SOME INSIGHTS INTO THE RESOURCE OF THE INDIAN MACKEREL, *RASTRELLIGER KANAGURTA* (CUVIER)

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OF
DOCTOR OF PHILOSOPHY

BY
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FEBRUARY 1986

CERTIFICATE

This is to certify that the thesis entitled 'SOME INSIGHTS INTO THE RESOURCE OF THE INDIAN MACKEREL, *RASTRELLIGER KANAGURTA* (CUVIER)' is a bonafide record of research carried out by Mr. A. Noble under my guidance and supervision and that no part thereof has been presented for any other degree.

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Central Marine Fisheries
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DECLARATION

I hereby declare that this thesis entitled 'SOME INSIGHTS INTO THE RESOURCE OF THE INDIAN MACKEREL, *RASTRELLIGER KANAGURTA* (CUVIER)' has not previpusly formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

10/2/1986

A. NOBLE,

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PREFACE

The candidate took M.Sc. Degree in Zoology with specialization in Fresh-water Fishes and Fisheries from Banaras Hindu University with a First Class in 1957 and joined the research team of the Central Marine Fisheries Research Institute the same year. To begin with for a year, he was engaged in the collection of catch statistics of fish landings along the Malabar Coast. Subsequently he took up research on mackerel at Karwar along with environmental studies along the North Kanara Coast for 6 years.

The food and feeding of the mackerel formed important aspects on investigation during this time. Relative importance of various food items were determined and their quality and quantity were found related to the variations in the occurrence of planktonic elements in inshore area. Feeding in relation to production of plankton and the size and maturity formed part of the investigation. The length of mackerel season and the fluctuations in landings were linked to certain hydrological conditions of the inshore areas and local rainfall. Results of the above investigations are already published.

Since 1965, the candidate took up investigations on the resource characteristics of the mackerel at Cochin. The catch trends and seasons; growth, age, maturity, spawning, and food and feeding of the fish; were investigated and an account on these is already published. Incursions of mackerel into back-waters, and abnormalities in the fish were noticed during the period of investigation at Cochin and were published.

The candidate is a pioneer in the programme of mackerel tagging. The recoveries of mackerel tagged and released by him are reported and growth traced in a published account on the fishery and biology of mackerel at Cochin.

Working on various aspects, the candidate found the mackerel fishery at many places in the country including Cochin as well as at all-India level, besides its seasonal changes to have long-term flucations apparemtly evincing a ten-year cycle. Published literature on the fishery and biology of mackerel at many places are available. But attempts on population studies and assessment of stock are scanty. The candidate's attention at this juncture turned to investigations on population dynamics of the mackerel. On account of the long-term fluctuations in the fishery, it was felt desirable to have data for a number of years together to facilitate adequate coverage of a unit of time in the 10-year cycle. Investigations on length - weight relationships for 16 seasons were hence carried out.

Estimates on age composition of commercial catches from season to season during July 1965 to June 1980 were made and mortality worked out. Various growth parameters of mackerel were also worked out and studies on yield and assessment of stock were done.

In spite of voluminous work at many places, information on the distribution of the mackerel in space and time at all-India level was lacking. The candidate hence made an attempt to fill this gap by identifying actual areas of good mackerel fishery all along the coasts of India and periods when it abounds there.

This thesis is written section by section embodying the results and findings of the work carried out under different subject areas. It contains sections on identity of the species, information on its spatial and temporal distribution along the Indian coast, study on length-weight relationships, growth and age determination, population studies and stock assessment, and discussions.

The candidate has a number of publications on mackerel. Reprints of 8 of them are attached at the end of this thesis as supporting papers. The supporting paper 1 deals with the food and feeding of mackerel at Karwar. Paper 2 contains the relation of the mackerel fishery at Karwar with local hydrological condition of the sea and south west monsoon. The fishery and biology of the mackerel at Manassery (Cochin) during 1965-'66 to 1967-'68 along with results of mark-recovery studies form the basis of paper No. 3. The paper 4 gives a review on the mackerel fishery in India. In publication No. 5, the candidate is the senior author and is responsible for analyses and interpretation of data for which the junior author rendered some assisstance in the field work. This publication contains annual mackerel landings and effort for 10 years from 1967-'68 to 1976-'77 at Manassery. The publication No. 6 gives the spatial and temporal distribution of mackerel in India in 1978 and contains also studies on biology and population at many places including Manassery. The paper 7 hints at the 10-year cycle of the mackerel fishery in its long-term fluctuations at all-India level and at selected centres including Cochin. Annual landings for 16 years from 1962-'63 to 1977-'78 for Manassery are given in it. Supporting item No. 8 deals with the distribution of mackerel in space and time along the coasts of India in 1979 and 1980.

This dissertation is the outcome of the works of the candidate on the Indian mackerel. The work, however is based on exploited resource of the inshore waters. In the course of this analysis, lacunae existing in the investigations on the Indian mackerel are therefore identified and presented for future work.

CONTENTS

1. INTRODUCTION

The Indian mackerel, Rastrelliger kanagurta (Cuvier) of family Scombridae is one of the 3 species recorded from our waters. Though found on east and west coast, as Silas (1974) points out, it is the only species reported from the west where it forms one of the 2 important pelagic fisheries affording large-scale exploitation on the southern areas.

Some statistics on this resource along the Malabar and South Kanara coast are available as far back as 1893-'94 to 1898-'99 (Thurston 1900). Subsequently its catch statistics from the same area for 1925-'26 to 1930-'31 were published by Raj (1927, 1931, 1933 and 1939) and for 1931-'32 to 1949-'50 by Chacko (1954 and 1955). Arrivals of mackerel to Bombay Market from Konkan and Karwar coast during 1936-'37 to 1952-'53 (Pradhan 1956) indicate the northward extent of this fishery.

In view of its commercial importance, the Department of Fisheries of the erstwhile Madras Presidency, paid special attention to this fishery. The works of Hornell (1910), Devanesan and John (1940), Devanesan (1942), Chidambaram (1944), Chidambaram and Krishnamurthy (1951) and Chidambaram et al. (1952) provide evidence to it. A concerted attempt on acquisition of knowledge on the fishery, by and large, commenced only with the inception of Central Marine Fisheries Research Institute in 1947. Consequently we have a good data base on its landings in all-India and State levels from 1950 onwards (CMFRI 1969, FRAD 1980, 1982 and 1983). Since then considerable amount of information on various aspects of the resource have been reported from Bombay (Narayanan Kutty 1962, Krishna Pillai and Jayaprakash 1978, and Krishna Pillai 1979), Ratnagiri (George and Annigeri 1960), Goa (Hamre et al. 1966; Dhawan 1973, 1976 and 1981; Dhawan and Belurkar 1974; and Doiphode 1974), Karwar (Pradhan 1956; Radhakrishnan 1958, 1962 and 1964; Banerji and Chakraborty 1962; Banerji 1963; and Noble 1962 and 1972 a), North Kanara (Vedavyasa Rao 1963, and Dharmaraja and Jacob 1980), South Kanara (Sekharan 1958,and Dharmaraja and Jacob 1980), Calicut (Bhimachar and George 1952, Sekharan 1958, Pradhan and Reddy 1962, Venkataraman 1960, Venkataraman and Mukundan 1970, and Venkataraman and Narayana Rao 1973), Cochin (George 1965; George and Banerji 1962; Noble 1971, 1972 b, 1974 a & b; and Noble and Narayanan Kutty 1978), Vizhinjam (Balakrishnan 1957, Balakrishnan and Narayana Rao 1967, Narayana Rao 1962 b, and Sam Bennet 1964), Mandapam (Sekharan 1962), Porto - Novo (Vijayaraghavan 1962), Madras (Basheeruddin and Nayar 1961, Kuthalingam 1956, Virabhadra Rao and Basheeruddin 1953, and Girijavallabhan and Gnanamuttu 1974), Yanam (Sudhakara Rao 1974, Kakinada (Appanna Sastry 1968), Waltair (Narayana

Rao and Pampapathi Rao 1957, and Narayana Rao 1962 a) and Andamans (Jones and Silas 1962 b, and Luther 1973) and accumulated on. But these contributions were specific to the localities from where the investigations were carried out.

The Indian mackerel has a wide distribution in the Indo - Pacific region. Synopsis of biological data on it by Jones and Rosa (1962 and 1965) and the picture on the mackerel fishery in Indian Ocean by Panikkar (1967) are fitting contributions ranking India as the major producer of this valuable commodity. An objective assessment of the results obtained through investigations carried out in the country on decades up to the end of nineteen sixties documented for the first time hence was given out by CMFRI in 1970.

The mackerel landings show great fluctuations from year to year, causing concern both for scientists and administrators and stress the need for critical appraisal on characteristics of the resource. The works of Panikkar (1949 and 1952), Chidambaram and Krishnamurthy (1951), Sivalingam (1955), Pradhan and Virabhadra Rao (1958), Seshappa (1958, 1969 and 1970), Silas (1962 and 1974), Hamre *et al*. (1966), Venkataraman (1967), Peter (1967), Virabhadra Rao (1962), Prabhu and Venkataraman (1970), Selvakumar (1970), Narayana Rao (1970), Noble (1972 c, 1976, 1979, 1980, and 1982 a, b, & c), Sadananda Rao _et al_. (1973), Chakraborty _et al_. (1973), Banerji (1973), Sekharan (1974), Sekharan, Noble and Reghu (1975), Dhulkhed and Nagesh (1976), Dhulkhed and Narasimha Rao (1976), Narasimha Rao and Dhulkhed (1976), Devaraj (1983), Udupa and Bhat (1984) and George (1984) are attempts of insight into varieties of problems akin to population dynamics in broad spectrum. A three-diamensional approach to the subject at national level aided by sophisticated modern methods of aerial and acoustic surveys synchronizing conventional investigations on its biology was a bold step taken by PFP. (1973 a & b, 1974 a & b, 1975 a, b, & c, 1976 a, b, c, & d). Gnanamuttu (1970) has worked out the osteology of the Indian mackerel and in 1971 he compared it with that of _R.faughni_.

All-India and statewise annual landing figures for a long period are now available. Yet what we know is far too short. The present study consisting of an appraisal of exploited resource in space and time through 1976 to 1980 adds to our knowledge on stock structure and other related problems of this resource.

An idepth survey on potentials of the resource through investigations on biological characteristics of the fish and fishery from the commercial catches at Cochin over a long stretch of 16 seasons, hoping to cover different phases if any in its long-term fluctuations, was made with the intention that it would serve the scientists and industrialists the picture of a stable fishery promising maximum sustainable yield without endangering the stock and exterminating the species from our fishery atlas. For this a study on age and growth is made, and estimates on mortality rates, $L\infty$, K, t_0, yield per recruit, standing stock, potential yield and the quantum of effort required obtained. The length-weight relationship of the fish from season to season was derived and implications on its fluctuations indicated.

2. ACKNOWLEDGEMENTS

My sincere thanks without any reservations are due to Dr. E.G.Silas, Director, Central Marine Fisheries Research Institute, Cochin; who is my supervising teacher for his constant guidance, valuable suggestions and provision of facilities in the course of this investigation. My heartfelt gratitude is also due to Dr. C.T.Samuel, Dean of the Faculty of Marine Sciences and Professor and Head of the Department of Industrial Fisheries, University of Cochin for continuous encouragement and immeasurable help extended to me at the University level. I am deeply idebted to the Head of Division of the Fishery Resources Assessment Division, Central Marine Fisheries Research Institute for placing at my disposal their records from which the monthly landing data for the coasts of India was extracted. I am thankful to Mr. K.S.Udupa, Professor and Head of the Department of Statistics, College of Fisheries, Mangalore for leading me through statistical analyses and computer programming. I am thankful to Mr. V.A.Narayanan Kutty, Technical Assistant, Late Mr. V.K.Ramachandran, Laboratory Attender and Mr. M.K.Peethambaran, Fieldman of the Institute for their help and assistance in the laboratory and field work.

3. MATERIAL AND METHODS

The material for all-India and statewise annual landings was taken from published accounts available in literature (CMFRI 1969, and FRAD 1980 & 1982). Statewise and coastwise percentages in all-India annual catches were calculated from it and the percentage of mackerel in marine fish landings computed. Distribution of mackerel in space and time along the coasts of India is projected with the help of landing data extracted from the records of the Fishery Resources Assessment Division of CMFRI for 5 years during 1976 to 1980.

Data on the fishery and biology of the Indian mackerel was monitored regularly at Manassery in Cochin thrice a week during July 1965 to June 1980. The season commences with the entry of juveniles in fishery and culminates with the exploitation of old ones. Broadly the trend of fishery shows the season to fall during July-June. But practically it may be longer or shorter; and longer ones overlap with each other. Through observations on length distribution, the young ones and adults appearing in such overlaps were singled out and appropriated to their proper seasons and all estimates and studies done. A sample of 25 fish caught by the non-selective gear, the boat seine Thangu vala was studied in the laboratory per day of observation for total length (tip of snout to end of upper caudal lobe) and weight. The lengths were made into groups of 5 mm intervals and used for size distribution. The day's catch in weight and number of fish was made from this and monthly and annual estimates obtained. The effort used for exploitation and the catch of mackerel per unit of effort were estimated. Through length studies, the rate of growth of mackerel was found out and their age fixed. With its help, the age composition in commercial catches in numbers from season to season was found out and used in mortality estimation.

Total lengths in millimetre and weight in grams of individual fish recorded from samples collected at Manassery for 15 seasons up to June 1980 and later for another season from the mackerel landed in the Cochin Fisheries Harbour by purse seine during July 1980 to June 1981 were utilized for finding length-weight relationship by least squares method. An unweighted average and a pooled value of the length-weight relationships for 16 seasons were found out. The 'b' value from season to season were put to 't' test against the pooled value and the isometric one.

Length-weight relationship between male and female were worked out for 4 seasons from July 1977 to June 1981. Similarly the length-weight relationship between indeterminate fish (sizes below 120 mm) and fish where sexes were different (sizes 120 mm and above) were also computed and their significance tested. The formulae used for the calculation of length-weight relationship and those utilized for testing significance of variation are given at each chapter dealing with them.

A regression between 'a' and 'b' values of the length - weight relationship of 16 seasons was worked out and used in testing the equations got in this study and those available in our literature for three-diamensional growth, mistakes sorted out and rectified.

Shifting of modal and average sizes from month to month in commercial catches were used to find out the rate of growth and age of the mackerel. From the mean-age/length structure growth parameters such as $L\infty$, K and $W\infty$ were calculated. The t_0 was calculated further and the formulae adopted for these computations are indicated in each case. The growth parameters were checked and the curve fitted in a diagram by von Bertalanffy's equation.

From the reduction in number of fishes of a given age-class in a season to the successive age-class of the following season or seasons, mortality was calculated. Relating the total mortality with effort, as also to mean environmental temperature; and from the rate at which the population reduces to 1% level in an unfished state during its effective life-span, the total mortality was split into fishing and natural mortality. Methods adopted for these calculations are elaborated at suitable places with references in the text.

Calculation of maximum sustainable yield was tried without success by the relation between annual catch against effort. Estimation of yield per recruit, eumetric fishing and yield curves, the rate of exploitation, standing stock and annual stock were hence done by methods indicated in respective chapters dealing with them and the potential yield in India calculated.

All observations are compared with past findings, suitability noted down and future prospects of fishery touched upon with recommendations in the chapter on discussions. The observations and findings are duly substantiated with tabulated data and or with appropriate illustrations.

4. STATUS

4.1. IDENTITY

The genus *Rastrelliger* is more like *Scomber* in its external appearance having adipose eyelids, poorly developed corselet, single and small inter-pelvic process, and small caudal peduncle with 2 small keels on each side. But it is distinguished from the latter in many respects as listed by Matsui (1967) in a review on the 2 genera as given below:

4.1.1. KEY FOR DISTINGUISHING *RASTRELLIGER* FROM *SCOMBER*

Diagnostic characters	*Rastrelliger*	*Scomber*
Vomer & Palatine	Toothless.	Toothed.
Teeth	Rounded without crenulations.	Somewhat laterally compressed with crenulated edges.
Basibranchials	1st longer than 2nd and half as long to longer than 3rd (in adult).	1st about as long as 2nd and half as long to less than half as long as 3rd.
Bristles on basibranchials	On plates not separable into rows and do not diverge near tongue.	On 2 rows of plates that diverge near tongue.
Last basibranchial ray	Form a wide plate.	Only slightly flattened.

Hypobranchials	Join with basibranchials from below; anterior to the joining of 1st and 2nd hypobranchials there is a large plate.	Join with basibranchials from side. Only a small process anterior to joining of the 1st and 2nd hypobranchials.
Suture joining epihyal and ceratohyal	Unossified parts form large squares. Ventral and dorsal parts about equal. Dorsal part somewhat more anterior than the ventral.	Unossified parts only slits. Dorsal part shallower than the ventral and not staggered.
Hypohyal	Less than 1/3 as long as epihyal.	Nearly as long or longer than epihyal.
Subopercle	Extends to ventralmost part of gill cover; posterior ventral border nearly square.	Not extending to ventralmost part of gill cover; posterior ventral border rounded.
Anal spine	Rudimentary (in adults).	Present.
Interneurals in 1st dorsal fin	11 rarely 10; distal section all crownlike.	12-28; several with distal section only a plate and not crownlike.
1st interhaemal	Anterior to haemal spine of 14th vertebra.	Anterior to haemal spine of 15th vertebra.
1st haemal spine	Flattened with the hooked distal part nearly vertically directed.	Somewhat flattened and bent backwards.

Colour of dorsum	2 horizontal rows of spots on each side and several horizontal stripes below them (not seen on most).	Vertically zigzag or wavy lines.

Three species of Rastrelliger occur in Indian waters, and they are Rastrelliger kanagurta (Cuvier), R.brachysoma (Bleeker), and R.faughni Matsui; which can easily be distinguished by the following key:

4.1.2. KEY FOR SPECIES IDENTIFICATION OF RASTRELLIGER[+]

1. Body slim, depth at margin of gill cover approximately 5 times in standard length. Maxillary stops at $\frac{3}{4}$ the length of lachrymal. Length of intestine approximately equal to standard length. Gill rakers shorter than snout and do not extend far into the mouth even when it is wide open. Gill rakers in lower limb of first gill arch in fish over

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[+] Based on Matsui (1967)

50 mm standard length number 20-25. Bristles on one side of longest gill raker in fish of 120-180 mm standard length 30 to 55 numbers only (The gill rakers and bristles increase in number with increase in size of fish. .... R.faughni

2. Body deep. Maxillary extends nearly to the end of lachrymal. Intestine longer than standard length and gets longer with increase in size of fish. Gill rakers very long and visible when mouth is open. Gill rakers in lower limb of first gill arch in fish over 50 mm standard length number 30-46. Bristles on one side of longest gill raker in fish of 120-180 mm standard length over 100 in numbers, with tendency to get more with increase in size of fish. 3

3. Body very deep, depth at margin of gill cover 3.7 to 4.0 times in standard length. Intestine 3.0 to 3.4 times long in

standard length. Bristles on one side of longest gill raker in fishes of 120-180 mm standard length 150 to 240 in numbers (may increase in longer fish). .... R.brachysoma

Body moderately deep, depth at margin of gill cover 4.0 to 4.8 times in standard length. Intestine 1.3 to 1.7 times in standard length. Bristles on one side of longest gill raker in fishes of 120-180 mm standard length 105 to 160 in number (may increase in longer fish). .... R.kanagurta

4.2. DESCRIPTION OF THE SPECIES

R.kanagurta possessing D^1. 8 - 10, D^2. 1/11 + V - VI, A. 1/11 + V - VI, P^1. 19 - 22, P^2. 1/5, C. 24, L.l. 128 - 150, L.tr. 10/28, Vert. 13/16; has a strong fusiform body covered all over with scales which are longer on cheeks and below pectoral origin. The body is moderately deep 4.0 to 4.8 times in standard length. Head is 3.5 to 4.3 times in length and is longer than depth of body. Head is longer than wide.

The caudal is 4.5 to 5.0 times in length. Eye is 4.0 to 4.3 times in head and 1.5 times in snout. The eye is with a thick adipose eyelid. Snout is pointed and is a little less than the interorbital space. Mouth is large and oblique. Cleft of mouth is deep. The maxillary reaches nearly vertical below the hind edge of eye. Lower jaw is a little longer than the upper one. There is only a single series of very small teeth in jaws which become obselete in adult. Vomer and palatine are edentulous. The gill rakers are long, the longest equalling the distance from pupil to snout, and are feathery and pointed. The gill rakers project into the mouth cavity and they are easily visible when the mouth is opened. There are about 17 to 24 gill rakers in the upper and 30 to 46 rakers in the lower arm of the first gill arch. Number of bristles on side of longest gill raker ranges between 105 and 160. The number of gill rakers and the bristles in them are more in bigger fishes than in smaller ones. Spines in dorsal fin are week. The first dorsal spine is shorter than the second and the last one is small and feeble. There are 5 and occasionally 6 finlets after the dorsal and anal fins, the upper and lower ones being similar and opposite. The anal is slightly behind the origin of second dorsal. Pectorals are trangular and pointed and are twice in length of head. Caudal fin is strong and deeply forked with pointed lobes.

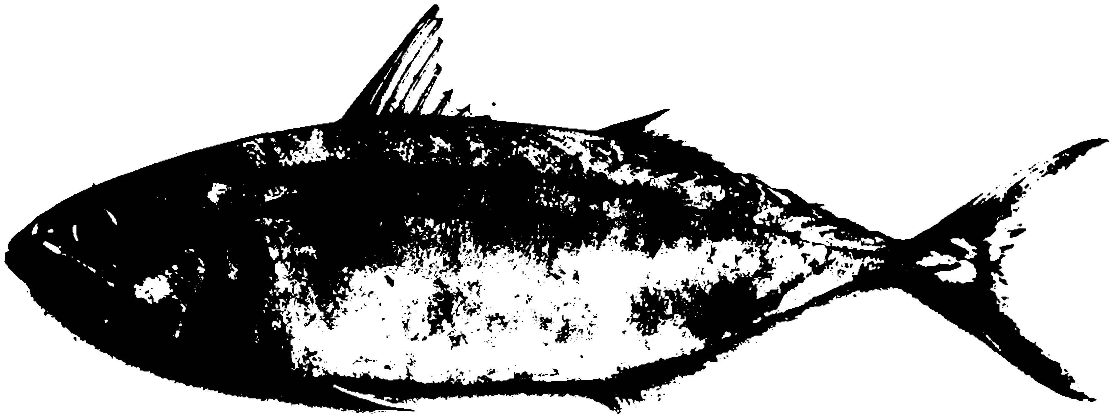
Body is blue green above and golden yellow on sides and belly with a silvery sheen. Two rows of dark spots on sides of dorsal fin base, and a black spot on body near lower margin of pectoral fin. A few golden yellow band along and below the lateral line. The colour and markings, however, are variable with age. Dorsal fin yellowish with greyish outer margin and black tips. Pectoral fins are yellow. Ventral and anal fins hyaline and faintly dotted when fresh. Caudal is yellow in colour, but dusky along the margin and extremities.

4.3. NOMENCLATURE

Russell (1803) described the Indian mackerel as "kanagurta" after its local Telugu name at Visakhapatnam from where it was first recorded. Cuvier in 1817, adopting binomial nomenclature named it as *Scomber kanagurta*. The name was further changed by him to *Somber canagurta* in 1829, but kept it again as *S.kanagurta* in 1831 (Cuv. & Val. 1831). With the acceptance of *Rastrelliger* as generic name (Jordan and Starks, 1908) for some of the fishes earlier described as *Scomber*, the name *Rastrelliger kanagurta* (Plate I) for the Indian mackerel has come to stay. Nevertheless,

Plate I. Photograph of an Indian mackerel, *Rastrelliger kanagurta* (Cuvier) caught at Cochin.

Plate I



it is appropriate here to deal with the synonyms of the species available in literature.

4.4. SYNONYMS

Scomber kanagurta	Cuvier 1817; Ruppell 1828, 1835; Cuvier & Valenciennes 1931; Klunzinger 1871, 1884; Gunther 1876; Macleay 1884; Kitahara 1897; Jordan & Evermann 1902; Fowler 1904, 1928; van Kampen 1907; Bean & Weed 1912; Fowler & Bean 1922.
Scomber canagurta	Cuvier 1829.
Scomber chrysosoma	Ruppell 1835.
Scomber loo	Cuvier & Valenciennes 1831; Bleeker 1852; Kner 1865; Steindachner 1868; Weber 1913.
Scomber microlepidotus	Ruppell 1938; Cantor 1850; Gunther 1860; Kner 1865; Steindachner 1868; Klunzinger 1871; Day 1878; Jordan & Seale 1907; Evermann & Seale 1907; Barnard 1927; Blegvad 1944.
Scomber muluccensis	Bleekér 1856; Weber 1913.
Scomber reani	Day 1870.

Scomber lepturus	Agassiz 1874.
Rastrelliger brachysomus	Jordan & Dickenson (nec Blkr.) 1908; Barnard (nec Blkr.) 1927.
Rastrelliger chrysozonus	Kishinouye 1923; Lin 1934; Manacop 1958.
Rastrelliger serventyi	Whitley 1944.
Rastrelliger kanagurta	Jordan & Starks 1917; Fowler 1935; Jones & Silas 1962 a.

A good lot of work on systematics of this fish is already available and the most recent one containing all previous references is by Jones & Silas (1962 a). Only this is hence cited in literature at the end.

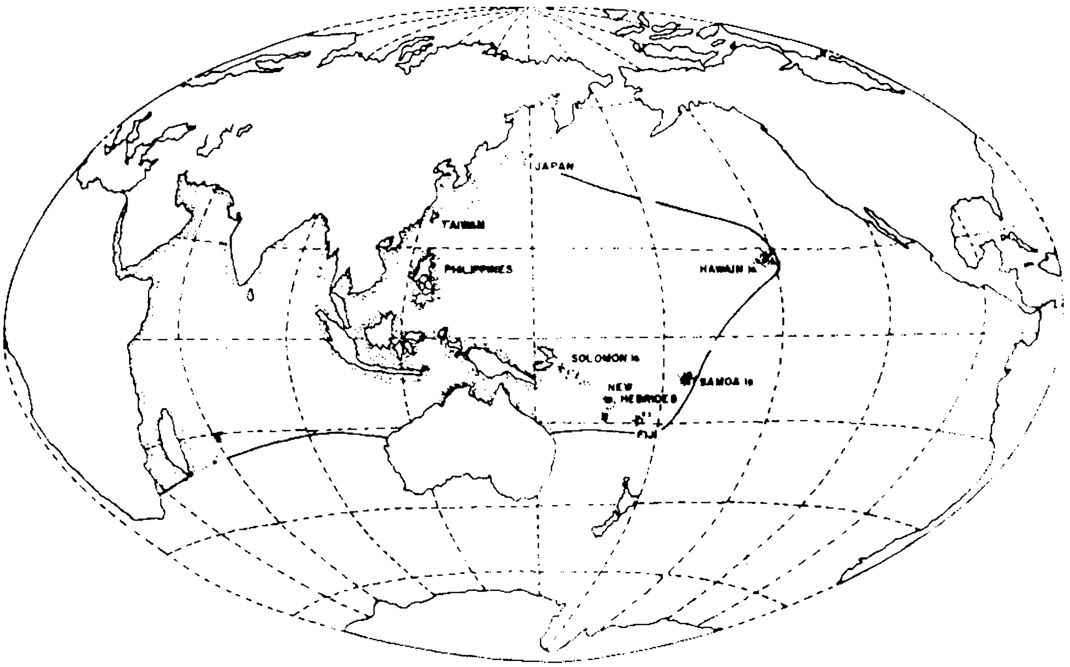
4.5. DISTRIBUTION

R.kanagurta is widely distributed in the tropical Indo - Pacific region stretching from the east coast of South Africa penetrating even to the eastern Mediterranean Sea in the west to Hawaiian Islands in the east, coast of Australia in the south and Japan in the north. It occurs around most of the islands scattered in the area (Fig.1).

In India it is recorded from both the east and west coasts and from the coasts of Andaman and Nicobar Islands. The fish,

Fig. 1: Distribution of the Indian mackerel
in the Indo-Pacific region.

Fig. 1


JAPAN
TAIWAN
PHILIPPINES
HAWAII Is
SOLOMON Is
NEW
HEBRIDES
SAMOA Is
FIJI

however, is not found in Lakshadweep.

4.6. COMMON NAMES

English	-	The Indian mackerel
Hindi	-	Bangdi
Sindhi	-	Obiagedar
Marathi	-	Kaulagedar, Bangada
Kannada	-	Bangada
Malayalam	-	Ayala, Ayila
Tamil	-	Ailai, Kumla, Kannangeluthi
Telugu	-	Kanagurta, Kannangadatha, Kamangadachalu, Vahijiramu
Oriya	-	Karankita

5. OBSERVATIONS

5.1. ALL-INDIA PRODUCTION

Annual landings of the mackerel in India from 1950 to 1981 extracted from published accounts (CMFRI 1969, and FRAO 1980 and 1982) are given in Fig. 2. During 1950-'53 the landings were good and in next 3 years poor. Again in 1957 - '60, the landings rose. The years 1951, 1958 and 1960 witnessed landings over 100,000 tonnes. From 1961 to 1968 except 1963 with 76,980 tonnes, the landings were comparatively poor. The lowest landing of 16,431 tonnes in 32 years under review, however, occurred in 1956. The landing which was 21,703 tonnes in 1968 increased four-fold to 91,837 tonnes next year. In the following 3 years the landings stood high. In fact, the highest ever recorded landing of 204,575 tonnes occurred then in 1971. In the succeeding years there was a decline in the landings till it reached 37,462 tonnes of 1974. Further it climbed to a peak with 85,233 tonnes in 1978, followed by a fall continuing up to 1981.

The average annual landings of mackerel for 1950-'81 period was 68,895 tonnes. The landings during 1950-'53, 1957-'60 (except 1959), 1963, 1969-'73, and 1978-'79 were higher than the average and during the rest lower (Fig.3).

Fig. 2

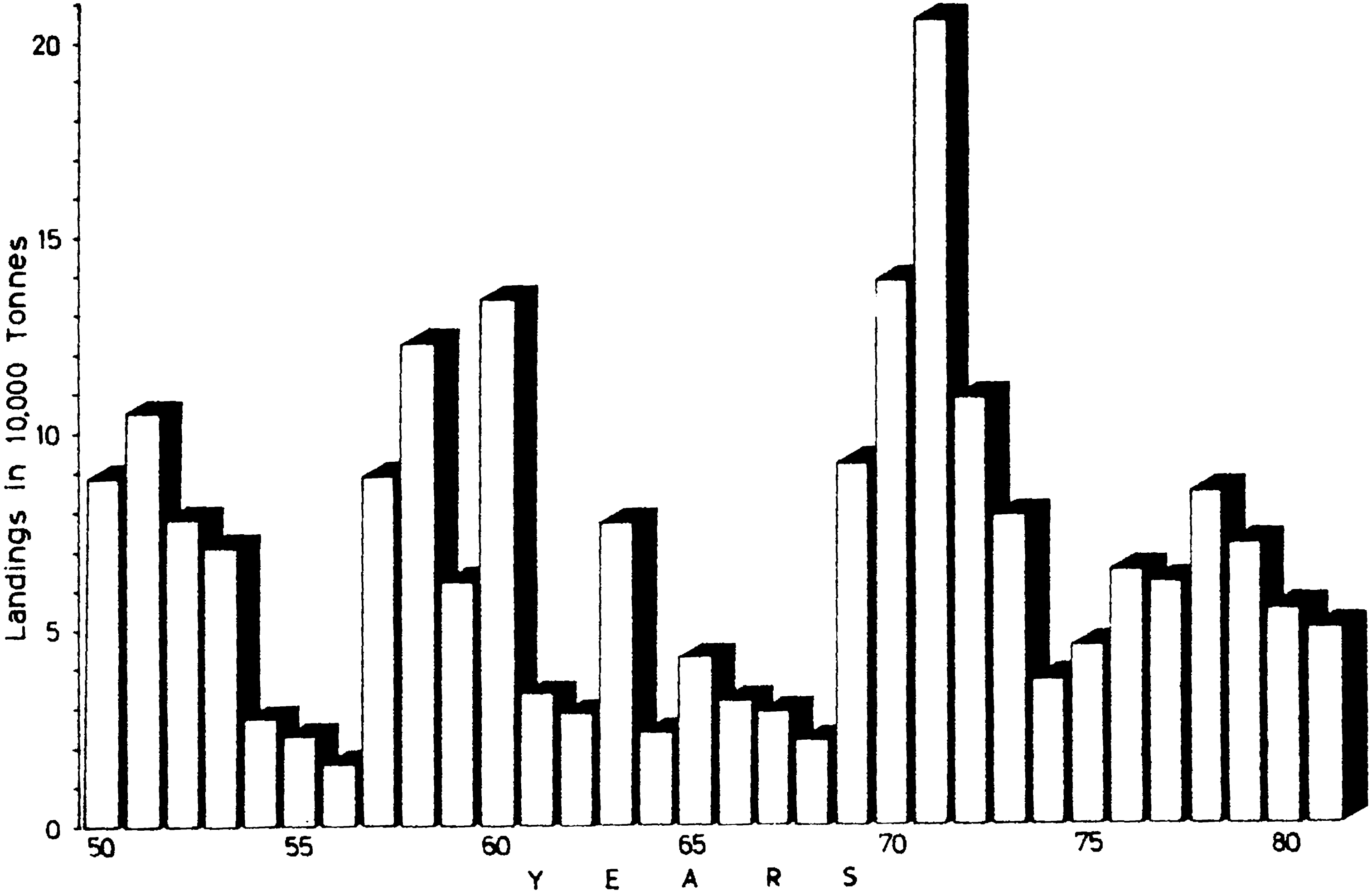
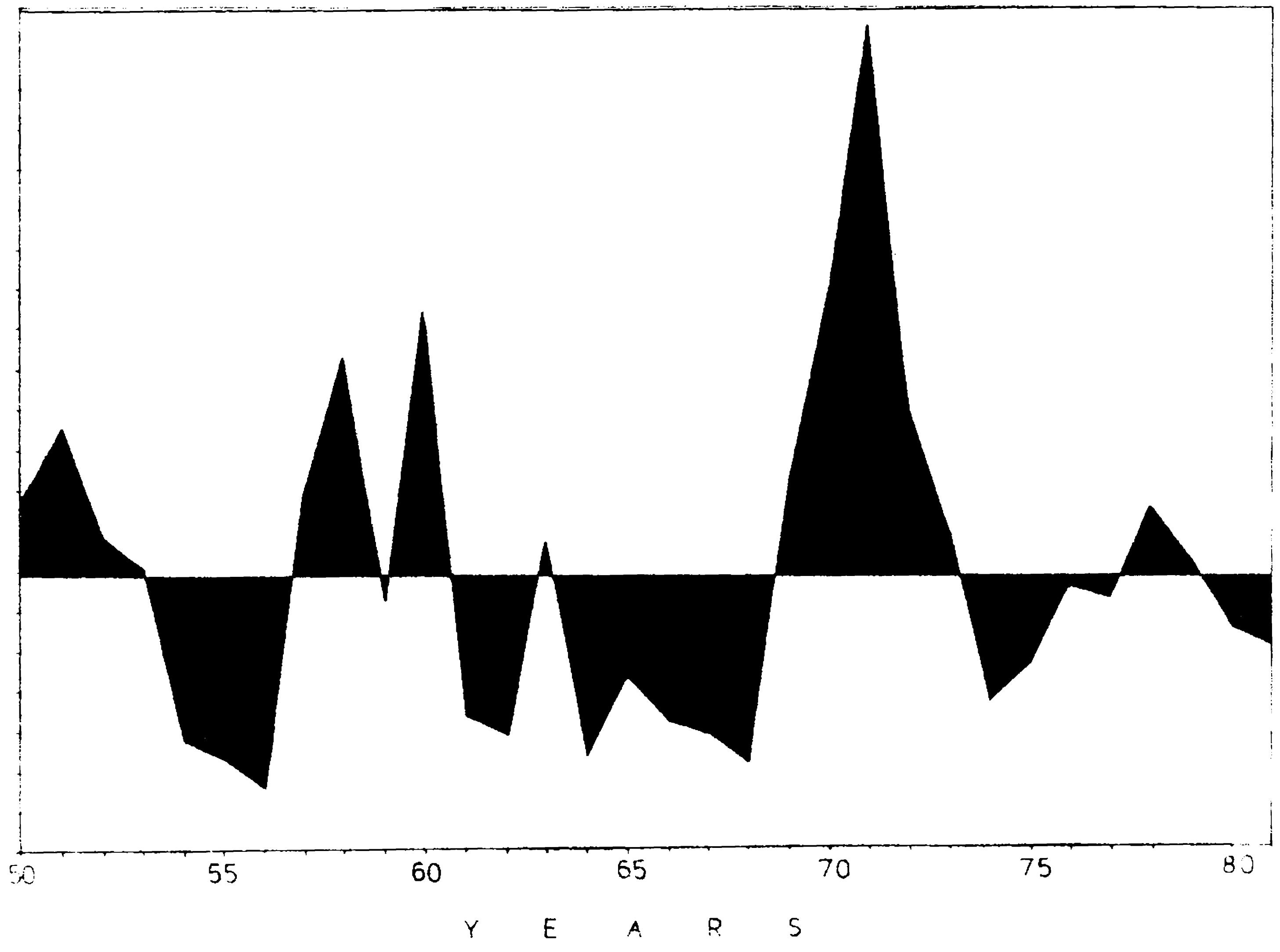


Fig. 3: Fluctuations of all-India annual mackerel production from average landings during 1950 to 1981.

Fig. 3



5.2. STATEWISE LANDINGS

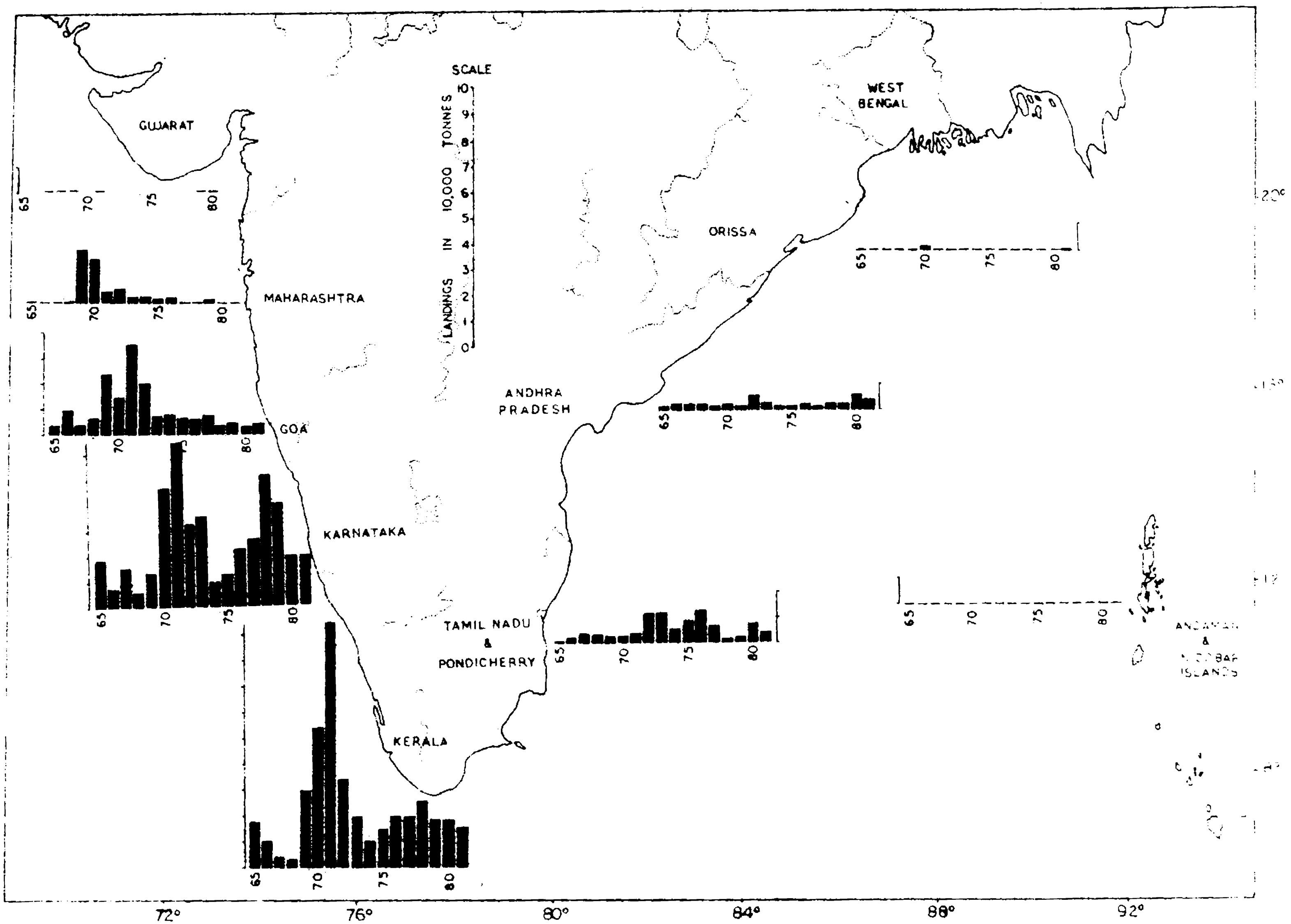
Full complements of statewise landings including that of the Union Territory of Goa is available only from 1965 onwards (Fig.4).

In Gujarat the landings ranged between zero and 35 tonnes except in 1980 when it turned out to be 112 tonnes. Often there was no mackerel landing in the state (Fig.4). On the other hand, the mackerel occurred in Maharashtra in all years (Fig.4). But the landing in 1967 was only 4 tonnes. The peak with 20,683 tonnes occurred in 1969. The landing in next year also remained high. Apart from these, the annual catches here were mostly below 2,500 tonnes. The average for the 17-year period however, works out to be 3,641 tonnes. Goa known to be an important place of mackerel production had an average annual landing of 9,894 tonnes. Though the landings here (Fig.4) varied between 2,446 tonnes of 1980 and 35,258 tonnes of 1971, production between 3,500 and 8,000 tonnes per annum was most common.

In Karnataka (Fig..4), the mackerel landings in the 17 - year period ranged between 5,736 and 64,047 tonnes. The landings were low and unsteady during 1965-'69. The lowest landing in the state in fact occurred during this period in 1968. During

Fig. 4: Statewise mackerel landings during 1965-'81.

Fig. 4



SCALE
LANDINGS IN 10,000 TONNES
GUJARAT
MAHARASHTRA
GOA
KARNATAKA
KERALA
TAMIL NADU & PONDICHERRY
ANDHRA PRADESH
ORISSA
WEST BENGAL
72°
76°
80°
84°
88°
92°

1970-'73, there was substantial increase in landings. As a result the peak production in the state was witnessed in 1971. Except the low landings in 1974, catches during the rest of the years were about 20,000 tonnes or more. On the whole, the landings here during the 17-year time averaged 25,787 tonnes per annum.

In 1965-'81 period, the landings in Kerala (Fig.4) ranged between 3,600 tonnes of 1968 and 95,164 tonnes of 1971. During 1967-'68 the landings were very low and in 1969-'72 very high. But for these, the annual production were mostly within 10,000 to 20,000 tonnes. The average annual landing for the 17-year period in the state was 24,434 tonnes.

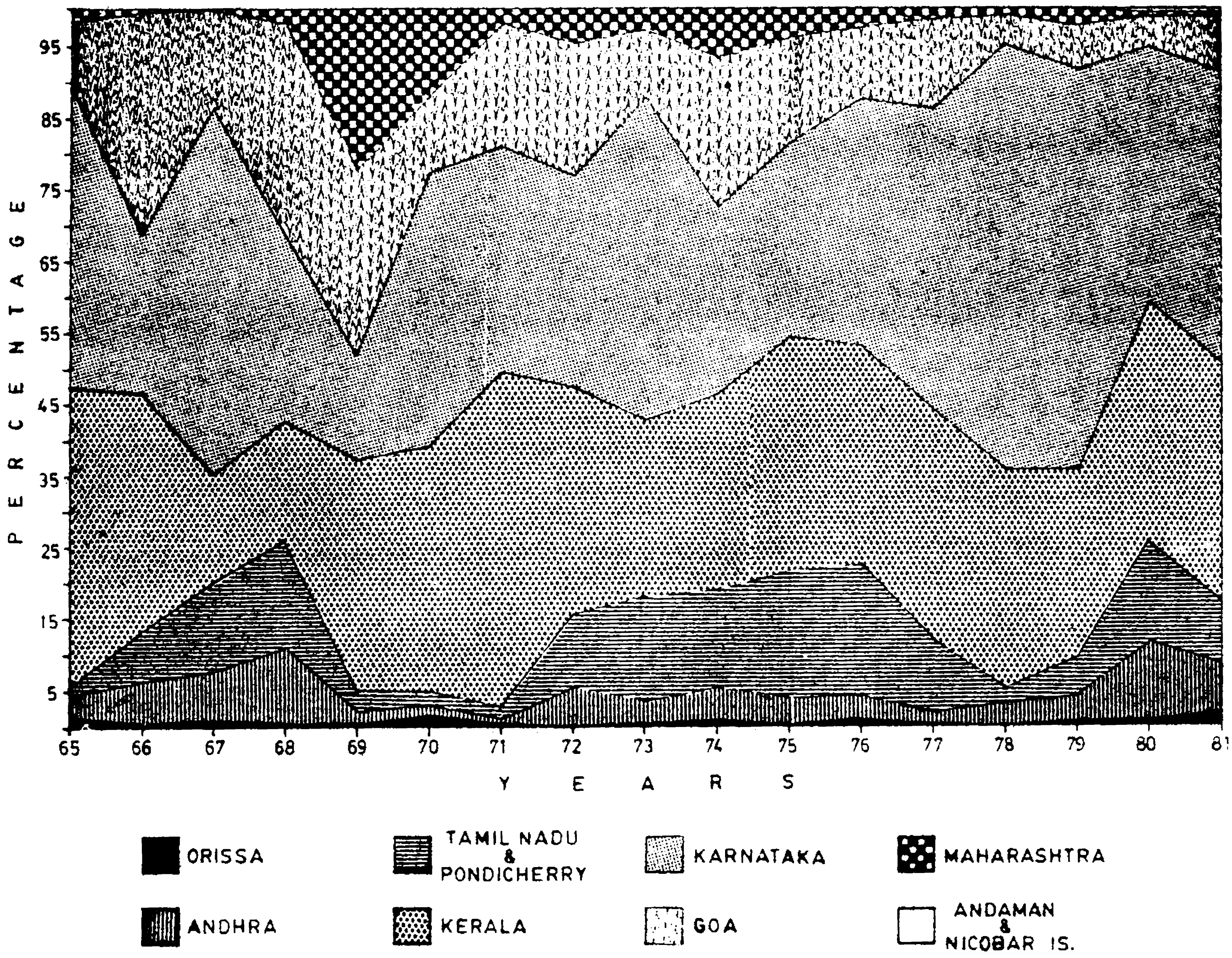
The landings in Tamil Nadu - Pondicherry (Fig.4) in 17 years ranged between 521 tonnes of 1965 and 12,086 tonnes of 1973, the average during the period being 5,254 tonnes. The landings were, however, mostly between 2,000 and 4,000 tonnes only. In Andhra Pradesh (Fig.4), the landings were uniformly low and within the range of 1,040 tonnes of 1977 and 3,255 tonnes of 1981 except 1972 and 1980 with 5,396 and 6,203 tonnes respectively. The landings in Orissa (Fig.4) were generally within a few hundred only. The lowest catch here was 13 tonnes of 1964. In Andaman and Nicobar Islands (Fig.4) the mackerel landings ranged between 12 and 183 tonnes, the average working out to be just 69 tonnes.

5.3 STATEWISE PERCENTAGE OF MACKEREL IN ALL-INDIA PRODUCTION

In all-India annual landing, 80% in 1965 came from Karnataka and Kerala in equal proportions (Fig.5) and another 9% came from Goa. But Goa's contribution was 31% in the next year. More than half (51%) of the all-India catch in 1967 came from Karnataka alone. Kerala's share in the year and the year next were only 15 and 16% respectively. In 1969, the percentage in Karnataka also was as low as 14. The catches in Goa in 1968 and 1969 registered respectively 29 and 26%. Maharashtra (Fig.5) too had an unusually good catch of 23% in 1969. The contributions by the states along east coast during 1969-'71 were low. During 1972-'76, the catches in Tamil Nadu - Pondicherry (Fig.5) accounted between 10 and 18%. The catches in Kerala from 1969 to 1981 ranged between 25 and 47%. In Karnataka the contributions during 1970-'75 were between 26 and 34% except 1973 when it was 45%. High concentrations up to 60% occurred here in later years. The percentage contribution from Goa and Maha-

Fig. 5: Statewise percentage of mackerel in annual all-India total from 1965 to 1981.

Fig. 5


PERCENTAGE
95
85
75
65
55
45
35
25
15
5
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
YEARS
ORISSA
ANDHRA
TAMIL NADU & PONDICHERRY
KERALA
KARNATAKA
GOA
MAHARASHTRA
ANDAMAN & NICOBAR IS.

rashtra more or less tapered during 1970-'81. Trends in percentage contributions in these 2 states broadly had a parallel run. The fluctuations in Andhra Pradesh and Tamil Nadu - Pondicherry too (Fig.5) were parallel.

In average production in the country during the 17-year period, Karnataka tops with 35.88% to its credit (Fig.6) followed by Kerala with 34.00%. The contribution of Goa in all-India annual mackerel production is 13.77%. States next in order of importance with regard to the percentage landings are Tamil Nadu - Pondicherry, Maharashtra, Andhra Pradesh, West Bengal & Orissa, Andaman & Nicobar Islands, and Gujarat each contributing respectively 7.31, 5.06, 3.40, 0.46, 0.10, and 0.02% (Fig.6).

5.4. COASTWISE PRODUCTION

Production of mackerel along the east and west coast of the country is given in Fig. 7. Along east coast (Fig.7), the catch during 1965-'81 varied between 2,233 tonnes of 1965 to 16,700 tonnes of 1972 and the average for the 16-year period was 8,100 tonnes. In the total for the country this formed only 11.3%. The remaining 88.7% of the mackerel caught in India

Fig. 6: Percentage of mackerel production by states in all-India total, average during 1965-'81.

Fig. 6

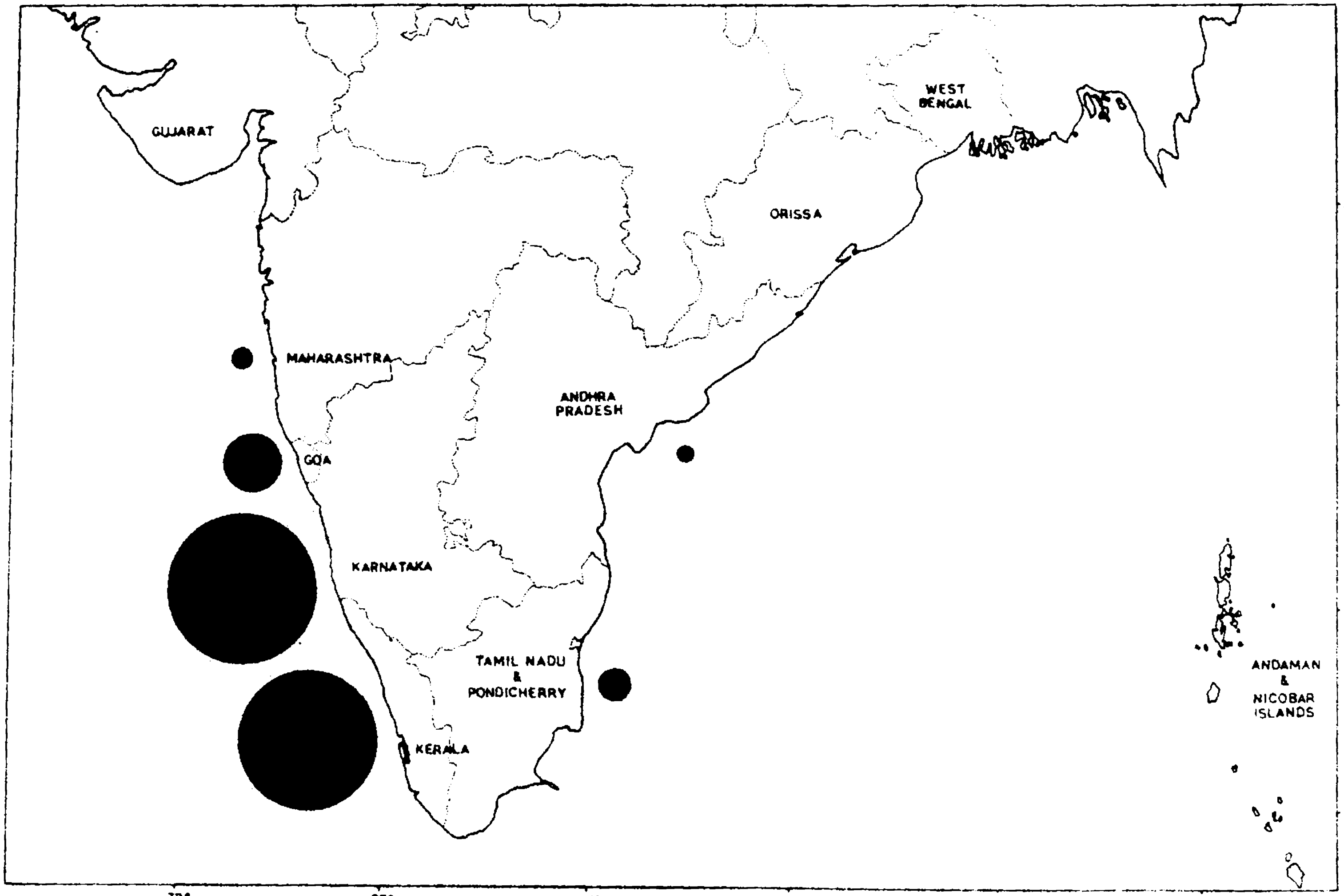
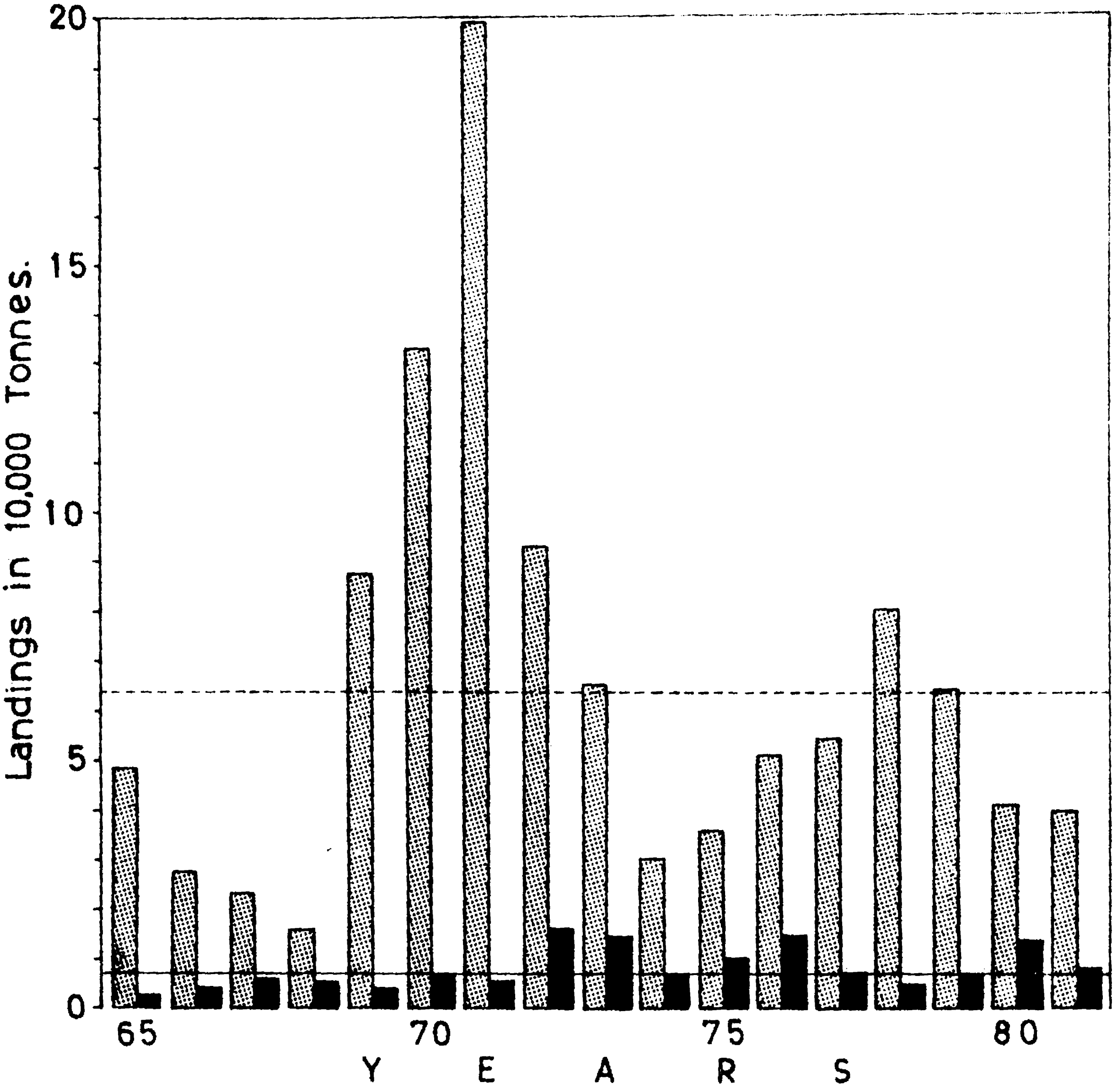

GUJARAT
WEST BENGAL
ORISSA
MAHARASHTRA
ANDHRA PRADESH
GOA
KARNATAKA
TAMIL NADU & PONDICHERRY
KERALA
ANDAMAN & NICOBAR ISLANDS
20°
16°
12°
8°
72°
76°
80°
84°
88°
92°

Fig. 7: Annual landings of mackerel in east coast (dark bars) and west coast (stippled bars) against their respective 17-year average (lines across).

Fig. 7



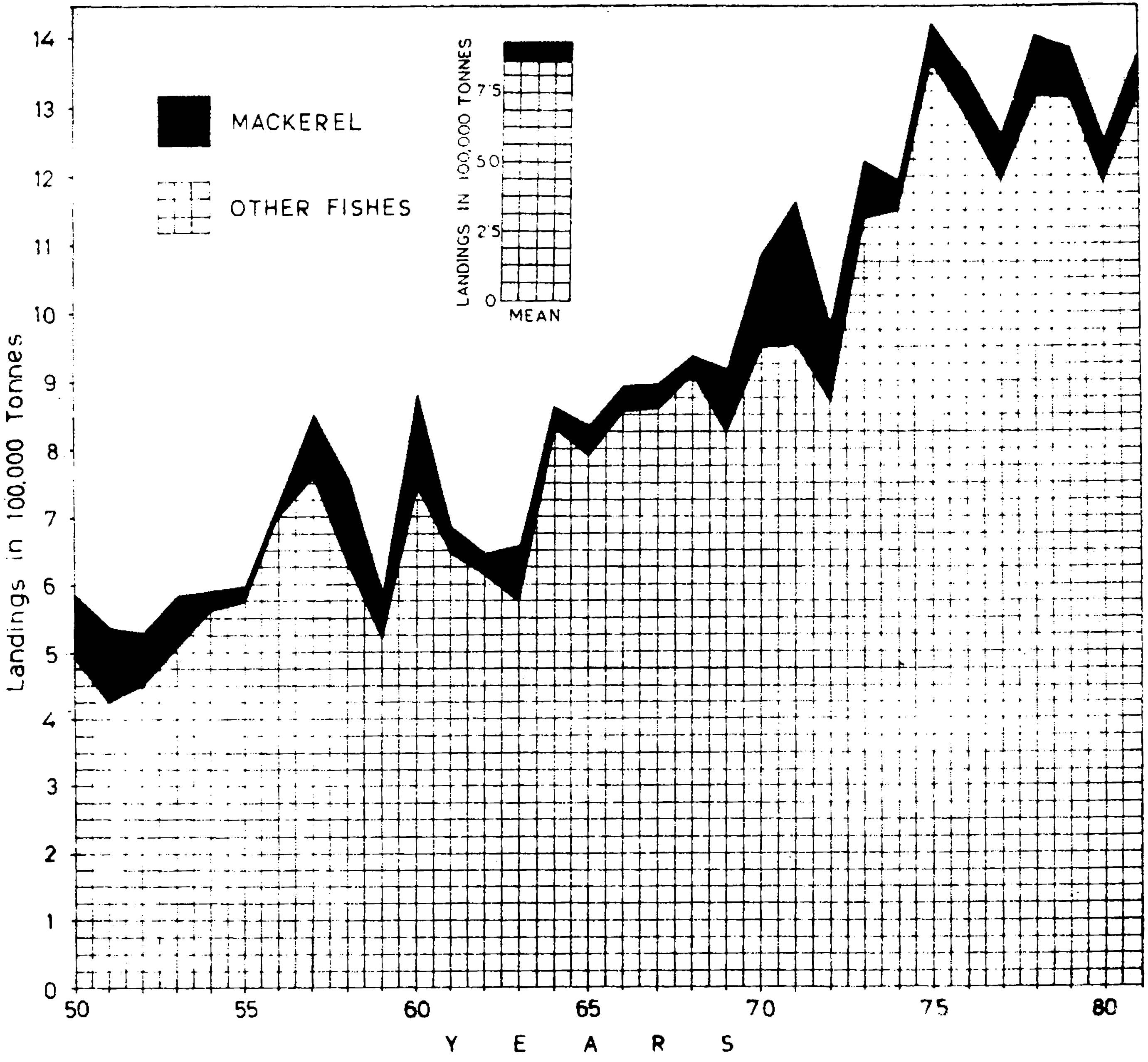
was fished along the east coast. Though the average percentage for 17 years in east coast was 11.3, annually it varied between 2.7% of 1971 and 25.9% of 1980. Along west coast (Fig.7), the average landing was 63,769 tonnes and the range was between 16,123 tonnes of 1968 and 199,120 tonnes of 1971. The landings during 1969-'72 and 1978 were above average, in 1973 and 1979 almost the same. The landings during other years were well below the average. Generally when the annual catch in the country was low, the percentage in west coast too appeared low. The total production at all-India level is nothing but a reflection of the fluctuation in catches along the west coast.

5.5. MACKEREL IN ALL-INDIA MARINE FISH CATCHES

Average annual production of marine fish in the country during 1950-'81 was 925,407 tonnes (Fig.8). In this the mackerel formed only 7.45% (Fig.9). However, the mackerel was found to contribute to a percentage as high as 19.65 in 1951 (Fig.10). In 1971, when the mackerel catch was the highest in the country, it formed only 17.61% in the year's marine fish landings. In the last 9 years beginning with 1973, the percentage of mackerel in marine fish catches was

Fig. 8: Mackerel in all-India marine fish catches from 1950 to 1981.

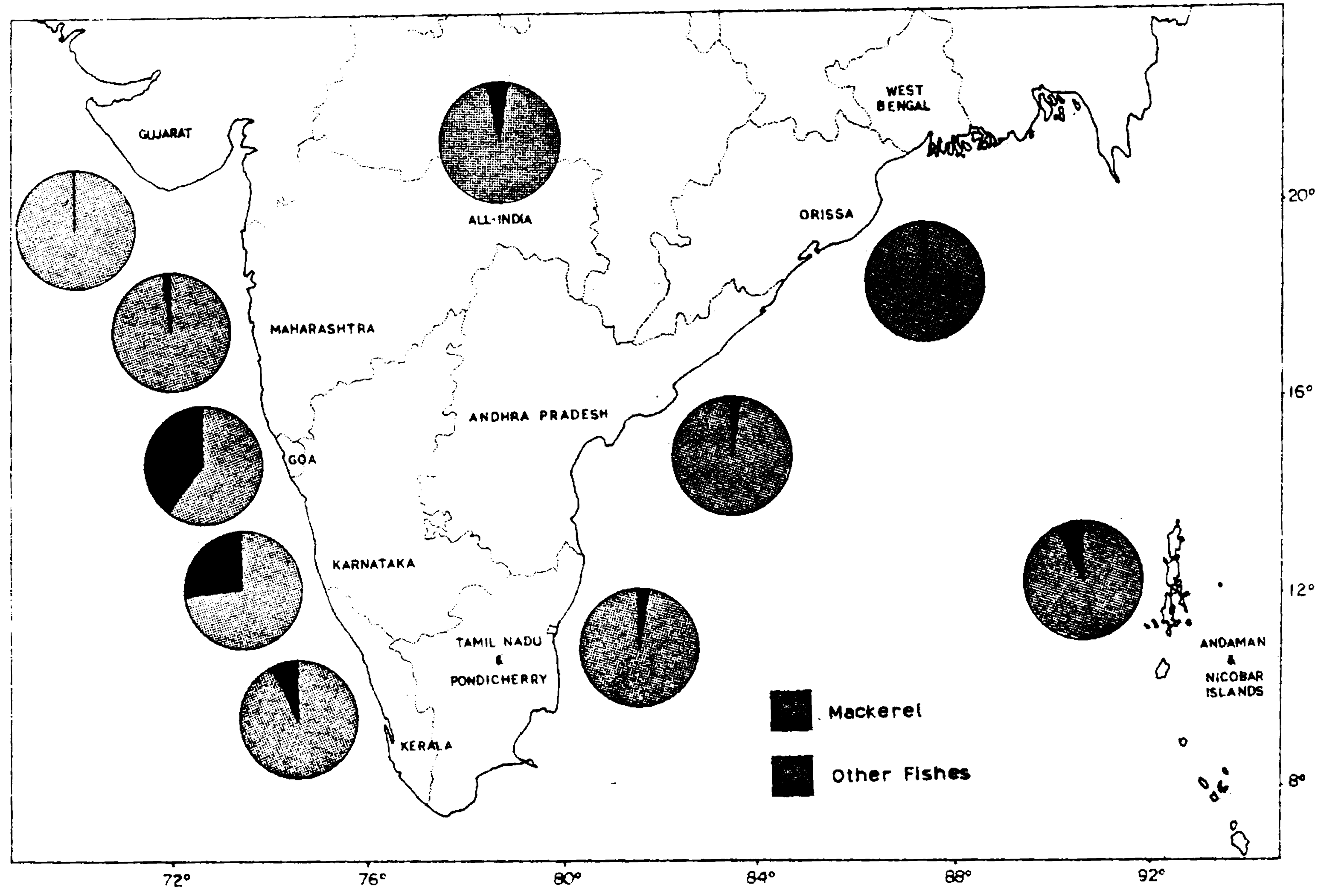
Fig. 8



MACKEREL
OTHER FISHES
LANDINGS IN 100,000 TONNES
7.5
5.0
2.5
0
MEAN
Landings in 100,000 Tonnes
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
50
55
60
65
70
75
80
Y E A R S

Fig. 9: Percentage of mackerel in marine fish landings of different states, and the country as a whole, 1965-'81 average.

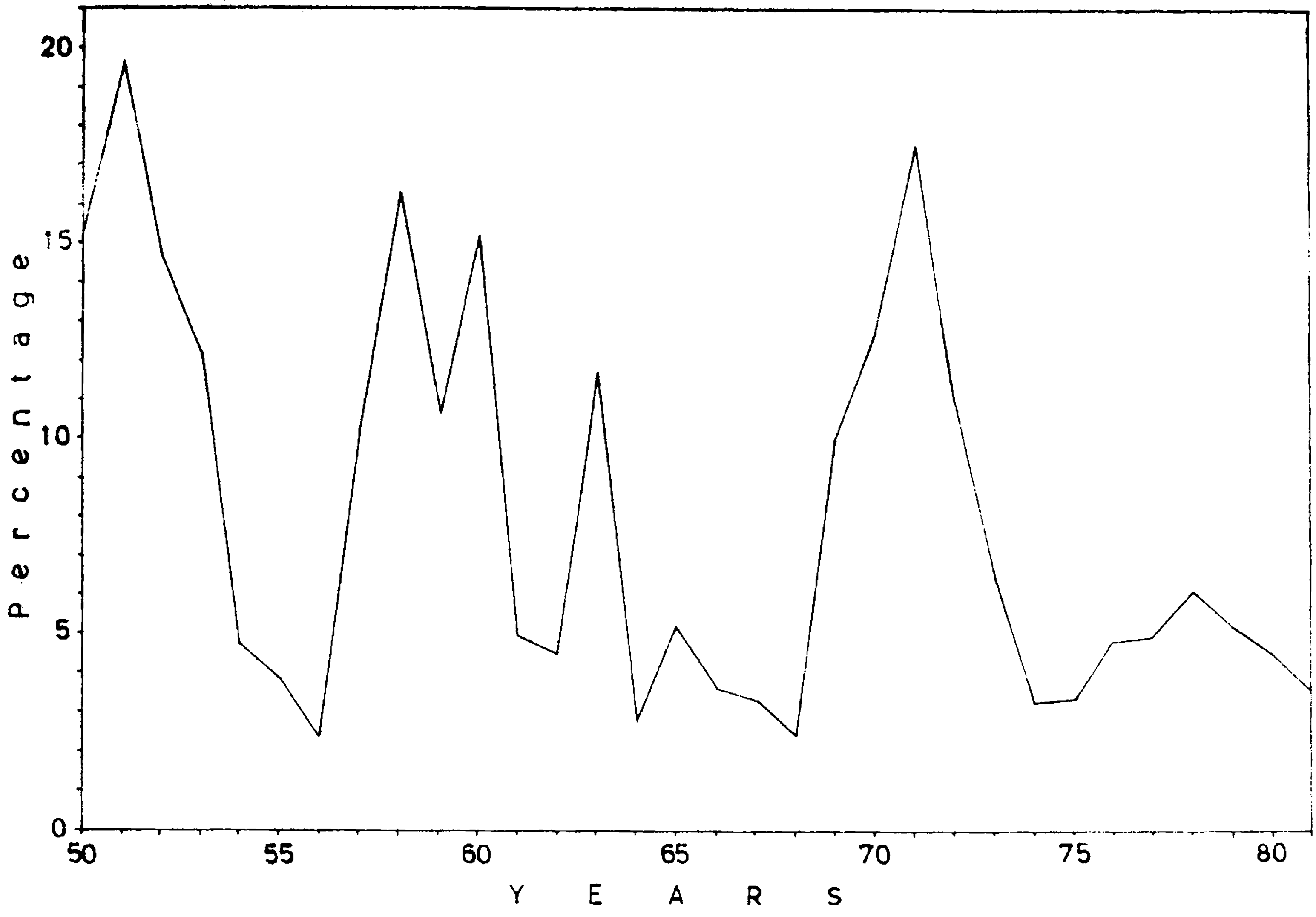
Fig. 9



GUJARAT
ALL-INDIA
WEST BENGAL
ORISSA
MAHARASHTRA
ANDHRA PRADESH
GOA
KARNATAKA
TAMIL NADU & PONDICHERRY
KERALA
ANDAMAN & NICOBAR ISLANDS
Mackerel
Other Fishes
20°
16°
12°
8°
72°
76°
80°
84°
88°
92°

Fig. 10: Percentage of mackerel in annual marine fish production of India.

Fig.10



low. Earlier for 8 years from 1961 (except 1963) and 3 years beginning with 1954 also, the percentage of mackerel in total marine fish catch was low. The percentage was the lowest at 2.29 in 1956 (Fig.10) when the catch also was incidentally the lowest (Fig.2).

5.6. ANNUAL MACKEREL CATCH IN STATES' MARINE FISH LANDINGS

In Maharashtra (Fig.11) during 1965-'81, the mackerel in marine fish catches varied between 0.003 and 12.3% of 1967 and 1969 respectively. But for another 8.7% of 1970, mackerel in marine fish in the state formed only below 2.5%.

Mackerel landings in marine fish stood at percentages between 10.0 of 1980 and 88.2 of 1972 in Goa (Fig.11). In Karnataka (Fig.11) the mackerel contributed to between 6.5 and 61.7% in marine fish catches. In Kerala (Fig.11), though the catch of mackerel in quantity more or less equalled to that of Karnataka, in marine fish catches of the state it varied only between 1.0 and 21.4%.

The percentage of mackerel in marine fish produce of Tamil Nadu - Pondicherry, and Andhra Pradesh was below 7.0 only (Fig.12). Along West Bengal & Orissa coast (Fig.12) it

Fig. 11: Percentage of mackerel in annual marine fish production of Maharashtra, Goa, Karnataka and Kerala.

Fig. 11

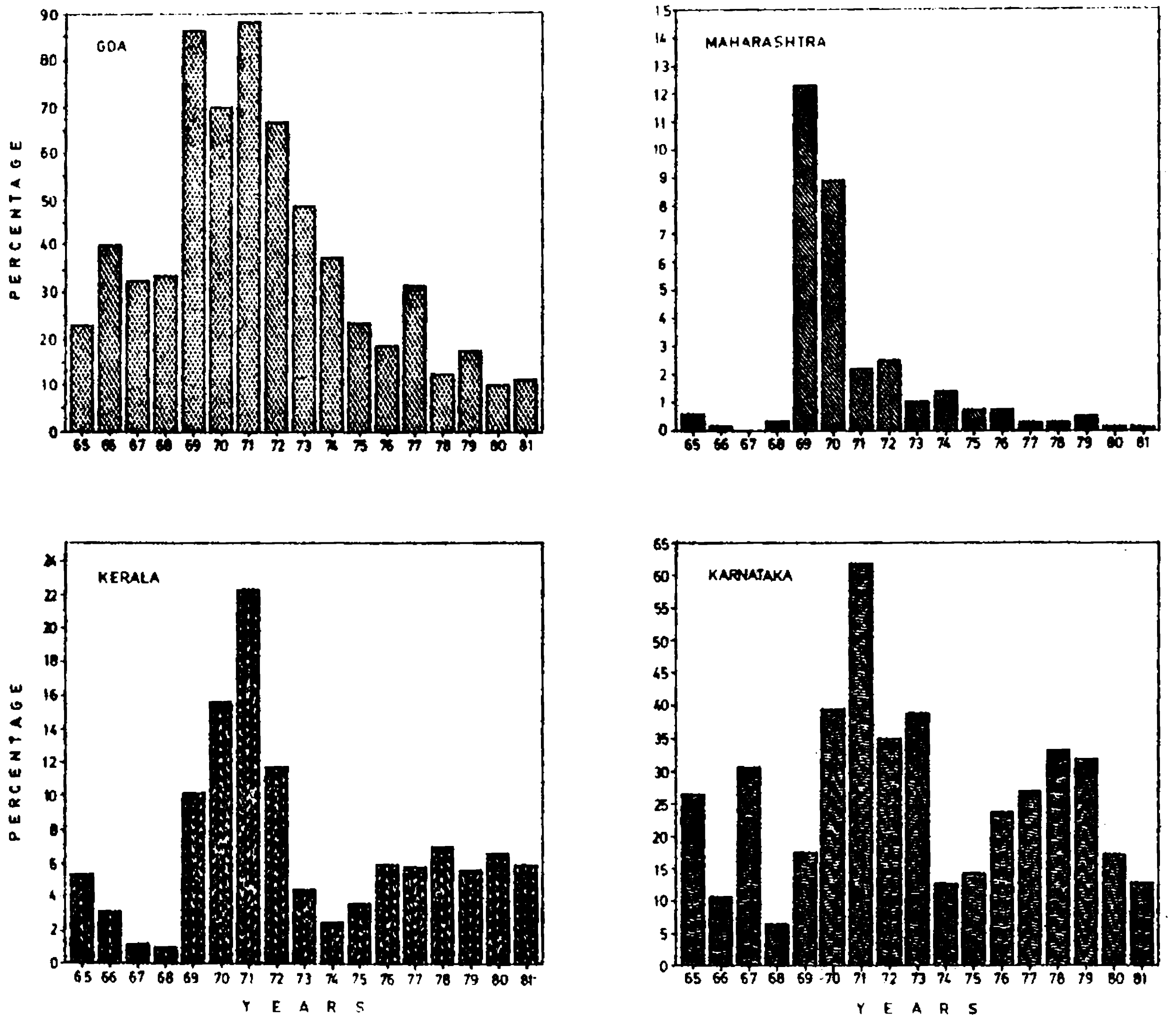
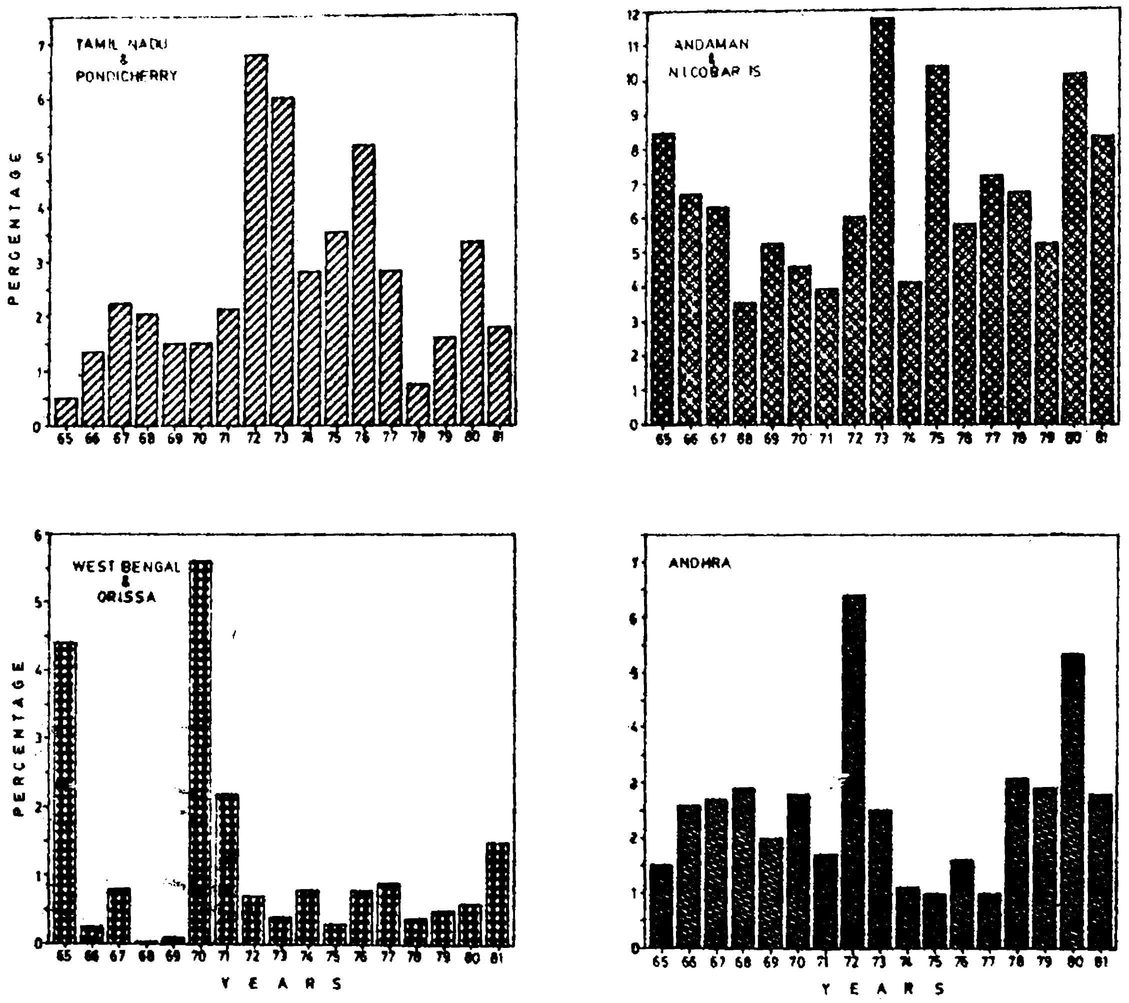

GOA
MAHARASHTRA
KERALA
KARNATAKA
PERCENTAGE
YEARS
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81

Fig. 12: Percentage of mackerel in annual marine fish production of Tamil Nadu - Pondicherry, Andhra, Orissa & West Bengal, and Andaman & Nicobar Islands.

Fig. 12


TAMIL NADU & PONDICHERRY
ANDAMAN & NICOBAR IS
WEST BENGAL & ORISSA
ANDHRA
PERCENTAGE
YEARS
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81

formed a maximum of only 5.6%. In Andaman & Nicobar Islands (Fig.12), the percentage of mackerel in marine fish catches ranged between 3.5 and 11.7 respectively of 1968 and 1973.

In spite of high catches, mackerel during the 17-year period as a whole in Kerala formed only 6.9% (Fig.9) in its marine fish landings. In Karnataka (Fig.9) it averaged 26.5% and in Goa (Fig.9) 39.5%. In the marine fishery of Andaman & Nicobar Islands (Fig.9), the catch of mackerel became 7.2%. In other maritime states of the mainland (Fig.9), the percentage of mackerel in marine fish catches was just less than 3.0. As already stated, no fishery for mackerel exists in Lakshadweep Islands.

5.7. SPATIAL AND SEASONAL DISTRIBUTION

Identification of areas and periods of abundance of a resource is necessary for its economic and judicial exploitation. Data for 1976-'80 available at the Fishery Resources Assessment Division of the Central Marine Fisheries Research Institute was utilized here and the following observations made. But for 2 small attempts made by Noble (1979 and 1982 a), no information on identification of areas and times of this fishery is available in literature.

5.7.1. DISTRIBUTION OF FISHERY IN SPACE

Statewise treatment of annual landings as shown in Fig.6 gives an overall picture where mackerel fishery abounds. The findings below, however, locate areas in each state where the fishery is prominent.

Along West Bengal & Orissa coast, the mackerel is available mostly in Ganjam district of Orissa (Fig.13: 2-3). Areas of good mackerel catches in Andhra Pradesh are the coasts of Kakinada (Fig. 14: 4) and Guntur district (Fig. 14: 7). The best mackerel production in Tamil Nadu - Pondicherry occurs along the South Arcot-Tanjavur area (Fig. 15: 7). Next to it, coasts of Karaikkal (Fig. 15: 8) and Pattukkottai (Fig. 15: 9) have some fishery. Other places in the state where similar fishery occurs are along the west coast of Kannyakumari district (Fig. 15: 17) and Pondicherry (Fig. 15: 5). Madras coast (Fig. 15: 2) also has a fishery in a smaller measure.

In Kerala, the coast from Ponnani to Kasargod (Fig. 16: 7-9) has the highest yield. Production from Ernakulam and

Fig. 13: Spatial distribution of mackerel in Orissa and Goa during 1976-'80.

Fig. 13

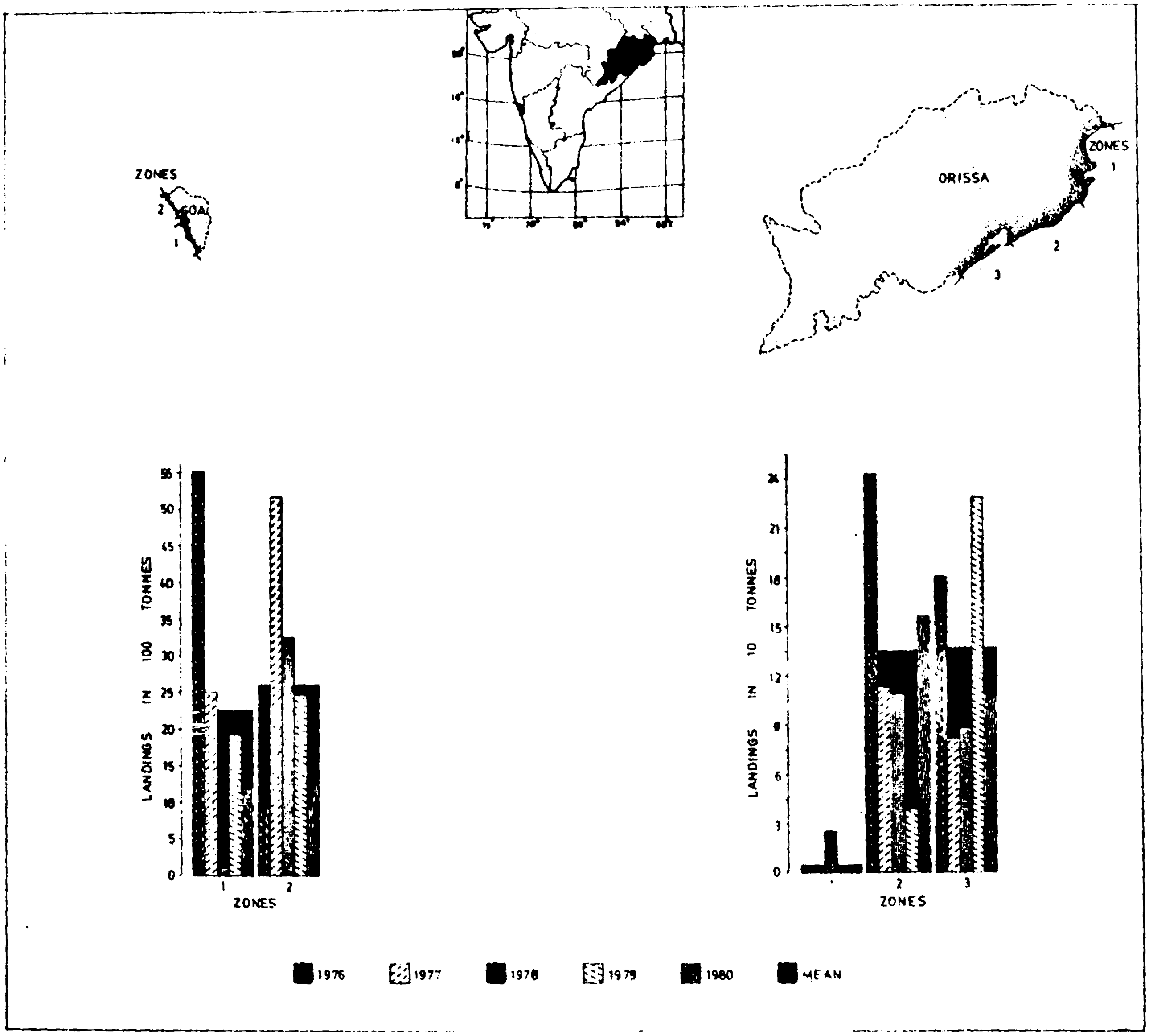
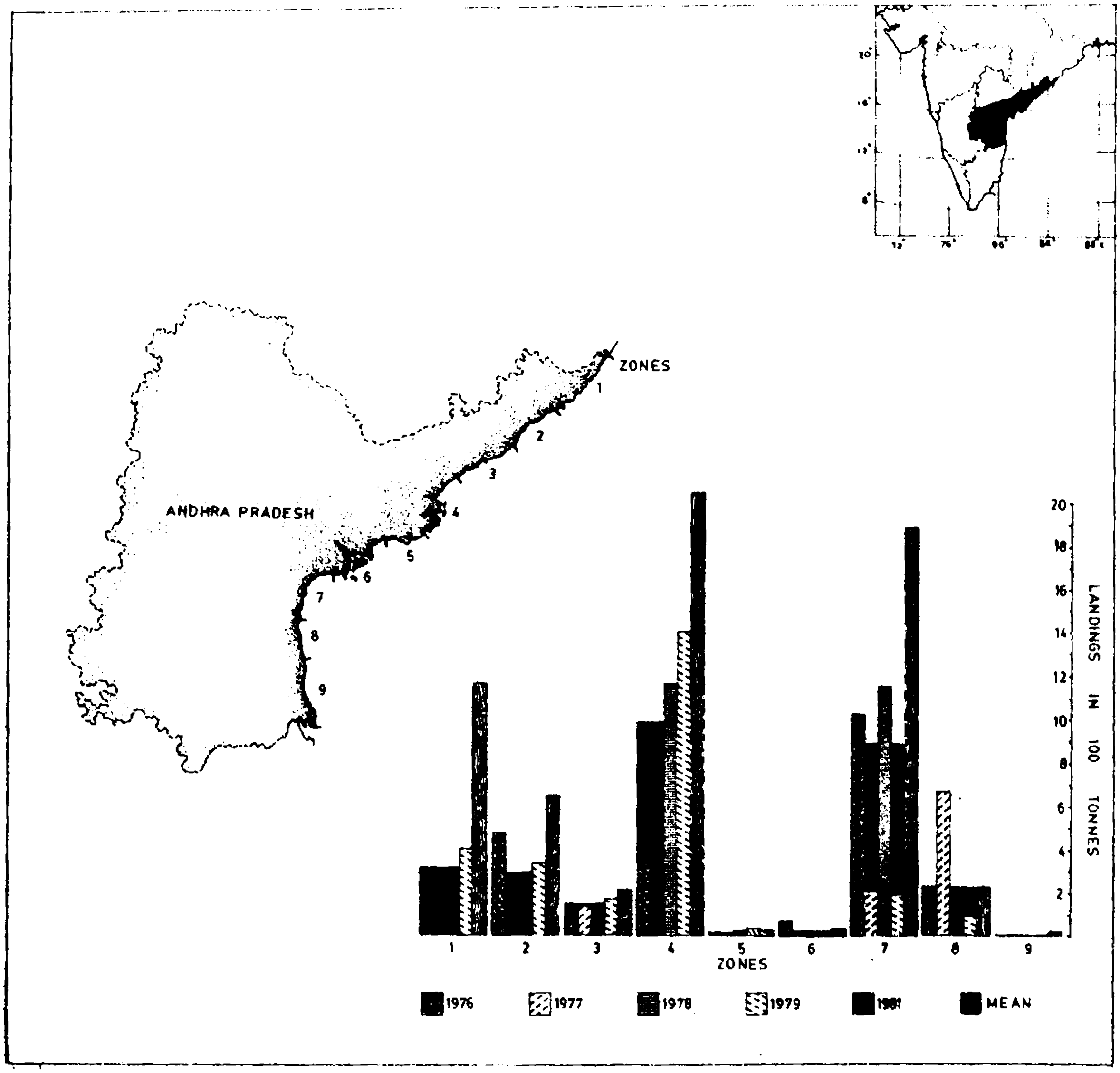

ZONES
2
GOA
1
ORISSA
ZONES
1
2
3
LANDINGS IN 100 TONNES
0
5
10
15
20
25
30
35
40
45
50
55
1
2
ZONES
LANDINGS IN 10 TONNES
0
3
6
9
12
15
18
21
24
2
3
ZONES
1976
1977
1978
1979
1980
MEAN

Fig. 14: Spatial distribution of mackerel in Andhra during 1976-'80.

Fig. 14



ANDHRA PRADESH
ZONES
1
2
3
4
5
6
7
8
9
LANDINGS IN 100 TONNES
20
18
16
14
12
10
8
6
4
2
ZONES
1976
1977
1978
1979
1981
MEAN

Fig. 15: Spatial distribution of mackerel in Tamil Nadu - Pondicherry during 1976-'80.

Fig.15

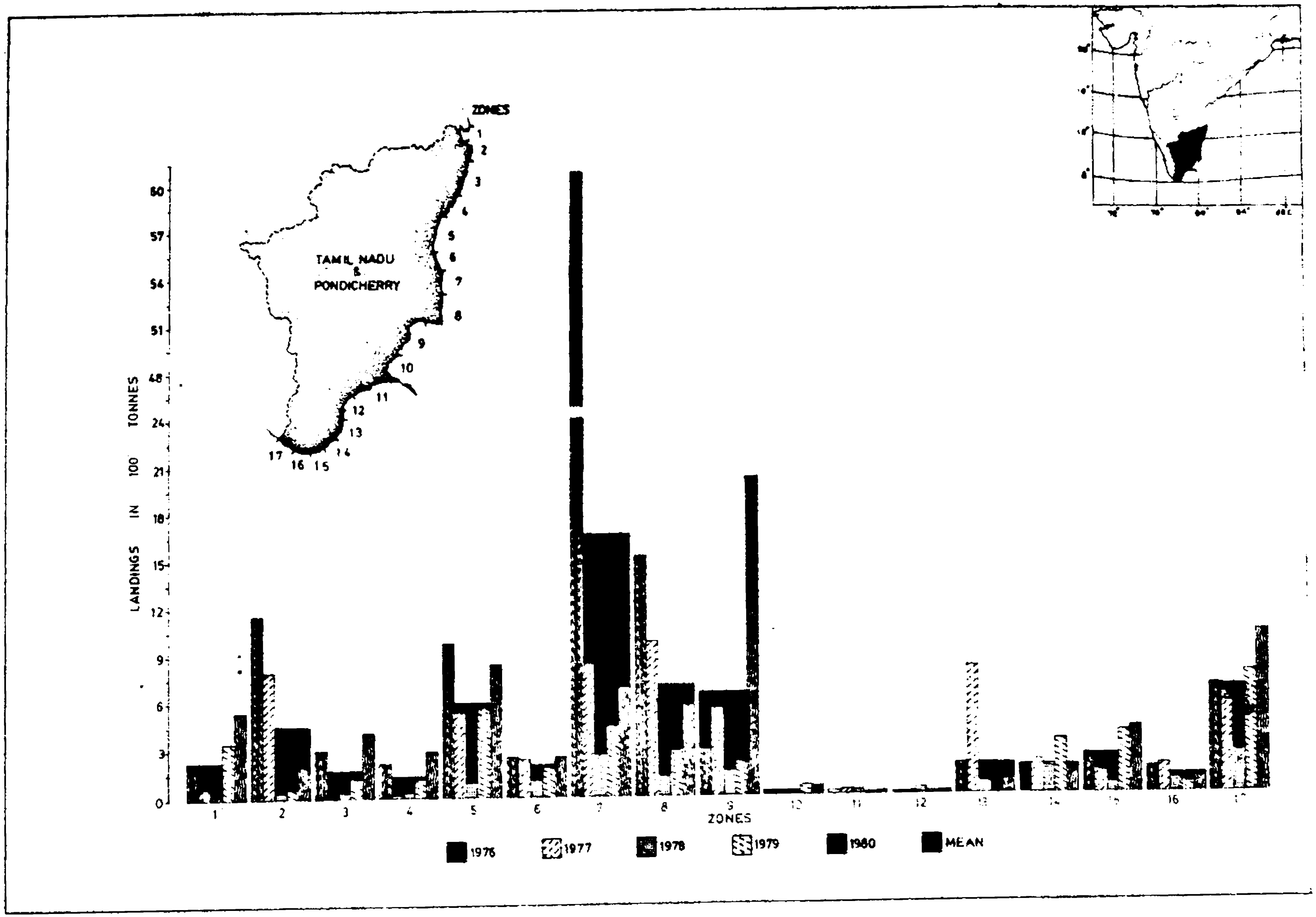
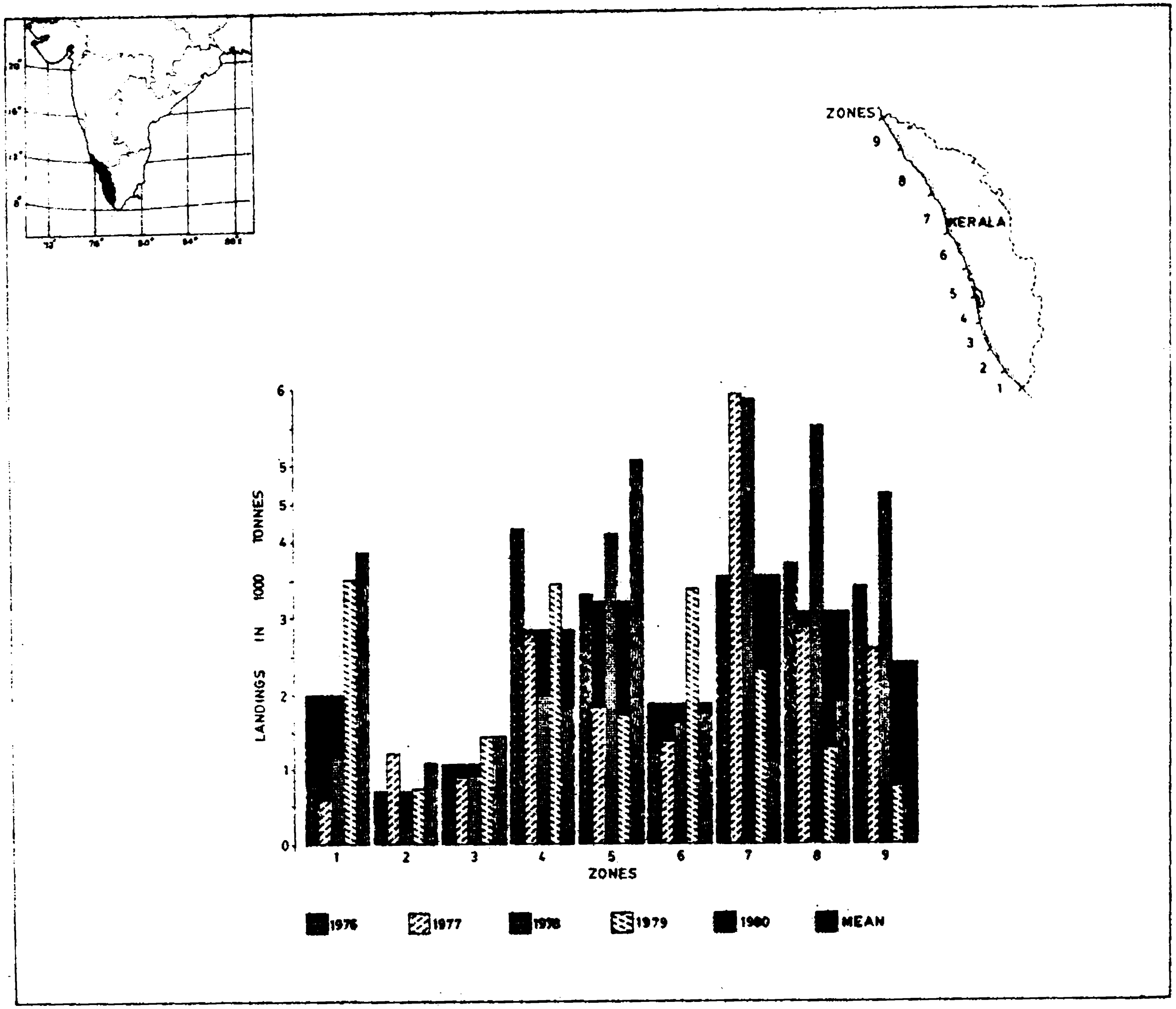

TAMIL NADU & PONDICHERRY
ZONES
LANDINGS IN 100 TONNES
ZONES
1976
1977
1978
1979
1980
MEAN

Fig. 16: Spatial distribution of mackerel in Kerala during 1976-'80.

Fig. 16



ZONES
KERALA
LANDINGS IN 1000 TONNES
ZONES
1976
1977
1978
1979
1980
MEAN

contiguous areas of Alleppey and Trichur districts (Fig. 16: 4-5) is also good. Some catches that occur off Vizhinjam in Trivandrum district (Fig. 16: 1) is significant as the fishery that exists to its immediate south and north are comparatively poor.

The fishery in and around Mangalore coast (Fig. 17: 1) in Karnataka state is high. Along Malpe-Coondapur section (Fig. 17: 3) and off Karwar area (Fig. 17: 5) the catches appear good. In Goa, the catches are more around Panaji (Fig. 13: 2). Maharashtra coast lying next to Goa up to Dandi in Ratnagiri district has the maximum landings (Fig. 18: 1). Landings off Bombay (Fig. 18: 7) are less than half of Ratnagiri area. In Gujarat what little mackerel caught, comes from Bhavanagar-Porbunder area.

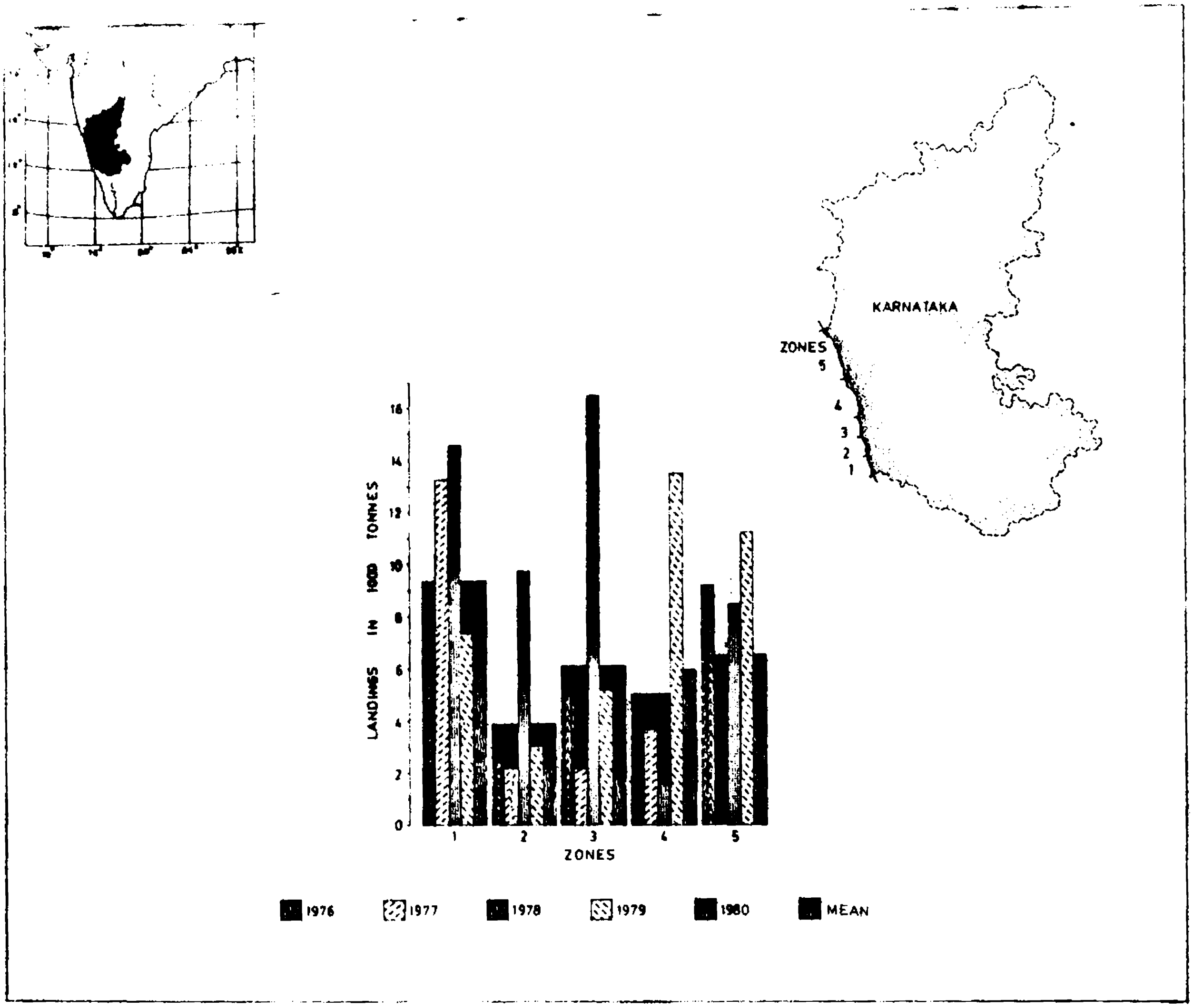
Almost the entire catch in Andaman & Nicobar Islands occurs along the coast of Andaman Islands (Fig. 19: 1-3), especially the Middle Andamans.

5.7.2. DISTRIBUTION OF FISHERY IN TIME

The mackerel besides being highly fluctuating in landings from year to year is seasonal in its occurrence. Information

Fig. 17: Spatial distribution of mackerel in Karnataka during 1976-'80.

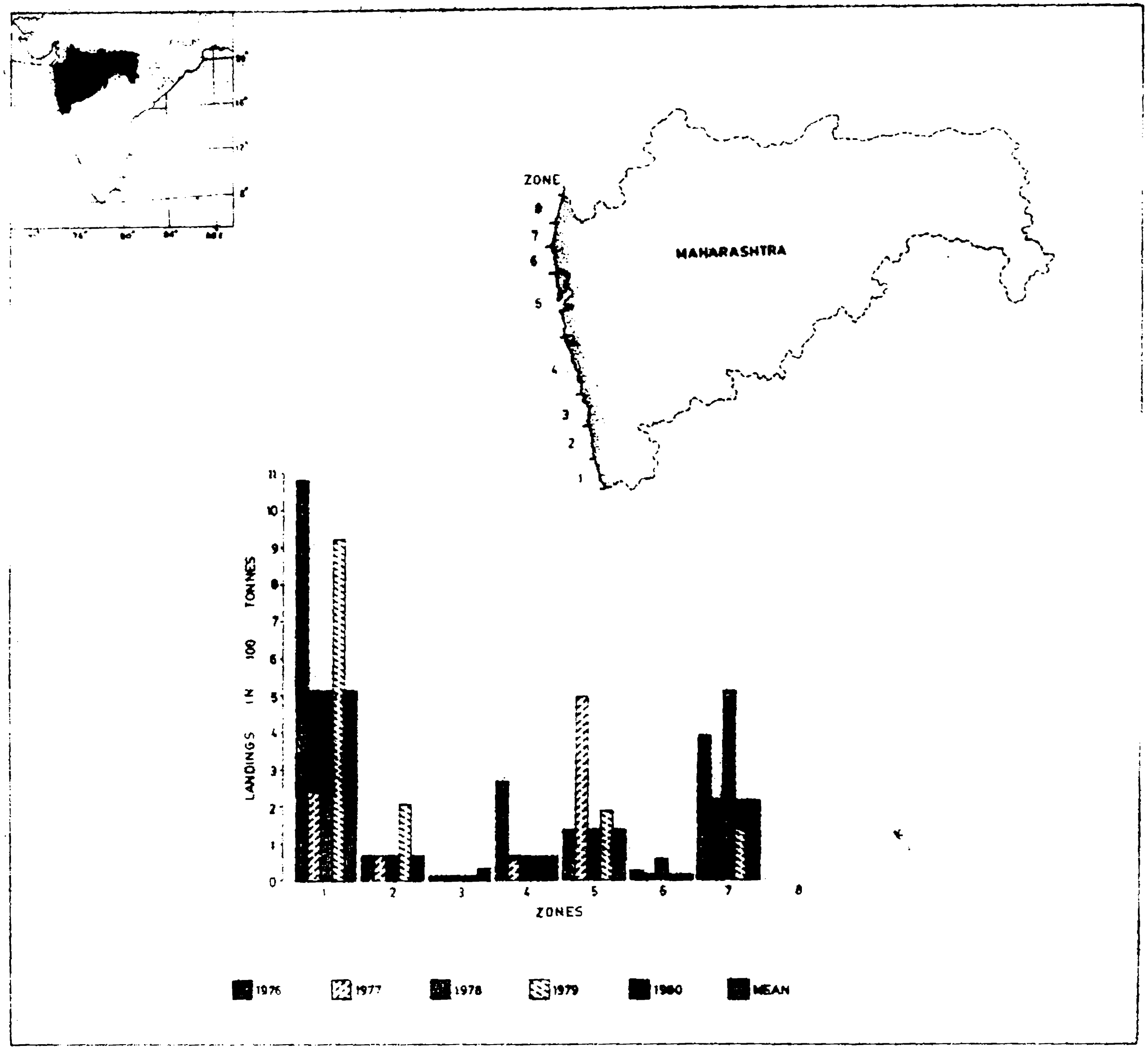
Fig. 17



KARNATAKA
ZONES
5
4
3
2
1
LANDINGS IN 1000 TONNES
0
2
4
6
8
10
12
14
16
1
2
3
4
5
ZONES
1976
1977
1978
1979
1980
MEAN

Fig. 18: Spatial distribution of mackerel in Maharashtra during 1976-'80.

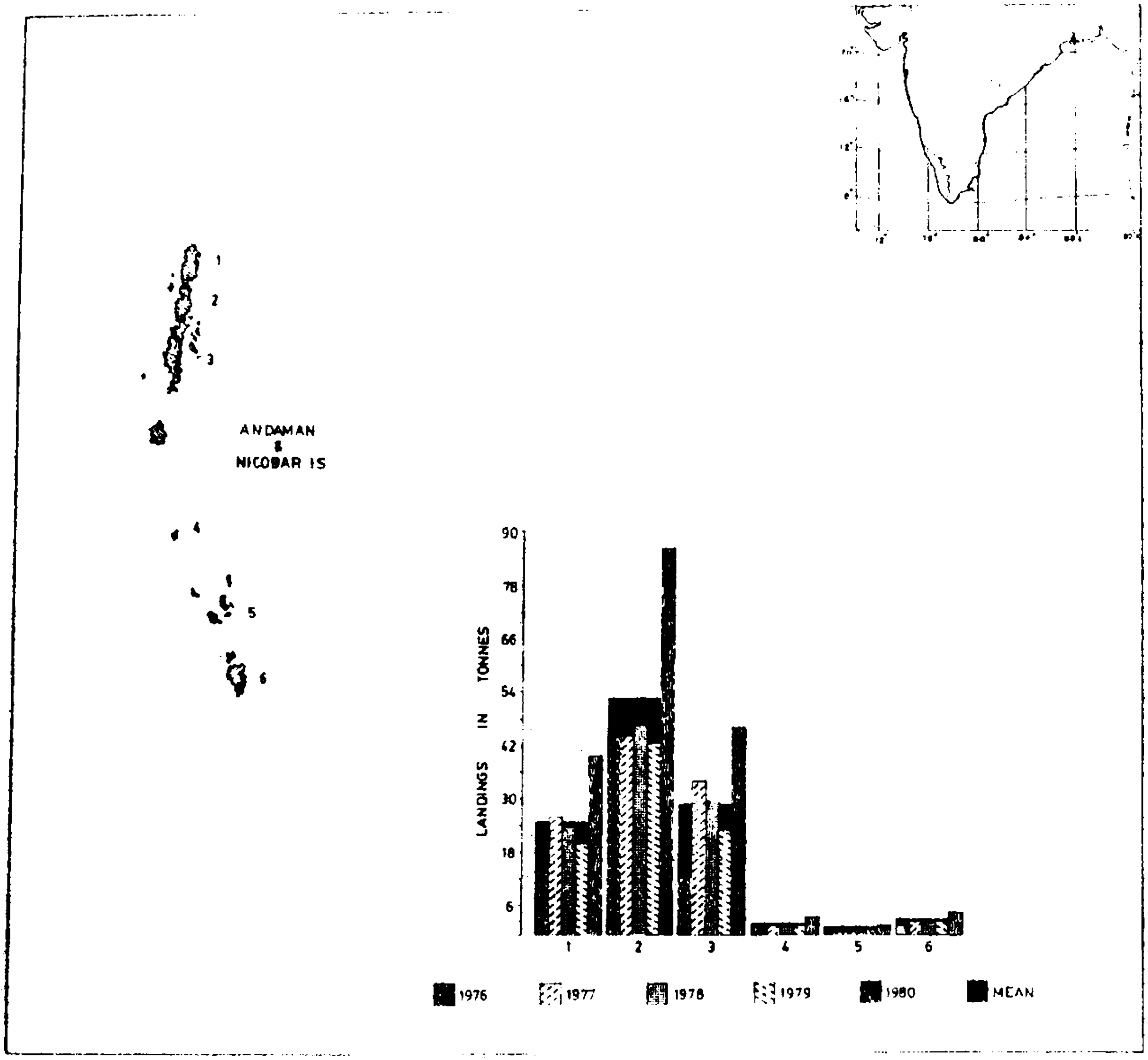
Fig. 18



ZONE
8
7
6
5
4
3
2
1
MAHARASHTRA
LANDINGS IN 100 TONNES
0
1
2
3
4
5
6
7
8
9
10
11
ZONES
1976
1977
1978
1979
1980
MEAN

Fig. 19: Spatial distribution of mackerel in Andaman & Nicobar Islands during 1976-'80.

Fig. 19


ANDAMAN
&
NICOBAR IS
1
2
3
4
5
6
LANDINGS IN TONNES
90
78
66
54
42
30
18
6
1976
1977
1978
1979
1980
MEAN

on it is, nevertheless lacking. Being one of the important pre-requisites in fisheries management, the study made on seasonal distribution of mackerel is presented below:

Maximum mackerel landings in Orissa (Fig.20) occur in February and March. It coincides with the catches in Ganjam district where the fishery as already stated in the state is concentrated (Fig. 21: Or. 3). During May-August, no fishery for mackerel exists in the state.

Catches in Andhra Pradesh (Fig.20) too are the maximum in February and March. Low percentages occur during June - September. In Kakinada (Fig. 21: Anp. - 4) the season is good in March. In Guntur (Fig. 21: Anp. - 7), on the other hand, season abounds in October. A secondary peak in the season in the state falls in October (Fig.20).

Along Tamil Nadu - Pondicherry also (Fig.20), as in Andhra Pradesh, the season is bimodal. It is more important during March-May than the one in December. The catches during the former period are high in South Arcot-Thanjavur and Karaikkal (Fig. 21: TnP. - 7 & 8). Immediately to its south in Pattukkottai (Fig. 21: TnP. - 9) the fishery is good in the latter period. The fishery in Tamil Nadu - Pondicherry on the

Fig. 20: Average statewise monthly percentage landings of mackerel during the 5-year period of 1976-'80 as a unit of time.

Fig. 20

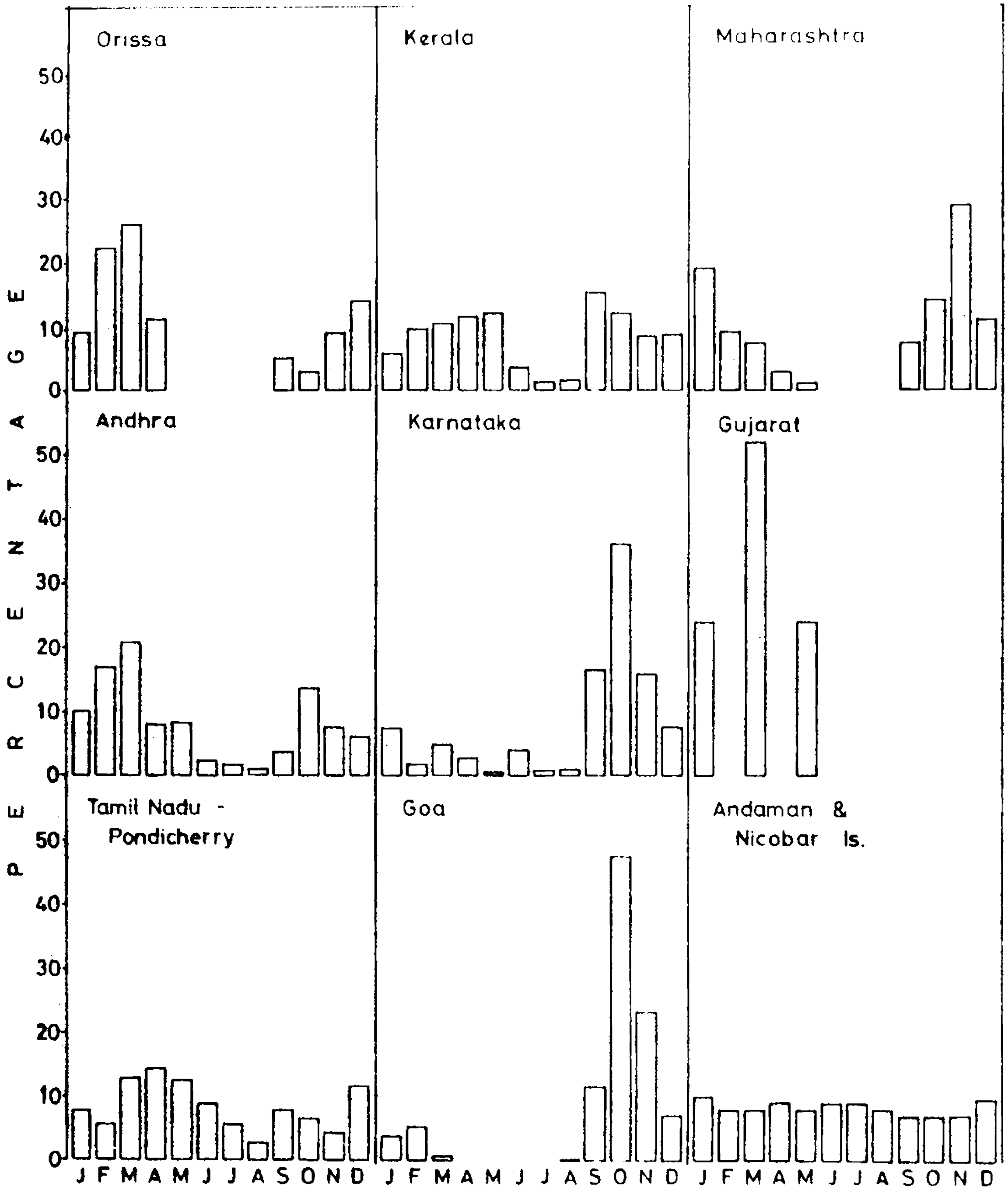
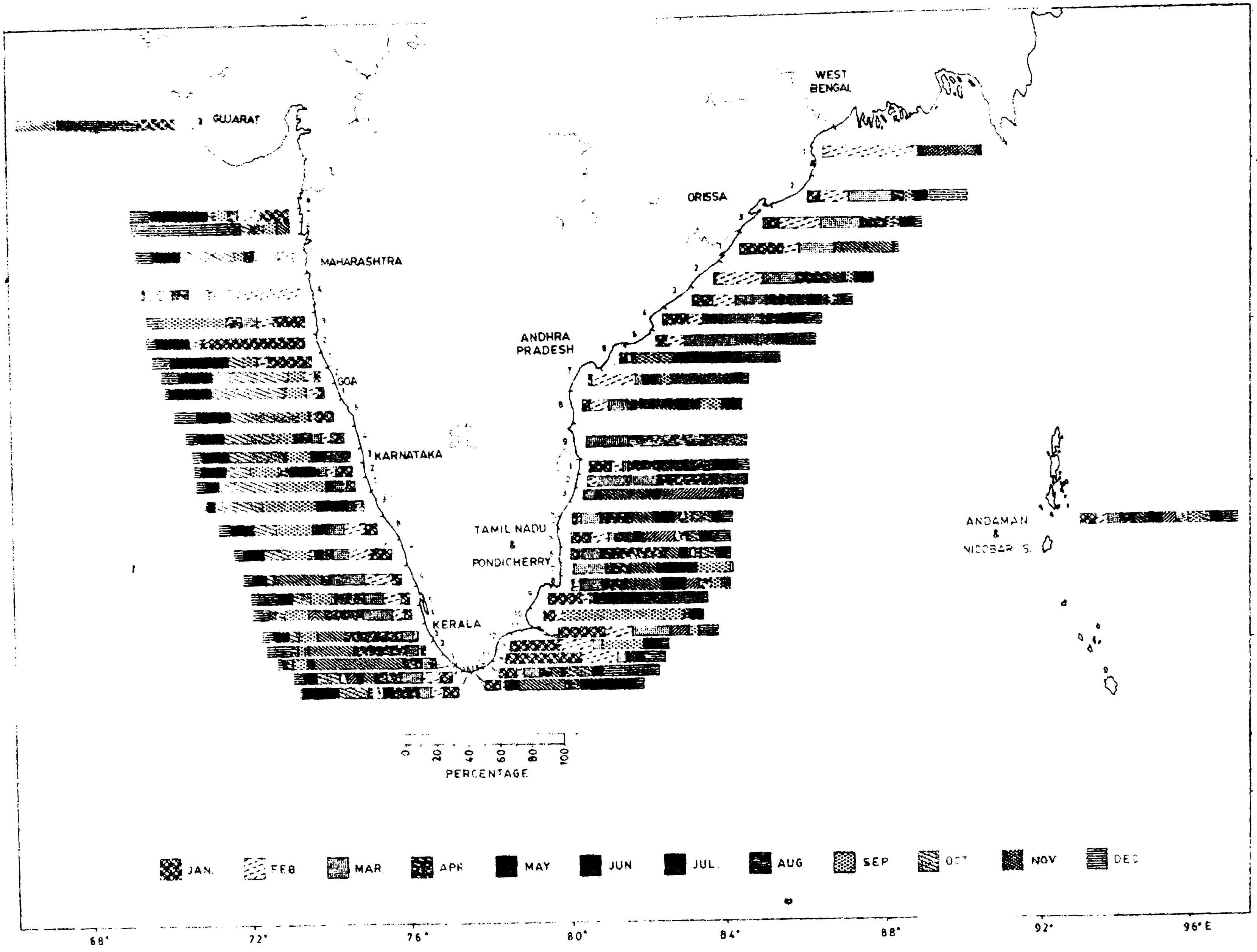

Orissa
Kerala
Maharashtra
Andhra
Karnataka
Gujarat
Tamil Nadu - Pondicherry
Goa
Andaman & Nicobar Is.
PERCENTAGE
0
10
20
30
40
50
J F M A M J J A S O N D

Fig. 21: Distribution of mackerel in space and time along Indian coasts. Percentage on average for the 5-year period during 1976-'80.

Fig. 21


GUJARAT
MAHARASHTRA
GOA
KARNATAKA
KERALA
TAMIL NADU & PONDICHERRY
ANDHRA PRADESH
ORISSA
WEST BENGAL
ANDAMAN & NICOBAR IS.
0 20 40 60 80 100
PERCENTAGE
JAN. FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
68° 72° 76° 80° 84° 88° 92° 96°E
20° 15° 12° 8° 4°

whole seems to be more in March-May in areas from north up to and including Karaikkal and December-January from Pattukkottai and to its south.

There are 2 seasonal peaks in the fishery in Kerala (Fig. 20). The peak in September is more important than the one that occurs in May. June-August is conspicuously slack time. Catches in the southern areas (Fig. 21: Ker. - 1-3) are more during March-May and in the northern sector (Fig. 21: Ker. - 7-9) during September-October. In Karnataka (Fig.20) the fishery is good during September-November with peak in October. At other times it is thin if not absent. The season in Goa (Fig.20) extends from September to March with peak in October.

In Maharashtra (Fig.20), the landings peak in November. Next best catches occur in January and an off-season spreads through June-August. What little mackerel fished in Gujarat (Fig.20) occurs in the first part of the year with peak in March.

The season in Andaman & Nicobar Islands (Fig.20) is a protracted one with catches almost equally spread out in all 12 months of the year.

The fishery along the east coast (Fig.22) peaks in March in a season spread out during December-May. In the west coast (Fig.22), high catches occur during September-November with peak in October. Bulk of the landings in the country coming from west coast, the all-India picture (Fig.22) is not different from that of the west coast. In March the fishery here is a little better than the preceding and succeeding months tempting to show a secondary peak.

5.8. THE FISHERY AND BIOLOGY OF MACKEREL BASED ON THE COMMERCIAL CATCHES AT COCHIN

Data on the commercial fishery at Cochin (Manassery) as mentioned in Material and Methods were monitored during 1965-'80 and some information on these are already published by Noble (1974 a, 1979, and 1980) and Noble and Narayanan Kutty (1978).

The indigenous units, Thangu vala and Ayila vala were the gear used for fishing here. The Ayila vala is a selective gear which catches fish by gilling. The Thangu vala is a boat seine (Noble 1974 a), and it being a non-selective gear, the fish caught by it were utilized for this investigation.

From length measurements, monthly size distribution of the mackerel at Cochin were made and given in Fig. 23.

Fig. 22: Seasonal distribution of mackerel on east coast, west coast, and India as a whole - monthly average percentages during the 5-year period of 1976-'80.

Fig. 22

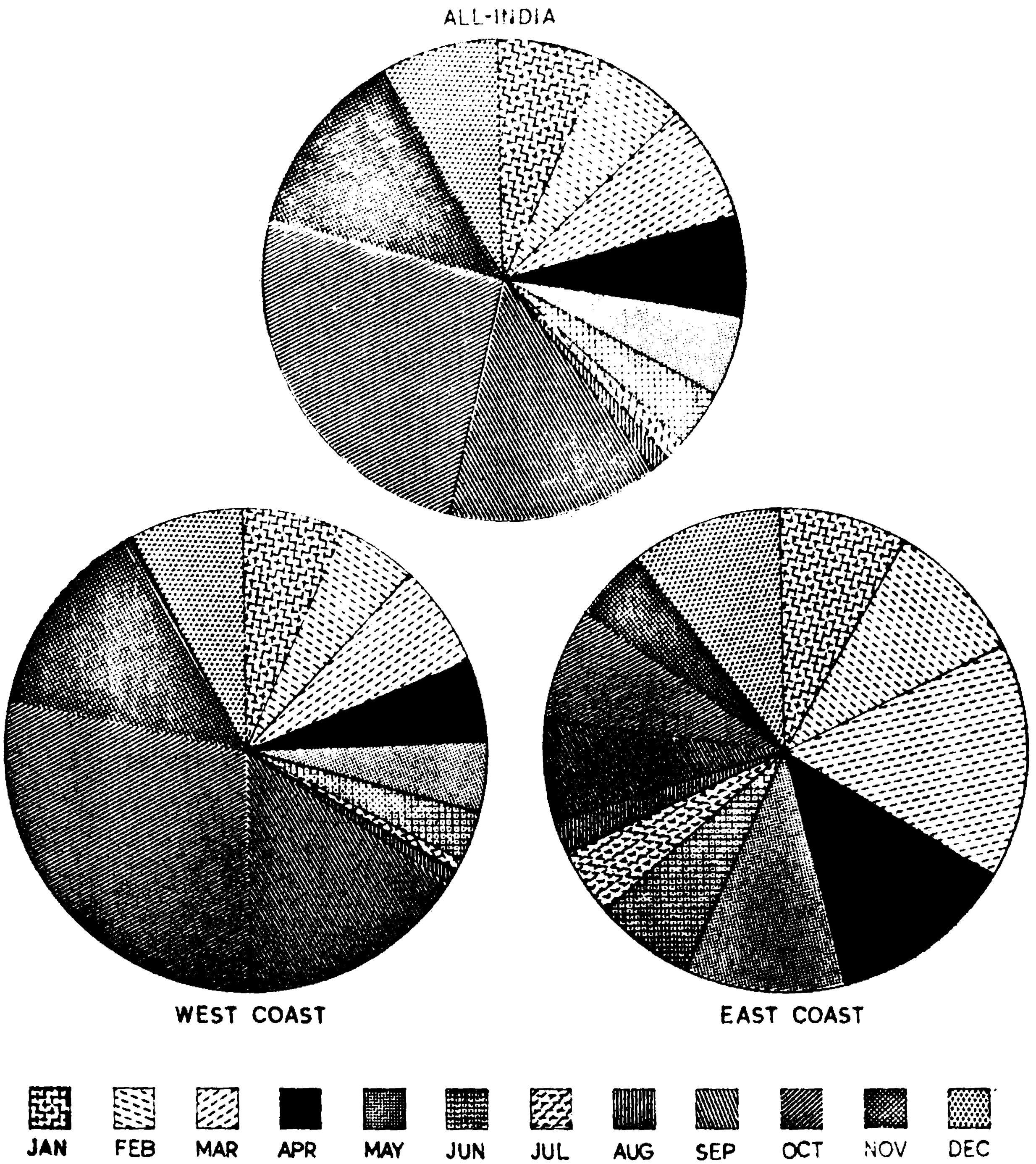
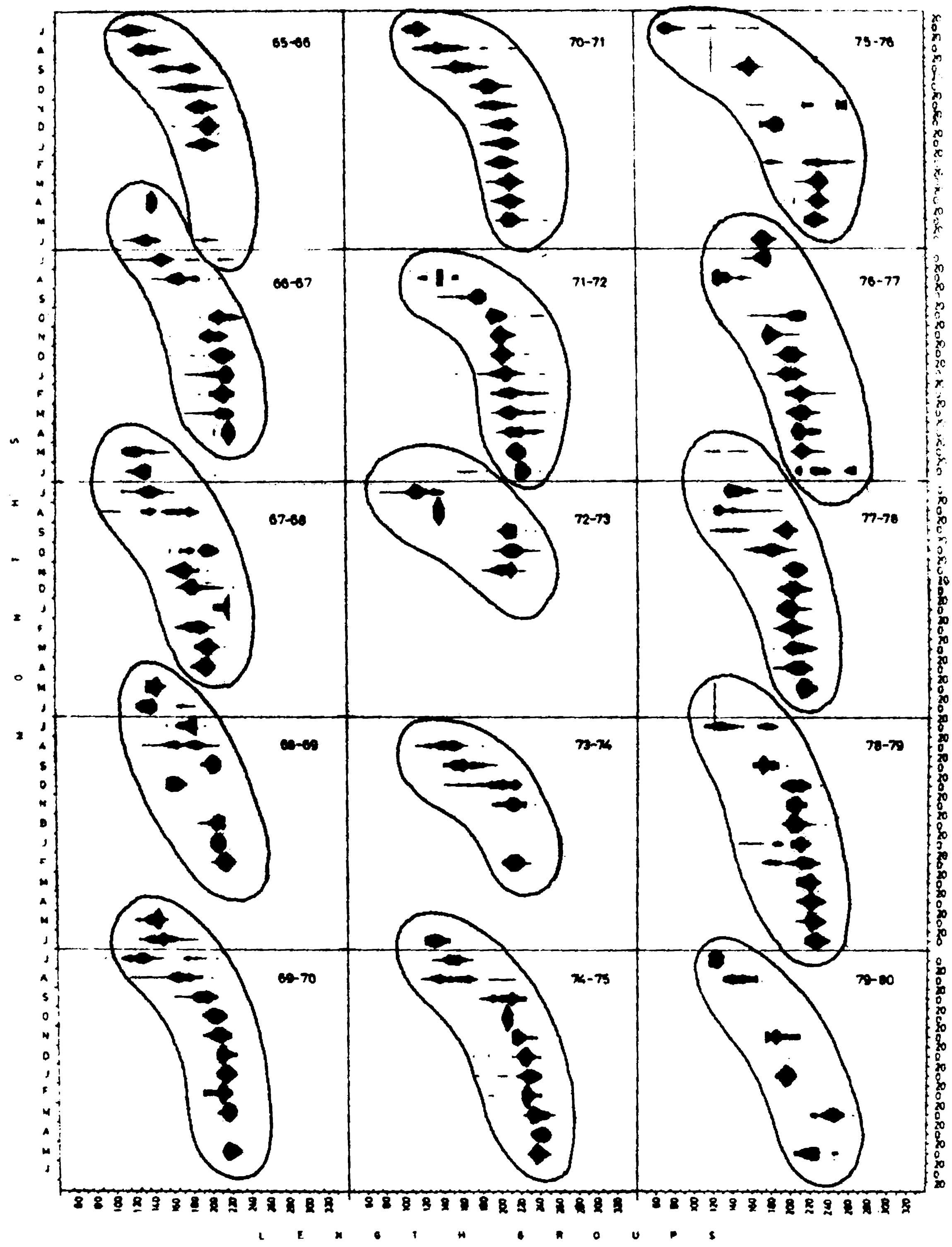

ALL-INDIA
WEST COAST
EAST COAST
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig. 23: Length distribution of mackerel landed at Cochin (Manassery) by *Thangu vala* from July 1965 to June 1980.

Fig. 23


65-66
70-71
75-76
66-67
71-72
76-77
67-68
72-73
77-78
68-69
73-74
78-79
69-70
74-75
79-80
M O N T H S
L E N G T H G R O U P S
P E R C E N T A G E

The fishery year (hereinafter referred to as season) for 1965-'66 commenced with the entry of juveniles in the catches in June 1965 and continued uninterruptedly up to January 1966. Later some old fish of this season appeared in the fishery in June and July 1966. Meanwhile juveniles of 1966-'67 season had already appeared in April 1966. Fishes belonging to consecutive seasons thus coexisting with, were sorted out and appropraited to their respective ones as dilineated in Fig. 23. In the computation of catch, effort, cpue, length and age composition, the seasons were separated accordingly carefully avoiding overlaps and duplication.

5.8.1. CATCH, EFFORT, AND CPUE

The estimated monthly mackerel landings in weight and in numbers of fish are given respectively in Fig. 24 and 25. These landings not only fluctuate from month to month but also show variation from season to season. The effort estimated and given in Fig. 26, however, does not move up and down much like it. But concurrent to the very low landing in 1979-'80, the effort also reduced. Fishing at Manassery at this stage dwindled as fishing by purse seiners based at Fisheries

Fig. 24: Mackerel landings in weight at Cochin (Manassery) from July 1965 to June 1980.

Fig. 24

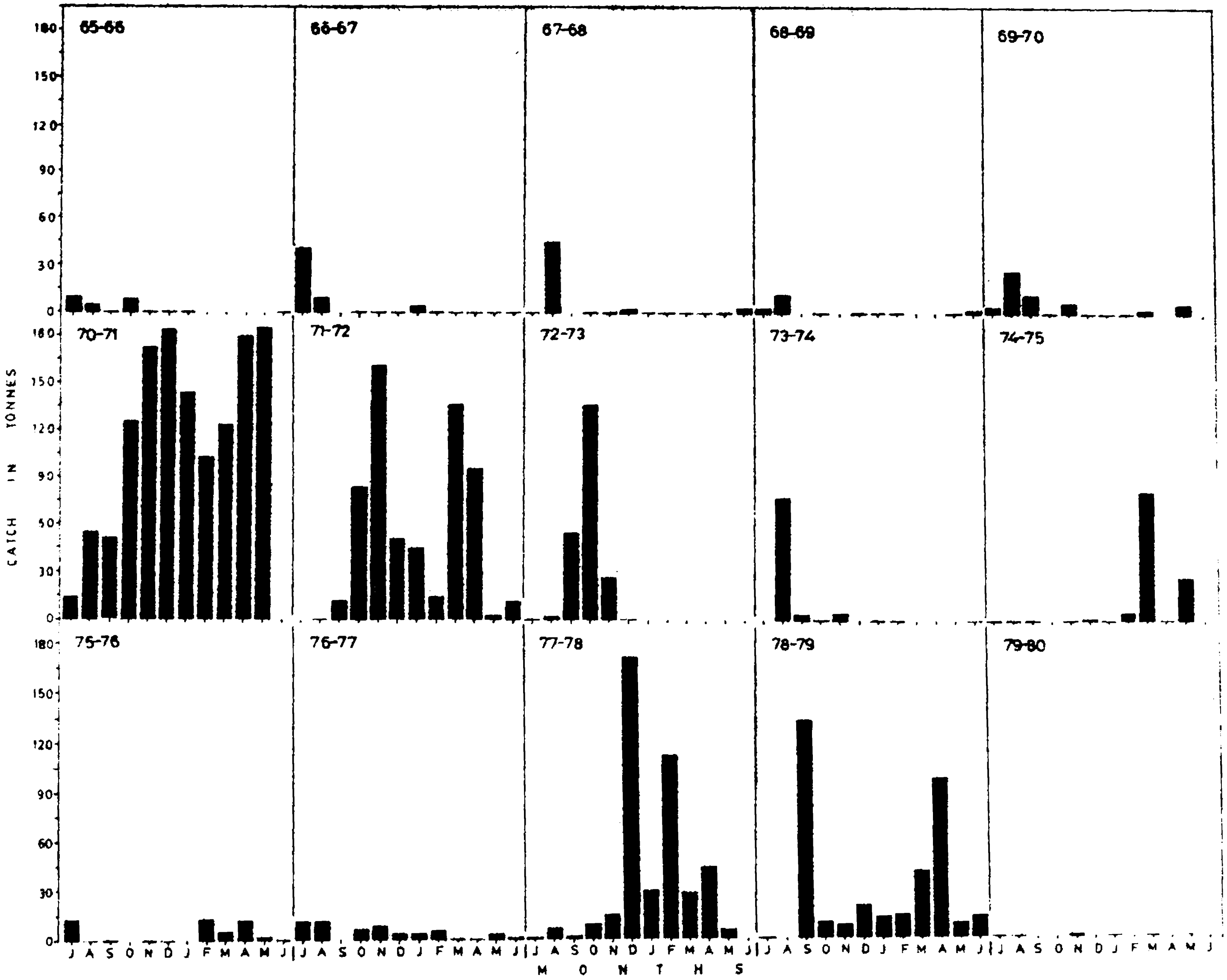

65-66
66-67
67-68
68-69
69-70
70-71
71-72
72-73
73-74
74-75
75-76
76-77
77-78
78-79
79-80
CATCH IN TONNES
M O N T H S

Fig. 25: Mackerel landings in number at Cochin (Manasser) by _Thangu_ _vala_ from July 1965 to June 1980.

Fig.25

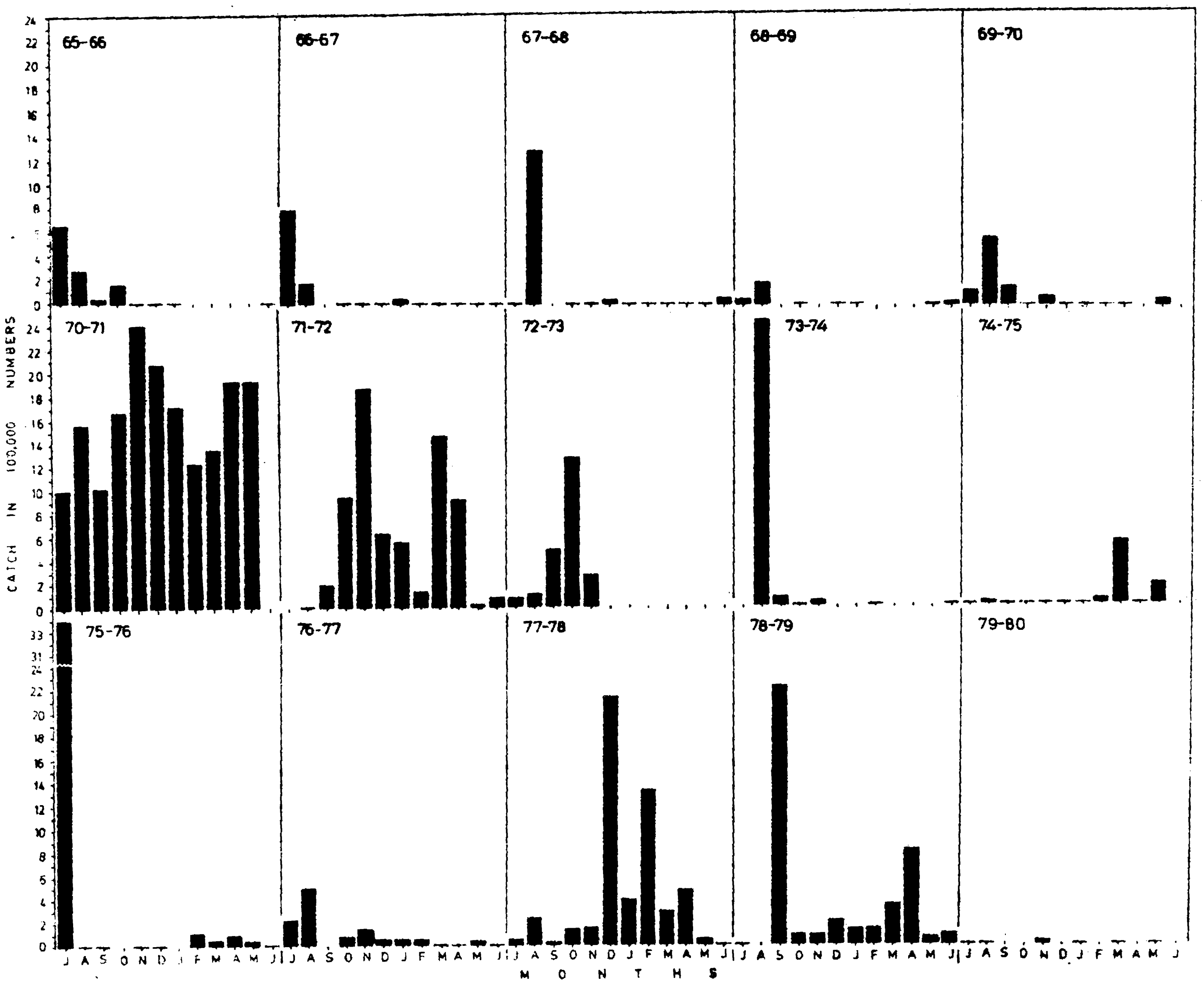
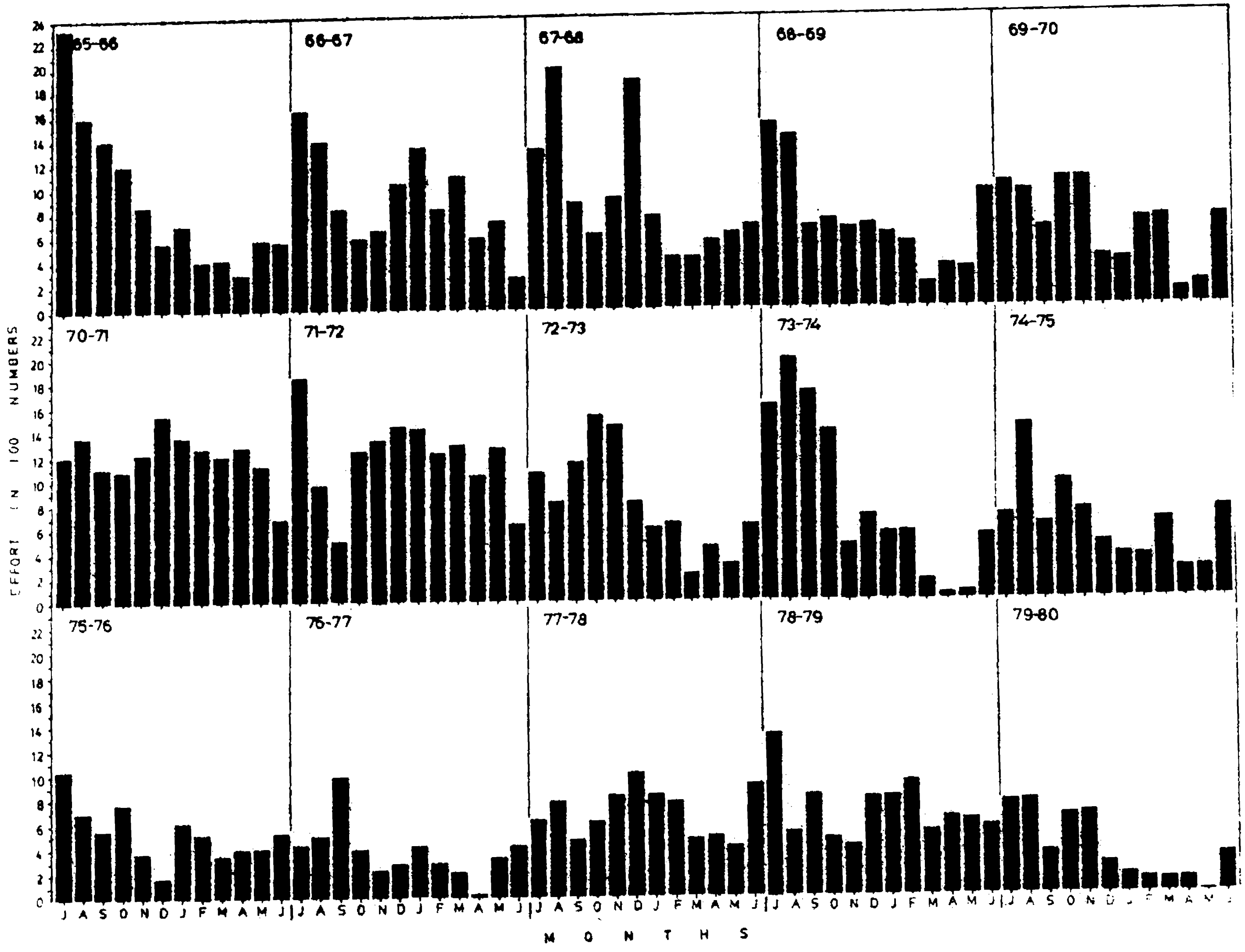

CATCH IN 100,000 NUMBERS
65-66
66-67
67-68
68-69
69-70
70-71
71-72
72-73
73-74
74-75
75-76
76-77
77-78
78-79
79-80
J A S O N D J F M A M J
MONTHS

Fig. 26: Effort of boat seine _Thangu vala_ used for fishing at Cochin (Manassery) from July 1965 to June 1980.

Fig. 26



65-66
66-67
67-68
68-69
69-70
70-71
71-72
72-73
73-74
74-75
75-76
76-77
77-78
78-79
79-80
EFFORT IN 100 NUMBERS
MONTHS
J A S O N D J F M A M J

Harbour gained momentum.

The catch of mackerel per unit effort of *Thangu vala* in weight and numbers (Fig.27) are also estimated for population studies and stock estimates. Like total landing, the cpue also exhibits large-scale fluctuations.

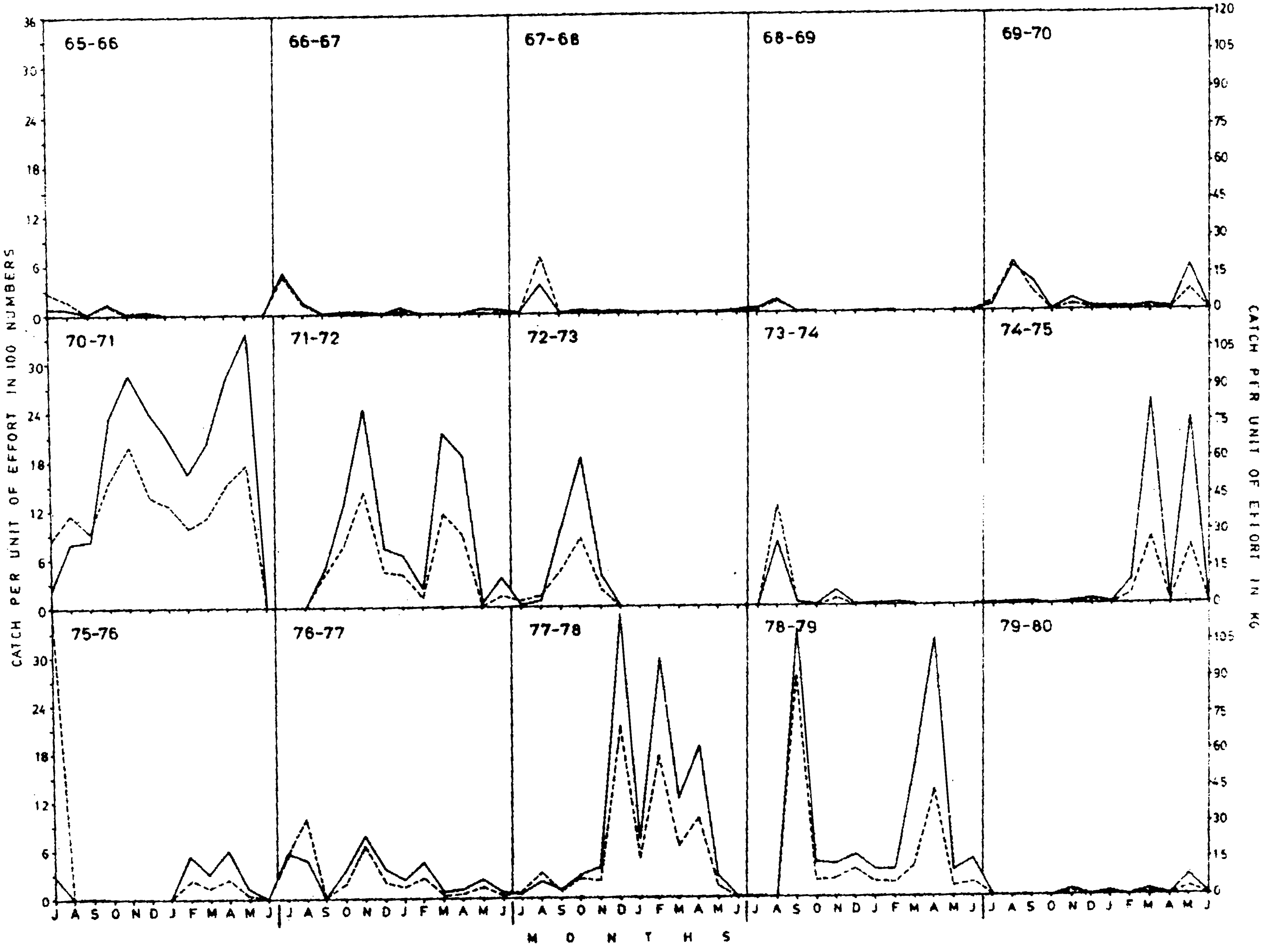
5.8.2. SIZE DISTRIBUTION

Monthly size range is given in Fig. 28. Generally juveniles beginning with 90 mm in length are caught at Manassery. In July 1972 and 1975, fishes as small as 75 mm and 65 mm respectively were caught. Juveniles of 65-95 mm sizes occurred in huge quantities in July 1975. Maximum sizes caught by *Thangu vala* were only 255 mm. But in February 1976, the size caught went up to 270 mm - the longest caught by *Thangu vala* during the entire period of this study. In June 1977 and March 1980, sizes of 265 mm were encountered. Broadly speaking maximum sizes that occurred in the last few seasons were high. On the other hand, the maximum size in the first few years was only 235 mm (Fig.28). In between, the maximum sizes in catches were increasing.

Modal sizes from month to month in catches during the

Fig. 27: Catch of mackerel per unit of effort of *Thangu vala* at Cochin in weight (continuous line) and in numbers (broken line) from July 1965 to June 1980.

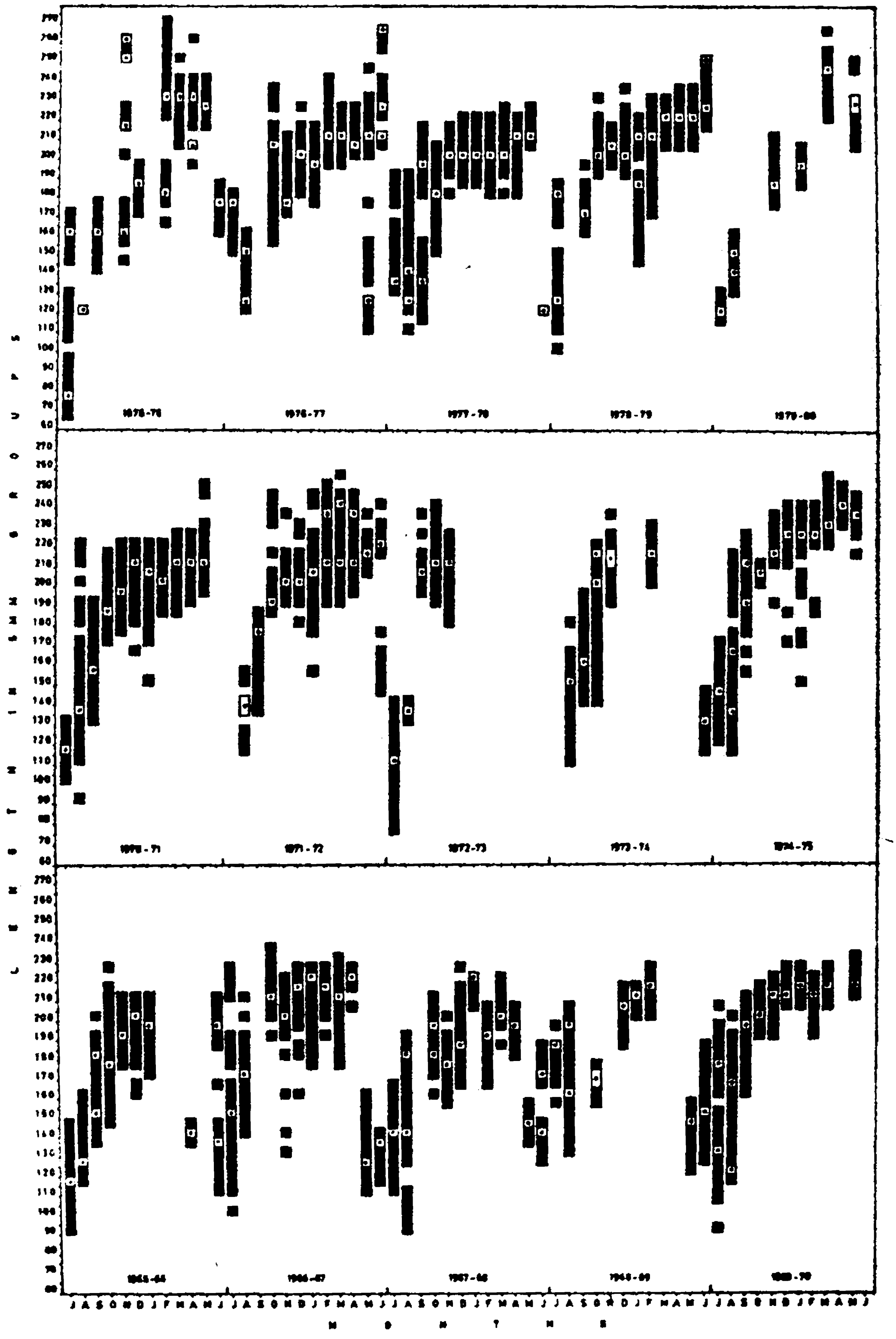
Fig. 27



65-66
66-67
67-68
68-69
69-70
70-71
71-72
72-73
73-74
74-75
75-76
76-77
77-78
78-79
79-80
CATCH PER UNIT OF EFFORT IN 100 NUMBERS
CATCH PER UNIT OF EFFORT IN KG
M O N T H S

Fig. 28: Monthly size range and mode of mackerel landed at Cochin (Manassery) by Thanguvala from July 1965 to June 1980.

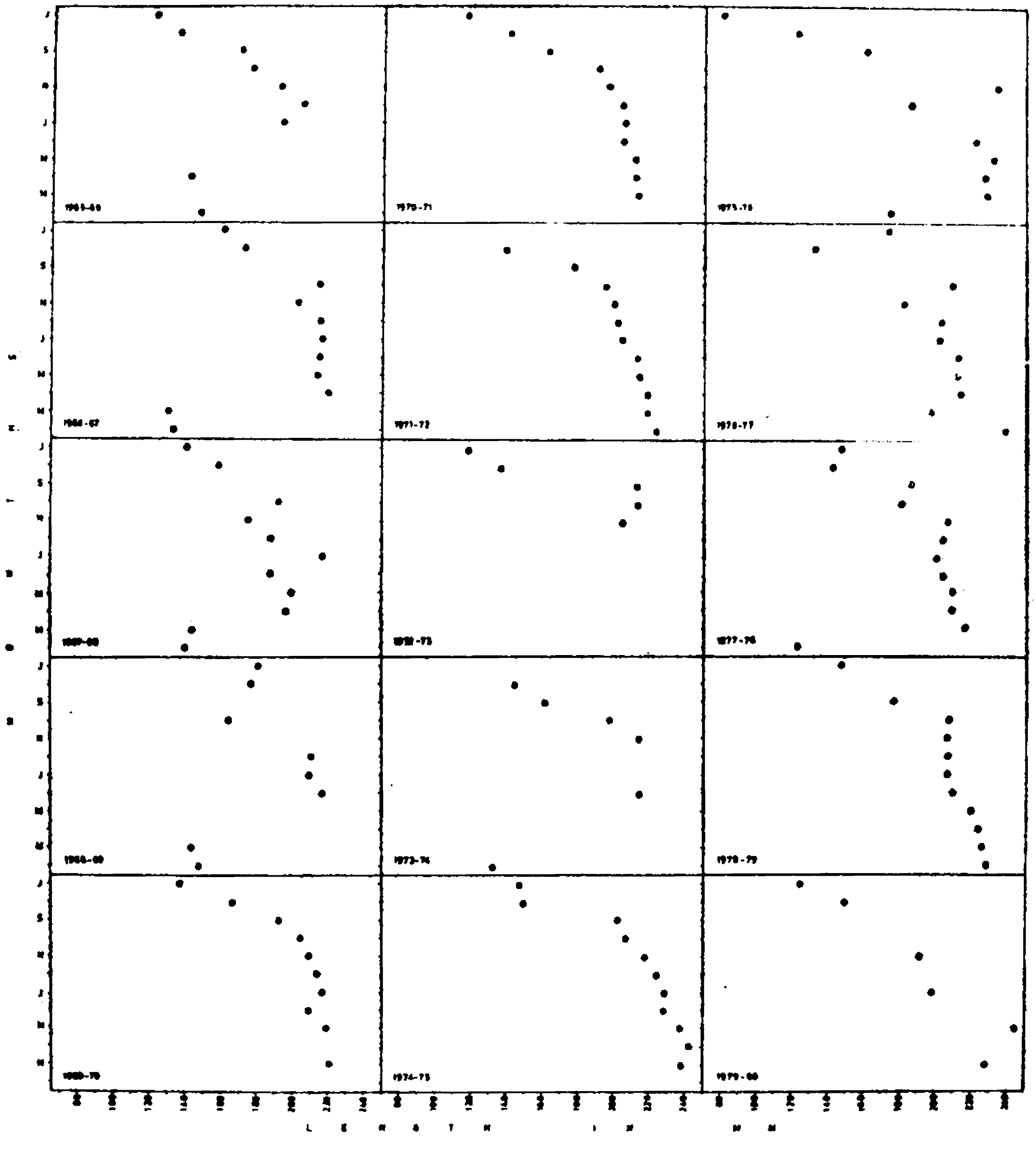
Fig. 28



entire period of study are given in Fig. 28. There is always good progression of modes in the early part of a season, and especially when juveniles are recruited it is very good. Among older fish, at times as for instance during November - March 1977-'78, the modes seem to remain static. The monthly average sizes are also hence computed and given in Fig. 29 for use in the estimation of growth.

Fig. 29: Observed monthly average length of mackerel landed at Cochin (Manassery) by Thangu vala from July 1965 to June 1980.

Fig. 29



6. STUDIES ON POPULATION

6.1. ON LENGTH AND WEIGHT

6.1.1. LENGTH-WEIGHT RELATIONSHIP

Individual total length and weight of a number of fish were utilized each season to calculate the length-weight relationship

$$\log W = a + b \log L$$

where

$$b = \frac{\Sigma XY - \frac{\Sigma X \, \Sigma Y}{N}}{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}$$

and

$$a = \frac{\Sigma Y}{N} - b\left(\frac{\Sigma X}{N}\right) .$$

The X and Y in the equation are log values of the total length in mm and the log values of the weight in grams respectively.

Data on 18,141 mackerel; collected at Manassery from the boat seine landings for 15 seasons during 1965-'66 to 1979-'80 and the purse seine landings at Fisheries Harbour for another season in 1980-'81, were treated in the above manner for finding out the relationship. The length-weight relationships thus calculated for 16 seasons are given in Table I, and illustrated in Fig. 30, 31, 32, and 33.

A simple arithmetic mean of the 'a' values and 'b'

Table I

Logarithmic value of the length-weight relationship from season to season.

1.	1965-'66	log W	=	$\bar{6}.6417570$	+	3.7351815 log L
2.	1966-'67	log W	=	$\bar{6}.5382332$	+	3.6715624 log L
3.	1967-'68	log W	=	$\bar{5}.7415300$	+	3.3295900 log L
4.	1968-'69	log W	=	$\bar{5}.2560758$	+	3.1187024 log L
5.	1969-'70	log W	=	$\bar{6}.1530601$	+	3.5182661 log L
6.	1970-'71	log W	=	$\bar{5}.1772416$	+	3.0732987 log L
7.	1971-'72	log W	=	$\bar{5}.0165294$	+	3.0046418 log L
8.	1972-'73	log W	=	$\bar{5}.4994377$	+	3.2320052 log L
9.	1973-'74	log W	=	$\bar{5}.1756602$	+	3.0865672 log L
10.	1974-'75	log W	=	$\bar{5}.5035330$	+	3.2296853 log L
11.	1975-'76	log W	=	$\bar{5}.8901883$	+	3.3959418 log L
12.	1976-'77	log W	=	$\bar{5}.7806300$	+	3.3503130 log L
13.	1977-'78	log W	=	$\bar{4}.8357030$	+	2.9336154 log L
14.	1978-'79	log W	=	$\bar{5}.5500726$	+	3.2491487 log L
15.	1979-'80	log W	=	$\bar{5}.3598009$	+	3.1675454 log L
16.	1980-'81	log W	=	$\bar{5}.0999085$	+	3.0570810 log L

Fig. 30: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1965-'66 to 1968-'69.

Fig. 30

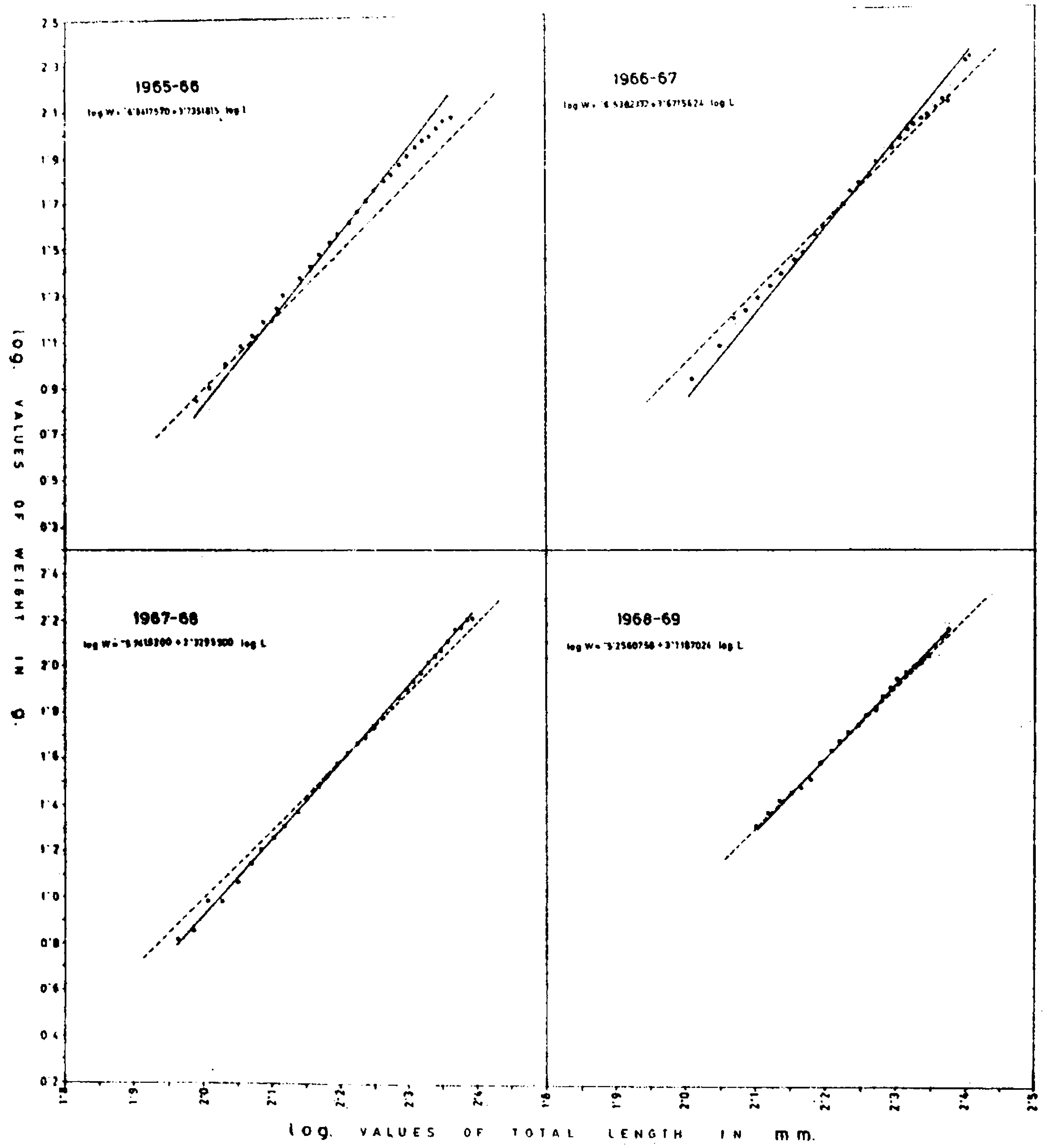
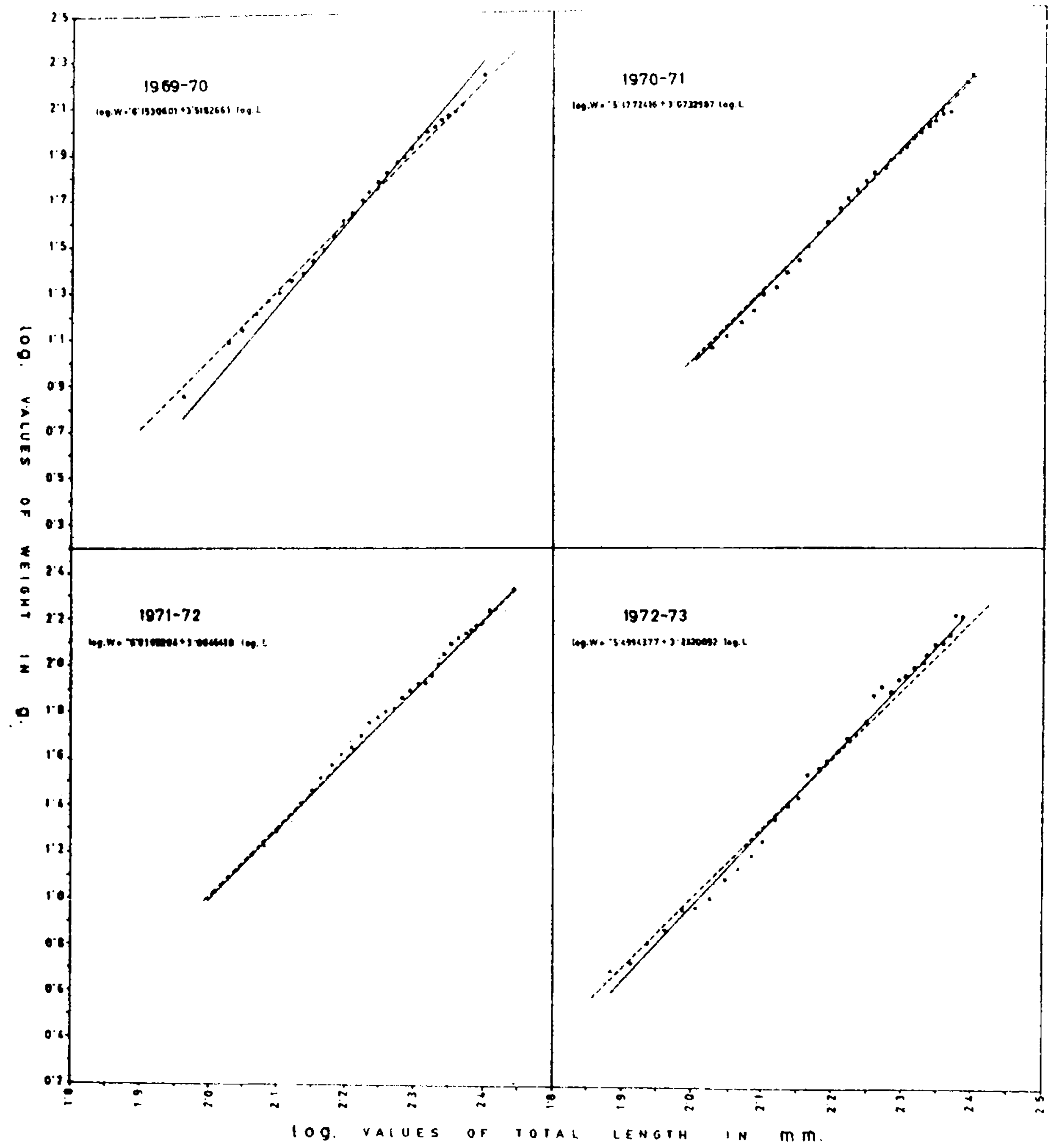

1965-66
log W = 6.8617570 + 3.7351815 log L
1966-67
1967-68
1968-69
log W = 5.2560758 + 3.1187024 log L
log. VALUES OF WEIGHT IN g.
log. VALUES OF TOTAL LENGTH IN mm.

Fig. 31: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1969-'70 to 1972-'73.

Fig. 31



1969-70
1970-71
1971-72
1972-73
log. VALUES OF WEIGHT IN g.
log. VALUES OF TOTAL LENGTH IN mm.

Fig. 32: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1973-'74 to 1976-'77.

Fig. 32

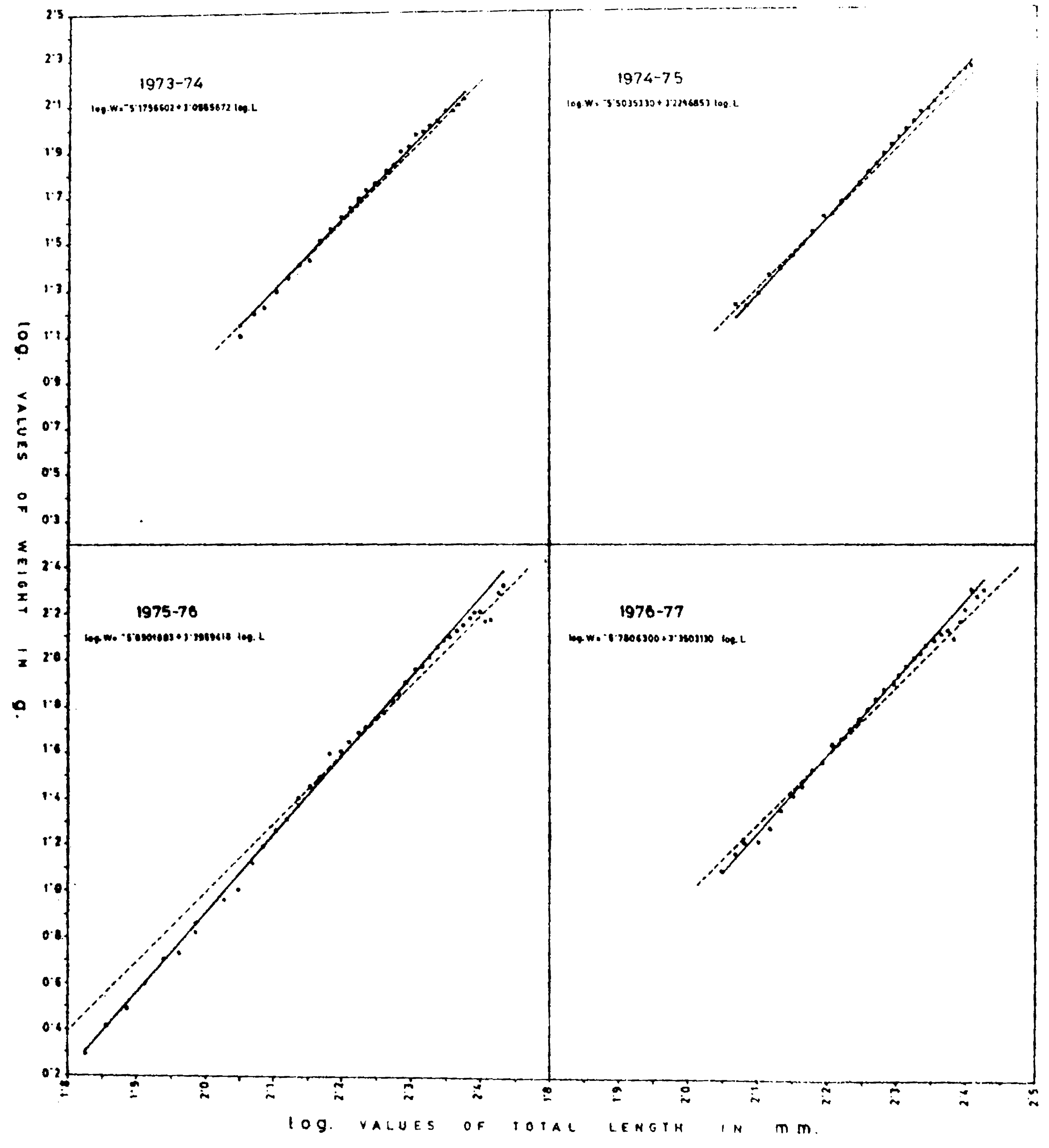
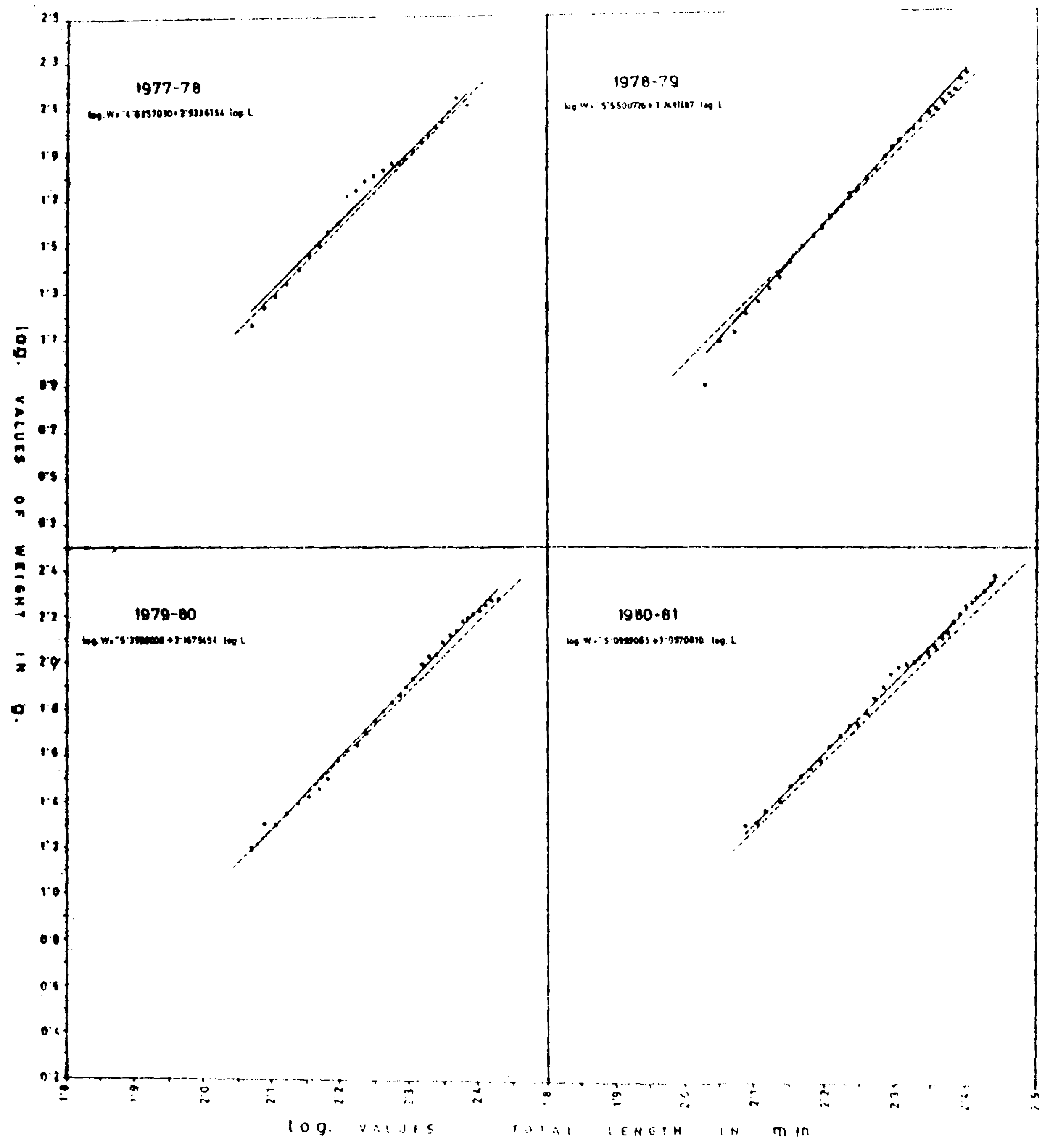

1973-74
log.W = ¯5·1796602 + 3·0885672 log.L
1974-75
log.W = ¯5·5035330 + 3·2296853 log.L
1975-76
log.W = ¯5·8901883 + 3·3989418 log.L
1976-77
log.W = ¯5·7806300 + 3·3503130 log.L
log. VALUES OF WEIGHT IN g.
log. VALUES OF TOTAL LENGTH IN mm.

Fig. 33: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1977-'78 to 1980-'81.

Fig. 33


1977-78
1978-79
1979-80
1980-81
log. VALUES OF WEIGHT IN g.
log. VALUES TOTAL LENGTH IN mm

values of the seasons was found out, according to which the average length-weight relationship of the mackerel was

$$\log W = \bar{5}.5762101 + 3.2595716 \log L.$$

From the pooled value of X and Y of 16 seasons, the 'a' and 'b' were calculated afresh and the length-weight relationship accordingly is

$$\log W = \bar{5}.6738829 + 3.2995842 \log L.$$

The values on exponential equation

$$W = a L^{b}$$

of the length-weight relationships for 16 seasons are given in Table II and in Fig. 34, 35, 36, and 37.

An arithmetic mean of these is

$$W = 0.000002653322 L^{3.2595716} .$$

Exponential value of the pooled length-weight relationship of the 16-season period is

$$W = 0.000002118932 L^{3.2995842} .$$

These calculations as already mentioned are based on length in mm. With reference to length in cm, the relation on pooled value would be

Table II

Exponential equations on the logarithmic values of length-weight relationship

1.	1965-'66	$W = 0.000000228162\ L^{3.7351815}$
2.	1966-'67	$W = 0.000000289579\ L^{3.6715624}$
3.	1967-'68	$W = 0.000001813301\ L^{3.3295900}$
4.	1968-'69	$W = 0.000005545289\ L^{3.1187024}$
5.	1969-'70	$W = 0.000000702975\ L^{3.5182661}$
6.	1970-'71	$W = 0.000006649032\ L^{3.0732987}$
7.	1971-'72	$W = 0.000009626548\ L^{3.0046418}$
8.	1972-'73	$W = 0.000003166375\ L^{3.2320052}$
9.	1973-'74	$W = 0.000006673287\ L^{3.0865672}$
10.	1974-'75	$W = 0.000003136657\ L^{3.2296853}$
11.	1975-'76	$W = 0.000001287691\ L^{3.3959418}$
12.	1976-'77	$W = 0.000001657181\ L^{3.3503130}$
13.	1977-'78	$W = 0.000014598122\ L^{2.9336154}$
14.	1978-'79	$W = 0.000002817912\ L^{3.2491487}$
15.	1979-'80	$W = 0.000004367160\ L^{3.1675454}$
16.	1980-'81	$W = 0.000007944956\ L^{3.0570810}$

Fig. 34: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1965-'66 to 1968-'69.

Fig. 34

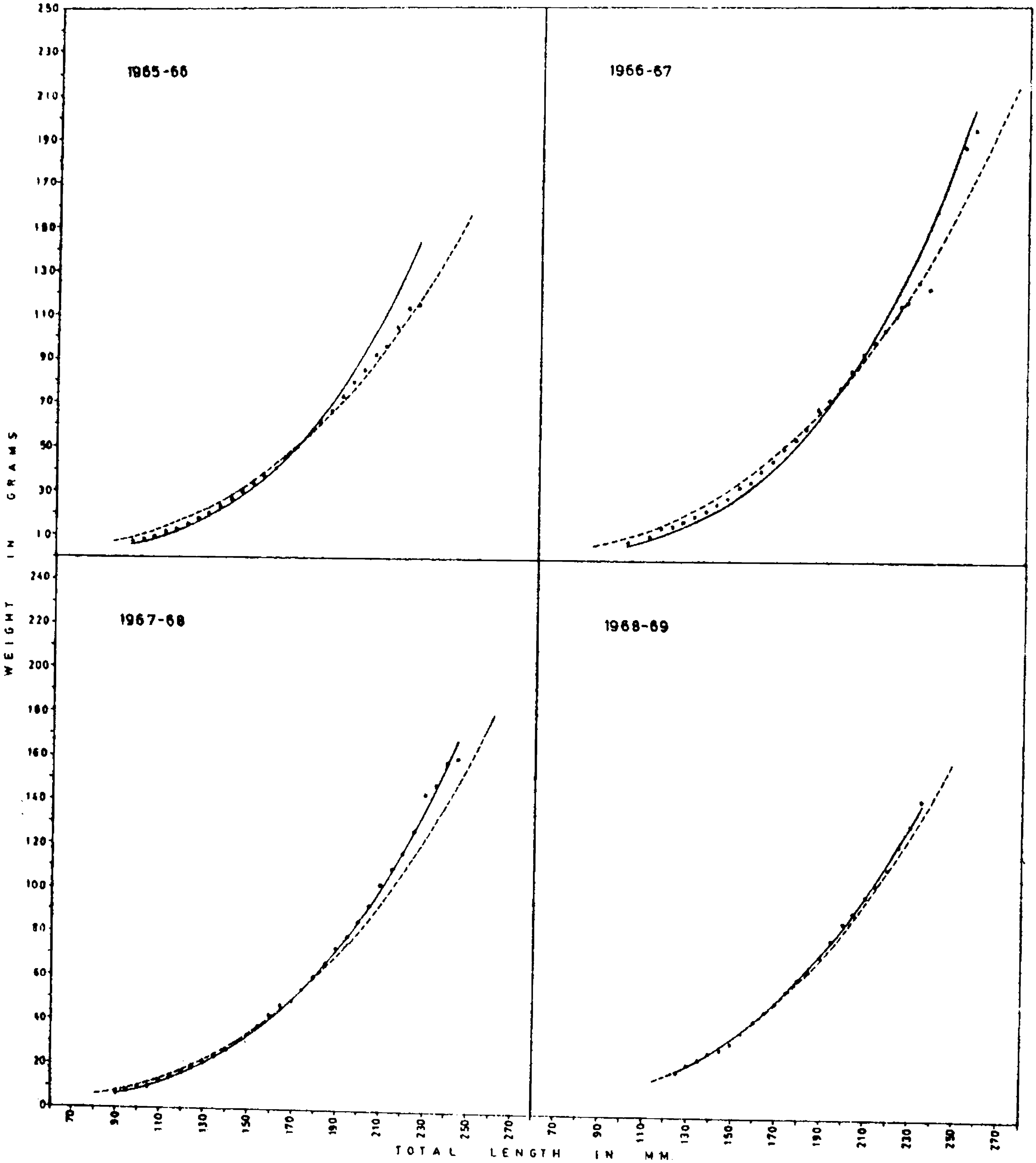

1965-66
1966-67
1967-68
1968-69
WEIGHT IN GRAMS
TOTAL LENGTH IN MM.

Fig. 35: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1969-'70 to 1972-'73.

Fig. 35

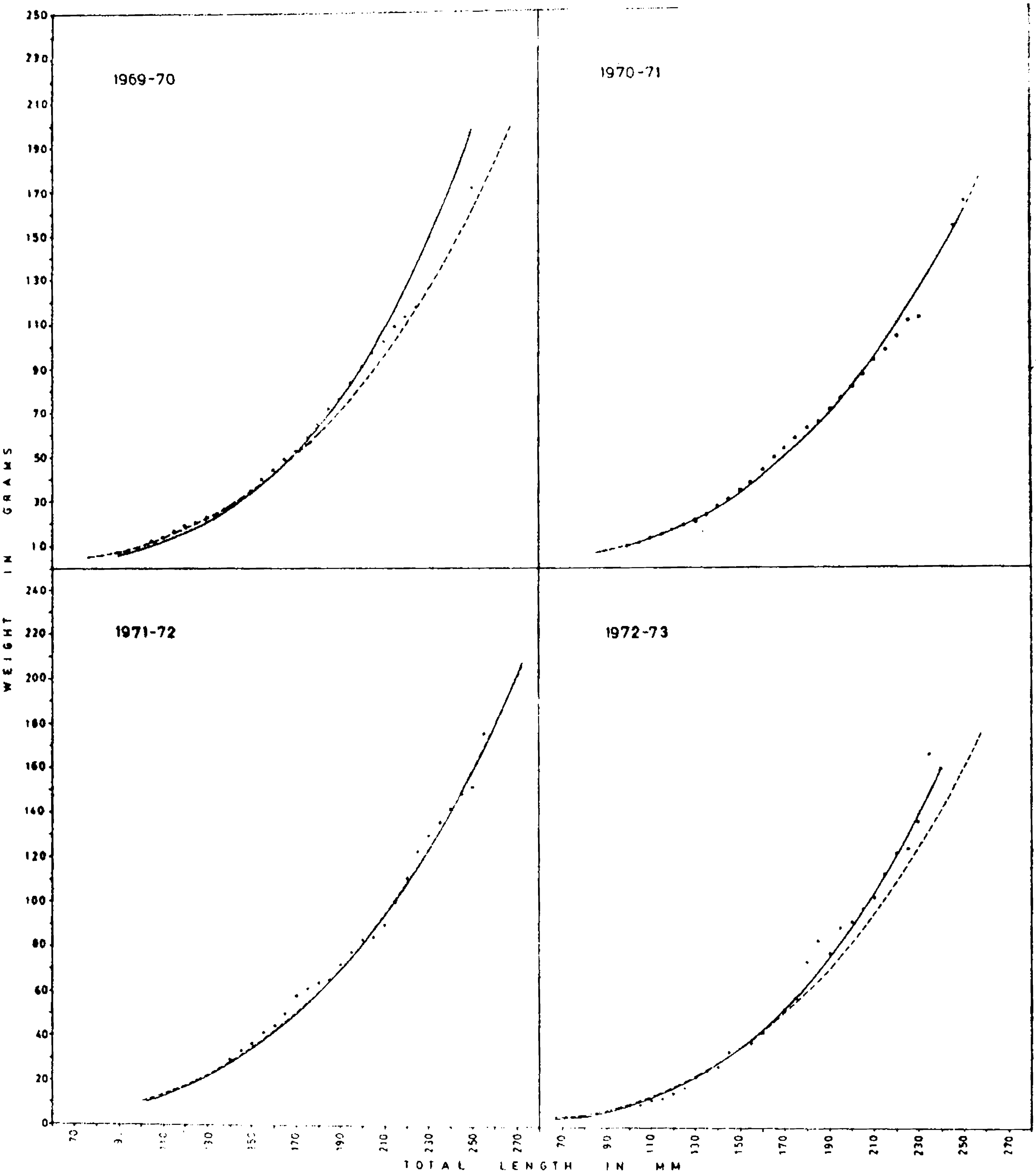
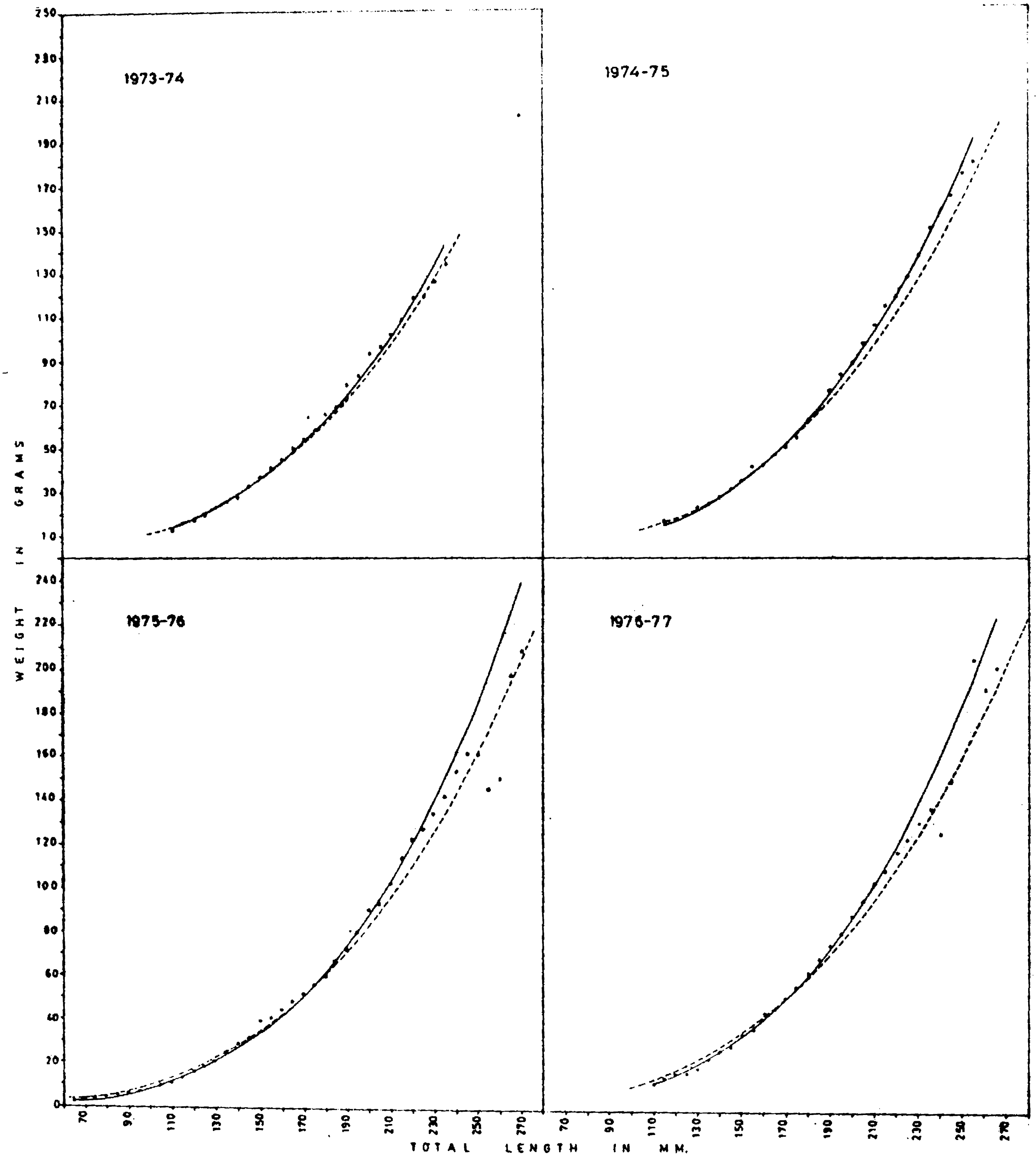

1969-70
1970-71
1971-72
1972-73
WEIGHT IN GRAMS
TOTAL LENGTH IN MM

Fig. 36: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1973-'74 to 1976'77.

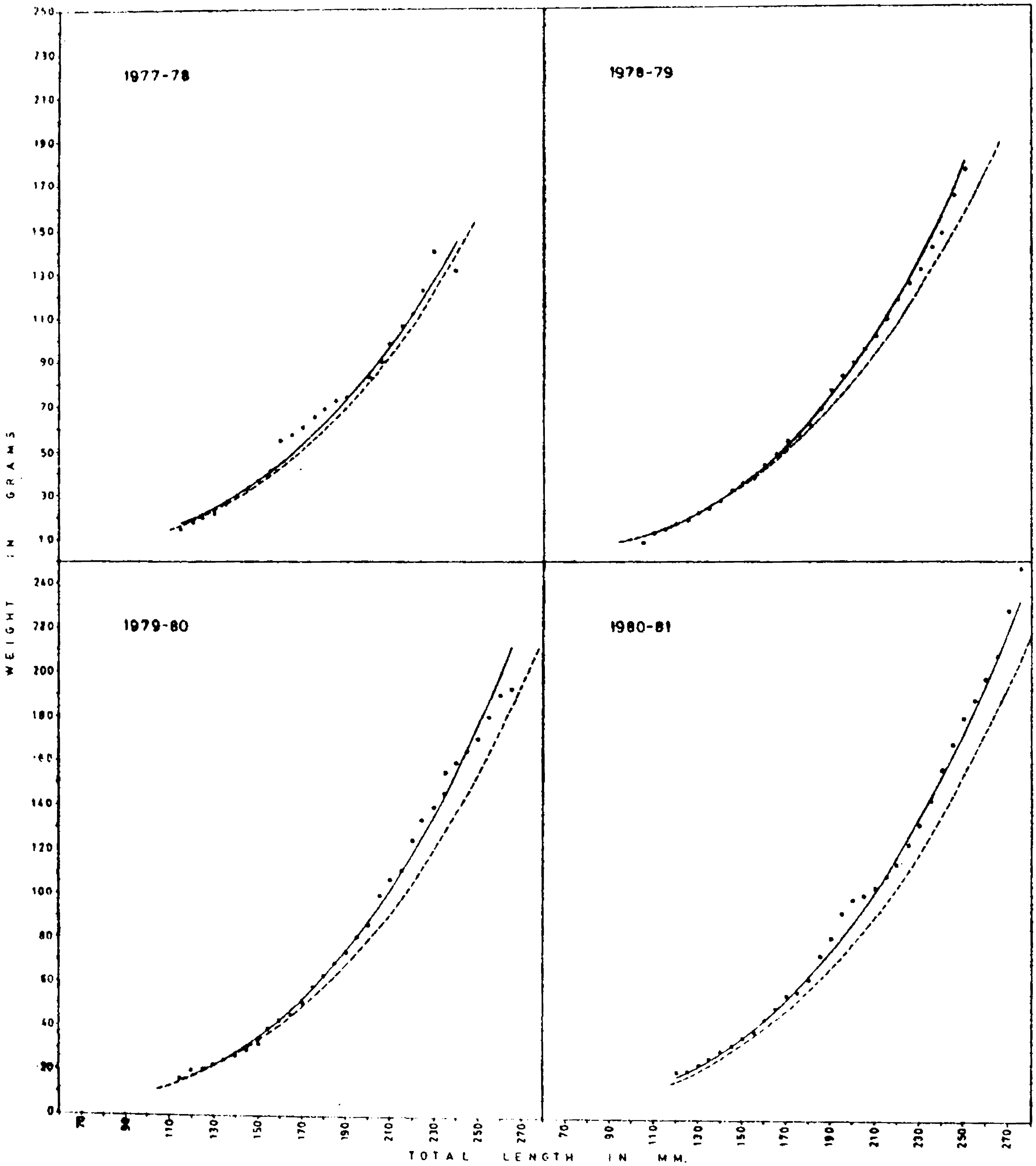
Fig. 36



1973-74
1974-75
1975-76
1976-77
WEIGHT IN GRAMS
TOTAL LENGTH IN MM.

Fig. 37: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1977-'78 to 1980-'81.

Fig. 37


1977-78
1978-79
1979-80
1980-81
WEIGHT IN GRAMS
TOTAL LENGTH IN MM.

$$\log W = \bar{2}.3742987 + 3.2995842 \log L$$

logarithmically and

$$W = 0.004223780\ L^{3.2995842}$$

exponentially. Against arithmetic mean the relationship for length in cm is

$$\log W = \bar{2}.3166385 + 3.2595716 \log L$$

logarithmically and

$$W = 0.004823491\ L^{3.2595716}$$

exponentially.

These values against measurements in cm are necessary for comparison with the findings of some earlier workers in discussion.

6.1.2. TEST OF SIGNIFICANCE

The 'b' values during the study differed from season to season within a range of 2.933614 of 1977-'78 and 3.7351815 of 1965-'66, and the average value was different from the pooled one. The number of fish utilized for calculating the length-weight relationship (Table III) each season was not equal. The test of significance between 'b' values

Table III

Test of 't' on seasonal 'b' values against pooled and isometric values

Year	No.of fish studied	'b' value	HO:B_1-B_2=0 weighted	HO:-0=0
1965-'66	931	3.7351815	4.0196	6.3133
1966-'67	1247	3.6715624	3.9408	7.0979
1967-'68	657	3.3295900	0.2342+	2.3253++
1968-'69	554	3.1187024	1.3048+	0.8335+
1969-'70	1058	3.5182661	2.1537++	5.2394
1970-'71	2135	3.0732987	3.0902	1.0857+
1971-'72	1184	3.0046418	3.1068	0.0674+
1972-'73	414	3.2320052	0.4255+	1.9098+
1973-'74	484	3.0865672	1.4530+	0.9937+
1974-'75	1097	3.2296853	0.9646+	2.3323++
1975-'76	842	3.3959418	0.8491+	3.4685
1976-'77	1641	3.3503130	0.6102+	4.1874
1977-'78	1879	2.9336154	4.7284	0.9436+
1978-'79	1307	3.2491487	0.5472+	2.7045++
1979-'80	886	3.1675454	1.1960+	1.5653+
1980-'81	1825	3.0570810	3.0864	0.7682+

+Not significant at 5% level and ++not significant at 1% level. The table values of 't' at 5% and 1% level are 1.96 and 2.5758 respectively.

from season to season against the pooled one was hence conducted with the help of following formula (Dixon and Massey 1969) giving weightage also to the number of fish each time, and the results given in Table III.

$$t = \frac{b_1 - b_2}{\sqrt{S^2 \left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

where

$$S^2 = \frac{(N_1 - 2)\frac{Sy_1^2}{Sx_1^2} + (N_2 - 2)\frac{Sy_2^2}{Sx_2^2}}{N_1 + N_2 - 4}$$

According to the results obtained, the values on 1965-'66, 1966-'67, 1970-'71, 1971-'72, 1977-'78, and 1980-'81 were significantly varying. The values on 1967-'68, 1968-'69, 1972-'73 to 1976-'77, 1978-'79, and 1979-'80 were not significant at 5% level. The 'b' values within the range of 3.0865672 and 3.3959418 were the ones not significant at 5% level. The values of 'b' beginning at 3.6715624 on 1966-'67 and more on the higher side, and 3.0732987 of 1970-'71 and below which are on the lower side of the pooled one were significantly varying. The difference in 'b' value of 1970-'71 from the pooled one is 0.2262855, and it amounts to 6.9% in the pooled value. In 1969-'70, the 'b' value was only 3.5182661 and it was only 6.6% in the pooled value and the 't' was not significant at 1% level. The lowest value 3.0865672 falling in the 5% confidence limit was 0.2130170 less from the pooled one and it forms only 6.45% in the pooled value. Probably variations around 6.5% of the pooled value are within the tolerance limits, beyond which it becomes significant in 't' test.

The values of 'b' in each season were similarly tested individually against isometric growth by using the formula (Snedecor 1959)

$$t = \frac{b_1 - 3}{\sqrt{\dfrac{Sy_1^2}{Sx_1^2}} \Big/ n-2}$$

and results given in Table III. Against isometric growth the 'b' values of 3.1187024 in 1968-'69 and below were found not significant at 1% level and between 3.2491487 of 1978-'79 and 3.3295900 of 1967-'68 not significant at 5% level (Table III). The values showed significant variations when they went 3.3503130 of 1976-'77 and above. The differences of the values in 1967-'68 and 1976-'77 from 3.0 were respectively 0.3295900 and 0.3503130 forming 11.0 and 11.7% in the isometric value and the tolerance limit of 'b' values against isometric growth falls somewhere between 3.33 and 3.35.

6.1.3. RELATION BETWEEN 'b' AND 'a' VALUES OF LENGTH-WEIGHT RELATIONSHIP

The 'a' and 'b' in Le Cren's (1951) formula are constants computed by least squares method from 2 variables. The 'a' is independent of 'b' in different species of fishes. Within a species, they may be related to each other in their fluctuations from season to season. Otherwise, there cannot be a set pattern of growth in the species concerned. For a species the growth can either be isometric or allometric but cannot be both occurring at different times. As the length-weight relationship of mackerel at Cochin is available for 16 seasons, and as the 'b' value during this period was ranging between 2.9336164 and 3.7351815 and the 'a' value between $\bar{4}.8357030$ and $\bar{6}.6417570$, a regression of 'a' on 'b' was found out by the formula

$$a = A + B\,b$$

where

$$B = \frac{\Sigma ba - \frac{\Sigma b\,\Sigma a}{n}}{\Sigma b^2 - \frac{(\Sigma b)^2}{n}}$$

and

$$A = \frac{\Sigma a}{n} - B\left(\frac{\Sigma b}{n}\right)$$

to be

$$a = \bar{1}.8209470 + 2.2693648\,b$$

depicting a perfect straight line as shown in Fig. 38. On a 'b' value of 3.0 of the Cube Law, the value of 'a' accordingly would be $\bar{5}.0$ and the length-weight relationship on isometric growth condition emerges as

$$\log W = \bar{5}.0 + 3.0 \log L$$

or

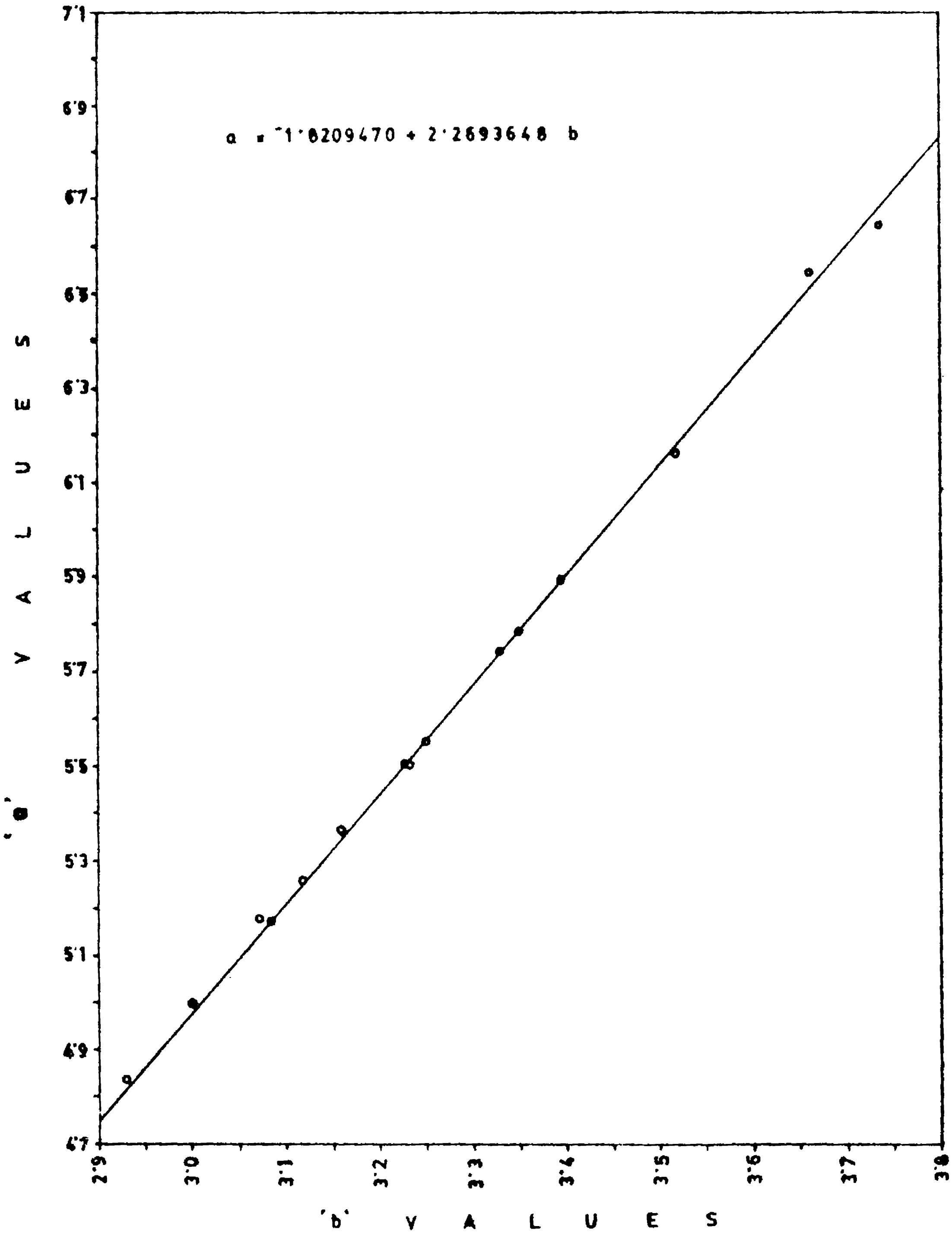
$$W = 0.00001\,L^{3.0}$$

for length measurements in mm, and

$$\log W = \bar{2}.0 + 3.0 \log L$$

Fig. 38: Relation between 'a' and 'b' values of logarithmic length-weight relationship of mackerel, calculated (continuous line) against observed values (dots).

Fig. 38



a = ¯1·8209470 + 2·2693648 b
'a' VALUES
'b' VALUES
7·1
6·9
6·7
6·5
6·3
6·1
5·9
5·7
5·5
5·3
5·1
4·9
4·7
2·9
3·0
3·1
3·2
3·3
3·4
3·5
3·6
3·7
3·8

or $$W = 0.01\ L^{3.0}$$

for lengths in cm.

A test of signficance was done on the relation between 'b' and 'a' values by applying the following formula (Snedecor 1959)

$$t = \frac{B}{\dfrac{\sqrt{\dfrac{\Sigma a - \hat{a}^2}{n-2}}}{\Sigma b - \bar{b}^2}}$$

where '$\hat{a}$' is calculated by using the regression equation on 'a' and 'b' found above, the value of 't' works out to be 132.344. As this value is very much higher than the table value of 2.977 at 1% level for df 14, it is highly significant showing good regression relationship between the 'a' and 'b' values of the length-weight equations. The value of B being positive, it indicates an increase in the 'a' value with every unit increase in 'b' value of the relationship. In other words, one can expect that with an increase or decrease of every unit of 'b' value there will be a corresponding increase or decrease of 2.2693648 units in the value of 'a'.

6.1.4. LENGTH-WEIGHT RELATIONSHIP BETWEEN SEXES

Morphometrically, male and female mackerel look externally alike. With no indication of sexual dimorphism even in their size and weight at any time of the life-span, there would normally be no difference in length-weight relationships between them. However, to be sure about it, the length-weight relationships of the male and female mackerel were separately found out for some seasons as given in Table IV.

Data for the 4 seasons were pooled together and the following logarithmic equations were found out for 1977-'81 as

$$\text{Male} \quad \log W = \bar{5}.3256977 + 3.1511524 \log L$$

$$\text{Female} \quad \log W = \bar{5}.1637076 + 3.0820961 \log L$$

$$\text{Combined} \quad \log W = \bar{5}.2462069 + 3.1172780 \log L$$

Exponential equivalents of the above equations for male and female are respectively

$$W = 0.000004723917 \; L^{3.1511524}$$

and

$$W = 0.000006859499 \; L^{3.0820961} .$$

The relationship of the sexes in lengths in cm are for

Table IV

Length-weight relationship between sexes in 4 seasons

<u>1977-'78</u>		
	Male	$\log W = \bar{4}.9518299 + 2.9829876 \log L$
	Female	$\log W = \bar{4}.6868760 + 2.8700984 \log L$
	Combined	$\log W = \bar{4}.8230999 + 2.9281299 \log L$
<u>1978-'79</u>		
	Male	$\log W = \bar{5}.4888035 + 3.2224718 \log L$
	Female	$\log W = \bar{5}.4616184 + 3.2114887 \log L$
	Combined	$\log W = \bar{5}.4760252 + 3.2173248 \log L$
<u>1979-'80</u>		
	Male	$\log W = \bar{5}.3960609 + 3.1828652 \log L$
	Female	$\log W = \bar{5}.3151701 + 3.1486472 \log L$
	Combined	$\log W = \bar{5}.3598009 + 3.1675454 \log L$
<u>1980-'81</u>		
	Male	$\log W = \bar{5}.1329277 + 3.0717023 \log L$
	Female	$\log W = \bar{5}.0671463 + 3.0425456 \log L$
	Combined	$\log W = \bar{5}.0999085 + 3.0570810 \log L$

Male:-(

$$\log W = \bar{2}.1745452 + 3.1511524 \log L$$

$$W = 0.006690442 \; L^{3.1511524}$$

and

Female:-(

$$\log W = \bar{2}.0816115 + 3.0820961 \log L$$

$$W = 0.0082868313 \; L^{3.0820961}$$

The 'a' and 'b' values as seen in this analyses for all the 4 seasons (Table IV) for females were slightly lower than those with the males.

A test of significance was done on the relationship between males and females with the equation (Bailey 1959)

$$t = \frac{\left| b_m - b_f \right|}{\sqrt{s_m^2 + s_f^2}}$$

where b_m and s_m^2 stand for males, and b_f and s_f^2 stand for females, and the equations for s_m^2 and s_f^2 were as follows:

$$s_{th}^2 = \frac{\dfrac{\left[\Sigma Y^2 - \dfrac{(\Sigma Y)^2}{N}\right]}{N-1}}{\dfrac{\left[\Sigma X^2 - \dfrac{(\Sigma X)^2}{N}\right]}{N-1}}$$

The values of 't' obtained on these computations were

1877-'78 = 0.026

1978-'79 = 0.002

1979-'80 = 0.008 and

1980-'81 = 0.007 .

The combined value for the 4 seasons of 1977-'81 of the 't' was 0.015. All these values being much lower to the Table value of 1.645 of t df ∝ at 1% level shows the regression coefficients of males and females not to differ significantly, and a combined equation composed on both sexes together will suffice.

6.1.5. LENGTH-WEIGHT RELATIONSHIP BETWEEN INDETERMINATE AND DETERMINATE FISH

As there is no difference between males and females, there appears to be no significant difference between the fish in which sexes are distinguishable (i.e. above 119 mm size) and the fish in which sexes are not discernible (below 120 mm size). Indeterminate fish of size 67-119 mm numbering 302 that occurred during the seasons from 1975-'76 to 1980-'81 were pooled together and their length-weight relationship worked out separately from that of the rest. The relationship for these 2 groups of fishes were as follows:

Indeterminate

$$\log W = \bar{5}.6652489 + 3.3064783 \log L$$

Others

$$\log W = \bar{5}.2462069 + 3.1172780 \log L$$

Exponential equivalent on the above relations respectively are

$$W = 0.000002161479 \; L^{3.3064783}$$

and

$$W = 0.000005672743 \; L^{3.1172780}$$

The relationship of them in length in cm are Indeterminate

$$\log W = \bar{2}.3587706 + 3.3064783 \log L$$

$$W = 0.004377533 \ L^{3.3064783}$$

and Determinate

$$\log W = \bar{2}.1289289 + 3.1172780$$

$$W = 0.007431408 \ L^{3.1172780}$$

6.2. GROWTH AND AGE

The growth of fish is generally depicted in the progression of modal sizes in catches from month to month. But the mode at times, whatever may be the reason, especially among older fish seems to remain static (Fig.28). The monthly average size provides more or less good positive progression (Fig.29), and through this the growth rate of mackerel up to December as displayed in Table V is calculated. The mean growth derived from this Table is 15.07 mm a month, and at this rate the fish in one year could attain a length of 180.84 mm.

The monthly average growth as given in Table V ranges

Table V

Growth of mackerel during season time up to December in mm

year	Months	Mean length range	Length gained	Period months	Mean growth
1965	Sep-Dec	169.2 - 204.6	35.4	3	11.80
1966	Jun-Aug	147.1 - 172.8	25.7	2	12.85
1967	May-Oct	130.2 - 191.4	61.2	4	15.30
1968	Jun-Dec	140.4 - 210.6	70.2	6	11.70
1969	Jul-Dec	137.4 - 214.2	76.8	5	15.36
1970	Jul-Dec	116.3 - 205.0	88.7	5	17.74
1971	Aug-Dec	138.7 - 202.1	63.4	4	15.85
1972	Jul-Aug	118.1 - 136.6	18.5	1	18.50
1973	Aug-Sep	145.2 - 162.1	16.9	1	16.90
1974	June-Dec	132.4 - 224.5	92.1	6	15.35
1975	Aug-Dec	122.0 - 185.4	63.4	4	15.85
1976	Aug-Dec	131.3 - 202.1	70.8	4	17.70
1977	Jul-Nov	146.5 - 205.7	59.2	4	14.80
1978	Jun-Oct	146.4 - 206.6	60.2	4	15.05
1979	Jul-Nov	123.8 - 190.4	56.6	4	14.15
Total			859.1	57	15.07

mostly between 11.70 mm of 1968 to 15.85 mm of 1971 and 1975. At this minimum, the annual attainable length is only 140.40 mm. But with 15.85 mm, the length attained in a year can be 190.20 mm. An average of the 2 works out the length reached in 12 months to be 165.30 mm. Fish below 160 mm, hence are treated in the study as 0-year old.

The period considered for growth in Table V ends in December. The length by then is mostly around 200 to 205 mm. Fish in subsequent months being bigger and older grow slower. This, in fact, is the time when stagnation in monthly modal sizes mostly occurs. Nevertheless, the monthly average length of the fish caught (Table VI) shows without doubt growth then also.

Growth of mackerel in the months immediately following December as treated in Table VI is 5.26 mm. Tagging mackerel at Cochin, a fish of 189 mm was found to grow to 191 mm in 7 days registering 2.0 mm increment. This observation was made in December 1967 (Noble 1974 a) and at this rate the mackerel of given size and time gains 8.57 mm in one month. Another mackerel of 195 mm size tagged and released on 29th of January 1968, during 25 days at liberty gained 5.0 mm in length. The monthly growth in February thus calculates to be

Tavle VI

Growth of mackerel in months following December in mm

Year	Months	Mean length range	Length gained	Period months	Mean growth
1967	Mar-Apr	213.0 - 219.7	6.7	1	6.70
1969	Jan-Feb	209.4 - 216.6	7.2	1	7.20
1970	Feb-May	209.0 - 221.1	12.1	3	4.03
1971	Feb-Mar	204.8 - 211.3	6.5	1	6.50
1972	Jan-Apr	204.8 - 219.1	14.3	3	4.77
1974/75	Nov-Jan	217.7 - 228.7	11.0	2	5.50
Total			57.8	11	5.26

6.00 mm.

At the rate of 5.26 mm per month derived from Table VI which agrees closely with tag recoveries, the fish in a year attains an additional 63.12 mm to the 165.30 mm already reached in previous year. The fish at the end of second year accordingly gets 228.42 mm length and those that are between 160 mm and 229 mm are therefore treated as 1-year old. As the fish becomes older, the rate of growth reduces still further. Enough data, however, is not available at Cochin to substantiate this. The fish between 230 and 269 mm lengths in consonance with the findings of earlier workers (Ramamohana Rao et al. 1962 and Seshappa 1969) are kept in the study as 2-year old. Those fish from 270 mm and above are considered hence as 3-year old.

6.3. AGE COMPOSITION OF CATCHES

Based on the above growth structure, the fish landed at Manassery by Thangu vala from season to season during July 1965 to June 1980 were compartmentalized into different age years and given in Table VII. As already dealt with in seasonal break up, care was taken in this excercise to ensure all the

Table VII

Age composition of mackerel landed at Manassery by boat seine

Thangu vala - cpue in numbers

Season	0-year <159 mm	1-year 160-229 mm	2-year 230-269 mm	3-year >270 mm	Total	Effort in number
1965-'66	92.93	24.34	.	.	117.27	10251
1966-'67	51.67	38.48	0.09	.	90.24	10632
1967-'68	54.50	71.97	.	.	126.47	10580
1968-'69	8.50	24.73	.	.	33.23	8614
1969-'70	36.79	120.00	0.46	.	157.25	6708
1970-'71	204.16	1055.17	5.03	.	1264.36	14279
1971-'72	1.07	449.82	33.79	.	484.68	14128
1972-'73	19.54	206.38	5.61	.	231.53	9589
1973-'74	253.05	25.23	0.12	.	278.40	9196
1974-'75	3.19	8.83	90.46	.	102.48	7819
1975-'76	582.16	26.69	21.85	0.14	630.84	5812
1976-'77	104.43	127.03	2.29	.	233.75	4847
1977-'78	35.19	698.59	.	.	733.78	7248
1978-'79	1.00	443.80	20.02	.	464.82	9188
1979-'80	0.72	8.19	0.53	.	9.44	4228

fish of a season included in it, even if they occur outside July-June period.

6.4. COMPUTATION OF K, $L\infty$ AND $W\infty$

In the chapter on growth and age, mackerel of 159 mm and below were considered as 0-year olds. Sizes between 160 and 229 mm were likewise found to be 1-year old and those between 230 and 269 mm as 2-year old. Taking the 3-year olds to attain a length up to 289 mm in the year, the parameters of K and $L\infty$ were worked out through least squares method, using the lengths at the end of successive year classes as X and Y. From its 'a' and 'b' values the K $(e\frac{1}{b})$, and $L\infty$ $(\frac{a}{1-b})$ were found out to be 0.600774 and 314.8785713 mm respectively.

Looking through monthly progression of modal sizes (Fig. 28) the fish at 120 mm reaches a length of 182 mm in 6 months time. Assuming the 120 mm fish to be 6 months old the 182 mm size would be 1-year old, and at the end of the 2nd year this attains a length of 254 mm.

Following the straightline method of Alagaraja (1984), the $L\infty$ and K from the above growth structure were found to be 316.7 mm and 0.7643 respectively. Majority of the modal progression in Fig. 28 conform to this growth pattern. Moreover these parameters are close to the L_∞ 314.8785713 mm and K 0.600774 calculated from average monthly sizes using least squares method. As most of the sizes fall on this and as there is no risk of assuming age at any stage involved, the pair of L_∞ and K calculated from monthly average sizes are considered the best fitting in this study.

A fish of 314.8785713 mm size according to the pooled value of length-weight relationship

$$\log W = \bar{5}.6738829 + 3.2995842 \log L$$

would weigh 370.64 g. The cube value of the above length, however, is only 312.20 g. The weight got from L_∞ through length-weight relationship was higher than the cube value of L_∞. An independent calculation of W_∞ was therefore made through least squares method from the following weights got converted from lengths with the help of length-weight relationship,

159 mm	=	38.89 g
229 mm	=	129.60 g
269 mm	=	330.44 g
289 mm	=	279.29 g

and found it out to be 586.02 g. The largest recorded size of mackerel is 360 mm (Dhulkhed and Annigeri 1983). According to length-weight relationship the above fish would weigh 576.57 g and it is nearer to the actual observed weight of 560 g and the above calculated value of 586.02 g. The cube value of 360 mm, however, is only 466.56 g, and all the weights calculated as well as observed are higher than this. These being isolated cases of individual fish, the $W\infty$ 370.64 g got converted from the $L\infty$ 314.8785713 mm through length-weight relationship is taken as the best for the population.

6.5. CALCULATION OF t_0

The $L\infty$ as calculated in the previous section was 314.8785713 mm and t_0 is found out through least squares method on the relation between X and Y where

$$X = \text{age in years } (t)$$

$$Y = \log_e \frac{L\infty - Lt}{L\infty}$$

$$Lt = \text{length at time } t.$$

Taking the lengths from which 1, 2, and 3 years of age

Fig. 39: Growth in length of mackerel fitted through von Bertalanffy's Growth Function.

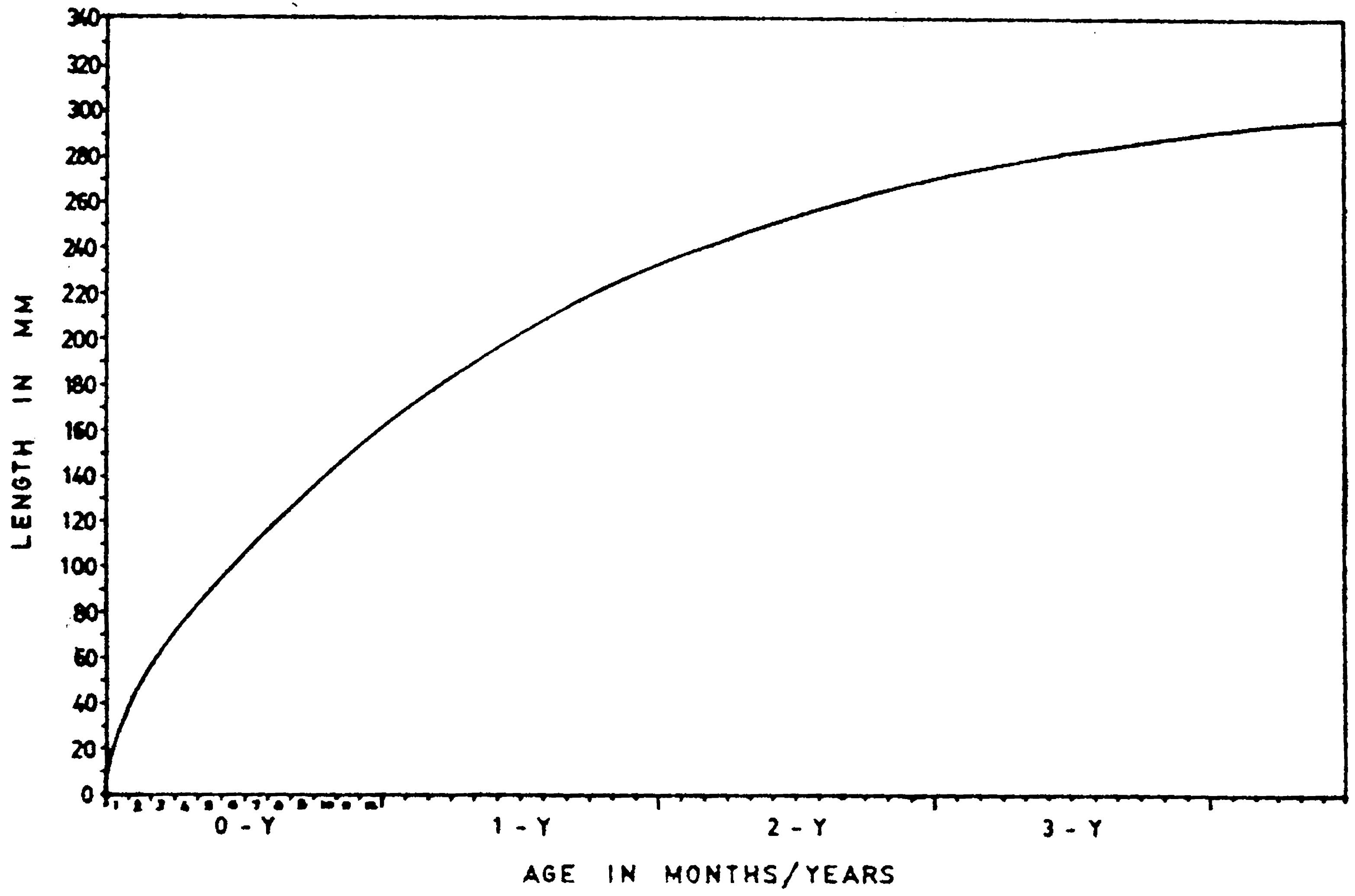

LENGTH IN MM
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0 - Y
1 - Y
2 - Y
3 - Y
AGE IN MONTHS/YEARS

Fig. 39

commence as 159, 229, and 269 mm respectively 'a' and 'b' values were computed and the t_0 ($-\frac{a}{K}$ where K = $^-$b) found out to be $^-$0.1413431664. Assuming the 120 mm fish to be 6 months old, according to Alagaraja's (1984) method the t_0 is found to be $^-$0.1232 and it being very near to the above value supports it.

Length at age back calculated by using von Bertalanffy's Growth Formula

$$Lt = L\infty \; 1-e^{-K(t - t_0)}$$

is plotted in Fig. 39, and the calculated values tally well with the observed ones.

6.6. MORTALITY

6.6.1. INSTANTANEOUS TOTAL MORTALITY

Based on the survival and progression of a year class in one season to the next higher one in the succeeding season, the instantaneous total mortality of the fish is computed by using the formula

$$Z = \log_e \frac{\bar{N}_o}{\bar{N}_1}$$

of Gulland (1969) where $\bar{N}_o$ and $\bar{N}_1$ are the seasonal catch per unit of effort of an year class during 2 consecutive seasons.

In mackerel, the 0-year old fish generally does not support the commercial catches, and it so happen that they are recruited only for a short time before the commercial exploitation commences. The 1-year olds constitute the bulk of the landings with 2-year olds also fished along with them (Table VII). Occurrence of 3-year olds in the coastal fishery is only negligible if not absent. The mortality in mackerel, hence can better be computed between the 1-year and 2-year old fishes occurring in the fishery.

In 1965-'66, for instance, 24.34 numbers of fish caught per unit of effort represented the 1-year old population. This seems to have reduced and represented as 0.09 fish in numbers of cpue next season as 2-year olds. In other words, a death of 99.63% of the fish and survival of only 0.37% is indicated in the season. The instantaneous total mortality (Z) here is 5.6001. The Z calculated likewise for other seasons at

Manassery are given in Table VIII along with the one that of 1965-'66. The Z during the period under study varied between 2.4557 of 1975-'76 and 7.4500 of 1972-'73.

6.6.2. INSTANTANEOUS NATURAL AND FISHING MORTALITY

The instantaneous total mortality of an underexploited species of fish exploited by a specific non-selective gear in principle should linearly be related to the effort expended in a season for its exploitation. Higher the effort, greater the Z becomes, and a lowering of the former causes a reduction of the latter. The values of Z for different seasons in this study were plotted against respective effort (f) of Thangu vala each season and given in Fig. 40. The Thangu vala being a multispecies gear exploiting other fishes as well, as and when they become available in the grounds, shows no apparent relation between its effort and the Z of mackerel (Fig. 40 A). The regression equation

$$Z = a + bf$$

where 'b' is the catchability coefficient (q) and 'a' is the instantaneous natural mortality (M) was fitted to the

Table VIII

Instantaneous total mortality (Z) and total effort (f) during different seasons

Seasons	Z	f
1965-'66	5.6001	10251
1968-'69	3.9845	8614
1969-'70	3.1721	6708
1970-'71	3.4413	14279
1971-'72	4.3843	14128
1972-'73	7.4500	9589
1973-'74	3.3554	9196
1974-'75	6.4710	7819
1975-'76	2.4557	5812
1977-'78	3.5523	7248
1978-'79	6.7303	9188

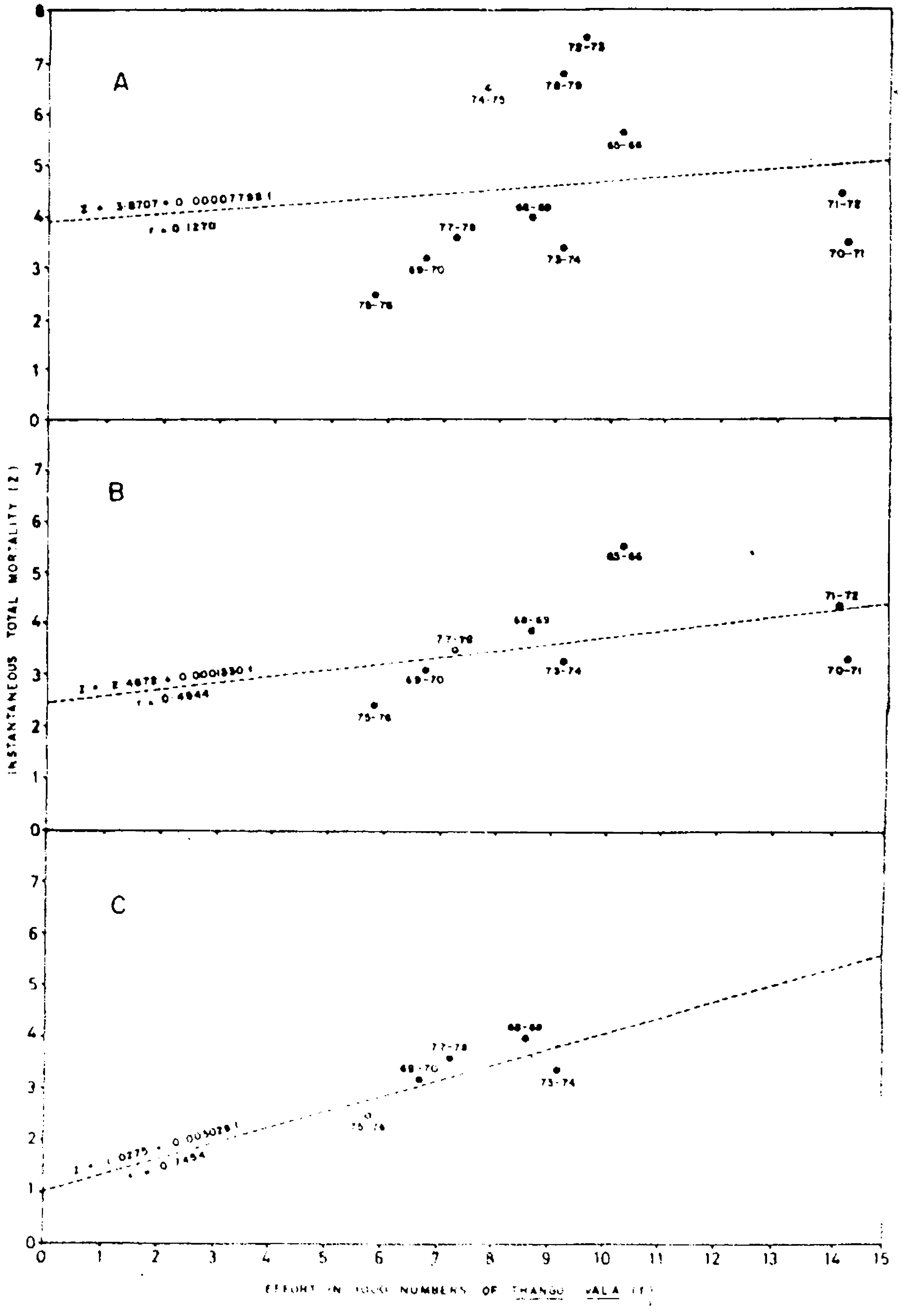
Fig. 40: Relation between effort *Thangu vala* and instantaneous total mortality (Z).

A. All seasons included.

B. Seasons of high Z omitted.

C. Seasons of high Z and F excluded.

Fig. 40



A
B
C
INSTANTANEOUS TOTAL MORTALITY (Z)
EFFORT IN 1000 NUMBERS OF THANGU VALA (f)
Z = 3.8707 + 0.00007798 f
r = 0.1270
Z = 2.4678 + 0.0001330 f
r = 0.4944
r = 0.7494
78-79
74-75
65-66
71-72
68-69
77-78
73-74
70-71
69-70
75-76

data. The 'q' for the available date in Table VIII in the equation was found to be 0.0000779849 and 'a' 3.8707.

Where

$$q = \frac{\bar{Z} - M}{\bar{f}}$$

the instantaneous fishing mortality (F) is the product of 'q' and 'f' as in the equation

$$F = q\bar{f} = \bar{Z} - M .$$

The $\bar{f}$ for the 11 seasons in Table VIII being 9348.36, the F is calculated to be 0.7290 and the $\bar{Z}$ is 4.5997. The value of 'r' in this being only 0.127 indicates absence of any linear relationship between fishing intensity by Thangu vala and Z and hence separation of M from Z by this method is not valid.

Invalidity of this calculation is comprehensible in yet another angle. The M 3.8707 as calculated above first of all is higher than the Z values of 1969-'70, 1970-'71, 1973-'74, 1975-'76 and 1977-'78 (Table VIII). Even in its simple arithmetic mean of 4.5997 for the period under study, death due to natural causes (3.8707) seems to be very high leaving only 0.7290 for mortality on account of fishing. In such a situation where exploitation is only 15.8% of the fishable stock, plenty of fish must be available in the grounds for further tapping at some time or other. Attempts to exploit mackerel with additional mechanized effort in recent years are with no positive results.

A regression of the data in Table VIII excluding 1972-'73, 1974-'75 and 1978-'79 seasons when Z was too high was attempted and the resultant equation is

$$Z = 2.4672 + 0.0001330 f .$$

The values of Z, F, and M were 3.7432, 1.2760 and 2.4672 respectively. Here too, the M is on the higher side (Fig.40 B). The exploitation accordingly is only one-third of the fishable stock. Moreover, the 'r' value at present being only 0.4544, it does not support a good linear relationship between fishing intensity and mortality.

A regression of Z and effort for 1968-'69, 1969-'70, 1973-'74, 1975-'76, and 1977-'78 avaoiding years of very high Z and f values in Table VIII was tried and the equation was

$$Z = 1.0275 + 0.003029 f .$$

According to this the Z, F, M, and r are respectively 3.3040, 2.2765, 1.0275, and 0.7454. The r value in this shows a linear relationship. The value of M being lower than that of F (Fig.40 C), it indicates an exploitation of 69%.

Separation of Z into F and M was tried again on the lines followed by Sekharan (1974) where the rate at which the population reduces to 1% level in unfished state during its effective life-span can be taken as its M. In the present study, the mackerel appears to enter into 4th year of life and its effective life-span (L max) hence is 5 years. According to the equation of Cushing (1968) which Sekharan seems to have followed

$$M = \frac{1}{L_{max} - 1} \log_e \frac{N_t}{N_{T\,max}}$$

when L_{max} = 5 years, N_t = 100 and $N_{T\,max}$ = 1, the value of M emerges as 1.1513.

Natural mortality in fishes can also be demonstrated as correlated to mean environmental temperature expressed for length - growth data by the multiple regression

$$\log_{10}M = {}^{-}0.0066 - 0.279 \log_{10}L\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T$$

of Pauly (1983).

The $L\infty$ and K as detailed elsewhere in the present study are 31.487857 cm, and 0.600774 respectively. The T according to an earlier study along the North Kanara Coast by Noble (1968) can be calculated as $28.28^{\circ}C$. Substituting the $\log_{10}$ values of these in the model, the M is calculated to be 1.2684.

Correlating the temperature data with weight - growth through Pauly's multiple regression equation

$$\log_{10}M = {}^{-}0.2107 - 0.0824 \log_{10}W\infty + 0.6757 \log_{10}K + 0.4687 \log_{10}T$$

the M turns out to be 1.2835 when $W\infty$ = 370.6385795 g (found from $L\infty$ using length-weight relationship), K = 0.600774, and T = $28.28^{\circ}C$ (Noble 1968). But with $W\infty$ 586.0178 calculated independently from the weights of the fish at different age classes the M becomes 1.2360 only.

An average of the values derived from the linear regression of 5 seasons, and through Cushing's (1968) and Pauly's (1983) methods gives the M in Indian mackerel to be 1.1708.

6.7. ESTIMATION OF MAXIMUM SUSTAINABLE YIELD

Based on the data on catch in kg (y), effort in numbers of Thangu vala (f), and cpue in kg (y/f) of the mackerel caught at Cochin given in Table IX, the value of 'b' and 'a' are found to be 0.00474017 and ¯20.21787573 respectively. The observed effort and cpue are plotted in Fig. 41 with the above regression equation fitted to it. As the 'b' value is positive and the 'a' value negative, the Schaefer's (1954) model

$$y/f = a - bf$$

or

$$y = af \; bf^2$$

$$MSY = \frac{a^2}{4b} \quad \text{and}$$

$$F_{max} = \frac{a}{2b}$$

are not useful here and the fishing as such does not seem to affect the stock.

The estimation of yield per recruit (Yw/R) using the

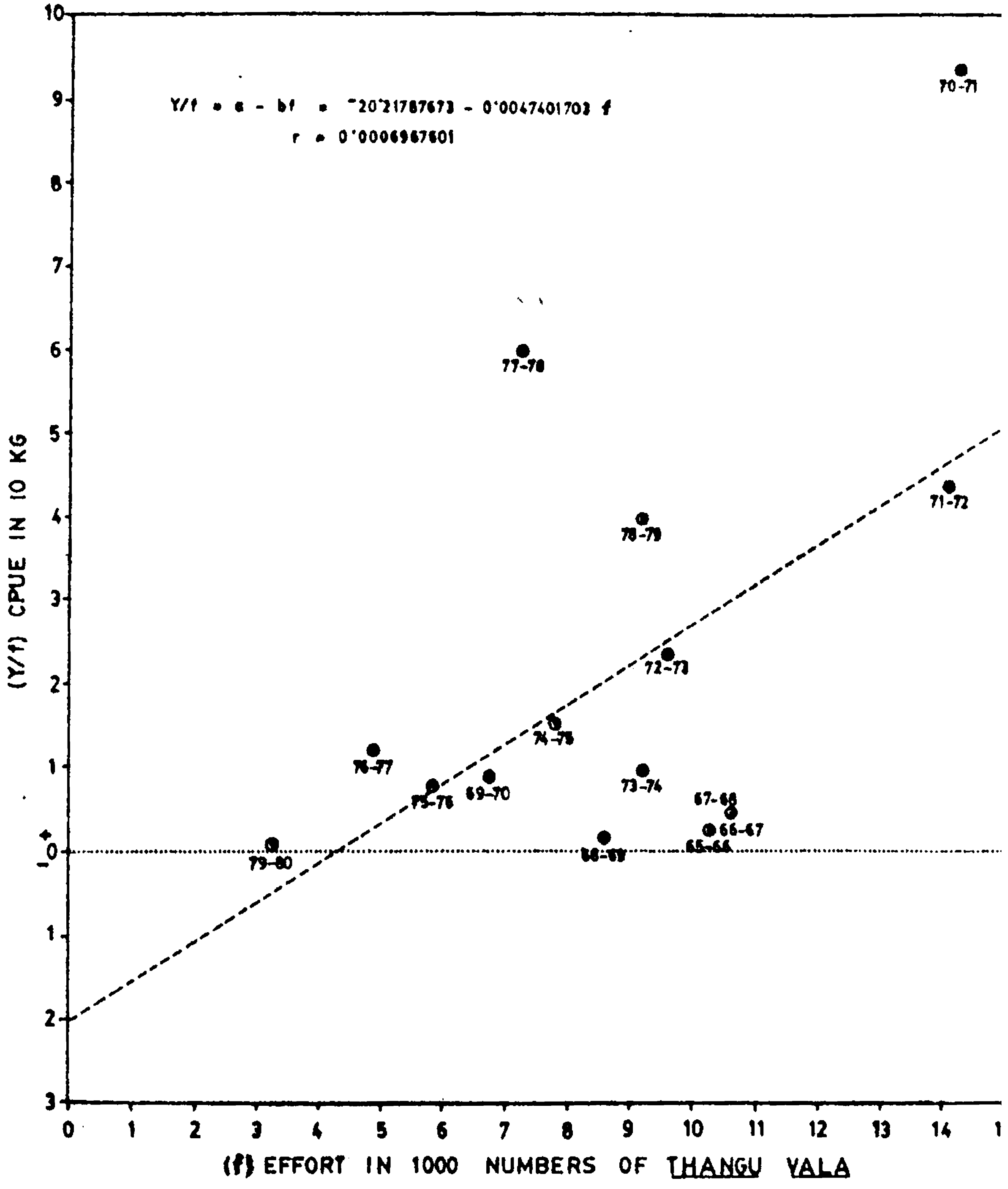
Table IX

Estimated catch in kg, effort of _Thangu vala_ in numbers, and catch per unit of effort in kg of the mackerel caught at Manassery (Cochin)

Season	Catch	Effort	cpue
1965-'66	28712	10251	2.801
1966-'67	50671	10632	4.766
1967-'68	48969	10580	4.628
1968-'69	15418	8614	1.790
1969-'70	61482	6708	9.165
1970-'71	1332468	14279	93.317
1971-'72	612422	14128	43.348
1972-'73	222030	9589	23.155
1973-'74	87591	9196	9.525
1974-'75	117693	7819	15.052
1975-'76	46233	5812	7.955
1976-'77	59131	4847	12.200
1977-'78	432406	7248	59.659
1978-'79	364451	9188	39.666
1979-'80	3013	4228	0.713

Fig. 41: Relation between effort (<u>Thangu vala</u>) and its catch per unit of effort in mackerel fishery.

Fig. 4



Y/f = a - bf = ¯20'21787673 - 0'0047401703 f
r = 0'0006967601
(Y/f) CPUE IN 10 KG
(f) EFFORT IN 1000 NUMBERS OF THANGU VALA
70-71
77-78
71-72
78-79
72-73
74-75
76-77
75-76
69-70
73-74
67-68
66-67
65-66
68-69
79-80

formula of Beverton and Holt (1957) simplified by Ricker (1958) where Yw/R is equal to

$$Fe^{-M(tc-tr)}W\infty\left[\frac{1}{F+M} - \frac{3e^{-K(tc-to)}}{F+M+K} + \frac{3e^{-2K(tc-to)}}{F+M+2K} - \frac{e^{-3K(tc-to)}}{F+M+3K}\right]$$

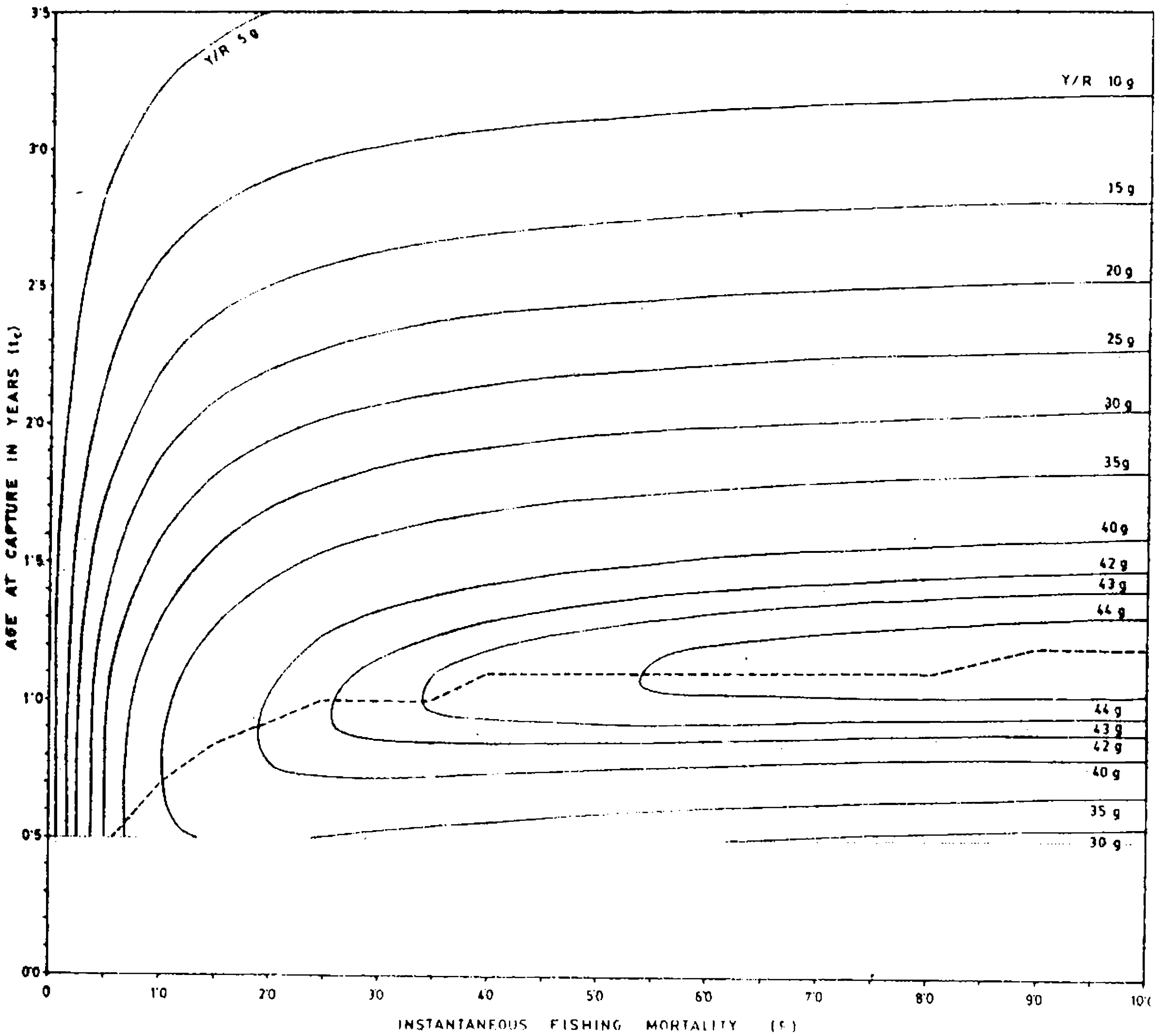
was done by feeding the values of

$W\infty$	=	370.6385795
K	=	0.600774
t_o	=	-0.1413431664
tr	=	age at recruitment
tc	=	age at capture and
M	=	1.1708

into a computer programme and the resultant Yw/R at various values of F against changing ages are found out and plotted in Fig. 42. The mackerel gets caught as and when they are recruited and hence its tr and tc are considered to be equal to one another. The fishing as already sensed while applying Schaefer's (1954) model, is not adversely affecting the stock in this computation also. Nevertheless enhancement of fishing intensity (F) does not seem to have any concurrent appreciable increase in the yield per recruit.

Fig. 42: Eumetric fishing curve of mackerel.

Fig. 42

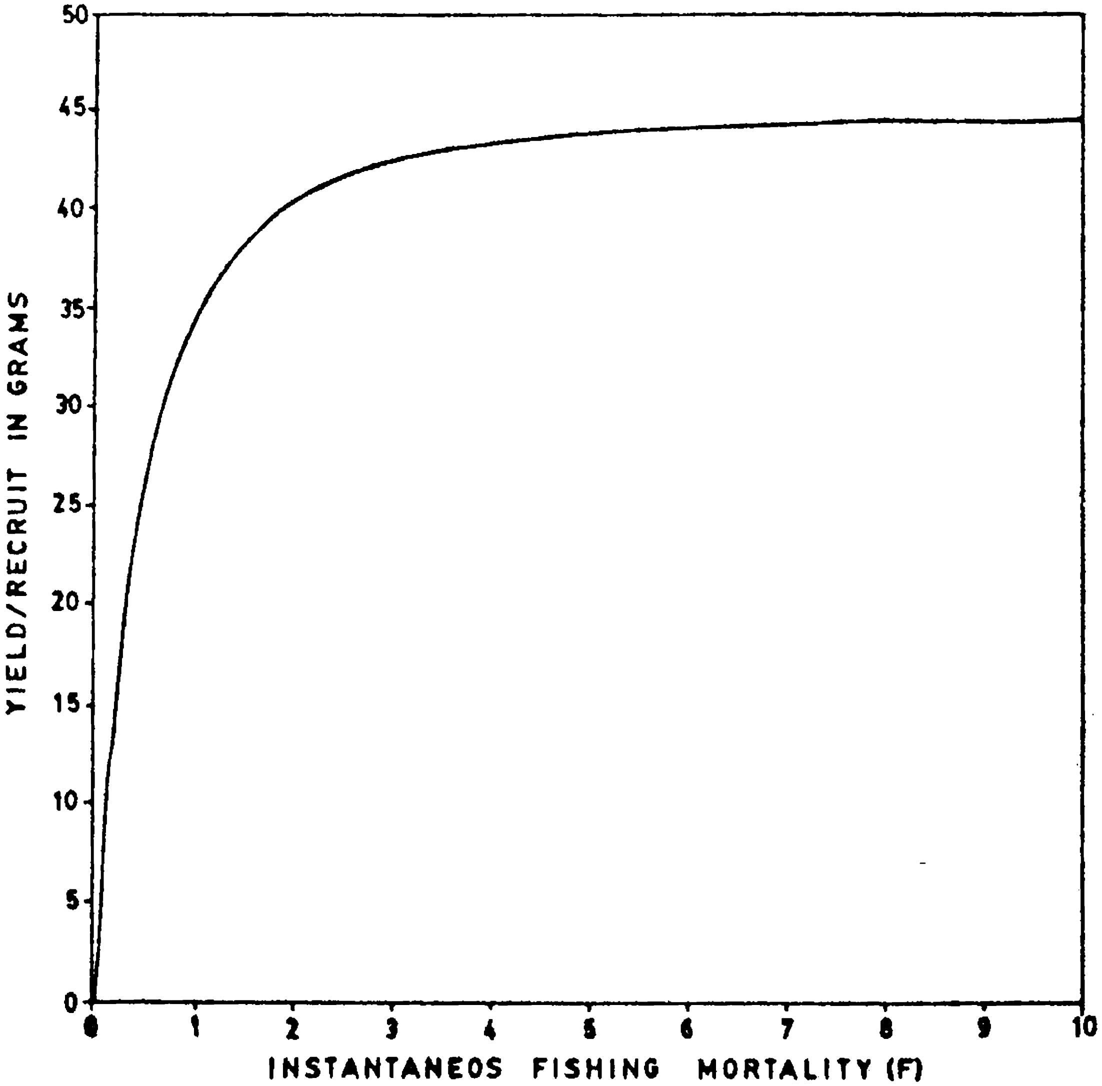


Y/R 5 g
Y/R 10 g
15 g
20 g
25 g
30 g
35g
40 g
42 g
43 g
44 g
44 g
43 g
42 g
40 g
35 g
30 g
AGE AT CAPTURE IN YEARS (t_c)
0·0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
0
1·0
2·0
3·0
4·0
5·0
6·0
7·0
8·0
9·0
10·0
INSTANTANEOUS FISHING MORTALITY (F)

Yield per recruit of the fish in each age at various F values was then computed separately and the maximum got against different fishing intensities are plotted for Eumetirc Yield Curve in Fig. 43. The curve according to this takes a right turn after F 2 and more or less stabilizes at 4 though it drags beyond and continues to ascend with almost insignificant additions to succeeding values on the preceding ones. The Eumetric Fishing Curve as plotted in Fig. 42 also shows stagnation between F 4 and 8. This stabilization attained at F beginning with 4 is exhibited right at the commencement of commercial exploitation itself when the fish is 1-year old (Fig.42). However, the best age for large-scale exploitation of commercial importance is derived by plotting the increment in Yw/R between fishes at consecutive ages at changing F values in Fig. 44. The best results according to this are obtained when the fish is 1.55 years of age. The length at age, back calculated by using VBGF and plotted in Fig. 39 indicates the length at age 1.55 years to be about 200 mm, and as per the pooled value of the length-weight relationship worked out in this study, it may weigh about 83 g.

Fig. 43: Eumetric yield curve in mackerel fishery.

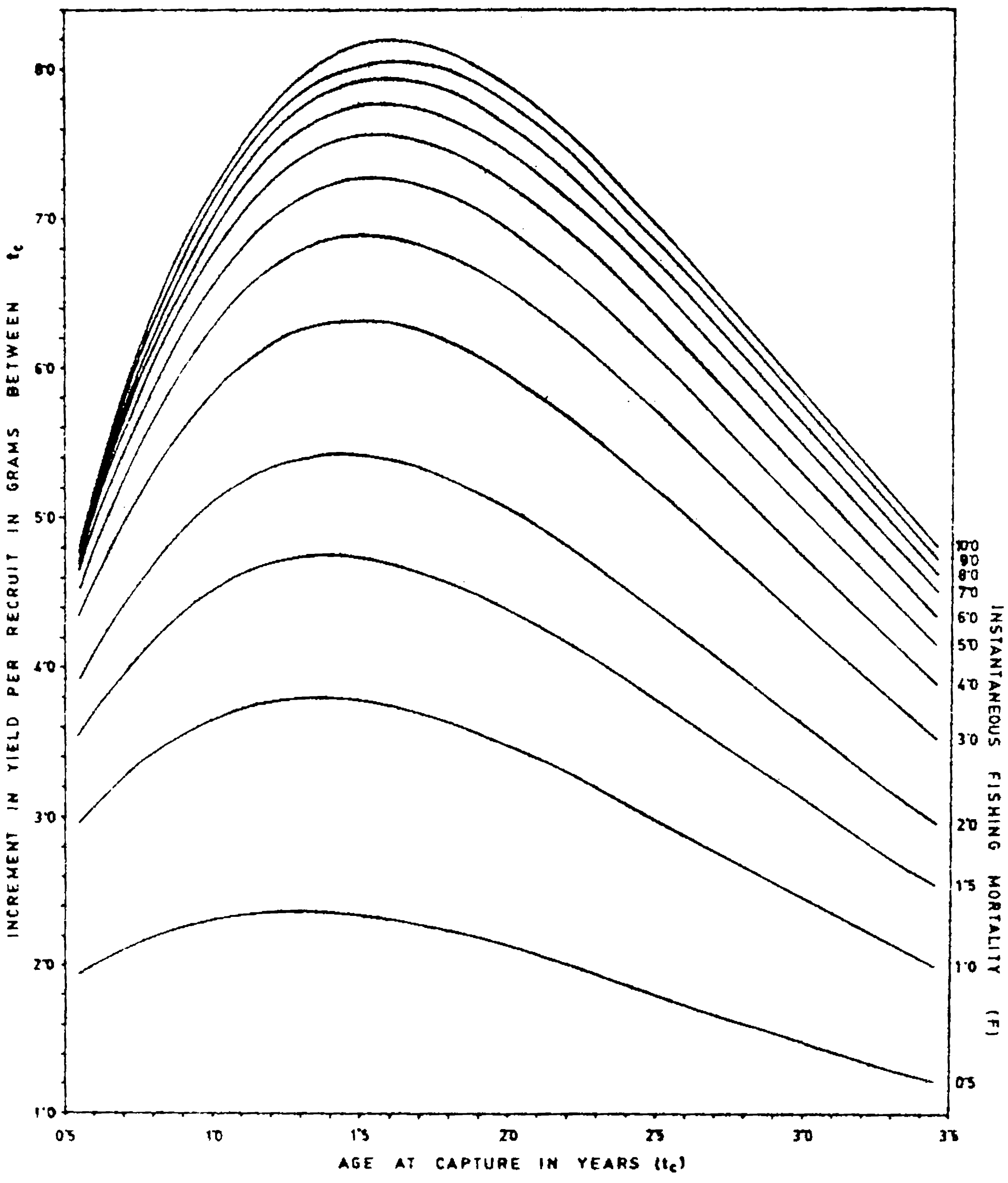
Fig. 43



YIELD/RECRUIT IN GRAMS
50
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
INSTANTANEOS FISHING MORTALITY (F)

Fig. 44: Yield per recruit of the mackerel fishery at different ages and varying values of F.

Fig. 44


INCREMENT IN YIELD PER RECRUIT IN GRAMS BETWEEN t_c
AGE AT CAPTURE IN YEARS (t_c)
INSTANTANEOUS FISHING MORTALITY (F)
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
10·0
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·5
1·0
0·5

6.8. RATE OF EXPLOITATION

The mackerel fishery in 1970-'71 season was the best (Fig.24) with highest catches in the history of the species. The fishery was widely spread out in all the months of the season and chances of representation of different year classes in the catches thereby were very good. In 1971-'72 also the season was a protracted one. The 1-year old population in 1969-'70 represented as 120.00 numbers of fish caught per unit of effort reduced to 5.03 numbers of 2-year old fish caught per unit of effort in 1970-'71. The 1055.17 numbers of 1-year old fish caught per unit of effort in 1970-'71 likewise reduced to 33.79 numbers of 2-year old fish caught per unit of effort in 1971-'72 (Table VII). The instantaneous total mortality in 1969-'70 and 1970-'71 accordingly were 3.1721 and 3.4413 respectively (Table VIII). Pooled data for the 15 seasons from 1965-'66 to 1979-'80 on the age composition of the catch was computed to be 90.33 fish caught per unit of effort in 0-year olds, 271.08 fish in numbers of cpue in 1-year olds, 12.32 fish caught per unit of effort in 2-year olds and 0.01 numbers of fish in cpue in 3-year olds. Between 1 and 2-year olds which form the bulk of the catch the instantaneous total mortality is 3.0913 and it closely approximates the values for the seasons of abundance with well spread out catches already dealt with above. An arithmetic mean of the above 3 values along with 3.3040 computed for 5 seasons excluding seasons of very high Z and effort, calculates the Z to be 3.2522. The average value of M derived early in this study being 1.1708, the F value emerges as 2.0814.

The rate of exploitation according to the formula

$$U = \frac{F}{M+F}\left[1-e^{-(F+M)}\right]$$

of Ricker (1958) based on above values of M and F is 0.6152. According to Gulland (1971), the maximum sustainable yield is optimized when F = M and the exploitation rate is about 0.5.

6.9. ESTIMATION OF STOCK

The average all-India yield (Y) of mackerel during 1969-'80 period was 87,257 tonnes. The standing stock (Y/F) accordingly is 41,922 tonnes, and the annual stock (Y/U) is 141,835 tonnes.

The F as already found in the Eumetric Fishing Curve stays almost stabilized between the values 4 and 8. Increase in yield after F 4 is very nominal and worth not bothering for. However, on account of the existence of a tendency for increase, it is felt safer to clamp the F max as 5.0, and at a value of 1.1708 M, the Z becomes 6.1708. The values of Z in most of the seasons as seen in Table VIII are within this limit only.

Where the F max is 5.0, and Y/F is 41,922 tonnes, from the relation

$$Y_{max} = F_{max} (Y/F)$$

the potential mackerel yield in India is 209,610 tonnes, and the highest annual estimated landing of 204,575 tonnes (Fig.2) as it occurred in 1971 approximates to it.

At F 2 where the yield curve turns to the right, the yield could be 83,844 tonnes and at F 4 where stabilization begins it would be 167,688 tonnes. The average yield of 87,257 tonnes during 1969-'80 is within this range.

7. DISCUSSIONS

7. DISCUSSIONS

Investigations in this study were carried out on resource characteristics of the species such as fluctuations in spatial and temporal production; biology such as length-weight relationship, growth and age; and parameters on population for stock assessment such as mortality, recruitment and yield. The results obtained thereof are discussed here, gaps that exist in its research identified and future course of action suggested.

7.1. DISTRIBUTION AND PRODUCTION

The Indian mackerel is known to be of commercial importance in India, Sri Lanka, Malaysia, Philippines, Cambodia and Thailand (Jones and Rosa 1965). As detailed by Panikkar (1967) India tops among them in its production. Eightynine per cent of the mackerel caught in India according to this study come from the west coast. As already identified early (Noble 1976, 1979, and 1982 a) Kerala, Karnataka and Goa (Fig.6) are the states here where mackerel are abundantly caught. Here too places of heavy production now identified with illustrations are Ernakulam and areas of contiguous districts (Fig. 16: 4-5), and Kozhikode - Cannannore and areas of contiguous districts (Fig. 16: 7-9) in Kerala; Mangalore (Fig. 17: 1), Malpe (Fig. 17: 3), and Karwar

(Fig. 17: 5) in Karnataka; and Panaji (Fig. 13: 2) in Goa.

Recent exploratory surveys conducted off Andhra and Orissa coasts report good concentrations of mackerel at 40-59 m depth range, 50-60 km away from shore during October-January period. About 12 tonnes of mackerel were caught in a single haul (Somvanshi and Joseph 1983) during this survey, and the coast is suggested as highly productive for the species. But it is yet to be commercially exploited.

Annual landing in the country (Fig.2) as well as the states (Fig.4), fluctuate from year to year. The fishery in the country as at different centres including Cochin shows a 10-year cycle in long-term fluctuations with peaks in catches at the confluence of 2 decades and troughs in the middle of each (Noble 1980). Moreover, the catch at Cochin as seen now (Fig.24) fluctuates widely from season to season. Causes governing these fluctuations are briefly considered below:

Fishery independent factors: Though the landings show wide fluctuations (Fig.24), the effort expended at Cochin (Fig. 26) does not move parallel to it. Fluctuations in the fishery evidently are not caused by fishing, and as Banerji (1962) suggested at other places, it is due to fishery-independent factors; like the following.

Recruitment strength: At Cochin no negative relation between the effort and production (Table IX), and effort and cpue (Fig.41) exist. Indigenous fishing likewise does not cause the fluctuations at Mangalore also.(Yohannan 1982). These fluctuations, as suggested by Banerji (1963) elsewhere, depend mainly on the recruitment strength from season to season. But study on the effect of fishing on stock throughout the country is necessary to draw final conclusions. As there is no specific gear for the exploitation of mackerel and a variety of selective and non-selective gear with mechanized and indigenous crafts are in use from place to place such a study may not be an easy task.

The recruitment strength in turn may depend on many factors such as spawning; fecundity; survival of eggs, larvae and young fish; habits of fish and environmental conditions.

Spawning: Occurrence of larval stages on shelf waters of south west coast alleges it to be the spawning ground for mackerel (Silas 1974, and PFP. 1974 a). However, no dense concentration of spawning fish or large quantities of eggs or larvae were detected in this area (PFP. 1974 a). As reported by Noble (1974 a) spawning fish were not encountered in the coastal fishery at Cochin. But maturing, spent and spent recovering fish are caught here indicating a likely pre-monsoon and post-monsoon spawning (Noble 1974 a). Possibility of such 2 distinct spawning periods for mackerel at other places is mentioned by Sekharan (1958), Radhakrishnan (1962), PFP. (1976 c) and Yohannan (1977). The fish of post-monsoon season according to Noble (1974 a) contribute largely to the fishery and the recruitment strength may depend, over and above the density of spawning, on the time of spawning also. Vessel bound programmes investigating on the spawning grounds, on spawning strength and periodicity need to be undertaken with priority.

Fecundity: It is important that the reproductive potential of the Indian mackerel be known. However, there is no attempt on this except that of Ramamohana Rao (1967) at Mangalore. Mature fish being not available in the landings at Cochin during the course of this work, fecundity studies could not be undertaken. Nevertheless, it is recommended as a topic for continuous monitoring to assess the number of eggs that could be released by the spawning population during breeding time.

Survival: The reruitment strength depends on the survival of the stock in all stages of the life of the fish particularly at its crucial early phase. Investigations on eggs and larvae, and young fish hence should follow the spawning survey and fecundity studies. In early nineteen seventies, the Pelagic Fishery Project (PFP. 1974 a, and 1975 a) made some pioneering studies on these regarding areas of their occurrence, season and densities from Ratnagiri to Tuticorin. But estimates on survival were not attempted though it could provide advance information on prediction of recruitment strength. It is suggested that such a study should form an annual feature in future.

Young mackerel of less than 100 mm size and below occur almost simultaneously at different centres along the west coast (Virabhadra Rao 1962) but no detailed study on their recruitment has so far been done. However, attempts made on this by Pelagic Fishery Project on west coast by trawling during March - August of 1972, 1973, and 1974 brought to light 45% of the hauls in May (other months remaining much less) to contain young fish ranging in size from 10 to 100 mm caught mostly in 20-29 m depth their relative abundance in these years being about 15,000; 4,000; and 6,000 numbers per haul respectively (PFP. 1975 b). As the fishery depends on annual replenishment of stock by young fish the study on their relative abundance from season to season is of prime importance. It will assist estimation of mortality, assessment of stock and prediction of fluctuations in advance.

Environment: Fluctuations in production depend upon survival of the fish and recruitment, influenced mostly by fishery-independent environmental factors of which monsoon, rainfall, upwelling, and physical, chemical and biological conditions of the sea are some major ones.

Monsoon and rainfall: Over a period of 11 years, the mackerel landings at Karwar were observed by Noble (1972) to be more when the local rainfall was less and less when the rainfall was more. The failure and success in the fishery coincided respectively with high and low records of rainfall at Calicut by Pradhan and Reddy (1962) also. At Cochin this aspect was not investigated on account of comparatively low landings. But verification of this phenomenon is necessary at all places and as the monsoon precedes the season of mackerel, it may indicate the prospects fishery of a given year in advance. According to Panikkar (1949), the delay in monsoon is often followed by a delay in the commencement of the season. This if further confirmed could help in short-term forecast of the commencement of the fishery.

Hydrological factors: Noble (1968) investigating on the sea-water off North Kanara Coast showed the temperature and salinity from their low values in monsoon season to gradually move up during October-March to the high values of summer months coinciding with the season for mackerel fishery. The temperature and salinity congenial for mackerel fishery according to Sadananda Rao et al. (1973) are 28.2 - 28.4°C and 33.5 - 36.0‰ respectively. The proximal optimums for mackerel according to Pradhan and Reddy (1962) at Calicut are temperature 29.1°C and salinity 33.27‰, and one criteria for a good mackerel season is the degree of their variations within tolerance ranges. No attempt, though necessary, is made at Cochin to correlate the fishery with environmental conditions for want of concurrent hydrological studies.

At Karwar, Noble (1972 a) found the mackerel season of long duration to follow the occurrence of very low minimum temperature in inshore waters during the south west monsoon period, and an elevation in this temperature was followed by a season short in length. Time taken for the transition from low values of temperature during monsoon to high values of summer also depends on this. As the occurrence of the minimum temperature precedes the season for mackerel, it could be used to predict its duration in advance and hence desirable to watch it at other centres of well defined seasonal fishery.

The annual mean values of <u>dissolved oxygen</u> content in the surface inshore waters at Karwar for a number of years showed an inverse relation to the mackerel catch there (Noble 1972 a). When the catch was more the oxygen was less and when the catch was less the oxygen was more. Is it due to the effects of upwelling or what really causes it is worth investigating.

<u>Upwelling</u>: It is an important process for fisheries and study on its period and quantity is imperative to correlate it with the commencement of the season and productivity of the area. Penetration of low oxygen layer of deep waters into the shelf area during August/September pushes the fish to surface (PFP. 1976) and also enriches the waters to a great extent leading to high organic production and good fishery after the monsoon (Sadananda Rao <u>et al</u>. 1973).

<u>Surface drift</u>: Noble (1968) investigating on the sea - water off North Kanara Coast detected a southerly drift of coastal cold water during the rainy season and northerly current during winter months, and said that in some years it does not reach up to Karwar or if it does, it is not possibly touching the inshore waters. There is every reason to believe the

mackerel to move with this drift and the coastal fishery fails when the drift stays away from nearshore waters. Sadananda Rao *et al*. (1973) suggested the mackerel to probably move with this northward current and Murthy (1965) said that it would provide a probable prediction system for our pelagic fisheries. The coastal drifts have to be intensively studied every year and it would probably bring to light some reasons that govern the fluctuations in the fishery.

Food and plankton: The mackerel is a feeder on plankton (Noble 1962 and 1974 a). According to the studies on the food and feeding at Karwar by Noble (1962) the quantity of food present in the stomach was almost directly proportional to the production of plankton in inshore area. Most active schooling and maximum concentrations of mackerel as said by (PFP.1973 b), depend on abundance and distribution of plankton.

According to Noble (1962 and 1974 a) copepods formed the prominent item of food for mackerel. Commenting on the occurrence of cladoceran swarms with the onset of mackerel fishery, Selvakumar (1970) said that there is enough reason to propose the appearance of cladocerans in swarms progressively from south to north to herald the mackerel shoals. But studies on the food by Noble (1962) at Karwar and (1974 a) at Cochin show the cladocerans to be an item of less importance than copepods. The mackerel being a general plankton feeder, there is little scope to connect its fluctuations with any planktonic item and identification of an indicator species. Work on food and feeding at Cochin was not included in this study.

Seasons: The mackerel besides being highly fluctuating in landings from year to year is seasonal in its occurrence too. In the northerm latitudes on west and east coasts according to the present study the season is good in the first part of the year and in the southern latitudes it gets abundant in the second part only (Fig.20). The season's peak gradually shifts from March in Orissa and Andhra to April in Tamil Nadu - Pondicherry in the east coast (Fig.20).

In the west coast, with the outbreak of south west monsoon shoals comprising of young fish appear in inshore waters followed later by commercial sizes (Noble 1972 b). Along this coast, the peak which occurs in April-May in South Kerala gets shifted to September-October in its north. In Karnataka and Goa the climax falls in October and in Maharashtra in November (Fig.20). The season on west coast starts early in the south and lasts long. Towards north it commences late and culminates early (Noble 1972 c).

In Gujarat (Fig.20), the peak as in Orissa, happens to be in March.

Making a quantitative study of the landings of the country Chakraborty et al. (1973) report two-thirds of the landings in a year to occur in October-December and one-fourth in January - March. In the present analyses, catches in west coast as also in the country as a whole are highest during September-November with peak in October (Fig.22). In east coast good catches occur in March-April with the highest occurring in March (Fig. 22).

What controls the season and how it is related to the environmental factors are matters requiring continuous investigations. At the same time changes that take place in the behaviour of the fish cannot be ignored.

Schooling: This is the major behavioural subject little understood and investigated. Though mackerel is believed to spawn along a long stretch between 8^{0}N to 16^{0}N on west coast no concentration of spawning fish and large quantities of eggs or larvae were collected at any time so far (PFP. 1974 a), and the non-availability of the mackerel larvae in really dense quantities is intriguing because larvae of some other scombroid fishes like frigate mackerel are caught in large numbers.

The mackerel is believed (PFP.1973 a) to form distinct schools from the size of about 90-100 mm onwards only. But according to the fishery at Cochin, it would appear to take place even at a smaller size as evidenced by the capture of 12.701 tonnes (Fig.24) ranging from 65 to 95 mm with mode at 75 mm in July 1975 (Fig. 23 and 28). The average length of the fish landed in the month was 79.9 mm only (Fig. 29). Work on physiological changes in the fish during its lifetime has to be taken up to find an answer to it. This should go hand in hand with more investigations on the spawning grounds and seasons.

Migration: Commencement of season first in the south and subsequent spreading towards north already explained, indicates northward migration of mackerel along west coast during the season. Dense occurrence of shoals in a continuous belt off Ponnani-Mangalore region and only isolated patches in grounds further north in September-October just before the commencement of the season as revealed by aerial surveys conducted in 1973 and 1974 (PFP. 1974 b and 1975 a) further fortifies the above findings. The northward movement of tagged mackerel at Cochin, in the experiments conducted by Noble (1974 a), in season time too endorses it. The season concludes first in the north and progressively southwards. The fish is believed to move to the south then, but it needs confirmation by large-scale tagging.

7.2. GROWTH AND AGE

Pradhan (1956) from his studies on the Indian mackerel at Karwar opined that those fish measuring 160 to 180 mm are 1-year old, while above 180 mm they are 2-year old. Dealing with the South Kanara coastal fishery, Sekharan (1958) concluded that 120 to 150 mm size fish are 1-year old, and at the end of 2nd year they measure 210 to 230 mm. Ramamohana Rao _et al_. (1962) on their study of mackerel at Mangalore say that the calculated lengths at age 1, 2, 3, and 4 years are 150.7, 225.3, 266.2, and 288.9 mm respectively. Seshappa (1969) through his investigations on scales and otoliths of mackerel explained them to reach a total length of 110-150 mm by the end of 1st year, 210-240 mm at the end of 2nd year, 250-270 mm at the end of 3rd year, and 280-290 mm at the end of the 4th year of life. From the studies of _R.kanagurta_ from Andamans, Luther (1973) provisionally estimated the size as 148, 218, 265, 302, and 330 mm respectively at the completion of 1, 2, 3, 4, and 5 years of life. On the other hand, George and Banerji (1962), opined that the mackerel at the 1st year itself to reach a length of 220 mm. Noble (1974 a) opined that the fish of the pre-monsoon brood to grow to around 140 mm in a year before appearing in the pre-season fishery. The fishes of post-monsoon brood according to him start life in favourable circumstances with abundant supply of food in calm weather grow more quickly than the ones in the pre-monsoon brood and attain about 180 mm in a year. Daily growth increment in the fish of the 2 brood have to be separately worked out for further elucidation of this observation. However, the following works lent support to it.

Investigations of the Pelagic Fishery Project (PFP. 1976 c) suggest about one major brood produced yearly, with its bulk probably occurring in the course of 2-3 pre-monsoon months. Spawning according to PFP. (1976 c), obviously occurs at other times of the year also and it is possible that they be of importance in some years. Studies of Yohannan (1979) on the growth pattern of Indian mackerel at Mangalore also suggest the occurrence of more than one brood and show the latter brood to grow faster than the earlier ones.

Commenting on the growth of mackerel at Cochin, Noble (1974 a) said that the fish may grow on an average of 10 to 15 mm only per month, and by one year a length between 120 to 180 mm may be attained depending on the time of birth. In the present investigation on monthly average sizes, in accord with the length adopted early by Noble (1974 a), the fish below 160 mm are considered here as 0-year old. Fish of 160-229 mm size and 230-269 mm size are worked out in this study as 1-year and 2-year old respectively. At a length of 270 mm and above the mackerel is here found to be 3-year old, and this age structure has already been used in the population studies of the Indian mackerel by Noble in 1979.

Observing the progression of modal sizes in commercial catches of successive months, George and Banerji (1962), assumed the fish at 1st month to average 60 mm in length. Using von Bertalanffy's Growth equation they calculated this fish to reach 135, 192, 214, and 224 mm at 3, 6, 9, and 12 months respectively. Supporting this Yohannan (1979) in his studies at Mangalore said the fish to attain a mean length of 194.5 and 234.5 mm respectively at about 6.5 and 15.5 months. While doing so, Yohannan has deliberately suppressed his views and findings already published in 1977 from the studies on the same material where he upheld the mackerel to measure 140-160 mm only in the 1st year of its life and 200-220 mm in the 2nd year. Udupa and Bhat (1984) investigating on the mackerel landed by purse seines at a few places along Karnataka coast expressed the view that mackerel measuring less than 200 mm in total length belong to the 1st year, between 200 and 240 mm to the 2nd year, and between 240 and 260 mm to the 3rd year. The average lengths, 194.5 and 234.5 mm considered as 6.5 and 15.5 months old by Yohannan (1979) were attributed to 1 and 2 years of age respectively by them. Moreover, fish of 252 mm mean length was assigned to the age of 3 years. While the findings of only George and Banerji (1962) disagree with the age-length structure derived in the present study, the views of almost the entire remaining works strengthen it.

Investigating on R.kanagurta of Andaman Islands, Luther (1973) stated the fish up to 110 mm to have a growth rate of 22 mm per month. As already opined by Noble (1974 a), mackerel is believed to grow very fast in its infancy. Fitting length-at-age data with von Bertalanffy's Growth equation, the mackerel in the current study at Cochin is calculated to attain a length of 39.8 mm in the 1st month of its life. In the subsequent 2 months it appears to reach 53.2 and 66.0 mm sizes respectively (Fig.39). Working on the growth pattern, George and Banerji (1962) said the fish to attain, as already stated, 60 mm in the 1st month itself. Yohannan (1979) while finding out the population parameters divided the growth of mackerel into premature and mature phases and said the fish to reach around 60 mm in the 1st month, 83 mm in the 2nd and 118 mm length in the 3rd month. Though the fish has fast growth in the beginning, those suggested by George and Banerji (1962), Banerji (1970) and Yohannan (1979) appear erroneous when growth parameters like $L\infty$, K and t_0 computed by them are taken into consideration.

The $L\infty$ of the Indian mackerel calculated by George and Banerji (1962) for Cochin, Calicut and Karwar were 217.7, 232.6, and 224.0 mm respectively. The pooled value for the above 3 places is 228.4 mm. The respective growth co-efficient K for the above were 0.43, 0.26, 0.36, and 0.30; and they assumed the t_0 of the fish to be just zero only. Fitting Bertalanffy's Growth equation to the average size attained by the fish at the end of successive months in its life, Banerji and Krishnan as quoted by Banerji (1970) subsequently obtained the estimates of $L\infty$, K and t_0 for some centres along the west coast as follows:

Place	Estimation of growth parameters		
	$L\infty$ in mm	K	t_0 in years
Cochin	222	0.40	$^{+}0.071$
Calicut	233	0.26	$^{-}0.005$
Cannannore	226	0.36	$^{+}0.053$
Mangalore	228	0.42	$^{+}0.154$
Karwar	229	0.41	$^{+}0.169$
West coast	235	0.26	$^{+}0.029$

For the mackerel at mature phase in Mangalore, Yohannan (1979) computed the $L\infty$, K, and t_0 as 271.82 mm, 0.659, and $^{-}1.142$ year respectively.

The commercial catches especially by mechanized units commonly contain fishes of 275 mm length (Pai _et al_. 1983). Even with indigenous units the sizes ranged between 170-320 mm at Andamans (Luther 1973), and between 240-320 mm at Vizhinjam (Narayana Rao 1962). The $L\infty$ values derived by George and

Banerji (1962), Banerji (1970) and Yohannan (1979) do not project the currect picture of growth.

At Mangalore Ramamohana Rao et al. in 1962 calculated the $L\infty$, K, and t_0 as 316 mm, 0.6 and $^{-}0.24$ respectively. This $L\infty$ closely approximates the sizes of 320 mm that are commonly caught both in the west and east coast (Narayana Rao 1962 and Luther 1973). Luther (1973) at Andamans found R.kanagurta to reach an asymptotic growth when it attains 390 mm length at a K of 0.74. Though the maximum size he got at Andamans was only 337 mm, his calculation of $L\infty$ equals exactly the one in record as the maximum (Beaufort 1951) for the species. Working on the age-length structure (given by Luther 1973) of R.kanagurta at Andamans, Devaraj (1983) computed the $L\infty$, K and t_0 of the Indian mackerel there to be respectively 401 mm, 0.316, and $^{-}0.4438$ respectively and said that the Indian mackerel with $L\infty$ of 253 mm, K of 1.97, and t_0 of $^{-}0.186$ in the west coast is different from that of the Andaman waters. The Indian mackerel of Andamans is generally bigger in size and hence it may be true. But length up to 348 mm and 360 mm are recorded respectively at Goa (Dhawan 1976) and Karwar (Dhulkhed and Annigeri 1983) in west coast also.

L_∞ calculated in the current investigation for the mackerel off Cochin (315 mm) is almost the same as the one (316) that which Ramamohana Rao et al. (1962) found out at Mangalore, and it compares favourably with the values of 300-330 mm estimated by Holt (1959). Being close to the maximum size (320 mm) that is exploited along the west coast (Narayana Rao 1962), this seems to be a more appropriate presentation of the population structure than any other available finding.

The parameter K stands for the co-efficient of growth in the fish. High values of it indicates that a high proportion of food is utilized for growth and vice versa. Since up to half of the food energy intake is likely to be used up in metabolism, values of K greater than 0.5 are high and values of 1.0 or more are 'absurdities' usually indicating faulty techniques (Hastings and Dickie 1972). The values of K given by Yohannan (1982) and Devaraj (1983) being 1.84 and 1.97 respectively, hence are to be considered incorrect. The value of K found out by Ramamohana Rao et al. (1962) as already stated is only 0.6. Similarly the K got by Holt (1959) too is o.65. The K derived at present being only 0.600774 is an almost balanced condition and hence considered suitable.

High values of K show the fish to be a short-lived one and low values proclaim long life. According to the K of 1.97 given by Devaraj (1983) the mackerel lives only for 1.5 years. On the contrary, on the K of 0.26 given by George and Banerji (1962) the fish lives for 11.5 years. At a K of 0.6 as seen in the present study, the life-span of mackerel is 5 years and it agrees with the L_{max} used in the study.

The value of $L\infty$ and K in the present study, as their corresponding t_0 is $^-0.141$ canmot be taken as fool-proof. The t_0 actually denotes the period of incubation of egg. The embryonic development takes place within the egg and the size of embryo on the eve of hatching cannot be zero as assumed by George and Banerji (1962). The size of the embryo will be zero only at the time of fertilization and time at which the size is zero should then always be negative. The positive values of t_0 got by Banerji (1970) at places other than Calicut are incorrect.

Working on R.neglectus in the Gulf of Thailand, Hongskul (1972) estimated its t_0 to be $^-0.03$ months or about a day. Through experiments on artificial fertilization and subsequent rearing of larvae of R.neglectus, Boonprakob and Dhebtaranon (1972) observed the eggs to hatch in 20.5 to 27.25 hours, depending on the temperature of the water. These in turn then suggest a t_0 of $^{-}0.028$ - $^{-}0.038$ months for R.neglectus in the actual developmental process too. Unfortunately, no such work is available for R.kanagurta. However, R.kanagurta being an allied species of R.neglectus its hatching time may also be around a day or so and its t_0 may too will be around $^{-}0.03$ months or $^{-}0.00274$ years. The values that are otherwise, though fitting well into the mathematical models with which they are derived, do not represent the actual condition prevalent with the species. The ultimate way to find an infallible structure on von Bertalanffy's Growth Function is to have its embryological and early life histories through juveniles worked out by artificial experimental provings fortified by corroborative investigations at the spawning grounds for natural stage by stage increment in length after hatching and through experiments on mark release when the fish are on migration. The t_0 $^{-}0.141$ got at present is thus not the final answer and it can serve only as a substitute on stop gap basis till such time the correct one is experimentally proved as in the case of R.neglectus.

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7.3. MORTALITY

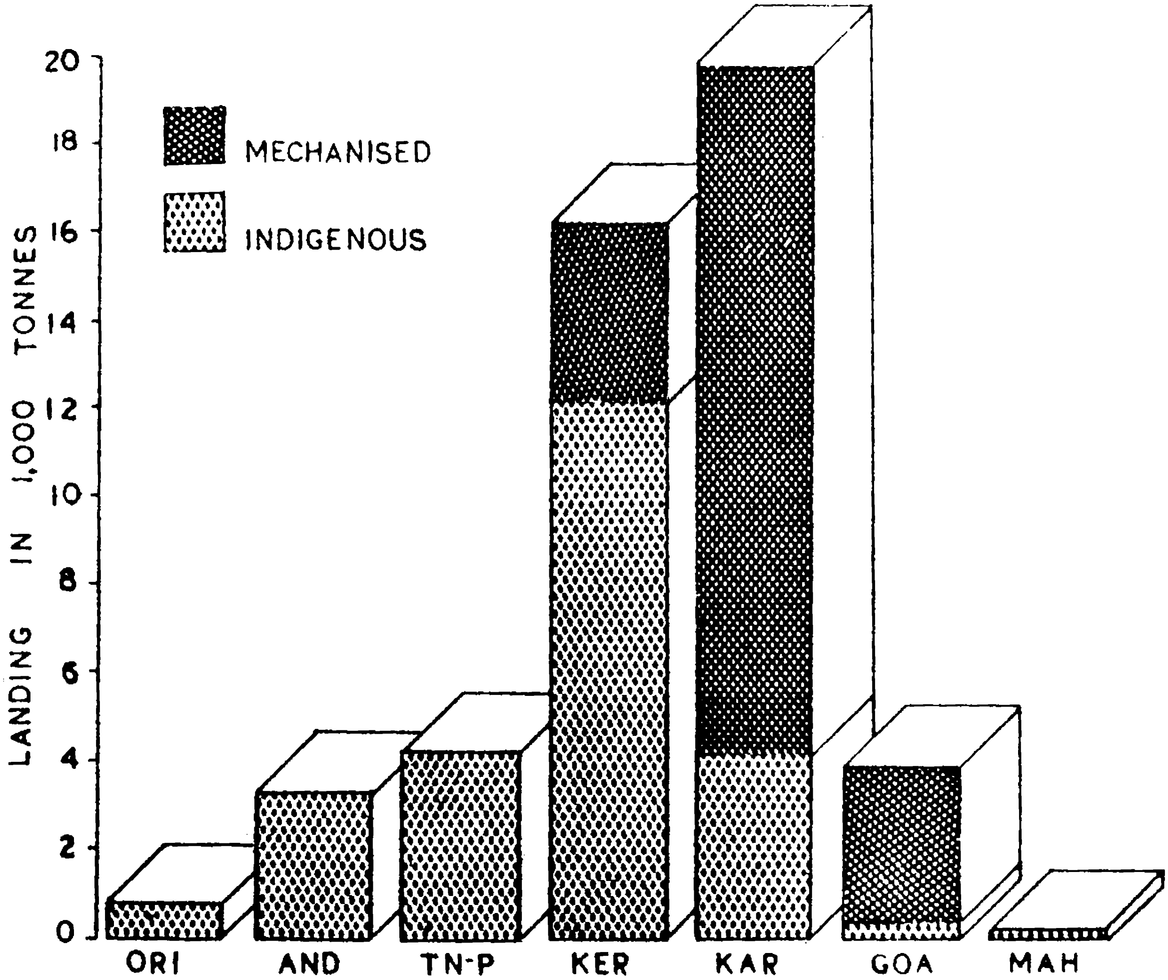
Banerji (1973) estimated the instantaneous total mortality (Z) of mackerel to be 2.05 and gave the instantaneous natural mortality (M) in it as 0.65 and instantaneous fishing mortality (F) as 1.40. Sekharan (1974) further fractioned the same Z into 0.9 M and 1.15 F. Yohannan (1982) found the Z to range between 2.54 and 6.21 with a mean of 4.41 at Mangalore and calculated the M to be 1.5. From the catch data for 1978 at a few important fishing centres on west coast, Noble (1979) estimated the Z to vary from 1.21 to 6.84. Re-examining Noble's published data, Devaraj (1983) computed the average Z for west coast to be 4.33 and said it to closely agree with the mean derived by Yohannan (1982) at Mangalore. Re-computing Yohannan's data, Devaraj (1983) got an Z of 4.89 but considered the M to be significantly very high. On the recovery data of tagged mackerel given by Prabhu and Venkataraman (1970), Devaraj (1983) estimated the F to be only 0.61. Deducting it from the Z of 3.22 he found the M at Calicut to stay as 2.61. Treating the stock and yield data for the entire south west coast he indicated the F to be only 0.23 out of 2.44 Z and considered the M to be 2.21.

Taking mackerel for a short-lived fish, Devaraj (1983) calculated the M on Cushing's (1968) method as 3.072 and says it to be fairly close to 2.61 and 2.21 computed by him for Calicut and west coast respectively.

The Z according to the present investigation is 3.2522 and it comprises of F 2.0814 and M 1.1708. The rate of exploitation (U) on this is 0.6152. Based on Sekharan's (1974) findings, the U works out to be 0.49 and on Banerji's (1973) figures it computes to 0.60. The U got at Mangalore by Yohannan (1982) too was 0.650. But according to the Z and F got by Devaraj (1983), the U at Calicut is 0.18 and on west coast 0.09. The M of 3.072 calculated by Devaraj (1983) stands well above the Z got at Calicut (3.22) and south west coast (2.44). Even with the high Z of 4.89 Devaraj (1983) got for Mangalore, the U works out to be only 0.34. With such low rates of exploitation, our coast might be teaming with plenty of mackerel yet to be exploited. However, recent experience with mechanized fishing in west coast which is especially high in Karnataka (Fig.45) does not show any appreciable concurrent escalation in the production (Fig.4) of mackerel (Noble 1982 b).

Fig. 45: Statewise landing of mackerel by mechanized and indigenous fishing in 1981.

Fig.45


MECHANISED
INDIGENOUS
LANDING IN 1,000 TONNES
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20
ORI
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KAR
GOA
MAH

7.4. LENGH-WEIGHT RELATIONSHIP

The length-weight relationship (LWR) of fish is a handy tool to transform length into weight or vice versa; and for the Indian mackerel it has been worked out for certain years at Karwar (Pradhan 1956), Mangalore (Yohannan 1977), Mandapam (Sekharan 1962), Waltair (Narayana Rao 1962) and Andamans (Jones and Silas 1962 b, and Luther 1973).

The equation evolved at Cochin in the present study from the pooled data for 16 seasons are

$$\log W = \bar{5}.6739 + 3.2996 \log L \quad \text{(logarithmic)}$$

and

$$W = 0.000001893 \; L^{3.2996} \quad \text{(exponential)}.$$

Pradhan (1956) and Narayana Rao (1962) worked out the LWR for lengths in cm in exponential form only. As the present study at Cochin and the studies of others cited above are for log L in mm, conversions were evolved for their equations and given below for better comparison.

Pradhan (1956) calculated the LWR for the mackerel at Karwar to be

$$W = 0.005978 \; L^{3.1737}$$

with L in cm. Logarithmically this calculates as

$$\log W = \bar{2}.2234 + 3.1737 \log L$$

and for lengths in mm these values were converted respectively into

$$W = 0.00000774 \; L^{3.1737}$$

and

$$\log W = \bar{5}.3971 + 3.1737 \log L$$

Sorting out males from females, Narayana Rao (1962) computed the LWR at Waltair for L in cm as

male: $$W = 0.004983 \; L^{3.2628}$$

and

female: $$W = 0.004784 \; L^{3.2785}$$

Logarithmic conversions made on these equations are respectively

male: $$\log W = \bar{2}.3025 + 3.2628 \log L$$

and

female: $\log W = \bar{2}.3202 + 3.2785 \log L$

For L in mm, these LWR at Waltair are transformed into

male: $W = 0.000002721\ L^{3.2628}$

and

female: $W = 0.000002519\ L^{3.2785}$

exponentially, and

male: $\log W = \bar{5}.5653 + 3.2628 \log L$

and

female: $\log W = \bar{5}.5987 + 3.2785 \log L$

logarithmically.

For the benifit of comparison for future work, logarithmic and exponential equations for L in cm at Cochin on the pooled data in the study are found and given to be respectively

$$\log W = \bar{2}.3743 + 3.2996 \log L$$

and

$$W = 0.004224\ L^{3.2996}$$

7.5. RELATION BETWEEN 'a' AND 'b' VALUES

Between 'a' and 'b' values of LWR for the 16 seasons under study at Cochin, the regression was found to be

$$a = \bar{1}.8209470 + 2.2693648\ b .$$

This relation being highly linear (Fig.38) and highly significant to 't' test, the equation of LWR on Cube Law works out to be

$$\log W = \bar{5}.0 + 3.0 \log L$$

The relation of 'a' on 'b' put into test with the equations on LWR given by earlier workers at other places showed the works of Sekharan (1962) and Jones and Silas (1962 b) to be different from it.

Sekharan (1962) at Mandapam gave the LWR of fish caught at day and night independently as

$$\log W = \bar{6}.2161 + 3.3390 \log L$$

and

$$\log W = \bar{6}.5662 + 3.1571 \log L$$

respectively and showed them not significantly different from each other. But these values as already stated do not agree with the regression relation of 'a' on 'b' given above. For the 'b' value of 3.3390 and 3.1571 of Sekharan's (1962) equations the values of 'a' should respectively be only $\bar{5}.7565$ and $\bar{5}.3437$. According to the equations of Sekharan (1962) a fish of 200 mm size in day haul would weigh 29.31 g and night haul 4.99 g only; when normally on Cube Law it should be 80.0 g. Calculating from the data given in his paper for 't' test the correct equations at Mandapam were found out here as

$$\log W = \bar{5}.7839 + 3.3390 \log L$$

for day hauls and

$$\log W = \bar{5}.4338 + 3.1571 \log L$$

for night hauls. The 'a' values in these are in close proximity to the values found through the application of regression on 'a' and 'b' values.

Jones and Silas (1962 b) computed the LWR of R.kanagurta at Andaman as

$$\log W = \bar{5}.5390 + 3.3087 \log L.$$

Luther (1973) too worked it out as

$$\log W = \bar{5}.6647 + 3.2874 \log L$$

and said it to be nearly the same as the value got by Jones and Silas (1962 b). The equation by Luther (1973) agrees well with the regression equation on 'a' and 'b' values. A fish of 200 mm size according to his equation itself weighs 79.38 g and it is the closest to the Cube value of 80.0 g. But on the equation of Jones and Silas (1962 b) a fish of 200 mm length would weigh 118.69 g. In other words, a fish of 118.69 g should according to Cube Law must measure 228 mm in length, and hence the LWR given by Jones and Silas (1962 b) is not correct, and not comparable to the equation got by Luther (1973). For the 'b' value of 3.3087 got by Jones and Silas (1962) the 'a' according to the relation on 'a' and 'b' works out to be $\bar{5}.6877$ and becomes comparable with the findings of Luther (1973) and Cube Law.

7.6. TEST OF SIGNIFICANCE

On 't' test, the 'b' values within ± 0.2158 of the pooled value of 3.2996 were found to be in tolerance limits, beyond which the variations appear significant. Against 3.0 11.5% variations of it are within the tolerance limits.

According to the present study, even when the 'b' values from season to season varied from the pooled value or 3.0 (Table III), they cannot be said to deviate from the Cube Law unless they violate the relation of 'a' on 'b'. For instance, the 'b' values in the period of study ranged between 3.7351815 and 2.9336154 and they were significantly varying from the pooled value of 3.2995842 (Table III). According to the regression relation of 'a' on 'b' in this study, the expected 'a' values for them can be calculated as $\bar{6}.6555424$ and $\bar{4}.8364965$ respectively; against the actuals of $\bar{6}.6417570$ and $\bar{4}.8357030$ observed (Table I). Growth of mackerel is thus perfectly under the Cube Law.

Though the growth in mackerel is three-diamensional, the 'b' value has certain important biological dependency on its environment. The LWR besides being an indicator of isometric or allametric growth can probably serve as an index of influence the environment has on the fish in its growth. The LWR, depending on the ecological and environmental conditions is bound to vary from season to season (Table I). The values in LWR being an annual function, it is dangerous to make statements like the one made by Korugans (1972) that the LWR of <u>R.kanagurta</u> is already established. The LWR from season to season has to be worked out to know the condition of the fish and its efficiency for propagation. Lower rates of growth can be due to unfavourable physical, chemical and biological characteristics of the environment. It may also be due to some inhibitions such as diseases or genetic factors in the fish itself. Indepth studies on the eco-system, their competitors and predators, together with behaviour and responses of the species may be taken up to understand it better.

7.7. LENGTH-WEIGHT RELATIONSHIP BETWEEN SEXES

While slight deviation was noticed at Waltair (Narayana Rao 1962) and partial significance got at Mangalore (Yohannan 1977) no significant difference between the LWR of sexes was seen at Andamans (Luther 1973). The computation at Cochin in the current investigation also provides no significant difference in the LWR between males and females.

During the 4 seasons studied here (Table IV), the 'b' values in females were slightly lower than that of the males. The 'b' of females in the above 3 works, on the contrary, were slightly more than that of males. While they studied only small number of fishes for limited period, at Cochin the study spreads to 4 seasons consecutively on good number of fishes and the phenomenon noticed should not be ignored. May be it can be connected to changes in long-term fluctuations in the fishery or regional differences. Study for long periods from many centres all along the coasts is to be undertaken to relate it with cyclical changes noticed by Noble (1980) in the fishery and identification of unit stocks if any.

7.8. LWR BETWEEN INDETERMINATE AND DETERMINATE FISH

Between these 2 groups of fishes, the LWR does not appear different and on 't' test they showed highly insignificant variations. Checking the LWR of the 2 groups with the relation of 'a' on 'b', both were found to be strictly under its purview exhibiting good three-diamensional growth.

7.9. STOCK ASSESSMENT

Sekharan (1974) estimated the stock of mackerel in the grounds off west coast as 130,000 tonnes. From the potential of 90,600 tonnes for Kerala and Karnataka estimated by Banerji (1973) an estimate for the west can be made as 122,310 tonnes. Yohannan (1982) found the average annual stock of the mackerel in the country as 140,306 tonnes. Expecting 90% of this from west coast, the potential there can get projected as 133,547 tonnes, a figure in harmony with values got by Banerji (1973) and Sekharan (1974). An average of the 3 gives the potential from the west coast as 128,619 tonnes.

According to present investigation, the country's annual stock is 141,835 tonnes. At the rate of 89% exploitation, 126,233 tonnes can be expected from west coast - a quantity very close to average got in the preceding paragraph.

Yohannan (1982) found the maximum yield of mackerel to take place when they are around 200 mm in length and 80 g in weight at fishing mortality (F) 4 to 6. In the present investigation, the yield curve takes a right turn at F 2 (Fig. 43) and more or less stabilizes at 4. The right turn at F 2 is very significant as it closely approximates the calculated F of 2.0814 for the mackerel. In the fishing curve (Fig.42) there is altogether a sort of stagnation in yield beyond F 4 suggesting the effort spent further to go waste as far as the yield of mackerel is concerned. The stabilization of F at 4 begins right at the commencement of commercial exploitation when the fish is already 1-year old (Fig.44). However, best yield occurs when the fish according to this study is 1.55 years old, and 200 mm in length and 83 g in weight. The present projection thus agrees well with the findings of Yohannan (1982) regarding the length and weight of the fish which can give the maximum yield.

Standing stock is the quantity of fish available at a time in the fishing ground vulnerable for capture at F 1. The average standing stock computed by Sekharan (1974) and Yohannan (1982) were 57,000 and 33,145 tonnes respectively. An average of these 2 is 45,073 tonnes, and the stock presently evaluated being 41,922 tonnes is close to it and looks appropriate. The potential yield of 126,233 tonnes on west coast on the basis of above standing stock can be gathered at F 3.0111. The F to amass the potential of 141,835 tonnes of the country in turn becomes 3.3833, and the F to exploit the highest landing of 204,575 tonnes in 1971 should have been 4.8799. The F that can be recommended for exploitation without waste in effort lies between 2 and 4 at annual potential stock between 83,844 and 167,688 tonnes for the country as a whole.

As in Rampani at Mangalore (Yohannan 1982), fishing by

Thangu vala at Cochin, according to present investigation also does not adversely affect the stock. Nevertheless, enhancement of fishing intensity does not recommend elevation in yield. Between effort and cpue, no negative co-efficient of correlation exists (Fig.41) and under such condition no F_{max} and Y_{max} can confidentally be fixed. The F_{max} fixed at 6 and Y_{max} as 198,870 tonnes by Yohannan (1982) are therefore baseless.

Through acoustic and aerial surveys, the Pelagic Fishery Project took census of the stock of mackerel along west coast as 450,000 tonnes in 1973 (PFP. 1974 b), 100,000 tonnes in 1974 (PFP. 1975 a), and 300,000 tonnes in 1975 (PFP. 1975 c). The natural mortality (M) according to the present study is 1.1708 and by using Gulland's (1971) formula

$$Y_{max} = 0.5 \times M \times Bo$$

where Bo is the unfished biomass, the potential yield for mackerel in 1973, 1974 and 1975 were 263,430; 58,540; and 175,620 tonnes respectively. An average of these is 165,863 tonnes and it is in close proximity to the value of 167,688 tonnes got at an F_{max} 4 and standing stock 41,922 tonnes derived in this study.

Direct estimate of the resource in the sea is the only solution to this problem. Yet no continuous effort is being done to fill this lacuna up. More systematic studies on fecundity followed by eggs and larval studies, young fish studies, and recruitment studies with exploratory, aerial, and acoustic surveys as already suggested in the beginning is an unavoidable must. When such estimates on spawners, spawns, and total mortality rates at all stages of life, right from eggs to spawners become available, it would be possible to make assessment of the population before the commencement of fishery as to aid the management programmes connected to the resource.

8. CONCLUSIONS

According to Banerji (1973) we were almost exerting the maximum fishing effort through indigenous gear nearer to optimum yield in 1973 itself and further increase in the fishing area already exploited by them might fetch only marginal increase in catch. In recent developments involving large-scale introduction of purse seining along the west coast especially Karnataka, the production of mackerel instead of increasing has not succeeded even in maintaining the status kept by the indigenous fishing. The stability or stagnation the fishery attains at F 4 is hence of prime importance. As addition in F has no appreciable increase in yield, it is better to restrict furtherance of fishing pressure. The fishery as already hinted at, has not reached over-exploitation and depletion. We are now in the middle of a decade when the trend of fishery in ten-year cycle normally is at its ebb. Giving weight to this fact too, this is the time to restrict fishing and allow the resource to recuperate and fishery to revive to a peak around the confluence of the decade nineteen eighties to nineteen nineties.

We must be still alert to assess the changes that take place in the fishery. Use of mechanized boats has increased the area of fishing far and wide. Mackerel caught and unloaded locally by country craft stationed at a number of landing centres lying only a few kilometres apart, on account of high mobility and range of mechanized craft are reached quickly, exploited, transported and emptied at selected centres where berthing and marketing facilities are available. Landings spread out early over a stretch of 70 to 80 km of coastline, being thus centralised, at a glance appear high. Truly there is no addition to the catches and hence no increase in the production.

The problem now at hand is the competition on exploitation developed between mechanized and indigenous fishing vessels. Regulations restricting their fishing activities to separate areas have already come. But as boundaries of these areas in sea canmot be marked, mechanized units often tresspass upon the prohibited part. Even if they don't, they can intercept the incoming shoals outside and deprive the indigenous unit of any catch. This being the crux of to-day's problem, fixing quota system and sharing of stock between mechanized and non-mechanized sector must get priority in the developmental activity for which stock assessment is the must.

9. SUMMARY

1. Description of *Rastrelliger kanagurta* with keys to the identification of genus and species are given at the outset.
2. An analysis of the production in India, and the maritime states are given amply illustrated and the status of mackerel in the marine fish catches touched upon.
   - Localities of high catches in each state are identified and details given.
3. Seasomal distribution of mackerel along Indian coasts is studied and presented. Maximum catches in east coast occur in March in its north and April in south. On west coast, around southern most part it peaks in April-May. To its north; from central part of Kerala it peaks during September-October, Karnataka and Goa in October and Maharashtra in November. In Gujarat in the northwest, as in Orissa of east coast, the maximum occurs in March.
4. The fishery and biology of mackerel landed by *Thangu vala* at Cochin during 15 seasons falling between July 1965 and June 1980 were studied. Though the catches fluctuated widely from season to season the effort did not change much. Fluctuatioms in catches hence depend upon fishery independent factors.

5. Utilizing the data collected for 15 seasons at Manassery and for another one collected during July 1980 to June 1981 at Fisheries Harbour, Cochin the length-weight relationship (LWR) were computed and found them to vary from one season to another within a range of

$$\log W = \bar{6}.6417570 + 3.7351815 \log L$$

and

$$\log W = \bar{4}.8357030 + 2.9336164 \log L.$$

The pooled value for the 16 seasons as a unit is

$$\log W = \bar{5}.6738829 + 3.2995842 \log L.$$

Exponential equations of the LWR and equations for L in cm were also worked out and given for comparisons.

6. The values of 'b' in each season tested against the pooled one of 3.2995842 showed them with ± 0.2158 difference to be in tolerance limits, beyond which the variations become significant. Against 3.0, around 11.5% of variations on it are within tolerance limits.

7. Between males and females the relations were worked out independently for 4 seasons between 1977-'78 and 1980-'81 and also for the period as a whole. The pooled value for 1977-'81 period is

$$\log W = \bar{5}.3256977 + 3.1511524 \log L$$

for male and

$$\log W = \bar{5}.2462069 + 3.1172780 \log L$$

for female. Tested against each other, variation between sexes was found insignificant. The 'b' value of females in all 4 seasons were slightly lower than that of males.

8. The LWR between indeterminate and determinate fish were found for some seasons from pooled data respectively as

$$\log W = \bar{5}.6652489 + 3.3064783 \log L$$

and

$$\log W = \bar{5}.2462069 + 3.1172780 \log L.$$

Tested against each other, variation between them was highly insignificant.

9. A regression,

$$a = \bar{1}.8209470 + 2.2693648\, b$$

showing perfect straightline relationship between 'a' and 'b' values of LWR of the 16 seasons under study was found out and in 't' test this relation was found to be highly significant.

Though some 'b' values were significant in 't' tests against the 'b' of pooled equation as also 3.0, between 'a' and 'b' all of them including indeterminate fish in relation to above equation showed good three-diamensional growth. Using this equation, the LWR at other places available in literature were verified and the mistakes found were rectified. According to the relation between 'a' and 'b', the LWR on Cube Law is

$$\log W = \bar{5}.0 + 3.0 \log L.$$

10. From monthly size distribution of mackerel in the commercial catches at Cochin the growth was found to be 15.07 mm per month in 1st year and 5.26 mm per month in the 2nd year.
11. The length of fish at different age found out in the study are $\leq$159 mm 0-year, 160-229 mm 1-year, 230-269 mm 2-year, and $\geq$270 mm 3-year old. This age-length structure was fitted into a curve with von Bertalanffy's Growth Function.
12. The commercial catches by Thangu vala accordingly comprised of 1-year old fish 72.5%, 0-year old 24.2%, and 2-year old 3.3% in the pooled value for the 15 seasons. The 3-year old occurred only in one season, that too in negligible numbers.
13. From age composition, the total instantaneous mortality (Z) was calculated to be 3.2522. It was further apportioned to

instantaneous fishing (F) and natural mortality (M) as 2.0814 and 1.1708 respectively. The rate of exploitation accordingly is 0.6152.

14. Between effort of Thangu vala and its cpue of mackerel, the regression relation gives a negative 'a' and a positive 'b' value indicating the fishing by this unit not to affect the stock. This relation hence cannot be used for yield studies.

15. The growth parameters like $L\infty$, K, and t_0 were therefore computed and found to be 315 mm, 0.6 and $^-$0.141 respectively.

16. In Beverton and Holt (1957) model the fishing curve steadily increases up to F 2, takes a right turn afterwards and gets more or less stabilized at 4. Beyond this there is no commendable gain in yield per recruit (Yw/R). Though the stock is not affected by fishing, the effort has to be restricted between F 2 and 4 to avoid waste in it. The Yw/R is observed to be at its best when the fish is 200 mm in length and 83 g in weight, and 1.55 year old. The F calculated in the study is very close to the turning point seen in the yield curve.

17. The average yield in India, during 1969-'80 representing a unit time in 10-year cycle in the long-term fluctuation of the fishery, is 87,257 tonnes; and the standing stock

(Y/F) and annual stock (Y/U) are calculated to be 41,922 and 141,835 tonnes respectively. The potential yield at F max 5 is 209,820 tonnes and the maximum recorded all-India catch of 204,575 tonnes is within its limit.

18. The findings in the study are discussed with relevant information in literature cited, suitability confirmed, infirmities indicated and improvements suggested.

19. Concludingly, regulation on more effort is pointed out, and an introduction of quota system and sharing of stock between the mechanized and non-mechanized sectors is proposed.

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