STUDIES ON FOOD AND FEEDING OF MARINE DEMERSAL FINFISHES WITH SPECIAL REFERENCE TO TROPHIC INTERACTIONS

Thesis submitted to Cochin University of Science and Technology in
partial fulfillment of the requirement for the degree of

Doctor of Philosophy

Under the faculty of Marine Sciences

By

ABDU RAHIMAN. KP
(Reg. No: 2239)

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
Indian Council of Agricultural Research
KOCHI 682 018

AUGUST 2006

Certificate

This is to certify that this thesis entitled "**Studies on food and feeding of marine demersal finfishes with special reference to trophic interactions**" is an authentic record of research work carried out by Abdu Rahiman K.P (Reg.No. 2239) under my guidance and supervision in Central Marine Fisheries Research Institute, in partial fulfillment of the requirement for the Ph.D degree in Marine Science of the Cochin University of Science and Technology and no part of this has previously formed the basis for the award of any degree in any University.

Dr. K. Sunilkumar Mohamed
(Supervising guide)
Head, Molluscan Fisheries Division
Central Marine Fisheries Research Institute.

Date: 25|08|12

Declaration

I hereby declare that the thesis entitled "Studies on food and feeding of marine demersal finfishes with special reference to trophic interactions" is an authentic record of research work carried out by me under the guidance and supervision of Dr. K. Sunilkumar Mohamed, Head, Molluscan Fisheries Division, Central Marine Fisheries Research Institute, in partial fulfillment for the Ph.D degree in Marine science of the Cochin University of Science and Technology and no part thereof has been previously formed the basis for the award of any degree in any University.

(ABDU RAHIMAN KP)

Date: 25-08-2006

Acknowledgement

I am greatly indebted to Dr. K. Sunilkumar Mohamed (supervising guide), HOD, Molluscan Fisheries Division, CMFRI, Kochi for his guidance, valuable suggestions, constant encouragement, criticism and support during the course of my investigation and documentation.

I owe many thanks to Dr. Mohan Joseph Modayil, Director, CMFRI, Kochi for extending all the facilities for successful completion of this research work.

I am very much grateful to Dr. C. Muthiah, Principal Scientist and Scientist-in Charge, Mangalore Research Center of CMFRI, Mangalore for providing me the facility to carry out my work during the course of this study.

I express my deep sense of appreciation and gratitude to Dr. P.V. Zacharia, Senior Scientist, Mangalore Research Center of CMFRI for his constant help and guidance during the course of my work.

It is my pleasure to acknowledge Dr. E. Vivekanandan, Head, Demersal Fisheries Division, CMFRI for his timely help, guidance, subjective criticism and encouragement in preparing the thesis.

I acknowledge my deepest sense of gratitude to Dr. P.K. Krishnakumar, Senior Scientist; Dr. Prathiba Rohit, Senior Scientist; Dr. Dinesh Babu, Scientist Sr. Scale; Mrs.Geetha Sasikumar, Scientist; Shri. Mahadevaswamy, Smt. Uma S. Bhat, Smt. Alli C. Gupta, Shri. B. Shridhara, Shri. S. Kemparaju, S.Y. Muniyappa, Shri. G.D. Nataraja, Shri. Sampath Kumar, technical assistants and staff of Mangalore Research center of CMFRI, Mangalore for their help during the course of my study.

Without the help of my colleague, Mr. Harish Nayak, Senior Research Fellow, Mangalore Research center of CMFRI, my study would not have been possible.

I am highly indebted to Dr. Paul Raj, Scientist-in Charge, PGPM, CMFRI for the timely help in all matters concerned with my Ph. D programme. The help and support extended by the PGPM staff is gratefully acknowledged.

I am thankful to Mr. Vinod, former Senior Research Fellow, Molluscan Fisheries Division and P.S. Alloycious, technical assistant, for their help rendered to me in the preparation of the thesis.

I thank Dr. K.K. Appukuttan, former HOD and Principal Scientist, Dr. T.S. Velayudhan, Principal Scientist., Shri P. Radhakrsihan, Shri. Mathew Joseph and Smt. Jenny Sharma, technical assistants., Smt Ambika, Shri. Zainudeen, Shri. Jeevanraj and two data entry operators Smt. Lakme Disilva and Miss. Menaka M.S and other staff of Molluscan Fisheries Division, CMFRI for their great help and constant encouragement offered in the preparation of the thesis.

My special thanks are due to Mr. Anoop L Krishnan, Mr. Ravi Durgekar and Smt. Veena Shettigar, Research Scholars working at Mangalore Research center of CMFRI, Mangalore and Mr. Ramalinga, Miss. Neetha Susan David and Miss. Anjana Mohan, Senior Research Fellows of CMFRI, Kochi for their timely help and constant encouragements during the course of my study.

My sincere thanks are to Dr. Ajmal Khan, Professor, Center for Advanced Studies, Annamalai University, Parangipettai and Dr. Somy Kuryakose, Scientist Sr. Scale, FRAD, CMFRI, for assisting me in statistical analysis of my data.

I greatly acknowledge the financial assistance from the AP Cess fund of Indian Council of Agricultural Research in the form of Senior Research Fellowship under the project "Application of tropic modeling and multi species virtual population analysis to formulate management options for the multigear marine fisheries of southern Karnataka".

Above all, I am greatly obliged to my parents and family for their blessings and encouragement without which the completion of this work would only have been a dream.

K.P.Abdu Rahiman

Contents

Chapter 1.

Introduction

1.1. General Introduction

Fish forms a vital source of food and is man's most important single source of high-quality protein, providing 16% of the animal protein consumed by the world's population (FAO, 2000). Fish consumption is on the increase in many countries and in India, fisheries has emerged as a major industry with an annual turnover of more than Rs.220 billion, accounting for 1.4% of the total GDP (Ayyappan and Biradar, 2000). Marine fisheries has emerged as one of the largest industries in the country employing about 10 million people in 3,651 fishing villages along the 8,129 km coastline of India earning a foreign exchange value of over Rs.7250 crores in 2005-06. The emphasis of coastal fisheries development in India since independence was to increase fish production through improving and increasing the techniques and efficiency of fishing and by offering welfare measures to the fishers. This paved the way for increasing the marine fish production from 0.5 million tonnes (mt) in 1950 to 2.6 mt in 2005-06. Of this 66% was landed by mechanized vessels, 26% by motorized units and 8% by non-motorized units. Fishing down marine food webs along Indian coast indicate that present exploitation patterns are unsustainable and reflects a gradual transition in landings from long-lived, high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fishes (Vivekanandan *et al.*, 2005). To ensure sustainable marine fisheries and to effectively manage the fish stocks, it has became increasingly necessary to understand the impact of fishing on fish. Such studies should include understanding of interspecific relationship among fish and also with other organisms in their environment. In order to understand the functioning within marine habitats, it is necessary to describe the trophic interactions in the habitats and then to quantify them where possible. To achieve these goals, interactions between the different components within marine ecosystems have to be acknowledged, understood and quantified (Cury *et al.*, 2003). Trophic interactions may change with time and may be affected by fishing pressure (Alonso *et al.*, 2002), making it necessary to periodically monitor them by conducting diet studies.

India has an EEZ of 2.02 million km^2 and is endowed with a rich variety of demersal fishery resources. The growth of demersal fishery in India during the post independence era is significant. The exploited demersal finfish resources increased from 0.75 mt in 1985 and registered a peak of 1.35 mt in 1998 but decreased to 1.15 mt in 2004 (Srinath *et al.*, 2006). About 700 species of finfishes are recorded from the Indian sea bottom of which about 250 are common to the demersal fisheries. Species richness of demersals is more off the east coast than off the west coast (Bensam, 2000). The important demersal finfish groups are: croakers, elasmobranchs, threadfinbreams, catfishes, major perches (rockcods, snappers, pigfacebreams, and other perches), silverbellies, pomfrets and flatfishes. They inhabit a wide range of habitats such as sandy, muddy to rocky and coral grounds as well as from shallow coastal waters to deep continental slope, from all geographical regions and through all the seasons in the subcontinent, at varying temporal and spatial diversities (Bensam, 2000).

Karnataka state with a coastline of 300 km along the southwest coast of India is one of the frontline states in the country in marine fisheries development (Mohamed *et al.*, 1998). Its contribution to annual marine fish production of India has varied between 6% and 14%. Pelagic and demersal finfishes, prawns and cephalopods are landed at 28 landing centers along the coast. Mechanised crafts employing purse seines and trawls contributed more than 95% to the landings. The principal gears used in the state are trawl net, purse seine, gillnet, longline and a variety of artisanal gears. Around 1,500 trawlers operate along this coast. Mangalore and Malpe fish landing centres account for more than 60 % of the total marine fish landings of Karnataka. The trawlers land 56% of the total catch. Demersal fishes formed the significant fishery in trawls. The trawl fleet in the state is distinctly of two types, a single day fishing fleet (SDF) consisting of small (overall length (OAL): 30'-32') coastal trawlers and multi-day fishing fleet (MDF) consisting of larger (OAL: 36'-52') trawlers operating in the 30-150 m depth zones (Zacharia *et al.*, 1996). The demersal fishes landed along the Karnataka coast ranged from 31,100 tonnes in 1985 to 78, 800 tonnes in 2004 (Srinath *et al.*, 2006). The important resources landed by trawlers include threadfin breams, carangids, anchovies, flatfishes, lizardfishes, seerfishes, cephalopods, shrimps, stomatopods and crabs. Mohamed *et al.* (1998) studied the exploitation status of marine fisheries along the coastal Karnataka.

Among the exploited demersal resources, the elasmobranchs are landed in all the maritime states of India. Sharks (61.4%), skates (5.7%) and rays (33%) are the major components of elasmobranchs in the fishery (CMFRI, 2005). It contributed 9% to the total demersal fish landings in the country. In Karnataka, sharks contributed 80% to elasmobranch catch. Sharks play an important role in the trophic structure of world's marine ecosystem (Cortes, 1999). Many sharks are large and abundant marine consumers and as such are likely to influence the aquatic communities in which they exist (Bowen, 1997). Little is known about the feeding behaviour and diet of sharks in India. The works of Aiyar and Nalini (1938), Sarangahar (1943) and Nair and Appukkuttan (1973) are too limited and there is complete lack of quantitative data on the food of sharks.

Perches occur all along the Indian coast. Perches contribute almost 30 % to the total marine fish production in the country (CMFRI, 2005). Groupers especially rockcods form the major component of perches in the catch. Karnataka contributed 6.4% of the total perch catch in the country with an average landing of 1,538t. A review of the Indian publications indicates that study of diet of rockcods in India is scanty and information given by Prabhu (1954), Premalatha (1989) and Tessy (1994) on different species of rockcods are some of the significant records.

The fishes of the family Nemipteridae (Order: Perciformes), which are popularly called threadfin breams, are distributed in the tropical and subtropical seas. Threadfin breams formed about 17.8 % of the total marine demersal fish landings of India (CMFRI, 2005). *Nemipterus* spp form an important demersal fishery resource along the Karnataka coast accounting 19, 812 t, of the total marine landing of the state (CMFRI, 2005). Nemipterids are one of the midlevel carnivores along the Indian coast (Vivekanandan *et al.*, 2006). Qualitative and some of the quantitative description of diet of different species of Nemipterids along the Indian coast was recorded by Kuthalimgam (1965), Krishnamurthy (1971), Muthiah and Pillai (1979), Mohan and Velayudhan (1985) and Rao and Rao (1991).

Silverbellies of the family Leiognathidae are an important group of small to moderate sized finfishes. In India, mechanization and modernization of fishing equipments and methods in the last few decades have made it technically feasible to increase the harvest of leiognathids manifold. They formed 8 % of total marine demersal fish landings in the country (CMFRI, 2005). *Leiognathus bindus, L. splendens* and *Secutor insidiator* are the most dominant species accounting for nearly 70-80%. The feeding habit studies by many Indian workers are qualitative in nature (Chacko, 1944; Venkataraman, 1960; Basheeruddin and Nayar, 1962; Jayabalan and Ramamoorthi, 1985).

Sciaenids contributed 18 % to the total marine demersal fish landing in India (CMFRI, 2005). More than 30 species under 14 genera of the family Sciaenidae are distributed in the Indian waters with *Otolithes cuvieri* being the most abundant species in Indian waters (CMFRI, 2003). In India, many authors have recorded the food and feeding habits of croakers (Jacob, 1948; Bapat and Bal, 1952; Suseelan and Nair, 1969; Jayaprakash, 1974; Lal Mohan, 1984 and Manojkumar, 2003).

Pomfrets are one of the most delicious food fish available along Indian coast. Pomfrets are represented by the silver pomfret (*Pampus argenteus*; 62.5%), black pomfret *Parastromateus niger*; 34.5%) and Chinese pomfret (*Pampus chinensis*; 2.98 %). They contributed 6% of the total marine demersal landings in the India (CMFRI, 2005). The observations of Kulkarni (1958), Rao (1964) and Pati (1978) on the diet provide information on the feeding pattern of pomfrets along the Indian coast.

The bullseye's or big eye (family Priacanthidae) is one of the major non-conventional fish resources, which of late has assumed significance as an emerging demersal fish in the commercial landings. The contribution of bullseye's to the total marine landing was low ranging between 0.1% and 3% at various centres. Four species of priacanthids namely (*Priacanthus hamrur*, *P. macracanthus*, *P. tayenus* and *P. blochii*) are reported from the Indian seas. *P. hamrur* (Forsskal) formed the most dominant species in the commercial landings (CMFRI, 2005). Philip (1998), Rao (1984) and Zacharia *et al.* (1991) have reported feeding behavior of priacanthids in India.

Flatheads are one of the important demersal fish resources of southern Karnataka. They form 2.11% of total landings along this coast. The spotfin flathead, *Grammoplites suppositus* is the most important and most abundant species in the trawl catches of Karnataka. Rao (1964) and George *et al.* (1968) have briefly described the diet of flatheads along the Indian coast.

Fishes belonging to the families Bothidae (flounders), Cynoglossidae (tongue soles), Psettodidae (Indian halibut) and Soleidae (Soles) are popularly known as flatfishes. Flatfishes belonging to 11 genera and 25 species contribute to minor and major fisheries along the Indian coast. The flatfish landings have increased consistently during the past few years and reached 36,202 t and accounted for 5.4% total marine demersal fish landings (CMFRI, 2005). Among all the species of flatfishes occurring along the Indian coast, it is only the tongue sole, *Cynoglossus macrostomus* that has formed a major fishery for several years, especially along the southwest coast. Jayaprakash (2000), Seshappa and Bhimachar (1955), Datta and Das (1983) and Kuthalimgam (1957) have reported the diet of flatfishes in India.

The white fish *Lactarius lactarius* is distributed all along the Indian coast. Trawlers and the indigenous drift gill netters are the major gears. The resource contributed 0.2% to the total marine production in India. In Karnataka, its landing ranged from 836 t in 1985 to 678 t in 2004 (Srinath *et al.*, 2006). The quantitative description of the diet of whitefish was given by Zacharia (2003) from the Karnataka coast.

The present study has been taken up to understand the trophic interaction among these demersal fishes for the management of multispecies fishery. The present study defines trophic guilds to characterize the trophic interactions to assess the potential for competition based upon patterns of resource use. The study also explores the utility of the guild concept as a tool for understanding and managing the complex demersal food web along the Karnataka coast.

1.2. Scope of the study

Fishing has become one of the most widespread anthropogenic activities on the marine ecosystem. The fishery resources are under constant threat of overexploitation in addition to natural and predation losses. In India, fisheries management based on ecosystem approach is in its infancy and needs a detailed study of various trophic components. In the modern ecosystem based fisheries analysis, fish diet analysis has become the core subject that will decipher the trophic relations in an ecosystem. Trophic interactions within ecosystems play a large role in multispecies modelling; hence diet and feeding data are of primary importance. Fish food habit studies also helps in understanding some of the higher level trophic relations in an ecosystem and is an important mechanism for gaining knowledge on feeding ecology and a means to explore interactions between predators and prey (Hall *et al.*, 1995; Garvey *et al.*, 1998; Vander Zanden *et al.*, 2000).

Studies on the food and feeding habits of marine fishes are not a new practice in India. However, the methods followed to study the stomach analysis of most of these fishes were qualitative in nature and the quantitative information available are inadequate to explain the complex food chain interaction between them. A review of dietary, food habit, and food consumption studies of Indian marine fishes reveals lack of consistent methodological approach and application of statistical tests to analyze results. In the last fifty years, the major Indian fisheries journals like Indian Journal of Fisheries and Journal of Marine Biological Association of India published 120 papers on the food and feeding habits of marine fishes. With the exception of a few researchers, most of them have used the traditional numerical methods to evaluate the relative importance of different preys. There is urgent need for the quantitative assessment of food habits as this assessment forms an important aspect of fisheries management and successful management enables us to effectively manage prey resources (DeVries and Stein, 1990). Moreover, the knowledge on the relative importance of different prey items can guide management efforts aimed at increasing fish production.

As the role of predators in controlling lower trophic level populations has been observed as a major structuring factor in benthic marine communities (Shears and Babcock, 2002), the trophic analysis of commercially important demersal finfish species was conducted in the present study. Trophic guilds formed by the union of fishes with similar feeding habits and the highly impacted prey groups due to predation were delineated in the present study.

The present study is aimed at understanding the variation of trophic level with ontogeny. Trophic level has been widely used to understand the functional position of fishes in the food web. Many recent researchers have used constant trophic levels for fish groups/species for ecosystem modeling and for detecting fishing down marine food web (Christensen, 1993; Vivekanandan *et al.*, 2005). As most of the predators have ontogenetic (Figueiredo *et al.*, 2005; Cortes, 1999; Vander Zanden and Rasmussen, 1996), seasonal and location specific feeding habits, assigning constant trophic levels may lead into erroneous results in trophic modeling.

In the present study, special attention has been given to the study of predator and prey relations. Knowledge on the size of prey is essential in order to identify their potential impact on prey survival and their role in structuring populations at lower trophic levels. This is particularly important for any ecosystem approach to fisheries management where knowledge of interactions is critical. From a behavioral standpoint, relative body sizes of prey and predator can have significant effects on predator feeding success.

The present study is expected to aid construction of mass-balance models like ECOPATH for modelling benthic ecosystems of Karnataka and to understand the energy transfer and trophic interactions.

Chapter 2.

Review of literature

2.1. Methods of estimation food and feeding

The study on the feeding habits of fish and other animals based upon analysis of stomach content has become a standard practice (Hyslop, 1980). Stomach content analysis provides important insight into fish feeding patterns and quantitative assessment of food habits is an important aspect of fisheries management. There are several qualitative and quantitative methods used to describe food habits and feeding pattern of fishes. Dietary descriptions of fish and other aquatic vertebrates are greatly influenced by the choice of the method used to quantify the relative importance or contribution of each prey type to the diet. Hynes (1950), Pillay (1952), Windell (1968), Hyslop (1980) and Bowen (1996) reviewed the methods for the gut content analysis of fishes.

Fish diets can be measured in a variety of ways. Methods of gut content analysis are broadly divisible into two, *viz.*, qualitative and quantitative. The qualitative analysis consists of identification of the organisms in the gut. Quantitative methods of analysis are of three types, *viz.*, numerical, gravimetric and volumetric.

Many earlier researchers followed traditional numerical methods to analyse stomach contents. Dhulked (1962) while studying the food and feeding habits of the Indian Oil Sardine, *Sardinella longiceps*, used the number method, as the fish is a plankton feeder. Kagwade (1964) in studies of *S. longiceps* used both number method and percentage frequency of occurrence and depending on the percentage when particular food items occurred in the stomach of the fish; grouped the different items as 'very common', 'common', 'frequent' and 'rare'. Rao (1968) used Pearse's method of eye estimation in gut analysis of *Gerres oyena* and *G. filamentosus* from the Pulicat Lake. Okera (1973) used both number method and percentage frequency of occurrence for the analysis of stomach contents of *S. gibbosa* and *S. albella*. As an improvement to numerical methods, Rao and Padmaja (1999) for the analysis of food items of *Megalops cyprinoides*, followed the "Points method" and points were assigned as 1.25 for gorged, 1 for full, 0.75 for ¾ full, 0.5 for half full, 0.25 for ¼ full and 0 for empty stomachs. Colin *et al.* (2001), Durr and Gonzalez (2002) are other important researchers who used both the number method and occurrence methods to analyze the stomach contents.

Many authors considered the volume or weight as a more satisfactory method for quantitative analysis of gut contents. Hynes (1950) proposed volumetric method as a very suitable means of assessment especially in case of herbivores and mud eating fishes where the numerical methods become meaningless and inaccurate. Volumetric methods included direct assessing by eye estimation, allotting certain points to stomach contents and measuring displaced volume of prey components. All these types of analysis are widely employed by different workers. Volumetric displacement method is considered to be one of the suitable measures to quantify carnivorous as well as predatory fishes. Pati (1978), Rao (1980) and Suseelan and Nair (1969) used both point methods and volumetric displacement methods. Joyce *et al.* (2002) during the diet study of Porbeagle shark, *Lamna nasus* in the northwest Atlantic, used both percentage of occurrence and percentage weight of each stomach content. Cord and Campana (2003) followed both displacement volumetric methods and percentage occurrence methods to describe the prey contents in the diet study of blue shark, *Prionace glauca.*

Natarajan and Jhingran (1961) later proposed Index of Preponderance as a definite and measurable basis to grade the food elements of different fish species. This index incorporates information of both frequency of occurrence and volume of each prey. Among other Indian workers who used Index of preponderance to study diet components are works of George *et al.* (1968), Sivakami (1995), Raje (1996) and Devaraj (1998).

Though many earlier researchers followed the above measures to quantify the diet, each of these measures provides different insight into the feeding habits of a predator. Expression of stomach contents with counts may give the impression that a specific prey item that occurs very frequently in stomachs represents one of the most important prey items. However, if these preys are small, they may represent only a small proportion of the total food consumed. Similarly, if diet is expressed in terms of weight or volume, consumption of a single large prey item would imply that this prey is a major component of the diet, when in fact very few individuals may have consumed it. Frequency of occurrence can provide information on how often (or not) a particular prey item was eaten, but provides no indication of the relative importance of prey to the overall diet. To overcome such limitations, diet has often been reported in terms of a combination of several indices (Cortés, 1997, 1999). One of the widely accepted measure is index of relative importance (IRI) proposed by Pinkas *et al.* (1971) as an integration of measurement of number, volume or weight and frequency of occurrence to assist in evaluating the relationship of the various food items found in the stomachs. Compound expressions of diet such as IRI provide less biased estimates of the contribution of various preys in the diet of a consumer, but their use has been criticized (Hansson, 1998). Nonetheless, Cortés (1997) suggested that presentation of stomach contents of sharks in terms of %IRI would both provide estimates of the diet that were intuitive and that would allow more direct comparison among studies. Thus IRI can be considered as the suitable dietary indices to quantify fish diets especially for the fishes of tropical countries where both prey and predator are abundant than that of temperate countries. Thus to promote consistency and facilitate comparison among studies, and to obtain a robust estimate of relative importance of the prey, whenever possible results of dietary analyses should be reported as %N, %W (or %V), %O, and %IRI for all taxonomic levels considered (Cortes, 1999). Vivekanandan (2001) from India and Abdel-Aziz (1986) from Kuwait were used IRI to analyse gut content data of threadfin breams and guitarfishes respectively. Bush (2003) when describing the diet of the hammerhead shark, *Sphyrna lewini*, used IRI as a best measure of index for comparison with other studies.

Many marine finfishes show strong degree of preference to its favorite prey in the environment. Most fishes select some food categories over others. To measure this selectivity, a variety of indices have been developed that incorporate measures of prey use and prey availability. Many workers used the index of electivity proposed by Ivlev (1961) as measure of selection, which has been widely used as a means of comparing the feeding habits of fishes and other aquatic organisms with the availability of potential food resources in natural habitats. Rao (1981) used electivity index to study selective feeding by *Saurida tumbil.* Like diet indices, there is much controversy over which preference index is best. Comparisons of different indices have revealed that the Manly-Chesson (Chesson, 1983) and the Linear index (Strauss, 1979) are good choices for quantifying prey preference. The Manly-Chesson index was frequently used to quantify prey preference. Strauss (1979) proposed a linear index of food selection and he made reliable estimates for Ivlev electivity index.

Diet overlap indices are often used to measure the magnitude of resource overlap among different species. A variety of indices have been proposed to quantify diet overlap and there is controversy as to which index is the best (Krebs 1989). Morista's index and Horn's index are referred to occasionally, though Schoener's index (1970) is preferred by many fishery biologists to compare the dietary overlap of two fish species or of two size/age categories or of two different habitats. In cases where prey numbers are available, Morista's index has been recommended as the most robust index for diet overlap. If gut content data are not expressed in numbers (as weight or volume), the Horn's index is recommended (Krebs, 1989). Hacunda (1981) used both IRI and diet overlap to study the trophic relationship of demersal fishes in a costal area of the Gulf of Maine. Colin *et al.* (2001) used simplified Morista's index for the comparison of the dietary overlap of two size groups of tiger shark, *Galeocerdo cuvier* and they used Langton's (1982) scale for measuring the degree of overlap. The prey diversities of size classes were compared using the Shannon-Weiner index (H'). Knight and Ross (1994) and Durr and Gonzalez (2002) used both diet overlap and Levin's (1968) diet breadth indices.

Working on elasmobranchs, Cortes (1997) reviewed the most commonly used indices of dietary importance and proposed the use of a standard index and a new graphical method to illustrate prey importance and predator feeding strategy and homogeneity at the population level. He suggested the use of multivariate statistics and multiway contingency table analysis to detect seasonal, ontogenetic or other differences in feeding among predators and the use of most common measures of dietary overlap to detect differences between diets.

2.2. Prey-predator interactions

For grouping multispecies fish assemblages based on prey-predator relationships, different statistical methods are followed. The PRIMER statistical package version 4.0 (Clark and Warwick, 1994) is widely used in prey-predator interaction studies. Bray-Curtis similarity coefficient followed by non-metric multidimensional scaling (MDS) is the most often used method.

Hajisamae *et al.* (2003) and Genner *et al.* (2003) used cluster dendrogram constructed by PRIMER and used ANOSIM (Analysis of similarities) to test for a differences in a group of predators falling in the same cluster and the raw data of each species were used to assess the robustness of the group, before constructing the model of trophic guilds. Bray-Curtis similarity coefficient followed by Non–metric MDS and ANOSIM was performed to study the dietary compositions of the three myctophid species from Northeast Atlantic Sea (Pusch *et al.*, 2004) and feeding guilds of western Mediterranean demersal fish and crustaceans (Cartes *et al.*, 2002). Gaskett *et al.* (2001) used Bray-Curtis similarity coefficient for the guild structuring of mesopelagic and bathypelagic fishes near Macquarie Island. **Luczkovich *et al.* (2002) used cluster analysis** followed by correspondence analysis to aggregate estuarine macro invertebrates and fish into trophic groups based on the measures of diet and predator similarity. He used cluster analysis first to group consumer taxa into a small number of clusters, which then was coded for further correspondence analysis. A factor scores plot was visually examined to distinguish consumer groups and match them with their food sources.

To distinguish ontogenetic diet changes in the white seabream, *Diplodus sargus* and the ballan wrasse, *Labrus bergylta*, Figueiredo *et al.* (2005) used Unweighted Pair Group Method with Arithmetic mean (UPGMA). The resulting dendrogram identified size groups with different level of dissimilarity.

As diet data are often measured as proportions, analytical techniques are affected by the constant sum-constraint. Hence ordination techniques such as Detrended correspondence analysis (DCA), Principal component analysis (PCA) and Redundancy Analysis (RDA) are often used for ecological as well as fish stomach content data analysis. Larsen and McIntire (1993) used DCA as an ordination procedure closely related to the method of reciprocal averaging (Hill and Gauch, 1980). Maria (1998) performed Multivariate analysis of PCA, DCA and RDA in order to study the trophic relationship and feeding ecology of four deepsea shark species off South coast of Portugal.

Bush (2003) described the diel feeding chronology in hammerhead sharks and these were assessed by combining data on stomach contents as percentage of body weight of all sharks. Seki and Somerton (1994) estimated the daily ration of pelagic armorhead, *Pseudopentaceros wheeleri* at Southeast Hancock Seamount using a mathematical model involving the change in the weight of stomach contents over time. Samples scored from these analyses were related to morphometric data by correlation analysis. All the analyses were performed with the programme DECORANA (Hill, 1979). Kitchell and Crowder (1986) described the predator-prey interactions in Lake Michigan, USA. Robb and Hislop (1980) described the size and number of food items eaten and relationship between mouth gape and prey size and variation of diet in relation to predator length in the food of five gadoid species in the northern North Sea.

2.3. Trophic guild structuring

The concept of trophic guilds is frequently used in fish community studies as it offers the possibility of dividing the community into functional groups (Garrison and Link, 2000; Gerking, 1994; Ross, 1986). Root (1967) formulated the original definition of a guild as 'a group of species that exploit the same class of environmental resources in a similar way' and explicitly focused on classifying species based on their functional role in a community without regard to taxonomy. Trophic groupings, which integrate large information of prey-predator relationships based on diet data, are of immense scope in ecosystem based fisheries management. In India such kind of studies are rare. Qasim (1972), based on the available literature, made trophic grouping of some marine fishes as phytoplankton feeder, detritus feeder, detritus and benthic plant feeder, zooplankton feeder, carnivores etc.

Many researchers grouped fish communities based on their similarity in prey composition. As an example, Gaskett *et al.* (2001) identified five trophic guilds among Myctophidae of Macquarie Island in the South Pacific Ocean that supports a variety of protected sea bird and seal populations. Based on the dominance of copepods, euphausids, amphipods and fish in the diets of 13 myctophids, the five trophid guilds identified were copepod feeders, euphausid, copepod and amphipod feeders, euphausid feeders, amphipod feeders and piscivores. Hajisamae *et al.* (2003) in an highly impacted waters from four sites of the eastern Johor Strait, Singapore, identified trophic guilds as worm predators, calanoid copepod feeders, shrimp predators, polychaete predators and phytoplanktivores. Even though important differences in feeding were apparent between most of predators, Clark (1985) could suggest two very broad feeding guilds such as 'benthic guild' and 'pelagic guild' among fishes on the Campell Plateau, New Zealand. The fish species within these two broad guilds fed on a wide range of prey items and shared many preys in common. Davenport and Bax (2002) suggested five trophic groups out of 87 teleost and elasmobranch species using stable isotopes of carbon and nitrogen from the southeastern continental shelf of Australia. Luczkovich *et al.* (2002) established trophic guilds of macro invertebrates and fish taxa for a seagrass food web in winter in the northeastern Gulf of Mexico. The trophic groups identified were herbivores, detritivores, suspension feeders, omnivores, molluscivores, meiobenthos consumers, macrobenthos consumers and piscivores. From India, none have investigated the trophic organization of marine ecosystem based on trophic interactions.

2.4. Feeding habits of the groups studied

2.4.1. Rock cods

Our present knowledge on the food and feeding habits of rock cods in India is limited to a few observations. Prabhu (1954) described the food of *Epinephelus tauvina, E. lanceolatus* caught by special traps for perch fisheries in the area around Mandapam in the Gulf of Mannar and Palk Bay. Menzel (1960) observed the feeding efficiency and growth rate of *E. guttatus*. Daily feeding rhythm of *E. labriformis* was observed by Hobson (1965) and Collette and Talbot (1972). Premalatha (1989) studied the food composition of some rock cods caught by traps (*E. areolatus, E. chlorostigma, E. diacanthus*) and recorded that rock cods are carnivorous and highly predacious. Heemstra and Randall (1993) and Brule and Canche (1993) described the crustacean feeding habits of rock cods. The feeding behaviour of *E. diacanthus* caught from Visakapatanam coast was described by Tessy (1994). The review reported that teleosts and crustaceans were the dominant prey of rockcods.

2.4.2. Flatheads

A review of literature on the flatheads from the Indian waters shows that the information on the biology of this group is limited to a few observations. Rao (1964) briefly described the food composition of *Grammoplites scaber* from the trawl catches in the Bay of Bengal and crabs appear to be the favourite food of the fish. George *et al.* (1968) studied the food habits of *Platycephalus maculipinna* from the trawl catches of Cochin region. Murthy (1975) has given an account of fishes of the family Platycephalidae of the seas around India. A brief account of the diet of similar species, *P. fuscus* was given by Paxton *et al.*, (1989) and on *P. indicus* by Marais (1984), Nasir (2000) and Wu (1984). Works of Jeyaseelan (1998) and Bauchot (1987) are also important to understand the benthic feeding habit of flatheads.

2.4.3. Bullseye

Rao (1964) briefly reported the food composition of *P. tayeneus* from the trawl catches in the Bay of Bengal. Study on the food and feeding of *Priacanthus* spp. were also made by Chomjurai (1970) and Wetchagarun (1971) from the Gulf of Thailand and Ambak *et al.* (1987) from the Malaysian waters. Rao (1984) studied the biology of *P. macrocanthus* from the Waltair coast and reported that crustaceans and teleosts form the major food. Some observation on the biology of *P. hamrur* from the Karnataka coast was made by Zacharia *et al.* (1991) and they recorded the feeding migration of priacanthids to deeper waters. Study by Premalatha (1997) from the southwest coast of India showed the highly carnivorous nature of *P. hamrur*. Philip (1998) studied the food and feeding habits of *Priacanthus hamrur* from the upper west coast of India and his study revealed that it is a carnivorous species feeding on crustaceans and teleosts. Feeding variation in relation to size, depth and location were studied.

2.4.4. Sciaenids

Large numbers of studies have been conducted on the diet of different species of sciaenids. Jacob (1948) mentioned the food of few sciaenids from Madras coast. Chacko (1949) gave an account of the food and feeding habits of *Sciaena albida, S. glauca* and *Otolithes ruber* from the Gulf of Mannar. Bapat and Bal (1952) reported on the food of juveniles of *Sciaena miles, S. albida, S. semilucuosa, S. glauca* and *Otolithes argenteus* of Bombay. Mohamed (1955) reported disgorging and extrevertion of the stomachs of the Sciaenids. Venkataraman (1960) studied the food and feeding relationship in shore fishes off Calicut. Rao (1964) described the food and feeding habits of some sciaenids from Bengal. Suseelan and Nair (1969), while studying the food of the demersal fishes of Bombay, dealt with the food of a few sciaenids.

Jayaprakash (1974) studied the food and feeding habits of juvenile 'koth' *Otolithes brunneus* from Bombay waters. Rao (1980) described the food and feeding habits of *Pennahia macrophthalmus* at Visakhapatnam. Nair (1980) studied the food and feeding habits of *Otolithes ruber, Johniops sina* from the inshore fishing grounds off Calicut. Pillai (1983) described the food and feeding habits of *Otolithes ruber* from Porto Novo coast. Rao (1985) reported that *Otolithes cuvieri* mainly feeds on prawns (viz., *Acetes* spp, *Solenocera* spp, and *Hippolysmata* spp) and teleosts. Lalmohan (1984) studied the food and feeding habits of the sciaenid fish, *Pennahia macrophthalmus*. They observed that juveniles of these species mainly feed on planktonic crustaceans and the adults on prawns, fishes, polychaetes, and molluscs.

Manojkumar (2003) observed feeding habits of *Otolithes cuvieri* from the trawl catches of Veraval. Chakraborty *et al.* (2000) briefly discussed the fishery, biology and stock assessment of jewfish resources of India. Xue *et al.* (2005) reported diversity of prey species in the stomach of the yellow croaker, *Pseudosciaena polyactis* from Central Yellow Sea.

2.4.5. Threadfin breams

Food and feeding habits of *Nemipterus japonicus* off Mangalore in relation to season and depth were studied by Kuthalingam (1965). He observed no seasonal variation in the feeding habits of fish, whereas depth wise analysis indicated remarkable changes in the composition of diet. He found that fishes occurring in the 10-20 m depth range were found to feed mainly on *Metapenaeus dobsoni* and *Parapenaeopsis stylifera* along with some other crustaceans, tube dwelling polychaetes, mud mixed with shell pieces, foraminiferans, partly digested fish remains, diatoms and algae. Diet of fishes caught in 20-30m depth included teleosts besides crustaceans. In 40-50m depth, the fish was found to be cannibalistic.

George *et al.* (1968) while studying the food habits of 7 commonly caught demersal fishes from the Cochin region found that the threadfin bream *N. japonicus* consumed small crustaceans dominated by amphipods. Polychaetes and echiuroids formed a significant portion. According to Krishnamurthy (1971), *N. japonicus* off Vishakapatanam was actively predaceous and feeding substantially on crustaceans, molluscs, annelids and echinoideans in the order of abundance. He studied the seasonal variation of food components and feeding intensity in relation to size. Food and feeding habits of 3 species of *Nemipterus viz*: *N. bathybus*, *N. japonicus*, *N. virgatus* were studied by Eggleston (1972) from Hong Kong waters and found that these fishes were active predators. He showed that adults of all these species feed mainly on crustaceans, fishes and cephalopods.

Muthiah and Pillai (1979) studied the food of *N. delagoae* from Bombay waters. Their study showed that the crustaceans were the major diet along with few teleosts. According to Rao (1989), *N. mesoprion* from Waltair was carnivorous subsisting mainly on crustaceans and teleosts. Among crustaceans young prawns, crabs and *Squilla* spp. were dominant. During a study of seasonal abundance of threadfin breams of Visakapatanam coast by Rao and Rao (1991), stomach analysis of the samples revealed that an average of 16% of the guts were full, 18% were ¾ full, 21% were ½ full and the remaining 44% were ¼ full.

2.4.6. Silverbellies

Several workers have reported the food and feeding habits of the leiognathids. One of the earliest Indian records was that of Chacko (1944, 1949) who observed the feeding habits of silverbellies of Pamban and Gulf of Mannar. Chidambaram and Venkataraman (1946) gave tabular statements on the natural history of certain silverbellies of the Madras Presidency. Venkataraman (1960) studied in detail the food of *Secutor* spp. and *Leiognathus* spp. off Calicut. Basheeruddin and Nayar (1962) conducted some studies on the juvenile silverbellies off Madras. Tiews *et al.* (1972) reported that certain genera of foraminiferans were recorded from the diet of leiognathids, which were not found in the benthos sample. The indices of relative abundance and main food type for some important silverbellies from Trinity Bay were estimated by Blaber (1980). The works of James and Badrudeen (1981) on *L. dussumieri* are the other important records among the silverbellies. Nasir (2000) conducted the dietary studies on the leiognathids in the inshore waters of Khor Al-Zubair, northwest Arabian Gulf. Blackler *et al.* (2002) reported prey composition of *L. equulus* from Durban harbour of South Africa.

2.4.7. Flatfishes

Seshappa and Bhimachar (1955) studied the food and feeding habits of *Cynoglossus semifasciatus* collected from 1948 to 1952 along the Calicut coast. The species mainly fed on benthic organisms. de Groot (1971) described the interrelationship between the morphology of alimentary tract, food, feeding behavior and the more general diurnal activity in flatfishes (Pleuronectiformes). Based on these characters, the flatfishes were divided into three behavioural groups namely fishfeeders, *eg*: Psettodidae, Bothidae and Pleuronectidae of type 1; crustacean feeders, *eg*: Pleuronectidae of type 2 and Cynoglossidae and Polychaete- Molluscan feeders, *eg*. Pleuronectidae of type 2 and 3. Braber and Groot (1973) studied the food composition of five commercially important flatfish species (Pleuronectiformes: Turbot, Plaice, Brill, Dab and Sole) inhabiting the southern North Sea. They found that during their growth rate, there is a shift in their food preference. Devadoss and Pillai (1973) studied the food of *Psettodes erumei* off Porto Novo. The stomach content consisted of larval and post larval forms of fishes such as *Polynemus* sp., sciaenids, *Thrissocles* sp., *Anchoviella* sp., and leiognathids besides small prawns and squids. Daracott (1977) studied the food and feeding habits of *Psettodes erumei* from the demersal fish stock of western Indian Ocean during 1969-1970. A total number of 69 stomachs analysed using the occurrence method showed that *P. erumei* mainly fed on fish, followed by molluscs and crustaceans. Devadoss *et al.* (1977) gave an account of feeding habits of *P. erumei* from Porto Novo waters. They found it to be a carnivore feeding mainly on fishes. Ramanathan *et al.* (1977) reported that crustaceans were the most preferred food of *Cynoglossus macrolepidotus*.

The food and feeding habits of *P. erumei* and *Pseudorhombus arsius* were studied by Ramanathan and Natarajan (1980) in Porto Novo waters. The study indicated that the juveniles preferred crustaceans, while the adults preferred fishes. Jayaprakash (2000) described the food and feeding habits of the tongue sole *Cynoglossus macrostomus* collected from the trawl catches of Cochin and Neendakara fishing harbours. Andersen *et al.* (2005) have given detailed account on the feeding strategy and ontogenetic variations in feeding of the flounder, *Platichthys flesus* in a vegetated and a bare sand habitat in a nutrient rich fjord.

2.4.8. Pomfrets

Earlier reports on the biology of the pomfrets are limited and are restricted to the general account given by Chidambaram and Venkataraman (1946), Moses (1947) and Devanesan and Chidambaram (1948). Preliminary investigations on the food and feeding habits of pomfrets from the Arabian Sea were undertaken by Rege (1958) and Kulkarni (1958). Rege (1958) made a preliminary study on the biology and the parasites of *Pampus argenteus* in the Bombay waters. Kulkarni (1958) studied the alimentation and rate of digestion in the fish from Bombay waters. Kuthalingam (1963) made some observations on its food and feeding from Bay of Bengal. Rao (1967) conducted brief observation on the food of *P. argenteus* from Andhra-Orissa coast. Information about the nature of the food of Chinese pomfret is confined to the brief accounts of Basheeruddin and Nayar (1962) from Madras waters and Rao (1964) from the Andhra coast. Pati (1977) has studied the feeding habits of Chinese pomfret, *Pampus chinensis* from the Bay of Bengal and has reported the behaviour of surface feeding of the fish. A detailed study on the food and feeding habits of silver pomfret, *Pampus argenteus* was undertaken by Pati (1978) from Bay of Bengal along the Orissa coast and the author has described the variation in .feeding with reference to maturity, migration and fishery.

2.4.9. Whitefish

Chidambaram and Venkataraman (1946) and Chacko (1949) from the Gulf of Mannar region, Devanesan and Chidambaram (1948) from the Madras waters and Venkataraman (1960) from the Malabar Coast studied the food and feeding of *Lactarius lactarius*. Basheeruddin and Nayar (1962) reported on the food and feeding of juvenile *L. lactarius* caught by the shore-seine along the Madras coast. Rao (1966) gave a brief account on the food and feeding of the whitefish from Waltair. George *et al.* (1968) studied the food and feeding of the species caught from the trawl grounds off Cochin. James *et al.* (1974) and. Neelakantan (1981) gave a detailed account on the food and feeding of *L. lactarius* from Karnataka waters. Zacharia (2003) described the feeding habits of *L. lactarius* from Mangalore waters. He reported the importance of teleosts and crustaceans in the diet of whitefishes.

2. 4. 10. Sharks

Information on the feeding habits of sharks in the Indian waters is limited to the studies by Aiyar and Nalini (1938), Mahadevan (1940), Sarangadhar (1943), Chidambaram and Menon (1946) and Setna and Sarangdhar (1949). The available literature of feeding habits of sharks from Indian coasts is mainly on *Galeocerdo tigrinus* from Bombay waters (Sarangdhar, 1943), *Rhincodon typus* from Tuticorin (Silas and Rajagopal, 1963) and *Chiloscyllium indicum* and *Scoliodon sorrakowah* from trawl catches off Waltair (Rao, 1964). Nair and Appukuttan (1973) observed the food of three deep sea sharks *Halaelurus hispidus, Eridacnis radcliffei* and *Iago omanensis* caught from the trawl catches of Mandapam, Gulf of Mannar at a depth ranging from 150 to 200 fathom. The percentage of volume and occurrence of each item of each item of food was found separately to determine the importance and abundance of various food items in the diet of these sharks. Mathew and Devaraj (1997) described the food of spadenose shark *Scoliodon laticaudus* in the coastal waters of Maharashtra and the diet consisted of fishes, prawns, molluscs and squilla. Cortes (1999) described the trophic level of sharks of four families and observed ontogenetic variation in trophic level with respect to size of predators. Colin *et al.* (2001) reported the diet of tiger shark *Galeocerdo cuvier* with respect to size, sex and location from the western Australian waters. Joyce *et al.* (2002) studied the stomach contents of the porbeagle shark *Lamna nasus*, a large cold-temperate pelagic shark found in the northwest Atlantic. Meaghen and Campana (2003) described the quantitative assessment of the diet of the blue shark *Prionace glauca* off Scotia, Canada and tested for dietary differences based on sex, maturity and locations. Bush (2003) studied the diet and diel periodicity of juvenile scalloped hammerhead shark *Sphyrna lewini* from Kaneohe Bay, Hawai and reported the effect of area, sex, year and season on diet and feeding.

2.4.11. Guitarfishes

Darracott (1977) while describing the diet of demersal fish stock of western Indian Ocean briefly mentioned the diet of *Rhynhcobatus djiddensis*, which included crustaceans, squid and eel. Studies on the food and feeding habits of different species of guitarfishes were made by Euzen (1987), Compagno *et al.* (1989), Michael (1993) and Nasir (2000). Abdel-Aziz (1986) used Index of Relative Importance for food studies of common guitarfish, *Rhinobatos rhinobatus* in the Egyptian Mediterranean waters and crustaceans mainly decapods formed the most important prey categories.

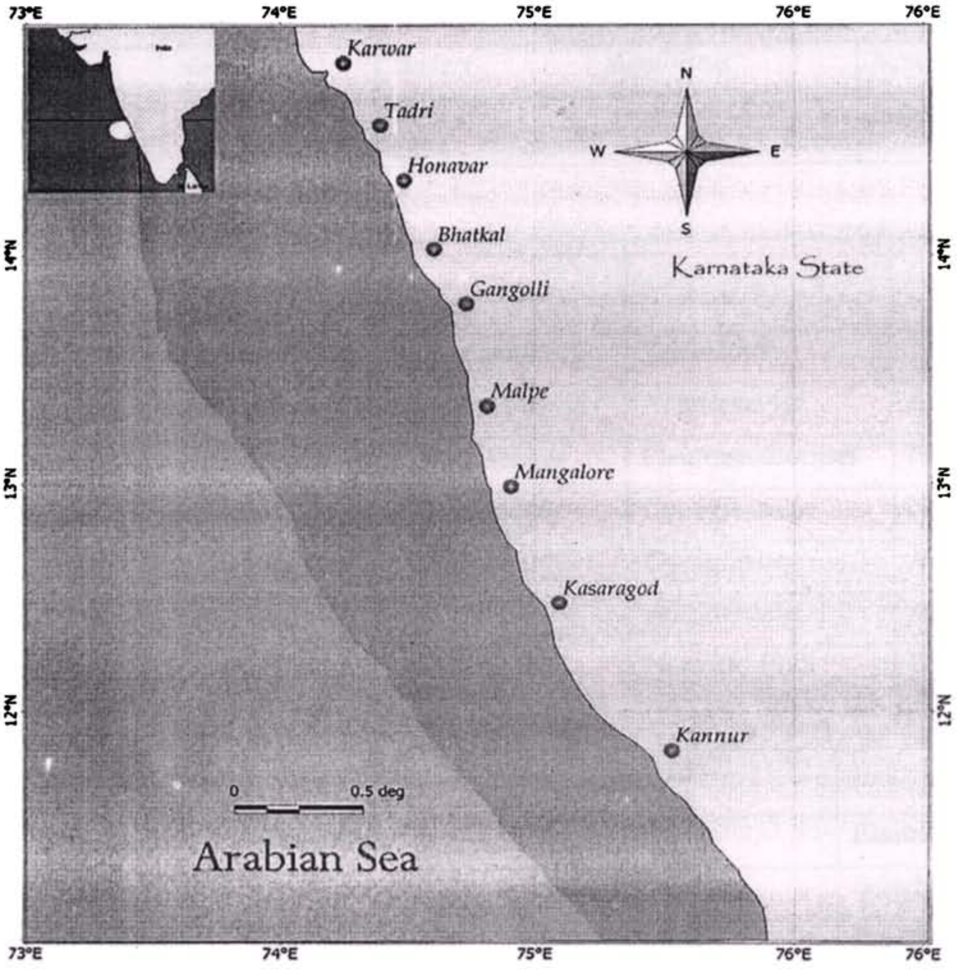
Chapter 3.

Material and Methods

3.1. Study area

There are 28 fish landing centers along the Karnataka coast. Mangalore and Malpe are the two major fishing harbours, which accounted for more than 60% of the State's marine fish landings. Karnataka state is situated between $11^{0}31'$ and $18^{0}45'$N latitude and $74^{0}12'$ and $78^{0}40'$E longitude (Fig 3.1). Fish samples were collected from commercial catches of MDF trawlers operating from Mangalore harbour during the period August 1999 to July 2001.

Fig. 3.1. Map of the study area, showing major trawl harbours along Karnataka coast in the southeast Arabian Sea



3.2. Species studied

Fourteen species of commercially important demersal finfishes in the trawl catch of Karnataka coast were selected for the study (Plate 1). For identifying the species, the publications of Day (1878), Weber and Beaufort (1931), Munro (1955), FAO (1981) and Smith (1961) were consulted. The taxonomic positions of the species studied are given in Table 3.1.

Table 3.1. Taxonomic details of the species selected for the study

Tax. Position	**1**	**2**	**3**	**4**	**5**
Class	Teleostomi	Teleostomi	Teleostomi	Teleostomi	Teleostomi
Sub class	Actinopterygi	Actinopterygi	Actinopterygi	Actinopterygi	Actinopterygi
Order	Perciformes	Perciformes	Perciformes	Scorpaeniformes	Perciformes
Family	Serranidae	Sciaenidae	Sciaenidae	Platycephalidae	Priacanthidae
Genus	*Epinephelus*	*Johnieops*	*Otolithes*	*Grammoplites*	*Priacanthus*
Species	*diacanthus*	*sina*	*cuvieri*	*suppositus*	*hamrur*
Author	Valenciennes, 1828	Talwar and Jhingran, 1991	Trewavas, 1974	Troschel, 1840	Forsskal, 1775

(Cuvier 18[illegible])

Tax. Position	**6**	**7**	**8**	**9**	**10**
Class	Teleostomi	Teleostomi	Teleostomi	Teleostomi	Teleostomi
Sub class	Acanthopterigii	Actinopterygi	Actinopterygi	Actinopterygi	Actinopterygi
Order	Stromiformes	Pleuronectiformes	Perciformes	Pleuronectiformes	Perciformes
Family	Stromatoidae	Bothidae	Lactaridae	Cynoglossidae	Nemipteridae
Genus	*Pampus*	*Pseudorhombus*	*Lactarius*	*Cynoglossus*	*Nemipterus*
Species	*argenteus*	*arsius*	*lactarius*	*macrostomus*	*japonicus*
Author	Euphrasen, 1788	Hamilton, 1822	Bloch, 1801	Norman, 1928	Bloch, 1791

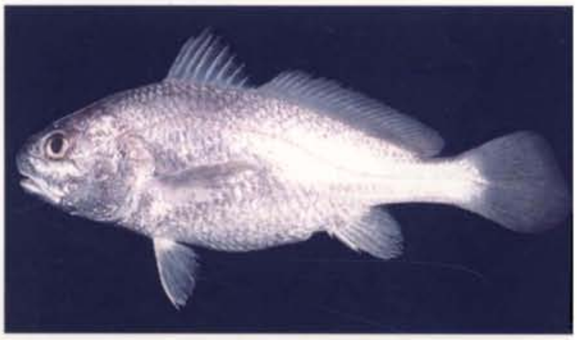
Tax. Position	**11**	**12**	**13**	**14**
Class	Teleostomi	Teleostomi	Elasmobranchii	Elasmobranchii
Sub class	Actinopterygi	Actinopterygi	Selachii	Selachii
Order	Perciformes	Perciformes	Laminiformes	Rajiformes
Family	Nemipteridae	Leiognathidae	Carcharhinidae	Rhinobatidae
Genus	*Nemipterus*	*Leiognathus*	*Carcharhinus*	*Rhynchobatus*
Species	*mesoprion*	*bindus*	*limbatus*	*djiddensis*
Author	Bleeker, 1853	Valenciennes, 1835	Muller and Henle, 1839	Forsskal, 1775

Plate. 1. Demersal finfish species selected for the study

Epinephelus diacanthus

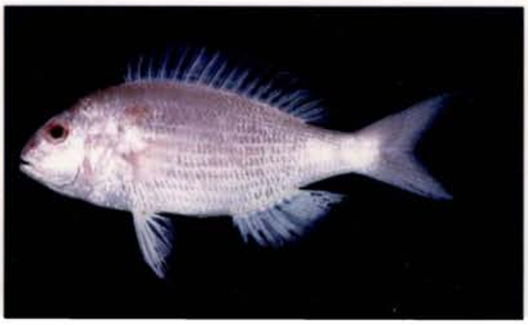
Grammoplites suppositus

Priacanthus hamrur

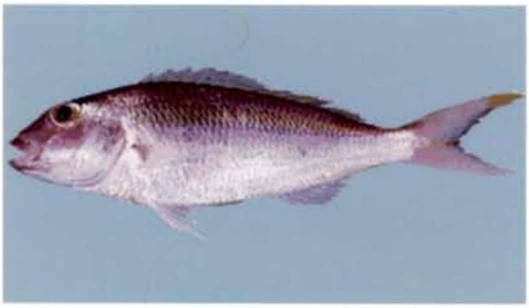


Johnieops sina

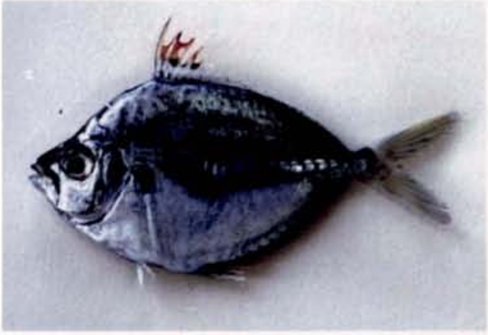
Otolithes cuvieri



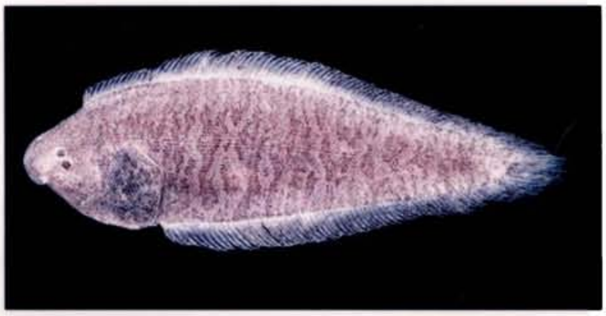
Nempiterus japonicus



Nemipterus mesoprion



Leiognathus bindus



Cynoglossus macrostomus

Pampus argenteus

Lactarius lactarius

Pseudorhombus arsius

Carcharhinus limbatus

Rhynchobatus djiddensis

3.4. Methods of Analysis

3.4.1. Sample collection

Biweekly samples were collected from the commercial landings of trawls at Mangalore and Malpe between Aug 1999 and July 2001. During sampling, the species composition of the target groups was examined and specimens were collected to represent different length groups from a representative part of the total catch of all species. For all the species, total length (TL) was measured from the tip of the snout to tip of the caudal fin. Large number of stomachs could be collected for the spotfin flathead, *Grammoplites suppositus* (581) and lesser number for the guitarfish, *Rhynchobatus djiddensis* (170). Table 3.2 shows the species selected for the present study with sample number (N), length and weight ranges and sampling period.

Table 3.2. Demersal finfishes sampled for stomach content analysis

Species	N	Length range (mm)	Weight Range (gm)	Sampling period
Epinephelus diacanthus	550	108-418	71-998	Aug 99-May 00
Grammoplites suppositus	581	143-282	19-169	Aug 99- May 00
Priacanthus hamrur	216	150-285	42-275	Sep 99- May 00
Johnieops sina	470	100-179	12-69.2	Sept 00- Jul 01
Otolithes cuvieri	364	97-295	8.14-300	Sept 00- Jul 01
Nemipterus japonicus	329	131-284	33-245	Aug 99-Jun 00
Nemipterus mesoprion	555	76-290	5.3-260	Aug 99-Jun 00
Leiognathus bindus	241	78-111	6.13-13	Aug 99- May 00
Cynoglossus macrostomus	241	105-158	8-25	Sept 00- Jul 01
Pseudorhombus arsius	285	137-315	22.95-313	Sep 99- May 00
Pampus argenteus	228	91-290	23-650	Sep 99- Jun 00
Lactarius lactarius	293	92-200	32-86	Sept 00- Jul 01
Carcharhinus limbatus	193	34.5-94	87-1085	Aug 99- May 00
Rhynchobatus djiddensis	170	234-720	24-4100	Sept 00- May 01

3.4.2. Laboratory analysis

The specimens were brought to the laboratory, and washed; total length was measured (to the nearest mm) and weighed (accuracy: 0.1 g). The fish was cut open and the sex and stage of maturity were recorded. The stomach of most species was removed carefully by cutting the pyloric sphincter and connective tissue as well as the oesophagus above the oesophageal sphincter to prevent loss of the contents. In case of pomfret, *Pampus argenteus*, the stomach was pulpy and flabby and hence was not separated from the remaining visceral mass and was preserved as such as. In the tongue sole, *Cynoglossus macrostomus* as the stomach was not clearly distinguishable from the remaining gut, a portion of the foregut was collected and analyzed. Each stomach was preserved by injecting with 10% formalin and wrapped in gauze or paper towels. Stomachs were sealed in plastic ziplock bags and stored for further analyses. The stomach contents were analyzed by both quantitative and qualitative methods. For analysis, a longitudinal cut was made across the stomach and the contents were transferred into a petri dish. The contents were kept for five minutes to remove excess formalin. Each gut was emptied in to a petri dish and was examined under binocular microscope. Gut contents were identified up to genus or species level depending upon the state of digestion. Wet weight of each prey was measured to the nearest 10 mg using an electronic balance. If the food items were in an advanced stage of digestion, they were treated as semi-digested matter. When identification of prey failed, the same was included in the categories "Unidentified fishes", "Unidentified prawns", etc. In several instances sand grains were found in the gut and the same were considered as accidental entry and hence excluded while grading various food items.

3.4.3. Data analysis

Diet data was analysed to study the most important and highly preferred prey components of each predator. Stomach fullness data was analysed to study the feeding activity and to measure to the intensity of feeding in accordance with the change in season and size. Number, occurrence and wet weight of each component were used to estimate certain indices, which determined the important prey types of each predator. Ontogenetic and temporal variation in feeding was also determined based on these indices. The mean length of the predator and prey, the mean weight of predator and prey and trophic level of each fish were estimated for studying the prey –predator relationships.

Feeding intensity was determined based on the state of distension of stomach and the amount of food contained in it. The stomachs were graded as empty, ¼ full, ½ full, ¾ full, and full. Fishes with gorged and full condition were considered to have been feeding actively. Stomach with ¼ full and trace food were considered to denote reduced feeding activity. The monthly percentage of occurrence of the stomach in active and reduced feeding condition was used to determine the seasonal and sizewise fluctuations in feeding intensity.

A variety of diet measures used and reviewed by Bowen (1996) to quantify the feeding preference of fishes were applied in the present study. The measures used in the present study are:

$$\text{Frequency of Occurrence, } O_i = \frac{J_i}{P}$$

Where, J_i is the number of fish containing prey *i* and P is the number of fish with food in their stomach.

$$\text{Percent by number, } N_i = \frac{N_i}{\sum_{i1}^{Q} N_i}$$

Where, N_i is the number of food category **i**

$$\text{Percent by weight, } W_i = \frac{W_i}{\sum_{i1}^{Q} W_i}$$

Where, W_i is the weight of the prey **i**

From these three indices, the relative importance of prey items was calculated by means of the Index of Relative Importance (*IRI*) (Pinkas *et al.*, 1971). The *IRI* was calculated for each prey as:

$$\text{Index of relative importance, } IRI_i = (\%N_i + \%W_i)\,\%O_i,$$

Where, N_i, W_i and O_i represent percentages of number, weight or volume and frequency of occurrence prey **i** respectively.

This *IRI* is a modified version of the index where the original term of percentage by volume was replaced by the %W term (Alonso *et al.*, 2000). In

Trophic position

Trophic position of each fish was calculated using quantitative gut content data (either percent weight or percent volume), weighted average formulas, and previously published estimates of the trophic position of different prey items (Odum and Heald, 1975) using the formula

$$\text{Trophic level } \mathbf{(TL)} = \sum (W_i T_i) + 1$$

Where W_i the percentage by weight contribution of i_{th} is prey item and T_i is the trophic level of the i_{th} prey item. Trophic level of prey groups was collected from the literature (Vivekanandan, 2006) and FISHBASE (Froese *et al.*, 2000).

Feeding strategy

A graphical technique that relates prey abundance (N_i or W_i) to frequency of occurrence developed by Costello (1990) and later modified by Amundsen *et al.* (1996) was used in the present study to interpret 1) predator feeding strategies, 2) relative prey importance and 3) diet variability. In the Amundsen plot, prey-specific abundance is plotted against frequency occurrence, where prey-specific abundance is defined as the proportion a prey item comprises of all prey items in only predators that contain prey ' (Amundsen *et al.*, 1996).

The equation used to calculate prey specific abundance (P_i) is,

$$P_i = \left(\sum S_i / \sum S_{ti}\right) 100$$

Where P_i equals prey-specific abundance (numbers, mass or volume) of prey i, S_i equals the abundance of prey in stomachs and S_{ti} equals the total abundance of prey in predators that contain prey i.

3.4.4. Statistical Analysis

Contingency table Analysis

Non-parametric two-way contingency table analysis (Sokal and Rohlf, 1995) was employed to test the independence between prey groups and seasons or length groups. This statistical test can be used to identify the source of variation when diets are expressed in numbers (Cortes, 1997). To conduct this statistical test different prey categories were pooled into large categories such as fishes, prawns, crabs, other crustaceans and cephalopods. Same procedure was used to check for significant variations (at 5% level) in feeding intensities among different seasons and length groups.

Multivariate methods

To analysis predator's diet data for trophic interactions, multivariate statistics were performed using the package Primer-5 (Clarke and Warwick, 2001. Multivariate methods of classification and ordination were used to analyse diet data on the basis Index of Relative Importance of prey of each predator. Multivariate analysis of diet data were accommodated under two collective terms, classification and ordinations. Classification analysis seeks to assign predators in to trophic guilds, where as ordination attempt to place these spatially so that similar predators are close and dissimilar ones are distant. Commonly used classification method is cluster analysis. This method was adopted since it is not affected by joint absence and it is sufficiently robust for marine data. It is often a satisfactory coefficient for biological data on community structure (Clarke and Warwick, 1994). Ordination techniques include correspondence analysis and non-metric multidimensional scaling (MDS). In the present study, the data were approached to cluster analysis and non-metric multidimensional scaling (MDS) ordination.

a. Cluster analysis

Cluster analysis was done to find out the similarities between groups. The most commonly used clustering technique is the hierarchical agglomerative method. The results of this are represented by a tree diagram or dendrogram with the X-axis representing all predators and Y-axis defining the similarity level at which the predators are fused. Bray-Curtis coefficient (Bray and Curtis, 1957) was used to produce the dendrogram. The coefficient was calculated by the following formula:

$$Sjk = 100\left\{1 - \frac{\sum_{i=1}^{p} \left|Y_{ij} - Y_{ik}\right|}{\sum_{i=1}^{p} \left(Y_{ij} + Y_{ik}\right)}\right\}$$

$$= 100\frac{\sum_{i=1}^{p} 2\min\left(Y_{ij} + Y_{ik}\right)}{\sum_{i=1}^{p} \left(Y_{ij} + Y_{ik}\right)}$$

where Y_{ij} **represent** the entry with i^{th} row and j^{th} column of the data matrix i.e. the %IRI for the i^{th} prey in the j^{th} predator. Y_{ik} is the %IRI for the i^{th} prey in the k^{th} predator; 'min' stands for , the minimum of two values and $\sum$ represents the overall rows in the matrix.

In PRIMER, stomach content data (%IRI) of predator groups were standardized and square root transformed prior to calculations of similarity matrices using the Bray-Curtis similarity coefficient.

b. MDS (Non-metric Multi Dimensional Scaling)

MDS was applied as an ordination technique for graphical representation of stomach content similarity data.

This method was proposed by Sheppard (1962) and Kruskal (1964) and was used to find out the similarities (or dissimilarities) between each pair of entities to produce a 'map', which would ideally show the interrelationships of all. This map, or configuration in a specified number of dimensions visually displays the ranking of the similarity matrix with the greatest 'goodness of fit', or lowest stress. This provided a snapshot of the variability in the diets of each predator. MDS plots one point for each predator. The closer the points: the more similar the predator assemblages. In addition, it combines the cluster results with ordination in order to further investigate whether the combination was an effective way of checking the sufficiency and mutual consistency of both representations. The data from the Bray-Curtis similarity matrix were used to construct the 'map'. The data were ordinated using the MDS program in PRIMER.

c. ANOSIM (Analysis of similarities)

ANOSIM permutation test was employed to test the differences between groups. It is denoted by 'R' and calculated using the following formula:

$$R = \frac{(r_B - r_W)}{(M/2)}$$

where r_B = is the average of rank similarities arising from all pairs of replicates between different predators; r_W = is the average of all rank similarities among replicates within predators and M= n(n-1).n represents the total number of predators under consideration. Each predator in a cluster was taken as replicates for ANOSIM between clusters.

ANOSIM constructs a similarity matrix and produces a R-statistic, which describes the extent of dissimilarity in diet composition among the predators of each cluster. If there are no differences between groups, then between-group similarities and within group similarities will be roughly equal. A R-statistic is never more than about 0.15 by chance, hence if $R > 0.15$, the null hypothesis that no differences between groups can be rejected at the 0.001 (or 0.1%) level. A significance level statistic is also produced, which calculates percent correspondence (Clarke and Gorley, 2001). A 'Global R' and significance level (%) is calculated for the entire data set, and an R-statistic and significance level (%) is also calculated for each pair-wise comparison. The 'Global R', which is scaled to lie between -1 and +1, a value of zero representing the null hypothesis (no difference among cluster groups). In ANOSIM, comparison of pair-wise R values, measuring how separate cluster groups are, on a scale of 0 (indistinguishable) to 1 (all similarities within cluster groups are less than any similarity between cluster groups) gives an interpretable number for the difference between cluster groups. The interpretation was like R-values >0.75 as well separated; R>0.5 as overlapping, but clearly different and R<0.25 as barely separable (The PRIMER-manual; Clarke & Gorley, 2001). Predators of each cluster groups were grouped according to Groups A, B, C or D as factors for the analyses.

d. SIMPER

SIMPER, or 'similarity percentage', was performed on the original data, providing a ranking that shows which prey items contributed most by percentage to the similarity in a within group test, or the percentage of dissimilarity contributed to a between group test. Thus SIMPER analysis was used for identifying which prey groups primarily account for observed differences in predator assemblages between types.

e. BVSTEP

BV Step uses the Spearman Rank Correlation in a forward and backward iteration that systematically calculates the variance explained by one prey category, then adding another and recalculating the variance each time. The output is a specific set of prey that explains the highest percentage of variability (Clarke and Gorley, 2001). It was employed to determine which prey groups were most influential in for the predators of demersal fish communities. Thus this process allowed deletion of prey groups that did not influence the ordination process and allowed to trim down the large prey data sets.

Chapter 4.
Results

4. 1. *Epinephelus diacanthus*

4.1.1. General diet composition

A total of 550 individuals of the rockcod, *E. diacanthus* ranging in total length from 108 to 418 mm (mean: 178mm) were analysed. Of all the stomachs, 73% were empty and 27% contained food items. A total of 20 prey items were identified from the stomach. After grouping all the food items in to four categories, it was found that crustaceans (%IRI=93.4) and fish formed the major prey category (Table 4.1.1). Fish formed the second important prey category (%IRI=5.5). Molluscs and detritus were the least preferred diet components. The weight of individual prey ranged between 0.014 g for *Acetes indicus* and 39.2 g for *Lutjanus* spp with a mean of 2.20 g. Mean number and weight of prey per stomach was 1.78 and 0.766g respectively. Benthic crabs (Plate 2*a*) occurred in large number of stomachs (44.5%) followed by *Oratosquilla nepa* (12.9%) and unidentified fishes (9.0%). In terms of number, 215 *A. indicus* (58.7% of total number of prey) were present in the stomach, followed by benthic crabs (20.2%) and *O. nepa* (5.5%).

Gravimetric analysis of stomach contents revealed that 30.2% of the diet consisted of benthic crabs. Thus the most important crustacean components were benthic crabs (%IRI= 69.4), followed by *A. indicus* (%IRI=15.9) and *Oratosquilla nepa* (%IRI= 6.1). The least important crustaceans included *Metapenaeus monoceros*, *Trachypenaeus* spp, *Solenocera* spp, penaeid prawns and *Hippa* spp. Unidentified fishes (%IRI=4.4) formed the major teleost component. Teleosts, which appeared in very minor quantities were *Trichiurus lepturus*, *Lutjanus* spp, *Nemipterus japonicus*, *Leiognathus* spp, *Saurida* spp, *G. suppositus*, *Stolephorus* spp *and* soles.

Loligo spp (%IRI= 1.1) were important among the molluscs. Detritus, despite being represented frequently (%FO=5.8) with comparatively good quantity (%W=3.9), could not be considered for calculating the index.

4.1.2. Feeding intensity

In all the seasons the percentage of empty stomach was high. It was higher in the post-monsoon (77.6%) followed by the monsoon and pre-monsoon seasons. Active feeding was higher in the pre-monsoon season when a relative decrease in empty stomach was observed (Table 4.1.2). Fishes in poorly fed condition were relatively higher throughout the season. There was no significant variation in the feeding intensities among seasons (χ^2 test, df= 6, P>0.001).

With increase in size the intensity of feeding was found to reduce (Table 4.1.3). The percentage of empty stomach was more in larger size groups when compared to smaller ones showing less regurgitation in juveniles. Active feeding was comparatively high in 141-180 and 181-220 mm length groups. Moderately fed fishes were very less in all the length groups. Among the length groups, there was significant variation in the feeding intensities (χ^2 test, df= 12, p<0.001) (Table 4.1.3). The major variation was from 101-140 mm length groups.

4.1.3. Seasonal variation in feeding

Crustaceans dominated the diet in all the seasons. However a distinct seasonal change was observed among the crustacean and fish prey components (Table 4.1.4). Two-way contingency table analysis showed significant variation in the number of major prey groups (χ^2 test, df= 6, p<0.001) (Table 4.1.5). Among the seasons, major cause for the variation was the pre-monsoon followed by the monsoon season. The two most important crustacean preys, benthic crabs and *A. indicus* showed an inverse relationship in all the seasons. Benthic crabs formed the most important prey during the pre-monsoon (%IRI= 82.6) and the post-monsoon seasons (%IRI= 61.2). *O. nepa* was the second most preferred prey in both of these seasons. *Loligo* spp also formed an important source of diet in the pre-monsoon season. During the monsoon season, rockcods preferred *A. indicus* (%IRI= 69.3) followed by penaeid prawns (%IRI= 12.5) and unidentified fishes (%IRI= 10.1). The ribbonfish, *T. lepturus* constituted 4th most highly preferred food in the monsoon season. Prawn species (*Solenocera choprai* and *Trachypenaeus* spp) were noticed only in the post-monsoon season.

4.1.4. Ontogenetic variation in feeding

Diet of fishes above 340 mm was not considered to study the ontogenetic variation as all the larger specimens had regurgitated guts (Table 4.1.6). Importance of fish as prey increased with increase in the size of the predator. There was significant variation among the size groups in the number of major prey groups (χ^2 test, df= 16, P<0.001) (Table 4.1.7). Among the prey groups, *A. indicus* and among size groups, 181-220 mm were the main reasons for the variation. The highest diversity in prey was observed in the size of 181-220 mm where benthic crabs (%IRI=75.4) was the most preferred prey. In the smallest size group (101-140 mm), *A. indicus* (%IRI=69.1) was the most preferred prey followed by *O. nepa* (%IRI=20.9) and soles (%IRI=9.5). Fish was highly preferred in 261-300 mm and unidentified fishes (%IRI=43.5), *Lutjanus* spp (%IRI=10.9) and *G. suppositus* (%IRI=3.7) were the important fish components. An increase in importance of prawns, particularly penaeid prawns with increase in size were observed. Next to fish, penaeid prawns (%IRI=18.0) formed the second important prey of the group 261-300mm. *Loligo* spp was important in 181-220 mm size groups (%IRI=4.5). Shell pieces were observed in 141-180mm group.

4.1.5. Variation in diet breadth and trophic levels

Breadth of diet in *E. diacanthus* was examined and it was found that prey diversity had significant variations. The greatest dietary diversity occurred in the post-monsoon season (3.42 ± 1.6). In the monsoon season, second highest diet breadth was observed (2.59 ± 1.5). Due to high preference for benthic crabs and *O. nepa*, diet breadth in the pre-monsoon season was significantly reduced (2.09 ± 1.0) (Fig 4.1.1). On the other hand, presence of large predator, *T. lepturus* and unidentified teleosts in monsoon (4.43 ± 1.5) caused trophic level to increase than in the pre-monsoon and post-monsoon seasons.

Fig 4.1.2 shows ontogenetic changes in diet breadth and trophic levels. It was observed that dietary diversity increased with increase in size of the fish. It was highest for fish between 181 and 220 mm (Db=5.8) where prey diversity was greater and fishes consumed large proportions of crustaceans such as benthic crabs and *O. nepa*. The lowest diet breadth was for fish between 101 and 140 mm (Db=2.8). The dietary breadth of fish between 261 and 300 mm (Db=4.0) was higher, because in addition to crustaceans, fishes such as *Lutjanus* spp, *T. lepturus*, soles, *G. suppositus* and unidentified fishes formed an important part of the diet. Trophic level had the same pattern as diet breadth. It ranged from 3.81 in 181-220 mm to 4.58 in 262-300 mm groups. Fishes ranging between 181-220 mm had the largest prey diversity, but the lowest trophic level.

4.1.6. Diet similarities

To know the biological significance of competition and food similarities, cluster analysis between the season as well as the size groups were conducted. Generally, very low similarity in diet was observed among the seasons (Fig 4.1.3). Due to the predominance of benthic crabs, diet of fishes during the pre-monsoon and post-monsoon seasons had significant similarities (69%). Similarity was insignificant in all length groups; however, the highest similarity of 71% was observed between 141-180 and 181-220 mm groups as these groups shared equal proportions of the most preferred prey benthic crabs in their diets (Fig 4.1.4).

4.1.7. Prey-predator relationship

In *E. diacanthus*, some prey types had a positive correlation to the size of the predator. To understand a potential shift in prey size with growth a comparison was made between the carapace length (CL) of the most important prey, the benthic crabs and the total length of *E. diacanthus*. It was observed that there is a significant ($P<0.05$) ontogenetic shift toward larger benthic crabs in the larger rockcod and a linear relationship could be fitted ($r^2= 0.68$, $n=30$) (Fig 4.1.5). Similarly, the consumption of the stomatopod, *O. nepa* was positively related to the size of *E. diacanthus* when the weight of the prey was correlated with the size of predator. Thus, juveniles of *E. diacanthus* consumed smaller stomatopods and adults consumed larger stomatopods ($r^2= 0.68$, $n= 18$) (Fig 4.1.6).

4.1.8. Predator feeding strategy

Fig 4.1.7 shows the Amundson plot for *E.diacanthus* based on 16 different prey categories. There are 20 different prey types represented by each point. *E. diacathus* has specialised on a single prey type while occasionally consuming other prey. It means that feeding in rockcod is homogenous, with most predators specialising on a single dominant crustacean prey, the benthic crabs.

4.1.9. Prey selection

Table 4.1.8 shows the prey selection pattern of rockcods and it showed strong positive selection for crustaceans in all the seasons. Benthic crabs were overwhelmingly selected in all the seasons. In the pre-monsoon season, prawns were not selected, instead, moderate selection for *O. nepa* and strong selection for benthic crabs and unidentified fishes were observed. Strong preference to unidentified teleosts, prawns and benthic crabs was observed during the monsoon season. However, the lizardfishes, *Saurida* spp were avoided during the monsoon even though their proportion in the trawl catch was very high. During post-monsoon, only benthic crabs were strongly selected while *O. nepa*, penaeid prawns, *T. lepturus* were moderately selected. The cephalopod, *Loligo* spp had negative selection in the post-monsoon in spite of high proportion in trawl catches.

Table 4.1.1. Prey of *E. diacanthus* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	**%FO**	**%W**	**%N**	**IRI**	**%IRI**
Fishes					
Trichiurus lepturus	1.94	5.70	0.82	11.44	0.39
Lutjanus spp	0.65	10.50	0.27	6.30	0.21
Nemipterus japonicus	1.29	2.91	0.55	4.04	0.14
Leiognathus spp	1.29	0.73	0.55	1.50	0.05
Saurida spp	0.65	0.07	0.27	0.20	0.01
Grammoplites suppositus	1.29	3.66	0.55	4.92	0.17
Stolephorus spp	1.29	0.23	0.55	0.90	0.03
Soles	1.29	2.52	0.82	3.91	0.13
Unidentified fishes	9.03	12.13	3.55	128.37	4.38
Crustaceans					
Benthic crabs	44.52	30.18	20.22	2033.54	69.37
Acetes indicus	8.39	2.40	58.74	464.87	15.86
Oratosquilla nepa	12.90	9.91	5.46	179.83	6.13
Metapenaeus monoceros	0.65	0.16	0.27	0.26	0.01
Trachypenaeus spp	1.29	4.02	0.55	5.34	0.18
Solenocera choprai	3.23	1.79	1.37	9.23	0.31
Penaeid prawns	7.74	3.10	3.28	44.79	1.53
Hippa spp	0.65	0.11	0.27	0.22	0.01
Molluscs					
Loligo spp	4.52	5.83	1.91	31.68	1.08
Shell pieces	1.94	0.07	0.00	0.13	0.00
Detritus	5.81	3.97	0.00	0.00	0.00

Table 4.1.2. Feeding intensity (%) of *E. diacanthus* in relation to seasons

Feeding intensity	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Active	18.32	7.16	6.34
Moderate	9.03	3.26	3.81
Poor	9.68	21.39	12.24
Empty	62.97	68.19	77.62

Table 4.1.3. Two way contingency table analysis of the ontogenetic variation in feeding intensities of *E. diacanthus*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each length group).

Feeding intensity	Length group (mm)					N_j	χ^2
	101-140	141-180	181-220	221-260	261-300		
Active	1	28	21	6	3	59	22.5
	(3.1)	(19.9)	(13.2)	(4.4)	(3.7)		
Moderate	0	9	7	4	4	24	3.4
	(0.0)	(6.4)	(4.4)	(2.9)	(4.9)		
Poor	11	17	22	15	7	72	13.0
	(34.4)	(12.1)	(13.8)	(11.0)	(8.5)		
Empty	20	87	109	111	68	395	5.9
	(62.5)	(61.7)	(68.6)	(81.6)	(82.9)		
N_j	32	141	159	136	82	550	
χ^2	14.6	14.4	1.2	7.9	6.6		**44.7****

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df= 12

Table 4.1.4. Seasonal variation in %IRI of *E. diacanthus*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Trichiurus lepturus	0.00	5.57	0.10
Lutjanus spp	0.00	0.00	1.12
Nemipterus japonicus	0.00	0.00	0.70
Leiognathus spp	0.30	0.00	0.00
Saurida spp	0.00	0.08	0.00
Grammoplites suppositus	0.00	0.00	0.15
Stolephorus spp	0.06	0.05	0.00
Soles	0.00	0.83	0.16
Unidentified fishes	1.26	10.10	2.72
Benthic crabs	82.61	0.19	61.39
Acetes indicus	0.00	69.30	11.91
Oratosquilla nepa	11.92	0.00	20.20
Metapenaeus monoceros	0.06	0.00	0.04
Trachypenaeus spp	0.00	0.00	0.10
Solenocera choprai	0.00	1.20	0.00
Penaeid prawns	0.05	12.45	0.22
Hippa spp	0.00	0.08	0.00
Loligo spp	2.78	0.00	0.45
Shell pieces	0.00	0.00	0.37
Detritus	0.97	0.15	0.37

Table 4.1.5. Two way contingency table analysis of seasonal variation of five prey categories of *E. diacanthus*. Values are number of prey groups observed in each season

Prey groups	Season			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	7	9	12	28	6.0
Benthic crab	35	1	41	77	115.3
Acetes indicus	0	230	125	355	62.0
Other crustaceans	13	12	21	46	16.3
Molluscs	5	0	7	12	16.3
N_j	60	252	206		
χ^2	142.2	66.7	6.9		215.8**

N_i, total numbers by species; N_j, total numbers by season
**, $P < 0.001$, df= 6

Table 4.1.6. Ontogenetic variation in %IRI of *E. diacanthus*

Prey	Length group (mm)				
	101-140	141-180	181-220	221-260	261-300
Trichuirus lepturus	0.00	0.00	0.18	2.47	3.22
Lutjanus spp	0.00	0.00	0.00	0.00	10.90
Nemipterus japonicus	0.00	0.77	0.00	0.00	0.00
Leiognathus spp	0.00	0.00	0.51	0.00	0.00
Saurida spp	0.00	0.00	0.09	0.00	0.00
Grammoplites suppositus	0.00	0.00	0.24	0.00	3.71
Stolephorus spp	0.00	0.00	0.10	0.10	0.00
Soles	9.52	0.00	0.00	0.00	2.79
Unidentified fishes	0.00	0.52	2.08	10.96	43.52
Benthic crab	0.54	92.85	75.43	21.18	15.76
Acetes indicus	69.06	0.64	0.21	61.98	0.00
Oratosquilla nepa	20.89	4.31	14.06	0.00	0.00
Metapenaeus monoceros	0.00	0.06	0.00	0.00	0.00
Trachypenaeus spp	0.00	0.12	0.52	0.00	0.00
Solenocera choprai	0.00	0.00	1.08	0.25	2.09
Penaeid prawns	0.00	0.10	0.92	3.05	18.00
Hippa spp	0.00	0.00	0.09	0.00	0.00
Loligo spp	0.00	0.61	4.48	0.00	0.00
Shell pieces	0.00	0.02	0.00	0.00	0.00
Detritus	0.00	0.00	0	0	0

Table 4.1.7. Two way contingency table analysis of the ontogenetic variation of the five prey categories of *E. diacanthus.* (Values are number of prey groups observed in each length groups)

Prey groups	Length group (mm)						
	101-140	141-180	181-220	221-260	261-300	N_i	χ^2
Fishes	2	4	10	5	8	29	51.6
Benthic crab	1	28	25	10	3	67	69.7
Acetes indicus	65	15	0	135	0	215	84.4
Other crustaceans	4	10	17	6	4	41	31.5
Molluscs	0	2	5	0	0	7	19.0
N_j	72	59	57	156	15		
χ^2	28.7	40.2	90.4	46.5	50.4		256.2**

N_i, total numbers by species; N_j, total numbers by length groups
**, $P < 0.001$, df= 16

Table 4.1.8. Seasonal Ivelev index of *E. diacanthus*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Trichuirus lepturus	-	-	0.463
Lutjanus spp*	-	-	-
Nemipterus japonicus	-	-	-0.170
Leiognathus spp	0.182	-	-
Saurida spp	-	-0.687	-
Grammoplites suppositus	-	-	0.047
Stolephorus spp	-0.198	-	-
Soles	-	-	0.001
Unidentified fishes	0.280	0.924	0.303
Benthic crab	0.962	0.711	0.919
*Acetes indicus**	-	-	-
Oratosquilla nepa	0.675		0.647
Metapenaeus monoceros	-0.373	-	-
*Trachypenaeus spp**	-	-	-
Solenocera choprai	-	0.911	-
Penaeid prawns	-0.694	0.994	0.453
Hippa spp*	-	-	-
Loligo spp	0.049	-	-0.451
Shell pieces	-	-	0.687
Detritus*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.1.1. Variation in trophic level and diet breadth of *E. diacanthus* in relation to seasons

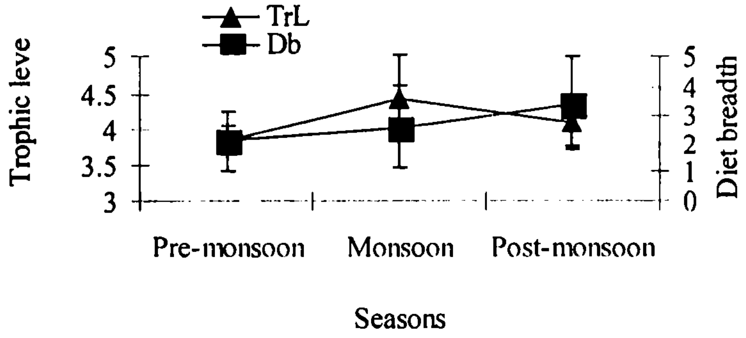


Fig. 4.1.2. Ontogenetic variation in trophic level and diet breadth of *E. diacanthus*

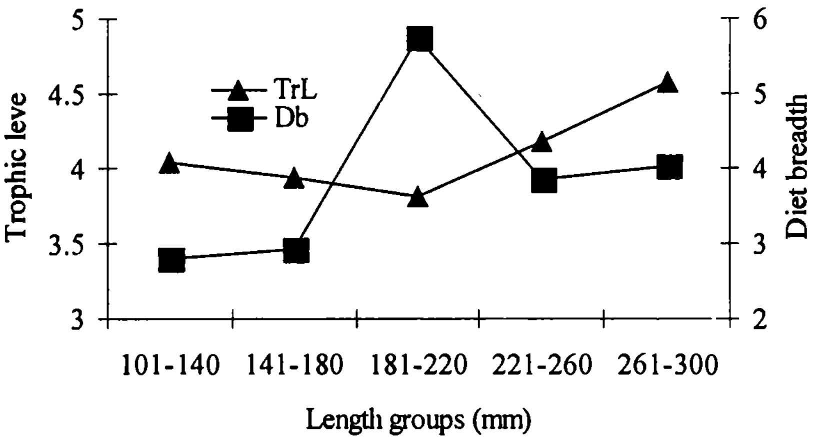


Fig.4.1. 3. Dendrogram based on %IRI values of different seasons for *E. diacanthus* using group average clustering

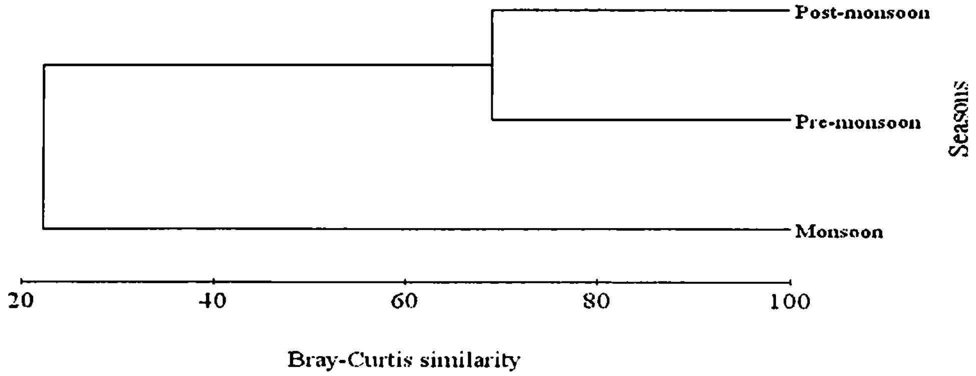


Fig.4.1. 6. Relationship between length of *E. diacanthus* and weight of *O. nepa* consumed

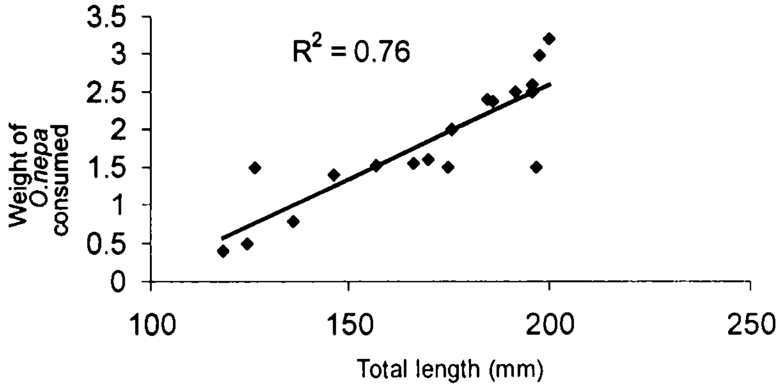
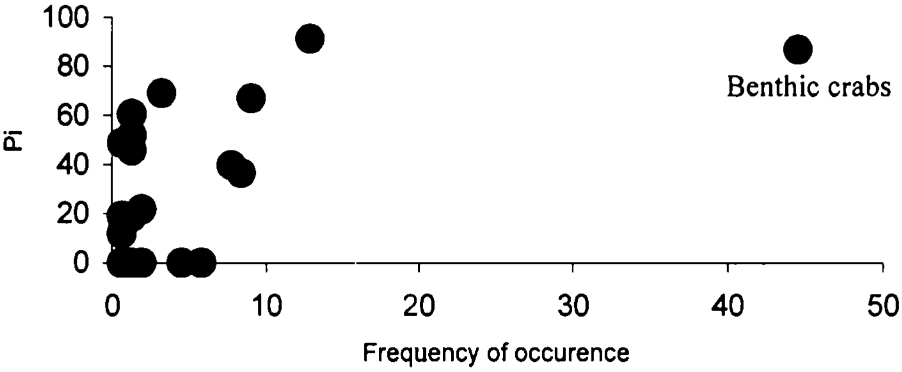


Fig. 4.1.7. Amundson plot for *E. diacanthus* showing prey specific abundance (Pi)



4. 2. *Grammoplites suppositus*

4.2.1. General diet composition

Out of 581 stomachs of the flathead, *G. suppositus* (total length: 143-280 mm) analysed, a total of 21 prey types were identified. Mean number and weight of prey per stomach were 1.78 and 0.766 g respectively. Crustaceans (%IRI= 86.9) and fishes (%IRI=12.9) were the most important food categories of *G. suppositus* (Table 4.2.1). Molluscs, sea urchins and detritus were insignificant in the diet. When considering the frequency of occurrence, penaeid prawns (28.3%), followed by benthic crabs (26.4%) and unidentified fishes (16.0%) were dominant. The most abundant prey by number was benthic crabs (27.9%) followed by *Acetes indicus* (23.2%) and *S. choprai* (16.2%). In terms of weight, the benthic crabs (20.0%) and *S. choprai* (19.7%) were the prominent prey of *G. suppositus*. Among the fishes, unidentified fishes (15.2%) and *Nemipterus mesoprion* (6.9%) were largely consumed.

Among the crustaceans, %IRI values for benthic crabs (39.6) and *S. choprai* (31.8) were higher. Penaeid prawns (8.1) and *A. indicus* (5.1) were the next in dominance among the crustaceans. Penaeid prawns such as *Metapenaeus* spp, *Trachypenaeus* spp and other crustaceans like *Hippa* spp and *Oratosquilla nepa* were also present. Among the fishes, unidentified fishes (11.8) were dominant followed by *N. mesoprion* (Plate 2*b*), *G. suppositus*, *Saurida* spp, *Trichiurus* spp, *Cynoglossus macrostomus*, *Stolephorus* spp and *Leiognathus bindus*.

4.2.2. Feeding intensity

Fishes with empty stomachs were high throughout the year. The highest percentage of empty stomach was observed during the pre-monsoon (60%) (Table 4.2.2). The proportion of fishes with active feeding condition was generally less though it showed an increasing trend from the monsoon to pre-monsoon seasons. There was no significant difference in the feeding intensity by seasons (χ^2 test, df= 6, p>0.001).

With increase in length, the incidence of empty stomach was reduced although its proportion was high in all the length groups. In general, the occurrence of active feeding was less in all the length groups (Table 4.2.3). Fishes with moderate feeding intensity was more in the larger length groups and the difference was significant (χ^2 test, df= 15, p<0.001) (Table 4.2.3). The main source of variation in feeding intensities came from empty, poor and moderately fed fishes. Among length groups, the main source of variation was from 191-215 mm group.

4.2.3. Seasonal variation in feeding

Prey shifting between crustacean and fish items was obvious in all the seasons. Crustaceans formed above 50% of total IRI in all the seasons. In the pre-monsoon season, fishes (45.6%) formed almost equal important diet as crustaceans (Table 4.2.4). Unidentified fishes (40.8%) followed by *S. choprai* (30.9%) and penaeid prawns (18.7%) formed a major portion of the diet in the pre-monsoon season. During the monsoon season, a shift was observed and the most preferred prey was *S. choprai* (53.1%); benthic crabs (38.4%) being the second in importance. Benthic crabs (44.4%) were the most important prey in the post-monsoon season followed by *A. indicus* (22.4%) and *S. choprai*. Penaeid prawns such as *Metapenaeus* spp, and *Trachypenaeus* spp were totally absent during the pre-monsoon season. Fishes such as *Trichiurus* spp, *C. macrostomus* and *Stolephorus* spp were found rarely in the post-monsoon season. Other fishes such as *G. suppositus, Saurida* spp and *L. bindus* were found sporadically. The least important prey was gastropods and sea urchins and they occurred in the monsoon and post-monsoon seasons. There were significant seasonal differences (χ^2 test, df= 6, p<0.001) in the number of major prey groups consumed (Table 4.2.5). Among the prey groups the source of variation mainly came from other crustaceans (occurrence of large number of *A. indicus* in the post-monsoon season) and fishes. Among seasons, the monsoon season caused the main source of variation.

4.2.4. Ontogenetic variation in feeding

The diet of *G. suppositus* of 141-165 mm length group comprised largely of unidentified fishes (%IRI= 46.8) and *C. macrostomus* (%IRI= 40.1) (Table 4.2.6). Fishes larger than 165 mm showed higher preference to crustaceans initially for *O. nepa* (166-190 mm) and later for *S. choprai* and benthic crabs. Cannibalism was found in 141-155 and 216-240 mm length groups. The preferred diets of fish of 216 to 240 mm were benthic crabs (%IRI= 52.0) followed by *S. choprai* (%IRI= 26.0) and penaeid prawns (%IRI= 8.5).

Consumption of benthic crabs and *S. choprai* increased above 166 mm length and a consequent decrease in fish groups in higher length groups was observed. In the length group 241-265 mm *S. choprai* (%IRI= 39.9) and benthic crabs (%IRI= 39.0) were dominant and fish groups were considerably reduced. Significant ontogenetic differences were found (χ^2 test, df= 20, $P<0.001$) in the number of major prey groups consumed (Table 4.2.7). Among prey groups the major source of variation came from other crustaceans (occurrence of large number of *A. indicus*) and fishes. Among length groups, the main source of variation was from 266-290 mm group.

4.2.5. Variation in diet breadth and trophic levels

In general, diet breadth was higher in monsoon period than in the other seasons (3.2 ± 0.26). There was marginal increase in the trophic level values from the monsoon to post-monsoon and pre-monsoon seasons (Fig 4.2.1).

The variation in diet breadth and trophic level among different length groups is shown in Fig 4.2.2. The diet breadth increased with increase in length until 191-215 mm length group fishes. Beyond this length the range of prey reduced. The mean trophic level was 3.78 ± 0.15 and it increased from 141-165 mm to a peak in 166-190 mm and thereafter showed a decreasing trend.

4.2.6. Diet similarities

Bray-Curtis similarity analysis grouped the seasons based on similarity (Fig 4.2.3). The highest similarity (58.9%) was observed between the monsoon and post-monsoon seasons when the flathead preferred crustaceans. The second highest similarity (51%) was found between the prey taxa of the monsoon and pre-monsoon seasons. Similarity analysis between different length groups showed that 216-240 and 241-265 mm had the highest similarities (Fig 4.2.4). These groups shared diets such as benthic crabs and prawns. The lowest similarity observed was between 141-165 and 166-190 mm length groups (10.8%).

4.2.7. Prey-predator relationships

The weight of benthic crabs consumed and the body length of *G. suppositus* was related and it was observed that larger flatheads consumed benthic larger crabs (Fig 4.2.5). Similarly, larger flatheads consumed larger prawns, *S. choprai* (45.5 ± 17.1mm). A distinct correlation was found between the total length of *S. choprai* and the body length of *G. suppositus* ($r^2 = 0.72$, n =17) (Fig 4.2.6).

4.2.8. Predator feeding strategies

The feeding strategy of *G. suppositus* was found by plotting prey-specific abundance against the frequency of occurrence (Fig 4.2.7). There were 21 different prey types represented by points. The analysis showed that *G. suppositus* has a specialised feeding strategy focussing on crustaceans especially benthic crabs and penaeid prawns, which they consume in very large quantities. Some individuals consume teleosts in small quantities but it constitutes only half the total weight of the stomach contents. Though the abundance of certain prey items was very high in the ecosystem, their occurrence was meagre in the diet. Most of the flatheads ate molluscs (squids, gastropods) and detritus in small quantities, while only some ate sea urchins.

4.2.9. Prey selection

The values of electivity index showed that *G. suppositus* had strong positive selection to certain prey types in different seasons (Table 4.2.8). Changes in catch proportion in different seasons were reflected in fish diets and prey selection. However, crustaceans were strongly selected in all the seasons. Among crustaceans, strong selection for benthic crabs and *S. choprai* was observed in all the seasons. Penaeid prawns were strongly selected in the pre-monsoon and post-monsoon seasons though it was completely avoided in the monsoon season. Among the fish groups, though *Saurida* spp formed good proportions in the fish catch, strong avoidance was observed for this group during the monsoon season. Moderate or poor selection was observed for *N. mesoprion, Trichiurus* spp, *G. suppositus* and other fishes although their species composition in the catch was high.

Table 4.2.1. Prey of *G. suppositus* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	%FO	%W	%N	IRI	%IRI
Fishes					
Nemipterus mesoprion	1.12	6.98	0.78	7.30	0.27
Grammoplites suppositus	0.74	0.72	0.39	0.70	0.03
Saurida spp	0.74	0.78	0.39	0.73	0.03
Trichiurus spp	1.12	1.99	0.59	2.42	0.09
Cynoglossus macrostomus	2.60	1.58	1.17	6.03	0.22
Stolephorus spp	0.37	0.09	0.20	0.09	0.00
Leiognathus bindus	1.12	1.06	0.78	1.73	0.06
Fish juveniles	2.97	1.41	3.52	12.34	0.46
Unidentified fishes	15.99	15.19	8.40	317.90	11.80
Crustaceans					
Metapenaeus spp	1.49	1.77	1.17	3.69	0.14
Trachypenaeus spp	2.97	3.66	1.76	13.58	0.50
Solenocera choprai	13.01	19.70	16.21	855.44	31.76
Penaeid prawns	28.25	11.70	8.20	218.38	8.11
Acetes indicus	6.32	2.55	23.24	137.47	5.10
Benthic crab	26.39	19.96	27.93	1065.87	39.57
Hippa spp	1.12	0.43	1.17	1.51	0.06
Oratosquilla nepa	5.20	7.18	3.52	46.94	1.74
Miscellanoeus items					
Loligo spp	0.74	1.54	0.59	1.33	0.05
Gastropods	0.00	0.01	0.00	0.00	0.00
Sea urchin	2.23	0.05	0.00	0.10	0.00
Detritus	4.09	1.67	0.00		0.00

Table 4.2.2. Feeding intensity (%) of *G. suppositus* in relation to season

Feeding intensity	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Active	8.9	2.8	7.4
Moderate	10.0	19.4	11.2
Poor	21.1	38.9	23.9
Empty	60.0	38.9	57.5

Table 4.2.3. Two way contingency table analysis of ontogenetic variation of feeding intensities of *G. suppositus*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each length group)

Feeding intensity	141-165	166-190	191-215	216-240	241-265	266-290	N_i	χ^2
Active	0	8	18	10	4	1	41.0	37.0
	(0.0)	(10.8)	(9.8)	(5.3)	(4.0)	(11.1)		
Moderate	1	8	17	30	14	2	72.0	11.3
	(3.7)	(10.8)	(9.3)	(15.9)	(14.1)	(22.2)		
Poor	8	19	47	46	34	2	156.0	39.7
	(29.6)	(25.7)	(25.7)	(24.3)	(34.3)	(22.2)		
Empty	18	39	101	103	47	4	312.0	96.2
	(66.7)	(52.7)	(55.2)	(54.5)	(47.5)	(44.4)		
N_j	27	74	183	189	99	9	581.0	
χ^2	4.5	1.7	169.4	3.1	4.3	1.1		184.2**

N_i, total numbers by species; N_j, total numbers by length groups;
**, $P < 0.001$, df= 15

Table 4.2.4. Seasonal variation in %IRI of prey of *G. suppositus*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Nemipterus mesoprion	3.42	0.00	0.00
Grammoplites suppositus	0.00	0.24	0.00
Saurida spp	0.14	0.03	0.00
Trichiurus spp	0.00	0.00	0.42
Cynoglossus macrostomus	0.16	0.00	0.53
Stolephorus spp	0.00	0.00	0.01
Leiognathus bindus	1.08	0.00	0.00
Fish juveniles	0.00	1.11	0.43
Unidentified fishes	40.81	5.67	1.43
Metapenaeus spp	0.00	0.23	0.20
Trachypenaeus spp	0.00	0.30	1.22
Solenocera choprai	30.91	53.11	12.41
Penaeid prawns	18.74	0.74	8.39
Acetes indicus	0.29	0.00	22.38
Benthic crab	3.68	38.36	44.43
Hippa spp	0.00	0.13	0.04
Oratosquilla nepa	0.00	0.00	7.83
Loligo spp	0.22	0.06	0.00
Gastropods	0.00	0.00	0.00
Sea urchin	0.00	0.01	0.00
Detritus	0.55	0.00	0.26

Table 4.2.5. Two way contigency table analysis of seasonal variation of five prey categories (values are number of prey groups observed in each seasons)

Prey groups	Seasons			N_i	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fish	31	27	25	83	50.3
Prawns	32	42	59	133	24.8
Crabs	11	38	63	112	13.4
Other crustaceans	5	2	205	212	94.1
Cephalopods	1	1	0	2	3.9
N_j	80	110	352	542	
χ^2	62.1	64.7	59.7		186.5**

N_i, total numbers by species; N_j, total numbers by season;
**, $P < 0.001$, df= 10

Table 4.2.6. Ontogenetic variation in %IRI of *G. suppositus*

Prey	Length groups (mm)					
	141-165	166-190	191-215	216-240	241-265	266-290
Nemipterus mesoprion	0.00	0.00	0.00	1.94	0.00	0.00
Grammoplites suppositus	3.94	0.00	0.00	0.07	0.00	0.00
Saurida spp	0.00	0.00	0.00	0.08	0.06	0.00
Trichiurus spp	0.00	2.78	0.12	0.00	0.00	0.00
Cynoglossus macrostomus	40.10	0.34	0.57	0.00	0.00	0.00
Stolephorus spp	0.00	0.28	0.00	0.00	0.00	0.00
Leiognathus bindus	0.00	0.00	0.35	0.00	0.08	0.00
Fish juveniles	0.00	0.00	0.05	0.20	3.60	0.00
Unidentified fishes	46.80	2.21	16.65	8.47	4.58	26.69
Metapenaeus spp	0.00	0.00	0.24	0.11	0.14	0.00
Trachypenaeus spp	0.00	0.00	1.44	0.13	0.74	0.00
Solenocera choprai	0.00	7.72	36.19	26.03	39.87	12.93
Penaeid prawns	0.00	4.85	4.10	8.47	9.83	21.09
Acetes indicus	0.00	0.00	7.44	1.88	2.06	39.29
Benthic crab	0.00	22.59	30.68	51.97	39.01	0.00
Hippa spp	0.00	0.00	0.00	0.47	0.00	0.00
Oratosquilla nepa	0.00	56.77	2.07	0.00	0.00	0.00
Loligo spp	0.00	1.38	0.00	0.05	0.00	0.00
Gastropods	0.00	0.00	0.00	0.00	0.00	0.00
Sea urchin	0.00	0.00	0.00	0.00	0.03	0.00
Detritus	9.16	1.08	0.10	0.13	0.00	0.00

Table 4.2.7. Two way contingency table analysis of ontogenetic variation in feeding with respect to five prey categories of *G. suppositus* (values are number of prey groups observed in each seasons)

Size groups	Length groups (mm)						N_i	χ^2
	141-165	166-190	191-215	216-240	241-265	266-290		
Fish	6	7	25	21	21	2	82	33.6
Prawns	0	9	45	45	37	4	140	13.6
Crabs	0	9	42	63	29		143	28.7
Other crustaceans	0	11	48	19	15	50	143	95.9
Cephalopods	0	2	0	1	0	0	3	16.1
N_j	6	38	160	149	102	56	511	
χ^2	31.4	14.7	1.4	24.0	11.3	105.0		187.9**

N_i, total numbers by species; N_j, total numbers by length groups;
**, $P < 0.001$, df= 20

Table 4.2.8. Seasonal electivity index of prey of *G. suppositus*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Nemipterus mesoprion	0.59	-	-
Grammoplites suppositus	-	0.18	-
Saurida spp	0.10	-0.84	-
Trichiurus spp	-	-	0.67
Cynoglossus macrostomus	0.47	-	-0.39
Stolephorus spp	-	-	-0.75
Leiognathus bindus	0.50	-	-
Fish juveniles	-	0.78	0.87
Unidentified fishes	0.88	0.33	0.46
Metapenaeus spp	-	-	1.16
Trachypenaeus spp	-	-	-
Solenocera choprai	0.86	0.77	0.68
Penaeid prawns	0.87	-	0.94
*Acetes indicus**	-	-	-
Benthic crab	0.95	0.97	0.95
Hippa spp*	-	-	-
Oratosquilla nepa	-	-	0.73
Loligo spp	-0.03	0.68	-
Gastropods	-	-0.44	-
Sea urchin*	-	-	-
Detritus*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.2.1. Seasonal variation in diet breadth and trophic level of *G. suppositus*

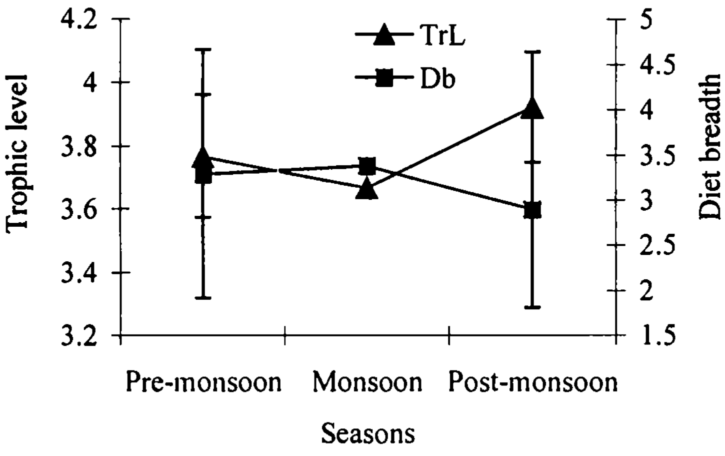


Fig. 4.2.2. Ontogenetic variation in diet breadth and trophic level of *G. suppositus*

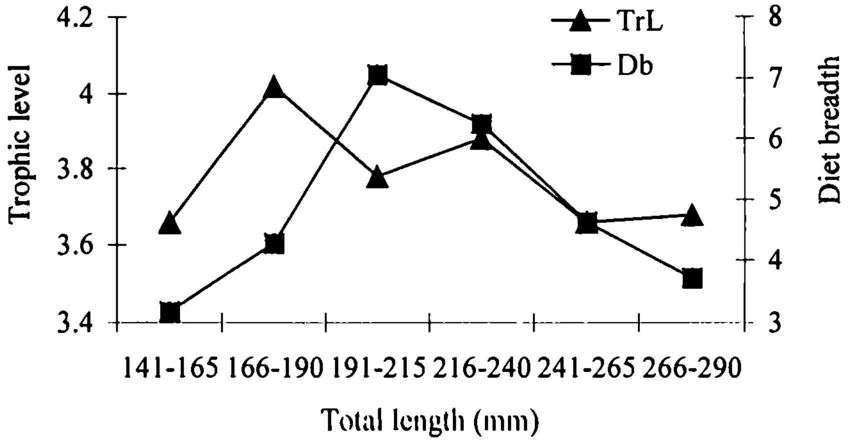


Fig. 4.2.3. Dendrogram of Bray-Curtis similarity of feeding among different seasons of *G. suppositus*

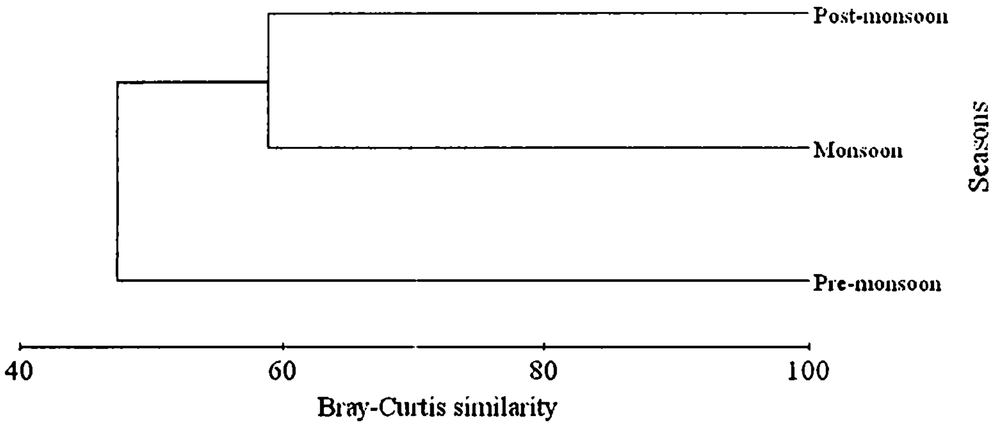


Fig. 4.2.4. Dendrogram of Bray-Curtis similarity of feeding among different length groups of *G. suppositus*

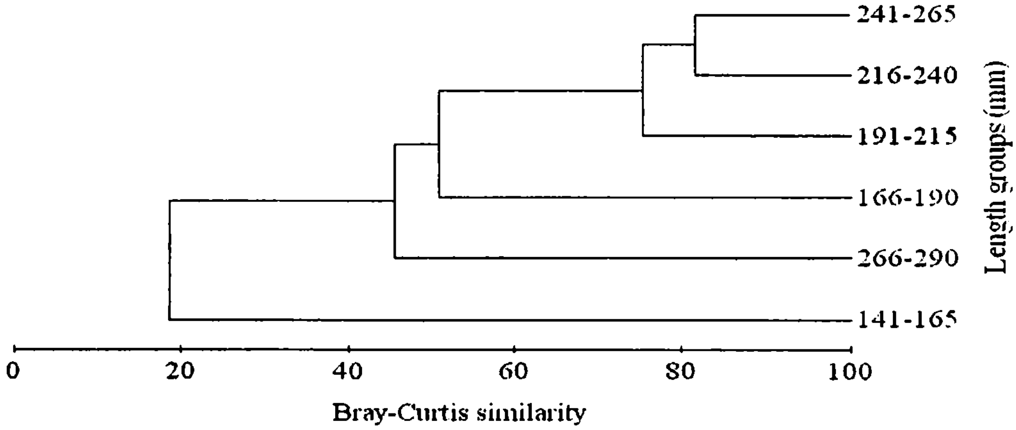


Fig. 4.2.5. Relationship between the weight of benthic crabs and the total length of *G. suppositus*

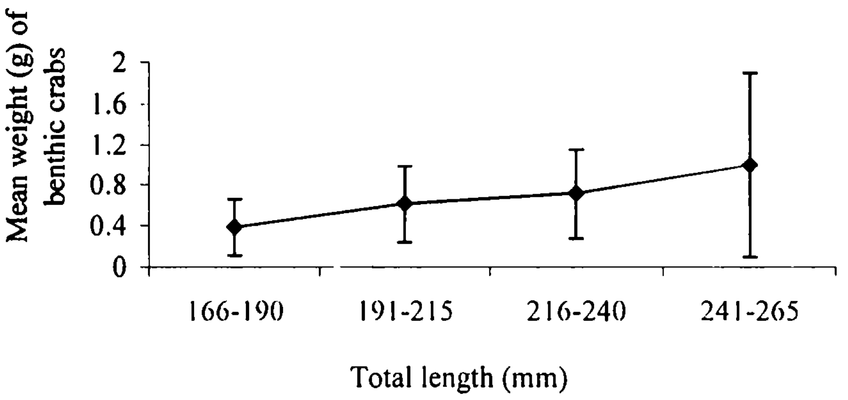


Fig. 4.2.6. Relationship between the total length of *S. choprai* and *G. suppositus*

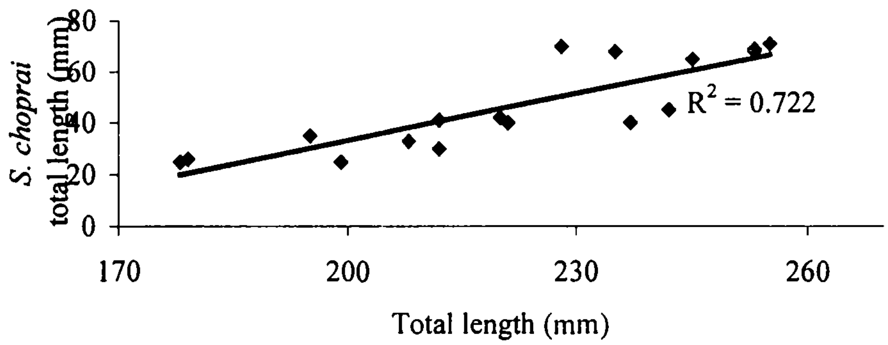
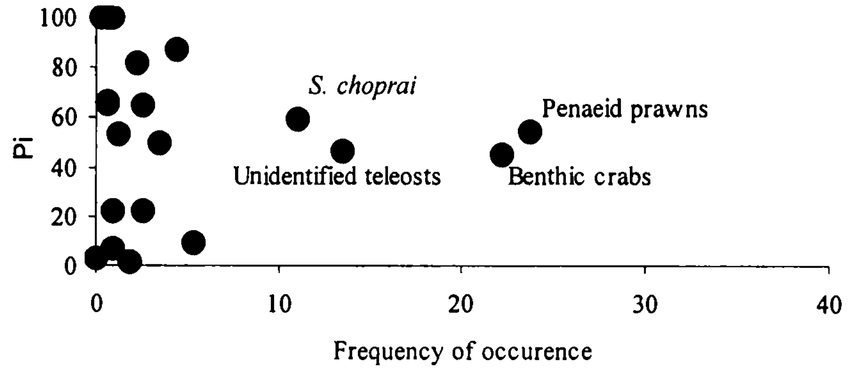


Fig. 4.2.7. Amundson plot for *G. suppositus* showing prey specific abundance (Pi)



4. 3. *Priacanthus hamrur*

4.3.1. General diet composition

The length of the bullseye, *P. hamrur* (n= 216) ranged from 150 to 228 mm in TL with a mean of 217 mm. A total of 16 different prey groups were identified from the stomach. After grouping the food items into four categories, it was found that the crustaceans formed the most important diet in number (97.0%), frequency of occurrence (62.3%), weight (57.3%) and IRI (84.5%) (Table 4.3.1). Cephalopods represented by *Loligo duvauceli* and polychaetes occurred rarely. *Acetes indicus* was the most important crustacean and the single dominant prey item out of all identified prey categories (%IRI=82.5). By weight (45.2%), frequency of occurrence (30.6%) and number (92.8%), *Acetes indicus* formed the most preferred food among the various items identified. Other crustaceans which occurred in minor quantities were the prawns such as *Solenocera choprai* (Plate 2g), penaeid prawns, benthic crabs, copepods, amphipods and crustacean larvae. Molluscs and detritus were the least preferred diet components.

Among various fish items identified, unidentified teleosts were more important (%IRI=7.1) and were present in 25.1 % of the stomach contents and comprised 13.4 % of the total weight of the food items. Other teleosts identified and found in minor quantities include *Saurida* spp, *Leiognathus* spp, *Cynoglossus* spp (Plate 2g) and *Stolephorus* spp. In case of detritus (%FO=26.8, %W=13.9), since numerical counts were not possible, IRI was calculated without including the number factor with the assumption that number will not make much distortion when other the two indices occurred in good quantities. Mean number and weight of prey was 26.16 and 1.22 g/stomach respectively.

4.3.2. Feeding intensity

Higher proportions of moderately and poorly fed fishes were observed in all the seasons. They constituted higher proportion in the pre- monsoon and post-monsoon seasons than in the monsoon season (Table 4.3.2). There was significant difference in the occurrence of various feeding condition (χ^2 test, df= 6, $p<0.001$) (Table 4.3.2). Among the seasons, the major variation came from the post monsoon season.

Ontogenetic increase in feeding activity was observed in the bullseye. Percentage of actively fed and moderately fed fishes increased with increase in the length of the fish (Table 4.3.3). As a result, fishes with empty stomach reduced in larger groups. Two way contingency analysis showed significant difference in feeding intensity among the different length groups (χ^2 test, df= 18, p<0.001) (Table 4.3.3). The main source of variation came from empty stomach and among the different length groups; 171-190 mm length group caused higher variation. Poorly fed fishes contributed higher proportions in all the seasons.

4.3.3. Seasonal variation in feeding

Crustaceans formed the major part of the diet in all the seasons. Bullseye primarily consumed *A. indicus* throughout the season in addition to the small crustaceans and teleosts (Table 4.3.4). Two way contingency analysis on the number of major prey categories showed that significant difference existed among the seasons (χ^2 test, df= 18, P<0.001, Table 4.3.5). The post-monsoon and pre-monsoon seasons were the main source of variation among the seasons and number of amphipods and copepods caused major variation among the prey categories. During the pre-monsoon and post-monsoon seasons, bullseye are monophagous to *A. indicus* that it alone formed more than 80% of total IRI, whereas, in the monsoon, detritus followed by amphipods were largely consumed. Unidentified fishes and *L. duvauceli* respectively constituted the second rank in the post-monsoon and pre-monsoon seasons.

4.3.4. Ontogenetic variation in feeding

Significant differences in diet were observed between the different lengths of *P. hamrur*. Overall, crustacean preys were relatively more important and fish preys were less important in the diet of all the length groups of bullseye (Table 4.3.6). The first two length groups <190 mm exclusively fed on detritus. However, in the 151-170 mm length group, benthic crabs (%IRI= 12.2) and *A. indicus* (%IRI= 6.9) formed the second and third preferred prey while in 171-190 mm, unidentified fishes (%IRI= 14.2) and *A. indicus* (%IRI= 10.1) contributed significantly to the diets. Significant difference in the number of major prey categories was found in length groups (χ^2 test, df= 18, P<0.001, Table 4.3.7). Among the length groups, fishes of 231-250 mm and 151-170 mm groups showed major variations. Polychaetes and copepods were the two major source of variation among prey categories. *A. indicus*, the most favorite prey category was present in all length groups except in 231-250 mm and its proportion was highest in larger fishes.

When *A. indicus* was absent in the diet of fish between 231-250 mm, the diet was comprised of *L. duvauceli* (%IRI=37.7), detritus (%IRI=29.1) and unidentified prawns (%IRI=21.8). Other crustaceans such as crabs, amphipods, copepods, and crustacean larvae and polychaetes were relatively important in fish <250 mm TL. Penaeid prawns including *S. choprai* were important in the diet of fish between 171-270 mm length groups. Detritus was an important part of diet in smaller fishes.

4.3.5. Variation in diet breadth and trophic levels

The diet breadth during the pre-monsoon and post-monsoon seasons was not similar (Fig 4.3.1). All prey types were recorded during the post–monsoon and diet breadth become higher at 2.71 ± 1.7. Significant amount of *A. indicus* reduced diet breadth to 2.33 ± 0.9 during the pre-monsoon season. Again, in the monsoon, very few prey types reduced diet breadth to 1.24. Fig 4.3.2 shows the ontogenetic changes in diet breadth. The highest diet breadth was found in the fishes between fish 191 and 210 mm (Db= 4.86) where prey diversity was greater and fishes consumed large proportions of teleost fishes and to a certain extent on larger crustaceans. Very low dietary breadth was observed in 271-290 mm length groups.

The value of trophic level had wide variation in different seasons. Consumption of large quantities of teleosts increased the trophic level to 3.54 ± 0.5 in the post-monsoon, whereas in the monsoon season, trophic level of fishes was very less owing to the complete lack of teleosts (Fig 4.3.1). Trophic level of each length group did not show much fluctuation even though juveniles had low trophic levels (Fig 4.3.2). Fish above 190 mm had trophic level above 3.5 with peak in the 191-210 mm group. Higher trophic level in all the length groups above 190 mm was due to the larger proportions of teleost fishes and cephalopods which were rare or absent in fish below 190 mm groups. The mean trophic level of *P. hamrur* is 3.40 ± 0.4.

4.3.6. Diet similarities

Bray-Curtis similarity based on %IRI of different prey items classified season into similar groups (Fig 4.3.3). The dendrogram showed that only the pre-monsoon and post-monsoon seasons had significant diet similarities (80.1%), mainly because of the preference for *A. indicus* during these seasons. Ontogenetically, similarity between the larger length groups 251-270 and 271-290 mm was very high (88%) followed by 211-230 and 251-270 mm (83%) and 191-210 and 211-230 mm (83%) length groups (Fig 4.3.4). *A. indicus* formed most important prey for these groups. Hence fishes, which fed on *A. indicus*, formed separate groups in the dendrogram.

4.3.7. Prey- predator relationships

The principal prey *A. indicus* had a direct positive relation to the length of the predator, *P. hamrur*. Most of the young ones of *P. hamrur* fed on small sized *A. indicus* (Fig 4.3.5). Significant difference in length of *A. indicus* with ontogenetic change in predator length was observed (ANOVA, $p<0.05$). There was slight increase in the mean weight of *A. indicus* consumed to the increasing length of predator (Fig 4.3.6). Relationship between the mean number of *A. indicus* and length of *P. hamrur* was positive ($r^2 = 0.6$) (Fig 4.3.7). However, ANOVA showed that there is no significant difference in both number and weight of *A. indicus* with increase in the length of fish ($P>0.05$).

4.3.8. Predator feeding strategy

Fig 4.3.8 shows the prey-specific abundance plot for *P. hamrur*. It showed that *P. hamrur* had specialized feeding strategy wherein it was specializing on individual prey types. As a result, these fish showed a high degree of prey diversity between different length groups. The important diet included *Acetes indicus*, unidentified fishes, penaeid prawns, *L. duvauceli* and detritus. Bullseye specialize at least on one of these during different seasons as well as during stages of ontogenetic growth. As a result, the bullseye showed a specialized feeding strategy.

Table 4.3.1. Prey of *P. hamrur* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	**%FO**	**%W**	**%N**	**IRI**	**%IRI**
Fishes					
Saurida spp	0.55	2.97	0.02	1.64	0.03
Leiognathus spp	1.64	1.82	0.15	3.24	0.06
Cynoglossus spp	0.55	0.47	0.02	0.27	0.01
Stolephorus spp	1.09	3.81	0.04	4.23	0.08
Unidentified fishes	25.14	13.40	0.99	362.92	7.08
Crustaceans					
Solenocera choprai	2.19	3.48	0.17	8.01	0.16
Penaeid prawns	10.38	5.69	0.41	60.21	1.17
Benthic crabs	1.64	2.60	0.06	4.37	0.09
Acetes indicus	30.60	45.16	92.75	4224.80	82.52
Amphipods	8.20	0.24	1.83	16.98	0.33
Copepods	6.01	0.02	1.38	8.42	0.16
Crustacean larvae	3.28	0.10	0.39	1.61	0.03
Cephalopods					
Loligo duvauceli	6.56	6.21	0.26	42.54	0.83
Polychaetes	5.46	0.14	1.51	9.03	0.18
Detritus	26.78	13.89	0.00	372.98	7.27

Table 4.3.2. Two way contigency table analysis of seasonal variation of feeding intensity of *P. hamrur*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each season)

Feeding intensity	Season			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Active	9	0	31	31	14.4
	(10.6)	(0.0)	(29.2)		
Moderate	41	1	37	38	10.9
	(48.2)	(3.8)	(34.9)		
Poor	31	3	30	33	4.3
	(36.5)	(11.5)	(28.3)		
Empty	4	22	8	30	89.9
	(4.7)	(84.6)	(7.5)		
N_j	85	26	106	132	
c^2	14.0	94.1	11.3		**119.4****

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df = 6

Table 4.3.3. Two way contigency table analysis of ontogenetic variation of feeding intensity of *P. hamrur*. Values are number of stomachs observed in each length groups

Feeding intensity	Length groups (mm)							N_j	χ^2
	151-170	171-190	191-210	211-230	231-250	251-270	271-290		
Active		4	5	15	10	6	1	41	4.8
	0.0	18.2	14.3	21.1	21.7	28.6	20.0		
Moderate	3	1	13	30	17	13	2	79	11.9
	18.8	4.5	37.1	42.3	37.0	61.9	40.0		
Poor	8	6	11	20	16	2	1	64	5.8
	50.0	27.3	31.4	28.2	34.8	9.5	20.0		
Empty	5	11	6	6	3		1	32	28.7
	31.3	50.0	17.1	8.5	6.5	0.0	20.0		
N_i	16	22	35	71	46	21	5	216	
χ^2	9.6	24.6	0.6	2.8	2.7	10.7	0.3		**51.2****

N_i, total numbers by species; N_j, total numbers by length groups
**, $P < 0.001$, df = 18

Table 4.3.4. Seasonal variation in %IRI of different prey types of *P. hamrur*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Saurida spp	0.00	0.00	0.07
Leiognathus spp	0.08	0.00	0.02
Cynoglossus spp	0.00	0.00	0.01
Stolephorus spp	0.00	0.00	0.20
Unidentified fishes	1.92	0.00	10.89
Solenocera choprai	0.00	0.00	0.36
Penaeid prawns	0.93	0.91	0.61
Benthic crabs	0.00	0.00	0.71
Acetes indicus	89.26	0.00	83.24
Amphipods	0.12	27.74	0.16
Copepods	0.07	11.54	0.08
Crustacean larvae	0.01	0.00	0.03
Loligo duvauceli	2.37	0.00	0.01
Polychaetes	0.09	1.93	0.11
Detritus	5.15	57.88	3.50

Table 4.3.5. Two way contigency table analysis of the seasonal variation of major prey categories of *P. hamrur*. (Values are number of stomachs observed in each seasons)

Prey groups	Season			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fish	13		54	67	18.8
A. indicus	2303		2782	5085	31.7
Amphipods	26	17	42	85	519.6
Copepods	24	12	28	64	341.6
Other crustaceans	70	1	33	104	21.3
Cephalopods	11		1	12	10.5
Polychaetes	29	4	37	70	29.6
N_j	2476	34	2977	5487	
χ^2	32.0	916.2	24.8		973.1**

N_i, total numbers by species; N_j, total numbers by season; **, $P < 0.001$, df = 14

Table 4.3.6. Ontogenetic variation in %IRI of different prey types of *P. hamrur*

Prey	Length groups (mm)						
	151-170	171-190	191-210	211-230	231-250	251-270	271-290
Saurida spp	0.00	0.00	1.02	0.00	0.00	0.00	0.00
Leiognathus spp	0.00	0.00	0.00	0.12	1.04	0.00	0.00
Cynoglossus spp	0.00	0.00	0.16	0.00	0.00	0.00	0.00
Stolephorus spp	0.00	0.00	0.00	0.08	0.00	0.48	0.00
Unidentified fishes	0.00	14.24	11.15	5.47	8.24	2.14	1.15
Solenocera choprai	0.00	0.00	0.37	0.14	1.66	0.00	0.00
Penaeid prawns	0.00	0.09	3.08	0.34	22.09	0.00	0.00
Benthic crabs	12.21	0.00	0.00	0.03	0.00	0.24	0.00
Acetes indicus	6.98	10.11	81.41	90.51	0.00	96.27	98.85
Amphipods	0.68	0.45	0.02	0.29	0.16	0.00	0.00
Copepods	0.41	0.03	0.00	0.09	0.05	0.00	0.00
Crustacean larvae	1.23	0.10	0.01	0.01	0.00	0.00	0.00
Loligo duvauceli	0.00	0.00	0.27	0.13	37.68	0.11	0.00
Polychaetes	2.97	0.74	0.03	0.09	0.00	0.00	0.00
Detritus	75.51	74.24	2.48	2.71	29.08	0.77	0.00

Table 4.3.7. Two way contingency table analysis of the ontogenetic variation of prey categories of *P. hamrur*. Values are number of stomachs observed in each length groups

Prey groups	Length groups (mm)							N_j	χ^2
	151-170	171-190	191-210	211-230	231-250	251-270	271-290		
Fish	0	3	13	24	10	6	1	4300	197.1
A. indicus	12	25	572	2220	0	1104	367	85	91.5
Amphipods	6	8	14	51	6	0	0	64	132.7
Copepods	9	9	4	28	14	0	0	48	515.7
Other crustaceans	7	4	12	17	6	2	0	12	189.5
Cephalopods	0	0	2	4	5	1	0	70	229.0
Polychaetes	16	16	12	26	0	0	0	4636	564.0
N_j	50	65	629	2370	41	1113	368	1919.5	
χ^2	543.5	385.2	12.2	8.8	871.9	71.0	26.8		1919.5

N_i, total numbers by species; N_j, total numbers by length groups;**, $P < 0.001$, df = 36

Fig.4.3.1. Seasonal variation in diet breadth and trophic level of *P. hamrur*

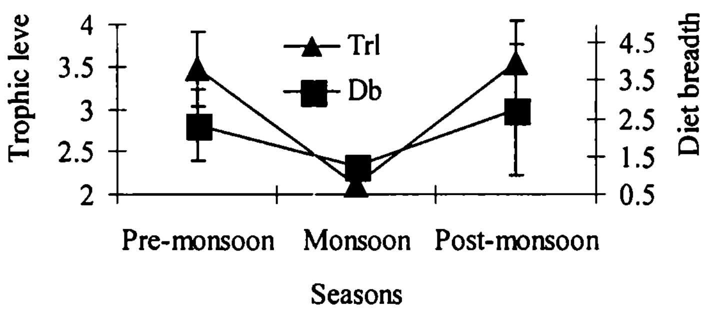


Fig. 4.3.2. Ontogenetic variation in trophic level and dietbreadth of *P. hamrur*

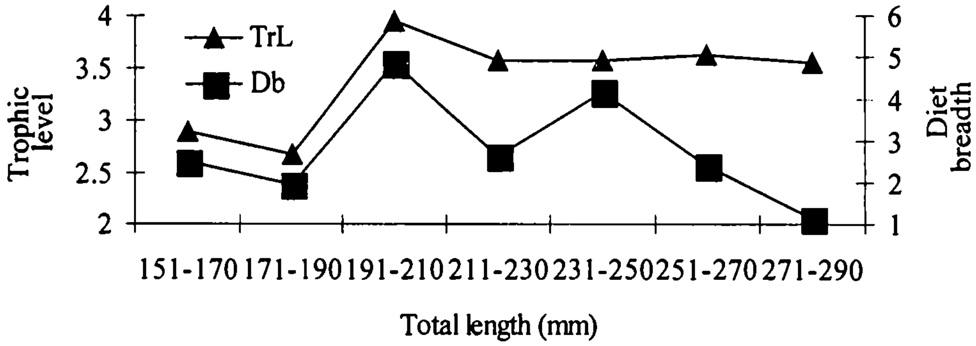


Fig.4.3.3. Dendrogram based on %IRI values of different seasons of *P. hamrur* using group average clustering

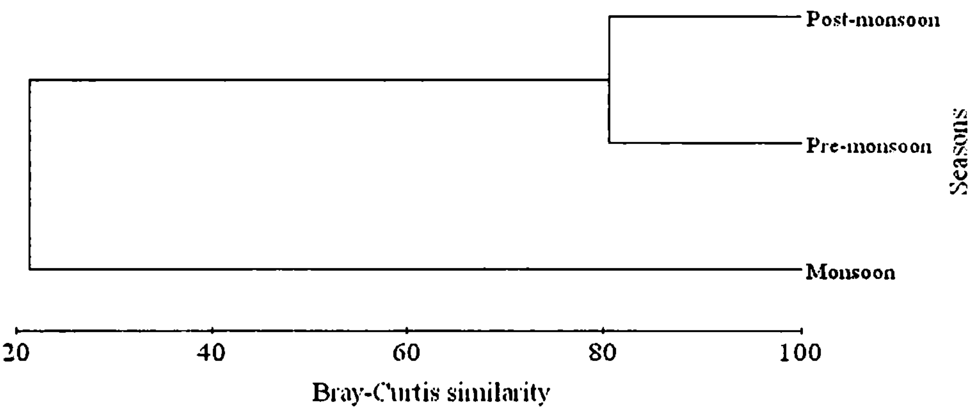


Fig. 4.3.4. Dendrogram based on %IRI values of different length groups of *P. hamrur* using group average clustering

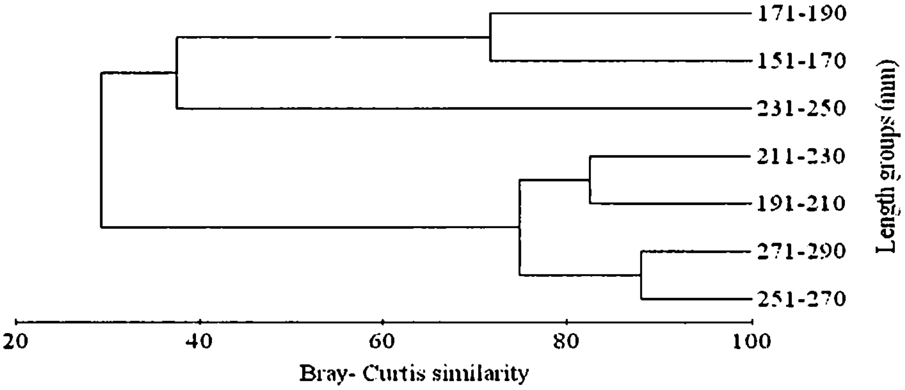


Fig.4.3.5. Relationship between the mean length of *A. indicus* and mean length of *P. hamrur*

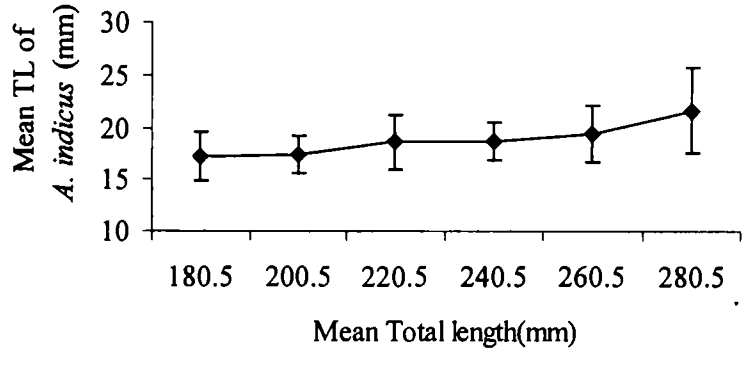


Fig. 4.3.6. Relationship between the mean weight of *A. indicus* and the mean total length of *P. hamrur*

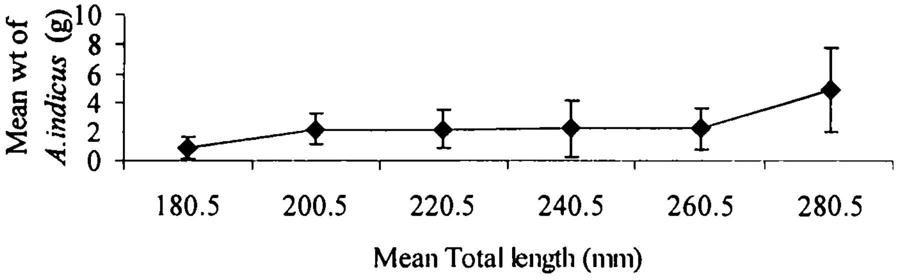


Fig.4.3.7. Relationship between the mean number of *A. indicus* and the mean length of *P. hamrur*

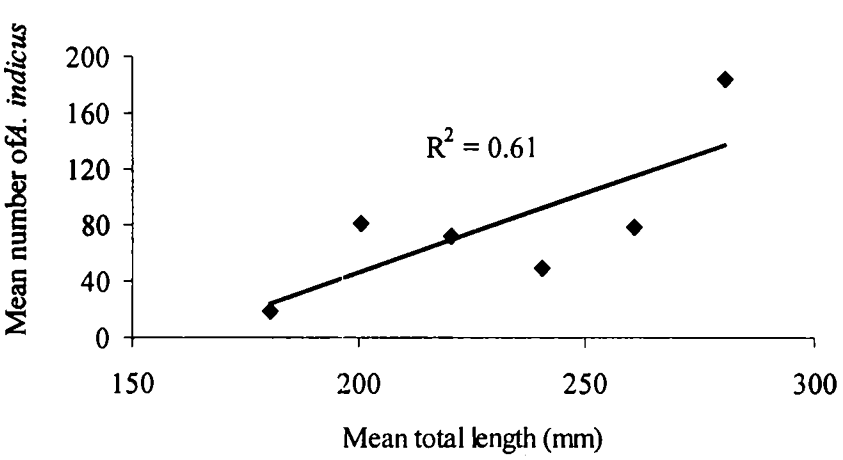
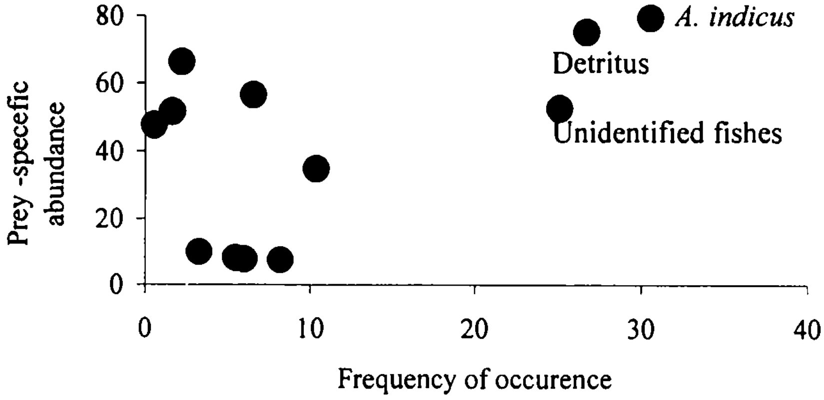


Fig. 4.3.8. Amundson plot for *P. hamrur* showing prey-specific abundance (Pi)



4. 4. *Johnieops sina*

4.4.1. General diet composition

Fishes, crustaceans, molluscs, foraminiferans, diatoms and detritus formed constituents of the diet of *J. sina*. Out of 24 prey components identified, 13 were crustaceans. Crustaceans (%IRI=79.0) were the most important and highly preferred food followed by fishes (%IRI=15.0) (Table 4.4.1). Polychaetes, foraminiferans and diatoms were the least ranked food items. *Acetes indicus* (%IRI=42.1), *Oratosquilla nepa* (%IRI=23.9) and unidentified fishes (%IRI=8.7) were the highly preferred prey component in the diet of *J. sina*. In abundance, out of 1041 prey enumerated, *Acetes indicus* (21.8%) followed by cycloid scales (19.4%) and copepods (16.0%) were most abundant in the stomach. The weight of prey consumed varied in between 0.0001g and 2.656g with a mean of 0.176g. By weight, the important prey consumed were *O. nepa* (43.7%), *A. indicus* (21.2%), unidentified fishes (8.7%), *Parapenaeopsis stylifera* (8.0%) and detritus (5.3%).

When considering the frequency of occurrence, detritus (26.0%), *A. indicus* (24.5%), unidentified fishes (20.5%) and *O. nepa* (16%) were the items frequently occurred in the diet. Cycloid scales (%IRI=5.2) formed the important fish item identified although *Bregmaceros* spp (Plate 2*d*) and *Stolephorus* spp occurred in less quantity. Prawn species such as *Metapenaeus monoceros, Solenocera choprai* were least in occurrence. Crabs, *Lucifer* spp, amphipods, mysids, ostracods, crustacean appendages and crustacean larvae were the minor crustacean items in the diet.

4.4.2. Feeding Intensity

Fishes with empty stomach were dominant throughout the year. Their proportion decreased from the pre-monsoon (66%) to the post-monsoon (54%). Actively fed fishes were rare in samples but relatively higher proportion was found only in the post-monsoon season (Table 4.4.2). There was no significant difference in the number of fish with different feeding conditions (χ^2 test, df= 6, P>0.001).

Occurrence of empty stomachs was high in smaller length groups. It was observed that active feeding gradually increased with increase in length (Table 4.4.3), moderately fed fishes were almost homogenously distributed in all length groups except in length >161mm where it was high. Poorly fed fish was found in all length groups with higher proportions and its peak were in 111-120 mm group.

4.4.3. Seasonal variations in feeding

Seasonal variation of the food items in terms of percentage IRI is given in the Table 4.4.4. The diet of *J. sina* during the pre-monsoon season was characterized by the large proportion of crustaceans especially, crustaceans appendages (%IRI= 24.0) and *A. indicus* (%IRI= 20.1). Similarly, largest proportion of detritus was observed in the pre-monsoon season. During the monsoon, 61.0% of IRI was fishes with the dominance of unidentified fishes and cycloid scales. Copepods and detritus also formed significant proportion in the monsoon season. *J. sina,* during the post-monsoon season, fed exclusively on crustaceans (%IRI= 98.0) and *O. nepa* and *A. indicus* was responsible for this large proportion. There were significant seasonal differences (χ^2 test, df= 8, P<0.001) in the number of major prey groups consumed (Table 4.4.5). Among the prey groups, variation mainly came from *A. indicus*. Among the seasons, the monsoon and post-monsoon seasons were the source of variation. Next to the monsoon, fish items were important in the pre-monsoon than the post-monsoon season. Prey groups such as crustacean larvae, bivalves, gastropods, polychaetes and diatoms were important only in the pre-monsoon season.

4.4.4. Ontogenetic variations in feeding

Analysis of ontogenetic variation or shift in feeding according to length groups showed that larger sized crustaceans were dominant in larger fishes and small sized crustaceans were observed in smaller fishes (Table 4.4.6). Likewise, *A. indicus* was fed upon only in length above 111 mm and below 160 mm. Detritus (%IRI=53.9) and copepods (%IRI=22.4) were the principal food of juveniles of 101-110 mm groups and their proportion gradually reduced with increase in length. The identified fish items such as *Bregmaceros* spp and *Stolephorus* spp were observed in stomachs of <150 mm groups. Smaller crustaceans such as amphipods, ostracods, mysids, crustacean larvae, crustacean appendages and molluscs such as bivalves and gastropods and foraminiferans and polychaetes and diatoms were important only in length between 101-110 mm and 151-160 mm groups, whereas fish above 160 mm fed on larger crustaceans such as *O. nepa* and *P. stylifera*. Among the fish groups, unidentified fishes were observed in high proportion in all length groups except in 171-180 mm. Significant ontogenetic differences were found (χ^2 test, df= 28, P<0.001) in the number of major prey groups consumed (Table 4.4.7). Among the prey groups the variation came from *A. indicus* and fishes.

4.4.5. Variation in diet breadth and trophic levels

Overall, diet breadth showed changes in different seasons. Mean diet breadth was highest in the pre-monsoon (3.4 ± 0.5) due to the proportion of large number of prey types to the total diet (Fig 4.4.1). A narrow spectrum of diet with less number of prey reduced diet breadth in the post-monsoon (2.4 ± 1.4) as well as in the monsoon (2.9 ± 1.2). Seasonally, highest value of trophic level was observed in the post-monsoon (3.8 ± 0.1) followed by the monsoon (3.7 ± 0.8) and pre-monsoon (3.5 ± 0.7) seasons.

Ontogenetically, diet breadth decreased gradually as the fish grew. Smaller individuals had wide variety of stomach contents composed of different fish and crustacean items (Fig 4.4.2). However, in the larger fishes diet was limited to only certain fish items. As against diet breadth, trophic level observed an increasing trend with increasing length. This was mainly due to avoidance of crustaceans with low trophic level and preference to fish items. Trophic levels ranged from 2.8 in 111-120 mm to 3.9 in 171-180 mm length groups. Fishes >120 mm showed higher trophic level (>3.5).

4.4.6. Diet similarities

Bray-Curtis similarity cluster analysis showed that highest similarity in diet was observed between the pre-monsoon and post-monsoon seasons (41.7%) (Fig 4.4.3). Due to dissimilar prey composition, fishes during the monsoon and post-monsoon seasons had very low similarity in the dendrogram (28.0%). In *J. sina*, certain length groups showed higher similarity with other length groups. Among the length groups, highest similarity was observed between 121-130 and 131-140 mm length groups (71 %) followed by 121-140 and 151-160 mm (69%) and 131-140 and 141-150 mm (67%) length groups (Fig 4.4.4).

4.4.7. Prey-predator relationships

The proportion of some prey items in the diet of *J. sina* had a direct relation to its length. Fig 4.4.5 shows the increasing proportion of the number of copepods in relation to the length of *J. sina*. Similar trend was also observed in the consumption of *A. indicus*, the proportion of which was higher in larger specimens (Fig 4.4.6).

4.4.8. Feeding Strategy

Fig 4.4.7 shows the Amundson plot for 24 prey types when prey-specific abundance was plotted against the frequency of occurrence. It shows that *J. sina* has a heterogeneous diet and specialized feeding strategy, focusing on certain prey types. *J. sina* frequently fed on copepods, *O. nepa*, unidentified fishes, *A. indicus* and detritus.

Table 4.4.1. Prey of *J. sina* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	%FO	%W	%N	IRI	%IRI
Fishes					
Bregmaceros spp	4	3.95	1.25	13.20	0.72
Stolephorus spp	1	2.01	0.58	1.64	0.09
Scales (ctenoid)	3.5	0.04	2.59	5.84	0.32
Scales (cycloid)	7.5	0.36	19.40	94.09	5.16
Unidentified fishes	20.5	8.70	3.55	159.55	8.74
Crustaceans					
Metapenaeus monoceros	0.5	0.08	0.10	0.06	0.00
Solenocera choprai	1.5	2.74	0.29	2.88	0.16
Parapenaeopsis stylifera	6	8.01	0.48	32.36	1.77
Crabs	1.5	1.30	0.38	1.60	0.09
Oratosquilla nepa	16	43.66	5.76	768.81	23.95
Acetes indicus	24.5	21.21	21.81	436.99	42.13
Lucifer spp	1	0.21	1.15	0.86	0.05
Copepods	15.5	0.61	16.04	163.84	8.98
Amphipods	2.5	0.02	2.40	3.84	0.21
Mysids	3	0.43	0.96	2.64	0.14
Ostracods	5	0.04	2.02	6.53	0.36
Crustacean appendages	5.5	0.75	5.09	20.40	1.12
Crustacean larvae	1	0.04	0.29	0.21	0.01
Molluscs					
Bivalves	1.5	0.25	1.92	2.07	0.11
Gastropods	2	0.12	3.46	4.50	0.25
Polychaete worms	2.5	0.08	3.27	5.37	0.29
Foraminiferans	4	0.14	2.31	6.20	0.34
Diatoms	1.5	0.00	4.90	4.67	0.26
Detritus	26	5.26	0.00	86.77	4.75

Table 4.4.2. Feeding intensity (%) of *J. sina* in relation to season

Feeding intensity	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Active	1.2	2.7	8.8
Moderate	7.1	7.4	12.4
Poor	25.9	31.9	25.3
Empty	65.9	58.0	53.6

Table 4.4.3. Feeding intensity (%) of *J. sina* in relation to length groups

Feeding intensity	Length groups (mm)							
	101-110	111-120	121-130	131-140	141-150	151-160	161-170	171-180
Active	0	1.4	3.3	5.8	7.3	8.0	28.6	16.7
Moderate	13.0	8.6	6.6	5.8	14.6	8.0	28.6	33.3
Poor	21.7	37.1	30.3	25.0	26.0	24.0	14.3	33.3
Empty	65.2	52.9	59.8	63.3	52.1	60.0	28.6	16.7

Table 4.4.4. Seasonal variation in %IRI of *J. sina*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Bregmaceros spp	0.40	0.17	0.42
Stolephorus spp	0.00	0.20	0.05
Scales (ctenoid)	0.03	0.00	0.00
Scales (cycloid)	6.81	18.58	0.39
Unidentified fishes	6.07	42.35	0.40
Metapenaeus monoceros	0.00	0.00	0.01
Solenocera choprai	0.00	0.06	0.15
Parapenaeopsis stylifera	0.13	3.10	0.16
Crabs	0.33	0.00	0.07
Oratosquilla nepa	2.53	0.98	51.71
Acetes indicus	20.09	0.00	44.46
Lucifer spp	0.95	0.00	0.00
Copepods	1.33	21.59	1.24
Amphipods	0.09	0.05	0.24
Mysids	0.07	0.35	0.05
Ostracods	0.00	1.33	0.01
Crustacean appendages	23.99	0.00	0.00
Crustacean larvae	0.24	0.00	0.00
Bivalves	2.39	0.00	0.00
Gastropods	4.34	0.00	0.00
Polychaete worms	5.02	0.00	0.00
Foraminiferans	0.29	0.22	0.15
Diatoms	6.34	0.00	0.00
Detritus	18.54	11.02	0.49

Table 4.4.5. Two-way contingency table analysis of seasonal variation of five prey categories of *J.sina.* Values are number of prey groups observed in each seasons

Prey groups	Seasons			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	50	175	57	282	85.3
Prawns	1	7	7	15	1.4
Oratosquilla nepa	7	2	52	61	42.1
Acetes indicus	19	0	213	232	210.8
Other crustaceans	79	144	68	291	56.8
N_i	156	328	397	881	
χ^2	28.9	164.0	203.4		**396.3****

N_i, total numbers by species; N_j, total numbers by season
**, $P < 0.001$, df= 8

Table 4.4.6. Ontogenetic variation in %IRI of prey of *J. sina*

Prey	Length groups (mm)							
	101-110	111-120	121-130	131-140	141-150	151-160	161-170	171-180
Bregmaceros spp	0.00	3.73	0.00	1.11	1.04	0.00	0.00	0.00
Stolephorus spp	0.00	0.00	0.00	0.44	0.15	0.00	0.00	0.00
Scales (ctenoid)	0.00	0.33	1.40	0.12	0.02	0.30	0.00	0.00
Scales (cycloid)	5.45	0.76	13.65	4.60	2.20	0.00	0.00	43.90
Unidentified fishes	0.96	25.02	16.74	8.55	1.17	1.58	4.02	0.00
Metapenaeus monoceros	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Solenocera choprai	0.00	0.00	0.00	1.32	0.07	0.00	0.00	0.00
Parapenaeopsis stylifera	6.88	0.78	0.76	1.30	0.37	0.00	42.06	0.00
Crabs	0.00	0.00	0.00	0.05	0.10	0.00	0.00	13.32
Oratosquilla nepa	0.00	0.00	37.42	30.22	69.50	25.44	53.49	42.78
Acetes indicus	0.00	2.05	17.67	39.83	15.61	56.74	0.00	0.00
Lucifer spp	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00
Copepods	22.40	37.82	4.75	1.31	4.68	10.68	0.00	0.00
Amphipods	0.00	0.91	0.78	0.15	0.00	0.00	0.00	0.00
Mysids	0.00	2.28	0.09	0.04	0.06	0.00	0.00	0.00
Ostracods	0.39	3.57	0.14	0.07	0.00	0.45	0.00	0.00
Crustacean appendages	0.00	0.44	0.95	3.45	0.68	0.00	0.00	0.00
Crustacean larvae	0.00	0.18	0.00	0.00	0.02	0.00	0.00	0.00
Bivalves	5.92	0.00	0.00	0.17	0.00	0.92	0.00	0.00
Gastropods	0.00	0.00	0.15	0.00	2.16	0.00	0.00	0.00
Polychaete worms	2.89	0.17	0.47	0.05	0.00	1.52	0.00	0.00
Foraminiferans	1.25	1.38	0.00	0.07	0.39	0.30	0.00	0.00
Diatoms	0.00	0.00	0.00	3.71	0.00	0.00	0.00	0.00
Detritus	53.87	20.58	5.04	2.73	1.75	2.06	0.43	0.00

Table 4.4.7. Two-way contingency table analysis of the ontogenetic variation of different prey groups of *J. sina*. (Values are number of stomachs observed in length groups)

Prey groups	Length groups (mm)								N_j	χ^2
	101-110	111-120	121-130	131-140	141-150	151-160	161-170	171-180		
Fishes	15	33	103	69	41	3	1	20	285	82.7
Prawns	0	0	3	5	4	0	2	0	14	43.7
Oratosquilla nepa	1	2	10	14	26	5	3	2	63	40.0
Acetes indicus	0	5	27	72	51	72	0	0	227	124.6
Other crustaceans	19	79	53	66	46	27	0	0	290	60.9
N_j	35	119	196	226	168	107	6	22	879	
χ^2	16.5	69.5	38.8	5.3	23.1	104.8	57.3	36.6		**351.8****

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df= 28

Fig. 4.4.1. Seasonal variation in trophic level and diet breadth of *J. sina*

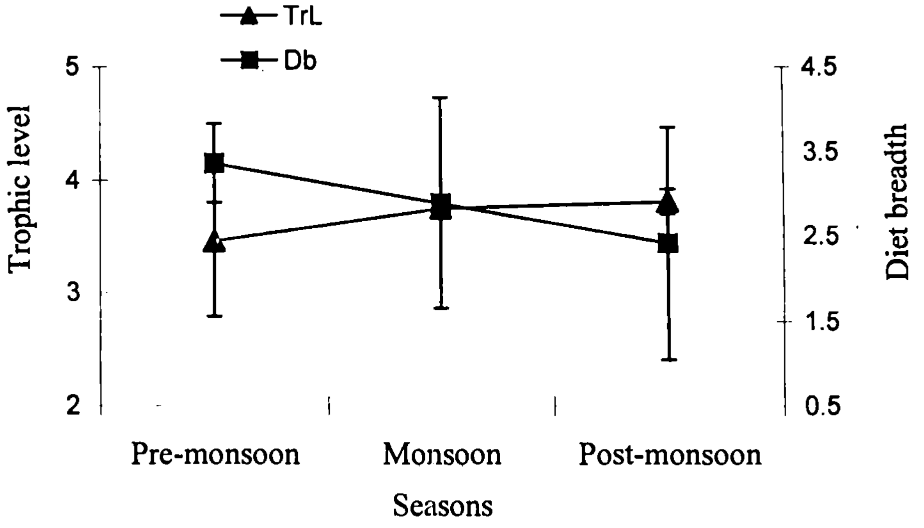


Fig. 4.4.2. Ontogenic variations in diet breadth and trophic level of *J. sina*

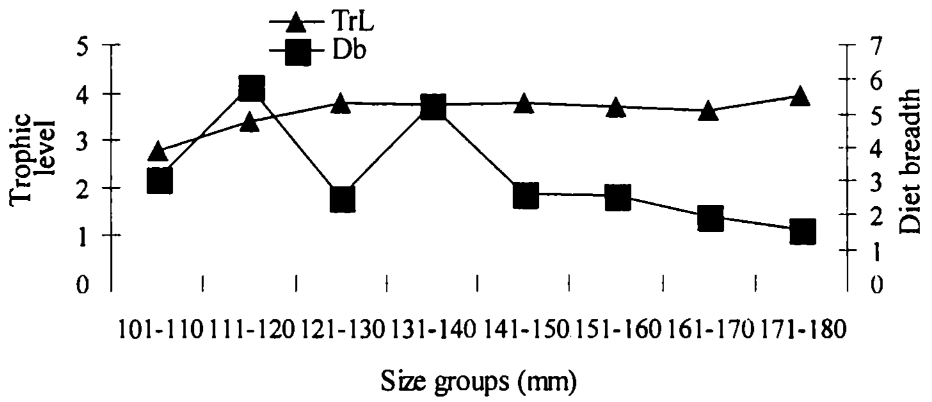


Fig. 4.4.3. Dendrogram based on %IRI values of different seasons of *J. sina* using group average clustering

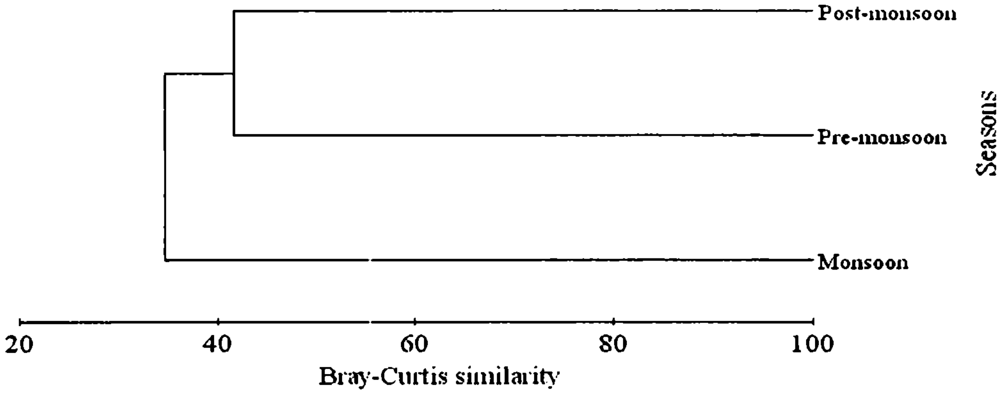


Fig. 4.4. 4. Dendrogram based on %IRI values of different length groups of *J. sina* using group average clustering.

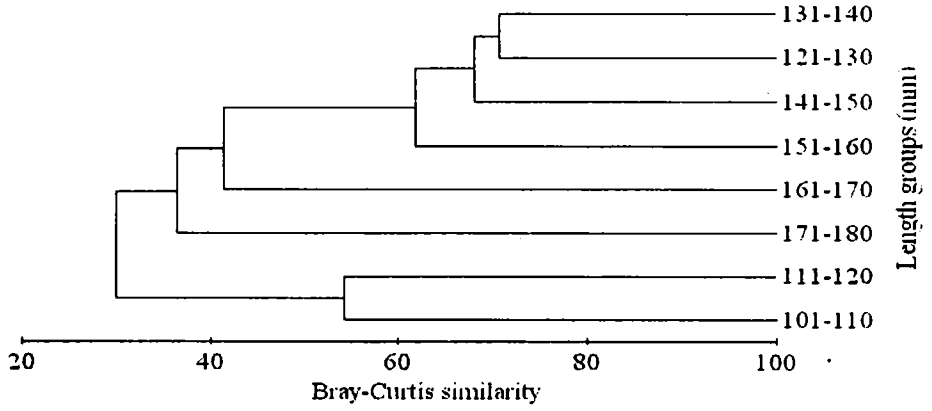


Fig. 4.4.5. Relationship between mean number of copepods and total length of *J.sina*

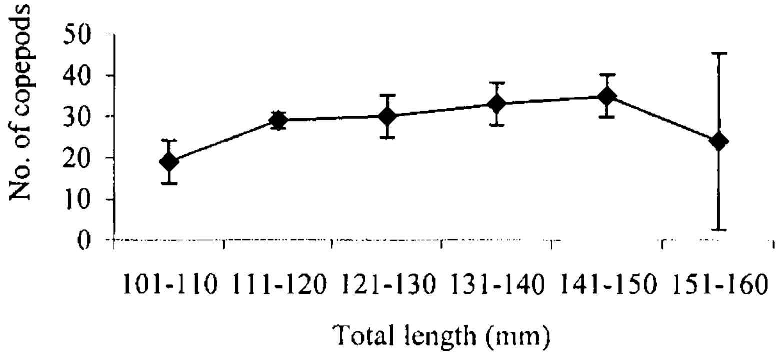


Fig. 4.4.6. Relationship between mean number of *A. indicus* and total length of *J. sina*

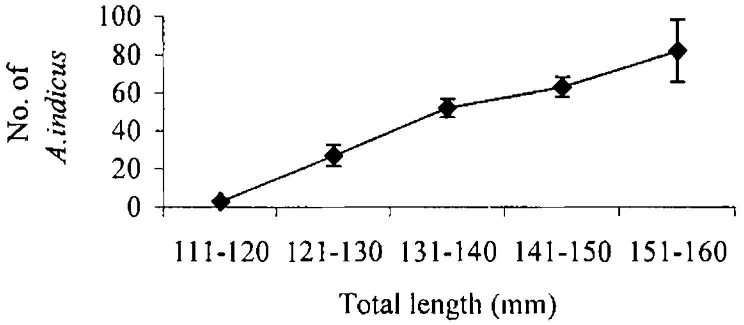
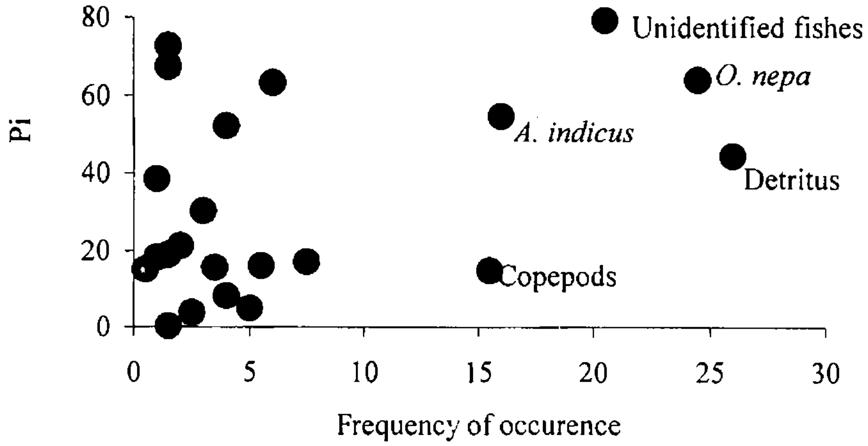


Fig. 4.4.7. Amundson plot for *J .sina* showing prey-specefic abundance (Pi)



4.5. *Otolithes cuvieri*

4.5.1. General diet composition

A total of 22 prey items were identified from the gut of the croaker, *O. cuvieri* ranging in total length from 97 to 295 mm (mean: 172 mm) and they comprised mainly of fishes, crustaceans, cephalopods and detritus. Crustaceans represent the major food groups in the stomach of this fish by the index of relative importance (IRI = 87.9 %, Table 4.5.1). Out of 22 prey taxa identified, *Acetes indicus* (%IRI=80.3) was the most important prey of *O. cuvieri* (Plate 2c). Among the fishes, *N. mesoprion* (%IRI= 6.0) and *Stolephorus* spp (%IRI= 2.9) were the most important prey. Detritus was excluded in the calculation of IRI, as it was not important in the diet of the fish. The most important prey by weight was fish (69.4%), mainly of *Nemipterus mesoprion* (33.6%), *Sardinella longiceps* (19.4%), *Stolephorus* spp (8.5%), and other teleosts (4.4%). The other fish species recorded in minor quantities include *Secutor insidiator, Opisthopterus tardoore, Leiognathus bindus, Cynoglossus macrostomus, Bregmaceros* spp, and *Plotosus* spp. Crustaceans contributed 29.4% to the total weight of the prey which consists of *A. indicus* (12.7%), *O. nepa* (5.7%), and penaeid prawns (5.3%). The prawns were *Parapenaeopsis stylifera, Metapenaeus affinis and Solenocera choprai* (Plate 2c). Crabs, amphipods, *Loligo duvauceli* and detritus were present infrequently in diet.

A total of 735 organisms were enumerated, 92.3% of which were crustaceans, 7.6% fishes and 0.14% cephalopods. The dominant crustacean prey by number was *A. indicus* (77.2%), amphipods (5.5%), and copepods (3.3%).

In frequency of occurrence, crustaceans were the important food in the diet of *O. cuvieri* (65.7%), particularly *A. indicus* (26.9%) and penaeid prawns (14.7%). Fishes occurred in 30.9 % of the samples, and the most common were other teleosts (9.7%), *Stolephorus* spp (8.0%) and *N. mesoprion* (5.1%).

4.5.2. Feeding intensity

Stomachs from 364 croakers were analyzed; of these 188 stomachs (52%) were empty (Table 4.5.2). It was observed that active feeding was generally low and the incidence of poor feeding and empty stomachs were comparatively higher throughout the season and the difference was significant (χ^2 test, df= 6, P<0.001) (Table 4.5.2). Among the seasons, variation was during the monsoon. During the monsoon season, percentage of empty stomach was as high as 84, whereas in the post-monsoon, active feeding was relatively high. Proportion of poorly fed fishes dominated the pre-monsoon followed by the post-monsoon and monsoon seasons.

In all the length groups, the occurrence of empty stomachs was high (Table 4.5.3). Generally, *O. cuvieri* showed a trend for increasing feeding intensity with the increasing length of the fish and moderate and poor feeding condition were higher in the smaller length groups and the difference was significant (χ^2 test, df= 15, p<0.001) (Table 4.5.3). Active feeding was comparatively higher in the largest class of 211-240 mm and 241-270 mm and was lesser in smaller length groups. The percentage occurrence of empty stomach was higher in 181-210 mm and 211-240 mm length groups.

4.5.3. Seasonal variations in feeding

Seasonal variation of the food items in terms of percentage index of relative importance is given in Table 4.5.4. When crustacean prey dominated in the stomach, a corresponding decrease in teleost preference was observed. This interchange of prey with the predominance of *S. longiceps* (%IRI= 96.2) and complete avoidance of *A. indicus* and other prey groups was more distinct in the monsoon season. Diet during the pre-monsoon season was mainly constituted by *A. indicus* and penaeid prawns and among teleosts, other teleosts and *Bregmaceros* spp were significant. In addition to *A. indicus*, which formed bulk of the diet in the post-monsoon, proportion of teleosts such as *N. mesoprion* and *Stolephorus* spp was also significant to *O. cuvieri*. Significant seasonal differences in the number of major prey categories were observed (χ^2 test, df= 6, p<0.001, Table 4.5.5). Among the seasons, significant variation was from the monsoon season.

4.5.4. Ontogenetic variations in feeding

Ontogenetic studies showed vast changes in feeding habits with increasing size (Table 4.5.6). In general, the percentage IRI of crustaceans was more in the smaller length groups (<210), indicating smaller *O. cuvieri* have a strong preference for crustaceans. The most preferred crustacean prey, *A. indicus* was frequently consumed by all length groups except in 241-270 mm groups. Significant differences in the number of major prey categories were found in length groups (χ^2 test, df= 15, p<0.001, Table 4.5.7). Among the length groups, fishes of 91-120 and 241-270 mm groups showed major variations. Fishes and copepods were the two major source of variation among prey categories. The IRI of *A. indicus* in 121-150 mm length group was very high (%IRI= 87.3). Among prawns, penaeid prawns were preferred in all the length groups except in 241-271 groups, whereas, *P. stylifera* was preferred in 91-120 mm (%IRI= 2.9) and 211-240 mm (%IRI =8.5) length groups. Prawn species such as *M. affinis* and other *Metapenaeus* spp were observed only in 151-180 and 181-210 mm length groups. Copepods and amphipods were highly important for young ones than adults. Among fishes, *O. cuvieri* preferred *N. mesoprion* from 151-180 mm length group and it was most predominant in the large groups (>240 mm). Next to *N. mesoprion,* the most preferred fish prey for 211-240 mm length groups was *S. longiceps* (%IRI=23.4).

4.5.5. Variation in diet breadth and trophic levels

Diet breadth was highest in the pre-monsoon (3.9 ± 1.4) and post-monsoon seasons (2.7 ± 1.2) due to larger prey diversity (Fig 4.5.1). Ontogenetically, the highest diet diversity was recorded for both 151-180 mm (Db= 7.51) and 181-210 mm (Db= 7.36) length groups, as these groups consumed at least 17 and 13 prey items respectively. Diet breadth in larger *O. cuvieri* (>241 mm) was very less (1.04) because of less diverse prey items (Fig 4.5.2).

The mean annual trophic level of *O. cuvieri* was 3.7 ± 0.2 and during the post-monsoon season, it was as high as 3.9 ± 0.3, mainly due to consumption of *N. mesoprion,* a benthic carnivore in significant quantities. The trophic level followed an increasing trend with length, reached its highest level in larger fishes (>240 mm; TrL =4.5).

4.5.6. Diet similarities

Cluster analysis showed highest similarity in diet between the pre-monsoon and post-monsoon seasons (56%, Fig 4.5.3). During these seasons, preference to most important prey, *A. indicus* was very high (>70% by IRI). No other significant similarity in diet existed among the seasons.

Highly significant diet similarity was observed between the two consecutive length groups, 121-150 and 151-180 mm (77%) and these groups were monophagous due to their preference to *A. indicus* in the diet (Fig 4.5.4). Significant similarity also existed between the fishes of 151-180 and 181-210 mm (75%) and 121-150 and 181-210 mm length groups (65%).

4.5.7. Prey-predator relationships

The length of the dominant fish prey, *N. mesoprion* showed direct relations to predator length. Fig 4.5.5 shows that large croaker consumed large quantity of *N. mesoprion* and the relationship was positively correlated (R^2 = 0.94). Consumption of teleosts was higher in larger sized *O. cuvieri*, whereas, preference to crustaceans was more in the young ones (Fig 4.5.6). The most preferred prey *A. indicus* was more abundant in groups up to length 181-210 mm; thereafter its preference was reduced in diet (Fig 4.5.7).

4.5.8. Feeding strategies

Prey-specific abundance was plotted against the frequency of occurrence to evaluate the feeding strategy of the croaker. Fig 4.5.8 shows the abundance of 22 prey types for *O.cuvieri*. Each point represents a different prey type and is expressed as prey-specific abundance. It was observed that *O. cuvieri* have a highly specialized feeding strategy.

4.5.9. Prey selection

The electivity studies indicated that *O. cuvieri* have a strong preference to most of the prey species observed in diet (Table 4.5.8). Changes in fish proportion in the trawl catch with seasons were highly reflected in fish diets and prey selection. As the abundance of smaller crustaceans in the wild was not available the index could not be calculated or such items. *O. cuvieri* showed strong selection to oil sardine and strong avoidance of other teleosts in the monsoon season. Similarly, *O. cuvieri* avoided *C. macrostomus* and *L. duvauceli* during post-monsoon. Strong positive selection for all types of crustaceans was observed both in the pre-monsoon as well as post-monsoon seasons.

Table 4.5.1. Prey of *O. cuvieri* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	%FO	%W	%N	IRI	%IRI
Fishes					
Secutor insidiator	0.57	0.41	0.28	0.39	0.01
Nemipterus mesoprion	5.14	33.57	1.52	180.49	6.01
Opisthopterus tardoore	0.57	0.68	0.14	0.47	0.02
Leiognathus bindus	0.57	0.89	0.14	0.59	0.02
Stolephorus spp	8.00	8.50	2.21	85.71	2.85
Bregmaceros spp	2.86	0.86	0.83	4.82	0.16
Plotosus spp	0.57	0.15	0.28	0.25	0.01
Sardinella longiceps	1.71	19.38	0.55	34.17	1.14
Cynoglossus macrostomus	1.14	0.54	0.28	0.93	0.03
Other teleosts	9.71	4.37	1.38	55.89	1.86
Crustaceans					
Parapenaeopsis stylifera	1.71	2.06	0.55	4.49	0.15
Metapenaeus affinis	1.14	0.94	0.28	1.39	0.05
Metapenaeus spp	1.14	0.76	0.28	1.18	0.04
Solenocera choprai	2.29	1.58	0.55	4.89	0.16
Penaeid prawns	14.86	5.32	2.90	122.14	4.06
Acetes indicus	26.86	12.67	77.18	2413.07	80.30
Crabs	0.57	0.29	0.28	0.32	0.01
Oratosquilla nepa	5.71	5.70	1.38	40.48	1.35
Amphipods	6.86	0.01	5.53	37.97	1.26
Copepods	4.57	0.01	3.32	15.24	0.51
Cephalopods					
Loligo duvauceli	0.57	0.11	0.14	0.14	0.00
Detritus	3.43	1.19	0.00	0.00	0.00

Table 4.5.2. Two way contingency table analysis of the seasonal variation in feeding intensity of *O. cuvieri*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each season)

Feeding intensity	Season			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Active	6	3	23	32	3.4
	(5.0)	(5.9)	(10.7)		
Moderate	10	0	38	48	12.6
	(8.4)	(0.0)	(17.7)		
Poor	50	5	56	111	14.2
	(42.0)	(9.8)	(26.0)		
Empty	53	43	98	194	13.4
	(44.5)	(84.3)	(45.6)		
N_j	119	51	215	385	
χ^2	11.1	24.8	7.7		**43.6****

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df= 6

Table 4.5.3. Two way contigency table analysis of the ontogenetic variation feeding intensity of *O. cuvieri.* (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each length groups)

Feeding intensity	Length groups (mm)						N_j	χ^2
	91-120	121-150	151-180	181-210	211-240	241-270		
Active		2	7	4	10	3	43	19.07
	(0.0)	(2.6)	(5.6)	(5.2)	(18.2)	(25.0)		
Moderate	2	14	16	5	5	1	107	4.90
	(11.8)	(17.9)	(12.8)	(6.5)	(9.1)	(8.3)		
Poor	12	23	39	20	9	4	188	13.50
	(70.6)	(29.5)	(31.2)	(26.0)	(16.4)	(33.3)		
Empty	3	39	63	48	31	4	364	6.60
	(17.6)	(50.0)	(50.4)	(62.3)	(56.4)	(33.3)		
N_j	17	78	125	77	55	12	44.0738	
χ^2	14.83	4.82	0.70	4.26	13.14	6.32		**44.07****

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df= 15

Table 4.5.4. Seasonal variation in %IRI of prey of *O. cuvieri*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Secutor insidiator	0.00	0.00	0.02
Nemipterus mesoprion	0.00	0.00	10.77
Opisthopterus tardoore	0.00	0.00	0.03
Leiognathus bindus	0.48	0.00	0.00
Stolephorus spp	0.49	0.00	4.07
Bregmaceros spp	2.22	0.00	0.01
Plotosus spp	0.14	0.00	0.00
Sardinella longiceps	0.00	96.15	0.00
Cynoglossus macrostomus	0.00	0.00	0.05
Other teleosts	4.20	3.85	1.15
Parapenaeopsis stylifera	0.00	0.00	0.26
Metapenaeus affinis	1.09	0.00	0.00
Metapenaeus spp	0.27	0.00	0.01
Solenocera choprai	3.73	0.00	0.00
Penaeid prawns	16.69	0.00	2.22
Acetes indicus	70.35	0.00	76.29
Crabs	0.21	0.00	0.00
Oratosquilla nepa	0.00	0.00	2.38
Amphipods	0.07	0.00	1.81
Copepods	0.00	0.00	0.83
Loligo duvauceli	0.00	0.00	0.01
Detritus	0.07	0.00	0.06

Table 4.5.5. Two way contingency table analysis of the seasonal variation in feeding intensity of *O. cuvieri* (Values are number of prey groups observed in each seasons)

Prey groups	Season			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	16	5	34	55	53.9
Penaeid prawns	17	0	16	33	11.2
Acetes indicus	144	0	414	558	4.2
Copepods	2	0	38	40	9.7
N_j	179	5	502	686	
χ^2	15.2	57.4	6.4		**79.0****

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df= 6

Table 4.5.6. Ontogenetic variation in %IRI of prey of *O. cuvieri*

Prey	Length groups (mm)					
	91-120	121-150	151-180	181-210	211-240	241-270
Secutor insidiator	0.00	0.00	0.14	0.00	0.00	0.00
Nemipterus mesoprion	0.00	0.00	1.82	11.26	31.43	100.00
Opisthopterus tardoore	0.00	0.00	0.22	0.00	0.00	0.00
Leiognathus bindus	0.00	0.00	0.00	0.94	0.00	0.00
Stolephorus spp	6.06	1.52	5.37	13.33	1.59	0.00
Bregmaceros spp	0.00	0.22	0.81	0.00	0.00	0.00
Plotosus spp	0.00	0.00	0.07	0.00	0.00	0.00
Sardinella longiceps	0.00	0.00	0.00	0.52	23.40	0.00
Cynoglossus macrostomus	0.00	0.16	0.10	0.00	0.00	0.00
Other teleosts	5.75	0.12	2.95	4.42	3.28	0.00
Parapenaeopsis stylifera	2.95	1.02	0.00	0.00	8.45	0.00
Metapenaeus affinis	0.00	0.00	0.10	0.50	0.00	0.00
Metapenaeus spp	0.00	0.00	0.26	0.13	0.00	0.00
Solenocera choprai	0.00	0.45	0.80	0.82	0.00	0.00
Penaeid prawns	9.97	6.29	7.21	8.47	0.57	0.00
Acetes indicus	34.16	87.31	79.20	54.49	22.34	0.00
Crabs	0.00	0.00	0.11	0.00	0.00	0.00
Oratosquilla nepa	0.00	2.30	0.36	3.21	2.68	0.00
Amphipods	20.19	0.51	0.27	1.32	6.25	0.00
Copepods	18.20	0.09	0.22	0.58	0.00	0.00
Loligo duvauceli	2.71	0.00	0.00	0.00	0.00	0.00
Detritus	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.5.7. Two way contigency table analysis of the ontogenetic variation in number of major preys of *O. cuvieri* (Values are number of prey groups observed in length groups)

Prey groups	Length groups (mm)						N_j	χ^2
	91-120	121-150	151-180	181-210	211-240	241-270		
Fishes	1	7	21	9	10	4	40	69.2
Penaeid prawns	3	12	13	7	5	0	557	6.4
Acetes indicus	9	180	172	175	21	0	40	16.6
Copepods	12	8	6	8	6	0	689	87.8
N_j	25	207	212	199	42	4	179.9	
χ^2	85.0	7.1	4.8	6.5	27.6	49.0		**179.9****

N_i, total numbers by species; N_j, total numbers by length groups **, $P < 0.001$, df= 15

Table 4.5.8. Seasonal Ivelev index of *O. cuvieri*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Secutor insidiator	-	-	0.20
Nemipterus mesoprion	-	-	0.86
Opisthopterus tardoore	-	-	0.81
Leiognathus bindus	0.75	-	-
Stolephorus spp	0.41	-	0.65
Bregmaceros spp	-	-	1.00
Plotosus spp	0.98	-	-
Sardinella longiceps	-	0.99	-
Cynoglossus macrostomus	-	--	-0.52
Other teleosts	0.55	-0.29	0.45
Parapenaeopsis stylifera	-	-	0.90
Metapenaeus affinis	0.99	-	
Metapenaeus spp	0.95	-	0.96
Solenocera choprai	0.88	-	
Penaeid prawns	0.88	-	0.85
*Acetes indicus**	-	-	-
Crabs	0.88	-	-
Oratosquilla nepa	-	-	0.56
Amphipods*	-	-	-
Copepods*	-	-	-
Loligo duvauceli	-	-	-0.86
Detritus*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.5.1. Seasonal variation in trophic level and diet breadth of *O. cuvieri*

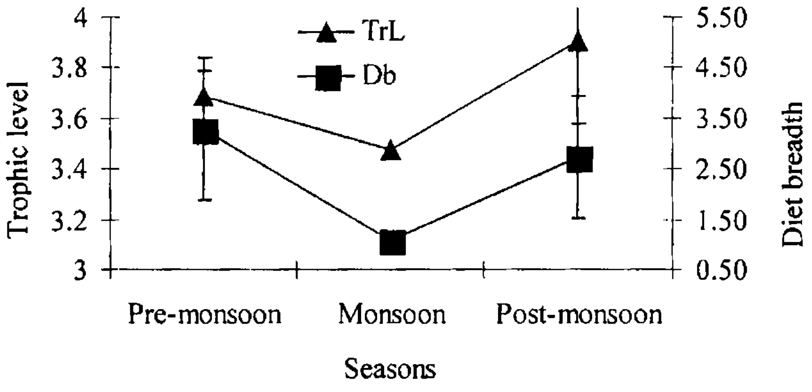


Fig. 4.5.2. Ontogenetic variation of diet breadth and trophic levels of *O. cuvieri*

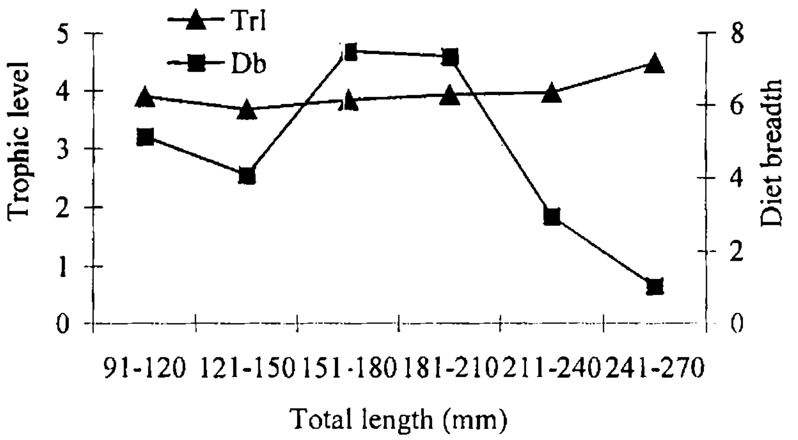


Fig. 4.5.4. Dendrogram based on %IRI values of different seasons of *O. cuvieri* using group average clustering

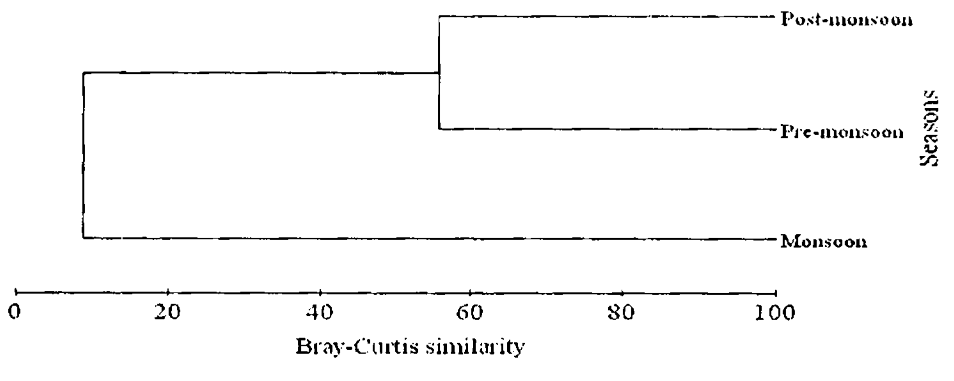


Fig. 4.5.4. Dendrogram based on %IRI values of different length groups of *O. cuvieri* using group average clustering

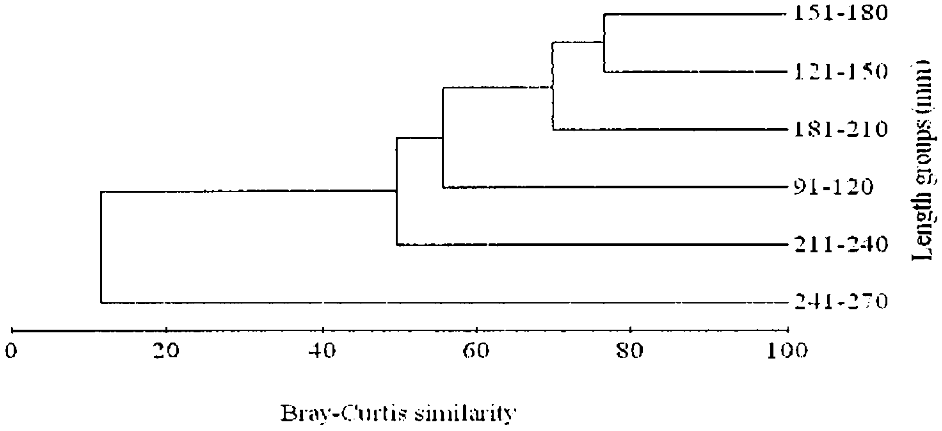


Fig .4.5.5. Relationship between weight of *N. mesoprion* and total length of *O. cuvieri*

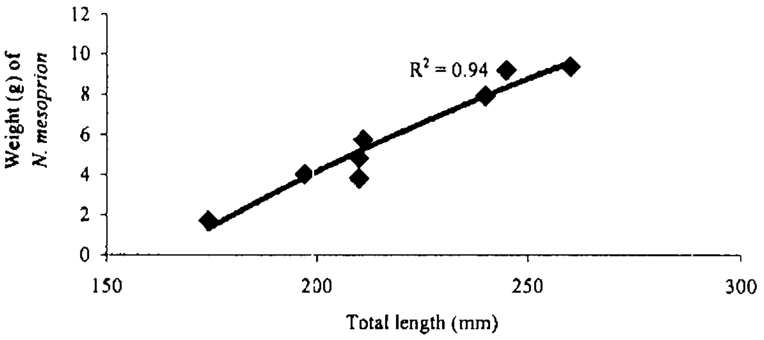


Fig. 4.5.6. Relationship between the weight of teleosts and crustaceans with the total length of *O. cuvieri*

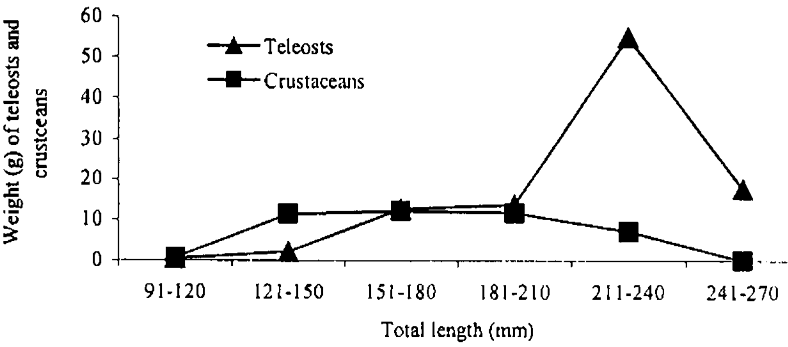


Fig. 4.5.7. Relationship between the number of *A. indicus* and the total length of *O. cuvieri*

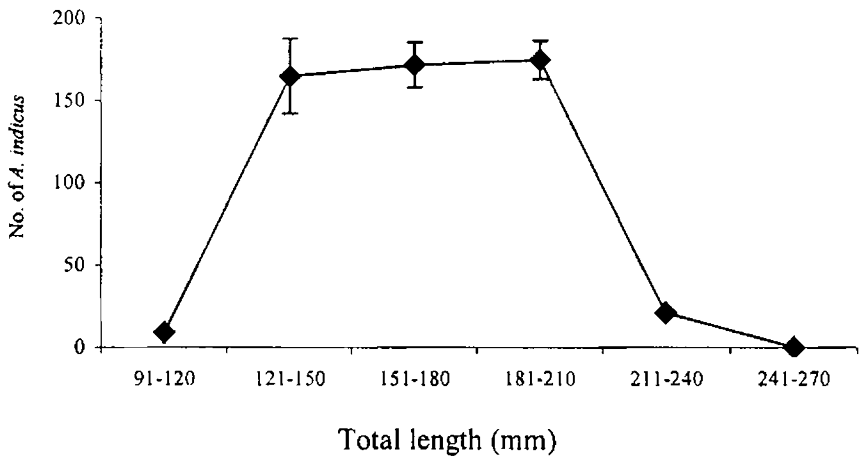
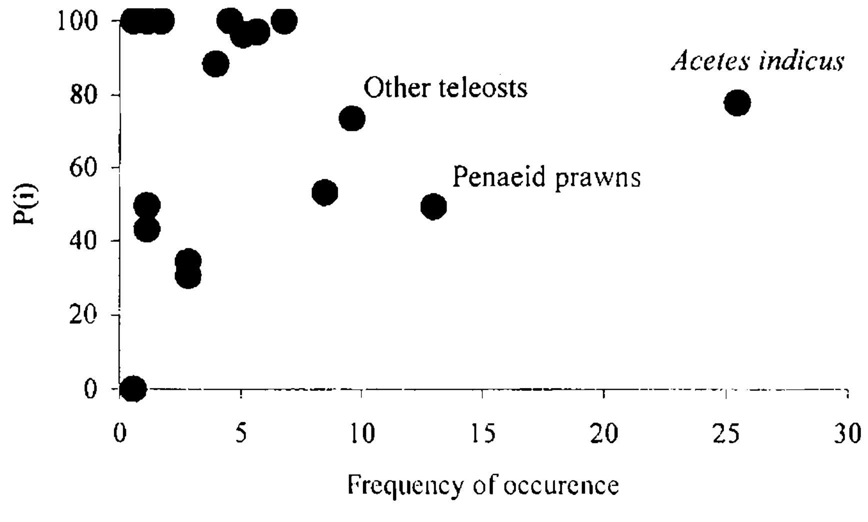


Fig. 4.5.8. Amundson plot for *O. cuvieri* showing prey-specific abundance (Pi)



4.6. *Nemipterus japonicus*

4.6.1. General diet composition

The trophic spectrum of *N. japonicus* consisted of three main groups: fishes, crustaceans and molluscs. Crustaceans (%IRI= 74.0) were the most important prey category, *Solenocera choprai* (%IRI=32.5), *Acetes indicus* (%IRI= 21.2) and benthic crabs (%IRI= 18.3) being the most important of gut contents (Table 4.6.1). Teleosts (%IRI= 20.4) were second in rank, *Stolephorus* spp. (%IRI= 11.8) and unidentified fishes (%IRI= 6.2) being the most important. Among molluscs, *Loligo duvauceli* (%IRI= 5.5) was significant in the diet. In terms of frequency of occurrence, *S. choprai* was observed in 43.9 % of the stomachs examined followed by benthic crabs (%FO= 23.9) and *A. indicus* (%FO=18.9). Teleosts were found in 67.8% of stomachs examined and unidentified fishes (%FO= 22.8) and *Stolephorus* spp (%FO= 21.1) were the most frequently occurring teleosts. Benthic crabs (%W= 18.4) and *S. choprai* (%W= 17.3) consistently made up the largest components of the stomach contents in weight. Among the teleosts, *Stolephorus* spp (%W= 15.2), unidentified fishes (%W= 7.2) and *N. mesoprion* (%W= 3.7) were largely consumed. In terms of abundance, *A. indicus* (%N= 42.5) formed the largest part of the diet followed by *S. choprai* (%N= 12.7) and benthic crabs (%N=12.6). In addition, fish groups especially *Stolephorus* spp (%N= 7.3), *Leiognathus bindus* (%N= 4.0) and unidentified fishes (%N= 3.9) also made up substantial proportion to the diet. Fishes such as *Pseudorhombus* spp, *Cynoglossus macrostomus*, juveniles of *Trichuirus lepturus*, *Grammoplites suppositus* (Plate 2*f*) fish juveniles and fish eggs were also preyed upon by *N. japonicus* but to a lesser extent. Detritus were represented infrequently and was not included in the calculation. The mean weight and number of prey were 1.47 ± 1.09 g and 2.63 ± 4.6 respectively.

4.6.2. Feeding Intensity

The proportion of fishes with empty stomach dominated the whole period and their occurrence was highest in the monsoon season (Table 4.6.2). The incidence of large quantities of poorly fed fishes throughout the year impaired the analysis of seasonal feeding active of *N. japonicus*. In the pre-monsoon and the post-monsoon seasons, the percentage of actively and moderately fed fishes was comparatively higher. The proportion of poorly fed fishes gradually increased from the pre-monsoon season to post-monsoon season. But, there was no significant variation in the feeding intensities among seasons (χ^2 test, df= 6, p>0.001)

Ontogenetically, *N. japonicus* showed wide variation in feeding intensity. It was observed that empty stomachs were dominant in most length groups and its proportion gradually increased from smaller length groups (<155 mm) to 181-205 mm length groups thereafter its proportion considerably reduced in both 231-255 mm and 281-305 mm length groups (Table 4.6.3). Proportion of fishes with active feeding reduced from smaller length groups (<155 mm) to 181-205 mm group, and thereafter, its proportion gradually increased up to 231-255 mm length groups and finally, it was totally absent in the larger length groups. There was a significant variation in the feeding intensities in relation to length (χ^2 test, df= 18, p<0.001, Table 4.6.3).

4.6.3. Seasonal variations in feeding

The diet composition of *N. japonicus* varied throughout the year (Table 4.6.4). In the pre-monsoon season, *A. indicus* (%IRI= 27.0) and *S. chop*rai (%IRI= 25.7) were almost equally ranked first followed by *L. duvauceli* and benthic crabs. Among the teleosts, *Leiognath*us spp followed by *Stolephorus* spp and unidentified fishes contributed significantly. Juveniles of large predators such as *S. tumbil, S. undosquamis, N. mesoprion* and *Pseudorhombus* spp appeared only in monsoon. Significant difference in the number of major prey categories was found among the seasons (χ^2 test, df= 10, p<0.001, Table 4.6.5). Significant variation came from the monsoon and post-monsoon seasons. During the monsoon, *S. choprai* ranked first (%IRI= 38.8) followed by *A. indicus* (26.2) and unidentified fishes (21.9). Proportion of *Bregmaceros* spp and *L. duvauceli* was also significant in the diet. However, benthic crabs were less preferred in the monsoon season due to preference for *O. nepa*. In the post-monsoon season, *Stolephorus* spp (%IRI= 22.3) were highly preferred, but was only next to *S. choprai* (%IRI= 30.8) and benthic crabs (%IRI= 25.8) in IRI. Proportion of *A. indicus* considerably reduced in the post-monsoon season due to the increasing consumption of benthic crabs and fish groups.

4.6.4. Ontogenetic variation in feeding

Diet of *N. japonicus* showed distinct ontogenetic variations. *N. jàponicus* showed opportunistic feeding habits in smaller and larger length groups. Diet of fishes <155 mm was dominated by benthic crabs (%IRI= 54.9) and *Stolephorus* spp (%IRI= 23.8). *O. nepa* (8.5%) and *L. duvauceli* (%IRI= 5.2) were second and third important preys (Table 4.6.6). Variation in the number of major prey groups was significant among length groups (χ^2 test, df= 30, P<0.001, Table 4.6.7). Among the length groups, 156-180 and 131-155 mm and among prey categories, *O. nepa* and cephalopods contributed to the major source of variation. In addition to *Stolephorus* spp (%IRI = 20.3), more or less an equal proportion of two crustaceans such as *A. indicus* (%IRI= 27.2) and *S. choprai* (%IRI= 26.2) formed the major diet of individuals of 181-205 mm length groups. Fishes of the length range 206-230 mm switched to feed on *S. choprai* (38.1%) and benthic crabs (21.9%) in large proportions. Fishes of these groups also consumed *L. duvauceli* (10.3%), *A. indicus* (9.6%) and *Stolephorus* spp (8.4%) in higher proportions. Individuals of length group 231-255 mm fed mostly on crustaceans dominated by *A. indicus* (%IRI=42.1), *S. choprai* (%IRI= 24.9) and benthic crabs (%IRI= 8.1). Among the fish groups consumed, *Stolephorus* spp (%IRI= 11.8), *Leiognathus* spp (%IRI= 5.0) and *N. mesoprion* (%IRI= 1.9) were important. Diet of length group 256-280 mm was characterized by high proportion of *A. indicus* (%IRI= 35.7) and *S. choprai* (%IRI= 34.8). In addition, *L. duvauceli* (%IRI= 10.6), *S. undosquamis* (%IRI= 4.7) and *Stolephorus* spp (%IRI= 4.5) were also consumed. Feeding of largest individuals (>280mm) was characterized by an increased incidence of fish groups such as unidentified fishes (%IRI= 39.8), *Stolephorus* spp (%IRI= 30.2) and a decreased proportion of crustaceans.

4.6.5. Variation in diet breadth and trophic levels

The dietary breadth of *N. japonicus* had wide variations in relation to different seasons. Overall, diet breadth was higher in the pre-monsoon compared to the post-monsoon and monsoon seasons (Fig 4.6.1). The mean diet breadth during the pre-monsoon was 6.43 ± 1.33. Fishes in the monsoon season had a mean diet breadth of 4.23 ± 0.99. During the post-monsoon, second highest diet breadth of 4.38 ± 0.54 was recorded. Ontogenetically, diet breadth varied greatly among different length groups (Fig 4.6.2). There was an increase in prey diversity from smaller to larger fishes with an average of 5.58 ± 2.18 and later a steep decline in very large length groups. The highest value of diet breadth was observed for the fishes of 231-255 mm length groups (8.42).

Seasonally trophic level had great changes; the highest value, as a consequence of large proportion of teleosts in diet, was observed in the pre-monsoon season (4.17 ± 0.21). During the monsoon, the trophic level declined to 4.03 ± 0.12 and in post monsoon, the mean trophic level was 4.02 ± 0.05. Trophic level, in general, considerably increased with increasing body length (Fig 4.6.2). The mean trophic level observed was 4.09 ± 0.154. The value of trophic level was highest in 256-280 mm length group where top predators such as *S. undosquamis* had its higher proportion in addition to *L. duvauceli* and other crustaceans. In general, higher values of trophic level were observed in the larger fishes (>231 mm) with an average of 4.21 ± 0.19 than younger ones (<231 mm) with an average of 4.06 ± 0.11.

4.6.6. Diet similarities

Similarity cluster formed in the dendrogram showed the occurrence of highest similarity between the pre-monsoon and post-monsoon seasons (70.3%) as a result of higher proportion of *S. choprai* and *A. indicus* (Fig 4.6.3). Ontogenetically, dendrogram distinguished length groups into similar clusters (Fig 4.6.4). Higher similarity was observed between 181-205 and 231-255 mm (82%) and 181-205 and 206-230 mm (76%) length groups and this formed distinct cluster in the dendrogram. The former groups shared *Stolephorus* spp, prawns, fish scales and fish remains almost in similar proportions. Higher proportion of *Pseudorhombus* spp in larger length groups caused higher similarity among them.

4.6.7. Prey-predator relationships

The most important prey such as *S. choprai* and *A. indicus* always had positive relation to the length of *N. japonicus*. Large individuals of *N. japonicus* always consumed *S. choprai* of larger size. The mean weight of *S. choprai* was marginally increased with the increasing length of *N. japonicus* (Fig 4.6.5). Similarly, the mean length, weight, and number of *A. indicus* were also related to length of *N. japonicus*. Fishes of small length groups consumed smaller *A. indicus* and the largest individuals preferred larger *A. indicus* (Fig 4.6.6). Similarly, the mean weight of *A. indicus* was marginally increased from the smallest length groups (131-155 mm) to 231-255 mm length group and thereafter decreased in the largest length group (256-280 mm) (Fig 4.6.7). Also the number of *A. indicus* was increased with the increasing length of *N. japonicus*. There was a positive correlation between the numbers of *A. indicus* consumed to the length of *N. japonicus* ($r^2 = 0.65$) (Fig 4.6.8).

4.6.8. Feeding strategy

Fig 4.6.9 showed a mixed feeding strategy of *N. japonicus*. Twenty different prey types represented by points were almost evenly distributed in the graph. It showed that some individuals always specialized on certain prey types while most of the others consumed other preys. *N. japonicus* most often specialized on crustaceans mainly *S. choprai* and benthic crabs. Unidentified fishes, benthic crabs, *A. indicus* and *L. duvauceli* were the next most often found prey items on which *N. japonicus* specialized. Other prey items were only occasional in the diet. As a result of this feeding strategy on certain prey types, *N. japonicus* has a high degree of diet breadth among the different length groups.

4.6.9. Prey selection

Prey preference calculated by index of electivity of *N. japonicus* showed that most of the preys were strongly selected while some others were strongly avoided (Table 4.6.9). The most important preys such as *S. choprai* and benthic crabs were highly selected during the pre-monsoon and post-monsoon seasons. Though the percentage of teleosts such as *S. tumbil*, *S. undosquamis* and *N. mesoprion* was higher in commercial catches, preference to them was very less. Teleosts such as *G. suppositus* and *Leiognathus* spp were moderately selected in the post-monsoon season. Strong selection for *Stolephorus* spp was observed in the monsoon and post-monsoon seasons. The cephalopod, *L. duvauceli* was actively selected in the monsoon season.

Table 4.6.1. Prey of *N. japonicus* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	%FO	%W	%N	IRI	%IRI
Fishes					
Saurida tumbil	2.22	3.16	0.65	8.46	0.21
Saurida undosquamis	1.67	2.16	0.43	4.32	0.11
Nemipterus mesoprion	2.22	3.67	0.54	9.36	0.23
Grammoplites suppositus	1.67	0.81	0.11	1.53	0.04
Leiognathus bindus	6.11	5.43	3.99	57.58	1.42
Bregmaceros spp	3.33	1.50	1.08	8.58	0.21
Pseudorhombus spp	2.22	1.36	0.54	4.22	0.10
Stolephorus spp	21.11	15.23	7.34	476.44	11.77
Cynoglossus macrostomus	0.56	0.07	0.11	0.10	0.00
Fish juveniles	2.78	0.39	0.65	2.89	0.07
Trichiurus lepturus juveniles	0.56	0.01	0.11	0.06	0.00
Fish eggs	0.56	0.28	0.00	0.16	0.00
Unidentified fishes	22.78	7.19	3.88	252.18	6.23
Crustaceans					
Solenocera choprai	43.89	17.26	12.73	1316.23	32.53
Metapenaeus dobsonii	2.22	0.35	0.54	1.99	0.05
Parapenaeus stylifera	3.89	0.44	1.19	6.32	0.16
Benthic crabs	23.89	18.39	12.62	740.91	18.31
Oratosquilla nepa	8.33	4.91	2.37	60.66	1.50
Acetes indicus	18.89	3.00	42.50	859.56	21.24
Mysids	2.78	0.01	1.29	3.63	0.09
Copepod	2.78	0.00	1.73	4.80	0.12
Molluscs					
Loligo duvauceli	12.22	14.05	4.21	223.08	5.51
Octopus spp	0.56	0.24	0.11	0.19	0.00
Bivalves	2.78	0.00	0.76	2.10	0.05
Foraminiferans	1.67	0.00	0.54	0.90	0.02
Detritus	0.56	0.08	0.00	0.04	0.00

Table 4.6.2. Feeding intensity of *N. japonicus* in relation to seasons

Feeding intensity	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Active	20.79	11.11	15.60
Moderate	18.54	9.26	15.60
Poor	16.85	20.37	32.62
Empty	43.82	59.26	36.17

Table 4.6.3. Two way contingency table analysis of ontogenetic variation in feeding intensity of *N. japonicus*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each length group)

Feeding intensity	Length groups (mm)							N_i	χ^2
	131-155	156-180	181-205	206-230	231-255	256-280	281-305		
Active	5	7	10	25	13	0	0	60	12.9
	(21.7)	(15.9)	(12.0)	(19.1)	(39.4)	(0.0)	(0.0)		
Moderate	1	2	19	24	6	4	2	58	16.9
	4.3	4.5	22.9	18.3	18.2	30.8	(100.0)		
Poor	5	10	6	32	7	2		62	9.1
	(21.7)	(22.7)	(7.2)	(24.4)	(21.2)	(15.4)	(0.0)		
Empty	12	25	48	50	7	7		149	11.2
	(52.2)	(56.8)	(57.8)	(38.2)	(21.2)	(53.8)	(0.0)		
N_i	23	44	83	131	33	13	2	329	
χ^2	2.8	6.0	11.9	3.7	12.4	3.9	9.3		**50.1****

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df = 18

Table 4.6.4. Seasonal variation in %IRI of prey of *N. japonicus*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Saurida tumbil	0.43	0.00	0.00
Saurida undosquamis	0.49	0.00	0.00
Nemipterus mesoprion	0.18	0.00	0.42
Grammoplites suppositus	0.00	0.00	0.05
Leiognathus bindus	3.90	0.00	0.54
Bregmaceros spp	0.23	2.83	0.03
Pseudorhombus spp	0.24	0.00	0.00
Stolephorus spp	3.94	1.90	22.28
Cynoglossus macrostomus	0.00	0.32	0.00
Fish juveniles	0.00	0.00	0.26
Trichiurus lepturus juveniles	0.01	0.00	0.00
Fish eggs	0.02	0.00	0.00
Unidentified fishes	2.35	21.86	4.11
Solenocera choprai	25.72	38.79	30.77
Metapenaeus dobsonii	0.01	0.00	0.11
Parapenaeus stylifera	0.09	0.00	0.23
Benthic crabs	13.77	1.37	25.77
Oratosquilla nepa	2.21	4.35	0.37
Acetes indicus	27.02	26.24	14.00
Mysids	0.07	0.00	0.09
Copepod	0.05	0.00	0.21
Loligo duvauceli	19.15	2.34	0.67
Octopus spp	0.09	0.00	0.03
Bivalves	0.00	0.00	0.08
Foraminiferans	0.02	0.00	0.00
Detritus	0.00	0.00	0.00

Table 4.6.5. Two-way contingency table analysis of seasonal variation of major prey categories of *N. japonicus*. (Values are number of stomachs observed in each seasons)

Prey groups	Seasons			N_i	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	69	1	96	97	9.0
Prawns	49	7	61	68	0.4
Crabs	39		76	76	14.7
O. nepa	12		8	8	2.5
A. indicus	177	34	180	214	10.7
Cephalopods	33	2	5	7	24.2
N_i	379	44	426	470	
χ^2	17.5	23.2	20.9		**61.5****

N_i, total numbers by species; N_j, total numbers by seasons. **, $P < 0.001$, $df = 10$

Table 4.6.6. Ontogenetic variation in %IRI of *N. japonicus*

Prey	Length groups (mm)						
	131-155	156-180	181-205	206-230	231-255	256-280	281-305
Saurida tumbil	0.00	0.00	0.00	1.04	0.34	0.00	0.00
Saurida undosquamis	0.00	0.00	0.00	0.37	0.00	4.72	0.00
Nemipterus mesoprion	0.00	0.00	1.37	0.00	1.90	0.00	0.00
Grammoplites suppositus	0.00	0.00	0.00	0.08	0.00	0.00	0.00
Leiognathus bindus	0.00	0.00	0.77	2.91	5.01	0.00	0.00
Bregmaceros spp	3.28	3.91	0.00	0.06	0.00	0.00	0.00
Pseudorhombus spp	0.00	0.00	0.00	0.07	0.44	0.00	0.00
Stolephorus spp	23.79	15.09	20.26	8.42	11.92	4.46	30.15
Cynoglossus macrostomus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish juveniles	0.00	0.00	0.00	0.07	0.38	2.19	0.00
Trichiurus lepturus juveniles	0.00	0.24	0.00	0.00	0.00	0.00	0.00
Fish eggs	1.88	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified fishes	0.86	3.35	3.48	5.43	0.35	0.00	39.78
Solenocera choprai	1.55	13.72	26.15	37.76	24.88	34.81	9.97
Metapenaeus dobsonii	0.00	0.40	0.00	0.11	0.05	0.00	0.00
Parapenaeus stylifera	0.00	2.31	0.00	0.14	0.46	0.00	0.00
Benthic crabs	54.90	12.55	16.85	21.94	8.11	7.58	20.10
Oratosquilla nepa	8.50	8.89	0.00	1.43	0.26	0.00	0.00
Acetes indicus	0.00	33.98	27.19	9.61	42.10	35.66	0.00
Mysids	0.00	0.68	0.00	0.07	0.30	0.00	0.00
Copepod	0.00	2.27	0.00	0.11	0.20	0.00	0.00
Loligo duvauceli	5.24	0.51	3.93	10.26	2.89	10.58	0.00
Octopus spp	0.00	0.00	0.00	0.07	0.40	0.00	0.00
Bivalves	0.00	1.81	0.00	0.01	0.00	0.00	0.00
Foraminiferans	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Detritus	0.00	0.28	0.00	0.00	0.00	0.00	0.00

Table 4.6.7. Two way contingency table analysis of ontogenetic variation of prey categories of *N. japonicus*. (Values are number of stomachs observed in each lengthgroups)

Prey groups	Length groups (mm)							N_i	χ^2
	131-155	156-180	181-205	206-230	231-255	256-280	281-305		
Fishes	9	7	35	69	38	4		162	6.1
Prawns	1	2	10	49	21	4	1	88	13.7
Crabs	9	6	24	50	15	3	2	109	19.9
O. nepa	12	6		10	2			30	111.0
A. indicus		4	60	100	125	19		308	53.8
Cephalopods	1	23	6	21	5	2		58	111.7
N_i	32	48	135	299	206	32	3	755	
χ^2	111.3	125.8	12.0	11.6	40.6	5.8	9.1		**316.3***

N_i, total numbers by species; N_j, total numbers by length groups

*, $P < 0.001$, df = 30

Table 4.6.8. Seasonal Ivelev index of *N. japonicus*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Saurida tumbil	0.20	-	0.45
Saurida undosquamis	0.29	-	-
Nemipterus mesorprion	-0.44	-	-
Grammoplitus suppositus	-	-	0.69
Leiognathus bindus	0.72	-	0.73
Bregmaceros spp	-	-	-
Pseudorhombus spp*	-	-	-
Stolephorus spp	0.29	0.96	-
Cynoglossus macrostomus	0.17	-	-
Fish juv*	-	-	-
Trichuirus lepturus juveniles*	-	-	-
Fish eggs*	-	-	-
Unidentified fishes	0.39	0.82	0.56
Solenocera choprai	0.81	0.93	0.77
Metapenaeus dobsonii	-0.85		0.19
Parapenaeus stylifera	-0.52		0.60
Benthic crabs	0.94	1.00	0.95
Oratosquilla nepa	0.32	0.95	0.33
*Acetes indicus**	-	-	-
Mysids*	-	-	-
Copepod*	-	-	-
Loligo duvauceli	0.56	0.96	-0.19
Octopus spp*	-	-	-
Bivalves*	-	-	-
Foraminiferans*	-	-	-
Detritus*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.6.1. Seasonal variation in diet breadth and trophic level of *N. japonicus*

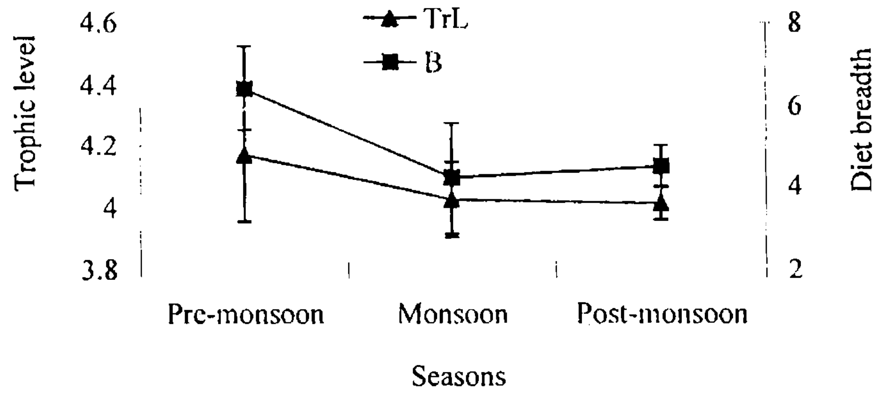


Fig. 4.6.2. Ontogenetic variation in diet breadth and trophic level of *N. japonicus*

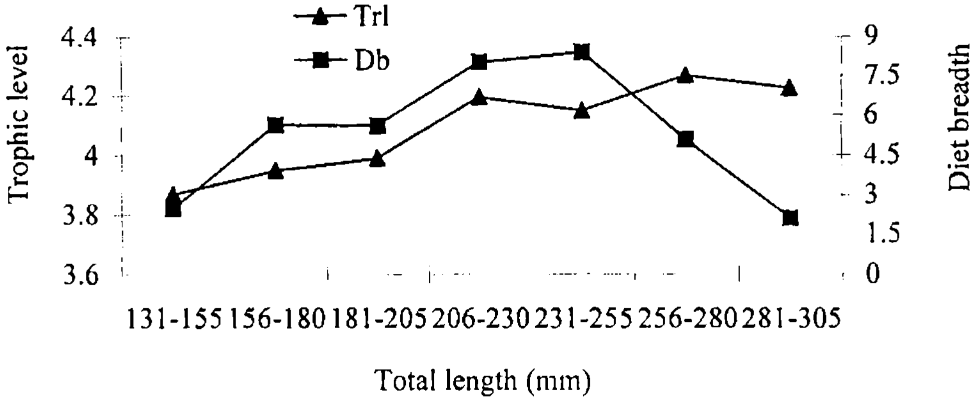


Fig. 4.6.3. Dendrogram based on %IRI values of different seasons of *N. japonicus* using group average clustering

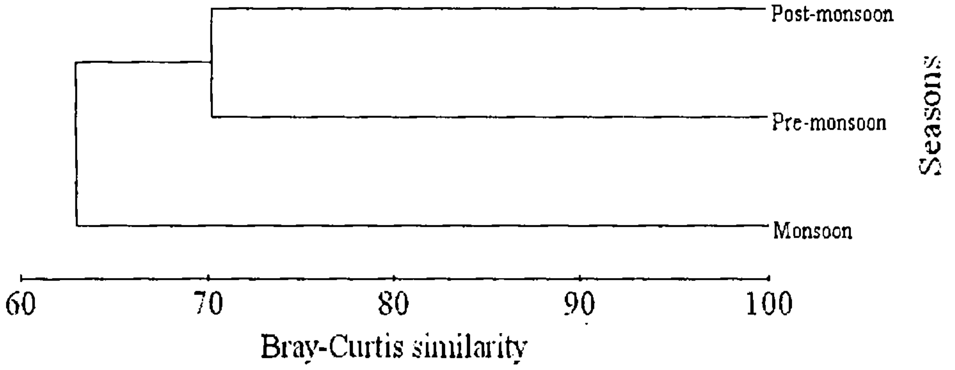


Fig. 4.6.4. Dendrogram based on %IRI values of different length groups of *N. japonicus* using group average clustering

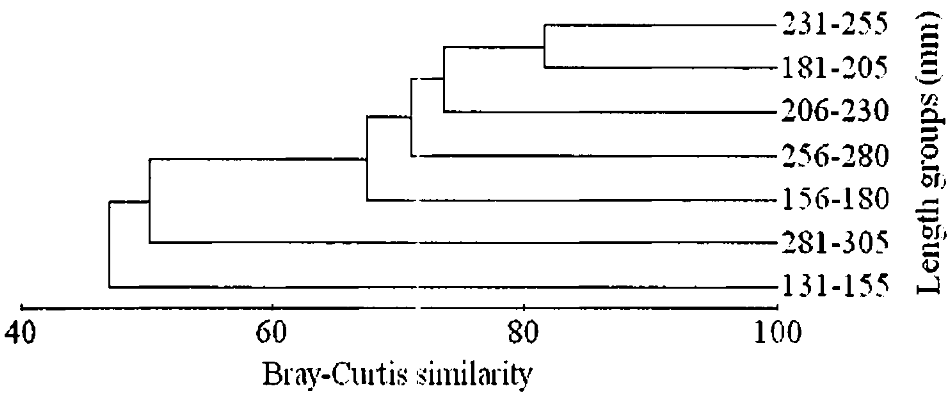


Fig. 4.6.5. Relation between the weightof *S. choprai* and total length of *N.japonicus*

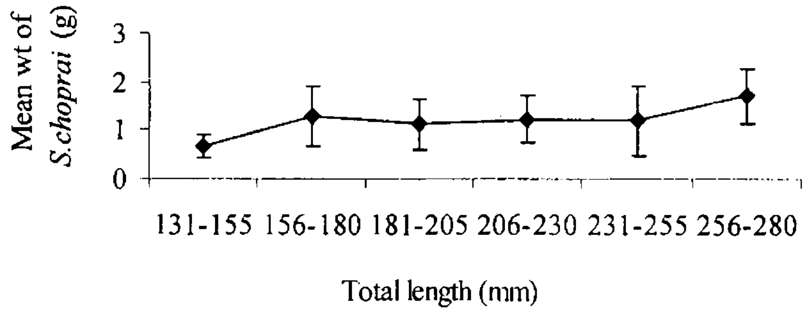


Fig. 4.6.6. Relationship between the total length of *A. indicus* and *N. japonicus*

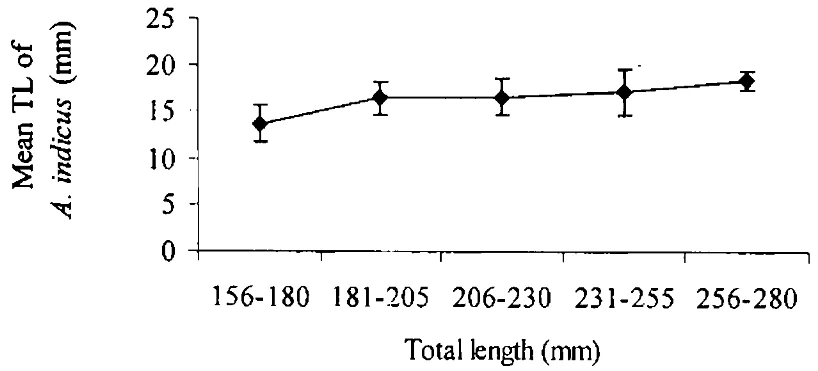


Fig. 4.6.7. Relationship between the mean weight of *A. indicus* and total length of *N. japonicus*

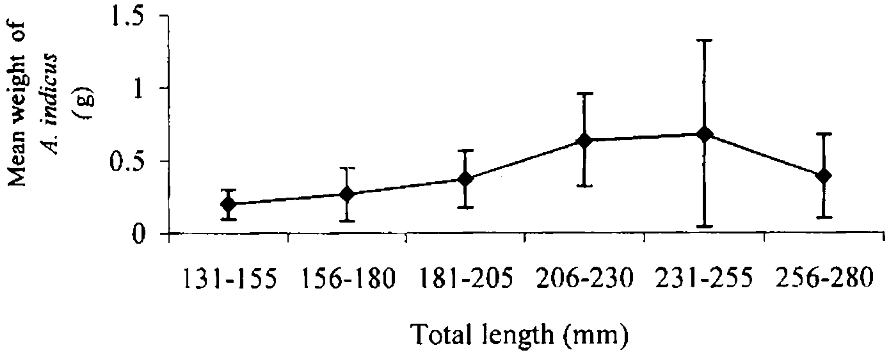


Fig. 4.6. 8. Relation between the number of *A. indicus* and the TL of *N. japonicus*

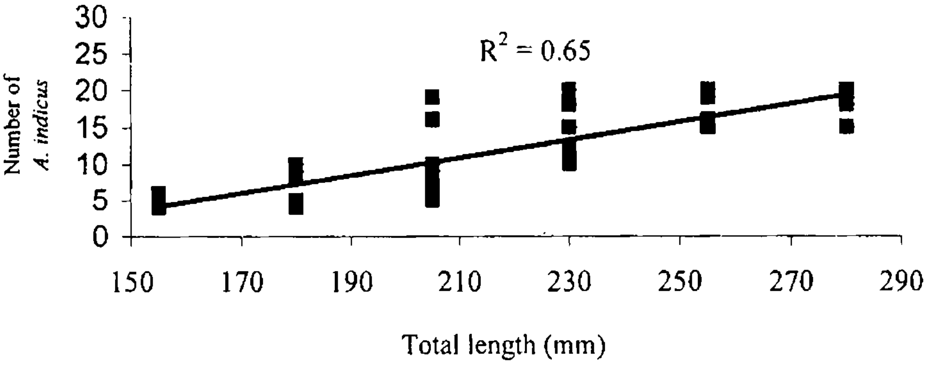
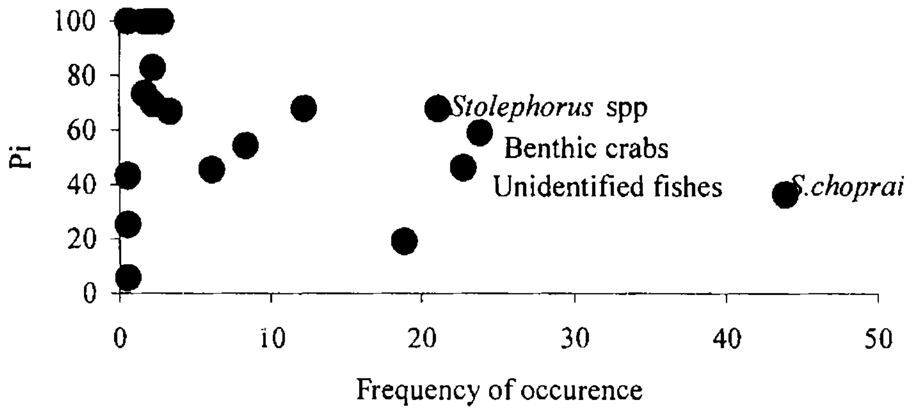


Fig. 4.6.9. Amundson plot for *N. japonicus* showing prey-specific abundance (Pi)



4.7. *Nemipterus mesoprion*

4.7.1. General diet composition

The dietary composition of *N. mesoprion* was dominated by three major food categories: fishes, crustaceans, and molluscs (Table 4.7.1). Crustaceans, which made up the highest proportion in occurrence (89.2%) and number (91.0%), formed the most important prey group (%IRI =90.6) followed by teleost fishes (%IRI= 6.4) and molluscs (%IRI= 3.0%). Of the crustaceans, *Acetes indicus* (%IRI= 57.0) and *Solenocera choprai* (%IRI= 33.1) were most important. The mean number and weight of prey per stomach were 5.84 ± 14.0 and 0.79 ± 1.2 g respectively. When considering frequency of occurrence, *N. mesoprion* fed most frequently on *S. choprai* (%FO= 46.2) and *A. indicus* (%FO= 31.2). Among teleosts, unidentified fishes were significant by occurrence (16.5%), weight (11.5%) and by number (2.2%) and thus ranked third in diet (%IRI= 4.60).

In terms of number, *A. indicus* (%N= 75.5%) followed by *S. choprai* (%N= 13.6%) were most abundant in the diet. By weight, *S. choprai* (%W= 21.7) followed by *L. duvauceli* (%W= 20.2) and *A. indicus* (%W= 14.6) were largely consumed. Other fish groups such as *N. mesoprion* (%W=6.9), *Stolephorus* spp (%W= 4.4), *Saurida undosquamis* (%W= 4.02), *Bregmaceros* spp (%W= 3.5, Plate 2*e*), *Grammoplites suppositus* (%W= 2.6) and *Johnius* spp (%W= 2.7) were also eaten. Fishes such as *Polynemus* spp, *Pseudorhombus* spp, *Cynoglossus macrostomus* and fish juveniles formed a minor component of the diet in terms of occurrence, number and by weight. Among the crustaceans, *Oratosquilla nepa* and crab juveniles were infrequent in diet and among cephalopods, octopus was consumed but at low levels.

4.7.2. Feeding intensity

Fishes with empty stomachs dominated during the whole year in *N. mesoprion*. Its proportion reached as high as 60.7 % in the pre-monsoon season. Fishes with active feeding was observed to be higher in the monsoon and post-monsoon seasons and, fishes with poor feeding were higher in the monsoon (Table 4.7.2). There was no significant variation in the feeding intensities among seasons (χ^2 test, df= 6, P>0.001)

Empty stomachs were common in all the length groups. Its proportion increased steeply from 106-135 mm to 196-225 mm length group then it decreased in the largest length group (>225 mm) (Table 4.7.3). Likewise, fishes with poor feeding condition was higher in smaller groups (<105 mm). Fishes of the largest length group (>225 mm) were relatively very active in feeding. However, there was no statistically significant variation in the feeding intensities among the length groups (χ^2 test, df= 15, P>0.001)

4.7. 3. Seasonal variations in feeding

The diet of *N. mesoprion* was uniform throughout the year. *A. indicus* and *S. choprai* were highly important to the fish during the whole year (Table 4.7.4). In the pre-monsoon season, *A. indicus* (%IRI= 52.3) followed by *S. choprai* (32.0) and *Bregmaceros* spp (6.8) formed the major diet. Low level of cannibalism was observed in the pre-monsoon when it fed on the juveniles of the same species. Significant difference in the number of major prey categories was found among the seasons (χ^2 test, df= 6, P<0.001, Table 4.7.5). During the monsoon, both *A. indicus* and *S. choprai* contributed >90% of the total IRI. In the post-monsoon, *A. indicus* was highly preferred (%IRI=63.4) followed by *S. choprai* and unidentified fishes. Importance of *L. duvauceli* and unidentified fishes gradually increased from the pre-monsoon to post-monsoon season.

4.7.4. Ontogenetic variations in feeding

S. choprai and *A. indicus* formed major portion of the diet in all the length groups (Table 4.7.6). Fishes of smaller length groups (<105 mm) were highly specialized on *O. nepa* (%IRI= 62.1) and unidentified fishes (%IRI= 36.1). Apparently, *S. choprai* and *A. indicus* were not so important for these groups. Significant differences occurred in major prey categories among the length groups (χ^2 test, df= 15, P<0.001, Table 4.7.7). Major variation came from the number of prawns and fishes. There was an increase in preference to *A. indicus* from 106 to 195 mm and thereafter its proportion again diminished. Diet of fishes in 106-135 mm showed an increase in proportion of *S. choprai* (%IRI= 68.6) followed by *A. indicus* (%IRI= 28.2) and unidentified fishes (%IRI=2.7). Diet of fishes in 136-165 mm consisted almost solely of *A. indicus* (%IRI= 57.7), *S. choprai* (%IRI= 30.2) and unidentified fishes (%IRI= 8.1). Fishes ranging from 166-195 mm mainly ate *A. indicus* (%IRI= 72.0). Diet of fishes in 196-225 mm were mainly consisted of *A. indicus* (%IRI= 51.3), *S. choprai* (%IRI=27.4) and unidentified fishes (%IRI= 15.4). Diet of largest individuals (>225mm) was characterized by increased incidence of *L. duvauceli* (%IRI= 46.4).

4.7.5. Variation in diet breadth and trophic level

The mean diet breadth was highest in the pre-monsoon (4.30 ± 0.7) followed by the post-monsoon (3.91 ± 1.26) (Fig 4.7.1). Diet breadth was less in the monsoon season with a mean of 3.35 ± 1.23. A distinct increase in diet breadth was observed from the smallest (<105 mm) to 166-195 mm length groups thereafter it again decreased with an average of 4.58 ± 2.16 (Fig 4.7.2). For the smaller fish groups (<165 mm), diet breadth was less (3.83 ± 2.47) when compared to the larger (>165 mm) length groups (5.34 ± 1.96).

The mean annual trophic level calculated was 4.10 ± 0.29 and the trophic level varied significantly with changing seasons. Fishes in the pre-monsoon season (4.22 ± 0.22) had comparatively higher values of trophic level and lower values during the monsoon (3.94 ± 0.36) and thereafter again increased in the post-monsoon (4.06 ± 0.34). Ontogenetically, trophic level increased with length (4.14 ± 0.30). For smaller fishes (<165 mm), the mean trophic level was 3.99 ± 0.25 and for larger groups (>165 mm) it was 4.28± 0.31 (Fig 4.7.2).

4.7.6. Diet similarities

Highest similarity in the diet was observed between fishes sampled during the monsoon and post-monsoon seasons (76.6%). The second highest similarity was between the monsoon and pre monsoon seasons (74.1%) (Fig 4.7.3). Diet of fishes of 136-165 and 196-225 mm length groups were highly similar (79.4%) due to almost an equal proportion of the dominant prey, *A. indicus* (Fig 4.7. 4). Significant diet similarity was also observed between 106-135 and 136-165 mm length groups (73%) and 136-165 and166-195 mm length groups (72.4%).

4.7.7. Prey-predator relationship

The two most important preys *viz., A. indicus* and *S. choprai* had positive relationship to the predator length. There was a gradual increase in the mean total length of *S. choprai* with the increase in the length of the predator (Fig 4.7.5). Similarly, mean total length of *A. indicus* increased in larger fishes (Fig 4.7.6). Thus, larger fishes preferred prey of larger length to meet the energy requirements.

4.7.8. Feeding strategy

The feeding strategy of *N. mesoprion* can be inferred from the Amundson plot as shown in Fig 4.7.7. *N. mesoprion* is essentially a specialized predator as the percentage of frequency of occurrence and the prey specific abundance of very few prey types was very high compared to other prey groups and the rare prey types were represented in the left corner of the plot. The prey specific abundance of *S. choprai*, *A. indicus* and unidentified fishes were comparatively very high and most often the fish was specialized on these prey items. Among these dominant prey types, *S. choprai* constituted more than 45% of frequency of occurrence and prey-specific abundance concurrently.

4.7.9. Prey selection

Seasonally, *N. mesoprion* showed strong preference to different prey groups available in the fishing ground (Table 4.7.8). Strong preference for the most favorite diet, *S. choprai* was observed only in the monsoon season. Though present in large proportions in the fishing grounds, complete avoidance of certain prey groups such as *P. stylifera, C. macrostomus* and *O. nepa* was observed. Similarly, unidentified fishes, fish juveniles and *L. duvauceli* were strongly selected only in the monsoon season. Moderate to strong selection was observed for *Johnius* spp, *N. mesoprion*, *G. suppositus* and crab juveniles in the post-monsoon season.

Table 4.7.1. Prey of *N. mesoprion* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N) and index of relative importance (IRI)

Prey	%FO	%W	%N	IRI	%IRI
Fishes					
Saurida undosqamis	1.15	4.02	0.20	4.87	0.10
Johnius spp	0.77	2.67	0.10	2.13	0.04
Nemipterus mesoprion	2.31	6.87	0.30	16.55	0.34
Grammoplites suppositus	1.92	2.64	0.25	5.57	0.11
Polynemus spp	0.38	0.78	0.05	0.32	0.01
Bregmaceros spp	8.46	3.54	1.82	45.33	0.92
Pseudorhombus spp	0.77	0.66	0.20	0.67	0.01
Stolephorus spp	1.92	4.40	0.35	9.14	0.19
Cynoglossus macrostomus	1.15	1.91	0.35	2.62	0.05
Fish juveniles	0.77	0.09	0.20	0.22	0.00
Fish scales	1.54	0.14	0.81	1.47	0.03
Unidentified fishes	16.54	11.48	2.17	225.83	4.58
Crustaceans					
Solenocera choprai	46.15	21.68	13.60	1628.27	33.05
Parapenaeopsis stylifera	5.77	1.90	0.91	16.24	0.33
Crab juveniles	4.62	1.38	0.71	9.65	0.20
Oratosquilla nepa	0.77	0.02	0.10	0.10	0.00
Acetes indicus	31.15	14.58	75.53	2807.18	56.99
Crustacean remains	0.77	0.36	0.10	0.35	0.01
Molluscs					
Loligo duvauceli	6.92	20.23	1.01	147.07	2.99
Octopus	0.38	0.40	0.05	0.17	0.00
Gastropods	1.92	0.06	0.46	0.99	0.02
Polychaetes	1.54	0.00	0.71	1.09	0.02
Detritus	1.15	0.17	0.00	0.20	0.00

Table 4.7.2. Seasonal variation in the feeding intensity (%)of *N. mesoprion*

Feeding intensity	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Active	19.66	26.97	23.31
Moderate	8.99	12.36	10.67
Poor	10.67	23.60	17.13
Empty	60.67	37.08	48.88

Table 4.7.3. Feeding intensity (%) of *N. mesoprion* in relation to length groups

Feeding intensity	Length groups (mm)					
	76-105	106-135	136-165	166-195	196-225	226-255
Active	20.00	21.23	15.43	16.36	11.54	29.63
Moderate	0.00	14.38	15.96	9.09	7.69	11.11
Poor	36.00	21.92	14.36	17.27	13.46	3.70
Empty	44.00	42.47	54.26	57.27	67.31	55.56

Table 4.7.4. Seasonal variation in %IRI of different prey of *N. mesoprion*

Prey	Pre-monsoon	Monsoon	Post-monsoon
Saurida undosquamis	0.77	0.00	0.00
Johnius spp	0.00	0.00	0.54
Nemipterus mesoprion	1.62	0.00	0.37
Grammoplites suppositus	0.10	0.03	0.31
Polynemus spp	0.06	0.00	0.00
Bregmaceros spp	6.81	0.11	0.00
Pseudorhombus spp	0.14	0.00	0.00
Stolephorus spp	0.00	0.10	1.08
Cynoglossus macrostomus	0.08	0.00	0.27
Fish juveniles	0.00	0.02	0.00
Fish scales	0.01	0.08	0.00
Unidentified fishes	1.29	4.57	10.42
Solenocera choprai	31.96	41.41	18.86
Parapenaeopsis stylifera	0.88	0.00	0.09
Crab juveniles	0.77	0.02	0.14
Oratosquilla nepa	0.00	0.00	0.00
Acetes indicus	52.34	50.98	63.43
Crustacean remains	0.00	0.00	0.10
Loligo duvauceli	2.14	2.68	4.14
Octopus	0.03	0.00	0.00
Gastropods	0.71	0.00	0.12
Polychaetes	0.08	0.00	0.14
Detritus	0.20	0.00	0.00

Table 4.7.5. Two way contingency table analysis of the seasonal variation of major prey categories of *N. mesoprion*. (Values are number of stomachs observed in each seasons)

Prey groups	Season			N_i	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	56	45	34	135	9.90
Penaeid prawns	99	146	38	283	15.39
Acetes indicus	430	694	370	1494	3.44
Molluscs	14	9	11	34	5.20
N_i	599	894	453	1946	
χ^2	9.78	9.53	14.63		**33.94****

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df= 6

Table 4.7.6. Ontogenetic variation in %IRI of different prey of *N. mesoprion*

Prey	Length groups (mm)					
	76-105	106-135	136-165	166-195	196-225	226-255
Saurida undosquamis	0.00	0.00	0.07	0.00	0.00	8.49
Johnius spp	0.00	0.00	0.11	0.21	0.00	0.00
Nemipterus mesoprion	0.00	0.00	0.07	1.69	1.36	1.57
Grammoplites suppositus	0.00	0.00	0.01	0.84	0.92	0.00
Polynemus spp	0.00	0.00	0.07	0.00	0.00	0.00
Bregmaceros spp	0.00	0.29	2.38	1.91	0.00	0.00
Pseudorhombus spp	0.00	0.03	0.00	0.09	0.00	0.00
Stolephorus spp	0.00	0.00	0.00	0.91	0.00	3.03
Cynoglossus macrostomus	0.00	0.00	0.27	0.00	0.00	1.25
Fish juveniles	0.26	0.01	0.00	0.00	0.00	0.00
Fish scales	0.27	0.05	0.01	0.00	0.00	0.12
Unidentified fishes	36.12	2.68	8.03	1.76	15.41	4.16
Solenocera choprai	1.23	68.43	30.15	13.12	27.36	9.83
Parapenaeopsis stylifera	0.00	0.00	0.23	0.00	1.49	0.00
Crab juveniles	0.00	0.01	0.23	0.00	0.91	2.24
Oratosquilla nepa	62.12	0.00	0.00	0.00	0.00	0.00
Acetes indicus	0.00	28.29	57.71	72.01	51.26	22.33
Crustacean remains	0.00	0.00	0.00	0.00	0.19	0.61
Loligo duvauceli	0.00	0.00	0.64	7.37	1.10	46.37
Octopus	0.00	0.00	0.00	0.07	0.00	0.00
Gastropods	0.00	0.09	0.00	0.02	0.00	0.00
Polychaetes	0.00	0.01	0.01	0.00	0.00	0.00
Detritus	0.00	0.11	0.01	0.00	0.00	0.00

Table 4.7.7. Two way contingency table analysis of the ontogenetic variation of prey categories of *N. mesoprion*. (Values are number of stomachs observed in each length groups)

Prey groups	Length groups (mm)						N_i	χ^2
	76-105	106-135	136-165	166-195	196-225	226-255		
Fishes	27	28	53	32	8	10	158	68.2
Penaeid prawns	2	111	81	28	31	10	263	123.5
Acetes indicus	65	209	594	447	161	18	1494	31.0
Molluscs	0	7	4	11	3	6	31	47.8
N_j	94	355	732	518	203	44	1946	
χ^2	60.38	97.94	10.80	34.64	5.02	61.76		**270.5****

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df= 15

Tables 4.7.8. Seasonal Ivelev index of *N. mesoprion*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Saurida undosquamis	0.41	-	-
Johnius spp	-	-	0.65
Nemipterus mesoprion	-0.09		0.78
Grammoplites suppositus	0.38	-0.03	0.56
Polynemus spp*	-	-	-
Bregmaceros spp*	-	-	-
Pseudorhombus spp	0.77		-
Stolephorus spp	-	0.73	0.99
Cynoglossus macrostomus	-0.44	-	-0.22
Fish juveniles	-	0.87	-
Fish scales*	-	-	-
Unidentified fishes	-0.12	0.61	0.16
Solenocera choprai	0.36	0.93	0.23
Parapenaeopsis stylifera	-0.20	-	-
Crab juveniles	-	0.92	0.50
Oratosquilla nepa	-1.00	-0.83	-
*Acetes indicus**	-	-	-
Crustacean remains*	-	-	0.43
Loligo duvauceli	-0.03	0.71	-0.09
Octopus*	-	-	-
Gastropods*	-	-	-
Polychaetes*	-	-	-
Detritus*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.7.1. Seasonal variation in trophic level and diet breadth of *N. mesoprion*

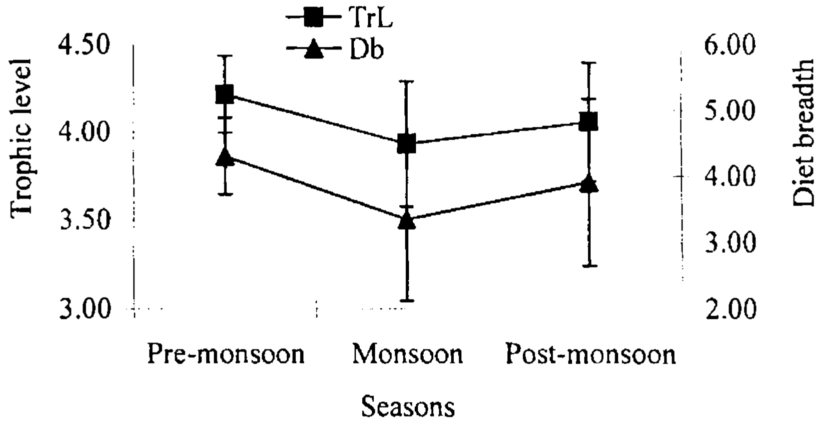


Fig. 4.7.2. Ontogenetic variation of trophic level and diet breadth of *N. mesoprion*

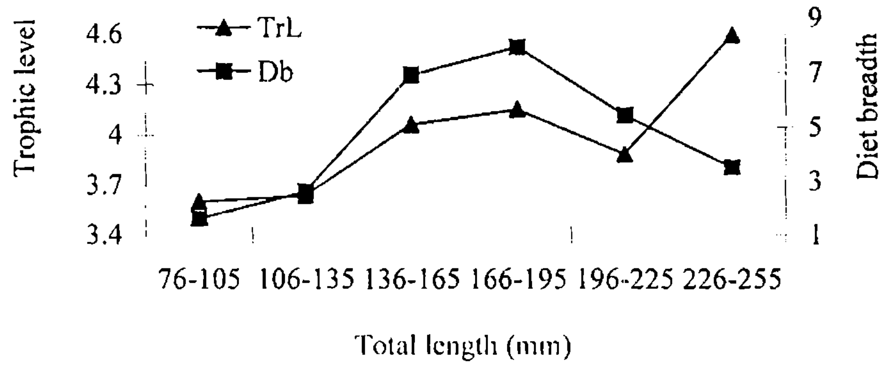


Fig. 4.7.3. Dendrogram based on %IRI values of different seasons of *N. mesoprion* using group average clustering

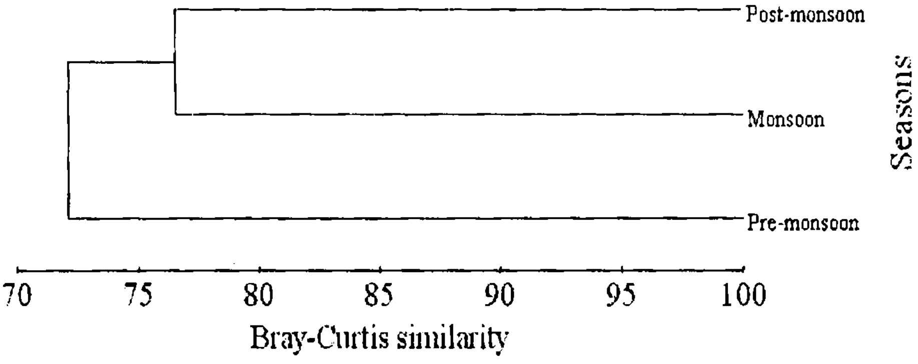


Fig. 4.7.4. Dendrogram based on %IRI values of different length groups of *N. mesoprion* using group average clustering

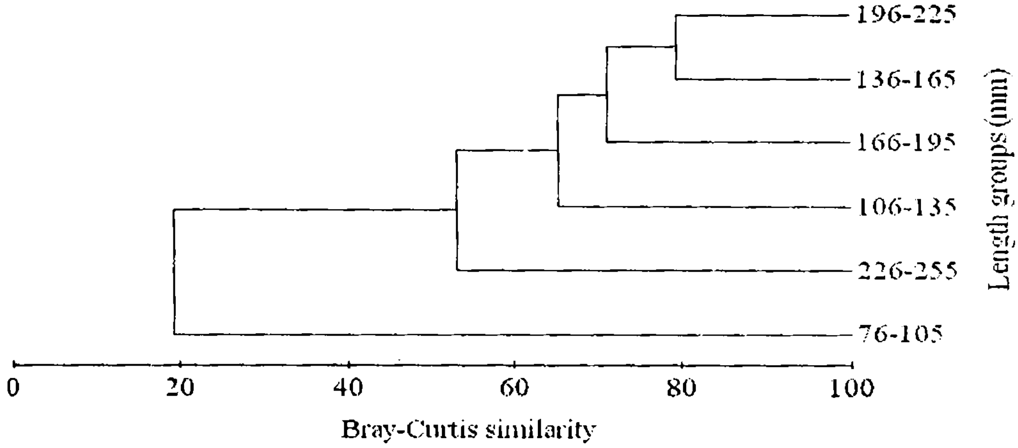


Fig. 4.7.5. Relationship between the mean total length of *S.choprai* and total length of *N.mesoprion*

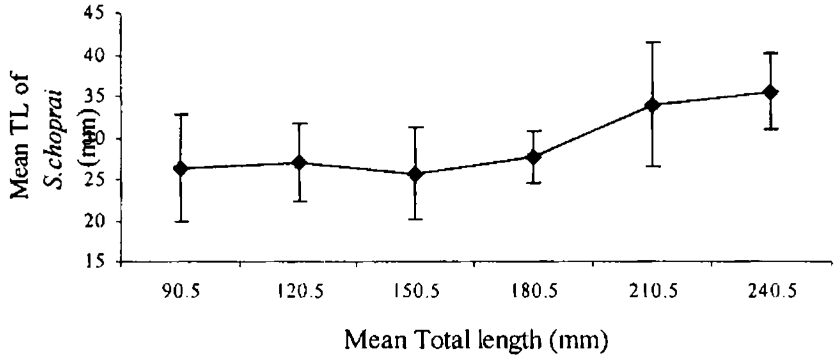


Fig. 4.7.6. Relationship between the mean total length of *A.indicus* and the total length of *N.mesoprion*

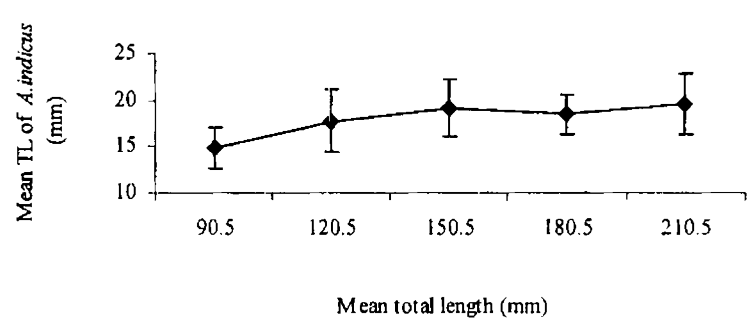
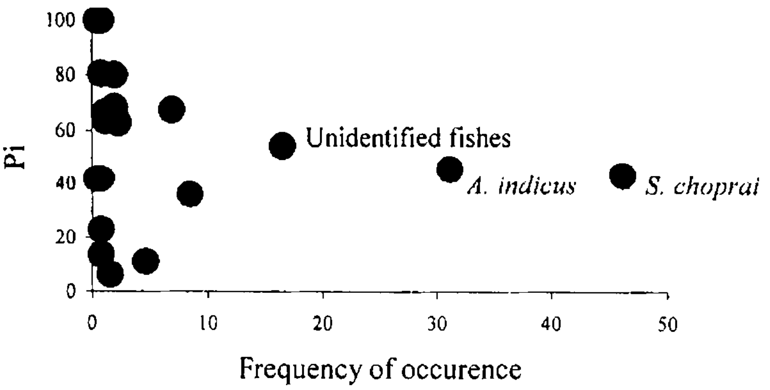


Fig. 4.7.7. Amundson plot for *N.mesorpion* showing prey-specific abundance (Pi)



4.8. *Leiognathus bindus*

4.8.1. General diet composition

The dietary components of *L. bindus* can be grouped under seven categories such as fishes, crustaceans, molluscs, foraminiferans, worms, diatoms and detritus respectively (Table 4.8.1). Detritus formed 68.8% of the total weight of stomach contents and 55.8% by IRI. The second most important food category was crustaceans (%IRI=28.0), which included mysids, copepods, amphipods, and crustacean remains (Plate 2*i*). This formed 35.1 % of total number of food and 15.5% of total weight and occurred in 78.0 % of the stomachs examined. Among the crustaceans, copepods, which occurred in 44.7 % of stomachs, formed the most abundant and most preferred prey item (%IRI=24.5). By weight, mysids constituted 6.7% of the total weight. Among the other crustaceans, amphipods, protozoans were less frequent in the diet of *L. bindus*

Fish ranked third in importance (%IRI= 6.5) and scales from the cycloid fishes formed the main fraction of the fish diet by frequency of occurrence (%FO=22.0), number (%N= 13.9) and weight (%W= 3.4). Among the other fish items, ctenoid scales and eggs were very rarely eaten by *L. bindus*.

Next to the crustaceans, diatoms constituted the second most abundant (%N=14.6) prey category and among these, *Coscinodiscus* spp (%IRI= 1.9) and other diatoms (%IRI= 2.5) were significant to *L. bindus*. Other diatoms, such as *Pleurosigma* spp, *Skeletonema* spp, *Biddulphia* spp and *Flavella* spp were recorded infrequently.

Polychaetes were recorded in 10.6 % of the stomachs and accounted for 3.2 % of total IRI. Molluscs, nematode worms and foraminiferans were least important prey groups for *L. bindus*.

4.8.2. Feeding intensity

The intensity of feeding in *L. bindus* showed wide variations seasonally (Table 4.8.2). Proportion of fishes with empty stomach was high in the pre-monsoon season and, fishes with poor feeding were dominant in the monsoon and the post-monsoon seasons and were significant (χ^2 test, df= 6, P<0.001, Table 4.8.2). Among the seasons, the major variation came from monsoon. Moderately and poorly fed fishes caused major variation among different feeding intensities. With increase in length, proportion of fishes with empty stomach was found to increase (Table 4.8.3). Poorly fed fishes made up higher proportion in the lower length groups and it was greatest at 57.1% in the smallest length group (<81 mm) and their proportion gradually reduced in the larger fishes. There was no significant difference in feeding intensity among different length groups (χ^2 test, P>0.001). Fishes with moderate feeding was generally higher in smaller fishes but actively fed fishes formed higher proportion in larger fishes.

4.8.3. Seasonal variation in feeding

Detritus formed substantial proportion of the diet throughout the seasons. Next to detritus, copepods formed a continuous source of diet during the whole period. However, in the monsoon season, cycloid fish scales (%IRI= 39.6) were the most important (Table 4.8.4). The two way contingency analysis on the number of major prey categories showed that significant difference existed among seasons (χ^2 test, df= 8, P<0.001, Table 4.8.5). The monsoon and pre-monsoon seasons were the source of variation among the seasons. Among the prey groups, the main variation came from foraminiferans and worms. In the pre-monsoon and the post-monsoon seasons, detritus followed by copepods and polychaetes were predominant. Significant percentages of diatoms were also recorded in pre-monsoon. During the monsoon season, in addition to cycloid fish scales, detritus and copepods were also highly preferred. Other diatoms such as *Coscinodiscus* spp, and nematode worms and bivalves also constituted important prey groups in the post-monsoon season.

4.8.4. Ontogenetic variations in feeding

Detritus constituted substantial proportion of diet in all length groups. Copepods, next to detritus, were the second most important prey in all length groups (Table 4.8.6). Amphipods, though minor in quantity, formed a regular source in the diet. Significant differences in the number of major prey categories were found in length groups (χ^2 test, df= 20, P<0.001, Table 4.8.7). Among the length groups, fishes of 106-111 and 88-93 mm groups showed major variations. Worms and diatoms were the two major source of variation among prey categories. In the smallest length (76-81 mm), next to detritus, ctenoid fish scales (%IRI= 18.3) followed by copepods (%IRI= 13.0), foraminiferans (%IRI= 6.5) and amphipods (%IRI= 4.9) were the most important items. Individuals of the length groups 82-87 and 88-93 mm fed almost equally on detritus, copepods and cycloid fish scales. In 94-99 mm length groups, in addition to copepods and detritus, third most important prey was polychaetes (%IRI=7.5). Next to detritus, diet of individual of the length group 100-105 mm were dominated by copepods, mysids, polychaetes and diatoms especially *Coscinodiscus* spp. Detritus (%IRI= 46.7) and copepods (%IRI= 36.7) respectively formed the first and second most important diets for the largest group (>106 mm).

4.8.5. Variation in diet breadth and trophic levels

Diet breadth and trophic level of *L. bindus* had distinct temporal and ontogenetic variations. The monsoon season exhibited followed the highest diet diversity (Fig 4.8.1). The mean diet breadth in the post-monsoon season was 2.40 ± 0.40 and in the pre-monsoon, it was only 1.75 ± 0.7. Ontogenetically, diet breadth had wide variation in all length groups with a mean diet breadth of 1.99 ± 1.10 (Fig 4.8.2). The greatest diet breadth was recorded for the individuals of the length from 88 to 93 mm (4.23). The mean diet breadth of smaller fishes (<93 mm) was generally higher (2.44 ± 1.56) than larger fishes (1.55 ± 0.16).

The mean annual trophic level was 2.42 ± 0.27. During the monsoon season, large proportion of fish scales increased the trophic level to 2.89. The mean trophic level of the post-monsoon (2.47 ± 0.21) was higher than that of the pre-monsoon season (2.25 ± 0.18). With increase in the length of *L. bindus*, trophic level was almost uniform in all the length groups. The mean trophic level of the smaller length groups (<93 mm) was comparatively greater (2.38 ± 0.28) than the larger fishes (2.21 ± 0.06). However, for 88-93 length groups, the trophic level was 2.69 due to large proportion of fish and crustaceans.

4.8.6. Diet similarities

Highest similarity in diet was observed between the fishes of the pre-monsoon and post-monsoon seasons (76.3%). Similarly, the monsoon and pre-monsoon seasons had higher similarity in feeding (61%, Fig 4.8.3). Among the different length groups, highest similarity in diet was observed for 82-87 and 88-93 mm length groups (79.5%). The length group 94-99 and 100-105 mm had the second highest similarity (78.5%) (Fig 4.8.4). Due to different prey composition, weak similarity in feeding was observed for 76-81 and 100-105 mm length groups.

4.8.7. Prey-predator relations

The mean number of copepods gradually decreased from small length groups to larger fishes (Fig 4.8.5). Similarly, larger length groups were observed to avoid detritus as the mean weight of detritus gradually reduced in them (Fig

4.8.6). However, the mean weight of copepods as against number, showed a decreasing trend towards larger length groups (Fig 4.8 7).

4.8.8. Feeding strategies

The prey-specific abundance plot of *L. bindus* with twenty different prey groups showed highly specialized feeding strategy (Fig 4.8.8). *L. bindus* was observed to specialize on detritus throughout the growth periods as well as in seasons. Among the different prey groups only detritus had high values of both prey-specific abundance and frequency of occurrence. The point denoted by detritus in the plot was separated from the remaining prey groups due to specialization by *L. bindus*. Next to detritus, specialization was observed on copepods throughout the period. Other prey groups were congregated to the corner as they were infrequently observed in the stomach.

Table 4.8.1. Prey of *L. bindus* in terms of frequency of occurrence (%FO), volumetric (%V), numerical (%N), and index of relative importance (IRI)

Prey	**%FO**	**%V**	**%N**	**IRI**	**%IRI**
Fish					
Fish scales (cycloid)	21.99	3.39	13.93	157.84	6.13
Fish scales (ctenoid)	2.84	0.21	1.19	1.65	0.06
Fish eggs	7.80	0.42	1.72	6.93	0.27
Crustaceans					
Mysids	14.89	6.68	2.21	54.90	2.13
Copepods	44.68	5.81	28.25	631.13	24.52
Amphipods	12.77	2.80	3.36	32.59	1.27
Tintinids	3.55	0.09	0.80	1.31	0.05
Crustacean remains	2.13	0.12	0.44	0.50	0.02
Molluscs					
Gastropods	5.67	1.90	1.50	8.01	0.31
Bivalves	5.67	2.94	1.86	11.29	0.44
Diatoms					
Coscinodiscus spp	15.60	0.02	7.69	49.89	1.94
Pleurosigma spp	9.22	0.03	3.67	14.14	0.55
Skeletonema spp	2.84	0.00	1.24	1.46	0.06
Biddulpia spp	2.13	0.00	0.93	0.82	0.03
Flavella spp	2.13	0.19	0.27	0.40	0.02
Other diatoms	5.67	0.01	14.59	64.39	2.50
Worms					
Nematods	18.44	0.23	6.85	6.25	0.24
Polychaetes	10.64	3.61	7.12	82.00	3.19
Foraminiferans	2.13	2.77	2.39	12.13	0.47
Detritus	50.35	68.79	0.00	1436.59	55.81

Table 4.8.2. Two-way contingency table analysis of seasonal variation of feeding conditons of *L. bindus*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each seasons)

Feeding intensity	Seasons			N_i	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Active	24	0	14	38	5.11
	(20.7)	(0.0)	(13.1)		
Moderate	16	7	10	33	9.82
	(13.8)	(38.9)	(9.3)		
Poor	24	7	48	79	10.14
	(20.7)	(38.9)	(44.9)		
Empty	52	4	35	91	3.41
	(44.8)	(22.2)	(32.7)		
N_i	116	18	107	241	
χ^2	8.49	12.54	7.45		**28.48****

N_i, total numbers by species; N_j, total numbers by seasons

**, $P < 0.001$, df = 6

Table 4.8.3. Feeding intensity (%) of *L. bindus* in relation to length groups

Feeding intensity	Length groups (mm)					
	76-81	82-87	88-93	94-99	100-105	106-111
Active	0.00	11.63	15.58	8.57	17.86	20.00
Moderate	14.29	20.93	9.09	20.00	7.14	0.00
Poor	57.14	39.53	36.36	30.00	25.00	40.00
Empty	28.57	27.91	38.96	41.43	50.00	40.00

Table 4.8.4. Seasonal variation in %IRI of prey of *L. bindus*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Fish scales (cycloid)	3.49	39.62	0.47
Fish scales (ctenoid)	0.00	0.41	0.02
Fish eggs	0.39	0.00	0.35
Mysids	1.52	0.00	4.10
Copepods	20.84	24.28	21.39
Amphipods	1.21	0.61	0.68
Tintinids	0.18	0.00	0.04
Crustacean remains	0.33	0.00	0.00
Gastropods	0.00	0.42	1.00
Bivalves	0.05	0.49	2.74
Coscinodiscus spp	1.17	0.10	3.85
Pleurosigma spp	1.05	1.05	0.03
Skeletonema spp	0.33	0.00	0.00
Biddulpia spp	0.13	0.00	0.00
Flavella spp	0.00	0.15	0.01
Foraminiferans	0.00	0.47	0.84
Polychaetes	6.12	0.00	4.62
Nematodes	0.00	0.00	2.27
Diatoms	1.87	0.00	5.03
Detritus	61.32	32.39	52.57

Table 4.8.5. Two-way contingency table analysis of the seasonal variation of major preycategories of *L. bindus*. (Values are number of stomachs observed in each seasons)

Prey groups	Seasons			N_i	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fish remains	74	205	62	341	459.5
Small crustaceans	280	162	466	908	7.3
Molluscs	**4**	17	**76**	**97**	**28.2**
Diatoms	215	27	380	622	74.4
Worms	85	0	353	438	134.3
N_i	658	411	1337	2406	
χ^2	49.10	503.95	150.56		703.6**

N_i, total numbers by species; N_j, total numbers by seasons

**, $P < 0.001$, $df = 8$

Table 4.8.6. Ontogenetic variation in %IRI of prey of *L. bindus*

Prey	Length groups (mm)					
	76-81	82-87	88-93	94-99	100-105	106-111
Fish scales (cycloid)	0.00	7.70	11.55	2.03	1.45	3.43
Fish scales (ctenoid)	18.25	0.05	0.05	0.00	0.00	0.00
Fish eggs	0.00	0.14	0.05	1.45	0.00	0.00
Mysids	0.00	0.05	5.31	2.04	8.98	1.42
Copepods	12.98	25.91	26.80	21.87	9.96	36.72
Amphipods	4.94	0.88	1.45	0.73	0.84	3.90
Tintinids	0.00	0.02	0.02	0.10	0.00	2.38
Crustacean remains	0.00	0.00	0.00	0.10	0.49	0.00
Gastropods	0.00	0.88	0.79	0.02	0.00	0.00
Bivalves	0.00	0.00	1.62	0.39	0.00	4.21
Coscinodiscus spp	0.00	2.44	4.35	0.19	4.94	0.00
Pleurosigma spp	0.00	0.48	0.03	1.61	1.03	1.18
Skeletonema spp	0.00	0.00	0.03	0.45	0.00	0.00
Biddulpia spp	0.00	0.00	0.00	0.06	2.27	0.00
Flavella spp	0.00	0.01	0.10	0.00	0.00	0.00
Foraminiferans	6.53	0.74	1.38	0.00	0.00	0.00
Polychaetes	0.00	1.73	2.32	7.45	6.71	0.00
Nematodes	0.00	2.97	0.00	0.00	0.00	0.00
Diatoms	0.00	0.73	6.07	1.94	5.15	0.00
Detritus	57.31	55.27	38.09	59.56	58.20	46.76

Table 4.8.7. Two way contingency table analysis of ontogenetic variation of prey categories of *L. bindus*. Values are number of stomachs observed in each length groups

Prey groups	Length groups (mm)						N_i	χ^2
	76-81	82-87	88-93	94-99	100-105	106-111		
Fish remains	11	150	141	68	7	4	381	102.5
Small crustaceans	12	246	236	220	38	41	793	63.7
Molluscs		18	39	15		4	76	24.6
Diatoms		126	270	173	70	3	642	200.2
Worms		182	24	92	18	316	632	707.4
N_j	23	722	710	568	133	368	2524	
χ^2	31.8	35.8	203.2	37.0	58.6	732.0		**1098.4****

N_i, total numbers by species; N_j, total numbers by length groups
**, $p < 0.001$, df = 20

Fig. 4.8.1. Variation in deit breadth and trophic level of *L. bindus*

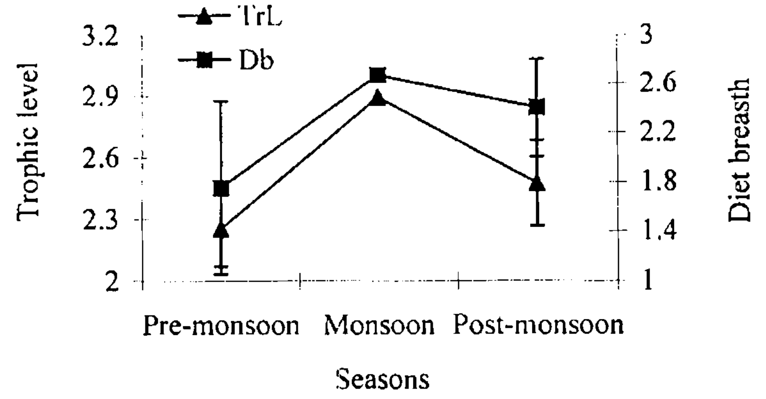


Fig.4.8.2. Variation in diet breadth and trophic level of *L. bindus*

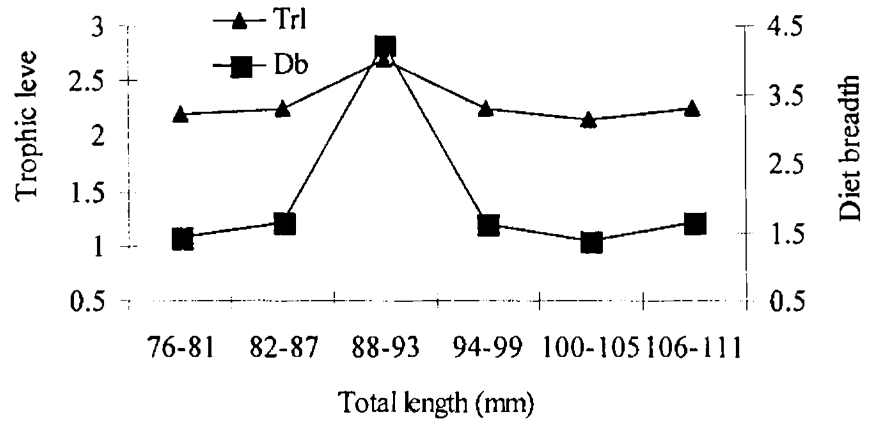


Fig. 4.8.3. Dendrogram based on %IRI values of different seasons of *L. bindus* using group average clustering

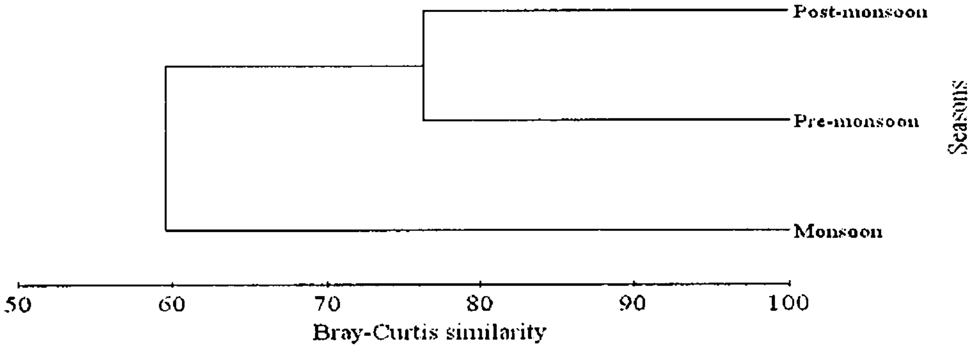


Fig. 4.8.4. Dendrogram based on %IRI values of different length groups of *L. bindus* using group average clustering

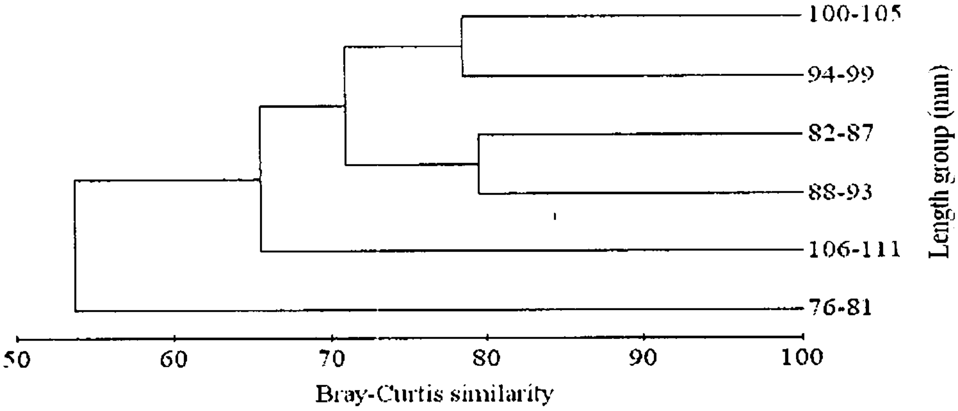


Fig. 4.8.5. Relationship between the mean number of copepods and mean total length of *L. bindus*

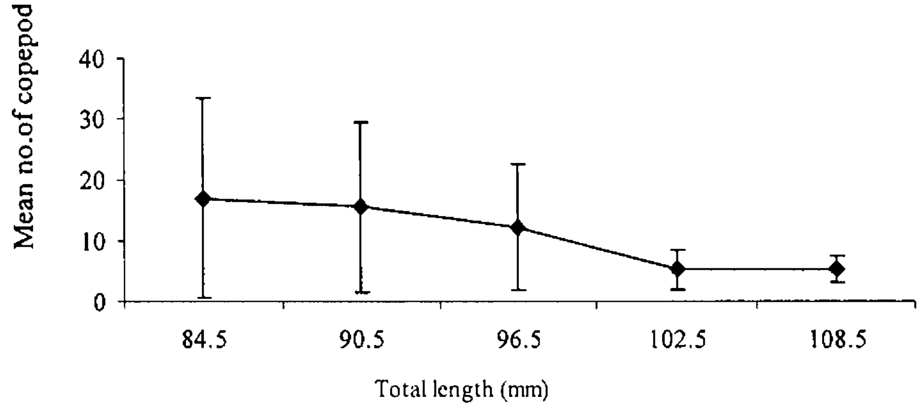


Fig. 4.8.6. Relationship between mean weight of detritus and total length of *L. bindus*

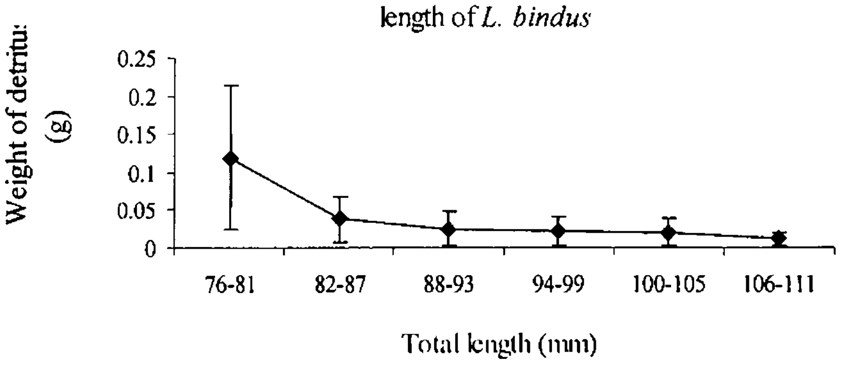


Fig. 4.8.7. Relationship between mean weight of copepods and total length of *L. bindus*

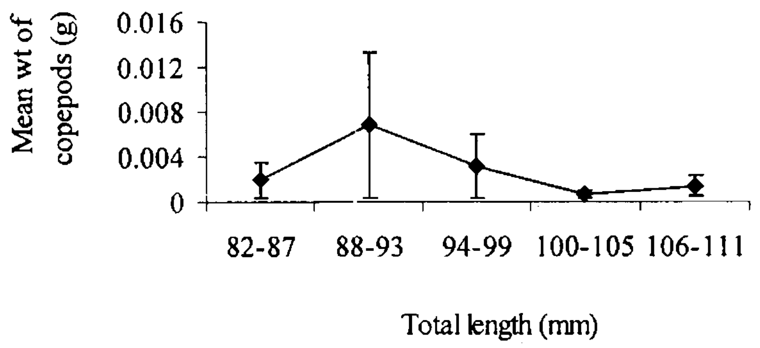
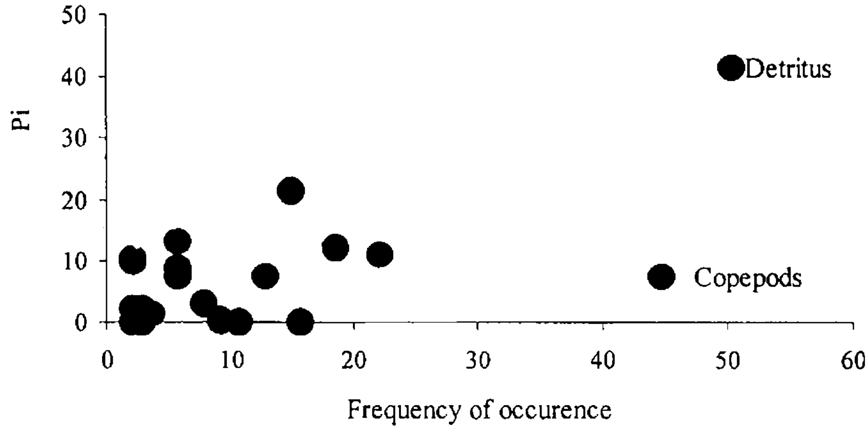


Fig. 4.8.8. Amundson plot for *L. bindus* showing prey-specific abundance (Pi)



4.9. *Cynoglossus macrostomus*

4.9.1. General diet composition

The diet of tongue sole consisted primarily of detritus, fishes, crustaceans, molluscs, foraminiferans, worms, diatoms and sand. Detritus was most important (%IRI= 38.3) occurring in 73.7% of the stomachs analyzed (Table 4.9.1). The mean weight of prey was 0.038g/ stomach.

Worms occurred in 48.4 % total stomachs examined of which polychaetes (%IRI=19.7) formed as much as 15.4 % of total number of food and 18.2 % of total weight (Plate 2*h*). Molluscs constituted by gastropods and bivalves were the next important diet, which contributed to 10.6% of IRI. Bivalves were the most abundant mollusc (%N=12.7), gastropods being the most frequent (%FO=19.6) and highly consumed (%V=5.2) items. Fishes could not be successfully identified from the diet, however, digested fishes contributed to 7.5% of total IRI. Fish scales were the more frequent (%FO= 15.0) and more abundant (%N= 8.1) fish category. Fish eggs were less important in the diet. Foraminiferans were the most abundant (%N=21.2) single prey category, with an IRI 10.2%.

Crustaceans with high prey diversity were the next the important diet of tongue sole (%IRI= 9.4). Mysids, copepods, and amphipods, formed a major portion of the food. Mysids were very important (%IRI= 5.1) and they occurred most frequently (%FO= 19.6) and were largely consumed (%V= 5.5). Copepods were the most abundant crustaceans (%N= 9.0), which occurred in 5.2% of the total stomachs analyzed. Crustacean appendages and squilla larvae were also observed in the diet.

Diatoms constituted by *Pleurosigma* spp and *Coscinodiscus* spp were less frequent and less important in the diet of tongue sole. Sand, which might have been included when the fish forages on the bottom, also had very low IRI value (<2).

4.9.2. Feeding intensity

As the stomach of tongue sole is not well demarcated from the remaining gut, the fullness of foregut was examined to understand feeding intensity seasonally and ontogenetically. It was observed that most often the gut contained prey components. Fishes with poor feeding condition dominated in all the seasons (Table 4.9.2). During the pre monsoon and monsoon seasons, fishes with poor feeding condition were more compared to the post-monsoon.

Generally, actively feeding fishes were very rare in all seasons. There were significant differences (χ^2 test, df= 6, p<0.001) in the intensity of feeding by seasons (Table 4.9.2). Among different seasons the variation came from monsoon and among different feeding intensities, the variation was from poorly fed and empty fishes.

Percentages of poorly fed fishes were high in all the length groups of tongue sole. Its percentage was highest in large sized fishes with a peak of 75% in the largest length group of 156-165 mm (Table 4.9.3). The proportion of poorly fed fishes was higher in 126-135 mm length group (39.1%). However, it was absent in the largest length group. Percentage of moderately fed fishes was more in 116-125 mm length group and in the largest group (156-165mm), where it again increased to 25%. Actively fed fishes were absent in all the length groups except in 126-135mm length group. There was no significant difference in the occurrence of different intensity of feeding by different length groups (χ^2 test, df= 6, p>0.001).

4.9.3. Seasonal variation in feeding

Poychaetes and detritus formed important proportions in the diet of tongue sole during all the seasons (Table 4.9.4). There were significant differences in the number of prey categories of tongue sole in different seasons (χ^2 test, df= 6, P<0.001, Table 4.9.5). Prey abundance in the monsoon caused the main source of variation. Among different prey categories abundance of crustaceans caused significant variation. In the pre-monsoon season, tongue sole preferred different prey items. Polychaetes ranked first (%IRI= 37.2) followed by an equal proportion of both sand and detritus. Crustacean appendages and sand were also observed in high proportion in pre-monsoon. During the monsoon, preference to crustaceans especially copepods (%IRI= 25.7) and mysids were higher, besides large proportion of fish remains (%IRI= 21.2) and detritus (%IRI= 23.3) were also observed. During the post-monsoon season, again polychaetes were observed to be largely preferred followed by detritus and gastropods. Large proportions of formaniferans, fish scales, gastropods and bivalves were also observed in the prost-monsoon season.

4.9.4. Ontogenetic variations in feeding

Food items observed in the stomach contents of different length groups of tongue soles are given in Table 4.9.6. It could be seen that food items were less diverse in very small and very large length groups. Significant ontogenetic differences were found (χ^2 test, df= 15, P<0.001) in the number of major prey groups consumed (Table 4.9.7). Among the length groups, the main source of variation was from 156-165 and 146-155 mm groups. Among the prey groups, main source of variation came from foraminiferans and worms. The observations revealed that within the various length groups, the %IRI of detritus and polychaetes determined the choice of diet in all length groups. Detritus formed most important diet by IRI up to 145 mm length group thereafter polychaetes formed the important prey. Diet of fishes of <115 mm length was dominated by detritus (%IRI= 32.6) and polychaetes (%IRI= 30.8) followed by gastropods (%IRI= 21.35) and foraminiferans (%IRI= 9.0). The preference of diatoms was low in smaller length groups. Foraminiferans and polychaetes formed the second and third important food category after detritus in the diet of fishes of length between 116 and 135 mm. In 116-125 length groups, in addition to detritus, polychaetes and foraminiferans, it consumed considerable quantities of fish remains, mysids and gastropods.

In the diet of fishes between 126 and 135 mm, crustaceans formed high proportions in addition to detritus and foraminiferans. However, in 136-145 mm length groups, fish remains (%IRI= 14.6) formed important food items after detritus and polychaetes. In higher length groups above 145 mm, polychaetes dominated over other food categories. In 156-165 mm length groups this preference to polychaetes was found to increase.

4.9.5. Variation in diet breadth and trophic level

Tongue sole exhibited changes in diet breadth in relation to different seasons. The broadest diet was recorded in the post-monsoon with an average of 3.75 ± 0.26. Very low diet breadth was observed in the monsoon season (2.26 ± 0.83) (Fig 4.9.1). Large prey diversity resulted in an increased diet breadth in the pre-monsoon (3.50 ± 0.15). Ontogenetically, tongue sole showed distinct variation in diet diversity. Fishes of smaller length had broadest diet than that of adults. The mean diet breadth was 3.76 ±0.93. Fishes of length group (<135 mm) had the largest diet breadths with peak of 5.06 in 116-125 mm length groups (Fig 4.9.2). Adult tongue sole had a restricted diet in 156-165 mm length groups (2.35).

Seasonally, large proportion of fish remains caused an increased trophic level in monsoon (3.20 ± 0.83). However, the mean trophic level for the entire season was 2.71 ± 0.35. Fishes during the post-monsoon season had second highest trophic level (2.87 ± 0.26). Trophic level was related to length in tongue sole and it was highest in 136-145 mm (3.25) and 166-125 mm (2.88) length groups due to relatively high proportion of unidentified fishes.

4.9.6. Diet similarities

Bray-Curtis similarity showed showed that among different seasons, the pre-monsoon and post-monsoon seasons had higher similarity (75.9%) due to similar proportion of different prey items (Fig 4.9.3).

Significant level of diet similarity was found between 116-125 and 116-125 mm length groups (78.5%) (Fig 4.9.4). This group primarily fed nearly equal proportion of detritus, fish remains, crustaceans and worms. The second significant similarity in feeding was observed between 126-135 and 136-145 mm length groups (76.9%). These groups also shared major prey groups. The lowest value of diet similarity was in between 126-135 and 156-165 mm length groups (57%).

4.9.7. Prey-predator relationships

The abundance of two important prey types viz; polychaetes and foraminiferans showed an increasing trend in the abundance with the ontogenetic increase in length of tongue sole. The mean proportion of polychaetes increased with increase in length of tongue sole (Fig 4.9.5). However, the mean weight of polychaetes did not show significant relation with total length of tongue sole (ANOVA, $P>0.05$). Likewise, the mean proportion of foraminiferans showed an ontogenetic increase from the smallest length group to the larger fishes. However, in the largest length group a decrease in the proportion of both prey types were observed (Fig 4.9.6).

4.9.8. Feeding strategy

Fig 4.9.7 shows the Amundson plot of tongue sole to infer the feeding strategy. It is very clear that the tongue sole very often fed on detritus than any other prey type. As the percentage frequency of occurrence of detritus was very high in conjunction with high prey specific abundance, tongue sole employed a specialized feeding strategy. At the same time, the tongue sole was also specialized on polychaetes, foraminiferans, gastropods, mysids and copepods. Though prey specific abundance of sand was very high in the diet, it did not constitute one of the highly consumed preys as it was less often found in the stomach.

Table 4.9.1. Prey of *C. macrostomus* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	%O	%V	%N	IRI	%IRI
Fish					
Digested fish	10.46	31.36	2.36	352.61	7.53
Fish eggs	1.31	0.06	0.41	0.62	0.01
Fish scales	15.03	0.51	8.10	129.51	2.76
Crustaceans					
Squilla larvae	1.31	0.46	0.41	1.14	0.02
Mysids	19.61	5.45	6.67	237.49	5.07
Copepods	12.42	0.97	9.03	124.18	2.65
Amphipods	5.88	0.33	2.87	18.84	0.40
Cladocerans	1.31	0.06	0.51	54.73	0.02
Crustacean appendages	9.15	1.57	4.41	292.12	1.17
Molluscs					
Gastropods	19.61	5.15	9.74	121.12	6.24
Bivalves	13.73	2.09	12.72	203.21	4.34
Worms					
Nereis worms	0.65	0.21	0.31	0.34	0.01
Polychaetes	27.45	18.22	15.38	922.44	19.69
Foraminiferans	20.26	2.42	21.23	479.30	10.23
Diatoms					
Coscinodiscus spp	1.96	0.00	2.05	4.03	0.09
Cladocerans	0.65	0.00	0.21	0.13	0.00
Sand	6.54	6.81	3.59	67.97	1.45
Detritus	73.86	24.31	0.00	1795.72	38.33

Table 4.9.2. Two way contigency table analysis of seasonal variation of feeding intensity of *C. macrostomus*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each season)

Feeding intensity	Seasons			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Active	1	0	1	1	1.3
	(1.1)	(0.0)	(1.0)		
Moderate	18	7	4	11	16.3
	(20.2)	(13.5)	(4.0)		
Poor	49	28	45	73	27.3
	(55.1)	(53.8)	(44.6)		
Empty	21	17	51	68	32.9
	(23.6)	(32.7)	(50.5)		
N_j	89	52	101	153	
χ^2	9.7	56.8	11.3		77.9**

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df = 6

Table 4.9.3. Ontogenetic variation in the feeding intensity (%) of *C. macrostomus*

Feeding intensity	Length groups (mm)					
	106-115	116-125	126-135	136-145	146-155	156-165
Active	0.00	0.00	1.45	0.00	0.00	0.00
Moderate	0.00	18.37	13.04	10.53	12.00	25.00
Poor	63.16	42.86	46.38	52.63	56.00	75.00
Empty	36.84	38.78	39.13	36.84	32.00	0.00

Table 4.9.4. Seasonal variation in %IRI of prey of *C. macrostomus*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Digested fish	0.17	21.24	0.14
Fish eggs	0.51	0.00	0.50
Fish scales	0.50	0.00	7.26
Squilla larvae	0.96	0.00	5.05
Mysids	0.24	11.52	2.64
Copepods	1.44	25.72	0.02
Amphipods	0.17	2.26	0.02
Cladocerans	0.00	0.66	0.02
Crustacean appendages	11.48	1.83	2.47
Gastropods	10.52	1.69	11.27
Bivalves	0.62	1.95	8.23
Neries worms	1.59	0.00	0.28
Polychaetes	37.23	9.63	28.16
Foraminiferans	5.44	0.15	7.57
Coscinodiscus spp	0.39	0.00	0.29
Cladocerans	0.00	0.00	0.23
Sand	14.68	0.09	4.37
Detritus	14.07	23.26	21.48

Table 4.9.5. Two way contingency table analysis of seasonal variation of five prey groups of *C. macrostomus*. (Values are number of stomachs observed in each seasons)

Prey groups	Seasons			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fish remains	45	8	42	50	7.7
Crustaceans	146	133	58	191	126.0
Molluscs	119	26	104	130	12.1
Worms	152	18	98	116	20.8
Foraminiferans	85	5	66	71	22.3
N_i	547	190	368	558	
χ^2	6.4	142.9	39.6		**188.9****

N_i, total numbers by species; N_j, total numbers by season. **, $P < 0.001$, df = 6

Table 4.9.6. Ontogenetic variation in %IRI of prey of *C. macrostomus*

Prey	Length groups (mm)					
	106-115	116-125	126-135	136-145	146-155	156-165
Digested fish	3.54	12.68	1.02	14.55	3.80	0.00
Fish eggs	0.00	0.14	0.00	0.04	0.00	0.00
Fish scales	0.80	2.22	3.33	3.72	0.57	0.00
Squilla larvae	0.00	0.00	0.27	0.00	0.00	0.00
Mysids	0.60	8.06	2.18	7.67	3.75	1.91
Copepods	0.00	1.95	3.61	2.33	2.88	0.64
Amphipods	0.00	0.50	0.05	1.22	0.21	0.64
Pleurosigma	0.00	0.00	0.00	0.00	0.18	0.00
Crustacean appendages	0.00	0.14	2.86	0.40	3.84	0.00
Gastropods	21.35	8.09	3.48	4.09	7.95	8.83
Bivalves	0.00	5.34	4.07	8.82	0.19	0.00
Nereis worms	0.00	0.00	0.00	0.00	0.00	2.74
Polychaetes	30.79	10.58	9.89	16.92	39.91	57.95
Foraminiferans	9.01	19.53	14.85	4.18	1.93	4.25
Coscinodiscus spp	0.00	0.00	0.00	0.08	2.67	0.00
Cladocerans	1.32	0.00	0.00	0.03	0.00	0.00
Sand	0.00	5.18	1.52	0.50	0.00	0.00
Detritus	32.59	25.59	52.87	35.45	32.12	23.04

Table 4.9.7. Two way contingency table analysis of the seasonal variation of prey categories of *C. macrostomus*. (Values are number of stomachs observed in each length groups)

Prey groups	Length groups (mm)						N_j	χ^2
	106-115	116-125	126-135	136-145	146-155	156-165		
Fish remains	3	15	41	42	5		106	9.1
Crustaceans	4	24	85	78	37	5	233	21.0
Molluscs	8	39	69	80	17	6	219	5.2
Worms	10	12	45	55	15	16	153	28.1
Foraminiferans	20	45	85	41	10	6	207	32.8
N_j	45	135	325	296	84	33	918	
χ^2	16.8	16.4	4.8	13.7	18.6	25.9		**96.2****

N_i, total numbers by species; N_j, total numbers by length groups **, $P < 0.001$, df = 15

Fig. 4.9.1. Seasonal variation in trophic level and diet breadth of *C. macrostomus*

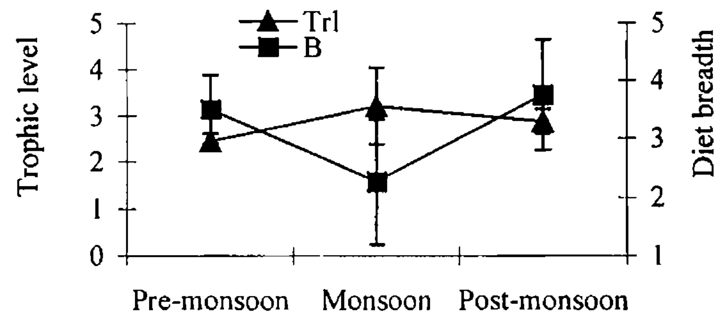


Fig. 4.9.2. Ontogenetic variation in trophic level and diet breadth of *C. macrostomus*

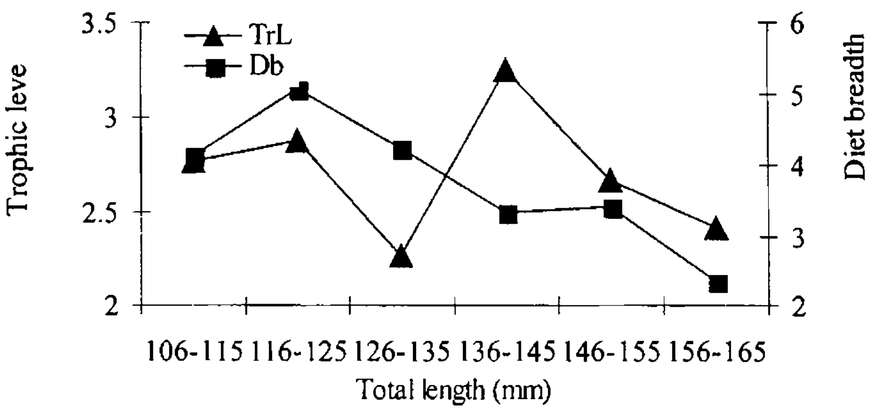


Fig. 4.9.3. Dendrogram based on %IRI values of different seasons of *C. macrostomus* using group average clustering

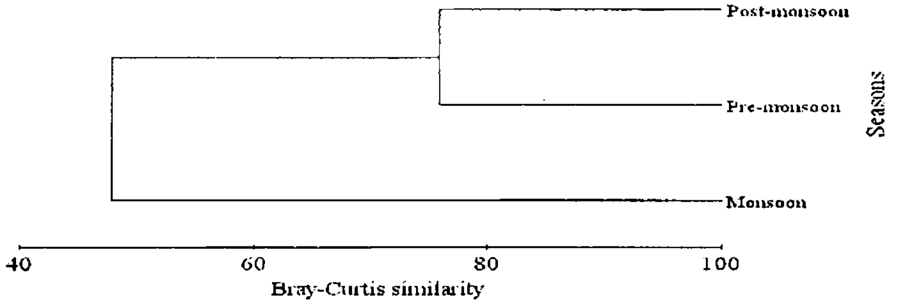


Fig. 4.9.4. Dendrogram based on %IRI values of different length groups of *C. macrostomus* using group average clustering

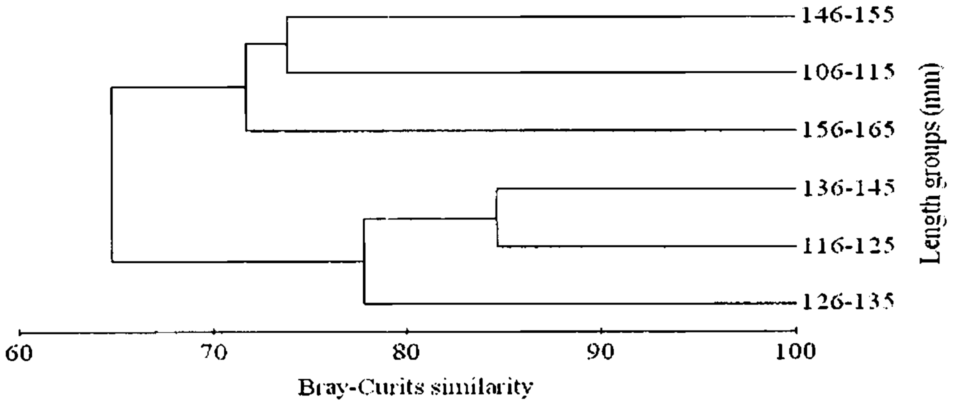


Fig. 4.9.5. Relationship between the number of polychaets and the total length of *C. macrostomus*

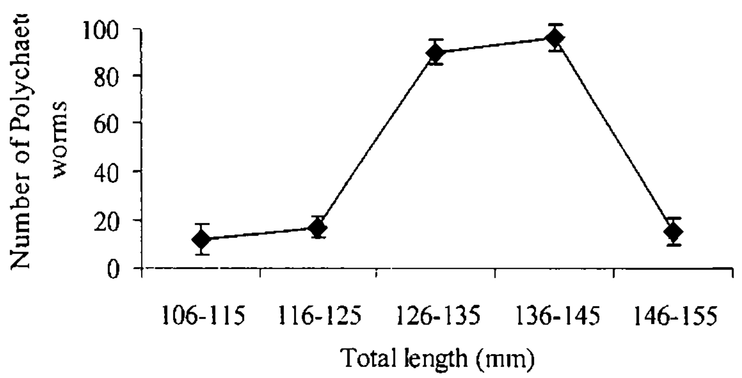


Fig. 4.9.6. Relationship between the number of foraminiferans and the total length of *C. macrostomus*

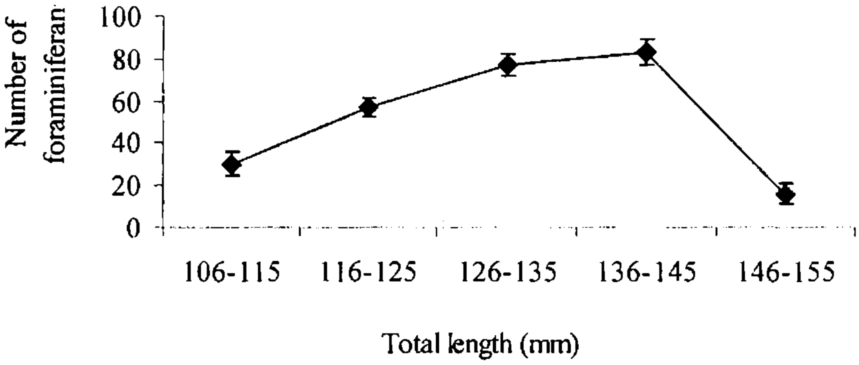
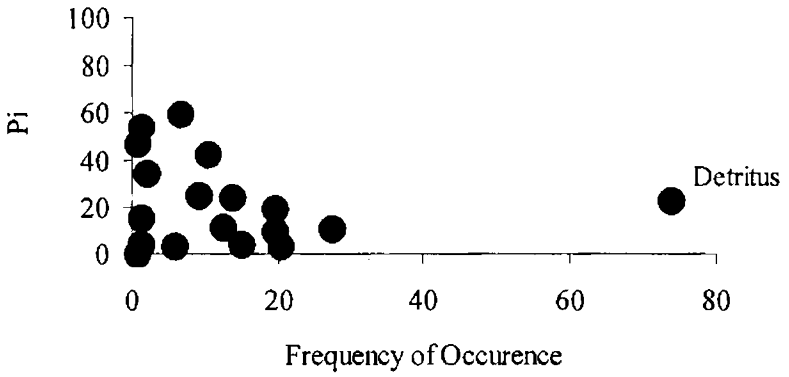


Fig. 4.9.7. Amundson plot for *C. macrostomus* showing prey-specific abundance (Pi)



4.10. *Pampus argenteus*

4.10.1. General diet composition

A total of sixteen prey taxa were identified from the gut of 228 individuals of the silver pomfret, *P. argenteus* examined. After grouping all prey items in to one of the five categories, crustaceans (%IRI= 48.2) and detritus (%IRI= 47.6) were the most important in diet (Table 4.10.1). Fishes, diatoms and worms were in decreasing order of importance. *P. argenteus* fed most often on crustaceans, copepods at 41.0 % being by far the most important item in the diet (Plate 2*j*). Among fish items, cycloid scales (%IRI= 1.1) and in diatoms, *Nitzschia* spp (%IRI= 1.3) were important. The most frequently occurred prey item was detritus (%FO= 67.1) followed by copepods (%FO= 51.5) and cycloid scales (%FO= 11.6). Among crustaceans, next to copepods the most frequently observed items were amphipods (%FO=9.3) and nauplii larvae (%FO= 7.5). Detritus (%V= 46.4) and amphipods (%V= 40.5) formed generally an important part of the diet by volume. A total of 1514 prey items were encountered, out of these, copepods alone formed (%N= 48.4) the largest proportion followed by *Nitzschia* spp (%N= 14.2) and *Coscinodiscus* spp (%N= 11.8). Among fish items cycloid scales (%N=6.1) was most abundant in the stomach. Diatoms together formed only 2.2 percentage of total IRI in the diet. Worms were least important item in the stomach.

4.10.2. Feeding intensity

The proportion of fishes with poor feeding condition was high throughout the season in *P. argenteus.* Their proportion was highest in the pre-monsoon followed by the monsoon season (Table 4.10.2). There was no significant difference in the number of fish with different feeding conditions (χ^2 test, df= 6, p>0.001). Fishes with empty stomachs were comparatively less in silver pomfrets, however, their proportion reached as high as 32% in the post-monsoon season. Ontogenetically, stomach conditions showed somewhat different trends among size groups. Percentage of empty stomachs was higher in large fishes which reached as high as 55. 7% in the largest length group, 271-300 mm (Table 4.10.3). Fishes with active feeding was observed to be highest in 241-270 mm (25%). Fishes with moderately fed stomachs were highest in younger fishes. Percentage of poorly fed fishes was higher in all length groups. However, there was no significant difference in the number of fishes with respect to feeding intensity (χ^2 test, df= 18, p>0.001).

4.10.3. Seasonal variation in feeding

Detritus and copepods, the most important prey groups, ranked first and second respectively throughout the season (Table 4.10.4). In none of the seasons, fish preys dominated the diet. During the pre-monsoon season, 65% of IRI was detritus followed by copepods (%IRI= 30.1). Diatoms such as *Nitzschia* spp were the next important prey in the pre-monsoon season. During the monsoon season, diatoms especially, *Coscinodiscus* spp formed third important diet after detritus and copepods. When approaching the post-monsoon season, importance of copepods increased to 38.5%. Fish remains constituted 2.4% by IRI in post-monsoon. There were significant seasonal differences (χ^2 test, df= 8, P<0.001) in the number of major prey groups consumed (Table 4.10.5). Among prey groups the variation mainly came from diatoms. Among seasons, the pre-monsoon and post-monsoon seasons were the source of variation.

4.10.4. Ontogenetic variations in feeding

Detritus and copepods were highly preferred in all the length groups of *P. argenteus*. The smaller sized fishes (<120 mm) ate mainly detritus (%IRI=55.6) and copepods (%IRI= 34.7); mysids and *Nitzschia* spp were also important for this group (Table 4.10.6). Copepods (%IRI= 9.7) and cycloid scales (%IRI= 3.3) were ranked 3rd and 4th important prey respectively in 121-150 mm size groups. Fishes of the size group 151-180 mm exclusively fed on detritus (%IRI= 71.7). In sizes >150mm copepods formed an important item in the diet and simultaneously a relatively decrease in proportion of detritus was observed. Detritus and copepods dominated the diet of fishes between 181-210 mm and 211-240 mm. Among the diatoms, *Coscinodiscus* spp (%IRI= 7.6) formed 3rd ranked prey item in 241-270mm size group. However in fish >270 mm, fish remains (%IRI= 13.5) and amphipods (%IRI= 11.1) contributed to 3rd and 4th ranked items after copepods (%IRI=47.6) and detritus (26.4). Significant ontogenetic differences were found (χ^2 test, df= 24, P<0.001) in the number of major prey groups consumed (Table 4.10.7). Among prey groups the main source of variation came from other crustaceans, diatoms, amphipods and fishes. Among size groups, the main source of variation was from 91-120 mm group.

4.10.5. Variation in diet breadth and trophic level

Diet breadth and trophic level had wide variations in relation to different seasons. Generally, diet breadth was very low among the seasons (1.9 ± 0.6) (Fig 4.10.1). The highest value of diet breadth was observed in the monsoon (2.0 ± 0.8) and lowest in the post-monsoon (1.8 ± 0.6). Ontogenetically, diet breadth was higher in smaller length groups, the highest being in 121-150 mm length groups (Db= 2.5) (Fig 4.10.2). A low value of diet breadth was observed in 211-240mm (Db= 1.1). Similarly, higher proportion of detritus and copepods reduced diet breadth in 211-240mm to 1.13.

Seasonally, the highest trophic level was recorded in the pre-monsoon season (2.6 ± 0.5) followed by the post-monsoon (2.5 ± 0.4), whereas in the monsoon season, less number of fish items reduced trophic level to 2.3 ± 0.2 (Fig 4.10.1). Ontogenetically, trophic level ranged from 2.2 in 241- 270 to 3.2 in 271-300 mm length groups with a mean of 2.6 ± 0.4. The higher proportion of fish remains caused trophic level to increase to 3.15 in larger fishes (>270 mm). The low trophic level in 241-270mm was mainly due to large proportions of copepods and detritus in the diet (Fig 4.10.2).

4.10.6. Diet similarities

P. argenteus had almost similar diet among the different seasons. The highest similarity in diet was observed between the monsoon and post-monsoon seasons (83%) (Fig 4.10.3). Almost similar proportions of detritus and copepods were observed during these seasons. The second highest similarity was recorded between the pre-monsoon and post-monsoon seasons (81.8%).

Ontogenetically, highest similarity in diet was recorded between the fishes of 91-120 and 211-240 mm length groups (88.9%) (Fig 4.10.4). These groups shared copepods, detritus and mysids in almost equal proportions. Second highest similarity was observed between 181-210 mm and 211-240 mm length groups. The lowest similarity was observed as 43.3% in 121-150 and 271-300 mm length groups.

4.10.7. Prey-predator relations

Detritus and copepods showed positive relations to the size of *P. argenteus*. The mean weight, number of copepods and the mean weight of detritus was compared with the size of *P. argenteus*. The mean weight of detritus gradually decreased with increasing length, but in the largest length class, it again increased (Fig 4.10.5). The mean weight of copepods was higher in the smallest fishes, where as in larger fishes, it was low (Fig 4.10.6). Similarly, the mean number of copepods fluctuated without a clear pattern between length groups (Fig 4.10.7).

4.10.8. Feeding strategy

Fig 4.10.8 showed that *P. argenteus* has a specialized feeding strategy. There were 16 different prey types represented by points, most of them were rarely preferred. Most of the individuals specialized on copepods and detritus, as its percentage frequency of occurrence and prey-specific abundance was comparatively very high. Among the teleosts, only fish scales were highly preferred. Some individuals prefer other prey types but their occurrence in the stomach was infrequent.

Table 4.10.1. Prey of *P. argenteus* in terms of frequency of occurrence (%FO), volumetric (%V), numerical (%N), and index of relative importance (IRI)

Prey	**%FO**	**%V**	**%N**	**IRI**	**%IRI**
Fishes					
Fish scales (ctenoid)	1.73	0.01	0.66	1.15	0.02
Fish eggs	6.36	0.53	3.24	23.93	0.37
Fish scales (cycloid)	11.56	0.13	6.01	70.97	1.09
Fish remains	5.20	5.64	0.00	29.32	0.45
Crustaceans					
Mysids	6.36	1.07	2.91	25.30	0.39
Oratosquilla nepa	0.58	0.99	0.07	0.61	0.01
Copepods	51.45	3.75	48.35	2680.21	41.00
Amphipods	9.25	40.49	3.76	409.32	6.26
Nauplii larvae	7.51	0.44	3.24	27.62	0.42
Zoea larvae	2.31	0.32	0.40	1.66	0.03
Crustacean appendages	2.31	0.07	2.77	6.58	0.10
Diatoms					
Coscinodiscus spp	5.20	0.03	11.82	61.67	0.94
Nitzschia spp	5.78	0.01	14.20	82.16	1.26
Other diatoms	2.31	0.01	0.00	0.01	0.00
Worms	2.89	0.15	2.58	7.89	0.12
Detritus	67.05	46.37	0.00	3108.88	47.56

Table 4.10.2. Feeding intensity of *P. argenteus* in relation to seasons

Feeding intensity	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Active	11.39	15.79	18.90
Moderate	22.78	26.32	11.81
Poor	50.63	42.11	37.01
Empty	15.19	15.79	32.28

Table 4.10.3. Ontogenetic variation in the feeding intensity of *P. argenteus*

Feeding intensity	Length groups (mm)						
	91-120	121-150	151-180	181-210	211-240	241-270	271-300
Active	12.50	20.00	19.61	11.11	12.00	25.00	0.00
Moderate	20.83	11.67	17.65	18.52	20.00	12.50	11.11
Poor	37.50	45.00	39.22	48.15	60.00	37.50	33.33
Empty	29.17	23.33	23.53	22.22	8.00	25.00	55.56

Table 4.10.4. Seasonal variation in % IRI of prey of *P. argenteus*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Fish scales (ctenoid)	0.04	0.00	0.01
Fish eggs	0.15	0.89	0.32
Fish scales (cycloid)	0.93	0.00	0.46
Fish remains	0.28	0.00	2.44
Mysids	0.51	0.25	0.38
Oratosquilla nepa	0.08	0.00	0.00
Copepods	30.86	36.61	38.45
Amphipods	0.00	0.83	1.03
Nauplii larvae	0.01	1.38	0.73
Zoea larvae	0.00	0.00	0.09
Crustacean appendages	0.00	0.56	0.14
Coscinodiscus spp	0.15	4.59	0.73
Nitzschia spp	1.79	2.14	0.22
Other diatoms	0.00	0.00	0.00
Worms	0.11	0.27	0.04
Detritus	65.08	52.48	54.96

Table 4.10.5. Two way contigency table analysis of seasonal variation of five prey categories of *P. argenteus*. (Values are number of prey groups observed in each seasons)

Prey groups	Season			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fish items	72	14	64	78	21.5
Copepods	293	151	288	439	9.6
Amphipods		9	26	35	25.7
Other crustaceans	23	38	74	112	25.8
Diatoms	147	158	89	247	55.6
N_j	535	370	541	911	
χ^2	34.2	55.3	48.6		**138.2****

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df= 8

Table 4.10.6. Ontogenetic variation in %IRI of *P. argenteus*

Prey	Length groups (mm)						
	91-120	121-150	151-180	181-210	211-240	241-270	271-300
Fish scales (ctenoid)	0.00	0.36	0.168	0.11	0.00	0.00	0.00
Fish eggs	0.00	3.26	0.220	0.55	0.55	1.58	0.00
Fish scales (cycloid)	0.11	1.06	0.817	2.40	0.00	0.00	1.49
Fish remains	0.00	0.00	0.948	0.00	0.00	0.00	13.46
Mysids	3.16	0.00	0.000	0.12	3.51	0.00	0.00
Oratosquilla nepa	0.00	39.73	0.282	0.00	0.00	0.00	0.00
Copepods	34.67	9.74	20.783	36.44	38.29	39.90	47.58
Amphipods	0.04	2.06	0.183	0.00	0.33	2.84	11.13
Nauplii larvae	0.14	0.29	0.077	0.00	0.05	1.99	0.00
Zoea larvae	0.00	0.00	0.000	0.00	0.00	0.00	0.00
Crustacean appendages	1.70	0.44	0.000	0.03	0.00	0.00	0.00
Coscinodiscus spp	0.94	0.09	0.000	1.08	0.98	7.61	0.00
***Nitzschia* spp**	3.44	0.00	4.199	0.00	1.49	0.00	0.00
Other diatoms	0.00	0.15	0.002	0.00	0.00	0.00	0.00
Worms	0.20	42.82	0.589	0.00	0.00	0.00	0.00
Detritus	55.60	42.82	71.732	59.27	54.81	46.09	26.34

Table 4.10.7. Two way contigency table analysis of the ontogenetic variation of the five prey categories of *P. argenteus*. (Values are number of prey groups observed in each length groups)

Prey groups	Length groups (mm)							N_j	χ^2
	91-120	121-150	151-180	181-210	211-240	241-270	271-300		
Fish items	8	39	41	41	12	7	2	150	71.2
Copepods	160	137	98	133	112	62	30	732	22.5
Amphipods	2	27	5	0	5	11	7	57	76.1
Other crustaceans	74	34	5	3	19	7	0	142	78.9
Diatoms	124	30	84	25	88	43	0	394	76.1
N_j	368	267	233	202	236	130	39	1475	
χ^2	85.2	58.9	38.3	68.3	18.6	14.5	41.0		**324.8****

N_i, total numbers by species; N_j, total numbers by length groups; **, $P < 0.001$, df= 24

Fig. 4.10.1 Seasonal variation in trophic level and diet breadth
of *P. argenteus*

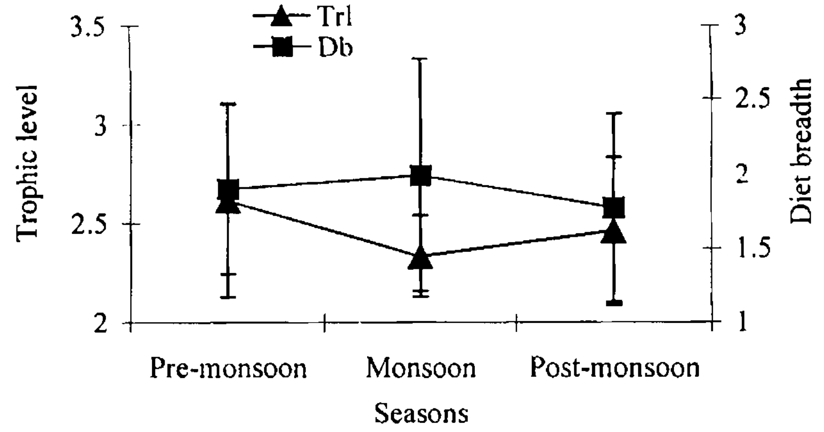


Fig. 4.10.2. Ontogenetic variation in trophic level and diet breadth of *P. argenteus*

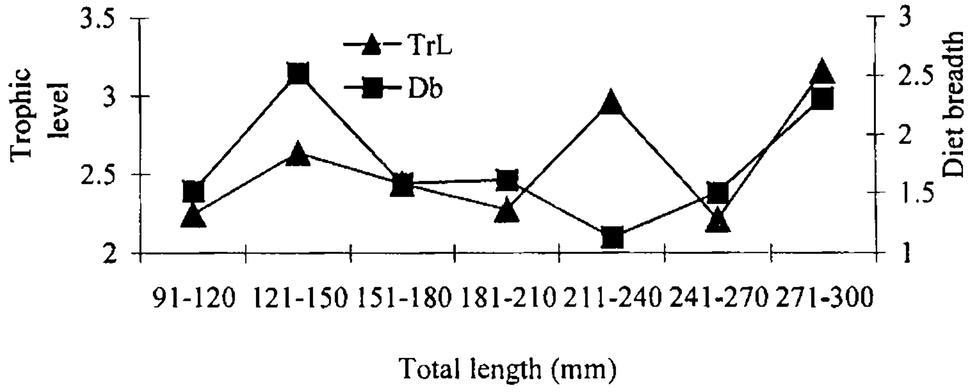


Fig. 4.10. 3. Dendrogram based on %IRI values of different seasons of *P. argenteus* using group average clustering

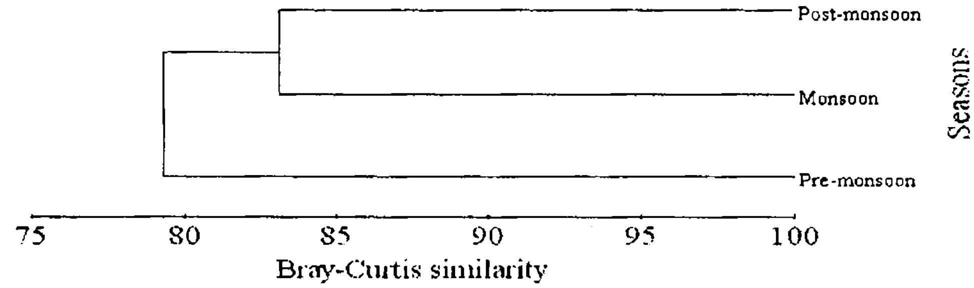


Fig 4.10.4. Dendrogram based on %IRI values of different size groups of *P. argenteus* using group average clustering

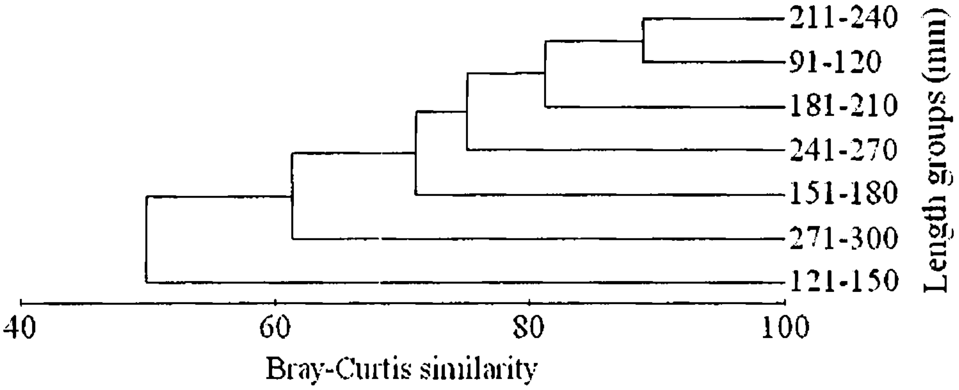


Fig. 4.10.5. Relationship between mean weight of detritus and the total length of *P. argenteus*

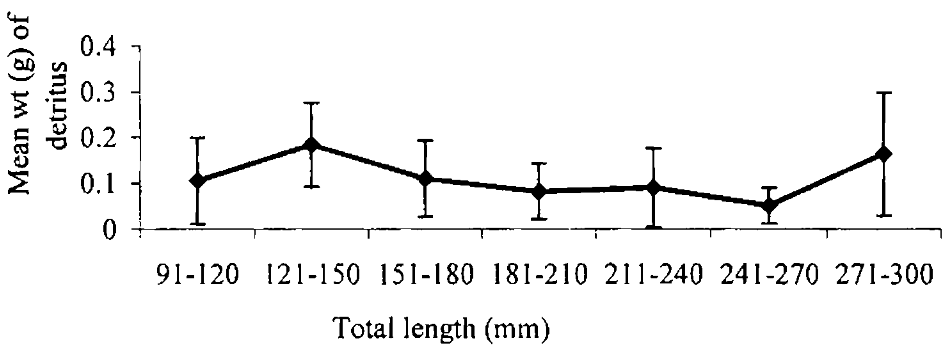


Fig. 4.10.6. Relationship between mean weight of copepods and total length of *P.argenteus*

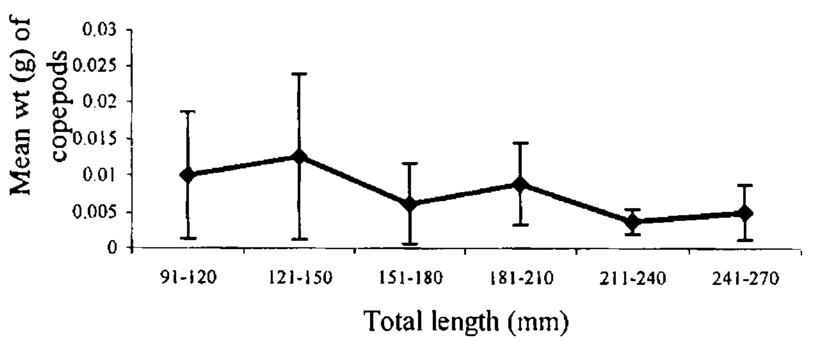


Fig. 4.10.7. Relationship between mean number of copepods and total length of *P. argenteus*

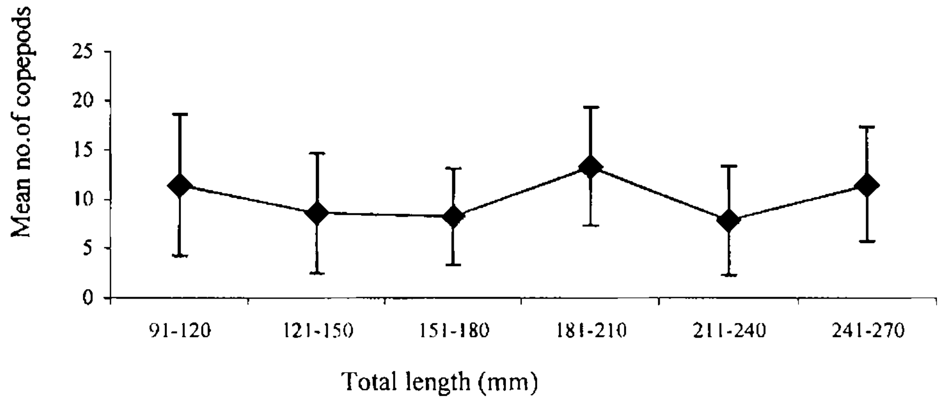
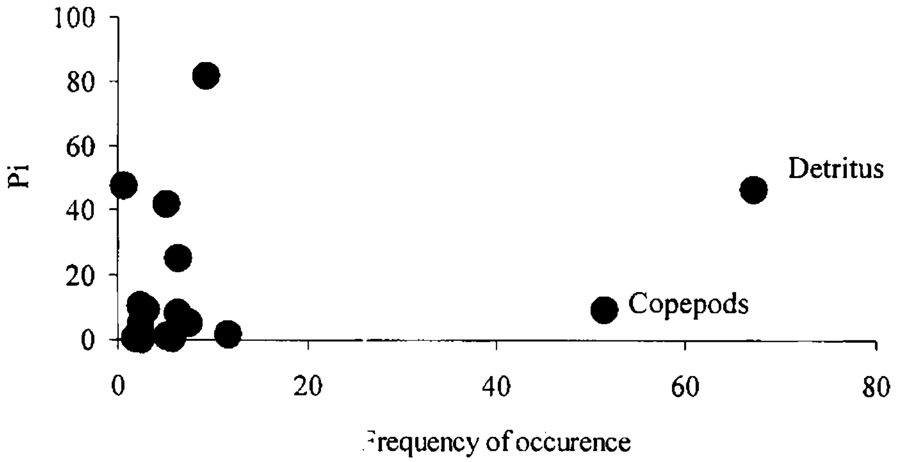


Fig. 4.10.8. Amundson plot for *P. argenteus* showing prey-specific abundance (Pi)



4. 11. *Lactarius lactarius*

4.11.1. General diet composition

Teleosts, crustaceans, molluscs and detritus formed the major diet of *L. lactarius* (Table 4.11.1). Teleosts (%IRI= 54.0) were the most important food item which made up the highest proportion in weight (%W= 73.6) as well as in occurrence (%FO= 52.8) of the total prey. Crustaceans (%IRI= 42.8) were the second important prey group accounting for 81.4% by number, 30.6% by occurrence and 17.7% by weight. Detritus was the third important prey group (%IRI= 3.20) occurring in 18.3% of the examined guts. Molluscs represented by *L. duvauceli* were recorded in trace amounts. The mean number and weight of prey per stomach were 0.87 ± 11.0 and 0.59 ± 4.6 respectively.

Among teleosts, *Stolephorus* spp was primarily eaten by *L. lactarius* (%IRI = 50.4), in terms of both occurrence (%FO= 32.8) and weight (%W= 56.5). Among the crustaceans, the most important prey item was *Acetes indicus* (%IRI= 41.6) which made up 77.8% in number. Unidentified teleosts were the second important (%IRI= 2.5) fish group that made up 11.1% by occurrence, 7.0 % by weight and 2.9 % by number of total prey. *Bregmaceros* spp (Plate 2*k*) formed the third largely consumed fish group in the diet (%W= 7.2). Other fish groups included *Terapon jarbua*, *Leiognathus bindus*, and fish scales. Stomatopods represented by *Oratosquilla nepa* accounted for the second frequent crustacean (%FO= 6.8) in the diet. Unidentified prawns formed another less abundant crustacean in the diet.

4.11.2. Feeding intensity

Percentage proportion of empty stomachs was high in most of the seasons. Proportion of poorly fed fishes was significantly higher in the monsoon and post monsoon seasons (Table 4.11.2). There was no significant variation in the feeding intensities among seasons (χ^2 test, df = 6, $p < 0.001$). During the monsoon season, similar proportions of both actively and moderately fed fishes were observed. Fishes during the post-monsoon had the highest proportion of empty stomachs (53.7%).

Ontogenetic shift in feeding intensity was clearly observed in *L. lactarius*. Individuals of smaller length group had the highest percentage of both empty and poorly fed stomachs (Table 4.11.3). However, there was no significant variation in the feeding intensities among length groups (χ^2 test, df = 15, P>0.001). Proportion of empty stomachs increased from the smallest length group (<110 mm) to 151-170 mm, but decreased in the larger length groups (>171 mm). Similarly, proportion of actively and moderately fed fishes increased with increasing the fish length.

4.11.3. Seasonal variation in feeding

Seasonal swapping of fish items and crustaceans was obvious throughout the period in *L. lactarius* (Table 4.11.4). Significant difference in the number of major prey categories was found among the seasons (χ^2 test, df= 6, p<0.001, Table 4.11.5). The main source of variation was from the pre-monsoon and fishes. The most important fish prey, *Stolephorus* spp showed decreasing trend from the pre-monsoon season to the post-monsoon season and accounted for 82.3% of IRI in the pre-monsoon followed by 37.1% in the monsoon and 30.0% in the post-monsoon seasons. In contrast, consumption of *A. indicus* increased from the pre-monsoon to post-monsoon season and it reached as high as 62.4% in the post-monsoon season. Similarly, unidentified teleosts, which were significant in diet, gradually reduced from the pre-monsoon to post-monsoon season. Other teleosts such as *T. jarbua*, *Bregmaceros* spp and *L. bindus* were totally absent in monsoon and *O. nepa* formed third most important diet during this period. Detritus was important only in the post-monsoon season.

4.11.4. Ontogenetic variation in feeding

Ontogenetic diet shift in feeding was clearly observed in *L. lactarius*. The fish appears to switch to fish prey when it grows to larger size (Table 4.11.6) by decreasing consumption of crustaceans. Individuals of 91-110 mm length groups fed primarily on *A. indicus* (%IRI= 76.3) and detritus (%IRI= 21.9) and unidentified teleosts in trace amounts. Variation in the number of major prey groups was significant among length groups (χ^2 test, df= 20, P<0.001, Table 4.11.7). Major variation came from 151-170 and 171-190 mm length groups. Among the prey groups, fishes were the main source of variation. Fishes of 111-130 mm moved very close to monophagy because *A. indicus* constituted 97.1% of total IRI of the diet. Almost similar proportion of *Stolephorus* spp (%IRI= 46.4) and *A. indicus* (%IRI= 47.7) constituted the diet of 131-150 mm length groups. The remaining 5.9% of IRI consisted of *L. bindus*, unidentified teleosts, penaeid prawns, *O. nepa* and detritus. Individuals of 151-170 mm length groups predated a wider diversity of prey. *Stolephorus* spp was the primary prey (%IRI= 84.6); *Bregmaceros* spp, unidentified teleosts, penaeid prawns and detritus also constituted significantly to the diet. For fishes of 171-190 mm length groups, again *Stolephorus* spp (%IRI= 91.5) was the primary food source. The remaining 8.5% of IRI consisted mainly of *Bregmaceros* spp, *L. bindus* and detritus. *L. lactarius* is as a piscivore in the largest length groups (>191 mm), 100 % of the diet was composed of fish items mainly unidentified teleosts (%IRI= 60.3). The remaining 39.7% of IRI consisted of *Stolephorus* spp, *L. bindus* and *T. jarbua*.

4.11.5. Variation in diet breadth and trophic level

The mean diet breadth of *L. lactarius* seasonally increased from the pre-monsoon to the monsoon season, thereafter, it decreased in the post-monsoon season (Fig 4.11.1). Fishes during the pre-monsoon season had a tendency to use broad range of prey items. The mean diet breadth during the monsoon and the post-monsoon season were 2.68 ± 0.09 and 2.37 ± 0.69 respectively. Ontogenetically, diet breadth had variations with a mean of 2.28 ± 0.25 (Fig. 4.11.2). The mean diet breadth of 2.25 ± 0.27 in smaller length groups (<150 mm) increased to 2.31 ± 0.28 in larger length groups (>150 mm). The greatest diet breadth of 2.63 was recorded for the largest length groups (191-210 mm).

Trophic level generally decreased from pre-monsoon to post-monsoon with an average of 4.03 ± 0.15. Occurrence of teleosts such as *T. jarbua*, *Bregmaceros* spp and *L. bindus*, in addition to large proportion of *Stolephorus* spp and other unidentified fishes, increased trophic level in the pre-monsoon to 4.17 ± 0.04. The mean trophic level estimated was 3.91 ± 0.37. The mean trophic level was 3.64 ± 0.32 in smaller length groups (<150 mm) and increased to 4.18 ± 0.13 in larger length groups (>150 mm).

4.11.6. Diet similarities

Fishes during the monsoon and post-monsoon seasons showed the highest sharing of diet (80.0%) on account of large proportion of *Stolephorus* spp and *A. indicus* (Fig 4.11.3). Second highest similarity was observed between the pre-monsoon and monsoon seasons. Ontogenetically, two adjacent groups, 151-170 and 171-190 mm length groups had higher diet similarity (82.1%) mainly because of the strict monophagy of these groups to *Stolephorus* spp. Diet similarity has also been observed for 91-110 and 110-130 mm length groups (74.2%) (Fig 4.11.4).

4.11.7. Prey-predator relationships

In *L. lactarius*, ontogeny is accompanied with increasing prey length. Both *Stolephorus* spp and *A. indicus* had positive relations to the predator length. Mean weight of anchovies increased with increase in the predator length (Fig 4.11.5). However, both mean number and weight of *A. indicus* increased gradually with the predator length and thereafter in 151-170 mm length groups, an abrupt decline was observed (Fig 4.11.6 and 4.11.7). Furthermore, the relation between total length of *A. indicus* and *L. lactarius* was positive showing that larger predators most often preferred larger *A. indicus* (Fig 4.11.8).

4.11.8. Feeding strategy

The plot of prey-specific abundance versus frequency of occurrence of the different prey categories indicated specialised feeding strategy for *L. lactarius* (Fig 4.11.9). *L. lactarius* had relatively two major diet groups, *Stolephorus* spp and *A. indicus* supplemented with other teleosts, other crustaceans, *L. duvauceli* and detritus. Though prey-specific abundance of most of the prey groups were higher, it most often fed only on *Stolephorus* spp (%FO >32%), *A. indicus* and unidentified fishes. This is indicative of a specialised feeding strategy as the diet is dominated by a few prey groups but also included a mixture of prey from several less common groups.

4.11.9. Prey selection

The Ivelev index based on different prey groups indicated that *L. lactarius* throughout the season strongly preferred the most important prey, *Stolephorus* spp (*Ei* = 0.91, averaged for the seasons) (Table 4.11.8). Unidentified fishes and penaeid prawns were selected moderately to strong during the pre-monsoon and monsoon, followed by strong avoidance in the post-monsoon season. Strong preference was observed for *T. jarbua* and *O. nepa* respectively in the pre-monsoon and monsoon seasons. Though other prey groups such as *Bregamaceros* spp and *A. indicus* were significant in the diet, it was never contributed to the commercial fisheries. Hence electivity index could not be calculated.for these groups.

Table 4.11.1. Prey of *L. lactarius* in terms of frequency of occurrence (%FO), weight (%W), number (%N), and index of relative importance (IRI)

Prey	**%O**	**%W**	**%N**	**IRI**	**%IRI**
Fishes					
Terapon jarbua	0.85	0.61	0.22	0.68	0.02
Bregmaceros spp	3.40	7.22	1.22	27.79	0.66
Leiognathus bindus	4.26	2.27	1.33	14.82	0.35
Stolephorus spp	32.77	56.53	10.18	2113.80	50.38
Unidentified fishes	11.06	6.97	2.88	105.30	2.51
Fish scales	0.43	0.04	2.21	0.93	0.02
Crustaceans					
Penaeid prawns	3.83	1.69	1.33	11.16	0.27
Acetes indicus	20.00	12.46	77.77	1745.14	41.60
Oratosquilla nepa	6.81	3.55	2.32	38.67	0.92
Molluscs					
Loligo duvauceli	1.70	1.06	0.55	2.66	0.06
Detritus	18.30	7.60	0.00	134.43	3.20

Table 4.11.2. Feeding intensity (%) of *L. lactarius* in relation to seasons

Feeding intensity	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Active	6.84	14.18	11.40
Moderate	14.74	14.18	11.07
Poor	24.74	35.46	35.18
Empty	53.68	36.17	42.35

Table 4.11.3. Feeding intensity (%) of *L. lactarius* in relation to length groups

Feeding intensity	Length groups (mm)					
	91-110	111-130	131-150	151-170	171-190	191-210
Active	8.89	6.47	11.17	12.61	13.33	22.22
Moderate	8.89	12.23	15.08	10.36	22.22	22.22
Poor	48.89	37.41	29.05	27.48	33.33	22.22
Empty	33.33	43.88	44.69	49.55	31.11	33.33

Table. 4.11.4. Seasonal variation in %IRI of prey of *L. lactarius*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Terapon jarbua	0.15	0.00	0.00
Bregmaceros spp	1.65	0.00	0.36
Leiognathus bindus	1.25	0.00	0.26
Stolephorus spp	82.26	37.08	30.14
Unidentified fishes	11.14	3.94	0.05
Fish scales	0.00	0.00	0.05
Penaeid prawns	1.12	0.29	0.04
Acetes indicus	2.04	49.58	62.42
Oratosquilla nepa	0.00	6.26	0.82
Loligo duvauceli	0.00	0.00	0.44
Detritus	0.40	2.86	5.42

Table 4.11.5. Two way contigency table analysis of the seasonal variation of the five prey categories of *L. lactarius*. (Values are number of prey groups observed in each seasons)

Prey groups	Seasons			N_i	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	73	95	125	220	102.8
Penaeid prawns	7	9	3	12	26.0
Acetes indicus	23	136	567	703	54.3
Oratosquilla nepa	1	10	11	21	6.0
Loligo duvauceli	1	1	5	6	0.4
N_j	105	251	711	962.000	
χ^2	115.3	26.3	47.9		189.5**

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df= 8

Table 4.11.6. Ontogenetic variation in %IRI of prey of *L. lactarius*

Prey	Length groups (mm)					
	91-110	111-130	131-150	151-170	171-190	191-210
Terapon jarbua	0.00	0.00	0.00	0.04	0.00	9.81
Bregmaceros spp	0.00	0.00	0.00	2.62	1.60	0.00
Leiognathus bindus	0.00	0.00	0.47	0.11	1.08	15.79
Stolephorus spp	0.00	0.33	46.44	84.56	91.45	14.12
Unidentified fishes	1.86	0.50	0.97	3.84	4.18	60.28
Fish scales	0.00	0.00	0.00	0.43	0.00	0.00
Penaeid prawns	0.00	0.04	0.29	0.89	0.00	0.00
Acetes indicus	76.25	97.08	47.70	2.00	0.21	0.00
Oratosquilla nepa	0.00	1.04	2.19	0.54	0.00	0.00
Loligo duvauceli	0.00	0.00	0.02	0.15	0.38	0.00
Detritus	21.90	1.00	1.90	4.83	1.09	0.00

Table 4.11.7. Two way contigency table analysis of ontogenetic variation of five prey categories of *L. lactarius*. (Values are number of prey groups observed in each length groups)

Prey groups	Length groups (mm)						N_i	χ^2
	91-110	111-130	131-150	151-170	171-190	191-210		
Fishes	1	5	45	81	25	6	163	336.3
Penaeid prawns		1	4	7			12	22.5
Acetes indicus	17	309	354	22	1		703	94.8
Oratosquilla nepa		5	12	5			21	4.2
Loligo duvauceli			3	3	1		5	10.5
N_j	18	319	416	118	27	6		
χ^2	3.0	68.9	15.6	246.7	106.7	27.4		468.2**

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df= 20

Table 4.11.8. Seasonal Ivelev index of *L. lactarius*

	Pre-monsoon	Monsoon	Post-monsoon
Terapon jarbua	0.80	-	-
Bregmaceros spp*	-	-	-
Leiognathus bindus	-0.12	-	0.52
Stolephorus spp	0.88	0.98	0.88
Unidentified fishes	0.76	0.58	-0.41
Fish scales*	-	-	-
Other penaeid prawns	0.70	0.97	-0.41
*Acetes indicus**	-	-	-
Oratosquilla nepa	-	0.86	0.09
Loligo duvauceli	-	-	-0.28
Detritus*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.11.1. Variation in trophic level and diet breadth of *L. lactarius*

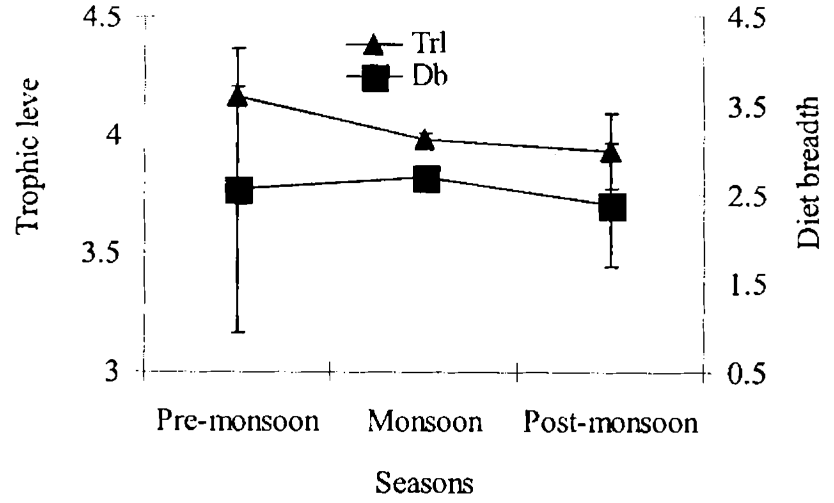


Fig. 4.11.2. Ontogenetic variation in trophic level and diet breadth of *L. lactarius*

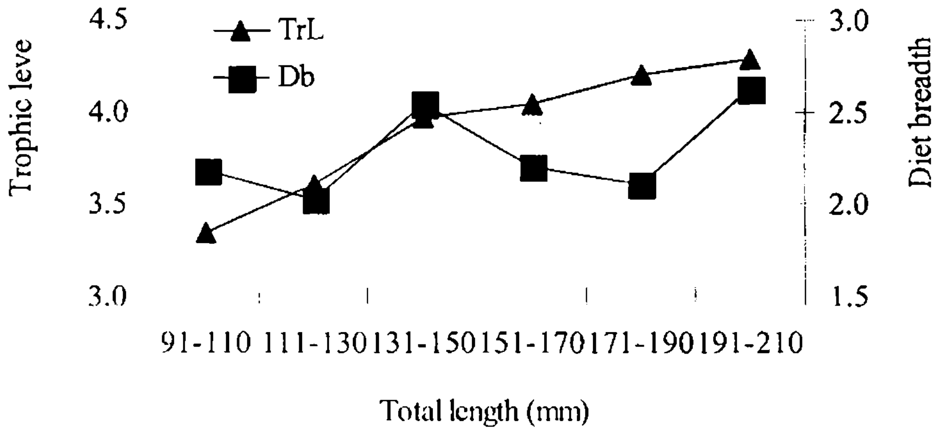


Fig. 4.11.3. Dendrogram based on %IRI values of different seasons of *L. lactarius* using group average clustering

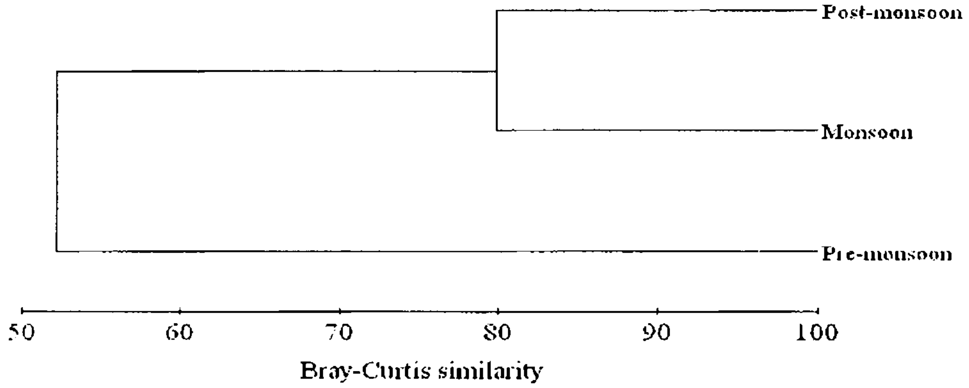


Fig. 4.11.4. Dendrogram based on %IRI values of different length groups of *L. lactarius* using group average clustering

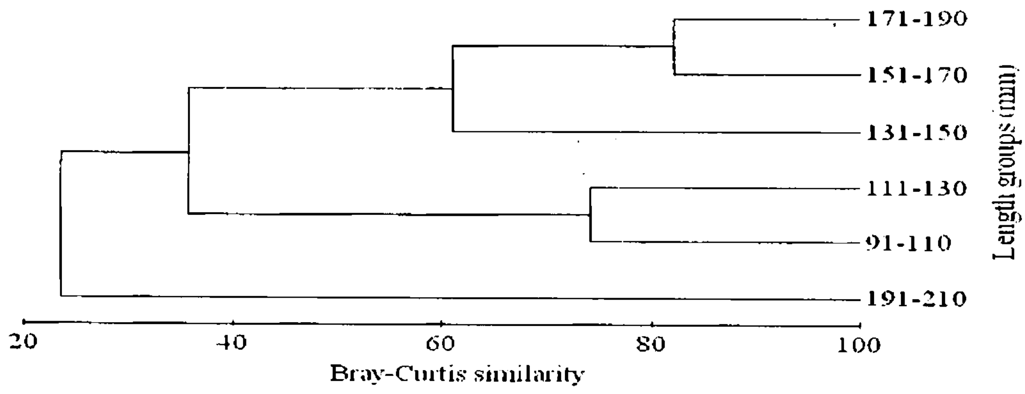


Fig. 4.11.5. Relationship between the weight of *Stolephorus* spp and total length of *L. lactarius*

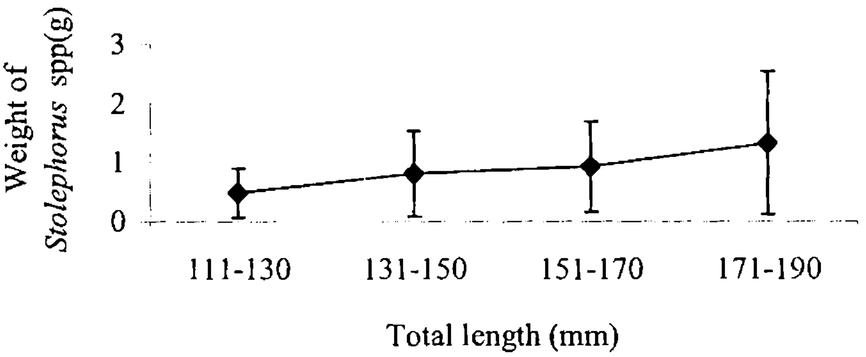


Fig. 4.11.6. Relationship between the number of *A. indicus* to the total length of *L. lactarius*

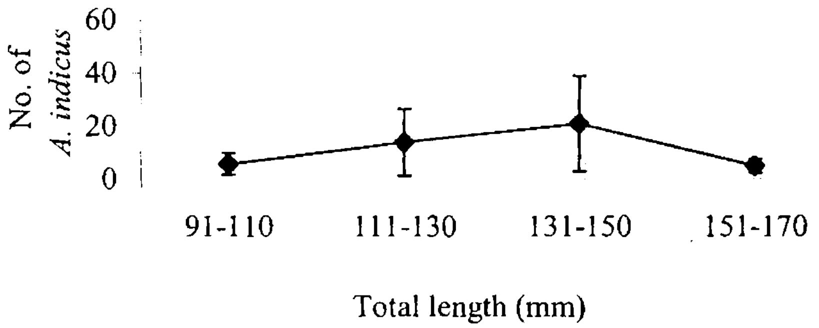


Fig. 4.11.7. Relationship between the weight of *A. indicus* and total length of *L. lactarius*

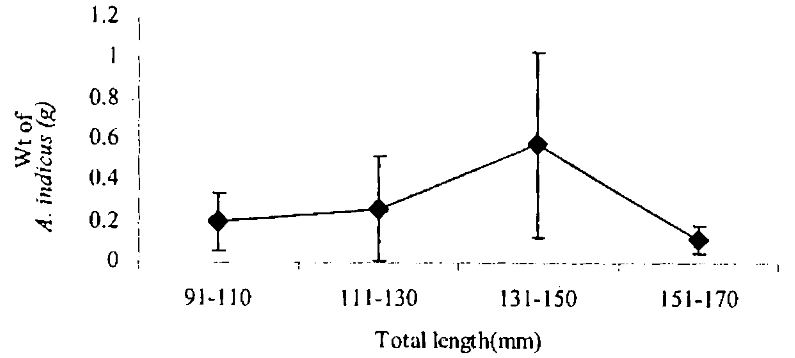


Fig. 4.11.8. Relationship between total length of *A. indicus* and *L. lactarius*

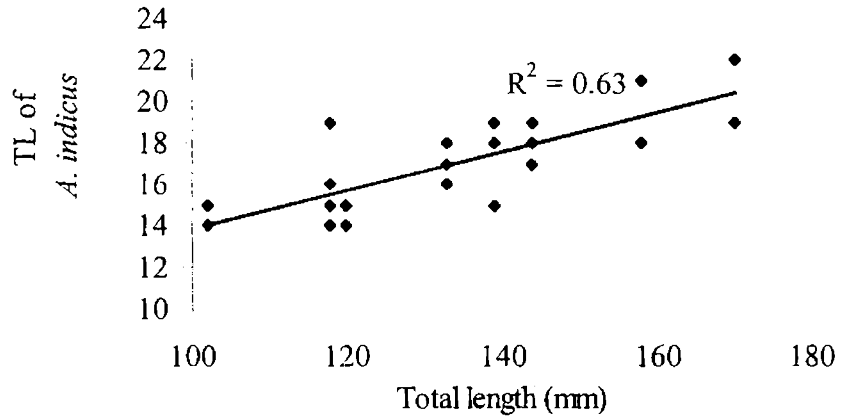
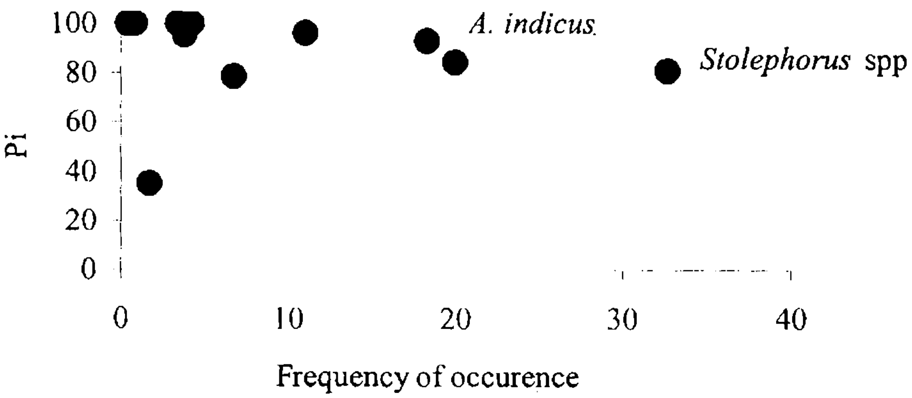


Fig. 4.11.9. Amundson plot for *L.lactarius* showing prey-specific abudance (Pi)



4.12. *Pseudorhombus arsius*

4.12.1. General diet composition

Out of 23 prey taxa identified from the gut of the largetooth flounder, *P. arsius*, fishes and crustaceans formed the principal food items (Table 4.12.1). Fishes ranked first (%IRI= 78.2) and were the most abundant (%N=62.8) prey category that accounted for 79.7% by weight and occurred in 79.2% of the analysed stomachs. *Pseudorhombus* spp (%IRI= 24.7) followed by *Polynemus indicus* (%IRI= 24.5) and *Stolephorus* spp (%IRI= 15.5) were the most important fish items. *P. indicus* constituted 19.2 % of the total stomachs examined while *Pseudorhombus* spp and *Stolephorus* spp occurred in 18.4 and 13.6 % of total stomachs. Out of 239 prey organisms enumerated, *Pseudorhombus* spp (11.3%) and *P. indicus* (11.3%) followed by *Stolephorus* spp (8.4%) were the most abundant fishes identified. In contrast, *Nemipterus mesoprion* was the largest fish prey (%W=12.7) in weight. Fish scales formed the most abundant fish items (%N=18.4) occurring in 4% of stomachs analysed. *Cynoglossus macrostomus* was another important fish (%IRI=2.4) which occurred in 5.6% of the total stomachs analyzed. Other items were a minor component of the diet both in number and weight. Fishes such as *Epinephelus diacanthus, Saurida* spp (Plate 2*l*), *Grammoplites suppositus, Terapon jarbua, Trichiurus lepturus*, eels and other unidentified fishes occurred infrequently in the diet of flounder.

Crustaceans, the second most important prey category (%IRI= 20.8) occurred in 35.2% of the stomachs analysed and was the second important prey in percentage by weight (18.6%) and abundance (30.9%). Crustaceans, especially *Metapenaeus affinis* (%IRI=10.4) and *Solenocera choprai* (%IRI=4.0) were very important in the diet. By weight, *M. affinis* contributed 13.6% to the total weight of stomach contents and occurred in 9.6% of the total stomachs analysed. Benthic crabs (%IRI= 2.92) and *Acetes indicus* (%IRI= 2.5) were also important in the diet. In addition, *Oratosquilla nepa*, lobster juveniles and isopods were also identified in the stomachs of the flounders examined.

Cephalopods represented by *Loligo* spp, nereis worms and detritus were noticed occasionally and were not important in the diet of the flounder, as their IRI values were very low.

4.12.2. Feeding intensity

Empty stomachs were dominant throughout the season in the largetooth flounder. Their numbers were as high as 61.3% in the pre-monsoon and 60.2% in the post-monsoon season (Table 4.12.2). However, there was no significant variation in the feeding intensities among seasons (χ^2 test, df= 6, P>0.001). Actively fed fishes were comparatively higher in monsoon. Percentage number of fishes with moderate feeding condition was comparatively higher in the monsoon and post-monsoon seasons.

In general, percentage of fishes with poor feeding condition increased with length (Table 4.12.3). There was a significant variation in the feeding intensities in *P. arsius* in relation to length (χ^2 test, df= 15, P<0.001, Table 4.12.3). Number of fishes with empty and active stomachs was the main source of variation. Among the different length groups, the major variation came from 136-165 and 196-225 mm length groups. Relatively, actively fed fishes were higher in the largest length group (286-315mm). Percentage of moderately fed fishes increased up to 226-255 mm, thereafter, its proportion was considerably reduced.

4.12.3. Seasonal variation in feeding

Seasonal variation in the diet of largetooth flounder is presented in Table 4.12.4. Teleosts represented by different fish species dominated throughout the season. Significant difference in the number of major prey categories were found among the seasons (χ^2 test, df= 6, P<0.001, Table 4.12.5). Significant variation came from the post-monsoon and monsoon seasons. The most important teleost, *P. indicus* was highly preferred both in the monsoon and post-monsoon seasons. The diet shift in the pre-monsoon was revealed with the cannibalistic nature of the flounder. It was observed that the fish ate fishes of the same genus (*Pseudorhombus* spp) more preferably than any others (%IRI= 32.8). Benthic crabs (%IRI= 18.2) followed by *Stolephorus* spp, unidentified teleosts, *T. lepturus* and *N. mesoprion* were the other most important preys in the pre-monsoon season. During the monsoon season, next to the most preferred prey, *P. indicus,* almost equal proportions of both penaeid prawns, *M. affinis* and *S. choprai* followed by *Stolephorus* spp and fish scales were the principal diet components. However, in the post-monsoon, flounder preferred large variety of preys in addition to the most important teleost, *P. indicus*. Among these, the pasteshrimp, *A. indicus*, *M. affinis*, fish scales, *Stolephorus* spp and to a lesser extent, nereis worms and isopods were important. Teleosts such as *E. diacanthus*, *Saurida* spp, *Terapon jarbua*, *C. macrostomus*, eels, and fish scales and crustaceans such as *O.nepa*, lobster juveniles, isopods and *Loligo* spp and nereis worms were distributed among the seasons without any clear pattern.

4.12.4. Ontogenetic variation in feeding

The IRI of different food items in relation to different length groups is shown in Table 4.12.6. Variation in the number of major prey groups was significant among length groups (χ^2 test, df= 15, P<0.001, Table 4.12.7). Among the length groups, 136-165 mm had major variation and among prey categories, miscellaneous items and other crustaceans contributed to the major variation. Cannibalism was more prevalent in younger fish and it was not common in fishes above 255 mm. The major diet of fishes between 136-165 mm was *Pseudorhombus* spp (%IRI= 79.0) followed by *P.indicus* (%IRI= 7.6). The most preferred teleost, *P. indicus* was recorded in all length groups except in 226-255 mm, and was highly preferred by the fishes of 166-195 mm and 196-225 mm length groups. In 166-195 mm length groups, *Pseudorhombus* spp (%IRI= 37.1) and *C. macrostomus* (%IRI= 8.8) formed second and third ranked prey items while in 196-225 mm length groups, *Stolephorus* spp (%IRI= 23.2) followed by *M. affinis* (%IRI= 12.3) contributed to second and third important items. Cannibalism was highly prevalent in fishes of 226-255 mm length groups. Non-penaeid prawns such as *A. indicus*, penaeid prawns such as *S. choprai* and *M. affinis*, teleosts such as *G. suppositus* and *T. jarbua* contributed substantially to the diet of these length groups. Diet of fish from 256 to 285 mm was dominated by *Stolephorus* spp (%IRI= 33.9). Other prey items such as *M. affinis* (%IRI= 15.5), *P. indicus* (%IRI= 14.6), benthic crabs (%IRI= 10.5) and *T. lepturus* (%IRI= 5.9) were also important to this group. The diet of fish >286 mm (largest length group) was dominated by *N. mesoprion* (%IRI= 39.1) followed by benthic crabs (%IRI= 24.8) and *M. affinis* (%IRI= 7.4). Food items such as *O. nepa*, lobster juveniles, isopods, *Loligo* spp and nereis worms did not form a significant part of the diet in any length groups.

4.12.5. Variation in diet breadth and trophic level

Considerable variation in the diet breadth was observed in relation to different seasons (Fig 4.12.1). Due to similar proportion of various prey taxa, fishes during the monsoon showed the highest diet breadth (3.19 ± 0.19) followed by the post-monsoon (3.15 ± 1.23). However, a comparatively low diet dietary breadth was observed in the pre-monsoon season (2.36 ± 0.24). Diet breadth generally increased with increasing body length of flounder (Fig 4.12.2). Very few prey types decreased the diet breadth in 136-165 mm length groups (1.43); and large prey diversity in 256-285 mm increased it to 6.88.

Trophic level showed wide variations among the seasons as well as length groups. Fishes during the pre-monsoon season were in highest trophic level mainly because of cannibalism (4.47 ± 0.16). However, during the monsoon, even with diet diversity, trophic level was observed to be less (4.15 ± 0.16) when compared to post-monsoon (4.38 ± 0.28) (Fig 4.12.1). But among the different length groups, fishes of the largest length group (>285) whose diets were supplemented with large carnivorous fishes, occupied the highest trophic level (4.61) and it showed an ontogenetic progression of trophic level (Fig 4.12.2). The mean trophic level recorded was 4.38 ± 0.17. Because of low trophic prey groups slightly reduced trophic level of 196-225 mm length groups to 4.09.

4.12.6. Diet similarities

Dendrogram constructed based on Bray-Curtis similarity of %IRI of different prey items is shown in Fig 4.12.3. Large proportion of the most important prey, *P. indicus* in the monsoon and post-monsoon season (67.4%) was responsible for the highest similarity in feeding between them. The second highest similarity recorded was between the pre-monsoon and post-monsoon seasons (33.9%).

Ontogenetically, dendrogram formed as a result of Bray-Curtis similarity analysis distinguished length groups in to similar clusters (Fig 4.12.4). Higher similarity was observed between 196-225 and 226-255 mm and 136-165 and 166-185 mm length groups and this formed distinct clusters in the dendrogram. The former groups shared *Stolephorus* spp, prawns, fish scales and fish remains almost in similar proportions. Similarity between 166-195 mm and 286-315 mm was very less due to dissimilar diet composition.

4.12.7. Prey-predator relations

With increase in length of *P.arsius*, the mean weight of fish prey items was observed to increase (Fig 4.12.5). Though the number of fish groups consumed by adults was less, their mean weight was comparatively higher than the juveniles. Among the fish groups, the mean weight of most important prey *P. indicus* increased in accordance to the increasing weight of the flounder (Fig 4.12.6). However, in the very large specimens the mean weight of *P. indicus* reduced.

4.12.8. Feeding strategy

The plot of prey-specefic abundance versus frequency of occurrence of the different prey categories indicated a mixed feeding strategy (Fig 4.12.7). The diet of *P. arsius* had a relatively a varied diet consisting of fishes, crustaceans, cephalopods and detritus. This is indicative of a mixed feeding strategy as the diet is dominated by a few prey groups but included a mixture of prey from several less common groups. 23 different prey items were recorded from the stomach, but none of these had frequency of occurrence >20. Among prey types the highest values of both frequency of occurrence and prey specific abundance was observed for only three fish items viz; *P. indicus, Pseudorhombus* spp and *Stolephorus* spp. In the monsoon and post monsoon seasons, the most often observed diet item was *P.indicus* where as in the pre-monsoon the fish changed preferred prey to another prey specifically to *Pseudorhombus* spp. Hence the frequency of occurrence was very much reduced for individual prey items. This indicated a mixed feeding strategy with a few dominant prey items.

4.12.9. Prey selection

Ivelev index clearly depicted the prey utilization available in the environment. Electivity index based on the percentage weight of prey items indicated that largetooth flounder strongly preferred large carnivorous teleosts and the species of same genus (*Pseudorhombus* spp) in the pre-monsoon (Table 4.12.8). However, there was strong preference to the epipelagic prey, *Stolephorus* spp in all the seasons. Crustaceans, mainly *S.choprai* and squilla were strongly selected in the monsoon; however, regular preference throughout the season was observed only for benthic crabs. Trawl catch variation in the species abundance were clearly reflected in the diet. Strong negative values were obtained for *Saurida* spp in the pre-monsoon even though their catch composition was very high in the trawls. Teleosts such as *C. macrostomus*, *T. lepturus* and unidentified fishes were strongly avoided in the post-monsoon season. Strong selection of the spotfin flathead, *G. suppositus* and moderate preference of *N. mesoprion* were also observed in the post-monsoon season. Though *Loligo* spp was abundant in the catch, largetooth flounder did not utilize them in their diet in all the seasons.

Table 4.12.1. Prey of *P. arsius* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	**%FO**	**%W**	**%N**	**IRI**	**%IRI**
Fishes					
Epinephelus diacanthus	1.6	6.69	0.84	10.10	0.70
Grammoplites suppositus	1.6	4.08	1.26	7.16	0.50
Saurida spp	1.6	1.54	0.84	3.20	0.22
Nemipterus mesoprion	1.6	12.70	0.84	18.17	1.26
Polynemus indicus	19.2	10.64	11.30	353.31	24.52
Terapon jarbua	1.6	9.15	0.84	13.41	0.93
Stolephorus spp	13.6	11.26	8.37	223.98	15.54
Cynoglossus macrostomus	5.6	3.87	3.35	33.89	2.35
Trichiurus lepturus	3.2	4.19	1.67	15.75	1.09
Pseudorhombus spp	18.4	11.72	11.30	355.33	24.66
Eel	0.8	1.66	0.42	1.40	0.10
Fish scales	4	0.28	18.41	62.73	4.35
Unidentified fishes	6.4	1.95	3.35	28.44	1.97
Crustaceans					
Metapenaeus affinis	9.6	13.62	5.02	150.11	10.42
Solenocera choprai	8.8	2.87	5.02	58.25	4.04
Oratosquilla nepa	0.8	0.07	0.42	0.33	0.02
Lobster juveniles	1.6	0.06	0.84	1.21	0.08
Benthic crabs	6.4	1.55	6.28	42.01	2.92
Acetes indicus	5.6	0.39	7.11	35.24	2.45
Isopods	2.4	0.05	6.28	12.75	0.88
Miscellaneous					
Loligo spp	1.6	1.60	0.84	3.27	0.23
Nereis worms	2.4	0.02	5.44	10.99	0.76
Detritus	0.8	0.03	0.00	0.00	0.00

Table 4.12.2. Feeding intensity of *P.arsius* in relation different seasons

Feeding intensity	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Active	2.70	6.41	3.54
Moderate	10.81	14.10	13.27
Poor	25.23	26.92	23.01
Empty	61.26	52.56	60.18

Table 4.12.3. Two way contingency table analysis of ontogenetic variation in feeding intensity of *P. arsius*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each length group)

Feeding intensity	Length groups (mm)						N_j	χ^2
	136-165	166-195	196-225	226-255	256-285	286-315		
Active	2		5	2	1	2	12	145.5
	(3.7)	(0.0)	(5.6)	(4.2)	(1.9)	(11.1)		
Moderate	5	3	11	10	7	2	38	8.6
	(9.3)	(12.5)	(12.4)	(20.8)	(13.5)	(11.1)		
Poor	8	9	23	12	15	8	75	6.5
	(14.8)	(37.5)	(25.8)	(25.0)	(28.8)	(44.40		
Empty	39	12	50	24	29	6	160	1262.0
	(72.2)	(50.0)	(56.2)	(50.0)	(55.8)	(33.3)		
N_j	54	24	89	48	52	18	285	
χ^2	432.6	94.8	424.7	189.1	248.8	32.5		1422.5**

Ni, total numbers by species; Nj, total numbers by length groups

**, $P < 0.001$, df = 15

Table 4.12.4. Seasonal variation in %IRI of prey of *P.arsius*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Epinephelus diacanthus	1.24	0.00	0.00
Grammoplites suppositus	0.00	0.00	2.57
Saurida spp	0.24	0.00	0.17
Nemipterus mesoprion	2.41	0.00	0.17
Polynemus indicus	1.78	73.02	46.23
Terapon jarbua	0.00	0.00	0.68
Stolephorus spp	21.92	8.77	4.28
Cynoglossus macrostomus	3.16	0.66	1.03
Trichiurus lepturus	5.33	0.00	0.17
Pseudorhombus spp	32.80	0.15	0.00
Eel	0.75	0.00	0.00
Fish scales	1.80	3.15	5.82
Unidentified fishes	8.66	0.18	0.17
Metapenaeus affinis	0.00	6.26	13.87
Solenocera choprai	0.83	6.19	2.74
Oratosquilla nepa	0.00	0.30	0.00
Lobster juveniles	0.00	0.24	0.00
Benthic crabs	18.19	0.18	1.03
Acetes indicus	0.00	0.23	15.41
Isopods	0.90	0.00	2.40
Loligo spp	0.00	0.21	0.17
Nereis worms	0.00	0.44	3.08
Detritus	0.00	0.01	0.00

Table 4.12.5. Two way contingency table analysis of seasonal variation of major prey categories of *P.arsius*. Values are number of stomachs observed in each seasons

Prey groups	Season			N_j	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	52	31	54	137	2.4
Prawns	2	9	13	24	8.1
Other crustaceans	20	2	25	47	7.9
Miscellaneous	0	4	10	14	7.1
N_j	74	46	102	222	
χ^2	11.2	10.1	4.1		25.5**

N_i, total numbers by species; N_j, total numbers by seasons **, $P < 0.001$, df = 6

Table 4.12.6. Ontogenetic variation in %IRI of prey of *P.arsius*

Prey	Length groups (mm)					
	136-165	166-195	196-225	226-255	256-285	286-315
Epinephelus diacanthus	0.00	0.00	0.00	0.00	2.36	6.22
Grammoplites suppositus	0.00	0.00	0.00	6.75	0.00	0.00
Saurida spp	0.00	0.00	0.00	0.00	0.62	2.89
Nemipterus mesoprion	0.00	0.00	0.00	0.00	0.00	39.11
Polynemus indicus	7.57	45.24	44.90	0.00	14.58	1.90
Terapon jarbua	0.00	0.00	0.00	2.75	3.84	0.00
Stolephorus spp	0.00	0.00	23.23	0.55	33.90	6.91
Cynoglossus macrostomus	2.16	8.84	5.07	0.00	0.00	0.00
Trichiurus lepturus	0.00	2.33	0.30	0.00	5.88	0.00
Pseudorhombus spp	79.01	37.12	2.86	66.93	0.00	0.00
Eel	0.00	0.00	0.00	0.00	0.00	3.62
Fish scales	5.60	0.00	3.51	1.50	3.95	0.00
Unidentified fishes	5.66	1.89	0.21	0.88	1.78	0.00
Metapenaeus affinis	0.00	0.00	12.26	3.57	15.54	7.38
Solenocera choprai	0.00	2.10	3.34	5.11	3.90	0.00
Oratosquilla nepa	0.00	0.00	0.15	0.00	0.00	0.00
Lobster juveniles	0.00	0.00	0.54	0.00	0.00	0.00
Benthic crabs	0.00	0.00	0.00	0.71	10.53	24.75
Acetes indicus	0.00	2.48	1.17	9.50	0.00	0.00
Isopods	0.00	0.00	0.25	1.75	1.97	0.00
Loligo spp	0.00	0.00	0.25	0.00	1.16	0.00
Nereis worms	0.00	0.00	1.97	0.00	0.00	7.22
Detritus	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.12.7. Two way contingency table analysis of ontogenetic variation of prey categories of *P. arsius*. (Values are number of stomachs observed in each length groups)

Prey groups	Length groups (mm)						N_j	χ^2
	136-165	166-195	196-225	226-255	256-285	286-315		
Fishes	24	15	47	22	34	8	150	13.0
Prawns	0	1	8	6	7	2	24	3.4
Other crustaceans	0	2	17	21	16	9	65	15.4
Miscellaneous	0	0	9	0	1	5	15	19.9
N_j	24	18	81	49	58	24	254	
χ^2	16.6	4.6	4.4	10.7	2.2	13.1		51.7**

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df = 15

Table 4.12.8. Seasonal Ivelev index of *P. arsius*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Epinephelus diacanthus	0.94	-	-
Grammoplites suppositus	-	-	0.92
Saurida spp	-0.02	-	0.27
Nemipterus mesoprion	0.80	-	0.57
*Polynemus indicus**	-	-	-
*Terapon jarbua**	-	-	-
Stolephorus spp	0.85	0.96	0.72
Cynoglossus macrostomus	0.07	0.56	-0.17
Trichiurus lepturus	0.51	-	-0.65
Pseudorhombus spp	0.99	0.69	-
Eel	0.98	-	-
Fish scales*	-	-	-
Unidentified fishes	0.56	-0.02	-0.17
Metapenaeus affinis	-	-	-
Solenocera choprai	0.25	0.94	0.14
Oratosquilla nepa	-	0.76	-
Lobster juveniles*	-	-	-
Benthic crabs	0.92	0.99	0.60
*Acetes indicus**	-	-	-
Isopods*	-	-	-
Loligo spp	-	-0.06	0.18
Nereis worms*	-	-	-
Detritus*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.12.1. Variation in trophic level and diet breadth in relation to different season of *P. arsius*

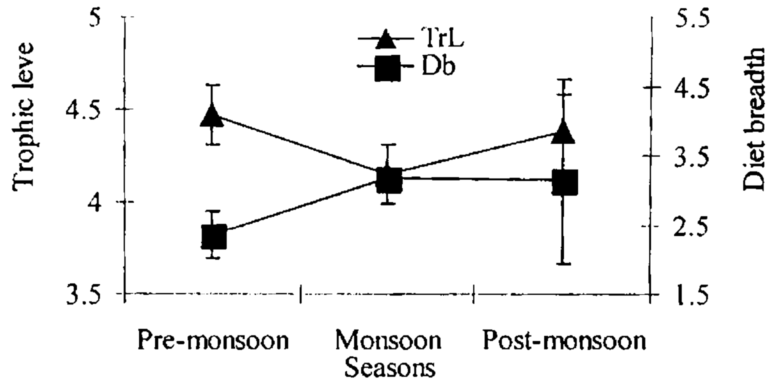


Fig.4.12.2. Ontogenetic variation in trophic level and diet breadth of *P. arsius*

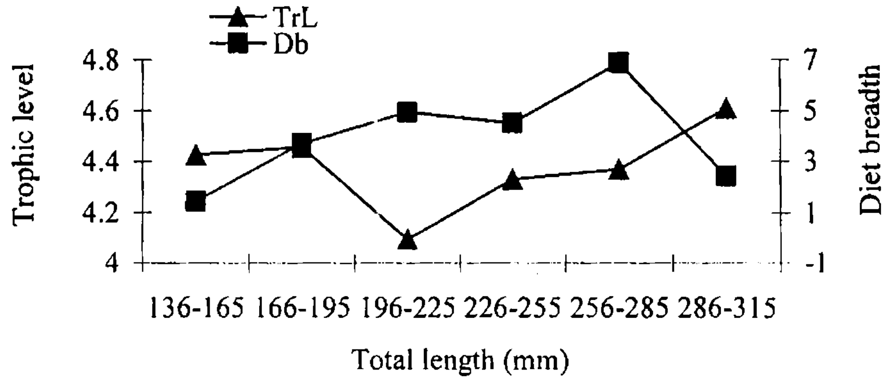


Fig. 4.12.3. Dendrogram based on %IRI values of different seasons of *P. arsius* using group average clustering

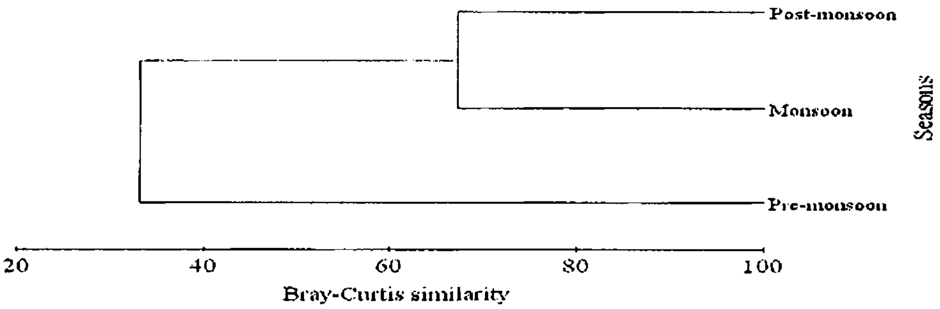


Fig 4.12.4. Dendrogram based on %IRI values of different length groups of *P. arsius* using group average clustering

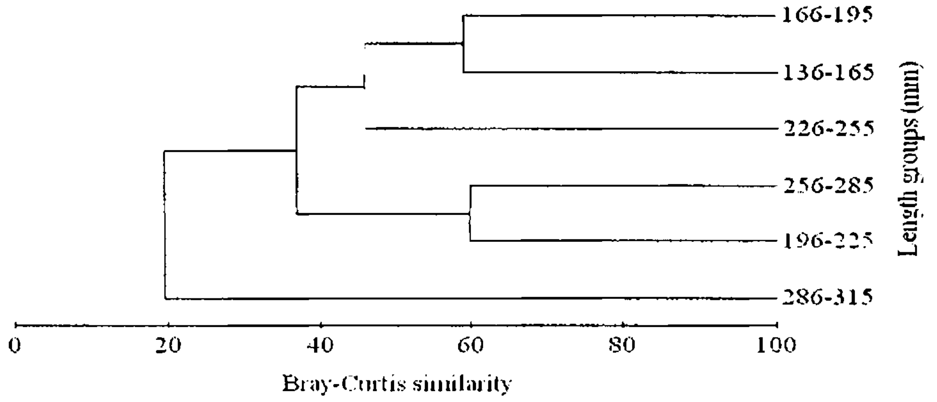


Fig. 4.12.5. Relationship between the weight of fish consumed and the total length of *P.arsius*

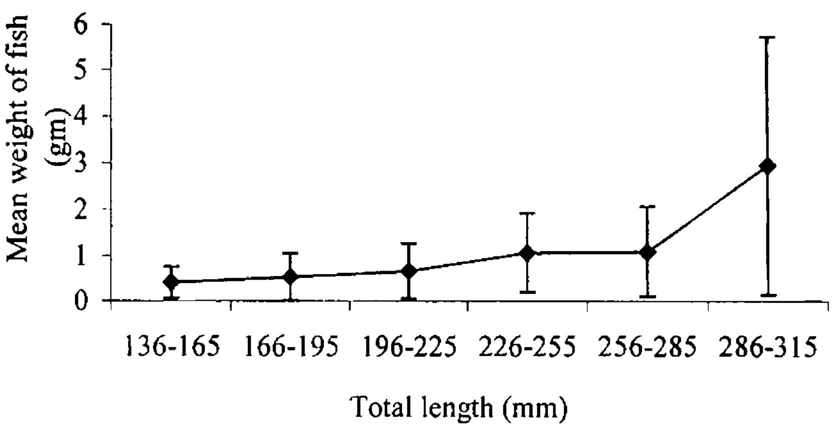


Fig. 4.12.6. Relationship between the mean weight of *P. indicus* and the total length of *P. arsius*

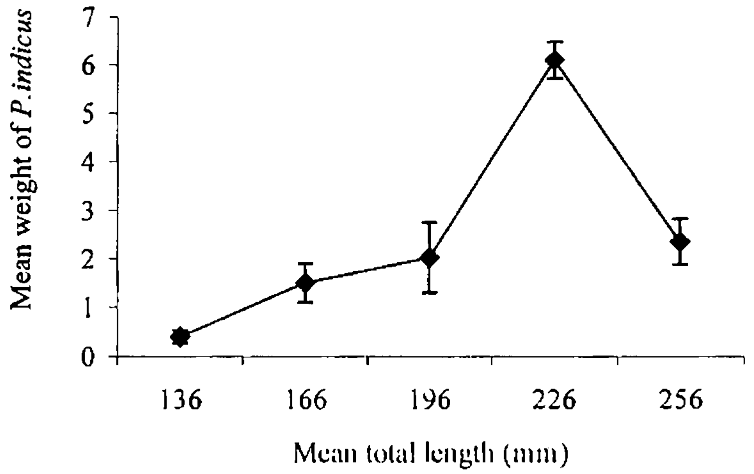
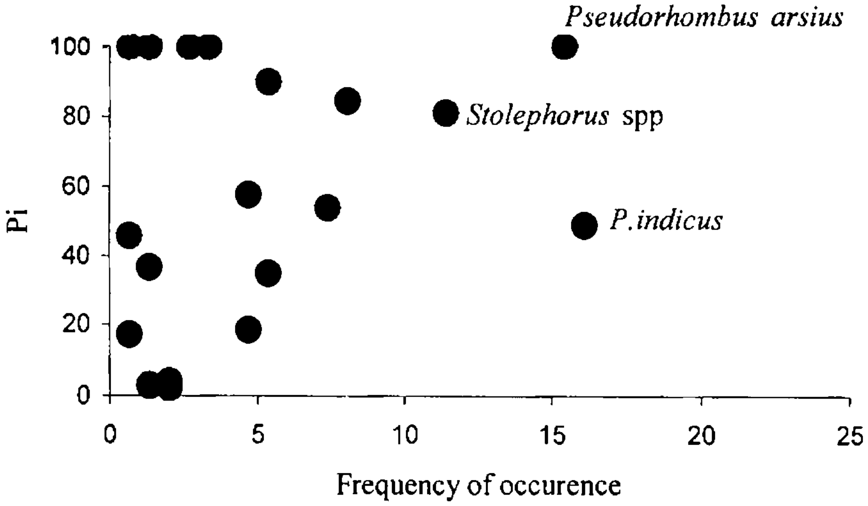


Fig. 4.12.7. Amundson plot for *P. arsius* showing prey-specific abundance (Pi)



4.13. *Carcharhinus limbatus*

4.13.1. General diet composition

The diet of *C. limbatus* consisted of 25 different prey items, dominated by teleosts and cephalopods (Table 4.13.1). Teleosts were the most important prey (%IRI= 73.1) scoring the highest values of 91.2% by frequency of occurrence, 85.0% by weight and 76.3% by number. The epipelagic teleosts, mainly represented by sardines and anchovies, formed the most preferred teleosts for *C. limbatus*. The epipelagic sardine, *Sardinella longiceps* represented by 29 individuals was the most important (%IRI= 28.3) prey, which occurred in 19.3% of the stomach examined as whole or in semi-digested forms. The second most important fishes were unidentified teleosts (%IRI= 14.8), which were found in 15.8% of stomachs accounting for 11.8% by number and 9.9% by weight of all the prey items. The third most important teleost was the epipelagic anchovy, *Stolephorus devisi* (%IRI= 12.0). They accounted for 13.0 % of all prey items and occurred in 17.5% of all stomachs. Sciaenids (%IRI= 6.9) and unidentified carangids (%IRI= 7.0) were the next important teleosts.

Fishes such as *Saurida* spp, *Nemipterus mesoprion*, *Grammoplites suppositus*, *Megalaspis cordyla*, *Decapterus rusellii*, *Rastrelliger kanagurta*, *Leiognathus bindus*, *Secutor insidiator*, *Liza* spp, eels and other clupeids were only minor dietary items in terms of percentage weight, number and frequency of occurrence.

Cephalopods, observed in the half digested states, mainly represented by *Loligo duvauceli* (Plate 2*m*) was the second most important food in the total diet (%IRI= 26.1) accounting for 21.1% by occurrence, 12.1% by weight and 16.6% by number of all identified food items. Octopus and mollusc remains were also preyed by *C. limbatus* but to a lesser extent. Crustaceans were the third prey category, composed mostly of Megalopa larvae, *Oratosquilla nepa*, unidentified prawns and crabs.

4.13.2. Feeding intensity

The proportion of both empty and poorly fed fishes was higher throughout the year (Table 4.13.2). Their proportion was comparatively very high in the monsoon and the post-monsoon seasons. The proportion of moderately and actively fed fishes was generally less. There was no significant difference in the feeding intensity by seasons (χ^2 test, df= 24, p>0.001).

Ontogenetically poor feeding condition was generally higher for smaller length groups (Table 4.13.3). Active and moderate feeding was totally absent in these groups. Larger fishes (>81 cm) were very active in feeding. Empty stomachs formed an important proportion in different length groups and the difference in general was significant (χ^2 test, df= 15, p<0.001). The length group, 81-90 cm was responsible for the main source of variations (Table 4.13.3).

4.13.3. Seasonal variation in feeding

The most important teleost prey, *S. longiceps* was consumed largely only in the pre-monsoon season (Table 4.13.4). *L. duvauceli* (%IRI= 22.9) followed by unidentified carangids (%IRI= 12.2) and unidentified fishes (%IRI= 6.2) were the 2nd and 3rd ranked prey groups in the pre-monsoon season. Sciaenids (%IRI= 80.4) followed by unidentified teleosts (%IRI= 19.6) were the most important prey in the monsoon season. The diet varied substantially in the post-monsoon season, but the difference was not significant (χ^2 test, df= 16, P>0.001). It frequently consumed almost equal proportion of the epipelagic *S. devisi* and *L. duvauceli* in the post-monsoon season. In addition, significant percentages of *S. longiceps*, unidentified teleosts, *M. cordyla* and equal proportion of both *Octopus* spp and molluscs remains were also eaten in the post-monsoon season.

4.13.4. Ontogenetic variation in feeding

Ontogenetic diet shift was marked by the preference of epipelagic teleosts (mainly *S. longiceps* and *S. devisi*) in smaller fishes and large carnivorous preys by those of larges fishes (Table 4.13.5). The main feature of diet shift was the gradual reduction of fish groups while *L. duvauceli* was dominant in the diet. However, the consumption of some prey items varied with fish length. Significant ontogenetic differences were found (χ^2 test, df= 10, P<0.001) in the number of major prey groups consumed (Table 4.13.6). Among the prey groups the source of variation came from crustaceans. Among length groups, the main variation was from 81-90 cm group. *S. devisi* was an important prey for the small length groups (<50 cm). Above this length, its incidence was considerably reduced or absent. Overall, younger fishes (<60 cm) were mostly piscivorous, feeding mostly on various epipelagic teleosts. For the fishes of 51-60 cm and 71-

80 cm length groups, *S. longiceps* was the main prey closely followed by unidentified teleosts. The diet of fishes of 61-70 cm length group was more diverse and constituted most of the large carnivorous fishes. Larger fishes (>81cm) consumed mainly *L. duvauceli* (%IRI= 74.0) and large carnivorous teleosts (mainly sciaenids, *Saurida* spp and *M. cordyla*).

4.13.5. Variation in diet breadth and trophic level

The diet breadth was higher in the pre-monsoon season (Fig 4.13.1). In the post-monsoon season, the average diet breadth was 2.19 ± 0.83. Seasonally, the trophic level was highest in the monsoon and post-monsoon seasons. Large proportion of *L. duvauceli* in the diet of black tip shark increased the trophic level in the post-monsoon season (4.35 ± 0.37), while in the pre-monsoon it was reduced to 3.97 ± 0.32. The mean annual trophic level calculated for the whole season was 4.19 ± 0.37.

Ontogenetically, diet breadth and trophic level had wide variations (Fig 4.13.2). Larger fishes had the highest diet breadth and it was as high as 8.26 in 61-70 cm length groups. The mean trophic level in relation to different length groups was 4.11 ± 0.19. The mean trophic level showed an increasing trend from 4.07 ± 0.19 from smaller groups (<60 cm) to 4.16 ± 0.24 in larger groups (>60 cm).

4.13.6. Diet similarities

The highest similarity in diet was observed between the pre-monsoon and post-monsoon seasons (Fig 4.13.3). During these seasons, contribution of most of the teleosts and *L. duvauceli* were highly significant. Similarly, the strict monophagy of smaller length groups (31-40 and 41-50 cm) to *S. devisi* led to highest similarity (66.7%) between them (Fig 4.13.4). The succeeding length groups (51-60 and 71-80 cm) also showed close similarity in diet (62.9%).

4.13.7. Prey-predator relationships

The mean weight of the most important prey, *S. longiceps* increased with the increasing length of *C. limbatus* (Fig 4.13.5). Similarly when the mean weight of *L. duvauceli* was compared with the mean length of *C. limbatus* it was observed that the mean weight increased with predator length (Fig 6). The weight of *S. devisi* had a positive correlation to the predator length (r^2= 0.65) (Fig 7).

4.13.8. Feeding strategy

The feeding strategy showed that black tip shark had a generalised feeding strategy. There were 25 different prey types in the whole diet of *C. limbatus* represented by points in the graph (Fig 4.13.8). Though, most of the individuals specialised on teleosts such as *S. longiceps*, *S. devisi*, unidentified fishes, and *L. duvauceli*, it was not always met with the diet. Frequency of occurrence of none of the prey groups increased or reached near 50%, instead, it fed on different prey groups.

4.13.9. Prey selection

The Ivelev index of electivity for black tip shark is given in the Table 4.13.7. The results showed the significant contribution of epipelagic teleosts in the diet of black tip sharks. Strong selection was observed for most of the prey groups consumed. Preference to teleost fishes was generally higher in the pre-monsoon and post-monsoon seasons. In the pre-monsoon season, the black tip sharks preferred the most important epipelagic *S. longiceps* and strong to moderate selection was observed for almost all benthic teleosts. However, for the epipelagic *Stolephorus* spp, weak selection was observed in the pre-monsoon season even though it formed good proportion in the fishing ground. In the monsoon season, sciaenids as well as unidentified fishes were highly preferred. Strong preference to molluscs particularly *L. duvauceli* was observed in the post-monsoon season.

Table 4.13.1. Prey of *C. limbatus* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	%FO	%W	%N	IRI	%IRI
Fishes					
Saurida spp	1.75	3.39	1.78	9.06	0.39
Nemipterus mesopion	1.75	7.58	1.18	15.38	0.67
Grammoplites suppositus	0.88	0.53	0.59	0.98	0.04
Eels	0.88	6.40	2.37	7.69	0.33
Sciaenids	7.89	11.32	8.88	159.42	6.89
Megalaspis cordyla	1.75	6.77	1.18	13.96	0.60
Decapterus russelli	1.75	2.09	1.18	5.75	0.25
Unidentified carangids	9.65	9.16	7.69	162.60	7.03
Stolephorus devisi	17.54	2.86	13.02	278.62	12.05
Cynoglossus macrostomus	2.63	1.65	2.37	10.57	0.46
Rastrelliger kanagurta	1.75	2.51	1.18	6.47	0.28
Leiognathus bindus	3.51	0.70	2.96	12.85	0.56
Secutor insidiator	0.88	0.66	0.59	1.10	0.05
Sardinella longiceps	19.30	16.76	17.16	654.58	28.30
Other clupieds	1.75	1.17	1.18	4.14	0.18
Liza spp	1.75	1.57	1.18	4.83	0.21
Unidentified fishes	15.79	9.90	11.83	343.12	14.83
Crustaceans					
Penaeid prawn	1.75	0.27	1.18	2.55	0.11
Digested crab	0.88	0.16	1.18	1.18	0.05
Megalopa larvae	0.88	0.01	0.59	0.52	0.02
Oratosquilla nepa	1.75	0.52	1.18	2.99	0.13
Molluscs					
Octopus spp	1.75	1.62	1.18	4.92	0.21
Loligo duvauceli	21.05	12.15	16.57	604.54	26.14
Mollusc remains	2.63	0.16	1.78	5.08	0.22
Miscellanoeus items					
Digested matter	1.75	0.09	0.00	0.15	0.01

Table 4.13.2. Feeding intensity (%) of *C. limbatus* in relation to seasons

Feeding intensity	Pre-monsoon	Monsoon	Post-monsoon
Active	5.15	0.00	6.33
Moderate	26.80	8.33	6.33
Poor	31.96	41.67	36.71
Empty	36.08	50.00	50.63

Table 4.13.3. Two way contigency table analysis of the ontogenetic variation of feeding intensity of *C. limbatus*. (Values are number of stomachs observed and figures in brackets are percentage feeding intensity in each length group)

Feeding intensity	Length groups (cm)						N_i	χ^2
	31-40	41-50	51-60	61-70	71-80	81-90		
Active	0	0		5	2	4	11	36.1
	(0.0)	(0.0)	(0.0)	(6.9)	(2.7)	(57.1)		
Moderate	0	0	5	19	12	0	36	10.1
	(0.0)	(0.0)	(33.3)	(26.4)	(16.0)	(0.0)		
Poor	12	3	5	27	20	0	67	10.4
	(70.6)	(42.9)	(33.3)	(37.5)	(26.7)	(0.0)		
Empty	5	4	5	21	41	3	79	7.1
	(29.4)	(57.1)	(33.3)	(29.2)	(54.7)	(42.9)		
N_j	17	7	15	72	75	7	193	
χ^2	11.0	2.3	2.8	5.1	6.3	36.2		**63.8****

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df = 15

Table 4.13.4. Seasonal variation in %IRI of prey of *C. limbatus*

Prey	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Saurida spp	1.05	0.00	0.00
Nemipterus mesopion	2.03	0.00	0.00
Grammoplites suppositus	0.11	0.00	0.00
Eels	0.89	0.00	0.00
Sciaenids	0.00	80.40	0.72
Megalaspis cordyla	0.15	0.00	1.95
Decapterus russelli	0.66	0.00	0.00
Unidentified carangids	12.15	0.00	2.04
Stolephorus devisi	3.57	0.00	39.71
Cynoglossus macrostomus	1.21	0.00	0.00
Rastrelliger kanagurta	0.75	0.00	0.00
Leiognathus bindus	1.45	0.00	0.00
Secutor insidiator	0.00	0.00	0.37
Sardinella longiceps	45.16	0.00	11.03
Other clupieds	0.47	0.00	0.00
Liza spp	0.56	0.00	0.00
Unidentified fishes	6.15	19.60	9.17
Penaeid prawn	0.08	0.00	0.17
Digested crab	0.13	0.00	0.00
Megalopa larvae	0.06	0.00	0.00
Oratosquilla nepa	0.46	0.00	0.00
Octopus spp	0.00	0.00	1.65
Loligo duvauceli	22.90	0.00	31.48
Mollusc remains	0.00	0.00	1.65
Digested matter	0.00	0.00	0.05

Table 4.13.5. Ontogenetic variation in %IRI of prey of *C. limbatus*

Prey	Length groups (cm)					
	31-40	41-50	51-60	61-70	71-80	81-90
Saurida spp	0.00	0.00	0.00	0.11	0.00	4.76
Nemipterus mesopion	0.00	0.00	0.00	1.25	0.44	0.00
Grammoplites suppositus	0.00	0.00	0.00	0.19	0.00	0.00
Eels	0.00	0.00	0.00	0.00	2.26	0.00
Sciaenids	0.00	0.00	0.00	11.63	0.90	11.65
Megalaspis cordyla	0.00	0.00	0.00	0.00	0.38	5.65
Decapterus russelli	0.00	0.00	0.00	1.14	0.00	0.00
Unidentified carangids	0.00	0.00	4.61	15.92	0.73	1.49
Stolephorus devisi	94.55	75.90	0.00	4.11	0.97	0.00
Cynoglossus macrostomus	0.00	0.00	0.00	1.03	0.27	0.00
Rastrelliger kanagurta	0.00	0.00	0.00	0.00	1.92	0.00
Leiognathus bindus	0.00	0.00	1.73	0.11	0.22	2.47
Secutor insidiator	0.00	0.00	0.00	0.00	0.33	0.00
Sardinella longiceps	0.00	0.00	58.43	13.74	51.91	0.00
Other clupieds	0.00	0.00	3.93	0.19	0.00	0.00
Liza spp	0.00	0.00	0.00	0.95	0.00	0.00
Unidentified fishes	0.00	24.10	26.06	5.29	26.91	0.00
Penaeid prawn	0.00	0.00	0.00	0.14	0.17	0.00
Digested crab	0.00	0.00	0.00	0.23	0.00	0.00
Megalopa larvae	0.00	0.00	1.51	0.00	0.00	0.00
Oratosquilla nepa	0.00	0.00	1.80	0.18	0.00	0.00
Octopus spp	0.00	0.00	0.00	0.38	0.18	0.00
Loligo duvauceli	0.00	0.00	1.92	43.41	12.40	73.97
Mollusc remains	5.22	0.00	0.00	0.00	0.00	0.00
Digested matter	0.23	0.00	0.00	0.00	0.01	0.00

Table 4.13.6. Two way contigency table analysis of the ontogenetic variation of prey categories of *C. limbatus*. (Values are number of stomachs observed in each length groups)

Prey groups	Length groups (cm)						N_i	χ^2
	31-40	41-50	51-60	61-70	71-80	81-90		
Fishes	11	3	10	54	42	9	129	3.4
Crustaceans	0	0	2	4	1	7	14	25.8
Molluscs	3	0	1	19	8	2	33	4.0
N_j	14	3	13	77	51	18	176	
χ^2	1.4	1.1	1.8	2.3	3.1	23.5		**33.2****

Ni, total numbers by species; Nj, total numbers by length groups

**, $P < 0.001$, df = 10

Table 4.13.7. Seasonal Ivelev index of *C. limbatus*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Saurida spp	0.50	-	-
Nemipterus mesopion	0.54	-	-
Grammoplites suppositus	0.70	-	-
Eels	0.99	-	-
Sciaenids	-	0.99	0.89
Megalaspis cordyla	0.90	-	0.98
Decapterus russelli	0.94	-	-
Unidentified carangids	0.82	-	0.92
Stolephorus devisi	0.10	-	0.51
Cynoglossus macrostomus	0.11	-	-
Rastrelliger kanagurta	0.64	-	-
Leiognathus bindus	-0.05	-	-
Secutor insidiator	-	-	0.88
Sardinella longiceps	0.90	-	0.99
Other clupieds	0.26	-	-
Liza spp*	-	-	-
Unidentified fishes	0.69	0.88	0.62
Penaeid prawn	0.35	-	-0.39
Digested crab	-0.05	-	-
Megalopa larvae*	-	-	-
Oratosquilla nepa	-0.42	-	-
Octopus spp *	-	-	-
Loligo duvauceli	0.06	-	0.70
Mollusc remains	-	-	0.99
Digested matter*	-	-	-

*The Index could not be calculated since the percentage composition data of the group in the environment was not available

Fig. 4.13.1. Seasonal variation in trophic level and diet breadth of *C. limbatus*

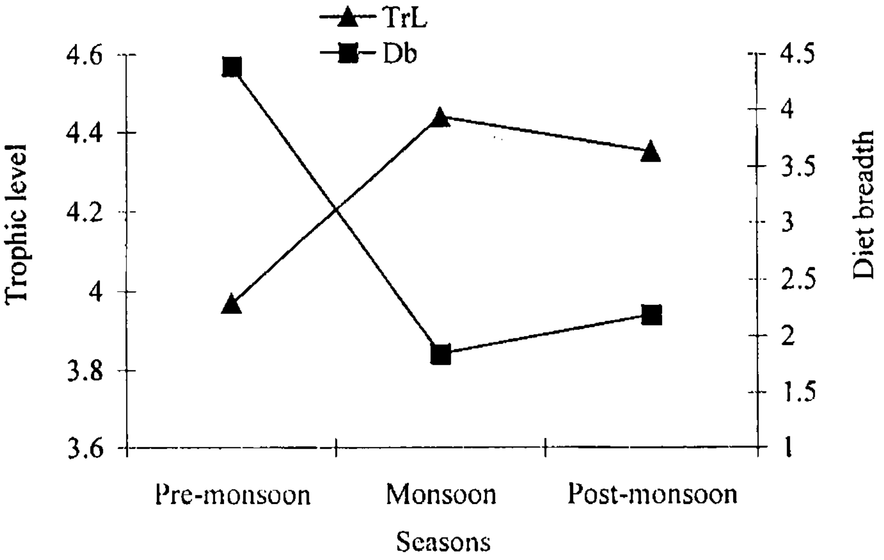


Fig. 4.13.2. Ontogenetic variation in trophic level and diet breadth
in *C. limbatus*

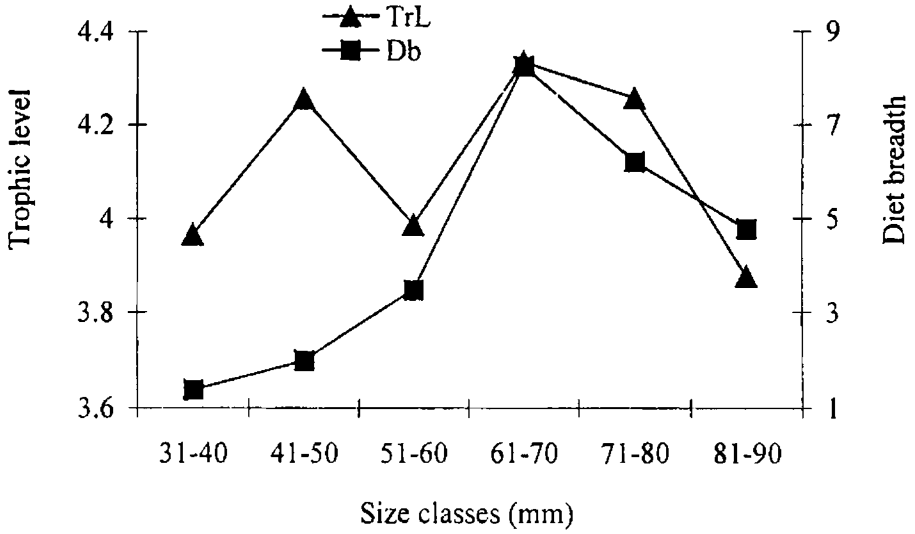


Fig. 4.13. 3. Dendrogram based on %IRI values of different seasons of *C. limbatus* using group average clustering

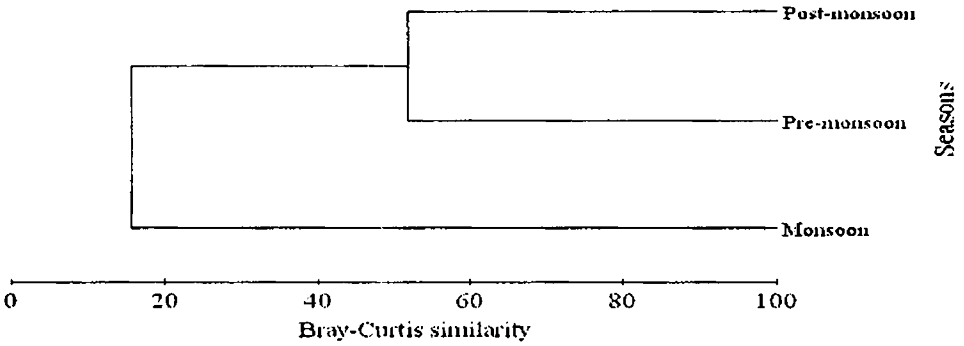


Fig. 4.13.4. Dendrogram based on %IRI values of different length groups of *C. limbatus* using group average clustering

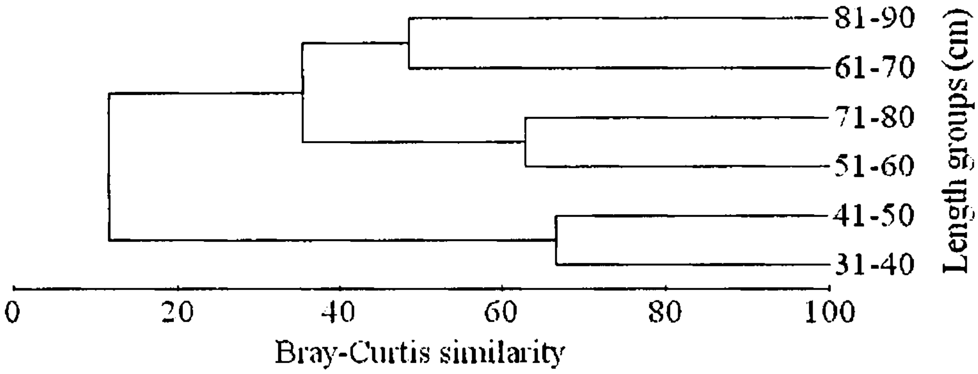


Fig. 4.13.5. Relationship between weight of *S. longiceps* and total length of *C. limbatus*

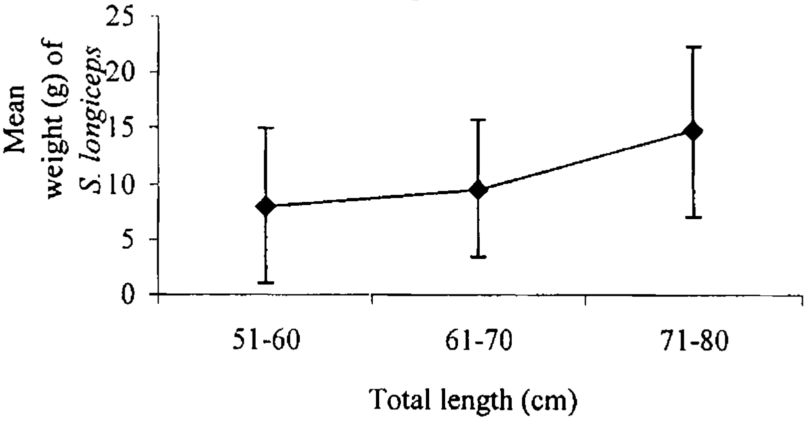


Fig. 4.13.6. Relationship between weight of *L. duvauceli* and total length of *C. limbatus*

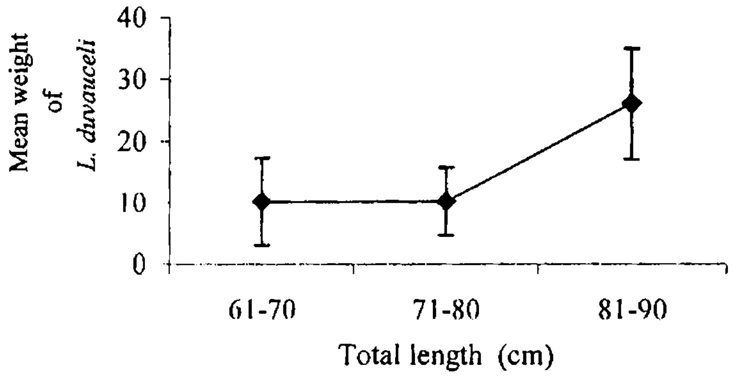


Fig 7. Relationship between the weight of *S. devisi* cand total length of *C. limbatus*

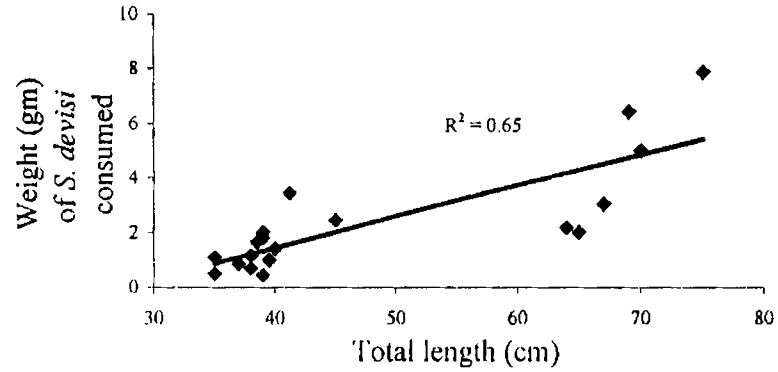
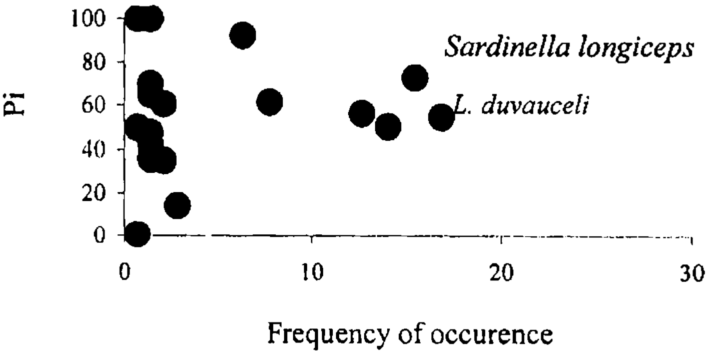


Fig. 4.13.8. Amundson plot for *C. limbatus* showing prey-specefic abundance (Pi)



4.14. *Rhynchobatus djiddensis*

4.14.1. General diet composition

A total of 10 prey items were identified from the stomach of guitarfish, *R. djiddensis*. It exhibited monophagy to the extent that crustaceans were the main food of *R. djiddensis* which caused the highest proportion of IRI (95.3%) in 79.4 % stomachs examined and also made up 95.3% by number and 72.8% by weight of all prey items (Table 4.14.1). *Acetes indicus* was primarily eaten by *R. djiddensis* (Plate 2*o*) and formed the most important food item (%IRI= 77.9), which in 31.9% of stomachs accounted for highest abundance (%N= 85.3) and weight (%W= 28.6) of all the prey components. The second most important component was *Solenocera choprai* (%IRI= 11.9) accounting for 23.4% of total stomachs examined and made up 19.0% by weight and 4.9% by number. Stomatopods represented by *Oratosquilla nepa* constituted the third most important prey (%IRI= 3.4) in 10.6 % of stomachs and also consumed significantly by weight (%W= 12.6), but not in number. Penaeid prawns and crabs, though represented a small fraction in terms of number, was also formed significant proportion by weight and occurrence.

Among the teleosts, only unidentified teleosts made significant proportion to the total diet (%IRI= 2.02) and were accounted for 11.4% by occurrence and 6.4% by weight. *Stolephorus* spp and *C. macrostomus* were a small proportion in terms of %IRI. Cephalopod represented by *Loligo duvauceli* occurred in 7.1% of stomachs and was consumed significantly by weight (%W= 9.7), but their number was very less in diet. Detritus, although also formed a part of diet spectrum, was not considered as an important to the total diet.

4.14.2. Feeding intensity

Percentage proportion of poorly fed fishes dominated throughout the season in *R. djiddensis*. Its proportion was comparatively higher in the post-monsoon season followed by the pre-monsoon and monsoon seasons (Table 4.14.2). Proportion of empty stomach fishes was less throughout the season and, was almost absent in the post-monsoon season. During the post-monsoon season, both moderately and actively fed fishes were comparatively higher. Seasonal differences feeding intensity was not significant (χ^2 test, df= 6, p>0.001).

Feeding was generally higher in smaller length groups in *R. djiddensis*. Proportion of poorly fed fishes was generally higher in smaller length groups and its proportion reached as peak as 62.5% in <300 mm length group but showed a gradual decreasing trend till 526-600 mm length group (Table 4.14.3). Actively fed fishes, even though less in number, formed comparatively higher proportion in the larger length groups (>451 mm). Ontogenetic variation in the feeding intensity was not significant (χ^2 test, df= 28, p>0.001).

4.14.3. Seasonal variation in feeding

During the pre-monsoon and post-monsoon seasons, feeding was monophagous to the most important prey, *A. indicus* (>75 %IRI, Table 4.14.4). Prey items such as crab, unidentified fishes and *C. macrostomus* recorded their highest proportion in pre-monsoon. During the monsoon season, *O. nepa* (%IRI= 43.8) followed by *S. choprai* and unidentified prawns were highly preferred. Consumption of *L. duvauceli* as well as *Stolephorus* spp was higher in the monsoon season. There were significant seasonal differences (χ^2 test, df= 12, p<0.001) in the number of major prey groups consumed (Table 4.14.5). Among the prey groups the source of variation was from prawns and other crustaceans. Among seasons, the monsoon was the main source of variation.

4.14.4. Ontogenetic variation in feeding

There were no consistent ontogenetic shifts in feeding of *R. djiddensis* (Table 4.14.6). However, there were significant ontogenetic differences (χ^2 test, df= 24, p<0.001) in the number of major prey groups consumed (Table 4.14.7). Among prey groups the source of variation mainly came from fishes. Among the length groups, 676-750 mm was the main source of variation. *A. indicus* was the most important food for the smaller sized fishes. Their proportion by %IRI decreased from the smallest length group (<300 mm) to 376-450 mm but thereafter again increased in the next length group (451-525 mm) and again thereafter decreased gradually till the largest length group (>675 mm). *A. indicus* formed the most important prey till 601-675 mm length group. For the smaller length group (<300 mm), *O. nepa* was the second most important prey. *S. choprai* consistently made up the second most important prey from 301-375 mm to 526-600 mm length groups. Individuals of 601-675 mm length group preferred *A. indicus* (%IRI= 48.2) in addition to large proportion of *L. duvauceli* (%IRI= 24.5) as well as crabs (%IRI= 12.9) and undientified fishes (%IRI= 9.9). Fishes of the largest length group (>675 mm) were typically piscivores that fish groups mainly represented by *C. macrostomus* (%IRI= 51.7) and undientified fishes (%IRI= 14.9) were largely consumed to the diet, in addition to the substantial proportion of *A. indicus* (%IRI= 21.5).

4.14.5. Variation in diet breadth and trophic level

Occurrence of all prey types increased diet breadth to 4.3 ± 1.9 in the post-monsoon season, where as during the monsoon and post-monsoon seasons, it was decreased due to less prey diversity (Fig 4.14.1). Significant ontogenetic variation in diet breadth was observed in *R. djiddensis* (Fig 4.14.2) and it varied from 1.4 in largest fishes (>675 mm) to 6.1 in 451-525 mm length groups with an average of 3.7 ± 1.7.

Fishes during the monsoon season were in higher trophic level mainly due to feeding largely on *O. nepa* and *L. duvauceli*. Similarly, presence of unidentified fishes increased trophic level in the pre-monsoon season to 3.9 ± 0.3. Trophic level steeply increased from the smaller length group to larger groups with an average of 3.9 ± 0.2. In general, juveniles (<525 mm) had low trophic level (3.6 ± 0.03) than larger fishes (4.2 ± 0.09), mainly due to increased consumption of both undientified fishes and *L. duvauceli*

4.14.6. Diet similarities

Dendrogram exhibited the highest similarity in feeding between the pre-monsoon and post-monsoon seasons (75%), mainly due to substantial proportion of *A. indicus* in the diet (Fig 4.14.3). Generally, significant similarity was observed among the length groups and it reached as high as 85% between 301-375 and 451-525 mm length groups and 84% between 376-450 and 451-525 mm length groups (Fig 4.14.4). For both of these groups, *A. indicus* and *S. choprai* were the main source of diet.

4.14.7. Feeding strategy

Fig 4.14.5 shows the prey-specific plot of *R. djiddensis* and it showed a highly specialized feeding strategy. Most of the points in the plot represented by different prey types were congregated on left bottom side owing to their intermittent occurrence in diet. However two points in plot, represented by *A.*

indicus and *S. choprai* were far from other points and means that the predator, *R. djddensis* was highly specialized on these prey organisms during their life.

Table 4.14.1. Prey of *R. djiddensis* in terms of frequency of occurrence (%FO), gravimetric (%W), numerical (%N), and index of relative importance (IRI)

Prey	%FO	%W	%N	IRI	%IRI
Fishes					
Stolephorus spp	4.96	3.32	0.85	20.69	0.44
Cynoglossus macrostomus	2.84	6.33	0.49	19.34	0.41
Unidentified fishes	11.35	6.38	1.94	94.38	2.02
Crustaceans					
Acetes indicus	31.91	28.63	85.32	3636.50	77.87
Solenocera chorpai	23.40	18.95	4.85	557.23	11.93
Peneaid prawn	5.67	8.56	1.33	56.15	1.20
Crab	7.80	4.02	1.58	43.65	0.93
Oratosquilla nepa	10.64	12.60	2.18	157.24	3.37
Cephalopods					
Loligo duvauceli	7.09	9.74	1.46	79.44	1.70
Detritus	3.55	1.47	0.00	5.21	0.11

Table 4.14.2. Seasonal variation in feeding intensity (%) of *R. djiddensis*

Feeding intensity	Season		
	Pre-monsoon	Monsoon	Post-monsoon
Active	9.5	13.0	14.5
Moderate	7.9	8.7	26.5
Poor	47.6	43.5	56.6
Empty	34.9	34.8	2.4

Table 4.14.3. Ontogenetic variation in feeding intensity (%) of *R. djiddensis*

	Length groups (mm)						
Feeding intensity	226-300	301-375	376-450	451-525	526-600	601-675	676-750
Active	12.5	7.7	8.3	27.6	25.0	20.0	20.0
Moderate	12.5	23.1	18.3	10.3	8.3	10.0	20.0
Poor	62.5	61.5	53.3	44.8	8.3	30.0	20.0
Empty	12.5	7.7	20.0	17.2	58.3	40.0	40.0

Table 4.14.4. Seasonal variation in % IRI of prey types of *R. djiddensis*

Prey	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Stolephorus spp	0.14	1.70	0.43
Cynoglossus macrostomus	3.11	0.00	0.16
Unidentified fishes	6.83	0.00	1.56
Acetes indicus	82.79	0.00	78.63
Solenocera chorpai	0.29	31.81	15.56
Penaeid prawn	0.00	14.36	1.23
Crab	4.89	0.00	0.53
Oratosquilla nepa	**0.94**	**43.78**	1.09
Loligo duvauceli	0.72	8.35	0.74
Detritus	0.28	0.00	0.07

Table 4.14.5. Two way contigency table analysis of the seasonal variation of the five prey categories of *R. djiddensis*. (Values are number of prey groups observed in each seasons)

Prey groups	Seasons			N_i	χ^2
	Pre-monsoon	Monsoon	Post-monsoon		
Fishes	9	1	17	18	12.1
Acetes indicus	77	0	626	626	16.1
Prawns	2	9	40	49	62.8
Other crustaceans	9	5	15	20	44.8
Loligo duvauceli	2	2	6	8	16.8
N_j	99	17	704	721	
χ^2	22.8	122.3	7.5		**152.6****

N_i, total numbers by species; N_j, total numbers by season

**, $P < 0.001$, df= 12

Table 4.14.6. Ontogenetic variation in %IRI of prey *R. djiddensis*

Prey	Length groups (mm)						
	226-300	301-375	376-450	451-525	526-600	601-675	676-750
Stolephorus spp	0.00	0.12	1.38	1.15	0.00	0.00	0.00
Cynoglossus macrostomus	0.00	0.59	0.00	0.97	0.00	0.00	51.74
Digested fishes	0.00	3.34	0.87	1.82	0.00	9.88	14.92
Acetes indicus	84.82	82.56	61.87	81.24	48.74	48.18	21.52
Solenocera chorpai	1.52	10.98	19.63	6.83	30.73	2.22	11.82
Digested prawn	0.00	0.09	5.72	3.07	0.00	0.00	0.00
Crab	0.00	0.33	1.65	1.16	0.00	12.90	0.00
Oratosquilla nepa	13.67	1.70	6.36	1.08	2.16	2.37	0.00
Loligo duvauceli	0.00	0.06	2.46	2.57	18.37	24.45	0.00
Detritus	0.00	0.24	0.06	0.10	0	0	0

Table 4.14.7. Two way contigency table analysis of the ontogenetic variation of the five prey categories of *R. djiddensis.* (Values are number of prey groups observed in each length groups)

Prey groups	Length groups (mm)							N_j	χ^2
	226-300	301-375	376-450	451-525	526-600	601-675	676-750		
Fishes	0	12	7	5	0	1	2	27	24.1
Acetes indicus	64	279	145	169	14	30	2	703	5.4
Prawns	1	14	22	8	4	1	1	51	21.9
Other crustaceans	3	9	11	4	1	3	0	31	6.3
Loligo duvauceli	0	1	5	2	2	2	0	12	19.2
N_i	68	315	190	188	21	37	5	824	
χ^2	6.4	5.7	14.7	3.4	16.6	6.7	23.6		76.9**

N_i, total numbers by species; N_j, total numbers by length groups

**, $P < 0.001$, df= 24

Fig. 4.14.1. Seasonal variation in trophic level and diet breadth of *R. djiddensis*

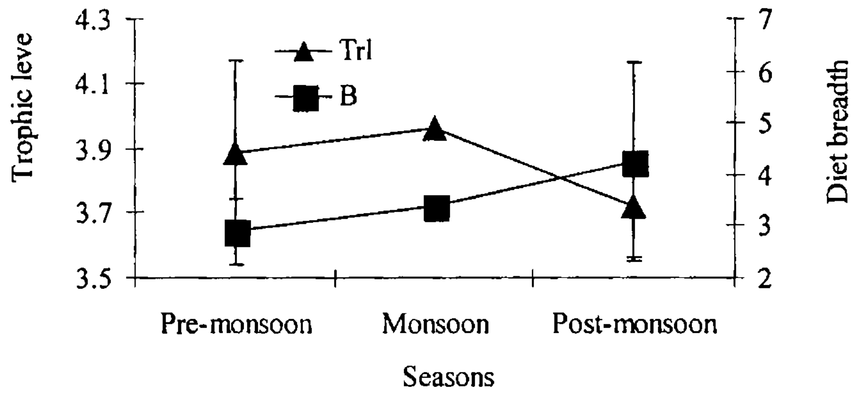


Fig. 4.14.2. Ontogenetic variation in trophic level and diet breadth of *R. djiddensis*

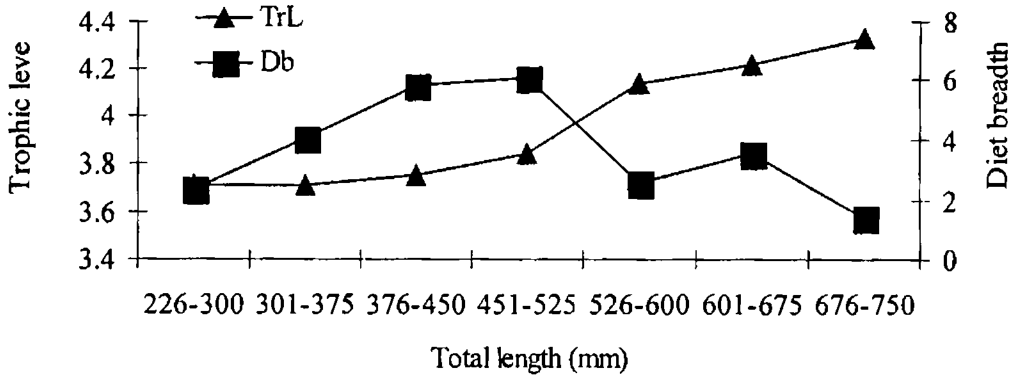


Fig 4.14.3. Dendrogram based on %IRI values of different seasons of *R. djiddensis* using group average clustering

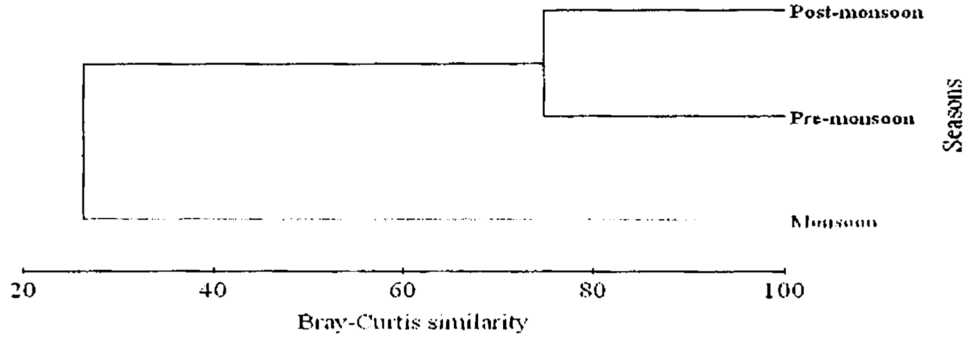


Fig. 4.14.4. Dendrogram based on %IRI values of different length groups of *R. djiddensis* using group average clustering

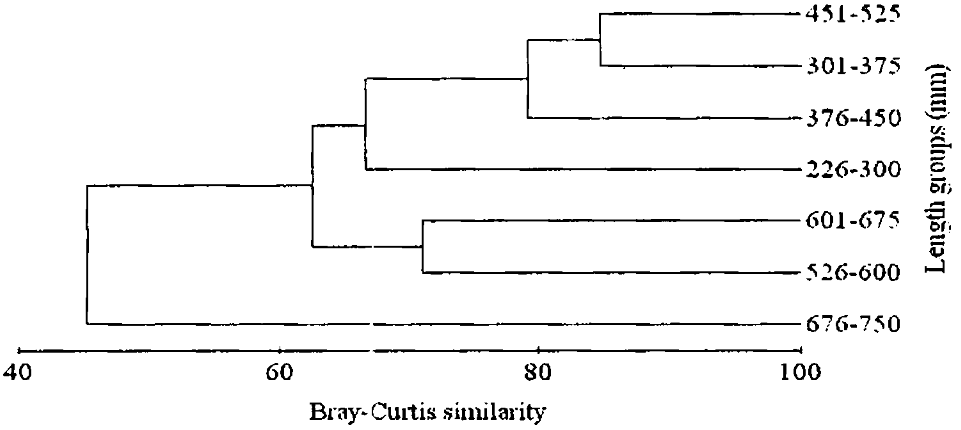


Fig. 4.14.5. Amundson plot for *R. djiddensis* showing prey-specefic abundance (Pi)

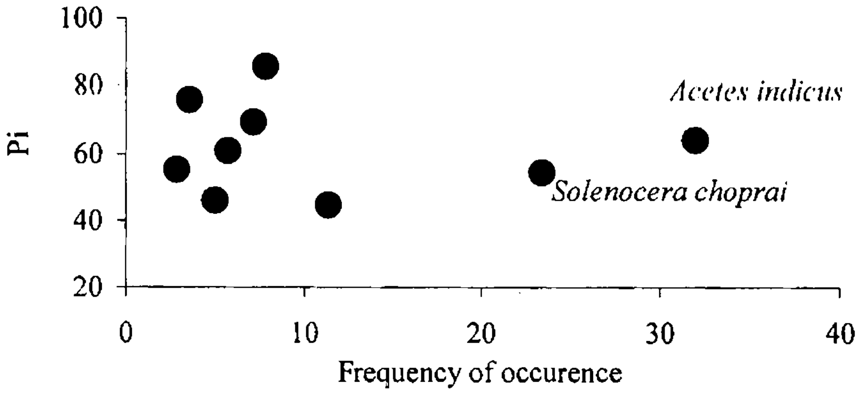


Plate 2. Prey groups identified from the stomach of demersal finfishes (species in brackets are the predators)

a) Benthic crab (*Epinephelus diacanthus*)

b) *Nemipterus* spp (*Grammoplites suppositus*)

c) *Solenocera choprai* and *Acetes indicus* (*Otolithes cuvieri*)

d) *Bregmaceros* spp (*Johnieops sina*)

e) *Bregmaceros* spp (*Nemipterus mesoprion*)

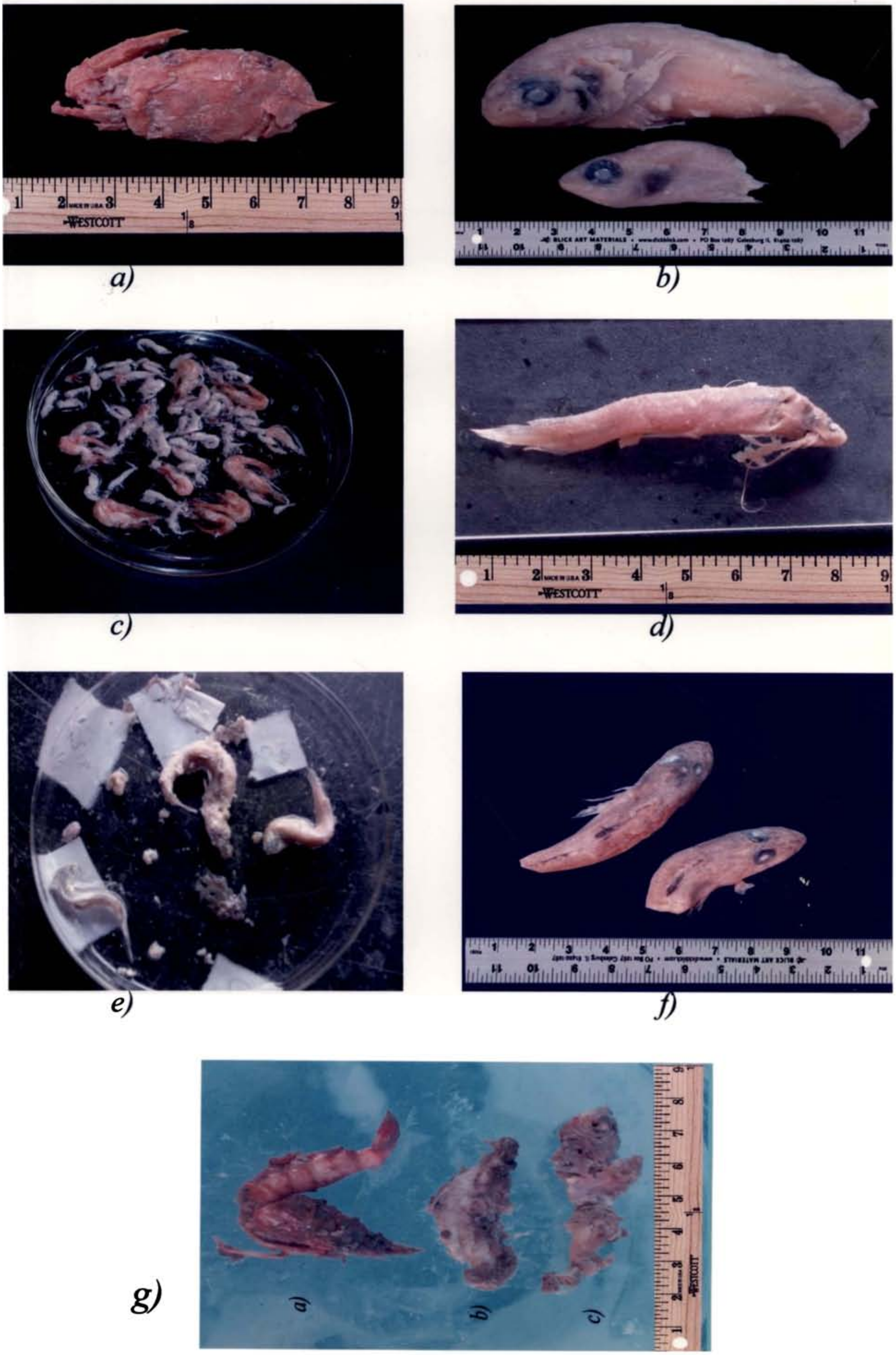
f) *Grammoplites suppositus* (*Nemipterus japonicus*)

g) a) *Solenocera choprai*

b) Digested *Cynoglossus macrostomus*

c) Digested *Leiognathus* spp (*Priacanthus hamrur*)

Plate 2. Prey groups identified from the stomach of demersal finfishes.



a)

b)

c)

d)

e)

f)

g)

Plate 2. (*Continued*)

h) Digested worm (*Cynoglossus macrostomus*)

i) Zooplankton (*Leiognathus bindus*)

j) Copepods (*Pampus argenteus*)

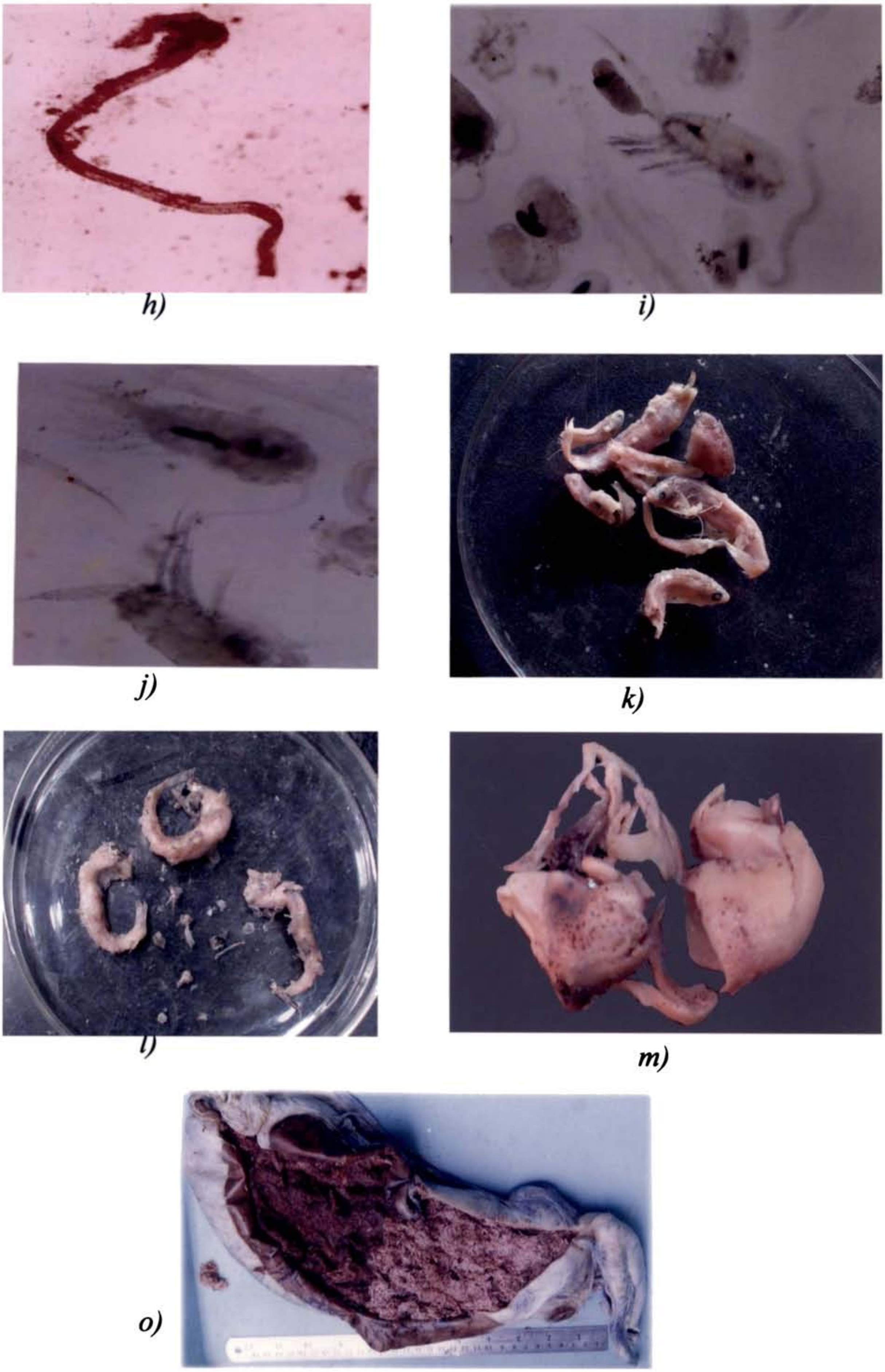
k) *Bregmaceros* spp (*Lactarius lactarius*)

l) Digested *Saurida* spp (*Pseudorhombus arsius*)

m) *Loligo duvauceli* (*Carcharhinus limbatus*)

o) Digested *Acetes* spp (*Rhynchobatus djiddensis*)

Plate 2. (*Continued*)



h)

i)

j)

k)

l)

m)

o)

4.15. Trophic interaction and trophic guilds

4.15.1 Trophic guild determination

Cluster analysis showed trophic guilds based on the predators feeding preference on different prey types and it showed a clear separation among different predators (Fig 4.15.1). There were four trophic guilds at a similarity level of 50%. The first guild is 'copepod and detritus feeders', which included *C. macrostomus* (CMAR), *P. argenteus* (PARG) and *L. bindus* (LBIN). The second trophic guild is 'prawn and crab feeders', which is constituted by *E. diacanthus* (EDIA), *G. suppositus* (GSUP) and *N. japonicus* (NJAP). Guild three is '*Acetes* feeders', the largest guild identified, included *L. lactarius* (LLAC), *O. cuvieri* (OCUV), *P. hamrur* (PHAR), *R. djiddensis* (RDJE), *N. mesoprion* (NMES) and *J. sina* (JSIN). Guild 4, 'piscivores', consisted of *C. limbatus* (CLIM) and *P. arsius* (PARS).

Non-metric multidimensional scaling (MDS) of different prey taxa supports the results of cluster analysis that the points represented by each predator-formed guilds were either entirely or almost entirely discrete from each other (Fig 4.15.2). The individuals such as CMAR, LBIN, PARG, aggregate together at the extreme top of the map, while predators such as CLIMB and PARS formed grouping at left hand side of the map. Species such as GSUP, NJAP and EDIA organized together at the bottom of the map. Very close to this group, NMES and RDJE formed another grouping to right hand side of the plot. The low stress value (0.07) for the MDS plot indicated that it is a good separation of the groups.

The mean trophic level of trophic guilds among the demersal fish community was 3.62 ± 0.5 and their variation is shown in Fig 4.15.3. In general, the mean trophic level of each predator had positive correlation with the mean diet breadth (Fig 4.15.4) with *L. lactarius* and *C. macrostomus* being exception to the rule.

4.15.2. Trophic guild attributes

a) Detritus and copepod feeders

This trophic guild included three members feeding largely on copepod and detritus. Among demersal fishes, CMAR, LBIN and PARG had highest similarity in feeding. SIMPER analysis showed an average group similarity of

61.4% (where 100% is complete similarity) with detritus contributing 67.4% and copepods contributing 19.2% to the similarities of the diet (Table 4.15.1). Highest similarity was observed for LBIN and PARG (78.7%) and they largely compete for detritus and copepods. CMAR, which consumed large proportion of polychaetes and foraminiferans in addition to detritus, reduced its diet similarity relatively to 63.2% with LBIN and 52.6% with PARG (Table 4.15.2). The mean trophic level and diet breadth of copepod and detritus feeders were 2.52 ± 0.21 and 2.49 ± 0.9 respectively.

b) *Prawn and crab feeders*

This is a clear trophic group composed of three demersal carnivores such as GSUP, EDIA and NJAP, which were prawn and crab feeders. This group equally competes for benthic crabs and prawns and formed a separate group in MDS plot. *A. indicus* and unidentified fishes also formed a secondary diet for these groups. SIMPER analysis showed that diet of this group had an average similarity of 56.3% with the main contributions of benthic crabs (45.1%), *S. choprai* (21.8%) and *A. indicus* (15.4%) to the diet. Among this group, the highest similarity was observed for NJAP and GSUP (79%) and they fed predominantly on penaeid prawn, *S. choprai*. Large quantities of benthic crabs in EDIA slightly reduced diet similarity with both NJAP and GSUP. The mean trophic level was 3.99 ± 0.18. Among the four trophic guilds, highest diet breadth of 4.7 ± 0.8 was for prawn and crab feeders.

c) *Acetes feeders*

Six demersal finfish species, namely PHAR, OCUV, NMES, LLAC, RDJE and JSIN were grouped as '*Acetes* feeders' due to their near monophagous feeding behavior to *A. indicus*. SIMPER analysis showed an average similarity of 62.5% with *A. indicus* alone contributing 82.8% to the total diet of this guild (Table 4.15.1). Highest similarity in feeding was observed between NMES and RDJE (79.5%). The mean trophic level and diet breadth of these groups were 3.8 ± 0.3 and 3.5 ± 0.9 respectively.

At a similarity level of 60%, *Acetes* feeders formed obvious sub guilds based on the differential proportion of *A. indicus* in their diet. The first sub guild, 'true *Acetes* feeders', constituted by PHAR and OCUV, has an average similarity of 84.4% in diet composition. This guild consumed *A. indicus*' (89.2%)

exclusively. The mean trophic level and diet breadth for these group were 3.7 ± 0.4 and 3.7 ± 1.7 respectively. The second sub guild, 'Acetes and prawn feeders' was composed of NMES and RDJE at similarity level of 74.9%. SIMPER results showed that *A. indicus* (76.1%) and penaeid prawns (17.5%) were the major contributors of diet similarity. This sub guild, which has the highest trophic level (4.0 ± 0.1) was also characterized by its highest diet breadth (4.2 ± 0.7) among 'Acetes feeders'. Third sub guild, constituted by LLAC and JSIN, was grouped as 'Acetes and fish feeders' with an average similarity of 61.0% with the main contribution of *A. indicus* (68.2%) and teleosts (24.6%). The average trophic level and diet breadth for this group were 3.8 ± 0.2 and 2.7 ± 0.16 respectively.

d) *Piscivores*

Demersal carnivores, which included predators such as CLIMB and PARS, were grouped as piscivores. Their diet was mainly constituted by teleosts (>70 % IRI). CLIMB preyed largely on *S. longiceps*, unidentified fishes and *S. devisi*, whereas, PARS consumed large quantities of the same genus *Pseudorhombus* spp and *P. indicus*. SIMPER analysis showed an average similarity of 73.5% with teleosts contributing 73.1% similarities to the diet. The mean trophic level and diet breadth of psicivores were 4.2 ± 0.2 and 2.2 ± 0.5 respectively.

4.15.3. Divergence of trophic guilds

SIMPER analysis revealed the niche partitioning in trophic guilds of the demersal fish communities. Table 4.15.3 shows the dissimilarities in the prey components of various trophic guilds. Trophic partition was highest between guild 1 (copepod and detritus feeders) and guild 2 (prawn and crabs feeders) which had the highest average dissimilarity of 94.3% with detritus contributing to 25.0 % and benthic crabs contributing 22.5 % of the difference. The second highest dissimilarity (92.9%) was observed for guild 1 (copepod and detritus feeders) and guild 4 (piscivores) with teleosts contributing 37.4 % and detritus contributing 25.4% of the difference. Significant trophic partition (90.9%) was also observed for guild 1 (copepod and detritus feeders) with guild 3 (*Acetes* feeders) with *A. indicus* (35.3%), benthic crabs (30.6%) and *S. choprai* (15.3%) contributing to the difference Similarly, other guilds also have significant partitioning in diet.

ANOSIM best described the existence of niche partitioning in demersal finfishes. The results of 999 permutations are given in Fig 4.15.5 and R-statistic values ranges from - 0.35 to +0.55. The results of ANOSIM between the different trophic guilds indicated significant differences (Global R-statistic: 0.88). Among trophic guilds, the highest significant partitioning was seen when comparing prey composition of predators of copepod-detritus feeders with Acetes feeders (R-statistic: 0.989) ($p<0.001$), secondly between copepod-detritus feeders with piscivores (R-statistic: 0.982) and thirdly, Acetes feeders with piscivores (R-statistic: 0.906). However, among demersal fishes, only moderate separation was observed for prawn and crab feeders with Acetes feeders (R-statistic: 0.543) and piscivores (R-statistic: 0.5).

4.15.4. Influential prey organisms

BVSTEP analysis provided the list of highly influential prey organisms to the survival of various trophic guilds of demersal fish communities (Table 4.15.4). In each step, after a series of deletion of prey groups that did not influence the ordination process, the prey types, which were observed to be highly influential for the predators were presented. Among the five variable lists, *A. indicus*, penaeid prawns, benthic crabs, teleosts and copepods were highly influential (R^2= 0.96), whereas in the list with six variables, in addition to teleosts, benthic crabs and *A. indicus*, groups/species such as of cephalopods, diatoms, polychaete worms, *Oratosquilla nepa* and detritus were highly influential. However, it is pertinent to note that *A. indicus*, teleosts and penaeid prawns were subjected to high predation by different demersal finfishes.

Based on the diets, a conceptual food web was created and shown in Fig 4.15.6. It is quite clear that *Acetes indicus* is a central prey organism in the food web.

Table 4.15.1. SIMPER results based on different prey category contributions to within guilds similarity for diets

	Trophic guilds	Prey category	Average Similarity	Sim/SD	%Contribution	%Cumulative contribution
1)	Copepods and detritus feeders		61.41			
		Detritus	41.4	7.8	67.4	67.4
		Copepods	9.9	0.79	19.2	83.6
2)	Prawn and crab feeders		56.33			
		Benthic crabs	25.4	2.07	45.1	45.1
		Penaeid prawns	12.3	0.69	21.8	66.9
		Acetes indicus	8.7	1.4	15.4	82.3
		Teleosts	8	1.86	14.2	96.4
3)	Acetes feeders		62.51			
		Acetes indicus	51.7	3.7	82.8	82.8
		Teleosts	7.1	1.6	94.2	94.2
4)	Piscivores		73.54			
		Teleosts	73.1	0	99.4	99.41

Table 4.15.2 Bray-Curtis similarity between predators

Predators	CMAR	EDIA	GSUP	JSIN	LBIN	OCUV	PARS	PHAR	PARG	LLAC	CLIMB	NMES	NJAP	RDJE
CMAR														
EDIA	11.05													
GSUP	15.05	69.58												
JSIN	41.41	46.02	39.10											
LBIN	63.21	11.59	12.53	44.74										
OCUV	24.81	45.58	46.93	65.52	23.79									
PARS	23.26	40.41	57.86	39.66	21.38	49.32								
PHAR	19.56	45.97	35.07	56.60	30.33	74.50	39.69							
PARG	52.56	7.90	8.83	37.67	78.74	20.39	14.06	21.01						
LLAC	22.60	43.48	40.45	62.02	21.28	66.17	54.65	55.49	17.57					
CLIMB	19.07	25.36	27.70	26.08	17.19	28.81	58.06	25.51	9.69	51.16				
NMES	12.70	49.01	58.62	49.57	13.99	68.23	48.78	68.48	8.21	54.85	29.34			
NJAP	16.97	66.03	78.63	49.54	15.25	59.25	59.05	48.87	9.88	53.02	41.62	71.37		
RDJE	9.33	57.10	52.13	53.40	9.68	73.66	45.55	69.62	9.43	56.87	23.54	79.47	63.57	

Table 4.15.3. SIMPER results based on different prey category contributions to between guilds dissimilarity for diets

Trophic guilds	Prey category	Average dissimilarity	Sim/SD	%Contribution	%Cumulative contribution
Guild 1 vs. Guild 2		94.29			
	Detritus	23.61	6.24	25.04	25.04
	Benthic crabs	21.21	1.91	22.49	47.54
	Penaeid prawns	12.55	1.42	13.3	60.8
Guild 1 vs. Guild 3		90.93			
	Acetes indicus	31.37	3.63	34.5	34.5
	Detritus	22.95	6.03	25.24	59.74
	Copepods	10.83	1.39	11.91	71.64
Guild 2 vs. Guild 3		68.87			
	Acetes indicus	24.34	2.62	35.34	35.34
	Benthic crabs	21.1	1.96	30.6	65.98
	Penaeid prawns	10.51	1.37	15.26	81.25
Guild 1 vs. Guild 4		92.94			
	Teleosts	34.71	14.84	37.35	37.35
	Detritus	23.61	6.04	25.41	62.75
	copepods	11.36	1.32	12.2	74.98
Guild 2 vs. Guild 4		77.81			
	Teleosts	31.34	8.68	40.28	40.28
	Benthic crabs	20.47	1.78	26.3	66.59
	Penaeid prawns	10.97	1.57	14.1	80.69
Guild 3 vs. Guild 4		77.87			
	Acetes indicus	30.76	3.51	39.5	39.5
	Teleosts	29.31	3.23	37.74	77.24

Table 4.15.4. BVSTEP results of influential prey groups

No. of variables	R^2	Prey groups with highest variability
5	0.960	Teleosts, penaeid prawns, benthic crabs, *Acetes indicus*, copepods
5	0.953	Teleosts, penaeid prawns, benthic crabs, *Acetes indicus*, cephalopods
6	0.953	Teleosts, benthic crabs, *Acetes indicus* cephalopods, diatoms, detritus
6	0.952	Teleosts, penaeid prawns, *Oratosquilla nepa, Acetes indicus*, polychaetes, detritus

Fig. 4.15.1. Dendrogram showing the existence of different trophic guilds within the demersal finfishes using group average clustering.

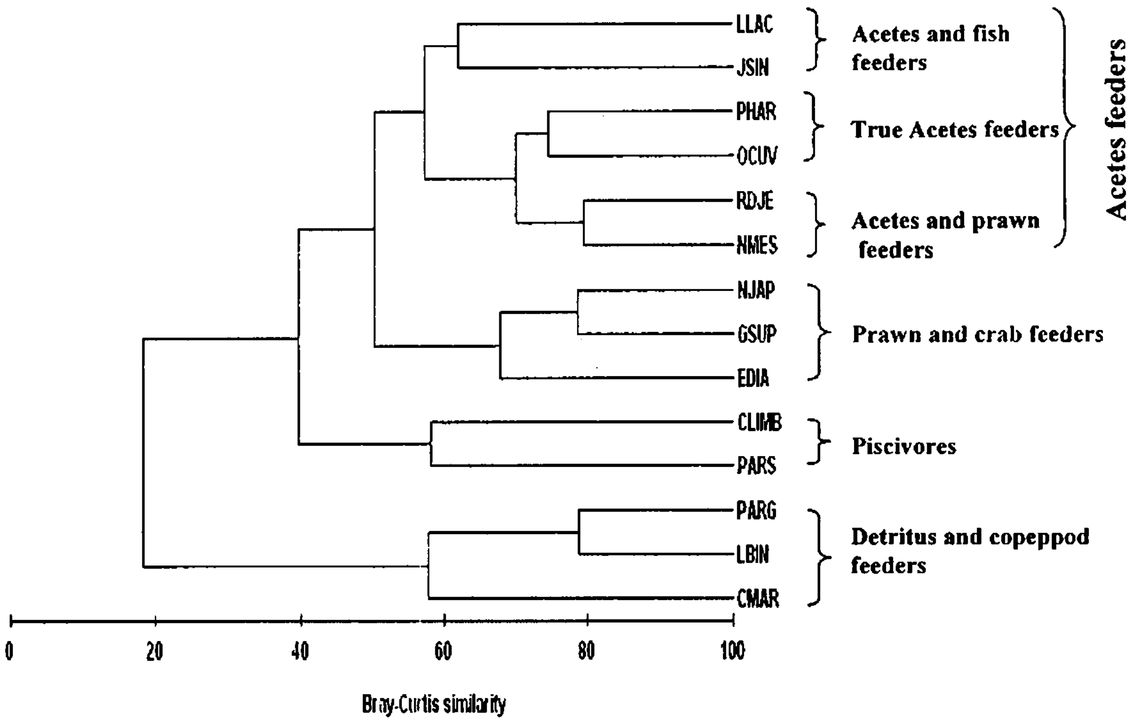


Fig. 4.15.2. Multi dimensional scaling (MDS) ordination of the finfishes based on the similarity matrix

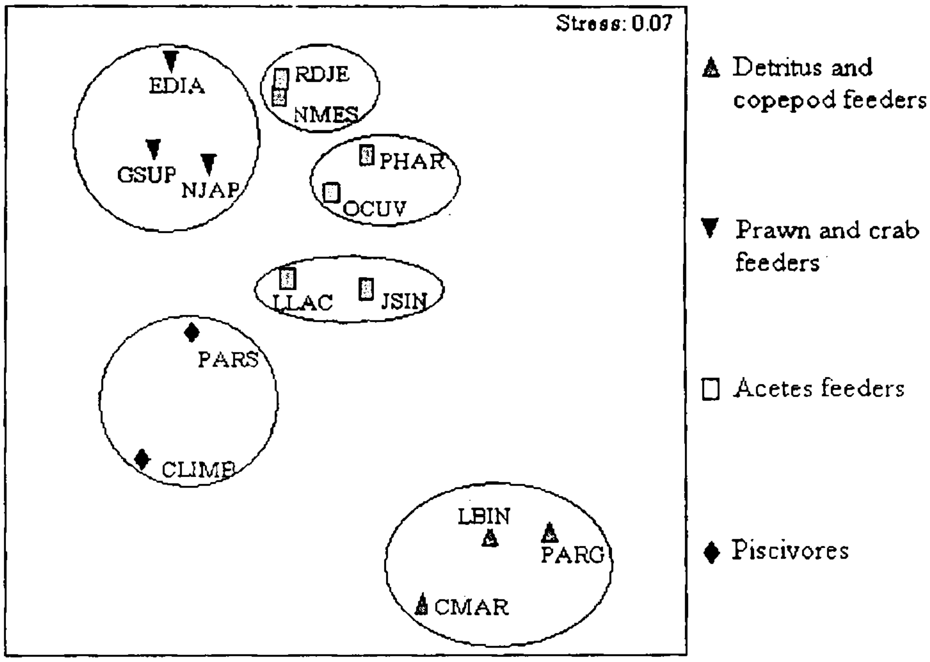


Fig. 4.15.3. Mean trophic level of trophic guilds of demersal fish communities

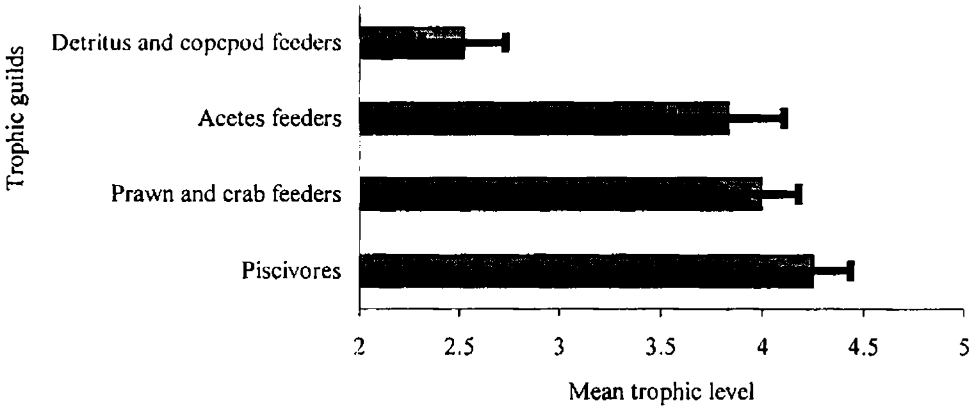


Fig. 4.15.4. Relationship between diet breadth and trophic level

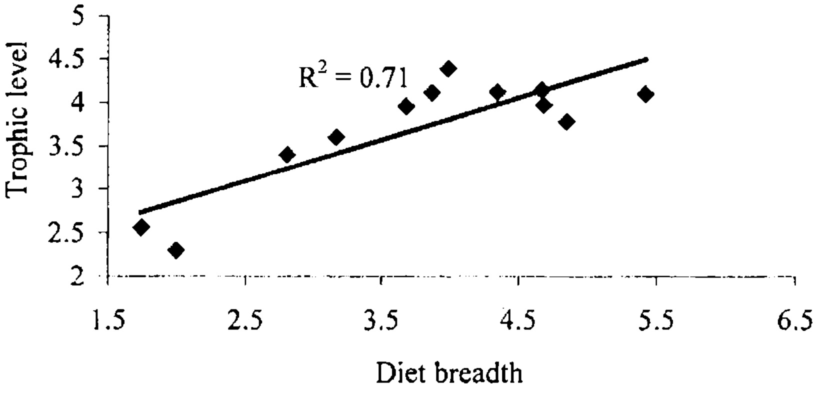


Fig. 4.15.5. The range of R-statistic values between the trophic guilds.

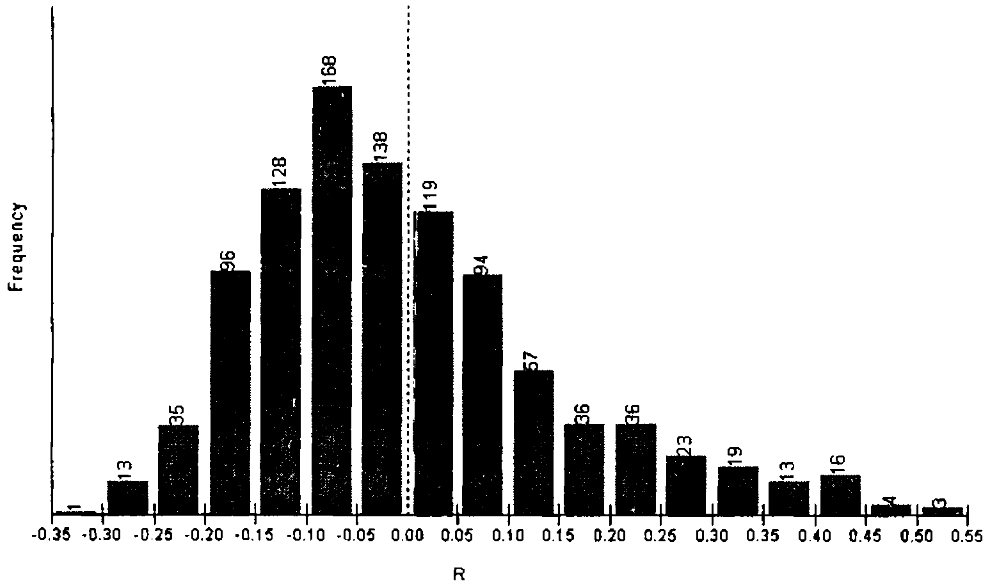
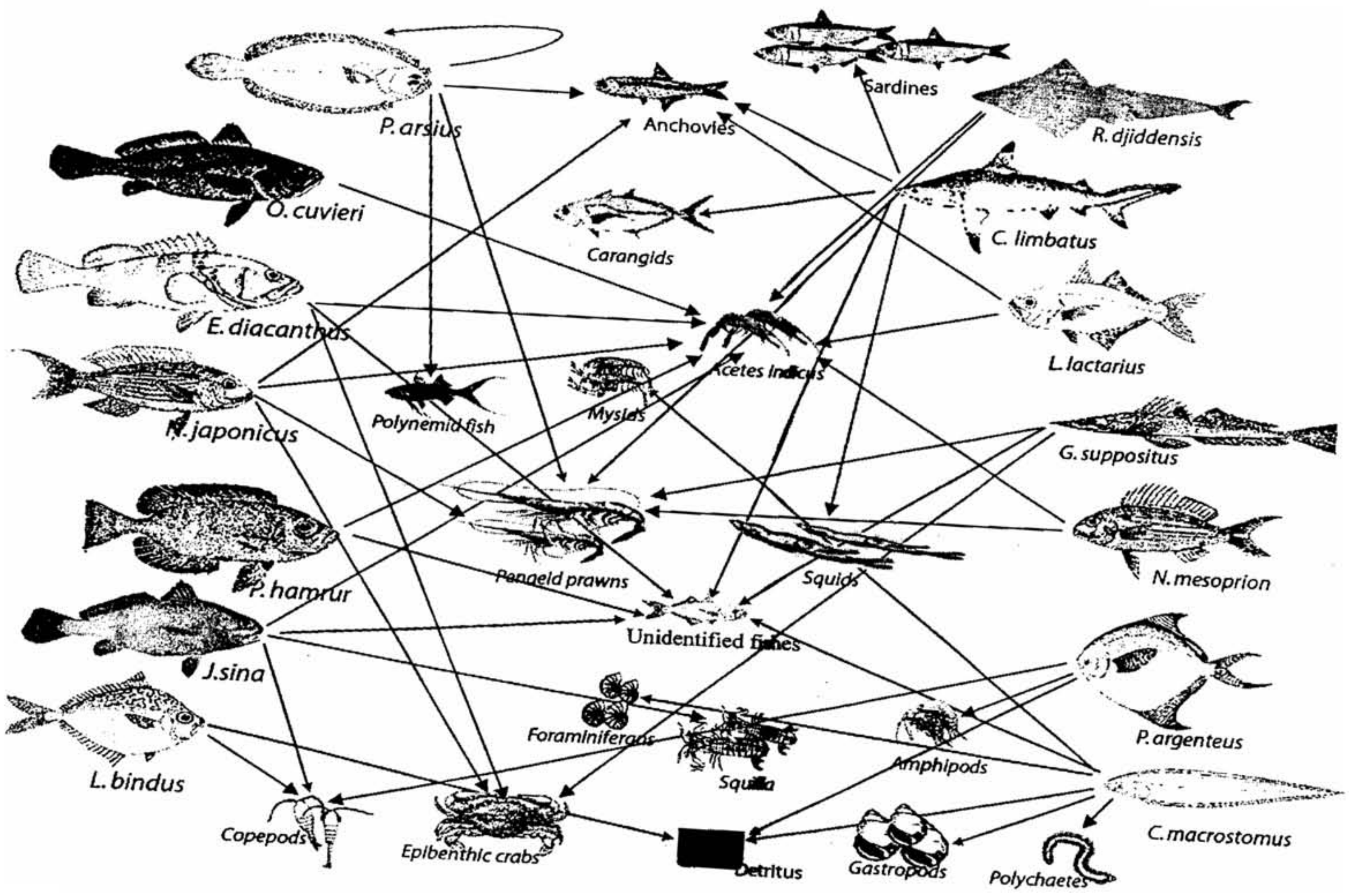


Fig. 4.15.6. Conceptual food web of demersal finfishes and their prey (only links with %IRI>5 were shown)



Chapter 5.

Discussion

5.1. *Epinephelus diacanthus*

Rockcods are demersal carnivores and preferred to feed largely on benthic crustaceans (Premalatha, 1989; Brule and Canche, 1993; Do drill *et al.*, 1993; Tessy, 1994; Eggleston *et al.*, 1998; Renones *et al.*, 2002). The present study confirms the importance of crustaceans in the diet of *E. diacanthus*. Specialisation of *E. diacanthus* to benthic crabs among crustaceans was also reported by Tessy (1994) from Visakapatanam. Crabs belong to the genus *Charybdis* followed by prawns, *Squilla* spp, hermit crabs etc were the important crustaceans in the diet of rockcods from Visakapatanam (Tessy, 1994). Brachyuran crabs formed the major diet of Nassau grouper (*E. striatus*) in the northern Gulf of Mexico. Heemstra and Randall (1993) also reported dominance of crabs in the diet of similar species *E. longispinis* from Can Mart Qeb. Therefore, it can be concluded that benthic crabs are favorite diet of rockcods. Tessy (1994) also reported significant proportion of prawn species such as *P. stylifera* and *Trachypenaeus* spp in the diet of *E. diacanthus* from Visakhapatnam. However, prawn species were never formed an important group in the present study. Besides crabs and prawns, stomatopods formed other important crustacean to *E. diacanthus* (Tessy, 1994) and to red grouper, *E. morio* (Brule and Canche, 1993). In the present study, stomatopods contributed significantly to the diet. Premalatha (1989) reported remnants of ostracods in *E. chlorostigma* and small cruastaceans in *E. areolatus* from the southwest coast of India.

In addition to crustaceans, the presence of teleosts in the diet added to the diversity of the diet spectrum. Tessy (1994) in *E. diacanthus* recorded different types of teleosts such as *Stolephorus* spp, *Nemipterus* spp, *Cynoglossus* spp, *Platycephalus* spp, Carangids etc. Similar teleosts were also observed during the present study and it is suggested that *E. diacanthus* generally feed on teleosts of demersal habitats.

A marginal ontogenetic diet shift in *E. diacanthus* was observed during the present study with preference for benthic crabs and paste shrimp during smaller sizes and a slight increase in preference for teleosts during larger sizes. Tessy (1994) observed that lower length groups had a preference for crustaceans while the higher length groups preferred teleosts. Renoneso *et al.*,(2002) reported size related diet shift in *E. marginatus* in western Mediterranean littoral ecosystem and reported that the largest dusky grouper fed primarily on fishes that represented 41% of prey identified. They also added that these shifts in diet were accompanied by a positive selection of increasingly large prey and by expansion of trophic niche. Similar to the present study, Eggleston *et al.* (1998) from the Gulf of California observed an ontogenetic shift in diet of small grouper, *E. striatus* (<20 cm TL) which consumed mainly brachyuran crabs and other small crustaceans, and large grouper (>30 cm TL) which consumed primarily fish. Also they reported least diverse diet in larger fishes. It is also supported by Randall (1965) that predatory fishes during their juvenile life stages most often eat crustaceans and when they become adults a shift to fish types as potential food organisms is common.

Seasonal changes in feeding indicated that in none of the seasons teleost prey dominated the diet, however, the predominance of *A. indicus* during monsoon may be possibly due to the non availability of the most preferred prey, benthic crabs in that season. Such as kind of diet change over season was also observed by Tessy (1994) with a preference for *Squilla* spp during the post-monsoon and penaeid prawns during the pre-monsoon seasons. Morato *et al.* (2000) reported the seasonal variation in diet composition of blacktail comber, *Serranus atricauda* from the north-eastern Atlantic. Blacktail comber responds to seasonal changes in food availability, which reflects the opportunistic behaviour and the trophic adaptability of this predator. Mysids were the most frequent in June-August and in other periods fish items dominated the diet (Morato *et al.*, 2000). Larger proportion of *A. indicus* in the monsoon season during the present study can be related to their dominance in the environment; where as, lack of information regarding the abundance of the same from the Karnataka coast makes this interpretation difficult.

Large proportion of empty stomachs in rockcods throughout the season as well as in all length groups have been reviewed by many workers. Feeding is related to the cyclic time patterns. Active feeding of grouper at dawn and dusk was observed by Randall (1967). Similarly, Silas (1969) observed grouper to stop intake of food after dusk. Moreover, Randall and Brook (1960) observed active feeding at dawn than after dusk. Hence there is possibility for higher proportion of empty stomachs in fishes caught after dusk. With a similar view, Collete and

Talbot (1972) observed active feeding of *E. guttatus* during daylight hours. Feeding pattern in rockcods is peculiar that they are able to swallow its food without chewing it in mouth. Tessy (1994) reported that the diet components of *E. diacanthus* are fairly easy to identify because they swallow their prey without chewing it. Hence unidentified prey groups are very less in the present study.

Rockcods are basically high level carnivores (Vivekanandan *et al.*, 2006). The mean trophic level calculated during the present study is almost in same range as recorded for groupers in other ecosystems. Trophic level of 3.9 for *E. coioides* (Randall and Heemstra, 1991), 4.1 for *E. longispinis* (Heemstra and Randall, 1993) and 4.1 for *E. malabaricus* (Thollot, 1996) also suggested that groupers are higher level carnivores. Higher trophic level of fishes during monsoon was mainly due to the presence of carnivorous fishes like *T. lepturus* and other teleosts in the diet. Vivekanandan *et al.* (2006) classified *T. lepturus* as one of the large carnivore form the Indian coast. Such occurrence of carnivores in the diet composition will increase the trophic level during that particular season. Similarly the occurrence of larger fishes in the diet is responsible for the increased trophic level with ontogeny as observed by Tessy (1994) and Egglesten *et al.* (1998). Groupers generally prefer low trophic level prey groups such as crustaceans in their young stages and fish items as adults.

5. 2. *Grammoplites suppositus*

The spotfin flathead, *G. suppositus* is essentially a benthic predator feeding on crustaceans, teleosts, cephalopods and other miscellaneous items. The various components of the food spectrum indicate that the species is mainly a bottom feeder preferring low trophic level benthic crustaceans. The most preferred food were the benthic crabs and penaeid prawns which are actively mobile in the substratum and therefore are hunted before the predator ingests them. The flat compressed body is designed for benthic mode of life. Teleost fishes such as *N. mesoprion*, *G. suppositus*, *Saurida* spp, *Trichiurus* spp, *C. macrostomus*, *Stolephorus* spp, and *L. bindus* are demersal fishes inhabiting the bottom which form the food of *G. suppositus* agreeing with its benthic feeding behaviour. Rao (1964) while studying G. *scaber* briefly described higher percentages of crustaceans (81.6%) followed by fishes (17.4%) in the diet. This agrees with the present study that crustaceans and fishes are the most important preys of flathead. Paxton *et al.* (1989) observed that in *Platycephalus fuscus*, small fish, crabs, prawns, small crustaceans, octopus, squid and polychaetes were the major components the diet. He observed that spines on the outer edge of their head can inflict deep cuts during handling of prey organisms.

Nasir (2000) reported that shrimps formed the major food component of *P. indicus* from Kuwait. Wu (1984) observed that in Hong Kong waters the mantis shrimp mainly represented by *Oratosquilla oratoria* and prawns were the most preferred diets of *P. indicus*. However, Marais (1984) while studying the feeding ecology of *P. indicus* from Eastern Cape estuaries of South Africa observed that fish components mainly *Liza richardsoni* formed the major proportion in the diet. Crabs were next in importance followed by a small fraction of other benthic crustaceans and algae. Bauchot (1987) identified crustaceans such as *Portunus hastatoides, Charybdis cruciata, Oratosquilla oratoria* and fishes such as *Apogon quadrifasciatus*, *Callionymus richardsonii, Plotosus lineatus* and unidentified clupeids in the diet of *P. indicus* from Hong Kong waters. Jeyaseelan (1998) recorded unidentified fishes, shrimps and other benthic invertebrates as the most important diet of the similar species *Cociella crocodila* from Asian mangroves. In another species, *P. maculipinna*, George *et al.* (1968) reported that crustaceans were next in importance to fishes in its diet. Along with fishes and crustaceans, small quantities of polychaetes, gastropods and sea urchin spines were also found in this study. These studies indicate that in the northern latitudes particularly in Asia, crustaceans like crabs and prawns are the major components of the diet of flatheads followed by fishes. While in the southern latitudes, like the waters around South Africa, fishes were the principal component of the diet of flatheads, followed by crustaceans.

The IRI of different prey categories showed considerable variation between seasons. Diet of flatheads during monsoon and post-monsoon did not show much variation as a result of equal proportion of crustaceans in the diet. However, *G. suppositus* during pre-monsoon ate large quantities of fish groups along with crustaceans. This may be due to the changes in the food organisms and their availability (Nikolsky, 1963). The present investigation also suggests that the nature of food of *G. suppositus* is size dependent. Fishes of smaller length groups (<165mm) preferred mainly teleosts. Consumption of crustaceans was more in larger length groups indicating a significant shift in feeding preference. The Bray-Curtis similarity analysis showed that food of fishes of length 216-240 and 241-265 mm had highest similarity indicating a possible competition among length groups. However, Colwell and Futuyma (1971) have shown that a high value of diet overlap does not necessarily indicate competition. Food resources can often be shared amongst fish species or length classes of single species.

A large number of *G. suppositus* were found to have empty stomachs. The high percentage of the empty stomachs and poor feeding condition may be due to the spawning activity and seasonal variations in the availability of food. Kagwade (1972) recorded such occurrence of high percentage empty stomachs in many species of fishes from Bombay. The frequent occurrence of empty stomachs or stomachs with little contents may be probably dependent on the ratio between the size of the fish and size of the prey (Allen, 1935). Longhurst (1957) stated that when the fish is an important food item, the daily intake will be less because of the higher calorific value of the diet and as such empty stomachs will be more common.

Ontogenetically and seasonally the trophic level showed variations. The mean trophic level (TrL) of *G. suppositus* was 3.78 ± 0.15 and it did show deviation among the different length groups. In juveniles, low trophic level was recorded owing to the fact that the prey composition and diversity was very less and usually trophic level increased during ontogeny, because larvae and juveniles are likely to feed at lower levels than conspecific adults (Pauly *et al.*, 2001). Hence there was a shift in trophic level in accordance with the ontogenetic diet shift. This is in agreement with studies of Cortes (1999) on elasmobranchs. His results suggested positive correlation between trophic level and body length especially in carcharhinid sharks. However, as the length of flathead increases, trophic level also increased but in larger length groups it again decreased. This shift in trophic level with body length is in accordance with view that trophic levels of aquatic organisms are inversely related to length (Pauly *et al.*, 1988a). Darnell (1961) stated that animals of a given size and belonging to single species take food from several sources and ontogenetic progression of food habits is common in animals. However, for some fishes, ontogenetic shifts in diet are not always necessarily accompanied by an increase in trophic level. Trophic level failed to increase with increase in body size of lake trouts (Vander Zanden *et al.*, 2000).

In *G. suppositus* there is broad variation in the mean diet breadth among different length groups and seasons. Higher diet breadth in monsoon is attributed to the largest prey diversity and higher proportion of individual prey resources. This trend in the diet breadth with length may suggest that as the predator grows, it targets new prey available to it together with prey, which it targeted at an earlier age. Darnell (1961) suggested that predators commonly utilize food resources according to their availability.

A positive linear relationship between lengths of predator and prey (*S. choprai*) was found. Likewise larger *G. suppositus* consumed bigger benthic crabs. Flavia *et al.* (2000) found in striped weakfish, *Cynoscion guttucupa* a positive linear trend for crustaceans, however, no relationship between the length of teleost prey and predator length was found. Co-existing fish species may differ in their morphology, feeding behaviour and, to some extent, size-selection of prey species (Gibson and Ezzi, 1987). A selection for small prey items, independent of predator length, has been recorded for many piscivorous fish under both laboratory and field conditions (Juanes *et al.*, 1993, Juanes and Conover, 1994). They attest that this 'preference' for small prey is a reflection of size-based attack success rates. Thus all sizes within predators mouth gape are attacked as encountered, but those most vulnerable are ingested most often, resulting in the apparent preference. Electivity study shows that *G. suppositus* strongly selected low trophic animals such as crustaceans mainly benthic crabs and penaeid prawns in the diet even though fishes formed largest proportions in the demersal catch. This may also depend on the feeding ability of *G. suppositus* to eat large demersal and pelagic fishes available in the habitat.

The feeding strategy of the spotfin flathead was such that it most often showed a specialised feeding strategy on benthic crustaceans. These results support the theory proposed by MacArthur and Pianka (1966) that feeding will become more selective and specialised when food is abundant. This is again supported by the optimal foraging theory that predicts diets will become more specialised as the abundance of preferred prey increase (Pyke *et al.*, 1977; Hart, 1997).

5. 3. *Priacanthus hamrur*

Priacanthids are generally the benthic carnivorous fishes preferring a diet composed largely of different types of crustaceans (Rao, 1984; Ambak *et al.*, 1987; Philip, 1998; Zacharia *et al.*, 1991). Philip (1998) from the Vishakpatanam coast described their crustacean feeding behavior both ontogenetically and seasonally. Rao (1964) observed crustacean feeding behavior of similar species such as *P. tayenus* and *P. macracanthus* from Bay of Bengal. Moreover, studies from Southeast Asian regions on similar species *P. tayenus* and *P. macracanthus* concluded that crustaceans are the most preferred food types from Malaysia (Ambak *et al.*, 1987) and Thailand (Chomjurai, 1970; Wetchgarun, 1971). Philip (1998) described the carnivorous nature of priacanthids with strong oblique mouth and slightly protrusible premaxilla, exposed maxilla and upturned and strongly projecting lower jaw with conical teeth on premaxilla, vomer and palatine.

Being a benthic carnivore, detritus and other micro and macro epibenthic organisms are very less in the stomach. The absence of such organisms in the diet indicates that browsing on the sea bottom for food is not a feeding behavior of *P. hamrur* (Philip, 1998). Tamura (1959) attributed the visual feeding by priacanthids that they generally take food which are above and ahead of it. Philip (1998) identified the crustaceans in the diet as alima, squilla, crabs, prawns and euphausids in addition to the sporadic occurrence of *Acetes* spp, isopods, mysids, *Lucifer* spp. etc. However, in the present study, *A. indicus* formed the most important species among crustaceans. Rao (1964) recorded *Penaeus* spp, *Metapenaeus* spp and *Solenocera* spp as the predominant crustaceans from the Waltair coast. *Solenocera* spp. as reported by these authors was identified as *Solenocera choprai* and it indicates that priacanthids prefer *Penaeus* spp, and *Metapenaeus* spp, when they are in shallow waters and *S. choprai* when in deeper waters. Teleosts also formed a significant part of the diet of *P. hamrur*. The epipelagic anchovies, which formed an usual component in most of the pelagic and demersal carnivores, also became one of the teleosts in the diet of *P. hamrur* and it indicates the ability of priacanthids to capture actively moving pelagic fishes.

Seasonal variation in the diet of *P. hamrur* was influenced by the sampling areas where prey abundance of different prey groups showed variations (Philip, 1998). Variation in diet composition according to season is a common trend in many of the demersal carnivores (Rao, 1981, Vivekanandan, 2001, etc). In the present study, *A. indicus*, was highly preferred in both the pre-monsoon and post-monsoon seasons. However, their absence in monsoon could have been replenished by the increased consumption of amphipods, copepods and detritus. Such a kind of seasonal variation in euphausids and *Bregmaceros* spp which formed predominant prey in *P. hamrur* in Visakhapatnam was observed by Philip (1998). Zacharia *et al.* (1991) have reported the migratory behaviour of *Priacanthus* spp. along the Karnataka coast from the deep waters in the monsoon season to shallow waters in the pre-monsoon season and to the deeper areas again in the post-monsoon season for breeding. They also reported this deeper waters migration to the feeding purpose of priacanthids.

Ontogenetic difference in feeding with increased consumption of detritus and other small benthic zooplankton in young fishes is an indication diet shift with ontogeny. Gradual increase in consumption of *A. indicus* with size illustrated the active feeding of preys present off bottom when they become old. The complete lack of teleosts in very small fishes (<170 mm) also indicates younger ones are not able to feed on fishes, instead, feeding largely on benthic zooplanktons and other infauna and detritus. In contrast to the present observation, Philip (1998) observed young ones to feed on *A. indicus* and copepods, amphipods and other benthic crustaceans.

5. 4. *Johnieops sina*

Different benthic invertebrate prey taxa encountered in the diet suggested the bottom feeding behavior of *J. sina* with specialization on crustaceans. The dominance of benthic invertebrates, especially crustaceans in the diet of many sciaenids has been noted by many authors (Rao, 1964; Suseelan and Nair, 1969; Pillai, 1983; Fennessy, 2000; Manojkumar, 2003). The present diet study on *J. sina* has brought out the dominance of crustaceans in the diet. Crustacean preys were dominant in the stomach of four species of sciaenids studied from the east coast of South Africa (Fennessy, 2000). George *et al.* (1968) while the feeding habits of another sciaenid, *Pseudosciaena sina* from trawl fishing grounds off Cochin observed a variety of crustaceans such as amphipods, copepods, mysids, sergestids, megalopa, alima larvae and caridean prawns and they constituted the majority of the diet. Qasim (1972) grouped sciaenids as carnivores based on the works published by many Indian authors. Venkataraman (1960) in *J. belengeri*, recorded prawns, polychaetes, Squilla, *Acetes* spp, amphipods, copepods and sand from the Calicut coast. Crustacean dominance especially prawns was also observed by Suseelan and Nair (1969) in a similar species, *J. dussumieri* from Bombay. They also analysed the diet of another similar species, *J. carutta* from Bombay and observed their carnivorous bottom feeding on penaeid prawns, *Acetes indicus*, portunid crabs and amphipods. Occurrence of crustaceans such as prawns, *Acetes* spp, stomatopods, amphipods, isopods, copepods and polychaetes in a similar species, *J. axillaris* (Suseelan and Nair, 1969) also supported the fact that sciaenids especially *Johnius* spp mostly prefer crustaceans.

Jacob (1948) recorded a number of crustaceans such as copepods mainly *Paracalanus* spp, *Lucifer* spp, foraminiferans, radiolarians, larval crabs, *Gammarus* spp, prawns from the gut of *J. carutta*. Suseelan and Nair (1969) observed *A. indicus* as the most dominant crustacean in *J. aneus* from Bombay. Second and third important prey groups such as *O. nepa* and copepods as recorded during the present study was also found to occur in similar species like *J. aneus, J, argenteus, J. carutta, J. belengeri* and *J. axillaris* (Venkataraman, 1960, Rao, 1964). As observed in the present study, *A. indicus* formed an important component of the diet of *Johnius* spp. Also among the different crustaceans, the most important prey, *A. indicus* is one of the highly preferred prey groups for many other demersal finfishes (Rao, 1989; Raje, 1996, Manojkumar, 2003). Hence these observations suggested that *J. sina* like other *Johnius* spp are specialized feeders on *Acetes* spp, stomatopods and copepods.

No significant proportion of teleosts was observed in the diet. This may be due the availability of most preferred crustaceans in the environment. The present observation agrees with those of earlier workers that fishes are not significant part of the diet of *J. sina*. The benthic teleost species, *Bregmaceros* spp was also recorded form the stomach of *J. dussumieri* caught from Bombay waters (Suseelan and Nair, 1969). Similarly, *Stolephorus* spp was identified from the gut of *J. carutta* in addition to other teleosts (Jacob, 1948).

Ontogenetic diet shift from small crustaceans to larger prey groups is common in many sciaenids (Bapat and Bal, 1952; Rao, 1980; Nair, 1980; Manojkumar, 2003). During the present study, diet shift was characterized by increased proportion of large preys such as *O. nepa* and teleosts in fishes of large size groups. Bapat and Bal (1952) observed ontogenetic diet shift in a similar species, *J. dussumieri*. They observed that juveniles are voracious feeders of crustaceans and adults are mainly feeding on teleosts. Similarly, Manojkumar (2003) observed preference to teleosts by the larger size groups of *Otolithes cuvieri* from Veraval coast. Rao (1980) observed that larger sized individuals become icthyophagous in another species, *Pennahia macrophthalmus*.

It is observed that seasonal variation in feeding is mainly correlated to the changes in the abundance among favorite prey types such as *A. indicus* and *O. nepa*. Their very low abundance in monsoon was replenished by increased consumption of fish in diet. Such kind of seasonal diet change was reported by many workers in sciaenids (Jayaparakash, 1974; Rao, 1980; Manojkumar, 2003). Trophic level of *J. sina* estimated during the present study is almost similar to the group average value of 3.5 calculated for sciaenids (Vivekanandan *et al.*, 2006). Ontogenetic increase of trophic level was accompanied by large proportion of teleosts in diet. Though trophic level of crustaceans, which dominated in diet, is low, occurrence of teleosts in considerable quantity both in seasons and size groups caused trophic levels to increase.

Both seasonally and ontogenetically, index of feeding, as observed in other scaenids, is generally very poor in *J. sina*. Disgorging and extrovertion of stomachs was reported in many sciaenids. Mohamed (1955) observed such a phenomenon in Ghol, *Protonibia diacanthus* and *Otolithes argenteus*. The probable reason for this behavior in sciaenids is the change in pressure and subsequent hauling during trawl fishing.

5. 5. *Otolithes cuvieri*

The present study revealed that *O. cuvieri* is a carnivorous species feeding primarily on crustaceans and teleost fishes and occasionally on cephalopods. The oblique mouth, slightly protrusible premaxilla, exposed maxilla, the upturned and strongly projecting lower jaw and the canine teeth on the lower jaw clearly indicate the carnivorous feeding nature. Many sciaenids prefer crustaceans as a favorite food (Suseelan and Nair, 1969; Pillai, 1983; Rao, 1980; Manojkumar, 2003). Among the crustaceans, *Acetes indicus* with highest value of IRI formed the principal prey of followed by the penaeid prawns. This is in agreement with the finding of Manojkumar (2003) from the Veraval coast where he observed that *O. cuvieri* is a carnivore, feeding mainly on *Acetes* spp., penaeid prawns, deepsea prawns, fishes, stomatopods, mollusks, isopods, copepods and fish larvae. Similarly, *O. cuvieri*, from the Saurashtra coast, subsisted on shrimps viz., *Acetes* spp, *Solenocera* spp, *Hippolysmata* spp and teleosts (Rao, 1985). Suseelan and Nair (1969) observed prawn and teleosts, besides a wide variety of organisms like stomatopods, amphipods, isopods, copepods, and salps in the diet of a very similar species, *O. ruber* from Mumbai.

With the help of conspicuous canine teeth, croakers like *O. ruber* can behave as a strong carnivore in surface and midwaters (Jacob, 1948; Chacko, 1949). Xue *et al.* (2005) observed greater than 30 prey species from the yellow croaker, *Pseudosciaena polyactis* from Central Yellow Sea, China and the most important prey were crustaceans, mainly euphausids and decapods. A number of other sciaenids followed the same pattern of feeding as observed in the present study such as *O. brunneus* (Jayaprakash, 1974) and *Pennahia macrophthalmus* (Rao, 1980)

Next to crustaceans, *O. cuvieri* preferred teleosts as a part of the diet. A number of teleosts were recorded from the diet indicating the carnivorous nature of croakers. Almost same teleost prey composition was also observed by Manojkumar (2003) from the Veraval coast indicating diet composition of *O. cuvieri* does not show much spatial variation along the west coast of India.

Higher proportion fishes with empty stomachs can be attributed to many reasons. The high percentage of the empty stomachs and poor feeding condition may be due to the spawning activity and seasonal variations in the availability of food. This type of findings has been recorded by many earlier workers. Mohamed (1955) reported disgorging and extrovertion of the stomachs in both *P. diacanthus* and *O. argenteus*. Rao (1963) observed that 95 % of the adult 'Ghol' (*P. diacanthus*) had extroverted stomachs. Jayaprakash (1974) observed stomachs in everted condition in *O. brunneus*. It appears that this phenomenon of disgorging and extrovertion is common in adult sciaenids due to the sudden change of pressure and shock when they are hauled up from the bottom waters.

Preference to crustaceans, mainly *A. indicus*, which dominated both in the pre-monsoon and post-monsoon seasons, can be related to their large abundance in Mangalore coast. Nair (1980) reported that prawns were the dominant food items in almost all the months of observation in *O. ruber*. During the first, second and fourth quarters of the year, *A. indicus* with highest IRI values were reported in juvenile koth, *O. brunneus* (Jayaprakash, 1974). However, predominance of teleost, *Sardinella longiceps* during monsoon may be due to the sudden drop in the abundance of most favoured crustacean prey, *A. indicus*. This indicates that *O. cuvieri* can change feeding according to the availability of food in the environment.

Study of the diet in relations to ontogeny showed that croakers became more ichthyophagous with size and age. All the length groups of *O. cuvieri* preferred crustaceans and the preference changed for teleost fishes as they grow in length with age (Manojkumar, 2003). Nair (1980) reported that young ones of *O. ruber* were found to be largely feeding on zooplankton and pelagic animals at surface, with a gradual change over to predatory and carnivorous habit, feeding mainly on teleosts and prawns at the bottom with increase in length. Xue *et al.* (2005) noted that as the small yellow croaker grew, the consumption of several small prey items, such as euphausids, copepods and amphipods decreased, whereas the consumption of larger prey, such as decapods and fishes increased. The most preferred crustacean preys, *A. indicus* and other penaeid prawns were dominant up to the 180 mm length group. The preference of *Acetes* spp, by small length groups of croakers has also been reported by Basheeruddin and Nayar (1962) in Bay of Bengal.

The preference of young ones to the crustacean prey also agrees with the observation of Bapat and Bal (1952), that younger ones of all sciaenids consume prawns as the main food and the percentage of fish in their food goes on slowly increasing as they grow in length. Change in feeding habits to piscivory is accompanied by the presence of teleost fishes like *Nemipterus mesoprion*, *Secutor insidiator*, *Opisthopterus tardoore*, *S. longiceps*, *Leiognathus bindus*, *Bregmaceros* spp and other teleosts in the length groups above 150 mm. This finding indicates that there is a change in the composition of food with the increase in length (age) of the fish. A similar change in composition of the diet with age has also been recorded in another sciaenid, *Pennahia macrophthalmus* (Rao, 1980). This ontogenetic switch in feeding habits is a general phenomenon among fishes as a result of increasing body length (Labropoulou *et al.*, 1997; Platell *et al.*, 1997; Schafer *et al.*, 2002). Such changes in food habits with fish length could decrease the competition of food resources between smaller and larger individuals (Grossman, 1980; Langton, 1982).

Sciaenids are midlevel carnivores along the Indian coast (Vivekanandan *et al.*, 2006). However, the mean trophic level recorded during present study suggests croakers to group under high level carnivores. Due to occurrence of teleosts, especially of larger length groups, the trophic level was above 3.8 in all the length groups. The preference of most dominant prey, *A. indicus* by many length groups in most of the seasons explains the specialized feeding strategy of *O. cuvieri.*

5. 6. *Nemipterus japonicus*

The dietary composition suggests that *N. japonicus* is a benthic carnivore that relies primarily on benthic crustaceans and fishes. Penaeid prawn, *S. choprai*, *A. indicus* and epibenthic crabs were major components and had higher values of IRI. Rao and Rao (1991), described food items as squilla, crabs, prawns, teleosts, cephalopods, amphipods, polychaetes and other miscellanous items in that order of importance from the gut of *N. japonicus.* As observed in the present study, benthic crustaceans were the most important and most favorite food of *N. japonicus.* This is supported by other studies around India (Kuthalingam, 1965; Krishnamoorthi, 1971; Mohan and Velayudhan, 1985; Gopal and Vivekanandan, 1991; Rao and Rao, 1991). According to Krishnamoorthi (1971), *N. japonicus* is actively predacious and possibly a sight feeder, feeding on crustaceans, molluscs, annelids and echinoderms. Kuthalingam (1965) from Mangalore coast studied the food and feeding habits of *N. japonicus* caught form trawlers and observed that *M. dobsoni* and *P. stylifera* were the dominant penaeid prawns up to a depth range of 30 m. However, the greater importance of penaeid prawn, *S. choprai* as observed during the present study, has not been previously recorded. Furthermore, this quantitative analysis highlights potential predation impact of *N.*

japonicus on benthic crustaceans. In contrast, Russel (1990) from Australia observed that cephalopods mainly squid and cuttlefish formed dominant food followed by finfishes and other benthic crustaceans. Next to *S. choprai*, the paste shrimp, *A. indicus* was next in importance by IRI. This is in accordance with previous studies that exclusively refer *Acetes* spp as the dominant food source for this species and other similar species (Krishnamoorthi, 1971; Muthiah and Pillai, 1979; Gopal and Vivekanandan, 1991).

Teleosts were also found to be major groups in *N. japonicus*. Among different fish groups, only *Stolephorus* spp and other unidentified fishes were most important. Mohan and Velayudhan (1985), in *N. delagoae*, recorded *Stolephorus* spp as the predominant fish item. From Vishakapatanam coast, unidentified teleosts ranked 4th by index of preponderance in *N. japonicus* (Rao and Rao, 1991). Teleosts such as *Cynoglossus* spp, *Platycephalus* spp, *Trichiurus* spp, were reported both in present study and by Mohan and Velayudhan (1985) in *N. delagoae*. The present study also recorded *S. tumbil, S. undosquamis, N. mesoprion, Leiognathus* spp, *Bregmaceros* spp, *Pseudorhombus* spp. These results showed that even though *N. japonicus* preferred benthic crustaceans, it could also use a broad spectrum of teleosts. However, George *et al.* (1968) reported from Cochin the presence of echiroids, amphipods and polychaetes in the diet of *N. japonicus*. Such preys were not observed in the present investigation. However, squilla, mysids, copepods, bivalves and foraminiferans though less important, were rarely observed in the diet. *L. duvauceli* was also important in present study as observed by Eggleston (1972) from North China Sea and Russel (1990) from Australia.

Seasonally, there were wide variations in the diet. Preference of *S. choprai* and *A. indicus* throughout the season signifies its importance as a prey. Benthic crabs also formed significant proportion in both the pre-monsoon and post-monsoons seasons. But in the monsoon season its proportion considerably reduced with the increasing proportion of *S. choprai*. Such an alteration of prawn and crab was observed by Mohan and Velayudhan (1985) in *N. delagoae*. But, this is in contrast to the findings of Rao and Rao (1991) and Krishnamurthy (1971) from Visakhapatnam. In their study, *squilla* spp was the most preferred food throughout the season. This may be due to the regional distribution pattern of prey organisms. In the present study, *O. nepa* never formed a dominant food in any season except in the pre-monsoon season where it ranked second by IRI. However, studies of Mohan and Velayudhan (1985) in *N. delagoae* showed prawn and crabs as the dominant prey throughout the period of study at Vizhinjam coast. He recorded *M. dobsoni* throughout the year. Benthic crabs were highly preferred in post-monsoon. This is in agreement with the findings of Krishnamoorthi (1971). Among teleosts, Mohan and Velayudhan (1985) recorded *Stolephorus* spp as dominant fish in all the months in *N. delagoae* while it was dominant only in post-monsoon during the present study.

Except in the largest length groups, benthic crustaceans dominated by *S. choprai*, benthic crabs and *A. indicus* formed most important preys for all the length groups. Large proportion of teleosts in the largest length groups (>281 mm) indicates shift in feeding towards fish items as length increases. Next to unidentified fishes, *Bregmaceros* spp, a coastal benthic non-commercial fish, formed large proportion and it proved that large fishes prefer bottom icthyofauna in addition to crustaceans as evident from the report of Rao and Rao (1991). He observed dominance of squilla in all the length groups followed by crabs and prawns. Large proportion of prawns mainly *S. choprai* and *A. indicus*, *L. duvauceli* and fish, which are active mobile benthic organisms recorded in large length groups clearly indicated predatory behavior of *N. japonicus* on benthic animals.

Predominance of empty stomachs was observed throughout the season. High proportion of empty stomachs in present study as well as earlier studies (Krishnamoorthi, 1971; Gopal and Vivekanandan, 1991) may be due to non-availability of preferred food items during certain months and /or regurgitation of freshly consumed and semi-digested food when the fish was caught. Gopal and Vivekanandan (1991) observed 43% of empty stomachs and 28% of full stomachs. Even then, average active feeding was observed in the monsoon season. Generally, active feeding was high in smaller length groups as well as the fish in some other length groups. Feeding intensity of *N. japonicus* was not related to size (Krishnamurthy, 1971). Likewise in the present study, empty stomachs were higher in both younger and larger fishes also support the view that feeding intensity is not size dependent in *N. japonicus*.

Fishes during the pre-monsoon season had the highest diet breadth. Large number of prey groups in pre-monsoon was the reason for such a higher value of diet breadth. The low value of diet breadth in monsoon was due to the fact that only *S. choprai* followed by *A. indicus* and unidentified fishes formed the bulk of diet. Likewise, the higher value of trophic level in pre-monsoon was due to consumption of large predatory fishes such as *S. tumbil, S. undosquamis, N. mesoprion* and *L. duvauceli.* Similarly, occurrence of these predators in the larger length groups also caused trophic level to increase in larger fishes.

The highest similarity in feeding between the pre-monsoon and post-monsoon seasons is an indication of possible competition. Similarly, feeding similarity between different length groups was observed to be higher. This indicates that most of the length groups sharing same prey groups. The proportions of most important prey groups, *S. choprai, A. indicus* and benthic crabs, increased with increasing length of *N. mesoprion.* This is in agreement with the work of Rao and Rao (1991) from Visakhapatnam. Electivity study showed strong preference to most important preys such as *S. choprai* and benthic crabs. Even though other prey groups were abundant in ecosystem, *N. japonicus* never fed on them as it is a basic crustacean feeder. The exhibition of mixed feeding was mainly due to individual preference to certain prey types and seasonal variations in the availability of prey in the ecosystem as suggested by MacArthur and Pianka (1966).

5. 7. *Nemipterus mesoprion*

N. mesoprion is primarily a benthic carnivore feeding on a varied diet that consists mainly of crustaceans and fishes and molluscs. Observations of Rao (1989) and Raje (1996) on *N. mesoprion* also indicated that crustaceans and teleosts were the most important diet. These two prey categories also formed most preferred diet of similar species around the world including *N. japonicus* (Krishnamoorthi, 1971; Gopal and Vivekanandan, 1991; Rao and Rao, 1991), *N. dealagoae* (Mohan and Velayudhan, 1985), *N. peronii* (Salini *et al.*, 1994), *N. hexadon, N. bipunctatus* (Salini *et al.*, 1994). *Acetes indicus,* which ranked first by IRI during the present study was also reported from the Veraval coast (Raje, 1996). However, along with *A. indicus,* Raje (1996) also observed *A. johni* follwed by fishes, prawns, other crustaceans, molluscs and annelids in *N. mesoprion.* The results by Rao (1989) form Waltair coast also recorded *Acetes* spp as an important crustacean in the diet. Thus it can be concluded from the present as well as previous works that *A. indicus* is the most preferred prey of *N. mesoprion* in Indian waters. Salini *et al.* (1994) observed dominance of crustaceans such as prawns and shrimps, crabs, amphipods, mysids and cephalopods mainly cuttlefishes and squids in the diet of similar fish, *N. peronii* from the Gulf of Carpentaria.

Next to *A. indicus*, the second most important prey was *S. choprai* in *N. mesoprion*. Rao (1989) and Raje (1996) also observed *Solenocera* spp along with other prawns in *N. mesoprion*. Fish items though were second important group after crustaceans, formed around 8% of total IRI. According to Raje (1996) fishes were the second important item and composed mainly of juveniles of *N. japonicus, N. mesoprion, sciaenids, Myctophid* spp, and *Harpodon neherus*. During the present study, unidentified fishes formed large proportions along with *S. undosquamis, Johnieops* spp, *N. mesoprion, G. suppositus, Polynemus* spp, *Bregmaceros* spp, *Pseudorhombhus* spp, *Stolephorus* spp and *C. macrostomus*. This study showed the carnivorous feeding behavior of *N. mesoprion*. Benthic icthyofauna was the main groups in the diet of *N. japonicus* (Rao and Rao, 1991; Russel, 1996;) and *N. delagoae* (Mohan and Velayudhan, 1985). In the present study, the squid, *L. duvauceli* contributed a significant proportion of the diet as also observed in the previous studies (Rao and Rao, 1991; Krishnamurthy, 1971; Raje, 1996). Gastropods and polychaetes only supplemented the dominant prey groups.

The most important prey groups, *A. indicus* and *S. choprai* alternately dominated throughout the year in the present study. *Acetes* spp was present in almost all the months with highest consumption in September and lowest in April in *N. mesoprion* from Veraval coast (Raje, 1996). However, in the present study, *A. indicus* formed highest proportion during post-monsoon. In general, the importance of *S. choprai* increased in monsoon and pre-monsoon. The results of Rao (1989) also showed that prawns were present largely during pre-monsoon. Such large occurrence of *S. choprai* may be due to its abundance in the benthic habitat. Among fish items, *Bregmaceros* spp dominated in pre-monsoon and unidentified fishes significantly contributed to the diet in remaining seasons. Such an irregular distribution of fishes during different months was also recorded by Rao (1989) in *N. mesoprion*. Except in September and April, fishes formed continuous source of food for *N. mesoprion* (Raje, 1996). Krishnamurthy (1971) reported for *N. japonicus* that squids were abundant in the diet during August and April.

Diet shift in *N. mesoprion* was characterized by consumption of large quantities of crustaceans mainly *O. nepa, A. indicus* and *S. choprai* by juveniles to larger prey types such as *L. duvauceli* and teleosts by adults. This behavior was also reported by Rao (1989) in *N. mesoprion*. He observed that fishes measuring less than 100 mm substantially feed on crustaceans rather than teleosts. Prawns ranked first in the lower length groups of *N. japonicus* (Rao and Rao, 1991). Large proportion of teleosts in larger length groups clearly showed diet shift to fishes by large sized fishes. Cannibalism was observed largely in larger length groups. Such a kind of cannibalism has also been observed by Kuthalingam (1965) in *N. japonicus*. Large proportion of *L. duvauceli* in the largest length groups (>225mm), along with other predatory fishes, suggested ontogenetic diet shift to high trophic level organisms.

In *N. mesoprion*, empty feeding condition was generally higher in the pre-monsoon and post-monsoon seasons as observed in most of the demersal fishes (Kuthalingam, 1965; Mohan and Velayudhan, 1985; Gopal and Vivekanandan, 1991; Rao and Rao, 1991). Raje (1996) recorded 55% empty stomachs in females and 59% in males in *N. mesoprion*. He also observed large proportion of empty stomachs in all the months. Rao (1989) also observed high percentage of empty stomachs both in the pre-monsoon and post-monsoon seasons in *N. japonicus*. Active feeding was mainly observed during the monsoon season and this can be related to the abundance of the most favorite food mainly prawns and *A. indicus* on which it fed regularly. All these studies indicated irregular feeding conditions with changing seasons. Percentage of empty stomachs increased with increasing length of fish. However, Krishnamurthy (1971) reported that feeding intensity is not related to the length in *N. japonicus*.

The highest diet breadth in both the pre-monsoon and the post-monsoon seasons in *N. mesoprion* were largely due to the use of broad spectrum of prey taxa. Occurrence of large predators increased the trophic position of *N. mesoprion* in pre-monsoon and post-monsoon as reported in other teleosts (Vivekanandan, 2001). Similarly, ontogenetic increase of trophic level as observed in many fishes was generally higher in larger length groups. These length groups preferred active mobile icthyofauna along with crustaceans. Diet similarity between the seasons was high and it was mainly due to the unvarying proportion of crustaceans. These observations also suggest that as the fish grow to larger size, the feeding spectrum of species broadened up to large number of organisms of high trophic level. Electivity study showed that the dominant prey, *S. choprai* was effectively selected by *N. mesoprion* in monsoon. However, *N. mesoprion* did not select large proportion of benthic fishes due to its prey preference for *A. indicus* and prawns.

5. 8. *Leiognathus bindus*

Quantitative gut analysis revealed that detritus and benthic zooplankton formed most important diet of *L. bindus*. Fish remains followed by diatoms and foraminiferans were also significant in diet. Dietary studies on several species of Leiognathids from South Asia (mainly India), East Asia, Canada and Australia also pointed out the importance of benthic zooplankton and diatoms (Balan, 1967; James and Badrudeen, 1981; Jayabalan and Ramamoorthi, 1985; Yamashita *et al*., 1987; Nasir, 2000). In the present study, detritus ranked first in IRI. Qasim (1972) grouped *L. bindus* as zooplankton feeder and it was grouped as carnivore based on the dietary study of Balan (1967). Indeed, Balan (1967) had observed large quantity of detritus in the form of mucous and digested matter but he could not quantify them effectively to highlight its importance in diet but as done in the present study. Among crustacean zooplankton, copepods formed favorite food followed by mysids and amphipods. This is in agreement with other studies of *L. bindus* and similar species such as *L. ducura, L. splendensis, L. blochii* and *L. brevirostris* (Kuthalingam, 1957; Balan, 1967; James and Badrudeen, 1981). In contrast, Blackler *et al.* (2002) recorded large quantities of bivalves in a similar species of *L. equulus* from Durban harbour of South Africa. This can be attributed to the regional difference in the prey distribution pattern and abundance.

Fish items represented by scales and eggs, were less important in diet. Fish items were also noticed by Venkataraman (1960) in *L. bindus* and fish scales by James and Badrudeen, (1981) in *L. dussumeiri*. Thus leiognathids also prefers fish items in addition to detritus and other zooplankton. Diatoms by number ranked second in the diet of *L. bindus*. Among diatoms, *Coscinodiscus* spp follwed by *Pleurosigma* spp and *Skeletonema* spp were dominant. This is in agreement with studies of James and Badrudeen (1981 and Venkataraman (1960) on *L. dussumeiri* and *L. bindus* respectively. Frequent occurrence of polychaetes, foraminiferans and large number of nematode worms and molluscs, which usually inhabit on the sea bottom, shows that *L. bindus* is essentially a benthic feeder.

Temporal changes were observed in different prey groups of *L. bindus*. Detritus being the most important diet was dominant both in the pre-monsoon and post-monsoon seasons. However, cycloid scales dominated the diet in monsoon. Venkataraman (1960) observed large quantifies of cladocerans in late monsoon from the Calicut coast. In a similar species, *S. insidiator*, Venkataraman (1960) observed polychaetes and *Squilla* spp in the post-monsoon season from the Calicut coast. James and Badrudeen (1981) observed no significant difference between months in major prey items in *L. dussumeiri*. Seasonal variations clearly highlighted importance of detritus and copepods in all the seasons in *L. bindus* from the Arabian Sea off Karnataka.

Ontogenetically, detritus and copepods were the important source of food to all length groups. Venkataraman (1960) observed large proportion of copepods in younger stages of *S. insidiator*. Fish scales never formed dominant diet in any of the length groups. Hence it may be due to accidental capture of scales, which might have fallen from live or dead fish to the bottom. Jayabalan and Ramamoorthy (1985) observed dominance of polychaetes in all the length groups of *Gazza minuta*.

Large proportion of both poorly fed and empty stomachs throughout the season indicates that *L. bindus* is not a voracious benthic feeder as like other carnivores and predators. Such a large proportion of poorly fed conditions were also observed in other detritivores (Philip, 1998, Jayaprakash, 2000). With increase in length, proportion of empty stomachs increased. This may be due to onset of maturity, which causes the body to lodge developing gonads as in other teleosts. The increased proportion of actively fed fishes with increasing length shows the active predatory nature of the fish in larger sizes. Jayabalan and Ramamoorthy (1985) also observed 50% of actively fed fishes in May in *G. minuta*.

The high dietary breadth as observed in the monsoon season clearly reflected the tendency to use a broader range of the available resources by *L. bindus* as observed by Durr and Gozalez (2002) in the deep sea fish, *Beryx splendens*. Presence of large proportion of fish scales increased trophic level of *L. bindus* in monsoon. Although there was no marked ontogenetic shift in trophic level, it could be assumed that large prey diversity increased both diet breadth and trophic level in 88-93 mm length groups. The Amundson plot clearly depicts the specialized feeding strategy adopted by *L. bindus* specializing on detritus and copepods. This support the theory proposed by MacArthur and Pianka (1966) that feeding will become more selective and specialized when favorite food is abundant.

5.9. *Cynoglossus macrostomus*

The present investigation revealed that *C. macrostomus* is a bottom feeder, preferring mostly detritus and other benthic microfauna and diatoms. The work of Sheshappa and Bhimachar (1955), Kuthalingam (1957), Jayaprakash (2000) and Datta and Das (1985) also revealed that cynoglossids are specialized to bottom habitat and they mostly rely on detritus and the feeding was strongly influenced by the structure of benthic fauna and flora. On the bottom, *C. macrostomus* preferred to feed on detritus. When the bottom conditions are undisturbed, the tongue sole resorted to feed frequently on detritus and other macro benthos (Jayaprakash, 2000). As a typical detritivore, it also consumes other microfauna, which were partly or fully entangled in detritus in the diet. Polychaetes as reported by Jayaprakash (2000) were mostly browsed from the soft mud and detritus. Among polychaetes, he identified *Prionospia pinnata* as the important species in addition to the occasional record of *Phyllochaetopterus* sp., *Pectinaia* spp., and *Clumene* spp. He ascertained that large proportion of crustaceans zooplankton, microfauna, mollusks and worms in the diet can be attributed to the disturbed bottom habitat. Filtration of these organisms from the detritus and mud can be attributed to the filtration by olfactory sense organs in the fish. De Groot (1971) observed the North Sea flatfishes to possess brush like groups of teeth on the gill arches which prevent the prey from struggling out and indicated that flatfishes are visual feeders. However, Jayaprakash (2000).reported that visual factor is not involved when feeding on detritus, but asserted that it is an important factor for tongue sole while feeding on polychaetes, copepods and amphipods. As a matter of fact, all cynoglossids are not detritivores but most of them are benthic carnivores. Datta and Das (1983) observed that cynoglossids such as *C. arel*, *C. lingua*, *C. bilineatus* and *Paraplaguisa blochii* are purely carnivorous in nature and their food comprising mainly of polychaetes and molluscs. Moreover, De Groot (1971) observed that crustaceans formed the main constituents of 12 species of *Cynoglossus* spp and concluded that these groups are crustacean feeders in nature. In case of large flatfishes like *P. elevatus* and *P. erumei* voracious feeding on fishes and crustaceans was reported by Pradhan (1959), Devadoss *et al.* (1977) and Ramanathan and Natarajan (1980).

Sheshappa and Bhimachar (1955) correlated the dominance of polychaetes, amphipods, lamellibranchs and other organisms from the gut contents of a similar species *C. semifasciatus* to the area from where samples were collected. He observed that the composition of different fauna of gut contents had a close correlation with those of the inshore fishing grounds with polychaetes being the most dominant. Thus it can be concluded from the present study as well as from other studies that all species of cynoglossids are benthic carnivores except for a few species like *C. macrostomus* which largely prefer detritus and other bottom organisms.

As an important diet source to *C. macrostomus*, detritus and polychaetes constituted large proportions throughout the seasons. The prey groups occurred in the diet throughout the year and detritus specifically with high index value was invariably observed throughout the season. The index was highest in May followed by March. Sheshappa and Bhimachar (1955) in *P. semifasciatus* observed the dominance of polychaetes especially *Prionospio pinnata* in the gut after the southwest monsoon season of Calicut coast. However, during the monsoon and the pre-monsoon seasons their occurrence in the gut was rather less. They stated that during the monsoon season, *C. semifaciatus* migrates to deeper waters and it return to the inshore grounds when there were polychaetes settling on sea bottom. Importance of copepods and fish remains were comparatively higher in monsoon which can be attributed to the disturbed bottom conditions, during such times tongue soles resort to off bottom feeding on different prey items as also reported by Jayaprakash (2000) off Cochin coast. Also, he added that seasonal variations in the occurrence of diet items were a reflection of the availability of these food items in the environment. Such a kind of seasonal variations influenced by macro benthic fauna was also described by Ortega – Salas (1980) and Lande (1976) in the North Sea dab *Limanda limanda*. Detritus contains a variety of benthic organisms and phyto-zooplankton and it occurs in bottom as most readily available, abundant and nutritive material in the shallow areas of the sea. Fishes like tongue sole can effectively utilize this energy source trapped in the detritus (Jayaprakash, 2000). Datta and Das (1983) observed that seasonal variation in feeding was evident in some flatfishes off Orissa coast and observed that polychaetes and crustaceans were in plenty during the winter, but reduced from the summer onwards and becomes negligible in the early monsoon season.

Detritus was consumed largely by fishes of smaller length groups. However, the dominance of polychaetes in the diet of larger fishes can be attributed to the feeding behavior of tongue sole on active and mobile benthic fauna on the bottom. In contrast to this, Jayaprakash (2000) observed dominance of polychaetes in fishes less than 90 mm in length. He also observed detritus as a dominant item in all length groups and such a kind of trend was also observed in the present study. Datta and Das (1983) also observed a clear shift in the feeding habits of flatfishes with increase of body length. They found that index of preponderance of amphipods was highest in the smaller fishes and a gradual decease with increase in body length was recorded. Polychaetes, which formed the third largely consumed prey decreased gradually with increasing body length in tongue sole. This finding agrees with the present study that polychaetes proportion in the smaller fisher was higher but a gradual decrease was observed in fishes of medium sizes and thereafter its importance steeply increased in larger fishes.

Very low trophic level observed in the present study is characteristic of detritivores. Vivekanandan *et al.* (2006) observed trophic level to vary between 2.0 to 2.5 in case of both herbivores and detritivores. However, in his classification *C. macrostomus* has not been included under detritivores but was grouped under soles. Clearly, the trophic level of tongue sole is dissimilar from that of the majority of soles which are carnivores (Pradhan, 1959; Devadoss *et al.*, 1977; Datta and Das, 1983).

5.10. *Pampus argenteus*

The present study revealed that *P. argenteus* is an omnivore, feeding largely on zooplankton and detritus. Crustacean zooplankton formed the largest proportion of the diet of silver pomfret along the Indian waters as well as in Middle East Asian countries. (Kulakarni, 1958; Kuthalingam, 1963; Pati, 1978; Dadzie *et al*., 2000). Zooplankton and phytoplankton, which were entangled in the detritus, were observed to be the most favorite diet of silver pomfret from Bombay waters (Rege, 1958). As observed in the present study, copepods constituted the major proportion of zooplankton in the diet of pomfrets in many other studies (Kularkani 1958, Rao, 1964, Pati, 1978 and Dadzie *et al*., 2000). Detritus, observed in large proportions, may be the same as digested pulpy like material observed by many workers in pomfrets (Pati, 1978, Sivprakasam, 1985). Suyehiro (1942) while studying the diet of silver pomfret observed some gelatinous substances and medusae in the gut. Rege (1958) also recorded gelatinous material in the diet of silver pomfret from Bomaby waters in addition to the occurrence of slaps, hydromedusae, amphipods, copepods, shrimps and other small fish groups. Kuthalingam (1963) in his study from north-west part of Bay of Bengal observed copepods and other crustaceans as the main item of food in addition to ostracods, amphipods, larval crustaceans, polychaetes, *Sagitta* sp, fish scales, algal filaments etc. Three commercially important pomfrets exploited along the Indian coast namely, *P. argenteus, P. chinenis* and *P. niger* hence are all basically copepod feeders (Pati, 1977, 1978; Sivaprakasam, 1986).

Rao (1964), while studying the feeding habits of *P. argenteus* observed a high percentage of copepods along with amphipods, ostracods, other crustacean zooplanktons, gastropod larvae and fish remains. Dadzie *et al.* (2000) from Kuwait waters investigated the feeding habits of silver pomfrets and stated that copepods were the most favorite food for silver pomfrets. The present study also shows that copepods are the most important diet source to silver pomfrets. Some authors described the vertical migration pattern of silver pomfrets (Clarke 1954, Gopalam, 1969) and correlated this to the dominance of copepods and detritus in the stomach contents caught from both gill nets and trawl nets as evidence to the diurnal migration of silver pomfrets. In addition, Nikolsky (1963) opined that many marine fishes perform regular vertical trophic movements. Based on these, Pati (1978) opinioned that the feeding behavior of silver pomfrets can be utilized for its commercial exploitation by shooting drift gillnets during night and trawl fishing in day.

In a similar species, *Parastromateus niger*, Sivaprakasam (1985) observed the food was present in highly macerated and in advanced state of digestion. In addition, a high proportion of pulpy semi digested matter rendered the identification and sorting of food components very difficult. In the present study, these pulpy materials were identified as detritus which formed largest proportion by weight of total prey. The reason for these difficulties while sorting food components was due to the peculiar nature of gut in pomfrets. Pati (1978) described that pomfrets possess toothed esophageal sac, which act as grinding mill to make food pulpy and hence making the identification of food components very difficult. Basheeruddin and Nayar (1962) recorded white pulpy matter on which scales, bones of fish, copepods and *Acetes* sp. were entangled.

Copepod abundance along with ctenophores and medusae in the environment can be considered as an indicator of silver pomfrets occurrence along the Gujarat coast Chopra (1960). Moreover, Pati (1978), based on the large proportion of copepods in the diet, postulated that copepods are indicator organisms for silver pomfret in Bay of Bengal. Zooplankters such as amphipods, crustacean larvae, and mysids were next in importance to copepods among the crustaceans in the present study.

As a basic copepod feeder, silver pomfret highly preferred them throughout the season. This indicates that copepods distribution is always uniform along the Mangalore coast. Copepods formed an important food group throughout the season. Copepods are a very important part of the diet both in the pre-monsoon and post-monsoon seasons in the Bay of Bengal (Pati, 1978). Occurrences of fish scales though in less quantities throughout the season during the present study and in other studies (Pati, 1978) indicate that for silver pomfrets small fishes are a small part of the diet throughout the seasons. Dadzie *et al.* (2000) observed more variety of food items in summer than in winter indicating that silver pomfrets are prone to seasonal change in feeding according to the availability of prey organisms in the environment. Seasonal variation in major food components especially copepods was also highly distinct in Chinese pomfret (Pati, 1977) and black pomfrets (Sivaprakasam, 1985).

An ontogenetic increase in consumption of copepods is observed to be the reason for decrease in proportion of detritus in large length groups. Also, as length progresses, silver pomfret shift to feed on more active moving zooplankton such as copepods, amphipods and even on fishes. Pati (1978) observed a striking change in the diet of *P. argenteus* from post-larvae to the adult. He observed that phytoplankton such as *Coscinodiscus centralis, Thallasiothrix frauenfeldii* and *Pleurosigma normanii* are most favorite diet of post-larvae but as the length progressed they shift to feed on copepods, nauplii and other crustaceans. Kuthalingam (1963) observed large crustaceans such as *Penaeus* spp, *Acetes* spp, *Squilla* spp and anomurans in large sized silver pomfrets as against the juveniles which were mainly feeding on small copepods and diatoms. Hence it is evident that diet change with ontogeny is common in silver pomfret.

5. 11. *Lactarius lactarius*

Analysis of dietary habits shows that *L. lactarius* is a demersal carnivore, foraging mainly on teleosts and shrimps. The epipelagic teleost, *Stolephorus* spp and the paste shrimp, *A. indicus* were the major components and had higher IRI values. Qasim (1972) grouped *L. lactarius* as a carnivore after a review on the work of Venkataraman (1960) from the Calicut coast. Moreover, work of Rao (1966), Chidambaram and Venkataraman (1946), Neelakantan, (1981) and Zacharia (2003) undoubtedly point to the carnivorous nature of *L. lactarius*. In addition, these authors also observed the piscivorous feeding behavior due to large proportion of teleosts. However, during the present study, teleosts formed only a little more than 50% of IRI, and therefore, indicate partial piscivory. Among teleosts, *Stolephorus* spp was very important. Zacharia (2003) recorded a high proportion of anchovies mainly *S. batavensis* and *S. devisi* from the gut of whitefish. During the present study *A. indicus* was found as most frequent next to *Stolephorus* spp. This is in accordance with other studies that observed *Acetes* spp as one of the important source for this species. Zacharia (2003) and James *et al.*, (1974) from the Mangalore coast reported *Acetes* spp as the most dominant crustacean in diet along with other prawns. This is in good support with the present study that *Acetes* spp are most favourite diet of *L. lactarius* along the Mangalore coast. Other teleosts such as *T. jarbua*, *Bregmaceros* spp, *L. bindus* and other crustaceans such as unidentified prawns and *O. nepa* were not important, even though its occurrence was also reported by Zacharia (2003) during 1991-98.

Seasonally, importance of *Stolephorus* spp decreased from the pre-monsoon to post-monsoon seasons and conversely *A. indicus* showed an increasing trend during this period. These results are in good agreement with the findings of Zacharia (2003), who observed that *Stolephorus* spp was highly preferred throughout the season except June and September and correlated this occurrence with trawl landings along the Karnataka coast. He also observed the signs of cannibalism during the post-monsoon season.

An ontogenetic shift to fish groups was obvious in *L. lactarius*. *A. indicus* was more important for younger groups, while larger length groups generally shifted to teleosts This kind of shift has also been described by Zacharia (2003), who observed that individuals up to 139 mm fed predominantly on *Acetes* spp, while specimens measuring from 140 mm switched to teleosts mainly, *Stolephorus* spp. Basheerusddin and Nayar (1962) also observed juveniles to feed largely on *Acetes* spp from the Madras coast.

Fishes with empty stomachs were dominant throughout the season and in most of the length groups. But during the monsoon and post-monsoon seasons, proportion of poorly fed fishes was comparatively higher. Large proportion of empty stomachs, reported by Zacharia (2003) and James *et al.* (1974), can be attributed to the faster digestion rate (Qasim, 1972), possible regurgitation during fishing (Job, 1940) and onset of maturity (Neelakandan, 1981). The low diet breadth throughout the season and in all length groups reflected the trend to use narrow range of the available resources. This was mainly due to the specialisation on favourite prey types, *Stolephorus* spp and *A. indicus*. This was in good accordance with the previous studies which reported few prey groups in *L. lactarius* (James *et al.*, 1974; Rao, 1966). Also, Durr and Gonzalez (2002) obtained a similar low diet breadth for deep sea fish, *Beryx decadactylus*. A higher value of trophic level of 3.91 ± 0.37 is characteristics of predatory fishes as reported by Vivekanandan *et al.* (2006). Ontogenetic diet change to teleosts from crustaceans obviously shifted up trophic level of larger size fishes.

Highest similarity in diet was observed between the monsoon and post-monsoon seasons since *L. lactarius* apparently fed largely on both *Stolephorus* spp and *A. indicus*. Like wise, fishes of 151-170 and 171-190 mm length groups shared similar diets, indicating these groups were competing for food in the same dietary niche. Larger predators showed preference to larger *A. indicus*. Similarly, reduction of the mean weight and number of *A. indicus* was due to the ontogenetic diet shift to *Stolephorus* spp by larger predators. Durr and Gonzalez (2002) also observed an increase in length of crustacean and fish prey according to increasing predator length.

L. lactarius exhibited a specialized feeding strategy in which diet was dominated by both *Stolephorus* spp and *A. indicus*. Such kind of mixed strategy was also observed by Andersen *et al.* (2005) in a flounder, *Platichthys flesus* from a vegetated habitat on the east coast of Jutland, Denmark. They observed polychaetes, amphipods and copepods in the diet at moderate to high frequency of occurrence with a moderate prey-specific abundance. Strong selection of *Stolephorus* spp clearly indicates the preference by *L. lactarius*. Even though other teleosts were more abundant, it did not switch to them, as the favorite diet was highly preferred (Zacharia, 2003). More over, the epipelagic anchovies are more vulnerable and formed an important teleost in the diet of many predators along the Indian coast (Rao, 1989; Sivakami, 1995). This suggests that prey preference is not just a function of prey abundance but also prey availability and vulnerability.

5.12. *Pseudorhombus arsius*

The dietary composition suggests that largetooth flounder is a benthic predatory piscivore, voraciously feeding upon benthic icthyofauna. Secondly, it preys on crustaceans as a supplement to teleosts in the diet. Earlier studies indicated that *P. arsius* and similar carnivorous flatfishes were bottom feeders, feeding largely on benthic teleosts (Devados and Pillai, 1973; Braber and Groot, 1973; Ramanathan and Natarajan, 1980; Das and Mishra, 1990; Hussain, 1990; Link *et al.*, 2005). Ramanathan and Natarajan, (1980) pointed out that this species is a voracious predator of teleosts, and they recorded Gobids, *Platycephalus* spp, *Cynoglossus* spp and *Apogon* spp as major and *Polydactylus* spp, *Stolephorus* spp, *Leiognathus* spp, *Otolithes* spp, *Sciaena* spp and eel larvae as minor teleosts. Predation upon the species of the same genus (*Pseudorhombus* spp) followed by *Polynemus indicus* and *Stolephorus* spp revealed a high degree of cannibalism and piscivory during the present study. The occurrence of epipelagic *Stolephorus* spp might be due to the occasional excursion of this fish up in the water column. These observations are in agreement with those of Ramanathan and Natarajan, (1980) on *P. arsius* from Porto Novo waters. Teleosts of insignificant groups during present observation were *C. macrostomus*, *N. mesoprion*, *T. lepturus*, *E. diacanthus*, unidentified teleosts and fish scales. Hussain (1990) emphasized the importance of flatfishes mainly *Solea* spp and *Cynoglossus* spp and *Stolephorus* spp in the diet of largetooth flounder. While in a similar benthic predatory flatfish, *Psettodes erumei*, Das and Mishra (1990) observed *Apogon* spp, Sciaenids and *Leiognathus* spp and Devados and Pillai (1973) recorded *Polynemus* spp, sciaenids, *Stolephorus* spp, *Leiognathus* spp as most encountered teleosts. Based on the previous and present studies, it is re-confirmed the high importance of teleosts in the diet of largetooth flounder.

Crustaceans formed second most important source of diet. Penaeid prawns mainly *Metapenaeus affinis* and *Solenocera choprai* were the most important in diet. Non-penaeid prawn, *A. indicus* and benthic crabs also contributed significantly. *Oratosquilla nepa*, lobster juveniles and isopods were insignificant. Such occurrence of crustaceans support the findings of Ramanathan and Natarajan (1980) and Hussain (1990), that prawns, crabs and squilla formed the major crustaceans in *P. arsius*. In addition, they also observed *Alpheus* spp, amphipods, cypris and larvae of prawns and crab as other crustaceans. Along with younger prawns, Devadoss and Pillai, (1973) recorded *Acetes* spp in similar species, *P. erumie*. In contrast, preference of gammarids like crustaceans in a similar species, *P. elevatus* as observed by Pradhan (1959) is against to the present observation. This can be attributed to regional differences in the abundance of crustaceans. Ramanathan and Natarajan (1980) and Hussain (1990) identified only *Sepia* spp among cephalopods, however, even though *Loligo* spp appeared in diet, it never formed an important diet source during the present study. Nereis worms formed insignificant part of the diet. It is probable that the fish swallowed worms along with other food items accidentally.

Teleosts were preferred throughout the season. Cannibalism was higher in pre-monsoon, but in the monsoon and post-monsoon seasons, *P. indicus* was largely preferred. Even though such a kind of cannibalism was not so far recorded in previous studies, teleost, in general became higher quantity in the late post-monsoon season (Ramanathan and Natarajan, 1980). The feeding habits can be related to those of *P. erumei* that teleosts constituted main food item around the year (Das and Mishra, 1990). As the post-monsoon season approached, importance of crustaceans mainly *M. affinis* and *A. indicus* was increased. However, Ramanathan and Natarajan (1980), observed dominance of crustaceans along with teleosts throughout the season. The dominance of benthic crabs in the pre-monsoon season also suggested crustaceans, mainly prawns and crabs are essential to the diet of flounder to supplement teleosts.

Teleosts invariably become the most important prey for all the length groups (Ramanathan and Natarajan, 1980; Hussain, 1990), as was the case in the present study. However, fishes of small length groups are more cannibalistic. Ramanathan and Natarajan (1980) were observed ontogenetic diet shift of teleosts in larger length groups of *P. arsius*. Ontogenetic diet shift to large and high trophic level demersal teleosts was due to the predatory piscivory of large length groups. Ontogenetic shifts are common in most of the piscivorous fishes and this shift generally progress from consumption of zooplankton to consumption of benthic macrofauna or fish with a concomitant increase in mean prey length (Werner and Gilliam, 1984). Hussain (1990) in *P. arsius* and *P. erumei* also observed ontogenetic diet shift from invertebrates in juveniles to teleosts in adults. Also, the comparison of food items of juveniles and adults in *P. arsius* and *P. elevatus* made by Rajaguru *et al.* (1988) revealed out the dominance of amphipods and copepods of low trophic low organisms in juveniles, and polychaetes and prawns in the diet of adults. The predominance of *Pseudorhombus* spp and *P. indicus* in different length groups reveals that the selection and cannibalism were irrespective of the length of flounder.

Large proportion of empty stomachs throughout the season as observed during the study is characteristics of other benthic predatory fishes (Vivekanandan, 2001; Mohan and Velayudhan, 1985). Feeding intensity slightly increased from the monsoon to pre-monsoon season. Ramanathan and Natarajan, (1980) observed an inverse relation of feeding intensity and occurrence of empty stomachs in *P. arsius*. He observed minimum feeding activity during breeding season along Porto Novo coasts. Das and Mishra (1990) also observed higher percentage of empty stomach round the year in *P. erumei*. All length groups had high percentage of empty stomachs. Fishes of very small length groups showed less feeding intensity and as the size progresses, feeding intensity slightly increased. The low feeding rate and higher incidence of empty stomachs can be attributed mainly to the spawning activity of fish (Sobhana, 1976). In *P. erumei*, percentage of full stomachs was high in largest length group, 75-79 mm (Devadoss and Pillai, 1973).

Both diet breadth and trophic level were higher in the pre-monsoon and post-monsoon seasons. Large number of prey items during these seasons was responsible for such an increased diet breadth. Very few prey types reduced diet breadth in the smallest length groups. Piscivory on large predators caused the trophic level to increase in the larger length groups. Highest prey similarity between the monsoon and post-monsoon seasons was mainly due to the dominance of *P. indicus* and certain other prey groups in these seasons. The low similarity among different length groups deciphers difference in prey selection. The increasing mean weight of teleosts in relation to length of flounder is in accordance to the view of high degree of piscivory in larger fishes. For piscivorous fishes, the length of prey consumed generally increase with predator length (Juanes *et al.*, 2002).

As none of the prey groups dominated more than 50% occurrence due to large diet breadth, flounders can be grouped as generalist feeders. The strong preference of teleosts from environment ensures the piscivorous feeding behavior. However, avoidance of *Saurida* spp and *Loligo* spp, even though they were high in catch composition, clearly suggested that flounder never turn to any other groups when preferred preys such as *Pseudorhombus* spp and *P. indicus* were abundant in the ecosystem.

5.13. *Carcharhinus limbatus*

The black tip shark, *C. limbatus* feeds on a wide variety of fishes and cephalopods. The large number of teleost prey consumed by the shark is a reflection of the diversity of fauna found in the study area. Teleost fishes were obviously the most important food and scored the highest values of IRI. Importance of teleosts in the diet of *C. limbatus* has been observed by many others (Dudley and Cliff, 1993; Heupel and Hueter, 2002; Barry, 2002). From off Natal, Dudley and Cliff (1993) identified at least 28 families of teleosts in which clupeids followed by anchovies were the most abundant. Mathew and Devaraj (1997) from the coastal waters of Maharashtra recorded at least nine teleost families in the diet of spadenose shark, *Scoliodon laticaudus*. The epipelagic teleosts, oil sardine, anchovy, unidentified teleosts, and sciaenids were the most important among teleosts in the present study. Haepel and Hueter (2002), observed predominance of sparids, sciaenids, and haemulids in addition to clupeids, in the diet of *C. limbatus* from Terra Ceia Bay, Florida. Clupeids and sciaenids were the most common teleosts in the diet of black tip shark form Terre Brunne Bay, Lousiana (Barry, 2002). All these studies around the world support the present findings that epipelagic fishes are the favorite diet of the black tip shark.

Next to teleost fishes, the squid *L. duvauceli* formed most important prey in the present study. This is in agreement with the other studies on the similar species of Carcharhinid sharks. Squid formed one of the most dominant prey in the diet of *C. galapagensis* (Galapagos shark), *C. plumbeus* (Sand bar shark), *Galeocerdo cuvier* (Tiger shark) (Stillwell and Kohler, 1993; Lowe *et al.*, 1996, Cortes, 1999; Ellis, 2003). Nair and Appukkuttan (1973) observed the carnivorous nature of deep seas sharks, feeding chiefly on squids in addition to fishes and crustaceans. *Sepia* spp and *Loligo* spp were the two important cephalopods in addition to teleosts and crustaceans in spadenose shark, *Scoliodon laticaudus* from the coastal waters of Maharashtra state (Mathew and Devaraj, 1997). In the North West Atlantic, cephalopods constituted a major proportion of the diet in porbeagle sharks (Joyce *et al.*, 2002). In the present study also cephalopods mainly squids formed an inevitable part of diet of *C. limbatus* after teleosts.

Proportion of both empty stomachs and poorly fed conditions was generally higher in black tip sharks. Such a large percentage of empty stomachs were observed in previous studies in the similar species of sharks (Lowe *et al.*, 1996). The proportion of empty stomachs is often variable in commercial shark catches. Also the high percentage of empty stomachs may reflect short periods of feeding followed by periods of rapid digestion. The elevated body temperature as observed in porbeagle sharks (Magnuson, 1969) probably helps to digest large volumes of food more rapidly and this may be the reason for large proportions of both poorly fed and empty feeding conditions.

The importance of epipelagic teleosts and other teleosts varied with seasons. However, teleosts apparently were the continuous source of food. This is in accordance with the observation of Joyce *et al.* (2002) in porbeagle sharks, in which, teleosts were abundant throughout the year. *Loligo* spp only substituted the diet whenever teleosts were less.

Ontogenetic shift in feeding was obvious in *C. limbatus*. Fishes of smallest length groups preferred mainly anchovies, midsize fishes preferred oil sardine and large ones shifted diet towards carnivorous teleosts and squids. Such ontogenetic dietary changes have been reported for the leopard shark, *Triakis semifaciata* (Talent, 1976), Sandbar shark, *C. plumbeus* (Ellis, 2003) and tiger shark, *Galeocerda cuvier* (Lowe *et al.*, 1996). Also when *Loligo* spp was more dominant, gradual reduction of teleosts was observed. Adult elasmobranchs of many species feed on larger, more active preys that juveniles cannot obtain, thereby reducing intraspecific competition within smaller, younger conspecifics (Lowe *et al.*, 1996; Ebert, 2002). Also larger porbeagle sharks appeared to become more piscivorous, capable of capturing large teleosts. This difference could be attributed to the size of the shark (Joyce *et al.*, 2002). Thus large sized black tip sharks are more strong predators for epipelagic fishes as well as cephalopods which are directly supporting important commercial fisheries along the Karnataka coast.

The mean diet breadth was greatest in the pre-monsoon season compared with other seasons indicating that fishes in this season fed on more diverse prey. The higher proportion of top predatory teleosts, which was essentially supplemented with epipelagic teleosts, apparently raised trophic level throughout the season. Similarly, the diet breadth in black tip sharks remain increased with increasing length of predator. Scharf *et al.* (2000) found that ontogenetically trophic niche breadth decreased for large predators (>500mm). The lack of high niche breadth in younger black tip sharks may be due to the difference in species foraging habits and /or swimming ability. The mean trophic level of blacktip shark was 4.11 ± 0.19 which is near to that calculated by Cortes (1999) for *C. limbatus* as 4.5. Among the four families of Carchariniformes sharks, Cortes (1999) fixed TrL of 4.1 for Carcharhinids, 3.8 for triakids and 3.9 for both Scyliorhinids and Sphyrinids. When compared to trophic level of other top predators of marine communities, mean TrL for sharks was significantly higher than for seabirds, but not for marine mammals (Cortes, 1999). However, Bennett (2005) pointed out that sharks with a mean trophic level of 4.0 occupy the same trophic level as marine mammals. Thus it can be confirmed from these studies that TrL of *C. limbatus* is high as compared to other top predators of marine communities. The mean trophic level increased from 4.07 ± 0.19 in the smaller length groups (<60 cm) to 4.16 ± 0.24 in larger groups in *C. limbatus*. Trophic level and body length also showed a stronger correlation in Carcharhinid sharks (r^2= 0.58) (Cortes, 1999). The positive trend between body length and trophic level contradict the view that trophic level of aquatic organisms is inversely related to size (Pauly *et al.*, 1998b).

The highest similarity in feeding between pre-monsoon and post-monsoon was due to the more or less equal proportions of teleosts and *L. duvauceli*. Similarly, large percentage of *S. devisi* was another reason for the highest similarity between 31-40 and 41-50 cm length groups. Such a kind of diet overlap between different length groups was also observed by Ellis (2003) in sandbar sharks, *C. plumbeus*.

Size correlations of prey and predator in shark species have not been well studied. The mean weight of two most important preys, *S. longiceps* and *L. duvauceli* increased with increasing shark length. Among sharks that generally feed on benthic invertebrates, Cortes *et al.* (1996) observed that bonnet head sharks *Sphyrna tiburo* in the Southeast Gulf of Mexico preyed mainly upon blue crab, *Callinectes sapidus*. Scharf *et al.* (2000) found that the range in absolute prey sizes increased dramatically with increasing predator length for eighteen of piscivorous marine predators they examined, four of which were elasmobranchs. Also, they observed that black tip shark were capable of taking larger prey than other species of sharks. Black tip sharks during the present study also consumed larger sized *S. longiceps* and *L. duvauceli.*

Although, epipelagic teleosts, *Loligo* spp and some of other prey groups had high IRI and prey-specific abundance values, none of this item occurred in more than 25% of stomachs of black tip shark. Hence it can be suggested that this species is a generalist predator. Sharks are generally considered to have an opportunistic feeding nature, consuming whatever prey is encountered, caused by changes in diet with size, season and habitat, but the extent to which they are opportunistic or selective feeders is not well defined (Wetherbee *et al.*, 1990). Ellis (2003) also observed in a similar species, *C. plumbeus* observed the generalized feeding strategies which support the present finding.

5.14. *Rhynchobatus djiddensis*

Quantitative analysis of stomach contents revealed the preference of *R. djiddensis* for crustaceans as food. Dietary studies on several species of guitarfishes from the different regions reveal that crustaceans are among the most important prey types (Abdel-aziz, 1986; Compagno *et al.*, 1989; Michael, 1993; Nasir, 2000). Previous studies on the food habits of guitarfishes from Indian waters are not known. Among crustaceans, mainly shrimps are very important for guitarfish. However, large quantity of *A. indicus* observed in guitarfish can be attributed to its regional availability along the Mangalore coast. The diet of guitarfish, *R. djiddensis* in Kuwait waters was dominated by shrimps, mainly *Exopalaemon styliferus* (Nasir, 2000) and in South African waters, it mainly feed on other decapods such as crabs and lobsters (Compagno *et al.*, 1989). Diet spectrum of other species of Rhinobatidae followed a similar pattern as observed for guitarfish. Decapods represented by caridean shrimps and brachyuran crabs were the most important food for the similar species *Rhinobatus rhinobatus* from Egyptian Mediterranean waters (Abdel- Aziz *et al.*, 1993). Some guitarfishes in Kuwait waters are bottom feeders, eating mainly shrimps and crabs (Euzen, 1987). All these studies are similar to present investigation, and revealed that decapods mainly shrimps and crabs are most important diet of guitarfishes.

Some workers observed small benthic crustaceans in the diet of guitarfish, though they were not recorded during the present study. Crustaceans such as amphipods, mysids and isopods were recorded from the diet of *R. annulatus* in South African waters (van der and Adkin, 1991). Similarly, molluscs form an important source to many guitarfishes and are found to be benthic feeders in that respect. Bivalves, mainly *Donax* spp.was identified from *R. annulatus* (van der and Adkin, 1991) and small unidentified bivalves from both *R. halavi* in California (Michael, 1993) and *R. autraliae* in western central Pacific Ocean (Compagno and Last, 1999). Though in less quantity, cephalopod represented by *L. duvauceli* formed a supplementary food to guitarfish in the present study. Very less proportion of teleosts in the diet of guitarfishes is an indication of the preference for crustaceans in large quantities. However, Euzen (1987) observed frequent occurrence of teleosts, mainly fishes belongs to the family *Gobidae* in Kuwait waters. Similarly, 12 species of teleosts dominated by Sparidae (*Pargrus pargrus* and *Boops boops*) were recorded from *R. rhinobatus* from Egyptian waters (Abdel-aziz *et al.*, 1993).

It is expected that a predator like guitarfish would also exhibit seasonal variation in diet composition. It is a strategy that predators have evolved to cope with temporal variability in prey abundance (Caddy and Sharp, 1998). The guitarfish fed mainly, *A. indicus* during pre-monsoon and post-monsoon but largely consumed *O. nepa* and prawns in monsoon. In sandskate, *Pammobatis extenta,* increased consumption of shrimps was observed during autumn and gammarids in summer and winter (Braccini and Perez, 2005). Similarly, Muto *et al.* (2001) observed a similar pattern in south-eastern Brazil and attributed it to seasonal environmental changes influencing the distribution and abundance of important prey groups.

Ontogenetic changes in feeding, a characteristic feature of many fishes during growth, was also observed in guitarfishes. Though mostly young fishes were analysed, during the present study, preference to teleosts by larger length groups is an indication of ontogenetic diet shift. This may be the reason for low proportion of *A. indicus* in larger fishes. In both sexes of common guitarfish, *R. rhinobatus*, ontogenetic diet shift was observed. Crustaceans, mainly shrimps constituted the main diet of smaller fish (<40 cm TL) and their contribution to the diet decreased with increasing length due to the increased proportion of both crabs and telesosts (Abdel-aziz *et al.*, 1993). In Mediterranean, similar observations for *R. rhinobatus* and *R. cemiculus* were made along the coast of

Tunisia showing that adults eat more teleosts and less invertebrates than the young ones (McEachran and Capape, 1984). This agrees with the present results that guitarfish when they become old prefer teleosts to invertebrates.

Ontogenetic diet shift was obviously reflected in the change in trophic level. Highest trophic level in larger fishes was mainly due to occurrence of teleosts in diet. Ebert *et al.* (1991) observed that juveniles of sandskates eat mainly crustaceans and thus are secondary consumers with trophic level >4, whereas larger one also feed on squid and teleosts, occupying higher trophic levels less than 4. The mean trophic level of guitarfish also suggested that they are secondary consumers as predicted from the general trophic pattern of small fishes.

More than 33% of the guitarfish preyed on *A. indicus*, which suggested a specialized feeding strategy for this predator. Similar feeding strategy with specialization to gammarids was also observed for the sandskate, *Pammobatis extenta* (Braccini and Perez, 2005).

5. 15. Trophic interaction and trophic guilds

The present study grouped demersal finfish communities of Karnataka coast in to four broad trophic guilds. The 'guild' concept was first proposed by Root (1967) for organisms which exploit the same type of resources in a similar fashion. Trophic guilds identified during the present study are based on the predator's feeding similarity in exploiting different prey resources along the Karnataka coast. Trophic guilds are widely defined and employed in macro benthos studies (Fauchald and Jumars, 1997). Although this concept is less used in megafaunal studies, many authors have used trophic guilds for fish and shellfish (Gartner *et al.*, 1997; Garrison and Link, 2000; Wennihage and Pihl, 2002). Some authors used similar terms such as trophic or eco groups (Qasim, 1972; Cortes, 1998; Vivekanandan, 2002) or feeding associations (Macpherson and Roel, 1987).

Hierarchical clustering based on the Bray-Curtis similarity coefficient was used to group trophic guilds because it is often considered as a satisfactory coefficient for biological data (Clarke and Warwick, 1994). Though hierarchical clustering frequently is used to identify such trophic guilds, one disadvantage is that dendrograms tend to over emphasize discontinuity or may force a graded series in to a discrete series. In view of this disadvantage, use of non-metric multidimensional scaling (MDS) becomes imperative to exhibit individual predator relationships. The stress value in the present study is 0.07. According to a rough rule of thumb for two dimensional ordinations, stress value <0.1 gives good ordinations with no prospect of misinterpretations (Clarke and Warwick, 1994). When compared, the results of both hierarchical clustering and MDS are reasonably consistent. The MDS ordination derived in the present study revealed the same grouping of predators as in the cluster analysis. The outliers noticed with the cluster analysis were evident there also. The structure within each grouping was in harmony with that revealed by the dendrogram.

In India, studies on trophic guilds of marine fauna are very limited. Based on available information, Qasim (1972) attempted to group Indian marine fishes, in to nine broad trophic groups. He reported the dominance of carnivores over other groups such as phytoplankton feeders, detritus feeders, detritus and benthic plant feeders, phyto and zooplankton feeders, zooplankton feeders, zooplankton and detritus feeders, zooplankton feeders and carnivores, carnivores and detritus feeders. Love (1980) recorded the dominance of carnivores (85%) out of 600 species of fish. Pandian and Vivekanandan (1985) concluded that majority of fishes resort to carnivory as against herbivory, detritivory and omnivory due to their relative low energy cost to maintain body temparature, the ease with ammonia excretion and their capacity to effectively digest a protein diet. More recently, Vivekanandan (2002) based on the feeding habits and ecological niche of the species groups, categorised fishes of southwest coast of India in to eight eco-groups. His grouping was dominated by demersal feeders followed by plankton feeders, medium predators and mesopelagic feeders. Many of the predators analysed in the present study were categorized as in demersal feeders with the exception of sharks (*C. limbatus* in the present study), which were considered as large predators. However, during the present quantitative multivariate study, *Acetes* feeders are dominant among the trophic guilds. The predators such as *N. japonicus* and *L. lactarius*, which were grouped by cluster analysis in different trophic guilds, are carnivores as per the grouping by Qasim (1972). Such a classification, based on the qualitative analysis of diet, fails to give an insight in to the prey-predator interactions. Hence trophic guilds, which were constructed specifically based on their most important prey, mainly of low trophic level organisms are important in diet partitioning among the predators.

The mean trophic level estimated for each trophic guild is similar to other studies that many fishes exhibited ontogenetic progression in trophic level. *E. diacanthus, G. suppositus, P. argenteus, N. mesoprion, J. sina* and *L. lactarius*, in their young age, preferred crustaceans, which are low in trophic level. But as the size/age of the predator increase, they switch to feed large prey, most often teleosts in higher trophic levels. Many considered 'trophic level' as an operational term as the feeding habits and trophic level of majority of fish groups are subjected to change depending on age, seasons, and availability of prey and the area of distribution (Vander Zanden and Rasmussen, 1996; Cortes, 1999; Figueiredo *et al.*, 2005). Pauly *et al.* (2001) suggested that usually trophic level increased during ontogeny, because larvae and juveniles are likely to feed at lower levels than conspecific adults. Also, predators are typically larger than their prey and thus trophic level often increases with body length within a given food web (Cohen *et al.*, 1993, Jennings et al.,2001, Jennings and Mackinson, 2003). This ontogenetic change in trophic level and the existence of trophic level–body size relationship has implications for the numerous studies of food web pattern and dynamics that are based on body size (Cousins, 1980; Cohen *et al.*, 1993). This will result in a range of trophic levels value for each fish group in the food web. For fitting mass balance models and evaluating fishing down marine food webs, trophic level of each fish group is being used as an input by several authors (Christensen, 1993, Pauly *et al.*, 1998b, Vivekanandan *et al.*, 2005). In these studies, use of a constant trophic level may lead to erroneous results trophic modeling. Therefore, instead of fixing a constant trophic level, ontogenetic shift in trophic level of animals must be considered in mass-balance ecosystem modelling studies.

Trophic guilds identified during the present study have similarity to other studies. Based on 7 years multi-season trophic data, Livingston (1982) grouped seagrass associated fishes in Aplachee Bay of Florida in to three major trophic groups. He grouped 'plankton, copepod and polychaete feeders' in group 1, 'benthic omnivores and carnivores' in group 2 and 'crustacean feeders' in group 3. 'Copepods and detritus feeders' identified during the present study and Livingston's group 1 are similar in that they include species that feed on small prey such as copepods, polychaetes, diatom and other zooplankton. However, the only difference was the lack of detritus as an important diet in Livingston's group 1. Similarly, 'crustacean feeders' in Livingston's group 1 showed very close resemblance to the 'prawn and crab feeders' of the present investigation. Both Livingston's group 3 (crustacean feeders) and group 2 (prawn and crabs feeders) of the demersal fish community off Mangalore coast tended to specialise on crabs and shrimps. In the present study, guild 4 (piscivores) included the large tooth flounder, *P. arsius* and blacktip shark, *C. limbatus*. There was no strict piscivorous group in Livingston's analysis, although he did report the flounder (*Paralichthys lethostigma*). Hence a comparison could not be done. *Acetes* feeders, which are specialised to feed mainly on *Acetes* spp and other crustaceans, were not reported in Livingston's analysis and this may be due to the regional differences in prey availability. In general, the present groupings show some resemblance to those reported by Livingston (1982), but many predators do not occur in both the communities.

Many workers divided the major guilds in to two, sometimes more than two sub guilds based on the share of major prey group with other preys. In the present investigation 'Acetes feeders' in the present investigation, it was divided in to three sub guilds such as 'Acetes and fish feeders', 'Acetes and prawn feeders' and 'true Acetes feeders'. This sub grouping signifies the differential proportion of other prey groups such as teleosts and prawns in diet along with the dominant *A. indicus*. Similar pattern of grouping was reported by Hajisame *et al.* (2003) from the eastern Johor Strait, Singapore, where they identified three major trophic guilds such as 'calanoid copepod feeders', 'shrimp predators' and 'polychaete predators'. Their grouping was dominated by calanoid copepods feeders with 19 predators. Apart from calanoid copepods, which formed major diet for calanoid copepod feeders, seven predators consumed great amount of polychaetes and were grouped as another sub guild under the main 'calanoid copepod feeders'.

SIMPER analysis showed resource partitioning in the demersal fish community off Mangalore. Generally, in marine systems, prey ranges from polychaetes to fish or small pelagic prey to benthic invertebrates. This kind of prey pattern occurs in coastal marine ecosystems, coral reefs and other habitats (Ross, 1986). In demersal fish community of Karnataka, food portioning was observed with predators feeding on epibenthic crabs and prawns (prawn and crab feeders) separated from those feeding on small copepods and detritus (copepods and detritus feeders) and were further distinct from those feeding on large prey like teleosts and *A. indicus* (piscivores and Acetes feeders). The results of ANOSIM clearly demonstrated the differences in guilds because all pair wise comparisons had high R-statistic values. Thus the diet of each guild was significantly different from other trophic guilds.

Although many fish species under each trophic guild consumed a variety of different prey items, it was the low trophic level crustaceans particularly *A. indicus*, penaeid prawns, benthic crabs and copepods that comprised of the majority of the food ingested by most species. Lowe-McConnell (1987) noted that tropical fish communities are often characterized by a large number of predatory fishes and consider that these predators are important in ecosystem dynamics. For example, the predation on more abundant species and the switching to other prey species as the number of particular prey species are reduced permits the coexistence of prey species by maintaining their number below the level at which they would compete with another for food /or habitat (Paine, 1966; Glasser, 1979; Low-McConnell, 1987). Liem (1990) concluded that food partitioning as observed in the present study among the sympatric species can be due to the flexibility of feeding structures observed in most fish species. He also stated that it may be a short-lived phenomenon, which could change quickly in response to environmental changes. However, this flexibility in feeding does not imply the absence of resource partitioning between sympatric species which may have evolved divergent feeding patterns to minimise the effects due to competition. Crowder (1986) provided strong evidence to divergence that has apparently occurred both in functional morphology and the diet of the Lake Michigan fish community due to inter-specific competition. In the present study, SIMPER analysis of dissimilarity partitioned trophic guilds based on the prey resource abundance. However, to establish competition as a critical factor for resource partitioning it must be shown that the food resources are in short supply (Pianka, 1981) and there was no evidence to assess whether food supply was scarce or abundant along Karnataka coast. However, Colwell and Futuyama (1971) concluded that the lack of demonstrable overlap in resource use by two species in nature can be evidence either for or against the existence of competition. These results indicate that there is considerable inter-specific resource partitioning among the demersal fish community, which reduces competition, allowing predators to coexist.

Guild members of 'detritus and copepods feeders' such as *C. macrostomus*, *P. argenteus* and *L bindus* were observed to fed exclusively on detritus. Qasim (1972) grouped *Cynoglossus* spp under detritus feeders based on the studies of earlier workers. He added that detritus occurs at the bottom in coarsely particulate form and is perhaps the most readily available and universally abundant food material in shallow areas of the sea. The importance of settled detritus as food of adult fish is much greater than all the other food groups combined. Detritivory is an important feeding mode in many food webs and detritus / detritivore interactions can strongly influence food web dynamics in many ecosystems (De Angelo 1992, Polis and Strong 1996). The detritus feeders graze upon the floor swallowing large aggregates of detritus with mud or by scraping adhered material from submerged objects (Qasim, 1972). Large proportions of detritus in the guild 'copepods and detritus' feeders indicate the large biomass of detritus along the Mangalore coast. Babenard *et al.* (1973) indicated large biomass of detritus varying between 2 and 5 mg / m^2 in shallow waters of the continental shelf of northwest coast of India. Off the coast of Karnataka the biomass of detritus was higher (Mohamed *et al.*, 2006). Similarly, Goswami (1996) estimated zooplankton biomass of the Indian EEZ and observed pockets of high zooplankton biomass along the Mangalore coast. Among the zooplankton, copepods are one of most dominant groups in the Arabian Sea (Madhupratap, 1999). Copepods formed another supporting diet to detritus for the guild 'copepod and detritus feeders'.

Another important predatory interaction is 'top down control' or 'top down predation' by piscivores and other carnivores of higher trophic level, which sometimes lead to trophic cascades. The term trophic cascade was first described by Haiston *et al.* (1960) and later by Estes and Palmisano (1974), indicating predatory interactions involving three trophic levels, whereby primary carnivores, by suppressing herbivores, increase plant abundance (Strauss, 1991). The present study revealed that the large scale predation of *C. limbatus* on the oil sardine, *S. longiceps* is likely to lead tc trophic cascades. Diatoms or algae form the most important diet of many of the planktivores along the Mangalore coast and the oil sardine particularly are the successful consumers of diatoms (Dhulked, 1962). When the consumption of oil sardine is high by the predators like *C. limbatus*, the resulting consequence would be a trophic cascade which indirectly results in the abundance of diatoms along the Mangalore coast. In theory, as long as a tri-trophic level interaction is observed, a trophic cascade need not always involve plants or algae at the bottom of food webs. Such a cascade may also occur in many other carnivores like *E. diacanthus* and *G. suppositus*, which most often feed on *Stolephorus* spp, which is a large consumer of zooplankton. A similar top-down control or trophic cascade was observed in Kenyan reefs on the abundance of sea urchin, *Echinometra mathaei* (McClanahan and Shafir, 1990). The trigger fish, *Balistapus undulates* is considered to be the single most important predator of sea urchins and controls the populations of some sea urchins (McClanahan, 1995). When this and other urchin predators were depleted, *E. mathaei* tends to become the dominant grazer of filamentous algae. However, these filamentous algae could withstand urchin grazing and become more abundant.

In a similar study, Garrison and Link (2000) identified 14 trophic guilds categorised in to six broad trophic groups in the northeast United States continental shelf ecosystem. Among these guilds, the largest guild, 'piscivores' was mainly constituted by demersal fishes such as large skates, large hakes and dogfishes. In the present study, the piscivore, blacktip shark feeds on demersal squids and epipelagic oil sardine. Hence feeding on both pelagic as well as demersal preys are a common trophic feature among piscivores (Garrison and Link, 2000). Large predators, including *C. limbatus* and *P. arsius* also utilise prey from pelagic and epipelagic habitats and provide pathways of energy transfer. The presence of *Stolephorus* spp in the diet of *P. arsius* and other predators such as *E. diacanthus, L. lactarius, G. suppositus* and threadfin breams also indicated their trophic link to the pelagic food web.

Members of various guilds mainly *Acetes* feeders showed strong impact on the sergestid shrimp, *A. indicus*. *Acetes* production in India contributes to about 11.2% of world production and *A. indicus* is the most abundant species among the sergestid shrimps (Jaiswar and Chakraborty, 2005). Its contribution forms 75% of the total non- penaeid prawn landing in India. Their landing is highest along the Saurashtra coast and it is about 20% of marine prawn landings along the Maharashtra coast (Arvindakshan and Karbhari, 1988). Bag nets, specifically the dol nets, are the major gear employed to catch *Acetes* in addition to the by-catch by trawls. *Acetes* spp are not fished along the Karnataka coast and there is no information on the biomass of *A. indicus*. The sergestid shrimp, *A. indicus*, being one of the low trophic level marine crustaceans (Vivekanandan *et al.*, 2006), is largely preyed upon by carnivores in the guild 'Acetes feeders'. In addition to this, many members of the guild 'prawn and crab feeder' also significantly consume *Acetes* sp. *Acetes* feeders are dominant in the Mangalore coast and some carnivores like *P. hamrur* and *O. cuvieri* are considered as 'true acetes feeders' since it had an IRI of >75% for *A. indicus* in their diet. The earlier works (Krishnamoorthy, 1989, Zacharia, 2003) also revealed very high preference for *Acetes* in the diet of many fishes along the Mangalore coast. This is an indicator of a large biomass can be considered as a direct indication of abundance of *Acetes* spp in the area which supports a rich demersal fishery.

This view agrees with Jaiswar and Chakraborty (2005) that *Acetes* is the most important food of almost all carnivorous food fishes exploited off Mumbai and northwest coast of India. Mention may be made about the selective feeding on *Acetes* by *Decapterus ru*sselli (Jaiswar *et al.*, 1993) and *Otolithes cuvieri* (Manojkumar, 2003). Being the primary food for many carnivorous and predatory fishes, Jaiswar and Chakraborty (2005) opined that overexploitation of *Acetes* spp may harm the demersal fishery as it may disturb the food chain and ultimately lead to depletion of food fishes. Thus the information gathered in the present study by BVSTEP analysis signifies the role of *A. indicus* as a major link to sustain the trophic guilds especially '*Acetes* feeders'. Hence it may be concluded that majority of the predators, which occupy higher trophic levels, have to depend on the low trophic level crustaceans as their major food along the Mangalore coast.

The food web of demersal community off Karnataka is extremely complex and highly connected, with a large number of trophic interactions between species. Guild identification is helpful to reduce this complexity to an ecologically meaningful level. Thus identifying trophic guilds is a useful first step for defining groups of functionally similar species and with the help of ECOPATH software, the information collected from guilds can be used for trophic modelling of demersal community off Karnataka.

Chapter 6.

Summary and conclusions

Summary and Conclusions

Food and feeding habits of fourteen demersal finfishes exploited off the Karnataka coast were studied to investigate trophic interactions within the marine food web. The demersal finfishes selected for the present study are *Epinephelus diacanthus* (rockcod), *Grammoplites suppositus* (spotfin flathead), *Priacanthus hamrur* (bulls eye), *Johnieops sina* (drab jewfish), *Otolithes cuvieri* (lesser tigertooth croaker), *Nempiterus japonicus* (threadfin bream), *Nemipterus mesoprion* (threadfin bream), *Leiognathus bindus* (silverbelly), *Cynoglossus macrostomus* (tongue sole), *Pampus argenteus* (silver pomfret), *Lactarius lactarius* (bigjawed jumper), *Pseudorhombus arsius* (largetooth flounder), *Carcharhinus limbatus* (blacktip shark) and *Rhynchobatus djiddensis* (guitar fish).

For understanding the importance of various diet components, the widely accepted diet index, the Index of Relative Importance (IRI), which integrates large data on three diet indices such as number, volume or weight and frequency of occurrence, was used to quantify diet components of each predator. Ontogenetic, seasonal (pre-monsoon, monsoon and post-monsoon) variation in feeding and prey-predator relationship studies were conducted. Prey-specefic abundance plots (Amundson plot) and Electivity index were drawn to interpret each predators feeding strategy and prey selectivity respectively.

The results showed that the rockcod, *E. diacanthus* is a demersal carnivore and preferred to feed largely on benthic crustaceans. Crustaceans followed by fishes and molluscs were the most important food components of *E. diacanthus*. Of all the stomachs analysed, 73% were empty and 27% contained food items. The most important crustaceans were benthic crabs (69.4%) followed by *Acetes indicus* (15.9%) and *Oratosquilla nepa* (6.1%). Dietary breadth had great seasonal variations. The mean trophic level was 4.11 ± 0.26. There was a significant ontogenetic shift toward larger benthic crabs in larger rock cods ($P<0.05$). Electivity study showed strong positive selection to all crustaceans in all the seasons.

- The spotfin flathead, *Grammoplites suppositus*, preyed primarily on crustaceans. Benthic crabs and penaeid prawns formed the most important preys and fishes were next in the rank. Smallest fish group (<165 mm) ate mostly *Cynoglossus macrostomus* and unidentified fishes, where as individuals of larger sizes (>165 mm) ate crustaceans mainly benthic crabs, penaeid prawns, *Acetes indicus* and *Oratosquilla nepa.* Highest similarity in diet was observed between 216-240 and 241-265 mm size groups. Broadest diet breadth was for 191-215 mm size groups. Strong selection for benthic crabs and *Solenocera choprai* was observed. A specialized feeding strategy on benthic crustaceans was exhibited by *G. suppositus*.

  The bull'seye, *Priacanthus hamrur* is a crustacean feeder, *Acetes indicus* is the most dominant prey. Significant difference in the number of major prey categories existed among the seasons ($P<0.001$). Similarity in diet between 251-270 and 271-290 mm was very high (88%). The mean trophic level and diet breadth were 3.40 ± 0.44 and 2.81 ± 1.29 respectively. The size of the principal prey *A. indicus* had a direct positive relation to the size of *P. hamrur*.

  Fishes, crustaceans, molluscs, foraminiferans, diatoms and detritus formed the major diet of jewfish, *Johnieops sina*. Crustaceans (77.0%) were the most important and highly preferred food followed by fishes (16.9%). *Oratosquilla nepa* (42.1%), *Acetes indicus* (25.1%) and unidentified fishes (9.2%) were the highly preferred prey component in the diet of *J. sina.* The mean trophic level and diet breadth were 3.6 ± 0.37 and 3.2 ± 1.53 respectively. The proportion of copepods increased with increasing size of the predator. *J. sina* showed a mixed feeding strategy.

  Out of 22 prey taxa identified, *Acetes indicus* was the most important prey in the diet of *Otolithes cuvieri.* Among fishes, *N. mesoprion* and *Stolephorus* spp were the most important prey. The mean trophic level and diet breadth were 3.97 ± 0.27 and 4.7 ± 2.5 respectively. The size of the dominant fish prey, *N. mesoprion* showed a direct relationship to predator size. Larger tooth croakers have a specialized feeding strategy on crustaceans.

- Crustaceans, fishes, molluscs and detritus were the four major groups in the diet of the threadfin bream, *Nemipterus japonicus*. *Solenocera choprai*, *Acetes indicus* and benthic crabs dominant among crustaceans. Teleosts were second in rank. Significant difference in the number of major prey categories was found between the seasons (P<0.001). Mean trophic level was 4.09 ± 0.15. Highest diet similarity was between pre-monsoon and post-monsoon. The mean weight of *S. choprai* marginally increased with the increasing size of *N. japonicus*. Specialized feeding strategy on crustaceans mainly on *S. choprai* and benthic crabs was observed. Strong selection of *S. choprai* and benthic crabs was observed during pre-monsoon and post-monsoon.
- The results of diet analysis of *Nemipterus mesoprion* showed the dominance of three food categories such as crustaceans, fishes and molluscs. Crustaceans made up the highest proportion in occurrence (65.0%) and number (92.0%). *Acetes indicus* (57.2%) and *Solenocera choprai* (33.2%) were most important in the diet. Significant differences in the number of major prey categories were observed among the seasons as well as size groups (P<0.001). The mean trophic level was 4.14 ± 0.30. Electivity index showed strong selection to S. *choprai* in monsoon. *N. mesoprion* is a specialized predator on *A. indicus* and *S. choprai*.
- The dietary component of silverbelly, *Leiognathus bindus* was grouped under six categories such as fishes, crustaceans, molluscs, foraminiferans, worms, diatoms and detritus respectively. Detritus formed the most important component. Mysids, copepods and amphipods were the most important crustacean preys. The mean diet breath and trophic level recorded were 1.99 ± 1.10 and 2.30 ± 0.20 respectively.
- The diet of tongue sole, *Cynoglossus macrostomus* consisted primarily of detritus. Fishes, crustaceans, molluscs, foraminiferans, worms, diatoms and sand were also consumed. Significant difference existed between the seasons and size groups in the number of major food groups (P<0.001). The mean diet breadth and trophic level were 3.76±0.93 and 2:71±0.35

respectively. The greatest diet similarity was observed between 116-125 and 116-125 mm length groups. Tongue sole employed a specialized feeding strategy on detritus.

- Crustaceans and detritus were the most important prey groups in the diet of the silver pomfret, *Pampus argenteus*. Fishes, diatoms and worms were the important prey, in that order. There were significant seasonal and ontogenetic differences in prey number. Mean diet breadth and trophic level were 1.74 ± 3.5 and 2.55 ± 0.37 respectively. The highest similarity in diet was observed between monsoon and post-monsoon.
- Teleosts were the most important food category followed by crustaceans and detritus in the trophic spectrum of bigjawed jumper, *Lactarius lactarius*. Significant differences in the number of major prey categories were observed between the seasons and length groups ($P<0.001$). The mean diet breadth and trophic level were 2.25 ± 0.27 and 3.91 ± 0.37 respectively. Electivity study showed strong preference to the most important prey, *Stolephorus* spp throughout the year.
- Fishes and crustaceans formed the principal food items of the largetooth flounder, *Pseudorhombus arisus*. Fishes occurred in 66.4% of the stomachs analysed and cannibalism was most often observed. *Pseudorhombus* spp (24.7%) followed by *Polynemus indicus* (24.5%) and *Stolephorus* spp (15.5%) were the most important teleosts. The mean diet breadth and trophic level were 3.99±1.93 and 4.37±0.23 respectively. Highest similarity in diet was observed between the diet of fishes in monsoon and post-monsoon. *P. arsius* exhibited a mixed feeding strategy.
- The diet of blacktip shark, *Carcharhinus limbatus* consisted of 26 different prey taxa. Teleosts and cephalopods were dominant in the diet. Epipelagic teleosts, mainly represented by sardines and anchovies, formed the preferred fish groups. The mean diet breadth and trophic level were 4.35 ± 2.61 and 4.07 ± 0.19 respectively. The highest similarity in diet was observed between pre-monsoon and post-monsoon. The mean weight of the most important prey *Sardinella longiceps* increased with the

increasing length of *C. limbatus*. Amundson's plot showed specialised feeding strategy for the blacktip shark.

- The guitarfish, *Rhynchobatus djiddensis* was monophagous to crustaceans. *Acetes indicus* was the most important target of *R. djiddensis*, which contributed 77.9% to the IRI. There were no ontogenetic shifts in the feeding of *R. djiddensis*. *A. indicus* was the most important food for the small sized fishes. Prey-specific plot of *R. djiddensis* showed a highly specialized feeding strategy on *A. indicus*.
- The results of prey-predator trophic interaction studies identified four major trophic guilds based on the predators feeding similarity. The low stress value (0.07) for the MDS plot indicated a good representation of the diet data. Trophic guild I is 'copepod and detritus feeders', which comprised of *C. macrostomus*, *P. argenteus* and *L. bindus* with an average group similarity of 61.4%. The second trophic guild, 'prawn and crab feeders' was formed by *E. diacanthus*, *G. suppositus* and *N. japonicus* with an average similarity of 52.7%. 'Acetes feeders', the largest trophic guild with an average group similarity of 62.5%, composed of six demersal finfish species, namely *P. hamrur*, *O. cuvieri*, *L. lactarius*, *P. hamrur*, *N. mesoprion* and *R. djiddensis*. The guild 'piscivores' is constituted by *C. limbatus* and *P. arsius* with an average similarity of 45%. The results of ANOSIM indicated highest difference between predators of copepod-detritus feeders and Acetes feeders. Low trophic level crustaceans such as *A. indicus* and penaeid prawns enlisted by BVSTEP, are highly impacted by the predators.
- It may be concluded that most of the demersal finfishes exploited from the Arabian Sea off Karnataka are benthic carnivores and are specialized feeders on benthic invertebrates. For each predator, ontogenetic diet shift is common and is characterized by prey of low to high trophic level. Similarly, many of the predators such as *E. diacanthus, G. suppositus*, and *C. limbatus* prefer to feed on larger preys as they grow in size. Strong selection of certain prey types was observed in some predators while most of them avoided abundant prey. Strong preference for fishes most often leads to cannibalism in the largetooth flounder, *P. arsius*. Prey-predator

interaction occasionally leads to trophic cascades in high trophic level predators such as *C. limbatus*, *E. diacanthus* and *G. suppositus*. Large scale predation by *C. limbatus* on the low trophic level oil sardine, *S. longiceps* is probably due to the abundance of the oil sardine along the Karnataka coast.

- It may also be concluded that pelagic teleosts such as sardines, anchovies, and carangids formed significant proportions in the diet of many demersal predators and hence, pelagic teleosts significantly support the benthic production along the Karnataka coast. *Acetes* feeders are dominant in the ecosystem. Six carnivores including two true *Acetes* feeders (*O. cuvieri* and *P. hamrur*) and other predators have a strong impact on the biomass of *Acetes* spp along the Karnataka coast. In addition to *Acetes* spp, strong predation impact was observed for penaeid prawns, epibenthic crabs and detritus.
- This information on trophic guilds and prey-predator interactions can be used to construct trophic model on the benthic ecosystem off Karnataka and to investigate fishery induced changes as well as predation impact of different animals on commercially important demersals.

References

References

Abdel-Aziz, S.H.1986. Food and feeding habits of Raja species (Batoidei) in the Mediterranean waters of Alexandria. *Bulletin of Institute of Oceanography and Fisheries* ARE 12:265-276.

Abdel-Aziz, S.H., A.N. Khalil and S.A. Abdel-Maguid.1993. Food and feeding habits of the common guitarfish, *Rhinobatos rhinobatos* in the Egyptian Mediterranean waters. *Indian J. Mar. Sci.*, 22: 287-290.

Aiyar, R.G. and K.P. Nalini. 1938. Observations on the reproductive system, egg case, embryos and breeding habits of *Chiloscyllium griseum* (Mull and Henle). *Proc. Indian. Acad. Sci.*, 7(5): 252-268.

Allen, K.R. 1935. The food and migration of the perch (*Perca fluviatilis*) in Windermere. *J. Anim. Ecol.*, 4: 264-273.

Alonso, K. M., E. A. Crespo, S. N. Pedraza, N. A. Garcý 'a and M. Coscarella. 2000. Food habits of the South American sea lion *(Otaria flavescens)* of Patagonia, Argentina. *Fish. Bull.*, 98: 250–263.

Alonso, K. M., E. A. Crespo, N. A. García, S. N. Pedraza, P. A. Mariotti, and N. J. Mora. 2002. Fishery and ontogenetic driven changes in the diet of the spiny dogfish, *Squalus acanthias*, in Patagonian waters, Argentina. *Environ. Biol. Fish.*, 63:193–202.

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

Amundsen, P. A., H. M. Gabler, and F. J. Staldvik. 1996. A new approach to graphical analysis of feeding strategy from stomach contents data – modification of the Costello method. *J. Fish. Biol.*, 48: 607-614.

Andersen, B.S., J.D. Carl, P. Gronkjaer, and J.G. Stottrup. 2005. Feeding ecology and growth of age 0 year Platichthys flesus (L.) in a vegetated and a bare sand habitat in a nutrient rich fjord. *J. Fish Biol.*, 66: 531-552.

Arvindandakshan, M. and J.P. Karbhari. 1988. *Acetes* shrimp fishery of Bombay coast., *Mar. Fish. Infor. Serv. T & Sev*, 80: 28-29

Ayyappan, S. and R.S. Biradar. 2000. Manpower requirement and human resource development in fisheries sector. Brainstorming session, CIFE, Mumbai.

Babenard, B., R. Boje, J, Key and Montecino. 1973. Macrobenthos and detritus in the upper 50m of Arabian Sea along the west coast of Africa and India during NE monsoon 1964-65. In: B. Zeitzschel and S.A. Gerlach (Eds), *The Biology of Indian Ocean*. Chapman and Hall Ltd, London, P.233-237.

Balan,V. 1967. Biology of the silverbelly, *Leiognathus bindus* (val) of the Calicut coast. *Indian J. Fish.*, 10 (1): 118-134.

Bapat, S.V. and D.V. Bal. 1952. The food of some young fishes from Bombay. *Proc. Ind. Acad. Sci.*, 25, (2B): 78-92.

Barry, K.P. 2002. Feeding habits of blacktip sharks, *Carcharhinus limbatus*, and Atlantic sharpnose sharks, *Rhizoprionodon terraenovae*, in Louisiana coastal waters. MS thesis, Louisiana State University, Baton Rouge, LA

Basheeruddin, S. and K.N. Nayar. 1962. A preliminary study of the juvenile fishes of the coastal waters of Madras City. *Indian. J. Fish.*, 8: 169-188.

Bauchot, M. L. 1987. Osseous Poisson. In: Fischer, W., Bauchot, M.L. Schneider, M. (Eds.), Cards FAO of identification for the needs for fishing (rev. 1). The Mediterranean and Black Sea. Fishing zone 37, Commission of the European Communities and FAO, Rome, pp. 891-1421.

Bennett, M. 2005. The role of sharks in the ecosystem. Seaweek 2005. p1-6.

Bensam, P. 2000. An introduction to demersal finfish resources. In: V.N Pillai and N.G. Menon (Eds). *Marine fisheries research and management.* Central Marine Fisheries Research Institute, Cochin. pp 495-498

Blaber, S. J. M. 1980. Fish of the Trinity Inlet System of North Queensland with notes on the ecology of fish faunas of tropical Indo-Pacific estuaries. *Aust. J. Mar. Freshwat. Res.*, 31:137-46.

Blackler, J.M., A.T. Forbes and N.T. Demertiades. 2002. Feeding ecology of *Leiognathus equula* and *Gerres filamentosus* associated with an intertidal sandbank and shallow water sub-tidal zone in Durban harbour. Southern African Marine Science Symposium: Currents-Coasts-Communities, 2002vp

Bowen, S. 1996. Quantitative description of the diet, In: B. R. Murphy and D. W. Willis, (Eds), *Fisheries Techniques*, American Fisheries Society, Bethesda, MD, 513–532.

Bowen, W. D. 1997. Role of marine mammals in aquatic ecosystems. Marine Ecology Progress Series, 158: 267–274

Braber, L. and S.J. De Groot. 1973. The food of five flatfish species (Pleuronectiformes) in the northern North Sea: *Neth. J. Sea. Res.*, 6: 163-172.

Braccini, M.and J.E. Perez. 2005. Feeding habits of the sandskate *Psammobatis extenta* (Garman, 1913): sources of variation in dietary composition.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of Southern Wisconsin. *Ecological Monographs*, **27**, 325-349.

Brule, T. and L.G.R. Canche. 1993. Food habits of juvenile red groupers, *Epinephilus morio* from Campeche Bank, Yucatan, Mexico. *Bull. Mar. Sci.*, 52: 772-779.

Bush, A. 2003. Diet and diel feeding periodicity of juvenile scalloped hammerhead sharks, *Sphyrna lewini*, in Kane 'ohe Bay, O'ahu, Hawai'i. *Environmental Biology of Fishes*, **67**: 1–11, 2003.

Cady, J.F. and G.D. Sharp. 1998. An ecological framework for marine fishery investigations. Fisheries Technical Paper No.283, Food an Agriculture Organization of the United Nations, Rome.

Cartes, J.E., P. Abello, D. Lloris, A. Carbonell, P. Torres, F. Maynou and L.G. Desola. 2002. Feeding guilds of western Mediterranean demersal fish and crustaceans: an analysis based on a spring survey. *Sci. Mar.*, 66: 209-220.

Cartes, J.E. 1998. Feeding strategies and partition of food resources in deep water decapod crustaceans in relation to depth (between 400-2300m). *J. Mar. Biol. Ass. U.K.*, 78: 509-524.

Chacko, P.I. 1949. Food and feeding habits of the fishes of the Gulf of Mannar. *Proc. Ind. Acad. Sci.*, 29, B (3): 83-97.

Chacko, P. I. 1944. On the bionomics of the Leiognathidae. *Curr. Sci.*, 13 (8).

Chakraborty, S.K., P. Devados, P.P. Manojkumar, M. Fersz Khan, P. Jayashankar, K.M.S. Hamza, M. Badruddin, P. Livingston, P. Ramalingam, V. Dareswar, V.V. Sheshagriri Rao, K. Nandakumaran, B.B. Chavan and P.K. Seetha. 2000. The fishery, biology and stock assessment of jew fish resources of India. In: V.N. Pillai and N.G. Menos (Eds), *Marine Fisheries Research and Management*, p 604-616.

Chesson, J. 1983. The estimation and analysis of preference and its relationship to foraging models. Ecology, 64:1297-1304.

Chidambaram, K. and R.S. Venkataraman. 1946. Tabular statement on the natural history of certain marine food fishes of the Madras Presidency West Coast. Govt. Press. Madras: 1-26.

Chidambaram, K. and M.D. Menon. 1946. Investigation on the shark fishery of Madras Presidency. Govt. Press Madras. pp18.

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

Chopra, S. 1960. A note on the sudden outburst of ctenophores and medusae in the waters off Bombay. *Curr. Sci.*, 29(10): 392-393.

Christensen, V. 1993. Trophic Models of Aquatic Ecosystems. In: Christensen, V. and D. Pauly.(Eds.), ICLARM Conf. Proc. 26, 390 p.

Clarke, K R and R. M. Warwick. 1994. Changes in marine communities: an approach to statistical analysis and interpretation. Natural Environment Research Council, Swindon, UK.

Clark, M.R. 1985. Feeding relationship of seven fish species from the Campbell Plateau, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 19: 365-374.

Clarke, G. L. 1954. Elements of Ecology. John. Wiley and Sons. Inc. New York. (Rev. Printing), 5, 560 pp.

Clarke, K.R. and R.M. Warwick. 2001. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation, 2nd Edition, Plymouth, Primer-E Ltd.

Clarke, K.R. and R.N. Gorley. 2001. PRIMER v5: User Manual/Tutorial. Plymouth Marine Laboratory, 91 pp.

CMFRI, 2003. Annual Report 2002-2003. Central Marine Fisheries Research Institute, Cochin.

CMFRI, 2005. Annual Report 2004-2005. Central Marine Fisheries Research Institute, Cochin, 134 p.

Cohen, J.E., S.L. Pimm, P. Yodzis, P and J. Saldana. 1993. Body size of animal predators and animal prey in food webs. *J. Anim. Ecol.* 62, 67-78

Colin A. S., B.A. Goodreide and R.B. McAuley. 2001. Size, sex and geographic variation in the diet of the tiger shark, *Galeocerdo cuvier*, from Western Australian waters. *Environmental Biology of Fishes*, 61: 37–46.

Colwell, R.K and D.J. Futuyma.1971. On the measurement of niche breadths and overlap. Ecology, 52: 567–576.

Collete, B.B. and F.H. Talbot. 1972. Activity pattern of coral reef fishes with emphasis on nocturnal-diurnal change over. *Bull. Nat. Hist. Mus. Los Angeles Co.*, 14: 98-124.

Compagno, L.J.V., D.A. Ebert and M.J. Smale, 1989. Guide to the sharks and rays of southern Africa. New Holland (Publ.) Ltd., London. 158 p

Compagno, L.J.V. and P.R. Last. 1999. Rhinidae (=Rhynchobatidae). Wedgefishes. p. 1418-1422. In: K.E. Carpenter and V. Niem (Eds.), *FAO identification guide for fishery purposes.* The Living Marine Resources of the Western Central Pacific. FAO, Rome.

Cord, E. M and S.E. Campana. 2003. A quantitative assessment of the blue shark, *Prionace glauca* off Nova Scotia, *Canada. J. Northw. Atl. Fish. Sci.*, 32: 57-63

Cortés E., C.A. Manire and R.E. Hueter. 1996. Diet, feeding habits, and diel feeding chronology of the bonnethead shark, *Sphyrna tiburo*, in southwest Florida. *Bull. Mar. Sci.*, 58: 353–367.

Cortés, E. 1997. A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes. *Can. J. Fish. Aquat. Sci.*, 54: 726-738.

Cortés, E. 1999. Standardized diet compositions and trophic levels of sharks. *ICES J. Mar. Sci.*, 56: 707–717.

Costello, M.J. 1990. Predator feeding strategy and prey importance: a new graphical analysis. *J. Fish. Biol.*, 36: 261-263.

Cousins, S. II. 1980. A trophic continuum derived from plant structure, animal size and a detritus cascade. J. Theoretical Biol. 82, 607-618.

Crowder, L.B. 1986. Ecological and morphological shifts in Lake Michigan fishes: glimpses of the ghost of competition past. *Environmental Biology of Fishes*, 16: 147-157.

Cury, P, L. Shannon and Y.J. Shin. 2003. The functioning of the marine ecosystems: a fisheries perspective. In: M. Sinclair and G. Valdimarsson (Eds). *Responsible fisheries in the marine ecosystem.* Rome, Italy, and Wallingford, UK. FAO and CAB International. pp. 103-123.

Dadzie, S., F. Abou-Seedo and E. Al-Qattan. 2000. The food and feeding habits of the silver pomfret, *Pampus argenteus* (Euphrasen), in Kuwait waters. *J. Appl. Ichthyol.*, 16: 61-67.

Daracott, A. 1977. Availability, morphometrics, feeding and breeding activity of multi-species, demersal fish stock of the western Indian Ocean. *J. Fish. Biol.*, 10(1): 1-16.

Darnell, R.M. 1961. Trophic spectrum of an estuarine community based on studied of Lake Ponchartrain, Louisiana. Ecology, 42: 553-568.

Das, M. and B. Mishra. 1990. On the biology of *Psettodes erumei* (Bloch & Schn) and Indian Halibut. *Indian J. Fish.*, 37(2): 79-92.

Datta, N.C. and M. Das. 1983. Observations on the food and feeding habits of some flat fishes of Orissa coast. *Indian. J. Fish.*, 30 (2): 241-248

Davenport, S.R. and N.J. Bax. 2002. A trophic study of a marine ecosystem off southeastern Australia using stable isotopes of carbon and nitrogen. *Can.J. Fish. Aquat. Sci.*, 59: 514-530.

Day, F. 1878. Fishes of India (Vol. I and II). William Dawson and Sons Ltd., London
DeAngeli, D.L. 1992. Dynamics of nutrient cycling and food webs. Chapman and Hall, London.

FAO, 2000. The state of world fisheries and aquaculture 2000. FAO, Rome, Italy.

Fauchald, K and P. Jumars. 1979. The diet of worms: a study of polychaete feeding guilds. *Oceanogr Mar Biol*, 17:193–284

Fennessy, S.T. 2000. Aspects of the biology of four Species of Sciaenidae from the east coast of South Africa. *Estuar. Coast. Shelf. Sci.*, **50**: 259-269.

Figueiredo, M., T. Morato, J.P. Barreiros, P. Afonso and R.S. Santos. 2005. Feeding ecology of the white seabream, *Diplodus sargus*, and the ballan wrasse, *Labrus bergylta*, in the Azores. *Fisheries Research*, 75: 107-119.

Flavia, M., T.V. Lucena, J.R. Ellis and C.M. O'Brien. 2000. Seasonal variation in the diets of bluefish, *Pomatomus saltatrix* (Pomatomidae) and striped weakfish, *Cynoscion guatucupa* (Sciaenidae) in southern Brazil: implications of food partitioning. *Env. Biol. Fish.*, 57: 423-434.

Froese, R. and D. Pauly. 2000. FishBase 2000: Concepts, design and data sources. ICLARM, Los Banos, Laguna, Phillippines. 344 p.

Garrison, L.P. and J.S. Link. 2000. Dietary guild structure of the fish community in the Northeast United States continental shelf ecosystem. *Marine Ecology Progress Series*, 202: 231-240

Gartner J.V., R.L. Crubtree and K.J. Sulak. 1997. The feeding ecology of deep sea fishes. In: Randall, D. J. and A.P. Darnell (Eds.), *Deep Sea Fishes*: Academic Press. San Diego.p. 115-182.

Garvey, J.E, N.A. Dingledine, N.S. Donovan and R.A. Stein. 1998. Exploring spatial and temporal variation within reservoir food webs: Predictions for fishassemblages. Ecological Applications 8: 104–120.

Gaskett, A.C., C. Bulman, X. He and S.D. Goldsworthy. 2001. Diet composition and guild structure of mesopelagic and bathypelagic fishes near Macquarie island, Australia. *New Zealand Journal of Marine and Freshwater Research*, 35: 469-476.

Genner, M.J., S.J. Hawkins and G.F. Turner. 2003. Isotopic change throughout the life history of a Lake Malawi cichilid fish. *J. Fish. Biol.*, 62: 907-917.

George, K.C., M.G. Dayanandan and P.K. Nair. 1968. Food of some demersal fishes from the trawl grounds off Cochin. *Indian. J. Fish.*, 15: 81-87.

Gerking, S.D. 1994. Feeding ecology of fish. Academic Press, San Diego, Calif.

Gibson, R.N. and A.I. Ezzi. 1987. Feeding relationships of a demersal fish assemblage on the west coast of Scotland. *J. Fish. Biol*, 31: 55–69.

Glasser, J.W. 1979. The role of predation in shaping and maintaining the structure of communities. *American Naturalist*, **113**: 631–41.

Gopal, C. and E. Vivekanandan. 1991. Threadfin bream fishery and biology of *Nemipterus japonicus* off Veraval. *Indian J. Fish.*, 38(2): 97-102.

Gopalan, U.K. 1969. Studies on the maturity and spawning of Silver pomfret, *Pampus argenteus* (Euphrasen) in the Arabian Sea. *Bull. Nat. Sci. India.*, 38(2): 785-796.

Goswami, S.C. 1996. Zooplankton biomass and potential fishery resources of the EEZ of India. India's EEZ. In: S.Z. Qasim and G.S. Roonwal (Eds), Omega Scientific Publishers, New Delhi, P95.

Grossman, G.D. 1980. Ecological aspects of ontogenetic shifts in prey size utilization in the Bay goby (Pisces:Gobiidae). Oecologia, 47: 233-238.

Hacunda, J.S. 1981. Trophic relationships among demersal fishes in a coastal area of the Gulf of Maine. *Fish. Bull.*, 79(4):775-788

Hajisamae, S., L.M. Chou and S. Ibrahim. 2003. Feeding habits and trophic organization of the fish community in shallow waters of an impacted tropical habitat. Estuarine, Coastal and Shelf Sciences, 58: 89-98

Hairston, N.G., F.E. Smith and L.B, Slodbodkin. 1960. Community structure, population control and competition. *American Naturalist*, 94: 421-425.

Hall, S.J., W.S.C. Gurney, H. Dobby, D.J. Basford, S.D. Heaney and M.R. Robertson. 1995. Inferring feeding patterns from stomach contents data. *J. Anim. Ecol.*, 64:39–62.

Hansson, S. 1998. Methods of studying fish feeding: a comment. *Can. J. Fish. Aquat. Sci.*, 55: 2706–2707.

Hart, P.J.B. 1997. Foraging tactics. In: Jean-Guy, G. J. (Ed), *Behavioural Ecology of Teleost Fishes*, Oxford, Oxford University Press, pp.104 – 133.

Heemstra, P.C. and J.E. Randall. 1993. FAO species catalogue. Vol. 16. Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO Fish. Synop. 125(16): 382.

Heupel, M.R. and R.E. Hueter. 2002. Importance of prey density in relation to the movement patterns of juvenile blacktip sharks *(Carcharhinus limbatus)* within a coastal nursery.

Hill, M.O. 1979. DECORANA - A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics. Cornell University (Ithaca, New York) (reissued by Microcompu erpower, Ithaca).

Hill, M.O.and H.G. Gauch. 1980. Detrended correspondence analysis and improved ordination technique. Vegetatuin, 42: 47-58.

Hobson, E. 1965. Diurnal –nocturnal activity of some inshore fishes in the Gulf of California. Copeia, 3: 291-302.

Hussain, S.M. 1990. Biology of *Psettodes erumei* (Schneider, 1801) and *Pseudorhombus arsius* (Hemiltor, 1822) from the northern Arabian Sea. *Indian J. Fish.*, 37(1): 63-66.

Hynes, H.B.N. 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies of the food of fishes. Journal of Animal Ecology, 19:36-58

Hyslop, E.J. 1980. Stomach contents analysis: a review of methods and their application. *J. Fish. Biol.*, 17:411-429.

Ivlev, V.S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, New Haven, 302 p.

Jacob P.K. 1948. Sciaenids of the west coast of Madras Province. Journal of Bombay Natural History Society. 48: 117-124.

Jaiswar, A.K. and S.K. Chakraborty. 2005. *Acetes*, the preferred food of fishes along the northwest coast of India. *Indian J. Fish.*, 52(2): 215-219.

Jaiswar, A.K., J.P. George, D.K. Gulati and R.P. Swamy. 1993. A study on length weight relationship, food and feeding habits of Indian scad *Decapterus russelli* (Ruppell, 1830) along north west coast of India. *J. Indian Fish Ass*, 23: 1-6

James, P.S.B.R., S.L. Shanbhougue and T.R.C. Gupta. 1974. Biology and fishery of *Lactarius lactarius* (Sheneider) off Mangalore, India. *Indian J. Mar. Sci.*, 3(1): 72-79.

James, P.S.B.R. 1984. Leiognathidae. In: W. Fischer and G. Bianchi (eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51). Vol. 2. FAO, Rome.

James, P.S.B.R. and M. Badrudeen. 1981. Biology and fishing of silverbelly *Leiognathus dussumeri* (Valenciennes) from Gulf of Mannar. *Indian. J. Fish.*, 28(1& 2): 154-182.

Jennings, S., Pinnegar, J. K., Polunin, N. V. C., Boon, T. W., 2001. Weak cross-species relationships between body size and trophic level belie powerful size-based trophic structuring in fish communities. *J. Anim. Ecol.*, 70, 934-944.

Jennings, S and Mackinson, S., 2003. Abundance-body mass relationships in size-structured food webs. Ecology Letters. 6, 971-974.

Jayabalan, N. and K. Ramamoorthi. 1985. Food and feeding habits of the silverbelly, *Gazza minuta* (Bloch) in Porto Novo Waters. *Indian Journal of Marine Sciences*, 14: 110-112.

Jayaprakash, A.A. 1974. Food and feeding habits of juvenile 'Koth' *Otolithoides brunneus* (Day) in Bombay waters. *Indian. J. Fish.*, 21 (1) : 127-140.

Jayaprakash, A. 2000. Food and feeding habits of Malabar sole *Cynoglossus macrostomus*. *J. Mar. Biol. Ass. India.*, 42 (1&2): 124-134.

Jeyaseelan, M.J.P. 1998. Manual of fish eggs and larvae from Asian mangrove waters.. United Nations Educational, Scientific and Cultural Organization. Paris. 193 p

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

Joyce, W., S.E. Campana, L.J. Natanson, N.E. Kohler, H.L. Pratt Jr., and C.F. Jensen. 2002. Analysis of stomach contents of the porbeagle shark, *Lamna nasus* in the Northwest Atlantic. *ICES J. Mar. Sci.*, 59(6): 1263-1269

Juanes, F. and D.O. Conover. 1994. Piscivory and prey size selection in young-of-the-year bluefish: predator preference or size dependent capture success. *Mar. Ecol. Prog. Ser.*, 114: 59–69.

Juanes, F., R.E. Marks, K.A. McKown and D.O. Conover. 1993. Predation by age-0 bluefish on age-0 anadromous fishes in the Hudson River estuary. *Trans. Amer. Fish. Soc.*, 122: 348–356.

Juanes, F., J.A. Buckel and S.F. Scharf. 2002. Feeding ecology of piscivorous fishes. / *In*: Hart, P. J. B. and Reynolds, J.D (Eds), Handbook of fish biology and fisheries. Vol. 1. Fish biology. Blackwell Science, pp. 267/283.

Kagwade, P.V. 1964. The food and feeding habits of the Indian oil sardine *Sardinella longiceps* Valenciennes. *Indian J. Fish.*, 11(1): 345-370.

Kagwade, P. 1972. Food and feeding habits of *Polynemus heptadactylus* Cuv.and Val. *Indian J. Fish.*, 16: 188-197.

Kitchell, J.F. and L.B. Crowder. 1986. Predatorprey interactions in lake Michigan: model predictions and recent dynamics. Environmental Biology of Fishes, 16: 205-211..

Knight, J.G. and T.S. Ross. 1994. Feeding Habits of the Bayou Darter. *Trans. Amer. Fish. Soc.*, 123(5): 794-802.

Krebs, C. J. 1989. Ecological methodology. Harper Collins, New York.

Krishnamurthy, B. 1971. Biology of the threadfin bream, *Nemiptrus japonicus* (Bloch). *Indian J. Fish.*, 18(1&2): 1-21.

Kruskal, J.B. 1964. Multidimensional scaling by optimizing goodness of fit for a nonmetric hypothesis. *Psychometrika*, **29**: 1-27.

Kulkarni, A.V. 1958. Studies on alimentation and rate of digestion in some of the teleosts of Bombay. M. Sc. Thesis, University of Bombay.

Kuthalingam, M.D.K.1957. Life history and feeding habits of *Cynoglossus lingua* (Ham-Buch). *J. zool. Soc. India.*, 9(2): 208-215.

Kuthalingam, M.D.K. 1963. Observations on the fishery and biology of the silver pomfret, *Pampus argenteus* (Euphrasen) from the Bay of Bengal. *Indian. J. Fish.*, 10(1) : 59-74.

Kuthalingam, M.D.K. 1965. Notes on some aspects of the fishery and biology of *Nemipterus japonicus* (Bloch) with special reference to feeding behaviours. *Indian. J. Fish.*,12 (2) : 500-506.

Labropoulou, M., A. Machias, N. Tsimenides, and A. Eleftheriou. 1997. Feeding habits and ontogenetic diet shift of the striped red mullet, *Mullus surmuletus* Linnaeus, 1758. *Fisheries Research*, 31: 257–267.

Lal Mohan, R.S., 1984. Sciaenidae. In: W. Fischer and G. Bianchi (eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51). Vol. 4. FAO, Rome.

Lande, R. 1976. Food and feeding habits of dab (*Limanda limanta*) in Borgen fjorden, North Trondelag, Norway, 24: 225-230.

Langton, R.W. 1982. Diet overlap between Atlantic cod, *Godus morhua*, silver hake, *Merluccius bilinearis*, and fifteen other North-west Atlantic finfish. *Fish. Bull.*, 80: 745-759.

Larson, G.L. and C.D. McIntire. 1993. Food habits of different phenotypes of threespine stickleback in Paxton Lake, British Columbia. Trans. Am. Fish. Soc. 122(4): 543-549.

Levins, R.1968. Evolution in changing environments: some theoretical explorations. Princeton University Press, Princeton, 120 p.

Liem, K.F. 1990. Aquatic versus terrestrial feeding modes: possible impacts on the trophic ecology of vertebrates. *American Zoologist*, 30: 209-221.

Link, J.S., M.J. Fogarty and R.W. Langton. 2005. The trophic ecology of flatfishes. In: Gibson R.N (Eds.) *Flat fishes: biology and exploitation*. Blackwell publishing. 185-212.

Livingston, R.J. 1982. Trophic organization of fishes in a coastal seagrass system. *Marine Ecology Progress Series*, 7: 1-12.

Longhurst, A. R., 1957. The food of demersal fish of a West African estuary. *J. Anim. Ecol.*, 26: 369-387.

Love, R.M. 1980. The chemical biology of fishes, p. 943. London, Academic Press.

Lowe, C.G., B.M. Wetherbee, G.L. Crow and T.L. Tester. 1996. Ontogenetic dietary shift and feeding behavior of the tiger shark, *Galeocerdo cuvier*, in Hawaiian waters. *Environ Biol Fish*, 47: 203–211.

Lowe-McConnell, R.H. 1987 *Ecological Studies in Tropical Fish Communities*. Cambridge University Press, Cambridge.

Luczkovich, J.J., G.P. Ward, J.C. Johnson, R.R. Christian, D. Baird, H. Neckles, W.M. Rizzo. 2002. Determining the trophic guilds of fishes and macroinvertebrates in a seagrass food web. *Esturies*, 25 (6): 1143-1164.

MacArthur, R.H. and E. Pianka. 1966. On optimal use of a patchy environment. *American Naturalist*, 100: 603-609.

Macpherson, E. and B.A. Roel. 1987. Trophic relationships in the demersal fish community off Namibia. *S. Afr. J. mar. Sci.*, 5: 585-596.

Maria, E.C. 1998. Trophic relationships and feeding habits of four deep-sea shark species off the south coast of Portugal. Ph.D thesis submitted to University of Algarve, Portugal.

McEachran, J.D and C. Capape. 1984. Rhinobatidae. *In*: P.J.P. Whitehead, M.L. Bauchot, J.C Hareau, J. Neilsen and E. Tortonese (Eds), Fishes of the northeastern Atlantic and Mediterranean, (Unesco, Paris), p156.

McClanahan, T.R and H Shafir. 1990. Causes and consequences of sea urchin abundance and diversity in Kenyan coral reef lagoons. *Oecologia*, 83: 362-370.

McClanahan, T.R 1995. Fish predators and scavengers of the sea urchin Echinometra mathaei in Kenyan coral reef marine parks. *Environmental biology of fishes*, 43: 187-193.

Madhupratap, M. 1999. Some special features of the trophic relationship in the Arabian Sea. India's EEZ, S.Z. In: Qasim and G.S. Roonwal (Eds), Omega Scientific Publishers, New Delhi, P87.

Magnuson, J.J. 1969. Digestion and food consumption by skipjack tuna (*Katsuwonus pelamis*). *Transactions of the American Fisheries Society*, 98: 379–392.

* Mahadevan, G. 1940. Preliminary observations on the structure of the uterus and the placenta of few elasmobranches . *Proc. Indian. Acad. Sci.*, (Sect B) 11(1): 1-44.

Manojkumar, P.P. 2003. Observations on the food and feeding habits of *Otolithes cuvieri* (Trewavas) off Veraval. *Indian J. Fish.*, 50(3): 379-385.

Marais, J.F.K. 1984. Feeding ecology of major carnivorous fish from four Eastern Cape estuaries. *S. Afr. J. Zool.*, 19: 210-223.

Mathew, C.J and M. Devaraj. 1997. The biology and population dynamics of the spadenose shark *Scoliodon laticaudus* in the coastal waters of Maharashtra state, India *Indian J.Fish.*, 44(1): 11-27.

Meaghen, E. M and E.S. Campana 2003. A quantitative assessment of the diet of the blue shark, *Prionace glauca* off Nova Scotia, Canada. *J. Northw. Atl. Fish. Sci.*, Vol. 32.

Menzel, D.W. 1960. Utilisation of food by a Bermuda reef fish, *Epinephelus guttatus*. *Jour. Conseil Internatl. Explor. Mer.*, 25 (2): 216-222.

Michael, S.W. 1993. Reef sharks and rays of the world. A guide to their identification, behavior, and ecology. Sea Challengers, Monterey, California. 107 p.

Mohamed, K.H. 1955. Preliminary observations on the biology and fisheries of thread fin *Polydactylus indicus* (Shaw) in the Bombay and Saurashtra waters. *Indian J. Fish.*, : 164-179

Mohamed, K.S., C. Muthiah, P.U. Zacharia, K.K. Sukumaran, P. Rohit and P.K. Krishnakumar. 1998. Status of marine fisheries in Karnataka state, South India. Naga ICLARM Q, 21 (2): 10-15.

Mohamed, K.S., P.U. Zacharia, C. Muthiah, K.P. Abdurahiman and T.H. Nayak. 2006. A Trophic Model of the Arabian Sea Ecosystem off Karnataka and Simulation of Fishery Yields for its Multigear Marine Fisheries. *CMFRI Publication* pp. 1-83.

Mohan, M and A.K. Velayudhan. 1985. A few observations on the taxonomy and Biology of *Nemipterus delagoae* smith from Vizhinjam. *Indian. J. Fish.*, 31: 113 –122.

Morato T., R.S. Santos and J.P. Andrade. 2000. Feeding habits, seasonal and ontogenetic diet shift of blacktail comber, *Serranvs atricauda* (Pisces: Serranidae), from the Azores, north-eastern Atlantic. *Fisheries Research*, 49: 51-59.

Moses, S.T. 1947. Baroda fisheries. Bull. No. XI, Dept. of Fisheries, Baroda State.

Munro, I.S.R., 1955. The marine and fresh water fishes of Ceylon. Halstead Press, Sydney. 351 p

Murty, S.V. 1975. On the fishes of the family Platycephalidae of the seas around Inida. *J. mar. biol. Ass. India*, 17 (3): 679-694

Muthiah, C. and S.K. Pillai. 1979. A. new distrubutional record of *Nemipterus delagoae* Smith form Bombay waters with notes on it biology. *J. Mar. Biol. Ass. India*, 21 (1&2): 174-178

Muto, E.Y., L.S.H. Soares and R. Goitein. 2001. Food resource utilization of the skates *Rioraja agassizii* (Muller & Henle, 1841) and *Psannibatis extenta* (Graman, 1913) on the continental shelf off Ubatuba, south-eastern Brazil, *Revista Brasileira de Biologia*, 61: 27-238.

Nair, R.V. and K.K. Appukuttan. 1973. Observation on the food of deep sea sharks *Halaelurus hispidus* (Alcock), *Eridacnis radeliffei* Smith and *Iago omanensis* Compagno and Springer. *Indian J. Fish.*, 20(2): 575-583.

Nair, K.V. 1980. Food and feeding habits of *Johnieops sina* (Cuvier). *Indian J. Fish.*, 27(1-2): 24-34

Nasir, N.A., 2000. The food and feeding relationships of the fish communities in the inshore waters of Khor Al-Zubair, northwest Arabian Gulf. *Cybium*. 24, 89-99.

Natarajan, A.V and A,C. Jhingran. 1961. 'Index of preponderance'-a method of grading th e food elements in the stomach analysis of fishes. *Indian J. Fish.*, 8: 54-59

Neelakantan, B. 1981. Studies on the false trevally, *Lactarius lactarius* (Block) & Shneider, 1801) from the Karwar waters. Ph. D thesis, Karnataka University, Dharward, pp.1-249. Bloch

Nikolsky, G.V. 1963. The Ecology of Fishes. Moscow State University, Moscow. 263 p.

Odum, W.E. and E.J. Heald. 1975. The detritus-based food web of an estuarine mangrove community. *In*: Cronin, L.E. (Ed), Estuarine Research. 1. New York, Academic Press, pp. 265-286.

Okera, W. 1973. The food of two species of sardines- *Sardinella gibbosa* (BLEEKER) and *Sardinella albella* (VALENCIENNES) in east African waters. *J. mar. boil. Ass. India.*, 15 (2): 632-651.

Ortega-Salas, A.A. 1980. Seasonal changes in the common dab *Limanda limanta* (L.) in the Isle of Man waters. *J. Fish. Biol.*, 16: 75-82.

Pandian, T.J. and E. Vivekanandan. 1998. Energetics of feeding and digestion. *In*: Tytler P and P. Calow (Eds), Fish enegetics. Pp 99-124. Croom Helm, London.

Paine, R.T. 1966. Food web complexity and species diversity. *American Naturalist*, 100: 65-75.

Pati, S. 1978. The food and feeding habits of silver pomfret, *Pampus argenteus* (Euphrasen) with a note on its signigicance in fishery. *Proc. 65th . Indian. Sci. Congr.*, Part-III (Abstract): 230-231

Pati, S., 1977. Food and feeding habits of the Chinese pomfret *Pampus chinensis* Euphrasen from the Bay of Bengal. *J. Mar. Biol. Ass. India.*, 19(1): 44-49.

Pauly, D., A. Trites, E. Capuli, and V. Christensen. 1998a. Diet composition and trophic levels of marine mammals. *ICES Journal of Marine Science*, 55: 467–481.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese. and F. Torres. 1998b. Fishing down marine food webs. Science, 279: 860–863.

Pauly, D., L. Palomares, R. Froese, P. Sa-a, M. Vakily, D. Preikshot. and S. Wallace. 2001. Fishing down Canadian aquatic food webs. *Can. J. Fish. Aquat. Sci.*, 58: 51-62.

Paxton, J.R., D.F. Hoese, G.R. Allen and J.E. Hanley. 1989. Pisces. Petromyzontidae to Carangidae. *Zoological Catalogue of Australia*, 7: 468-469.

Philip, K.P., 1998. Food and feeding habits of *Priancanthus hamrur* (Forsskål) from the upper east coast of India. *Bull. Fish. Surv. India.*, 26: 12-25.

Pianka, E.R. 1981. Competition and niche theory. In: R.M. May (ed.), *Theoretical Ecology*, pp. 167-196. Oxford : Blackwell

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

Pillai, P.K.M., 1983. On the biometry, food and feeding and spawning habits of *Otolithes ruber* (Schneider) from Porto Novo. *Indian J. Fish.*, 30(1):69-73.

Pinkas, L.M., S. Oliphant and I.L.K. Iverson. 1971. Food habits of albacore, bluefin tuna and bonito in Californian waters. *Calif. Fish Game*, 52: 1–105.

Platell, M.E., G.A. Sarre and I.C. Potter. 1997. The diets of two co-occurring marine teleosts, *Parequula melbournensis* and *Pseudocaranx wrighti*, and their relationships to body size and mouth morphology, and the season and location of capture. *Environmental Biology of Fishes*, 49: 361–376.

Polis, G.A. and D.R. Strong. 1996. Food web complexity and community dynamics. *The American Naturalist*, 147: 813-846

Prabhu, M.S. 1954. The perch fishery by special traps in the area around Mandapam in the Gulf of Mannar and Palk Bay. *Indian. J. Fish.*, 1 (1&2): 94-130.

Pradhan, M.J. 1959. A preliminary note on the food and feeding habits of *Pseudorhombus elevatus* Ogilby. *J. Bombay. Nat. Hist. Soc.*, 56(1): 141-144.

Premalatha, P. 1989. Fishery and biology of rock cods (order: Perciformes) from the southwest coast of India. *Indian. J. Fish.*, 36 (4): 285-291.

Premalatha, P. 1997. On the fishery and biology of *Priacanthus hamrur* Forskal along the Southwest cast of India. *Indian J. Fish.*, 44(3) : 265-270.

Pusch, C., P.A. Hulley and K.H. Kock. 2004. Community structure and feeding ecology of mesopelagic fishes in the slope waters of King George Island (South Shetland Islands, Antartica. *Deep Sea Research*, 1: 1-24

Pyke, G.H., H.R. Pulliam and E. L. Charnov. 1977. Optimal foraging: a selective review of theory and tests. *Q. Rev. Biology.*, 52: 137 –153.

Qasim, S.Z. 1972. The dynamics of food and feeding habits of some marine fishes. *Indian. J. Fish.*, 19(1&2): 11-28.

Rajaguru, A., G. Shantha and R. Natarajan. 1988. Mangrove waters as nursery grounds for juveniles of marine flatfishes. *CMFRI, Spl. Publi.*, No: 40, 62pp.

Raje, S.G. 1996. Some observations on the biology of *Nemipterus mesoprion* (Bleeker) from Veraval (Gujarat). *Indian J. Fish.*, 43(2) : 163-170.

Randall, J.E. 1965. Food habits of the Nassu grouper (*Epinephelus striatus*). *Assocls. Mar. Labs. Carib.* Sixth meeting, 13-16.

Randall, J.E. 1967. Food habits of reef fishes in the West Indies. *Stud. Trop. Oceanog. Univ. Miami.*, 5: 655-847.

Randall, J.E. and V.E. Brook. 1960. Observations on the ecology of Epinepheline and Lutjanid fishes of the Society Islands with emphasis on food habits. *Trans. Am. Fish. Soc.*, 89(1): 9-16.

Randall, J.E. and P.C. Heemstra, 1991. Revision of Indo-Pacific groupers (Perciformes: Serranidae: Epinephelinae), with descriptions of five new species. Indo-Pacific Fishes (20): 332 p.

Ramanathan, N.P., V.V. Ramaiyan and R. Natarajan. 1977. On the biology of the large-scale tongue sole *Cynoglossus macrolepidotus* (Bleeker). *Indian J. Fish.*, 24(1&2): 83-89.

Ramanathan, N. and R. Natarajan. 1980. Food and feeding habits of *Psettodes eumei* (Bloch and Schn.) and *Pseudorhombus arsius* (Ham. Buch.). — Jour. no., ? pg ?

Rao, S.K.V. 1963. Some aspects of the biology of 'Ghol', *Pseudosiaena diacanthus* (Lacepede). *Indian. J. Fish.*, 10(2): 413-459.

Rao, K.S. 1964. Food and feeding habits of fishes form trawl catches in the Bay of Bengal with observations on diurnal variation in the nature of the feed. *Indian J. Fish.*, 11: 277-314.

Rao, T.A. 1966. On some aspects of the biology of *Lactarius lact*arius (Sheneider). *Indian. J. Fish.*, 13(1&2): 334-347.

Rao, P.A.V. 1968. Observations on the food and feeding habits of *Gerres oyen*a (Forskal) and *Gerres filamentosus* (Cuvier) from the Pulicat Lake with notes on the food of allies species. — No jour/pg.

Rao, T.A. 1980. Food and feeding habits of *Pennahia macrophthalmus* Bleeker at Visakhapatnam. *Indian J. Fish.*, 27(1-2): 61-65

Rao, K.V. 1981. Food and feeding of lizard fishes (*Saurida* spp.) from north western part of Bay of Bengal. *Indian J. Fish.*, 28(1&2): 47-64.

Rao, T.A. 1984. On some aspects of biology of *Priacanthus macracanthus* (Cuvier). *Indian J. Fish.*, 31(3): 380-382, Rao, T.A. 1985. Observations on some aspects of biology of *O. cuvieri* (Trewaves) from Veraval. *J. Mar. Biol. Ass. India.*, 27(1&2): 186-188

Rao, T.A. 1989. Fishery of threadfinbreams at Waltair with notes on some aspects of biology of *Nemipterus mesoprion* (Bleeker). *J. mar.* boil. *Ass. India.*, 31 (1&2): 103-109

Rao, L.M. and G. Padmaja. 1999. Variations in food and feeding habits of *M. cyprinoids* from coastal waters of Visakhapatnam. *Indian J. Fish.*, 46(4): 407-410.

Rao, D.M and K.S. Rao. 1991. Food and feeding behaviour of *Nemipterus japonicus* (Bloch) populations off Visakhapatnam, South India. *J. Mar. Biol. Ass. India.*, 33(1&2): 335-345.

Rege, M.S. 1958. A study of the Stromateid fishes of Bombay. Ph. D Thesis, University of Bombay.

Renones, O., N.V. Polunin and R. Goni. 2002. Size related dietary shifts of *Epihephelus marginatus* in a western Mediterranean littoral ecosystem: an isotope and stomach content analysis. *J. Fish. Biol.*, 61: 122-137.

Robb, A.P. and J.R.G. Hislop, 1980. The food of five gadoid species during the pelagic 0-group phase in the northern North Sea. *J. Fish. Biol.*, 16:199-217.

Ross, S.T. 1986. Resource partitioning in fish assemblages: a review of field studies. *Copeia*, 352-388.

Root, R.B. 1967. The niche exploitation pattern of the blue-gray gnatcatcher, *Ecological Monographs*, 37: 317-350.

Russell, B.C. 1990. Nemipterid fishes of the world. (Threadfin breams, whiptail breams, monocle breams, dwarf monocle breams, and coral breams). Family Nemipteridae. An annotated and illustrated catalogue of nemipterid species known to date. FAO Fish. Synops,12(125):1-149.

Russell, B.C. 1996. *Parascolopsis capitinis*, a new species of nemipterid fish from Sri Lanka. *J. South Asian Nat. Hist*, 2(1): 63-66.

Salini, J.P., S.J. Blaber and D.T. Brewer, 1994. Diets of trawled predatory fish of the Gulf of Carpentaria, Australia, with particular reference to predation on prawns. *Aust. J. Mar. Freshwat. Res.*, 45(3): 397-411.

Sarangdhar, P.N. 1943. Tiger shark, *Gelaeocerdo tigrinus* (Muller and Henle) feeding and breeding habits. *J. Bombay nat. Hist. Soc.*, 44: 102-110.

Scharf, F.S., F. Juanes and R.A. Rountree. 2000. Predator-prey relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic-niche breadth. *Mar. Ecol. Prog. Ser.*, 208: 229–24.

Schafer, L.N., M.E. Platell, F.J. Valesinni and I.C. Potter. 2002. Comparisons between the influence of habitat type, season and body size on the dietary compositions of fish species in nearshore marine waters. *Journal of Experimental Marine Biology and Ecology*, 278: 67–92.

Schoener, T.W. 1970. Nonsynchronous spatial overlap of lizards in patchy habitats. Ecology, 51(3): 408-418.

Seki, M.P. and D.A. Somerton. 1994. Feeding ecology and daily ration of the pelagic armourhead, *Pseudopentaceros wheeleri*, at Southeast Hancock Seamount. Environmental Biology of Fishes, 39: 73-84.

Seshappa, G. and B.S. Bhimachar. 1955. Studies on the fishery and biology of the Malabar sole, *Cynoglossus semifasciatus* Day. *Indian J. Fish.*, 2 (1): 180-230.

Shears, N.T. and R.C. Babcock. 2002. Marine reserves demonstrate top-down control of community structure on temperate reefs. Oecologia, 132: 131-142.

Setna, S.B. and P.N. Sarangdhar. 1949. Studies of development of some Bombay elasmobranches *Rec. Indian Mus.*, 47: 203-216.

Shepard, R.N. 1962. *Psychometrika*, 27: 219-246

Silas, E.G. 1969. Exploratory fishing by VARUNA. *Bull. Cent. Mari. Res. Inst.*, 12: 53-66.

Silas, E.G. and M.S. Rajagopalan. 1963. On a recent capture of a whale shark (*Rhincodon typus* Smith) at Tuticorin with a note on the information to be obtained on whale sharks from Indian waters. *J. mar. boil. Ass. India.*, 5 (1): 105-106.

Sivakami, S. 1995. Fishery and biology of the carangid fish *Megalaspis cordyla* (Linnaeus) off Cochin. *J. Mar. Biol. Ass. India.*, 37(1&2): 237-248.

Sivaprakasan T.E. 1985. Observations on the food and feeding habits of *Parastromateus niger* (Bloch) of the Sourashtra coast.

Smith, J.L.B. 1961. The sea fishes of southern Africa. 4th ed. Central News Agency, Ltd., Johannesburg. 580 p.

Sobhana, B. 1976. Studies on certain cyprinid fishes of Kerala. Ph.D. *Thesis, Submitted to the Univ. Kerala.*

Sokal, R.R. and F.G. Rohlf. 1995. Biometry. W.H. Freeman & Co, New York.

Srinath, M., S. Kuriakose, P.L Ammini, C.J. Prasad, K. Ramani and M.K. Beena. 2006. Marine fish landings in India. 1985-2004. Estimates and Trend. *CMFRI Spl. Publ.*, NO. 89, 161 pp.

Strauss, R. E. 1979. Reliability estimates for Ivlev's electivity index, the forage ratio, and a proposed linear index of food selection. *Transactions of the American Fisheries Society*, 108:344-352.

Stillwell, C.E. and N.E. Kohler. 1993. Food habits of the sandbar shark *Carcharhinus plumbeus* off the U.S. northeast coast, with estimates of daily ration. *Fishery Bulletin*, 91:138-150

Strauss, S.Y. 1991. Indirect effects in community ecology: their definition, study and importance. *Trends in Ecology and Evolution*, 6: 206-210.

Suyehiro, Y. 1942. A study on the digestive system and feeding habits of fish. *Japan. J. Zool.*, 10.

Suseelan, C and K.V. Nair. 1969. Food and feeding habits of the demersal fishes off Bombay. *Indian J. Fish.*, 16(1&2): 56-74

Talent, L.G. 1976. Food habits of the leopard shark, *Triakis semifasciata*, in Elkhorn Slough, Monterey Bay, California. *Calif Fish Game*, **62**: 286.298.

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

Tessy, K.L. 1994. Studies on the biology of three cultivable species of Epinephelus from the South west coast of India. Ph. D thesis, Cochin University of Science and Technology, Cochin. Pp.1-219.

Tiews, K., A. Mines and I.A. Ronquillo, 1972. On the biology of *Saurida tumbil* (Bloch 1801), Family Synodontidae in Philippine waters. The Philipp. *J. of Fish*, 10(1-2):1-29

Thollot, P. 1996. Les poissons de mangrove du lagon sud-ouest de Nouvelle-Calédonie. ORSTOM Éditions, Paris.

van der Elst, R.P. and F. Adkin. 1991. Marine linefish: priority species and research objectives in southern Africa. *Oceanogr. Res. Inst., Spec. Publ.*, 1. 132 p.

Vander Zanden, M.J., J.S, Brian, N.P. Lester and J.B. Ramussen. 2000. Within- and among – poulation variation in the trophic position of a pelagic predator, lake trout (*Salvelinus namaycush*). *Can. J. Fish. Aquat. Sci.*, 57: 725-731.

Vander Zanden, M.J. and J.B. Rasmussen.1996. A trophic position model of pelagic food webs: impact on contaminant bioaccumulation in lake trout. *Ecological Monographs*, 66: 451–477.

Venkataraman, G. 1960. Studies on the food and feeding relationships of the inshore fishes off Calicut on the Malabar Coast, 7(2): 275-305.

Vivekanandan, E. 2001. Predatory diversity of two demersal finfish species in the trawling grounds off Veraval. *Indian J. Fish., 48(2)*: 133-143.

Vivekanandan, E, 2002. Application of an ecosystem model on the fish stocks in the southwest coast of India. RAP Publication (FAO), 2002/27, 47-60

Vivekanandan, E., M. Srinath and S. Kuriakose, 2005. Fishing the marine food web along the Indian coast. *Fish. Res.*, 72: 241-252.

Vivekanandan, E., M.M. Meiyappan, S. Gomathy, P. Thirimilu and S.K Balakumar. 2006. Trophic levels of marine fishes occurring along the Indian coast. Naga (in press).

Weber, M. and L.F. De Beaufort. 1931. The fishes of the Indo-Australian Archipelago. VI. Perciformes: Serranidae, Theraponidae, Sillaginidae, Emmelichthyidae, Bathyclupeidae, Coryphaenidae, Carangidae, Rachycentridae, Pomatomidae, Lactariidae, Menidae, Leiognathidae, Mullidae. A.J. Reprints Agency, New Delhi, 6:448.

Wennihage, H and L. Pihl. 2002. Fish feeding guilds in shallow rocky and soft bottom areas on the Swedish west coast. *Journal of Fish Biology*, 61: 207-228.

Werner, E.E and J.F. Gilliam. 1984. The ontogenetic niche and species interactions in size-structured populations. *Annual Review of Ecology and Systematics*, 15: 393-425.

Wetchagarum, K. 1971. Some aspects of biology of spotfinned big eye (*Priacanthus tayenus*) in the inner part of Thailand (1969-1970); paper presented in the second Symposium on Marine Fisheries, Bangkok, Marine Fishery Laboratory. 19-20 April 1971. 24 p. (mimeo).

Wetherbee, B.M., S.H. Gruber, and E. Corte's. 1990. Diet, feeding habits, digestion, and consumption in sharks, with special reference to the lemon shark, *Negaprion brevirostris*. NOAA Technical Report NMFS, 90: 29-47.

Windell, J.T. 1968. Food analysis and rate of digestion. *In*: W.E. Ricker (ed), Methods for the assessment of fish production in fresh waters. Blackwell, Oxford. p. 197-203.

Wu, R.S.S. 1984. The feeding habits of seven demersal fish species in a subtropical estuary. *Asian. Mar. Bio.*, 1. 17-26

Xue, Y., X. Jin, B. Zhang and Z. Liang. 2005. Seasonal, diel and ontogenetic variation in feeding patterns of small yellow croaker in the central Yellow Sea. *Journal of Fish Biology*, 67: 33–50

Yamashita, Y., N. Piamthipmanus and K. Mochizuki. 1987. Gut contents analysis of fishes sampled from the Gulf of Thailand. p.33-55. *In*: K. Kawaguchi (ed.) Studies on the mechanism of marine productivity in the shallow waters around the South China Sea with special reference to the Gulf of Thailand. Grant-in-Aid no.

Zacharia, P.U. 2003. Studies on the fishery biology and population dynamics of the white fish *Lactarius lactarius* (Block & Sheneider, 1801) along the Karnataka coast. Ph. D thesis, Mangalore University, Mangalore. pp. 1-188.

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

Zacharia, P.U., K.S. Mohamed, C. Purandahara, H. S. Mahadevaswami, Ali. C. Gupta, D. Nagaraja and U. S. Bhat. 1996. A bio-economic evaluation of the dual-fleet trawl fishery of Mangalore and Malpe. *Mar. Fish. Infor. Serv. T & E Sev.*, 144: 1-12.