STUDIES ON THE BIOLOGY OF THREE CULTIVABLE SPECIES OF *EPINEPHELUS* FROM THE SOUTH WEST COAST OF INDIA

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MARCH 1994

TO MY PARENTS

CERTIFICATE

This is to certify that the thesis entitled **"Studies on the biology of three cultivable species of Epinephelus from the South West Coast of India"** is the bonafide record of the work carried out by MISS K.L.TESSY under my guidance and supervision in the CMFRI and that no part thereof has been presented for any other degree.

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DECLARATION

I hereby declare that this thesis entitled" **Studies on the biology of three cultivable species of** **<u>Epinephelus</u>** **from the South. WestCoast of India"** has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

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PREFACE

The marine fishery resources of India have been remaining more or less stagnant during the past few years. The exploitation of the resources is limited to the inshore waters upto 50 m depth. To change this condition there are two alternatives, one is the exploration and exploitation of the resources of the deeper waters and the other is to go for aquaculture/sea farming. The main draw back of the deep sea fishing is that it is capital intensive and risk prone. Hence it is felt that further increase in fish production can happen through technically and economically viable aquaculture. Culturing of shell fishes has gained much popularity and priority within the country, however the culturing of fin fishes is restricted to freshwater fishes mainly and to a limited extent brackish water ones.

Though fin fish culture practices are well established in the inland waters. scientific way of sea farming has not developed in our country when compared with the remarkable progress achieved in the field, employing open sea farming techniques like pen culture, cage culture etc., in other parts of the world. Many species of fishes such as milkfish, mullets. perches and eels are found to be suitable for culturing in saline lagoons and ponds. Experimental net cage culture of Epinephelus tauvina conducted by CMFRI at its Research Centre at Mandapam recently showed that the fish is suitable for culture practice.

Perches are highly esteemed export quality fish having great demand in foreign markets. Though there are trade enquiries from abroad for marketing different species of perches, the export of this item has not yet reached the desired levels due to the inadequate availability and seasonal nature of catch. The exploratory fishing carried out by the various agencies in the rocky grounds of south west, south east and Gulf of Mannar regions revealed concentration pockets of this resource. As this resource could achieve high prices in foreign markets all effort should be made not only for the mere exploitation from the fishing grounds, but also culturing candidate species. There is growing awareness among many nations on the need to mass culture marine carnivorous fin fishes like groupers, snappers, sea basses etc. Attempts were already made in this direction in countries like Hong Kong, Singapore, Thailand and Malaysia and achieved appreciable results.

Epinephelids of the family serranidae constitute a very large and important group of fishes of the tropical and subtropical regions and they sustain one of the major demersal fisheries in India. Some species of the genus Epinephelus are suitable candidates for mariculture especially along identified habitats of the south east and south west coasts of India. But unfortunately no specific attempt has been made towards a comprehensive study of this genus from Indian waters. Therefore in order to fill the lacuna on the biology of these candidate species the present investigation is carried out. One of the dominant species, E. diacanthus is taken up for detailed biological investigations. The study on the biology of E. chlorostigma and E. bleekeri were also incorporated in this study for comparison and also for a comprehensive understanding of this group of fishes as a whole. The complex sexuality involving protogynous hermaphroditism in this group, makes it an interesting specimen for research purpose. Though high priced and relished, capture fishery resources of this group are restricted. So the alternative is to develop culture technology for the fish.

The main objective of this study is to develop a background knowledge about the biology, stock position and abundance of this group which would help the aquaculturists in their venture to experiment with a fish which is not less important than crustaceans.

The thesis is presented in two parts. Part I describes the biology of E. diacanthus in detail in six chapters. Chapter 1 introduces the subject with a review of the important works carried out by earlier workers in this field. Chapter 2 describes the age and growth of the fish determined from skeletal hard parts like otoliths, scales and vertebrae. Theoretical growth and length-weight relationship are also included in this Chapter. Chapter 3 describes the food and feeding habits of E. diacanthus, the relative importance and percentage composition of each item is described in great detail. Chapter 4 describes the reproductive biology of the three species at length giving special emphasis to protogynous hermaphroditism, age and size at sex reversal etc. Racial investigations within the species, carried out with the help of morphometric characters among the samples collected from Cochin and Calicut are described in Chapter 5. And Chapter 6 deals with the external and internal parasites obtained during the entire course of study. In Part II the fishery and stock positions of the three species is described.

This thesis is the result of field and laboratory studies for a period of two years after completing statutory course studies for six months in mariculture.

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PART I

CHAPTER 1

INTRODUCTION

The coastal marine fish production of the country is stagnating around 1.4 million metric tonnes during the last few years, inspite of increased fishing pressure, new technological innovations in the harvesting sector and industrialization. In this circumstance, to increase fish production, it is imperative to culture food fishes and shell fishes in brackishwater and enclosed marine habitats. With this view in recent years culture of fin fishes and shell fishes in coastal waters has been given priority in the context of augmenting fish production, creating employment opportunities and the improvement of rural economy. Among the cultivable marine fishes, the rock cods (Kalava) are promising candidates for mariculture. Culturing of carnivorous fishes such as groupers, snappers and seabass has gained considerable importance and popularity in Hongkong, Singapore, Thailand and Malaysia. With the stagnating or diminishing landing of marine fishes in India, the urgency of culturing fin fishes of commercial importance hardly needs further emphasis.

The genus Epinephelus belongs to the family serranidae. This multispecies genera is a demersal denizen of tropical and subtropical areas ranging from shallow coastal waters to moderate depths, rarely occurring beyond 200 m. However a few species are abundant and commercially important in temperate waters. Some serranids show preference for sea grass beds and mud or sandy bottom, while many other genera prefer coral and rocky grounds. Juveniles of a few species are common in the lower reaches of estuaries. Except for breeding aggregations, most species are solitary. All are predators on fishes and invertebrates, sometimes including crabs and spiny lobsters. Most are either synchronous or transforming hermaphrodites that begin life as females and later become males; a few have separate sexes. Groupers are caught in traps, on hooks and line, or on longlines, and those inhabiting soft bottom are caught in bottom trawls. They are excellent food fishes sought in commercial fisheries for domestic consumption and export markets.

Smith (1961)has found that the genera Epinephelus has representatives in the Indo-Pacific fauna. E. bleekeri occurs in tropical waters of the Indo-West Pacific from the west coast of India and Srilanka, east ward to China and Philippines. E. chlorostigma has wide spread distribution in the western Indian ocean including Red sea and the Gulf. It is also found in the Eastern Indian Ocean and the Western Central, Pacific eastward to Japan, new Carolina and Carolina Islands. It occurs over a wide range of depths (4 to 280 m) and habitats generally associated with coral reefs. E. diacanthus occurs in the Gulf of Oman and coasts of Pakistan, India and Srilanka. It occurs in depths of 2 to 50 m. The young of the year have a wider distribution than do adults (Smith, 1961).

Exploratory fishing carried out by various agencies have located several rich demersal fishing grounds. Of the demersal fishes that have figured on the exploratory fishing grounds, the most significant ones that foretell large developmental potential are the perches. They are abundant in rock bound coral areas in the south west, south east and Gulf of Mannar region. Hornell (1916) has reported the existence of good line fishing grounds off the Travancore coast. John (1948) has mentioned that the seas of Anjengo and Chavara, within the depth belt 60-70 fathoms, provide good fishing grounds for line fishing. These grounds are rich in snappers, rock hind, red perch, sharks and rays. These grounds are unsuitable for trawling since the bottom is with rocky outcrops. There is a seasonal fishery on the south west coast of India, from December to March especially from Colachal to Alleppey with handlines from indigenous canoes and catamarans for perches. The existence of 'Kalava' grounds in rocky areas off Varkala, Trivandrum, Poovar and Pulluvila has been known for decades to the fishermen of these coastal areas. Chacko and Sheriff (1949) discussed the experimental fishing with handlines on the Dory fishing principles in the Wadge Bank. In the fishing investigation by Gopinath (1954) off Travancore coasts, the largest individual landing was of E. chlorostigma. The experimental handline fishing conducted by Indo-Norwegian Project provided considerable information on the species composition of 'Kalava' occurring in the Southwest coast. Menon and Joseph (1969) have carried out a survey on the perch fishing grounds off Travancore coast and reported that 'Kalava' is found in schools only on uneven sea bottom particularly where there are rocks or coral formations. Silas (1969) has given information about the numerical abundance of the Kalava in different grounds and also about the species composition, and behaviour. Tholasilingam et al., (1973) has reported the occurrence of perches in the grounds south of Alleppey including Cape Comorin by exploratory trawl fishing. Fishery Survey of India undertook an exhaustive survey of the demersal resources of the Wadge Bank during 1981-83 deploying the vessal Matsya Nireekshani. The periodic report on the survey and the fishing charts give detailed information on the structure, composition and seasonal abundance of the fish stocks. Joseph (1986) has described the existence of perches from the Indian Exclusive Economic zone. Joseph et al., (1987) have found that, the density of the perch population in Wadge Bank as 3.37 tonnes per sq.km. Kasim et al., (1987) have described the present status of perch fishery resources in India and its prospects. Sulochanan and John (1988) have described that the concentration of perches in the areas below Lat. 8°N yielding catch per hour of 62 to 96 Kg during October-December and to 60 to 78 Kg during March-May in the 40-50 m depth zone. Premalatha (1989) has given an account on the trap fishing for rock cods of south west coast of India and recently Grace Mathew (1990) has detailed the hooks and line fishery for 'Kalava' at Cochin. Depth wise catch rates obtained in demersal trawling by FSI vessel Matsya Nireekshani in March 1993 for perch were 26.00 and 37.40 Kg/hr in the depths 0-50 m and 50-100 m respectively along the south west coast, Wadge Bank and Gulf of Mannar.

In order to obtain optimal and economic production, it is necessary to have a complete knowledge of the biology, behaviour, stock positions, seasonal and spatial distribution and abundance of this group which are at present either scanty or incomplete. All the available informations on the biology of Epinephelid fishes are mostly on foreign species.

Some of the earlier works on the systematics of Epinephelus were by Smith (1961) and Rivas on the species from Western Atlantic. Smith

(1971) revised the American groupers - Epinephelus and allied genera and Randall and Ben-Tuvia (1983) gave the systematics on the groupers (Epinepheline) of the red sea.

Bardach and Menzel (1957) have studied the growth of common grouper species in Bermuda. Indications of growth were also obtained by Randall (1962, 1963) in the Virgin Islands and by Beaumariage (1969) in Florida, during the course of tagging experiments. Moe (1969) determined the age of E. morio from the eastern Gulf of Mexico and found that the annulus formation coincides with the end of the spawning season and warming of summer water temperatures. Burnett-Herkes (1975) used the length-frequency distributions to estimate the age and growth of E. guttatus from the tropical western Atlantic. Length-frequency study conducted by Menon et al., (1977) have shown that the size of E. chlorostigma was found to vary from 34 cm to 65 cm. But fishes of the size ranging from 45 cm to 60 cm were more predominant in the catches through out the period. The size of E. diacanthus ranged from 30 to 55 cm in which 40 cm to 50 cm size groups were more common. Chen et al., (1980) reported the connection between reproductive cycle and ring formation in E. diacanthus in the waters of Northern Taiwan. Calliart and Moriz (1989) demonstrated that a validation of the periodicity of the incremental pattern is absolutely necessary prior to aging adult fish using otolith microstructure of E. microdon (Bleeker) with a fluorescent marker, oxytetracycline. Sadovy et al., (1992) studied the age and growth of red hind, E. guttatus in Puerto Rico and St. Thomas. Luckhurst (1992) commented on the age of an unusually large red hind, E. guttatus from Bermuda.

Hussain and Abdullah (1977) described the length-weight relationship of six commercial fishes including one Epinephelid in Kuwaiti waters. The relationships between total length and standard length, maximum body depth and weight were established for the most abundant species of caribbean groupers by Thompsun and Munro (1983). Baddar (1982) has studied the length-weight relationship of hamoor, E. tauvina.

The groupers are unspecialised carnivores feeding mainly on fishes and crustaceans. They feed both by day and night, but according to Randall (1967) they are more active at dawn and at dusk. Generally the food is engulfed whole (Bardach et al., 1958). Beebe and Tee Van (1928) commented on the food of E. striatus. Randall (1960) detailed the food habits and habitats of Epinepheline and Lutjanid fishes of Society Islands. Menzel (1960) described the food of E. guttatus from Bermuda, and Randall (1965) studied the food habits of E. striatus from Virgin Islands and Puerto Rico waters. Randall (1967) mentioned the food of five species of Epinephelus from West Indies. Moe (1969) commented on the food and feeding habits of E. morio from the Gulf of Mexico and Burnett-Herkes (1975) on the food and feeding habits of E. guttatus from the tropical Western Atlantic. Thompsun and Munro (1978, 1983) described the food habits of hinds and groupers from the Caribbean reefs. Very little information is available from the Indian waters on the food and feeding habits of groupers. Attempts were made by Job (1940) on the nutrition of perches of Madras coast and Prabhu (1954) on the food habits of perches caught in traps of Gulf of Mannar and Palkbay. Silas (1969) mentioned about the food of Kalava in the exploratory fishing by Varuna. Premalatha (1989) commented on the food of rock cods from the south west coast of India.

Protogynous hermaphrodotism is known to occur in several species of groupers (Lavenda, 1949; Smith, 1959, 1961; Moe, 1969; Clark, 1958; Atz, 1964; Mc Erlean and Smith, 1965; Bruslé and Bruslé, 1975; Bouain and Siau, 1980; Shapiro, 1987 and Webb and Kingsford, 1992). The histological changes in the gonad during the process of sex change has been studied in detail for a number of groupers (Bruslé and Bruslé, 1975; Moe, 1969). A perusal of the literature reveals that the relationship between the sex change and age composition is still not yet well understood due to the difficulties in determining age. A broad overlap of the length distribution of the sexes is encountered in most species suggesting that there is no close correlation of age or size with sexual transition. Moe (1969) found that in E. morio all fish do not transform into males and that the size of most of the transforming fish ranges from 480 to 650 mm SL. He further reported that the sex transformation in fish is more closely related with oogenetic and spawning activity than with age or growth of the individual. Evidence of the protogynous condition in different species of Epinephelus has been described by Smith (1959). No males were found in smaller size groups even when gonads were examined histologically and in the case of mature fish, the proportion of males increased with increasing size. Burslé and Burslé (1975) found in E. aeneus and E. gauza that, all young fishes were females and males occur among the largest individuals after a sex reversal. Chen et al., (1980) have described that sex changes occurred during the 'non-reproductive' period from age 2^+ to 6^+ but mainly between ages 2^+ and 3^+.

Little information is available on the actual mating process in groupers. Ukawa et al., (1966) described the spawning behaviour of E. akaara (Temminck and Schlegel) as the interaction between a single male and female. There is no coupling during spawning of groupers and fertilization is external. Under natural conditions, in the caribbean, at Bermuda and Bahamas, groupers apparently aggregate during the spawning season (Thomsun and Munro, 1983). Spawning aggregations of E. guttatus and E. striatus have been described by Colin et al., (1987). Colin (1992) also described the spawning aggregations of Nassu grouper, E. guttatus at the South Long Island. Shapiro et al., (1993) described the size, composition and spatial structure of annual spawning aggregations of the red hind E. guttatus. Erdman (1956) reported that E. guttatus spawn in January. Bardach et al., (1958) have noted that the spawning season of most species in Bermuda extends from late April to late August. Moe (1969) has reported that E. morio spawned in Gulf of Mexico from March to July with peak spawning activity in April and May. Randall and Brock (1960) found that peak spawning activity of certain Indo-Pacific species occurred a few days before full moon. Ukawa et al., (1966) have noted that E. akaara always spawned between 1530 and 1630 hr in culture ponds. E. diacanthus has spawned during April and May in Taiwan (Chen et al., 1980). Bouain and Siau (1983) found that E. aenus, E. guaza and E. alexandrinus have the same ripening scheme in the south east Tunisian waters. Vadiya (1984) reported that the spawning season of E. aenus is from June to September and that of E. alexandrinus from May to August. Spawning period of E. tauvina in Kuwaiti waters is from April to May and is associated with increasing water temperature and relatively low salinity as reported by Abu-Hakima (1987). In E. guttatus December and January are the spawning seasons at the South Long Island (Colin, 1992).

Chen et al.,(1980) found the fecundity of E. diacanthus to range from 63 x 10^3 to 233 x 10^3. Vadiya (1984) has reported that the relative fecundity increases with length and weight in E. aenus, while it decreases with increasing size in E. alexandrinus. According to Abu-Hakima (1987) the fecundity estimate for E. tauvina of length 35.1-62.3 cm, ranged from 8502 to 2904921.

The eggs of E. morio were described by Moe (1969) as being less than 1 mm in diameter, containing an oil droplet and with no filaments or other appendages. Ukawa et al., (1966) described the eggs of E. akaara as pelagic, spherical in shape and measuring 0.70 to 0.77 mm in diameter. Thompsun and Munro (1983) found that egg diameters of E. guttatus vary between 0.70 mm and 0.90 mm. Colin et al., (1987) have reported the egg diameter of E. guttatus and E. striatus as 0.97 and 0.96 mm respectively.

Ukawa et al.,(1966) described the early life history of E. akaara in the western Pacific. Presely (1970) described 16 larval specimens of E. niveatus which were collected in the Florida straits. Moe (1969) found that juvenile red groupers occur in less abundance over rocky bottom in the Gulf of Mexico, upto a depth of 20 fathoms. The vital population parameters of Epinephelus are not estimated from Indian waters. However few scattered literature on the subject are available from abroad. Blanco et al., (1980) have assessed the resource potential of E. morio from the Campeche's Bank area applying yield-per-recruit model. Matheson and Huntsman (1984) studied the growth, mortality and yield-per-recruit models for speckled hind, E. drummondhayi and snowy grouper, E. niveatus from the United States South Atlantic Bight. Moore and Labsiky (1984) have studied the population parameters of E. niveatus in the lower Florida keys. The status of the red hind fishery in Puerto Rico and St. Thomas was described by Sadovy and Figuerola (1992). Sadovy (1993) has studied the spawning stock biomass per recruit of E. guttatus from Puerto Rico. Sadovy (1993) has also reported the grouper stocks of the western central Atlantic.

Very few references were available regarding the parasites of Epinephelus. Some of the earlier works were by Linton (1908) and Reese (1969, 1970). Linton (1908) reported Distomum levenseni, a digenetic trematode and cestode, Rhynchobothrium sp. from E. striatus, an acanthocephalan worm, Echinorhynchus (=Gorgorhynchus) medius and a cestode, Scolex polymorphus from E. maculosus. Kirtisinghe (1934) described a copepod, Lernaeenicus ramosus from E. morrhua caught in Ceylon waters. Nahas and Cable (1964)found a single trematode,Postprous epinepheli in the in testis of E. guttatus in Curacao. Krishna Pillai and Sebastian(1967) reported an anthostomid copepod, Sagum epinepheli from the gills of Epinephelus sp. off Calicut. Yamaguti and Yamasu (1960) also described the same parasite from the gills of E. akaara from Japan. Reese (1969) and Burnett-Herkes (1975) found pleurocoid larvae of Callitetrarhynchus gracilis(Rudolphi) from E. guttatus. Hochberg and Ellis (1972) reported E. guttatus to be infested with the cymathoid isopod, Anilocra laticauda at St. John, Virgin Island. Burnett-Herkes (1975) observed the same isopod parasite on the gill arch, cheek, and inter orbital area of E. guttatus. Thompsun and Munro (1974) reported the presence of larval tape worms in a variety of groupers. Linton (1908) and Thompsun and Munro (1974) reported the infection of red hind gonads with nematodes. Burnett-Herkes (1975) observed Philometra sp. from E. guttatus in Bermuda.

Groupers are suitable for culture in net cages as well as in ponds receiving a tidal flow of seawater. Successful culture practices have been undertaken by different south east asian countries like, Philippines, Taiwan and Malaysia. Teng and Chua (1979) used artificial hides like used car tyres to increase the stocking density and production of estuary grouper E. salmoides reared in floating net cages in Malaysia. Hussain and Higuchi (1980) could rear the larvae of E. tauvina obtained by the natural spawning of the fish in captivity. The larvae were reared to metamorphosis using rotifers, artemia nauplii, copepods and minced shrimp meat as food. Chua and Teng (1980) described the economic production of estuary grouper, E. salmoides, reared in floating net cages. Under such efficient management procedures there is every possibility of developing grouper culture on a commercial scale in India also. An experimental culture of E. tauvina in a netcage, conducted at Mandapam realised a net income of Rs. 2,193/- in 11 months period .

For technologically and economically viable culture practice, selection of the candidate species is equally or more important than any of the environmental factors and culture system management. In order to achieve the maximum production from a well managed culture system it is highly imperative to nave deep knowledge on the biology, behaviour and physiological requirements of the species cultured. The present work attempts to bring out all the important biological aspects such as age and growth, food and feeding, reproductive biology, racial studies parasites stock and fishery of the three commonly occurring Epihephelinae such as Epinephelus diacanthus, E. chlorostigma and E. bleekeri from south west coast of India.

CHAPTER 2

AGE AND GROWTH

2.1. INTRODUCTION

Age and growth studies are important for population dynamics research, fishery forecasts, fish culture in natural habitats, acclimatization, racial studies and rational commercial exploitation. In order to provide biological information relevant to mariculture, detailed knowledge on the growth of the candidate species, their seasons of maximum growth, age at marketable size, age at maturation and spawning and fecundity in relation with age is highly essential. The age and growth studies of fishes was first proposed by Peterson in 1895 who evolved a method for determining The age of fish from length-frequency curves.

Both direct and indirect methods are used to determine the age of fish. In the direct method, the fish is reared in aquaria or other enclosed or semienclosed habitats or they are tagged and released back into the sea, after noting down the length at the time of release and again after recapture. The indirect method is accomplished in two ways which are used as counterchecks to each other. These are (a) Peterson's or the size frequency distribution method and (b) growth checks in skeletal hard parts like, otolith, scale, operculum and vertebra from which the lengths at ages are back-calculated. The growth is estimated theoretically by using von-Bertalanffy growth equation. The direct method of rearing fish in enclosures for age determination is usually difficult for marine fishes, due to several reasons like (1) non availability of the seeds or young ones,

(2) transportation hazards (3) lack of an elaborate infrastructure facility for continuous sea water supply and maintainance in aquarium tanks etc. Therefore the more frequently used indirect methods are used in the present study.

The use of skeletal hard parts has become an accepted procedure for the determination of the age of many fishes. Chugunov (1926, 1963) and Van Oosten (1929) have reviewed the literature on age determination of fishes by scales and other skeletal structures and have dealt with the assumptions and the validity of different methods. Menon (1950) reviewed the literature concerning the determination of age and growth of fishes by using various bones, other than otoliths and scales. The works of other authors are also of great importance on this subject.

Hiyama and Ichikawa (1952) injected fishes with lead acetate to mark the time in the scale and other hard tissues of fishes to see their growth. They combined this method with the tagging experiment to see the natural growth. Marzolf (1955) used pectoral spines and vertebrae for determining age and rate of growth of channel cat fish. Calstrom (1963) made a study on a microscopic and X-ray crystallographic analysis of otoliths from a representative collection of vertebrates. McEarlean (1963) used otoliths to determine age of Mycteroperca mircolepis. Bilton and Jenkinson (1967) used the otolith and scale methods for aging sock eye (Onchorhynchus nerka) and (O. keta) Salmon.

Moe (1969) used otoliths for aging the red grouper, Epinephelus morio. Hile (1970) reviewed the body scale relation and calculation of growth in fishes. Pannella (1971) has described about the daily growth layers and periodic patterns in fish otoliths. The seasonal pattern of otolith growth and its application to back-calculation studies in Ammodytes tobianus L. has been described by Reay (1972). In this fish, he found that during the period of opaque zone depositions, body growth is at a maximum and this is followed by a period of slower growth coinciding with hyaline zone formation in the otolith. As a result, the ratio of otolith length to fish length shows sharp decrease in spring, followed by an increase during summer to a more stable level. Thompsun and Munro (1974) analysed modal progressions of length-frequency distributions of Epinephelus guttatus, E. fulves and E. cruentatus from Jamaica. Burnett-Herkes (1975) studied age and growth based on length-frequency distributions and also based on otoliths.

Brothers et al., (1976) studied daily growth increments in otoliths from larval and adult fishes of anchovies, California grunion, gobies, striped bass, hakes, etc. Mercer (1978) aged Centropristis striatus using otoliths. Johnson (1979) proved that stained vertebrae are best for aging teleost fishes. Berger and Williams (1980) have summarized age and growth of spot, Leiostomus xanthurus Lacepede; and sand seatrout Cynoscion nothus (Holbrook) based on a literature review.

Nekrasov (1979) discussed the factors affecting annulus formation on the recording structures in the tropical fishes. It has shown that annulus formation occurs once a year in tropical fishes, especially Trachurus indicus and Nemipterus virgatus and is connected with spawning. For fishes in temperate and high latitudes, the ring formation is connected with the changing seasons, and it is clear that the annulus forms once a year; whereas the causes of annulus formation remain unclarified for tropical species, living under conditions in which there are no marked fluctuations in water temperature, in the hours of daylight, the food resources etc., although such clarification is very important for determination of their age. Age and growth of the grouper, Epinephelus diacanthus, in waters of northern Taiwan using scales has been described by Chen et al., (1980), Nielson and Gean (1981) aged juveniles of Salmon, Onchorhynchus tschawytscha using otolith mircostructures. Beamish and Fournier (1981) used an index of average percent error to compare the precision of a set of age determinations. Wilson and Larkin (1982) studied the relationship between thickness of daily growth increments in sagittae and change in body weight of sock eye salmon (Onchorhynchus nerka) fry. Campana and Neilson (1982) studied the daily growth increments in otoliths of starry flounder, Platichthys stellatus and the influence of some environmental variables in their production by injecting tetracycline. Gjøsaeter et al., (1984) reviewed the information on primary growth rings in otoliths, and the methods used to prepare them for counting and their use in aging fish. Johnson and Saloman (1984) estimated age, growth and mortality of gray trigger fish, Balistes capriscus from the north eastern Gulf of Mexico.

Johnson (1984) compared the dorsal spine and vertebrae as aging structures for little tunney, Euthynnus alletteratus from the north east Gulf of Mexico. Ralston (1985) introduced a novel approach to aging tropical fish. In his method, the otolith is subdivided into regions which are small enough so that the growth of the otolith can be considered constant within a subregion. He found that, growth rate of the otolith declines as the size of the otolith increases. Caillart (1989) used a fluorescent marker, oxytetracycline to study the frequency of increment formation on the otoliths of a tropical serranidae, Epinephelus microdon.

Francis (1990) reviewed literature concerning the calculation of fish lengths at successive ages from marks on scales, otoliths etc. Barger (1990) used the skeletal hard parts like vertebrae, scales and otoliths to determine the age and growth of Blue fish Pomatomus saltatrix from the Northern Gulf of Mexico and U.S. South Atlantic Coast. Campana (1990) discussed in detail about the reliability of growth back-calculations based on otoliths. Martin and Cook (1990) used a combined age-length analysis which fits a statistical model to both the age and length data. Panfili and Ximenes (1992) discussed about the possibilities of bias by measuring the ground or sectioned otoliths. Sadovy et al., (1992) used sectioned otoliths to age the red hind, Epinephelus guttatus. Luckhurst (1992) commented on the age of an unusually large red hind, Epinephelus guttatus from Bermuda using sectioned otolith. Ricker (1992) described about the back-calculation of fish lengths based on proportionality between scale and length increments.

Since there is definite periodicity in the seasons of the temperate region, the growth rings or checks are more or less clear and easy to interpret. Similar growth checks have been noticed in the hard skeletal parts of tropical and subtropical fishes also and among the references on the subject are the works of Seshappa and Bhimachar (1954), Jhingran (1957), Kasim (1973) etc.

The primary purpose of this study was to evaluate and use the best of several bony structures to estimate the age and to determine growth of Epinephelus diacanthus, E. chlorostigma and E. bleekeri from the south west coast of India.

2.2 MATERIALS AND METHODS

The samples included E. diacanthus, E. chlorostigma and E. bleekeri. Small fishes of E. diacanthus were obtained from trawl catches and larger ones from hook and line catches off Cochin. The samples of E. chlorostigma and E. bleekeri were constituted only by larger ones from hook and line catches off Cochin. All the fish were weighed and measured, weights were taken to the nearest gram. Standard length was measured in millimeter from the tip of the lower jaw to the base of the caudal rays. Otoliths, scales and vertebrae were removed from the fresh fish for age analysis.

1. **Otoliths:** (Pl. IV - VII)

The labyrinth containing the sagittae is located in the otic capsules at the base of the cranium. A thin envelope of connective secretory and sensory tissue, the sacculus, contains the sagitta and is usually removed from the labyrinth with the otolith. The sacculus produces the sagitta in a shape characteristics of the species.

Otoliths were removed by cutting through the otic capsules at the base of the cranium with the help of a bone cutter. Of the three pairs of otoliths, only sagittae, the largest, were used for aging the fish. Otoliths were washed, dried and stored in envelops. Otoliths were kept in glycerine for a week for clearing before counting the number of opaque rings. Otoliths of groupers are translucent and display readily discerneable growth checks under reflected light and hence sectioning, grinding and mounting were not necessary.

The sagitta is thin, elliptical and concave and is a mirror image of its mate. Little variation in form or size was noted between members of a pair. The convex surface of each sagitta is oriented in situ toward the central axis of the fish and bears a deep groove the Sulcus acousticus. This groove appears as an opaque scar and a marginal notch on the concave side. The focus at the centre of the sagitta is a tiny translucent area surrounded by a dense white ring. This central translucent area has a tendency to become opaque as the otolith thickens with age. Narrow opaque zones and broad translucent zones radiate outward from the central core area. The region in which outer margin of translucent zone and inner margin of opaque zone is taken as annuli. (Plate IIIa).

Otoliths were immersed in glycerine and measurements were taken using an ocular micrometer. Measurements were made on the left sagitta using an ocular micrometer at a magnification of 20X. At this magnification one ocular micrometer equals 0.0425 mm. If the left otolith was broken, measurements were made on the right otolith. Measurements were taken from the focus, the center of the central opaque zone, to the outside margin of the dorsal edge projection. This constituted the otolith radius (OR). Measurements were made to each annulus along this line for back calculation of lengths. The distance from the last annulus to the ventral margin (marginal increment) was measured to determine the time of the annulus formation. Each otolith was examined thrice at different times and an accurate count was taken for the analysis of growth characteristics. The Lee method (Carlander, 1981) of back calculating body length from prior annuli was used.

$$L_i = a + [(L_c - a)(O_i/OR)]$$

Where, L_i = Length at the time of annulus formation

a = Intercept

L_c = Length at the time of capture (SL)

O_i = Otolith radius at the time of i^{th} annulus formation

OR = Otolith radius at the time of capture

This method requires knowledge of the relationship between OR along the line of measurement and SL. The constant, a is obtained from this relationship and used in Lee's formula.

In order to study the consistency of the number of rings on the left and right sagittae, a few materials were examined and found that the number of rings perfectly coincided in both the sagittae of a fish.

Four hundred and forty five pairs of otoliths of E. diacanthus, 59 pairs of otoliths of E. chlorostigma and 38 pairs of otoliths of E. bleekeri were studied during this two year period.

2. **Scales:** (Pl. VIII)

Scales were removed from the left side of the body, near the pectoral fin region, bounded by the 6-9th dorsal spines and the 15-20th scale lines below lateral line. Scales were stained with Alizarin Red-S and mounted on slides with glycerine. The annual rings were distinguished from regular bony ridges (circuli) in two ways as recommended by Chen et al., (1980) (1) the annual ring has a discontinuous ridge (cutting over) in the scale's lateral field and also shows compact ridges in the scale's anterior field (2) when stained with Alizarin Red-S, the annual ring becomes a red line which shows bright red colour when observed under a transmitted light. The annual rings are considered to be at the outer border of this red line. A false ring may be present when two red lines lie very close to each other. False rings were usually discontinuous and are recorded infrequently. Such scales were not included in the study.

The scale radius (SR) was measured from the centre of the scale's focus to its outer margin using an ocular micrometer at a magnification of 40 X. (Plate IIIb). At this magnification, one ocular minometer unit equals 0.0446 mm. Measurements were also made to each annulus for black-calculation of lengths at age following Lee's method.

3. Vertebrae (Pl. IX - XI)

A portion of the vertebral column immediately following the cranium was removed from fresh fish with the help of a bone cutter, taking care to include the 5th vertebra for the study. This portion of the vertebral column is immersed in boiling water for a few seconds, so as to remove adhering musculature. The 5th vertebra is separated from the vertebral column and it is kept in ether to remove the adhering fat. The fifth vertebra of each specimen was examined under reflected light which makes the narrow transparent zones appear black and the broad opaque zones appear white. True annual rings were distinct, complete and often accompanied by a change in elevation of the surface of the centrum. The vertebra was cleaved lengthwise in the dorsoventral direction. Vertebral radius (VR) was measured as the distance from the centrum to the outer margin of the vertebra and measurements were made to each annulus along this line for the back calculation of lengths, using an ocular micrometer at a magnification of 20X.(Plate III c). At this magnification, one OMD equals 0.0425 mm.

2.3. RESULTS

Van Oosten (1929) established the following criteria that must be met before check marks on scales or bones can be considered annulii- (1) scales or bones must remain constant in number and identity throughout the life of the fish (2) growth of the scale or bone must be proportional to the overall growth of the fish. (3) growth check marks must be formed at approximately the same time each year and (4) back-calculated lengths should agree with empirical lengths of younger age groups.

1. The relationship between the standard length and radius of skeletal hard parts.

Regression of standard length on otolith radius, scale radius and vertebra radius revealed linear relationship for E. diacanthus, E. chlorostigma and E. bleekeri.

E. diacanthus

The regression equation of standard length on otolith radius for E. diacanthus, is SL = 48.71 + 67.5856 OR (r = 0.9971) based on a sample size of 431 fish ranging from 53 to 430 mm standard length (Figure 1a).

The regression equation of standard length on scale radius for E. diacanthus is SL = 41.0862 + 91.7026 SR (r = 0.9966) based on a sample size of 353 fish ranging from 65 to 431 mm standard length (Figure 1b).

The regression equation of standard length on vertebra radius is SL = -63.5091 + 71.6502 VR (r = 0.9789) based on a sample size of 436 fish ranging from 63 to 476 mm standard length (Figure 1c).

E. chlorostigma

Regression analysis of standard length on otolith radius of E. chlorostigma involved 67 specimens ranging from 154 to 457 mm Standard Length and yielded the following relationship (Figure 2 a).

Fig. 1 . THE RELATIONSHIP OF STANDARD LENGTH WITH (a) OTOLITH RADIUS (b) SCALE RADIUS AND (c) VERTEBRA RADIUS OF *E. DIACANTHUS*

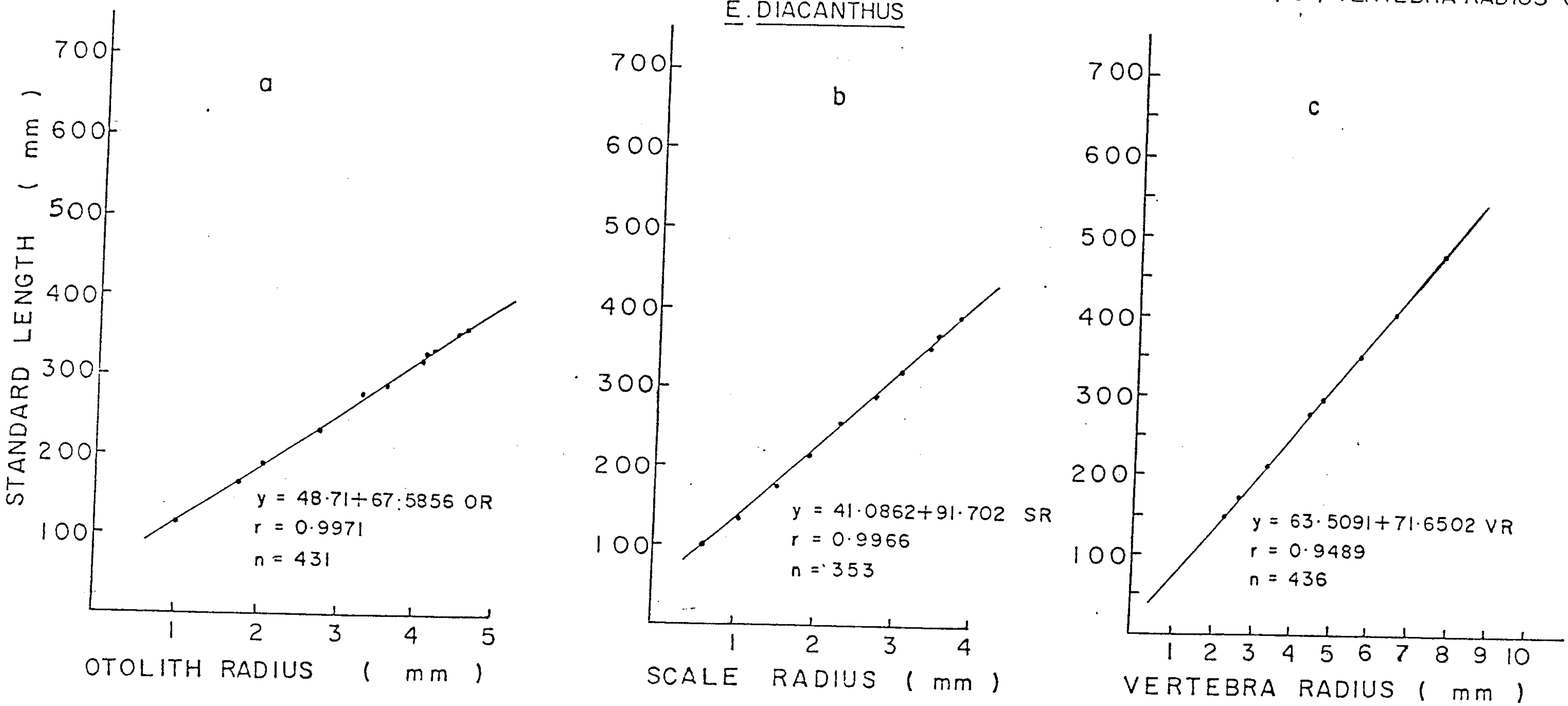
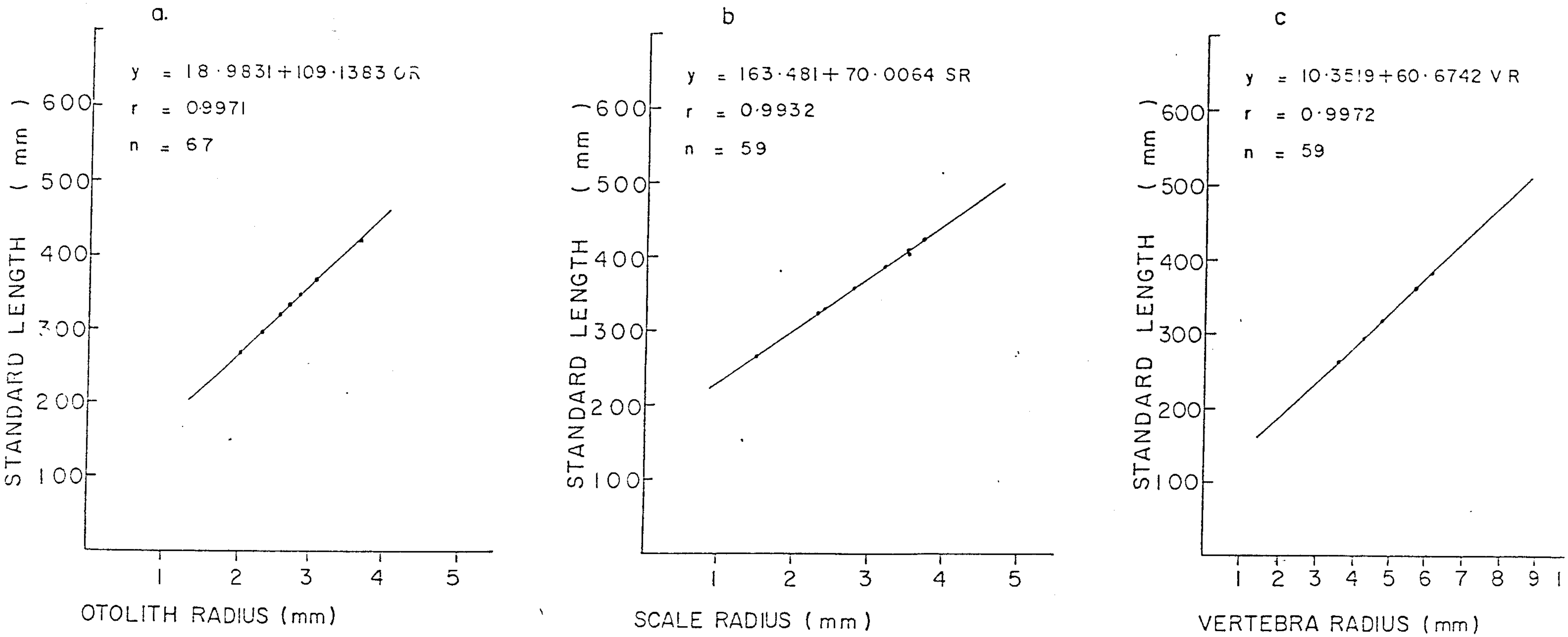


Fig. 2. THE RELATIONSHIP OF STANDARD LENGTH WITH (a) OTOLITH RADIUS (b) SCALE RADIUS AND (c) VERTEBRA RADIUS OF *E. CHLOROSTIGMA*



SL = 18.9831 + 109.1383 OR (r = 0.9971)

Regression equation of standard length on scale radius for *E. chlorostigma* is SL = 163.48 + 70.0064 SR (r = 0.9932) based on a sample size of 58 fish ranging from 154 to 457 mm standard length (Figure 2b).

Regression equation of standard length on vertebra radius is SL = 10.3519 + 60.6742 VR (r = 0.9972) based on a sample size of 59 fish ranging from 154 to 457mm standard length (Figure 2c).

E. bleekeri:

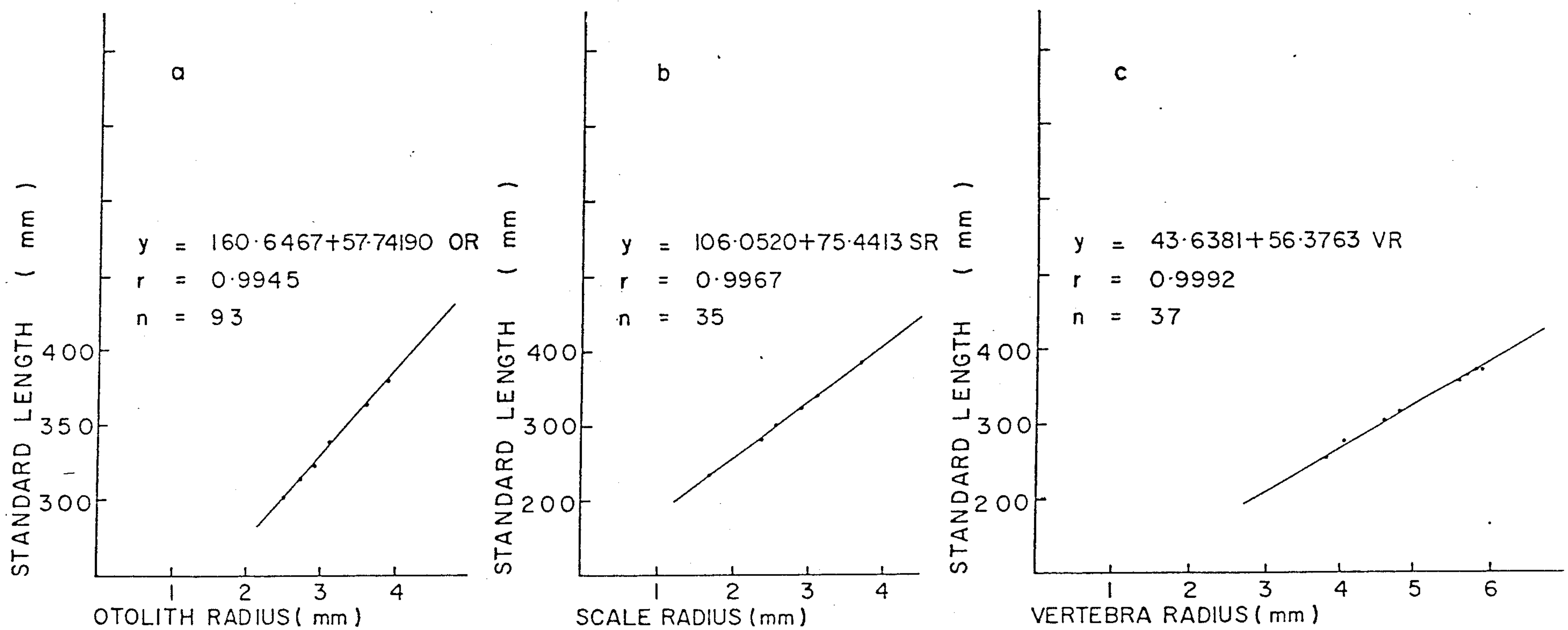
Regression equation of standard length on otolith radius is SL = 160.6467 + 57.7469 OR (r = 0.9945) based on a sample size of 33 fish ranging from 215 to 448mm standard length (Figure 3a).

Regression equation of standard length on scale radius is SL = 10.0520 + 75.4413 SR (r =0.9967) based on a sample size of 35 fish ranging from 215 to 448mm standard length (Figure 3b).

Regression equation of standard length on vertebra radius is SL = 43.6381 + 56.2763 VR (r = 0.9992) based on a sample size of 37 fish ranging from 215 to 448mm standard length (Figure 3c).

Regression analyses on skeltal hard parts revealed that their growth is proportional to the growth of the fish, fulfilling Van Oosten's Second criterian.

Fig. 3. THE RELATIONSHIP OF STANDARD LENGTH WITH (a) OTOLITH RADIUS (b) SCALE RADIUS AND (c) VERTEBRA RADIUS OF *E. BLEEKERI*



2. Marginal increment analysis

Monthly mean marginal increment analysis (from otoliths) of E. diacanthus plotted separately for age groups 1 through V (Figure 4). If one growth mark is formed at a particular time each year, the mean marginal increment should drop to near zero at the time of annulus formation. In E. diacanthus this occurs from March through July, coinciding with the onset of reproductive activity, thus fulfilling Van Oosten's third criterion.

Monthly marginal increment analysis could not be plotted for E. chlorostigma and E. bleekeri with the limited number of samples.

3. Back-calculated standard lengths from skeletal hard parts:

Results of back-calculation of standard lengths using otoliths, scales and vertebrae of E. diacanthus, E. chlorostigma and E. bleekeri are presented in the tables 1-9.

Back-calculated standard lengths of E. diacanthus

The mean back-calculated lengths for the first eight years of life of E. diacanthus using otoliths were 92, 135, 176, 206, 244, 278, 310 and 339 mm respectively (Table-1). The mean back calculated lengths for the first eight years of life, derived from scales were 93, 131, 168, 210, 246, 278, 310 and 339 mm respectively (Table-2). The mean back-calculated lengths for the first eight years of life derived from vertebrae were 96, 137, 172, 204, 238, 270, 286 and 313 mm respectively (Table-3).

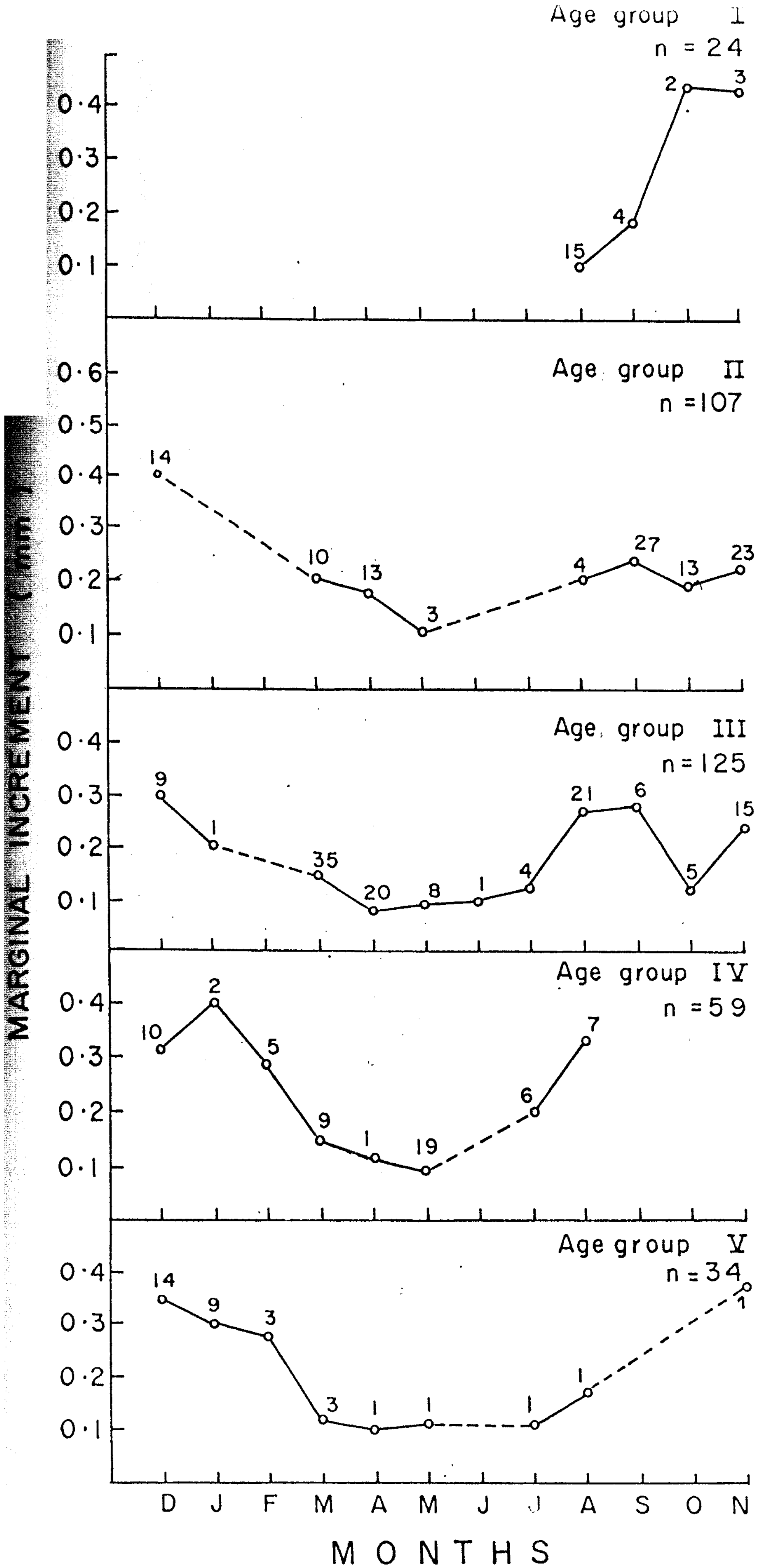

Age group I
n = 24
Age group II
n = 107
Age group III
n = 125
Age group IV
n = 59
Age group V
n = 34
MARGINAL INCREMENT (mm)
D J F M A M J J A S O N
MONTHS

TABLE-1. **Back-calculated standard lengths (mm) from otoliths of *E. diacanthus***

Age Group	N	Mean total length at capture(mm)	Mean Standard length at caputre (mm)	1	2	3	4	5	6	7	8
1	37	105	81	75							
2	104	161	134	86	120						
3	127	197	158	84	114	143					
4	59	252	204	90	128	166	185				
5	34	320	280	106	147	189	224	262			
6	16	344	285	100	142	179	184	209	268		
7	14	361	328	98	148	188	212	252	283	308	
8	15	392	355	109	144	188	223	244	278	310	339
Mean back-calculated lengths				92	135	176	206	244	278	310	339
Growth increments					43	41	30	38	34	32	29
Number of fish				406	369	265	138	79	45	29	15

TABLE-2. **Back-calculated standard lengths (mm) from scales of *E. diacanthus***

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7	8
1	21	122	99	89							
2	89	168	137	90	123						
3	86	206	170	94	126	152					
4	48	274	115	99	133	171	208				
5	30	331	275	93	137	180	214	253			
6	30	367	306	92	134	172	214	251	285		
7	23	400	334	91	132	169	211	243	280	318	
8	25	409	343	92	131	166	204	235	270	301	328
Mean back-calculated lengths				93	131	168	210	246	278	310	328
Growth increments					38	37	42	36	32	32	18
Number of fish				342	321	232	146	98	68	38	15

TABLE-3. **Back-calculated standard lengths (mm) from vertebrae of *E. diacanthus***

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7	8
1	38	108	88	78							
2	101	165	135	88	121						
3	126	200	165	94	127	155					
4	53	251	205	96	131	165	193				
5	32	312	268	100	152	180	199	229			
6	17	360	299	101	145	182	221	257	289		
7	16	369	307	107	144	173	202	231	258	282	
8	11	388	322	100	140	175	207	235	262	289	313
Mean back-calculated lengths				96	137	172	204	238	270	286	313
Growth increments					41	35	32	34	32	16	27
Number of fish				394	356	255	129	76	44	27	11

There is reasonable agreement between the back-calculated standard lengths at ages derived from the different skeletal hard parts. Mean standard lengths at capture for each age group is greater than the average calculated length. Burnett-Herkes (1978) says that this discrepency is as a result of growth between the time the last ring is formed and the time the fish was captured.

Back-calculated standard lengths of E. chlorostigma

The mean back-calculated lengths derived from otolith radius of E. chlorostigma for the first seven years of life were, 153, 197, 237, 266, 295, 331 and 339 mm respectively (Table-4).

The mean back calculated lengths derived from scale radius of E. chlorostigma ages 1 to 7 years of life were 145, 183, 213, 238, 255, 289 and 307mm respectively (Table-5).

The mean back calculated lengths derived from vertebra radius of E. chlorostigma for the first seven years of life were 158, 192, 221, 247, 268, 305 and 318mm respectively (Table-6).

In the case of E. chlorostigma also the mean standard lengths at capture is greater than the mean back-calculated standard lengths.

Back-calculated standard lengths of E. bleekeri

The mean back calculated lengths derived from otolith radius of E. bleekeri for ages 1 to 7 years of life are 192, 232, 263, 288, 310, 330 and 352 mm respectively (Table-7).

TABLE-4. **Back-calculated standard lengths (mm) from otoliths of *E. chlorostigma***

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7
2	2	272	223	158	204					
3	16	312	282	161	211	255				
4	13	336	284	145	195	242	266			
5	14	360	292	147	190	225	251	275		
6	34	431	356	153	198	238	283	315	340	
7	6	439	358	151	185	226	263	294	321	339
Mean back-calculated lengths				153	197	237	266	295	331	339
Growth increments					44	40	29	29	36	8
Number of fish					55	53	37	24	10	6

TABLE-5. **Back-calculated standard lengths (mm) from scales of *E. chlorostigma***

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7
2	2	272	223	154	201					
3	9	303	260	164	205	237				
4	15	337	279	144	191	225	259			
5	11	340	284	141	178	209	240	253		
6	10	362	299	134	157	200	227	255	283	
7	9	406	326	134	165	196	227	258	286	307
Mean back-calculated lengths				145	183	213	238	255	289	307
Growth increments					38	30	25	17	34	18
Number of fish					56	54	45	30	19	9

TABLE - 6. **Back-calculated standard lengths (mm) from Vertebrae of *E. chlorostigma***

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7
3	13	301	249	157	194	226				
4	16	332	275	164	204	235	259			
5	9	319	261	150	178	204	227	250		
6	5	401	330	161	194	220	255	281	309	
7	7	398	327	156	190	218	248	274	302	318
Mean back-calculated lengths				158	192	221	247	268	305	318
Growth increments					34	29	26	21	37	13
Number of fish						50	37	21	12	7

TABLE-7. **Back-calculated standard lengths (mm) from otoliths of E. [redacted]**

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7	8	9
3	5	347	287	197	240	270						
4	12	380	315	189	238	269	297					
5	7	381	317	189	228	260	286	304				
6	3	389	320	203	240	263	283	300	313			
7	4	478	400	207	248	295	332	366	393	420		
8	1	409	337	172	205	227	249	271	282	293	326	
9	1	455	383	186	222	254	279	311	331	344	357	370
Mean back-calculated lengths				192	232	263	288	310	330	352	342	370
Growth increments					40	31	25	22	20	22	-10	28
Number of fish					33	28	16	9	6	2	1	

The mean back calculated lengths derived from scale of radius of E. bleekeri for the first seven years of life were 149, 189, 220, 249, 271, 300, and 313 mm respectively. (Table - 8)

The mean back calculated lengths derived from vertebra radius of E. bleekeri for the first seven years of life were 112, 164, 201, 240, 273, 297 and 323 mm respectively. (Table - 9)

The mean standard lengths at capture were greater than the mean back calculated standard lengths in the case of E. bleekeri also.

4. Theoretical growth

The von-Bertalanffy growth equation (Ricker, 1975) was fitted to growth data developed from otolith radius for E. diacanthus, E. chlorostigma and E. bleekeri. The equation describes the linear relation between length at time 't' and length at time t_{+1} .

In this equation, $L_t = L_\infty (1-e^{-k(t-to)})$,

L_t	=	Length at age t
L	=	Maximum size towards which the length of the fish in tending
e	=	base of the naparian logarithm
K	=	Brody growth coefficient, a measure of the rate at which length approaches L_∞
t	=	age of the fish
to	=	a parameter indicating the hypothetical time at which the fish would have been zero size if it had always grown according to the above equation.

TABLE -8. **Back-calculated standard lengths (mm) from scales of *E. bleekeri***

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7	8	9
2	1	306	255	172	233							
3	3	342	284	157	205	249						
4	7	394	329	172	210	257	299					
5	5	338	280	135	176	207	238	266				
6	9	360	347	142	184	222	260	301	332			
7	5	386	319	137	165	196	226	257	282	307		
8	2	417	349	133	168	201	234	266	290	313	334	
9	3	457	382	138	179	210	238	265	296	320	341	365
Mean back-calculated lengths				148	189	220	249	271	300	313	338	365
Growth increments					41	31	29	22	29	13	25	27
Number of fish					35	34	31	24	19	10	5	3

Age Group	N	Mean total length at capture(mm)	Mean standard length at caputre (mm)	1	2	3	4	5	6	7	8	9
2	2	315	262	149	235							
3	5	316	270	106	161	238						
4	7	376	312	101	157	212	270					
5	6	368	304	109	153	190	232	277				
6	8	378	314	111	153	191	226	258	293			
7	3	423	354	113	163	205	237	274	288	320		
8	2	464	385	107	146	208	256	308	328	349	364	
9	3	423	351	97	141	163	218	247	277	299	321	341
Mean back-calculated . lengths				112	164	201	240	273	297	323	343	341
Growth increments					52	37	39	33	24	26	20	-2
Number of fish					37	33	29	22	16	8	5	3

L_∞ and K can be estimated from the Walford plot, but a more accurate value can be derived from a graph of Log_e $(L_\infty - l_t)$ against t.

Theoretical growth in length of <u>E</u> <u>diacanthus</u>.

The Walford line for <u>E. diacanthus</u> is

Y = 52.2505 + 0.8897 X

Trial values of K = 0.1169 and of L_∞ = 474 mm SL were obtained using the Walford line (Figure 5a). The value of L_∞ and trial values were used to plot Log_e $(L_\infty - l_t)$ against age to obtain the straightest plots. The slope of these lines, K and the Y axis intercept can be used to determine 't_o'.

$$t_o = \frac{(\text{Y axis intercept} - Log_e\ L\ \ )}{K}$$

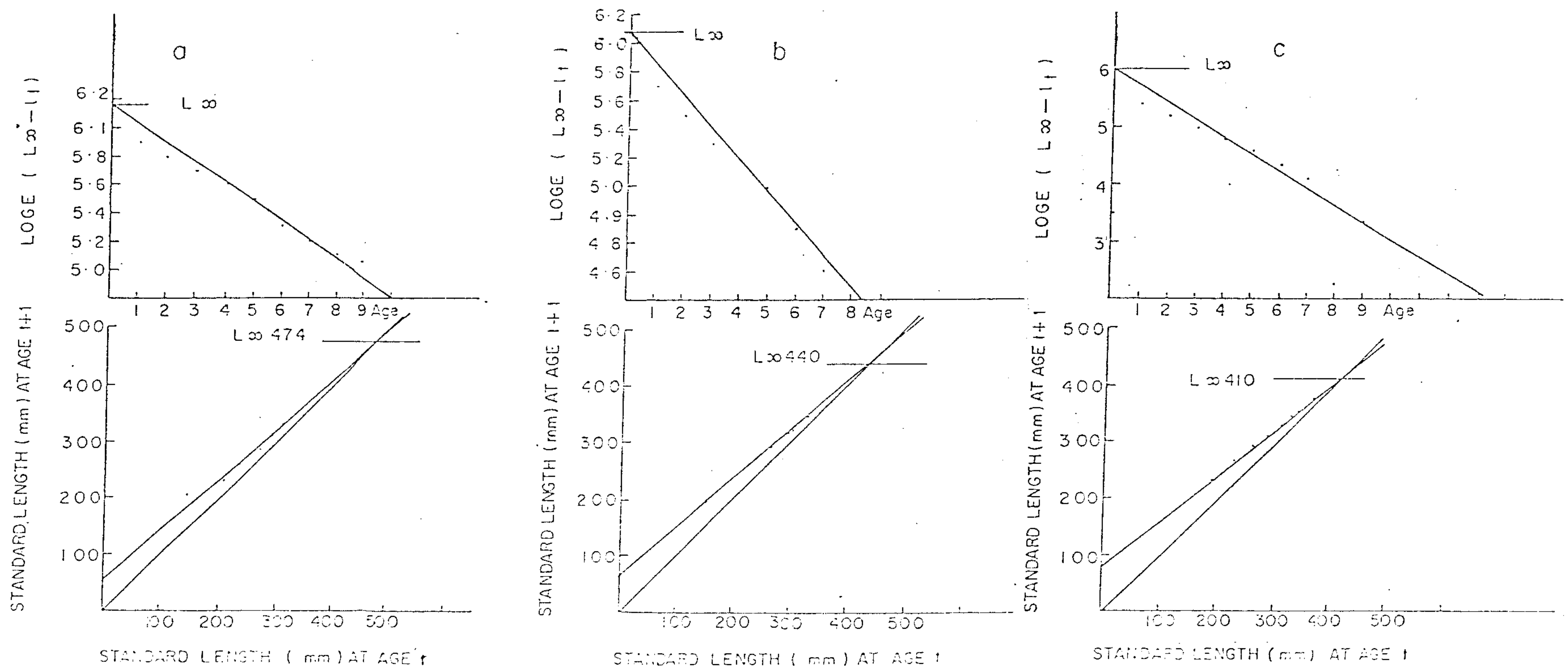
The resulting growth equation describing growth in length is

$L_t = 474\ (1-e^{-0.1169(t-0.1074)})$.

Theoretical growth in length of <u>E.</u> <u>chlorostigma</u>

The Walford line for <u>E. chlorostigma</u> is Y = 70.4154 + 0.8401 X

Trial values of K = 0.1742 and of L = 440 mm SL were obtained using the Walford line (Figure 5b). The value of L_∞ and trial values were used to plot Log_e $(L_\infty - l_t)$ against age to obtain the straightest plots. The slope of this line K and the Y-axis intercept can be used to determine 't_o'.



a
b
c
L ∞
L ∞ 474
L ∞ 440
L ∞ 410
LOGE (L∞ − l t)
Age
STANDARD LENGTH (mm) AT AGE t+1
STANDARD LENGTH (mm) AT AGE t

$t_o = \frac{\text{Y axis intercept} - \text{Log}_e\ L_\infty)}{K}$. the resulting von-Bertalanffy growth equation describing growth in length is $L_t = 440\ (1-e^{-0.1742(t-0.1354)})$.

Theoretical growth in length of E. bleekeri:

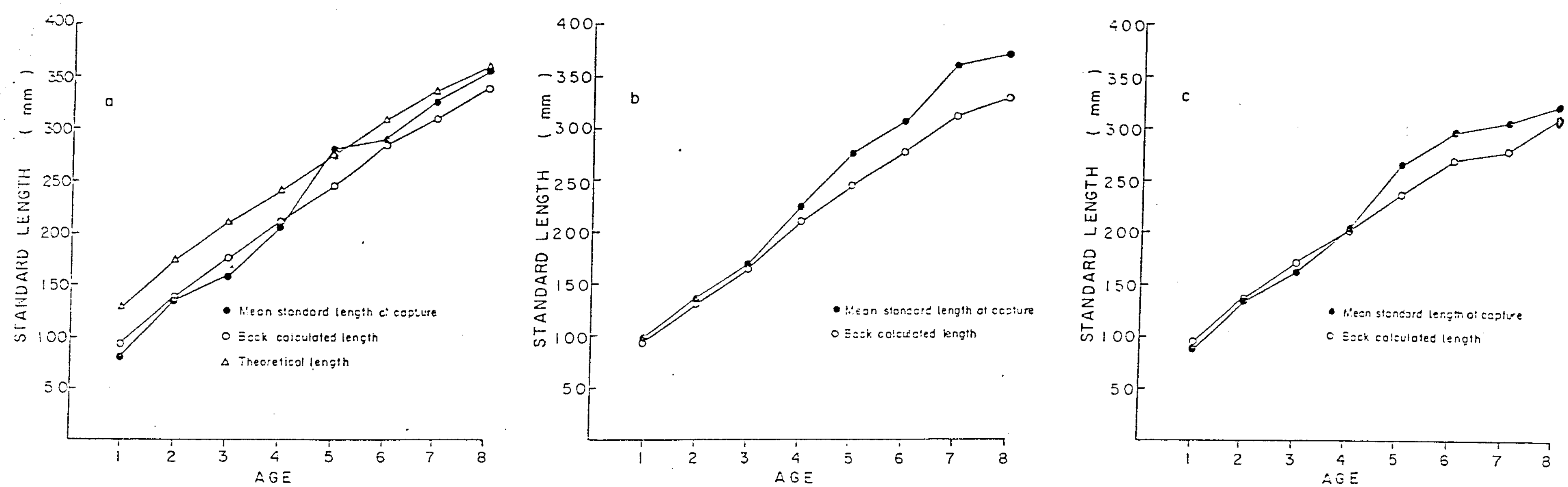
The Walford line for E. chlorostigma is Y = 83.1687 + 0.7799X. Trial values of K = 0.2025 and of L_∞ = 410 mm SL were obtained using the Walford line (Figure 5e). The value of L_∞ and trial values were used to plot $\text{Log}_e\ (L_\infty - l_t)$ against age to obtain the straightest plots. The slope of this line K and the Y-axis intercept can be used to determine 't_o'. The resulting von-Bertalanffy growth equation describing growth in length are $L_t = 410\ (1-e^{-0.2025(t-0.1783)})$.

5. Comparison of lengths derived from different methods used in the determination of age.

The mean standard length at capture, mean back-calculated standard lengths and theoretical length with respect to each age group is compared in the figures 6, 7, & 8 for each species. For this comparison, the lengths derived from otolith measurements were used.

Comparison of lengths derived from different methods used in the age determination with each age group in E. diacanthus

Figure 6a shows the growth curves derived from mean standard length at capture, mean back-calculated length and theoretical growth in length. The curves derived from theoretical growth in length and mean back-calculated length illustrate a smooth curvilinear growth. The


a
b
c
STANDARD LENGTH (mm)
AGE
400
350
300
250
200
150
100
50
1
2
3
4
5
6
7
8
● Mean standard length at capture
○ Back calculated length
△ Theoretical length

growth curve of mean standard length at capture indicate a smooth curvilinear growth till fourth year and a sudden change in the fifth year.

Figure 6b showing growth curves derived from mean standard lengths at capture and mean back calculated lengths based on scale radius illustrate a smooth curvilinear growth.

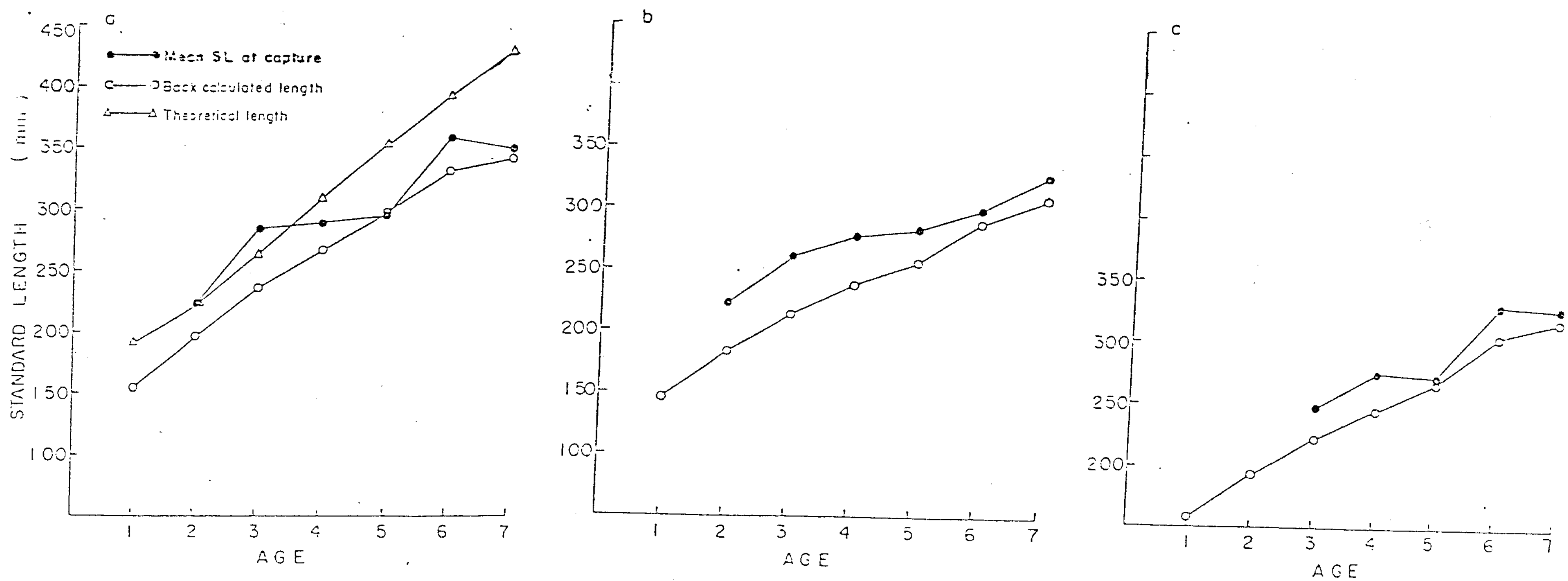
Figure 6c showing growth curves derived from the mean standard length at capture and mean back-calculated lengths based on vertebrae radius also show a smooth curvilinear growth.

Comparison of lengths derived from different methods with each age group in *E. chlorostigma*

Growth curves derived from mean standard lengths at capture, mean back calculated standard length and theoretical growth in length in *E. chlorostigma* are illustrated in the figure 7a. The growth curve derived from the mean standard length at capture shows a zig zag growth pattern must be due to the low sample numbers. Fish in the first age group could not be collected since the samples comprised only the hook and line catches. The back-calculated length curve and theoretical growth in length curve indicated a smooth curvilinear growth.

Figure 7b illustrates the growth curves derived from mean standard length at capture and mean back-calculated lengths based on scale radii. Both the curves show a smooth curvilinear growth. However, the mean length at capture was slightly higher than the mean back-calculated lengths.

Figure 7c indicates the growth curves derived from mean standard lengths at capture and mean back-calculated lengths based on vertebra


a
Mean SL at capture
Back calculated length
Theoretical length
STANDARD LENGTH (mm)
AGE
b
AGE
c
AGE

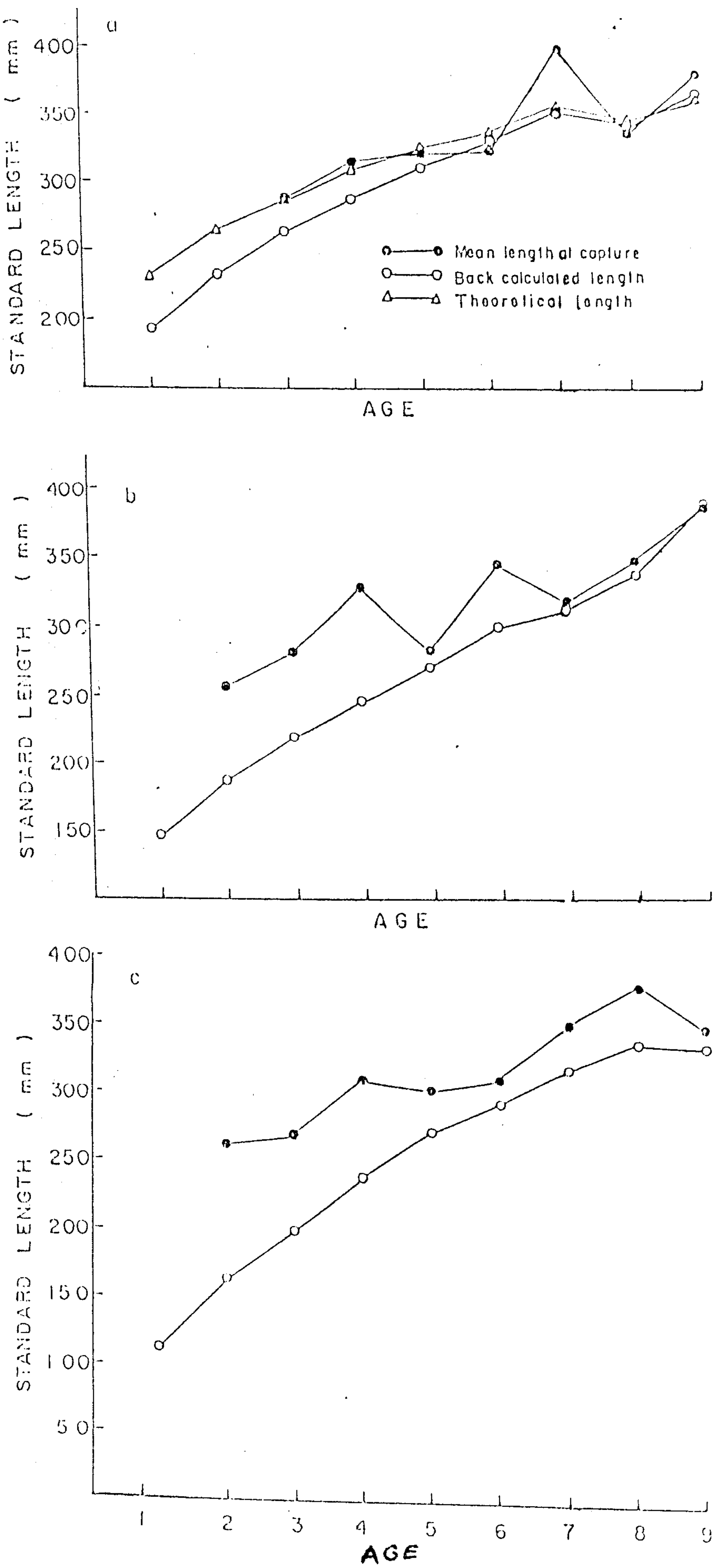
radii. The curve derived from mean standard length at capture shows a sudden decrease at the age 5. This variation in length must be due to the small sample size. The mean back-calculated length has shown a smooth curvilinear growth pattern.

Comparison of lengths derived from different methods with each age group in E. bleekeri

The growth curves derived from mean standard lengths at capture, mean back-calculated lengths and theoretical growth in length based on otolith radii of E. bleekeri are illustrated in figure 8a. The curve drawn from the mean standard length at capture shows a smooth curvilinear growth till the age 6 and at age 7 the growth curve has shown a sudden increase in length. The curves obtained from back-calculated lengths and theoretical growth in length show a smooth curvilinear growth.

Figure 8b shows the growth curves derived from mean standard lengths at capture and mean back calculated lengths based on scale radii. The growth curve of mean standard length at capture shows a smooth curvilinear growth upto 4 and at 5 and 7 it shows a sudden decrease in length and then the curve continues its curvilinear growth pattern. This sudden change must be due to the small sample size. The mean back-calculated length shows a smooth curvilinear growth curve.

Growth curves derived from mean standard lengths at capture and the back-calculated lengths based on vertebra radii of E. bleekeri is shown in the figure 8c. The curve of mean standard length at capture shows a slight increase in length at the age 4 and a slight decrease at



a
b
c
STANDARD LENGTH (mm)
400
350
300
250
200
150
100
50
AGE
1
2
3
4
5
6
7
8
9
Mean length at capture
Back calculated length
Theoretical length

age 9. The back calculated length curve shows a curvilinear growth pattern.

2.4. DISCUSSION

Thompsun and Munro (1974) showed that the fishery at Pedro Bank is made up of fish having at least four modal lengths. They show modal length progressions at bimonthly intervals over a period of nearly two years and indicate the modal differences are annual increments of length. In the present study, analyses of modal progression in the length frequency distribution of the samples were not possible because the samples were irregularly spaced to produce coherent results. Hence skeletal hard parts like otoliths, scales and vertebrae were used for age determination. The formation of the rings in the otoliths, scales, pectoral spines, vertebrae and opercular bones has been attributed to several factors. Menon (1953) has reviewed the literature on growth determinations in fishes from tropical and subtropical waters and pointed out that the physiological rhythms associated with spawning and decrease in food intake during gonad maturation " perhaps play a great and effective part in the periodic formation of the annual growth checks in the skeletal hard parts of the fish", Croker (1962) aged Gray Snapper, Lutjanus griseus from South Florida using scales; McEarlean (1963) aged gag, Mycteroperca microlepis from the West Florida coast using otoliths; De Sylva (1963) aged, the barracuda, Sphyraena barracuda using scales and they considered that annulus formation was caused by water temperature fluctuations, although it usually corresponded with some point in the spawning season as well. According to Nekrasov (1979) the rings may be formed at the time of spawning on the recording structure of tropical fishes. Chen et al., (1980) studied the age and growth of E. diacanthus using scales and suggested a connection between reproductive cycle and ring formation They also opined that the fish physiological relationship between the relative rates of calcium deposition and calcium resorption may influence the formation of rings as the external environmental factors like temperature, salinity, food and light influence the deposition of annual rings. Moe (1969) suggested that spawning activity coupled with environmental factors could be the causes of ring formation in E. morio. Campana and Neilson (1982) noted an internal circadian rhythm for the production of daily increments in juvenile starry flounders. Annual nature of otoliths is proved by many authors, like Moe (1969), Burnett-Herkes (1975), Mercer (1978), Chen et al., (1980) Sadovy et al., (1992). In this study also annual nature of the otoliths was proved by marginal increment analysis, opaque zones were formed March, April and May in the case of E. diacanthus. And invariably March, April, May formed the spawning months of E. diacanthus. So in E. diacanthus also the formation of ring might be due to spawning check. In E. chlorostigma and E. bleekeri, the annual nature of the otolith could not be proved by marginal increment analysis due to small sample sizes and discontinuous sampling. However, further investigation is needed on the age and growth of E. chlorostigma and E. bleekeri, especially to determine the time and cause of annulus formation

Moe (1969), Burnett-Herkes (1975) and Mercer (1978) were of the opinion that, mean lengths at capture were greater than the mean back calculated lengths. In this study also the mean standard lengths at capture were always greater than the mean back-calculated lengths derived from otoliths, scales and vertebrae. The mean back calculated lengths derived from otoliths, scales and vertebrae of E. diacanthus have shown almost equal lengths, indicating completion of ring formation at the same time. Comparison of mean back-calculated lengths derived from otoliths, and vertebrae of E. chlorostigma were of equal lengths, while that of scale is smaller in length. This might be due to the completion of ring formation in scale after the completion of ring formation in otoliths and vertebrae as Johnson (1984) has observed in little tunny. In the case of E. bleekeri the mean back-calculated lengths derived from otoliths were greater than the mean back calculated lengths derived from scales and vertebrae indicating the completion of ring formation otoliths before the completion of ring formation of scales and vertebrae. Johnson (1984) observed in litttle tunny that, the mean lengths based on spines were consistently longer than their respective mean lengths based on vertebrae, which could indicate that the vertebral ridge couplet formation is completed before the spine band completion. According to Simkiss (1974), these differences may be the result of differential response of the structures to mineralization (i.e., Calcium metabolism). However, it can not rule out the possibility that the differences are the result of small sample size.

2.5. LENGTH-WEIGHT RELATIONSHIP

The study of the length-weight relationship of fishes according to Le Cren (1951) has two different objectives. First to determine the mathematical relationship between length and weight, so that if length is known the weight can be computed and vice-versa, secondly to measure the variation from the expected weight for a given length of individual fish or groups of fishes as indications of fatness, general well-being or gonadal development. The length-weight relationship of E. diacanthus, E. chlorostigma and E. bleekeri was determined for the present study.

Since the length of fish can be measured more easily than weight it would be convenient to determine the weight when the length is known. Hence the general length-weight relationship of fish is given by parabolic equation of the form $W = aL^b$, where W = weight, L = length of fish, 'a' and 'b'are constants to be determined empirically from the data. Usually for an ideal fish, which maintains the same shape during its growth, b = 3 (Allen 1938). But in majority of fishes the shape and density change with increasing age which often causes the coefficient of regression of logarithm of weight on logarithm of length depart from 3. In such cases the value of the exponent 'b' in the parabolic equation may lie between 2.5 and 4 (Hile, 1936 and Martin, 1949). Beverton and Holt (1957) found that large variations from the isometric growth (b = 3) are rare in adult fishes. Brown (1957) showed that the exponent 'b' which is the ratio between the specific growth rates of length and weight usually equals 3. Le Cren (1951) recorded some instances where the value of 'b' differs for the fish of the same species from different environments or for larval, immature and mature fishes.

MATERIALS AND METHODS

The materials comprised of three species of Epinephelus, E. diacanthus chlorostigma and E. bleekeri. For a detailed study on the length-weight ationship the fish were separated into indeterminate, male and female the case of E. diachanthus, male and female in the case of E. chlorostigma l E. bleekeri. A combined length weight relationship was also given en the relationship was proved statistically non-significant.

RESULTS

The length-weight relationship of indeterminate, male and female s found out using the formula, $W = aL^{b}$. This expression can be tra-ormed to:

$$\text{Log } W = \log a + b (\log L)$$

e length weight relationship of E. diacanthus

The length weight relationship of indeterminates (Figure 9a).

$$W = 1.02904 \times 10^{-5} L^{3.177}$$

$$\text{Log } W = -4.9875 + 3.177 (\log L)$$

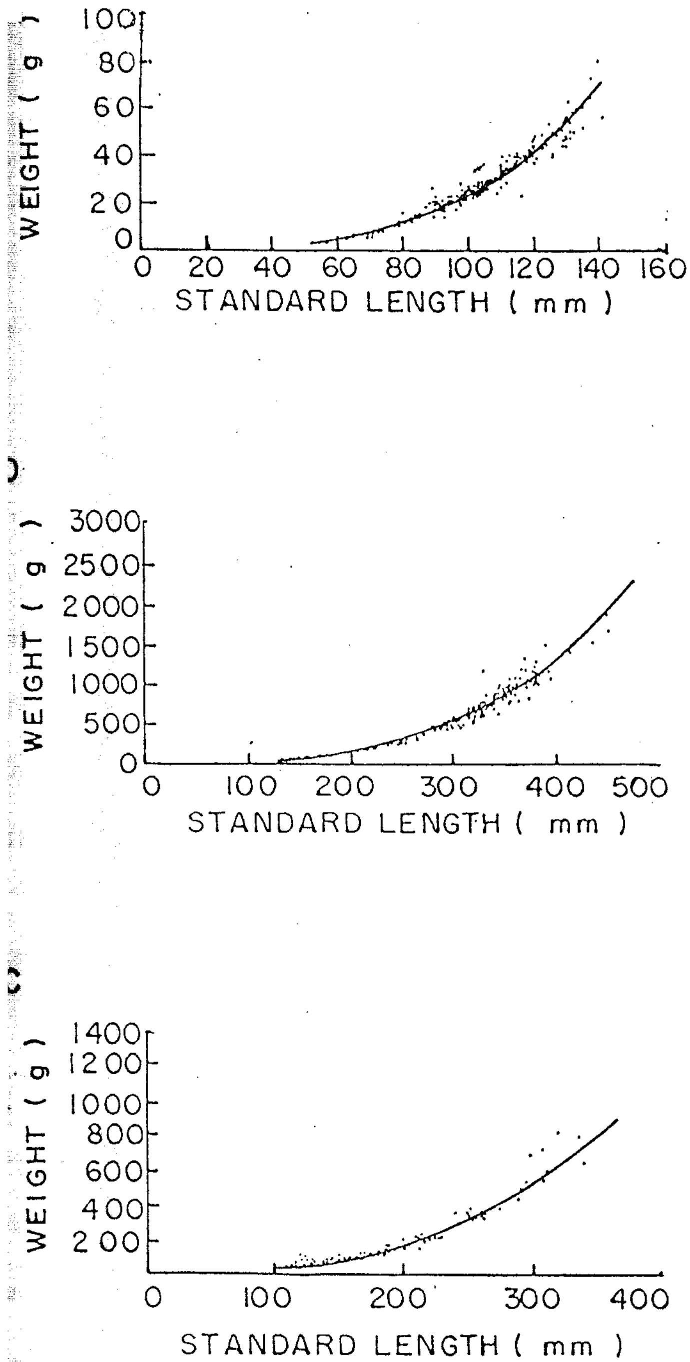
The correlation coefficient 'r' was 0.9810.

The length-weight relationship of male (Figure 9b).

$$W = 1.07913 \times 10^{-5} L^{3.111}$$

$$\log W = -4.9669 + 3.111 (\log L).$$

9. LENGTH-WEIGHT RELATIONSHIP OF E. DIACANTHUS INDETERMINATES (b) MALES AND (c) FEMALES.



The correlation coefficient 'r' was 0.9930.

The length weight relationship of female (Figure 9c).

$W = 9.46408 \times 10^{-5} L^{2.744}$

$\text{Log } W = -4.0724 + 2.744 (\log L)$

The correlation coefficient 'r' was 0.9780

The 't' test has proved that the exponent 'b' is significantly different from the cube law 3, for indeterminates, males and females (Table-10). Analysis of variance on these regression indicates that the residual variances were homogenous and significant F values obtained for the regression coefficients (Table 11).

TABLE-10. **Statistical anaysis to test deviation from the Cube law – <u>E. diacanthus.</u>**

	b	DF	sb	$t = \frac{b-3}{sb}$	P%
Indeterminate	3.1772	245	0.0403	4.397	0.000
Male	3.1112	153	0.0300	3.707	0.000
Female	2.7437	366	0.0310	8.268	0.000

TABLE-11. **Analysis of variance for _E. diacanthus_ length-weight regressions**

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Differences	2	130.0	65.0	19.95	S
Differences in level	1	0.8	0.8	0.24	N.S
Error	520	1820.1	3.5		
Differences in angle	1	129.2	129.2	39.65	S
Error	519	1690.9	3.3		

The analysis of variance proved that the length-weight relationship between males and females are statistically significant.

The length weight relationship of _E. chlorostigma_

The following length-weight relationships were calculated for _E. chlorostigma_

Length-weight relationship for males (figure 10a)

$$W = 1.96937 \times 10^{-5} L^{2.987}$$

$$\log W = -4.7057 + 2.987 (\log L)$$

The correlation coefficient 'r' = 0.9630.

g. 10. LENGTH-WEIGHT RELATIONSHIP OF E. CHLOROSTIGMA (a) MALES (b) FEMALES AND (c) COMBINED

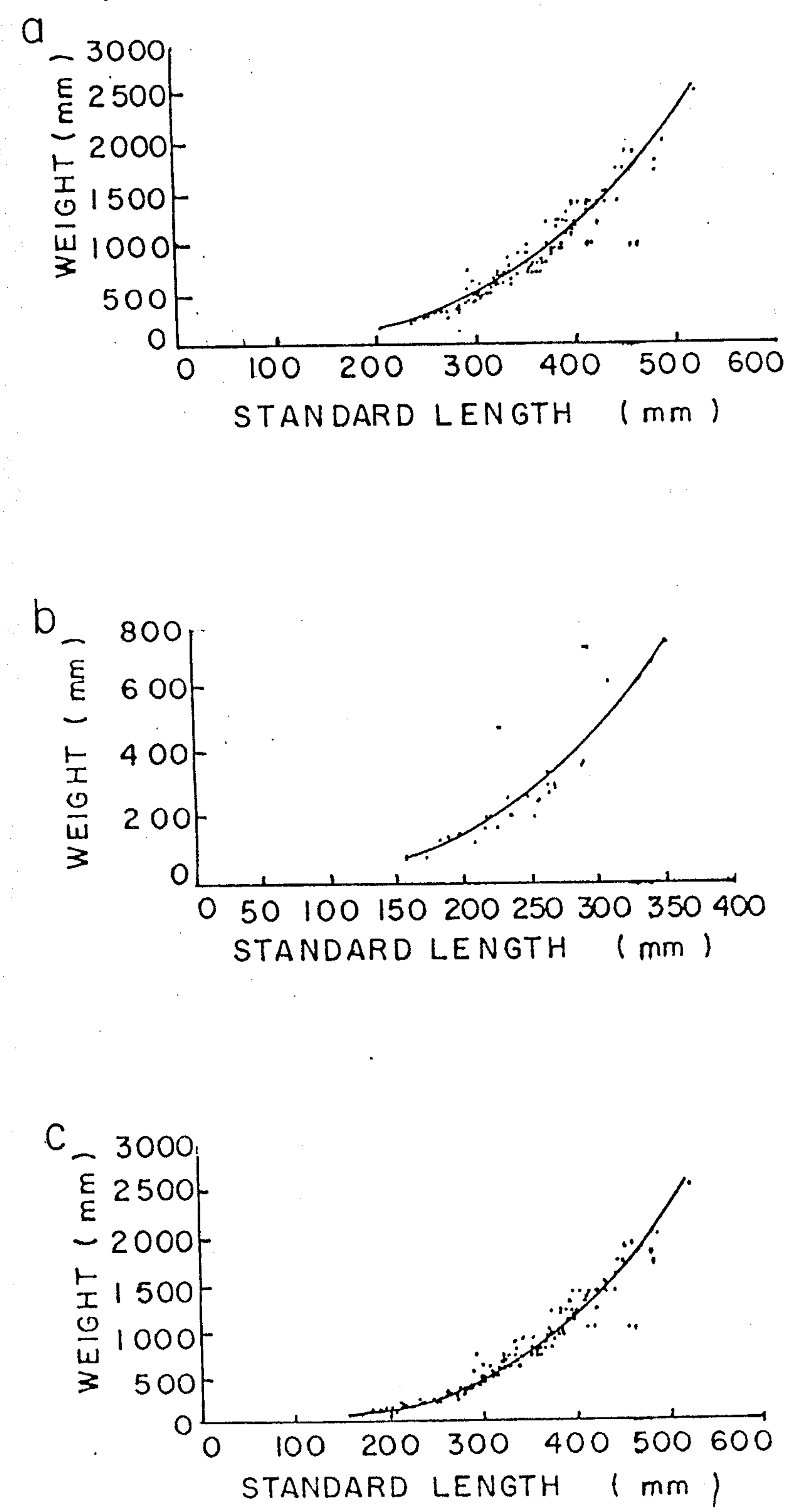


TABLE-12. **Statistical analysis to test deviation from Cube law – *E. chlorostigma*.**

	b	DF	sb	$t = \frac{b-3}{sb}$	P%
Male	2.9871	124	0.0752	0.1715	NS
Female	2.8599	33	0.2167	0.6465	NS

Length weight relationship for females (Figure 10b)

$$W = 3.86907 \times 0^{-5} L^{2.860}$$

$$\log W = -4.4124 + 2.860 (\log L)$$

The correlation coefficient r = 0.9170

In this case 't' test has proved that the exponent 'b' is close to 3 for males and females showing isometric growth (Table-12). Analysis of variance on the regressions was not significant for *E. chlorostigma* (Table 13).

TABLE-13. **Analysis of variance for *E. chlorstigma* length-weight regressions.**

Source	Degree of freedom	Sum of Squares	Mean Square	F Value	Prob.
Differences	2	2.90	1.5	0.53	N S
Differences in level	1	1.60	1.6	0.57	N S
Error	158	435.30	2.8		
Differences in angle	1	1.4	1.4	0.50	N S
Error	157	433.9	2.8		

Hence the data of both the sexes were pooled together and a common formula was obtained (Figure 10c).

$$W = 1.85074 \times 10^{5}\ L^{2.997}.$$

$$\log W = -4.7327 + 2.997 \log L$$

with a correlation coefficient 'r' = 0.974

Length-weight of relationship of E. bleekeri

The length-weight relationship of E. bleekeri was as follows:

The length-weight relationship of males (Figure 11a).

$$W = 5.09537 \times 10^{-6}\ L^{3.217}$$

$$\log W = -5.2928 + 3.217 (\log L)$$

With a correlation coefficient 'r' = 0.9820

TABLE-14. **Statistical analysis to test deviation from Cube law - E. bleekeri**

	b	DF	sb	$t=\frac{b-3}{sb}$	P%
Male	3.2169	73	0.0728	2.9794	0.000
Female	3.1202	56	270.0603	1.9934	N S

The length weight relationship of females (Figure 11b)

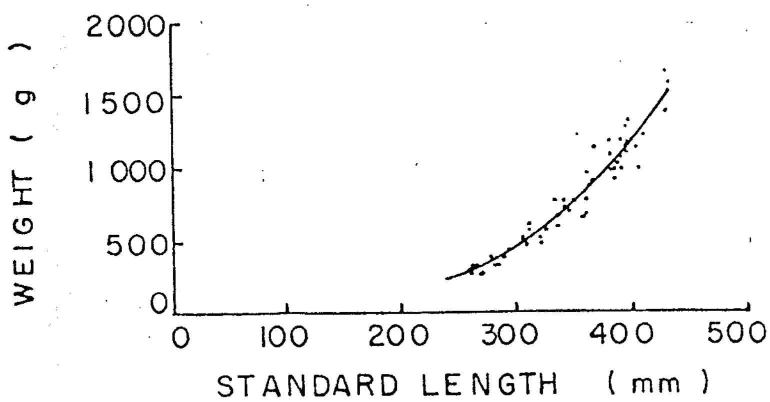
$$W = 9.00962 \times 10^{-6}\ L^{3.120}$$

$$\log W = -5.0453 + 3.120 (\log L)$$

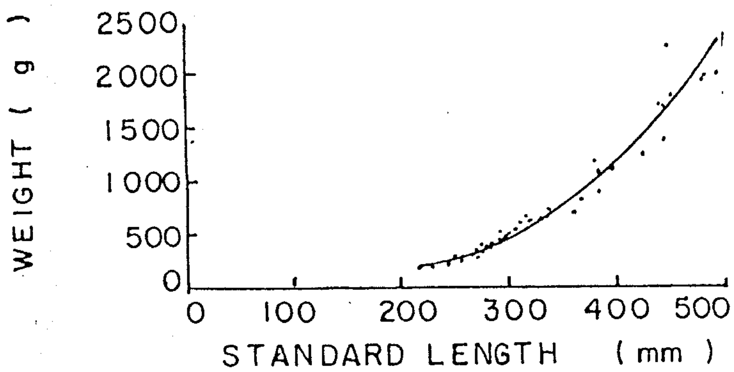
With a correlation coefficient 'r' = 0.9900

11. LENGTH-WEIGHT RELATIONSHIP OF *E. BLEEKERI* (a) MALES (b) FEMALES AND (c) COMBINED

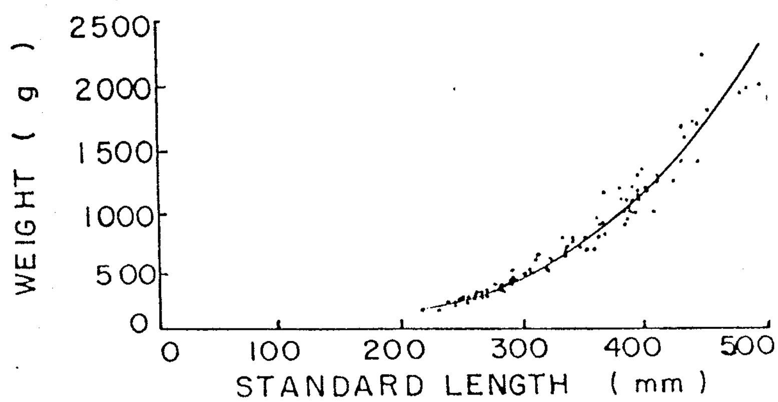
a



b



c



In E. bleekeri the 't' test has proved that the exponent 'b' significantly varies from the cube law in the case of males while no such variation is seen in females (Table-14).

Analysis of variance on the regressions was not significant (Table-15) Hence the sexes were pooled together and a common formula was obtained (Figure 11c).

W = $7.38071 \times 10^{6}\ L^{3.154}$

log = $-5.1319 + 3.154 \log L.$

with a correlation coefficient 'r' = 0.9880

TABLE-15. **Analysis of variance for E. bleekeri length weight regressions**

Source	Degrees of freedom	Sum of squares	Mean Square	F Value	Prob.
Differences	2	1.20	0.6	0.6	N S
Differences in level	1	0.20	0.2	0.22	N S
Error	130	126.70			
Differences in angle	1	1.00	1.0	1.000	N S
Error	129	125.70	1.0		

3. DISCUSSION

In E. diacanthus, E. chlorostigma and E. bleekeri, the 'r' values showed a very good correlation between length and weight. The analysis of variance of regression co-efficients were significant for E. diacanthus and insignificant for E. chlorostigma and E. bleekeri. A quite variable length-weight relationships were obtained to different workers on different species of Epinephelus.

Moe (1969) has found that the logarithmic length-weight relationship for Epinephelus morio to be log W = 1.4343 + 2.9294 log L, exponentially it is $W = 0.2918 \times L^{2.9294}$. Thompsun and Munro (1974) expressed the relationship between the total length and weight of E. guttatus as log W = -1.754 + 2.960 log L, exponentially it is $W = 0.0176\ L^{2.960}$. Burnett-Herkes (1975) found that the calculated regression curve for length-weight relationship for E. guttatus is log W = 4.5509 + 2.9770 log L, (or $W = 3.605 \times 10^{-5}\ L^{2.9770}$) and the regression coefficient was 0.99. Chen et al., (1980) have seen in E. diacanthus that the length-weight relationship to be $W = 1.621 \times 10^{-5}\ SL^{3.08908}$ and the equatioon of length weight relationship of between ages, b is $W = 2.679 \times 10^{-5}\ SL^{2.99790}$. Here both the 'b' values are very close to 3 i.e. the growth of this grouper is isometric. However, the above values were not subjected to any statistical testing and hence comparison with the present investigation is not possible.

Premalatha (1989) has found that in E. aerolatus the length-weight relationship of males and females was log W = 2.328 log $L^{-0.8994}$ and log W=2.5572 log $L^{-1.2521}$ respectively with regression coefficients (r) 0.8876 and 0.9116. For E. chlorostigma she got the relationship was as follows: males, log W = 2.8497 log L-1.7501 (r = 0.9388) and females, log W = 3.0425 log L-2.71175 (r = 0.9633).

The 'a' values of indeterminate and males are found to be lowest compared to females in the case of E. diacanthus, which Brown (1957) interpreted as due to low fat content. In E. chlorostigma, the 'a' value is low for males and there is not much difference in the 'a' value in the case of E. bleekeri for males and females. Generally the weight of the fish will be proportional to the cube of length, based on its dimensional equality. The results of 't' test employed by dividing the difference between 'b' and '3' by standard error of 'b' showed that the 'b' values vary significantly from '3' in the case of E. diacanthus for indeterminate, males and females and males in the case of E. bleekeri. While E. chlorostigma exhibits isometric growth. Deviation from isometric value of 3 have been obtained in sardines (Antony Raja, 1967) and the gold spot mullet, Liza parsia (Madhusoodana Kurup and Samuel, 1992).

Depending upon the deviation of 'b' values from '3' fishes can be classified into three groups (a) $b = 3$ where the body form of fish remains constant at different lengths (isometric) (Allen, 1938), (b) $b < 3$ when fish becomes more slender as the length increases and (c) $b > 3$ when fish grows more stouter with increase of length (allometric), (Growner and Juliano, 1976). But the value of 'b' usually remains between 2.5 and 4 (Hile, 1936). The present observation is also in agreement with the above view and it can be concluded that the cube formula $W = a\, l^3$ will not be a proper representation of the length-weight relationship at least for E. diacanthus.

CHAPTER 3

FOOD AND FEEDING HABITS

3.1 INTRODUCTION

Information on the food and feeding habits of fishes is essential for a clear understanding of their life history, including growth and migration and also for their exploitation and management. A knowledge of the favourable feeding grounds and preferred food components of commercial fish stocks, are of paramount importance to fishermen to extend or diversify their fishing effort profitably. It is essential to have a knowledge about the food and feeding habits of the candidate species for culture aspects also.

Das and Moitra (1956, 1963) classified fishes as herbivores, carnivores and omnivores based on the percentage of animal and vegetable matter they consumed. They further classified fishes into three subgroups according to the zone of their feeding, they are surface feeders, column feeders and bottom feeders. The correlation between the availability of a particular food and the abundance of the predator species is well established by different authors. To quote few instances, the peak fishery of mackeral and sardines along the Malabar coast during September-December, when the inshore waters are rich in phyto and zooplankton (George, 1953); the abundant fishery of Malabar sole, Cynoglossus semifasciatus with the availability of their favourite food item Prionospio pinnata (Polycheate) between October-May (Seshappa and Bhimachar, 1955) and the fishery of silver bellies and white baits during monsoon months along the Malabar coast when the water is rich in copepods (Venkataraman, 1960).

Some of the notworthy works on the food and feeding habits of Indian demersal fishes are by Tandon (1960) on *Selaroides leptolepis*, Venkataraman (1960) on the food and feeding relationships of the inshore fishes off Calicut, Rao (1963) on *Pseudosciaena diacanthus*, Rao (1964) on the fishes from the Bay of Bengal, George *et al*., (1968) on the demersal fishes from the trawling grounds off Cochin, Kagwade (1969) on *Polynemous heptadactylus*, Rangarajan (1970) on *Lutjanus kasmira* from Andaman Sea and Krishnamoorthi (1971) on threadfin bream, *Nemipterus japonicus*. Qasim (1972) gave a detailed review of the dynamics of food and feeding habits of some marine fishes. The works of the food and feeding habits of some Indian teleosts like *Psettodus erumei* (Mathew and Balakrishnan, 1976); *Tachysurus thalassinus* (Menon, 1978) *Caranx malabaricus* and *Alepes kalla* (Venkataramani and Natarajan, 1983); *Nemipterus japonicus* (Rao and Rao, 1991) and *Tachysurus dussumeri* (Vasudevappa and James, 1992) are also noteworthy.

Very little information is available on the food and feeding habits of the subfamily Epinephelinae, from the Indian waters. One of the earliest studies on the nutrition of perches was by Job (1940) from Madras coast. Mention was also made by Prabhu (1954) on the perches caught by traps in the Gulf of Mannar and Palkbay. Silas (1969) has mentioned about the food of 'Kavala' from the south west coast of India in the exploratory fishing by *R.V. Varuna*. More recently the rockcods from the south west coast of India was investigated by Premalatha (1989).

Many workers from abroad have reported the food and feeding habits of different species of Epinephelus and other related genera. Some of the works on the related genera were by Croker (1962) on the gray snapper, Lutjanus griseus, Hobson (1965) on Mycteroperca rosacea; Talbot and Goldman (1972) on the feeding relationships of the reef fishes at one Tree Island, Smith and Tyler (1973) on Mycteroperca bonaci, M. venenosa and M. interstitialis and Manooch (1977) on the red porgy, Pagrus pagrus from the North carolina and South Carolina.

Although attempts were made on the food and feeding habits of Epihephelus, a detailed study on E. diacanthus is lacking. Some of the important works on allied species of Epinephelus are as follows. Beebe and Tee-van (1928) reported the food of E. striatus. Randall (1960) described the food habits and habitats of Epinepheline and Lutjanid fishes of the Society Islands. Menzel (1960) mentioned the food of E. guttatus from Bermuda reef. Randall (1965) gave a brief account on the food habits of E. striatus from the Virgin Islands and Puerto Rico waters. Randall (1967) examined the gut contents of E. adscensionis, E. guttatus, E. itajara, E. morio, and E. striatus from West Indies. Moe (1969) mentioned the food of E. morio. Burnett-Herkes (1975) mentioned the food and feeding habits of E. guttatus. Thompsun and Munro (1978) studied in detail the food habits of hinds and groupers from the Caribbean reefs. Mention was also made by Munro (1983) on the coral reef fishes from the Caribbean.

2 MATERIALS AND METHODS

The materials consisted of 731 fish, Epinephelus diacanthus collected from the trawl landing of Cochin fisheries harbour during the period, December 1990 to November 1992. The stomachs of the fishes were preserved in 5% formalin after noting down the total length, standard length, total weight and gonad condition of each fish.

Analysis of gut contents were carried out by two methods (1) qualitative - identifying the organisms in the gut to the nearest taxon possible and (2) quantitative - volumetric method. The prevalence of each food item in the diet during different months and size groups was calculated by the occurrence method (Hynes, 1950). 'Index of preponderance' proposed by Natarajan and Jhingran (1961) was used to grade the relative importance of the food item as it was found suitable for carnivorous fishes. The percentage occurrence of different items of food in different months was determined by summing the total number of occurrence of all items from which the percentage occurrence of each item was calculated. The percentage volume of each food item was determined from the total volume of all the stomach contents. The index of preponderance was given by the formula $\frac{ViOi}{\Sigma ViOi} \times 100$, where Vi and Oi represent percentage volume and percentage occurrence of a particular item of food respectively.

The degree of fullness of stomach was determined on the basis of distension of stomach folds (Rao, 1964). Average amount of feeding (Rao, 1991) was taken into consideration to determine the feeding intensity.

omachs were classified into 'gorged' when the stomach was full with od and the wall become thin and transparent, 'full' when the stomach is filled with food and the wall become thin but not transparent, similarly /4 full', '1/2 full' '1/4full' and 'empty' depending on their relative fullness d the space occupied by the stomach contents. An empty stomach had ly shrunken wall with little mucous. Numerical values '1.50', '1', '0.75', .50', '0.25' and '0.0' were given respectively to the above categories. e values gained by all the stomachs examined in a given sample were alysed to obtain the feeding intensity according to season and size. e fish in the given sample were considered intensely fed when the average nount of feeding reached 0.75 or above.

The fish obtained from the gut contents of E. diacanthus were ouped in a single head, fish. Miscellaneous items constituted the sand ains, crushed molluscan shells, cuttlebones, partially digested cephalopods, ysis larvae, lucifer etc. since they were observed in very low quantities, ce or twice among the food components. Digested matter is excluded hile ranking the food items according to the 'index of preponderance'. he fish were grouped into 10 mm class interval, standard length groups. o describe the food and feeding habits of fish according to size groups, ey were divided into lower length groups (immature ones from to 71 to 30 mm) and higher length groups (mature ones from 131 to 220 mm)

.3 RESULTS

E. diacanthus showed a preference for crustacean and fish diet. he crustaceans consisted of crabs, prawns, Squilla sp., hermit crabs etc.

'he crabs belonging to the genus Charybdis, prawns like Parapenaeopsis tylifera, Trachypenaeus sp. and Acetes sp. were the major crustacean diet. Among the fishes Stolephorus sp. and Nemipterus sp. were common in the gut. Cynoglossids, platycephalids, ambasids, leognathids, carangids, lacterids were also met with infrequently. Occasional items like molluscs. molluscan shells, albunia, cuttle bones of cephalopods, cephalopods, fish bones, and scales were also observed. Hermitcrabs were observed along with and without molluscan shells. The molluscs observed in the gut contents were the button shell, Umbonium vestiarium; the basket shell, Nassarius nodiferus and Pelecyora sp.

1. **Feeding intensity in different seasons:**

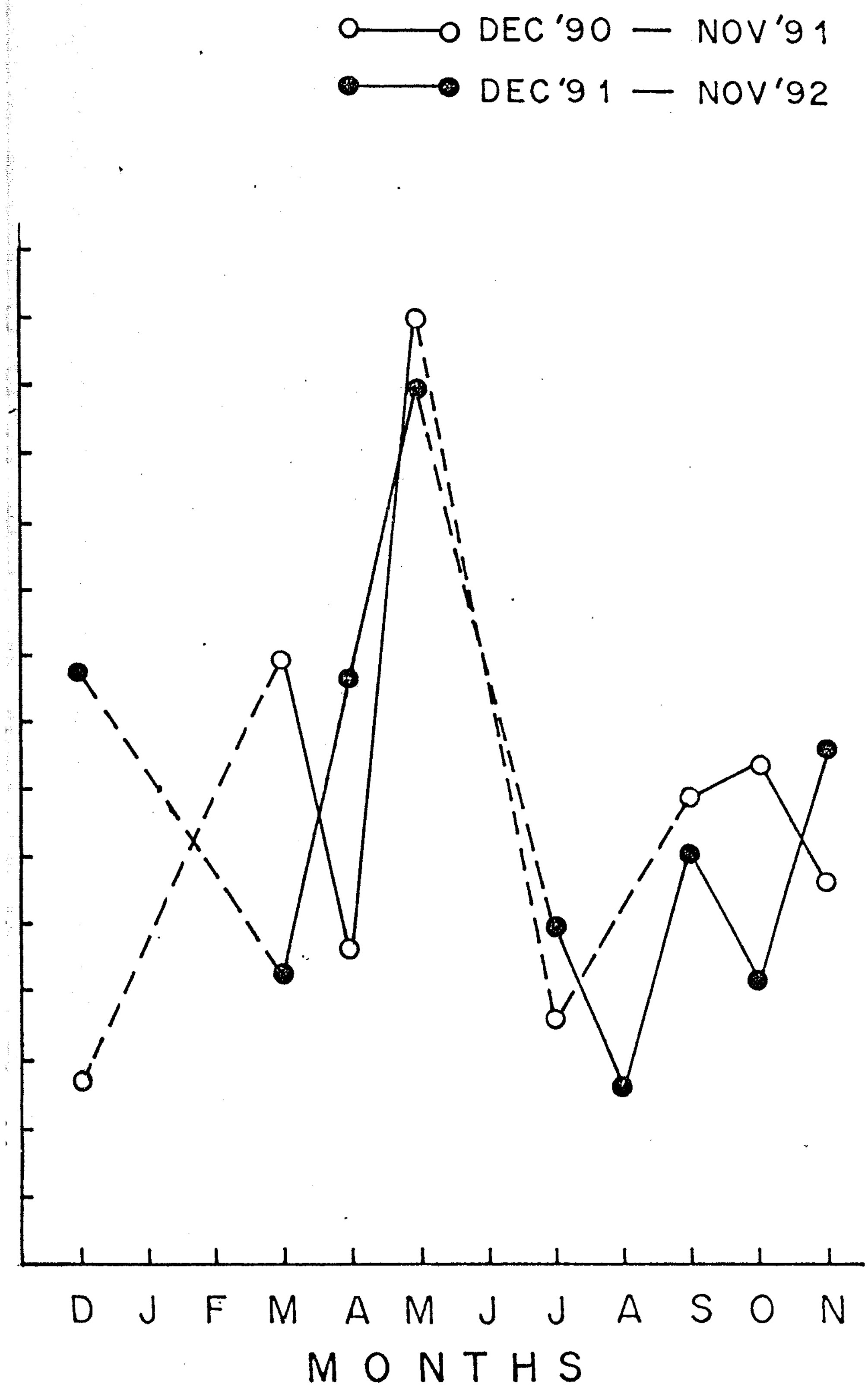
During 1990-1991, high feeding intensity was observed in March and May, when the average amount of feeding reached 0.9 and 1.5 respectively. Whereas April (0.41) July (0.36) and December (0.27)were regarded as the least fed months. In September, October and November the feeding intensity in terms of average amount of feeding were 0.69, 0.74, and 0.56 respectively (Figure-12).

December, April. May and November formed the actively fed months during the year 1991-1992, when the values were 0.88, 1.4, 0.87 and 0.77 respectively. March (0.43), July (0.50), August (0.26), September (0.61) and October (0.41) were the low fed months.

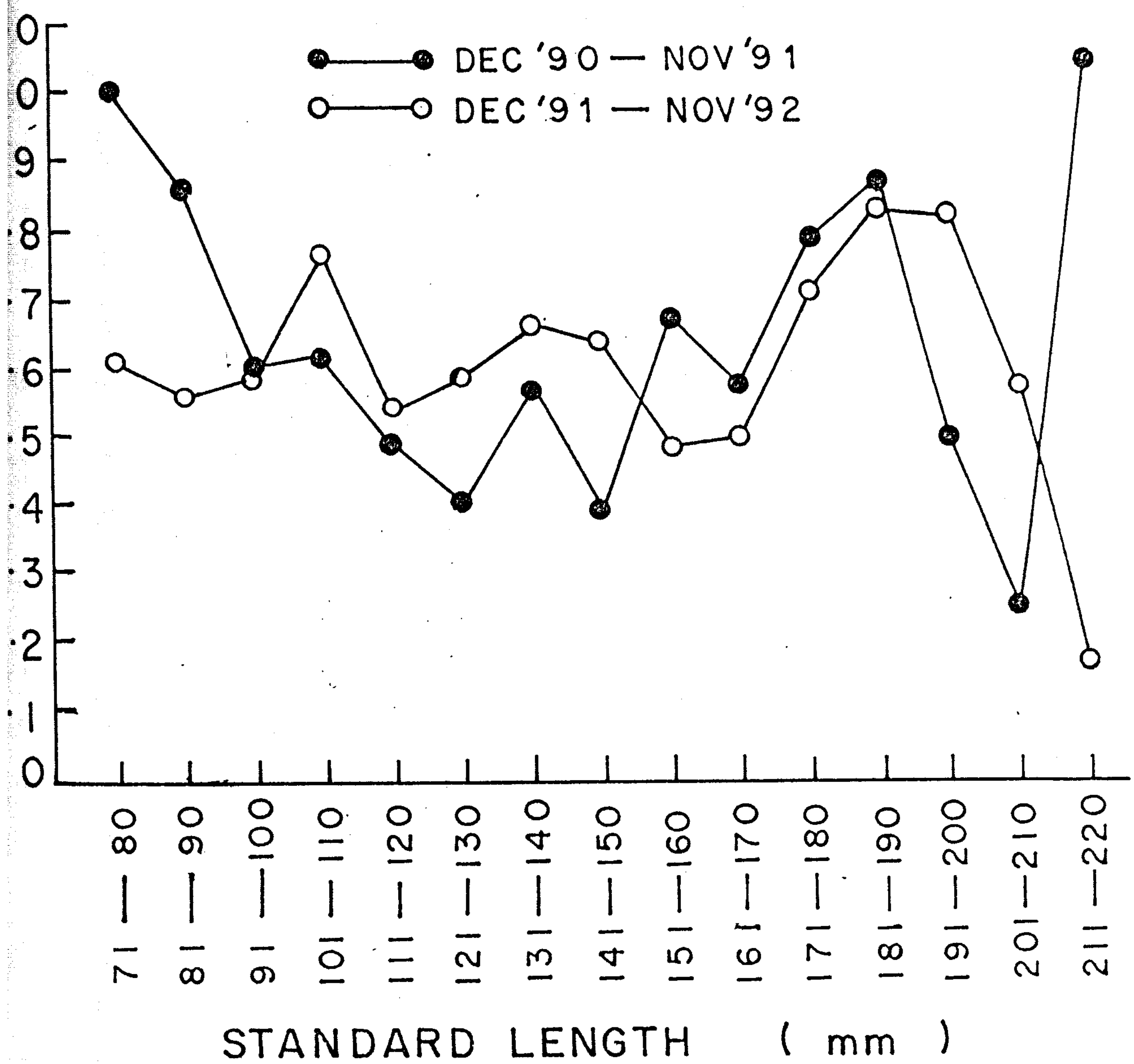
2. **Feeding intensity in different length groups:**

In 1990-1991 fishes in the length groups 71-80 mm (1.0) 81-90 mm (0.86) were the intensely fed ones in the lower length groups (Figure-13

EASONAL VARIATION IN THE FEEDING INTENSITY OF
E. DIACANTHUS DURING 1990-'92



FEEDING INTENSITY OF E. DIACANTHUS IN DIFFERENT LENGTH GROUPS DURING 1990-'92



The feeding intensity in the size range 91-130 mm varied between 0.40-0.62. In 1991-1992,fishes of 101-110 mm (0.77) size group was intensely fed. (figure-13).The feeding intensity of the size group, 71-100 mm ranged from 0.59-0.61 and for the size groups, 111-120 mm and 121-130 mm the feeding intensity ranged from 0.54 and 0.59 respectively.

During 1990-1991, the feeding intensity of 171-220 mm length groups was from 0.79 to 1.50. A lower feeding intensity of 0.39 to 0.68 was noticed among fishes of the size range 131-170 mm. While the size range 191-210 mm showed a feeding intensity range of 0.25-0.50. The feeding intensity was generally high (0.84) among size classes 181-200 mm 1991-1992 period.The feeding intensity value was found to be low (0.60 - 0.20) in larger fishes above 200 mm.

3. Indices of Preponderance of different food items during December 1990 - November 1992:

Crabs ranked first with a high value 77.06 in 1990-1991. Fish ranked second (11.62), Squilla sp. (4.23), hermitcrabs (1.23), prawns (0.9), miscellaneous items (0.35) and molluscs (0.18) ranked third, fourth, fifth, sixth and seventh respectively. (Table-16).

During 1991-1992 period, Squilla sp. ranked first (50.14). Prawns (29.50) came second in ranking, while third, fourth, fifth, sixth and seventh ranking were given to fish (15.13), crabs (2.23), miscellaneous items (1.08), hermitcrabs (0.14), and molluscs (0.04) respectively. (Table - 17).

TABLE-16. **Indices of preponderance of different food items of *E. diacanthus* during 1990-1991.**

Food items	Volume (ml)	Occurrence	Vi	Oi	Vi Oi	$\frac{ViOi}{\sum ViOi} \times 100$
Squilla sp.	16.50	26	11.60	9.39	108.92	4.23 (3)*
Crabs	65.75	119	46.22	42.96	1985.61	77.06 (1)
Prawns	7.00	13	4.92	4.69	23.07	0.90 (5)
Hermit crabs	6.25	20	4.39	7.22	31.70	1.23 (4)
Fish	30.25	39	21.27	14.08	299.48	11.62 (2)
Molluscs	2.25	8	1.58	2.89	4.57	0.18 (7)
Miscellaneous items	3.00	12	2.11	4.33	9.14	0.35 (6)
Digested matter	11.25	40	7.91	14.44	114.22	4.43
TOTAL	142.25	277.00	100.00	100.00	2576.71	100.00

*Figures in parenthesis indicate ranks of individual item in their respective periods.

Squilla sp	94.25	126	35.70	23.55	840.74	50.14 (1)*
Crabs	19.50	27	7.39	5.05	37.32	2.23 (4)
Prawns	44.50	157	16.86	29.35	494.84	29.50 (2)
Hermit crabs	4.25	8	1.61	1.50	2.42	0.14 (6)
Fish	56.00	64	21.21	11.96	253.67	15.13 (3)
Molluscr	1.75	5	0.61	0.93	0.61	0.04 (7)
Miscellaneous items	10.25	25	3.88	4.67	18.12	1.08 (5)
Digested mattter	33.50	123	12.69	22.99	29.17	1.73
TOTAL	264.00	535.00	100.00	100.00	1676.89	100.00

* Figures in parentheses indicate ranks of individual item in their respective periods.

When the average of the indices of preponderance for the two years (Dec. 1990-Nov. 1992) were taken, Squilla sp. ranked first (28.46) then came crabs (21.05). Fish (15.17) ranked third. Prawns (14.81), miscellaneous items (0.63), hermitcrabs (0.5) and molluscs (0.10) were ranked respectively, the fourth, fifth, sixth and seventh positions (Table-18).

4. Indices of preponderance in different seasons:

According to the indices crabs formed the most preferred item in 1990-1991 period. Prawns, Squilla sp., hermit crabs and fish were the other items next in importance. During 1991-1992 period, the fish showed no specific preference for any food item. Squilla sp. came first in ranking in December, July, September, October, and November; prawns in March, April and August and fish in May. Seasonal variations in the indices of preponderance of different food items are detailed below:

Fish:

Fish was observed in all the months in both the years and thus formed the most preferred item. In the year 1990-1991, fish was observed in every month except July. May has shown high value, 85.06. April showed the lowest value for fish, 1.35. In December, March, September, October and November the values were 2.46, 11.51, 65.82, 5.920 and 4.815 respectively (Table-19).

During 1991-1992, fish (62.8) were more in the gut contents in May. In September (2.29) fish was observed in low quantities (Table-20).

Food items	Volume (ml)	Occurrence	Vi	Oi	Vi Oi	$\frac{Vi\ Oi}{\sum Vi\ Oi} \times 100$
Squilla sp.	55.375	76	25.69	18.86	484.51	28.46
Crabs	42.625	73	19.78	18.11	358.22	21.05
Prawns	25.750	85	11.95	21.09	252.03	14.81
Hermit crabs	5.250	14	2.44	3.47	8.47	0.5
Fish	43.125	52	20.01	12.90	258.13	15.17
Molluscs	2.000	7	0.93	1.74	1.62	0.10
Miscellaneous items	60.625	14	3.08	3.47	10.69	0.63
Digested matter	22.375	82	16.12	20.36	328.20	19.28
TOTAL	215.52	403	100.00	100.00	1701.87	100.00

Indices of preponderance in different seasons - from December 1990 - November 1991.

	Volume(ml)	Occurrence	Vi	Oi	ViOi	$\frac{ViOi}{\sum ViOi}$ X 100
1990						
	1.50	1	18.18	7.14	129.81	4.91 (3)*
	3.75	6	45.46	42.86	1948.42	73.78 (1)
abs	1.50	3	18.18	21.43	389.60	14.75 (2)
	0.75	1	9.09	7.14	64.90	2.46 (4)
ous items	0.25	1	3.03	7.14	21.63	0.82 (5)
matter	0.50	2	6.06	14.29	86.60	3.28
	8.25	14	100.00	100.00	2640.96	100.00
91						
	3.50	6	40.00	33.33	1333.20	60.43 (1)
	1.50	3	17.14	16.67	285.72	12.95 (2)
Crabs	1.00	4	11.43	22.22	253.97	11.51 (3)
	2.00	2	22.86	11.11	253.97	11.51 (3)
	0.50	2	5.71	11.11	63.44	2.88 (4)
matter	0.25	1	2.86	5.56	15.90	0.72
	8.75	18	100.00	100.00	2205.20	100.00
91						
	4.50	15	31.03	33.33	1031.23	36.48 (1)
	2.25	4	15.52	8.90	138.13	4.87 (2)
	1.25	2	8.62	4.44	38.36	1.35 (4)
neous items	1.25	5	8.62	11.11.	95.77	3.38 (3)
d matter	5.25	19	36.21	42.22	1528.79	53.92
	14.50	45	100.00	100.00	2835.28	100.00
91						
	3.25	5	26.0	33.33	866.58	14.94 (2)
	9.25	10	74.0	66.67	4933.58	85.06 (1)
	12.50	15	100.00	100.00	5800.16	100.00
91						
aneous items	0.25	1	12.50	20.00	2500.00	26.32 (1)
d matter	1.75	4	87.50	80.00	7000.00	73.68
	2.00	5	100.00	100.00	9500.00	100.00
ber 1991						
	0.5	1	10.00	10.00	100.00	2.53 (2)
	3.25	4	65.00	40.00	2600.00	65.82 (1)
ed matter	1.25	5	25.00	50.00	1250.00	31.65
	5.0	10	100.00	100.00	3950.00	100.00
er 1991						
sp.	4.25	7	16.67	11.29	188.20	11.01 (3)
	8.25	18	32.35	29.03	939.12	54.91 (1)
s	1.00	3	3.92	4.84	18.97	1.11 (2)
Crabs	3.75	13	14.71	20.97	308.47	18.05 (2)
	4.00	4	15.69	6.45	101.20	5.92 (1)
es	1.75	6	6.86	9.68	66.40	3.89 (5)
llaneous items	1.25	6	4.90	9.68	47.43	2.77 (6)
ted matter	1.25	5	4.90	8.06		2.31
	25.50	62	100.00	100.00	1709.28	100.00
nber 1991						
sp	10.75	15	16.41	14.15	232.20	4.975 (2)
	42.25	69	64.50	65.09	1198.31	89.975 (1)
s	1.75	2	2.67	1.90	5.07	0.109 (1)
	9.75	16	11.89	15.09	224.69	4.815 (4)
ted matter	1.00	4	1.53	3.77	5.77	0.121
	65.50	106	100.00	100.00	1666.04	100.00

ures in parentheses indicate the ranks of individual food items in their respective months

TABLE-20. Indices of preponderance in different seasons from December 1991-November 1992.

Month	Volume (ml)	Occurrence	VI	OI	VIOI	VIOI / Σ VIOI X 100
December 1991						
Squilla sp.	6.25	5	48.08	31.25	1502.60	64.78 (1)*
Crabs	3.00	3	23.08	18.75	432.75	18.65 (2)
Fish	1.50	3	11.53	18.75	216.19	9.32 (3)
Molluscs	0.75	2	5.77	12.50	48.1	2.07 (4)
Miscellaneous items	0.50	1	3.85	6.25	24.06	1.04 (5)
Digested matter	1.00	2	7.69	12.50	96.13	4.14
Total	13.00	16	100.00	100.00	2319.76	100.00
March 1992						
Squilla sp.	1.5	2	4.41	3.23	14.24	0.644 (5)
Crabs	5.5	7	16.18	11.29	182.67	8.258 (3)
Prawns	11.75	26	34.56	41.94	1449.45	65.524 (1)
Hermit Crabs	1.00	1	2.94	1.61	4.73	0.214 (6)
Fish	7.75	9	22.80	14.52	331.06	14.966 (2)
Molluscs	0.50	1	1.47	1.61	2.37	0.107 (7)
Miscellaneous items	3.00	5	8.82	8.06	71.09	3.214 (4)
Digested matter	3.00	11	8.82	17.74	156.47	7.073
Total	34.00	62	100.00	100.00	2212.08	100.00
April 1992						
Squilla sp	3.75	4	20.00	12.500	250.00	10.20 (3)
Crabs	2.50	3	13.33	9.375	124.97	5.10 (4)
Prawns	6.50	13	34.67	40.625	1408.47	57.43 (1)
Fish	5.0	7	26.67	21.875	583.41	23.81 (2)
Digested matter	1.0	5	5.33	15.625	83.28	3.40
Total	18.75	32	100.00	100.00	2450.13	100.00
May 1992						
Squilla sp.	6.0	4	23.53	12.50	294.13	9.30 (3)
Crabs	1.0	2	3.92	6.25	24.50	0.77 (4)
Prawns	5.0	14	19.61	43.75	857.94	27.13 (2)
Fish	13.50	12	52.94	37.50	1985.25	62.80 (1)
Total	25.50	32	100.00	100.00	3161.82	100.00
July 1992						
Squilla sp	3.5	3	46.67	30.00	1400.1	48.84 (1)
Fish	3.0	2	40.00	20.00	800.00	27.91 (2)
Digested matter	1.0	5	13.33	50.00	666.5	23.25
	7.5	10	100.00	100.00	2866.6	100.00
August 1992						
Prawns	2.00	8	42.105	47.06	1981.49	52.89 (1)
Fish	1.00	2	21.053	11.76	247.58	6.61 (2)
Digested matter	1.75	7	36.842	41.18	1517.15	40.50
Total	4.75	17	100.00	100.00	3746.19	100.00
September 1992						
Squilla sp.	44.60	58	60.96	34.52	2104.34	72.886 (1)
Prawns	8.25	54	11.30	32.14	363.18	12.579 (2)
Fish	9.00	9	12.33	5.36	66.09	2.28 (3)
Miscellaneous items	1.50	3	2.05	1.79	3.67	0.129 (4)
Digested matter	9.75	44	13.36	26.19	349.90	12.119
Total	73.00	168	100.00	100.00	2887.18	100.00
October 1992						
Squilla sp.	9.75	15	38.61	31.915	1232.24	46.062 (1)
Crab	2.75	4	10.90	8.511	92.77	3.468 (3)
Fish	7.15	11	28.71	23.404	671.93	25.117 (2)
Miscellaneous items	0.50	1	1.98	2.128	4.21	0.157 (4)
Digested matter	5.00	16	19.80	34.042	674.03	25.196
	25.25	47	100.00	100.00	2675.18	100.00
November 1992						
Squilla sp.	19.00	35	30.50	23.18	706.99	39.19 (1)
Crabs	4.75	8	7.60	5.30	40.28	2.23 (5)
Prawns	11.00	42	17.70	27.82	492.41	27.30 (2)
Hermit Crabs	3.25	7	5.20	4.64	24.13	1.34 (6)
Fish	8.0	9	12.90	5.96	76.88	4.26 (3)
Molluscs	0.5	2	0.8	1.32	1.06	0.06 (7)
Miscellaneous items	4.75	15	7.6	9.93	75.47	4.18 (4)
Digested matter	11.00	33	17.70	21.85	386.75	21.44
	62.25	151	100.00	100.000	1803.97	100.00

* Figures in parenthesis indicate the ranks of individual food item in respective months.

abs:

Crabs formed the second most preferred item in the 1990-1991 period and ey were observed in all the other months except July and September. he Indices of preponderance for crabs in the other months were-December-.78, March-60.43, April-36.48, May-14.94, October 54.94 and November-.98 (Table-19).

But in the year 1991-1992, crabs formed the third most preferred od item along with the prawns. The indices of preponderance were high December (18.65), crabs were absent in July, August and September the gut contents. In other months the indices were, March-8.25, April-10, May-0.77, October-3.468 and November 2.23 (Table-20).

rawns:

Prawns ranked third in importance in the 1990-1991 period. March d a high index of 12.95. The other months in which prawns were observed ere, April (1.35), September (2. 53) October (1.11) and November (0.109) 'able-19).

In the 1991-1992 period also prawns formed the third most preferred em and the index was high in March (65.524) and very low in September 2.579. Prawns were absent in the gut contents in December, July and ctober. The indices for April, May, August and November were 57.49, 7.13, 52.89 and 27.30 respectively (Table-20).

quilla sp.

Squilla sp formed the fifth important item in the ranking by indices f preponderance. The index was high in October (11.01). In November nd December the values were 4.98 and 4.91 respectively (Table-19).

During the 1991-1992 period Squilla sp ranked second in position and were present in all the months except August. High value was observed in September (72.89) and low value in March (0.644). In December, April, May, July, October and November the values were 64.78, 10.20, 9.30, 48.84, 46.06 and 39.19 respectively (Table-20).

Hermit crabs:

Hermit crabs were observed as the fifth important item in 1990-1991 with high ranking in October (18.05). In December and March the indices of preponderance were 14.75 and 11.51 respectively. Hermit crabs were absent in other months (Table-19).

In the year 1991-1992 also hermit crabs formed the fifth important item and were observed only in March (0.214) and November (0.06) (Table 20).

Molluscs:

Molluscs were present in very low quantities in both the years. In 1990-1991, they were seen only in March (2.88) and October (3.89) (Table-19) while in 1991-1992 they were seen in December (2.07) and March (0.107) (Table-20).

Miscellaneous items:

Miscellaneous items were ranked in the third position during the 1990-1991 period with the highest index noticed in July (26.32). The other months, December (0.82) April (3.38) and October (2.77) showed low indices of preponderance, (Table-19).

Miscellaneous items formed the fourth important item in E. diacanthus in 1991-1992. It was present in very low quantities in December (1.04), March (3.214), September (0.129) October (0.517) and November (4.18). The other months lacked miscellaneous items in the gut contents (Table-20).

5. Indices of preponderance of different food items in the different length groups:

Values of indices of preponderance were taken as the basis of studying the variations in food composition in different length groups.

During 1990-1991 the young fishes showed a preference for crustaceans like crabs, prawns, Squilla sp etc. The size range 81-130 mm showed high preference for crabs and have high ranking in the indices of preponderance. The values varied from 30.47 to 92.68. The second dominant item in fishes of the 81-130 mm range, was hermit crabs, with the indices of preponderance ranging from 0.85 to 75.00. The next important item was Squilla sp., where the values varied between 0.21-12.01. Fish was the fourth important item in this size group and the indices ranged between 1.13-9.20. Prawns ranked fifth followed by molluscs (Indices ranged from 0.06 to 11.43) (Table-21).

During the 1991-1992 period the most preferred food items of young fish, was Squilla sp. The indices of preponderance varied from 49.57 to 73.88 among the fishes of the size class 81-130 mm. Prawns were seen second in ranking with a range in the indices of preponderance of 1.76 to 36.83 for the fish in the size range 71-120 mm. Fish ranked

Length group (mm)	*Squilla* sp.	Crabs	Prawns	Hermit crabs	Fish	Molluscs	Miscellaneous items	Digested matter
71- 80	-	-	-	75.00	-	-	25.00	-
81- 90	-	30.47	7.62	41.91	7.62	11.43	-	0.95
91-100	4.20	92.31	0.35	-	1.39	-	0.70	1.05
101-110	12.01	82.02	0.25	1.66	2.49	0.37	0.83	0.37
111-120	4.38	92.68	0.06	0.88	1.13	0.06	0.06	0.75
121-130	0.21	84.94	0.21	-	9.20	-	0.42	5.02
131-140	39.44	5.63	-	-	50.71	-	-	4.22
141-150	-	48.00	-	-	16.00	-	-	36.00
151-160	-	25.45	2.73	-	43.64	-	0.90	27.28
161-170	-	24.06	-	1.08	48.13	-	0.53	26.20
171-180	-	23.08	5.77	-	63.46	-	-	7.69
181-190	-	34.04	25.53	-	19.15	-	2.13	19.15
191-200	12.01	8.00	-	-	32.00	-	-	47.99
201-210	-	-	-	-	-	-	-	100.00
211-220	-	50.00	-	-	50.00	-	-	-

third in position with values 0.08 to 21.51 for the size range 71-130 mm. Crabs and miscellaneous items were less important in the diet of young fishes. Hermit crabs were observed in the length groups 71-80 mm (27.47), 81-90 mm (3.77) and 101-110 mm (0.03) only. Molluscs were seen only in 91-100 mm (0.01) and 121-130 mm (1.55) size groups (Table-22).

In adult fishes Squilla sp. were observed in the 131-140 mm and 191-200 mm size groups only during 1990-1991 (Table-21). A preference for fish was shown by the fishes in the size range, 131-220 mm. As it formed the most important food item, a corresponding reduction in the consumption of crustaceans was noticed. Crabs showed a decrease in the values of indices of preponderance for higher length groups, the range of the values were 5.63 to 50.00 in the fish with a size range 131-220 mm. The 201-210 mm size group had only digested matter in their stomach. The length groups 131-140 mm, and 141-150 mm lacked prawns, hermit crabs, molluscs and miscellaneous items in their gut contents and were represented by Squilla sp, crabs and digested matter.

During the 1991-1992 period, in higher length groups, an equal preference for prawns and fishes was observed (Table-22). There is a decrease in the Squilla sp. in the higher length groups where it appears in the stomachs of fishes of 141-150 mm (9.44), 161-170 mm (0.54), 171-180 mm (1.02) and 191-200 mm (5.19) size groups. Crabs were a less frequent item and the indices value ranged from 0.94 to 18.18 in the size class 131-220 mm, except in the size class 141-150 mm which showed a high value for crabs (50.36). The fishes in the size range 151-200 mm.

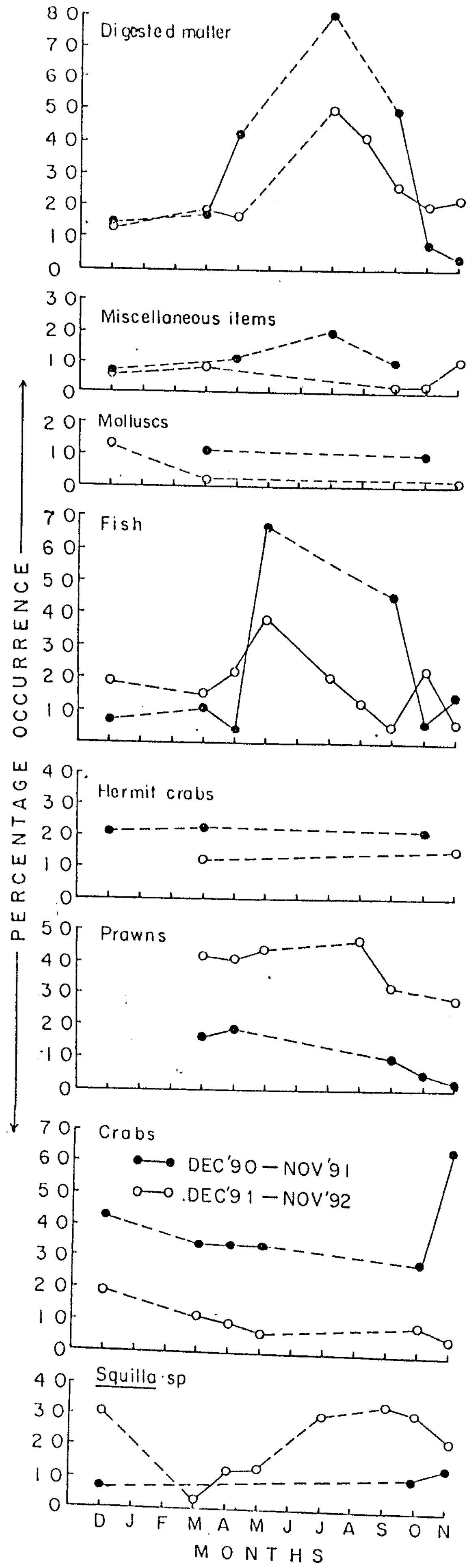
Length Group (mm)	*Squilla* sp.	Crabs	Prawns	Hermit crabs	Fish	Molluscs	Miscellaneous items	Digested matter
71- 80	-	-	13.99	27.97	2.09	-	3.50	52.44
81- 90	52.24	0.88	36.83	3.77	0.08	-	0.34	5.86
91-100	55.44	0.06	24.42	-	2.20	0.01	1.74	16.13
101-110	56.32	0.26	22.82	0.03	5.50	-	0.60	14.47
111-120	73.88	0.50	1.76	-	4.89	-	0.13	18.84
121-130	49.57	0.52	-	-	21.51	1.55	1.03	25.82
131-140	11.60	10.72	4.77	-	54.76	-	0.30	17.85
141-150	9.44	50.36	18.17	-	14.52	0.24	-	7.27
151-160	-	0.94	41.61	0.24	46.34	-	0.94	9.93
161-170	0.54	-	79.93	-	14.89	-	0.18	4.46
171-180	1.02	-	73.72	-	19.11	-	-	6.15
181-190	-	3.54	58.41	-	37.17	-	-	0.88
191-200	5.19	5.19	38.97	-	50.65	-	-	9.10
201-210	-	18.18	-	-	72.72	-	-	-
211-220	-	-	-	-	-	-	-	100.00

showed high values for prawns with the indices of preponderance ranging from 41.61-79.93. The size groups 131-140 mm (4.77) and 141-150 mm (18.17) have shown low values for prawns. Hermit crabs were observed in 151-160 mm (0.24) group. Fish were common in higher length groups with high values of indices of preponderance. They ranged between 19.11 to 72.72 for the size range 131-210 mm. Molluscs were absent in higher length groups, except 141-150 mm (0.24). Miscellaneous items were represented in 131-140 mm (0.30), 151-160 mm (0.94) and 161-170 mm (0.18) size groups.

6. Food items in relation to different seasons:

The percentage occurrence of different food items in different seasons has shown the prevalence of each food item in the diet. (Figure-14) Squilla sp occurred in very low percentages in 1990-1991 period, compared to 1991-1992. In 1990-1991 period crabs occurred in high percentage, November forming the peak season and in the year 1991-1992 they were found in very low percentages. Prawns occurred in high percentages in 1991-1992 and August formed the peak season for it. Hermit crabs and molluscs occurred in low percentages in both the years. Fish were the common food item, found in every month with May being the peak season for it in both the years. Miscellaneous items were not so common but were observed in different months in low percentages. Digested matter was also observed in every month in high percentages.

Fig. 14. SEASONAL VARIATIONS IN THE COMPOSITION OF FOOD IN *E. DIACANTHUS*



Squilla sp.

During the year 1990-1991, Squilla sp. occurred in high percentages in November (14.15%) and October (11.29%). Low percentage of occurrence was observed in December (7.14%). Squilla sp. was absent in March, April, May, July and September.

In the year 1991-1992, the high percentage of occurrence for Squilla sp. was in September (34.52%). In December (31.25), July (30.30), October (31.92) and November (23.18) the percentage of occurrence was comparatively high. Squilla sp occurred in low percentages in March (3.23), April (12.5) and May (12.5). It was absent in August.

Crabs:

High percentage of occurrence was observed in November for crabs (65.09%) in the year 1990-1991. The percentage of occurrence were 42.86, 33.33, 33.33, 33.33 and 29.03 respectively for the months December, March, April, May and October. Crabs were absent in July, August and September during this period.

In 1991-1992 period, the highest percentage of occurrence was in December (18.75). The low percentages of occurrence were in March (11.22), April (9.38), May (6.25), October (8.5) November (5.3). In July, August and September crabs were absent in the gut contents of E. diacanthus

Prawns:

In the year 1990-1991, high percentage of occurrence of prawn was noticed in March (16.67%) while the percentages of occurrence in April, September, October, and November were 8.90, 10.10 , 4.84 and 1.90 respectively. In December, March, July and August prawns were absent.

During the 1991-1992 period, high percentage of occurrence was in August (47.06) and low percentage of occurrence was in November (27.82). In March, April, May and September prawns occurred in 41.94, 40.25, 43.75, and 32.14 percentages respectively. There were no crabs in December, July and October.

Hermit crabs:

In the year 1990-1991 the percentage of occurrence of hermit crabs were 21.43 in December, 22.24 in March and 20.97 in October. In the 1991-1992 period they were 1.61 in March and 4.64 in November.

Fish;

Fish occurred in all the months except July in 1990-1991. High percentage of occurrence was in May (66.67). In December, March, April, September, October and November it occurred in 7.14, 11.11, 4.44, 40.00 6.45 and 15.09 percentage respectively.

High percentage of occurrence was in May (37.50) in the 1991-1992 period. The percentages of occurrence in December, March, April, July, August, September, October and November were 18.75, 14.52, 21.87, 20.00, 11.76, 5.36, 23.44 and 5.96 respectively.

Molluscs:

Molluscs occurred only in March (11.11%) and October (9.68%) in the year 1990-1991. Very low percentage of occurrence of molluscs was observed in December (12.5), March (1.61) and November (9.93) in 1991-1992 and they were absent in other months.

Miscellaneous items:

During 1990-1991, miscellaneous items occurred in December (7.14), April (11.11) July (20.10) and October (9.68). July showed high percentage of occurrence. In other months miscellaneous items were absent.

Miscellaneous items occurred in December (6.25), March (8.06), September (1.79), October (2.128) and November (9.93) in 1991-1992 and they were absent in other months.

Digested matter:

Digested matter occurred in all months except, March in the 1990-1991 period. July (87.5%) showed high percentage of occurrence. The percentage of occurrence in December, March, April, September, October and November were 14.29, 5.56, 42.22, 50.01, 8.06 and 3.77 respectively. There was no digested matter in May.

During the year 1991-1992, highest percentage of occurrence was in July (50%). In December, March, April, July, August, October and November the percentage of occurrence was 12.5, 17.74, 15.63, 41.18, 26.19, 34.04 and 21.85 respectively. In May there was no digested matter in the gut contents.

Food items in rèlation to size groups:

In the percentage occurrence of different food items in different size groups, Squilla sp. was found to be the preferred food item by the lower length groups in both the years. Similar was the case with the crabs. But prawns have shown a relative decrease in the percentages in lower length groups and high percentage of occurrence in higher length groups. Hermit crabs, molluscs and miscellaneous items were also preferred occasionally by the lower length groups in both the years. Fish occurred in all the length groups in both years, low percentage of occurrence in the lower length groups and high percentage of occurrence in higher length groups. Digested matter was also common in all the length groups in both the years (Figure-15).

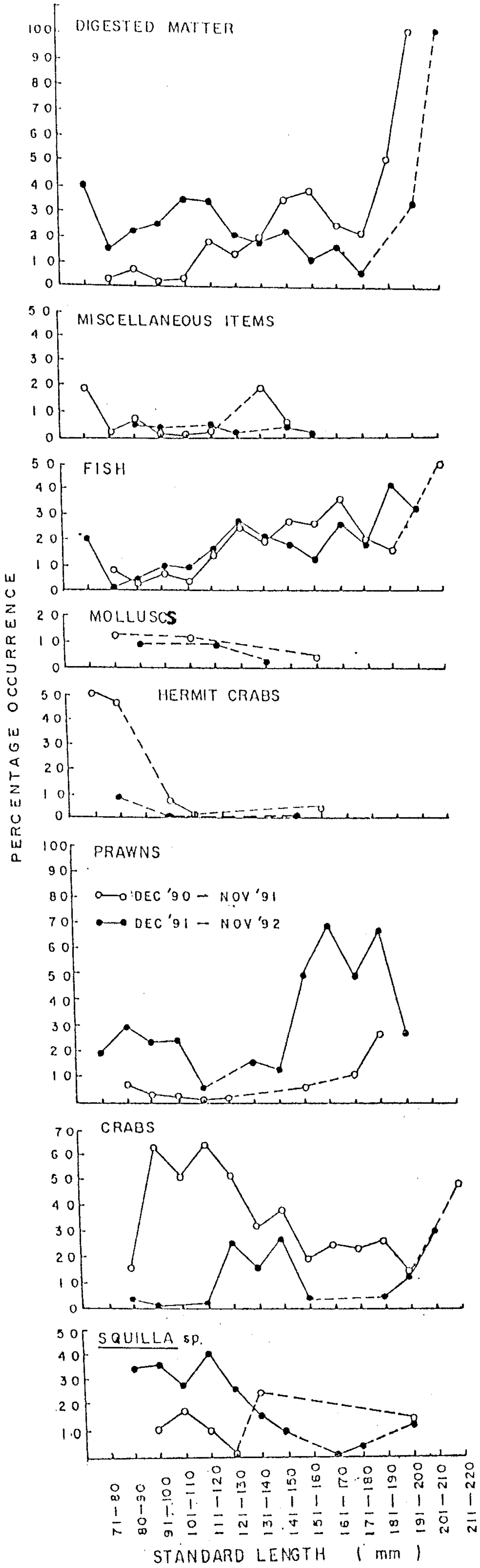
Squilla sp.

During the year 1990-1991, Squilla sp. occurred in high percentage in the 101-110 mm size group of the lower length groups. The length groups 71-80 mm and 81-90 mm lacked Squilla sp. in their gut contents, while the other lower length group fish had Squilla in very low percentages.

In 1991-1992 the fish in the lower length groups showed Squilla sp. in high percentage of occurrence, with the highest being in the size group 111-120 mm (41%).

Squilla sp. occurred in 131-140 mm and 191-200 mm size groups in 26 and 16 percentages respectively and in other length groups, Squilla sp. were absent during the 1990-1991 period.

Fig.15. PERCENTAGE COMPOSITION OF FOOD ITEMS IN E. DIACANTHUS IN DIFFERENT LENGTH GROUPS



Squilla sp. occurred in low percentages in the year 1991-1992. The size groups 161-170 mm, 171-180 mm and 191-200 mm showed 0.2, 0.5, and 14 percentages respectively. Other length groups lacked Squilla sp. in their gut contents.

Crabs:

In the year 1990-1991, Crabs occurred in high percentages in lower length groups. The length groups 91-100 mm and 111-120 mm were the ones which showed high percentage of occurrence. The percentage of occurrence were 64% and 65% respectively.

During 1991-1992, high percentage of occurrence was observed in lower length groups. The length group 121-130 mm (27%) had the highest percentage of occurrence.

High percentage of occurrence was also noticed in higher length groups in the year 1990-1991. The size group 211-220 mm, showed the highest percentage, while in the 201-210 mm size group crabs were absent.

In the year 1991-1992, 201-210 mm size group showed high percentage (32%) in the higher length groups. Crabs were absent in the length groups, 161-170 mm, 171-180 mm and 211-220 mm.

Prawns:

The percentage of occurrence of prawn was very low in lower length groups in both the years.

In the year 1990-1991, prawns were observed in low percentages in higher length groups, 151-160 mm, (5%) 171-180 mm (10%) and 181-190 mm (29%). A high percentage of occurrence of prawns were observed in higher length groups, 161-170 mm (70%) and 181-190 mm (68%) during 1991-1992.

Hermit crabs:

Hermit crabs occurred in high percentages in lower length groups, in the size ranges 71-90 mm and 101-120 mm in the year 1990-1991.

In 1991-1992 period, hermit crabs occurred in 81-90 mm and 101-111 mm in the lower length groups.

In higher length groups hermit crabs occurred in 161-170 mm in 1990-1991 and in 151-160 mm in the year 1991-1992.

Molluscs:

Molluscs occurred in very low percentages in both the years. In 1990-1991, it was observed in 81-90 mm and 111-120 mm in lower length groups, while in 1991-1992, molluscs occurred in 91-100 mm and 121-130 mm.

In higher length groups, molluscs occurred only in 161-170 mm size group in the year 1990-1991 and 141-150 mm only in 1991-1992.

Fish:

Fish occurred in all the length groups in both the years, low percentage of occurrence in lower length groups and high percentage of occurrence in higher length groups.

In 1990-1991 period, the high percentage of occurrence in lower length groups was in 121-130 mm (15%).In 1991-1992,71-80 mm (20%) was the size group which showed high percentage of occurrence in lower length groups.

In higher length groups, the high percentage of occurrence was in 211-220 mm size in 1990-1991 while the size group 201-210 mm lacked fish in their stomach contents. In the '91-'92 period, high percentage of occurrence was in the size group 191-200 mm (42%) while the 211-220 mm size group lacked fish in their gut contents.

Miscellaneous items:

Miscellaneous items were common in lower length groups in both the years. Miscellaneous items occurred in low percentages in lower length groups during 1990-1991. In 1991-1992, high percentage of occurrence was in 71-80 mm (20%) size group amongest lower length groups.

In higher length groups miscellaneous items were present in 141-150 mm (20%) and 151-160 mm (0.7%) size groups in the year 1990-1991. While in the year 1991-1992 miscellaneous items occurred in very low percentage in higher length groups.

Digested Matter:

Digested matter occurred in low percentages in lower length groups, and high percentages in higher length groups. Highest percentage of f occurrence was in the 201-210 mm (100%) size group in the year 1990-1991.

In the year 1991-1992, there was a slight increase in the percentage of occurrence of digested matter with the increase in length, in the lower length groups. In higher length groups there was a decline in the percentage of occurrence. The size group 191-200 mm lacked digested matter in their gut contents. But the 201-210 mm size group showed an increase in the percentage. The maximum was seen in the 211-220 mm (100%) size group.

8. Food and feeding habits in relation to sex:

Among the 731 fish examined, 692 were females and 39 were males. There were no marked differences between the food of males and females.

9. Feeding Habits:

Groupers are characteristically robust build, with large mouth, numerous depressible inner teeth, and usually a few stout fixed canines in the jaws. The canines are largest towards the symphasis of jaws and are in two series in each row. The outer series consists of a single row of enlarged canines and the inner jaw, of a band of smaller caniniform teeth. Caniniform teeth are variously developed on the vomer. palatines, premaxillae, dentaries and branchial bones. The canines are hinged, and yield to backward pressure, but snap into locked position when pushed towards the mouth opening - clearly an adaptation to retain living, moving prey.

During the examination of stomach contents, certain interesting observations were also made on the feeding habits. It was observed that the fish mostly preyed upon whole organisms. The common items that were found whole in the stomachs were Squilla sp., prawns, crabs, hermit crabs, molluscs, and fishes like Stolephorous sp., leognathids, nemipterids, cyanoglossids etc. Rarely fish bones, scales, sand particles, half digested cephalopods, pieces of cuttle bones, crushed molluscan shells etc. were also met with in the gut contents.

In E. diacanthus, it was observed that, the head and tail portions of prawns and Squilla sp. were directed towards the anterior end. No other food item showed this type of orientation in the stomach. In some cases, the gut contents of certain fishes lacked head portion of prawns and these head portions were observed in the stomach of other fishes in the same catch. Once or twice planktonic orgamisms like mysis larvae, lucifer etc. were seen in very low quantities. One Albunia sp. and one berried crab were also met with in the gut contents. From the nature of the stomach contents, it may be inferred that, the fish mainly feed on the bottom, on the actively moving crustaceans and fishes.

3.4 DISCUSSION

Epinephelus diacanthus is a demersal fish in the south west coast of India, which prefers to life on rocky habitats and as such they are undant in the Wadge Bank, Quilon Bank and Gulf of Mannar. Here the a bottom is mostly rocky with outcrops of rocks forming ideal habitats r groupers.

Investigation on the food and feeding of larger size group fishes f E. diacanthus, E. chlorostigma and E. bleekeri obtained from hook and ine have not been found successful, as the stomachs in most of the fish rought up from the depths were everted, or the contents of the stomach were spewed out when the fish were removed from the hooks. Reguritating the food and everting of stomachs during hauling up is common in demersal fishes. Eversion of stomach and disgorging its contents had been observed in gadoides by Menon (1950). According to Fairbridge (1951) a large proportion of flat head disgorge their stomach contents when they are brought to surface. Mohamed (1955) observed that Sciaena diacanthus and Otolithus rubber showed extroverted stomachs while Polydactylus indicus taken from the same place in the same haul didn't show disgorging of the food and the extroversion of the stomachs. Job (1940) mentioned that live specimens when suddenly thrown in to perserving fluid very often vomit the food materials in the stomach. Tandon (1960) observed that the absence of food in the stomachs of 'Choo Parai', Seleroides leptolepis was not due to any regurgitation when hauled up but due to the difference in the time of catching as the fish showed indications of the cessation of feeding during night. The probable causes for the extraoversion and disgorging of the stomach contents were described by Rao (1963) in ghol, Pseudosciaena diacanthus. Silas (1969) also observed everted stomachs in Epinephelus sp. According to Randall (1960) physoclistic fishes from the deep water may be expected to have the stomach fully everted into the mouth.

Groupers form the most important carnivorous fishes of coral reefs feeding mainly on crustaceans and fishes (Smith, 1961; Thompsun and Munro, 1978). The qualitative and quantitative analysis of gut contents have shown that crustaceans and fishes were the most preferred food item of E. diacanthus. During 1990-1991 crabs ranked first and in 1991-1992 Squilla sp came in first position in the ranking by indices of preponderance. The lower length groups (immature) have a preference for crustaceans while the higher length groups (mature) preferred fish the most as has been observed in the ranking. When the indices of preponderance in different seasons taken, fish and crabs came in first and second position respectively in the ranking. The percentage occurrence of food items in different seasons revealed that E. diacanthus didn't show any season wise selectivity or specificity in feeding. The percentage occurrence of food item in different length groups has shown that the higher length groups prefer fishes to crustaceans.

From the information obtained from the fishermen, the trawlnet operation and hook and line operation were in the day time only and thus the materials collected belonged to the day catch. The different food items obtained from the stomach indicate that it is a bottom feeder, feeding mainly on the active mobile crustaceans like Squilla sp., crabs, prawns and fishes. When the intestinal contents of the larger length group fishes which showed everted stomachs were examined, apart from the digested food, remnants of fish, crustaceans skeletons and calcarious matters were also met with.

The feeding intensity in E. diacanthus doesn't show much increase with increasing size. The feeding intensity however was found to increase as the fish advanced to maturity, as in Gasterosteus aculeatus (Hynes, 1950) and in Nemipterus japonicus (Krishnamoorthi, 1972). Menzel (1960) has showed that the feeding efficiency and growth rate of E. guttatus decreases with increase in size, however the rate of food intake also decreases with age. He also found that there is an increase in weight gain and the amount of food taken with an increase in temperature and this indicates faster growth among the caribbean population compared with those of Florida and Bermuda.

Randall (1967) observed that groupers fed both day and night, but more actively at dawn and dusk while smaller serranids were dirunal. But the diurnal groupers in Tahitian water may not feed usually on bright moon lit nights (Randall 1960). Silas (1969) reported that the Kalava would stop biting after dusk. Starck and Davis (1966) have found that the groupers at Alligator reef showed peak feeding activity at Crepuscular periods. Hobson (1965) noted that Mycteroperca rosacea exhibited maximum feeding activity at dawn and dusk and E. labriformis only during the day. Hobson (1968) also suggested that E. labriformis feeds mainly on fishes during the day and on crustaceans at night. Randall and Brock (1960) noticed that crepuscular periods are correlated with greatest feeding activity but more full stomachs were observed after dawn than after dusk. Collette and Talbot (1972) reported that E. guttatus was active during crepuscular and day light hours. Bardach and Mowbray (1955) suggested that most groupers are day feeders since they first locate their prey by smell but sight takes over before feeding commences.

As Smith (1961) observed in other groupers, E. diacanthus also swallows its food without chewing it and so it was fairly easy to identify the organisms present in the stomach. The large eyes of the fish is an indication that the fish feeds by sight. Job (1940) observed that even the disposition of the mouth of perches like E. tauvina is more suited for browsing and pecking off food from the ground. The fish opens its mouth and dilates the gill covers rapidly draw in a current of water and literally inhales the food (Smith, 1961). Some fishes change the composition of the diet as they grows in size as has been observed by Hynes (1950) and Rao and Rao (1957). In E. diacanthus also the nature of the food components is size dependent. The lower length group fish showed a preference for crustaceans while the higher length groups preferred fishes as primary constituent of food. Allen (1935) found that the summer food of perch changes with the size of the fish. Randall (1965) observed that in predatory species, crustaceans were eaten by the small fishes, and as the fish grows, fishes become progressively more important as potential food organisms.

In Tahitian waters E. merra prefer crustaceans and fishes as their major food items (Randall, 1969). Menzel (1960) observed that crustaceans were the major food components in E. guttatus from Bermuda. Randall (1967) mentioned the food of E. striatus as crustaceans. E. striatus from the virgin islands and Puerto Rico also fed more upon fish and less on crustaceans (Randall, 1965). He also observed in E. striatus the tendency of larger length group fish to eat more of fish. Thompsun and Munro (1978) reported that E. guttatus feeds on small grunts (Haemulon aurolineatum and H. melanurum), crabs (small Mithrax spp) and Scyllarid lobsters. Randall (1967) studied the food habits of reef fishes of West Indies and discussed the food habits of five species of Epinephelus. In E adscensionis and E. guttatus crabs formed the primary food item and in E. itajara spiny lobsters formed the primary the primary food item. Curstaceans and fishes were the most preferred item by E. morio. Fishes formed the primary food component in the case of E. striatus. Premalatha (1989) studied the food habits of E. aereolatus, E. chlorostigma, E. bleekeri and E. diacanthus and reported that the diet composition of E. areolatus was mainly small crustacean and molluscs. E. chlorostigma fed mainly upon crustaceans. Remnants of ostracods, fish scales and cuttle bones were also met with in them. In E. diacanthus red calcarious matters and shell fragments were common. In general she observed that the rock cods inhabiting the rough-bottom are carnivorous and active predators feeding mainly on crustaceans, cephalopods and fishes.

In the present study, there was no sex-wise difference in the food and feeding habits of E. diacanthus. A good number of empty stomachs were also met within the fish. Maximum number of empty stomachs were noticed in November during the 1990-'91 period and September and October in the year 1991-'92. The frequent occurrence of empty stomachs or stomachs with little food contents in this case may probably be dependent on the ratio between the size of the fish and size of the prey as reported by Allen (1935) for the perch, *Perca fluviatitis.* When the fish feeds on smaller organisms, they require a number of them and hence the necessity to feed constantly so that their stomachs will be rarely empty. When the prey is larger the fishes obtain enough food quickly and there may be some interval between the consecutive feeds.

CHAPTER 4

REPRODUCTIVE BIOLOGY

4.1. INTRODUCTION

Studies on the reproductive biology of fish are useful to arrive at a better understanding of the annual regeneration of their stocks. Reproductive parameters such as size at first maturity, spawning season, spawning frequency, fecundity and recruitment are of great value in fishery predictions and formulation of management measures.

Groupers are well known for their protogynous hermaphroditism (Smith, 1959, 1961, 1965, 1971) a condition that is derived from synchronous hermaphroditism of other serranids of the subfamily serraninae (Smith, 1965). According to Atz (1964) hermaphroditism is the presence of recognizable ovarian and testicular tissue in a single individual. He described that normal hermaphroditism exists, in a uniform way, at sometime during the ontogeny of all or many members of a species. Functional hermaphroditism is the hermaphroditism in which the individual functions both as male and female during its life time. In synchronous hermaphroditism the individual is capable of functioning as male and female at the same time. Here the ripe eggs and sperms develop in the gonad or gonads simultaneously. Protandrous hermaphroditism is the condition in which the individual functions first as male and later in life as a female. But in protogynous hermaphroditism the individual functions first as a female and later in life as a male.

Atz (1964) also described intersexuality as the presence of both male and female characteristics or of intermediate sexual characteristics, in a single individual. All hermaphrodites are intersexes, but some intersexes are not hermaphrodites. Gonochorism is the existence of one sex, either male or female, in the individual. Sex reversal is the change from one sex to another, that is from the possession of recognizable ovarian tissue to that of testicular tissue, or vice versa. Sex inversion is the aquisition by an individual belonging to one sex of characteristics similar to those of the opposite sex, but not including recognizable gonadal tissue of that sex.

Sex reversal is wide spread in a number of tropical fishes including the families labridae, scardiae and serranidae. The general types of hermaphroditism in the serranidae have been shown to be a useful systematic character. Hermaphroditism is found in at least 18 families of teleost fishes scattered throughout five orders (Atz, 1964) and is also wide spread among the invertebrates (Ghiselin, 1969).

The phenomenon hermaphroditism has been observed by many workers. Dean (1923) and Herbert (1932) observed hermaphroditism in teratological condition, Lavenda (1949) found protogynous hermaphroditism in Centropristes striatus, Spurway (1957) discribed first functional hermaphroditism resulting in self-fertilization in a viviparous fish Lebistes reticulatus, and Clark (1959) reported the self fertilization in Serranus subligarius. Smith (1959) described synchronous hermaphroditism in four Bermuda species of the subfamily serraninae. He put the members of the subfamily Epinephelinae under proterogynous on the basis of the following evidence (1) no males were found in the smaller- sized groups (2) males appeared among medium-sized fish and the proportion increased among the higher-sized classes until the larger sized groups were exclusively males and (3) regressive oocytes were found in the testes of functional males. Smith (1959) has also suggested that more than one spawning season is passed in the female phase before changing sex. Liem (1963) described that in Monopterus albus every individual starts its reproductive cycle as a functional female and that males are produced only by sex reversal. He also found that individuals of intermediate age and length possess ovotestes. McEarlean and Smith (1964) suggested that the gag, Mycteroperca microlepis mature as females during their fifth or sixth year and transform to males during their 10th or 11th year. He also suggested a closer correlation between age and sex than there is between size and sex and that some mechanism other than growth alone triggers the change. Smith (1965) described three patterns of hermaphroditism in serranids, the Serranus type, in which the male tissue confined to the posteroventral region, the Epinephelus type in which the entire gonad is an admixture of ovarian and testicular tissue and the Rypticus-Anthias type which is in some respects intermediate between the Serranus and the Epinephelus condition. Ghiselin (1969) has stated that hermaphroditism should evolve under the following conditions, (a) where it is hard to find a mate (b) where one sex benefits from being larger or smaller than the other or (c) where there are small, genetically isolated populations. Moe (1969) has proposed that sequential hermaphroditism is used as a population control mechanism, with the mean transformation age shifting earlier or later to provide fewer or more females respectively, in times of overly high or low population density. Heterogamety in teleostean fishes has been described by Ebeling and Chen (1970). Harrington (1971) described about the self fertilizing hermaphrodites of Rivulus murmoratus Brusle`and Brusle´(1972) described ovarian and testicular intersexuality in the protogynous Mediterranian groupers E. aenus and E. guaza where the gonads were ovotests and of Epinephelus type. They also observed that in E. aenus and E. guaza all young fishes were females and the first functional activity was oogenetic. Males occurred among the largest individuals after sex reversal. Sex-reversal occurred during sexual inactivity. The period of sex reversal (ovary ⟶ ovotestis ⟶ testis) frequently showed transitional stages in the form of ovarian and testicular intersexuality. Sex reversal has also been described by many workers like Warner, (1975), Warner et al., (1975), Manooch (1976), Bortone (1977), Thompsun and Munro (1978), Bruce (1980), Hastings (1981), Walter et al., (1982), Young and Martin (1982), Cole (1983), Abu Hakima (1984), Erikson and Grossman (1986), Hastings and Peterson (1986) etc.

Aldenhoven (1986) has conducted experiments under field condition and observed that females of protogynous, Centropyge bicolor may be induced to change sex by recruitment of a threshold number of additional adult females in to the group even in the presence of the male. The presence of yellow-brown bodies in the testes was used uncritically in the past to conclude in favour of hermaphroditism (Sadovy and Shapiro 1987). Shapiro (1981, 1987) found that social environment has a control over the sex in the case of coral reef fishes. Fisher and Petersen (1987) gave an account on the evolution of sexual patterns in the sea basses. Cole and Robertson (1988) have not observed any remnants of ovarian tissue in Coryphopterus personatus, a protogynous hermaphrodite. The sperm produced are transported through a newly formed, permanent system of anastomosing tubules that comprise the body of the gonad. Nakamura et al., (1989) described three phases in the protogynous hermaphrodite Thalassoma duperrey, small initial phase males (primary males), initial-phase females (primary females) and large terminal-phase males, which may be derived from either females which have undergone sex change to become males (secondary males) or from initial-phase males (terminal-phase primary males). Recently the subject was discussed by Cole (1990), Horvath et al., (1990), Ross (1990), Kusen (1991), Nakazono and Kusen (1991); Kusen and Nakazono (1991), and Webb and Kingsford (1992), in various species of fishes.

Hermaphroditism in Indian fishes were reported by Chacko and Krishnamoorthy (1949) in the Indian Shad, Hilsa ilisha, Prabhu and Antony Raja (1959) in the Indian mackeral, Rastrelliger kanagurta, Nayak (1959) in Polynemus heptadactylus, Raju (1960) in the skip jack Katsuwonus pelamis Antony Raja (1963) in the oil sardine Sardinella longiceps, Hida (1967) in polynemids, Patnaik (1967) in the Indian salmon, Eleutheronema tetradactylum, Kagwade (1969) in Polydactulus indicus and Dorairaj (1973) in the threadfin fish Polynemus microstoma. No references regarding hermaphroditism in groupers from Indian waters were available.

4.2. MATERIALS AND METHODS

The materials for the study on the reproductive biology of E. diacanthus, E. chlorostigma and E. bleekeri were collected from the commercial trawler and hook and line landings of Cochin Fisheries Harbour during December '90 to November '92. Microscopical examination of the gonads is essential since the sex can not be identified macroscopically except for the ripe male and female fishes. The fish were brought to the laboratory in fresh condition and the total length, standard length and weight of each individual fish were noted. The gonads were removed and weighed. A small piece of the gonad was cut and sexed microscopically using the acetocarmine squash method (Guerrero, 1974) and the remaining portion was kept in Bouin's fixative for histological examinations.

Observations carried out on maturity stages for two years were analysed and their percentages calculated monthwise. Spawning season was determined on the basis of the distribution of the different maturity stages, particularly the dominance of advanced stages with respect to time.

Gonosomatic indices for different months, stages, and length groups for both sexes were also determined using the formula $GSI = \frac{GW}{TW} \times 100$, where 'GW' is the weight of gonad and 'TW' is the total weight of the fish.

Spawning periodicity was determined by studying the ova-diameter frequency (Clark, 1934; Hickling and Rutenberg, 1936; Prabhu, 1956). A small piece of the ovary was taken and teased on a microslide. The ova spread over it. Ova-diameters were measured from 100 ova, with the help of an ocular micrometer at a magnification which gave a value of 0.0166 mm to each micrometer division. The ova were taken from the anterior, middle and posterior portions of the ovary and ova-diameter frequency polygons were drawn.

Fecundity, the number of eggs released by an individual fish during a spawning season was determined from 28 ovaries of E. diacanthus in the stages 4 and 5 and 19 ovaries of E. bleekeri in the stage 4. Ovaries were removed and excess moisture was blotted out with a blotting paper. Weight of the ovary was taken to the nearest 1 mg, using digital electric balance. A piece of ovary was taken from the middle portion and weighed. This sample was preserved in modified Gilson's fluid (100 ml of 60% alcohol + 800 ml water + 15 ml of 80% nitric acid + 18 ml glacial acetic acid + 20 g mercuric chloride) in screw capped glass vials. These vials were periodically shaken to liberate the ova from the ovarian tissue. Fecundity was estimated using the formula, $F = \frac{nG}{g}$, where 'n' is the number of ova is the sample, 'G' is the weight of the ovary and 'g' weight of the small piece of ovary

Gonads from fresh specimens were fixed in Bouin's fixative for 24 hours. The tissues were then washed under running tap water and stored in 70% ethyl alcohol until further processing. The stored tissues dehydrated in graded alcohol series, and kept in methyl benzoate until they became transparent. They were then transferred to benzene followed by benzene-wax mixture, and impregnated with and embedded in molten wax (58°C melting point). The embedded material was sectioned at 7-10 μ on a rotary microtome. The sections were spread over glass slides on which the adhesive Mayer's albumen was applied. They were later deparaffinised in xylene, hydrated, stained with Delafield's haematoxylin, counter stained with 1% aqueous eosin, dehydrated and mounted in DPX.

.3. RESULTS

The structure of protogynous epinephelid gonad was found to be similar to that described by Smith (1965) (Plate-XII-XIII). Each organ consists of of a hollow sac, lying below and behind the posterior part of the air bladder and connected to it by mesentries. The gonads are relatively small, the weight of the ripe gonads relative to the total weight of the fish is small. The right and left lobes are usually unequal in size, which join posteriorly and descend as an oviduct to the genital region immediately behind the anus. The urinary bladder is closely bound to the posterior face of the common oviduct. Supporting mesentries continue forward from the anterior end of each gonad as ligaments that join a complex of ligament and mesenteries at the anterior end of the swimbladder.

The wall of the gonad is covered externally with a peritonial layer. The muscular tunica is composed of an intermixture of longitudinal, oblique and circular fibres. The lumen is lined with germinal epithelium which forms the surface layer of a series of longitudinal, slightly obique folds or lamellae. The oocytes as they enlarge fill and extend the lamellae. There are no lamellae in the common oviduct or in the ventro-lateral sector of the gonad proper and as Smith (1965) suggested, this alamellar sector possibly allows the distension of the gonads with ripe eggs without injuring the germinal epithelium.

The male tissue is of the acinus type in which the sperms are formed in small, more or less spherical crypts (acini) and all the cells within a given crypt are at the same stage of meiosis. These crypts are surrounded by connective tissue membranes that break down when the sperms reach maturity. Thus the groups of sperm cells are isolated during spermatogenesis and merge when the sperm are fully developed. Prespawning individuals have, some crypts containing tailed sperm, many crypts with spermatogonia, many with primary spermatocytes and many with secondary spermatocytes. At the height of sexual activity most crypts are filled with mature sperms and only a few contain spermatogonia. After spawning, most crypts are empty, but it is nearly always possible to find a few sperms in crypts or duct. The sperm sinus and duct are developed only during the male phase.

1. Oogenesis

Moe (1969) utilized the criteria established by Kraft and Peters (1963), Smith (1965) and Yamamoto and Yamazaki (1961) for the descriptions of the stages of oogenesis in red grouper, Epinephelus morio. In this study description established by Moe (1969) was followed. The description were made on the basis of gonad sections of E. diacanthus.

Primary stage - oogonia:

In this stage the oocyte diameter ranges from 5 to 17 /u. It includes premeiotic meiotic and postmeiotic oogonia. These cells are embedded in the ovigerous tissue usually found along the periphery of the ovarian lamellae. They are most abundant before vitellogenesis. A single nucleolus is centred in the nucleus and chromatin strands form a network through the remaining nuclear area. The cytoplasm stains lightly with little affinity for haematoxylin.

Stage I - early oocytes:

In this stage the diameter of the oocyte ranges from 17 to 50/u. The nucleus is reduced in relative size. The nuclear margin is usually not sharply defined and the large central nucleolus moves to the periphery of the nucleus during this stage. Chromatin strands in the nucleus are still visible but are losing organization. The cytoplasm becomes strongly basophilic cytoplasmic reaction first occurs at the periphery of the oocytes and then apparently spreads rapidly and unevenly throughout the remaining cytoplasm. A thin follicular layer surrounds the oocyte at this stage (Plate XIVa).

Stage 2 - resting; previtellogenic oocytes:

In this stage the oocyte diameter ranges from 40 to 90 /u. This stage occurs before vitellogenesis. The relative size of the nucleus is highly variable because of the inconsistency of form exhibited by oocytes in this stage. The nuclear margin is sharply defined and there are several nucleoli one larger than others, present around the nuclear periphery. Chromatin granules are scattered throughout the nucleus. The cytoplasm is strongly and evenly basophilic. A thin follicular layer surrounds the oocyte (Plate XIV a).

Stage 3 - early vitellogenic oocytes:

The oocyte diameter in this stage ranges from 60 μ to 200 μ. The oocyte expands usually and regains its rotundity. The nucleus increase in relative size. The cytoplasm loses its strong affinity for haematoxylin and yolk vesicles appear in the less basophilic granular cytoplasm. Yolk globules appear around these vesicles in the middle and late stage 3. The zona radiata forms as a thin acidophilic membrane. The follicular layer is well formed at this stage (Plate XIV b).

Stage 4 - vitellogenic oocytes:

The oocytes in this stage range from 80 μ to 520 μ in diameter. The oocyte continues to expand and reaches maximum attainable size before ovulation. The nucleus is well defined in early stage 4. Yolk vesicles are prominent and usually surround the nucleus in early stage 4 and coalesce, usually toward the center, when nucleus loses definition. These yolk vesicles are usually evident in late stage 4 near the oocyte periphery. Acidophilic yolk globules largely replace the basophilic cytoplasm in early stage 4 and become large and well defined in mid stage. The yolk globules coalesce in late stage 4 and present a smooth acidophilic appearance. The zona radiata remains as a broad band into late stage 4 but the radial striations lose definitions. The follicular layer is well developed (Plate XIV c).

Stage 5 - egg stage:

This is final stage before spawning. Maturation into this final stage apparently takes place very quickly, probably within few hours, for eggs at this stage have not been found in intact follicles, but in the lumen or in ruptured follicles. These early stage 5 eggs have a lightly staining, acidophilic, granular yolkmass with a few yolk vesicles and yolk globules forming a loosely defined nucleus. The zona radiata forms a thin non-striated oolemma and the follicular layer, if present is ruptured.

Moe (1969) described an "oocyte rejuvenilization" characterized by a broad inner band strongly basophilic cytoplasm surrounding the nucleus and a rather narrow outer band of granular, relatively light basophilic cytoplasm.

Formation of atretic bodies:

Mature E. diacanthus exhibited distinctive atretic bodies formed from the remnants of yolk globules and yolk vesicles (Plate XIVd). These atretic bodies form a characteristic brownish mass, the corpus atreticum and are composed of amorphus brownish granules, phagocytes and clear yellow pigment globules (Smith, 1965; Moe, 1969). Unshed stage 4 oocytes are retained in the post spawning gonad and unlike early stage 3 oocytes, they can not regress to the resting state and must be resorbed. The zona radiata is rapidly lysed and the follicle then contains only yolk vesicles, yolk globules and undifferentiated ooplasm. The yolk vesicles tend to remain in situ after the yolk globules have dispersed in the lamella and the undifferentiated ooplasm has been resorbed. The yolk globules lose their smooth appearance and become granular due to the formation of small internal globules. These liberated acidophilic yolk globules disperse throughout the lamellae and persist when other evidence of spawning or vitellogenic activity have disappeared. Atretic bodies often form at the site of a degenerated oocyte, but these bodies eventually move to the centre of the lamella. Old established atretic bodies are usually seen near a veinule in the centre of a lamella or near the dorsal vein.

2. Spermatogenesis

Spermatogenesis has been divided in to five stages viz. spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids and spermatozoans (Plate XV to XVII). The testicular tissue of Epinephelus spp is of the acinus type, in which sperms are formed in small crypts (acini) and all cells within each crypt are at the same stage of meiosis (Smith, 1965). Spermatogonia arise from the primary germ cells. Spermatogonia develop into primary spermatocytes through cell division and reduction of cytoplasm. Primary spermatocytes have no visible nuclear membranes and are composed mainly of deeply staining chromatin material (3 μ). There is great variation in the number of spermatocytes in the crypts of primary spermatocytes. Secondary spermatocytes are formed through cell division and subsequent concentratoion of nuclear material. Secondary spermatocytes are smaller (2 μ) than primary spermatocytes. Spermatids are formed from secondary spermatocytes after reduction division. Spermatids are smaller than secondary spermatocytes. They generally occur in large numbers in expanded crypts and are randomly spaced within the crypt. Spermatids give rise to tailed spermatozoa.

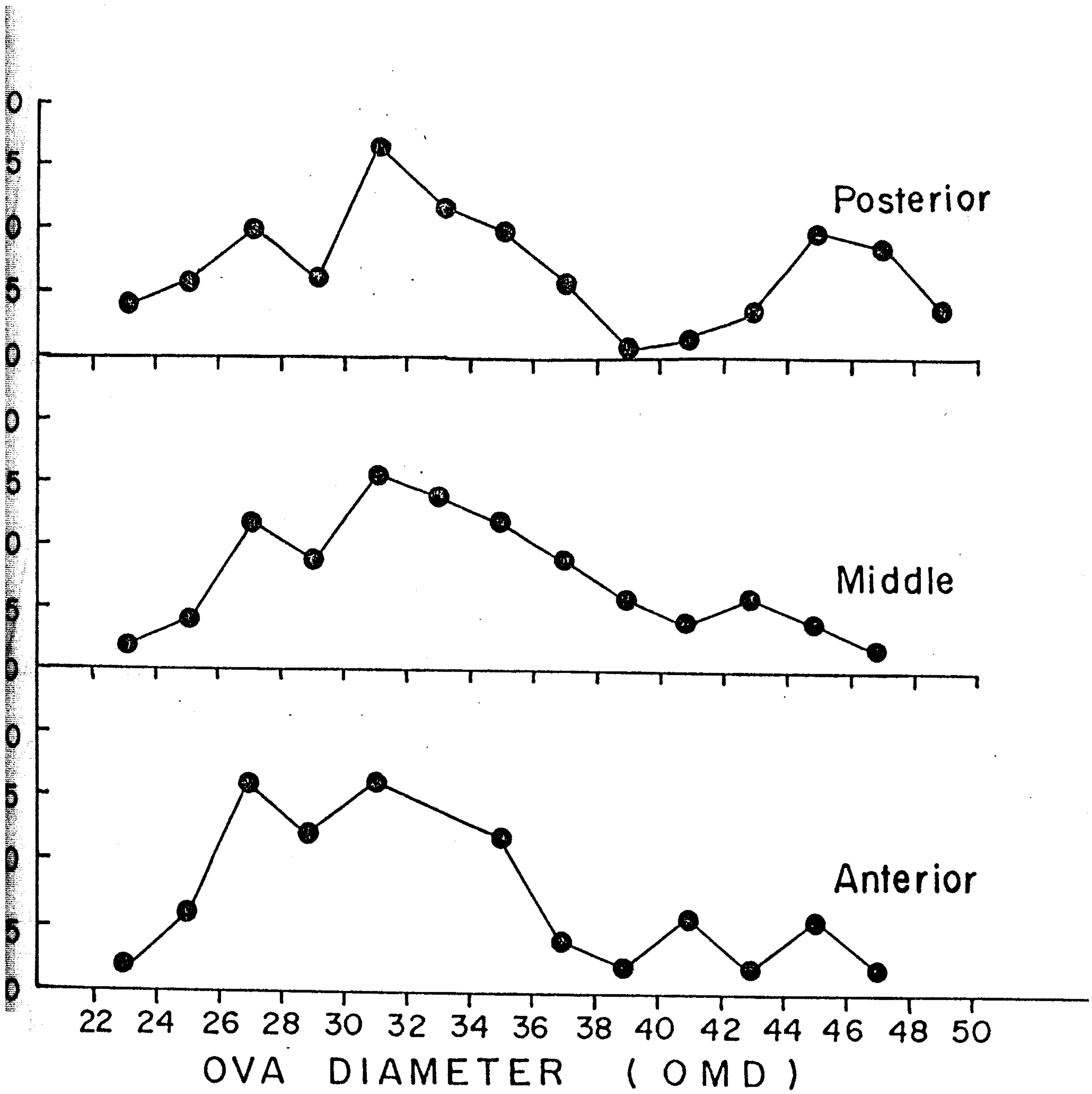
3. Spawning periodicity in E. diacanthus:

Spawning periodicity is determined from the ova-diameter frequency polygons.. The diameter of ova was. measured and grouped at class intervals of 2 ocular micrometer divisions. Oocytes were measured with the help of an ocular micrometer at a magnification of 100X. At this magnification one micrometer equals 16.6 µ. The percentage size frequency distribution of ova in the anterior, middle and posterior regions of the same lobe of mature ovary is represented graphically in figure 16 to show that there is no significant variation in the size distribution of ova in the different parts of the same lobe of the ovary.

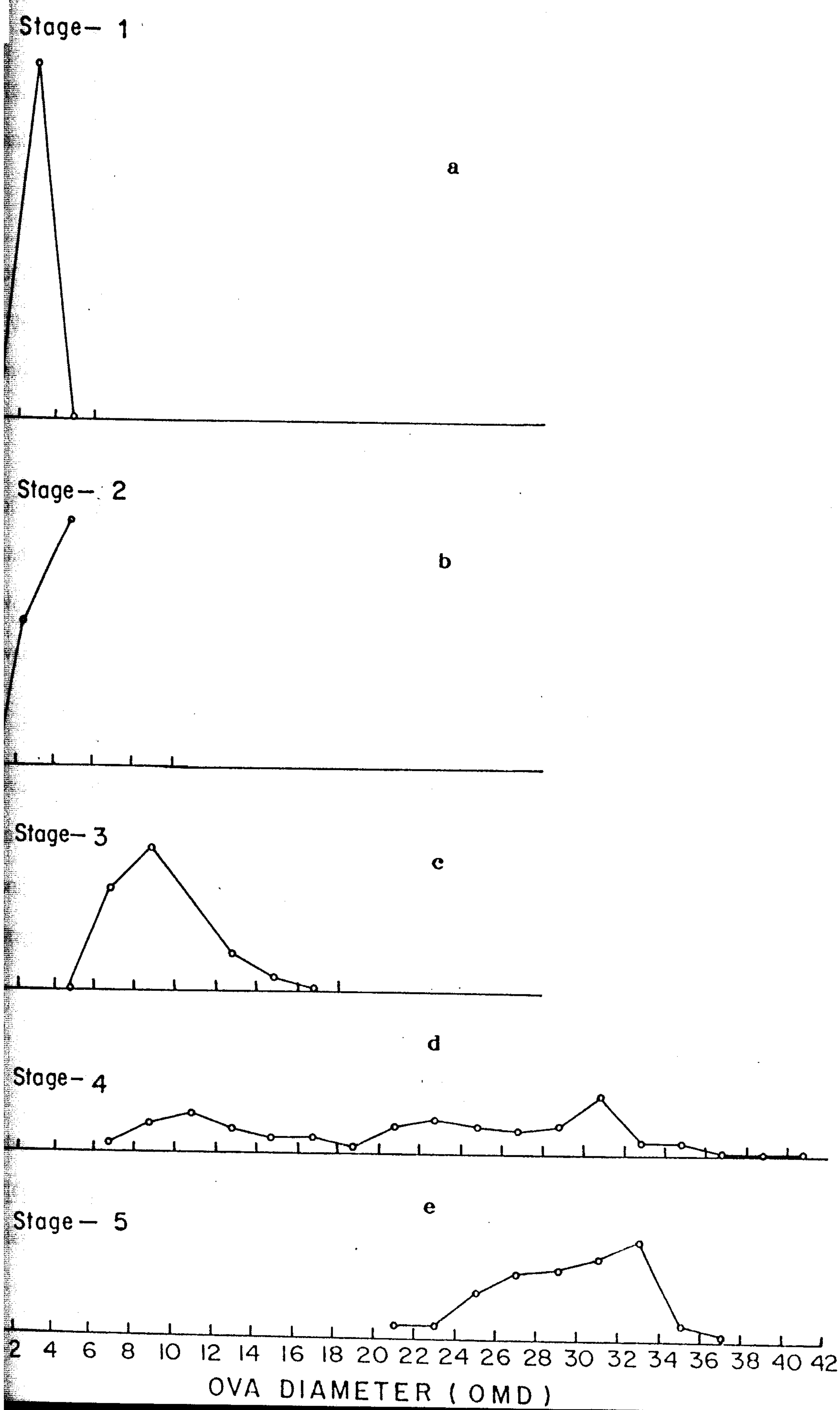
In stage 1 the oocyte-diameter frequency polygon was drawn from the oocytes of 125 ovaries. In this stage only one mode appeared at the class interval 2-4 (OMD) (Figure 17a).

In stage 2, the oocyte-diameter frequency polygon was drawn from the oocytes of 101 ovaries. Here two modes appeared in the class intervals 2-4 and 4-6 (OMD). But the mode at 4-6 (OMD) was more conspicuount (Figure 17 b).

THE OVA DIAMETER FREQUENCY POLYGON OF THE ANTERIOR, MIDDLE AND POSTERIOR REGIONS OF A MATURE OVARY OF *E. DIACANTHUS*



IE OVA DIAMETER FREQUENCY POLYGONS OF THE OVARIES OF DIACANTHUS IN VARIOUS STAGES OF MATURITY



In ova-diameter frequency polygon of stage 3 oocytes taken from 76 ovaries, the oocytes in the class interval 8-10 have a prominant mode and modes in other class intervals were inconspicuous (Figure 17 c).

In stage 4, oocyte frequency polygon was drawn from oocytes of 20 ovaries. In this stage 3 distinct modes appeared in the class intervals 10-12, 22-24 and 30-32 (OMD) more conspicuous mode was at 30-32 class interval (Figure 17 d).

The stage 5, oocyte frequency polygon was drawn from the oocytes of 8 ovaries. In this stage only one prominant mode could be seen in the class interval 32-34 . The other modes were vary inconspicuous. No oocytes smaller than 21 OMD and no oocytes larger than 37 OMD were seen in this stage (Figure 17e).

The ova-diameter frequency polygons have shown that the mature ova in the Stage 5 are distinctly separated from the immature stocks in stages 1, 2 and 3. Thus it is clear that the fish E. diacanthus spawns only once a year for a short duration and spawning takes place in the Stage 5 in the case of female.

4. Gonad development classes:

Following Smith (1965) and Moe (1969) the seasonal and ontogenetic changes in gonad development in these three species of viz. Epinephelus diacanthus, E. chlorostigma and E. bleekeri have been divided into ten classes the basis for seasonal analyses of sex distribution and spawning. The classes 1 to 4 are pertaining to female classes, class 5 is transitional and classes 6 - 10 represent males. In female, class 1 is immature and classes 2, 3 and 4 are seasonal stages in the mature female. Classes 5 and 6 are developmental classes in male, ie., transitional and immature male respectively and classes 7, 8, 9 and 10 are seasonal classes in the mature male. Males are broadly divided into primary males and secondary males based on the presence or absence of early oocytes (oocyte stage 2) in the matrix of the testicular tissue. Secondary males contain great numbers of stage 2 oocytes held over from the female phase of sexuality. These early oocytes diminish in size and number as the male ages and eventually disappear from the testis. Atretic bodies remain with the testis and are vestiges of the female phase that always remain in the gonad. The early stage 2 oocytes are either resorbed by the testis or perhaps flushed from the testis during repeated spawnings.

Class 1 - Immature female   Plate XIV a

Class 1 is defined as an ovary that shows no signs of prior spawnings The ovary is relatively small in diameter and contains oocytes in stages 1 and 2. Atretic bodies are not present in this class.

Class 2 - mature resting females   Plate XIV b.

Class 2 is defined as an ovary that had undergone extensive vitellogenesis and recovered into resting state. Oocytes in stages 1, 2 and sometimes 3 are present, with those in stage 2 dominating the ovary. Atretic bodies are present indicating past spawning.

Class 3 - mature active female (pre-spawning) Plate XIV c.

Class 3 is defined as an ovary that is in active vitellogenesis and is in preparation for spawning. Oocytes are in stages 1, 2, 3 and 4 with stage 3 oocytes dominating during early development of this class. Stage 4 oocytes then dominate the ovary until spawning taken place. The ovary may remain in class 3 for several weeks or more until spawning conditions are present. Oogonia and stage 1 oocytes are uncommon in class 3 ovaries. Atretic bodies are usually present, but they are obscured by extensive oocyte development.

Class 4 - spent female (post spawning) Plate XIV d.

Class 4 is defined as an ovary that exhibits evidence of recent spawning. This class develops into either class 2 or class 5 and while development into class 5 is very rapid, development in to class 2 is gradual. The muscular tunica is loose and flaccid at first and gradually contracts to the resting state. The structure of the gonad is greatly disrupted and individual lamellae are not clearly distinguishable. All five stages of oocytes are found, but stages 3, 4 and 5 are degenerating. Yolk globules from stage 4 oocytes are scattered throughout the gonad and are forming into atretic bodies. The empty follicles collapse soon after release of the egg and the follicular cells are resorbed into the restructuring gonad.

Class 5 - transitional; Plate XV a.

Class 5 is defined as an ovary in the early stages of development into testis. This is a temporary class and the fish rapidly develop through this class into class 6. Sexual transition usually occurs immediately after spawning or vitellogenic activity in the female. Remains of stage 2, stages 3 and stage 4 oocytes are common. Atretic bodies present. Semi-niferous crypts proliferate in the germinal epithelium (A gonad with fully formed crypts is regarded as a testis even though it may contain abundant oocytes, Moe, 1969).

Class 6 - immature male; Plate XV b

Class 6 is defined as a young disorganized testis with extensive proliferation of semniferous tissues. Though stage 2 oocytes are present, their nuclei are pycnotic indicating the cessation of oogenesis. Crypts of semniferous tissue are active in the germinal epithelium of all lamellae during this class, but have not invaded and surrounded the stage 2 oocytes near the centre of the lamellae. The germinal epithelium and dorsal musculature of the gonad separate and form sinuses for collection and transmission of sperm to the posterior sperm duct.

Class 7 - mature inactive male; Plate XV c

Class 7 is defined as a fully developed testis dominated by the early stages of spermatogenesis. Most crypts contain primary spermatocytes spermatogonia, secondary spermatocytes may also be present. Atretic bodies are conspicuous in this class.

Class 8 - ripening mature male; Plate XVI a

Class 8 is defined as a fully developed testis dominated by the later stages of spermatogenesis and the early stages of spermiogenesis. This class is common during spawning reason. Secondary spermatocytes and spermatids are contained in most crypts and tailed sperm are seen collecting in the dorsal sinuses.

Class 9 - ripe male; Plate-XVII a.

Class 9 is defined as a fully developed testis dominated by spermatogenesis and collection of tailed sperm. Crypts are expanded and contain spermatids or tailed sperm. Dorsal collecting sinuses are dense with collected tailed sperm and the entire gonad is moderately distended. Crypts of spermatogonia and spermatocytes are rare.

Class 10 - post spawning male; Plate-XVII b.

Class 10 is defined as a fully developed testis dominated by stromal tissue and rapidly developing crypts of spermatogonia. The old crypts stand empty with a few tailed sperm. The muscular tunica is somewhat extended and loose and the individual testicular lobules (lamellae) are well separated.

The three species of Epinephelus, E. diacanthus, E. chlorostigma and E. bleekeri are protogynous hermaphrodites and sex can not be determined macroscopically unless the gonad is ripe. A total of 522 E. diacanthus, 161 E. chlorostigma and 115 E. bleekeri were sexed histologically and 28 E. diacanthus and 19 E. bleekeri macroscopically since they were ripe fish and there was no doubt as to their sex. No ripé female fish were observed in E. chlorostigma and no transitionals in E. bleekeri. The data for E. chlorostigma and E. bleekeri were fr the seasonal fishing which start from the end of November and stop by the beginning of March. Thus the data collected for these two species are for two years from 1990-1992, in the months December, January, February, March and November. Table-23 lists the basic data on all sexed fish, E. diacanthus in each age group according to their size.

Seasonality of gonad development and sexual transitions in E. diacanthus

Distribution of gonad classes of all sexed E. diacanthus in different months is shown in Table -24. Pooled (1990-92) monthly distribution of different gonadal classes in percentages are represented in the figure-18.

Ripe gonads were encountered from March through July, with peak occurrence in May. Mature male gonads were found in December, January, February, March, April and May. Post spawning females were common in July, August and September. Post spawning males observed only in January. Most of transitional males were observed in December, January, February, August, September and November. August and September appeared to be out of season for sexual development and December, January and February as the months of active sexual development, sexual transition is mostly observed before or after the spawning season.

In December, the female classes, 1, 2 and 4 were observed in 27, 53 and 0.9 percentages respectively. Class 3, mature active females were absent. Transitionals were observed in 9 percent. Male classes 6,7,8 and 9 were present in 0.9, 0.9, 6 and 2.3 percentages respectively.

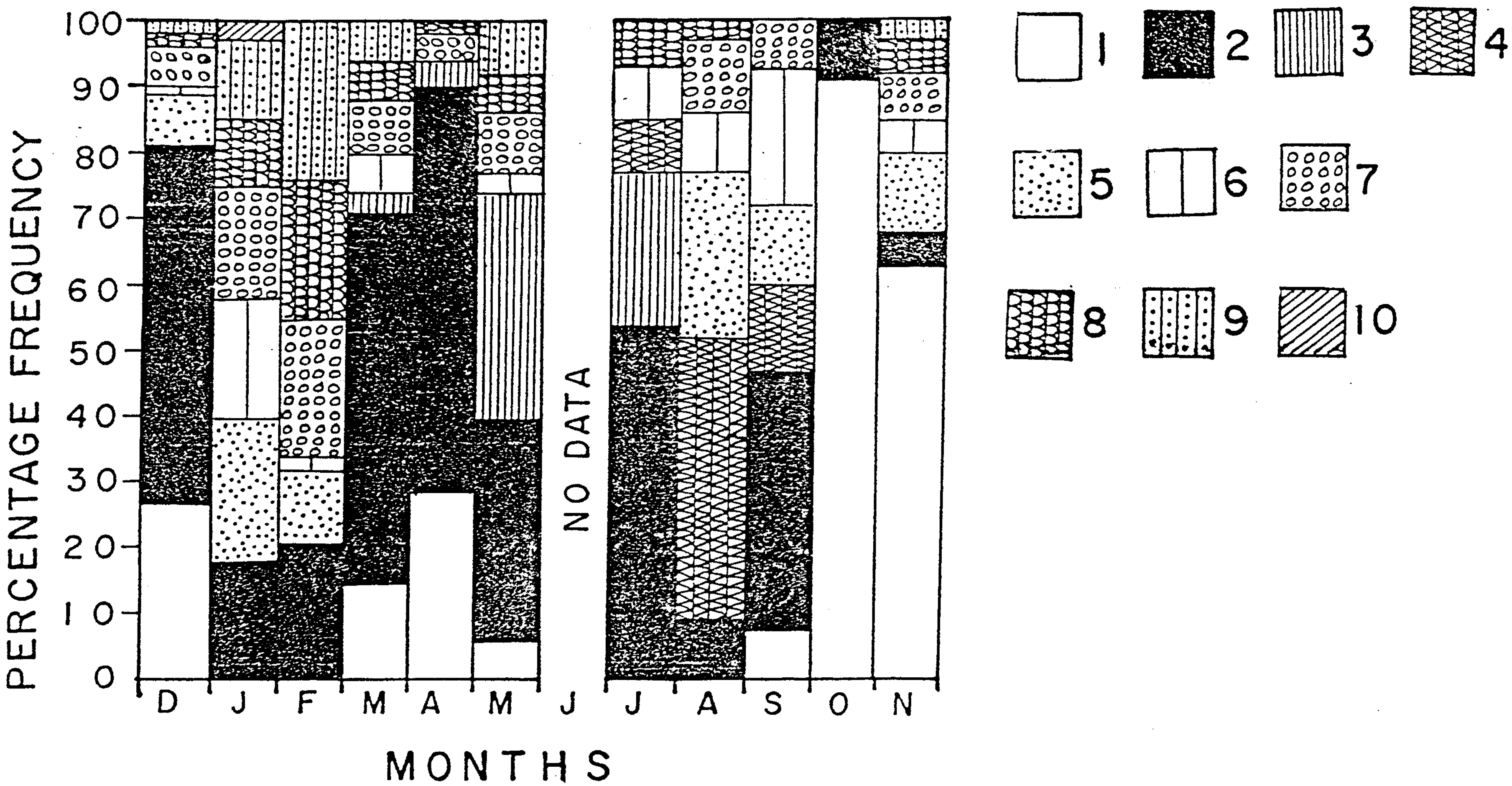
Total distribution of gonadal development class and standard length (mm) in each age group of sexed *P. diacanthus*

Gonad class	91-110	111-130	131-150	151-170	171-190	191-210	211-230	231-250	251-270	271-290	291-310	311-330	331-350	351-370	371-390	391-410	411-430	Total	Age group Total
1	2	2	1															5	5
1	13	12	11	3	1													40	78
3			9	11	8	2		1										31	
4			2		1													3	
5					1													1	
6					1													1	
7				1														1	
8				1														1	
1	2	13	10	4	1													30	119
2		1	12	25	8	2	1	1	4	1								55	
3				1	1													2	
4			2	8	1													11	
5				4		1	1											6	
6			1	2	2	1												6	
7			4	1	1													6	
8					2													2	
9					1													1	
1			2															2	
2			1	3	5	4	3	2	1	2	2	2						25	58
3				2	6	3												11	
4					1													1	
5					2	1	1	1		1								6	
6			1	1		2	2											6	
7					2	1			1									4	
8					2					1								3	
2						3	2	1		2	1	2		1				12	33
4							1											1	
5					1		1	4	1	3	1	1						12	
6										1	1							2	
7							1	1										2	
8											1							1	
9						1							1					2	
10																1		1	
2								1	4	1								6	13
5								1	2		3							6	
6												1						1	
2														1				1	14
4								1										1	
5									1									1	
6											2	2		1				5	
7												1						1	
8												1		1	1			3	
9									1							1		2	
2										1			2					3	16
5											1	2	1		1			5	
7										1			3		1			5	
8											1	2						3	
6											1	1	1					3	13
7										1	1	1	1		1			5	
8														2				2	
9												1		2				3	
6													2					2	10
7												2			1			3	
8																	1	1	
9													1		2			3	
10												1						1	
9														1					1
	17	28	56	67	48	21	13	14	15	15	15	19	13	9	7	2	1		

TABLE-24. **Monthly distribution of *E. diacanthus* in each gonad development class from the period Dec.'90–Nov'92**

Gonadal Class	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Augu.	Sept.	Oct.	Nov.
1	30	–	–	10	15	2	–	–	–	1	32	36
2	59	14	10	36	31	11	–	7	3	6	3	3
3	–	–	–	2	2	11	–	3	–	–	–	–
4	1	–	–	–	–	–	–	1	5	2	–	–
5	10	17	5	–	–	–	–	–	8	2	–	7
6	1	14	1	4	–	1	—	1	3	3	–	3
7	7	13	10	5	2	3	–	–	4	1	–	4
8	2	8	10	4	1	2	–	1	1	–	–	3
9	2	9	11	5	–	2	–	–	–	–	–	1
10	–	3	–	–	–	–	–	–	–	–	–	–

Fig. 18. SEASONAL CHANGES IN GONAD DEVELOPMENT CLASSES IN *E. DIACANTHUS*



Female gonadal classes, 1, 3 and 4 were absent in January, and only 15 % females were represented by the gonadal class 2. The transitionals, class 5 were 20 percent. The male gonadal classes 6 and 7 were represented in 17 and 16 percents respectively. Classes 8, 9 and 10 were represented in 10, 12 and 10 percentages respectively. In February, males showed greater percentages than females. Females were represented only by the class 2 with 21 percent. The transitional class 5 had 11 percentage, class 6 was with 2 percent, class 7 with 21 percent, class 8 with 22 percent and class 9 with 23 percent. Class 10, the post spawning males were absent. In March the female classes 1, 2 and 3 were seen in 15, 54 and 3 percents respectively. No post spawned female and transitionals were observed in this month. Male gonadal classes, 6, 7, 8 and 9 were present in 6, 8, 6 and 8 percentages respectively. Maturing female, ie. class 2 had the highest percentage (62%) in April , while immature female 29% and mature active female, class were 4%. Post spawned female, transitional and early males were absent in this month. Other male classes, class 7 and 8 occurred in very low percentages 4 and 2 respectively. Female classes were more active in May. Class 1 was represented by 6 percent, while the classes 2 and 4 were in equal percentage, (34%). In this month also post spawning females and transitionals were absent. Male gonadal classes, 6 and 7 were represented by 3 and 9 percentages respectively. The other gonadal classes 8 and 9 showed equal percentage (7). There was no data for the month June, as fishing is banned in the bad weather during monsoon season. Class 1 was absent in July, while class 2 females had a high percentage (53%). Class 3 females were only 23%. Post spawning females made their appearance first in this month (8%). Transitionals were absent. Male classes seen were class 6 and 8 in equal percentage (8%). Other male stages were absent. Only female gonadal class 2 and class 4 were present in August with 9 and 44 percentages respectively. Transitional class showed a high percentage, 25% in this month in comparison with other months. Male gonadal classes, 6,7 and 8 were represented by 9,10 and 3 percentages respectively. In September, Class 1, 2 and 4 were represented by 7, 40 and 13 percentages. Thirteen percentage of transitionals were also present in this month. Class 6 and 7 were represented by 20 and 7 percentages respectively. Other male gonadal classes were absent. Only females were observed in October. Class 1 was seen in high percentage (91%) and class 2 represented by 9 percentage. In November class 1 was seen in high percentages (63%) and class 2 was represented by 5%. Class 3 and 4 were absent in this month. The transitionals were represented by 12 percentage. While in the other male classes, 6, 7, 8 and 9 were by 5, 7, 5 and 3 percentages respectively.

Seasonality in gonad development classes in E. chlorostigma:

Seasonality in gonad development classes in E. chlorostigma is shown in Table-25. Immature gonads were encountered in January, February March and December. Maturing gonads were seen in December and February. No mature active and post spawning females were observed during the course of study. Transitional gonads were observed in January and December. Early and maturing males were observed in January, February, March, November and December. Mature active males were

TABLE-25. **Seasonal distribution of gonad development classes in *E. chlorostigma***

	December	January	February	March	November
Class 1	-	2.78	-	-	-
Class 2	44.11	13.89	6.38	28.21	-
Class 3	-	-	-	-	-
Class 4	-	-	-	-	-
Class 5	5.88	16.67	-	-	-
Class 6	29.41	20.59	19.15	7.69	80
Class 7	20.59	13.89	31.91	15.38	20
Class 8	-	13.89	23.40	28.21	-
Class 9	-	19.44	17.02	20.51	-
Class 10	-	-	2.13	-	-

seen in January, February and March. Post spawning males were present in February.

In December females were represented by class 2 (44.12) while the male classes, 5, 6 and 7 were represented by 5.88, 29.41 and 20.59 percentages respectively. In January female classes 1 and 2 and male classes 6, 7, 8 and 9 were present, class 6 being predominant. In February classes 1, 6, 7, 8, 9 and 10 were seen, class 8 being predominant. During March females were represented by class 2. No transitionals were seen. Male classes 6, 7, 8 and 9 were also seen, class 8 being predominant. In November only males were seen, 80% of class 7 and 20% of class 7.

Seasonality in Gonad development classes in *E. bleekeri*.

Males and females were observed in December, January, February and March. Monthly distribution of gonadal development classes in *E. bleekeri* were shown in the Table-26.

In December class 2 gonads were seen in highest percentage 34.21%. Class 3 females were seen in low percentage (5.26). Males were represented by the classes 6, 7, 8 and 9, class 8 being the prominant (6.32) among males.The class 3 was the most prominant class in January with a percentage of occurrence 33.33. No transitionals were seen in this month. Males were represented by the classes 6, 7, 8 and 9 and class 6 being the prominant (26.32) among males. The class 3 was the most prominant class in January with a percentage of occurrence 33.33. No transitionals

TABLE-26. **Monthly distribution of gonadal development classes in *E. bleekeri***

	Dec.	Jan.	Feb.	Mar	Nov.
Class 1	–	–	–	–	–
Class 2	34.21	–	29.27	65.00	–
Class 3	5.26	33.33	17.07	–	–
Class 4	–	–	–	–	–
Class 5	–	–	–	–	–
Class 6	16.16	30.00	26.83	30.00	75.00
Class 7	26.32	20.00	4.88	–	25.00
Class 8	15.79	10.00	9.76	5.00	–
Class 9	2.26	6.67	9.76	–	–
Class 10	–	–	–	–	–

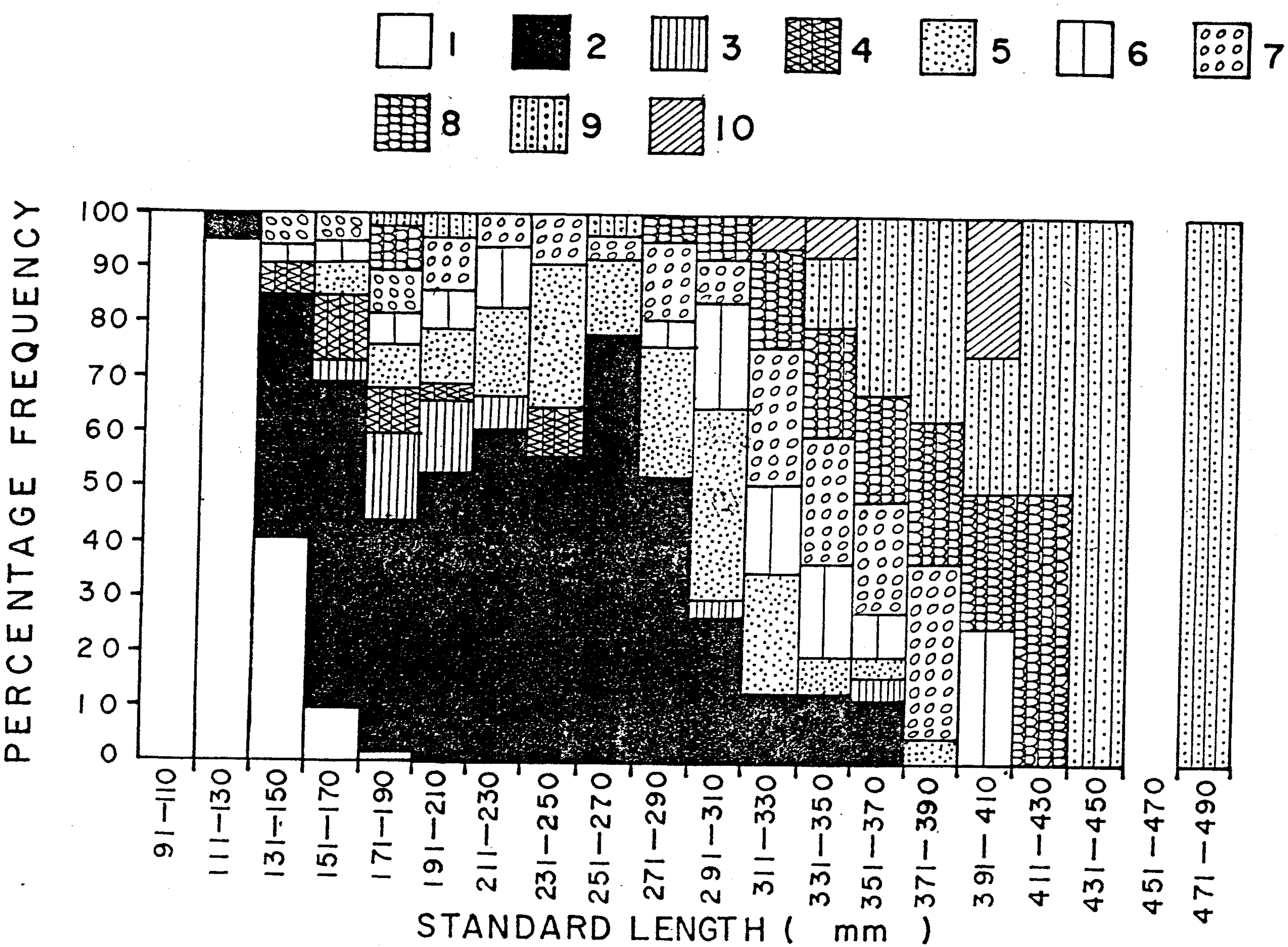
were seen in this month. Males were represented by the classes 6, 7, 8 and 9 and class 6 being prominant among males. In February females were represented by class 2 and 3 and males by class 6, 7, 8 and 9. Class 2 was the dominant class during February. No transitionals were seen. In March females were represented by class 2 while males by classes 6 and 8, class 2 was the dominant class showing high percentage of occurrence (65%). In November only males were seen, they belonged to the class 6 and 7, class 6 being the most prominant (75%).

Eventhough no transitionals were seen, the males observed were all secondary males since remnants of regressing oocytes were seen in the sections of the testes.

Gonad development class of E. diacanthus in different size groups.

Figure 19 has shown the distribution of gonadal development classes in different length groups by percentage. Only immature females belonging to the class 1 were seen in the lower length group, 91-110 mm. Class 1 was by 95% and class 2 by 5% in the size group 111-130 mm. In 131-150 mm, 41% of class , 44% of class 2, 6% of class 4, 3% of class 6, 6% of class 7 were seen. Class 2 females were in highest peercentage (59%) in 151-170mm and others, 10% of class 1, 4% of class 3, and 12% of class 4. In this size group all the four females classes were seen. Transitional class, class 5 were also represented by 6% in this size group. While class 6, 7 and 8 were represented by 4, 3 and 2 percentages respectively. As the size increases, the percentage of immature females in

E. DIACANTHUS IN DIFFERENT LENGTH GROUPS

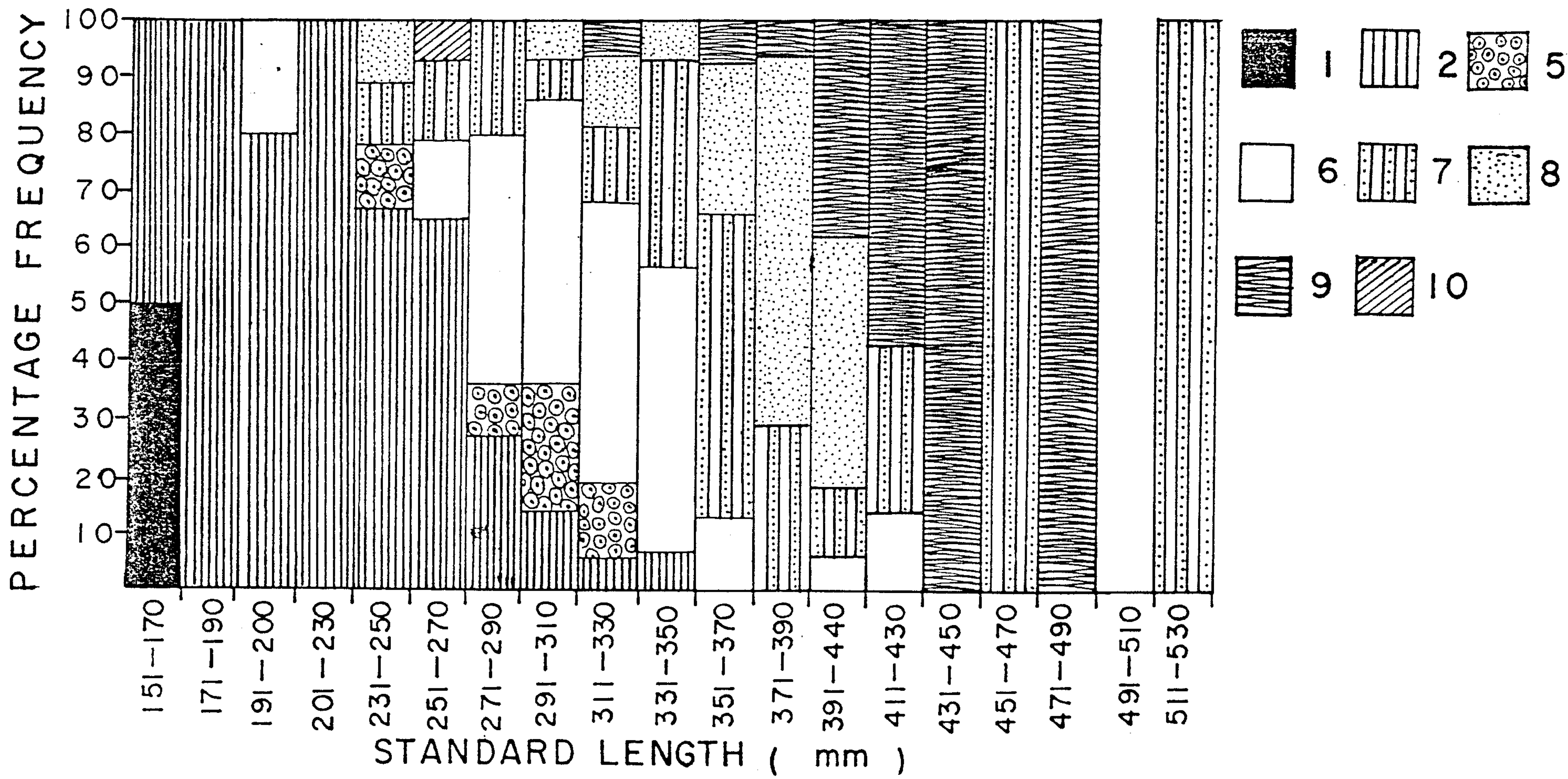


the class 1 were seen decreasing. Only 2% of class 1 females were present in the size group 171-190 mm, 42% of class 2 females, 16% of class 3 females 8% of class 4 females, 8% of transitionals, 6% of class 6, 8% of class 7 and 8 and 2% of class 9 were observed in this size group. From the length 191 mm onwards, class 1 females were completely absent. In 191-210 mm size group 53% of class 2, 13% of class 3, 3% of class 4, 10% of class 5, 7% of class 6, 10% of class 7 and 3% of class 9 were seen. In the length group 211-230 mm 61% of class 2 females, 6% of class 3, 16% of transitionals, 11% of class 6, 6% of class 7 were seen. In the size group 231-250 mm, 56% of class 2, 9% of class 4, 26% of class 5, 9% of class 7 were seen. The length group 251-270mm, 78% of class 2 were seen, while 14% of class 5 and 4% of class 7 and 9 were also seen in this size group. Maturing female class, 2 decreased from the size group 271 mm to 370 mm and were absent in the size groups beyond that. In 271-290 mm size group, 52% of class 2, 24% of class 5, 5% of class 6, 14% of class 7 and 5% of class 8 were seen. In the length group, 291-310 mm 27% of class 2, 4% of class 3, 34% of class 5, 19% of class 6, 8% of class 7 and 8 were seen. In 311-330 mm size group had 13% of class 2, 22% of class 5, 16% of class 6, 25% of class 7, 18% of class 8, 6% of class 9. In the length group 331-350 mm 13% of class 2, 7% of class 5, 17% of class 6, 23% of class 7, 2% of class 8, 13% of class 9 and 7% class 10 were observed. In the length group 351-370 mm 12% of class 2, 4% of class 3 and class 5, 8% of class 6, 20% of class 7, 20% of class 8 and 32% of class 9 were seen. No females were observed beyond this size group. In 371-390 mm size group, 5% of class 5, 32% of class 7, 26% of class 8 and 37% of class 9 were seen. No transitionals were observed beyond 391 mm standard length. In 391-410 mm size group, all ther male classes, 6, 7, 8, 9 and 10 were equally distributed (25% each). In the length group 411-430 mm class 8 and 9 were represented by 50 percentages each. The class 9 only was seen in the length group 431-450 mm. No fish were observed in 451-470 mm size group. In 471-490 mm size group, class 9 only seen.

Distribution of gonad development classes by standard length in E. chlorostigma

Figure 20 shows the distribution of gonadal development classes by standard length in E. chlorostigma. Females were observed only in lower length groups. Class 1 and class 2 were represented by 50 percentages in 151-170 mm length group. In 171-190 mm length group females class 2 only were present. In the length group 191-210 mm 80% of class 2and 20% of class 6 were seen. In 211-230 mm group, females in the class 2 only were seen. In the size group 231-250 mm 67% of class 2, 11% of class 5, 7 and 8 were observed. In the length group 251-270 mm, 65% of class 2, 14% of class 6 and 7 and 7% of class 10 were seen. In the length group 271-290 mm 27% of class 2, 9% class 5, 46% class 6 and 18% class 7 were observed. In 291-310 mm size group 14% of class 2, 22% of class 5, 50% of class 6, 7% of class 7 and 7% of class 8 were seen. In the size group 311-330mm, 6% of class 2, 13% of class 5, 49% of class 6, 13% of class 7 and 8 and 6% of stage 9 were seen. The size group 331-350 mm had 7% of class 2, 50% of class 6, 36% of class 7 and 7% of class 8 were observed. From 351 mm standard length

Fig. 20. DISTRIBUTION OF GONAD DEVELOPMENT CLASSES IN E. CHLOROSTIGMA BY STANDARD LENGTH

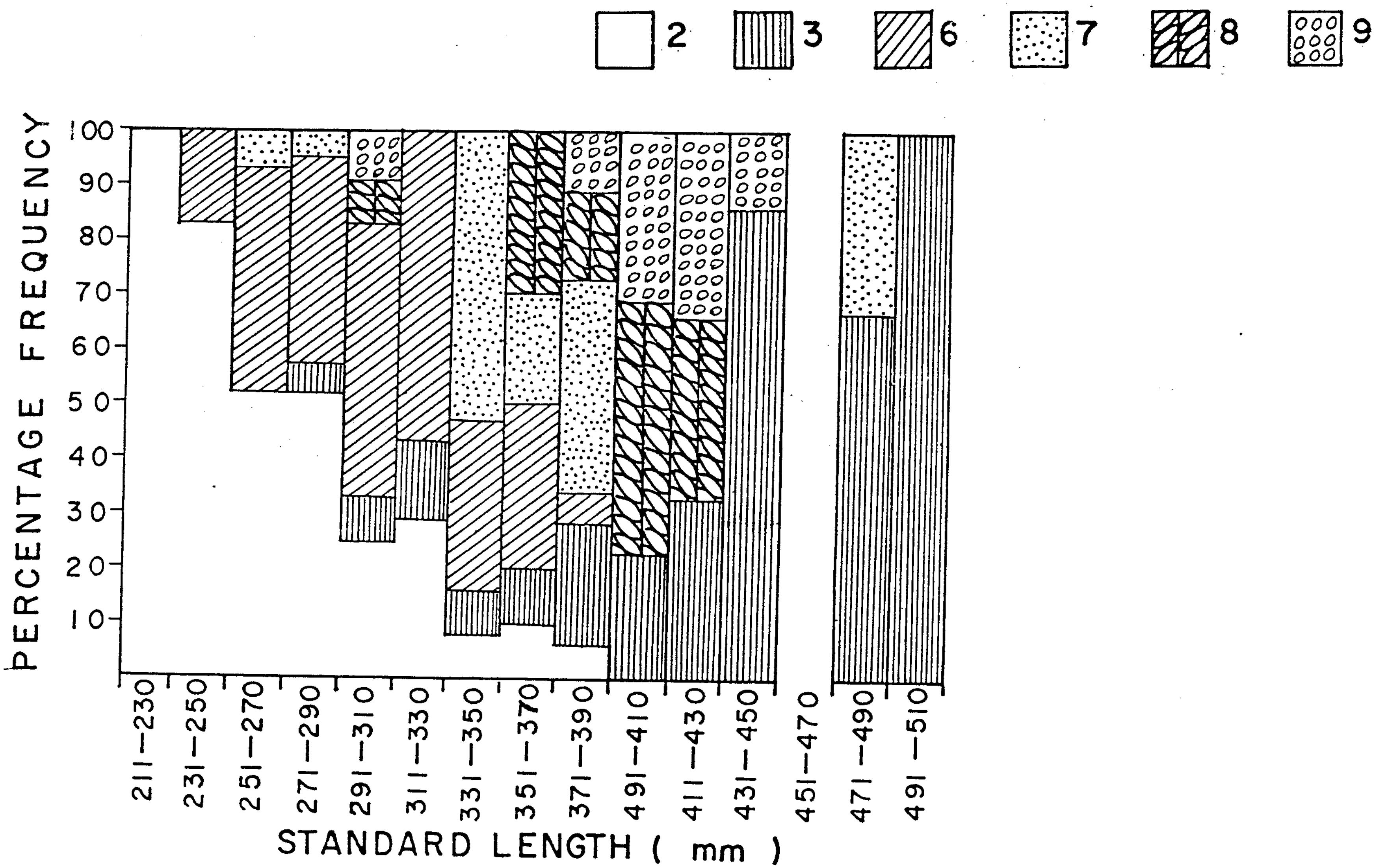


onwards only males were present and no transitionals were seen. In 351-370mm length group, 13% of class 6, 53% of class 7, 27% of class 8 and 7% of class 9 were seen. In the size group 371-390 mm 29% class 7, 65% class 8 and 6% class 9 were observed. In 391-410mm length group, 6% of class 6, 12% of class 7, 44% of class 8, and 38% of class 9 were seen. The length group 411-430mm had 14% class 6, 29% of class 7 and 57% of class 9. In the length group 431-450 mm class 9 only was present. In the length group 451-470 mm 100% of class 7, and in the length group 471-490 mm 100% of class 9 were seen. No fish were seen in 491-510 mm length group. Class 7 only were seen in the length group 511-530 mm.

Size-wise distribution of gonad development classes of E. bleekeri

Figure 21 shows the distribution of gonadal development classes of E. bleekeri by standard length. The lower length group, 211-230 mm had 100 percent maturing female class, class 2. In 231-250 mm length group 83% were class 2 and 17% were class 6. The 251-270mm length group had 52% class 2, 41% class 6, and 7% class 7. The 271-290 mm length group had 52% class 2, and 5% class 3, 38% class 6 and 5% class 7. In the size group 291-310 mm 25% of class 2, 8% of class 3, 50% of class 6, and 8% of class 8 and 9 were seen. The length group 311-330 mm had 29% class 2, 14% class 3 and 57% class 6. The length group 331-350 mm had 8% class 2 and 3. The male gonadal classes seen in this size group were 31% class 6, and 53% class 7. The length group 351-370 mm had 10% each of class 2 and 3, 30% class 6, 20% class 7

Fig. 21. DISTRIBUTION OF GONAD DEVELOPMENT CLASSES IN E. BLEEKERI



and 30% class 8. In 371-390 mm length group, 6% of class 2, 22% class 3, 6% class 6, 38% class 7, 17% class 8 and 11% class 9 were seen. The length group 391-410 mm had 15% class 2, 8% class 3, 46% class 8 and 31% class 9. The length group 411-430 mm had 34% class 3, 33% class 8 and 33% class 9. In 431-450 mm length group 14% class 2, 72% class 3 and 14% class 9 were observed. No fish were observed in the length group 451-470. In 471-490 mm 67% were class 3 and 33% were class 7. In 491-510 mm length group only class 3 were seen.

5. Seasonal variation in the frequency of primary and secondary males:

Primary males are males by birth and secondary males are those derived from females after sex change. Among 193 males, 33 were primary males and 160 were secondary males. The Table-27 shows that primary males were more in spawning months, March, April and May. Primary males were also seen in post spawning months, August and September. In pre-spawning months no primary males were seen except January, where only one primary male was present. Secondary males were more in pre-spawning months, November, December, January and February. In lesser number they were seen in post spawning months, August and September.

Frequency of primary males and secondary males in *E. diacanthus* in different length groups.

Primary males were seen from the length group 130 mm onwards till 220 mm. This shows that not all males are derived from females. In higher length groups only 340-350 mm size group had one primary male.

TABLE-27. **Frequency of primary males and secondary males (including 49 transitionals) in different months from Dec. '90-Nov. '92. in *E. diacanthus*.**

Month	No. of Primary Males	Month	No. of Secondary males
December	-	December	22
January	1	January	63
February	-	February	37
March	9	March	9
April	3	April	-
May	8	May	-
June	-	June	-
July	2	July	-
August	8	August	8
September	2	September	3
October	-	October	-
November	-	November	18
TOTAL	33	TOTAL	160

Secondary males were observed from the length group 151 mm to 490 mm. More number of secondary males were seen from 271 mm to 390 mm. From 390 mm to 490 mm the number of secondary males decreases (Table -28).

6. Gonosomatic Index

The state of maturity of a fish may be determined by the ova-diameter frequency studies as well as from the size of the ovaries, provided there exists a measurable relation between the ovary weight at any stage of maturity and the weight of the whole fish. Gonosomatic index has been used by many earlier investigators like, Htun-Han (1978) to explain the degree of ripeness of ovary in a number of fishes.

Gonomatic index of E. diacanthus in different maturity stages.

The immature ovaries in the maturity stage 1 have a GSI value, 0.1; the maturing ovaries in the maturity stage 2 have the value 0.24, in the mature active ovaries of the maturity stage 3, the value is 1.8 and in the egg stage, GSI value is 0.9. From the Figure 22 it is cleaar that in E. diacanthus the increase of ovary weight is associated with the progress of the maturity of tne ovary.

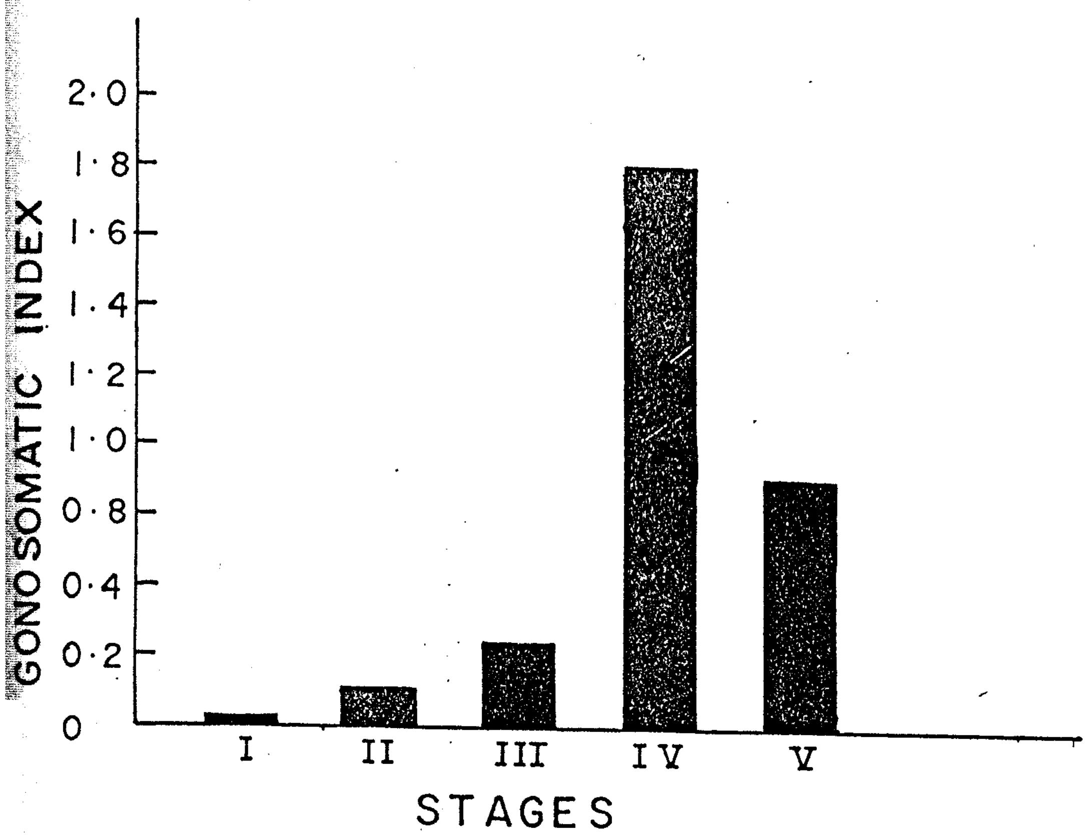
Monthly variation of GSI in E. diacanthus:

Monthly variation in the GSI from Dec. 1990 to Nov. 1992 in E. diacanthus is represented in the Figure 23. GSI has shown an increase in value in March, April, May and July in the case of females, and these months are considered as the spawning months. The GSI values for these

TABLE-28. **Frequency of primary and secondary males of E. diacanthus in different length groups.**

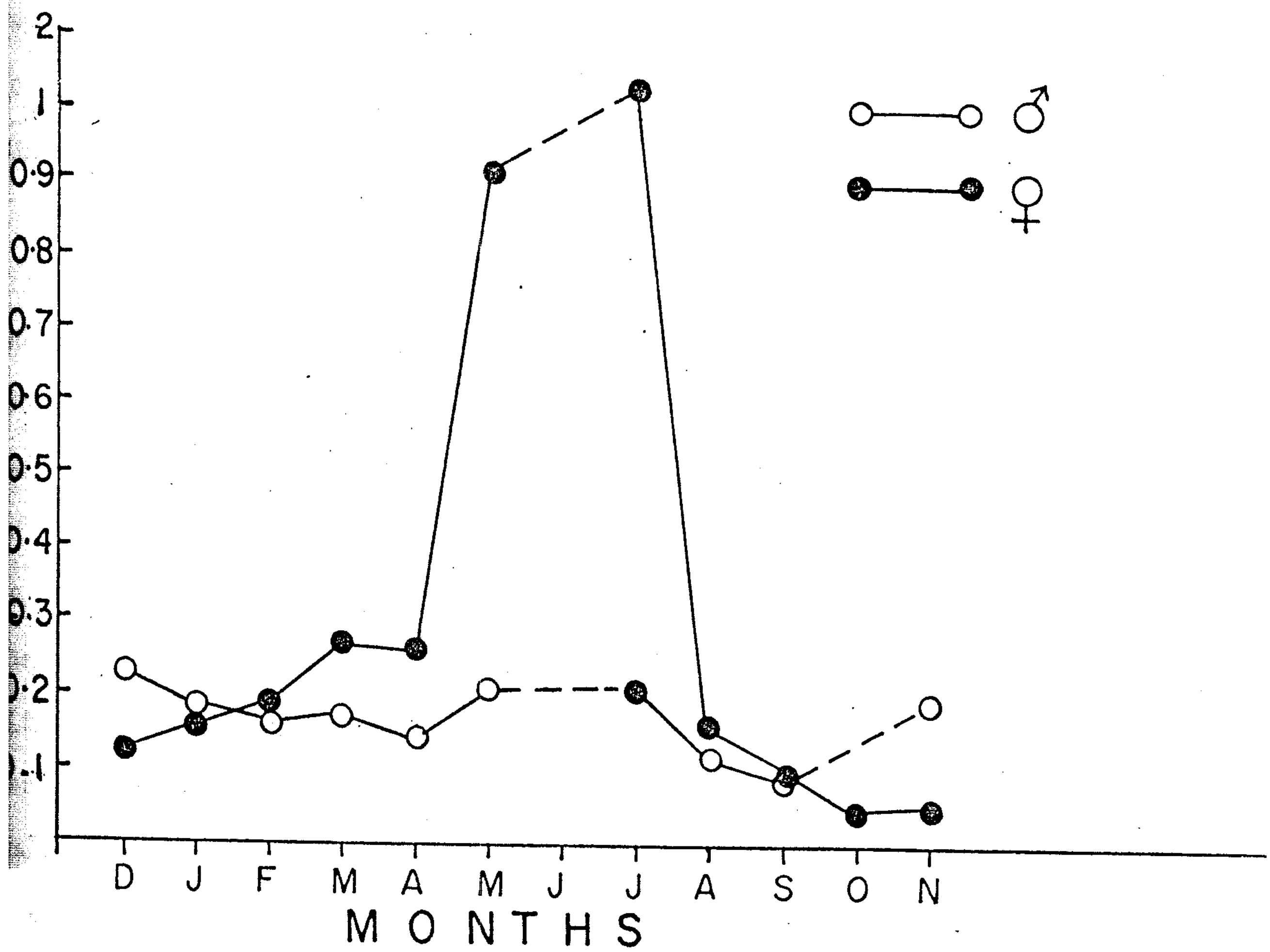
Length group (mm)	No. of secondary males	Length group (mm)	No. of primary males
151 - 170	6	130 - 140	1
171 - 190	4	140 - 150	4
191 - 210	1	150 - 160	4
211 - 230	4	160 - 170	2
231 - 250	8	170 - 180	4
251 - 270	6	180 - 190	6
271 - 290	10	190 - 200	8
291 - 310	18	200 - 210	1
311 - 330	28	210 - 220	2
331 - 350	25		
351 - 370	21	340 - 350	1
371 - 390	19		
391 - 410	4		
411 - 430	2		
431 - 450	3		
451 - 470	-		
471 - 490	1		
TOTAL	160		33

ig.22. GONOSOMATIC INDEX OF E. DIACANTHUS IN DIFFERENT LENGTH GROUPS



23

SEASONAL VARIATIONS IN GONO SOMATIC INDEX OF E. DIACANTHUS



months were 0.27,0.2,60.91 and 1.3 respectively. The females have shown low values of GSI in the months, December (0.12),January (0.16),February (0.19), August (0.16) September (o.1),October (0.04) and November (0.05). In the case of males the GSI values were high in December (0.23), March (0.20), July (0.21) and November (0.19). Low values were observed in January (0.17), February (0.11) April (0.14), August (0.11) and September (0.08). There were no males in October.

Monthly variations of GSI of female E. diacanthus between Dec. '90-Nov. '91 and Dec. '91 and Nov.'92 are compared in the Figure 24. During '90-'91 period, the females had high GSI values in March (0.46) May (1.0) and July (0.4) and invariably these are the spawning months of E. diacanthus. Lowest value was observed in April and November (0.03). In other months, December, January, February, September and October. The GSI values were respectively 0.11, 0.11, 0.19, 0.09 and 0.04. In '91-'92 period, April (0.42), May (1.2) and July (0.4) were the months showing high values of GSI. During this period also lowest GSI value was observed in October (0.025). GSI values for December, January, February, March, August, September and November were 0.12, 0.2, 0.17 and 0.06, 0.16, 0.11 and 0.6 respectively.

Monthly variations of GSI for males during Dec. 90 to Nov. 91 and Dec. '91 - Nov. '92 are shown in the Figure 25. In the period, Dec. '90-Nov.'91, March had highest GSI value (0.29). The lowest value was observed in September and June 0.09. In December, January, February, April, May and June the GSI values were 0.13, 0.18, 0.13 and 0.17

Fig. 24. SEASONAL VARIATIONS IN THE GONO SOMATIC INDEX OF FEMALE *E. DIACANTHUS*

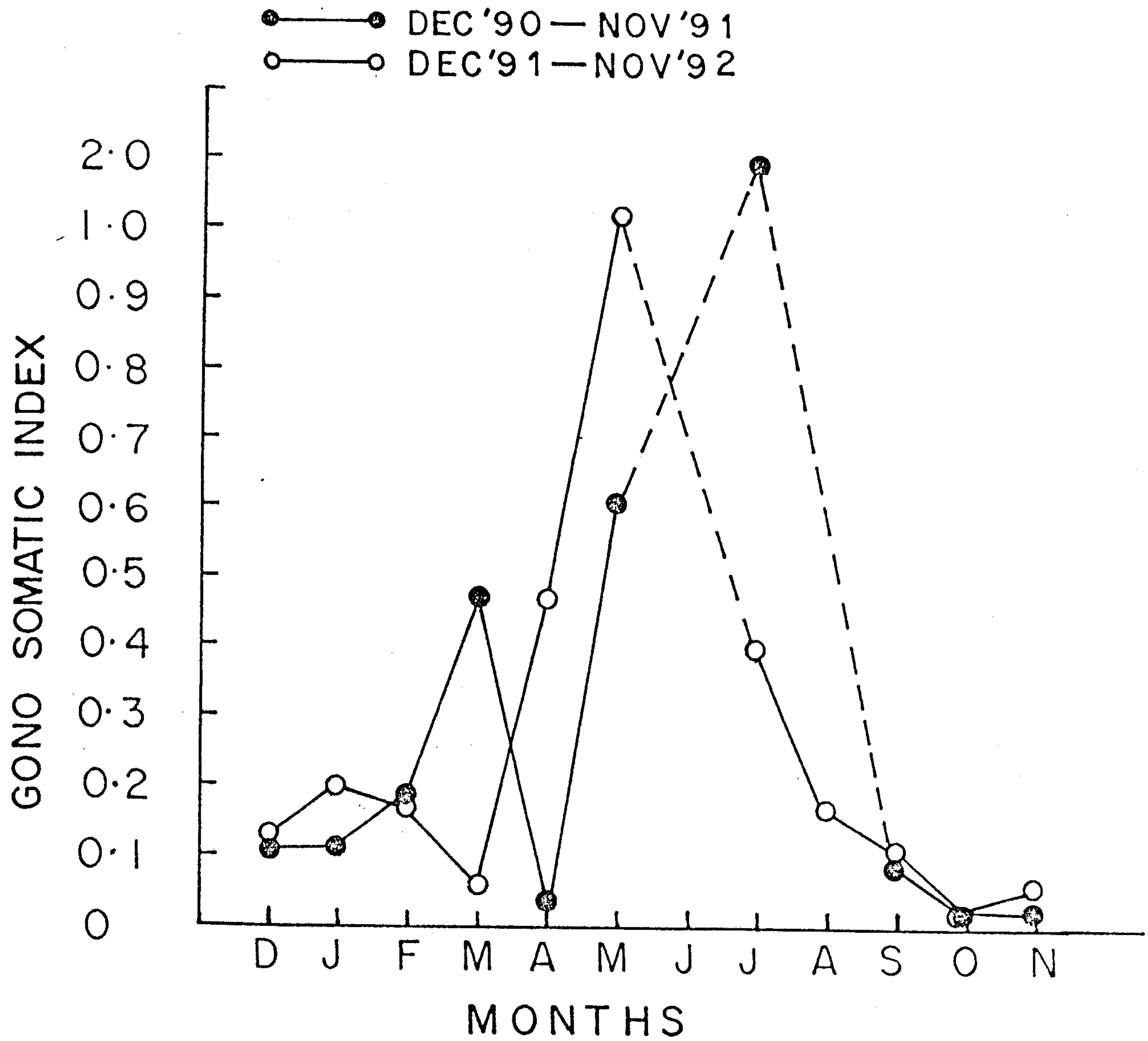
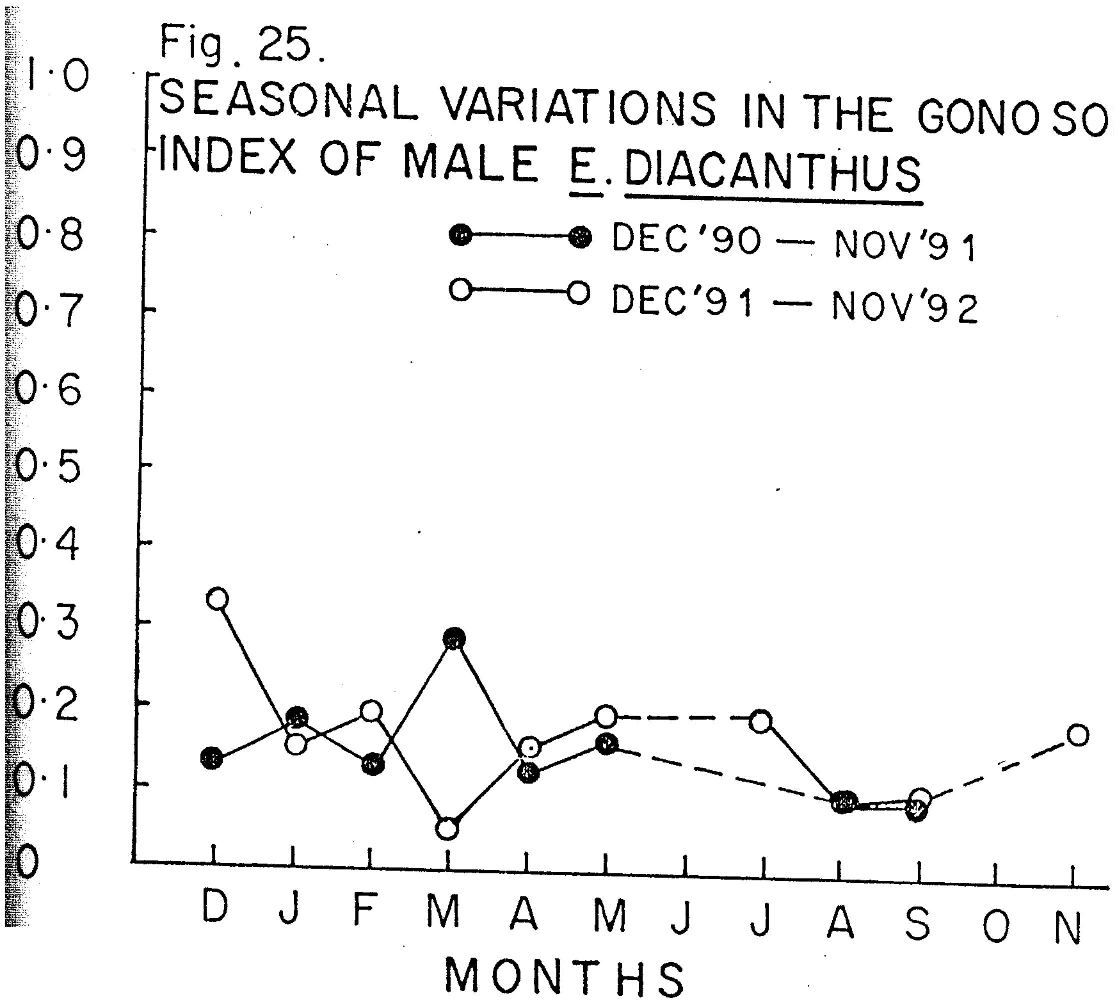


Fig. 25.

SEASONAL VARIATIONS IN THE GONOSOMATIC INDEX OF MALE *E. DIACANTHUS*



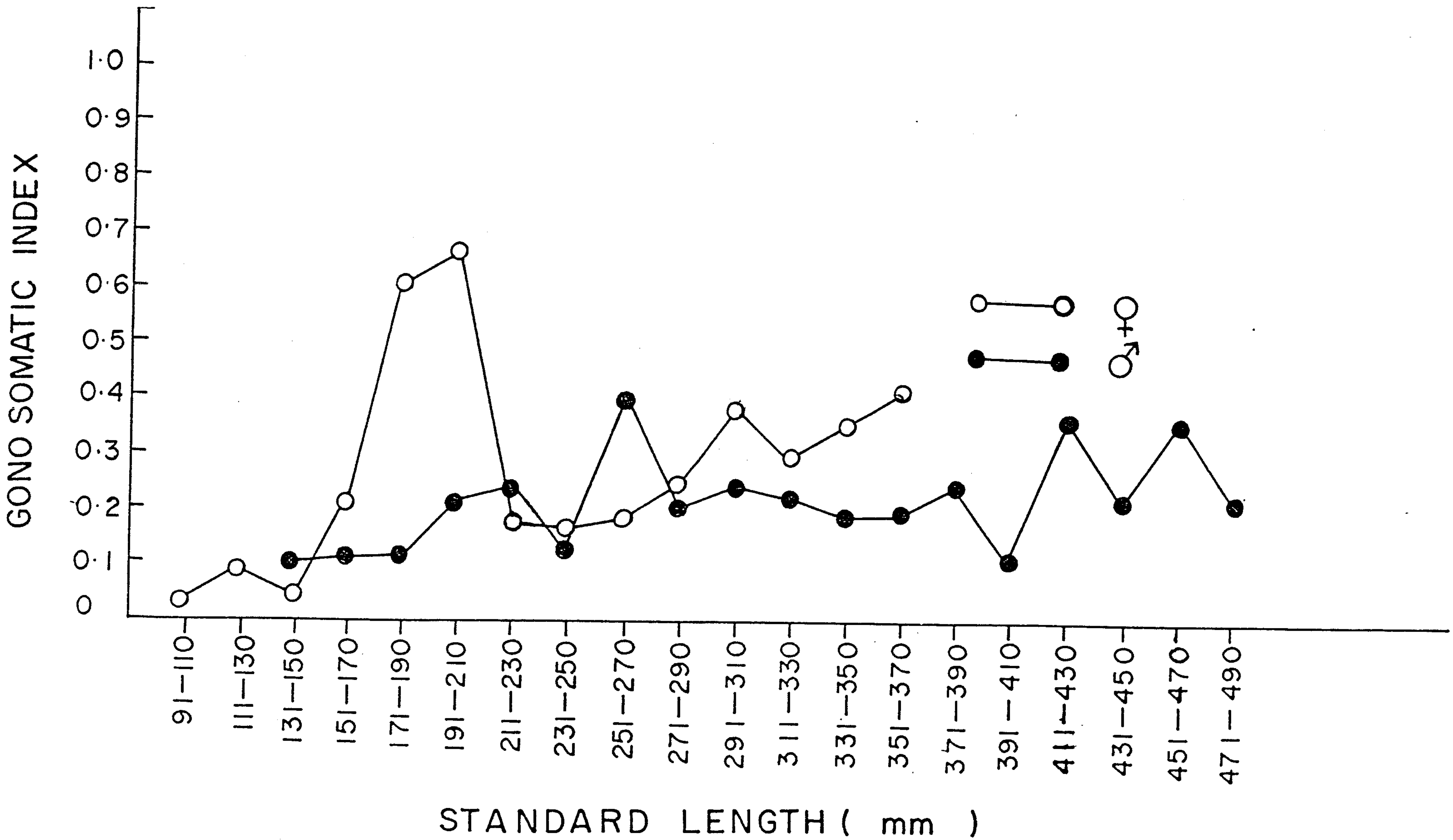
respectively. During this period, in July, August, October and November there were no males. In Dec. '91 Nov.' 92 period, December had highest GSI value, (0.33) and March, the lowest value (0.05). January, February, April, May, July, August, September and November had 0.16, 0.02, 0.15, 0.2, 0.2, 0.1, 0.1 and 0.19 GSI respectively

Gonosomatic Index for different length groups in E. diacanthus

Gonosomatic index for different length groups during Dec. ' 90-Nov.' 92 are shown in the Figure 26. The males and females were grouped in to 20 mm class interval size groups. High GSI values were observed in the size group 171-190 mm (0.6) and 191-210 mm (0.66) in the case of females. The lowest value was observed in 91-110 mm size group (0.03). Following are the GSI values for the other size groups, 111-130 mm (0.09), 131-150 mm (0.04), 151-170 mm (0.21), 211-230 mm (0.17), 231-250mm (0.16), 251-270 mm (0.18) 271-290 mm (0.25), 291-310 mm (0.38) 311-330 mm (0.29), 331-350 mm (0.35) and 351-370 mm (0.41). There were no females larger than the 351-370 mm size group.

In the case of males, the lower length groups have shown low GSI values. Length groups 131-150 mm, 151-170 mm and 171-190 mm had . GSI values 0.10,0.11 and 0.11 respectively. In 191-210 mm length group the GSI value was 0.21 and in 211-230 mm it was 0.24. Length group 231-250 mm had a low value (0.13). The 251-270 mm length group had a relatively high value (0.4). From 271-370 mm, the GSI value fluctuates between 0.18 - 0.2. Following are the GSI values for other length groups, 271-290 mm (0.2), 291-310 mm (0.24), 311-330 mm (0.22), 331-350 mm (0.18) and 351-370 mm (0.19). The GSI value for 371-390 mm was 0.24

Fig. 26. GONOSOMATIC INDEX OF *E. DIACANTHUS* IN DIFFERENT LENGTH GROUPS



and that of 391-410 mm was 0.11. GSI values for the length groups 411-430 mm, 431-450 mm, 451-470 mm and 471-490 mm were 0.35,and 0.21 0.35 and 0.2, respectively.

Gonosomatic Index of E. chlorostigma in different size groups:

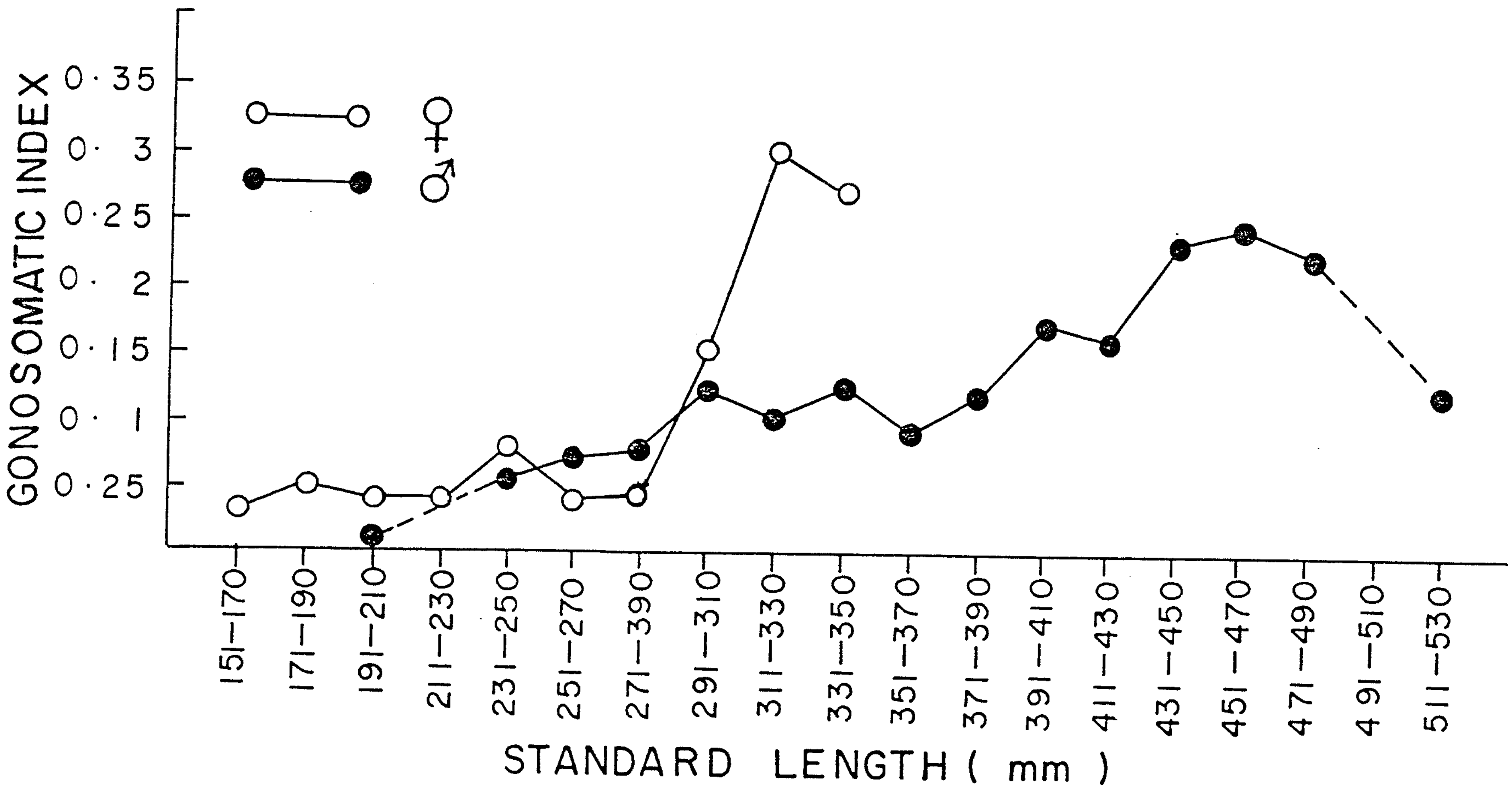
Lower length groups had low GSI values and higher length groups high GSI values in the case of females (Figure 27). The females showed highest GSI in the 311-330 mm size group (0.3) and the lowest GSI in 151-170 mm group (0.03). GSI values in other length groups were 171-190 mm (0.05), 191-210 mm (0.045) 211-230 mm (0.045) 231-250 mm (0.08), 251 270 mm (0.04) and 271-290 mm (0.45).

In the case of males, the length group 451-470 mm had highest GSI value, 0.24. The lowest GSI value 0.01 was observed in the length group 191-210 mm. The length groups 231-250 mm, 251 - 270 mm and 270-290 mm had respectively 0.055, 0.070 and 0.075 as GSI. The GSI values in other length groups were 291-310 mm (0.12), 311-330 mm (0.1), 331-350 mm (0.125), 351-370 mm (0.09), 371-390 mm (0.09), 391-410 mm (0.17) 411-430 mm (0.16), 431-470 mm (0.23), 471-490 mm (0.225) and 511-530 mm (0.12). No fish were observed in the length groups 211-230 mm and 491-510 mm. The low GSI values seen in E. chlorostigma might be due to the absence of mature fish in the sample.

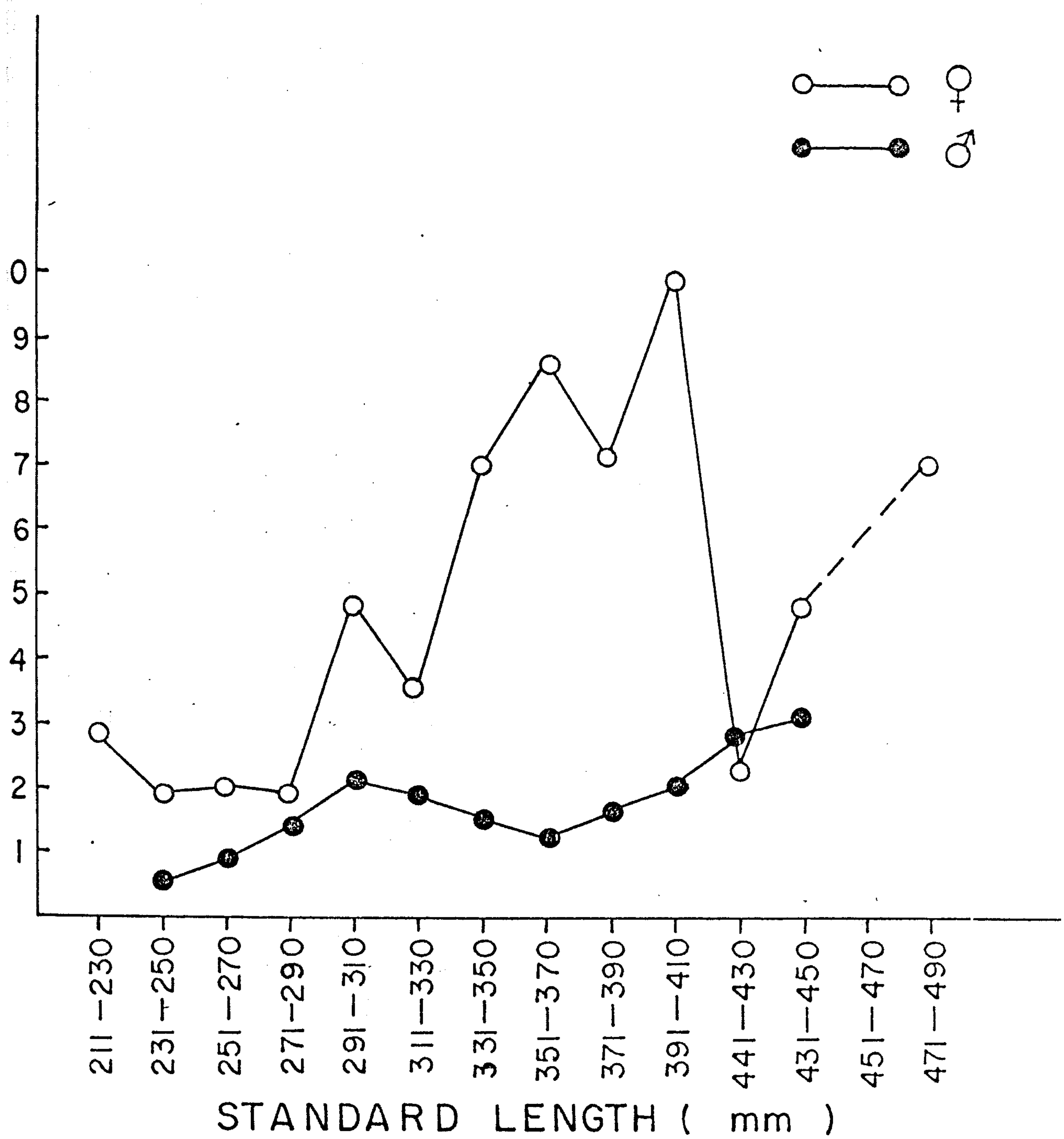
Gonosomatic Index of E. bleekeri in different length groups:

Figure 28 shows the gonosomatic index of E. bleekeri in different length groups from Dec. '90 to Nov. '92. Both in females and males GSI values have shown a tendency to increase from lower to higher length groups.

Fig.27. GONOSOMATIC INDEX OF *E. CHLOROSTIGMA* IN DIFFERENT LENGTH GROUPS



GONOSOMATIC INDEX OF E. BLEEKERI IN DIFFERENT LENGTH GROUPS



In the case of females, 391-410 mm length group had the highest GSI value (1.0) and the lowest value (0.19) was shown by the length groups 231-250 mm and 271-290 mm. The GSI values of other length groups were as follows, 211-230 mm (0.29), 231-270 mm (0.2), 291-310 mm (0.49), 311-330 mm (0.35), 331-350 mm (0.7), 351-370 mm (0.87) 371-390 mm (0.71), 411-430 mm (0.23) and 431-450 mm (0.49). No fish were seen in 451-470 mm length group. In 471-490 mm the GSI value was 0.72.

In the case of males, highest GSI value, (0.31) was observed in 431-450 mm length group and the lowest value (0.05), in the length group 231-250 mm. The GSI values for other length groups were, 251-270 mm (0.08), 271-290 mm (0.14), 291-310 mm (0.21), 311-330 mm (0.79), 331-350 mm (0.15) 351-370 mm (0.13), 371-390 mm (0.17), 391-410 mm (0.21), 411-430 mm (0.29) and 431-450 mm (0.30). Males showed comparatively low GSI than females.

GSI values in the case of E. bleekeri is slightly greater than that of E. chlorostigma. Monthly variation in GSI could not be taken as the samples were got for a period of five months in the case of E. chlorostigma and E. bleekeri.

7. Hepatosomatic Index

Krivobok (1964) has shown a direct correlation between liver weight and the size of oocytes in the Baltic herring, Clupea harengus membras and also reported that females with heavier livers were more fecund than those with lighter ones. The usual method of expressing liver weight is, as the hepatosomatic index (HSI), using the formula,

$$HSI = \frac{\text{Liver weight}}{\text{Wholebody weight}} \times 100$$

Monthly variation in Hepatosomatic Index of E. diacanthus

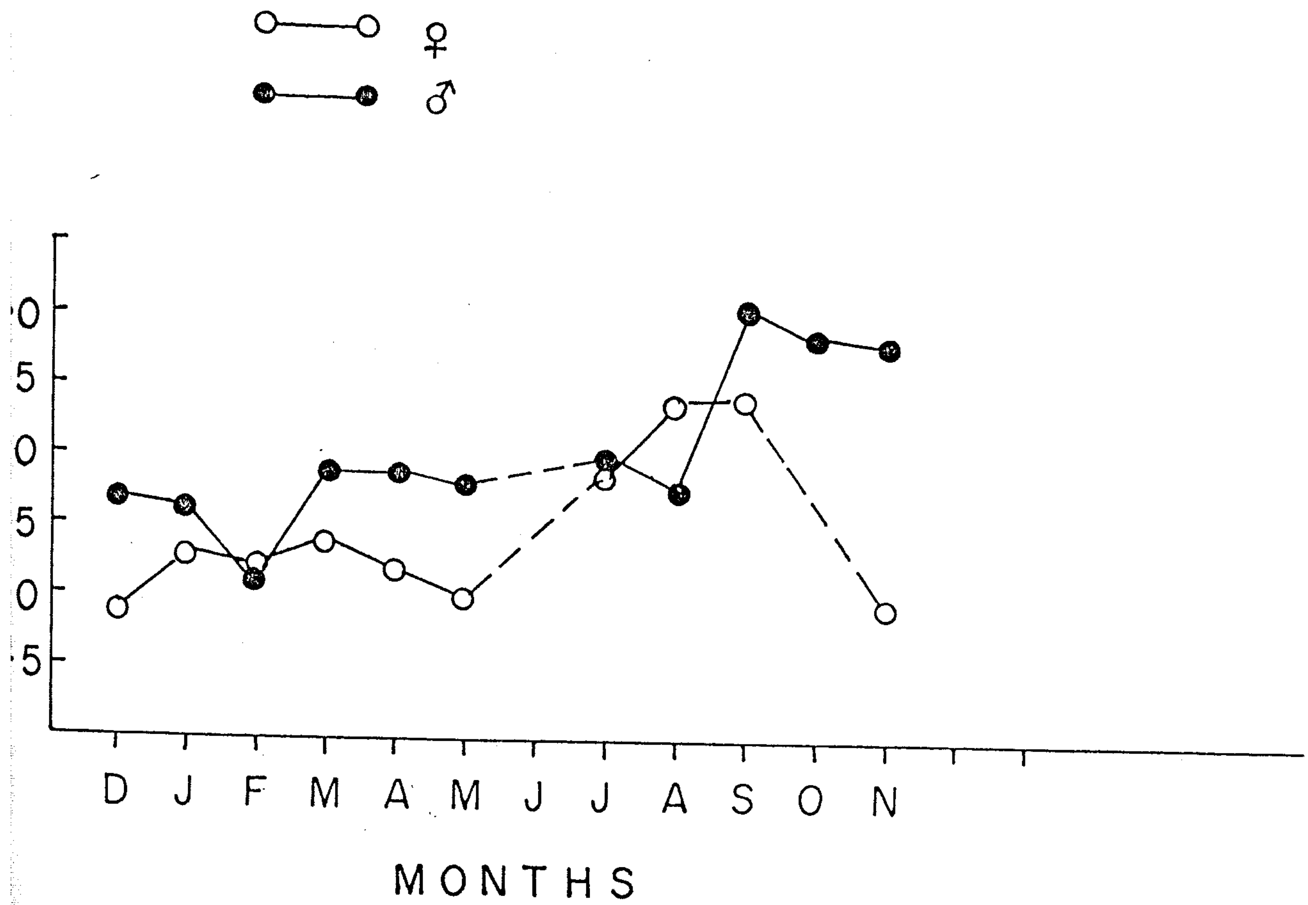
Monthly variation in the HSI of E. diacanthus during Dec. '90 - Nov. '92 are given in the Figure 29. In females highest HSI value was observed in September (3.1) and the lowest value, 1.1 in February. The HSI values for other months were, December (0.17), January (1.65) March (1.85), April (1.9) May (1.8) July (2.0) August (1.75) October (2.85) and November (2.8).

In males, highest HSI value (2.24) were noticed in August and September while December had the lowest HSI value, 0.9. HSI values in January, February, March, April, May, July and November were 1.3, 1.2, 1.4, 1.15, 1.2, 1.9 and 0.95 respectively.

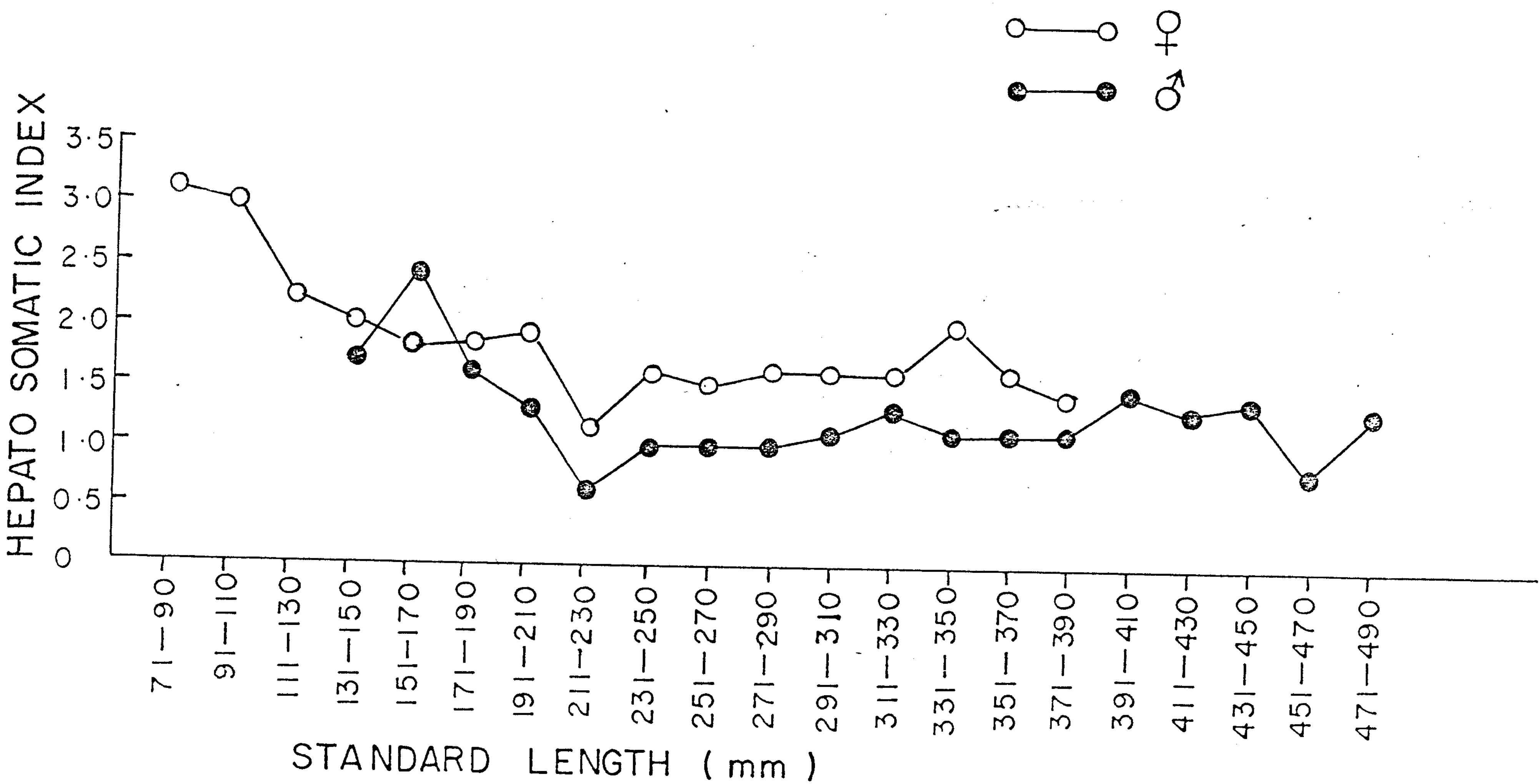
Hepatosomatic Index in different length groups in E. diacanthus:

HSI in different length groups are given in the Figure 30. In females high HSI values were noticed in lower length groups than higher length groups. The lower length group, 71-90 mm had the highest value 3.1. In the 91-150 mm length groups the HSI values showed a decrease: 91-110 mm, 111-130 mm and 131-150 mm had 3.0, 2.2, and 2.0 HSI values respectively. The 151-170 mm length group onwards there was a slight increase till 171-210 mm size. The HSI values of these length groups were 151-170 mm (1.8),171-190 mm (1.85) and 191-210 mm (1.9). Lowest HSI value (1.1) was noticed in 211-230 mm length group. In the length group 231-250 mm the HSI value was 1.6. From 251 mm to 350 mm

MONTHLY VARIATIONS IN THE HEPATO SOMATIC INDEX OF *E. DIACANTHUS*



GROUPS



♀
♂
HEPATO SOMATIC INDEX
3·5
3·0
2·5
2·0
1·5
1·0
0·5
0
71—90
91—110
111—130
131—150
151—170
171—190
191—210
211—230
231—250
251—270
271—290
291—310
311—330
331—350
351—370
371—390
391—410
411—430
431—450
451—470
471—490
STANDARD LENGTH (mm)

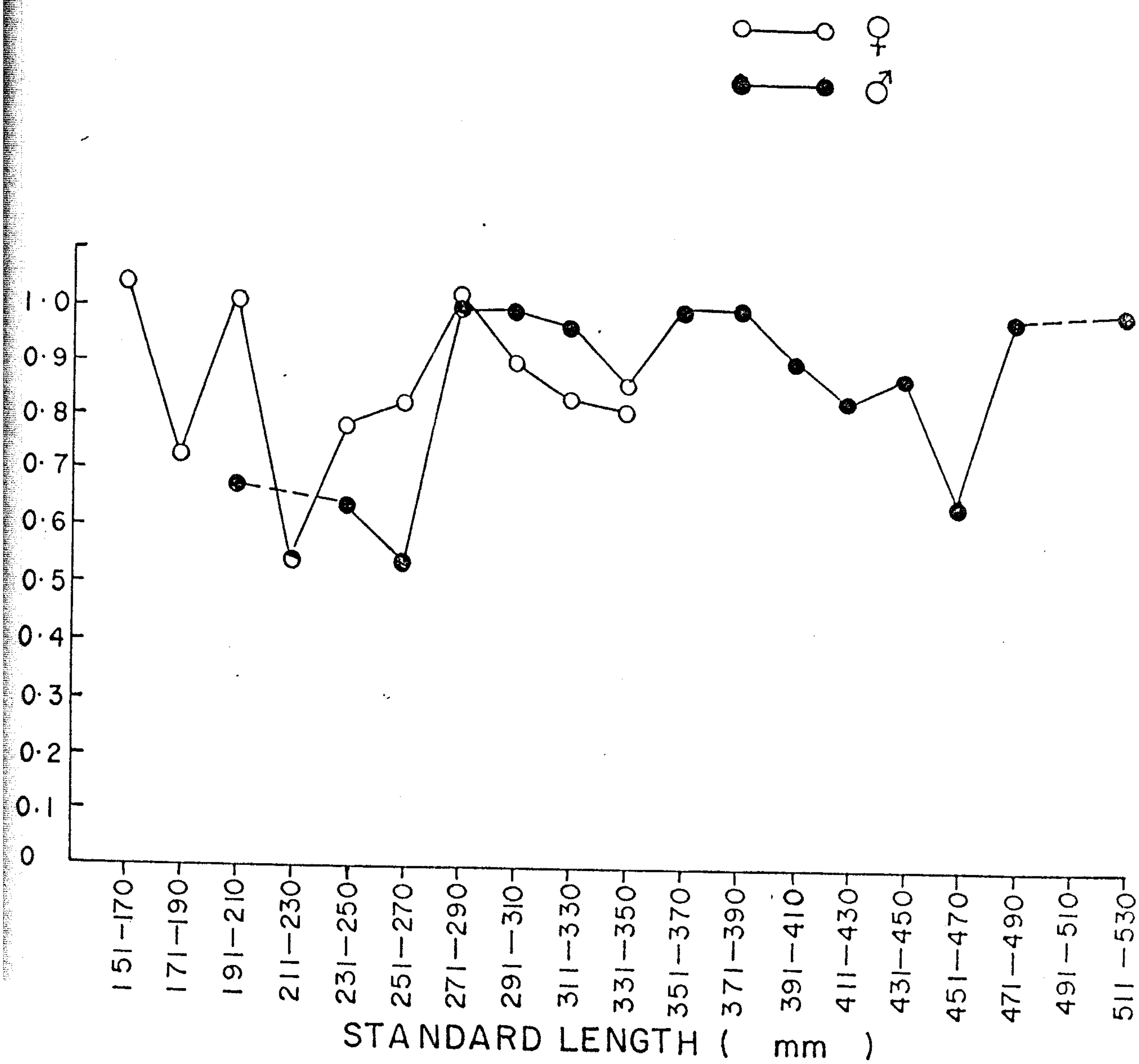
the HSI values showed an increase, the values for each length group were as follows, 251-270 mm (1.5), 271-290 mm, 291-310 mm and 311-330 mm had same value 1.6 and 331-350 mm (2.0). From 351-390 mm the values have shown a slight decrease. The HSI values in 351-370 mm and 371-390 mm length groups were 1.6 and 1.4 respectively.

HSI values were high in lower length groups in the case of male also. Highest HSI value (2.4) was observed in 151-170 mm size group and the lowest value 0.6 in 211-230 mm length group. The HSI value in length group 131-150 mm were 1.7. The 171-190 mm length group had 1.6 and 191-210 mm had 1.3 as HSI. The HSI values were uniform throughout the length groups from 231-290 mm (1.0). In 291-310 mm, and 311-330 mm the HSI values were 1.1 and 1.3 respectively. Again there were a uniform HSI value throughout the length group 331-390 mm (1.1). Size groups 391 mm to 490 mm showed a regular increase and decrease in the HSI values. The values were 391-410 mm (1.05), 411-430 mm (1.3) 431-450 mm (1.4) 451-470 mm (0.8) and 471-490 mm (1.3). In E. diacanthus, observation on HSI it seems that there is no relationship between weight of the liver and reproduction, since lower immature fishes had shown high HSI in both males and females.

Hepatosomatic Index in E. chlorostigma in different length groups:

Figure 31 illustrates HSI in E. chlorostigma in different length groups. In the case of females, the highest HSI was noticed in 151-170 mm length group (1.04) and lowest in 0.53 in 211-230 mm. In the length groups 171-190 mm, 191-210 mm, 211-230 mm, 231-250 mm 251-270 mm, 271-290 mm, 291-310 mm, 311-330 mm and 331-350 mm

31. HEPATO SOMATIC INDEX OF *E. CHLOROSTIGMA* IN DIFFERENT LENGTH GROUPS



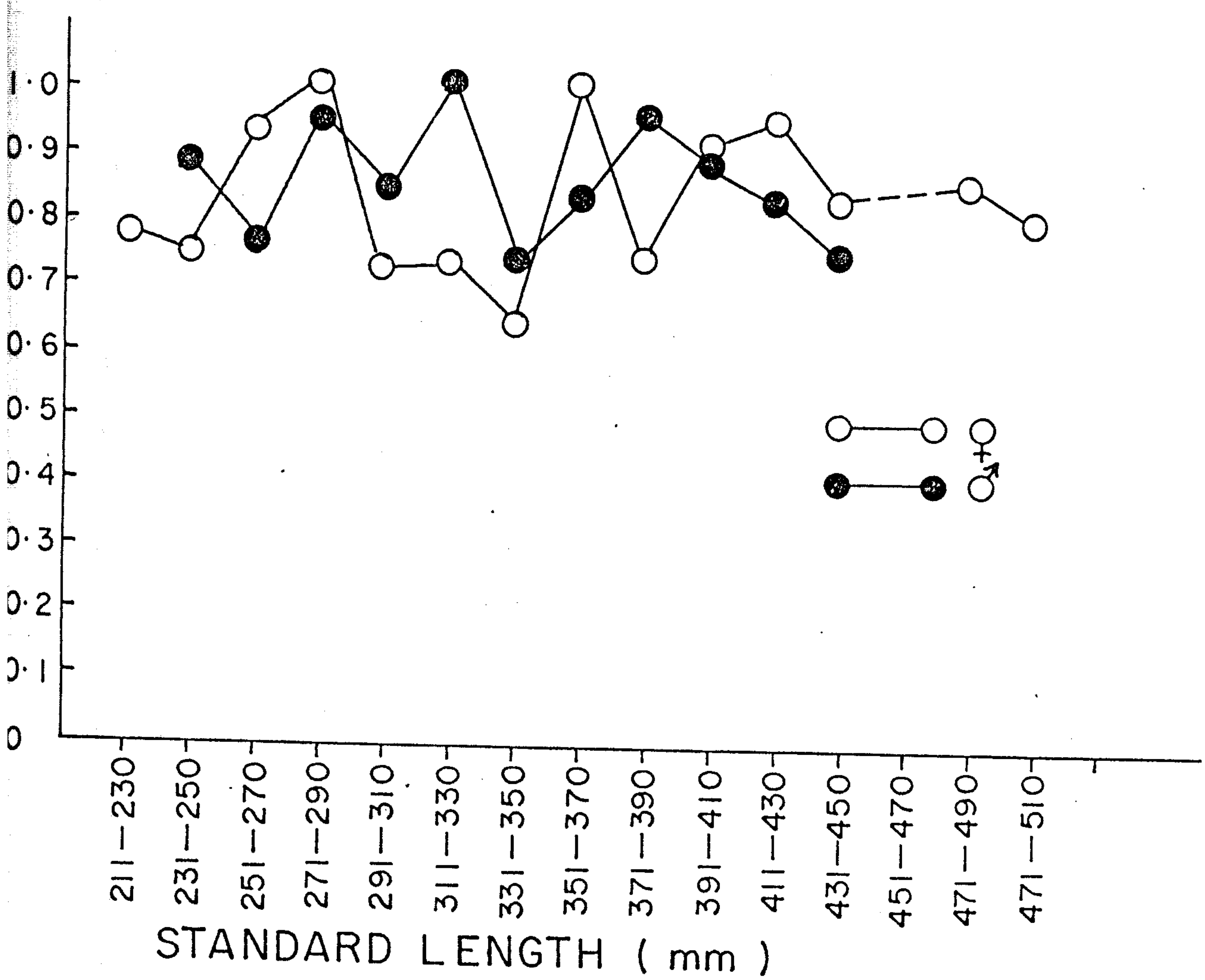
the HSI values were 0.73, 1.02, 0.79, 0.82, 1.02, 0.82, 0.9, 0.89 and 0.81 respectively.

In case of males the lower length groups had low HSI. Highest HSI values were noticed in five different length groups, 271-290 mm, 291-310 mm, 351-370 mm, 371-390 mm and 511-530 mm (1.0) and lowest value was observed in 251-270 mm (0.53). The HSI value in 191-210 mm length group was 0.67. No male fish was observed in 211-230 mm length group. In 231-250 mm length group the HSI value was 0.64. In higher length groups, 311-330 mm, 331-350 mm, 391-410 mm, 411-430 mm 431-450 mm, 451-470 mm, 471-490 mm the HSI values noticed were 0.98, 0.86, 0.91, 0.83, 0.88, 0.64 and 0.99 respectively. No males were observed in 491-510 mm length group.

Hepatosomatic Index in E. bleekeri in different length groups:

Figure 32 shows HSI in different length groups from Dec. '90 to Nov. '92 in E. bleekeri. In females the highest HSI value, 1.1, was met with in the length groups 271-290 mm, and 351-370 mm and the lowest value 0.64 in the length group 331-350 mm. In the length groups, 211-230 mm, 231-250 mm, 251-270 mm, 291-310 mm, 311-330 mm, 371-390 mm, 391-410 mm, 411-430 mm 431-450 mm, 451-470 mm and 471-510mm the HSI values were 0.78, 0.74, 0.94, 0.72, 0.74, 0.74, 0.92, 0.96, 0.84, 0.86 and 0.80 respectively. No fish were seen in the length group 451-470 mm.

32. HEPATO SOMATIC INDEX OF *E. BLEEKERI* IN DIFFERENT LENGTH GROUPS



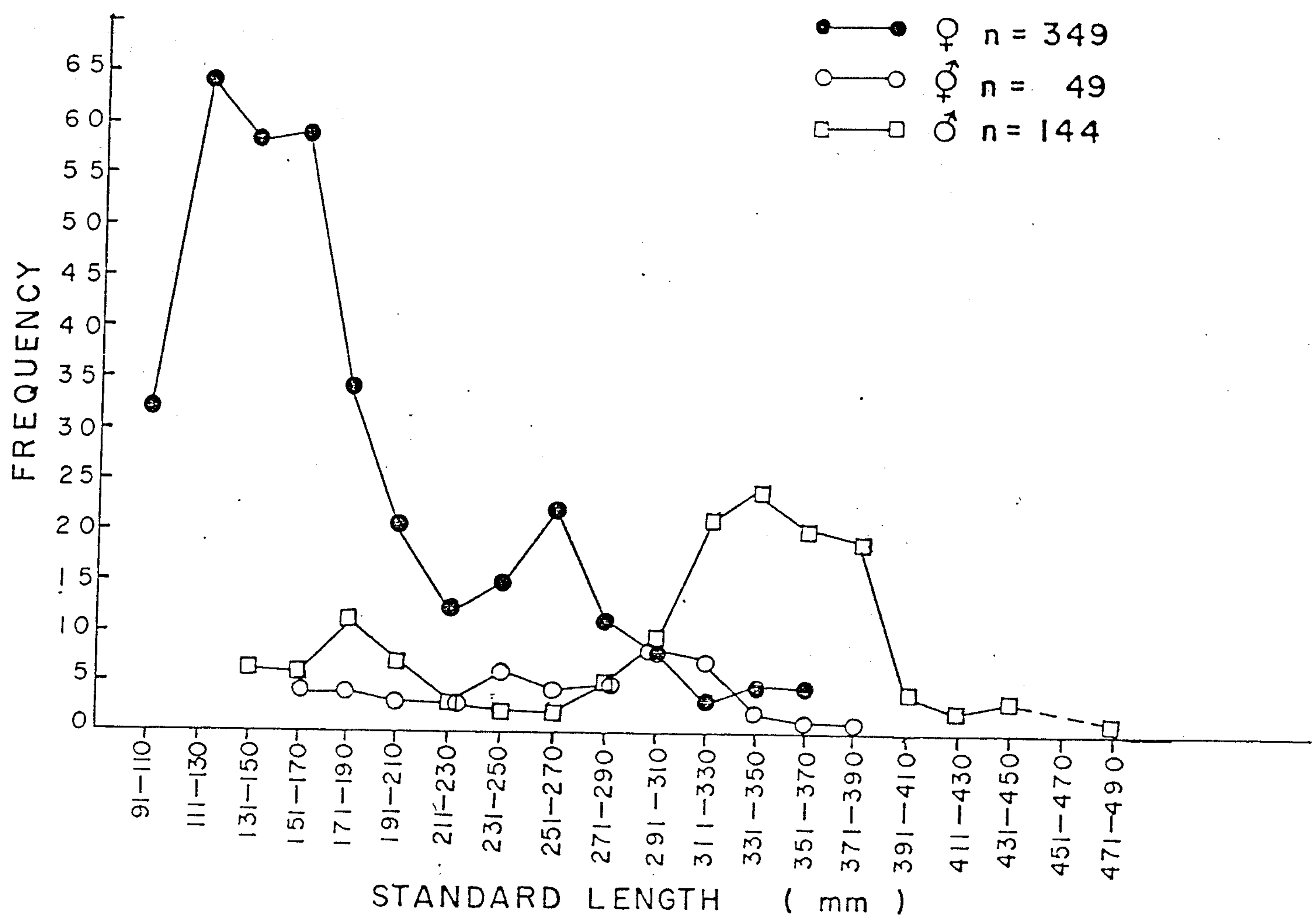
In males highest HSI, 1.1 was observed in the length group 311-330 mm and the lowest value 0.75 in 431-450 mm. In other length groups the HSI values were, 231-250 mm (0.89), 251-270 mm (0.76), 271-290 mm (0.96) 291-310 mm (0.85), 331-350 mm (0.74), 351-370 mm (0.84), 371-390 mm (0.96) 391-410 mm (0.89) and 411-430 mm (0.84).

8. Age/length-wise distribution of sex in E. diacanthus:

Standard length has been used by several investigators to age the fish accurately. Table-29 gives the basic data for distribution of sex in 20 mm SL size groups and the mean age of each sex in each size group. Smaller size groups showed higher distribution of females. The distribution of females was more than 50% till 270 mm SL. The percentage of females decreased with the increase in standard length. In larger size groups females disappeared altogether. Males were also distributed broadly over the upper half of the size range of females (Figure 33), Mean age of males in each size group was greater than the mean age of females. The percentage of males increased with increase in size group like wise the mean age. The percentage of the males in the population did not rise above 25%, until 290 mm SL had been attained by the population and an equal distribution of males and females did not occur. Sexual transition may occur at any length over about 150 mm SL, but most takes place between 230 mm and 310 mm SL.

The percentage of males in the population did not show 25% increase till the age reaches 7. Transitional fish appeared from the age 2 to 8 and the highest percentage of transitionals were in the age 6 (Table-30).

Size Group (mm)	Grand Total	Females			Males			Transitionals		
		Number	Percent	Mean age	Number	Percent	Mean age	Number	Percent	Mean age
91 - 110	17	17	100	2.0	-	-	-	-	-	-
111 - 130	28	28	100	2.3	-	-	-	-	-	-
131 - 150	56	50	89	2.6	6	11	3.2	-	-	-
151 - 170	67	57	85	2.8	6	9	2.5	4	6	3.0
171 - 190	48	33	69	3.1	11	23	3.7	4	8	3.8
191 - 210	21	14	67	3.8	5	24	4.0	2	9	3.5
211 - 230	13	7	54	4.3	3	23	4.3	3	23	4.0
231 - 250	14	7	50	4.4	1	7	5.0	5	43	5.0
251 - 270	15	10	61	4.4	2	13	5.5	4	26	6.0
271 - 290	15	7	46	5.0	4	27	6.5	4	27	4.8
291 - 310	15	3	20	4.3	7	47	7.1	5	33	6.2
311 - 330	19	4	21	4.5	12	63	8.1	3	16	7.0
331 - 350	13	2	15	8.0	10	77	8.7	1	8	8.0
351 - 370	9	1	11	7.0	7	78	8.7	1	11	7.0
371 - 390	7	-	-	-	6	86	9.0	1	14	8.0
391 - 410	2	-	-	-	2	100	6.0	-	-	-
411 - 430	1	-	-	-	1	100	10.0	-	-	-



♀ n = 349
⚥ n = 49
♂ n = 144
FREQUENCY
65
60
55
50
45
40
35
30
25
20
15
10
5
0
91–110
111–130
131–150
151–170
171–190
191–210
211–230
231–250
251–270
271–290
291–310
311–330
331–350
351–370
371–390
391–410
411–430
431–450
451–470
471–490
STANDARD LENGTH (mm)

TABLE-30. **Distribution of females, males and transitionals in each age group of *E. diacanthus***

Age Group	Grand Totals	Females			Males			Transitionals		
		Number	Percent	Mean Std Length(mm)	Number	Percent	Mean Std Length(mm)	Number	Percent	Mean Std Length(mm)
1	5	5	100	115	-	-	-	-	-	-
2	78	74	95	128	3	4	172	1	1	174
3	119	98	82	132	15	13	168	6	5	178
4	58	39	67	249	13	23	196	6	10	198
5	33	13	39	280	8	25	298	12	36	325
6	13	6	46	265	1	8	285	6	46	294
7	14	2	14	365	11	79	342	1	7	259
8	16	3	19	314	8	50	325	5	31	341
9	13	-	-	-	13	100	330	-	-	-
10	10	-	-	-	10	100	352	-	-	-
11	1	-	-	-	1	100	360		-	-

Females were more in smaller age group, most abundant from the age group 1 to 4. Males exceed the age group of females eventhough both were distributed within the same size range.

Sex ratio of E. diacanthus

Sex ratio about 540 E. diacanthus were examined in a wide range of sizes. There were no external characters by means of which the sexes can be differentiated. Sex of the fish is determined histologically. In order to find out the sex ratio of different size groups all the fish collected during the period December '90 to November '92 were grouped in 20 mm size groups. The ratio between the males and females during each month and age group were also determined. The transitionals were counted as males while sexing for this purpose since there is no sex transition back to females.

The over all ratio between the males and females during December '90 to November '92 was found to be 1:1.78 with highly significant, chi-square value 43.91. Thus when overall ratio is considered females showed an increase in the catch (Table-31). Females were abundant in all the months except January, February and August. The chi-square values were insignificant for the fishes in August and September showing there is much variation from the normal sex ratio 1:1

The sex ratio of E. diacanthus among different size groups are given in the Table-32. The females out number males in smaller size groups, i.e. from 91 mm to 130 mm SL. From 131 mm to 270 mm SL

TABLE-31. **Sex Ratio of _E. diacanthus_ from December '90 - November '92**

Month	Males	Females	Sex Ratio	x^2 value
December	22	90	1 : 4.09	41.28
January	64	14	1 : 0.22	32.05
February	37	10	1 : 0.27	15.51
March	18	48	1 : 2.67	13.636
April	3	48	1 : 16	39.7058
May	8	24	1 : 3	8
June	-	-	-	-
July	2	11	1 : 5.5	6.3208
August	15	19	1 : 1.27	0.4706
September	6	9	1 : 1.5	0.6
October	0	35	-	-
November	18	39	1 : 2.17	7.7368
TOTAL	193	347	1 : 1.78	43.91

TABLE-32. **Sex ratio of <u>E.</u> <u>diacanthus</u> among different length groups.**

Length group (mm)	Males	Females	Sex Ratio	X^2 value
91 - 110	-	32	-	-
111 - 130	-	64	-	-
131 - 150	6	58	1 : 9.67	42.25
151 - 170	10	59	1 : 5.90	34.7972
171 - 190	16	34	1 : 2.13	6.48
191 - 210	10	20	1 : 2	3.334
211 - 20	6	12	1 : 2	2
231 - 250	8	15	1 : 1.88	2.1304
251 - 270	6	22	1 : 3.67	9.1304
271 - 290	10	11	1 : 1.10	0.0476
291 - 310	18	8	1 : 0.44	3.8462
311 - 330	28	3	1 : 0.11	20.162
331 - 350	26	4	1 : 0.15	16.1334
351 - 370	21	4	1 : 0.19	11.56
371 - 390	19	-	-	-
391 - 410	4	-	-	-
411 - 430	2	-	-	-
431 - 450	3	-	-	-
451 - 470	-	-	-	-
471 - 490	1	-	-	-

females are more in number than males in all size groups with significant chi-square values. In the size group 271-290 mm there was no significant difference from the normal 1:1 sex ratio. From 291-370 mm, males were more than females and showed significant difference in sex ratio favouring males. From the size group 371-490 mm the males out numbered the females. It is reported by many workers that in protogynous hermaphrodites, the males will be more in larger size groups.

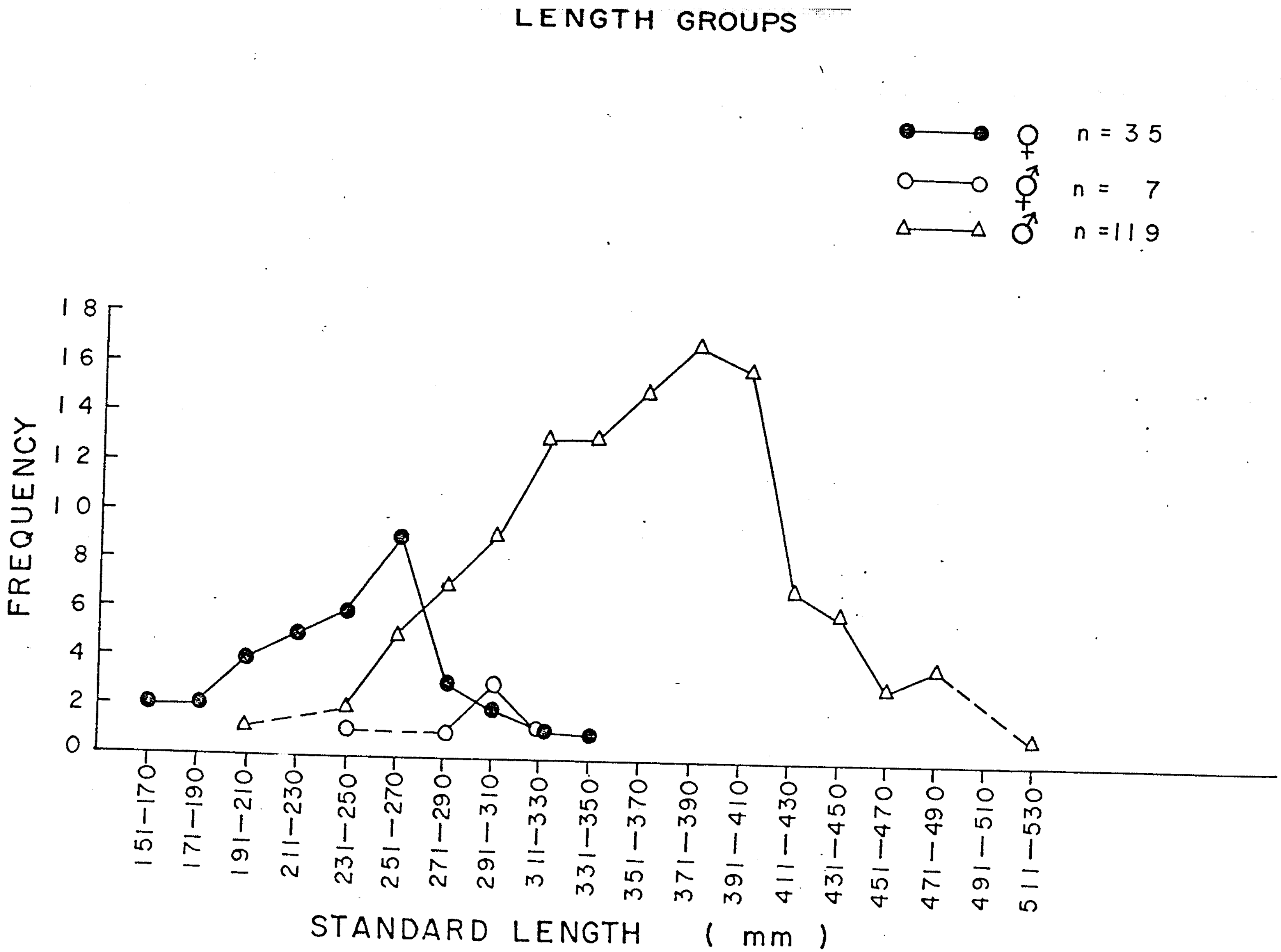
The sex ratio of females and males in different age groups are given in the Table-33. Only females were present in the age group 1. In age groups 2, 3, and 4 females were more in number. From age group 5 onwards there was considerable decrease in the number of females till age group 8. From age group 9 onwards only males were present. In all cases the chi-square value has shown a significant difference in the observed sex ratio than the normal sex ratio 1:1.

Sex composition in E. chlorostigma in different length groups.

Among the 161 E. chlorostigma sexed histologically, 35 were females, 119 were males and 7 were transitionals (Figure 34). The 151-170 mm and 171-190 mm size groups included two females each. The length group 191-210 mm had one male and four females and 211-230 mm had only five females and neither males nor transitionals. In 231-250 mm length group there were two males, one transitional and six females while 251-270 mm had five males and nine females. No transitionals were observed in this length group. In the size group 271-290 mm seven males, three females and one transitional were seen. The 291-320 mm length group had nine males, two females and three transitionals. The frequency of

TABLE-33. **Sex ratio of *E. diacanthus* in different age groups during December '90 to November '92.**

Age group	Grand Totals	Males	Females	Sex Ratio	x^2 value
1	5	-	5	-	-
2	78	4	74	1 : 18.5	6.282
3	122	24	98	1 : 4.08	44.886
4	58	18	39	1 : 2.05	6.896
5	33	20	13	1 : 0.65	1.4848
6	13	7	6	1 : 0.86	6.07692
7	14	12	2	1 : 0.17	7.142
8	16	13	3	1 : 0.23	6.25
9	13	13	-		-
10	10	10	-		-
11	1	1	-		-



LENGTH GROUPS
♀ n = 35
⚥ n = 7
♂ n = 119
FREQUENCY
0
2
4
6
8
10
12
14
16
18
151–170
171–190
191–210
211–230
231–250
251–270
271–290
291–310
311–330
331–350
351–370
371–390
391–410
411–430
431–450
451–470
471–490
491–510
511–530
STANDARD LENGTH (mm)

males increased with the increase in length and the frequency of females decreased with the increase in length. The 311-330 mm length group had thirteen males, one females and two transitionals. In 331-350 mm length group, there were 13 males and only one female. No transitionals were obsered in and beyond this length group. Though females start changing sex at any length on or beyond 250 mm more transitionals were observed in 291-310 mm length group. Larger length groups included only males. Male, female and transitionals were shown overlapping in length groups.

Sex ratio of E. chlorostigma:

The overall sex ratio between males and females during Dec. '90 - Nov.' 92 were found to be 1:0.331. Here sex ratio favours males. This might be because the samples included only larger fishes. Monthwise sex ratio could not be found out for E. chlorostigma since the samples were available only in November December, January, February and March.

Sex ratio of E. chlorostigma in different length groups:

To find sex ratio, transitionals were counted as males. The sex ratio of E. chlorostigma among different length groups were given in Table-34. The females out numbered males in lower length groups. The length group 191-210 mm had a sex ratio of 1:4 with chi-aquare value 1.8. In 211-250 mm length group, the sex ratio was 1:2, 251-270 mm had 1:1.8 271-290 mm had 1:0.375, 291-310 mm had 1:0.167 and 311-330 mm length group had 1:0.067. From 331 onwards males out numbered females. In

TABLE-34. **Sex ratio of E. chlorostigma in different length groups.**

Length group (mm)	Males	Females	Sex Ratio	x^2 value
151 - 170	-	2	-	-
171 - 190	-	2	-	-
191 - 210	1	4	1 : 4	1.8
211 - 230	-	5	-	-
231 - 250	3	6	1 : 2	1.0
251 - 270	5	9	1 : 1.8	1.1428
271 - 290	8	3	1 : 0.375	2.2728
291 - 310	12	2	1 : 0.167	7.0888
311 - 330	15	1	1 : 0.0667	12.2500
331 - 350	13	1	1 : 0.0769	10.2858
351 - 370	15	-	-	-
371 - 390	17	-	-	-
391 - 410	16	-	-	-
411 - 430	7	-	-	-
431 - 450	6	-	-	-
451 - 470	3	-	-	-
471 - 490	4	-	-	-
491 - 510	-	-	-	-
511 - 530	1	-	-	-

each case the chi-square value obtained revealed that the fish showed significant variation in the sex ratio from the normal sex ratio 1:1.

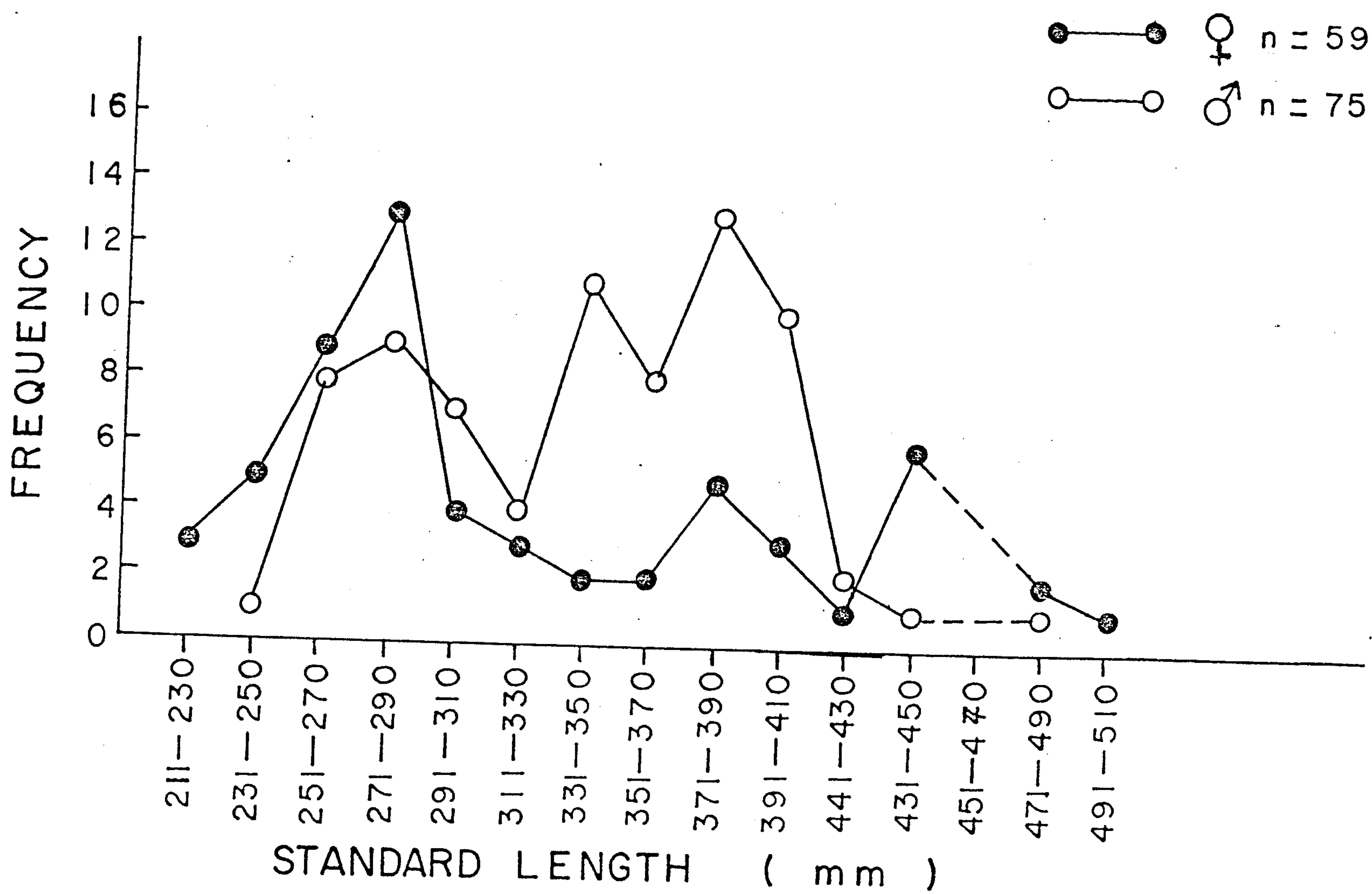
Sex composition of E. bleekeri in different length groups:

Among the 134 sex determined E. bleekeri, 59 were females and 75 were males. No transitionals were observed during the study period. Males and females were present in all the length groups except two length groups, 211-230 mm and 491-510 mm where only females were present. No fish either male or females were seen in 451-470 mm length group (Figure 35). In the length group 211-250 mm one male and five females were seen. The length group had 251-270 mm, eight males and nine females while that of 271-290 mm had nine males and thirteen females. The length group 291-310 mm had seven males and four females, that of 311-330 mm had four males and three females, and the length group 331-350 mm had eleven males and two females. While length group 351-370 mm had eight males and two females, the 371-390 mm group had thirteen males and five females, 391-410 mm length group had ten males and three females and the 411-430 mm group had two males and one female. From the length group 291 mm to 430 mm, males showed a relative increase in number with increase in length. But the length group 431-450 mm had one male and six females likewise the length group 471-490 mm had one male and two females. The length group 491-510 mm had only one female and no males.

Sex ratio of E. bleekeri

The overall sex ratio of E. bleekeri was 1:0.65, showing a signifi-

OF SEX IN *E. BLEEKERI* IN DIFFERENT LENGTH GROUPS



cant variation from the normal sex ratio. Since the samples included only larger ones the sex ratio favoured males. Monthwise sex ratio could not be found due to the non-availability of fish in other months except November, December, January, February and March.

Sex ratio of E. bleekeri in different length groups:

No 1:1 sex ratio was observed in any of the length groups (Table-35). Females outnumbered males in the length group 211-230 mm. From 231 mm to 290 mm SL the sex ratio favour females since females were more in number compared to males. In the length group 291-310 mm the sex ratio of females became half of that of males (1:0.57). In length group 311-330 mm it became 3/4 of that of males (1:0.75). From the length group 331- 410 mm, the ratio of females became still lower (1:0.182) and in 411-430 mm it reached 1:0.5. The sex ratio in 431-450 mm and 471-490 mm length groups favour females 1:6 and 1:2 respectively. In 451-470 mm length group, there were neither males nor females. The 491-510 mm length group had only one female. In each length group except 471-490 mm the chi-square test has proved that there was significant variation in the observed sex ratio from the normal.

9. Fecundity:

A knowledge of the fecundity of the species is essential for estimating the spawning population and seed propagation capacity of the species concerned. Fecundity of an individual fish is determined from the total number of mature ova, that are destined to be shed at the ensuing spawning season.

TABLE-35. **Sex ratio of *E. bleekeri* in different length groups.**

Length group (mm)	Males	Females	Sex Ratio	x^2 value
211 - 230	-	3	-	-
231 - 250	1	5	1 : 5	2.6666
251 - 270	8	9	1 : 1.125	0.0588
271 - 290	9	13	1 : 1.44	0.7272
291 - 310	7	4	1 : 0.57	0.0992
311 - 330	4	3	1 : 0.75	0.1428
331 - 350	11	2	1 : 0.182	6.2308
351 - 370	8	2	1 : 0.25	3.6000
371 - 390	13	5	1 : 0.385	3.5556
391 - 410	10	3	1 : 0.3	3.7692
411 - 430	2	1	1 : 0.5	0.3334
431 - 450	1	6	1 : 6	3.5714
451 - 470	-	-	-	-
471 - 490	1	2	1 : 2	0.3334
491 - 510	-	1	-	-

Fecundity of E. diacanthus:

For fecundity determination in E. diacanthus ovaries in stages 4 and 5 of maturity which were just on the verge of spawning were taken into account. In order to incorporate adequate data for fecundity studies mature fish during May '93 and June '93 were also taken in addition to the ones sampled in March, April, May and July 1991-92. Twenty eight mature ovaries in stages 4 and 5 were examined and the details are given in the Table-36.

Average fecundity for 28 fish was 57,458.00 the lowest fecundity observed was 7,830.0 and the highest 1,65,048.0. The fecundity of E. diacanthus ranges from 7.8×10^3 to 1.6×10^5.

Relationship between fecundity and ovary weight, total weight, standard length and relationship between ovary weight and standard length, total weight were also worked out.

Relationship between fecundity and ovary weight

In order to study the relationship between the fecundity and the weight of the ovary, the observed values of fecundity were plotted against the respective ovary weight which gave a linear relationship between the variables (Figure 36) according to the formula $F = 14.32 + 11.9771\ OW$, coefficient of correlation 'r' was found to be 0.9631.

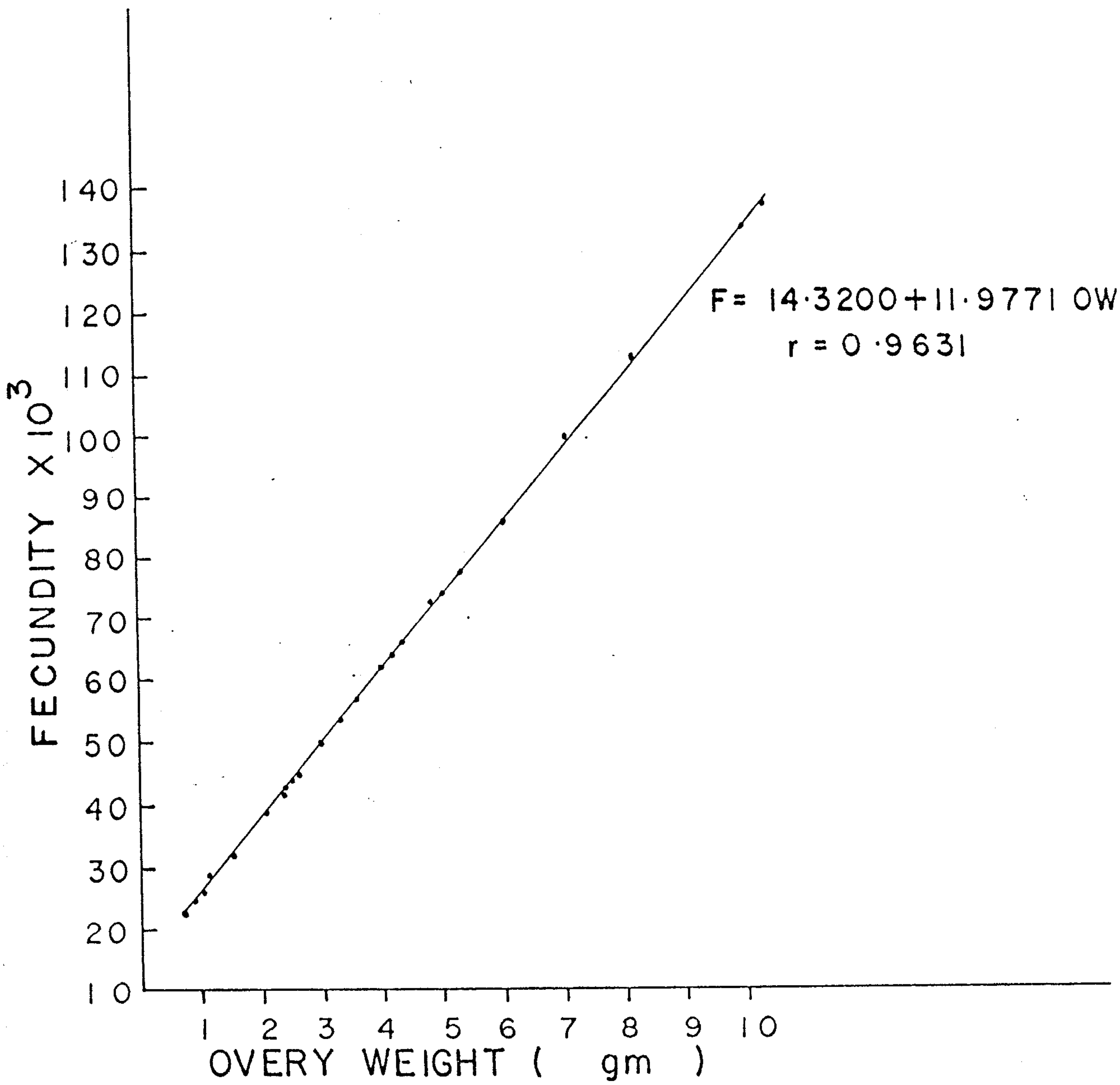
Relationship between fecundity and total weight:

The scatter diagram on the fecundity - fish weight relationship gave

TABLE-36. **Fecundity estimates of *E. diacanthus*.**

Month & year	Total Length mm	Standard Length mm	Total weight gm	Gonad weight gm(G)	Number of ova present in 0.10m (g) of ovary (n)	Fecundity $F = \frac{nG}{g}$
March 91	360	300	540	5.00	1483	67409.09
"	430	355	1000	10.02	782	78356.40
April 92	246	203	188	0.75	1750	13125.00
"	225	185	200	2.10	1582	33222.0
May 91	254	214	230	2.50	1680	40200.0
"	208	166	200	2.09	1452	30346.9
"	209	169	145	1.01	995	10049.5
"	231	190	150	1.20	1012	12144.0
May 92	227	187	133	3.35	1718	57533.0
"	237	195	157	4.35	1804	78474.0
"	219	180	137	3.00	1727	51810.0
"	219	180	123	5.35	1942	103897.0
"	220	180	129	1.48	1449	21445.2
"	201	167	98	3.60	1815	65340.0
May 93	241	197	171	7.12	1463	104165.6
"	225	185	130	2.38	1596	37984.8
"	236	193	158	6.05	1642	99341.0
"	236	192	156	4.30	1746	75078.0
""	221	180	121	8.20	1397	110454.0
"	215	176	124	3.98	1560	62088.0
"	203	163	109	4.15	1805	74907.5
June 93	235	194	188	4.88	1452	70857.6
"	231	189	144	1.90	1728	32832.0
"	210	174	111	2.60	1400	36400.0
"	194	158	86	2.42	1612	39010.4
July 91	231	188	134	0.90	870	7830.0
"	235	194	149	10.40	1587	165048.0
July 92	257	210	197	1.47	2004	29458.8

.36. THE REGRESSION RELATIONSHIP BETWEEN THE FECUNDITY AND OVARY WEIGHT OF <u>E. DIACANTHUS</u>



a linear relationship (Figure 37). The regression of fecundity (F) on total body weight (TW) can be expressed as F = 57.13 + 0.0143 TW and the correlation coefficient 'r' was found to be 0.6609.

Relationship between fecundity and standard length

To get better correlation of fecundity from standard length 185 mm onwards were plotted. This gave a linear relationship, according to the formula F = 45.7377 + 0.0778 SL. The correlation coefficient 'r' calculated to be 0.8437 (Figure 38).

Relation between ovary weight and standard length:

Weight of ovaries at stages 4 and 5 were plotted against standard length (Figure 39). A regression line was fitted to the data which gave a linear relationship according to the formula OW = -1.7562 + 0.0285 SL, the correlation coefficient 'r' was calculated to be 0.8600.

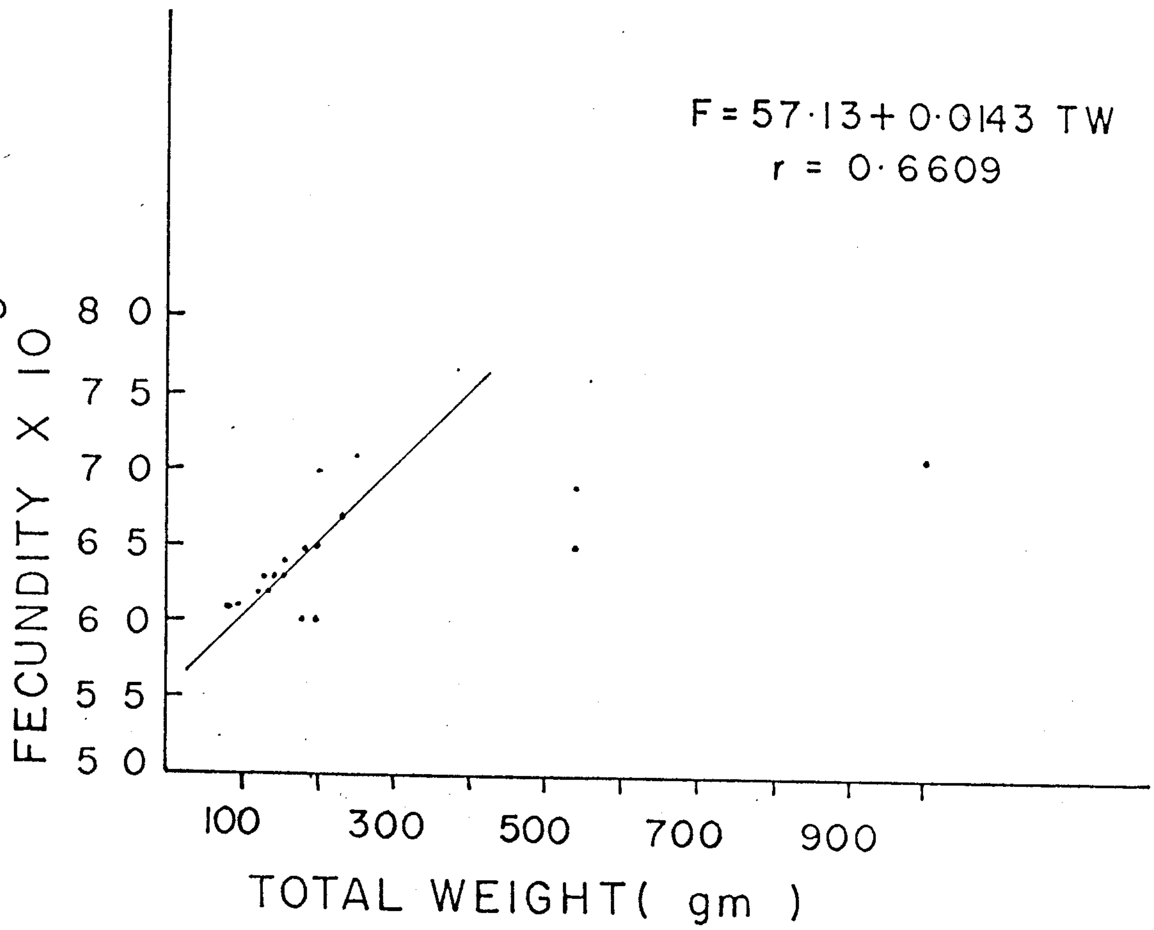
Relation between ovary weight and total weight:

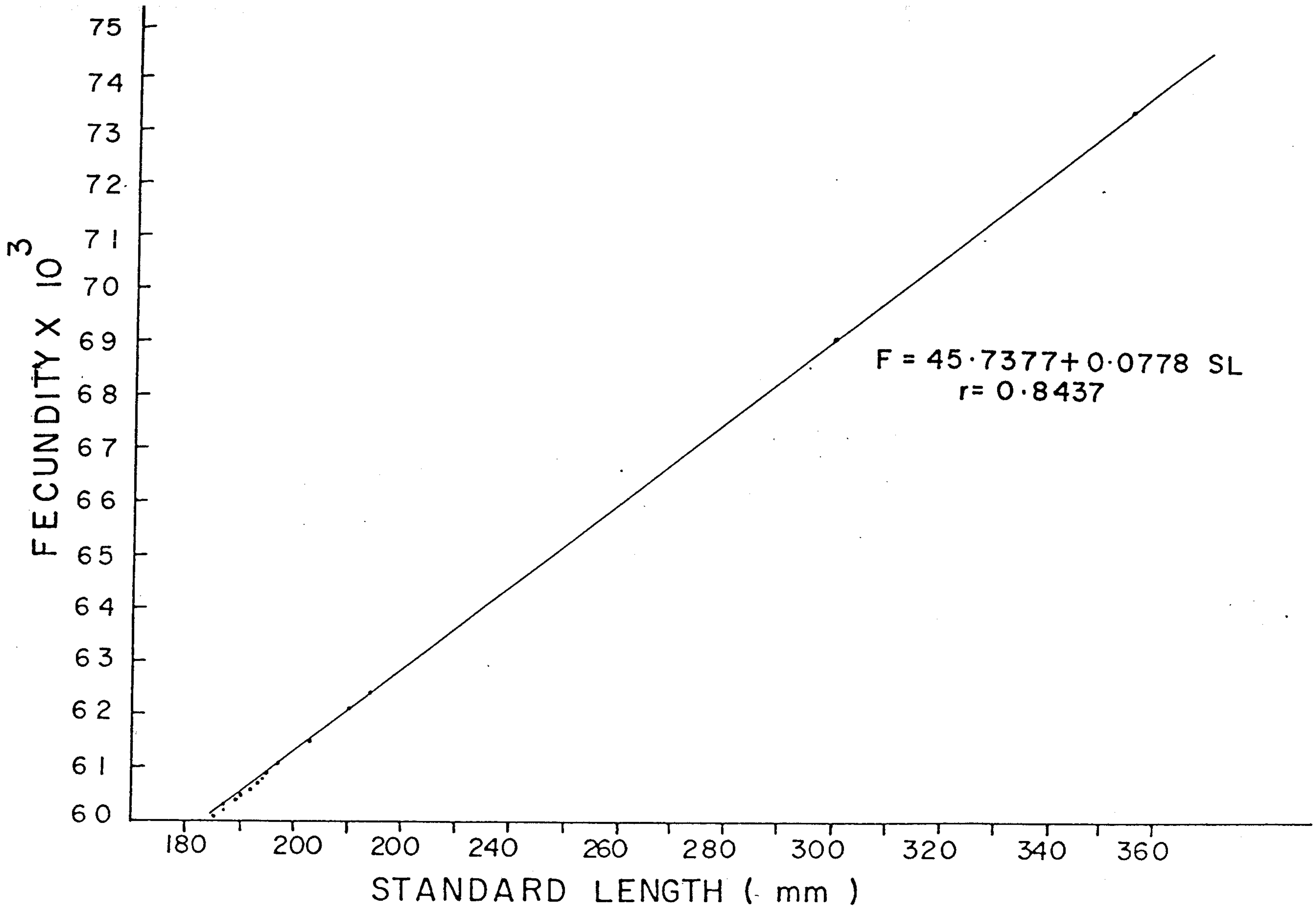
Weight of ovaries were plotted against corresponding total weight (Figure 40). A regression line was fitted using the formula, OW = 2.550 + 0.0065 TW. Correlation coefficient 'r' was found to be 0.7800.

Fecundity of E. bleekeri:

Fecundity was estimated from 19 mature ovaries. Marture females were available during December '91, January '91 and '92 and February '91 and '92. The Fecundity of E. bleekeri ranges from 1.09 x 10^5 to 2.9 x 10^6 (Table-37) with average fecundity 73,731. Relation between fecundity and standard length, total weight, oary weight and the relation between ovary weight and standard length, total weight were also worked out.

Fig. 37. THE REGRESSION RELATIONSHIP BETWEEN FECUNDITY AND TOTAL WEIGHT OF *E. DIACANTHUS*





FECUNDITY X 10^3
75
74
73
72
71
70
69
68
67
66
65
64
63
62
61
60
180
200
200
240
260
280
300
320
340
360
STANDARD LENGTH (mm)
F = 45·7377+0·0778 SL
r= 0·8437

WEIGHT AND STANDARD LENGTH OF
E. DIACANTHUS

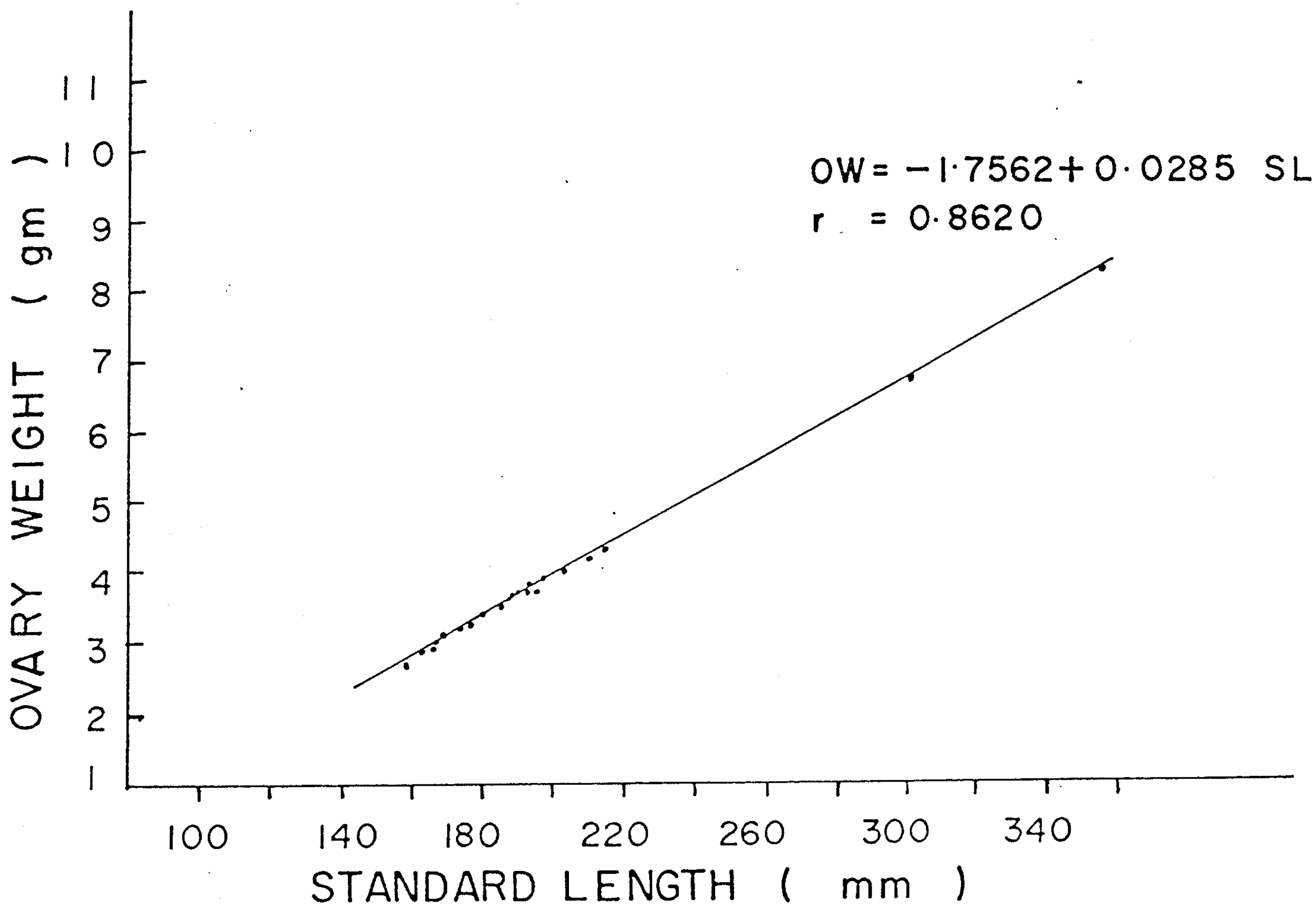
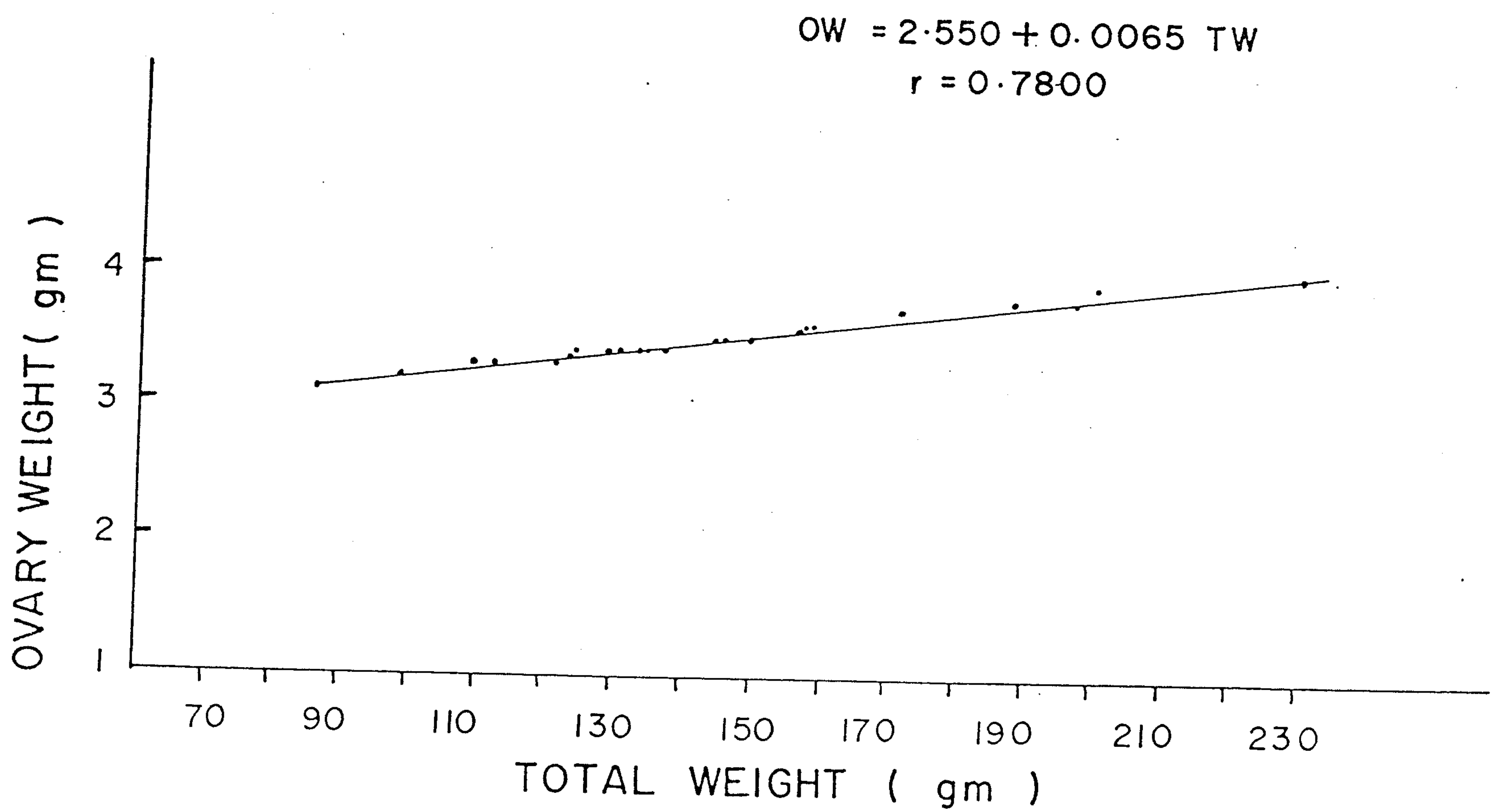


Fig. 40. THE REGRESSION RELATIONSHIP BETWEEN TOTAL WEIGHT AND OVARY WEIGHT OF *E. DIACANTHUS*



LE-37. **Fecundity estimates of *E. bleekeri.***

Month & Year	Total Length mm	Std. Length mm	Total Weight gm	Gonad Weight gm(G)	Number of ova present in 0.10m(g) of ovary (n)	Fecundity $F = \frac{nG}{g}$
December 91	359	290	452	6.0	5819	349140
"	384	310	600	12.0	5768	288400
January 91	453	380	1200	12.0	8185	982200
"	465	383	1100	6.0	5674	340440
"	573	484	1980	20.0	6008	1201600
"	530	443	1700	5.0	5604	280200
"	598	495	2000	24.0	12356	2965440
January 92	475	395	1100	18.0	5768	1038240
"	440	367	820	12.0	11411	1369320
"	409	337	720	10.0	5026	502600
"	455	383	900	12.0	6172	740640
"	388	321	620	6.0	5232	313920
February 91	50	445	1400	12.0	7855	942600
"	500	425	1260	3.0	4974	149220
"	460	380	1200	3.0	3978	119340
"	545	440	1720	7.5	6728	504600
"	540	450	1800	10.0	5264	526400
"	563	480	1940	14.0	6269	877660
February 92	540	448	2250	10.3	5030	518090

Relation between fecundity and standard length:

This was found out by plotting the fecundity estimates obtained for 19 fish in scatter diagram which showed a linear relationship according to the formula F = -127.5334 + 0.4995 SL. The correlation coefficient was calculated to be, 'r' = 0.7941 (Figure 41).

Relation between fecundity and total weight:

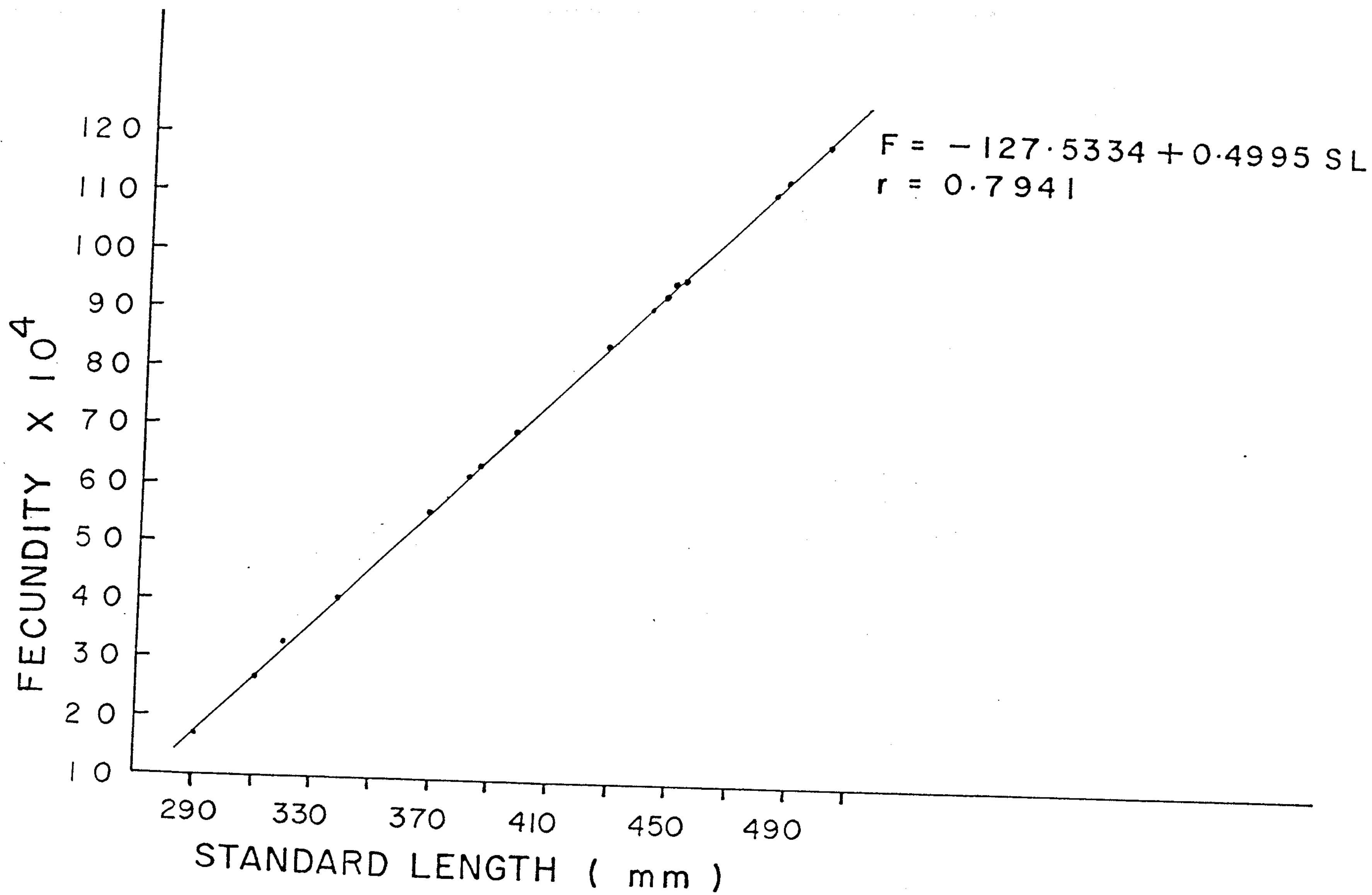
The scatter diagram on the fecundity total weight relationship of E. bleekeri gave a linear relationship (Figure 42). The regression of fecundity on total weight (TW) can be expressed as F = 9.2604 + 0.0418 TW the correlation coefficient 'r' was found to be 0.7883.

Relation between fecundity and ovary weight

In order to study the relationship between the fecundity and weight of the ovary, the observed values of fecundity were plotted against the respective ovary weights, which gave a linear relationship (Figure 43) between the variables according to the formula F = -41.8724 + 10.5987 OW. The correlation coefficient 'r' as 0.9295 (To get best correlation, the ovary weight from 5 g onwards were taken and thus 17 ovaries and their corresponding fecundity were taken in to account).

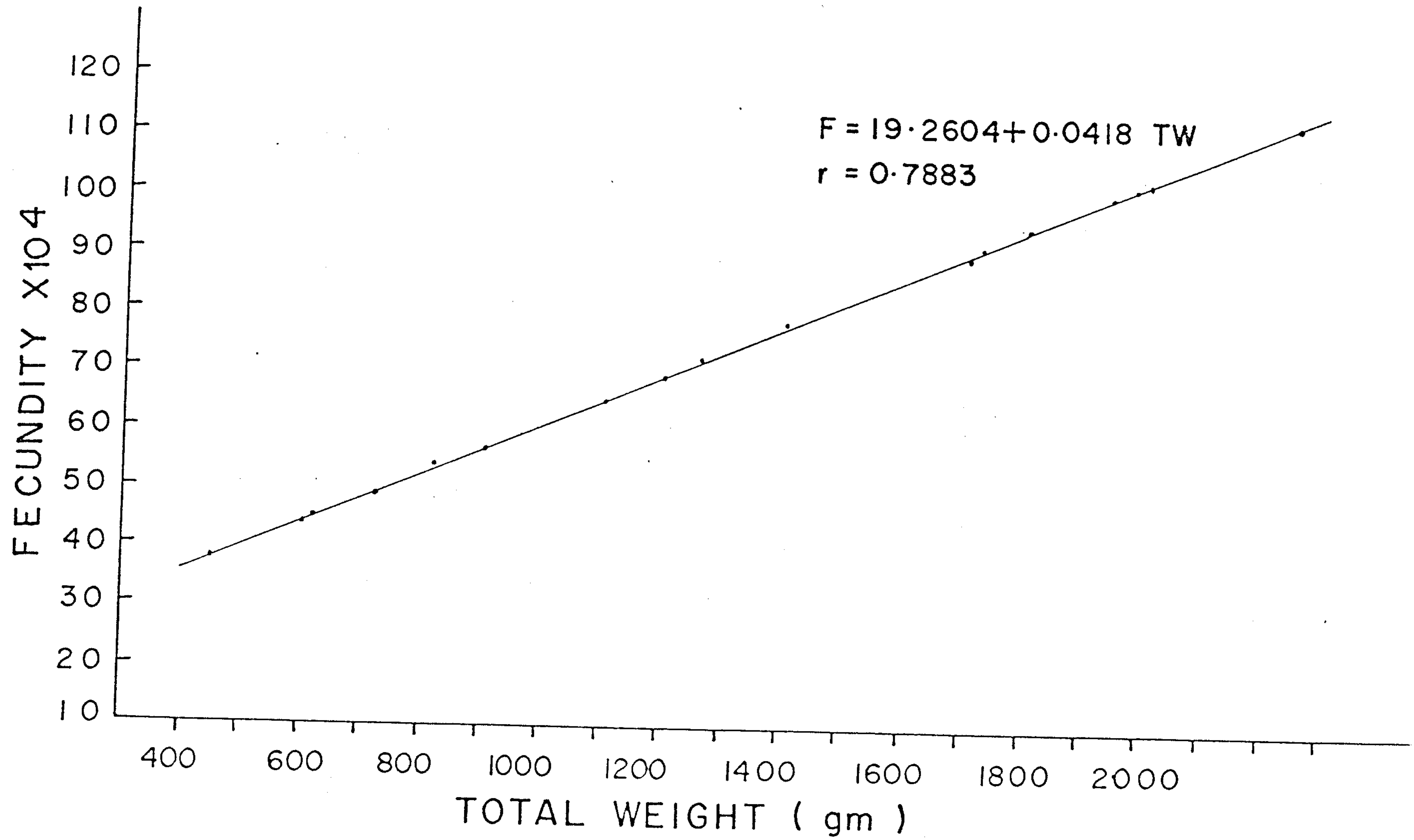
Relation between ovary weight and standard length:

Weight of ovaries were plotted against the corresponding standard length (Figure 44). A regression line was fitted to the data, which gave a linear relationship, according to the formula OW = -5.6052 + 0.0404 SL and the correlation coefficient 'r' = 0.9100.

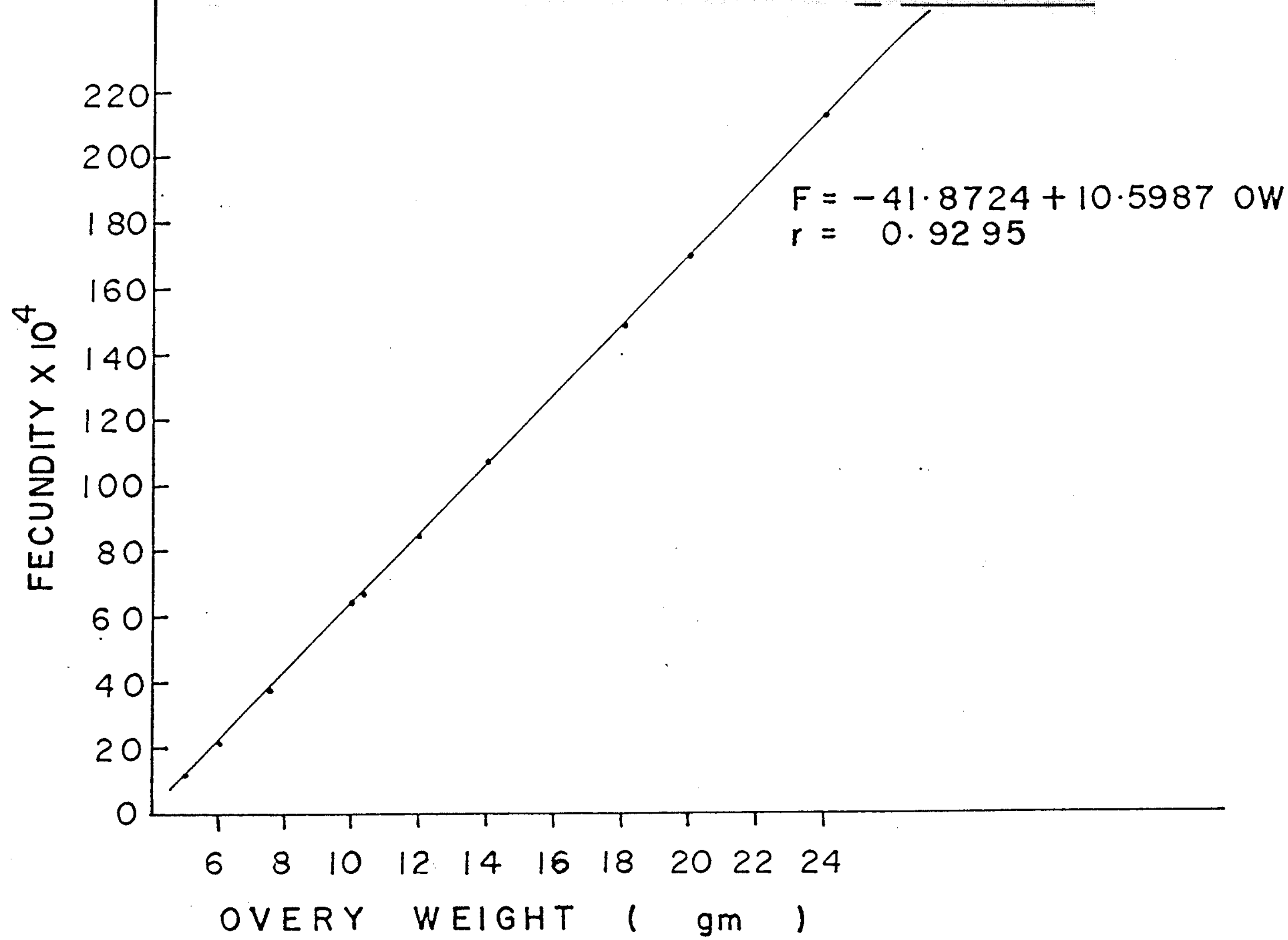


F = −127·5334 + 0·4995 SL.
r = 0·7941
FECUNDITY X 10^4
120
110
100
90
80
70
60
50
40
30
20
10
290
330
370
410
450
490
STANDARD LENGTH (mm)

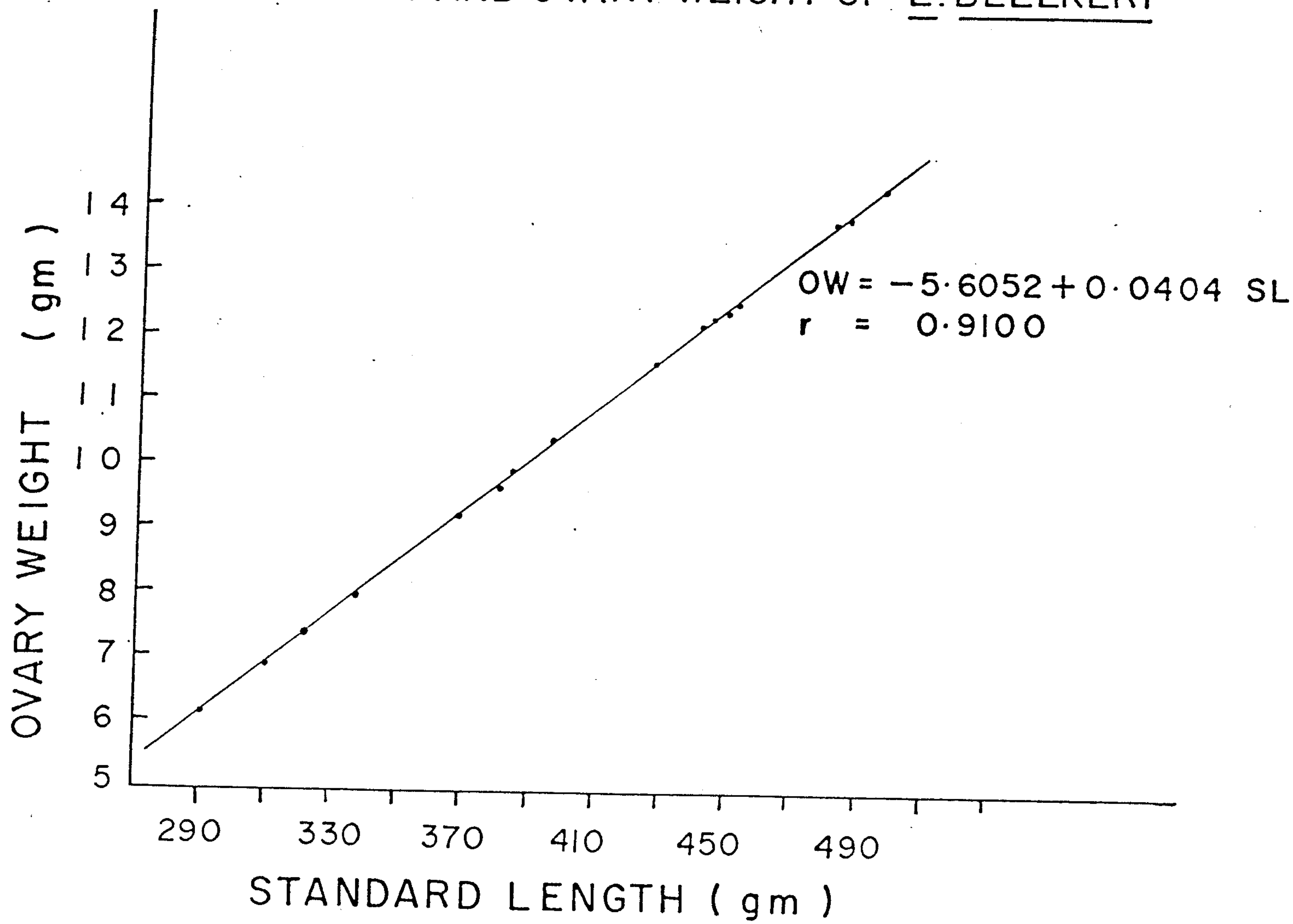
WEIGHT OF *E. BLEEKERI*



AND OVARY WEIGHT OF E. BLEEKER



THE REGRESSION RELATIONSHIP BETWEEN STANDARD LENGTH AND OVARY WEIGHT OF *E. BLEEKERI*

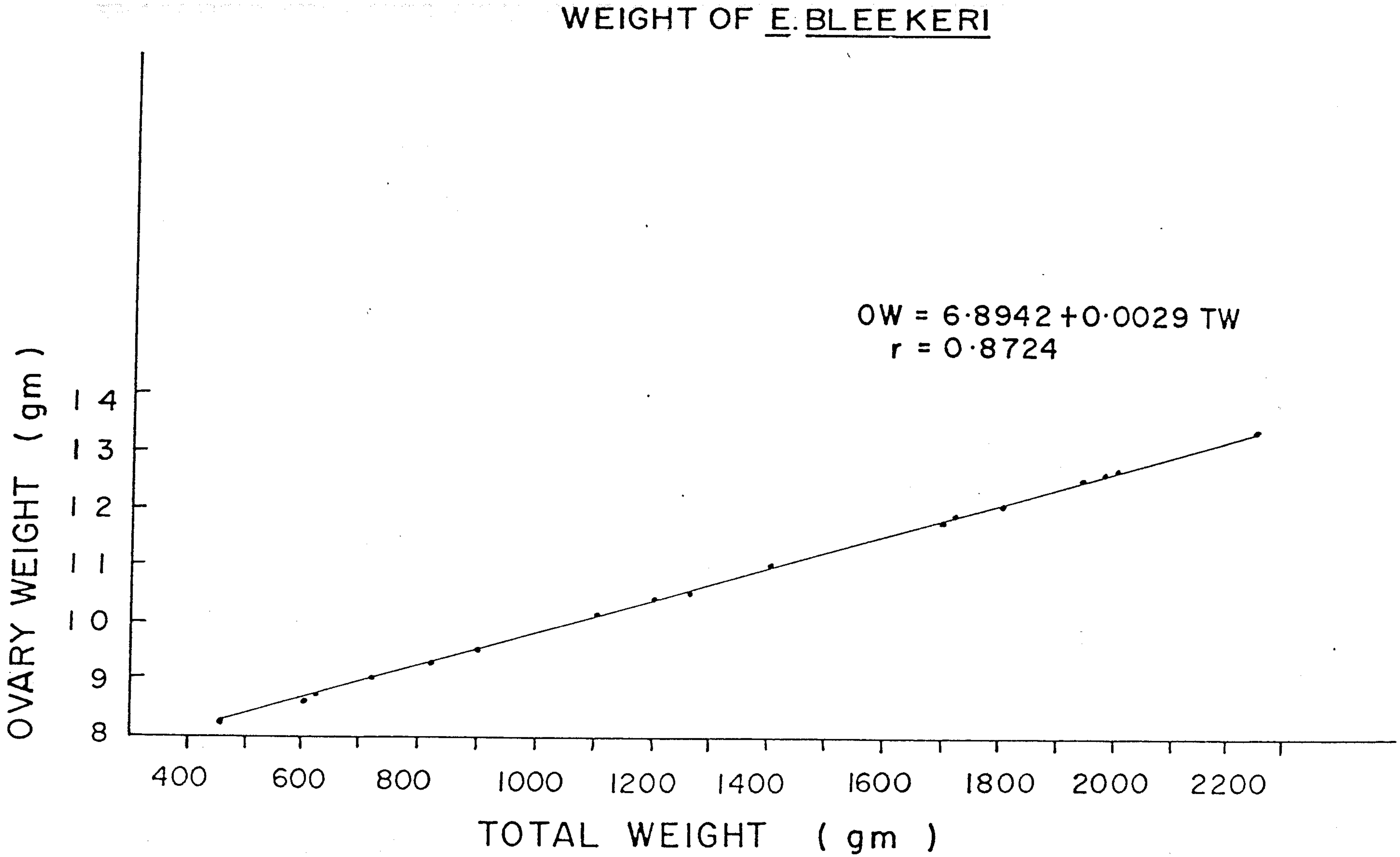


Relation between ovary weight and total weight

Weight of ovaries were plotted against total weight (Figure-45). A regression line was fitted to the data which gave a linear relationship according to the formula, OW = 6.8942 + 0.0029 TW and the correlation coefficient 'r' = 0.7824.

4.4. DISCUSSION

Teleost fishes are the only vertebrates that exhibit hermaphroditism as a normal mode of reproduction. Atz (1964) has given a vivid account on the intersexuality in fishes. Moe (1969) reported that sex transformation is more closely related with oogenetic and spawning activity than with age or growth of the individual. He also found that sex determination in red grouper, E. morio does not seem to have genetic basis. Liu (1944) opined that severe ecological conditions cause malnutrition which in turn produce sex reversal in fishes. Sexual transition can be stimulated under the influence of population pressures as Moe (1969) mentions "under conditions of over crowding and food scarcity numerous individuals may be induced to transform during the critical ages of 7 to 12 years. Since each transformation is equivalent to the death of the female, the cumulative effect of transition may be sufficient to alter the reproductive potential of the population". He also recommends that "if sexual transition is influenced by population pressure, then an intensive fishery would increase the number of females by preventing over crowding and inducing a drop in the transition rate. This would initially increase the reproductive potential by increasing the relative number of females". Studies by Liem (1963)


WEIGHT OF E. BLEEKERI
OW = 6·8942 + 0·0029 TW
r = 0·8724
OVARY WEIGHT (gm)
8
9
10
11
12
13
14
TOTAL WEIGHT (gm)
400
600
800
1000
1200
1400
1600
1800
2000
2200

and Harrington (1967) show that, environmental fators determine sex ratio of the Synbranchid and Cyprinodontid fishes respectively. Ross (1990) identified five distinct sex change mechanisms among sequentially hermaphroditic fishes based on socio-ecological characteristics.

Ovaries in many teleosts possess a maximum reproductive capacity at a certain age beyond which they lose their reproductive powers. Liem (1963) correlated this possibility in older females of Monopterus but because of their labile sex determination the reproductive capacity of the old females instead of termination continues as functional males by sex reversal. Thus "the occurrence of hermaphroditism in phylogenetically unrelated species in radically different environments may be regarded as the result of chance evolution". Warner (1975a) viewed the high overall zygote production which may occur under conditions of hermaphroditism as an advantage rather than positive adaptation. In his own words "in any group of animals sequential hermaphroditism may develop only when the individual carries the genetic capacity to function both as female and as a male with all concomittant anatomical, physiological and behavioural details. In addition the individual must have the capacity to shift from one sex to another after differentiation has occurred." As the age-specific fecundity in many populations is not distributed in the same way for males and females, so in some cases sequential hermaphroditism can convey a selective advantage to an individual by increasing reproductive potential relative to non-transforming members of the population.

The present study indicates that the length at sexual maturity is variable for E. diacanthus. Age studies have shown that mature active females were encountered only in age groups 3 and 4. Mature active males were observed from the age 2 to 11. Both male and female mature at the same age. Transitionals were seen from ages 2 onwards till age 8. So it is assumed that a female can change sex before it attains maturity. The data on primary males and secondary males shows that there were less number of primary males and most of the males are derived from the females after sex reversal. The data on E. chlorostigma and E. bleekeri do not reveal the existance of primary males. In E. bleekeri, eventhough it don't show any transitionals all the males show regressing oocytes in their testicular sections confirming they were derived from the females after sex change. No males were seen in age group 1 in E. diacanthus. Both sexes mature at about the same size between 151-170 mm SL. In E. diacanthus the smallest mature active female and male observed were 166 mm and 156 mm standard lengths respectively.

Warner (1975) said that in sequential hermaphroditism the growth rate of the individual is also an important parameter to consider as the animals undoubtedly react more to size than to age of their conspecifies in social interactions especially mating. Warner et al.,(1975) reported that more rapidly growing fishes change sex sooner than other individuals of the same age and fish that grow slowly may not change sex. Burnett-Herkes (1975) considers this factor for the occurrence of "giant females" in the Epinephelines. Most of the workers agree that if length or age is closely related to the sex reversal males should be larger or older than females of the same age or length group. (Warner 1975b; Burnett-Herkes, 1975; Mercer, 1978). Chen et al., (1980) found in E. diacanthus that the intersexual fish appeared first in the 2 year old class, and was present till 6 and none beyond this class. The first male emerged in the 2 year old class, males increased quickly and took over female's dominant position after 4 year old. The present study also indicates that in E. diacanthus the mean age and length of males exceeds that of females.

Erdman (1956) reported that in Puerto Rican waters E. fulvus spawns in December and E. guttatus, in January. Randall and Brock (1960) noted that peak spawning activity of certain Indo-Pacific species occurred a few days before full moon. Ukawa et al., (1966) reported that E. akaara always spawned between 15.30 and 16.30 hrs in culture ponds. Moe (1969) found in E. morio, the time of peak spawning as April and May in Gulf of Mexico. Munro et al., (1973) have seen that the spawning period of groupers in Jamaica and off-lying banks to be confined to the period between January and May with most spawning in February and March. Burnett-Herkes (1975) found that in Jamaica, spawning in E. guttatus is temperature correlated. Thompsun and Munro (1978) reported that E, guttatus spawns in January and E. striatus from January to April. Vadiya (1984) reports that spawning season begins in June and ends in September for E. aenus and it is from May to August for E. alexandrinus in South eastern mediterranean. Abu Hakima (1987) found that the spawning period of E. tauvina is from April to May in Kuwaiti waters. Premaletha (1989) reported that matured ova were met within the months June-July in E. aerolatus, the spawning season of E. chlorostigma was found to be during October-November period and ripe and running stages of E. diacanthus were obtained during May-June and young ones in September-October months from Cochin waters. Present study shows that spawning season for E. diacanthus is from March to July with peak spawning in May and that of E. bleekeri from December to February with peak spawning in January. No ripe females were seen in E. chlorostigma during the study period.

Ukawa et al., (1966) described the egg of E. akaara as pelagic spherical in shape and measuring 0.70 to 0.77 mm in diameter. The egg diameter of E. morio was found to be less than 1 mm by Moe (1969). Thompsun and Munro (1974) have found that in E. guttatus the egg diameter varies between 0.70 mm and 0.90 mm and Burnett-Herkes (1975) observed eggs varied in diameter from 1.07 to 1.32 mm for the same fish. Colin et al., (1987) reported that eggs of E. guttatus were 0.97 x 0.98 mm, Kitajima et al., (1991) described the eggs of E. septemfasciatus obtained by artificial fertilization were pelagic and spherical, 0.82 ± 0.017 mm in diameter. Powell and Tucker (1992) observed in E. striatus eggs of 0.92 mm (0.86-0.97 mm) in diameter. In the present study the maximum oocyte diameter in E. diacanthus was 0.60 mm and that of E. bleekeri was 0.58 mm.

Spawning aggregations help in reproductive potential. Thompsun and Munro (1974) reported spawning aggregation of E. striatus on the eastern shelf of Cayman Brac, Grand Cayman, the Belize (British Honduras) shelf and in the Bahamas. Burnett-Herkes (1975) has seen, spawning aggregations of four species of grouper, E. striatus, E. guttatus, Paranthias furcifer and E. fulvus from Bermuda platform aggregations, Colin (1987) reported the spawning aggregations of E. guttatus from Puerto Rico Colin (1992) described the spawning aggregation of Nassu grouper; E. striatus occurring at the southern end of Long Island and it was known for and exploited for many years by local fishermen. In his own words "the role of spawning aggregations in reproductive success is superficial at best. Because of the potential for dispersal of pelagic larvae of E. striatus away from spawning grounds the effects of over fishing of spawning stocks on recruitment and eventual renewal of spawning stocks may not necessarily be apparent. When relatively few aggregations were heavily fished and most others, because of their remote locations, were almost untouched, the effects of intensive fishing were not apparent".

Weight of ripe gonads relative to the total weight of the fish is small (Smith, 1965). Fecundity estimates have shown that there is a good correlation between size, total weight and gonad weight in both E. diacanthus and E. bleekeri. Moe (1969) observed the mean number of eggs for 14 gonads from E. morio was 1,469,200. Vadiya (1984) saw that fecundity in E. aenus increased with increase in the length and weight of the fish and the relative fecundity in E. alexandrinus decreased with increase in the length. Chen et al., (1980) found that the fecundity of E. diacanthus ranges from 63×10^3 to 233×10^3. Bouian and Siau (1983) reported that for equal sizes (SL 44 cm) E. aenus (Fecundity = 643,922) is more fecund than E. guaza (Fecundity = 606,246) and E. alexandrinus (435,202). Estimates of potential fecundity in E. tauvina ranged from 850,186 for a fish 35.1 cm long to 29,04,912 for a fish 62.3 cm long (Abu-Hakima, 1987). Selvaraj and Rajagopalan (1973) found in one E. tauvina that the total ova for an ovary weighing 17 Kg was estimated as 341.8 millions, of which the mature ova of the advanced mode constituted 258.9 millions. In the present study the average fecundity of E. diacanthus was 57458 and that of E. bleekeri was 737371.

Most of the workers on the sequential hermaphroditism have considered that the differences in the proportion of females and males in the successive age classes must be due to sex changes (Atz, 1964; Moe, 1969; Mercer, 1978; Chen et al., 1980). Jones (1980) has said that "protogyny is advantageous in species in which large males can exclude small males from normal pair spawning and consequently have a disproportionately high reproductive success and also that the optimal age of sex change is determined by the size at which a female can give access to a female gamete larger than she can produce herself". Leigh (1970) has said that the variations from one to one sex ratios may be due to the different mortality of the sexes, restricted nutrition, one sex being more active than the other, an out-migration of one sex and utilization of different habitats by the two sexes. Variations from the 1:1 sex ratio in hermaphrodites may also be due to the sex reversal as pointed out by Warner (1975b) and Manooch (1976). Burnett-Herkes (1978) got 1:1.7 ratio for E. guttatus from Bermuda.

The predominance of female E. diacanthus in smaller size intervals is the result of protogynous hermapnroditism. Burnett-Herkes (1975) reported that the relatively large size of male fish support evidence for protogynous hermaphroditism. Mercer (1978) described that in protogynous hermaphrodite mortality causes sex to be biased towards females, the later the age of sex reversal the more biased the sex ratios become. In E. diacanthus the overall sex ratio for different months was found to be 1:1.78. In E. chlorostigma and E. bleekeri the overall sex ratio was 1:0.331 and 1.0.65 respectively. This variation favouring males might be due to the small sample size or because the samples belonged to only larger sized fishes.

Warner (1975a) has stated that, when age-or size specific sex ratios are investigated in sequentially hermaphroditic populations, there is often a fairly sharp change in ratio at a particular point. This is the "initial" size or age where the transformation at earlier or later sizes or ages leads to a reduction in the expected net reproductive rate. This occurs between 291-370 mm SL for E. diacanthus and 271-290 mm SL for E. chlorostigma. For E. bleekeri this critical size occurs in 291-310 mm but from 431 mm SL onwards the sex ratio favours females. Since the groupers are subjected to the intensive hook and line fishing during post-monsoon season in off Cochin areas, the larger and older individuals are removed from the population. This may be the reason for skewed sex ratios in the larger size intervals and older age classes.

As Smith (1965) suggested groupers show the Epinephelus type of hermaphroditism, where the entire gonad is an admixture of ovarian and testicular tissue. Self fertilization is prevented by the separation of sexes temporally. During juvenile and female phases, the testicular tissue is present as small groups of cells in the germinal epithelium of all the lamellae. The spermatogonial crypts can be differentiated from the oogonial cells by the simultaneous development of spermatogonia rather than the asynchronous development of oogonia. Fishelson (1970) showed the regulation of protogynous sex reversal in Anthias squamipinnis by the presence or absence of a male fish. Shapiro (1981) said that the continuous and internal tendency of a female to change sex is often inhibited by the presence and aggression or dominance of the male or more dominant female. In the absence of a dominating individual, the inhibition is released and a female changes sex.

Chen et al., (1980) reports that in E. diacanthus self fertilization is prevented in such a way that, sex transformation takes place soon after the spawning season and is finished before the next spawning season. Erickson and Grossman (1986) also said that in tile fish Lopholatilus chamaeleonticeps sex reversal may be rapid and restricted to a short time span and may not occur in all the individuals in the population. Webb and Kingsford (1992) found sex changing individuals throughout the year in half banded sea perch, Hypoplectrodes maccullochi. In the present study sexual transformation in E. diacanthus occurs before and after the breeding season.

Mercer (1978) has pointed out that post spawning season is the most opportune time for sex reversal to take place since the gonad is already disrupted from spawning. Highest percentage of transitional individuals in E. diacanthus were seen in the post spawning month, August. No transitionals were seen in the spawning months, March to July. Only 7 transitionals were seen in E. chlorostigma and highest percentage was seen in January. In E. bleekeri no transitionals were seen. The spawning season was from December to February. Chan and Philips (1967) have found in Monopterus albus, the ricefield eel, the initiation of testicular development was always found in post spawning condition. Moe (1967) found most transitional stages of E. morio in post spawning ovaries. Warner (1975b) observed sexual transformation in Pimelometopon pulchrum, the California spheepshead, in the winter months between breeding seasons.

The size and age at sex reversal are highly variable in E. diacanthus. Transitional individuals were collected throughout the length range of females and this indicates that some females do not change sex or they change sex in a very irregular pattern. Highest percent of transitionals were observed in 291-310 mm size group in E. diacanthus and the males (83%) were derived from the females after sex change since regressing oocytes were present in their gonad sections. Only 17 percent were primary males, which are the males by birth itself and not derived from females after sex change.

The percentage of transitional individuals 23% seems to be too low to account for the percentage of males (77%) which have been derived from females. Therefore sex reversal might have taken place over a short time period.

Sex reversal has been controlled variously, hormonally (Yamamoto, 1962) environmentally (Harrington 1971) and socially (Fishelson, 1970; Robertson and 1972; Ross, 1990). Atz (1964) has suggested that the apparent lack of separation of masculine (medullary) and feminine (cortical) element during embryological development must be the cause of the relative frequent occurrence of hermaphoditism in teleosts.

Each sex change mechanism may be viewed as adaptive in a social contexct imposed by ecological constraints. Ghiselin (1969) in his size advantage model explained that the sex change should occur whenever an individual's fitness increases with size (or age) at a faster rate through one sex function than through the other. Early sex change may also confer a long term advantage through growth acceleration when size affects reproductive success greatly (Warner 1975). Ross (1990) described that the advantage of not changing sex to fish at the bottom of the hierarchy, is that premature sex change might well result in their inability to compete against much larger males or females and result in a loss of feeding sites or possibly death.

Sequential hermaphroditism occurs as Ghiselin (1969) explained with the help of size advantage model, where an individual reproduces not efficiently as a member of one sex when small or young, but as a member of the other sex when it gets older or larger. And he continued that proterogyny might occur when it is advantageous for a male to be large, for example, where there is sexual selection, or where the male cares for the young, like wise the protandry would be favoured when it is advantageous for the female to be larger such as to produce a larger number of eggs.

Warner (1975a) concluded that in sequential hermaphroditism protandry may be selected for in populations when individuals mate randomly, as along as female fecundity increases with age for at least first few years of the mature life span. Selection for protogyny can exist when such things as inexperience, male dominance, mate selection or territoriality lead to a differential in male expected fecundities in succeeding ages or when female fecundity decreases with age.

Ross (1990) made an effort to develop a comprehensive theory of exchange in that, given a set of ecological conditions and social organization, one can predict whether sex change is likely in a given fish species, and by what general mechanism the process of sex change will proceed. According to him sex change suppression is characteristic of species with small group size and rigid dominance hierarchies, and for them sex change is inevitable in the absence of group dominance. Early sexchange appears to have evolved from protogynous suppression under special conditions involving the loss of mating control by a single dominant individual in certain species (Centropyge).

In sex change induction, a characteristic of species with large social groups lacking dominance hierarchies, sex change must be induced by specific characteristics of the social group. His universal induction - inhibition model says that all cases of sex change require stimulation from smaller conspecifics, while the behavioural - scaling models, say that all fish have the genetic capacity to switch mechanisms depending on changing ecological conditions and resulting changes in mating system. Neuro-physiological models suggest that induction mechanisms which require at least two categories of environmental stimuli may have evolved from the simpler suppression mechanisms which require only one kind of input from that environment

The present study view sex change as Ross (1990) viewed, as an integrative, multilevel phenomenon caused by specific environmental stimuli, reaching certain neuroendocrine pathways, and resulting in predi-ctable anatomical changes in the reproductive system of a hemaphroditic fish.

CHAPTER 5

RACIAL STUDIES

5.1. INTRODUCTION

Racial studies of fishes are carried out with an objective to determine whether a species consists of heterogenous groups or is homogenous throughout its range of distribution. It is of utmost importance in any fishery to have a knowledge of the nature and composition of the exploited stocks for rational exploitation and management. For this purpose, a stock may be defined as a population in which the vital parameters of recruitment, growth and mortality are homogenous. If the exploited species comes from one stock, the fishing intensity at any one place will have its effects at other places also. But if the fishery is supported by more than one stock, the effect of over fishing on a stock at one place will not affect the fishery for the other stocks.

Population studies of various fishes were made from different parts of the world and to distinguish them, different workers have adopted different methods. Some workers have taken into consideration only meristic counts, while others have studied both meristic counts as well as morphometric characters. In some cases, a number of characters analysed might not show significant differences while in others, a single charcter might well be useful to denote distinct population.

Ahlstrom (1957) stated that under conditions of partial or complete isolation of groups of fish, slight difference in morphological or meristic characters will be preserved in each group. The small differences will not necessarily be apparent in individual specimens but often only in an average of a large number of specimens.

It has been shown by experimental work on several groups of fishes that environmental factors such as temperature, salinity, pH and oxygen tension can modify the expression of genes responsible for meristic characters (Tanning, 1952; Orska, 1957; Trojner, 1977; Todd *et al.*, 1981 etc.). The number of serially repeated characters evidently alters with the environmental changes associated with latitude, has been demonstrated by Hubbs (1926) and Gross (1977). Thus phenotypic expression of characters represents a complex reciprocity between epigenetic, physiological and environmental factors. Barlow (1961) described that, morphological clines, especially for those forms which have some what disjunct populations, are regarded as the consequences of environmental modifications coupled with adaptive genetic changes.

Some of the earlier works on racial studies were by Tester (1937), who indicated the existence of local populations in the herring, *Clupea pallasi* in the coastal waters of British Columbia, from an analysis of meristic counts and morphometric characters, Pillay (1951) used morphometric characters in a study of the species of Barbus, Raney and De Sylva (1953) and Lund (1957) on the striped bass, *Roccus saxatilis*, Royce (1964) on yellow fin tuna, *Thunnus albacores*, Mais (1972) on the Pacific sardine, Sharp *et al.*, (1978) on Capelin, *Mallotus villosus* and Meng and Stocker (1984) on the Pacific herring *Clupea harengus pallasi*, Eknath *et al.*, (1991) described a new method, the truss morphometrics to detect subtle differences in variations of shape, independent of size and Melvin et al., (1992) studied the usefullness of meristic and morphometric characters in discriminating populations of American Shad, Alosa sapidissima using linear discriminant analysis. Recently Li et al., (1993) have described the advantages of truss morphometrics over traditional morphometrics.

The relative growth of body parts of a fish vary at different stages of its life history and this was exemplified by Godsil (1948) and Marr (1955). It is therefore imperative that the ratios between the body parts of fishes from different localities can not be used for distinguishing populations unless the stage of development (size range of fish) is kept uniform. In order to overcome this difficulty the comparison of the different samples is based on the comparison of the regression of one dimension on that of another, taken as a measurement of overall size. This method is widely used by almost all the workers who have attempted a study of the populations of various fishes (James, 1967). The other approach for the removal of size influences in analysis of shape is multivariant analysis including discriminate and principal component analysis (Winans, 1985).

5.2. MATERIALS AND METHODS

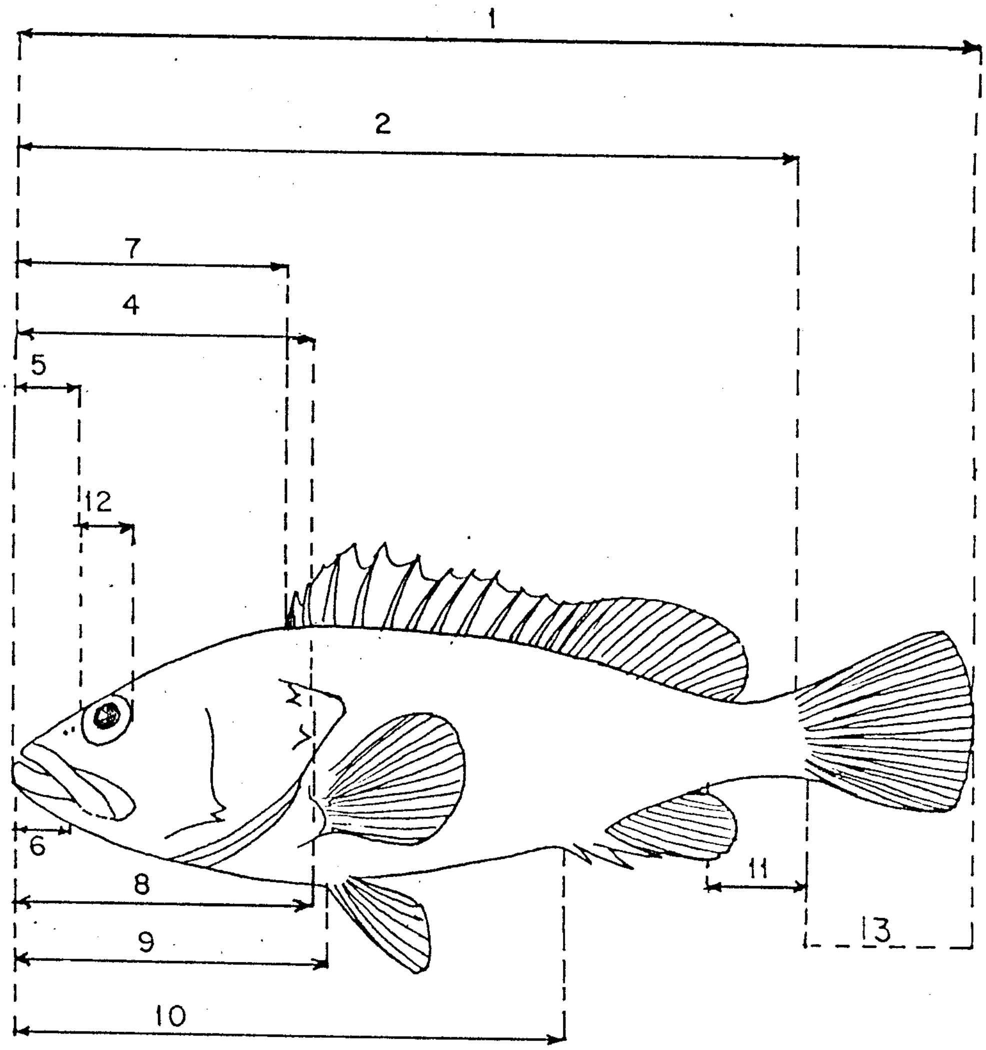
For the racial investigations the E. diacanthus were collected from Cochin and Calicut. These two places belong to the south west coast of India. The locations studied were limited to the areas from which large specimens were available. Fish were brought to the laboratory in fresh condition and measurements were taken with the help of a twine. Twenty four general morphometric measurements were made on the lines described by Holden and Raitt (1974) and Barel et al., (1976) (Figure 46 and 47).

General morphometric characters:

1. Total length (TL)
2. Standard length (SL)
3. Total weight (WT)
4. Head length (HL)
5. Snout length (SNL)
6. Lower jaw length (LJL)
7. Pre-dorsal distance (LD)
8. Pre-pectoral distance (L)
9. Pre-ventral distance (LVL)
10. Pre-anal distance (LA)
11. Caudal peduncle length (CPL)
12. Eye diameter horizontal (EYL)
13. Caudal fin length (CFL)
14. Eye diameter vertical (EYD)
15. Head depth (HD)
16. Cheek depth (CHD)
17. Greatest depth (GH)
18. Dorso-anal depth (D_1A_1)
19. Perpendicular depth (A_1A_2)
20. Caudal peduncle depth (LPD)
21. Length of pectoral fin (PH)
22. Length of ventral fin (VH)
23. Largest dorsal fin ray (LDFR)
24. Largest anal fin ray (LAFR)

In addition to the above morphometric measurements, measurements were also made of 21 distances between homologous land marks on the body outline as proposed by Eknath et al., (1991) (Figure-48). This measurements were made to avoid the biases of traditional measurements, like dense measurements in some areas of the body and a paucity elsewhere.

Fig . 46. MORPHOMETRIC LINEAR MEASUREMENTS OF *E. DIACANTHUS*



MORPHOMETRIC VERTICAL MEASUREMENTS OF E. DIACANTHUS

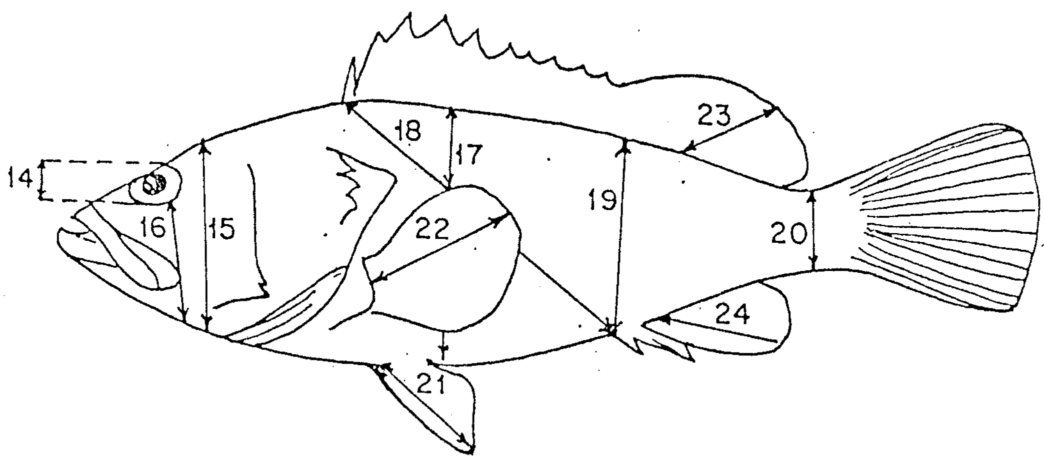
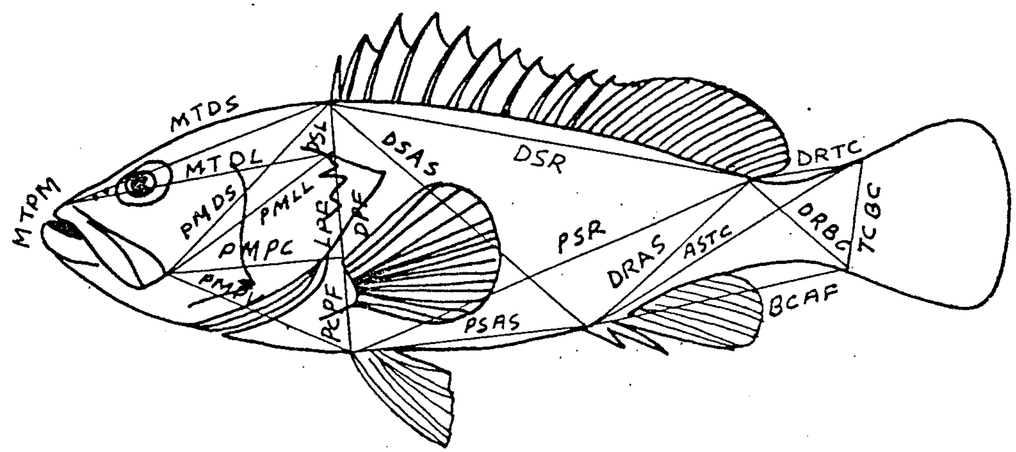


Fig. 48. TRUSS NET WORK OF 21 LAND MARK POINTS ON THE BODY OUTLINE MEASURED DURING MORPHOMETRIC CHARACTERIZATION OF E. DIACANTHUS



Morphometric characters for truss net work:

1. MTPM - The distance between the upper jaw and lower jaw.

2. MTDS - The distance from the tip of the upper jaw to the base of the first dorsal spine.

3. MTDL - The distance from the tip of the upper jaw to the upper point of attachment of operculum.

4. PMDS - The distance from the maxilla to the base of the first dorsal spine.

5. PMLL - The distance from the maxilla to the base of the upper point of attachment of operculum.

6. PMPC - The distance from the maxilla to the base of the first pectoral fin ray.

7. PMPV - The distance from the maxilla to the base of the first pelvic fin ray

8. PCPF - The distance between the bases of first pelvic fin ray and first pectoral fin ray

9. LPF - The distance from the first pectoral fin ray to the upper point of attachment of operculum.

10. DSL - The distance from the upper point of attachment of operculum to the base of the first dorsal spine.

11. DPF - The distance between the bases of first pelvic fin ray and the first dorsal spine.

12. DSR - The distance from the base of the first dorsl spine to the last dorsal fin ray

13. DSAS - The distance between the bases of first dorsal spine and first anal spine

14. PSR - The distance between the first pelvic fin ray and the last dorsal fin ray.

15. PSAS - The distance from the base of first pelvic fin ray to the base of the first anal spine.

16. DRAS - The distance between the bases of first anal spine and the last dorsal fin ray.

17. ASTC - The distance from the base of first anal spine to the base of the first upper caudal fin ray

18. BCAF - The distance from the base of first anal spine to the base of the last lower caudal fin ray.

19. DRBC - The distance from the last dorsal fin ray to the base of last lower caudal fin ray.

20. DRTC - The distance from the last dorsal fin ray to the base of the first upper caudal fin ray.

21. TCBC - The distance between the bases of first upper caudal fin ray and the lower last caudal fin ray.

The general morphometric characters and truss morphometric characters were treated for their mean, variance, standard deviation and standard error. The characters were tested by 't' test to see whether they are coming from the same population. The regressions of the general morphometric chracters like SL,HL, SNL, LJL, LD, LP, LVL, LA, CPL and EYL from the two places were tested for significance using analysis of covariance (Snedcor and cochran, 1967). Standard length was taken as independent variable. Ten characters from general morphometrics and truss morphometrics were selected for principal component analysis.

5.3. RESULTS

1. General morphometrics

Twenty four general morphometric characters were tested for mean, variance, standard deviation and standard error (Table 38 and 39). To know whether they belong to homogenous population or not, 't' test was performed (Table-40). Analysis of covariance was performed for the characters standard length, head length snout length lower jaw length, pre-dorsal distance, pre-pectoral distance, pre-ventral distance,pre-anal distance, caudal peduncle length, horizontal eye diameter (Table-41).

TABLE-38. **Results of various statistical treatments of general morphometric characters of *E. diacanthus* from Cochin**

Characters	Mean	Variance	Standard Deviation	Standard Error
TL	335.500	8687.105	93.205	20.841
SL	283.650	6571.924	81.067	18.127
WT	560.850	206181.713	454.072	101.534
HL	107.050	849.629	29.148	6.518
SNL	26.800	74.484	8.630	1.930
LJL	54.400	256.568	16.018	3.582
LD	103.450	924.471	30.405	6.799
LP	107.400	923.095	30.382	6.794
LVL	110.550	1025.103	32.017	7.159
LA	182.450	3628.997	60.241	13.470
CPL	32.400	108.884	10.435	2.333
EYL	23.000	30.737	5.544	1.240
CFL	57.550	207.208	14.395	3.219
EYD	20.900	33.568	5.794	1.296
HD	91.550	1505.208	38.797	8.675
CHD	28.350	158.029	12.571	2.811
GH	107.500	1381.632	37.170	8.312
D_1A_1	132.300	1563.484	39.541	8.842
A_1A_2	70.150	521.082	22.827	5.104
CPD	31.100	137.358	11.720	2.621
PH	59.500	255.737	15.992	3.576
VH	45.150	114.766	10.713	2.395
LDFR	34.650	76.976	8.774	1.962
LAFR	38.300	82.116	9.062	2.026

TABLE-39. **Results of various statistical treatments of general morphometric characters of *E. diacanthus* from Calicut.**

Characters	Mean	Variance	Standard Deviation	Standard Error
TL	380.233	1430.185	37.818	6.905
SL	318.367	1111.068	33.333	6.086
WT	684.667	55025.747	234.576	42.827
HL	111.933	155.030	12.451	2.273
SNL	27.300	11.734	3.426	0.625
LJL	66.400	37.972	6.162	1.125
LD	114.233	145.426	12.059	2.202
LP	125.033	196.240	14.009	2.558
LVL	130.300	198.148	14.077	2.570
LA	230.100	644.852	25.394	4.636
CPL	35.333	15.471	3.933	0.718
EYL	27.000	18.138	4.259	0.778
CFL	62.600	131.352	11.461	2.092
EYD	26.633	22.378	4.731	0.864
HD	121.733	176.340	13.279	2.424
CHD	27.467	12.189	3.491	0.637
GH	122.700	220.838	14.861	2.713
D_1A_1	147.767	244.323	15.631	2.854
A_1A_2	81.533	82.326	9.073	1.657
CPD	33.467	14.464	3.803	0.694
PH	66.233	55.978	7.482	1.366
VH	49.833	21.247	4.609	0.842
LDFR	38.733	21.789	4.668	0.852
LAFR	43.767	50.875	7.133	1.302

TABLE-40. **Summary of the results of 't' test in respect of general morphometric characters of *E. diacanthus* between Cochin and Calicut**

Characters	Degrees of freedom	Calculated Value
TL	48	15.9841**
SL	48	14.2249**
WT	48	8.5708**
HL	48	5.5206**
SNL	48	1.6762*
LJL	48	53.3570**
LD	48	11.8521**
LP	48	16.6450**
LVL	48	20.1778**
LA	48	26.1125**
CPL	48	9.5912**
EYL	48	19.5217**
CFL	48	9.4640**
EYD	48	24.6662**
HD	48	26.6822**
CHD	48	2.6070**
GH	48	13.6592**
D_1A_1	48	38.3251**
A_1A_2	48	16.6735**
CPD	48	6.9802**
PH	48	13.5855**
VH	48	14.3827**
LDFR	48	14.4993**
LAFR	48	16.0620**

** Significant at 5% level

* Non significant

ıBLE-41. Analysis of covariance of different general morphometric characters from Cochin and Calicut

	Source of variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	P%
ɪad length	Deviation from individual regression between places	46	1261	27		
	Differences between regressions	1	22	22	0.8148	NS
	Deviations from total regression	47	1283	27		
ɪout length	Deviation from individual regression between places	46	234	5.0870		
	Differences between regression	1	79	79.000	15.5298	S
	Deviation from total regression	47	313	6.5208		
ɪwer jaw ɪngth	Deviation from individual regression between places	46	2486	54		
	Differences between regressions	1	16	16	3.375	NS
	Deviation from total regression	47	2502	53		
ɪedorsal ɪstance	Deviation from individual regressions between places.	46	627278	13636		
	Differences between regressions	1	356	356	0.2611	NS
	Deviation from total regression	47	627634	13354		
ɪe-pectoral ɪstance	Deviation from individual regressions between places	46	1525	33.1522		
	Differences between regressions	1	91	91.0000	2.7479	NS
	Deviation from total regression	47	1616	34.3829		
ɪe-Ventral ɪtance	Deviation from individual regressions between places	46	6223	135		
	Differences between regressions	1	1486	1486	11.0074	S
	Deviation from total regression	47	7709	164		
ɪe-anal ɪtance	Deviation from individual regressions between places	46	13976	304		
	Differences between regressions	1	1123	1123	3.6941	NS
	Deviation from total regressions	47	15099	321		
ɪudal ɪdunde ɪgth	Deviation from individual regressions between places	46	421	9.1522		
	Differences between regressions	1	91	91.0000	9.9430	S
	Deviation from total regressions	47	512	10.8936		
ɪediameter ɪizontal	Deviation from individual regressions between places	46	328	7.1304		
	Differences between regressions	1	5	5.0000	0.7102	NS
	Deviation from total regressions	47	333	7.0850		

Total length:

The 't' test has proved that there was significant difference in total length between fishes from two localities. The mean total length (mm) from Cochin sample was 335.500 with a range 211-508. The variance, standard deviation and standard error were 8687.105, 93.205 and 20.841 respectively. The mean total length (mm) from Calicut sample was 380.233 with a range 310-454. The variance, standard deviation and standard error respectively were 1430.185, 37.818 and 6.905.

Standard length:

The 't' test has proved that there was significant difference in standard length between fishes from the two localities. The mean standard length from Cochin sample is 283.650 mm with a range 172-431. The variance, standard deviation and standard error were 6571.924, 81.067 and 18.127 respectively. The mean standard length from Calicut sample was 318.367 mm ranging between 257-382. The variance, standard deviation and standard error were 1111.068,33.333 and 6.086 respectively.

Total weight:

The 't' test has proved that there was significant difference in total weight between fishes from the two localities. The mean total weight (g) from Cochin sample was 560.850 ranging from 97 to 1700. The variance, standard deviation and standard error were 206181.713,454.072 and 101.534 respectively. The mean total weight from Calicut sample was 684.667 g with a range 320-1240. The variance, standard deviation and standard error were 55025.747, 234.576 and 42.827 respectively.

Head length:

The 't' test has proved that there was significant difference in the head length between fishes from the two localities. The mean head length from Cochin sample was 107.050 mm with a range 66-162. The variance, standard deviation and standard error were 849.629, 29.148 and 6.518 respectively. The mean head length from Calicut sample was 111.933 mm ranging between 91-133. The variance, standard deviation and standard error were 155.030, 12.451 and 2.273 respectively.

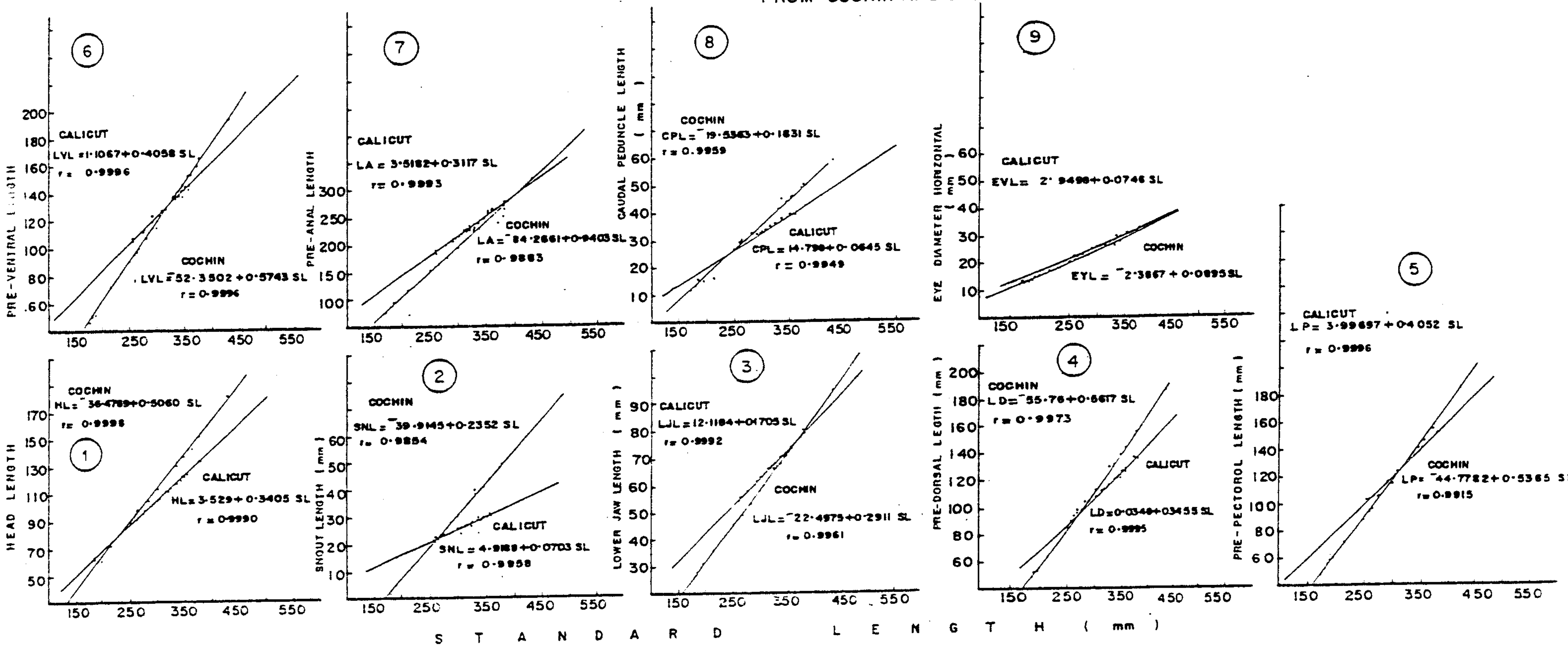
The relationship between standard length and head length from the Cochin sample was found to be linear. The regression equation was HL = -36.4769 + 0.5060 SL with a correlation coefficient 'r' = 0.9988. The relationship between standard length and head length from the Calicut sample was also found to be linear. The regression equation was HL = 3.5290 + 0.3405 SL with a correlation coefficient 'r' = 0.9990 (Figure 49-1).

Analysis of covariance revealed that the head length is insignificant between Cochin and Calicut.

Snout length:

The 't' test has proved that there was no significant difference in snout length between fishes from the two localities. The mean snout length from Cochin sample was 26.8 mm with a range 14-45. The variance,

Fig. 49 THE RELATIONSHIP OF STANDARD LENGTH (mm) WITH (1) HEAD LENGTH (mm) (2) SNOUT LENGTH (3) LOWER JAW LENGTH (mm) (4) PRE-DORSAL LENGTH (mm) (5) PRE-PECTORAL LENGTH (mm) (6) PRE-VENTRAL LENGTH (mm) (7) PRE-ANAL LENGTH (mm) (8) CAUDAL PEDUNCLE LENGTH (mm) AND (9) EYE DIAMETER HORIZONTAL (mm) OF *E. DIACANTHUS* FROM COCHIN AND CALICUT



standard deviation and standard error were 74.484, 8.630 and 1.930 respectively. The mean snout length from Calicut sample was 27.300 mm with a range 21-34. The variance, standard deviation and standard error were 11.734, 3.426 and 0.625 respectively.

A linear relationship was established between standard length and snout length from the Cochin sample. The regression equation was SNL = -39.9145 + 0.2352 SL, with a correlation coefficient 'r' = 0.9854. The relationship between the standard length and snout length for the Calicut sample was found to be linear. The regression equation was SNL = 4.9188 + 0.0703 SL, with a correlation coefficient 'r' = 0.9958 (Figure 49-2). Analysis of covariance revealed that snout length was significant between fishes from two localities.

Lower jaw length:

The 't' test has proved that there was significant difference in lower jaw length between fishes from the two localities. The mean lower jaw length from Cochin sample is 54.400 mm with a range 33-88. The variance, standard deviation and standard error respectively were 256.568, 16.018 and 3.582. The mean lower jaw length from Calicut sample is 66.400 with a range 52-78. The variance, standard deviation and standard error respectively were 37.972, 6.162 and 1.125.

The relationship between standard length and lower jaw length from the Cochin sample was found to be linear. The regression equation was LJL = -22.4975 + 0.2711 SL, with a correlation coefficient 'r' = 0.9961. A linear relationship was established between the standard length and lower jaw length from the Calicut sample. The equation was LJL = 12.1184 + 0.1705 SL, with a correlation coefficient 'r' = 0.9992 (Figure-49-3).

Analysis of covariance revealed that lower jaw length is not significant between the fishes from Cochin and Calicut.

Pre-dorsal distance:

The 't' test has proved that there was significant difference in pre-dorsal distance between fishes from two localities. The mean pre-dorsal distance from Cochin sample was 103.450 mm with a range 62-156. The variance, standard deviation and standard error were 924.471, 30.405 and 6.799 respectively. The mean pre-dorsal distance from Calicut sample is 114.233 mm with a range 90-136. The variance, standard deviation and standard error were 145.426, 12.059 and 2.202 respectively.

The relationship between the standard length and pre-dorsal distance from the Cochin sample was found to be linear. The regression equation was LD = -55.8760 + 0.5617 SL the correlation coefficient 'r' was 0.9973. For the Calicut sample the relationship between standard length and pre-dorsaal distance was also found to be linear. The regression equation was LD = 0.0348 + 0.3455. SL; with a correlation coefficient 'r' = 0.9995 (Figure-49-4).

Analysis of co-variance revealed that pre-dorsal distance is insignificant between Cochin and Calicut samples.

Pre-pectoral distance:

The 't' test has proved that there was significant difference in the pre-pectoral distance between fishes from the two localities. The mean pre-pectoral distance from Cochin sample was 107.400 mm with a range 68–145. The variance, standard deviation and standard error respectively were 923.094, 30.382 and 6.794. The mean pre-pectoral distance from the Calicut sample was 125.033 mm with a range 98-150. The variance, standard deviation and standard error were 196.240, 14.009 and 2.558 respectively.

The samples from Cochin gave a linear relationship between standard length amnd pre-pectoral distance. The regression equation was found to be LP = -44.7782 + 0.5365 SL with a correlation coefficient 'r' = 0.9915. The relationship between the standard length and pre-pectoral distance from the Calicut sample was also found to be linear. The regression equation was LP = 3.9697 + 0.4052 SL with a correlation coefficient 'r' = 0.9996 (Figure-49-5).

The analysis of covariance revealed that the pre-pectoral distance was insignificant between Cochin and Calicut samples.

Pre-ventral distance:

The 't' test has proved that there is significant difference in the pre-ventral distance between fishes from the two localities. The mean pre-ventral distance from Cochin sample was 110.550 mm with a range 71-156. The variance, standard deviation and standard error were 1025.103, 32.107 and 7.159.respectively. The mean pre-ventral distance from Calicut sample was 130.300 mm with a range 100-155. The variance, standard deviation and standard error were 198.148, 14.077 and 2.570 respectively.

The relationship between standard length and pre-ventral distance from the Cochin sample was found to be linear with a regression equation LVL = -52.3502 + 0.5743 SL. The correlation coefficient 'r' was 0.9996. For the Calicut sample, the relationship between the standard lengtn and pre-ventral distance was found to be linear. The regression equation was LVL = 1.1067 + 0.4058 SL with the correlation coefficient 'r' = 0.9996. (Figure-49-6).

Analysis of covariance revealed that there was significant difference in the pre-ventral distance between Cochin and Calicut samples.

Pre-anal distance:

The 't' test has proved that there was significant difference between fishes from the two localities. The mean pre-anal distance from Cochin sample was 182.450 mm with a range 123-318. The variance, standard deviation and standard error were 3628.997, 60.241 and 13.470 respectively. The mean pre-anal distance from Calicut sample was 230.100 mm with a range 171-284. The variance, standard deviation and standard error respectively were 644.852, 25.394 and 4.636.

The relationship between the standard length and pre-dorsal distance from the Cochin sample was found to be linear. The regression equation was LA = -84.2661 + 0.9403 SL. The correlation coefficient 'r' was 0.9883.

The relationship between the standard length and pre-anal distance was also found to be linear, with an equation, LA = 3.5182 + 0.3117 SL and the correlation coefficient 'r', 0.9993 (Figure-49-7).

Analysis of covariance revealed that this character is significant in the two localities.

Caudal peduncle length:

The 't' test has proved that there was significant difference in caudal peduncle length between the fishes from the two localities. The mean caudal peduncle length from the Cochin sample was 32.400 mm with a range 16-53. The variance, standard deviation and standard error were 108.884, 10.435 and 2.333 respectively. The mean caudal peduncle length, from the Calicut sample was 35.333 with a range 28-45. The variance, standard deviation and standard error were 15.471, 3.933 and 0.718 respectively.

Linear relationship was established between standard length and caudal peduncle length from the Cochin samples. The equation was CPL = -19.5363 + 0.1831 SL, with a correlation coefficient 'r' was 0.9959. The sample from the Calicut also showed a linear relationship between standard length and caudal peduncle length. The regression equation was CPL = 14.7980 + 0.0645 SL, with a correlation coefficient 'r' = 0.9949 (Figure-49-8).

Analysis of covariance revealed that there is significaant difference in caudal peduncle length between Cochin and Calicut samples.

Eye diameter horizontal:

The 't' test has proved that there is significant difference in the horizntal eye diameter between the fishes from the two loalities. The mean horizontal eye diameter from Cochin sample was 23.00 mm with a range 15-33. The variance, standard deviation and standard error were respectively 30.737, 5.544 and 1.240. The mean horizontal eye diameter from Calicut sample was 27.00 mm with a range 22-38. The variance, standard deviation and standard error were 18.138, 4.259 and 0.778 respectively.

The relationship between the standard length and eye diameter horizontal was found to be linear from the Cochin sample. The regression equation was EYL = -2.3867 + 0.0895 SL. The correlation coefficient 'r' was 0.9969. The samples from the Calicut have shown linear relationship between the standard length and eye diameter horizontal. The regression equation was EYL = 2.9498 + 0.0746 SL with a correlation coefficient 'r' = 0.9939 (Figure-49-9).

The analysis of covariance revealed that this character is insignificant between the two localities.

Caudal fin length:

The 't' test has proved that there was significant differences in caudal fin length between fishes from the two localities. The mean caudal fin length from the Cochin sample is 57.550 mm with a range 38-79. The variance, standard deviation and standard error respectively were 207.208, 14.395 and 3.219. The mean caudal fin length from the Calicut sample was 62.600 with a range 56-74. The variance, standard deviation and standard error were 131.352, 11.461 and 2.092 respectively.

Eye diameter vertical

The 't' test has proved that there was significant difference in the vertical eye diameter between fishes from the two localities. The mean eye diameter vertical from Cochin sample was 20.900 with a range 13-34. The variance, standard deviation and standard error were 33.568, 5.794 and 1.296 respectively. The mean eye diameter from the Calicut sample was 26.633, with a range 16-40. The variance, standard deviation and standard error were respectively 22.378,4.731 and 0.864.

Head depth:

The 't' test has proved that there was significant difference in the head depth between fishes from the two localities. The mean head depth from Cochin sample was 91.550 mm with a range 55-181. The variance, standard deviation and standard error were 1505.208, 38.797, and 8.675 respectively. The mean head depth from Calicut sample was 121.733, with a range 97-152. The variance, standard deviation and standard error were 176.340, 13.279 and 2.424 respectively.

Cheek depth:

The 't' test has proved that there was significant difference in the cheek depth between the fishes from the two localities. The mean cheek depth from the Cochin sample was 28.350 mm with a range 15-56. The variance, standard deviation and standard error were respectively, 158.029, 12.571 and 2.811. The mean cheek depth from the Calicut sample was 27.467 with a range 22-36. The variance, standard deviation and standard error were respectively 12.189, 3.491 and 0.637.

Greatest depth:

The 't' test has proved that there was significant difference in the greatest depth between the fishes from the two localities. The mean greatest depth from Cochin sample was 107.500 with a range 57-183. The variance, standard deviation and standard error were respectively, 1381.032, 37.170 and 8.312. The mean greatest depth from Calicut sample was 122.700 with a range 97-148. The variance, standad deviation and standard error were respectively, 220.838, 14.861 and 2.713.

Dorso-anal depth:

The 't' test has proved that there was significant difference in the dorso-anal depth between the fishes from the two localities. The mean dorso-anal depth from Cochin sample was 132.300 mm with a range 80-213. The variance, standard deviation and standard error were 1563.484, 39.541 and 8.842 respectively. The mean dorso-anal depth from Calicut sample was 147.767 mm with a range 123-182. The variance, standard deviation and standard error were 244.323, 15.631 and 2.854 respectively.

Perpendicular depth:

The 't' test has proved that there was significant difference in the perpendicular depth between the fishes from the two localities. The mean perpendicular depth from Cochin sampe was 70.150 mm with a range 40-112. The variance, standard deviation and standard error were 521.052, 22.827 and 5.104 respectively. The mean perpendicular depth from the Calicut sample was 81.533 with a range 67-100. The variance, standard deviation and standard error were 82.326, 9.073 and 1.657 respectively.

Caudal peduncle depth:

The 't' test has proved that there was significant difference in the caudal peduncle depth between fishes from the two localities. The mean caudal peduncle depth from Cochin sample is 31.100 mm with a range 18-44. The variance, standard deviation and standard error were 137.358, 11.720 and 2.621 respectively. The mean caudal peduncle depth from Calicut sample was 33.467 mm with a range 27-42. The variance, standard deviation and standard error were 14.464, 3.803 and 0.694 respectively.

Length of pectoral fin:

The 't' test has proved that there was significant difference in the length of pectoral fin between fishes from the two localities. The mean pectoral fin length from Cochin sample was 59.500 mm with a range 36-87. The variance, standard deviation and standard error were 255.737, 15.992 and 3.576 respectively. The mean pectoral fin length from Calicut sample was 66.233 mm with a range 57-81. The variance, standard deviation and standard error were 55.978, 7.482 and 1.366 respectively.

Length of ventral fin

The 't' test has proved that there was significant difference in the length of ventral fin between fishes from the two localities. The mean ventral fin length from Cochin sample was 45.150 mm with a range 29-62. The variance, standard deviation and standard error were respectively 114.766, 10.713 and 2.395. The mean ventral fin length from Calicut sample was 49.833 mm with a range 44-61. The variance, standard deviation and standard error were respectively 21.247, 4.609 and 0.842.

Length of largest dorsal fin ray

The 't' test has proved that there was significant difference in the length of the largest dorsal fin ray between fishes from the two localities. The mean of largest dorsal fin ray length from Cochin sample was 34.650 mm with a range 22-48. The variance standard deviation and standard error were respectively 76.976, 8.774 and 1.962. The mean of the largest dorsal fin ray length from Calicut sample was 38.733 mm with a range 31-45. The variance, standaard deviation and standard error respectively were 21.789, 4.668 and 0.852.

Length of the largest anal fin ray:

The 't' test has proved that there was significant difference in the length of the largest and fin ray between fishes from the two localities The mean length of the largest and fin ray from Cochin sample was

38.300 mm with a range, 25-56. The variance, standard deviation and standard error were respectively 82.116, 9.062 and 2.026. The mean length of the largest anal fin ray from Calicut sample was 43.767 mm with a range 35-56. The variance, standard deviation and standard error respectively were 50.875, 7.133 and 1.302.

Principal component analysis:

The ten general morphometric characters selected for principal component analysis were standard length, head length, snout length, lower jaw length, pre-dorsal distance, pre-pectoral distance, pre-ventral distance, pre-anal distance, caudal peduncle length and eye diameter horizontal (Table-42). *PCA showed that the percentage of variance for principal component* I and principal component II were 92.6% and 5.5% respectively for the samples collected from Cochin, while that of Calicut samples were 94.1% and 2.5% respectively. The principal components derived from PCA showed that though there is a slight overlapping of Cochin sample with Calicut sample, altogether the two samples two distinct populations (Figure-50).

2. **Truss morphometrics**

The twenty one homologous points on the body outline of the fish taken from Cochin and Calicut were subjected to statistical analysis like mean, variance, standard deviation and standard error (Table 43 and 44). The significance of the characters were tested using 't' test (Table-45).

MTPM:

The 't' test has proved that there was significant difference in MTPM between the fishes from the two localities. The mean MTPM

TABLE-42. **Character loadings of general morphometric variables of <u>E. diacanthus</u> used for principal component analysis.**

CHAR	COCHIN		CALICUT	
	PR1	PR2	PR1	PR2
SL	0.693	0.347	0.677	-0.470
HL	0.243	0.209	0.233	-0.300
SNL	0.064	0.078	0.047	-0.088
LJL	0.133	- 0.091	0.117	0.038
LD	0.255	0.172	0.235	-0.074
LP	0.252	0.207	0.279	-0.066
LVL	0.270	0.112	0.281	0.031
LA	0.478	- 0.857	0.504	0.809
CPL	0.087	- 0.020	0.045	0.113
EYL	0.046	0.027	0.051	0.050
VAR(%)	92.6	5.5	94.1	2.5

Figures indicate the character loadings

Fig.50. PRINCIPAL COMPONENT ANALYSIS

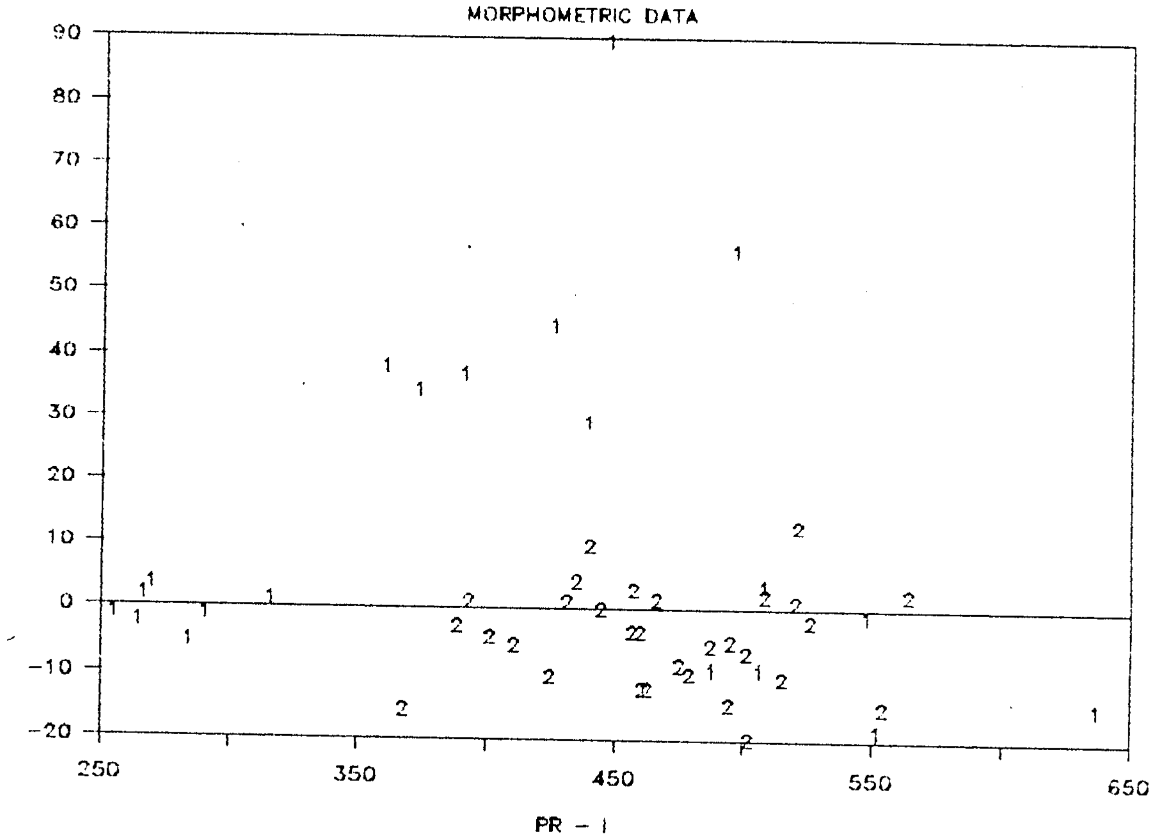


Fig.51. PRINICIPAL COMPONENT REPRESENTATION

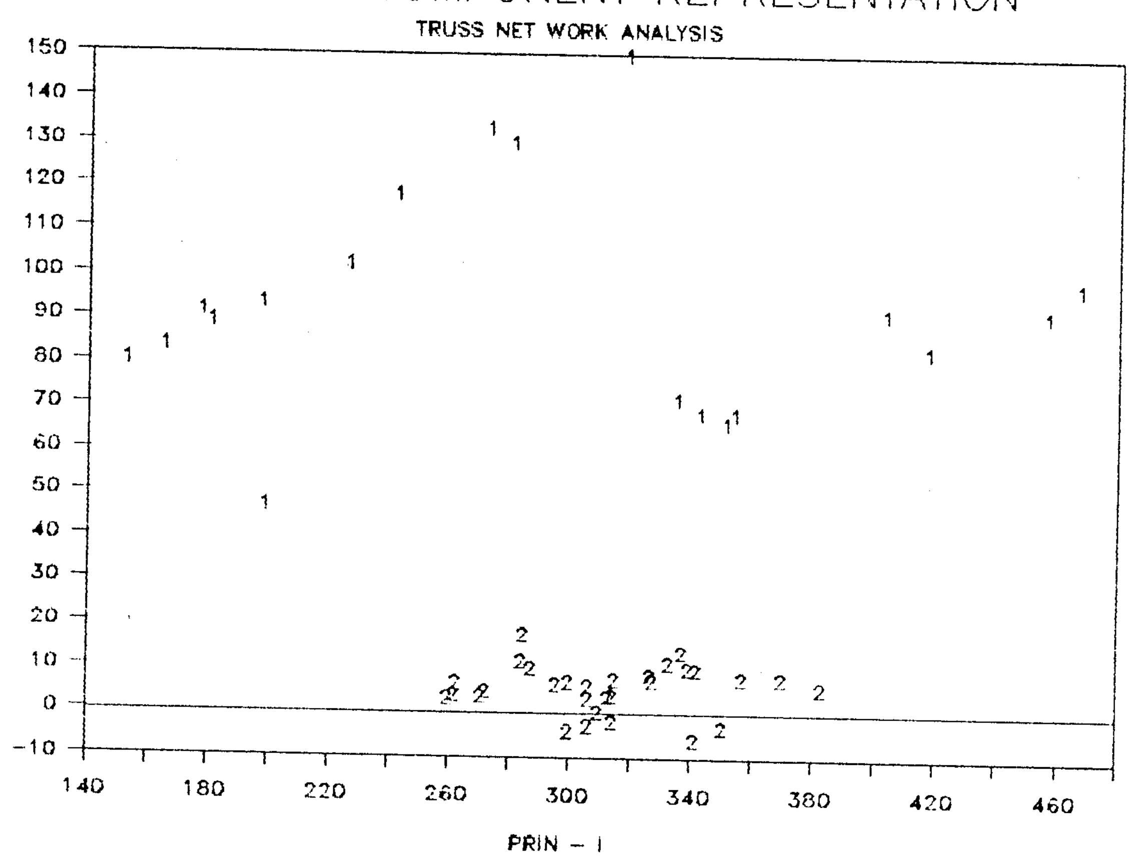


TABLE-43. **Results of various statistical treatments of truss Morphometric characters of *E. diacanthus* from Cochin.**

Characters	Mean	Variance	Standard Deviation	Standard Error
MTPM	14.526	12.485	3.533	0.811
MTDS	113.158	774.807	27.835	6.386
MTDL	135.579	1035.924	32.186	7.384
PMDS	104.526	744.374	27.283	8.259
PMLL	96.368	635.801	25.215	5.785
PMPC	69.000	383.889	19.593	4.495
PMPV	81.842	741.918	27.238	6.249
PCPF	41.789	182.287	13.501	3.097
LPF	43.158	202.696	14.237	3.266
DSL	48.579	357.924	18.919	4.340
DPF	93.000	3106.889	55.739	12.788
DSR	151.053	3397.386	58.287	13.372
DSAS	157.421	1551.257	39.386	9.036
PSAS	109.526	1059.819	32.555	7.469
PSR	183.158	2504.696	50.047	11.482
DRAS	86.737	499.982	22.360	5.130
DRTC	34.368	98.801	9.940	2.280
DRBC	68.579	1283.257	35.823	8.218
ASTC	107.895	782.099	27.966	6.416
BCAF	82.632	1312.690	36.231	8.312
TCBC	41.000	218.667	14.787	3.392

TABLE-44. **Results of various statistical treatments of truss morphometric characters of *E. diacanthus* from Calicut.**

Characters	Mean	Variance	Standard Deviation	Standard Error
MTPM	11.467	2.878	1.697	0.310
MTDS	108.433	104.599	10.227	1.867
MTDL	131.533	176.602	13.289	2.426
PMDS	100.900	119.334	10.924	1.994
PMLL	94.467	118.947	10.906	1.991
PMPC	67.500	111.431	10.556	1.927
PMPV	80.733	162.409	12.744	2.327
PCPF	37.733	24.271	4.927	0.899
LPF	41.700	28.907	5.377	0.982
DSL	47.233	33.702	5.805	1.060
DPF	117.767	155.702	12.478	2.278
DSR	165.500	318.810	17.855	3.260
DSAS	148.567	261.289	16.164	2.951
PSAS	103.933	126.064	11.228	2.050
PSR	170.567	338.668	18.403	3.360
DRAS	80.133	78.051	8.835	1.613
DRTC	34.100	16.438	4.054	0.740
DRBC	52.167	166.833	12.916	2.358
ASTC	104.467	96.395	9.818	1.793
BCAF	90.633	136.930	11.702	2.136
TCBC	33.667	13.264	3.642	0.665

TABLE-45. **Summary of the results of 't' test in respect of truss morphometrics of *E. diacanthus* between Cochin and Calicut.**

Characters	Degrees of freedom	Calculated value
MTPM	47	10.4367**
MTDS	47	5.6675**
MTDL	47	4.1036**
PMDS	47	4.3661**
PMLL	47	2.4359*
PMPC	47	2.3314**
PMPV	47	1.2899*
PCPF	47	10.0426**
LPF	47	3.4024**
DSL	47	2.441**
DPF	47	15.730**
DSR	47	8.5067**
DSAS	47	7.3476**
PSAS	47	5.7971**
PSR	47	8.3989**
DRAS	47	9.7285**
DRTC	47	0.8824**
DRBC	47	12.8882**
ASTC	47	4.1243**
BCAF	47	7.5251**
TCBC	47	14.2426**

** Significant at 5% level

* Non significant

from Cochin sample was 14.526 mm with a range 10-22. The variance, standard deviation and standard error were 12.485, 3.533 and 0.811 respectively. The mean MTPM from Calicut sample was 11.467 mm ranging from 8 to 15. The variance, standard deviation and standard error were 2.878, 1.697 and 0.310 respectively.

MTDS:

The 't' test has proved that there was significant difference in MTDS between fishes from the two localities. The mean MTDS from Cochin sample was 113.158 mm with a range 70-166. The variance, standard deviation and standard error were 774.807, 27.835 and 6.386 respectively. The mean MTDS from Calicut sample was 108.433 mm ranging from 91 to 126. The variance, standard deviation and standard error were 104.599, 10.227 and 1.867 respectively.

MTDL:

The 't' test has proved that there was significant difference in MTDL between fishes from the two localities. The mean MTDL from Cochin sample was 135.579 mm with a range 90-197. The variance, standard deviation and standard error were 1035.924, 32.186 and 7.384 respectively. The mean MTDL from Calicut sample was 131.533 mm with a range 107-158. The variance, standard deviation and standard error were 176.602, 13.289 and 2.426 respectively.

PMDS:

The 't' test has proved that there was significant difference in PMDS between fishes from the two localities. The mean PMDS from the Cochin sample was 104.526 mm with a range 63-160. The variance, standard deviation and standard error were 744.374, 27.283 and 8.259 respectively. The mean PMDS from the Calicut sample was 100.900 mm with a range 78-118. The variance, standard deviation and standard error were 119.334, 10.924 and 1.994 respectively.

PMLL:

The 't' test has proved that there was significant difference in PMLL between fishes from the two localities. The mean PMLL from the Cochin sample was 96.368 mm with a range 61-150. The variance, standard deviation and standard error were 635.801, 25.215 and 5.785 respectively. The mean PMLL from Calicut sample was 94.467 mm with a range 74-113. The variance standard deviation and standard error were 118.947, 10.906 and 1.991 respectively.

PMPC:

The 't' test has proved that there was significant difference in PMPC between fishes from the two localities. The mean PMPC from Cochin sample was 69.00 mm with a range 40-116. The variance, standard deviation and standard error were 383.889, 19.593 and 4.495 respectively. The mean PMPC from Calicut sample was 67.500 mm with a range 48-86.

The variance, standard deviation and standard error were respectively 111.431, 10.556 and 1.927.

PMPV:

The 't' test has proved thaat there was no significant difference in PMPV between fishes from the two localities. The mean PMPV from Cochin sample was 81.842 mm with a range 44-138. The variance, standard deviation and standard error respectively were 741.918, 27.238 and 6.249. The mean PMPV from Calicut sample was 80.733 mm with a range 59-102. The variance, standard deviation and standard error were respectively 162.409, 12.744 and 2.327.

PCPF:

The 't' test has proved that there was significant difference in PCPF between fishes from the two localities. The mean PCPF from Cochin sample was 41.789 mm with a range 21-67. The variance, standard deviation and standard error were respectively 182.287, 13.501 and 3.097. The mean PCPF from Calicut sample was 37.733 with a range 27-45. The variance, standard deviation and standard error were 24.271, 4.927 and 0.899 respectively.

LPF:

The 't' test has proved that there was significant difference in LPF between samples from two localities. The mean LPF from Cochin sample was 43.158 mm with a range 23-85. The variance, standard deviation and standard error were respectively, 202.696,, 14.237 and 3.266. The mean LPF from Calicut sample was 41.700 mm with a range 32-53.

The variance, standard deviation and standard error were respectively 28.907, 5.377 and 0.982.

DSL:

The 't' test has proved that there was significant difference in DSL between fishes from two localities. The mean DSL from Cochin sample was 48.579 with a range 29-85. The variance, standard deviation and standard error were respectively 357.924, 18.919 and 4.340. The mean DSL from Calicut sample was 47.233 with a range 39-61. The variance, standard deviation and standard error were respectively 33.702, 5.805 and 1.060.

DPF:

The 't' test has proved that there was significant difference in DPF between fishes from the two localities. The mean DPF from Cochin sample was 93.000 mm with a range 66-189. The variance, standard deviation and standard error were respectively were 3106.889, 55.739 and 12.788. The mean DPF from the Calicut sample was 117.767 mm with a range 95-145. The variance, standard deviation and standard error were respectively 155.702, 12.478 and 2.278.

DSR:

The 't' test has proved that there was significant difference in the DSR between samples of two localities. The mean DSR from Cochin sample was 151.053 mm with a range 166-253 the variance, standard deviation and standard error were respectively 3397.386, 58.287 and 13.372. The mean DSR from Calicut sample was 165.500 mm with a range 137-204. The variance, standard deviation and standard error were respectively 318.810, 17.855 and 3.260.

DSAS:

The 't' test has proved that there was significant difference in the DSAS between the samples from two localities. The mean DSAS from Cochin is 157.421 mm with a range 98-223. The variance, standard deviation and standard error were respectively 1551.257, 39.386 and 9.036. The mean DSAS from Calicut was 148.567 mm with a range 124-185. The variance, standard deviation and standard error were 261.289, 16.164 and 2.951 respectively.

PSAS:

The 't' test has proved that there was significant difference in the PSAS between the samples from the two localities. The mean PSAS from Cochin is 109.526 mm with a range 61-164. The variance, standard deviation and standard error were respectively 1059.819, 32.555 and 7.469. The mean PSAS from Calicut was 103.933 mm with a range 83-132. The variance, standard deviation and standard error were respectively 126.064, 11.228 and 2.050.

PSR:

The 't' test has proved that there was significant difference in the PSR between fishes from the two localities. The mean PSR from Cochin sample was 183.158 with a range 113-267. The variance, standard deviation and standard error were respectively 2504.696, 50.047 and 11.482. The mean PSR from Calicut sample was 170.567 mm with a range 136-214. The variance, standard deviation and standard error were respectively 338.668, 18.403 and 3.360.

DRAS:

The 't' test has proved that there was significant difference in DRAS the between the fishes from the two localities. The mean DRAS from Cochin sample was 86.737 mm with a range 56-125. The variance, standard deviation and standard error were 499.982, 22.360 and 5.130 respectively. The mean DRAS from Calicut sample was 80.133 mm with a range 64-101. The variance, standard deviation and standard error were respectively 78.051, 8.835 and 1.613.

DRTC:

The 't' test has proved that there was no significant difference in DRTC between the fishes from two localities. The mean DRTC from Cochin sample was 34.368 mm with a range 22-61. The variance, standard deviation and standard error respectively were 98.801, 9.940 and 2.280. The mean DRTC from Calicut sample was 34.100 mm with a range 27-43. The variance, standard deviation and standard error were respectively, 16.438, 4.054 and 0.740.

DRBC:

The 't' test has proved that there was significant difference in DRBC between fishes from two localities. The mean DRBC from Cochin sample was 68.579 mm with a range 30-143. The variance, standard deviation and standard error were respectively 1283.257, 35.823 and 8.218. The mean DRBC from Calicut sample was 52.167 mm with a range 40-113. The variance, standard deviation and standard error were respectively 166.833, 12.916 and 2.358.

ASTC:

The 't' test has proved that there was significant difference in ASTC between fishes from two localities. The mean ASTC from Cochin sample was 107.895 mm with a range 74-167. The variance, standard deviation and standard error were respectively 782.099 mm 27.966 and 6.416. The mean ASTC from Calicut was 104.467 mm with a range 89-131. The variance, standard deviation and standard error were respectively 96.395, 9.818 and 1.793.

BCAF:

The 't' test has proved that there was significant difference in BCAF between fishes from the two localities. The mean BCAF from Cochin sample was 82.632 mm with a range 37-149. The variance, standard deviation and standard error were respectively 1312.690, 36.231 and 8.312. The mean BCAF from Calicut sample was 90.633 mm with a range 58-116. The variance, standard deviation and standard error were respectively 136.90, 11.702 and 2.136.

TCBC:

The 't' test has proved that there was significant difference in TCBC between fishes from the two localities. The mean TCBC from Cochin sample was 41.000 mm with a range 21-63. The variance, standard deviation and standard error were respectively, 218.667, 14.787 and 3.392. The mean TCBC from Calicut was 33.667 mm with a range 29-42. The variance, standard deviation and standard error respectively were 13.264, 3.642 and 0.665.

Principal component analysis of Truss morphometrics:

Ten selected truss morphometric characters were treated for principal component analysis, they were MTPM, MTDS, LPF, DSL, DPF, DSR, DSAS, PSAS, DRAS and DRTC (Table-46). The percentage variations for principal component I and II were 92.6 and 5.9 respectively from the Cochin samples while it was 94.0 and 2.6 respectively from the Calicut sample. The figure 51 illustrates the principal components of samples from Cochin and Calicut. In the figure the principal components were seen clearly separated out indicating two distinct population.

5.4. DISCUSSION

The phenotypic differences among populations may be due to both genetic and environmental differences. From the present study based on twenty four general morphometric characters and twenty one truss morphometric characters it can be assumed that the two stocks are coming from two different populations, based on principal component analysis and 't' test. Principal component analysis on ten selected general morpho-

TABLE-46. **Character loadings of truss morphometric variables of *E. diacanthus* used for principal component analysis.**

CHAR	COCHIN PR1	COCHIN PR2	CALICUT PR1	CALICUT PR2
MTPM	0.025	0.019	0.017	0.021
MTDS	0.261	0.312	0.310	0.053
LPF	0.131	0.149	0.134	-0.104
DSL	0.184	0.033	0.137	0.347
DPF	0.526	-0.625	0.378	0.110
DSR	0.571	-0.219	0.543	-0.689
DSAS	0.368	0.489	0.501	0.102
PSAS	0.302	0.380	0.322	0.551
DRAS	0.208	0.236	0.258	0.237
DRTC	0.087	0.030	0.090	-0.087
VAR(%)	92.6	5.9	94.0	2.6

Figures indicate the character loadings.

metric characters showed some overlapping of some variables but altogether it revealed a heterogenous population. Except for snout length, 't' test was significant for other characters. Analysis of covariance proved significant differences in snout length, preventral distance and caudal peduncle length between Cochin and Calicut.

For over thirty years most morphometric investigations were based on the traditional morphometric characters. These characters like standard length, total length, total height, depth and width of fish shape were primarily in the head and tail regions. Recently new ideas were introduced in this field (Humphries et al., 1981; Winans, 1984; Taylor and McPhail, 1985). It is often disputed that the conventional type characters concentrate along the anterior-posterior body axis and in the head as well as the caudal region and therefore produce uneven and biased area coverage of the entire body form. The suggestion is to cover the shape or outline of a fish uniformly with a net work of distance measures. This criss cross pattern along the body form is called a truss net work (Humphries et al., 1981). The measurements after appropriate data manipulation, are subjected to multivariate statistical analysis, discriminant analysis or principal component analysis (PCA). Discriminant analysis categorizes individuals based on a priori recognition of groups, e.g., sex or species. PCA, on the other hand, does not require a priori recognition of groups, and if there are several groups, data are pooled irrespective of groups, PCA constructs principal components (PC) which are linear combinations of the variables that describe the shape variations in the pooled sample

(Eknath et al., 1991). Truss morphometrics employed in this study was to detect the subtle differences in variations of shape, independent of size. The twenty one land mark points in truss morphometrics were tested for significance by 't' test and only PMPV and DRTC proved to be insignificant. Principal component analysis on ten selected characters revealed that the Cochin and Calicut samples are from two different populations. However a detailed study is required to arrive at a more reliable conclusion on the occurrance of heterogenous population in the fishing grounds. off Cochin and Calicut.

CHAPTER 6

PARASITES

6.1. INTRODUCTION

During the study period both internal and external parasites were noticed in the three species of Epinephelus studied. It was found that E. diacanthus was more prone to infestation of parasites. The external parasites on the Epinephelus spp. were cymathoid and other copepods and the internal parasites included, trematodes, cestodes and nematodes. The occurrence of parasites in different species of Epinephelus were reported by many workers. The works of Linton (1908), Wilson (1913), Delmare-Deboutteville and Nunes-Ruivo (1954), Yamaguti and Yamasu (1960), Krishna Pillai & Sebastian (1967) Thompson & Munro (1974) Burnett-Herkes (1975), Ong (1988) and Leong and Wong (1988) are noteworthy in this field.

6.2. MATERIALS AND METHODS

Specimens of Epinephelus diacanthus, E. chlorostigma and E. bleekeri were examined for both internal and external parasites during the course of this study. External parasites found in the gill region, dorsal and ventral body surfaces were removed from the host fish and preserved in 5% formalin for identification. Internal organs like, liver, swimbladder, intestine, gonads etc. were examined for parasites. The internal parasites were preserved in 70% ethyl alcohol, passed through alcohol series, stained in Borax carmine and mounted in DPX for identification. The external and internal parasites were identified up to generic/species level whenever possible.

6.3. RESULTS

External parasites recorded from Epinephelus belonged to isopods, lernaeidae and anthosomatidaeand internal parasites belonged to trematoda, cestoda, sarcotacidae and nematoda.

1. External parasites

Isopoda:

Cymathoid copepods are common ectoparasites on teleost fishes. During the present study, three E. diacanthus were found infested by cymathoa in the gill region and one E. bleekeri in the tail region. No isopodes were seen on E. chlorostigma.

Lernaeidae:

They are the largest tissue invading copepods. Lernaeenicus sp. were seen on 63 fishes of E. diacanthus (Plate-XVIIIa). The parasite was found attached to the body, the head was embedded in the body muscle and can reach visceral organs with the help of much branched tentacle like things on the head, only the black body and greenish ovarian sacs were visible outside. Of the 63 infested, 58 E. diacanthus belonged to smaller length groups (the range in Std. length was 105-216 mm) (Table-47) the remaining five belonged to the large length group (the range in std. length is 265-450 mm). The five larger length group fish showed parasites in February and in the smaller length group the parasites observed were in March, April and May. The parasites could be seen on both sides of the fish, and more infestation were on the dorsal side. Each fish was

TABLE-47. **Frequency of infestation of Lernaeenicus sp. in E. diacanthus in different length groups.**

Class interval (mm)	Frequency
105 - 115	2
115 - 125	-
125 - 135	3
135 - 145	12
145 - 155	11
155 - 165	14
165 - 175	4
175 - 185	4
185 - 195	3
195 - 205	4
205 - 215	-
215 - 225	-
TOTAL	58

infested by more than one Lernaeenicus. In severe case of infestation more than twenty five, parasites were observed on the fish. Generally the parasites were seen on the dorsal side of the head region.

Anthosomatidae:

Anthosomatid copepods were seen attached to the gill region of two E. diacanthus of standard length 360 mm and 321 mm (Plate-XVIIIb). The carapace of the parasite is triangular and broader than long. Its hind border is nearly transverse. The antennal area is very small but clearly demarcated. Postero-laterally the carapace is drawn out into triangular lobes and the lateral parts folded ventrally. A short neck, is drawn out into triangular lobes and the lateral parts are folded ventrally, and connects the carapace with the trunk. The anterior division of the trunk is only slightly longer than the carapace, it is broader than long and the antero-lateral regions are broadly rounded and shoulder like; the postero-lateral parts are produced backwards into long lobes reaching nearly two-thirds the length of the dorsal plate. The dorsal plate is about one and a half times as long as broad and completely covers the legs and the egg strings, its hind border is evenly rounded. The parasite closely resembles the specimens Sagum epinepheli collected from Calicut and described by Krishna Pillai and Sebastian (1967).

2. Internal parasites

Trematoda:

Metacercariae of Stephanostomum sp. were observed in 24 E. diacanthus and 2 E. bleekeri (Plate- XIX). The number of metacercariae ranged from 5 to 25 in a single swim bladder. The cysts were yellowish in colour and the parasite inside was white in colour. There was enough chance to mistake these cysts for fish embryos, as the fish is protogynous hermaphrodite and internal fertilization was reported from its relative genera. The inner lining of swim bladder extends to the gonads by mesentries and these mesentries were often occupied by metacercariae. In the present study five metacercariae were noticed in the transforming gonad of E. bleekeri of standard length 380 mm. Metacercariae were often found in large length group fishes. Only two E. diacanthus of smaller length group (156 mm) showed metacercaria in the swim bladder (Table-48). About 10 species of Indian marine fishes were reported to be infested with Stephanostomum spp. (Dr. R. Madhavi, Pers. Comm).

Cestoda:

'Wormy' marine fish often result from parasitism by trypanorhynch plerocercoid larvae. These cestodes infect elasmobranchs as final hosts and teleosts as intermediate hosts and were often transmitted to these fishes by crustaceans. They are distinctive because of their four eversible, hooked tentacles on the scolex. The worm proper is often enveloped by a thin membrane and a protective blastocyst. The blastocyst and encysted organism appear chalky-white or yellowish, folded or twisted and relatively large and elongated or small or spherical. When one end of a blastocyst is enlarged, it usually contains the scolex with its organs of attachment and presumptive germinal region.

TABLE-48. **Frequency of infestation of *Stephanostomum* sp. on *E. diacanthus* in different length group.**

Class interval (mm)	Frequency
150 - 175	2
175 - 200	-
200 - 225	-
225 - 250	-
250 - 275	3
275 - 300	2
300 - 325	7
325 - 350	3
350 - 375	3
375 - 400	3
400 - 425	1
TOTAL	24

TABLE-49. **Frequency of infestation of Trypanorhynchid larvae in E. diacanthus in different length groups.**

Class interval (mm)	Frequency
250 - 300	1
300 - 350	4
350 - 400	3
400 - 450	1
450 - 500	1
TOTAL	10

In the present study ten of E. diacanthus were found to be infested by the trypanorhynchan larvae (Table-49). The locations of this parasite were viscera, mesentries and gonads. Some were found in the body cavity or in the cavities made by the larvae near vent. The larvae had a black silvery outer covering. All the fish belonged to the larger length group (Standard length ranged from 259-450 mm). Only one E. chlorostigma of standard-length 399 mm was infested with trypanorhynchan in the gonad and one E. bleekeri of standard length 307 mm in the inner lining of swim bladder.

Sarcotacidae:

The parasite Sarcotaces arcticus observed frequently in small sized Epinephelus diacanthus. Sarcotaces arcticus is a copepod endoparasite, belonging to the order Sarcotacidae, parasitizes vertebrate hosts (Kabata, 1958). Sarcotaces has been found in both Atlantic and Pacific oceans. The female Sarcotaces is a pyriform bag with verrucose surface and vestigeal appendages grouped in small rosette like patch. It is enclosed in a cyst within the trunk musculature or in the visceral cavity of the fish. The pointed posterior of the parasite protrudes externally but more commonly the concealment is complete. Sarcotaces can not be easily detected, only dissection will reveal its presence. The male Sarcotaces relatively dwarf, living one in each cyst with a female, virtually flattened between her surface and the wall of the cyst. The cyst has an opening through the skin of the fish by which the nauplius larvae are discharged. The parasite feeds on blood obtained from the rich vascular wall of the cyst. The alimentary canal of the female is always filled with black fluid, a derivative of the digested blood. Eventhough the ill effects of the parasite is not known the fishes infested by these parasites are always found among the smaller length group.

In each infested fish there were usually one to three cysts with living parasites and adjacent to these there were small atrophied cysts. The cyst is gray in colour, smooth, firm and pyriform in shape. It hangs loosely in the body cavity or in the tissues of the host, except for its attachment near the surface of the skin. Parasite can be seen through the broad distal end, it gradually thickens towards the tapered end of the cyst. The atrophied cysts were considered to be the end stage of the life cycle. Kuitunen-Ekbaum (1949) reported that in some cysts the parasites had apparently failed to keep the communication with exterior the contents of such rudimentary cysts contained countless dead, but fully developed nauplii encased within the cyst wall.

The morphology of the parasite has been described by Kuitunen-Ekbaum (1949). According to him, the body is verrucose, without apparent limbs or antennae. The verrucae are larger at the anterior end of the body and gradually diminish in size towards the caudal end. The body of the parasite is composed of seven segments which represent the cephalothorax, followed by three abdominal segments, the latter are smooth, firm, composed of thick cuticle and with very few verrucae. On the ventral surface near the anterior end of the cephalothorax is a shallow depression in which is included a rosette of five to six radiating papillae and near the centre of it is another minute rosette of papillae which surround the oral opening. The oral area shows two or three pairs of small rudimentary appendages which are probably the mandibles and maxillae.

In the present study, five E. diacanthus were found infected with Sarcotaces arcticus. (Plate XX). The parasites were seen on the dorsal side of the body embedded in the muscles near the kidney and were identified by the slight bulge in that region. The tappered end of the posterior region was found protruding through the small opening in the body of the fish made by the parasite. There was slight discolouration in that region and loss of few scales. Each fish had three cysts containing live parasites inside. The distal end of the cyst was projected into the wall of the abdominal cavity. No male parasite was found within the cyst. In one cyst numerous nauplii were seen on and between the cyst and the female parasite. The female parasite and nauplii looked similar to the description given by Kuitunen-Ekbaum (1949). The parasites measured from 15mm to 35 mm in length and 5 mm to 20 mm in width. The nauplii measured 0.2 mm in length and 0.15 mm in width. The infected fish belonged to the smaller length group (The range in Std. length 161-237 mm).

Nematodes:

Unidentified nematodes were always observed in the viscera and in gonads at times in the Epinephelus spp. The nematodes were common in the gonads of larger fishes. (Plate-XIXb).

3. Abnormality

No other abnormalities were noticed during the present study except the presence of extra growth or excrescences on the ventro-lateral concave side of the otoliths (Plate-VIIb). These excrescences were most common on older, larger otoliths, their size increasing with the size of the otoliths. These growths were opaque with a roughened surface and expanded in size above the point of attachment. Except for the extra growth, the otoliths were usually normal in form and structure. These excrescences were more frequent on the otoliths of E. diacanthus and less frequent in E. chlorostigma and E. bleekeri.

6.4. DISCUSSION

Hochberg and Ellis (1972) reported Epinephelus guttatus to be infested with cymathoid isopod, Anilocra laticauda at St. John, Virgin island. Infestation by female A. laticauda resulted in the loss of pigment and erosion of tissue at the area of infestation. Mature females of A. laticauda infestation on the cheek and interorbital areas of small red hinds resulted in obvious impairment of binocular vision. The isopod parasite cymathoa was not a common ectoparasite in Epinephelus spp. during the present study.

In the present study, only E. diacanthus was infested with lernaeenicus sp. and often the infestation was among smaller size fishes inhabiting inshore waters. The first Indian record on species of Lernaeenicus, L. polynemi was by Basset-Smith (1898), collected from Polynemus tetradactylus caught at Bombay. Kirtisinghe (1933) described L. hemiramphi from Hemiramphus xanthopterus, from Ceylon and Gnanamuthu (1953) redescribed the same from Hemiramphus far caught at Madras. He also described L. nemipteri and L. stromatei from the host fishes Nemipterus marginatus and Stromateus niger respectively. Rao (1951) reported the occurrence of a species Lernaeenicus on Scomber scomber in the Waltair region. Kirtisinghe (1934) described L. seeri from an unidentified species of Cybium and in 1956 another species; L. ramosus from Epinephelus morrhua caught in Ceylon waters. Rangnekar (1961) described a new species, L. alatus from Cybium commersoni and redescribed L. ramosus from Synagris japonica and L. sayori, Yamaguti (1939) from Rastrelliger kanagurta. The first species of L. anchovillae together with three post-larval stages is described by Sebastian and George (1964). Sebastian (1965) described L. bataviensis from Anchoviella batavensis. Voorheis and Schwartz (1979) reported Lernaeenicus sprattae, embedded in the eye of sprat, Sprattus sprattus and sardines, Sardina pilchardus in Europe. Kabata (1979) observed *Lernaeenicus encrasicoli* in sardines, sprat and anchovies, *Engraulis encrasicolus* in Europe. Heavy parasitization results in weight loss in some individuals as well as sexual retardation and even parasitic castration (Crehuet and Val cordan, 1973). Templeman *et al.*, (1976) has been reported that in *Gadus morhua* parasitization can lower fecundity, by delaying onset of maturity or by reducing the gonad weight and number of eggs produced.

Reports on the occurrence of *Sagum* species by earlier workers include Van Beneden (1857) on the *S. petersi* from the gills of *Serranus goliath* from Mozambique and Congo. Kroyer, (1863) on *S. angulatum* from the gills of *Serranus* from West Indies and Wilson (1913) on *S. flage-llatum* from the gills of *Epinephelus adscensionis* caught at Jamaica. Pearse (1952) reported on the occurrence of *S. texanus* from the gills of *Lachnolaimus maximus* and Delmare-Deboutteville and Nunes-Ruivo (1954) described *S. posteli* from the gills of *Epinephelus aeneus* Senegal. Yamaguti and Yamasu (1960) have given an account of *S. epinepheli* from the gills of *Epinephelus akaara*, Japan. Krishna Pillai and Sebastian (1967). have mentioned that all the species except *S. texanum* appear to be parasite of fishes of the genus *Epinephelus* and thus the genus *Sagum* shows an unusual host specificity. During the entire course of study only two *E. diacanthus* were seen infested by *S. epinepheli.*

The earlier reports on the presence of parasitic tremode were by Linton (1908) in *Epinephelus guttatus* and *E. striatus*, Nahas and Cable (1964) and Burnett-Herkes (1975) in *E. guttatus* . The trematodes observed by them were Distomum levenseni, Postporous epinepheli and Benedia sp. respectively. Wolfgang (1954) reported the trematode Stephanostomum buccatus in winterflounder. In the present study metacercariae of Stephanostomum sp. were common in the Swim blader of E. diacanthus and very rarely in E. bleekeri and E. chlorostigma.

The genus stephanostomum Loss, 1899, belongs to the trematode family Acanthocolpidae Luhe 1909. Members of this family mature in marine teleosts and the species of the genus Stephanostomum occur in marine fishes in all the hemisphere. Martin (1939) found the primary intermediate hosts of Stephanostomum tenue, to be the snail, Nassa obsoleta Say and the Silver side, Menidia m notata (Mitchell), the second intermediate host. The worm matured most commonly in the striped bass, Roccus lineatus Bloch, but was found in a number of carnivorous hosts, including the sea raven. Wolfgang (1954) found numerous small cysts from the intestine of sea raven, corresponding closely to the metacercarial cysts found in the winter flounders, later examinations revealed at least 30% of the sea raven recta to be infected with adults of Stephanostomum buccatum. According to him the first intermediate host of S. buccatum were the marine gastropods, Buccinum undatum L. and Neptuna decemcostatum Say and the second intermediate host was winterflounders or pleuronectid fish. The definitive host was raven. The cysts were found in the muscles. In heavy infestation, dermal cysts found all over the ventral peripheral surfaces and may in extreme cases give the fish rough 'measely' appearance. Since the number of cysts in the winter flounder is related to the size of the fish, it follows that the infection may be related to the growth of the host. He found no seasonal variation in infection. The flounders were infected most heavily when they live in deeper water and when they are larger in size. In E. diacanthus mostly large sized fishes were more prone to infestation. Wolfgang (1954) reported that S. buccatum occurs in a number of marine teleosts from the Baltic sea to the Bay of Fundy. Adult trematodes parasitize the recta of carnivorous teleosts and generally inhabit fish-eating cottids, Metacercarial cysts are found in the superficial musculature and dermal surfaces of flat fish as well as in the gills and soft exposed parts of round fish. The winter flounder was the flat fish most frequently parasitized by the metacercariae. Gastropods of the family Buccinidae serve as primary intermediate hosts in whose digestive gland and gonad were found the rediae from which escape the free living cercariae which eventually penetrate the flounder. Studies have shown that the parasitism in this flat fish was greater in deeper than in shallow inshore waters, that large flounders bear heavier infection than do small ones. The life cycle of S. buccatum is completed by the transfer of infective stages from host to host, either by ingestion of the intermediate larval stage found in the flounder by a suitable carnivorous host in which the adult develops or by passage of a free-living stage from a gastropod into the skin of the flounder.

Chandler (1935) reported the presence of plerocercal stage of a trypanorhyncan cestode, Otobothrium robustum from the sciaenids caught in various Texas bays. The parasite was common in the dorsal muscle masses of Cynoscion nebulosus from Galveston Bay. Later, Chandler

(1954) reported heavy infestations in Pogonias cromis and Poeciliancistrium robustum (Chandler) or a closely related species, occurs in other sciaenids, lutjanids and serranids. Schlicht and McFarland (1967) observed in sciaenids the larval cestodes in the dorsal muscle masses adjacent to the vertebral column and in the vicinity of the vent and in the muscles behind the cranium under the skin adjacent to the dorsal fin and in the muscles of caudal peduncles. The larvae from Menticirrhus americanus were entwined about the viscera and in the mesentries but not in the muscles. Larvae from the black drum, Pogonias cromis had the blastocyst enclosed in a well defined cavity. The authors observed the larval cestods only in sciaenid fishes and the infestation varied with the species of fish. They observed that the presence of plerocerci in sciaenids appears to be a function of age, and infestation reflects, a change in food habits and consequent introduction of a parasitized vector into the diet of the fish. Young fish were not infested by these parasites. Darnell (1958) found that two major diet-patterns occur in sciaenids. In very young sciaenids, the primary food is composed of microplankton. A distinct shift to a varied crustacean diet occurs in sub-adult fish, which often shifts to a diet of fish and larger crustaceans in adults. Schlichit and McFarland (1967) observed three species of trypanorhynchan cestodes in the fishes examined, Diplootobothrium springeri in Pogonias cromis, Pterobothrium sp. in Menticirrhus americanus and Poeciliancistrium caryophyllum in sciaenids except P. cromis and M. americanus. In the present study trypanorhynchan parasites were found mostly in the large sized fishes of E. diacanthus. Overstreet (1978) reported the occurrence of trypanorhynchs in the commercial, sport and seldom utilized fishes along the coasts of the northeastern United States and Northern Gulf of Mexico. Typically trypanorhynchs inhabit the viscera of fishes or tissues of invertebrates. In addition to the sciaenids, it is seen in butter fish bluefish hake, winter flounder, Atlantic mackerel, swordfish and other fish in North east. In the Gulf, infection was noticed in amberjacks, crevalle hack, sea catfish, bluefish and red grouper. Several trypanorhynchs infect sciaenids (Overstreet 1978) in the north Gulf of Mexico. Pseudogrillotia pleistacantha occurs in large blackdrum, Pterobothrium lintoni in southern King fish, P. heteracanthum infects Atlantic croaker and other hosts. The hosts for Poecilancistrium caryophyllum were sciaenids from Mississippi and in the Gulf and along the U.S. Atlantic seaboard, spotted sea trout, silver perch and red drum comprise the most prevalent hosts in Mississippi. Prevalence of the parasite increased with increasing host length. Linton (1908) recorded the cestode Scolex polymorphus from Epinephelus maculosus. He also described the two species of Rhyncobothrium, encysting on the viscera of hind at Bermuda. But Rees (1969) noted that R. speciosum is a synonym of Callitetrarhynchus gracilis (Rudolphi). She found that red hinds were infected with encysted pleurocoid larvae of C. gracilis. Thompsun and Munro (1974) reported larval tape worms in a variety of groupers including E. guttatus from the Jamaican shelf of pedro Bank. Burnett-Herkes (1975) noted the infection of C. gracilis on E. guttatus from Bermuda. Chandler and Manter (1953) listed the Lemon shark, Negaprion brevirostris as the definitive host of C. gracilis at Dry Tortugas, but the most common reef shark at Bermuda is the dusky shark, Carcharhinus obscurus and it is likely that this is the definitive host at that locality. Burnett-

Herkes (1975) observed that mostly smaller groupers were infected by C. gracilus rather than the larger ones.

The infestation of Sarcotaces arcticus on E. diacanthus observed during the present study is the first report from Indian water. There were no earlier reports about the infestation of such a parasite on any species of Indian fish. The first specimen of Sarcotaces was one female collected by Goes from Acanthurus species caught in the West Indies in 1866 and described by Olsson as Sarcotaces verrucosus in 1872. Collet described the second species, S. arcticus in 1874 from Molva abyssorum which were caught in arctic Norway at Oxfjord, Finmark. The copepod was differentiated from S. verrucoses by the larger size and by the absence of oral appendages. Hjort (1895) confirmed the identity of S. arcticus from the specimen received from Collet. Komai (1924) described the third species S. pacificus from an Antennarius species in Japan. The copepod was differentiated from S. verrucosus by the absence of setae around the oral opening and from S. arcticus by smaller size 5 to 15 mm long and by the presence of oral appendages. Dollfus (1928) reported the occurrence of S. verrucosus in an Iridio radiatus at Martinique and Aitkin (1942) S. arcticus from Molva abyssorum in Aberdeen.

An unidentified nematode was always observed in the viscera and in gonads at times in all the three species of Epinephelus, studied. Linton (1908) and Thompsun and Munro (1974) reported infections of red hind gonads with nematodes. Rees (1970) recorded Philometra Lateolabrium (Yamaguti) from the testes of M. Myctroperca bonaci and Philometra sp. from the M. venenosa. Burnett-Herkes (1975) found that at least one lobe of the gonad of E. guttatus were infested with Philometra sp. and that higher proportion of male gonads have infested compared with female ones. But Thompsun and Munro (1974) found no male fish infected with nematodes. The presence of extensive necrotic tissue in the above male fish and other heavily parasitized specimens indicates a reduction in reproductive potential of these fish. This was true in the case of E. diacanthus, E. chlorostigma and E. bleekeri. These fishes exhibit protogynous hermaphroditism and usually the smaller length group fishes were females and larger length groups, males. The gonads of larger length group fishes were infested by the nematodes.

Excrescences on the otoliths were also reported by Moe (1969). He observed these excrescences at the same place and about the same size on each otolith pair. But during this study period only one otolith of a pair, usually the left one exhibited the excrescence on their ventro lateral surface. According to Calstrom (1963 : 449) the abnormal teleost otoliths may be formed as calcite rather than arogonite. But Moe (1969) is of opinion that, malformations of the otolith itself were rare and seemed to be caused by irregular deposition of the aragonite in one area. It is not possible to derive at a conclusion whether the cause of the excrescence is aragonite or calcite unless after a detailed study.

Internal parasites were mostly helminths including cestoda, trematoda and nematoda. They occur in larger length group fishes that live in the deeper waters. Among the external parasites copepods ranked first in infestation and most often found in smaller length group fishes of inshore waters, Mann (1970) reports that copepods also act as the intermediate hosts of tetraphyllidea and trypanorhynchidae as well as harbouring many nematodes such as Philometra species. The copepods can become involved in the spread of the fungus, Ichthyophonus. Literatures say trypanorhynchan larvae and the nematode philometra species were common in certain fishes, including groupers. Schlicht and McFarland (1967) found that the infestation of trypanorhynchan larvae is related to age, the younger fish were not infested. It suggested that infestation occurs only with ontogenic food changes which introduce the vector into the host and the most likely vector for at least many of the species must be commercial shrimp. In this instance it is interesting to note that the study of the food and feeding habits of E. diacanthus revealed that the smaller length group fish has a preference for crustacean diet and higher length group for fish. E. chlorostigma and E. bleekeri were mostly infested by internal helminth parasites while E. diacanthus were by helminth and crustacean parasites.

PART II

FISHERY

Perches and perch like fishes are abundant in coastal waters particularly around coral reefs and rocky bottom of the sea upto 200 mm depth along the Indian waters. Among these 'Kalava' or rockcods form an important group of demersal resources with immense potentialities. Adequate information on the magnitude of the catches of various species of rock cods along the Indian coasts are not available. They have been grouped under a single head on "Perches". Even though perches form an important fishery resource, exploitation of this is limited to the narrow belt of the inner continental shelf of about 50 m depth covering an area of 1,80,539 Sq.km. Considering the commercial and economic importance of this resource and high demand from abroad a systematic study was undertaken to investigate the abundance of this genous in their natural habitat.

The groups coming under perches are rock cods, snappers, threadfin breams, pig-face breams, Scolopsis, Pomadasys, Therapon and Sillago. The average annual perch landed in India during 1985-1989 was 90083 t. The total potential yield of perches, predominated by thread-fin breams from the Indian Exclusive Economic Zone is 2,390,00 t of which 1,140,00 t come from within 50 m depth zone and 125000 t from the depth zone beyond 50 m. The average annual perch landing during 1990-1992 was 1,127,72 t showing a general improvement in its fishery.

Rock cods constitute the genus Holocantrus, Serranus and Epinephelus. The total rock cods landed in India during 1990-1992 is shown in the

Table-50. The annual average percentage composition of rock cods during 1990-1992 was 0.29%. A total of 4,718 t of rock cods were landed in the year 1990. Maharashtra has shown the highest landing 1952 t in 1990 followed by Kerala 998 t, Tamilnadu 978 t, Gujarat 363 t, Karnataka 200 t, Andhrapradesh 193 t, Orissa 17 t, Goa 4 t and Pondicherry 3 t. The total landing of rock cods in India during 1991 was 6203 t. Highest landing was in Tamil Nadu, 3124 t. The landings in other states were in 1446 t, Maharashtra, 724 t, Kerala, 628 t, Karnataka, 611 t Gujarat 68 t Andhrapradesh, and 2 t Goa. In the year 1992 the total landing of rock cods was 8548 t and Kerala showed highest catch of 2994 t. The landing of rock cods in Tamilnadu, Maharashtra, Gujarat, Karnataka, Andhrapradesh, Goa and West Bengal were 2383 t, 2059 t, 658 t, 369 t, 60 t, 2 t and 1 t respectively.

Exploratory surveys conducted by different government organizations like FSI, FORV Sagar Sampada etc. have estimated the potential available in different regions as well as the concentration pockets along Gulf of Mannar, southwest and southeast coasts in India. The surveys of the FSI vessel revealed that perches constituted 21% of the catch from Gulf of Mannar during the five months from October 1983 to March 1984. This group consists of mainly *Epinephelus diacanthus*. *Lutianus argentimaculatus* and *Lethrinus ramak* besides other species. They were abundant in the depth belt of 30-120 m (Joseph, 1984). A survey of the Wadge Bank completed by *Matsya Nireekshani* in May 1984 indicated that perches of identical species constituted about 37% of the catch from 20-225 m.

TABLE-50. **Statewise landing of rock cods (tonnes) during 1990-1992**

	WB	OR	AP	TN	PON	KEL	KAR	GOA	MH	GUJ	LAK	AND	TOTAL
1990	0	17	193	978	3	998	200	4	1952	363	0	0	4718
1991	0	0	68	3124	0	724	628	2	1446	611	0	0	6203
1992	0	0	60	2383	0	2994	369	2	2059	658	0	0	8548

It was found to occur in 25-100 Kg. per hour of trawling. The depth range 25-46 m and 183-225 m were found to be most productive for this group. The highest catch per hour was observed during the month of August followed by April-September. Perches formed 75% of catch during March-April. But perches constituted only 2% of the catch of Matsya Shakti and Matsya Vishwa operated from Mangalore. Perches formed 7% of the catch of Matsya Jeevan from 50-160 m depth from areas north of Madras. Somvanshi and Bhar (1984) reported that perches including E. diacanthus and other Epinephelus spp. contribute 38% of the catches from the Gulf of Mannar within 125 m depth. Philip et al., (1984) found the area of abundance for perch was 14° - 15°N with highest catch rate 4.29 kg/hr. Joseph and John (1987) found that perches were abundant upto 100 m depth zones along the Indian coasts while in Wadge Bank and Gulf of Mannar region its abundance noticed from 100-200 m.

Wadge bank with an area of 12000 km^2 indicated to have an encouragingly high density of perches and the catch rate was 67 Kg/hr (Joseph and John, 1987). According to them a highly productive perch ground yielding an average 94.26 Kg/hr was located south east of Cape Comorin below 50 m depth. During July-September the catch rate of perches obtained from this area was 153.4 kg/hr and in April-June 130.7 Kg/hr. This conspicuous seasonal variation in yield pattern has been attributed to the presence of two stocks viz., the resident stock which is present on the fishing ground throughout the year and the migrant stock that appears on the bank during south-west monsoon (Sivalingam and Medcof

1957; Silvalingam, 1969). In Gulf of Mannar highest concentration (26.5 kg/hr) was recorded in 50-100 m depth zone. Along west coast, Menon and Joseph (1969) observed possibilities of hand line fishing for serranids in the rocky patches beyond 60 m depth off Kerala coast. Survey of M.T. Murena in north west coast indicated the highest catch rate of rock cods in lat. 19° between 125-360 m depth yielding 43.5 kg/hr in February-April (Bapet et al., 1982). The group occurred in fairly good concentration along east coast where average catch rate of 12-44 kg/hr was recorded from areas upto 100 m depth.

Exploratory surveys conducted by FORV Sagar Sampada during 1985-'88 recorded 0.73% (212 hr/15 min) of Epinephelus spp. from west coast, 2.25% (118 hr) from east coast and 3.24% (12 hr/40 min) from Andaman and Nicobar Archipelagoto (Sivakami, 1990). The survey of FSI vessel Matsya Nirakshani along south west coast between latitudes 7°N and 10°N during January to March '92 has shown that Lat. 8°N recorded the highest catch rate of 164 kg/hr and perches recording catch rate of 51 kg/hr formed the major components of the catch. The major contribution from lat. 7°N (Wadge Bank) was perches recording a catch rate of 49 kg/hr. Areas along the lat. 10°N gave a poor catch rate of 23 kg/hr. Perches were significant in the catches from Wadge Bank and Gulf of Mannar. The dermersal resources survey along lower east coast by the same vessel between Lat. 12°N and 15°N showed very poor catch rate of perch.

The gearwise catch data for rock cods in Kerala during 1990-1992 is shown in the Table-51. The outboard hooks and lines landed

TABLE-51 **Gearwise landing (tonnes) of rock cods in Kerala**

	MTN	MHL	OBDN	MGN	PS	OBRN	OBGN	OBBS	OBTN	OBHL	NM	TOTAL
1990	84	374	47	–	–	–	–	–	–	461	32	998
1991	59	419	–	–	–	–	18	1	–	174	53	724
1992	2353	189	–	–	–	–	4	–	–	443	5	2994

461 t of rock cods the mechanised hooks and lines landed 374 t, mechanised trawlers netted 84 t, out board drift net landed 47 t and non mechanised gears landed 32 t. Thus in 1990 the total landing of rock cods was 998 t. In the year 1991 a total of 724 t rock cods were landed. Mechanised hooks and lines contributed most of the catch, 419 t. The other gears landed rock cods were by out board hooks and lines 174 t, mechanised trawl net 59 t, non mechanised gears 53 t, outboard gillnet 18 t and outboard boat seine 1 t. In 1992 out of 2994 t total landing of Kerala, 2353 t came from mechanised trawl net, 443 t from outboard hooks and line, 189 t from mechanised hooks and line 5g from non-mechanised gears and 4 t from outboard gill net.

In Cochin fisheries harbour rock cods were landed by hooks and line and trawlers. Major contribution was by hooks and line. Hooks and lines contributed 91.37% of total catch during 1990-1992, while only 8.63% came from trawlers. A variety of rock cods were caught by hooks and lines where as only *E. diacanthus* was observed in trawlers and very rarely *E. undulosus* in very low numbers. Gearwise catch data of Cochin fisheries harbour during 1990-1992 is given in the Tables 52 to 54 respectively. In 1990 out of the 701 t total landing, 684 t came from mechanised hooks and lines for 4157 units of effort and 17 t from mechanised trawlers for 70456 units of effort. In 1991, the total catch was 426 t, of which the hooks and line contributed 407 t of which the hooks and line contributed 407 t for 37338 units of effort and 9 t by the trawlers for 108911 units of effort. Hooks and line contribution in 1992 was 169 t for 2118 units of effort and trawlers landed 8 t for 92784 units of effort. The total catch during this year was 252 t.

TABLE-52. **Quarterly gearwise landing (tonnes) of rock cods in Cochin Fisheries Harbour during 1990.**

Quarter	TN Effort	TN Catch	MHL Effort	MHL Catch	Total Catch
I	19882	5	3879	652	657
II	27457	8	96	9	17
III	8420	2	0	0	2
IV	14787	2	182	23	25
TOTAL	70546	17	4157	684	701
%	-	2.4	-	97.6	

TABLE-53. **Quarterly gearwise landing (tonnes) or rock cods in Cochin Fisheries Harbour during 1991.**

Quarter	TN Effort	TN Catch	MHL Effort	MHL Catch	Total Catch
I	29804	6	2516	316	322
II	34946	3	290	5	8
III	22447	7	224	0	7
IV	21714	3	708	86	89
TOTAL	108911	19	3738	407	426
%	-	4.5	-	95.5	

TABLE-54. **Quarterly gearwise landing (tonnes) of rock cods in Cochin Fisheries Harbour in 1992.**

Quarter	TN Effort	TN Catch	MHL Effort	MHL Catch	Total Catch
I	29017	5	907	57	62
II	31492	3	100	0	3
III	11739	16	207	0	16
IV	20536	59	904	112	171
TOTAL	92784	83	2118	169	252
%	-	33	-	67	

Quarterwise species composition of rock cods in hooks and lines during 1991-1992 from Cochin fisheries harbour is shown in the Table-55 and 56 E. diacanthus was the most dominant species among rock cods. In the year 1991 the composition of E. diacanthus was 40.18%. The next dominant species was E. bleekeri and the composition was 21.50%. E. chlorostigma is composed of 17.05% and other rock cods were composed of 21.27%. In 1992 also E. diacanthus was the most dominant species and the percentage composition was 41.72, E. chlorostigma composed 13.67%, E. bleekeri, 13.64% and other rock cods composed 30.97%. The average total rock cods landed during 1990-92 was 288 t, at a catch rate of 16.06 kg. The annual average percentage composition of E. diacanthus was 40.63, E. chlorostigma 16.1 E. bleekeri 19.2 and others 24.1. Other species of Epinephelus observed in hooks and line were E. albomarginatus, E. latefasciatus, E. tauvina and E. malabaricus. Rock cods landed by trawlers were very less when compared with hooks and lines and comprised only of F. diacanthus (Table 57 and 58). An estimated annual average catch of E. diacanthus was 51 t at a rate of 0.56 Kg. The depth of operation of trawlers were from 30 to 50 mts while the operation of hooks and lines were from 120-130 meters.

The fish has got immense commercial and economic importance as a good quality table fish. The meat is very firm but soft and excellent to taste when cooked. They remain in ice in prime condition for 7-10 days and are good for making fish fillets and slices. The fish is marketed in fresh condition. As the fish has good market abroad, some of the private firms are engaged in exporting the fish. Small perches upto 1 Kg. are

TABLE-55. **Quarterwise species composition (Kg) of rock cods from hooks and line during 1991 in Cochin Fisheries Harbour.**

Quarter	Effort (Units)	Total catch	E. diacan-thus	E. chloro-stigma	E. bleekeri	Others	Catch per unit effort (Kg)
I	2516	316000	142200	63200	56880	53720	125.60
II	290	5000	-	-	- -	5000	17.24
III	224	0	-	-	30630	-	-
IV	708	86000	21350	6180		278440	121.47
TOTAL	3738	407000	163550	69380	87510	86560	108.88
%			40.18	17.05	21.50	21.27	

TABLE-56. **Quarterwise species composition (Kg) of rock cods from hooks and line during 1992 in Cochin Fisheries Harbour.**

Quarter	Effort (Units)	Total catch	E. diacan-thus	E. chloro stigma	E. bleekeri	Others	Catch per unit effort (Kg)
I	907	57000	28500	8550	5136	14820	62.85
II	100	-	-	-	- -	-	-
III	207	-	-	-	17920	-	-
IV	904	112000	42000	14560		37520	123.89
TOTAL	2118	169000	70500	23110	23050	52340	79.79
%			41.72	13.67	13.64	30.97	79.79

TABLE-57. **Quarterwise catch data (Kg) of *E. diacanthus* from trawlers in the year 1991 from Cochin Fisheries Harbour**

Quarter	Effort	Total catch	*E. diacanthus*	Catch per unit effort (Kg)
I	29804	6000	6000	0.20
II	34946	3000	3000	0.09
III	22447	7000	7000	0.31
IV	21714	3000	3000	0.14
TOTAL	89311	19000	19000	0.21

TABLE-58. **Quarterwise catch data (Kg) of *E. diacanthus* from trawlers in the year 1992 from Cochin Fisheries Harbour.**

Quarter	Effort	Total catch	*E. diacanthus*	Catch per unit effort (Kg)
I	29010	5000	5000	0.17
II	31492	3000	3000	0.10
III	11739	16000	16000	1.36
IV	20536	59000	59000	2.87
TOTAL	92777	83000	83000	0.89

exported after IQF (Individual quick frozen) and large ones as fillets and slices.

Stock assessment:

As the landings of the rock cods were highly seasonal, the samples obtained from any of the two gears were inadequate to assess the stock of the fish. Eventhough many methods were attempted to assess the stock, no reliable result was obtained. As it was stated earlier the type of gears used are selective and the fish obtained in hooks and line were larger (in the range 175–476 mm in the case of E. diacanthus) while those obtained in trawls were smaller (in the range 43-250 mm in E. diacanthus) and there was an overlapping of the size of the fishes in the two gears. Apart from the gear selectivity, the area of fishing by the two gears are different. The commercial trawlers fish in the inshore areas whereas the hooks and line in deeper offshore waters. Epinephelus chlorostigma and E. bleekeri were caught frequently in hooks and line only. The data obtained from hooks and line were inadequate for assessing the stock due to the small numbers obtained in each landing. Although there are references on stock assessment of groupers using data from selective gears it is quite possible that the error of gear selectivity would have been overlooked in those assessments. Hence the actual size of the stock might be different from what is assessed. It is therefore felt that a proper assessment of the stock of Epinephelus may not be possible with the available data and using the standard methods.

SUMMARY

1. Samples of *Epinephelus diacanthus, E. chlorostigma* and *E. bleekeri* were collected from the Cochin Fisheries Harbour for a period of two years. Total length, standard length and total weight were recorded. Otoliths, scales, vertebrae, stomach contents and gonadal tissue were removed and perserved.

2. Otoliths, scales and vertebrae were chosen for age determination in the three species.

3. Otoliths were translucent to read the annual rings. The relationship between the otolith radii and standard lengths was established. The standard length at each age, one to eight, is back-calculated using the growth checks in otoliths in the case of *E. diacanthus,* and ages one to seven in the case of *E. chlorostigma* and *E. bleekeri.*

4. The linear relationship between standard length and scale radii was established in all the three species. The standard lengths at ages one to eight were back-calculated for *E. diacanthus* one to seven for *E. chlorostigma* and one to nine for *E. bleekeri.*

5. The relationship between standard length and vertebrae radii were established in all the three species. Standard lengths at ages one to eight were back-calculated for *E. diacanthus,* one to seven for *E. chlorostigma* and one to eight for *E. bleekeri.*

6. Among the three skeletal hard parts, otoliths and vertebrae were found to be more reliable for age studies.

7. Marginal increment analysis of E. diacanthus were conducted to determine the time of annulus formation and it was found that annulus formation coincided with the onset of reproductive activity.

8. A close agreement was obtained between the mean standard length at capture of each age group and the mean back-calculated standard lengths in the case of E. diacanthus while reasonable agreement was there in the case of E. chlorostigma and E. bleekeri.

9. The spawning and associated physiological processes seemed to be the primary case of annulus formation in E. diacanthus.

10. The theoretical growth of the three species calculated by the von-Bertalanffy growth equation, was approximately equal to the back-calculated lengths. The von-Bertalanffy growth equation in each species is as follows:

E. diacanthus, $L_t = 474\ (1-e^{-0.1169(t-0.1074)}$

E. chlorostigma, $L_t = 440\ (1-e^{-0.1742(t-0.1354)}$

E. bleekeri, $L_t = 410\ (1-e^{0.2025(t-0.1783)}$

11. The length-weight relationship of the three species showed that $W = al^3$ may not be a proper representation of the length-weight relationship in the case of Epinephelus.

12. The food analysis of E. diacanthus revealed its preference for crustacean and fish diet. Crustaceans were the most preferred item for the small sized fish while the larger length groups showed a preference for fish diet. The fishes obtained from hooks and line showed everted stomachs. But their intestinal contents revealed that they also prefer crustacean and fishes. A number of empty stomachs were also met within Epinephelus diacanthus.

13. Based on histological sections, oogenesis and spermatogenesis are described in five stages. The stage is oogenesis are, primary stage, composed of oogonia, Stage 1 - early oocytes in a developmental stage, stage 2 - oocytes in a resting pre-vitelloginic stage, stage 3 - oocytes in a developmental early vitellogenic stage, stage 4 - oocytes in the final stage before maturation and stage 5 - oocytes in the mature egg stage prior to spawning. The unspawned stage 4 oocytes transform to atretic bodies in the post spawning gonad. Spermatogenesis is described in five stages viz., spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids and spermatozoa.

14. Seasonal and developmental changes in the gonads are described in ten classes. In this class 1 to 4 are female classes, class 5 is transitional and classes 6 to 10 are male classes. Each class is described as follows, class 1 immature female, class 2 maturing female, class 3 - active female, class 4 post spawning female,

class 5 - transitional between female and male, class 6 - immature male, class 7 - mature inactive or recovering male, class 8 - mature ripening male, class 9 ripe male and class 10 - post spawning male.

15. It is seen from ova-diameter frequency polygons that E. diacanthus spawns only once a year and spawning takes place in the female at stage 5.

16. Gonad development in different seasons and different length groups were found out for the three species of Epinephelus. The season just prior to spawning was the most active season for the gonad development. In E. diacanthus sexual transition may occur at any length over 150 mm SL, but mostly between 230 mm - 310 mm SL. In E. chlorostigma transitionals were seen between 291 and 310 mm SL. No transitionals were seen in E. bleekeri. But regressing oocytes were common in the sections of male tissue. Transitional fish form only a small percentage of the population at any age and occur between ages 2-8 in E. diacanthus.

17. In E. diacanthus, April-May formed the peak spawning season while in the case of E. bleekeri it was January. No ripe females was observed in E. chlorostigma

18,. Primary and secondary males were seen in E. diacanthus. Secondary males were more in number and larger in length. No primary males were observed in E. chlorostigma and E. bleekeri and the secondary males were confirmed by the presence of regressing oocytes in their testicular tissue.

19. Gonosomatic and hepatosomatic indices were worked out for each species. The gonosomatic index showed high values in spawning season, while the hepatosomatic index showed no definite relation with the reproduction.

20. In E. diacanthus the sex ratio always favoured females because the fish being a protogynous hermaphrodite. In E. chlorostigma and E. bleekeri the gear selectivity might be the cause for less number of females.

21. Fecundity was determined from 28 ripe ovaries of E. diacanthus and 19 ovaries of E. bleekeri. A good correlation was obtained between the fecundity and standard length, total weight and gonad weight. A linear relationship was established between the gonad weight and standard length and gonad weight and total weight. In E. diacanthus the average fecundity was 57,458 with a range $7.8\text{x}10^3$ - 1.6 to 10^5, while that of E. bleekeri was 73,731 with a range $1.09\text{x}10^5$ - $2.9\text{x}10^6$

22. Racial investigations within the species, E. diacanthus were carried out with the help of general morphometric characters and truss morphometrics among the samples collected from Cochin and Calicut. The studies revealed that the fishes from the two regions belonged to two distinct population.

23. External and internal parasites were collected and identified. The external parasites obtained were isopods, anthosomatids and lernaeids and the internal parasites were trematodes, cestodes and nematodes.

The occurrence of the parasite, Sarcotaces arcticus is reporting for the first time from Indian waters.

24. The rock cod landing in India showed a general improvement in its fishery during 1990-1992. The data on statewise, gearwise and centrewise rock cod landings obtained from Fishery Resource Assessment Division CMFRI, Kochi is employed to describe nature of the rock cod fishery. Rock cods are fished mostly with the help of hooks and line in offshore areas while trawling is limited in to the inshore waters upto 50 m depth. E. diacanthus was the most prominant species observed among rock cods in hooks and line and trawls. The fish after auction is taken to the internal markets and to the cold storages From the cold storages the fish is exported to abroad.

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