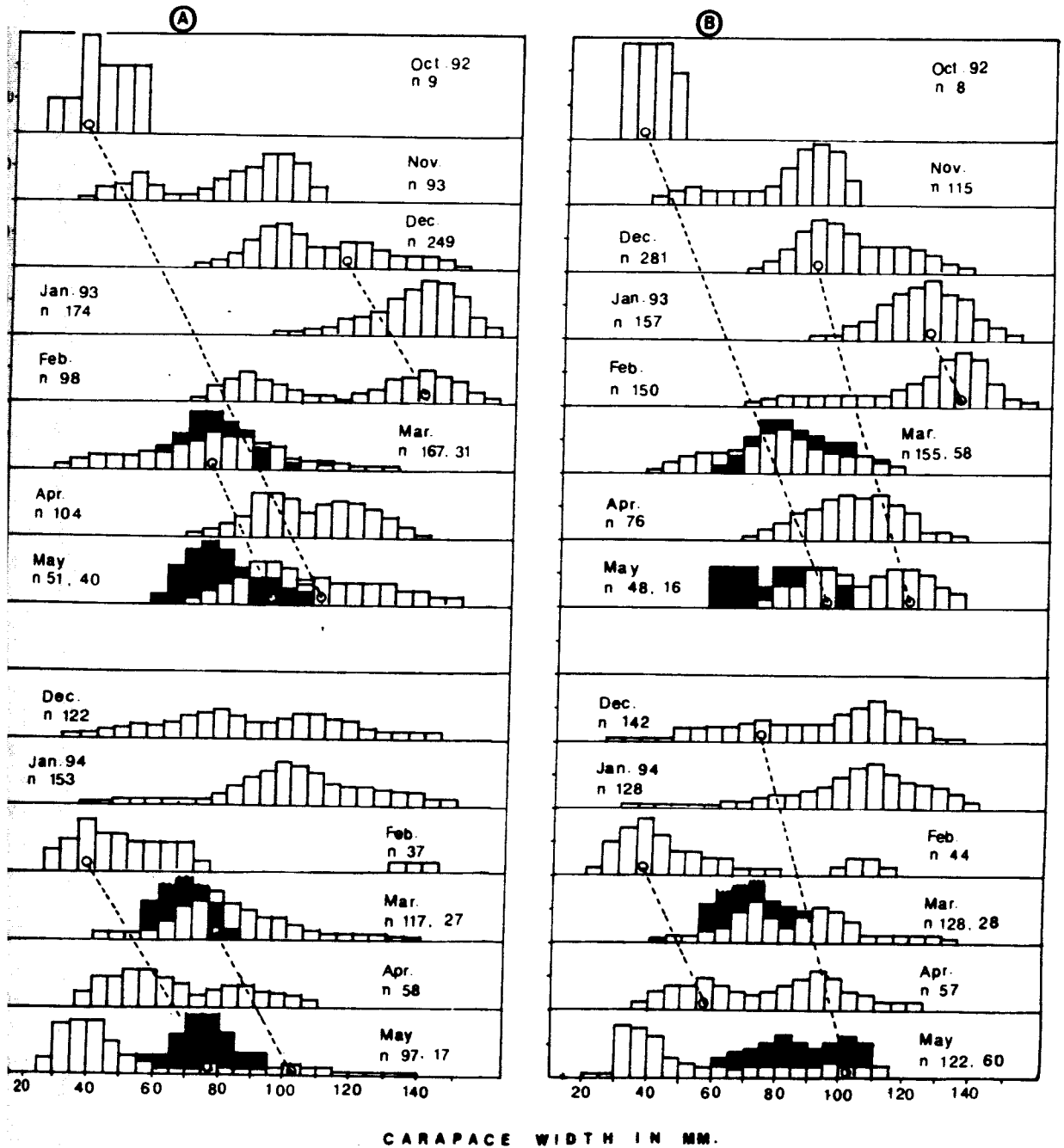
TABLE 6.34.

Age composition of *P. pelagicus* at Mangalore, Malpe and Karwar.

	MALE						FEMALE									
	MANGALORE (TN)		MALPE (TN)		KARWAR (TN)		MANGALORE (TN)		MALPE (TN)		KARWAR (TN)					
Age groups	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94				
<0.5	212	388	130	146	95	57	144	249	94	131	89	50				
0.5 - 1.0	130	234	194	166	133	160	181	324	263	160	234	198				
1.0 - 1.5	13	3	56	32	39	20	18	8	4	-	9	6				
1.5 - 2.0	-	-	-	-	-	-	1	-	-	-	-	-				
2.0 - 2.5	-	-	-	-	-	-	-	-	-	-	-	-				
Sample size	355	625	380	344	267	237	344	581	361	291	332	254				
sum nos. x age	166.8	276.3	248.0	201.0	172.3	159.3	196.0	315.3	225.8	152.8	209.0	168.5				
mean age	0.47	0.44	0.65	0.58	0.65	0.67	0.57	0.54	0.62	0.52	0.63	0.66				
	MALE								FEMALE							
	MANGALORE (IG)		MANGALORE (IG) (estuary)		MALPE (IG)		KARWAR (IG)		MANGALORE (IG)		MANGALORE (IG) (estuary)		MALPE (IG)		KARWAR (IG)	
Age groups	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94
<0.5	-	-	305	261	44	-	321	108	-	-	368	232	46	-	308	85
0.5 - 1.0	8	11	47	40	23	-	52	23	2	6	94	108	30	-	26	36
1.0 - 1.5	4	18	-	-	21	-	-	2	16	20	-	-	10	-	2	16
1.5 - 2.0	-	-	-	-	-	-	-	-	1	4	-	-	-	-	1	2
sample size	12	29	432	301	88	-	373	133	19	30	462	340	86	-	337	139
sum nos. x age	11.0	30.8	111.5	95.3	54.5	-	119.3	46.8	23.3	36.5	162.5	139.0	46.5	-	100.8	71.8
mean age	0.92	1.06	0.26	0.32	0.62	-	0.32	0.35	1.22	1.22	0.35	0.41	0.54	-	0.30	0.52

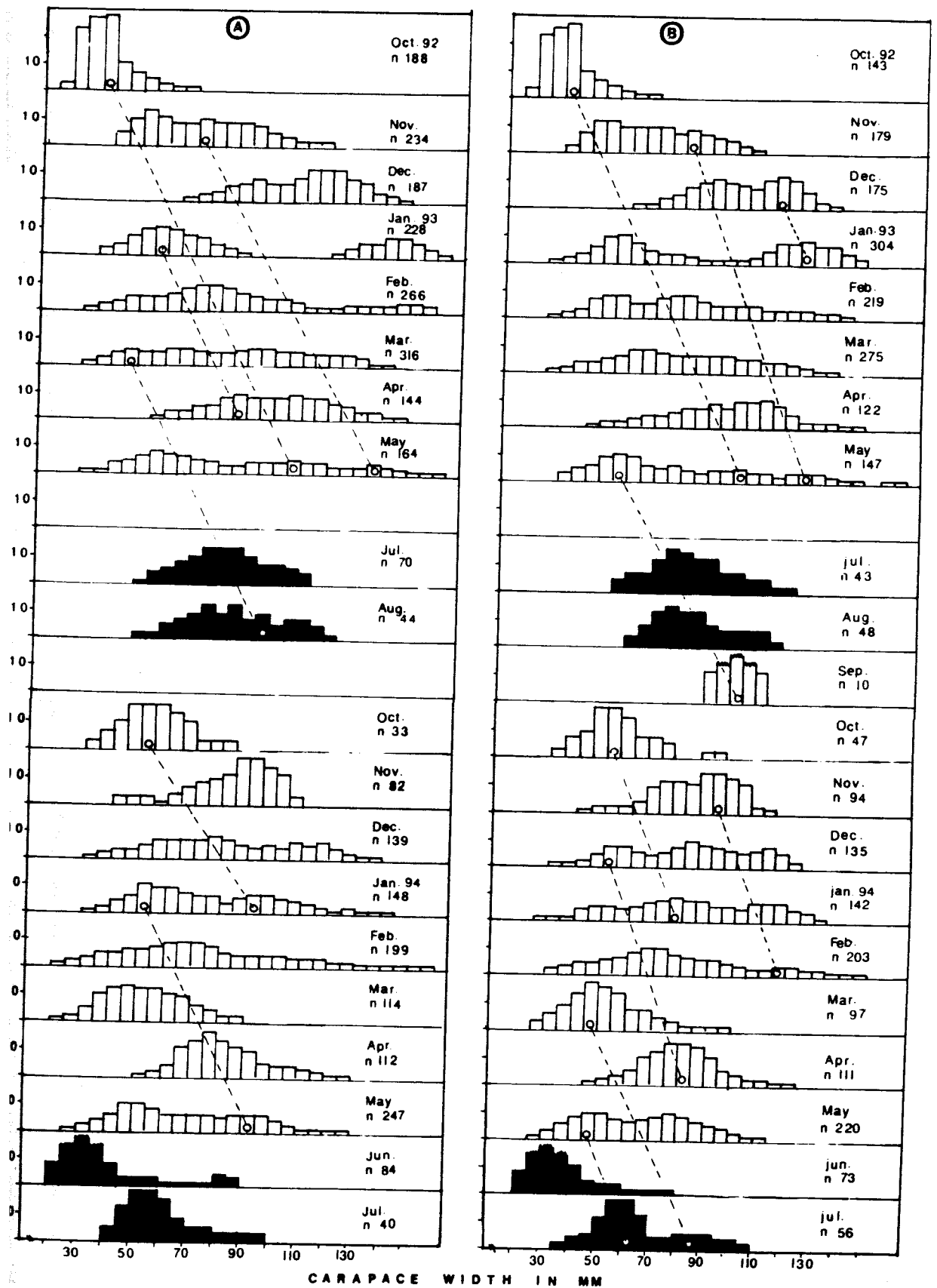
T N -Trawl; IG-indigenous gear;

Age composition in nos.



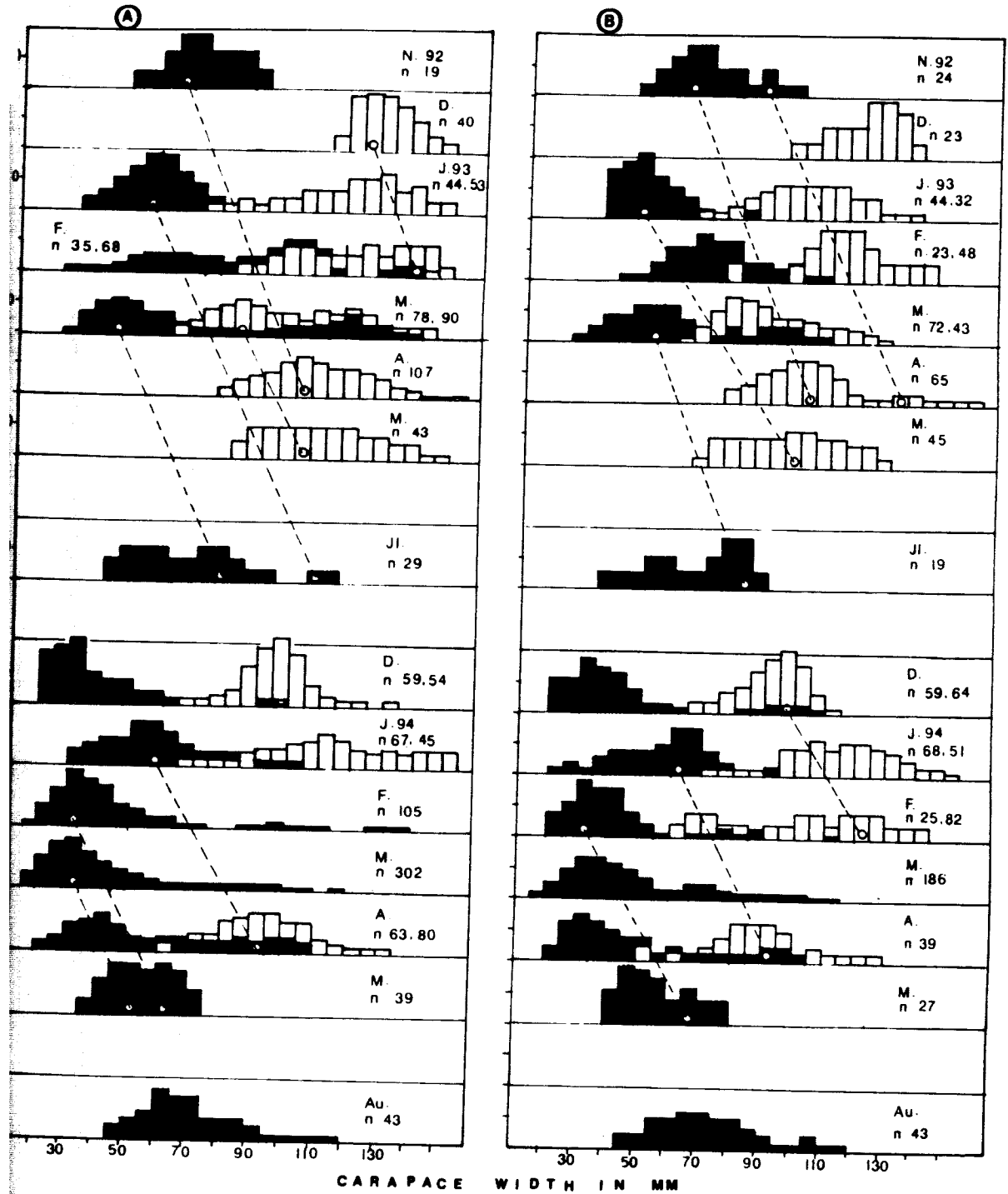
6.1. *P. sanguinolentus*.

Size frequency histograms of males (A) and females (B) at Mangalore during 1992-94. (hollow bars = trawl data; filled bars = indigenous gear data; n = number of crabs analysed).



6.2. *P. sanguinolentus*.

Size frequency histograms of males (A) and females (B) at Malpe 1992-94. (hollow bars = trawl data; filled bars = indigenous gear data; n = number of crabs analysed).



3. *P. sanguinolentus*.

Size frequency histograms of males (A) and females (B) at Karwar 1992-94 (hollow bars = trawl data; filled bars = indigenous gear data; n = number of crabs analysed).

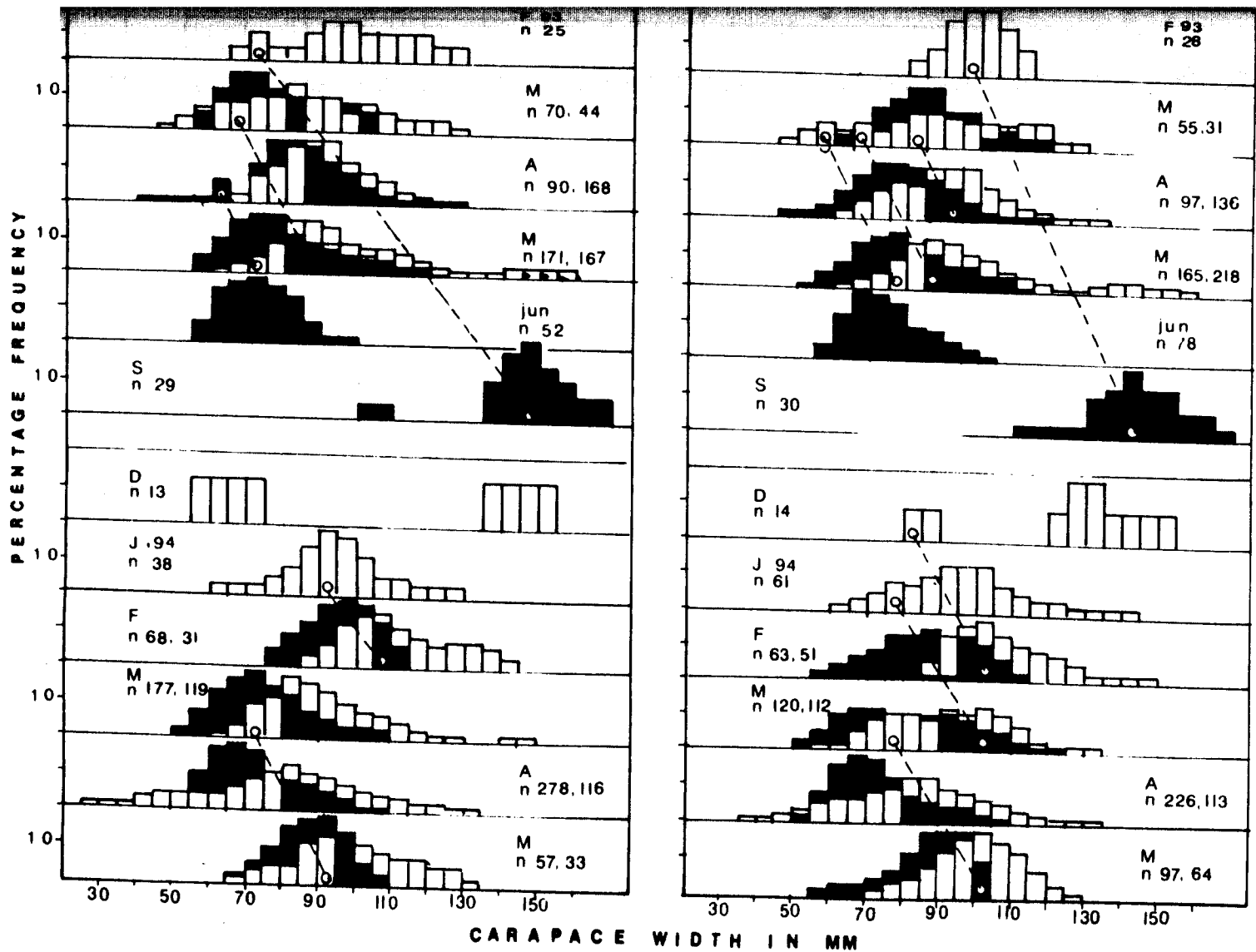
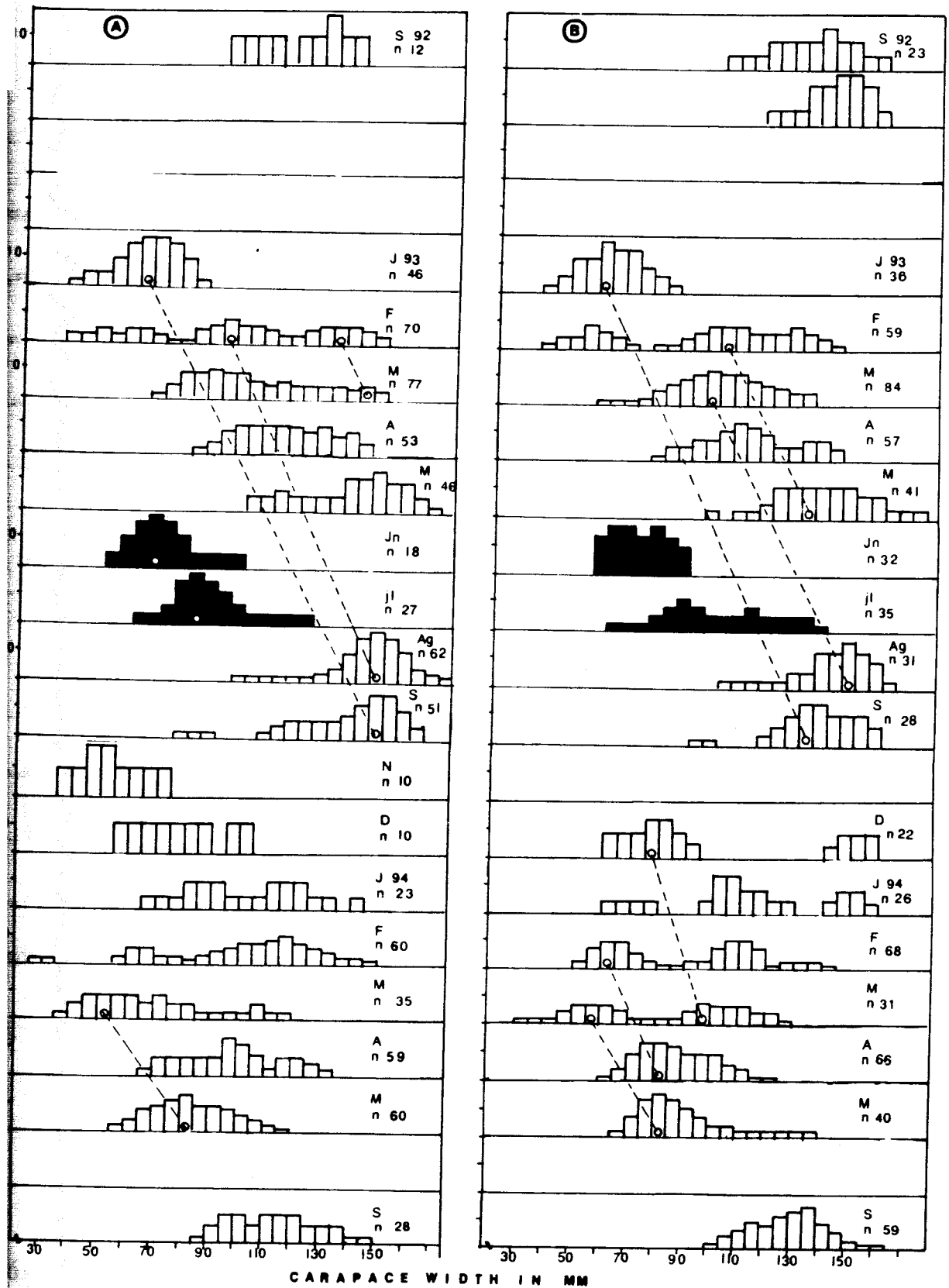
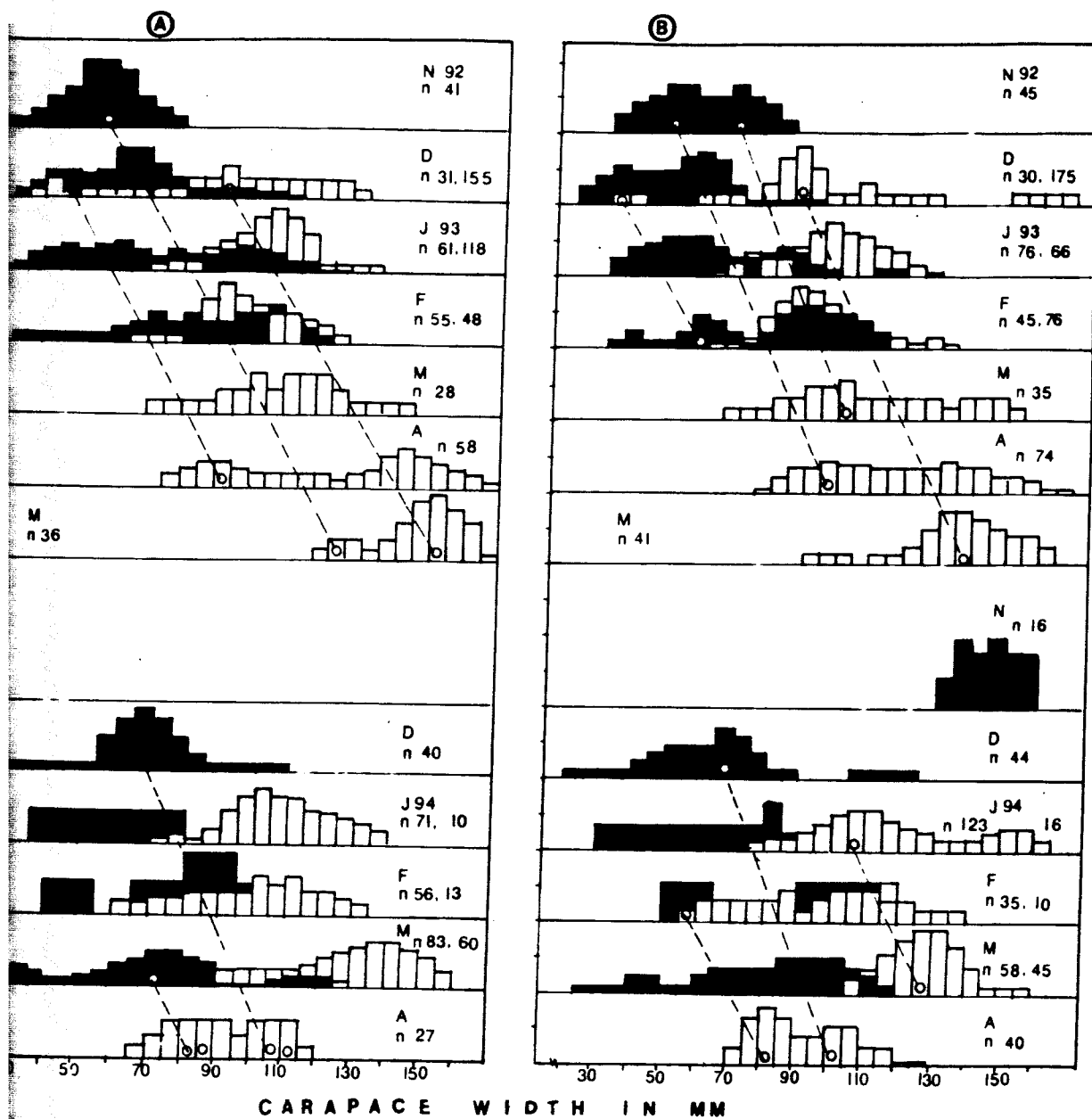


Fig. 6.4. *P. pelagicus*.
 Size frequency histograms of males (A) and females (B) at Mangalore 1992-94
 (hollow bars = trawl data; filled bars = indigenous gear data; n = number of crabs analysed).



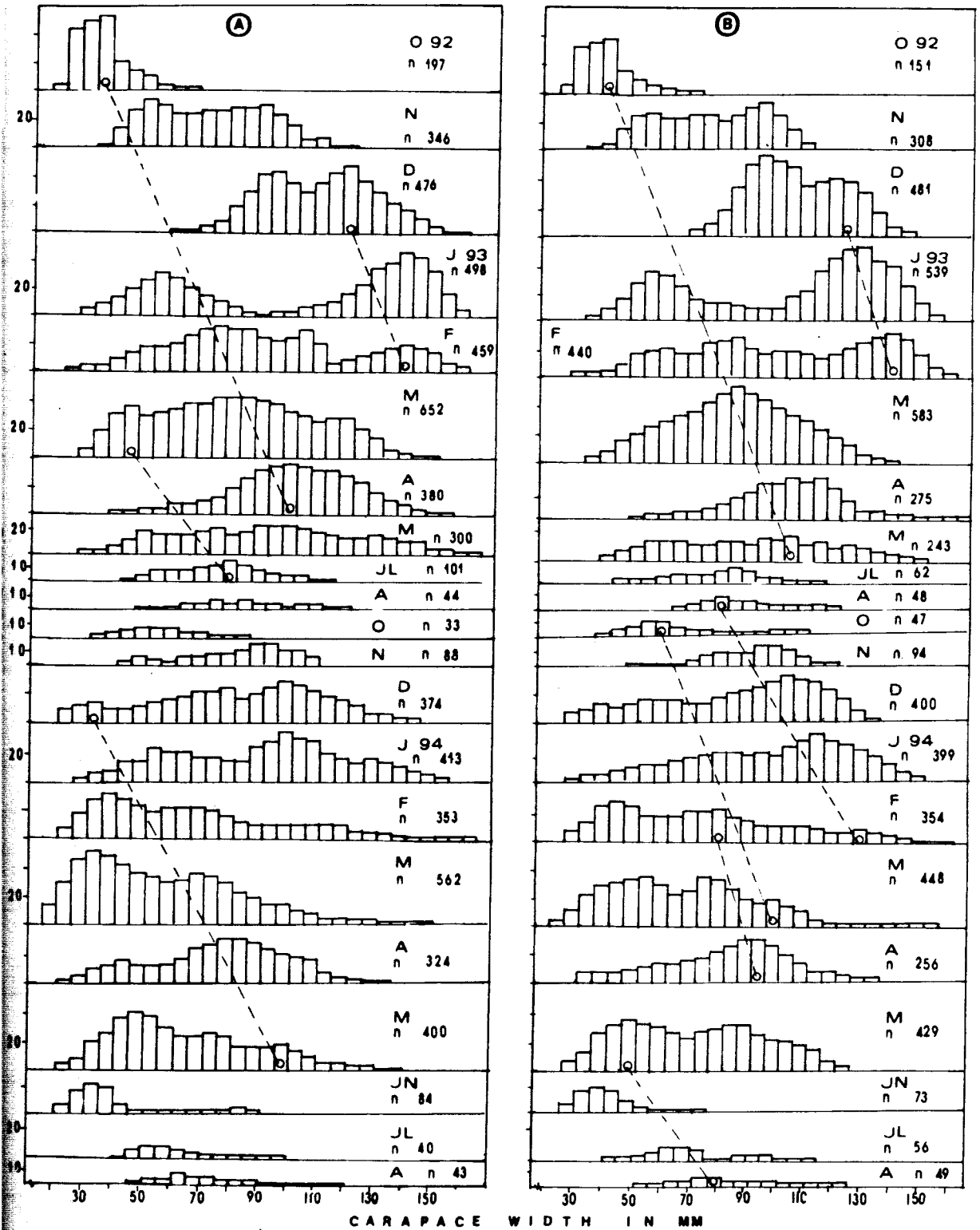
6.5. *P. pelagicus*.

Size frequency histograms of males (A) and females (B) at Malpe 1992-94 (hollow bars = trawl data; filled bars = indigenous gear data; n = number of crabs analysed).

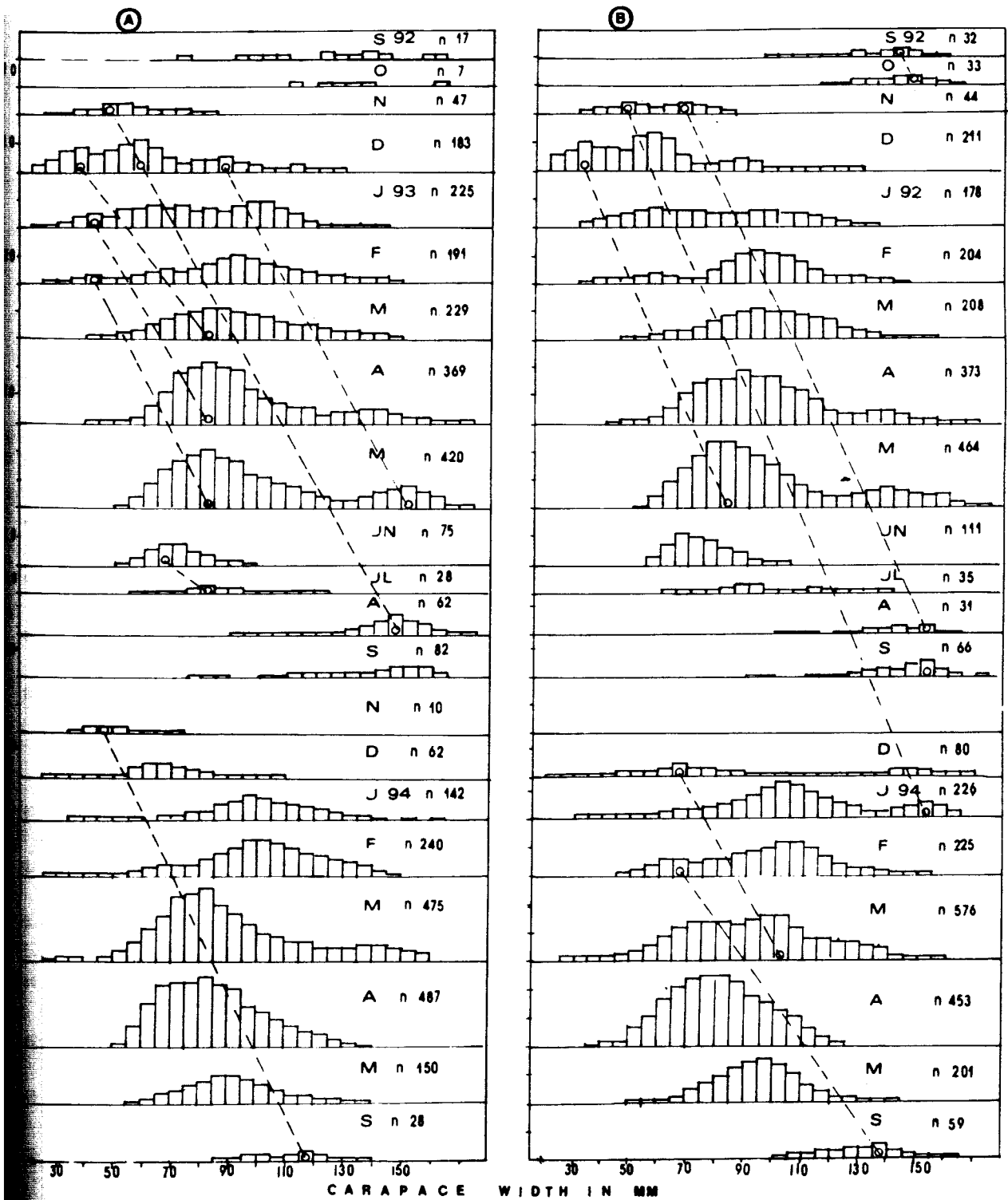


16. *P. pelagicus.*

Size frequency histograms of males (A) and females (B) at Karwar 1992-94 (hollow bars = trawl data; filled bars = indigenous gear data; n = number of crabs analysed).

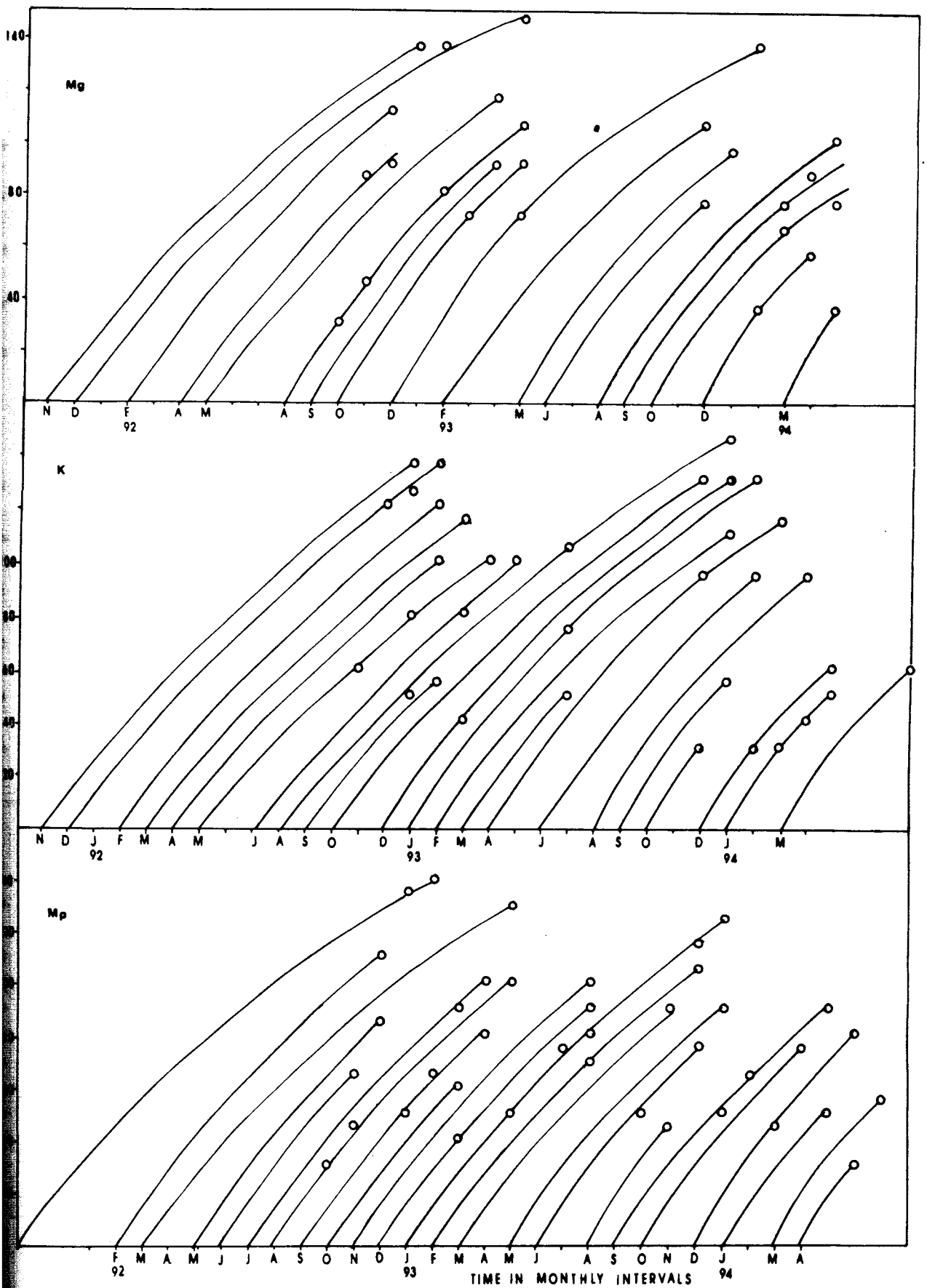


6.7. *P. sanguinolentus*.
 Size frequency histograms of males (A) and females (B) pooled data for all centres/ gears during 1992-94.



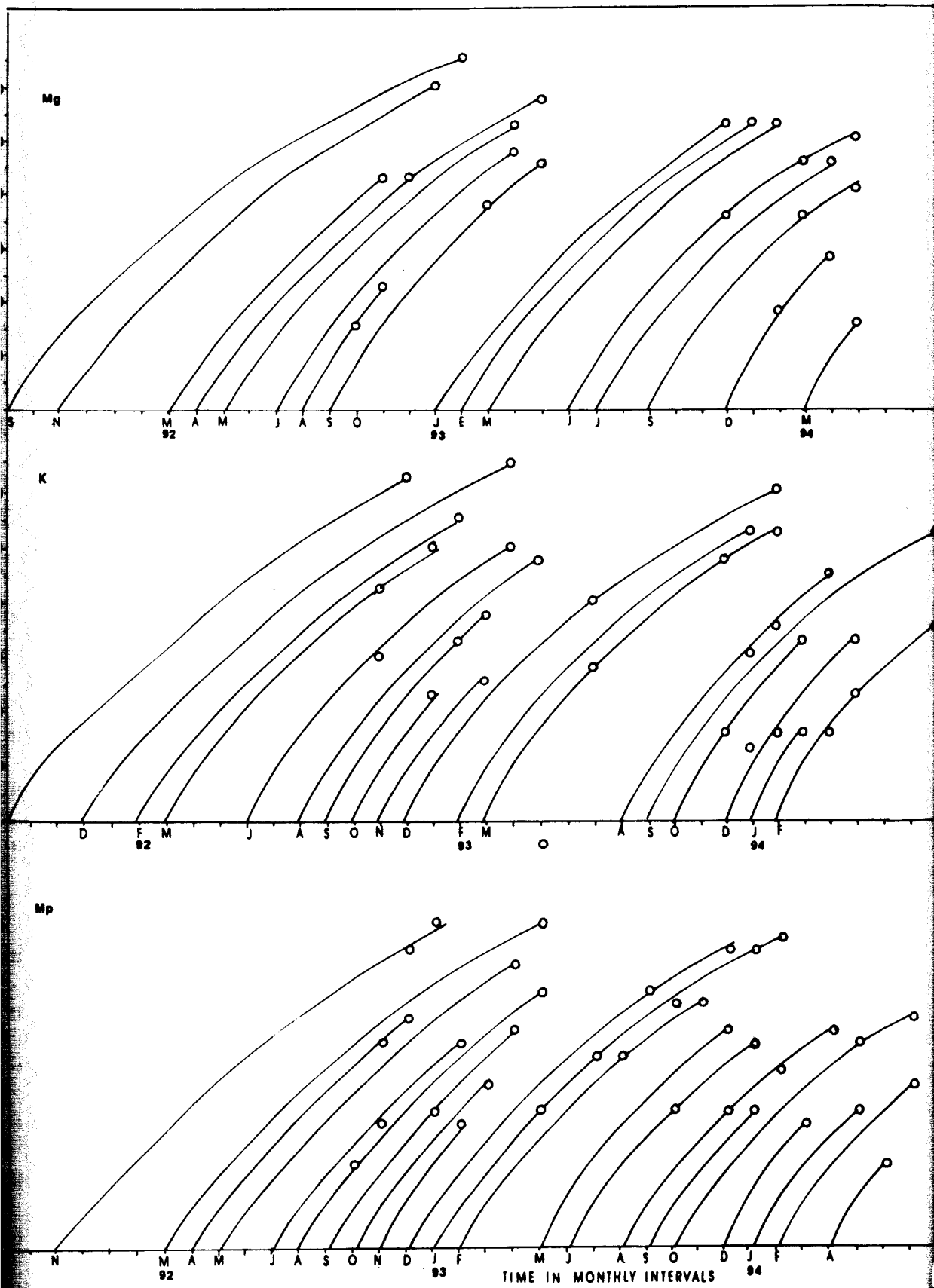
6.8. *P. pelagicus.*

Size frequency histograms of males (A) and females (B) pooled data for all centres/ gears during 1992-94.

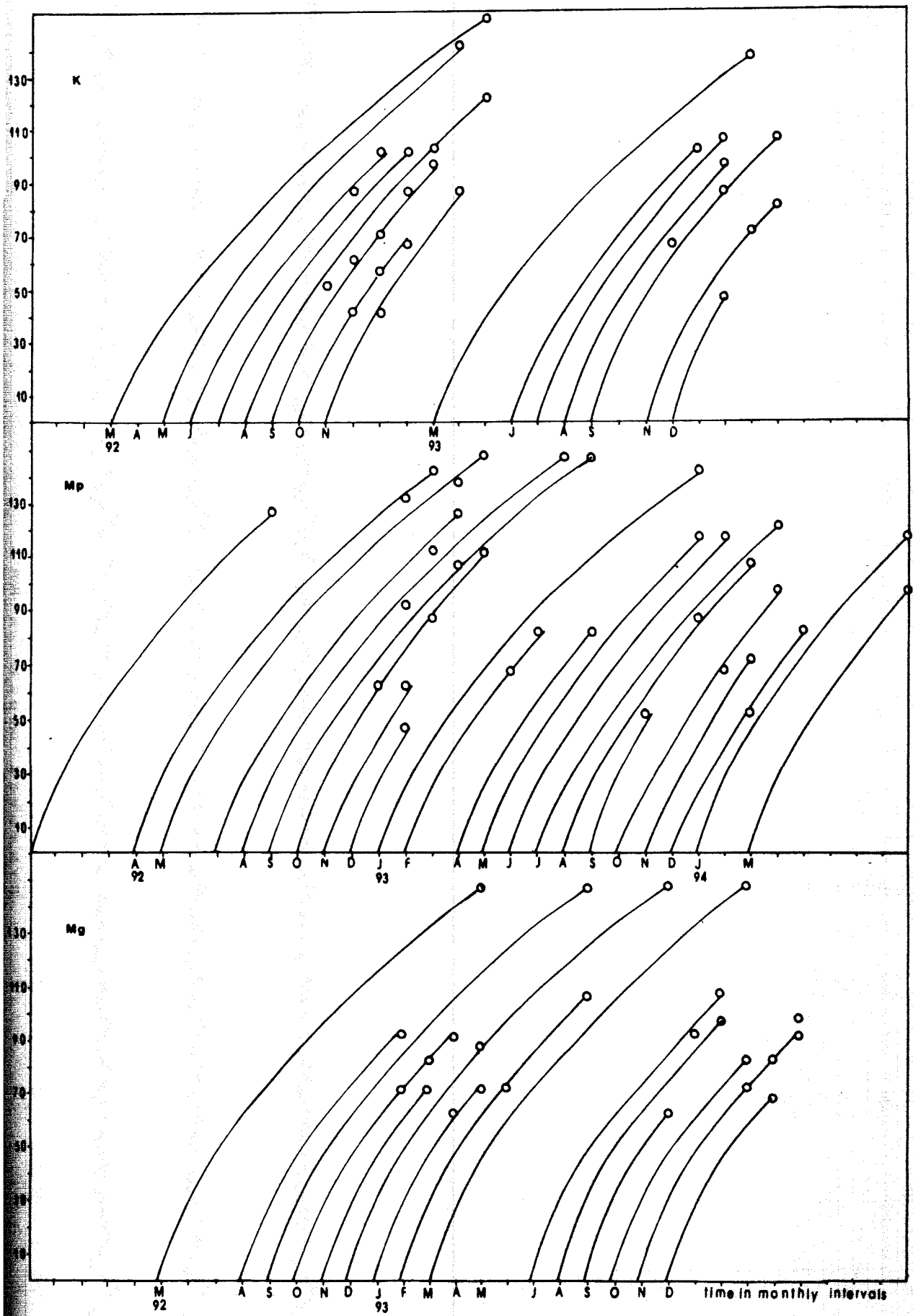


6.9. *P. sanguinolentus* males.

Scatter diagram for modal lengths (CW) - month at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-94.

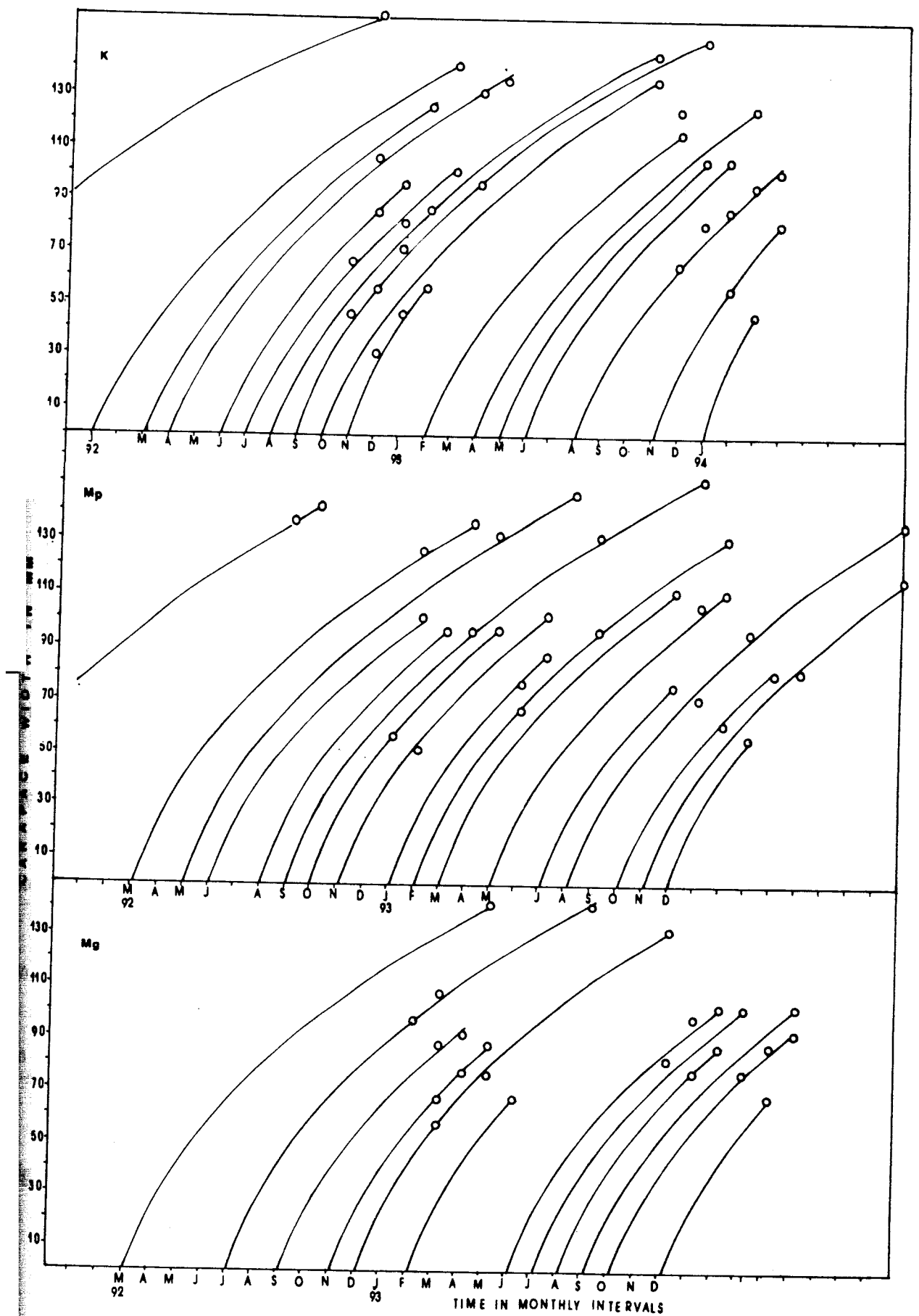


6.10. *P. sanguinolentus* females.
 Scatter diagram for modal lengths (CW) - month at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-94.



6.11. *P. pelagicus* males.

Scatter diagram for modal lengths (CW) - month at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-94.



6.12. *P. pelagicus* females.
 scatter diagram for modal lengths (CW) - month at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-94.

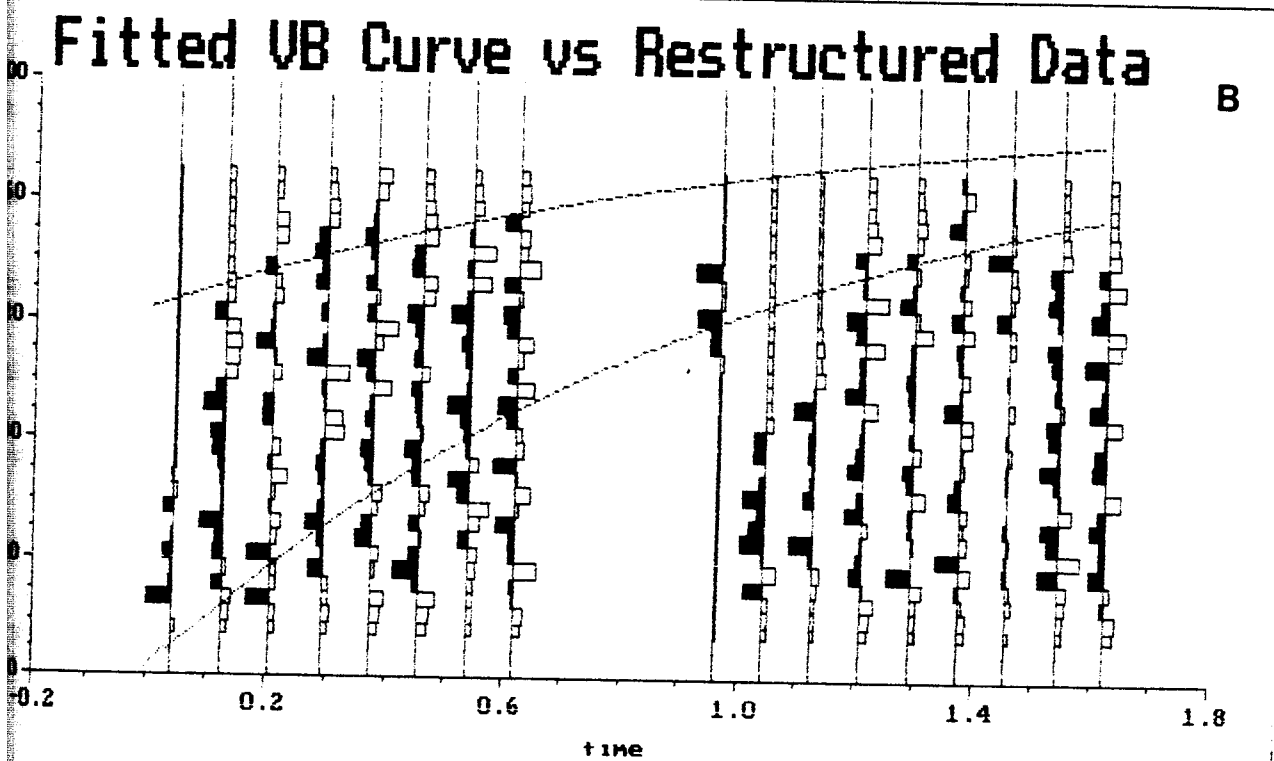
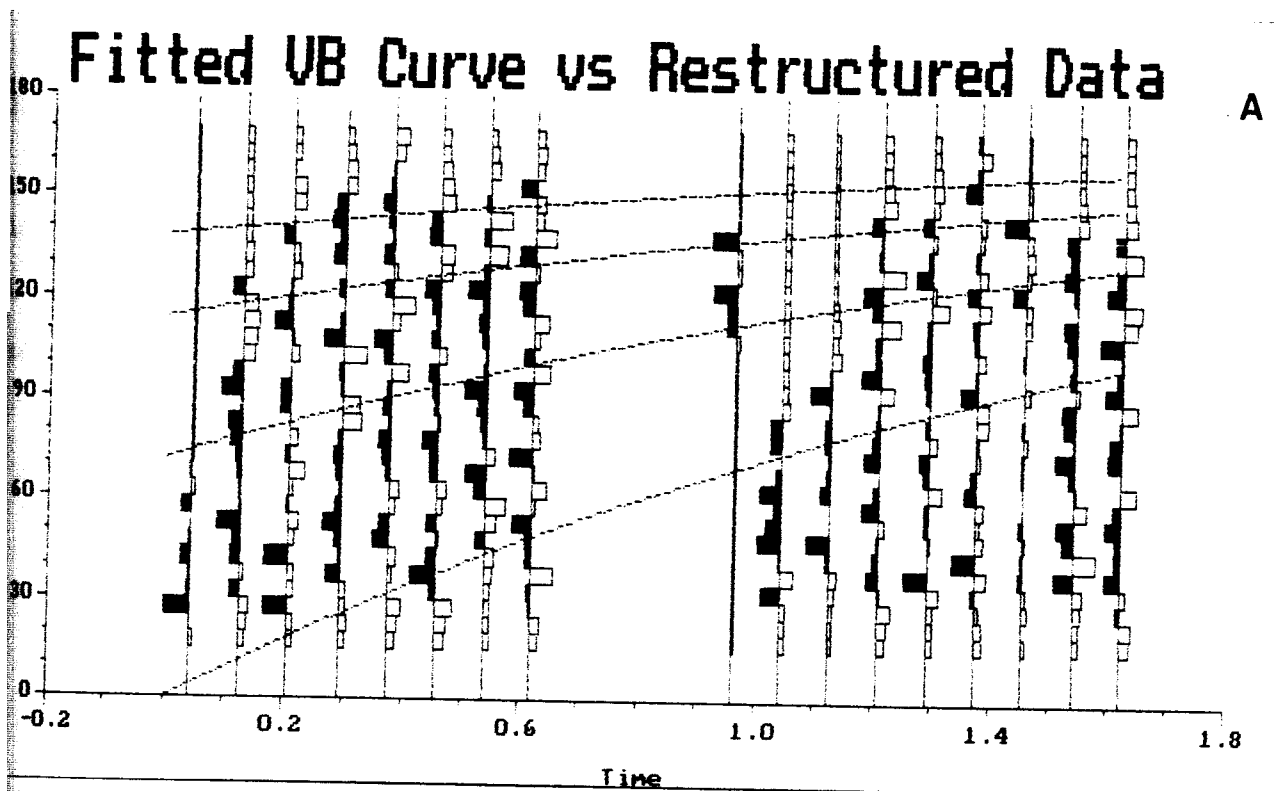


Fig. 6.13. *P. sanguinolentus* males (pooled data).
 A - the growth curve fitted by ELEFAN superimposed on the restructured data;
 B - the growth curve determined by the mean growth parameters estimated by Gulland and Holt plot / Ford-Walford plot superimposed on the restructured data.

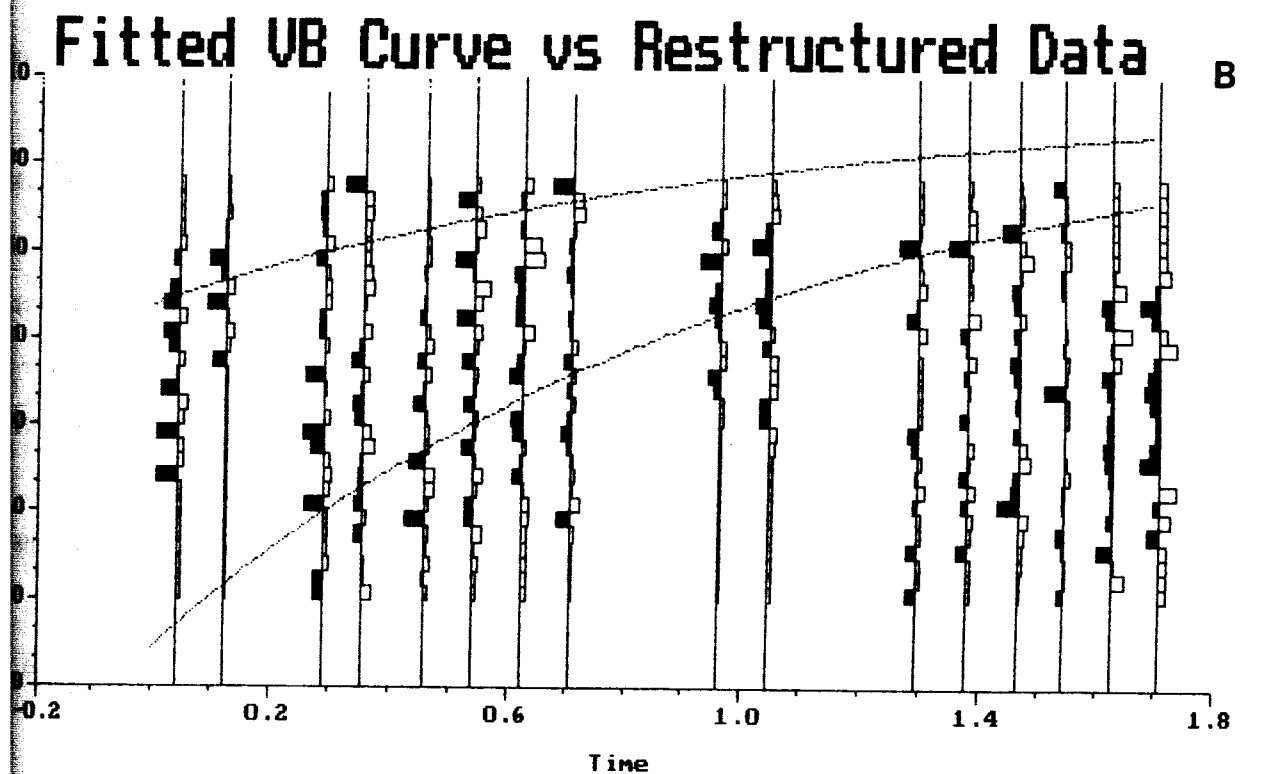
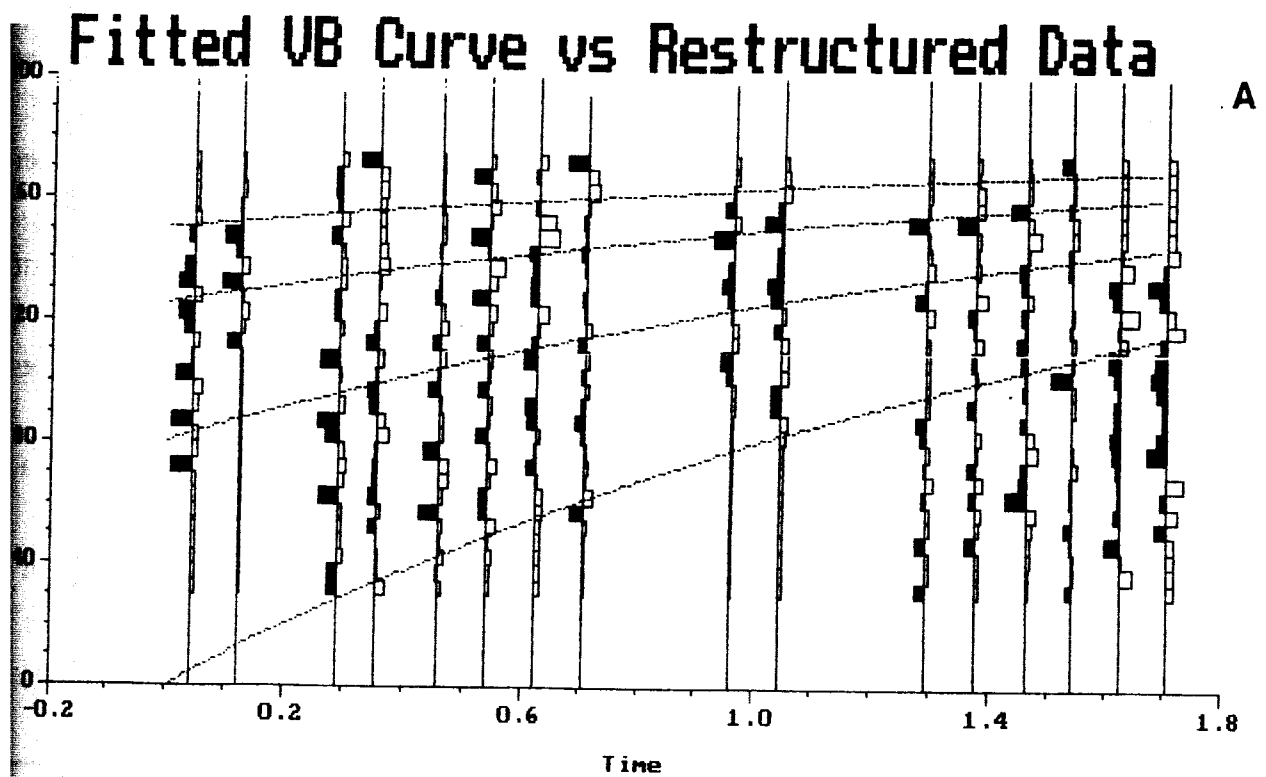


Fig. 6.14. *P. sanguinolentus* females (pooled data).
 A - the growth curve fitted by ELEFAN superimposed on the restructured data;
 B - the growth curve determined by the mean growth parameters estimated by Gulland and Holt plot / Ford-Walford plot superimposed on the restructured data.

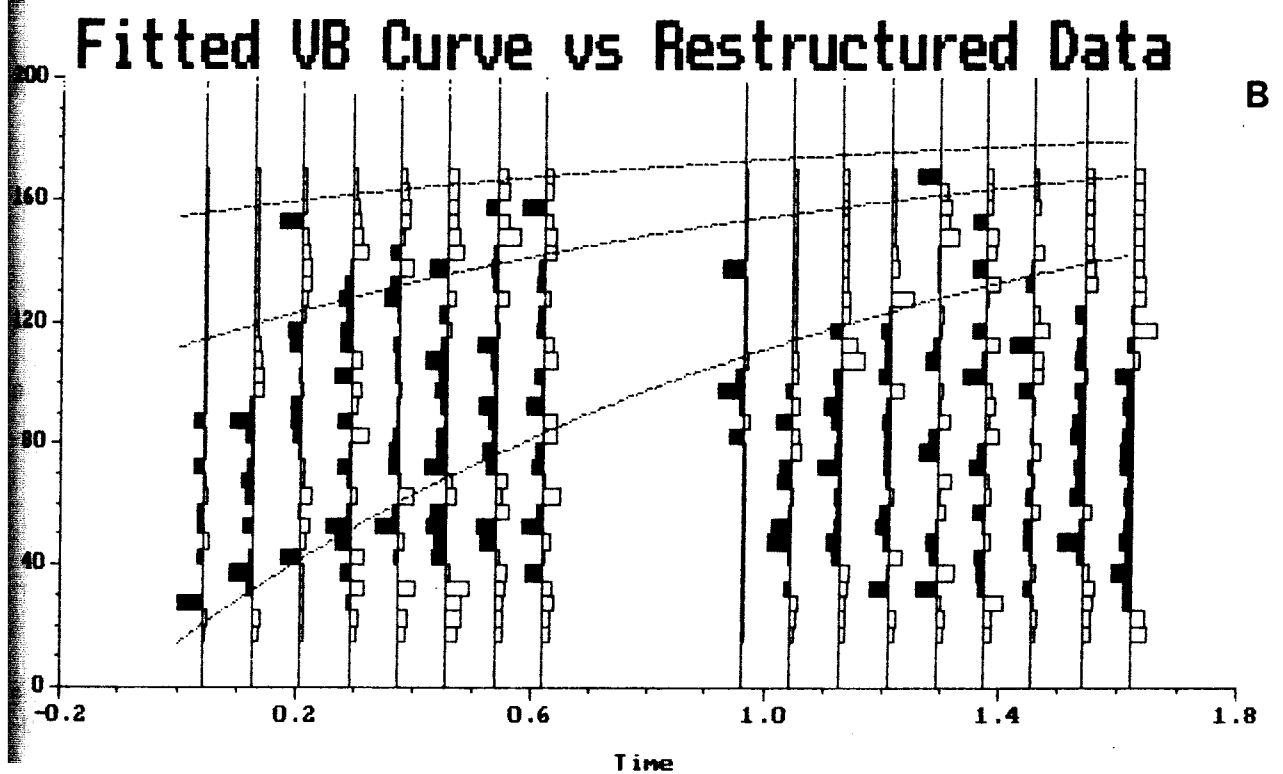
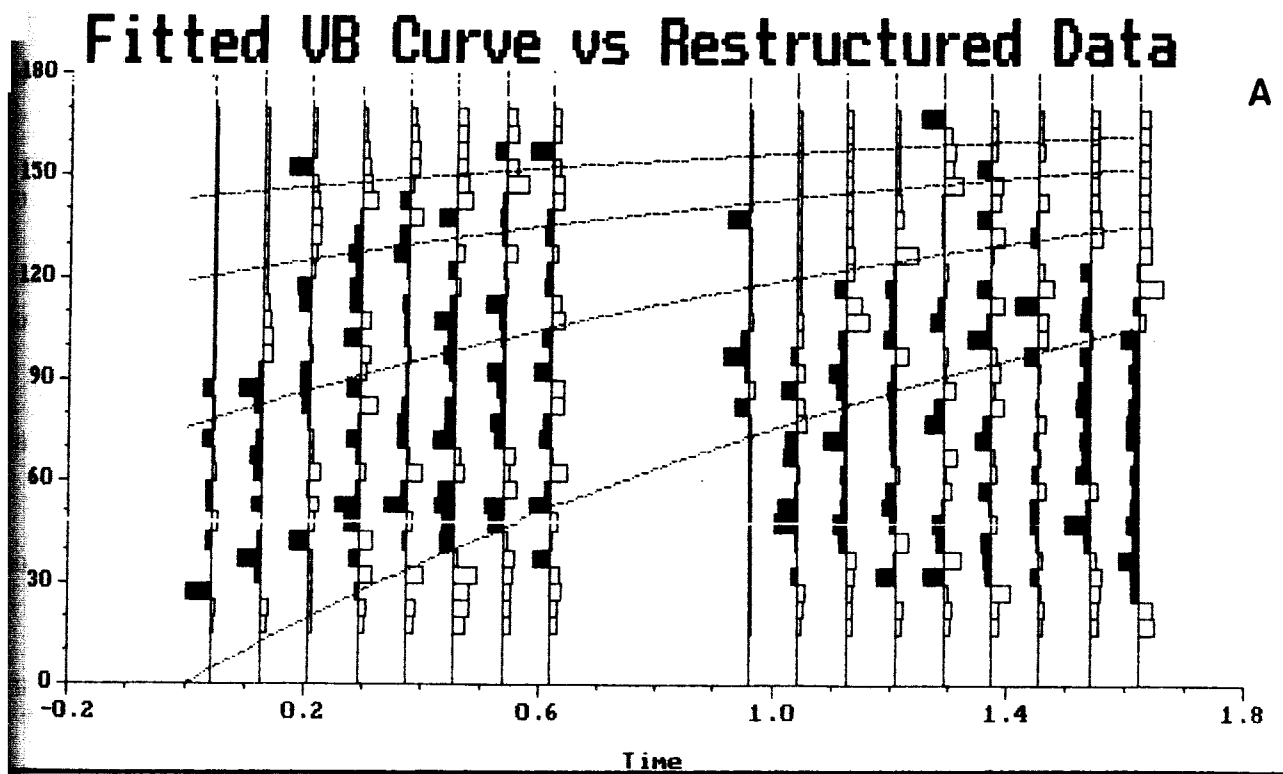


Fig. 6.15. *P. pelagicus* males (pooled data).
 A - the growth curve fitted by ELEFAN superimposed on the restructured data;
 B - the growth curve determined by the mean growth parameters estimated by Gulland and Holt plot / Ford-Walford plot superimposed on the restructured data.

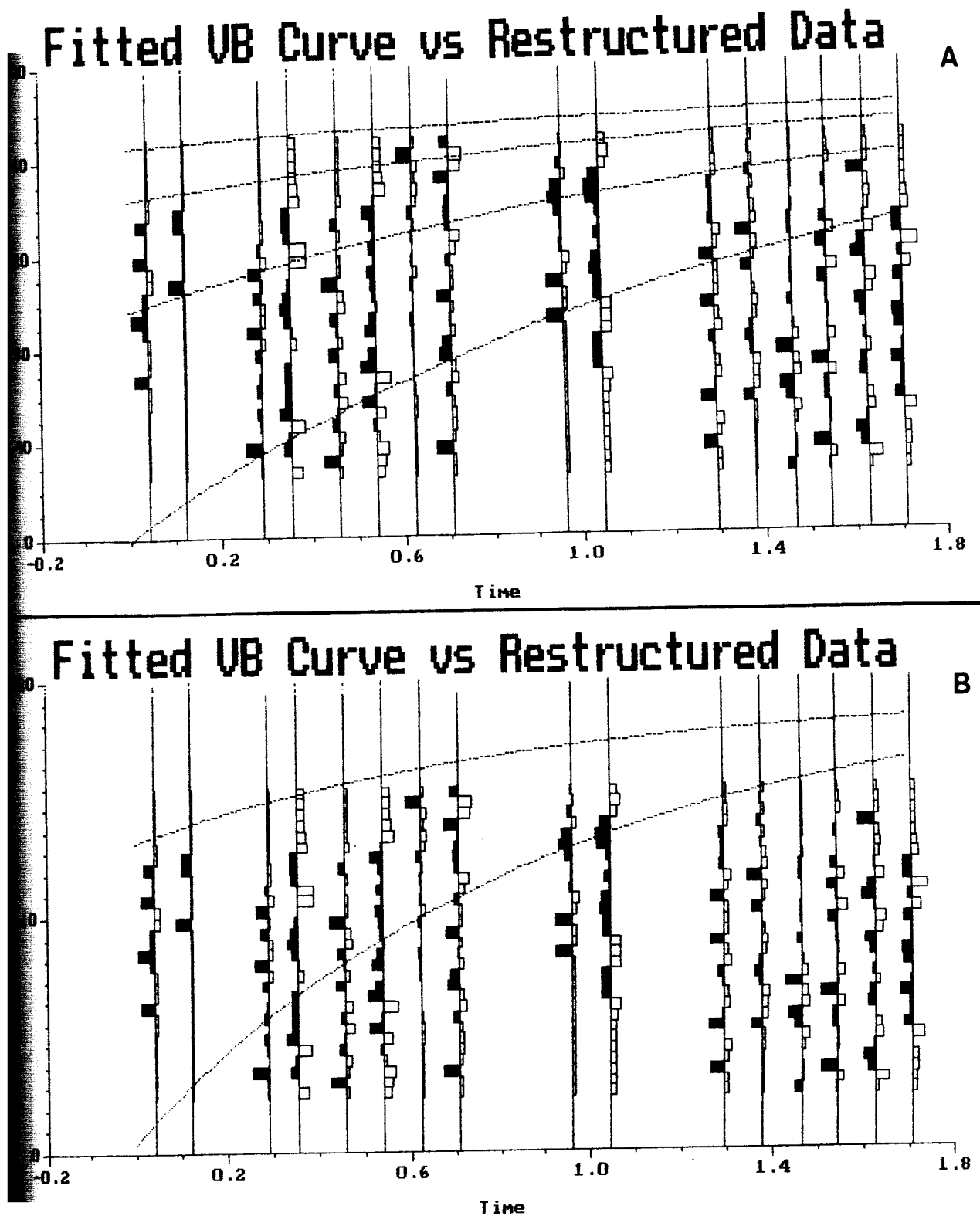


Fig. 6.16. *P. pelagicus* females (pooled data).
 A - the growth curve fitted by ELEFAN superimposed on the restructured data;
 B - the growth curve determined by the mean growth parameters estimated by Gulland and Holt plot / Ford-Walford plot superimposed on the restructured data.

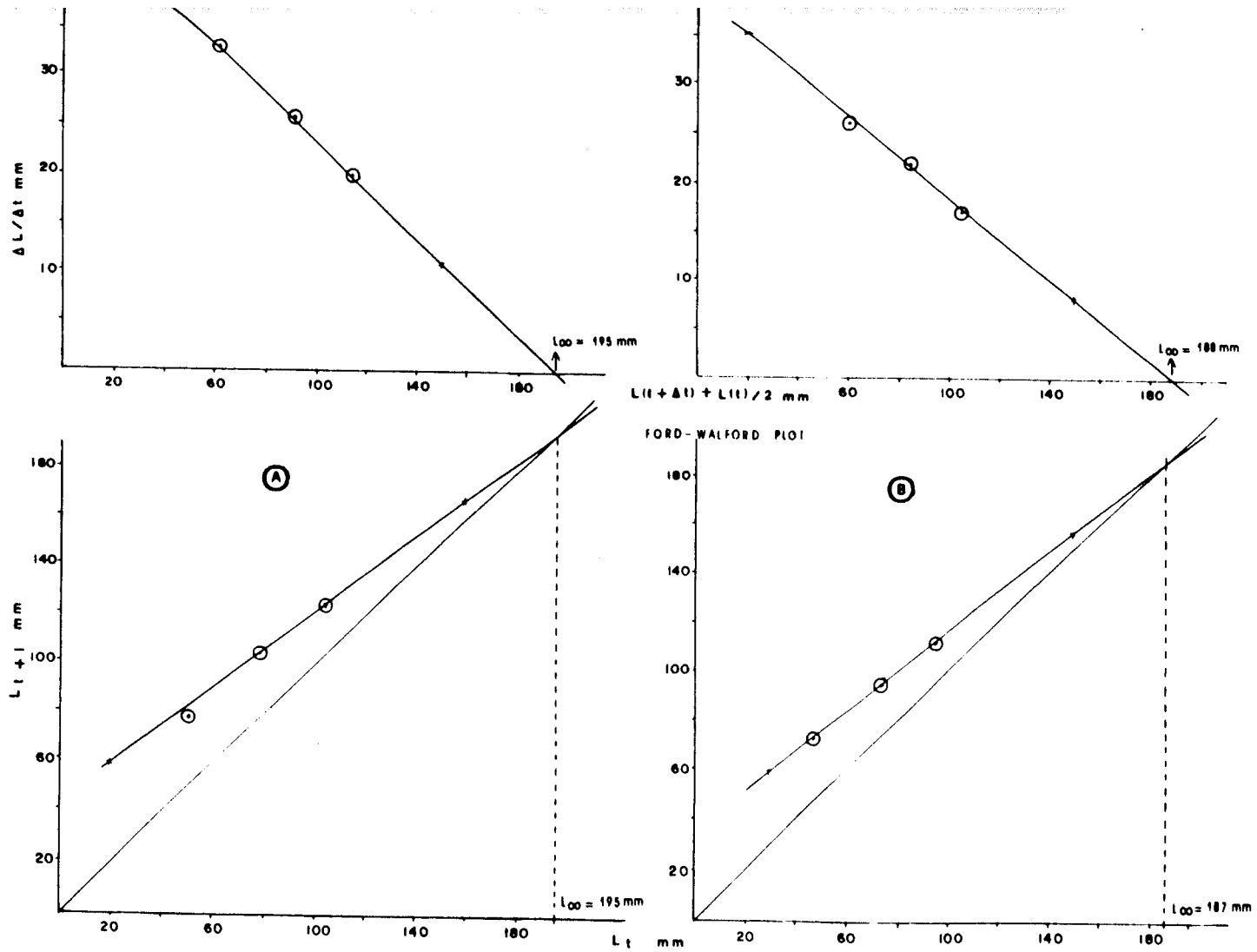


Fig. 6.17. *P. sanguinolentus*.
 Estimation of L_∞ for males (A) and females (B) by Gulland and Holt plot and Ford-Walford plot.

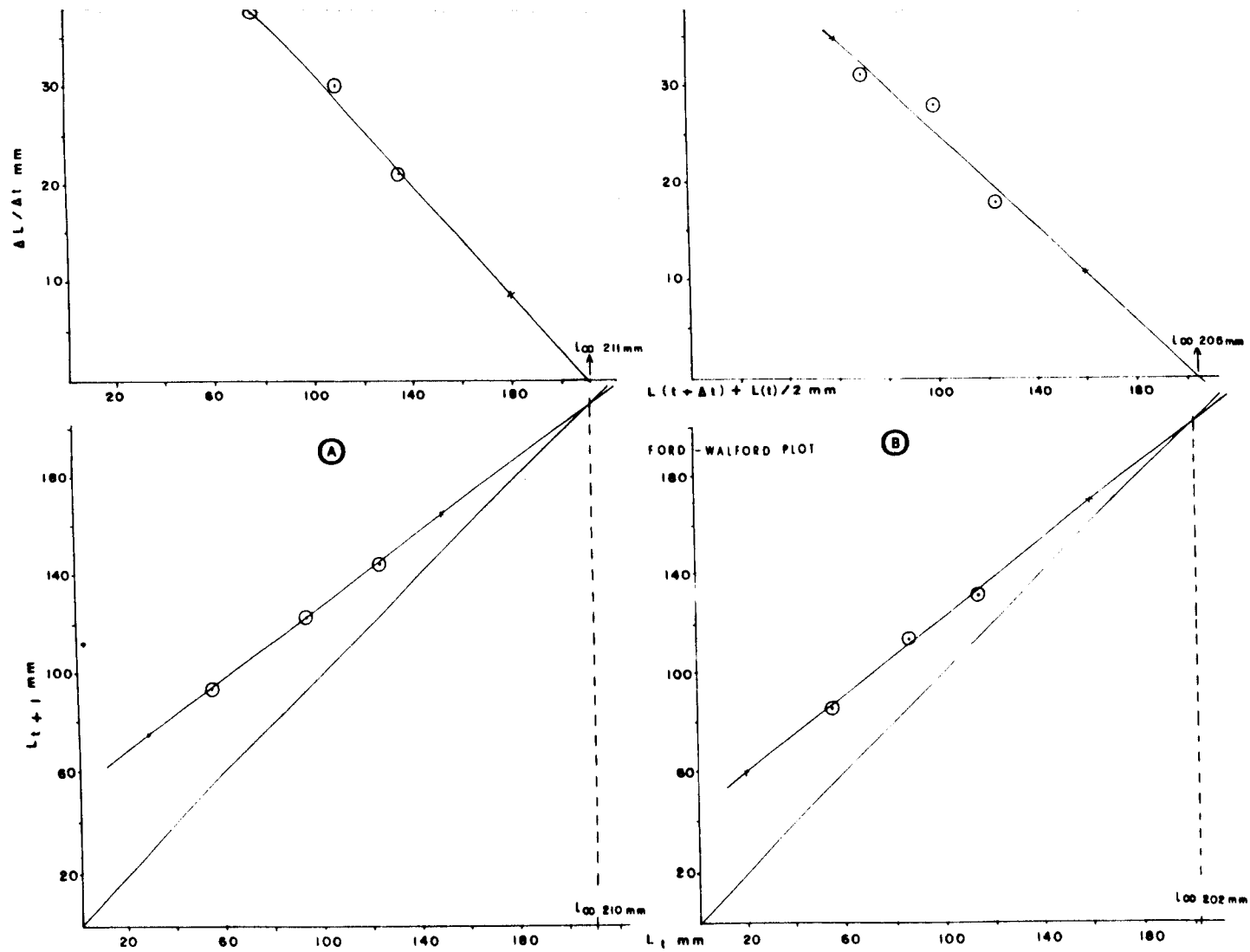
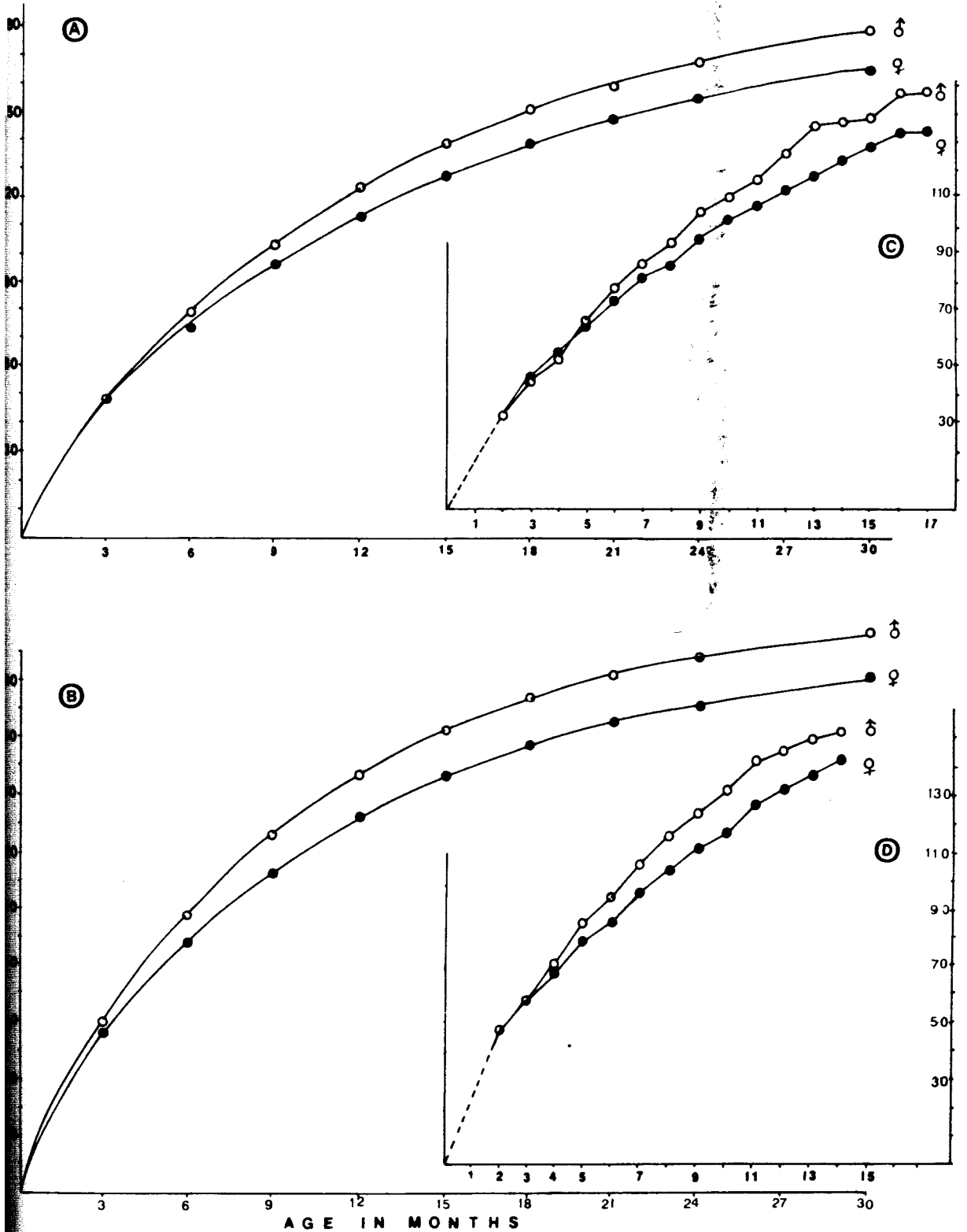


Fig. 6.18. *P. pelagicus*.
 Estimation of L_{∞} for males (A) and females (B) by Gulland and Holt plot and Ford-Walford plot.



19. Von Bertalanffy growth curve for *P. sanguinolentus* (A) and *P. pelagicus* (B). The mean size (CW) at age in months based on the scatter diagram for modal lengths - months for *P. sanguinolentus* (C) and *P. pelagicus* (D).

Chapter VII
STOCK ASSESSMENT

STOCK ASSESSMENT

INTRODUCTION

The introduction of mechanised trawling in early fifties for ground fishes has revolutionised the marine fisheries sector in India. It has not only resulted in locating new fishing grounds, exploiting a number of unexploited and underexploited finfish and shellfish resources, but also in substantial increase in marine fish production in the country. With the establishment of export market for marine products, particularly shrimps, there has been a spurt in trawling activities. Concomitant with these increased fishing activities, the marine fish production in the country has risen from 0.58 million tonnes in 1950 to 2.24 million tonnes in 1993 (Annon.,1995), of which bulk of the catch was landed by mechanised trawlers.

Several finfish and shellfish contribute to the exploited marine fishery resources of our country. Among shellfishes, crabs form an important group in the trawl fisheries as they are commercially important and have got export potential. Although their contribution to all-India catch was low in early sixties amounting to 4,000 tonnes, it increased steadily to 25,000 tonnes by nineties due to the expansion of trawl fisheries (In recent years, the trawl operations have extended to deeper waters upto 75 m, besides a change in pattern of fishing from single day to multi-day fishing).

In Karnataka, the annual average catch of marine crabs for the period 1983-93 amounted to 1,179 tonnes forming around 5.1 % of the marine crab production in the country and 1 % of the marine fish landing in the state.

The heavy exploitation by mechanised trawlers, operated mainly in the narrow coastal water regions, has resulted in wide fluctuations in abundance of these crabs as indicated by commercial catch statistics. This situation warranted better understanding

the magnitude and dynamics of exploitation of the individual species and the present study is directed to provide information on growth parameters, mortality, yield-per-recruit and stock assessment of these crabs from the Karnataka coast. The results of the study are also useful to evolve rational management strategies for judicious exploitation of these valuable resources.

2.0. MATERIALS AND METHODS

An integration of the data of different types of fishery was not attempted as there was marked variation in the size composition of the catches of these gears. Hence, for stock assessment, the data pertaining to trawl, which is the major single gear in the exploitation of crabs, are used.

It is assumed that the growth in carapace width follows VBG formula. The von Bertalanffy growth parameters, L_{∞} and K for males and females of *P. sanguinolentus* and *P. pelagicus* were estimated by using methods like, the Gulland and Holt plot (1959); the Ford-Walford plot (Ford, 1933; Walford 1946), in addition to the computerised method of ELEFAN (Pauly and David, 1981) from the size composition (carapace width) data collected from the trawl catches landed at Mangalore, Malpe and Karwar during 1992-94 (see chapter VI). However, for the stock assessment studies the growth parameters (mean) determined by the Gulland and Holt plot and the Ford-Walford plot and the results obtained in the modal size progression analysis were used as these values were found to be realistic and fairly accurate (see Chapter VI).

The total instantaneous mortality coefficient (Z) in respect of *P. sanguinolentus* and *P. pelagicus* were estimated from the size frequency data by the Beverton and Holt method (1957), the Length converted catch curve method of Pauly (1983), the Cumulative catch curve method of Jones and Van Zalinge (1981), and the Ssentongo and Larkin

method (1973), for 1992-93 and 1993-94 fishing seasons separately as done earlier (Murthy, 1990; Sukumaran, MS). In the case of length converted catch curve method and cumulative catch curve method, the confidence limits were calculated (Sparre *et al.*, 1989). Since there is variation in growth parameters, the Z has been estimated sex-wise.

Since it is not known, which method gives a true and realistic estimate of the Z , various methods were used to determine this parameter to facilitate comparison and cross checking.

The instantaneous natural mortality coefficient, M , is difficult to estimate. Since there is uncertainty in the value of M , different methods were used to determine this parameter. In the present study, M was found out by the following methods.

The Sekharan's (1974) method. Under this method, M was estimated assuming 99 % crabs by number would die if there was no exploitation by the time they attained t_{\max} and t_{\max} as corresponding to L_{\max} in the catch.

The Rikhter and Efanov (1976) method employing the following formula:

$$M = 1.521 (t_{m50})^{0.72} - 0.155$$

where, t_{m50} = age at which 50 % of the population mature.

The Pauly's (1980) method using the following empirical formula:

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

where, L_{∞} is expressed in cm, and T is the mean annual environmental temperature (29° is taken as the T in the present study). Although, Pauly (1980) has cautioned against use of his formula for crustaceans, it is useful in getting a reasonable estimate of M in penaeid prawns (Garcia *et al.*, 1981) and in the present study, it has been used along with other methods for comparison.

Since there was considerable variation in the Z and the M estimates, the mean values of these parameters were considered for rest of the studies.

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

$$F = Z - M$$

For size at capture (l_c) the value of carapace width corresponding to the mid-point of the first part in the descending part of the catch curve was taken. Mid-point of the smallest size group in the catch was taken as the size at recruitment (l_r).

Since the exponent of the carapace width-body weight relationship is nearer to 3, the BH yield-per-recruit analysis was adopted to study the present status of the stock. The yield-per-recruit (Y/R) as a function of annual fishing intensity, F (or annual exploitation ratio, $E = F/Z$) for the present age at capture (t_c) was estimated as per the analytical model of Beverton and Holt (1957) by employing the following equation suggested by Halland (1969).

$$Y/R = F \exp[-M(t_c - t_r)] W_\infty [1/Z - 3S/Z + K + 3S^2/Z + 2K - S^3/Z + 3K] \quad \dots 1$$

where,

$$S = \exp [-K(t_c - t_0)]$$

K = von Bertalanffy growth parameter

t_0 = von Bertalanffy growth parameter

t_c = age at first capture

t_r = age at recruitment

W_∞ = asymptotic body weight

F = fishing mortality

M = natural mortality

= F + M, total mortality

The weight asymptote, W_{∞} was calculated as the weight in g at L_{∞} , using the carapace width-weight relationship of the respective species.

For yield in weight (Y_w), the average annual catch of *P. sanguinolentus* and *P. flagicus* for the period 1991-93 was taken (this was estimated from the annual average crab landing in the state, using the mean percentage composition of these two species for Mangalore, Malpe and Karwar).

To estimate maximum sustainable yield (MSY), the absolute annual yield (Y) was calibrated graphically from the yield-per-recruit curve after plotting the mean annual Y for 1991-93 against the corresponding values of F or E (Corten, 1974). Since the yield curve was flat topped without any maxima, it was not possible to estimate the MSY by this graphical method. Hence, the MSY was estimated by obtaining the F_{max} and finding at the corresponding yield.

Estimation of stock in weight and number, absolute number of recruits, yield in number and mean weight of the species in the catch for various levels of Y/R as function of F and t_c is important for fishery prediction and management (Devaraj, 1983).

The annual exploitation rate (U) was estimated by the following equation of Ricker (1958):

$$U = F/Z [1 - \exp(-Z)] \quad \dots 2$$

The total stock at the beginning of the year, P is estimated from,

$$P = Y/U \quad \dots 3$$

where, Y = annual yield in tonnes, and U = exploitation rate. The absolute number of recruits (R) at age at capture (t_c) is estimated from the relation,

$$R = Y / Y/R \quad \dots 4$$

here, Y/R = yield in weight per recruit. The mean number in the exploited phase (\bar{P}_n) is estimated from,

$$\bar{P}_n = R (\bar{P}_n/R) \quad \dots 5$$

here, \bar{P}_n/R = the mean population number per recruit. The yield in number (Y_n) is computed from,

$$Y_n = R (Y_n/R) \quad \dots 6$$

here, Y_n/R = yield in number per recruit.

$$Y_n/R = \bar{P}_n/R \times F \quad \dots 7$$

The mean population number per recruit (\bar{P}_n/R) is computed from the following relationship given by Beverton and Holt (1957),

$$\bar{P}_n/R = \{1 - e^{-Mp}/M + e^{-Mp(1-e^{-(F+M)\lambda})} / (F+M)\} \quad \dots 8$$

p = recruits in numbers; M = natural mortality coefficient; F = fishing mortality coefficient; λ (lambda) = fishable life span of the species.

The mean weight of the crab in the annual catch, \bar{W}_y is estimated from,

$$\bar{W}_y = Y_w / Y_n \quad \dots 9$$

The initial population in number (N_o) is computed from,

$$N_o = Y_n / U \quad \dots 10$$

The average standing stock was estimated from,

$$Y/F \text{ or } Y_n \bar{W}_y / F = N \bar{W}_y \quad \dots 11$$

For studying the effect of change in the cod end mesh size, the following

procedure was followed. For each species, the present l_c values were converted into t_c values using VBG parameters employing the following inverse von Bertalanffy's equation.

$$t(L) = t_0 - 1/K \ln (1 - L/L_\infty) \quad \dots 12$$

The present t_c values were decreased and increased by the same factor (as 10%, -20 %, +10 %, +20 % etc.). Using these t_c values, the present F and other relevant parameters, the Beverton and Holt (1957) yield-per-recruit analysis was made using the computer programme BHYP incorporated in LFSA sub package (Sparre, 1987) for creating yield-mesh-curves.

To obtain the yield at different t_c , the Y_w/R obtained at different t_c for the current were raised to the R estimated as mentioned above.

The Y_w/R as a function of F for different M , keeping t_c and other parameters constant, were estimated for males and females of *P. sanguinolentus* and *P. pelagicus* to find out the influence of M on the yield curve.

The optimum age of exploitation (t_y) and potential yield-per-recruit (Y') were estimated from the following equation developed by Kutty and Qasim (1968).

$$Y' = a e^{-M(t_y - t_r)} \{ L_\infty - (L_\infty - l_0) e^{-k t_y} \}^b \quad \dots 13$$

where, t_y estimated from the equation,

$$e^{k t_y} = (L_\infty - l_0) (b k + M) / M L_\infty$$

and l_0 from,

$$l_0 = L_\infty (1 - e^{-k(t - t_0)})$$

k = growth coefficient; t_y = optimum age of exploitation in years; t_r = age at recruitment in years; l_0 = length in cm when $t = 0$; b and a = exponent and constant respectively in the carapace width- body weight relationship; Y' = optimum yield per recruit; M = natural mortality coefficient; L_∞ = length infinity in cm)

For Karnataka, the annual trawler effort in boat hour (bh) for 1983-1993 was calculated by dividing the annual crab catch by the average crab catch per boat hour estimated for the major centres (Mangalore and Malpe) for the respective years (see Chapter II). The total annual effort in boat hour was divided by the average trawling hours per day (8 hours) to convert effort into boat day (bd) which was then divided by the observed number of fishing days per year (215 days) for expressing the effort in trawlers per day (tpd) as suggested by Smitha and Devaraj (1990). The trawler effort for several years were calculated (Table 7.1) in order to monitor the growth of trawler fleet and also to facilitate the regulation of effort.

As there was no size composition data in respect of *P. sanguinolentus* and *P. lagicus* from 1983 to 1991, Z was estimated from the mean values of catchability coefficient ($q = F/f$) determined for the period 1992-94 (assuming that the mean values of q for 1992-94 to be true for the previous years, 1983-91 also) for which both annual fishing mortality coefficient (F) and fishing effort (f) are available. The F for the previous years were estimated to study the variability in fishing intensity over the years.

The optimum level of effort, $f(\text{MSY})$ and maximum sustainable yield (MSY) were also estimated using the 'surplus production models' like the Schaefer model (1954) and the Fox model (1970).

$$\text{Schaefer : } y(i)/f(i) = a + b f(i) \text{ if } f(i) \geq -a/b$$

$$\text{Fox : } \ln (y(i)/f(i)) = c + d f(i)$$

where, $y(i)$ = catch in the i th year; $f(i)$ = effort in the i th year; a and c = intercepts; b and d = slopes.

3.0. RESULTS

3.1. Instantaneous total mortality coefficient (Z)

The Z estimated by various methods for males and females of *P. sanguinolentus* and *P. pelagicus* exploited by different type of gears at Mangalore, Malpe and Karwar are presented in Tables 7.2-7.3. The Z estimated by length converted catch curve method and cumulative catch curve method for *P. sanguinolentus* and *P. pelagicus* are illustrated in Figs. 7.1-7.8. In *P. sanguinolentus* males, it ranged from 1.63 to 5.96, while in females, it ranged from 2.00 to 5.94. In the case of *P. pelagicus*, it ranged from 2.94 to 8.08 and from 2.75 to 8.10 in males and females respectively. The mean values of Z estimated for males and females in respect of trawl were 4.2 ± 0.51 and 3.9 ± 0.42 for *P. sanguinolentus* and 5.6 ± 0.71 and 4.8 ± 0.69 for *P. pelagicus*.

3.2. Instantaneous natural mortality coefficient (M) and Fishing mortality coefficient (F)

The natural mortality coefficient (M) estimated by various methods for males and females of *P. sanguinolentus* and *P. pelagicus* are given in Tables 7.4. It is seen that the M values varied from 1.08 to 1.85 in males and from 0.96 to 1.8 in females in the former species. In the latter species, it ranged from 1.15 to 2.09 in males and from 1.04 to 2.01 in females. The mean values of M in males and females were 1.6 and 1.5 for *P. sanguinolentus* and 1.7 and 1.6 for *P. pelagicus*.

The F values obtained in males and females were 2.6 and 2.4 for *P. sanguinolentus* and 3.9 and 3.2 for *P. pelagicus*.

3.3. Size at capture (l_c)

The size at capture (l_c) for *P. sanguinolentus* was 72.5 mm ($t_c = 0.45$ year) in

males and 82.5 mm ($t_c = 0.61$ year) in females. The l_c values for *P. pelagicus* were 92.5 mm ($t_c = 0.49$ year) and 97.5 mm ($t_c = 0.60$ year) in males and females respectively.

The size at recruitment (l_r) in males and females were 22.5 mm ($t_r = 0.11$ year) and 17.5 mm ($t_r = 0.02$ year) for *P. sanguinolentus* and 27.5 mm ($t_r = 0.12$ year) and 32.5 mm ($t_r = 0.11$ year) for *P. pelagicus*.

3.4. Yield-per-recruit (Y/R)

The values of W_∞ corresponding to L_∞ was calculated as 457.5683 g for males and 35.6378 g for females of *P. sanguinolentus*. The similar values for *P. pelagicus* were 16.2474 g and 535.4558 g respectively.

The yield per recruit in weight (Y_w/R) for males (at $M=1.6$; $t_c = 0.46$ year) and females (at $M = 1.5$; $t_c = 0.61$ year) for varying F in respect of *P. sanguinolentus* is depicted in Figs. 7.9A- 7.9B and Tables 7.5-7.6. Similarly, the Y_w/R for males (at $M = 1.7$; $t_c = 0.49$ year) and females ($M= 1.6$; $t_c = 0.60$ year) for varying F in the case of *P. pelagicus* is given in Tables 7.7-7.8 and Figs. 7.10A - 7.10B.

It is seen that the Y_w/R , at $M= 1.6$ and $t_c = 0.46$ year, steadily increased and reached a maximum of 21.95 g at $F_{max} = 2.23$ ($E = 0.53$) for 970 tpd (208.4×10^3 bd) and thereafter, marginally reduced to 21.87 g at the present $F = 2.6$ ($E = 0.62$) for 1130 tpd (243.0×10^3 bd) in *P. sanguinolentus* males (Fig.7.9A). The maximum sustainable yield (MSY) was estimated at 403.0 tonnes.

In the case of *P. sanguinolentus* females, at $M = 1.5$ and present $t_c = 0.61$ year, the Y_w/R increased to a maximum of 15.19 g at $F_{max} = 3.14$ ($E=0.81$) for 1490 tpd (320.0×10^3 bd). At the present of $F = 2.4$ ($E = 0.62$) for 1140 tpd (245.1×10^3 bd) the Y_w/R was 10.07 g. The maximum sustainable yield (MSY) was estimated at 373.0 tonnes (Fig. 7.9B).

In *P. pelagicus* males, the Y_w/R at $M = 1.7$ and $t_c = 0.49$ year, steadily increased to a maximum value of 49.93 g at $F_{max} = 3.06$ ($E = 0.55$) for 900 tpd (193.5×10^3 bd) and at the present $F = 3.9$ ($E=0.70$) for 1150 tpd (247.2×10^3 bd) the Y_w/R was 49.57 g (Fig. 7.10A). The MSY was estimated at 275.0 tonnes.

In *P. pelagicus* female, at $M=1.6$ and $t_c =0.60$ year, the Y_w/R steadily increased to 31.15 g at $F_{max} = 3.87$ ($E = 0.81$) for 1380 tpd (296.7×10^3 bd). At the present level of $F = 3.2$ ($E = 0.67$) for 1140 tpd (245.1×10^3 bd), the Y_w/R was 31.04 g (Fig. 7.10B). The MSY was estimated at 292.0 tonnes.

In *P. sanguinolentus* males, the yield increases with increasing effort and reaches a maximum of 403.0 tonnes at 85 % of the present effort (Fig 7.9A). In the female of the same species, the yield at MSY level was realised at 130 % of the present effort (Fig. 7.9B).

In *P. pelagicus* males, the yield increases with the increasing effort and reaches a maximum of 275.0 tonnes at 79 % of the present effort (Fig. 7.10A). In the female of the same species, it is seen that the yield increases with increasing effort and attain a maximum of 292.0 tonnes at 120 % of the present effort (Fig.7.10B).

Keeping M at the present level ($M =1.6$ and 1.5 in males and females of *P. sanguinolentus* and 1.7 and 1.6 in males and females of *P. pelagicus* respectively), the Y_w/R as a function of F for different values of t_c (Figs. 7.11A,7.11B, 7.12A, 7.12B),and yields as a function of the % of the present t_c for the present F in males and females of these species have been calculated (Figs. 7.11C,.7.11D, 7.12C, 7.12D). In addition, yields as percentage of the present t_c were also estimated for varying F for males and females of these crabs (Table 7.9). This study has indicated that the yield of *P. sanguinolentus* could be increased by 10.2 % in males and 3.8 % in females if the size at capture (l_c) is increased by 20 % in both sexes [from 72.5 mm (0.46 year) to 87 mm (0.58 year) in males and from

92.5 mm (0.61 year) to 99 mm (0.81 year) in females]. Similarly, in the case of *P. pelagicus*, the yield could be increased by 10.1 % in males and 2.6 % in females by increasing the l_c by 20 % in both sexes [from 92.5 mm (0.49 year) to 110 mm (0.63 year) in males and from 97.5 mm (0.61 year) to 117 mm (0.82 year) in females].

The Y_w/R as a function of fishing intensity for different values of M , keeping t_c constant are shown in Figs. 13A, 13B, 14A, and 14B. It is seen that the variation in the magnitude of M can have great influence on the shape of the curve of Y_w/R . The range of M taken (the maximum and the minimum values obtained in the study) taken as a possible range within which the mean natural mortality might lie. All the curves have the general same shape. It is seen that as M increases there is a marked decrease in $(Y_w/R)_{max}$ and an appreciable increase in the corresponding value of F_{max} .

The Figs. 7.15A, 7.15B, 7.16A and 7.16B show isopleths of annual yield in weight per recruit (Y_w/R) as a function of F and t_c for males and females of *P. sanguinolentus* and *P. pelagicus*. The horizontal lines at $t_c = 0.46$ year in Fig. 7.15A, $t_c = 0.61$ year in Fig. 7.15B, $t_c = 0.49$ year in Fig. 7.16A and $t_c = 0.60$ in Fig. 7.16B indicate the section corresponding to the curve of Figs. 7.9A, 7.9B, 7.10A and 7.10B respectively. The change of $(F)_{max}$ with t_c is shown approximately by the dotted line AA' (MSY curve). The value of $(t_c)_{max}$ increases with F . The course of this increase is indicated by the upper dotted line BB' (Eumetric fishing curve). The maximum possible value of Y_w/R is seen from Figs. 7.15A, 7.15B, 7.16A, 7.16B to be at $F = \infty$ ($E = 1$) corresponding to the value of t_c between 0.9 and 1 which is the meeting point of Eumetric fishing curve with MSY curve. This is the age at which the total weight of the brood is at its greatest. This is the optimum age of exploitation (t_y) and Y_w/R at t_y is the potential yield per recruit (Y'/R) according to Kutty and Qasim (1968).

For *P. sanguinolentus* males, the potential yield per recruit (Y') was 28.04 g at E

$E=1$ (F_{∞}) and $t_y = 1.0$ yr in the yield isopleth diagram shown in Fig. 7.15A. The optimum age of exploitation (t_y) and potential yield per recruit (Y') were estimated independently according to the method of Kutty and Qasim (1968) at 1.07 years ($l_c = 128$ mm) and 27.55 g respectively which were very close to the values determined by yield per recruit analysis and shown in Fig. 7.15A.

In *P. sanguinolentus* females, Y' was found to be 17.2 g for $t_y = 1.0$ year at $E = 1$ (F_{∞}) (Fig. 7.15B). The independent estimates of Y' and t_y were 19.28 g and 1.08 years respectively which were very near these values obtained by yield per recruit analysis.

In *P. pelagicus* males, the potential yield per recruit (Y') was 58.48 g for $t_c = 0.9$ year for $E=1$ (F_{∞}) (Fig. 7.16A). The independent estimates of Y' and t_y were 47.3 g and 0.96 years ($l_c = 149$ mm) respectively. Although there was marginal variation in these estimate of Y' , the t_y value was very close to the values determined by yield per recruit analysis (Fig. 7. 16A).

In the *P. pelagicus* females, the Y' and t_y estimated independently at 30.9 g and 0.95 years (135 mm) which were very near the estimates obtained by yield per recruit analysis (34.63 g and 0.96 year respectively)(Fig. 7.16B).

3.5. Stock assessment

The annual average yield (Y), the Standing Stock (Y/F), the average stock (Y/U), the MSY, mean population number (\bar{P}_n), yield in number (Y_n), mean population number per recruit (\bar{P}_n/R), mean number per recruit (\bar{Y}_n/R), yield in weight per recruit (Y_w/R) and biomass per recruit (P_w/R) estimated for the present F and t_c in respect of males and females of *P. sanguinolentus* and *P. pelagicus* for Karnataka waters are given Table 7.10-7.11. The initial population number (N_0) is estimated at 99.228 million for *sanguinolentus* and 40.563 million for *P. pelagicus*.

The Standing Stocks were estimated at 308.0 tonnes for *P. sanguinolentus* (154.0 tonnes for males and 154.0 tonnes for females) and 161.0 tonnes for *P. pelagicus* (70.0 tonnes for males and 91.0 tonnes for females).

As a first approximation the MSYs for the species (sexwise) were pooled to arrive at a 'pooled MSY' for the crab stocks and the corresponding $f_{(MSY)}$ were estimated graphically. The MSY estimated by Beverton and Holt model were 776.0 tonnes (403.0 tonnes for males and 373.0 tonnes for females) for *P. sanguinolentus* and 567.0 t (275.0 for males and 292.0 for females) for *P. pelagicus*, while the annual average yield for the period 1991-93 were 771.0 tonnes (401.0 tonnes and 370.0 tonnes for males and females respectively) for the former species and 564.0 tonnes (273.0 t for males and 291.0 tonnes for females) for the latter.

The Annual Average Stock for *P. sanguinolentus* and *P. pelagicus* were 1272.0 tonnes (658.0 tonnes for males and 614.0 tonnes for females) and 834.0 tonnes (394.0 tonnes for males and 440.0 tonnes for females) respectively.

The annual mean number of the population (\bar{P}_n) in the exploited area and the yield in number (Y_n) for the present level of F and t_c in *P. sanguinolentus* were 24.149 million and 59.965 million respectively. For *P. pelagicus*, the \bar{P}_n and Y_n were 7.897 million and 27.251 million respectively (Tables 7.10-7.11).

The MSY and $f_{(MSY)}$ estimated for *P. sanguinolentus* and *P. pelagicus* by different methods are as follows.

Method	MSY	$f_{(MSY)}$
Beverton and Holt	1343 tonnes	1190 tpd (225.8 x 10 ³ bd)
	1100 tonnes	1120 tpd (240.8 x 10 ³ bd)
Lafer	1450 tonnes	1660 tpd (356.9 x 10 ³ bd)

4.0. DISCUSSION

Despite their economic significance, the dynamics of the exploited population of these crabs remain poorly understood as there is no information on mortality and stock assessment of brachyurans from India. Hence, the present results could not be compared with works of similar nature. However, there are some studies on the stock assessment of other crustaceans, particularly on prawns from the southwest coast of India (Alagaraja *et al.*, 1986; George *et al.*, 1988; Smitha and Devaraj, 1990, Sukumaran *et al.*, 1993; Sukumaran *et al.*, 1993a; and Sukumaran, MS).

It is seen that the total mortality (Z) in the penaeid prawn, *Metapenaeus monoceros* estimated by various authors ranged from 3.2 to 11.6 in males and 1.1 to 8.5 in females (George *et al.*, 1988; Sukumaran *et al.*, 1993; Sukumaran, MS), whereas, in the case of another penaeid, *Metapenaeus dobsoni*, the annual average Z ranged from 16.5 to 25.3 in males and from 16.3 to 20.5 in females. (Sukumaran *et al.*, 1993a). In another study on the same species, Smitha and Devaraj (1990) estimated Z ranging between 3.4 and 5.3. In the case of the portunids studied, the Z ranged from 1.63 to 5.96 in males and from 2.00 to 5.94 in females of *P. sanguinolentus*, while in *P. pelagicus*, it ranged from 4 to 8.08 in males and from 2.75 to 8.10 in females in the trawler catches. It is seen that the Z values obtained in these portunids were near to the similar values estimated for *M. monoceros*. However, in *M. dobsoni*, the Z is very high since it is an intensively exploited coastal resource.

Although there was wide variation in the annual Z for *M. dobsoni* estimated by various workers, the annual average M determined by these workers was found to be 2.3 for both sexes in this species (Smitha and Devaraj, 1990; George *et al.*, 1988, Alagaraja *et al.*, 1986, Sukumaran *et al.*, 1993a). In the case of *M. monoceros*, The annual M , estimated by various workers, ranged from 1.8 to 2.6 in males and 1.8 to 2.3 in females

(George *et al.*, 1988, Sukumarn *et al.*, 1993, Sukumaran, MS).

It is well known that information on mortality is extremely critical to the study of population dynamics. Considering the fact that there was no previous record on the estimation of Z in portunids, care was taken to estimate this vital parameter. As a cross-check, different methods were employed in estimating Z in the present study. Accordingly, the annual average Z for males and females were 4.2 and 3.9 in *P. sanguinolentus* and 5.6 and 4.8 in *P. pelagicus* respectively.

In view of the uncertainty in the estimation of M , it was estimated by three different methods. The annual mean values of M for males and females were 1.6 and 1.5 for the former and 1.7 and 1.6 for the latter species respectively.

In the penaeids, *M. dobsoni* and *M. monoceros*, the fishing mortality coefficient (F) was found to be relatively high in males as compared to that of females (Sukumaran *et al.*, 1993, 1993a). This may be largely due to the fact that males are subjected to more fishing mortality as they remain in the fishing ground throughout the fishing season, whereas, females avoid the gear during certain part of the year as they move out of the fishing ground for breeding purposes. A similar situation is discernible in portunids too, with males having higher F values (2.6 in *P. sanguinolentus* and 3.9 in *P. pelagicus*), while females recording lower values of F (2.4 for the former and 3.2 for the latter species). This may probably be due to the migration of females to deeper waters for hatching their eggs thereby subjected to less fishing mortality as compared to males (see Chapter V).

In the first half of eighties (1983-86), the Z was relatively low ranging from 2.0 to 3.3 in males and 2.3 to 3.0 in females of *P. sanguinolentus* (Table 7.12). In *P. pelagicus*, Z ranged from 3.5 to 4.2 in males and 2.7 to 3.3 in females. Since the second half of eighties, the fishing became more intense due to the addition of more and more trawlers

resulting in higher values of Z (3.5-6.7 in males and 3.5 - 6.4 in females of *P. sanguinolentus* and 4.6 - 9.2 in males and 3.9 - 7.8 in females of *P. pelagicus*).

The catchability coefficient (q) could be estimated only for 1992-94 season since Z and f values were available only for this period. Although, q may vary significantly from year to year, a constant value of q was used to estimate F for the previous years as there was no alternate means of estimating F for this method. However, this method gave a fairly accurate values of F as is evident from Figs. 7.9A, 7.9B, 7.10A and 7.10B, where the catch during 1983-93 were superimposed against F or E . In addition, the values of average annual F estimated by this method for 1983-93 period and the same arrived by several other methods for 1992-94 in males and females of *P. sanguinolentus* and *P. pelagicus* were more or less same.

For Karnataka waters, the annual average stock was estimated at 2106 tonnes (*P. sanguinolentus* = 1272 tonnes + *P. pelagicus* = 834 tonnes), whereas the maximum sustainable yield (MSY) was estimated at 1343 tonnes (*P. sanguinolentus* = 776 tonnes + *P. pelagicus* = 567 tonnes) by the yield per recruit model of Beverton and Holt which is found to be very close to the annual average yield of 1335 tonnes (*P. sanguinolentus* = 771 tonnes + *P. pelagicus* = 564 tonnes) obtained during 1991-93 period.

To estimate the optimum level of effort, i.e. the effort which produces the maximum sustainable yield, $f_{(MSY)}$, the surplus production models like the Schaefer (1954) model and the Fox (1970) model were used in addition to the yield per recruit model of Beverton and Holt in order to arrive at a true estimate of $f_{(MSY)}$. The estimates of the MSY and the $f_{(MSY)}$ for total crabs for Karnataka waters were 1610 tonnes and 40 tpd (395.6×10^3 bd), whereas the similar values got by employing the Fox model are 1220 tonnes and 1250 tpd (268.7×10^3 bd) respectively for 1983-93 period. Since the MSY estimated by these two models include other crabs (which form about 10 % of

all crabs) also, the MSY for *P. sanguinolentus* and *P. pelagicus* alone may be around 90 % of these estimates (i.e. 1450 tonnes by the Schaefer model and 1100 tonnes by the Fox model). The MSY estimates by the yield per recruit model (1343 tonnes for these two species together) was between the estimates obtained by the Schaefer model and the Fox model and found to be fairly accurate. Although the annual yield was lower than the MSY in most of the years, it exceeded MSY level in 1986, 1987 and 1992.

The annual average of $f_{(MSY)}$ for *P. sanguinolentus* and *P. pelagicus* together was estimated at 1190 tpd which is very close to the value obtained by the Fox model (1120 tpd which is 90 % of $f_{(MSY)}$ estimated for all crabs). The estimate of $f_{(MSY)}$ by the Schaefer model was found to be on the higher side (1660 tpd or 356.9×10^3 bd).

The present studies indicate that, for *P. sanguinolentus* and *P. pelagicus*, the prevailing fishing intensity for males ($F = 2.6$ or $E = 0.62$ for the former species, $F = 3.9$ or $E = 0.70$ for the latter) was more , whereas it was low for females ($F = 2.4$ or $E = 0.62$ for the former species, and $F = 3.2$ or $E = 0.67$ for the latter). However, since the current yield of males and females of these two crabs are very close to MSY level, it will be advantageous if the effort is maintained at the current level (1130 tpd or 243.0×10^3 bd) itself to obtain biologically optimum yields.

Since the cod-end mesh size is small (28- 35 mm), large quantities of juveniles of these crabs are retained by trawl net all through the year. This is detrimental to the crab stocks and warranted some urgent regulatory measures for the conservation of the resources. As the exploited area contains several species of commercial importance that are caught simultaneously by the same gear, any method of regulation applied for one resource should not affect another resource adversely. Hence several factors have to be taken into account in arriving at the most suitable form of regulation for the area as a whole. Eventhough there are several methods of regulation (minimum mesh size,

minimum legal size, reduction of power of fishing vessels, reduction of catch, control of fishing activity, closed season, closed areas, controlled building of fleets etc.), taking into consideration several factors (economic, social, biological etc.), mesh regulation along with certain amount of control of fishing intensity appears to be the most appropriate and suitable method for the conservation and management of the marine crab resources in Karnataka.

In the light of the requirements for optimum fishing and also to increase the size at capture (l_c) by 20 % (t_c by around 30 %) to permit the young crabs to escape through the meshes of the net and thereby enhance the yield subsequently, an increase in cod-end mesh size to 40 mm from 33 mm (mean) would seem to be a practical and ideal one. In addition, there is an urgent need to restrict the effort at the present level (1130 tpd or 243.0×10^3 bd) as a management strategy to prevent over-exploitation of these valuable resources in the coastal waters of Karnataka.

TABLE 7.1.
Crab catch and trawl effort estimated for 1983-93 for the
Karnataka coast.

Year	total crabs	catch rate	Effort	
	(t)	(t)	bd x 1000	tpd
	Y	Y/f		
1983	533	0.722	158.6	738
1984	476	0.769	83.8	390
1985	596	0.963	133.0	619
1986	1868	3.565	112.8	524
1987	2575	1.703	325.1	1512
1988	762	0.344	476.2	2215
1989	771	0.809	205.0	953
1990	948	1.135	179.5	835
1991	1181	1.136	223.6	1040
1992	2069	1.377	323.3	1503
1993	1174	1.376	182.4	853
Average for 1983-93	1179	1.158	218.6	1016
Average for 1991-93	1475	1.303	243.1	1132

bd =boat day; tpd = trawl per day.

TABLE 7.2

Estimates of total mortality coefficient (Z) in *P. sanguinolentus* at Mangalore, Malpe and Karwar during 1992-93 and 1993-94 .

Centre/gear	Fishing season	Pauly's method (1983)	Cumulative catch curve method of Jones & Van Zalinge (1981)	Beverton & Holt (1956)	Ssentongo & Larkin method (1973)	Average
MALE						
Mangalore (TN)	1992-93	5.62 ± 1.83	2.57 ± 0.46	2.66	3.12	3.49
	1993-94	4.24 ± 1.42	4.14 ± 0.34	4.93	5.37	4.67
Malpe (TN)	1992-93	1.63 ± 0.82	2.26 ± 0.72	2.78	3.24	2.48
	1993-94	4.93 ± 0.40	5.49 ± 0.23	5.01	5.47	5.23
Karwar (TN)	1992-93	4.33 ± 1.01	5.07 ± 0.35	5.53	5.96	5.22
	1993-94	4.19 ± 0.72	3.38 ± 0.97	4.23	4.66	4.13
Karwar (SS)	1992-93	4.35 ± 1.01	4.44 ± 0.30	5.06	5.41	4.82
		4.91 ± 1.39	4.75 ± 0.47	5.16	5.62	5.11
Average for TN		4.17	3.82	4.19	4.64	4.20
FEMALE						
Mangalore (TN)	1992-93	2.00 ± 1.02	2.80 ± 0.97	2.69	3.06	2.64
	1993-94	5.19 ± 0.88	5.31 ± 0.50	5.58	5.94	5.50
Malpe (TN)	1992-93	3.78 ± 0.63	4.33 ± 0.43	4.57	4.94	4.40
	1993-94	3.72 ± 1.40	4.18 ± 0.38	3.60	3.99	3.87
Karwar (TN)	1992-93	3.49 ± 0.45	3.71 ± 0.34	3.90	4.25	3.84
	1993-94	2.64 ± 1.37	2.91 ± 0.19	3.09	3.45	3.02
Karwar (SS)	1992-93	3.63 ± 0.97	5.02 ± 0.59	5.39	5.79	4.95
	1993-94	4.20 ± 1.09	4.36 ± 0.67	4.12	4.52	4.30
Average for TN		3.47	3.87	3.90	4.27	3.88

N = trawl net; SS = shore seine

TABLE 7.3.
Estimates of total mortality coefficient (Z) in *P. pelagicus* at Mangalore, Malpe and Karwar during 1992-93 and 1993-94.

Centre/gear	Fishing season	Pauly's method (1982)	Cumulative catch curve method of Jones & Van Zalinge (1981)	Beverton & Holt (1956)	Ssentango & Larkin method (1973)	Average
MALE						
Mangalore (TN)	1992-93	7.27 ± 1.66	6.90 ± 1.14	6.31	6.83	6.85
	1993-94	6.14 ± 1.07	7.69 ± 0.62	7.34	7.99	7.32
Mangalore (MT) (estuary)	1992-93	9.70 ± 2.71	10.12 ± 2.69	11.58	12.09	10.91
	1993-94	6.42 ± 1.91	9.85 ± 1.12	9.53	10.03	9.03
Malpe (TN)	1992-93	7.47 ± 0.83	8.08 ± 1.68	6.09	6.53	6.95
	1993-94	2.94 ± 0.90	3.84 ± 1.72	4.11	4.62	3.87
Karwar (TN)	1992-93	6.07 ± 1.84	3.56 ± 0.53	3.51	4.03	4.29
	1993-94	3.10 ± 0.73	4.04 ± 0.41	4.48	4.47	4.01
Karwar (SS)	1992-93	5.57 ± 1.63	5.08 ± 1.53	4.92	5.54	5.29
		7.19 ± 2.10	6.54 ± 0.89	7.59	8.04	7.40
Average for TN		5.50	5.69	5.31	5.75	5.56
FEMALE						
Mangalore (TN)	1992-93	6.46 ± 1.99	4.77 ± 0.77	4.22	5.80	5.31
	1993-94	7.67 ± 1.44	7.34 ± 0.84	7.53	8.04	7.65
Mangalore (MT) (estuary)	1992-93	7.43 ± 2.46	8.94 ± 0.92	8.91	9.42	8.68
	1993-94	4.07 ± 1.70	4.18 ± 1.78	6.39	6.90	5.39
Malpe (TN)	1992-93	3.58 ± 1.49	4.28 ± 1.12	4.55	5.03	4.36
	1993-94	4.10 ± 2.26	3.04 ± 1.26	3.45	3.93	3.63
Karwar (TN)	1992-93	4.90 ± 1.51	2.98 ± 0.56	2.91	3.42	3.55
	1993-94	2.75 ± 1.30	3.27 ± 0.64	5.69	3.82	3.88
Karwar (SS)	1992-93	8.17 ± 1.75	6.09 ± 1.65	7.44	7.93	7.41
	1993-94	2.68 ± 0.55	4.69 ± 1.69	2.40	2.89	3.17
Average for TN		4.91	4.28	4.73	5.01	4.73

N = trawl net; MT = mini trawl; SS = shore seine

TABLE 7.4.
Estimates of natural mortality coefficient (M) for *P. sanguinolentus* and *P. pelagicus* by different methods.

Method	<i>P. sanguinolentus</i>		<i>P. pelagicus</i>	
	Male	Female	Male	Female
Pauly (1980)	1.08	0.96	1.15	1.04
Beverton & Efanov (1976)	1.85	1.77	2.09	2.01
Charan (1974)	1.80	1.80	1.80	1.80
Average	1.60	1.50	1.70	1.60

TABLE 7.5.
Yield per recruit (Yw/R) and Biomass per recruit (Bw/R)
for different Fishing mortality coefficient (F) in
***P. sanguinolentus* males.**

F	Y/R in g	B/R in g
0.000	0.000	45.734
0.200	7.436	37.181
0.400	12.344	30.860
0.600	15.636	26.061
0.800	17.865	22.332
1.000	19.378	19.378
1.200	20.398	16.998
1.400	21.075	15.053
1.600	21.508	13.443
1.800	21.769	12.094
2.000	21.906	10.953
2.200	21.953	9.978
2.400	21.935	9.139
2.600	21.871	8.412
2.800	21.773	7.776
3.000	21.653	7.217
3.200	21.516	6.723
3.400	21.368	6.284
3.600	21.213	5.892
3.800	21.055	5.541
4.000	20.896	5.224
4.200	20.737	4.937

Fmax = 2.236

MSY/R = 21.954

F0.1 = 1.151

Y/R for F = F0.1 : 20.186

Parameters used

W ∞ = 457.57g
 K = 0.99
 t0 = -0.0132
 M = 1.6
 tc = 0.46
 tr = 0.11

TABLE 7.6.

**Yield per recruit (Yw/R) and biomass per recruit (Bw/R)
at different fishing mortality coefficients (F) for
P. sanguinolentus females.**

F	Y/R in g	B/R in g
0.000	0.000	29.153
0.200	4.745	23.727
0.400	7.905	19.762
0.600	10.064	16.773
0.800	11.569	14.461
1.000	12.634	12.634
1.200	13.396	11.163
1.400	13.944	9.960
1.600	14.339	8.962
1.800	14.624	8.124
2.000	14.827	7.413
2.200	14.970	6.804
2.400	15.067	6.278
2.600	15.130	5.819
2.800	15.167	5.417
3.000	15.185	5.061
3.200	15.187	4.746
3.400	15.178	4.464
3.600	15.161	4.211
3.800	15.137	3.983
4.000	15.108	3.777

F_{max} = 3.137 MSY/R = 21.954

F_{0.1} = 1.259 Y/R for F = F_{0.1}: 13.578

Parameters used

W_∞ = 355.64g

K = 0.82

t₀ = -0.0975

M = 1.5

t_c = 0.61

t_r = 0.02

TABLE 7.7.
Yield per recruit (Yw/R) and biomass per recruit (Bw/R)
at different fishing mortality coefficients (F) for
***P. pelagicus* males.**

F	Y/R in g	B/R in g
0.000	0.000	86.734
0.200	14.460	72.303
0.400	24.536	61.340
0.600	31.686	52.810
0.800	36.830	46.038
1.000	40.568	40.568
1.200	43.301	36.084
1.400	45.305	32.361
1.600	46.772	29.232
1.800	47.839	26.577
2.000	48.606	24.303
2.200	49.145	22.338
2.400	49.510	20.629
2.600	49.743	19.132
2.800	49.873	17.811
3.000	49.923	16.641
3.200	49.913	15.598
3.400	49.856	14.663
3.600	49.763	13.823
3.800	49.642	13.064
4.000	49.501	12.375
4.200	49.344	11.748
4.400	49.175	11.176
4.600	48.998	10.652
4.800	48.816	10.170
5.000	48.631	9.726
5.200	48.443	9.316
5.400	48.256	8.936
5.600	48.069	8.583
5.800	47.883	8.255

$F_{max} = 3.061$ $MSY/R = 49.221$

$F_{0.1} = 1.39$ Y/R for $F = F_{0.1} : 45.222$

Parameters used

$W_{\infty} = 816.25g$
 $K = 1.14$
 $t_0 = -0.0194$
 $M = 1.7$
 $t_c = 0.49$ yr
 $t_r = 0.12$ yr

TABLE 7.8.
Yield per recruit (Yw/R) and Biomass per recruit (Bw/R)
at different fishing mortality coefficients (F) for
***P. pelagicus* females.**

F	Y/R in g	B/R in g
0.000	0.000	52.215
0.200	8.672	43.362
0.400	14.688	36.721
0.600	18.961	31.603
0.800	22.055	27.569
1.000	24.329	24.329
1.200	26.020	21.683
1.400	27.290	19.493
1.600	28.249	17.656
1.800	28.977	16.098
2.000	29.531	14.765
2.200	29.950	13.614
2.400	30.268	12.611
2.600	30.505	11.732
2.800	30.680	10.957
3.000	30.807	10.269
3.200	30.894	9.654
3.400	30.951	9.103
3.600	30.984	8.606
3.800	30.998	8.157
4.000	30.996	7.749
4.200	30.981	7.376
4.400	30.957	7.035
4.600	30.926	6.723
4.800	30.888	6.435
5.000	30.845	6.169

Fmax = 3.87 MSY/R = 30.999 g
 F0.1 = 1.437 Y/R for F = F0.1: 27.486

Parameters used

W ∞ = 535.46g
 K = 0.97
 t0 = -0.0691
 M = 1.6
 tc = 0.601 yr
 tr = 0.11 yr

TABLE 7.9.
Yield at different tc in relation to varying F in males and females of *P. sanguinolentus* and *P. pelagicus*.

<i>P. sanguinolentus</i>								
				RELATIVE F				
Male		tc (year)	corresponding lc (mm)	-20 %	-10%	No Change	+10 %	+20 %
				2.1	2.3	2.6	2.9	3.1
RELATIVE VALUE OF tc	-20 %	0.37	61.0	386.3	385.1	381.7	377.0	373.7
	-10 %	0.41	67.0	368.3	365.6	382.0	353.7	349.3
	No change	0.46	72.5	401.6	402.5	401.0	398.1	395.8
	+10 %	0.50	78.0	415.8	417.5	417.9	416.7	415.4
	+20 %	0.55	83.0	427.1	430.0	432.0	432.7	432.3
	+30 %	0.59	87.0	435.9	440.1	444.0	445.9	446.4
<i>P. pelagicus</i>								
				RELATIVE F				
Female		tc (year)	corresponding lc (mm)	-20 %	-10%	No Change	+10 %	+20 %
				1.9	2.2	2.4	2.6	2.9
RELATIVE VALUE OF tc	-20 %	0.49	71.5	343.5	345.3	345.3	344.6	342.8
	-10 %	0.54	77.0	354.1	358.0	359.2	359.7	359.4
	No change	0.61	82.5	361.8	367.6	370.0	371.5	3722.7
	+10 %	0.67	87.6	366.8	374.2	377.7	380.2	382.7
	+20 %	0.73	92.5	369.1	378.0	382.3	385.7	389.4
	+30 %	0.79	97.1	368.9	379.1	384.2	388.3	393.0
<i>P. pelagicus</i>								
				RELATIVE F				
Male		tc (year)	corresponding lc (mm)	-20 %	-10%	No Change	+10 %	+20 %
				3.1	3.5	3.9	4.3	4.7
RELATIVE VALUE OF tc	-20 %	0.39	78.7	248.7	245.3	241.7	239.9	234.1
	-10 %	0.44	85.7	262.9	261.0	258.5	255.8	252.9
	No change	0.49	92.5	274.9	274.3	273.0	271.3	269.3
	+10 %	0.54	99.0	284.6	285.2	285.0	284.3	283.2
	+20 %	0.58	105.0	291.8	293.6	294.4	294.6	294.3
	+30 %	0.63	110.7	296.8	299.6	301.4	302.3	302.8
<i>P. pelagicus</i>								
				RELATIVE F				
Female		tc (year)	corresponding lc (mm)	-20 %	-10%	No Change	+10 %	+20 %
				2.6	2.9	3.2	3.5	3.8
RELATIVE VALUE OF tc	-20 %	0.48	84.3	269.9	269.8	269.0	267.9	266.0
	-10 %	0.54	91.1	280.1	281.2	281.5	281.1	280.5
	No change	0.60	97.5	287.4	289.7	291.0	291.7	292.0
	+10 %	0.66	103.5	291.9	295.2	297.4	298.9	299.9
	+20 %	0.72	109.0	293.8	297.9	301.0	303.2	304.9
	+30 %	0.78	114.6	293.2	298.1	302.0	304.8	307.1

tc = age at first capture ; lc = size at capture

TABLE 7.10.

Estimates of Total Annual Stock (Y/U), Annual Standing Stock (Y/F), Yield-per-recruit (Yw/R), Biomass-per-recruit (Bw/R), Recruits in Numbers and Maximum sustainable Yield (MSY), mean population in number, yield in number and mean population number per recruit, yield in number per recruit for *P. sanguinolentus* in the Karnataka waters.

	Z	M	F	E	U	Annual average yield (t)	Total Annual Stock (Y/U)	Average Standing Crop (Y/F)	Yw/R (g)	Bw/R (g)	Recruits ('000 nos.)	MSY (t)	Pn (millions)	Pn/R	Yn (millions)	Yn/R	Wy (g)
Male	4.2	1.6	2.6	0.62	0.61	401.0	658.0	154.0	21.8	8.4	18334.7	403.0	10.029	0.547	26.076	1.422	15.38
Female	3.9	1.5	2.4	0.62	0.60	370.0	614.0	154.0	15.1	6.3	24557.0	373.0	14.120	0.575	33.889	1.380	10.92
Total						771.0	1272.0	308.0	36.9	14.7	42891.7	776.0	24.149	1.122	59.965	2.802	12.86

TABLE 7.11.

Estimates of Total Annual Stock (Y/U), Annual Standing Stock (Y/F), Yield-per-recruit (Yw/R), Biomass-per-recruit (Bw/R), Recruits in Numbers and Maximum sustainable Yield (MSY), mean population in number, yield in number and mean population number per recruit, yield in number per recruit in *P. pelagicus* in the Karnataka waters.

	Z	M	F	E	U	Annual average yield (t)	Total Annual Stock (Y/U)	Average Standing Crop (Y/F)	Yw/R (g)	Bw/R (g)	Recruits ('000 nos.)	MSY (t)	Pn (million)	Pn/R	Yn (millions)	Yn/R	Wy (g)
Male	5.6	1.7	3.9	0.70	0.70	273.0	394.0	70.0	49.6	12.7	5507.1	275.0	2.827	0.503	11.027	2.001	24.76
Female	4.8	1.6	3.2	0.67	0.66	291.0	440.0	91.0	31.0	9.7	9374.1	292.0	5.070	0.541	16.224	1.731	17.94
Total						564.0	834.0	161.0	80.6	22.4	14881.2	567.0	7.897	1.054	27.251	3.732	20.70

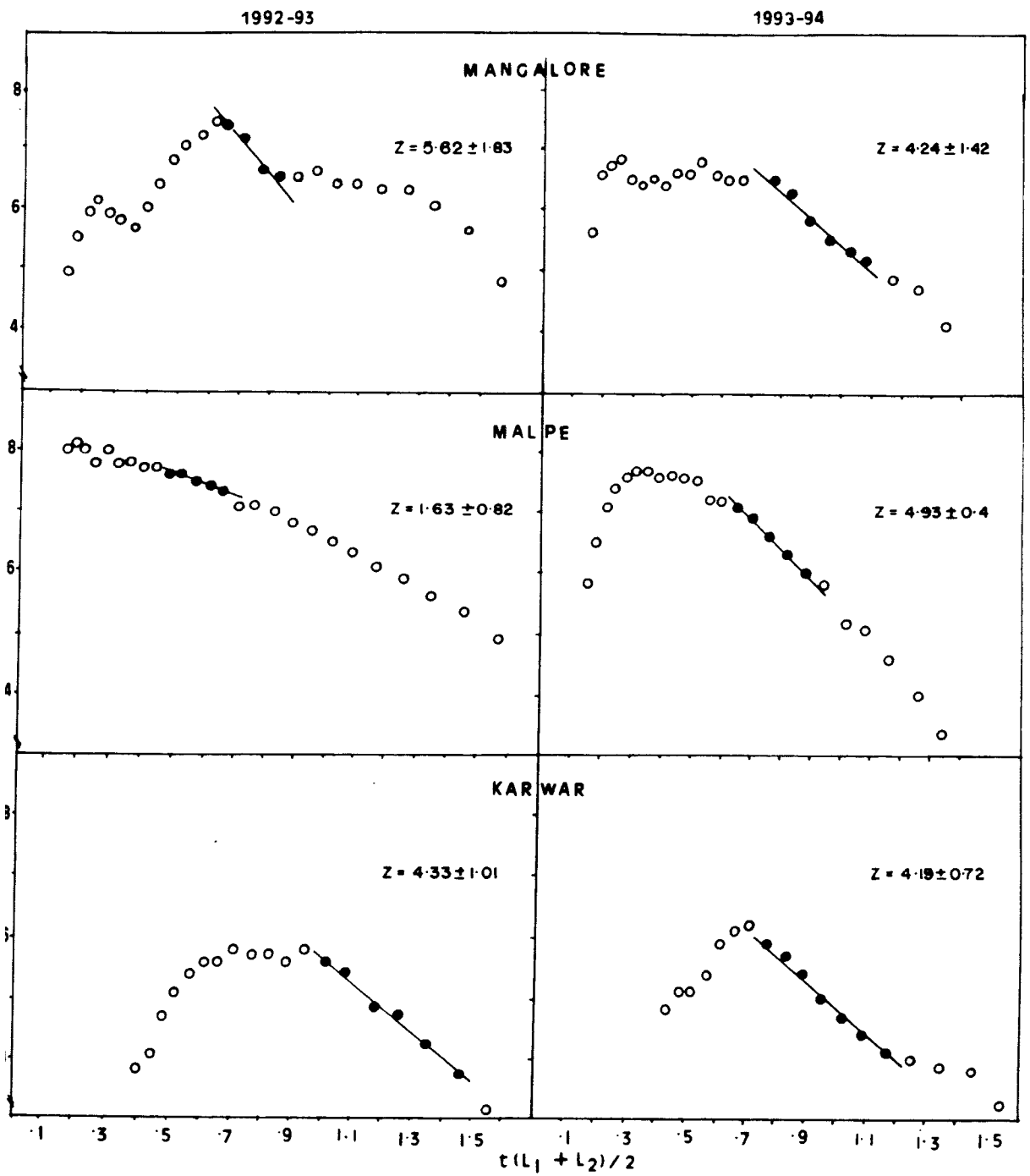
Z = Instantaneous total mortality coefficient; M = natural mortality coefficient; F = fishing mortality coefficient;
E = exploitation ratio; U = exploitation rate; Pn = mean population number; Yn = yield in number; Pn/R = population number per recruit; Yn/R = yield in number per recruit

TABLE 7.12.

Z, F, E and Yw/R estimated for males and females of *P. sanguinolentus* and *P. pelagicus* during 1983-93 along the Karnataka coast.

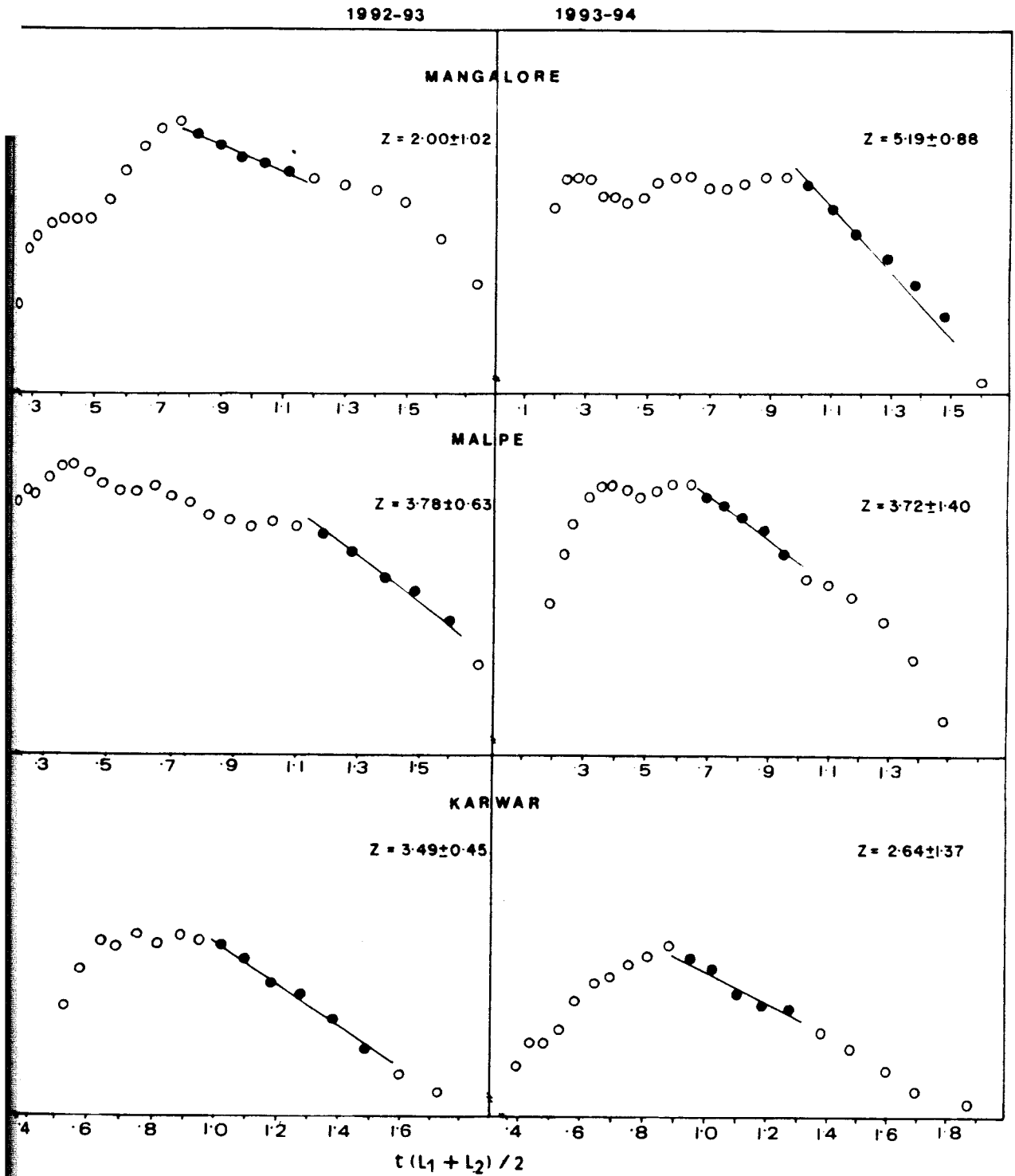
Year	<i>P. sanguinolentus</i>								<i>P. pelagicus</i>							
	MALES				FEMALES				MALES				FEMALES			
	Z	F	E	Yw/R	Z	F	E	Yw/R	Z	F	E	Yw/R	Z	F	E	Yw/R
1983	3.3	1.7	0.52	21.7	3.0	1.5	0.50	14.2	4.2	2.5	0.60	49.6	3.2	2.1	0.57	29.9
1984	2.5	0.9	0.36	18.7	2.3	0.8	0.35	11.6	4.0	1.3	0.33	44.3	2.7	1.1	0.41	25.4
1985	3.0	1.4	0.47	21.1	2.8	1.3	0.46	13.7	3.8	2.1	0.55	48.8	3.3	1.7	0.52	28.8
1986	2.8	1.2	0.43	20.4	2.6	1.1	0.42	13.0	3.5	1.8	0.51	47.8	3.2	1.5	0.47	27.9
1987	5.1	3.5	0.69	21.4	4.7	3.2	0.68	15.2	6.8	5.1	0.75	48.5	5.8	4.2	0.72	31.0
1988	6.7	5.1	0.76	20.8	6.4	4.7	0.73	15.3	9.2	7.5	0.82	47.5	7.8	6.2	0.79	30.4
1989	3.8	2.2	0.58	22.0	3.5	2.0	0.57	14.8	4.9	3.2	0.65	49.9	4.3	2.7	0.63	30.7
1990	3.5	1.9	0.54	21.8	3.3	1.8	0.55	14.6	4.5	2.8	0.62	49.9	3.9	2.3	0.59	30.3
1991	4.0	2.4	0.60	21.9	3.7	2.2	0.59	15.0	5.2	3.5	0.67	49.8	4.5	2.9	0.64	30.9
1992	5.1	3.5	0.69	21.4	4.7	3.2	0.68	15.2	6.8	5.1	0.75	48.5	5.8	4.2	0.72	31.0
1993	3.6	2.0	0.56	21.9	3.5	1.8	0.51	14.6	4.6	2.9	0.63	49.9	4.0	2.4	0.60	30.4
Average for 83-93	3.9	2.3	0.59	22.0	3.7	2.1	0.57	14.9	5.2	3.4	0.65	49.9	4.5	2.6	0.58	30.7
Average for 91-93	4.2	2.6	0.62	21.9	3.9	2.4	0.62	15.1	5.5	3.8	0.68	49.6	4.8	3.2	0.67	31.0

* F estimated from the catchability coefficient ($q = F/f$) determined for 1992-94 data
E and Yw/R given for the respective F values.

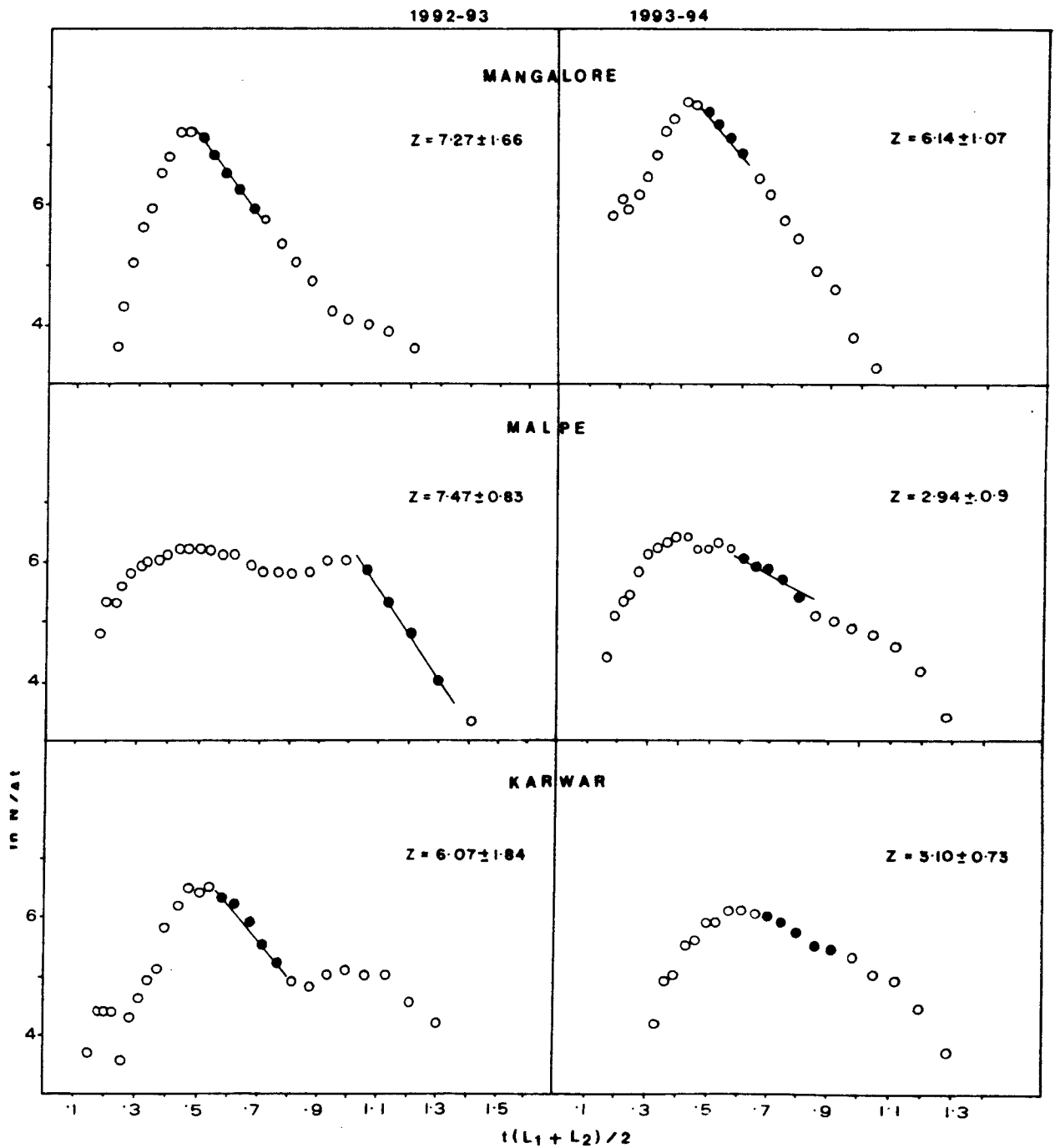


7.1. *P. sanguinolentus* males.

Estimation of Z by length converted catch curve of Pauly (1983) at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-93 and 1993-94.



7.2. *P. sanguinolentus* females. Estimation of Z by length converted catch curve of Pauly (1983) at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-93 and 1993-94.



g. 7.3. *P. pelagicus* males.
 Estimation of Z by length converted catch curve of Pauly (1983) at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-93 and 1993-94.

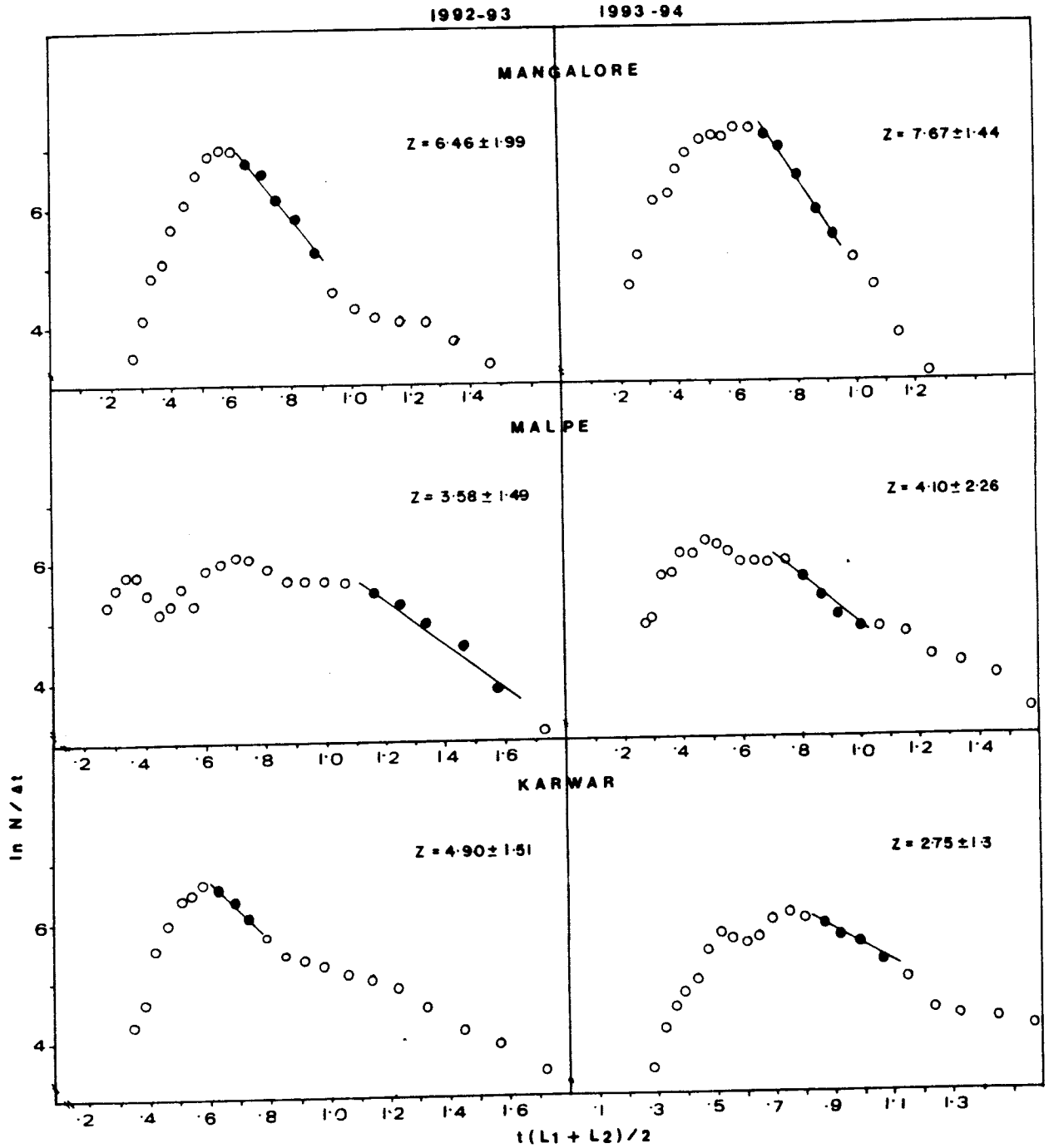
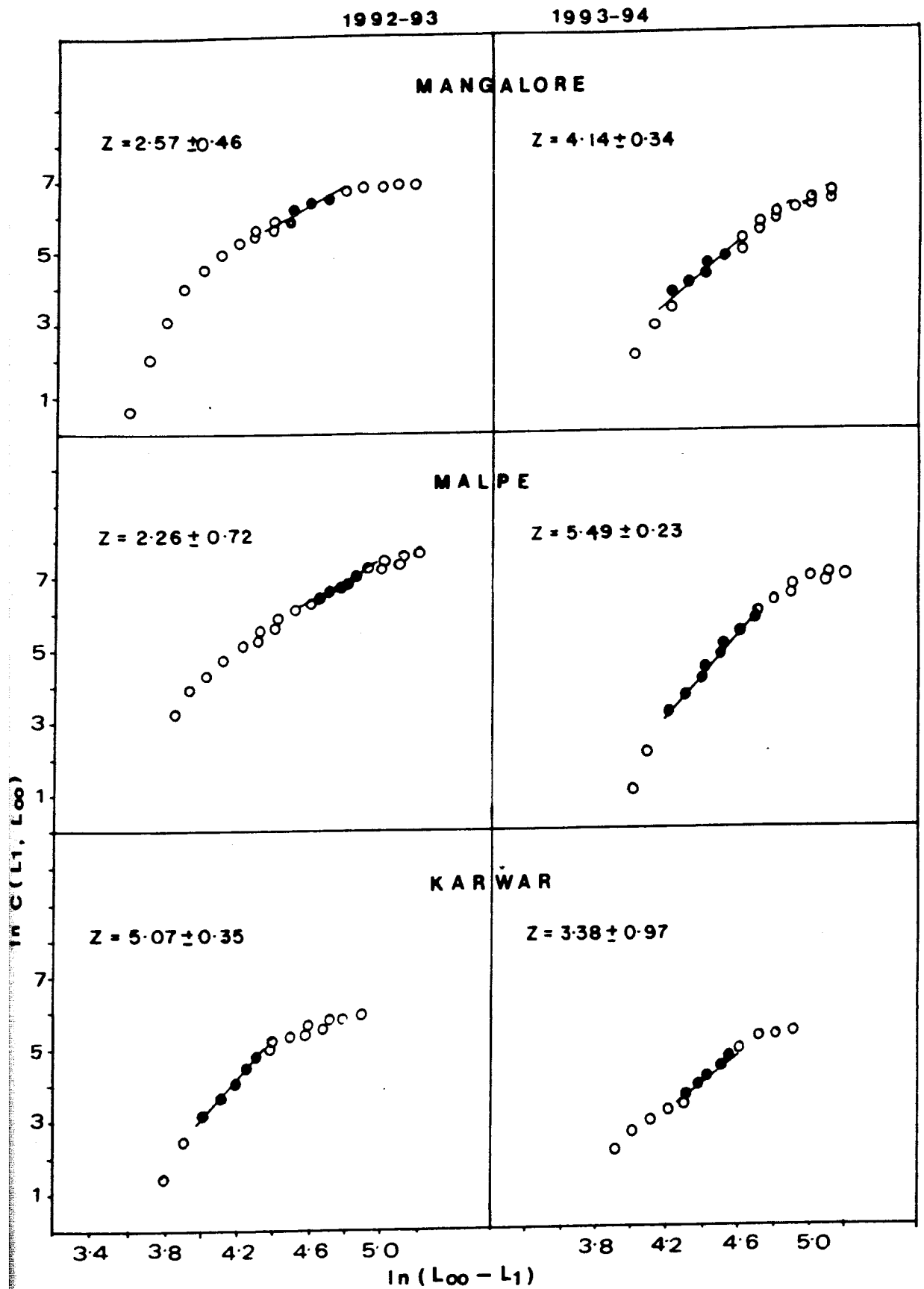
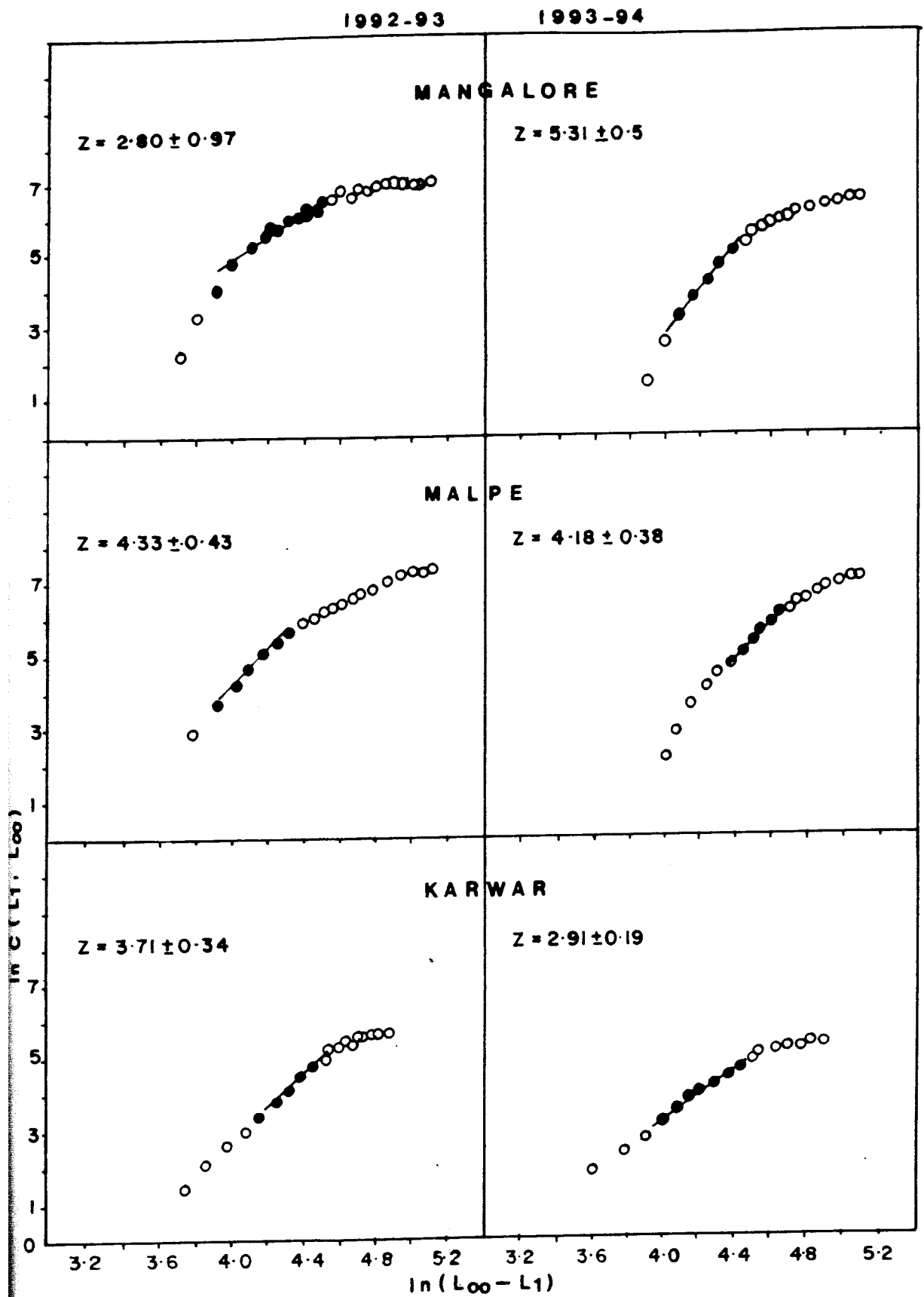


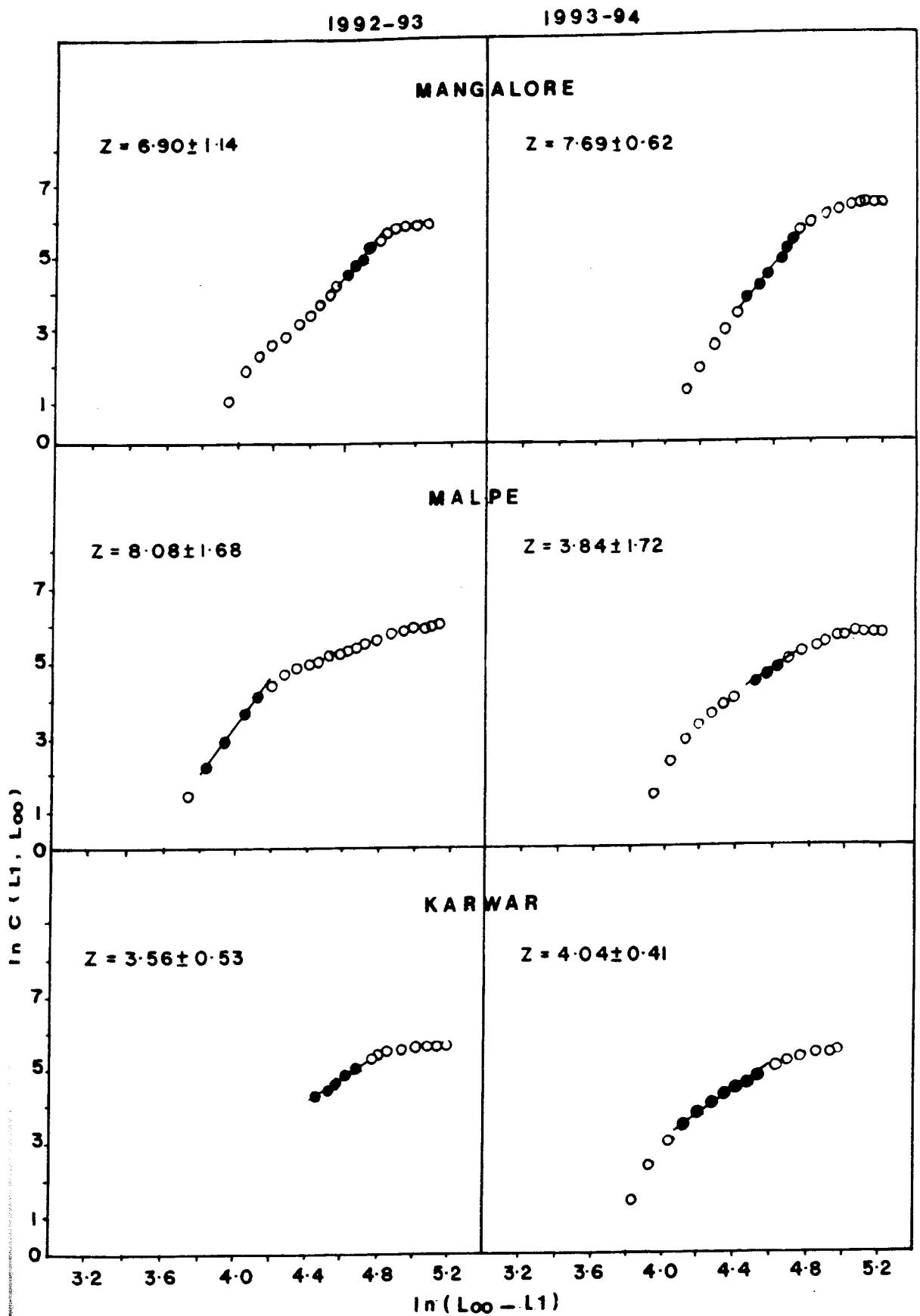
Fig. 7.4. *P. pelagicus* females. Estimation of Z by length converted catch curve of Pauly (1983) at Mangalore (Mg), Malpe (Mp) and Karwar (K) during 1992-93 and 1993-94.



7.5. *P. sanguinolentus* males. Estimation of Z by cumulative catch curve based on length (CW) composition data during 1992-93 and 1993-94 at Mangalore (Mg), Malpe (Mp) and Karwar (K).



7.6. *P. sanguinolentus* females. Estimation of Z by cumulative catch curve based on length (CW) composition data during 1992-93 and 1993-94 at Mangalore (Mg), Malpe (Mp) and Karwar (K).



7.7. *P. pelagicus* males.

Estimation of Z by cumulative catch curve based on length (CW) composition data during 1992-93 and 1993-94 at Mangalore (Mg), Malpe (Mp) and Karwar (K).

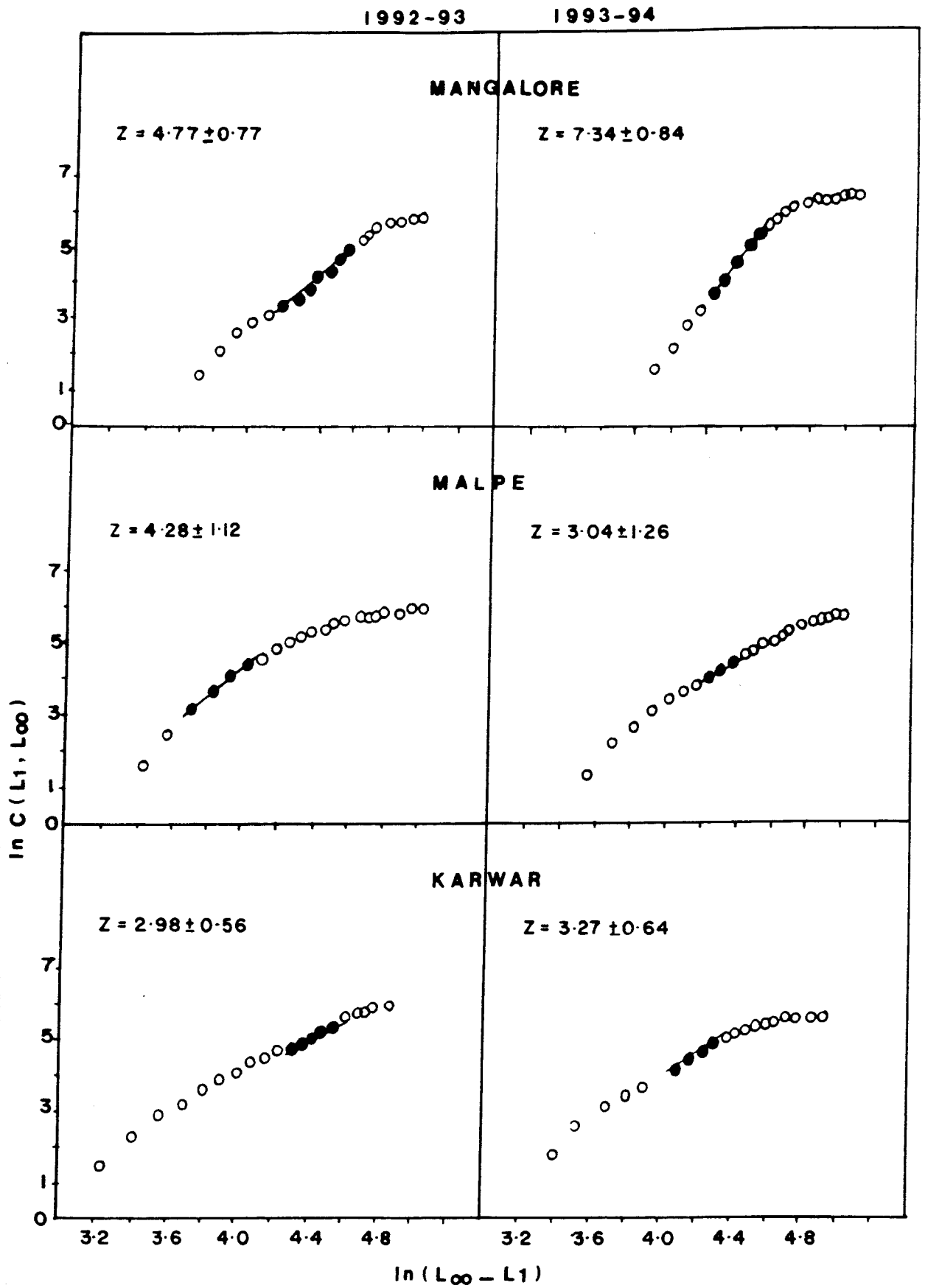
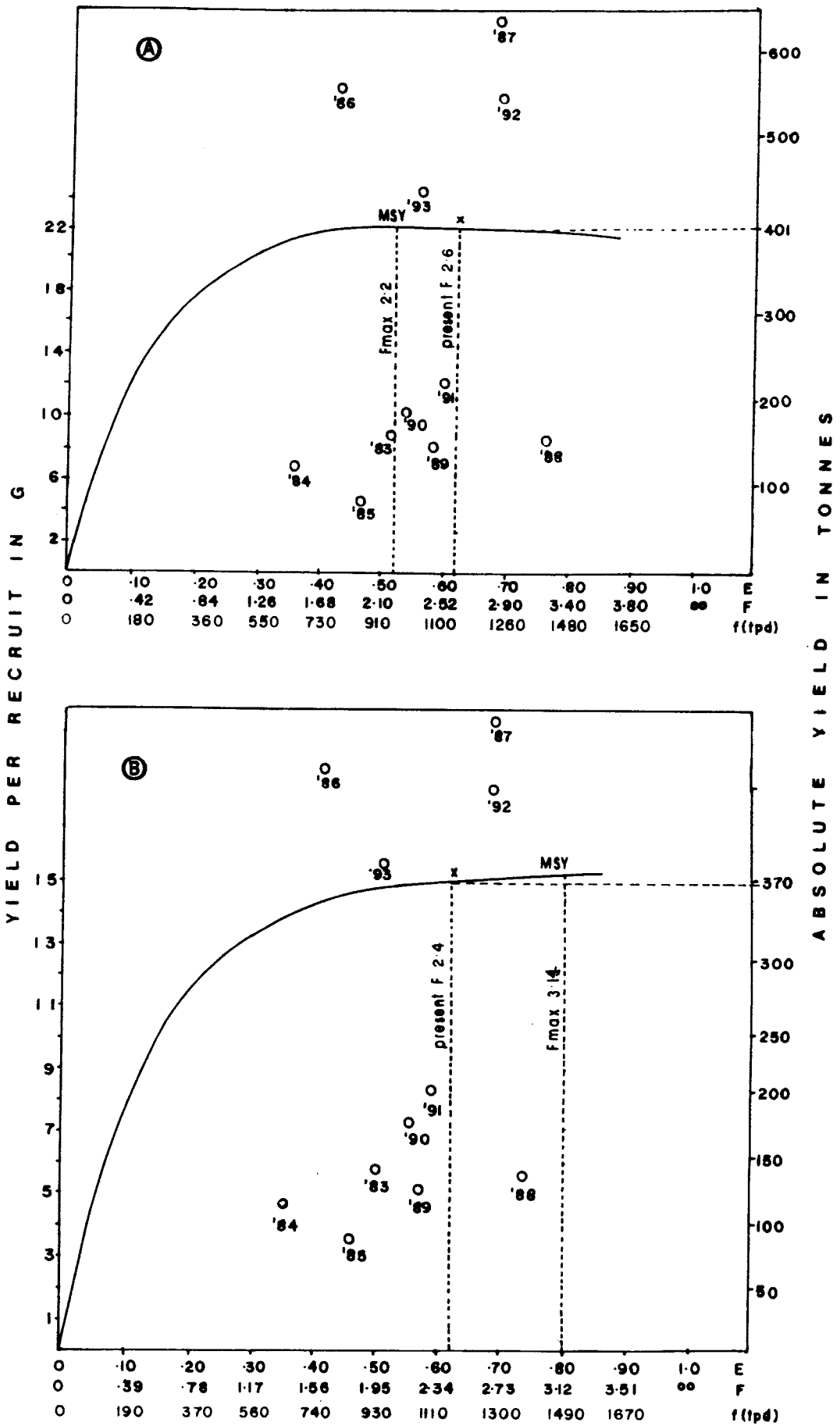
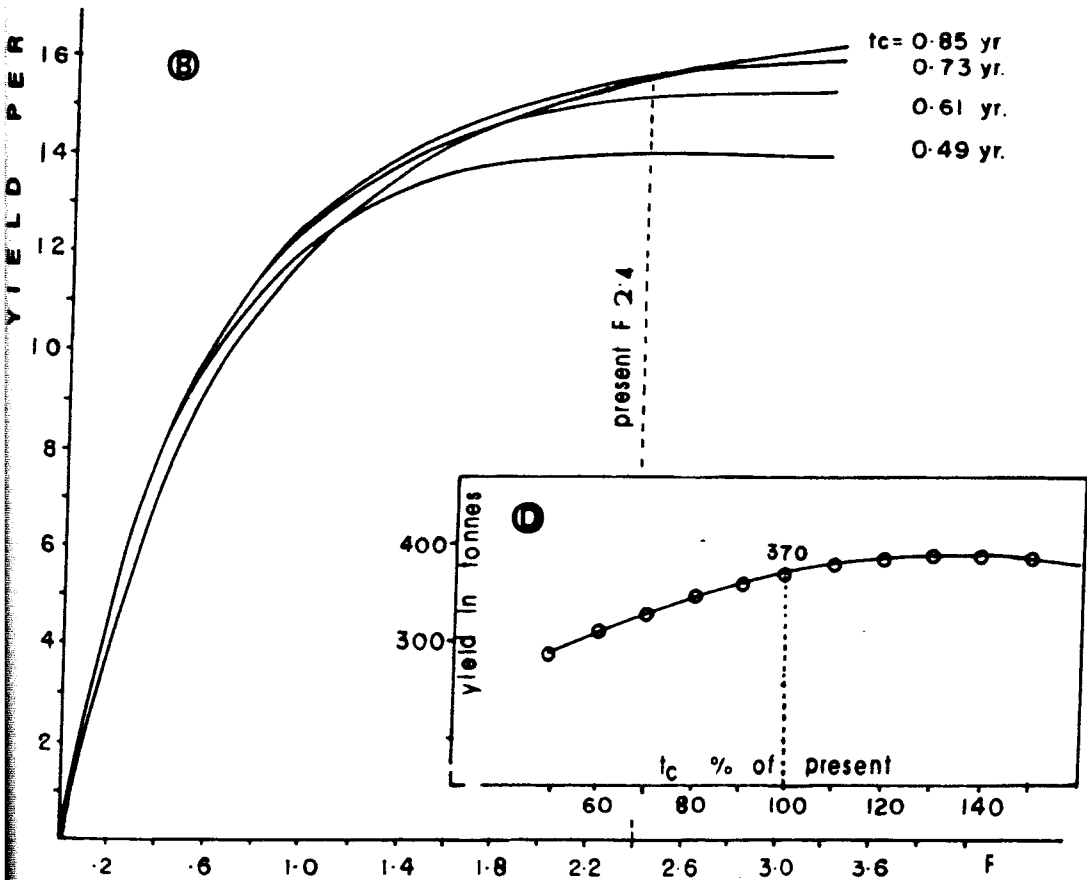
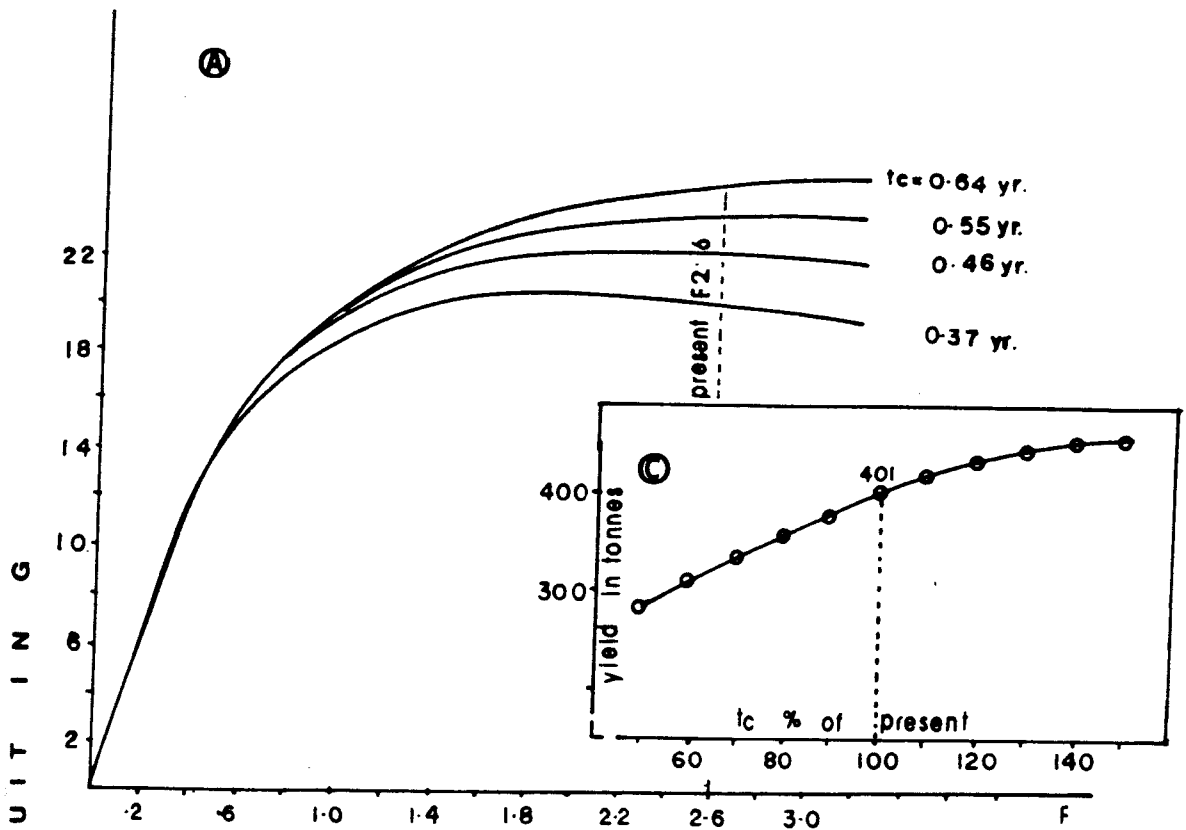


Fig. 7.8. *P. pelagicus* females. Estimation of Z by cumulative catch curve based on length (CW) composition data during 1992-93 and 1993-94 at Mangalore (Mg), Malpe (Mp) and Karwar (K).



ig. 7.9. *P. sanguinolentus*.

Yield per recruit (in g) as a function of E or F or tpd for males (A) and females (B). Conversion of Yw/R into absolute yield is also indicated. X = average annual yield for 1991-93. The annual yields for 1983-93 is also superimposed.



7.11. *P. sanguinolentus*. yield per recruit (in g) as a function of F with different age of exploitation (t_c) for males (A) and females (B). Yield as % of the present t_c for males (C) and females (D). $M = 1.6$ for males and 1.5 for females.

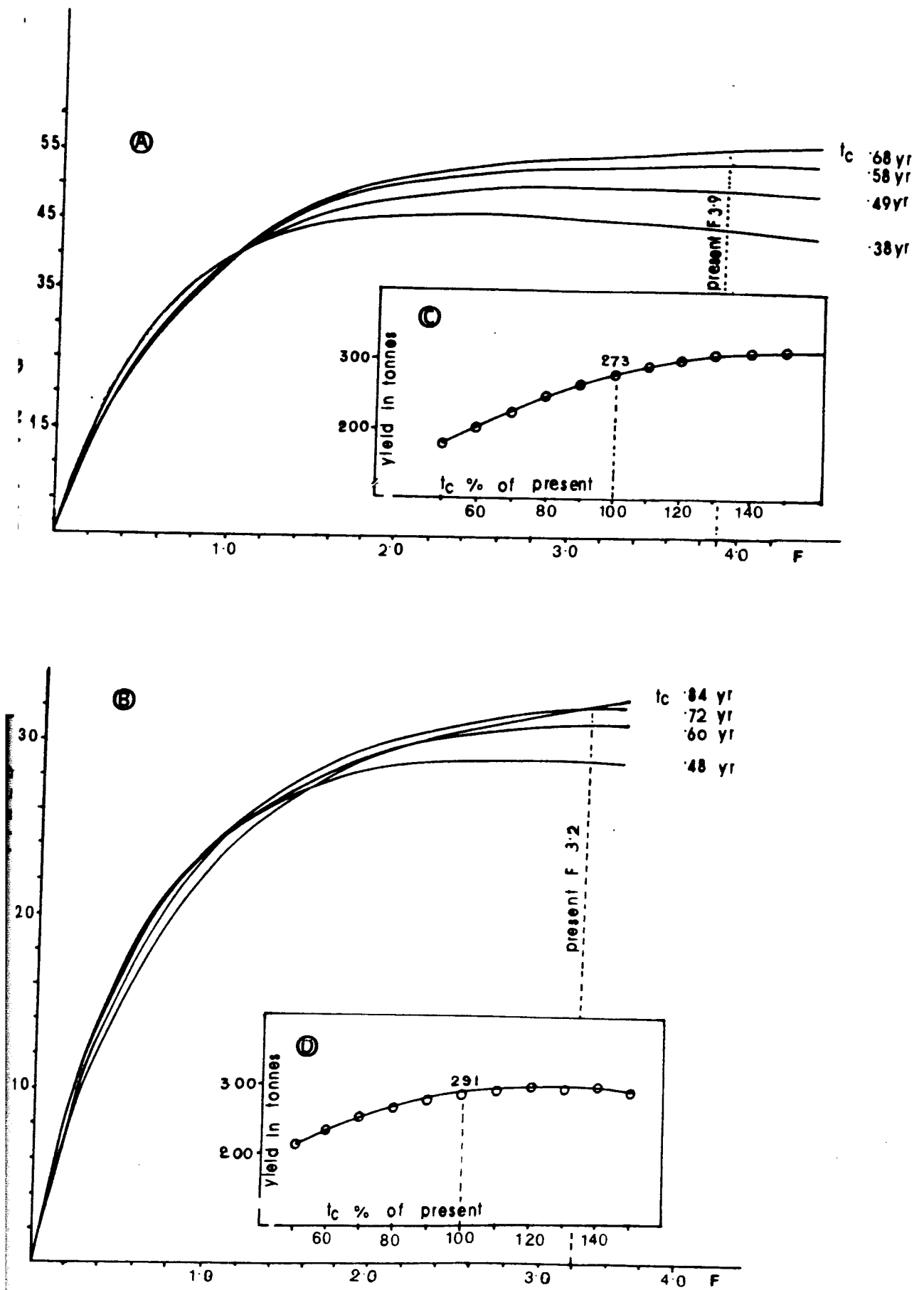


Fig. 7.12. *P. pelagicus*.

Yield per recruit (in g) as a function of F with different age of exploitation (t_c) for males (A) and females (B). Yield as % of the present t_c for males (C) and females (D). $M = 1.6$ for males and 1.5 for females.

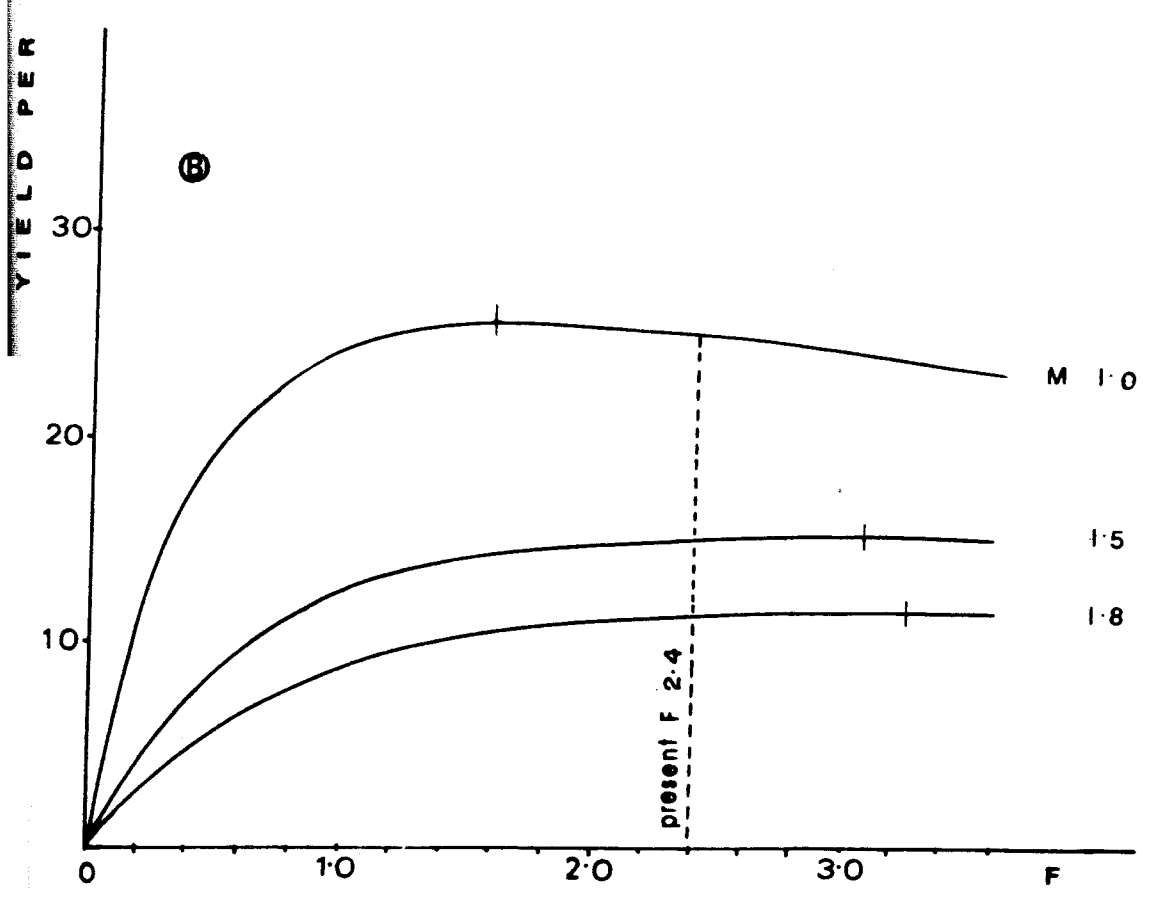
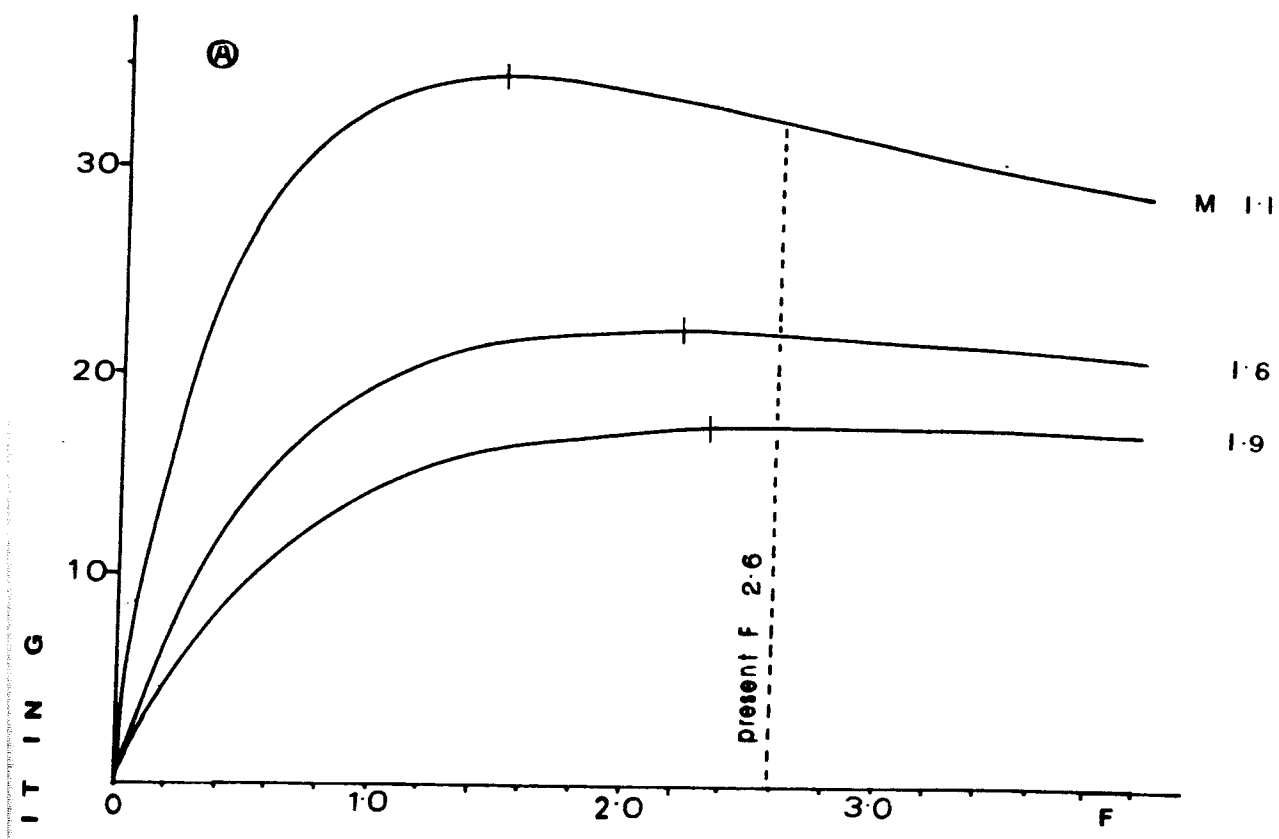
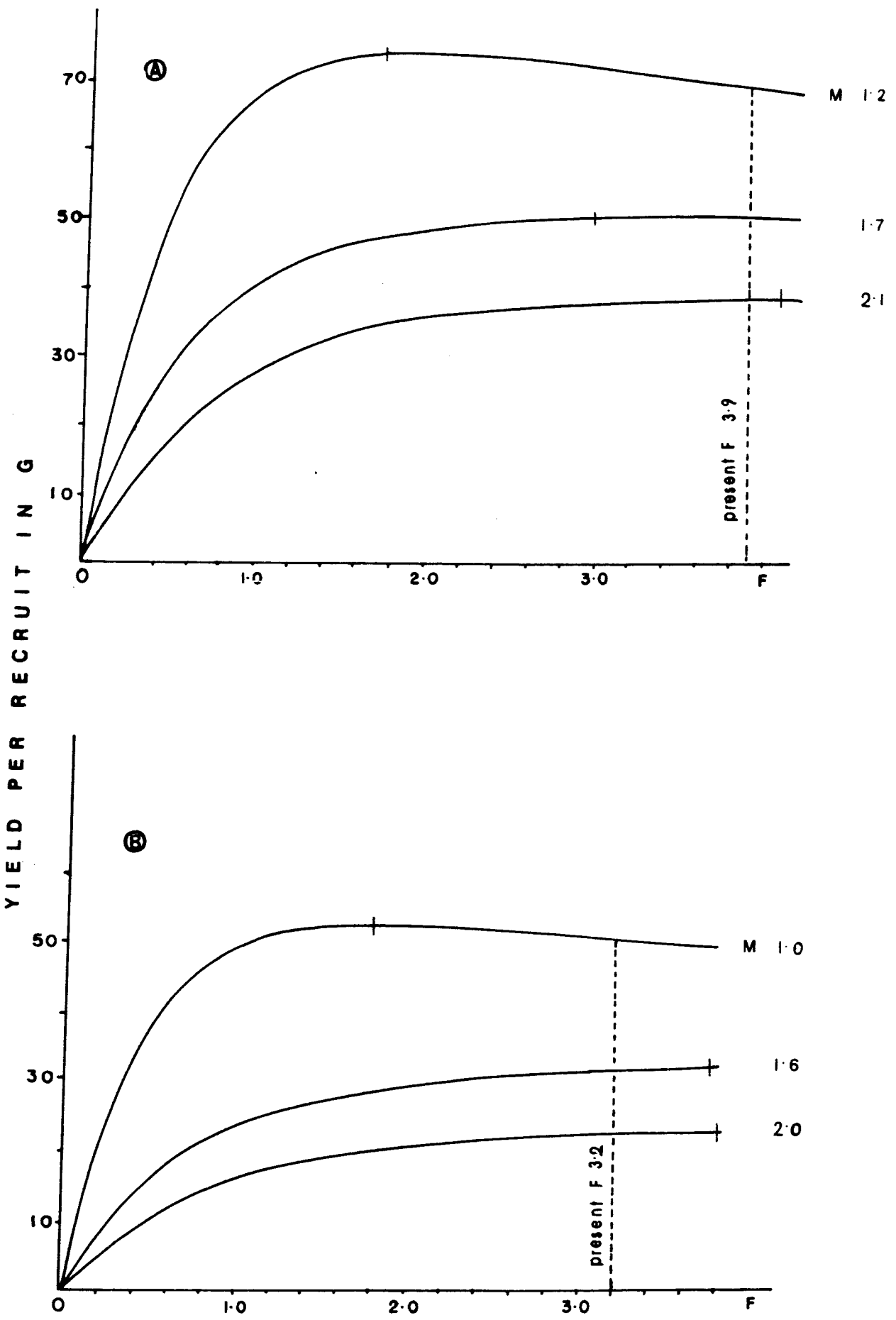
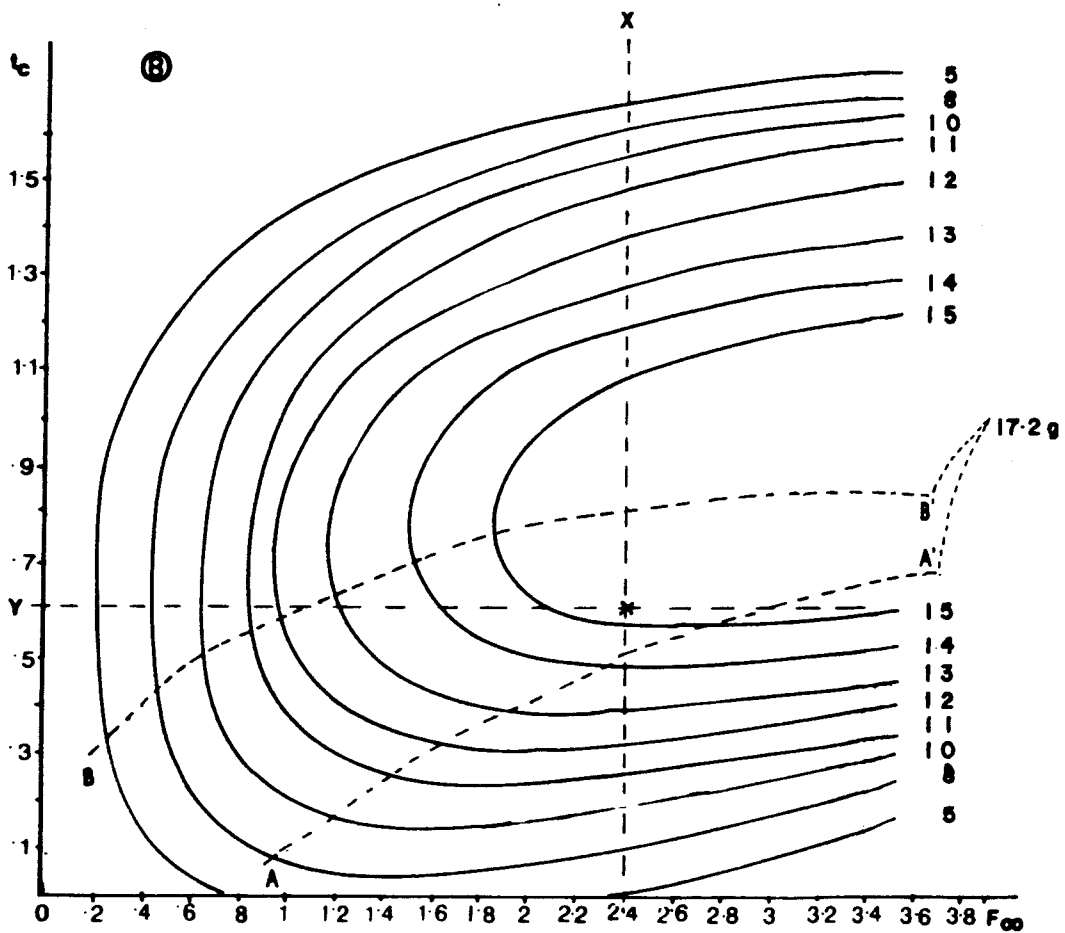
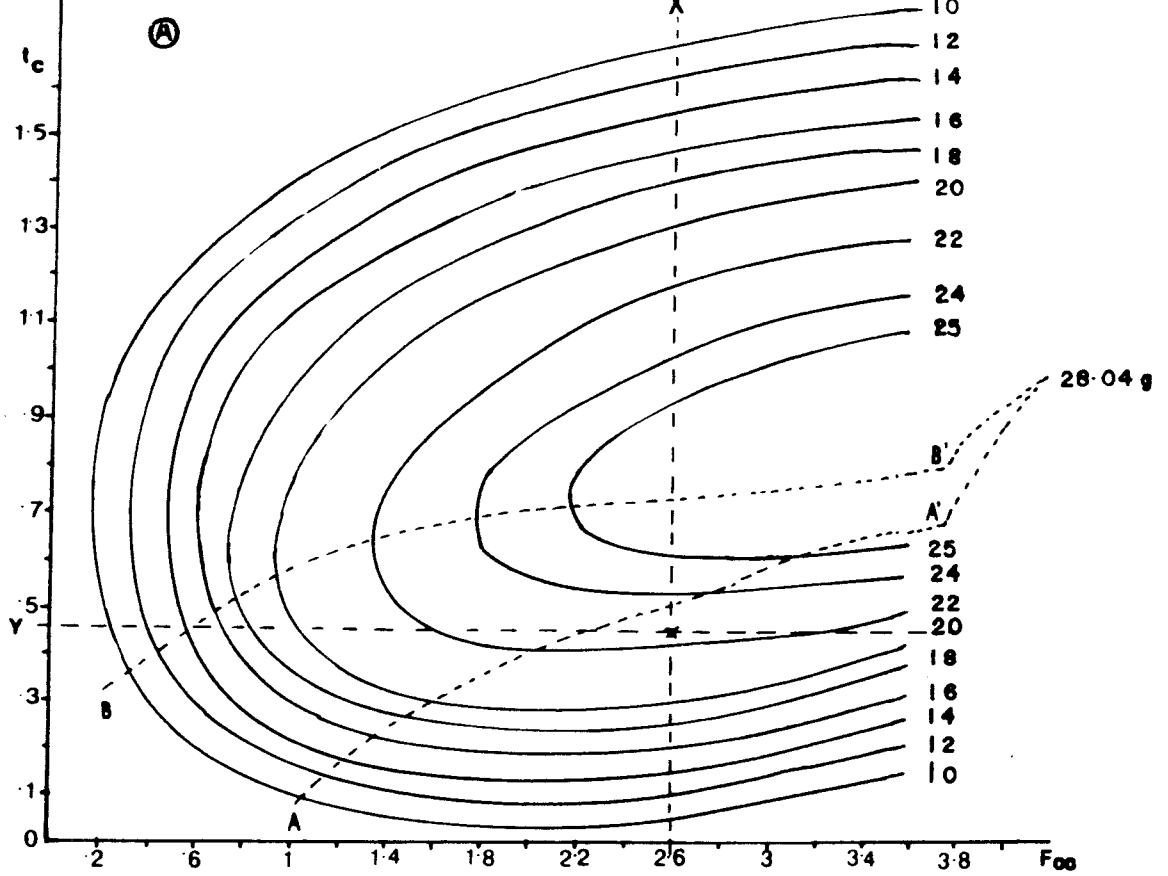


Fig. 7.13. *P. sanguinolentus*. Yield per recruit (in g) as a function of F with different natural mortality coefficient (M) for males (A) and females (B). The vertical line indicate the yw/R at the present F ($t_c = 0.46$ year for males and 0.61 year for females).



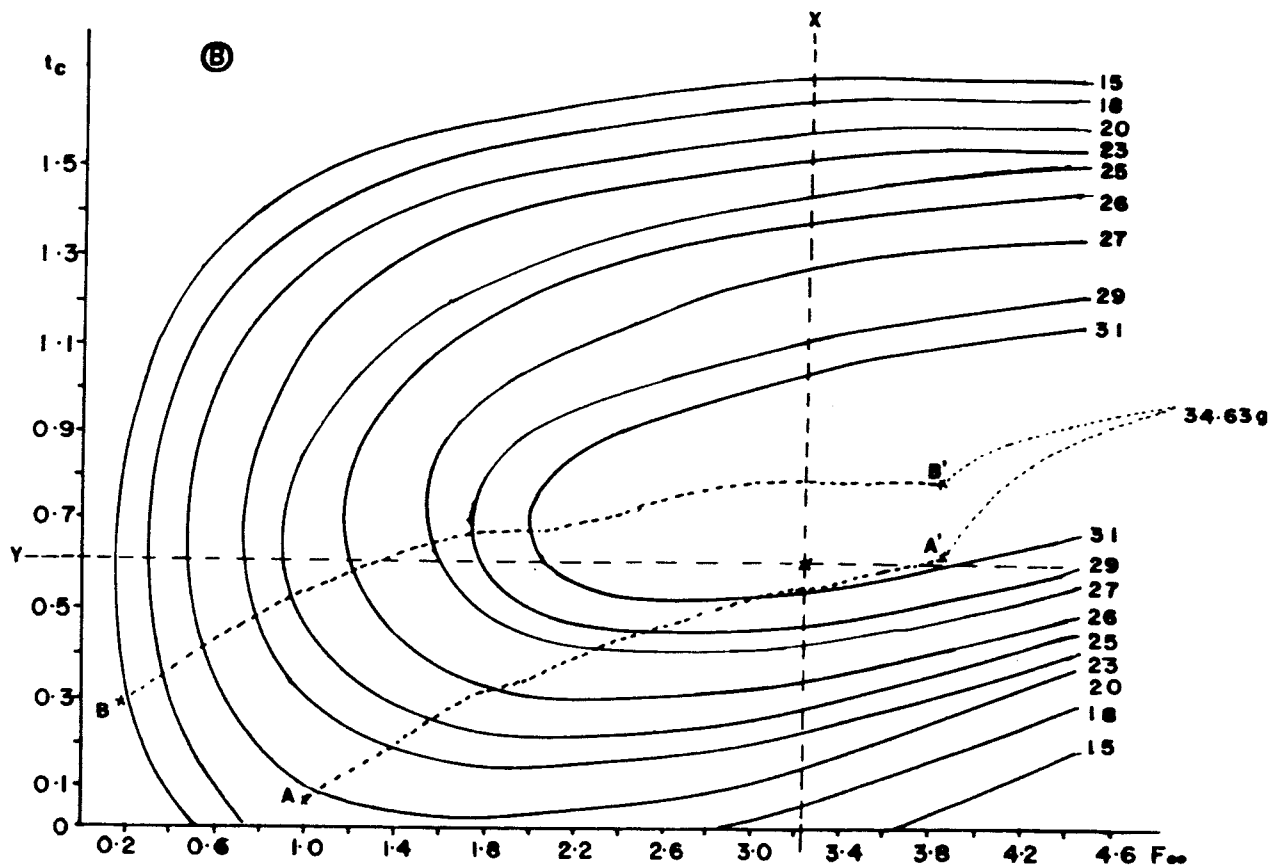
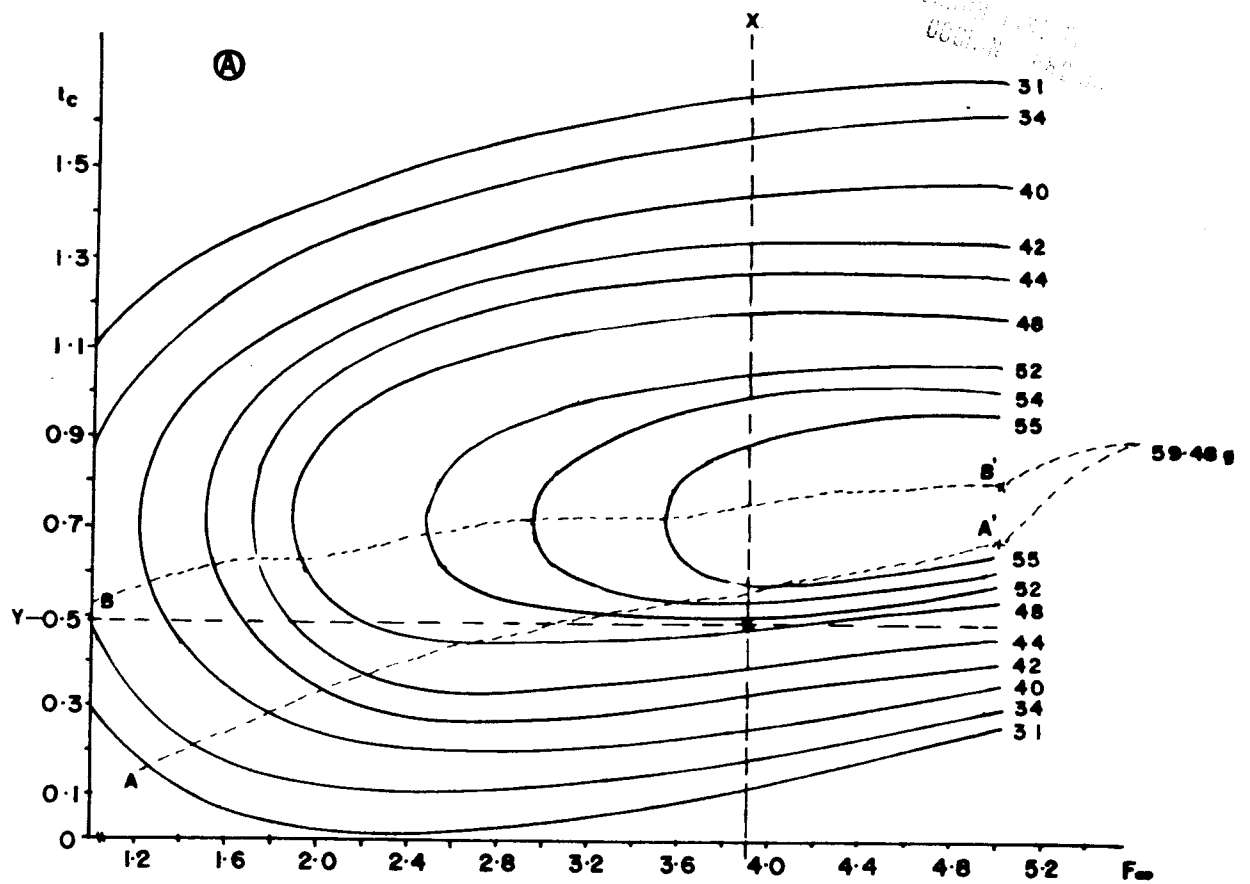
§ 7.14. *P. pelagicus*.

Yield per recruit (in g) as a function of F with different natural mortality coefficient (M) for males (A) and females (B). The vertical line indicate the yw/R at the present F ($t_c = 0.46$ year for males and 0.61 year for females).



7.15. *P. sanguinolentus*.

Isopleth diagram for yield per recruit (in g) for males (A) and females (B). BB' line = eumetric fishing line; AA' = MSY curve; the vertical line at X indicate the present F and horizontal line at Y, the present t_c .



g. 7.16. *P. pelagicus*
 Isopleth diagram for yield per recruit (in g) for males (A) and females (B).
 BB' line = eumetric fishing line; AA' = MSY curve; the vertical line at X indicate the present F and horizontal line at Y , the present t_c .

GENERAL DISCUSSION

GENERAL DISCUSSION

With an annual average production of 1,179 tonnes during 1983-93, crab landing in Karnataka formed around 5.1 % of the all India crab landings. Although different types of gears are employed in crab fishery in the state, the bulk of the crab catch was obtained by trawls operated by mechanised fishing vessels. The important species contributing to the fishery were *P. sanguinolentus* and *P. pelagicus* and these two species together formed around 93 % of the crab landing in the state. Although they are caught in varying quantities from September to May, the bulk of the catch was landed during January-February which coincided with the peak breeding activity of these crabs along this coast. Despite a steep rise in the trawl effort, there had been no proportional increase in crab landings which remained between 1000-2000 tonnes during the last few years.

Although advanced fishing countries of the world have adopted certain measures for the proper management of crab fisheries, no conservatory measure is observed or prevalent at present in India. Due to this, immature, moulting and berried crabs are fished indiscriminately. Consequently, often they are exploited at an age at which most of them might not have spawned even once. Since most of the gears employed (shrimp trawl, shore seine, minitrawl) are non-selective in nature, appreciable quantity of immature and juveniles are caught inadvertently and are unutilised. Present study has shown that juveniles (< 80 mm cw) of *P. sanguinolentus* formed around 58 % of the crab catch in shrimp trawls and 82 % in indigenous gears, whereas, in *P. pelagicus*, juveniles constituted upto 25 % in trawls and 71 % in indigenous gears. This large scale destruction of young crabs would obviously have adverse effect on the crab resources. This situation required to be remedied by educating the fishermen through audio-visual media such as, TV, radio, and news papers about the adverse effect of catching and destroying these

young ones on the crab stocks, and also by creating an awareness among them about the importance of releasing young crabs back to the sea or fattening them through short-term culture for the sustenance of these valuable resources. In addition, it is also required to enforce certain regulatory measures like fixing legal minimum size, protection of ovigerous females and soft-shelled crabs as practiced in several advanced fishing countries.

Despite their economic significance, the dynamics of the exploited population of these crabs remain poorly understood as there is no information on the mortality and stock assessment of brachyurans from India. In the present study, the status of the crab fishery is assessed based on the data emanating from the trawl fishery (for the period 1992-94) which accounts for more than 90 % of the crab landing in the state.

Portunus sanguinolentus and *P. pelagicus* are marine species and support fishery of considerable magnitude in all maritime states of India. It is caught from the inshore and estuarine waters often in appreciable quantities. The breeding season is extending from August to May in both the species with peak activity during December-February in *P. sanguinolentus* and during January-February and September in *P. pelagicus*. The size at sexual maturity in female is at 92 mm in the former species and 99.0 mm in the latter, and in males, it is at 97 mm and 105 mm respectively. Sex ratio is nearly equal in both these crabs. The fecundity ranged from 0.044 to 1.19 million in *P. sanguinolentus* and from 0.56 to 1.07 in *P. pelagicus*. The larval development takes place in the marine environment. The young crabs migrate to the inshore waters and often to estuaries. They grow relatively at a fast rate, and males and females attain a mean carapace width of 124.1 mm and 112.5 mm in *P. sanguinolentus* and 145.2 mm and 132.5 mm in *P. pelagicus* at the end of one year. The life span is around 2.5 years for both these species. The high fecundity, fast growth and multiple spawning help to maintain the resource.

For Karnataka waters, the annual average stock was estimated at 2,106 tonnes (*P. sanguinolentus* = 1,272 tonnes + *P. pelagicus* = 834 tonnes), whereas, the MSY was estimated at 1,343 tonnes (*P. sanguinolentus* 776 tonnes + *P. pelagicus* = 567 tonnes) by the yield-per-recruit model of Beverton and Holt, which is very close to the annual average yield of 1,335 tonnes (*P. sanguinolentus* = 771 tonnes + *P. pelagicus* = 564 tonnes) obtained during 1991-93 period.

The optimum level of effort, $f(\text{MSY})$, for these crabs was estimated at 1,190 tpd by yield-per-recruit model which is very close to the value obtained by the Fox model (1,120 tpd).

The present study indicate that the prevailing fishing intensity for males was more ($F = 2.6$ or $E = 0.62$ for *P. sanguinolentus*, and $F = 3.9$ or $E = 0.70$ for *P. pelagicus*), whereas, it was low for females ($F = 2.4$ or $E = 0.62$ for *P. sanguinolentus* and $F = 3.23$ or $E = 0.67$ for *P. pelagicus*). However, since the current yield of males and females of these two species are very close to MSY level, it will be advantageous if the effort is maintained at the current level itself to obtain biologically optimum yields.

Since the cod-end mesh of trawl is small (28-35 mm mm), large quantities of juveniles of these crabs are retained by the trawl net. This is detrimental to the crab stocks and some management measures for the conservation of the resources are warranted. In the light of requirements for optimum fishing and also to increase the size at capture (l_c) by 20 % (t_c by around 30 %) to permit the young crabs to escape through the meshes of the trawl net and thereby enhance the yield subsequently, an increase in cod-end mesh size to 40 mm from 33 mm (mean) would seem to be a practical and ideal one. In addition, there is an urgent need to restrict the effort at the present level (1,130 tpd or 243×10^3 bd) as a management strategy to prevent over exploitation of these valuable resources in the coastal waters of Karnataka. Eventhough, several methods of

management, such as, closed season, restricting the area of fishing etc. are available, mesh regulation along with certain amount of control of fishing intensity appears to be the most appropriate and suitable for the conservation and management of the marine crab resources of Karnataka.

Since crab meat is a delicacy in many parts of the world, it is exported alive, frozen and canned to several foreign countries. During 1993-94 alone, crabs worth Rs. 196.3 million (2,034 tonnes) were exported from India. Due to the ever-increasing demand for crabs for human consumption, there has been a recent upsurge of interest in the culture of crabs to augment the resources in several countries. These crabs can be bred in captivity as they can withstand wide environmental fluctuations (like salinity, temperature etc.) and offer little problem for artificial propagation. With multiple spawning, high fecundity and fast rate of growth, these portunids are suitable candidates for culture for augmenting the resources.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The thesis presents a detailed account on the fishery, biology and population dynamics of two species of portunid crabs, *Portunus sanguinolentus* and *P. pelagicus* exploited along the Karnataka coast.

The study is based on the fishery and biological data collected at Mangalore, Malpe and Karwar, the three major fish landing centres of Karnataka state during 1992-93 through 1993-94.

For food and feeding studies, the foregut contents of the crabs were analysed. Percentage of the total volume of the stomach contributed by each food group was determined visually. Importance of food groups was evaluated by ranking them by percentage frequency of occurrence and percentage points.

Altogether 579 crabs comprising 267 numbers of *P. sanguinolentus* and 312 numbers of *P. pelagicus* collected from the commercial catches at Mangalore and Malpe were analysed for determining the carapace width/carapace length - body weight relationship.

The gonadal development in female was studied by gross examination of ovary and by studying the ova diameter frequency distribution. Six stages by gross examination and nine stages by microscopical studies in the development of ovary and 3 stages in the development of testis were recognised. The size at maturity was determined by tabulating the mature crabs in relation to size and finding out the percentages. The size at which 50 % of crabs found to be mature was taken as the size at sexual maturity. Fecundity studies were made on the basis of the extruded eggs on pleopods. After recording the carapace width, body weight and eggmass weight, a sample of eggs was taken, weighed

accurately and the number of eggs counted from which the fecundity was computed.

The growth pattern was determined by graphical analysis of progression of modes in the successive size frequency distributions. The von Bertalanffy's growth parameters were determined by the Gulland and Holt plot (1959), the Ford-Walford plot (Ford, 1933, Walford, 1946) and by the computer based ELEFAN method (Pauly and David, 1980).

For stock assessment, the data pertaining to trawl fishery which is the major single gear in the exploitation of crabs, was used. The total mortality coefficient (Z) was estimated sex-wise in respect of *P. sanguinolentus* and *P. pelagicus* from the size frequency data by the Beverton and Holt method (1957), the length converted catch curve method of Pauly (1983), the cumulative catch curve of Ssentongo and Larkin method (1973) for 1992-93 and 1993-94 fishing seasons separately. Similarly, the natural mortality coefficient (M) was estimated by Sekharan's method (1974), the Rikhter and Efanov method (1976) and the Pauly's method (1980). The yield per recruit as a function of annual fishing intensity (F) for the present age at capture (t_c) was estimated as per the analytical model of Beverton and Holt (1957). The optimum level of effort, $f(\text{MSY})$ and maximum sustainable yield (MSY) were also estimated using 'the surplus production models' like the Schaefer model (1954) and the Fox model (1970).

Annual crab production in India, catch trends, species of commercial value, their seasons and the important regions/states contributing to the all India catch are presented and discussed. The catch and effort data in respect of the fishery at Mangalore, Malpe and Karwar, the three important fish landing centres in

Karnataka are given monthwise and specieswise. The crab catch for the three centres together amounted to 850 tonnes and 410 tonnes respectively during 1992-93 and 1993-94 fishing seasons. The fishery was constituted by *Portunus sanguinolentus* (49.3 %), *P. pelagicus* (43.6 %) and *Charybdis (Charybdis) feriatus* (7.1 %). In addition, a brief description of the gears employed in the crab fishery was given.

- III. The crustaceans were the most favoured food item of *P. sanguinolentus* and *P. pelagicus* followed by fishes and molluscs. Sexwise, sizewise and seasonal variability in diet was studied and discussed. The occurrence of detritus and unidentified items in the stomach suggest that these crabs are detritivorous consuming decaying plant debris and inorganic material and scavengers consuming fresh and decaying flesh of all kinds.
- IV. The carapace width-body weight relationship and carapace length-body weight relationship in juveniles, adult males and females of *P. sanguinolentus* and *P. pelagicus* were studied and results presented. Study indicated that the increase in body weight in juveniles and adult males was proportional to cube of width, while in adult females, the increase in body weight was lower than the cube of width in *P. sanguinolentus*. In *P. pelagicus*, however, the increase in body weight of adult males and adult females was faster than the cube of width, whereas, in juveniles, the increase in weight was lower than cube of width.
- V. The 50 % level of maturity in female was at 92 mm cw in *P. sanguinolentus* and 99 mm cw in *P. pelagicus*. In males, the 50 % level of maturity was observed at a mean carapace width of 97 mm in the former and 105 mm in the latter species.

In *P. sanguinolentus*, the spawning season extended from August to May

with peak activity during December-February. In *P. pelagicus* also, the spawning season was found to be from August to May with peak activity during January- February and September. These crabs might spawn three times in a spawning season. The breeding population of females was mainly supported by 100-130 mm size groups in *P. sanguinolentus* and 100-160 mm in *P. pelagicus*. During the peak period of breeding, 35-60 % of the adult population of the former and 25-70 % of the latter species were actively involved in spawning. Study indicated that these crabs breed within the fishing ground itself during non-monsoon months.

Sex ratio was nearly equal in both these species. In *P. sanguinolentus* females were more pronounced in the lower sizes, while males dominated in the larger size groups. In *P. pelagicus*, no such pattern was observed.

The fecundity was found to increase with the size of the crab. The number of eggs carried by an ovigerous female ranged between 0.044 and 1.19 million in *P. sanguinolentus* and between 0.56 and 1.07 million in *P. pelagicus*. The 120-130 mm size group in the former species and 130-140 mm size group in the latter species were more productive and contributed to 22.9 % and 15.5 % respectively of the estimated egg production of the population.

- VI. In *P. sanguinolentus*, the mean monthly growth rates were 10.3 mm and 8.8 mm and on completion of one year, this species attains a size of 124.1 mm and 112.5 mm by males and females respectively. In *P. pelagicus*, the average growth rates were 11.0 mm and 9.6 mm and attained a size of 145.2 mm and 132.5 mm by males and females respectively at the end of one year.

The growth parameters, L_{∞} , K and t_0 were 195 mm, 0.99 yr^{-1} and -0.0132 in males and 188 mm, 0.82 yr^{-1} and -0.0975 in females in *P.*

sanguinolentus. In *P. pelagicus*, these growth parameters were 211 mm, 1.14 yr⁻¹ and -0.0194 in males and 204 mm, 0.97 yr⁻¹ and -0.0691 in females.

- VII. In *P. sanguinolentus*, the mean values of Z, M and F were 4.2 ± 0.51 , 1.6, and 2.6 for males and 3.9 ± 0.42 , 1.5 and 2.4 for females. In *P. pelagicus*, the average values of Z, M and F were 5.6 ± 0.71 , 1.7 and 3.9 in males and 4.8 ± 0.69 , 1.6 and 3.2 for females. Using these parameters as input, the exploitation rate (U), the exploitation ratio (E), the total annual stock were estimated. Based on these studies, the present status of the stocks was discussed. The standing stocks were estimated at 308.0 tonnes for *P. sanguinolentus* (154.0 tonnes for males and 154.0 tonnes for females) and 161.0 tonnes for *P. pelagicus* (70.0 tonnes and 91.0 tonnes for males and females respectively) for the state of Karnataka. The annual average stocks were 1272.0 tonnes for *P. sanguinolentus* (658.0 tonnes for males and 614.0 tonnes for females) and 834.0 tonnes for *P. pelagicus* (394.0 tonnes for males and 440.0 tonnes for females). The maximum sustainable yield (MSY) estimated for *P. sanguinolentus* was 776.0 tonnes (403.0 tonnes for males and 373.0 tonnes for females) and for *P. pelagicus*, was 567.0 tonnes (275.0 tonnes for males and 292.0 tonnes for females) which is very close to the annual average yield of 771.0 tonnes and 564.0 tonnes respectively.

Based on the results obtained, some management measures for the rational exploitation of the stocks of crabs are suggested and discussed. It is felt imperative to increase the cod-end mesh size of trawl gear from 33 (mean) to 40 mm, and to restrict the level of effort at the present level (1,130 tpd or 243×10^3 bd) which would prevent over exploitation of the stocks of crabs in the coastal fishery sector of Karnataka.

REFERENCES

REFERENCES

- ADAMS, A.E. 1982. The mating behaviour of *Chinoecetes bairdi*. Proceedings of the International Symposium on the Genus *Chinoecetes*. Lowell Wakefield Fisheries Symposia Series, Alaska Sea Grant Report, No.82-10:233-268.
- ABELLO, P. 1989. Reproduction and moulting in *Liocarcinus depurator* (Linnaeus,1758)(Brachura: Portunidae) in the northwest Mediterranean Sea. *Scientia Marina*, 53:127-134.
- ADIYODI, K.G. AND ADIYODI R.G. 1970. Endocrine control of reproduction in decapod Crustacea. *Biol. Rev. Cambridge Philos. Soc.*, 45:121-165.
- ADIYODI, R.G. 1985. Reproduction and its control. In: "The biology of Crustacea". Vol. 9. Integument, Pigments and Hormonal processes.(D.E. Bliss and L.H. Mantel, eds.) pp. 149- 215.
- AIKEN, D.E. AND S.L. WADDY. 1980. Reproductive biology. In: "The Biology and Management of Lobsters". (J.S. Cobb and B.F. Phillips, eds.). Vol.1, pp. 215-276. Academic Press, New York.
- AJMALKHAN, S AND R. NATARAJAN. 1977. Annual reproductive cycle of the hermit crab *Clibanarius longitarsus* (de Haan) and factors influencing breeding. *Indian J. Mar. Sci.*,6:102-104.
- ALAGARAJA, K. M.J. GEORGE, K.N. KURUP AND C. SUSEELAN. 1986. Yield-per-recruit analysis on *Parapenaeopsis stylifera* and *Metapenaeus dobsoni* from the Kerala state, India. *J. Appl. Ichthyology*, 2:1-11.
- ALCOCK, A. 1885, '96, '98, '99a, 1900, 1901. Materials for a Carcinological fauna of India. Reprint 1968. Wheldon and Wesley Ltd., Stechert-Hafner Service Agency Inc., New York.
- AL-KHOLY, A.A. AND M.M. EL-HAWARY. 1970. The biology of *Lupa pelagicus* (Linnaeus). *Bull. Inst. Oceanogr. Fish.,Cairo*, 1:395- 425
- ALLEN, K.R. 1938. Some observations on the biology of the trout (*Salmo trutta*) in Windermere. *J. Anim. Ecol.*,7: 333-349.

- ANNON, 1950. "The wealth of India. A dictionary of Indian Raw materials and Industrial Products." Vol. 2. Council of Scientific and Industrial research, Delhi.
- ANNON, 1994. Annual report 1994. Central Marine Fisheries Research Institute, Cochin.
- ANNON, 1994. " Marine Products Export Review 1993-94". Marine Products Export Development Authority, Cochin.
- ANZARI, Z.A. AND S.N. HARKANTRA. 1976. Crab resources of Goa. **Seafood Export J.**,8(3):21-24. ARCHAMBAULT, J.A., E.L. WENNER AND J.D. WHITAKER. 1990. Life history and abundance of blue crab *Callinectes sapidus* Rathbun, at Charleston Harbour, South California. Presented at Blue crab conf. Virginia Beach, VA(USA),15-17 May 1988. **Bull. Mar. Sci.**,46(1):145-158.
- ARRIOLA, 1940. A preliminary study of the life history of *Scylla serrata* (Forsk.) **Philipp. J. Fish.**,73 (4): 437-454.
- ARULDHAS, M.M., T. SUBRAMONIAM, SUDHA VARADARAJAN AND P. GOVINDARAJULU. 1980. Germinal zone activity and oocyte differentiation in the marine crab *Portunus pelagicus*. **Indian natn. Sci. Acad.** B46(3): 287-292.
- ATTRILL, M.J. AND R.G. HARTNOLL. 1991. Aspects of biology of the deep sea crab *Geryon trispinosus* from the Porcupine Sea bight. **J. mar. biol. Ass. U.K.**,71:311-328.
- BAILEY, R.F.J. AND R.W. ELNER. 1989. Northwest Atlantic snow crab fisheries. Lessons in Research and Management. In: **Marine Invertebrate Fisheries: Their assessment and management.** (J.F.Caddy, ed.),pp.261-280. **Wiley-Inter Science**, New York.
- BAL, D.V. AND K.V. RAO. 1984. The crabs. In: **Marine Fisheries.** (D.V.Bal and K.V. Rao, eds.), pp.375- 385. **Tata McGraw- Publishing Company Ltd.**, New Delhi.
- BALASUBRAMANIAN, K.K AND C. SUSEELAN. 1990. Preliminary observations on the distribution and abundance of the swarming crab *Charybdis*

- (Goniohellenus) smithii* Macleay in the Deep Scattering Layers along the west coast of India. **Proceedings of the First workshop on scientific results of FORV SAGAR SAMPADA** (K.J. Mathew, ed.), pp. 385-392.
- BARDACH, J.E., J.H. RITHER AND W.O. MCLARNEY. 1972. "Aquaculture: The farming and Husbandry of Freshwater and Marine Organisms." Wiley (interscience), New York.
- BAWAB, F.M. AND EL-SHERIEF. 1988. Stages of the reproductive cycle of the female crab *Portunus pelagicus* (L. 1766) based on the anatomical changes of the spermatheca (Decapoda, Brachyura, Portunidae). **Crustaceana**, 56(2):139-148.
- BAWAB, F.M. AND S.S. EL-SHERIEF. 1989. Contributions to the study of the origin, nature and formation of the sperm plug in the spermatheca of the female crab *Portunus pelagicus* (Linnaeus 1766)(Decapoda, Brachyura). **Crustaceana**, 57(1):9-24.
- BENINGER, P.G., R.W. ELNER, T.P. FOYLE AND P.H. ODENSE. 1988. Functional anatomy of the male reproductive system and the female spermatheca in the snow crab *Chionoecetes opilio* (O. Fabricius)(Decapoda: Majidae) and a hypothesis for fertilization. **J. Crust. Biol.**,8(3):322-332.
- BENNET, R.D. 1974. Growth of the edible crab (*Cancer pagurus* L.) off south-west England. **J. mar. biol. Ass. U.K.**,54:803-823.
- BENSAM, P. 1980. A culture experiment on the crab *Scylla serrata* (Forsk.) at Tuticorin during 1975-77 to assess growth and production. In: **Proceedings of the Symposium on coastal aquaculture, held at Cochin from January 12 to 18, 1980. Part 4: Culture of other organisms, environmental studies, training, extension and legal aspects.** pp.1183-1189.
- BERRIL, M. 1982. The life cycle of the green crab *Carcinus maenas* at the north end of its range. **J. Crust. Biol.**,2:31-39.
- BERTALANFFY, L.VON. 1934* Untersuchungen uber die Gesetz lichkeiten des wachstums. 1. **Allgemeine Grundlagen der Theorie.** Roux' Arch.

Entwicklungsmech. Org.,131:613-53.

- BEVERTON, R.J.H. 1954.* Notes on the use of theoretical methods in the study of dynamics of exploited fish populations. **U.S. Fish. Lab., Misc. contribs.**2:181pp.
- BEVERTON, R.J.H. AND S.H. HOLT. 1957. On the dynamics of exploited fish populations. **Fishery Investigations (Ministry of Agriculture, Fisheries and Food, London), Series II, Vol.XIX**, 533pp.
- BOOLOOTIAN, R.A., A.C. GIESE, A. FARMANFARMANIAN AND J. TUCKER. 1959. Reproductive cycles of five west coast crabs. **Physiol. Zool.**,32:213-220.
- BROEKHUYSEN, G.J. 1941*. The life history of *Cyclograpsus punctatus* M. Edw.: Breeding and growth. **Trans. R. Soc. S.Afr.**,28: 331-366.
- BROWMAN T.E. AND L.G. ABELE. 1982. Classification of recent Crustacea. In:"**The Biology of Crustacea. Vol.1. Systematics, the Fossil Records and Biogeography**" (L.G. Abele, ed.) pp.1-27 Academic Press, New York.
- BROWN, R.B. AND G.C. POWELL. 1972. Size at maturity in the male Alaskan tanner crab, *Chionoecetes bairdi* as determined by chela allometry, reproductive tract weights and size of pre copulatory crabs. **J. Fish. Res. Bd. Canada.**,294:423-427.
- BUTLER, T.H. 1960. Maturity and breeding of the Pacific edible crab, *Cancer magister* Dana. **J. Fish. Res. Bd. Canada**,17(5):641- 646.
- BUTLER, T.H. 1961. Growth and age determination of the Pacific edible crab, *Cancer magister* Dana. **J. Fish. Res. Bd. Canada**,18(5):873-889.
- CAINE, R.A. 1974. Feeding of *Ovalipes guadulpenis* and morphological adaptations to a burrowing existence. **Biol. Bull. Woods Hole, Mass.**, 147: 550-559.
- CAMPBELL, B.M. AND W. STEPHENSON. 1970. The sublittoral Brachyura (Crustacea: Decapoda) of Moreton Bay. **Mem. Qd. Mus.**, 15(4):235- 301. 1pl., text-figs.1-49.
- CAMPBELL, G.R. 1984*. A comparative study of adult sexual behaviour and larval ecology of three commercially important portunid crabs from the Moreton Bay

- region of Queensland, Australia. **Unpublished Thesis, University of Queensland, Australia.**
- CAMPBELL, G.R. AND D.R. FIELDER. 1986. Size at sexual maturity and occurrence of ovigerous females in three species of commercially exploited portunid crabs in S.E. Queensland. **Proc. R. Soc. Qd.**,97:79-87.
- CARGO, D.G. 1958. The migration of adult blue crab *Callinectes sapidus* Rathbun, in Chincoteague Bay and adjacent waters. **Sears Foundation J. Mar. Res.**,16(3):130-141.
- CARROLL, J.C. 1982. Seasonal abundance, size composition and growth of rock crab, *Cancer antennarius* Stimpson off Central California. **J. Crust. Biol.**,2(4):549-561.
- CASTRO, P. 1978. Settlement and habitat selection in the larvae of *Echinoecus pentagonus* (A. Milne Edwards), a brachyuran crab symbiotic with sea urchins. **J. Exp. Mar. Biol. Ecol.**, 34: 259- 270.
- CHACE, F.A. JR. AND H.H. HOBBS JR. 1969. Fresh water and terrestrial decapod crustaceans of the West Indies with special reference to Dominica. **U.S. Natl. Mus. Bull.**,292: 258 pp.
- CHAKRABARTI, K. 1981. A growth study of the crab *Scylla serrata* Forskal in the upper tertiary of Hathab Bhavanagar (Kathiawar). **J. Asiat. Soc., Bengal**,10:239-241
- CHANDRAN, M.R. 1968. Studies on the marine crab, *Charybdis (Goniosoma) variegata* (De Haan). **Proc. Ind. Acad. Sci.**,67:215- 223.
- CHANDY, M. 1973. New records of brachyuran decapods from the Gulf of Kutch. **J. Bombay Nat. Hist. Soc.**,70(2):401-402.
- CHACKO, P.I. AND E. PALANI. 1952. An unusual crab fishery in the sea off Ennur near Madras. **J. Bombay Nat. Hist. soc.**, 52: 946- 947.
- CHARNIAUX-COTTON, H. 1960. Sex determination. In: "The Physiology of Crustacea. Vol. 1. Metabolism and Growth" (T.H. waterman, ed.), p. 411-448. **Academic Press, New York.**

- CHHAPGAR, B.F. 1956. On the breeding habits and larval stages of some crabs. **Rec. Indian Mus.**,54(1):33-52.
- CHHAPGAR, B.F. 1957. On the marine crabs (Decapoda: Brachyura) of Bombay. **J. Bombay nat. Hist. Soc.**,54(2):399-439.
- CHHAPGAR, B.F. 1957a. On the marine crabs (Decapoda: Brachyura) of Bombay. **J. Bombay nat. Hist. Soc.**,54(3):503-549.
- CHHAPGAR, B.F. 1962. Crab-fishing at Bombay. **J. Bombay nat. Hist. Soc.**,59(1):306-309.
- CHIBA, A. AND Y. HONMA. 1971. Studies on gonad maturity in some marine invertebrates - II. Structure of the reproductive organs of the lined shore crab. **Bull. Jap. Soc. Sci. Fish.**,37(8):699- 703.
- CHIBA, A. AND Y. HONMA. 1972. Studies on gonadal maturity in some invertebrates - VI. Seasonal changes in the lined shore crab. **Bull. Jap. Soc. Sci. Fish.**,38(4):317-322.
- CHOPRA, B. 1936. The cape crawfish industry of S. India with some observation on the prawn and crab fisheries of India. **Curr. Sci.**, 4(7): 529-532.
- CHOPRA, B. 1939. Some food prawns and crabs of India and their fisheries. **J. Bombay nat. Hist. Soc.**,41(2):221-234.
- CHOY, S.C. 1986. Natural diet and feeding habits of the crabs *Liocarcinus puber* and *L. holsatus* (Decapoda, Brachyura, Portunidae). **Mar. Ecol. Progr. Ser.**,31:87-99.
- CHOY, S.C. 1988. Reproductive biology of *Liocarcinus puber* (L.) and *L. holsatus* (Decapoda, Brachura, Portunidae) from the Gower Peninsula, South Wales., **Marine Ecology**, 9: 227-241.
- CLARK, F.N. 1934. Maturity of the California sardine (*Sardinella caerulea*), determined by ova diameter measurements. **Division of Fish and Game of California Bureau of Commercial Fisheries. Fish. Bull. No. 42:** 1-49.
- COLBY, D.R. AND M.S. FONSECA. 1984. Population dynamics, spatial dispersion and somatic growth of the sand fiddler crab *Uca pugilator*. **Mar. Ecol. Prog.**

Ser.,16:269-279.

- CONOVER, R.J. 1967. Reproductive cycle, early development, and fecundity in laboratory populations of the copepod, *Calanus hyperboreus*. **Crustaceana**, **13:61-72.**
- CORTEN, A. 1974. Recent changes in the stock of Celtic sea herring (*Clupea harengus* L.). **J. Cons. perm. int. Explor. Mer.,35:194-201.**
- COTT, H.B. 1929.* The Zoological Societie's expedition to the Zambesi, 1927. No. 3. Observations on the natural history of the racing crab, *Ocypoda ceratophthalma* from Beira. **Proc. Zool. Soc., Lond., 4: 755-765.**
- CRESWELL, P.D. AND I.D. MARSDEN. 1990. Morphology of the feeding apparatus of *Cancer novaezelandiae* in relation to diet and predatory behaviour. **Pacif. Sci., 44(4): 383-400.**
- CRISTY, J.H. 1980*. The mating system of the sand fiddler crab, *Uca pugilator*. **Ph.D. Dissertation, Cornell University, Ithaca, N.Y.**
- CRONIN, L.E. 1942*. A histological study of the development of the ovary and accessory organs of the blue crab, *Callinectes sapidus* Rathbun. **Masters thesis, University of Maryland, 70 pp.**
- CRONIN, L.E. 1947. Anatomy and histology of the male reproductive system of *Callinectes sapidus* Rathbun. **J. Morph. 81(2): 209- 239.**
- CROTHERS, J.H. 1967. The biology of the shore crab, *Carcinus maenas* (L). **Fld. Std.,2: 407-434.**
- CUNNINGHAM, D.T. 1969*. A study of the food and feeding relationships of the Alaskan king crab, *Paralithodes camtschatica*. **M.S. Thesis, San Diego State College, 78 pp.**
- DATTA, S.N. 1973. The edible crabs of the deltaic West Bengal. **Seafood Export J.,5(12):26-28.**
- DELSMAN H.C. AND DE MAN, J.C. 1925*. On the Radjungans of the Bay of Batavia. **Treubia,6: 308-323. 6 pls., 8 text-figs.**

- DESHMUKH, R.D. 1968. Some aspects of biology of the marine crab *Scylla serrata* (Forsk.) **Ph.D. Thesis. University of Bombay.**
- DEVARAJ, M. 1977. The biology and fishery for the seerfishes of India. **Ph.D. Thesis. Madurai Kamaraj University, 337 pp.**
- DEVARAJ, M. 1983. Fish population dynamics. Course manual. **Bull. Central Institute of Fisheries Education,3(10):98pp.**
- DHAWAN, R.M., S.N. DWIVEDI AND G.V. RAJAMANICKAM. 1976. Ecology of the blue crab *Portunus pelagicus* (Linnaeus) and its potential fishery in Zuari estuary. **Indian J. Fish.,23(1&2):57- 64.**
- DITTEL, A.I., C.E. EPIFANIO AND J. BAUTISTA. 1985. Population biology of the portunid crab *Callinectes arcatus* Ordway in the Gulf of Nicoya, Costa Rica, Central America. **Estuarine, Coastal and Shelf Science,20:593-602.**
- DIESEL, R. 1989. Structure and function of the reproductive system of the symbiotic spider crab *Inachus phalangium* (Decapoda:Majidae): Observations on sperm transfer, sperm storage, and spawning. **J. Crust. Biol.,9(2):266-277.**
- DOMINISAC, J.B. AND H.E. DEIARME. 1974. Some observations on the reproduction and larval development of *Scylla serrata* Forskal. **Tech. Rep. Mindanao State Univ. Inst. Fish. Res. Dev.,1974:57- 64.**
- DU PLESSIS, A. 1971. Preliminary investigation into the morphological characteristics, feeding, growth, reproduction and larval rearing of *Scylla serrata* Forskal (Decapoda:Portunidae), held in captivity. **South Africa, Fisheries Development Corporation,24pp.**
- DU PREEZ, H.H. 1984. Molluscan predation by *Ovalipes punctatus* (De Haan) (Crustacea: Brachyura: Portunidae). **J. Exp. Mar. Biol. Ecol., 84: 55-71.**
- EALLES, A.W. 1972*. Ethological studies of some portunid crabs. **M.Sc. Thesis, University of Queensland, Australia.**
- EDGAR, G.J. 1990. Predatory-prey interactions in sea grass beds.2. Distribution and diet of the blue marine crab *Portunus pelagicus* Linnaeus at Cliff Head, Western

- Australia. **J. Exp. Mar. Biol. Ecol.**,139(1&2):23-32.
- EDWARDS, E. 1979. The edible crab and its fishery in British waters. **Fishing News Books Ltd.,Farnham, Surrey, England.**142pp.
- EDWARDS, E. 1989. Crab fisheries and their management in the British Isles (Shell fish Ass. Great Britain, London, UK). In: "**Marine Invertebrate Fisheries: Their assessment and management**" (J.F.Caddy, ed.),pp.241-259.**New York: Wiley Inter Science.**
- EHRHARDT, N.M. 1990. Mortality and catchability estimates for stone crab (*Menippe mercenaria*) in Everglades National Park. **Bull. Mar. Sci.**,46(2):324-334.
- ELNER, R.W. 1980. The influence of temperature, sex and chela size in the foraging strategy of the shore crab *Carcinus maenas*. **Mar. behav. Physiol.**, 7:15-24.
- EL-SHERIEF, S.S. 1987. Histochemical study of the spermatophores of the crab *Portunus pelagicus* (L.) (Crustacea, Brachyura). **Sci. Bull. Minia Univ.**,1(2):1-18.
- EL-SHERIEF, S.S. 1988. Histochemical study of the secretions of the male reproductive system of *Portunus pelagicus* (L.) (Crustacea, Brachyura). **Folia Morphol.**,1(36):95-106.
- EL-SHERIEF, S.S. 1991. Fine structure of the sperm and spermatophores of *Portunus pelagicus* (L.)(Decapoda, Brachyura). **Crustaceana**, 61(3):271-279.
- EMMERSON, W.D. 1994. Seasonal breeding cycles and sex ratios of eight species of crabs from Mgzana, a mangrove estuary in Transkei, Southern Africa. **J. Crust. Biol.**, 14(3): 568-578.
- ENNIS, G.P. 1973. Food, feeding and condition of lobsters, *Homarus americanus*, throughout the seasonal cycle in Bonavista Bay, Newfoundland. **J. Fish. Res. Bd. Can.**, Vol.30:1905-1909.
- ERDMAN, R.B. AND N.J. BLAKE. 1988. Reproductive ecology of female golden crab *Geryon fenneri* Manning and Holthuis, from southeastern Florida. **J. Crust. Biol.**,8(3):392-400.
- ESCRITOR, G.L. 1970. Report on experiment in the culture of the mud crab (*Scylla*

serrata). **Proc. Indo-Pacif. Fish. Counc.**, 14:11pp.

ESCRTOR, G.L. 1972. Observations on the culture of the mud crab, *Scylla serrata*. In: **Coastal Aquaculture in the Indo-Pacific Region**. (V.R. Pillay, ed.),pp.355-361. **Fishing News Books. West Byfleet.**

ESTAMPADOR, E.P. 1949*. *Scylla* (Crustacea: Portunidae), II. Comparative studies on spermatogenesis and oogenesis. **Phillip. J. Sci.**,78(3):301-353.

EZHILARASI, S. AND T. SUBRAMONIAM. 1982. Spermathecal activity and ovarian development in *Scylla serrata* (Forsk.) (Decapoda:Portunidae). In:"**Progress in Invertebrate Reproduction and Aquaculture**". (T. Subramoniam, and S. Varadarajan, eds.), pp.77-88. **First All India Symposium on Invertebrate Reproduction, Madras (India) 28-30 Jul. 1980.**

FAROOQUI, U.M. 1980. Reproductive physiology of the marine crab *Scylla serrata*. **Ph.d. Thesis, Marathwada University.**

FEDER, H.M. AND S.C. JEWETT. 1977. The distribution, abundance and diversity of the epifauna of two bays (Alitak and Ugak) of Kodiak Island, Alaska. **Institute of Marine Science Report R 77- 3, University of Alaska, Fairbanks, 74 pp.**

FEDER, H.M. AND S.C. JEWETT. 1980. Survey of the epifaunal invertebrates of the southeastern Bering sea with notes on the feeding biology of selected species - **Institute of Marine Science Report R 78-5, University of Alaska, Fairbanks, 105 pp.**

FEDER, H. M. AND M.K. HOBERG. 1981. The epifauna of three bays (Port Etches, Zaikof Bay and Rocky Bay) in Prince William Sound, Alaska, with notes on feeding biology - **Institute of Marine Science Report R 81-2, University of Alaska, Fairbanks, 39 pp.**

FEDER, H.M. AND A.J. PAUL. 1981. Food of the king crab *Paralithodes camtschatica* and the dungeness crab *Cancer magister* in the Cook Inlet, Alaska. **Proc. natn. Shellfish. Ass.**, 70: 240-246.

FIELDER, D.R. AND E.J. EALES. 1972. Observations on courtship, mating and

- sexual maturity in *Portunus pelagicus* (L. 1766) (Decapoda, Portunidae). **J. Nat. Hist.**,**6**(3):273-277.
- FIELDING, A. AND S.R. HALEY. 1976. Sex ratio, size at reproductive maturity and reproduction of the Hawaiian konar crab, *Raina vanina* (Linnaeus). **Pacif. Sci.**,**30**(2):131-145.
- FORD, E. 1933. An account on the herring investigations conducted at Plymouth during the years 1924-1933. **J. mar. biol. Ass. U.K.**, **19**: 305-384.
- GARCIA,S AND L. LE RESTE. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. **FAO Fish. Tech. Pap.**,**(203)**: 215p.
- GEORGE, M.J. 1949. Biology of the edible crab *Neptunus sanguinolentus* Herbst. **M.Sc. Thesis, University of Madras, India.** 199 pp.
- GEORGE, M.J. 1961. On the internal skeleton and musculature of crab *Neptunus sanguinolentus* (Herbst). **J. Madras Univ.**,**31B**(3):217-240.
- GEORGE, M.J. 1961a. The anatomy of the crab *Neptunus sanguinolentus* (Herbst). Part II. Nervous system and sense organs. **J. Madras Univ.**,**31B**(3):241-256.
- GEORGE, M.J. 1961b. The anatomy of the crab *Neptunus sanguinolentus* (Herbst). Part III: Respiratory, excretory and blood vascular system. **J. Madras Univ.**,**31B**(3):257-273.
- GEORGE, M.J. 1963. The anatomy of the crab *Neptunus sanguinolentus* (Herbst). Part IV: Reproductive system and embryological studies. **J. Madras Univ.**,**33B**(3):289-304.
- GEORGE, M.J. 1982. Scientific basis for the management of penaeid shrimp fishery. **Mar. Fish. Infor. Serv. T & E. Ser.No.****39**:6-11.
- GEORGE, M.J., K. ALAGARAJA, K.K. SUKUMARAN, G. NANDAKUMAR, S. RAMAMURTHY AND K.Y. TELANG. 1988. The present status of shrimp trawling and its impact on shrimp stocks of Karnataka coast. **Seminar Proc. Problems and Prospects of Marine Fishing and Fish Processing in Karnataka**

(K. Karunasagar, ed.), p1-14.

- GEORGE, P.C. AND K.R. NAYAK. 1961. Observations on the crab fishery of Mangalore coast. *Indian J. Fish.*,8(1):44-53.
- GEORGE, P.C. AND P. VEDAVYASA RAO. 1967. An annotated bibliography of the biology and fishery of the commercially important crabs of India. *Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part V*:1521-1547.
- GEORGE, P.C., B.T.A. RAJA AND K.C. GEORGE. 1977. Fishery resources of the Indian Exclusive Economic Zone, *Souvenir, Silver Jubilee IFP, Cochin, India*, pp.79-116.
- GIESE, A.C. 1959. Comparative physiology: Annual reproductive cycles in marine invertebrates. *A. Rev. Physiol.*,21:547-576.
- GIESE A.C. AND J.S. PEARSE. 1974. Introduction. In: "**Reproduction of marine invertebrates. Vol. I. Acoelomate and Pseudocoelomate metazoans**". (A.C. Giese and J.S. Pearse, eds.), pp. 1-49. Academic Press, New York.
- GNANAMUTHU, C.P. 1954. *Choniosphaera indica*, a copepod parasite on the crab *Neptunus* sp. *Parasitology*, 44:371-378.
- GRAY, G.W. AND G.C. POWELL. 1966. Sex ratio and distribution of spawning king crabs in Alitak bay, Kodiak island, Alaska (Decapoda, Anomura, Lithodidae). *Crustaceana*, 10(3):303-309.
- GURRIARAN, E.G. AND J. FREIRE. 1994. Sexual maturity in the velvet-swimming crab *Necora puber* (Brachyura, Portunidae): morphometric and reproductive analysis. *ICES J. mar. Sci.*,51: 133-145.
- GOTSHALL, D.W. 1977. Stomach contents of Northern California Dungeness crab *Cancer magister*. *Calif. Fish Game*, 63:43-51.
- GOY, J.W., S.G. MORGAN AND J.D. COSTLOW JR. 1985. Studies on the reproductive biology of the mud crab *Rhithropanopeus harrisi* (Gould): induction of spawning during the non-breeding season (Decapoda, Brachyura). *Crustaceana*,49(1):83-87.

- GRIFFIN, D.J.G. 1970. Australian crabs. *Aust. Nat. Hist.*,**16**:304- 308.
- GRINO, E. 1977. Notes on the local importance of culturing *Scylla serrata* in Aklan, Capiz and Ibodla Provinces. *SEAFDEC. Phil.*
- GUINOT, D. 1966. *Les crabes comestibles de l'Indo-Pacifique*. Editions de la Fondation Singer-Polignac, Paris, 145 pp.
- GUINOT, D. 1977. Propositions pour un nouvelle classification des crustaces Decapodes Brachyaures. *C.R. Acad. Sci., Ser. D.*,**285**:1049-1052.
- GULLAND, J.A. AND S.J. HOLT. 1959. Estimation of growth parameters for data at unequal time intervals. *J. Cons. CIEM*: **25**(1): 47-49.
- HAEFNER, P.A. JR. 1976. Distribution, reproduction and moulting of the rock crab, *Cancer irroratus* Say, 1917, in the mid- Atlantic Bight. *J. nat. Hist.*,**10**:377-397.
- HAEFNER, P.A., JR. 1977. Reproductive biology of the female deep sea red crab, *Geryon quinquedens*, from the Chesapeake Bight. *Fish. Bull.*,**75**:91-102.
- HAEFNER, P.A. JR. 1978. Seasonal aspects of the biology, distribution and relative abundance of the deep sea red crab, *Geryon quinquedens* Smith, in the vicinity of the Norfolk Canyon, eastern North Atlantic. *Natl. Shellfish. Assoc. Proc.*,**68**:49-62.
- HAEFNER, P.A. JR. 1985. Morphology, reproduction, diet, and epizoites of *Ovalipes stephensoni* Williams, 1976 (Decapoda, Brachyura). *J. Crust. Biol.*,**5**(4):658-672.
- HAEFNER, P.A. JR. 1985a. The biology and exploitation of crabs. In: *The Biology of Crustacea. Vol.10. Economic aspects: Fisheries and Culture*" (A.J. Provenzano, Jr. ed.), pp.111-166, Academic Press, New York.
- HAEFNER, P.A. JR. 1990. Morphology and size at maturity of *Callinectes ornatus* (Brachyura, Portunidae) in Bermuda. *Bull. Mar. Sci.*,**46**(2):274-286.
- HAEFNER, P.A. JR. AND VAN ENGEL, W.A. 1975. Aspects of moulting in the rock crab, *Cancer irroratus* Say. *Chesapeake Sci.* **16**(4):221-243.
- HALEY, S.R. 1969. Relative growth and sexual maturity of Texas ghost crab, *Ocypode*

- quadrata* (Fabri.)(Brachyura,Ocypodidae). **Crustaceana**,17(3):285-297.
- HAMSA, K.M.S.A. 1978. On the meat content of *Portunus pelagicus* with some observations on lunar periodicity in relation to abundance, weight and moulting. **Indian J. Fish.**,25(1&2):165- 170.
- HAMSA, K.M.S.A. 1978a. Fishery of the swimming crab *Portunus pelagicus* Linnaeus from Palk Bay and Gulf of Mannar. **Indian J. Fish.**,25(1&2):229-232.
- HAMSA, K.M.S. 1978b. Chemical composition of the swimming crab *Portunus pelagicus* Linnaeus. **Indian J. Fish.**,25(1&2):268-270.
- HAMSA, K.M.S. 1979. On the moulting of *Portunus pelagicus* Linnaeus. **Indian J. Fish.**,26(1&2):247-249.
- HAMSA, K.M.S. 1982. Observations on moulting of crab *Portunus pelagicus* (Linnaeus) reared in the laboratory. **J. mar. biol. Ass. India**, 25(1&2):69-71.
- HAILEY, S.R. 1973. On the use of morphometric data as a guide to reproductive maturity in the ghost crab, *Ocypode ceratophthalmus* (Pellas)(Brachyura,Ocypodidae). **Pac. Sci.**,27(4):350-362.
- HARTNOLL, R.G. 1963. The biology of manx spider crabs. **Proc.Zool. Soc. London**, 141(3):423-496.
- HARTNOLL, R.G. 1965. Notes on the marine grapsid crabs of Jamaica. **Proc. Linn. Soc. London.**, 176: 113-147.
- HARTNOLL, R.G. 1968. Reproduction in burrowing crab *Corystes cassivelaunus* (Pennant,1777)(Decapoda, Brachyura). **Crustaceana**,15:165-170.
- HARTNOLL,R.G. 1969. Mating in Brachyura. **Crustaceana**, 16: 161-181.
- HARTNOLL, R.G. 1972. The biology of the burrowing crab, *Corystes cassivelaunus*. **Bijdragen tot de dierkunde**, 42: 139-155.
- HARTNOLL, R.G. 1974. Variation in growth pattern between some secondary sexual characters in crabs (Decapoda,Brachyura). **Crustaceana**,27(2):131-136.

- HARTNOLL, R.G. 1982. Growth. In: "The biology of crustacea, 2. Embryology, morphology and genetics. (L.G. Abele, ed.), 111-195, Academic Press, New York.
- HARTNOLL, R.G. 1993. The epibiota of spider crabs. Bios (Macedonia, Greece). *Scientific annals of the School of Biology*, 1(1):163-176. *Proceedings of the fourth Colloquium Crustacea Decapoda Mediterranea, Thessaloniki, April 25th-28th, 1989.*
- HARTNOLL, R.G., A.D. BRYANT AND P. GOULD. 1993. Size distribution in spider crab populations - Spatial and temporal variation. *J. Crust. Biol.*, 13(4):647-655.
- HAVENS, K.J. AND J.R. MCCONAUGHA. 1990. Moulting in the mature female blue crab, *Callinectes sapidus* Rathbun. *Bull. Mar. Sci.*, 46(1):37-47.
- HEASMAN, M.P. AND D.R. FIELDER. 1977. Management and exploitation of the Queensland mud crab fishery. *Aust. Fish.*, 36(8):4-71.
- HEASMAN, M.P. 1980*. Aspects of the general biology and fishery of the mud crab *Scylla serrata* (Forsk.) in the Moreton Bay, *Ph.D. Thesis, University of Queensland*. 506pp.
- HEASMAN, M.P. AND D.R. FIELDER, 1983. Laboratory spawning and mass rearing of the mangrove crab, *Scylla serrata* (Foskal) from first zoea to first crab stage. *Aquaculture*, 34 (3-4):303-316.
- HEASMAN, M.P., D.R. FIELDER AND R.K. SHEPHERD. 1985. Mating and spawning in the mud crab, *Scylla serrata* (Forsk.) (Decapoda:Portunidae) in the Moreton Bay, Queensland. *Aust. J. Mar. Freshw. Res.*, 36(6):773-783.
- HENMI, Y., T. KOGA AND M. MURAI. 1993. Mating behaviour of the sand bubbler crab, *Scopimera globosa*. *J. Crust. Biol.*, 13(4):736-744.
- HIATT, R.W. 1948. The biology of the lined shore crab, *Pachygrapsus crassipes* Randall. *Pacif. Sci.*, 2:135-213.
- HIATT, R.W. 1977. Field studies of size - dependent changes in waving display and

- other behaviour in the fiddler crab, *Uca pugilator* (Brachyura, Ocypodidae). **Mar. behav. Physiol.**, **4** :283- 292.
- HILL, B.J. 1975. Abundance, breeding and growth of the crab *Scylla serrata* in two South African estuaries. **Mar. Biol.**, **32**:119-126.
- HILL, B.J. 1976. Natural food, foregut clearance-rate and activity of the crab *Scylla serrata*. **Mar. Biol.**, **34**(2):109-116.
- HILL, B.J. 1979. Aspects of feeding strategy of the predatory crab *Scylla serrata*. **Mar. Biol.**, **55**(3):209-214
- HILL, B.J. 1979a. Biology of the crab *Scylla serrata* (Forsk.) in the St. Lucia system. **Trans. R. Soc. S.Afr.**, **44**(1):52-62.
- HILL, B.J. 1980. Effect of temperature on feeding and activity in the crab *Scylla serrata*. **Mar. Biol.**, **59**: 189-192.
- HILL, B.J. 1994. Offshore spawning by the portunid crab *Scylla serrata* (Crustacea: Decapoda). **Mar. Biol.**, **120**:379-384.
- HILL, B.J., M.J. WILLIAMS AND P. DATTON. 1982. Distribution of juvenile, subadult and adult *Scylla serrata* (Crustacea:Portunidae) on tidal flats in Australia. **Mar. Biol.**, **69**(1):117-120.
- HINES, A.H. 1988. Fecundity and reproductive output in two species of deep water crabs, *Geryon fenneri* and *G. quinquedens*. **J. Crust. Biol.**, **8**(4): 557-562.
- HINSCH, G.W. 1988. Ultrastructure of the sperm and spermatophores of the golden crab, *Geryon fenneri* and a closely related species *G. quinquedens*, from the eastern Gulf of Mexico. **J. Crust. Biol.**, **3**(2): 340-345.
- HOGGARTH, D.D. 1993. The life history of the lithodid crab, *Paralomis granulosa*, in the Falkland Islands. **ICES J. mar. Sci.**, **50**:405-424.
- HONMA, Y.U. AND A. CHIBA. 1981. Studies on gonad maturity in some marine invertebrates. XI. Maturation and spawning behaviour of the land crab, *Sesarma haematoecheirs* (De Haan) on the west of Sado island in the sea of Japan. **Ann. Rep. Sado Mar. Biol. Stat. Nigato Univ.**, **11**.

- HOOPES, D.T. AND J.F. KARINEN. 1972. Longevity and growth of tagged King crabs in the eastern Bering sea. **Fish. Bull. Nat. Oceanic Atmos. Admin.**,70:225-226.
- HORA, S.L. 1935. Crab fishing at Uttarbhag, Lower Bengal. **Curr. Sci.**,3(1):543-546.
- INGLES, J.A. 1988. On the biology and fishery of *Portunus pelagicus* (L.1766) in the Ragay Gulf, Philippines. **Fachber Biologie**,pp.311 (in German).
- INGLES, J.A. AND E. BRAUN. 1989. Reproduction and larval ecology of the blue swimming crab *Portunus pelagicus* in Ragay Gulf, Philippines. **Int. Rev. Gesam. Hydrobiol.**,74(5):471-490.
- JACOB, R., P.N. PRASAD AND M.S. KUSUMA. 1990. Maturity and dimentional studies in female crabs of *Portunus sanguinolentus* and *P. pelagicus* (Decapoda:Portunidae). **Ind. J. Mar. Sci.**,19:221-223.
- JAMESON, J.D., A. MURUGAN AND P. NATARAJAN. 1982. Studies on the distribution pattern and morphometry of *Scylla serrata* (Forsk.) along the Tuticorin coast. **Seafood Export J.**14(4):17- 20.
- JEWETT, S.C. AND H.M. FEDER. 1982. Food and feeding habits of the king crab *Paralithodes camtschatica* near Kodiak Island, Alaska. **Mar. Biol.**,66:243-250.
- JEWETT, S.C. AND H.M. FEDER. 1983. Food of the tanner crab *Chionoecetes bairdi* near Kodiak Island, Alaska. **J. Crust. Biol.** 3(2):196-207.
- JEYALECTUMI, C AND T. SUBRAMONIAM. 1989. Cryopreservation of spermatophores and seminal plasma of the edible crab *Scylla serrata*. **Biol. Bull.**, 177(2): 247-253.
- JHINGRAN, A.G. 1952. General length-weight relationship of the major carps of India. **Proc. Nat. Inst. Sci. India**, 18: 449-460.
- JOEL, D.R. AND P.J.S. RAJ. 1980. Epizoic fauna of some portunid crabs of the Pulicat Lake. In: **Symposium on Coastal Aquaculture, Cochin, India, 12-18 Jan. 1980. Abstracts. Cochin, Marine Biological Association of India.** p.154.
- JOEL, D.R. AND P.J.S. RAJ. 1982. The breeding of three edible portunid crabs of

- Pulicat Lake. In: " **Progress in Invertebrate Reproduction and Aquaculture.**"(**T. Subramoniam and Sudha Varadarajan, eds.**), pp.135-140. **Indian Soc. Inver. Reproduction, Madras.**
- JOHNSON, P.T. 1980. Histology of the blue crab, *Callinectes sapidus*: a model for the Decapoda. Chapter 15. The reproductive system, pp. 327-367. **Praeger Publishers, New York.** pp I-XV, 1- 440.
- JONES, D.A. 1984. Crabs of the Mangal ecosystem. In: "**Hydrobiology of Mangal**" (F.D. Por and I. Dor, eds.) pp. 89- 109. **Dr.W. Jung Publishers, The Hague.**
- JONES, S. AND K.H. SUJASINGANI. 1952. Notes on the crab fishery of Chilka Lake. **J. Bombay Nat. Hist. Soc.,51:** 128-134. .
- JONES, C.M., J.R. MCCONAUGHA, P.J. GEER AND M.H. PRAGER. 1990. Estimates of spawning stock size of blue crab, *Callinectes sapidus*, in the Chesapeake Bay, 1986-1987. **Bull. Mar. Sci.,46(1):**159-169.
- KANCIRUK, P. AND F. HERRNKIND. 1976. Autumnal reproduction in *Panulirus argus* at Bimini, Bahamas. **Bull. Mar. Sci.,26(4):**417- 432.
- KANNAIAH, N. 1981. Fecundity studies in crabs. **M.Sc. dissertation, Annamalai University.**
- KATHIRVEL, M. 1980. Abundance of portunid crab seeds in Cochin backwater. In: **Symposium on Coastal Aquaculture, Cochin, India, 12-18 Jan. 1980. Abstracts. Cochin, Marine Biological Association of India.** p.55.
- KENNELLY, S.J. and D. WATKINS. 1994. Fecundity and reproductive period and their relationship to catch rates of spanner crabs, *Ranina ranina*, off the east coast of Australia. **J. Crust. Biol., 14(1):** 146-150.
- KNUDSEN, J.W. 1960. Reproduction, life history and larval ecology of the California Xanthidae, the pebble crabs. **Pac. Sci.,14:3- 17.**
- KRISHNASWAMY, S. 1967. Reproduction and nutritional cycles in a few invertebrates from the east coast of India. **International Indian Ocean Expedition, News letter, 4(4):**18p.

- KURATA, H. 1962. Studies on the age and growth of crustacea. **Bull. Hokkaido Reg. Fish. Res. Lab.**,24: 1-115.
- KURATA, K. AND T. MIDORIKAWA. 1975. The larval stages of the swimming crabs *Portunus pelagicus* and *P. sanguinolentus* reared in the laboratory. **Bull. Nansei Reg. Fish. Res. Laboratory**, 8: 29-38.
- KUSUMA, M.S. 1983. Biology of *Johnius belangeri* (Cuvier) with notes on the sciaenid fishery of the North Kanara coast. **Ph.D. Thesis. Karnatak University.**
- KUTTY, M.K. AND S.Z. QASIM, 1968. The estimation of optimum age of exploitation and potential yield in fish populations. **J. Cons. perm. int. Explor. Mer.**,32(2):249-255.
- KWEI, E.A. 1974*. Coastal lagoons in Ghana and the ecology of the blue crab, *Callinectes latimanus* (Rathbun). **Ph.D. Thesis, Faculty of Science, University of Ghana, Legon.**
- LALITHA DEVI, S. 1985. The fishery and biology of crabs of Kakinada region. **Indian J. Fish.**,32(1): 18-32.
- LAUGHLIN, R.A. 1982. Feeding habits of the blue crab, *Callinectes sapidus* Rathbun, in the Apalachicola Estuary, Florida. **Bull Mar. Sci.**,32(4): 807-822.
- LAVINA, A.F. AND A.S. BULING. 1977. The propagation of the mud crab *Scylla serrata* (F.)de Haan. **SEAFDEC., Q. Res. Rep.**,2:9-11.
- LE CREN, C.D. 1951*. The length-weight relationship and seasonal cycle in gonad weights and condition in perch (*Perca fluviatilis*). **J. Anim. Ecol.**,30: 201-209.
- LEWIS, E.G. 1977. Relative growth and sexual maturity of *Bathynectes superbus* (Costa) (Decapoda:Portunidae). **J. nat. Hist.**,11: 629-643.
- LINDBERG, W.J. AND F.D. LOCKHART. 1993. Depth stratified population structure of Geryonid crabs in the eastern Gulf of Mexico. **J. Crust. Biol.**,13(4): 713-722.
- LIPCIUS, R.N. AND W.A. VAN ENGEL. 1990. Blue crab population dynamics in Chesapeake Bay. Variation in abundance (York river, 1972-1988) and stock

- recruitment fluctuations. **Bull. Mar. Sci.**, **46**(1): 180-194.
- LOVRICH, G.A. AND J.H. VINUESA. 1993. Reproductive biology of the false southern king crab, (*Paralomis granulosa*, Lithodidae) in the Beagle Channel, Argentina. **Fish. Bull.**, **91**: 664-675.
- LUBA SHINKARENKO, 1979. Development of the larval stages of the blue swimming crab *Portunus pelagicus* L. (Portunidae, Decapoda, Crustacea). **Aust. J. Mar. Freshw. Res.**, **30**: 485-503.
- LUCAS, J.S. AND E.P. HODGEKIN. 1970. The growth and reproduction of *Halicarcinus australis* (Haswell)(Crustacea: Decapoda) in the Swan Estuary, western Australia. **Aust. J. Mar. Freshw. Res.**, **21**: 149-162.
- MACKAY, D.C.G. 1942. Relative growth of the European edible crab, *Cancer pagurus*: 1. Growth of carapace. **Growth**, **6**: 251-258.
- MACKAY, D.C.G. 1942a. The Pacific edible crab, *Cancer magister*. **Bull. Fish. Res. Bd. Can.**, **LXII**: 1-32.
- MANOHARA RAM, B.H. AND K. CHANDRAMOHAN. 1978. Some preliminary observations on the trend in commercial crab fishery of Mangalore. **Seafood Export J.**, **10**(5): 25-27.
- MANNING, R.B. AND L.B. HOLTHUIS. 1981*. West African Brachyuran Crabs (Crustacea: Decapoda). **Smithsonian Contributions to Zoology** **306**: 1-379, 89 figs.
- MARICHAMY, R. 1980. Culture of fishes in cages and pens along the coastal waters of India. **Proc. Intl. Woshp. on Pen culture of fish. SEAFDEC. Phil.**, pp.41-44.
- MARICHAMY, R., S. SHANMUGAM AND S. RAJAPACKIAM. 1980. Polyculture experiment in coastal waters at Tuticorin. **Proc. Sem. on Coastal and Inland fish culture in Tamilnadu. Fish. College, TNAU, Tuticorin**, pp. 241-248.
- MARICHAMY, R. MANICKARAJA, M. AND S. RAJAPACKIAM. 1986. Culture of the mud crab *Scylla serrata* (Forsk.) in Tuticorin Bay. **Proc. Symp. on**

- Coastal Aqua., Mar. Biol. Ass. India., Part 4: 1176-1182.
- MARICHAMY, R. AND S. RAJAPACKIAM. 1984. Culture of larvae of *Scylla serrata*. Mar. Fish. Infor. Serv. T & E. Ser., 58:13-15.
- MCLAY, C.L. 1982. Population biology of the sponge crab *Cryptodromia hilgendorfi* (Dromiacea) in the Moreton Bay, Queensland, Australia. Mar. Biol., 70: 317-326.
- MEAGHER, T.D. 1970. The larval ecology of the blue swimming crab *Portunus pelagicus* in the south western Australia. Aust. Mar. Sci. Bull.,22: 10-16.
- MELVILLE-SMITH, R. 1989. A growth model for the deep sea red crab (*Geryon maritae*) off South west Africa/ Namibia (Decapoda, Brachyura). Crustaceana, 56(3): 279-292.
- MENON, M.K. 1952. A note on the bionomics and fishery of the swimming crab *Portunus sanguinolentus* (Herbst) on the Malabar coast. J. Zool. Soc. India, 4(2): 177-184.
- METHOT, R.D. 1989. Management of a cyclic resource: The dungeness crab fisheries of the Pacific coast of North America. In: "Marine Invertebrate Fisheries. Their assessment and management." (J.E. Caddy, ed.), pp.205-240. Wiley - Inter Science, New York.
- MOTOH, H., M. LA PENA AND E. TAMPOS. 1977. Laboratory breeding of the mud crab, *Scylla serrata* (Forsk.) through the zoea and megalopa stages to the crab stage. SEAFDEC, Q. Res. Rep.,1(4): 14-18.
- MOTOH, H., M. LA PENA, M. DIMAANO AND E. TAMPOS. 1978. Preliminary report on the first production of the crab stages of alimasag, *Portunus Pelagicus* (Linnaeus). SEAFDEC, Q. Res. Rep., 1(3): 16-21.
- MURTHY, V.S. 1990. Biology and population dynamics of the silver belly *Secutor insidiator* (Bloch) from Kakinada. J. mar. biol. Ass. India, 32 (1 & 2):10-24.
- NAGABHUSHANAM, R. AND U.M. FAROOQUI. 1981. Photoperiodic stimulation of ovary and testis maturation in the immature marine crab *Scylla serrata*

- Forskal. **Indian J. Mar. Sci.**,10(4): 396-398.
- NAIDU, K.G. RAJABAI. 1955. The early development of *Scylla serrata* (Forskal) and *Portunus sanguinolentus* (Herbst). **Indian J. Fish.**, 2: 67-76.
- NARASIMHAM, K.A. 1970. On the length-weight relationship and relative condition in *Trichiurus lepturus* (Linnaeus). **Indian J. Fish.**, 17: 90-96.
- NATARAJAN, P. AND G.S. THANGARAJ. 1983. Studies on the growth of edible crab *Scylla serrata* in the brackish water cage. **Proc. Nat. Seminar on cage and pen culture, Fisheries College, TNAU, Tuticorin**: 107-110.
- NEELAKANTAN, B. 1981. Studies on the false travelly *Lactarius lactarius* (Bloch & Schneider) from the Karwar waters. Ph. D. Thesis. Karnatak University.
- NEWCORBE, C.L., M.D. SANDOZ AND R. ROGERS-TALBERT. 1949. Differential growth and moulting characteristics of the blue crab, *Callinectes sapidus*. **J. Exp. Zool.**, 110: 1-41.
- ONG, K.S. 1964. The early developmental stages of *Scylla serrata* Forskal (Crustacea: Portunidae), reared in the laboratory. **Proc. Indo-Pacif. Fish. Council.**, 11th Session, Sec.2, pp. 135- 146.
- ONG, K.S. 1966. Observations on the post-larval history of *Scylla serrata* Forskal reared in the laboratory. **Malay. Agric. J.**, 45: 429-443.
- PADAYATTI, P.S. 1990. Notes on the population characteristics and reproductive biology of the portunid crab *Charybdis (Charybdis) feriatus* (Linnaeus) at Cochin. **Indian J. Fish.**,37(2); 155-158.
- PANIKKAR, N.K. AND R.G. AIYAR. 1939. Observations on the breeding in brackish water animals of Madras. **Proc. Indian Acad. Sci.**, 9: 343-364.
- PANIKKAR, N.K. AND R. JAYARAMAN. 1966. Biological and oceanographic differences between the Arabian sea and the Bay of Bengal as observed from the Indian region. **Proc. Indian Acad. Sc.**, 64B: 231-240.
- PASSONO, L.M. 1960. Moulting and its control. In: "**Biology of Crustacea, Vol.2. Embryology, Morphology and Genetics**". (L.G. Abele, ed.), pp.473-536.

Academic Press, New York.

- PATEL, N.M., N.D. CHHAYA AND M. BHASKARAN. 1979. Stomach contents of *Portunus pelagicus* (Linn.) from the AD nets. **Indian J. Mar. Sci.**, **8**(1): 48-49.
- PAUL, R.K. 1981. Natural diet, feeding and predatory activity of the crabs *Callinectes arcuatus* and *C. toxotes* (Decapoda, Brachyura, Portunidae). **Mar. Ecol. Prog. Ser.**, **6**: 91-99.
- PAULY, D. 1980. On the interrelationships between natural mortality, growth parameters and environmental temperatures in 175 fish stocks. **J. Cons. inst. Explor. Mer.**, **39**:175-192.
- PAULY, D. AND N. DAVID. 1981. ELEFAN I, a basic programme for the objective extraction of growth parameters from length frequency data. **Meeresforschung**, **28**(4):205-211.
- PAULY, D. 1983. Length converted catch curves. A powerful tool for fisheries research in tropics (Part I). **ICLARM Fishbyte**, **1**(2):9-13.
- PENN, J.W. 1977. Trawl caught fish and crustaceans from Cockburn Sound. **Report, Department of Fisheries and Wildlife, Western Australia**, **20**: 1-24
- PILLAI, K. KRISHNA AND N.B. NAIR. 1970. Observations on the reproductive cycles of some crabs from the southwest coast of India. **J. mar. biol. Ass. India**, **10**(2): 384-386.
- PILLAI, K. KRISHNA AND N.B. NAIR. 1971. The reproductive cycles of three decapod crustaceans from the southwest coast of India. **Curr. Sci.**, **40**(7): 161-162.
- PILLAI, K. KRISHNA AND N.B. NAIR. 1971a. The annual reproductive cycles of *Uca annulipes*, *Portunus pelagicus* and *Metapenaeus affinis* (Decapoda, Crustacea) from the southwest coast of India. **Mar. Biol.**, **11**(2): 152-166.
- PILLAI, K. KRISHNA AND N.B. NAIR. 1976. Observations on the breeding biology of some crabs from the southwest coast of India. **J. mar. biol. Ass. India**, **15**(2): 754-770.

- PILLAI, N.K. 1951. Decapoda (Brachyura) from Travancore. **Bull. Cent. Res. Zost. Univ. ser. C**,1:1-46, 5 text-figs.
- PILLAY, T.V.R. 1954. The biology of grey mullet *Mugil tade* (Forsk.) with notes on its fishery in Bengal. **Proc. Nat. Inst. India.**, 20:187-217.
- POTTER, I.C., P.J. CHRYSTAL AND N.K. LONERAGON. 1983. The biology of the blue marine crab *Portunus pelagicus* in an Australina estuary. **Mar. Biol.**,78(1): 75-86.
- POTTER, M.A., W.D. SUMPTON AND G.S. SMITH. 1991. Movement, fishing sector impact and factors affecting the recaptured rate of tagged sand crabs *Portunus pelagicus* (L.) in the Moreton Bay, Queensland. **Aust. J. Mar. Freshw. Res.**, 42(6): 751-760.
- PRABHU, M.S. 1955. Some aspects of the biology of ribbon fish *Trichiurus haumela* (Forsk.). **Indian J. Fish.**,2:132-163.
- PRAGER, M.H., J.R. CONAUGHA, C.M. JONES AND P.J. GEER. 1990. Fecundity of the blue crab, *Callinectes sapidus*, in the Chesapeake Bay: Biological, statistical and management considerations. **Bull. Mar. Sci.**, 46(1): 170-179.
- PRASAD, P.N., R. SUDHARSHANA AND B. NEELAKANTAN. 1988. Feeding ecology of the mud crab *Scylla serrata* (Forsk.) from the Sunkeri backwaters. **J. Bombay Nat. Hist. Soc.**,85(1): 79-89.
- PRASAD, P.N. AND B. NEELAKANTAN. 1988. Food and feeding habits of the mud crab *Scylla serrata* (Forsk.) (Decapoda, Portunidae) from Karwar waters. **Indian J. Fish.**, 35(3): 164-170.
- PRASAD, P.N. AND B. NEELAKANTAN. 1988a. Morphometry of the mud crab *Scylla serrata*. **Seafood Export J.**, 20(7): 19-22.
- PRASAD, P.N. AND B. NEELAKANTAN. 1989. Fishery of the mud crab, *Scylla serrata* (Forsk.) from Karwar waters. **Fish. Technol. Soc. Fish. Technol. Cochin.**,26(1): 15-18.
- PRASAD, P.N. AND B. NEELAKANTAN. 1989a. Fecundity of the mud crab, *Scylla*

- serrata* (Forsk.) **Mahasargar**, **22(1)**: 23-28.
- PRASAD, P.N. AND B. NEELAKANTAN. 1989b. Maturity and breeding of the mud crab, *Scylla serrata* (Forsk.) (Decapoda:Brachyura: Portunidae). **Proc. Indian Acad. Sci.(Anim. Sci.)**, **98(5)**: 341- 439.
- PRASAD, P.N., J. REEBY, N. KUSUMA AND B. NEELAKANTAN. 1989c. Width-weight and length-weight relationships in three portunid crab specis. **Uttar Pradesh J. Zool.**,**9(1)**: 116-120.
- PRASAD, P.N. AND B. NEELAKANTAN. 1990. Size at maturity in the male crab *Scylla serrata* as determined by chela allometry and gonad condition. **Fish. Technol. Soc. Fish. Technol. Cochin**, **27(1)**: 25-29.
- PRASAD, P.N., B. NEELAKANTAN AND M.S. KUSUMA. 1990. Distribution and abundance of the mud crab *Scylla serrata* from Karwar waters. **Environ. Ecol.**,**8(3)**: 798-804.
- PRASAD, R.R. AND P.R.S. TAMPI. 1951. An account of the fishing methods for *Neptunus pelagicus* (Linnaeus) near Mandapam. **J. Zool. Soc. India**, **3(2)**: 335-339.
- PRASAD, R.R. AND P. R.S. TAMPI. 1953. A contribution to the biology of the blue swimming crab *Neptunus pelagicus* (Linnaeus), with a note on the zoea of *Thalamita crenata* Latrelle. **J. Bombay nat. Hist. Soc.**,**51**: 674-689.
- PRASAD, R.R. AND P.R.S. TAMPI. 1954. Some aspects of relative growth in the blue swimming crab *Neptunus pelagicus* (Linnaeus). **Proc. nat. Inst. Sci. India**, **20(2)**: 218-234.
- PREMKUMAR, V.K. AND A. DANIEL. 1971. Crustaceans of economic value of Great Nicobar Islands. 2. Decapoda, Brachyura, Portunidae. **J. Zool. Soc. India**, **23(2)**: 109-112.
- RADHAKRISHNAN, C.K. 1979. Studies on portunid crabs of Porto Novo (Crustacea; Decapoda: Brachyura). **Ph.D. Thesis, Annamalai University**.
- RADHAKRISHNAN, C.K. AND C.T. SAMUEL. 1980. Prospects of fishery utilization

- and culture of crabs in India. **Fish.Technol.**,17: 67-69.
- RADHAKRISHNAN, C.K. AND C.T. SAMUEL. 1985. Crab meat and its utilization. **Proc. Symp. Harvest and Postharvest Technology of fish, Soc. Fish. Technologists (India)**, pp. 545-547.
- RAHAMAN, A. A. 1967. Reproductive and nutritional cycles of the crab *Portunus pelagicus* (Linnaeus)(Decapoda:Brachyura) of the Madras coast. **Proc. Indian Acad. Sci.,(B)** 65: 76-82.
- RAI, H.S. 1933. Part II. Shell fisheries of Bombay Presidency. **J. Bombay Nat. Hist. Soc.**, 36: 884-897.
- RAMAMURTHY, S. AND K.K. SUKUMARAN. 1984. Observations on the prawn fishery of the Mangalore coast during 1970-1980. **Indian J. Fish.**,31(1):100-107.
- RAMAN, K., S. SRINIVASAGAM AND S. KRISHNAN. 1980. Preliminary studies on culture of portunid crabs *Scylla serrata* and *Portunus pelagicus*. **Symp. on Inland Aquaculture, CIFRI, Barrachpore, Abstract No.111.**
- RAMAN, K. S. SRINIVASAGAM, C.P. RANGASWAMY, S. KRISHNAN, K.O. JOSEPH AND M. SULTANA. 1987. A note on larval rearing of the edible crab *Portunus pelagicus* Linnaeus at Ennore hatchery, Madras. **Indian J. Fish.**, 34(1): 128-131.
- RAO, P. VEDAVYASA AND M. KATHIRVEL. 1971. On the seasonal occurrence of *Penaeus semisulcatus* de Haan, *Panulirus polyphagus* (Herbst) and *Portunus (P.) pelagicus* (Linn.) in the Cochin backwaters. **Indian J. Fish.**, 18: 124-134.
- RAO, P. VEDAVYASA, M.M. THOMAS AND G.S. RAO. 1973. The crab fishery resources of India. In: **Proceedings of the Symposium on living resources of the seas around India. CMFRI Sp. Publ.**: pp.581-591.
- RATHBUN, M.J.1901.* The Brachyura and Macrura of Porto Rica. **U.S. Fish. Comm. Bull.**, 2: 1-37.
- REDDY, H.R.V.S. AND S.L. SHANBHOGUE. 1990. Estuarine fishery resources of Uttara Kannada district, Karnataka. **Environ. Ecol.**,8(3): 888-993.

- REEBY, J., P.N. PRASAD AND M.S. KUSUMA. 1990. Size at maturity in the male crabs of *Portunus sanguinolentus* and *P. pelagicus*. **Fish. Tech.**, 27:115-119.
- REEBY, J., P.N. PRASAD AND M.S. KUSUMA. 1990a. Fecundity of *Portunus* species from Karwar waters. **Fish. Tech.**, 27:153-154.
- REES, G.H. 1963. Edible crabs of United States. **Fish. Lflt. No. 550**, 18 pp.
- REKHA, D.D. 1968. Some aspects of biology of the marine crab, *Scylla serrata* (Forsk.) Ph.D. Thesis, University of Bombay.
- RICE, A.L. 1980. Crab zoel morphology and its bearing on the classification of Brachyura. **Trans. Zool. Soc. London**, 35:271- 424.
- 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 pp.
- ROBERTSON, W.D. AND A. KRUGER. 1994. Size at maturity, mating and spawning in the portunid crab *Scylla serrata* (Forsk.) in Natal, South Africa. **Estuar, estl. Shelf Sci.**(in press).
- ROPES, J.W. 1968. The feeding habits of the green crab, *Carcinus maenas* (L.). **U.S. Fish. Wild Serv. Fish. Bull.**,67: 183-203.
- ROPES, J.W. 1988. The food habits of five crab species at Pettaquamscutt River, Rhode Island. **U.S. Fish. Wild Serv. Fish. Bull.**, 87: 197-204.
- ROSAS, C., E.L. CHAVEZ., AND F.B. RAMIREZ. 1994. Feeding habits and food niche segregation of *Callinectes sapidus*, *C. rathbunae* and *C. similis* in the subtropical coastal lagoon of the Gulf of Mexico. **J. Crus. Biol.**, 14(2):371-382.
- RYAN, E.P. 1967. Structure and fuction of the reproductive system of the crab *Portunus sanguinolentus* (Herbst) (Brachyura: Portunidae). I. Male system. **Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part II**: 506-521.
- RYAN, E.P. 1967a. Structure and function of the reproductive system of the crab *Portunus sanguinolentus* (Herbst) (Brachyura: Portunidae).II. Female system. **Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part II**: 522-544.

- RYAN, E.P. 1967b. The morphometry of sexually mature instars in the crab *Portunus sanguinolentus* (Herbst) (Brachyura: Portunidae). **Proc. Symp. Crustacea. Mar. Biol. Ass. India. Part II: 715-723.**
- SAINTE-MARIE, B. 1993. Reproductive cycle and fecundity of primiparous and multiparous female snow crab, *Chionoecetes opilio* in the northwest Gulf of St. Lawrence. **Can. J. Fish. Aquat. Sci., 50(10): 2147-2156.**
- SAKAI, T. 1934*. Brachyura from the coast of Kyushu Japan. **Sci. Rept. Tokyo Bunrika Daigaku, sect.B.1(25):281-330.**
- SAKAI, T. 1936*. Studies on the Crabs of Japan. I. Dromiacea. **Sci. Rept. Tokyo Bunrika Daigaku, sec.B. Supplement 2(1): 1-66, 9 pls, 13 text-figs.**
- SAKAI, T. 1974*. Notes from the Carcinological Fauna of Japan (V). **Res. on Crustacea 6: 66-102.**
- SAKAI, T. 1976*. Crabs of Japan and the Adjacent Seas. Kodansha Ltd. pp. 1-725. pls.1-151.
- SANKARANKUTTY, C. 1961. On some crabs (Decapoda Brachyura) from the Laccadive Archipelago. **J. mar. biol. Ass. India, 3: 120- 136.**
- SANKARANKUTTY, C. 1962. On decapod brachyura from the Andaman and Nicobar Islands. 1. Families of Portunidae, Ocypodidae, Graspidae and Myctyridae. **J. mar. biol. Ass. India, 3(1&2): 101-119, 5 figs.**
- SANKARANKUTTY, C. 1962a. On Decapoda Brachyura from the Andaman and Nicobar Islands. 2. Family Xanthidae. **J. mar. biol.Ass. India, 4: 121-150, 50 figs.**
- SANKARANKUTTY, C. 1965. On decapod brachyura from the Gulf of Mannar and Palk Bay. **Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part I: 347-362.**
- SASTRY, A.N. 1983. Ecological aspects of reproduction. In: "The Biology of Crustacea. Vol. 8 (F.J. Vernberg and W.B. Vernberg, eds.). pp. 179-270. Academic Press, New York.
- SCHAEFER, M. 1954. Some aspects of the dynamics of populations important to the

- management of the commercial marine fisheries. **Bull.I-ATTAC/Bol. CIAT,1/(2):27-56.**
- SEIPLE, W.H. AND M. SALMON. 1987. Reproduction, growth and life history constraints between two species of graspid crabs, *Sesarma cinerium* and *S. reticulatum*. **Mar. Biol.,94(1):1-46.**
- SHANMUGAM, S. AND P. BENSAM. 1980. On the fishery for the crab *Scylla serrata* (Forsk.) at Tuticorin during 1974-75. **Indian J. Fish., 27(1&2): 102-110.**
- SHEEBA, K. THARIYAN. 1988. Size distribution and reproductive biology of the mud crab *Scylla serrata* at Cochin during the monsoon period. **M.Sc. Dissertation, Cochin University of Science and Technology, Cochin. 50 pp.**
- SHEN, C.J. 1932*. The Crabs of Hong Kong, pt. 3. **Hong Kong Naturalist, 3(1):32-45. pls.6-9, 10 text-figs.**
- SHEN, C.J. 1937*. Notes on a collection of Swimming Crabs (Portunidae) from Singapore. **Bull. Raff. Mus. Singapore 13: 96-139, figs. 1-20.**
- SHIELDS, J.D. AND A.M. KURIS. 1988. An *In Vitro* analysis of egg mortality in *Cancer anthonyi*: the role of symbionts and temperature. **Biol. Bull., 174:267-275.**
- SHIELDS, J.D., R.K. OKAZAKI AND A.M. KURIS. 1990. Fecundity and reproductive potential of the yellow rock crab *Cancer anthonyi*. **Fish. Bull.,U.S.,89: 299-305.**
- SHIELDS, J.D. AND P.E.I. WOOD. 1991. Pathology and fine structure of *Ameson* sp. a microsporidian from the blue sand crab *Portunus pelagicus pelagicus*. **Mem. Queensland Mus., 31: 403.**
- SIMPSON, G.G., A. ROE AND R.C. LEWONTIN. 1960. **Quantitative Zoology. Harcourt, Brace and Co., New York. pp.440.**
- SIMON, J. AND P. SIVADAS. 1978. Morphological changes in the development of ovary in the eyestalk ablated estuarine crab *Scylla serrata* (Forsk.). **Mahasagar-Bull. Natl. Inst. Oceanogr., 11: 57-62.**

- SIMON, J. AND P. SIVADAS. 1979. Histological changes in the oocytes of the estuarine crab *Scylla serrata* (Forsk.) after eyestalk ablation. **Mahasagar - Bull. Natl. Inst. Oceanogr.**, 12: 11-16.
- SMITH, B.D. AND G.S. JAMIESON. 1991. Movement, spatial distribution and mortality of male and female dungeness crab *Cancer magister* near Tofino, British Columbia. **Fish. Bull., U.S.**, 89: 137-148.
- SMITH, G.S. AND W.D. SUMPTON. 1989. Behaviour of the commercial sand crab *Potunus pelagicus* (L.) at trap entrances. **Asian Fish. Sci.**, 3: 101-113. **Asian Fisheries Society, Manila, Philippines.**
- SMITH, H. 1982. Blue crabs in South Australia- their status, potential and biology. **Safic (Adelaide, Australia)** 6:6-9.
- SMITHA, P. AND M. DEVARAJ. 1990. Population dynamics of the prawn *Metapenaeus dobsoni* (Miers) exploited in the trawl fishery along the southwest coast of India. **Fish. Res.**, 8: 381-395.
- SNEDECOR, G.W. AND W.G. COCHRAN. 1967. **Statistical methods**, 6th ed. Iowa State Univ. Press, Ames, Iowa. 593 pp.
- SPALDING, J.F. 1942*. The nature and formation of the spermatophore and sperm plug in *Carcinus maenas*. **Quart. J. Micros. Sci.**, 83:399-422.
- SPARRE, P., E. URSIN AND S.C. VENEMA. 1989. Introduction to tropical fish stock assessment. **FAO Fisheries Technical Paper No. 306.1**, Rome, FAO, 337pp.
- SRINIVASAGAM, S. 1975. Studies on the edible crabs of Porto Novo waters. **M.Sc. Thesis, Annamalai University.**
- SRINIVASAGAM, S. 1979. On the nutritive value of the meat of portunid crabs of Porto Novo. **J. Inland Fish. Soc. India**, 11(2): 128-131.
- SRINIVASAGAM, S. AND K. RAMAN. 1985. Crab fisheries of Pulicat Lake with special reference to catches from the southern sector. **Proc. Symp. Harvest and Postharvest Technology of Fish, Soc. Fish. Technologists (India)**, pp.63-68.

- SSENTONGO, G.W. AND P.A. LARKIN. 1973. Some simple methods of estimating mortality rates of exploited fish populations. *J. Fish. Res. Bd. Canada*, **30**:695-698.
- STEAD, D.G. 1898*. Contributions to the knowledge of the Australian crustacean fauna. I. Observations on the genus *Neptunus*. *Proc. Lin. Soc., New South Wales*, **23**: 746-758.
- STEPHENSON, W. 1961. The Australian Portunids (Crustacea: Portunidae) V. Recent collections. *Aust. J. Mar. Freshw. Res.*, **12**(1):92-128, pls.1-5.
- STEPHENSON, W. 1965. A morphometric analysis of certain western Australian swimming crabs of the genus *Portunus* Weber, 1795. *Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part. I*: 362-385.
- STEPHENSON, W. 1972*. Portunid crabs from the Indo-West Pacific and Western America in the Zoologica. Museum Copenhagen (Decapoda, Brachyura, Portunidae). *Steenstrupia*, **2**(9):127-156, figs.1-8.
- STEPHENSON, W. 1972a. An annotated check list and key to the Indo-Pacific swimming crabs. (Crustacea:Decapoda, Portunidae). *Bull. Roy. Soc. N.Z.*, **10**:1-64.
- STEPHENSON, W AND B. CAMPBELL. 1959. The Australian Portunids (Crustacea: Portunidae) III. *Aust. J. Mar. Freshw. Res.* **10**(1):84-124., pls. 1-5.
- STEPHENSON, W AND B. CAMPBELL. 1960. The Australian Portunids (Crustacea: Portunidae) IV. Remaining genera. *Aust. J. Mar. Freshw. Res.* **11**(1):73-122.
- STEPHENSON, W AND M. REES. 1967*. Some portunid crabs from the Pacific and Indian Oceans in the collections of the Smithsonian Institutions. *Proc. U.S. natn. Mus.* **120**(2556):1-114.
- STEHLIK, L.L. 1993. Diets of the brachyuran crabs *Cancer irroratus*, *C. borealis* and *Ovalipes ocellatus* in the New York Bight. *J. Crus. Biol.*, **13**(4): 723-735.
- STEPHEN, C.J. AND H.M. FEDER. 1983. Food of the tanner crab *Chinocoetes bairdi*

- near Kodiak Island, Alaska. **J. Crus. Biol.**,3(2); 196-207.
- STEVENS, B.G., D.A. ARMSTRONG, AND R. CUSIMANO. 1982. Feeding habits of the Dungeness crab, *Cancer magister* as determined by the index of relative importance. **Mar. Biol.**, 72: 135-145.
- STONER, A.W., AND B.A. BUCHANAN. 1990. Ontogeny and overlap in the diets of four tropical *Callinectes* species - **Bull. Mar. Sci.**,46:3-12.
- SUBRAMONIAM, T. 1979. Some aspects of reproductive biology of the mole crab *Emerita asiatica* Milne Edwards. **J. Exp. Mar. Biol.Ecol.**, 36: 259-268.
- SUHALYA, A. AND L.J. RASHAM. 1986. Length - weight relationship of the mud crab, *Potomon magnum* Pretzman. **Curr. Sci.**, 55(20): 1030-1031.
- SUKUMARAN, K.K., K. Y. TELANG AND O. THIPPESWAMY. 1986. On the fishery and biology of the crab *Portunus sanguinolentus* (Herbst) along the South Kanara coast. **Indian J. Fish.**, 33(2): 188-200.
- SUKUMARAN, K.K. MS. Population characteristics of the brown shrimp *Metapenaeus monoceros* (Fabricius) exploited off Mangalore, Southwest coast of India.
- SUKUMARAN, K.K., V.D. DESHMUKH, G.S. RAO, K. ALAGARAJA AND T.V. SATHYANANDAN. 1993. Stock assessment of the penaeid prawn *Metapenaeus monoceros* Fabricius along the Indian coast. **Indian J. Fish.**,40(1&2):20-34 (1995).
- SUKUMARAN, K.K., K. ALAGARAJA, C. SUSEELAN, K.N. RAJAN, D.B. JAMES, T. SUBRAMANIAN, V.S. KAKATI, G. NANADAKUMAR, N.S. KURUP, P.T. SARADA AND T.V. SATHYANANADAN. 1993a. Stock assessment of the penaeid prawn, *Metapenaeus dobsoni* (Miers) along the Indian coast. **Indian J. Fish.**, 40 (1&2):35-49(1995).
- SULKIN, S.D. 1977. Blue crab study in Chesapeake Bay - Maryland completion report. vols. I & II. Chesapeake Biol. Lab., Rep. No. 77-16 HPEL. 86pp.

- SUMPTON, W.D. 1990. Morphometric growth and fisheries biology of the crab *Charybdis natator* (Herbst) in the Moreton Bay, Australia (Decapoda: Brachyura). *Crustaceana*, **59**(2): 113-120.
- SUMPTON, W.D. 1990a. Biology of the crab *Charybdis natator* (Herbst) (Brachyura, Portunidae). *Bull. Mar. Sci.*, **46**(2): 425- 437.
- SUMPTON, W.D. AND G.S. SMITH. 1990. Effect of temperature on the emergence activity and feeding of male and female sand crabs (*Portunus pelagicus*). *Aust. J. Mar. Freshw. Res.*, **41**(4): 545- 550.
- SUMPTON, W.D. AND G.S. SMITH. 1991. The facts about sand crabs. *Fisheries Biology*, 3pp.
- SUMPTON, W.D., A.M. POTTER AND G.S. SMITH. 1989. The commercial pot and trawl fisheries for sand crab (*Portunus pelagicus* L.) in the Moreton Bay, Queensland. *Proc. Roy. Soc. Queensland*, **100**: 89-100.
- SUMPTON, W.D., G.S. SMITH AND A.M. POTTER. 1989a. Notes on the biology of the portunid crab *Portunus sanguinolentus* (Herbst) in the subtropical Queensland waters. *J. Aust. J. Mar. Freshw. Res.*, **40**(6): 711-717.
- SUMPTON, W.D., M.A. POTTER AND G.S. SMITH, 1994. Reproduction and growth of the commercial sand crab, *Portunus pelagicus* (L.) in Moreton Bay, Queensland. *Asian Fish. Sci.*, **7**: 103-113, Asian Fisheries Society, Manila, Philippines.
- TAGATZ, M.E. 1968. Biology of the blue crab *Callinectes sapidus* Rathbun in the St. Johns River, Florida. *Fish. Bull., Fish. Wildl. Serv., US*, **67**: 17-33.
- TEISSIER, G. 1982. Relative growth. In: "The Biology of Crustacea. Vol. 2. Embryology, Morphology and genetics". (L.G. Abele. ed.), pp.537-560. Academic Press, New York.
- THOMAS, A. J. 1972. Crab fisheries of the Pulicat Lake. *J. mar. biol. Ass. India*, **13**(1&2): 278-280.
- THOMAS, M . 1984. Studies on portunid crabs. (crustacea: Decapoda: Brachyura),

Ph. D. Thesis, Department of Marine Sciences, University of Cochin, Cochin.
155 pp.

- THOMSON, J. M. 1951. Catch composition of sand crab fishery at Moreton Bay. **Aust. J. Mar. Freshw. Res.**, **2**:237-244.
- TRIVEDI, Y.A. AND N.M. PATEL. 1975. Crab fishery of Gujarat. **Seafood Trade J.**, **7**(11): 17-19.
- TURABOYSKI, K. 1973. Biology and ecology of the crab *Rithropanopeus harrisi* ssp. *tridentatus*. **Mar. Biol.**, **23**: 303- 313.
- VAN ENGEL, W.A. 1958. The blue crab and its fishery in Chesapeake Bay. Part I - Reproduction, Early Development, Growth and Migration. **Commercial Fisheries Review**, **20**(6): 6-17.(Also separate No. 512, Virginia Institute of Marine Science, Contr. No. 79).
- VAN ENGEL, W.A. 1962. The blue crab and its fishewry in Chesapeake Bay. Part. 2- Types of gear for hard crab fishing. **Commercial Fisheries Review**, **24**(9):1-10.
- VAN ENGEL, W.A. 1987. Factors affecting the distribution and abundance of the blue crab in Chesapeake Bay. In:" **Contaminant Problems and Management of Living Chesapeake Bay resources**" (S.K. Mujumdar, L.W. Hall, Jr. and H.M. Austin. eds.), pp.177- 209. **The Pennsylvania Academy of Science, Virginia.**
- VAN ENGEL, W.A. 1990. Development of the reproductive functional form in the male blue crab, *Callinectes sapidus*. **Bull. Mar. Sci.**, **46**(1): 13-22.
- VIRNSTEIN, R.W. 1977. The importance of predation by crabs and fishes on benthic infauna in Chesapeake Bay. **Ecology**, **58**: 1199- 1217.
- WALFORD, L.A. 1946. A new graphic method of describing the growth of animal. **Biol. Bull.**, **90**(2): 141-147.
- WARNER, G.F. 1967. The life history of the mangrove tree crab *Aratus pisoni*. **J. Zool., London.**, **153**: 321-335.
- WARNER, G.F. 1977. "The biology of crabs". **Van Nostrand Reinhold, Princeton, New Jersey.**

- WASSENBERG, T.J. AND B.J. HILL. 1987. Feeding by the sand crab *Portunus pelagicus* on the material discarded from prawn trawlers in Moreton Bay, Australia. **Mar. Biol.**, **95**(3): 387-393.
- WATERMAN AND F.A.CHACE JR. 1960. General Crustacean Biology. In:"The Physiology of Crustacea. Vol. 1. Metabolism and Growth" (T.H. Waterman, ed.), pp.1-30. Academic Press, New York.
- WATSON, J. 1970. Maturity, mating and egg laying in the spider crab, *Chionoecetes opilio*. **J. Fish. Res. Bd. Canada**, **27**: 1607- 1616.
- WEAR, R.G. AND M. HADDON. 1987. Natural diet of the crab *Ovalipes catharus* (Crustacea, Portunidae) around central and northern New Zealand. **Mar. Ecol.Progr. Ser.**, **35**: 39-49.
- WILLIAMS, M. J. 1981. Methods for analysis of natural diet in portunid crabs (crustacea: Decapoda: Portunidae). **J. Exp. Mar. Biol. Ecol.**, **52**: 103-113.
- WILLIAMS, M.J. 1982. Natural food and feeding in the commercial sand crab *Portunus pelagicus* Linnaeus, 1766 (Crustacea: Decapoda: Portunidae) in the Moreton Bay, Queensland. **J.Exp. Mar. Biol. Ecol.**, **59**: 165-176.
- YATSUZUKA, K. AND T. MERUANE. 1987. Growth and development, especially on external sexual characters of *Portunus (portunus) pelagicus* (Linn.) (Crustacea, Brachyura). **Rep. Usa Mar. Biol. Inst., Kochi Univ., No. 9**: 1-37.

* not referred to in original